



PARTNERS IN RIVALRY:

U.S.-China civil nuclear ties
in historical perspective

Yanliang Pan
Siegfried Hecker
with William Potter

CNS

October 2026



Middlebury College
Center for Nonproliferation Studies

Center for Nonproliferation Studies
Middlebury College

499 Van Buren Street, Monterey, CA 93940, USA

Phone: +1 (831) 647-4154

Fax: +1 (831) 647-3519

Website: www.nonproliferation.org

The views, judgments, and conclusions in this report are the sole representations of the authors and do not necessarily represent either the official position or policy or bear the endorsement of CNS or Middlebury College.

©2026, The President and Trustees of Middlebury College

PARTNERS IN RIVALRY:

U.S.-China civil nuclear ties
in historical perspective

Yanliang Pan
Siegfried Hecker

with William Potter

Acknowledgments

This report was made possible by the generous support of the Kathryn Wasserman Davis Collaborative in Conflict Transformation at the Middlebury Institute of International Studies at Monterey, Middlebury College. The authors are grateful for the comments of reviewers, many of whom offered personal recollections of previous U.S.-China cooperative activities along with expert insights. Research benefited from the work of CNS graduate research assistants, including Daihan Cheng, Ranna Jarukin, Ying Li, and Amelia Wang.

Foreword

The United States and China are engaged in heated competition across the economic, technological, and military domains. Nuclear energy, with its strategic civilian and defense applications, rests at their intersection. The first Trump administration explicitly linked the revival of the U.S. civil nuclear enterprise to national security priorities including energy dominance, defense mission assurance, influence over global nuclear norms, and the race against Russia and China to establish global civil nuclear partnerships. Recently, U.S.-China competition in artificial intelligence has placed additional emphasis on nuclear energy because it is viewed by many as a possible solution to the growing electricity demands of datacenters.

These rivalry-centered narratives have had the unfortunate effect of obscuring the long history of U.S.-China cooperation in the peaceful applications of nuclear energy and in the broader areas of nuclear safety, security, and nonproliferation. This history is worth reviewing as it sheds light on the present moment of mistrust and decoupling: prior cooperation illustrates shared interests and mutual complementarities that continue to bind while prior frictions clarify how longstanding obstacles to cooperation may be more constructively managed at present.

This report begins its historical review with the underappreciated scientific exchanges between the United States and China in high-energy physics, nuclear physics, and magnetic fusion following President Richard Nixon's 1972 visit. Chapters 2 to 4 recount how the United States facilitated China's adoption of more prudent nuclear safety, security, and nonproliferation practices through technical engagement – and how China evolved as a U.S. partner in global nuclear security and nonproliferation governance. Chapter 5 traces the history of negotiations leading up to the 1985 U.S.-China civil nuclear cooperation agreement and the obstacles that were subsequently overcome to enable its implementation, setting the scene for civil nuclear commerce. Chapter 6 characterizes cooperation under the flagship AP1000 reactor deal, with implications for the U.S.-China nuclear power and nuclear safety partnership. Chapter 7 expands the historical narrative to parallel joint research in advanced fission energy technologies in the 2000s and 2010s. Chapter 8 analyzes the drivers of the first Trump administration's policy shift curtailing civil nuclear cooperation with China. Chapter 9 concludes with reflections regarding the past, present, and future of U.S.-China civil nuclear cooperation across science, technology, commerce, and governance.

The historical review presented in this report is far from comprehensive. It focuses far more on government-driven activities than on Track 1.5 and Track 2 exchanges, many of which have had to

do with nuclear-weapon and strategic-stability issues. Lawrence Livermore National Laboratory's Center for Global Security Research, Stanford University's Hoover Institution, the Pacific Forum, the Institute for Defense Analyses, the Center for Strategic and International Studies, and the Carnegie Endowment for International Peace, among others, have compiled reports on U.S.-China dialogues surrounding these strategic issues. This report fills a different gap with its focus on nuclear science, technology, commerce, and governance in terms of safety, security, and nonproliferation. Both Washington and Beijing are finding it politically inconvenient to revisit their historical cooperation in these domains due to their present rivalry. It is therefore incumbent upon nongovernmental researchers to review and reflect upon this history. That said, information that may be gleaned from web sources, print publications, and archives is limited. The authors hope that this report might invite input from those who recall the recounted events from personal participation and those who are willing to offer reflections from alternative perspectives.

Contents

Executive Summary	1
Chapter 1. Origin – U.S.-China scientific exchanges	8
Chapter 2. A brief history of lab-to-lab exchanges	20
Chapter 3. Nuclear security and nonproliferation cooperation beyond lab-to-lab	29
Chapter 4. Early nuclear safety cooperation	45
Chapter 5. Setting the scene for civil nuclear commerce	54
Chapter 6. The AP1000 deal: broadening cooperation along the energy and safety tracks ...	62
Chapter 7. Cooperation in advanced fission energy	71
Chapter 8. From cooperation to rivalry	88
Chapter 9. Reassessing U.S.-China nuclear cooperation	101
Taking stock of the past	101
Present and future cooperation: interests, paths, and boundaries	110

Executive Summary

This report traces the history of U.S.-China cooperation in nuclear science, technology, energy, and governance. It assesses the benefits of historical cooperation to the policy agendas of successive U.S. administrations as well as the objectives of the U.S. civil nuclear enterprise, re-evaluates longstanding tensions in light of the present strategic and technological rivalry, and offers recommendations for carefully bounded engagement that can still advance U.S. interests within security constraints.

Scientific exchange served as an important bridge during early U.S.-China rapprochement, culminating in the bilateral Science and Technology Agreement of 1979 following diplomatic normalization. Cooperation in high-energy physics, nuclear physics, and magnetic fusion created durable ties among the scientists and research institutions of the two countries. Cooperation proved mutually beneficial despite early asymmetry, frictions over intellectual property, and security sensitivities. China's high-energy physics and magnetic fusion programs benefited from early U.S. assistance. Chinese contributions, in turn, advanced both fields in ways that benefited U.S. science. Chinese accelerator and tokamak facilities subsequently became valuable platforms for U.S. researchers, filling key gaps in U.S. experimental infrastructure investment.

Meanwhile, ties between American and Chinese nuclear weapons laboratories laid the foundation for exchanges in nuclear security. U.S. national laboratories helped China build capacity in safeguards and nuclear material protection, control, and accounting (MPC&A). Starting with informal exchanges and visits in the 1980s, China gave the United States remarkable access to its nuclear weapon complex, including the Lop Nur nuclear test site. These interactions paved the way to a formal Lab-to-Lab Technical Exchange Program between their nuclear weapon laboratories. Beyond MPC&A, technical exchanges took place or were envisioned across additional dimensions of arms control and nonproliferation ranging from treaty verification to export controls. The Congressional Cox Report alleging Chinese nuclear espionage derailed the program in 1999, but civilian nuclear security and nonproliferation cooperation subsequently resumed, shaped by Washington's post-9/11 security agenda. Cooperation extended to radiological security, counter-nuclear trafficking, export controls, and regional proliferation challenges, complemented by Track 1.5 engagement. The Nuclear Security Summits deepened the partnership, including joint work to convert Chinese-origin research reactors from highly enriched to low-enriched uranium fuel. Cooperation also supported negotiation and implementation of the Joint Comprehensive Plan of Action with Iran.

Beginning in the 1980s, the U.S. Nuclear Regulatory Commission (NRC) helped the Chinese National Nuclear Safety Administration develop civilian nuclear safety oversight capacity through the

transfer of standards, methods, and practices and hands-on regulator training. Initially narrow and asymmetric exchanges developed into a broad regulatory partnership spanning reactor licensing, inspections, emergency preparedness, radiation protection, and nuclear material safety and security. Nuclear safety was viewed as a common good, and cooperation proved resilient. The United States gained transparency with respect to China's civil nuclear development while shaping its safety practices early on. Sustained people-to-people ties linked the NRC to rising Chinese technocrats. Over time, cooperation increasingly involved mutual learning, particularly surrounding the regulation of advanced reactors that China deployed ahead of the United States.

Westinghouse's sale of AP1000 reactors to China with technology transfer marked the key breakthrough in U.S.-China civil nuclear commerce. But the scene for cooperation was set in the late 1970s and 1980s. As the U.S. nuclear industry sought access to the Chinese market, the Reagan administration negotiated and concluded a nuclear cooperation agreement with China in 1985. Prospective civil nuclear commerce served as an inducement for China to accept nonproliferation principles and obligations. However, implementation of the agreement was delayed by U.S. congressional resistance, persistent concerns over China's commitment to nonproliferation, and, after 1989, sanctions tied to China's human rights behavior.

In the 1990s, pressure grew in the United States to normalize civil nuclear trade with China. The U.S. nuclear industry was fated to decline in the absence of new reactor orders. Access to the Chinese market was seen as a solution. The Clinton administration ultimately implemented the bilateral nuclear cooperation agreement in 1998 after concluding that China had made sufficient progress on nuclear and dual-use export controls and had provided the nonproliferation assurances Washington required, including commitments related to Iran and Pakistan. In 2003, the two governments established a case-by-case assurance process for sensitive technology retransfer in a compromise that finally opened the door to full-scale civil nuclear commerce. Subsequently, Westinghouse sold four of its AP1000 reactors to China with extensive technology transfer, backed by the U.S. government in line with its high-technology trade and clean energy agendas, though it did not surrender intellectual property rights. China gained the ability to construct the indigenized CAP1000 domestically, though not the right to export it in competition against Westinghouse. The deal also allowed China to develop larger reactors based on AP1000 technology for domestic deployment and export, but on the condition of treating Westinghouse as the technology provider or partner, subject to U.S. technology controls. Rather than strengthening Chinese competition in the global reactor market, cooperation advanced an initially incomplete American reactor design toward deployment readiness. When the four AP1000 units were completed in 2018, China became the first country to operate the Westinghouse reactor. Their construction, testing, and regulatory experience subsequently benefited the Vogtle AP1000 reactor project in the United States.

Under bilateral agreements on the peaceful use of nuclear energy and technology, both the George W. Bush and Obama administrations fostered cooperation with China in advanced fission energy. Joint research under a Bush-era action plan associated with the Global Nuclear Energy Partnership drew on complementary expertise and facilities. TerraPower's planned Traveling Wave Reactor partnership with China National Nuclear Corporation offered a route to demonstration in China. Meanwhile, the U.S. Department of Energy and Chinese Academy of Sciences pursued cooperative molten-salt reactor research. The joint endeavor supported Oak Ridge National Laboratory's team and experimental infrastructure when U.S. funding was scarce, helping preserve capabilities relevant to U.S. commercialization of fluoride salt-cooled high-temperature reactors.

Beginning with the announcement of a new export control policy framework in 2018, the U.S. government moved to curtail civil nuclear cooperation with China, citing risks of Chinese military diversion, forced technology transfer, and intellectual property theft. Previous administrations recognized these risks but judged that the strategic benefits of cooperation outweighed the risks as confined by negotiated guardrails. The new administration challenged this net benefit assessment as Washington's focus shifted toward technological competition. This restrictive approach continued under the Biden and second Trump administrations. Advanced-reactor collaboration was curtailed, and a crackdown on scientific collaborations and talent recruitment aimed at addressing legitimate research security concerns ended up undercutting U.S.-based research and accelerating a scientific brain drain.

Present U.S.-China strategic and technological competition does not alter the historical fact that U.S. interests drove and benefited from decades of cooperation with China in nuclear science, technology, and governance. Early scientific exchanges contributed, by Washington's design, to political rapprochement and diplomatic normalization. The U.S. government deliberately loosened restrictions on dual-use technology transfers to China during this period to strengthen China as a counterweight to the Soviet Union. Engagement during the 1980s and 1990s surrounding the bilateral civil nuclear agreement, coupled with technical capacity-building assistance, helped align China with global nuclear safety, security, and nonproliferation norms in accordance with Washington's expectations. Lab-to-lab exchanges gave the U.S. government remarkable access to China's otherwise opaque nuclear-weapon complex. Continued exchanges in civilian nuclear and radiological security reduced threats to the United States and the rest of the world. During the Bush and Obama administrations, bilateral nuclear energy cooperation supported the U.S. government strategy of enlisting China's contribution to global energy security and climate action. Commercially, access to the Chinese civil nuclear market yielded substantial revenue for U.S. companies, and joint research in advanced fission energy technologies complemented rather than displaced U.S. domestic R&D. Over the past fifty years, China has benefited greatly from nuclear cooperation with the United States, as has the United States – with China.

China's civil nuclear industry has risen to world class while America's nuclear industry has declined for several decades. It is politically convenient to attribute America's civil nuclear decline to the naïve policies of successive American administrations that allowed China to steal America's technological edge. Historical facts point to the contrary. The U.S. civil nuclear industry started to atrophy in the 1970s, before significant nuclear cooperation with China began. Subsequent commerce and technological exchanges produced opportunities for U.S. industry to revitalize business and for U.S. laboratories to preserve advanced reactor capabilities. China has not exported U.S.-derived or indigenous power reactor technology in competition against U.S. industry to date. Neither industry nor policymakers in Washington were naïve about the IP and dual-use risks of technology transfer, as reflected by the painstaking negotiation of intergovernmental understandings surrounding technology controls as well as commercial agreements regarding intellectual property.

There is no doubt that China has benefited enormously from cooperation with the United States. However, China's civil nuclear progress today is not a result of U.S. technology transfer alone, and the United States could not have stifled China's civil nuclear ambitions by withholding cooperation. Even without U.S. technology transfer, China's indigenous capability and diverse foreign partnerships would have allowed it to develop a competent and well-rounded civil nuclear program, albeit one less transparent to the United States, less complementary to the U.S. nuclear industry and technology advancement, and less robustly shaped by U.S. standards of nuclear governance. The U.S.-China civil nuclear partnership is distinguished by its emphasis on global responsibility in terms of energy and climate security as well as safety, security, and nonproliferation governance. Although the United States views its global responsibility differently today, it should not regret previous cooperation with China to advance global governance objectives because Americans ultimately benefit from a better governed world.

On the debit side, recent U.S. administrations have highlighted the risk that Chinese entities might divert U.S. technology for military purposes, but this is not a new revelation. Nuclear technologies are inherently dual use. U.S. policymakers have been aware of the dual-use implications of nuclear technology transfers to China and implemented guardrails against diversion since transfers were first contemplated in the 1980s. These guardrails are not intended to address espionage and export control violations that bypass them altogether, but nor is narrowing the field of legitimate cooperation an effective solution.

An equally difficult challenge is to define the boundary of collaboration in basic science and pre-commercial technology. U.S.-based university researchers have lacked clear, coherent, and consistent guidance in this regard. Restrictions on previously encouraged collaborations have caused fear, confusion, compliance fatigue, and productivity erosion among U.S. scientific researchers while accelerating the departure of U.S.-based scientists, particularly those of Chinese descent. Withdrawal from

joint research has also deprived U.S. scientists of access to valuable Chinese experimental infrastructure. Mitigating genuine IP and dual-use risks without undermining America's own innovation potential requires carefully rethinking the rules and boundaries of scientific exchanges.

Joint endeavors must serve the strategic interests of both countries. U.S.-China nuclear cooperation has done so over the years and benefited global nuclear governance. The competition-oriented outlook of recent U.S. administrations has undercut prior justifications for cooperation. However, strategic rivalry has not eliminated all cooperative opportunities and benefits, even though it may demand a rethinking of prior modes, objectives, and boundaries of interaction.

The second Trump administration recognizes the importance of U.S. scientific and technological leadership. Even as its July 2026 science policy report cautions against unilateral openness, it acknowledges that open and transparent research is central to scientific progress. No country commands all the knowledge and infrastructure needed to advance across the scientific frontier. China has caught up to the United States in overall R&D investment and volume of scientific publications. U.S. researchers co-author more scientific publications with researchers in China than with those in any other country. In the nuclear domain, China has displayed increasing openness to international scientific cooperation. It is possible for U.S. researchers to realize gains including access to Chinese talent, scientific funding, and experimental infrastructure as long as the U.S. government takes responsibility for defining the boundaries and guardrails of joint scientific work.

Beyond basic science, there is significant space for technology cooperation. Current U.S. government restrictions on collaboration with China in civil nuclear innovation are based on at least three assumptions: first, that advanced civil nuclear technologies like SMRs and advanced reactors have foreseeable commercial and military potential; second, that these technologies are strategically crucial for powering the growth of AI and other emerging technologies; and third, that the United States has an innovation advantage over China, which it can best protect by limiting collaboration with China. All three assumptions are subject to debate and should be reassessed.

Many advanced reactor concepts are years, if not decades, away from commercial maturity and are unlikely to play a near-term role in bridging the AI power gap. Meanwhile, China's domestic capabilities and diverse foreign partnerships limit the effectiveness of technology denial. Its leading position is a reason to embrace rather than withdraw from collaboration, provided that strong guardrails against IP leakage and military diversion are in place. Where China is ahead in developing or deploying these reactor concepts, U.S. advanced reactor companies could benefit from Chinese experience. Those seeking demonstration or commercial deployment opportunities could also benefit from access to the Chinese market as well as Chinese financing, project management efficiency, and civil

construction competence for first-of-a-kind prototypes. Similarly, U.S. scaling of conventional large power reactors could benefit from Chinese lessons.

The road to the next nuclear renaissance for the United States will be long and arduous. China is not the reason behind any of the challenges that the U.S. nuclear industry now faces, and cutting civil nuclear ties with China will not solve these problems. The second Trump administration has recognized the challenges to civil nuclear reindustrialization, and its policies could strengthen U.S. domestic competence. But restoring self-sufficiency will take years. In the meantime, there are ways in which coordination with China could strengthen U.S. supply chain resilience and protect U.S. capacity investments.

In recent years, the United States has cited the opacity of the Chinese nuclear enterprise, particularly the indistinct programmatic and organizational separation between its defense and civilian elements, as a reason to scale back engagement. However, transparency is best advanced through engagement, as demonstrated by the history of exchanges involving U.S. and Chinese laboratories across the civil and defense nuclear domains. Prior U.S. administrations recognized transparency as one of the top benefits of cooperation. This benefit remains a compelling justification for reviving engagement, if only to equalize the transparency balance – in the absence of engagement, the U.S. nuclear enterprise is far more transparent to China than the other way around. As an example, closed-fuel-cycle technologies represent an area where mutual transparency is consequential. Continued engagement related to civilian fast reactors and alternative closed-fuel-cycle technologies can offer important assurances about their dual-use potential.

Reviving collaboration is as much a question about boundaries and guardrails as it is about paths toward mutual benefit. Basic science remains the path of least risk. In fields distinguished by high collaborative need and low dual-use sensitivity, such as high-energy physics and magnetic fusion, restrictions should be scaled back. The same principles could apply to pre-commercial fission technologies with few sensitive military applications and no proprietary IP. The approach to commercial civil nuclear innovation should be similarly risk informed. Rather than imposing blanket restrictions on entire technology categories, controls should reflect technology readiness as well as commercial and strategic significance. Technologies at high readiness levels are more likely to become the basis for near-term competition and may have greater military relevance, warranting stronger IP protections and safeguards against diversion. Excessive restrictions on less mature technologies can constrain U.S. gains from Chinese research and development.

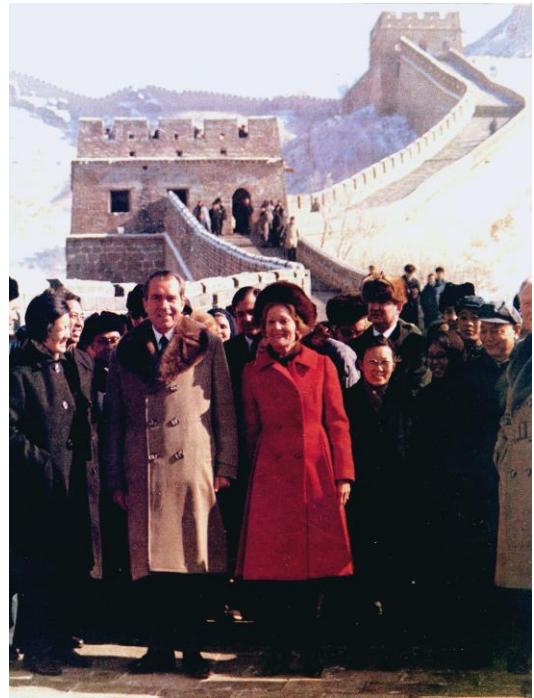
Clear boundaries, stringent guardrails, and robust enforcement can substantially reduce IP leakage and military-diversion risks. Even so, no system of controls can eliminate diversion risks entirely because nuclear technology is inherently dual use. Eliminating strategic benefits to China and limiting

cooperation to zero-risk scenarios are not realistic objectives. It is more pragmatic to ensure that, in each case, the expected U.S. gain outweighs the loss in security and strategic advantage. This “net benefit” as opposed to “zero risk” criterion, is what justified U.S. cooperation with China historically and what continues to justify cooperation today.

Enhanced nuclear governance is a key benefit of cooperation. Apart from reindustrialization, the success of the next nuclear renaissance depends on a well-maintained global nuclear order in safety, security, and nonproliferation. Cooperation is necessary as a global expansion of nuclear power will heighten safety regulatory burdens while multiplying security and nonproliferation challenges that no one country can tackle alone. China is bound to increasingly shape global nuclear governance norms as it becomes a powerhouse in nuclear technology deployment. U.S.-China coordination should anchor global nuclear norms. Their confrontation threatens to fragment the global nuclear order. In parallel with continuing nuclear safety cooperation, the legacy of prior security and nonproliferation cooperation could serve as the foundation for further strides. Track 1.5 dialogues addressing security and nonproliferation should be revived with a focus on rebuilding prior relationships and bringing in the next generation. Engagement in global nuclear governance should be insulated from other, more contentious aspects of bilateral relations. Regardless of how strategic interests may shift, the fact that nuclear technology is inherently dual use means it always must be responsibly governed and controlled. The United States and China may be locked in competition in strategic and emerging technologies. Yet in nuclear governance, they are doomed to cooperate.

Chapter 1. Origin – U.S.-China scientific exchanges

In 1966, the U.S. National Academy of Sciences, the American Council of Learned Societies, and the Social Science Research Council jointly founded the Committee on Scholarly Communication with the People's Republic of China, or CSCPRC, to foster exchanges with the mainland Chinese scientific community. The aim was not only to resume U.S.-China scientific contact but also to promote broader people-to-people exchanges and understanding.¹ However, the timing was unfortunate. China's Cultural Revolution – characterized by the politicization of science, worship of anti-intellectualism, and intense suspicion of foreign ties – had just begun. There were no diplomatic relations between the United States and the PRC. In its early years, the CSCPRC was confined to monitoring and translating Chinese scientific research and encouraging American scholars to correspond directly with colleagues in the PRC, with very limited response from the Chinese side.² The opening came in 1972, when U.S. President Richard Nixon visited China, and the two countries jointly issued the Shanghai Communiqué explicitly encouraging people-to-people exchanges in science and technology, among other fields.³ Scientists would act as informal envoys between the two diplomatically estranged nations.⁴



Richard and Pat Nixon on the Great Wall, February 1972 · Byron E. Schumaker / White House

It was no accident that Washington and Beijing began their rapprochement by fostering scientific exchange. The sciences, insofar as they were considered neutral and objective, created politically safe

¹ Pete Millwood, "An 'Exceedingly Delicate Undertaking': Sino-American Science Diplomacy, 1966–78," *Journal of Contemporary History* 56, no. 1 (2021): 169–70.

² Kathlin Smith, "The Role of Scientists in Normalizing U.S.–China Relations: 1965–1979," *Annals of the New York Academy of Sciences* 866, no. 1 (1998): 119; Millwood, "An 'Exceedingly Delicate Undertaking': Sino-American Science Diplomacy, 1966–78," 171.

³ "203. Joint Statement Following Discussions with Leaders of the People's Republic of China," Office of the Historian, U.S. Department of State, February 27, 1972, <https://history.state.gov/historicaldocuments/frus1969-76v17/d203>.

⁴ Office of Science & Technology Cooperation, Bureau of Oceans & International Environmental & Scientific Affairs, "United States – China Science and Technology Cooperation," December 2006, <https://2001-2009.state.gov/documents/organization/96437.pdf>.

ground for resuming engagement. Previously, Beijing encouraged people-to-people exchanges especially with U.S.-based leftist groups – from the Black Panthers to the Committee of Concerned Asian Scholars.⁵ The latter was founded in the late 1960s to protest the Vietnam War. With a view toward diplomatic normalization, Henry Kissinger pressed his counterparts in Beijing to establish links with more centrist groups like the CSCPRC.⁶ He found a receptive audience in Premier Zhou Enlai, who considered scientific exchange with the United States an opportunity to advance his broader agenda to modernize China. In 1973, following Kissinger's visit, a CSCPRC delegation negotiated the first formal U.S.-China scientific exchange agreement with China's Science and Technology Administration. In a meeting with that delegation on May 27, Premier Zhou Enlai personally reviewed their proposals and "gave his blessing to nine scientific areas of cooperation," thereby putting his political weight behind the new exchange relationship.⁷ With both governments' blessing, the CSCPRC arranged a wide range of scientific exchanges and organized the travel of dozens of delegations in both directions over the next decade.⁸

High-energy physics emerged as a focal point of these exchanges early on. In 1969, the U.S. Atomic Energy Commission's High Energy Physics Advisory Panel (HEPAP) stated that "scientific contacts and collaborations serve the cause of peace and the improvement of relations between nations." High-energy physics was a particularly suitable field for exchanges, the HEPAP argued, because its foundational nature entailed fewer security precautions while supporting broad technological advancement; its expensive facilities and instrumentation justified international cost-sharing; and senior high-energy physicists tended to have high-level political access, offering a "useful channel" of inter-governmental communication.⁹ In 1970s China, high energy physics was a popular, albeit emerging, field: Mao favored theories dealing with the division of physical matter on ideological grounds while the migration of nuclear bomb veterans into the discipline lent it further scientific clout. Chinese-American scientists such as Lee Tsung-Dao and Yang Chen-Ning had also become well-known in China for their Nobel Prize-winning work in physics.¹⁰

During his meetings with Zhou Enlai in 1971 and 1972, Yang underscored the importance of supporting basic scientific research in addition to research in technology applications. Lee, for his part,

⁵ John H. Holdridge, "248. Memorandum From John H. Holdridge of the National Security Council Staff to the President's Assistant for National Security Affairs," Office of the Historian, U.S. Department of State, August 28, 1972, <https://history.state.gov/historicaldocuments/frus1969-76v17/d248>.

⁶ Millwood, "An 'Exceedingly Delicate Undertaking': Sino-American Science Diplomacy, 1966–78," 172–73.

⁷ Zuoyue Wang, "U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond," *Historical Studies in the Physical and Biological Sciences* 30, no. 1 (1999): 255.

⁸ David M. Lampton, Joyce A. Madancy, and Kristen M. Williams, *A Relationship Restored: Trends in U.S.-China Educational Exchanges, 1978-1984* (Washington, DC: National Academy Press, 1986), 239–41.

⁹ "30 Years of US-China High-Energy Physics Cooperation," *Symmetry*, January 31, 2009, <https://www.symmetrymagazine.org/breaking/2009/01/31/30-years-of-us-china-high-energy-physics-cooperation>.

¹⁰ Wang, "U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond," 261–63.

encouraged the Chinese premier to set up a high energy physics program in China and foster foreign exchanges in the field.¹¹ Consequently, in September 1972,¹² Zhou tasked Zhang Wenyu – a UK-trained nuclear physicist who worked in the United States in the 40s and 50s – and the U.S.-trained nuclear physicist Zhu Guangya with the founding of a national high-energy physics program. Zhang was then a senior physicist at the China Institute of Atomic Energy (CIAE), and Zhu was deputy head of the Defense Science and Technology Commission.¹³ Just two months later, in November 1972, Zhang Wenyu visited the Stanford Linear Accelerator Center (SLAC) run by Wolfgang K.H. Panofsky to “explore the best approach for China to enter the world of accelerator-based [high-energy physics].”¹⁴ He returned in 1973 leading a larger Chinese delegation on a Kissinger-approved¹⁵ and CSCPRC-organized tour of U.S. high-energy physics labs.¹⁶ The delegation spent five days at SLAC, four days at Brookhaven,¹⁷ and three days at Fermilab – then known as the National Accelerator Laboratory.¹⁸ Their tour laid the foundation for subsequent exchanges, including visits by U.S. lab directors to China. Panofsky first visited China in 1976 to advise his Chinese colleagues on their accelerator program.¹⁹ Fermilab’s Robert R. Wilson visited even earlier, in 1974. A personal invitation he extended to Zhang Wenyu during that visit eventually allowed a group of ten Chinese scientists to spend several months at the National Accelerator Laboratory in 1978 to conduct high-energy physics research in support of China’s accelerator plans. The visit was coordinated by Lee Teng, a Chinese-American scientist at Fermilab.²⁰

By then, Washington and Beijing were already on the verge of normalizing their diplomatic relations, and visits by senior government officials had begun taking place. The CSCPRC’s activities played an important supporting role in the normalization process. For years, Beijing insisted that normalization must be predicated upon Washington’s abrogation of all but economic and cultural ties with Taipei. But with the end of the Cultural Revolution in 1976, Deng Xiaoping emerged as China’s pro-reform and pro-modernization leader. The CSCPRC sensed China’s growing need for exchanges in advanced technology to fulfill Deng’s vision of accelerated modernization. It therefore sought to

¹¹ Wang, 260, 262–63.

¹² Institute of High Energy Physics, Chinese Academy of Science, “History,” Institute of High Energy Physics, Chinese Academy of Sciences, accessed November 6, 2025, <https://english.ihep.cas.cn/au/hy/>.

¹³ Wang, “U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond,” 261–63.

¹⁴ Wolfgang K.H. Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers* (New York: Springer, 2007), PS 26.

¹⁵ “High Energy Group from China Ends Four-Day Visit,” *Brookhaven Bulletin* (Upton: Brookhaven National Laboratory, May 25, 1973), <https://www.bnl.gov/bnlweb/pubaf/bulletin/files/1973/19730525.pdf>.

¹⁶ “30 Years of US-China High-Energy Physics Cooperation.”

¹⁷ “Farewell Banquet,” *Brookhaven Bulletin* (Upton: Brookhaven National Laboratory, June 8, 1973), <https://www.bnl.gov/bnlweb/pubaf/bulletin/files/1973/19730608.pdf>.

¹⁸ “Physics Joins East, West,” *FermiNews* (Batavia: Fermi National Accelerator Laboratory, July 1, 1978), https://history.fnal.gov/historical/people/prc_physics_joins.html.

¹⁹ Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers*, 130–31.

²⁰ “Physics Joins East, West.”

leverage the promise of deeper scientific and technological ties to entice Beijing toward normalization. The Carter administration soon took up the same strategy.²¹ In July 1978, President Carter's science and technology advisor, Frank Press, led a delegation of U.S. government representatives on a visit to Beijing²² to discuss opportunities for cooperation.²³ Press's counterpart was Fang Yi, chair of the State Science and Technology Commission,²⁴ although he was also received by Deng Xiaoping.²⁵

Frank Press was an ideal figure to spearhead Carter's science and technology outreach to China. Before becoming the president's science advisor, Press was chair of the CSCPRC and knew China directly from having led a CSCPRC seismology mission there in 1974. He was also well-versed in arms-control diplomacy since he had participated in nuclear test ban talks with Soviet experts in Geneva in the late 1950s and early 1960s as a seismologist.²⁶ In late 1977, he pressed Carter to ease restrictions on the export of dual-use high-technology items to China, arguing it would help strengthen U.S.-China ties.²⁷ As head of the U.S. delegation visiting China in 1978, Press's mission was to cultivate those ties as a signal of U.S. support for Deng's new policy of modernization and openness to the West. Further, Washington was now aligned with Beijing against Moscow. Press was scheduled to lead a smaller U.S. delegation to the Soviet Union shortly after his China trip, though the trip was cancelled in protest over Moscow's trial of dissidents.²⁸ It was in both the United States' and China's interests to signal to the Soviets their strong cooperation in technology and science. The message was received: Soviet state media was quick to denounce Press's China trip as a cover for military transfers.²⁹ That accusation was exaggerated: the cooperation was meant to be civilian. But Washington indeed recognized the dual-use implications of its technology transfers and

²¹ Millwood, "An 'Exceedingly Delicate Undertaking': Sino-American Science Diplomacy, 1966–78," 19–22.

²² Jimmy Carter, "United States Delegation's Visit to the People's Republic of China White House Statement on the Mission to Discuss Science and Technology Matters," The American Presidency Project, June 27, 1978, <https://www.presidency.ucsb.edu/documents/united-states-delegations-visit-the-peoples-republic-china-white-house-statement-the>.

²³ Richard Holbrooke, "137. Briefing Memorandum from the Assistant Secretary of State for East Asian and Pacific Affairs (Holbrooke) to Secretary of State Vance," Office of the Historian, U.S. Department of State, accessed November 6, 2024, <https://history.state.gov/historicaldocuments/frus1977-80v13/d137>.

²⁴ Frank Press, "144. Memorandum From the Chairman of the Policy Review Committee (China S&T) (Press) to President Carter," Office of the Historian, U.S. Department of State, October 13, 1978, <https://history.state.gov/historicaldocuments/frus1977-80v13/d144>.

²⁵ Cyrus Vance, "129. Telegram From the Department of State to the Liaison Office in China," Office of the Historian, U.S. Department of State, August 17, 1978, <https://history.state.gov/historicaldocuments/frus1977-80v13/d129>.

²⁶ Jimmy Carter, "Office of Science and Technology Policy Nomination of Frank Press To Be Director," The American Presidency Project, March 18, 1977, <https://www.presidency.ucsb.edu/documents/office-science-and-technology-policy-nomination-frank-press-be-director>.

²⁷ Pete Millwood, *Improbable Diplomats: How Ping-Pong Players, Musicians, and Scientists Remade US-China Relations* (Cambridge: Cambridge University Press, 2023), 282.

²⁸ Susanna McBee, "Another Mission to Soviet Union Canceled by U.S.," The Washington Post, July 25, 1978, <https://www.washingtonpost.com/archive/politics/1978/07/25/another-mission-to-soviet-union-canceled-by-us/09db6263-3bd8-4efa-aff7-58770f8574cd/>.

²⁹ Millwood, *Improbable Diplomats: How Ping-Pong Players, Musicians, and Scientists Remade US-China Relations*, 293; Washington Post Foreign Service, "Soviets Assail China Visit by U.S. Scientific Delegation," The Washington Post, July 5, 1978, <https://www.washingtonpost.com/archive/politics/1978/07/06/soviets-assail-china-visit-by-us-scientific-delegation/6fc2a04c-bc87-4e05-80e9-35c653987734/>.

was taking “a calculated risk in the hope that a modernized China would help in the balance against the Soviet Union.”³⁰

For U.S.-China relations, the Press visit was most significant in laying the foundation for intergovernmental science and technology cooperation as part of broader diplomatic normalization. In October 1978, James R. Schlesinger, head of the Department of Energy (DOE) – institutional successor to the Atomic Energy Commission – led another U.S. delegation to China to continue the discussion on cooperation both in scientific fields such as high-energy physics, nuclear physics, and magnetic fusion,³¹ and in applied energy technologies.³² Schlesinger had visited China in 1976, though as a private citizen.³³ As he traveled to Beijing in 1978, he carried with him President Carter’s directive to prioritize broad-scoped energy cooperation with China.³⁴ As expected, the Chinese were “very anxious to embark now on major cooperative projects in high energy physics, nuclear physics, and magnetic fusion” and presented proposals for “exchanges of scientists and technicians” aimed at engaging U.S. assistance in “the design and fabrication of large, modern experimental facilities” to be built in China, according to Schlesinger.³⁵ But somewhat unexpectedly, they showed equally great interest in the non-fossil fuel energy technologies – such as hydro and renewables – that the United States had to offer.³⁶ Additional “side discussions” took place on nuclear energy as the Chinese “expressed an interest in exchanging delegations on nuclear energy research and development.” Schlesinger recommended to Carter on behalf of DOE that such cooperation “should be positively pursued.”³⁷

In January 1979, the foregoing exchanges and visits culminated in the U.S.-China Science and Technology Agreement. This first major post-normalization agreement between the two countries was signed by President Jimmy Carter and



Jimmy Carter and Deng Xiaoping at the White House signing ceremony, January 31, 1979 · Karl H. Schumacher / White House

³⁰ Wang, “U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond,” 254–55.

³¹ Office of Science & Technology Cooperation, Bureau of Oceans & International Environmental & Scientific Affairs, “United States – China Science and Technology Cooperation,” 11.

³² Press, “144. Memorandum From the Chairman of the Policy Review Committee (China S&T) (Press) to President Carter.”

³³ “Schlesinger Plans Visit at Invitation of Chinese,” *The New York Times*, July 26, 1978, sec. A.

³⁴ Christopher Vassallo, “A Resource History of US-China Rapprochement: An Applied History Analysis,” *Journal of Applied History* 6, no. 2 (2024): 152.

³⁵ James Schlesinger, “157. Memorandum From Secretary of Energy Schlesinger to President Carter,” Office of the Historian, U.S. Department of State, November 27, 1978, <https://history.state.gov/historicaldocuments/frus1977-80v13/d157>.

³⁶ Vassallo, “A Resource History of US-China Rapprochement: An Applied History Analysis,” 151–52.

³⁷ Schlesinger, “157. Memorandum From Secretary of Energy Schlesinger to President Carter.”

Deng Xiaoping just weeks after the establishment of diplomatic relations.³⁸ One of its first implementing accords signed on the same day formalized cooperation in high-energy physics between the U.S. Department of Energy and Chinese State Science and Technology Commission.³⁹ Panofsky attended the signing ceremony.⁴⁰ In essence, the accord created “a framework for cooperation” between the two countries’ high-energy physics research institutions, including exchanges of information and staff, with an initial focus on “accelerator design and construction.” At the center of the framework was a bilateral Committee on High Energy Physics with a mandate to “encourage contacts between scientists, universities, and laboratories” of both countries. In practice, the committee would meet annually to agree upon a roster of collaboration activities.⁴¹ The first meeting took place in Beijing in June 1979.⁴² Within just a few years, the roster had grown to include as many as 13 collaborative projects,⁴³ most of them centered on the design and construction of a large particle accelerator in Beijing.

U.S. scientists’ input shaped the project from its inception. In the late 1970s, Chinese scientists favored the construction of a proton synchrotron as the country’s first large-scale high-energy accelerator facility. U.S. scientists like Panofsky, on the other hand, urged that an electron-positron collider would be more cost-effective while enabling experiments that would contribute to the field in significant ways.⁴⁴ China’s program eventually aligned with their suggestion. An “improved version” of the SPEAR facility at SLAC, the Beijing Electron Positron Collider (BEPC), would become China’s first high-energy physics research facility.⁴⁵ In 1982, a team of Chinese scientists and engineers spent several months at SLAC developing the design of the BEPC in consultation with the lab’s engineering and physics staff. The conceptual design was sent back to China, where it was quickly approved.⁴⁶ Construction began in October 1984.⁴⁷ Deng Xiaoping personally lifted a shovel at the groundbreaking ceremony, with Panofsky at his side.⁴⁸

³⁸ Emily G. Blevins and Karen M. Sutter, “U.S.-China Science and Technology Cooperation Agreement,” December 13, 2024, <https://www.congress.gov/crs-product/IF12510>.

³⁹ “Accord Implementing Cooperation in High Energy Physics Under the Agreement on Science and Technology,” The American Presidency Project, January 31, 1979, <https://www.presidency.ucsb.edu/documents/accord-implementing-cooperation-high-energy-physics-under-the-agreement-science-and>.

⁴⁰ Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers*, 131.

⁴¹ “Accord Implementing Cooperation in High Energy Physics Under the Agreement on Science and Technology.”

⁴² James E. Leiss, “Science and Technology: Cooperation between the United States and China” (Washington, DC: U.S. Government Printing Office, October 31, 1983), 80, <https://files.eric.ed.gov/fulltext/ED242517.pdf>.

⁴³ Leiss, 7.

⁴⁴ Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers*, 131; Vera G. Lüth, “Wolfgang K.H. Panofsky: Scientist and Arms-Control Expert,” *Annual Review of Nuclear and Particle Science* 63 (2013): 12.

⁴⁵ Leiss, “Science and Technology: Cooperation between the United States and China,” 86.

⁴⁶ Leiss, 86; Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers*, 131.

⁴⁷ Wang, “U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond,” 264.

⁴⁸ Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers*, 132.



BROOKHAVEN BULLETIN

Published by the Brookhaven National Laboratory Public Relations Office



Volume 27 - Number 21

May 25, 1973

High Energy Group From China Ends Four-Day Visit

A 13-member delegation from the Scientific and Technical Association of China, who had been visiting Brookhaven Lab for the past four days, ended its visit on Friday morning.

The visit is being hosted by the Committee on Scholarly Communication with the People's Republic of China, which is jointly sponsored by the American Council of Learned Societies, Social Science Research Council and the National Academy of Sciences.

This delegation is one of the scientific groups to visit the United States agreed upon by Dr. Henry Kissinger in consultation with the People's Republic of China.

May 25, 1973 issue of the Brookhaven Bulletin documenting the visit of China's high-energy-physics delegation led by Zhang Wenyu, Brookhaven National Laboratory

Chinese Scientists Visit



Before boarding a bus for a short tour of the Lab, members of the visiting delegation posed for a picture with Brookhaven staff members.



BROOKHAVEN BULLETIN

Published by the Brookhaven National Laboratory Public Relations Office

Volume 27 - Number 22

Farewell Banquet



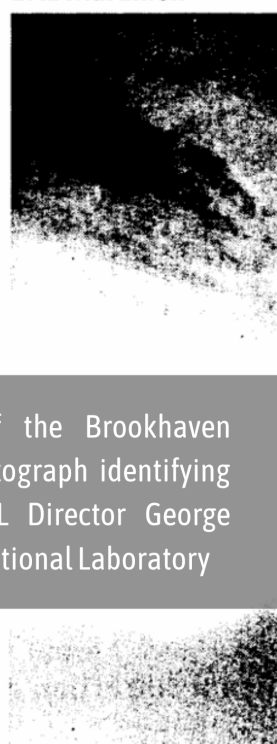
Dr. Chang Wen-Yu, Vice Director of the Institute of Atomic Energy at the Chinese Academy of Sciences, and BNL Director Dr. George Vineyard offer a toast during a farewell banquet at Berkner Hall recently. Dr. Chang headed a delegation of scientists from the People's Republic of China that spent four days at BNL meeting with scientific personnel and touring research facilities here.

New Beam Intensity Record At The AGS

On May 25, 1973, the AGS proton beam intensity reached a level in excess of 9×10^{12} protons per pulse. This achievement came toward the end of a continuous one-week accelerator study effort which was mainly devoted to commissioning a novel mode of fast beam extraction (reported elsewhere in the *Bulletin*) and the attempt to reach higher beam intensities in the AGS.

During the past seven months, the overall performance of the accelerator has been significantly improved. Compared with the previous running period, the AGS outage time due to beam loss has been reduced by approximately 40%. As a result, it became possible, during the past seven months, to prove the precise "tune-up" of both the 200 MeV linear accelerator injector and the synchrotron proper. Routinely, weekly average beam intensities of approximately 4×10^{12} protons per pulse were obtained for operation of the high energy physics program. It was evident, however, that

BNL Marathon



Walter C. Hamilton

此, 在該處此路不可計
請採用。

這件學公研再送給
研究所也給把專研計書
和建議研究報告與同時
又要把建議研究的科學
方法告訴他，這樣就使研究
者了解如自當的科學新研究，
在這時有研究所裏所設定的
題目之一。而又有許多種研
究的學者。

周昌榮

现在读与研同时并举

Zhou Enlai's September 1972 handwritten reply concerning high-energy physics research · Institute of High Energy Physics, Chinese Academy of Sciences

西堂明清 米五子 石渠
有之 方西一 清江 清江 清江



Deng Xiaoping lifting a shovel at the Beijing Electron-Positron Collider (BEPC) groundbreaking · Institute of High Energy Physics, Chinese Academy of Sciences

Cooperation intensified thereafter – coordinated by the U.S.-China Joint Committee on High-Energy Physics. Many critical components for the BEPC were purchased from the United States.⁴⁹ A small group of Chinese engineers with procurement responsibilities remained at SLAC. Panofsky, meanwhile, became a consultant for the project and made frequent trips to Beijing to resolve on-site technical issues. A “leading group” of high-ranking Party officials ensured that the project proceeded smoothly. The completed BEPC, as envisioned, laid the foundation for Chinese experimental high-energy physics research and paved the way for Chinese and American scientists to contribute jointly to the field.⁵⁰

In parallel with joint work in high-energy physics, in 1983, DOE and China’s State Science and Technology Commission signed a protocol on cooperation in nuclear physics and magnetic fusion. Similar to the 1979 implementing accord, the protocol set up a U.S.-China joint working group to facilitate programmatic lab-to-lab exchanges⁵¹ ranging from short tours and workshops to more extended research assignments.⁵² By then, DOE had already established “major bilateral fusion exchanges” with the Soviet Union, Euratom, and Japan.⁵³ The U.S. Congress had passed the Magnetic Fusion Energy Engineering Act in 1980 calling on the Secretary of Energy to “actively seek to enter into or to strengthen existing international cooperative agreements in magnetic fusion research and development activities” and to “explore, to the extent feasible, the prospects for joint financial participation by other nations with the United States in the construction of a fusion engineering device.”⁵⁴ One pathway of international cooperation was multilateral – through International Atomic Energy Agency (IAEA)-organized conferences and International Energy Agency (IEA)-coordinated fusion experiments. The other was bilateral.⁵⁵ The 1983 U.S.-China protocol on cooperation in magnetic fusion brought the two countries’ national laboratories, universities, and research institutes into extensive collaboration.⁵⁶

At the time, China’s Southwestern Institute of Physics (SWIP), having splintered from CIAE and moved to remote Sichuan to pursue fusion energy research, was finishing construction of the HL-1

⁴⁹ Leiss, “Science and Technology: Cooperation between the United States and China,” 26.

⁵⁰ Panofsky, *Panofsky on Physics, Politics and Peace: Pief Remembers*, 132–35.

⁵¹ “Di wu lun Zhong Mei zhanlüe yu jingji duihua kuangjia xia zhanlüe duihua juti chengguo qingdan,” Embassy of the People’s Republic of China in the United States of America, July 12, 2013, https://us.china-embassy.gov.cn/zmgx_1/zxxx/201307/t20130712_5057670.htm.

⁵² Leiss, “Science and Technology: Cooperation between the United States and China,” 87.

⁵³ “Status of DOE’s Implementation of The Magnetic Fusion Energy Engineering Act of 1980” (Washington, DC: U.S. General Accounting Office, April 29, 1983), 24, <https://www.gao.gov/assets/rced-83-105.pdf>.

⁵⁴ “Magnetic Fusion Energy Engineering Act,” Pub. L. No. 96–386, 94 Stat. 1539 (1980), <https://www.congress.gov/96/statute/STATUTE-94/STATUTE-94-Pg1539.pdf>.

⁵⁵ “Status of DOE’s Implementation of The Magnetic Fusion Energy Engineering Act of 1980,” 23.

⁵⁶ “Zhong Mei ciyueshu he jubian hezuo,” ITER China, August 9, 2018, <https://www.iterchina.cn/zmhz/info/2018/11120.html>; “Hejubian zhongxin chuxi di jiu jie Zhong Mei ciyueshu hejubian hezuo yantaohui,” ITER China, June 8, 2018, <https://www.iterchina.cn/zmhz/info/2018/12187.html>.

tokamak that allowed China to conduct large-scale magnetic fusion experiments.⁵⁷ U.S.-China collaboration began at the HL-1 in 1984. Thereafter, fusion scientists from both countries carried out joint experiments – starting in 1985 at UT Austin’s Texas Experimental Tokamak (TEXT), in 1994 at the Chinese Institute of Plasma Physics (ASIPP)’s HT-7, in 1997 at General Atomics’ DIII-D National Fusion Facility, and in 2002 at SWIP’s HL-2A.⁵⁸

Since early exchanges under the protocols across high-energy physics, nuclear physics, and magnetic fusion involved transfers of U.S. technology and know-how to China, the security and intellectual property (IP) implications of such transfers became an inevitable issue. In his 1983 congressional testimony, James E. Leiss, Associate Director for High Energy and Nuclear Physics at DOE’s Office of Energy Research, acknowledged that patent clauses were “the touchiest, most difficult part” of the accords that he had negotiated with the PRC. The high-energy physics accord was initially signed without a patent clause: a “patent-copyright annex” was only agreed to four-and-a-half months later. Meanwhile, talks over the patent clause of the second protocol on nuclear physics and magnetic fusion stalled for two years due to China’s lack of experience with international IP agreements and inconsistent coordination on the U.S. side.⁵⁹ For a time, cooperation in fusion research was limited to university-level exchanges pending resolution on IP issues.⁶⁰ Compromises had to be made.

However, Leiss insisted that U.S. security interests were not compromised by the exchange of people, information, and equipment between the labs. Prior to engaging with Chinese counterparts through the high-energy physics committee, DOE had consulted with other U.S. government departments including Commerce and Defense to work out technology transfer and export licensing issues. As for the exchange of personnel, Leiss underscored that Chinese visits to U.S. national laboratories, especially weapons labs such as Oak Ridge and Los Alamos where basic science and weapons research were co-located, were strictly controlled to exclude access to classified research. Moreover, both protocols, Leiss argued, involved only joint research in the basic sciences – far from practical application – and therefore did not compromise U.S. policies on nuclear transfers.

Overall, cooperation with China was expected to yield a net benefit to the United States. Once China was brought into the scientific mainstream in high-energy physics, nuclear physics, and magnetic fusion, it was expected to contribute to U.S. and broader international research in these fields through exchanges and publications. There was also the argument that cooperation with China in

⁵⁷ Kaihui He and Changchun’ Yang, “Introduction to Magnetic Confinement Fusion Research in the People’s Republic of China,” *ITER IIA Newsletter* (Vienna: International Atomic Energy Agency, November 2003), 2.

⁵⁸ H.Y. Guo and X.R. Duan, “Highlights of Major US-PRC Collaborations over Last Five Years,” March 2021, 1, https://pls.llnl.gov/sites/pls/files/2023-12/12_Guo_Duan_highlights.pdf.

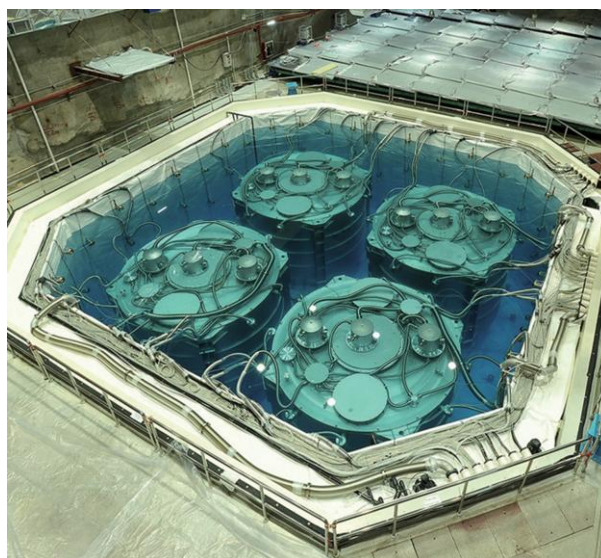
⁵⁹ Leiss, “Science and Technology: Cooperation between the United States and China,” 85, 106, 114.

⁶⁰ Robert S. Price, “A History of Sino-American Energy Cooperation,” *China Environment Series* (Washington, DC: Wilson Center, 1998), 4–5.

cutting-edge science would strengthen the basis for future high-technology trade while enhancing “mutual respect and understanding.”⁶¹

For the most part, these expectations have been fulfilled. Today, the upgraded BEPC II still serves as the “main accelerator facility” of China’s Institute of High-Energy Physics⁶² and continues functioning as a platform of international collaboration in experimental high-energy physics research.⁶³ U.S. high-energy physicists have benefited from access to the accelerator facility. In 2003, China decided to upgrade the aging BEPC to the BEPC II, adding an extra ring that allowed electrons and positrons to travel separately and collide with much higher intensity.⁶⁴ One driver of the upgrade was the launch of the CLEO-c experiment at Cornell University’s particle accelerator, the Cornell Electron Storage Ring (CESR). In 2003, the CESR was lowered to the tau-charm energy region – previously the BEPC’s exclusive niche.⁶⁵ The upgraded BEPC II with the new BES III detector was intended to overmatch the CESR and CLEO. Instead, it became CLEO’s successor. In 2008, CLEO was decommissioned as the experiment concluded and funding dried up, and the CESR was repurposed away from the study of high-energy physics.⁶⁶ U.S. researchers flocked to Beijing to continue their discovery of new physics. They found a facility that could “produce collisions at a rate more than 10 times higher than at CLEO-c.” Among the U.S. universities that joined the collaboration were Hawaii, Minnesota, Florida, Rochester, and Carnegie Mellon.⁶⁷

At the same time, the U.S. DOE and CAS’s Institute of High Energy Physics embarked on a parallel experiment at Daya Bay in the area of neutrino science. Neutrinos and their antimatter counterpart, antineutrinos, are tiny, omnipresent particles created in specific types of nuclear de-



The Daya Bay neutrino-oscillation experiment · Institute of High Energy Physics, Chinese Academy of Sciences

⁶¹ Leiss, “Science and Technology: Cooperation between the United States and China,” 86–88, 108–9.

⁶² “Beijing Electron Positron Collider (BEPCII),” Chinese Academy of Sciences, Large Research Infrastructures User Service Platform, accessed November 11, 2025, <https://lssf01.cas.cn/en/facilities-view.jsp?id=ff8080814ff56599014ff5a8f2680059>.

⁶³ Lüth, “Wolfgang K.H. Panofsky: Scientist and Arms-Control Expert,” 13.

⁶⁴ Jie Gao, “China’s Bid for a Circular Electron–Positron Collider,” CERN Courier, June 1, 2018, <https://cerncourier.com/a/chinas-bid-for-a-circular-electron-positron-collider>.

⁶⁵ Weiguo Li, “BEPCII/BESIII Upgrade and the Prospective Physics” (4th Conference on Flavor Physics and CP Violation, Vancouver, 2006), https://www.slac.stanford.edu/econf/C060409/papers/fpcp2006_WeiguoLi.pdf.

⁶⁶ Susan Newman, “CHESS Celebrates 75 Years of Synchrotron Light,” Cornell University, May 16, 2022, <https://physics.cornell.edu/news/chess-celebrates-75-years-synchrotron-light>.

⁶⁷ Kelen Tuttle, “Chasing Charm in China,” Symmetry, May 1, 2009, <https://www.symmetrymagazine.org/article/may-2009/chasing-charm-china>.

cays and high-energy collisions. Nuclear fission in reactors produces antineutrinos. The collaboration on neutrino physics at Daya Bay allowed scientists to measure one of the last key neutrino parameters, called θ_{13} , which governs the mixing between the electron flavor and the third mass state. If it could be shown that θ_{13} had a significant, non-zero value, it might help explain why the universe is made of matter instead of an equal mix of matter and antimatter.

Nuclear reactors were considered an ideal source of (anti)neutrinos for experiments that would solve this puzzle given the large number of radioactive decays taking place in their cores. But it was expensive to construct a reactor-adjacent facility that could house the huge neutrino detectors required for θ_{13} measurement. China had the funding and capability to construct the necessary infrastructure. The idea for a neutrino experiment at Daya Bay came from Wang Yifang, a Chinese high-energy physicist who began working with neutrinos while a postdoc in the United States. After spending time at MIT and Stanford, Wang moved back to China in 2001 to become a researcher at CAS's Institute of High-Energy Physics, where he was later appointed director. In the early 2000s, American scientists were encountering difficulty setting up Daya Bay-like neutrino experiments, in no small part because the United States had lost its forte in assembling large-scale scientific infrastructure. They therefore turned to their Chinese colleagues. In late 2003, Lawrence Berkeley National Laboratory scientist Kam-Biu Luk, who later became the Daya Bay neutrino experiment's U.S. lead, reached out to CAS's Institute of High Energy Physics to seek collaboration. Originally from Hong Kong, Luk knew the Daya Bay location well. The reactor units of the Daya Bay and Ling'ao nuclear power plants can produce a high volume of antineutrinos while the low mountains in which they are nestled can shield against distracting cosmic rays.⁶⁸

The project soon gained U.S. DOE support, and the Daya Bay Neutrino Experiment became the largest U.S.-China collaboration in basic sciences. The two countries co-led the experiment involving other international partners.⁶⁹ The United States ended up contributing \$35 million, covering half of the experiment's detector costs while China excavated the tunnels and underground halls that housed the detectors, bearing all civil construction costs and half the costs of the detectors.⁷⁰ Detector engineering was a collaborative effort, as were component fabrication and procurement.⁷¹ Critically, U.S. and Chinese scientists collaborated to develop the liquid scintillator that would emit light upon interacting with an antineutrino. Brookhaven National Laboratory perfected the scintillator

⁶⁸ Ling Xin, "How the Daya Bay Experiment Helped China Build a Neutrino Legacy," *Physics World*, April 21, 2021, <https://physicsworld.com/a/how-the-daya-bay-experiment-helped-china-build-a-neutrino-legacy>.

⁶⁹ Kendra Snyder, "Catching Neutrinos in China," *Symmetry* (Batavia: Fermilab/SLAC, 2006), 17.

⁷⁰ Toni Feder, "Daya Bay Experiment Revs Up," *Physics Today*, October 1, 2011, <https://physicstoday.aip.org/news/news-notes-daya-bay-experiment-revs-up>.

⁷¹ "Daya Bay Project Technical Design Report (V2)," January 22, 2008, 176–81, <http://kirkmc.d.princeton.edu/dayabay/tdr.pdf>.

“recipe”⁷² while Russia’s Joint Institute for Nuclear Research in Dubna contributed to producing the wavelength shifter for the scintillator allowing the flashes of light indicating antineutrino interactions to be detected.⁷³ The key discovery came sooner than expected. In 2012, the international team of scientists at Daya Bay reported their θ_{13} measurement.⁷⁴ This last mixing angle was not only non-zero but larger than expected. The discovery paved the way to further experiments to measure the relative masses of the neutrinos, which would in turn allow scientists to discover the reason behind the asymmetry of matter versus antimatter in the universe.

As in the high-energy physics domain, U.S. researchers have benefited from access to Chinese magnetic fusion facilities as well as high-flux reactors, neutron sources, and accelerators for irradiation experiments to study prospective fusion reactor materials.⁷⁵ From the 1990s onward, as China ramped up investment in fusion research facilities, the U.S. fusion community recognized that many remaining gaps in magnetic fusion research and development could not be addressed via experiments in U.S. facilities alone.⁷⁶ It was for this reason that the United States decided to rejoin the International Thermonuclear Experimental Reactor (ITER) program in 2003 – five years after announcing its withdrawal – about the same time China entered negotiations to become a partner in the multinational fusion advancement effort.⁷⁷ Bilaterally, the United States contributed to China’s Experimental Advanced Superconducting Tokamak (EAST) achieving first plasma in September 2006.⁷⁸ Built by ASIPP, EAST is a tokamak device known for using superconducting coils to enable long-pulse high-performance plasma, meaning it could confine the plasma for up to 1000 seconds – much longer than what other devices could achieve. To U.S. fusion researchers, EAST has offered a test bed for plasma control approaches as well as plasma-facing components, materials, and diagnostics in long-pulse steady state operation.⁷⁹ As such, the Chinese device, built on a modest \$37 million budget, has filled a critical gap for U.S. researchers.⁸⁰

⁷² Kendra Snyder, “The Daya Bay Reactor Neutrino Experiment Begins Taking Data,” Brookhaven National Laboratory, August 15, 2011, <https://www.bnl.gov/newsroom/news.php?a=111318>; Justin Eure, “National Lab Neutrino Hunters Win DOE Project Management Award,” Brookhaven National Laboratory, June 18, 2013, <https://www.bnl.gov/newsroom/news.php?a=24055>.

⁷³ “Shutdown of the Detector of the Daya Bay Reactor Antineutrino Experiment,” Joint Institute for Nuclear Research, December 11, 2020, <https://www.jinr.ru/posts/shutdown-of-the-detector-of-the-daya-bay-reactor-antineutrino-experiment/>.

⁷⁴ Paul Preuss, “Announcing the First Results from Daya Bay: Discovery of a New Kind of Neutrino Transformation,” Berkeley Lab, March 7, 2012, <https://newscenter.lbl.gov/2012/03/07/daya-bay-first-results/>.

⁷⁵ “Zhong Mei ciyueshu he jubian hezuo”; “Hejubian zhongxin chuxi di jiu jie Zhong Mei ciyueshu hejubian hezuo yantaohui.”

⁷⁶ International Collaboration Task Group, U.S. Burning Plasma Organization, “International Collaboration Opportunities for the US Fusion Sciences Program,” July 26, 2011, 3, https://fire.pppl.gov/int_collab_BPO_rpt_072811.pdf.

⁷⁷ Audrey Leath, “Abraham Announces U.S. Will Rejoin ITER,” American Institute of Physics, January 30, 2003, <https://www.aip.org/fyi/2003/abraham-announces-us-will-rejoin-iter>.

⁷⁸ U.S. Department of Energy, Office of Science, “FY 2008 Congressional Budget: Volume 4—Science, Nuclear Waste Disposal, Departmental Administration, Loan Guarantee, Working Capital Fund,” 399, accessed January 14, 2026, https://science.osti.gov/-/media/budget/pdf/sc-budget-request-to-congress/fy-2008/Cong_Budget_2008_Science.pdf.

⁷⁹ International Collaboration Task Group, U.S. Burning Plasma Organization, “International Collaboration Opportunities for the US Fusion Sciences Program,” 14–16.

⁸⁰ Dennis Normile, “Waiting for ITER, Fusion Jocks Look EAST,” *Science* 312, no. 5776 (May 19, 2006): 992–93.

Since 1979, the U.S.-China Science and Technology Agreement has served as an “umbrella” for dozens of bilateral protocols, including in energy science and technology.⁸¹ Since DOE laboratories conduct research not only in basic science and energy technologies but also in nuclear security, safeguards, and verification technologies, lab-to-lab ties established via early cooperation in high-energy physics, nuclear physics, and magnetic fusion beneficially complemented parallel nuclear security, nonproliferation, and arms control exchanges. The latter exchanges were particularly important for securing civil applications of nuclear technology in China and establishing the nonproliferation framework for China’s international civil nuclear commerce. For a time, it appeared that the exchanges would lead to extensive technical collaboration in arms control between the two countries.

⁸¹ U.S.-China Economic and Security Review Commission, “2014 Report to Congress” (Washington, DC: U.S. Government Printing Office, November 2014), 206, https://www.uscc.gov/sites/default/files/annual_reports/Complete%20Report.PDF.

Chapter 2. A brief history of lab-to-lab exchanges

In the 1980s and 1990s, China took incremental steps to align itself with international nuclear security and nonproliferation norms, which entailed the establishment of a robust nuclear material protection, control, and accounting (MPC&A) system as well as nuclear and dual-use export controls. The responsibility for developing modernized civilian nuclear safeguards fell upon CIAE, whose director, Sun Zuxun, recognized the importance of developing Chinese safeguards expertise and began encouraging activities related to safeguards in the early 1980s.⁸²

Founded as the Institute of Modern Physics under the Chinese Academy of Sciences in 1950, CIAE became one of China's nuclear weapon research laboratories as control over its activities was transferred to the Second Ministry of Machine Building during the country's sprint to the bomb.⁸³ The institute delivered the uranium hexafluoride feedstock and the neutron generator for China's first atomic bomb⁸⁴ and developed the tritium production techniques that ensured the supply of fusion fuel for China's hydrogen bombs.⁸⁵ Zhang Wenyu was the deputy director of CIAE when he first visited U.S. national labs to establish high-energy physics exchanges in 1972. Shortly after his visit, a branch of CIAE split to form the Institute of High Energy Physics under the Chinese Academy of Sciences.⁸⁶ The rest of CIAE remained under the Second Ministry of Machine Building, which morphed into the Ministry of Nuclear Industry, and then China National Nuclear Corporation (CNNC).

Formal technical cooperation between CIAE and DOE over nuclear material safeguards began with a 1984 visit by Robert Keepin, an expert in non-destructive assay (NDA) from the Los Alamos National Laboratory who pioneered physics-based nuclear safeguards at the lab and at the IAEA. Keepin had gone to China the previous year on an unofficial visit arranged by the Institute of Nuclear Materials Management at the invitation of the Chinese Nuclear Society. Accompanied by a CIAE researcher, the group of Americans traveled to Beijing, Shanghai, and Chengdu to give

⁸² George W. Eccleston, "Summary of Safeguards Interactions between Los Alamos and Chinese Scientists" (Los Alamos: Los Alamos National Laboratory, April 20, 1994), 2, https://inis.iaea.org/collection/NCLCollectionStore/_Public/25/059/25059367.pdf.

⁸³ Jingfu Zhang, "Qing lishi jizhu tamen — guanyu Zhongguo Kexue Yuan yu 'Liang Dan Yi Xing' de huiyi," 12371.cn, September 28, 2014, <https://news.12371.cn/2014/09/28/ART11411885937738939.shtml>.

⁸⁴ "Deng mi xia guo," China National Nuclear Corporation, March 5, 2022, <https://www.cnncc.com.cn/cnncc/xwzx65/zt25/hgylbq/1165473/1165478/1240906/index.html>.

⁸⁵ Tao Huang and Zhecan Zou, "Xiao Lun: wei wo guo fangshexing tongweisu shiye dianji," Tsinghua Alumni Association, May 22, 2024, <https://www.tsinghua.org.cn/info/1023/40653.htm>.

⁸⁶ "75 nian jie li Zhongguo he kexue 'yao lan' de bianqian shi," China Scientists Museum, May 19, 2025, https://mmcs.cast.org.cn/xwz/kxjrl/art/2025/art_99e88f369c1a4ae98da720e79c46bf25.html.

presentations on nuclear material control, accounting, and safeguards. Keepin's presentation on NDA instrumentation attracted particular interest from the Chinese audience.⁸⁷

The following year, DOE and CIAE initiated a formal program co-funded by the State Department “to develop nuclear measurement instrumentation and safeguards systems technologies that will help China support implementation” of the NPT. Under the arrangement, Chinese personnel were



Aerial view of Los Alamos Scientific Laboratory, c. 1964 · U.S. Department of Energy

trained through DOE's State Systems of Accounting and Control (SSAC) course as well as more extended, one-to-two-year technical rotations, chiefly at Los Alamos, where they studied NDA instrumentation and learned about IAEA safeguards and inspections. Meanwhile, U.S. experts traveled to China at CIAE's invitation to deliver lectures on these subjects and on nuclear material control and accounting.⁸⁸

The capacity-building program laid the foundation of China's civil nuclear safeguards. The first Chinese scientist who was sent on technical assignment, for 18 months, at Los Alamos under

the safeguards exchange program became the head of CIAE's newly established safeguards group upon his return in 1991. He was subsequently assigned to Vienna as a technical attaché responsible for China's liaison with the IAEA.⁸⁹ Meanwhile, CIAE facilities were voluntarily offered to the IAEA for safeguards, as was the reactor at Qinshan, where China's peaceful use agreement with Japan required safeguards application due to the pressure vessel having been supplied by Mitsubishi.⁹⁰ In setting up the State System for Accounting and Control that allowed these IAEA safeguards to be applied, CIAE had the help of Los Alamos safeguards specialists who made periodic trips to China.⁹¹

By the 1980s, Los Alamos scientists had also linked up with China's nuclear weapon research establishment organized under the China Academy of Engineering Physics (CAEP). The impetus had been a CSCPRC-sponsored visit of Chinese scientists to Los Alamos in 1978. One of the visiting scientists, Yang Fujia, had a Los Alamos connection. He and Los Alamos nuclear physicist J. Ray-

⁸⁷ William A. Higinbotham, “Foreign Trip Report,” *Journal of the Institute of Nuclear Materials Management* 12, no. 4 (1983): 20–21.

⁸⁸ Eccleston, “Summary of Safeguards Interactions between Los Alamos and Chinese Scientists,” 1.

⁸⁹ Eccleston, 2.

⁹⁰ Mark Hibbs, “Doosan May Replace MHI in Westinghouse China Bid over Japan Safeguards,” *Nucleonics Week* 47, no. 50 (December 14, 2006).

⁹¹ Eccleston, “Summary of Safeguards Interactions between Los Alamos and Chinese Scientists,” 2.

ford (Ray) Nix had studied together as postdoctoral fellows at the Institute of Theoretical Physics in Copenhagen, Denmark, a decade earlier. Yang became an academic at Fudan University and the Shanghai Institute of Nuclear Research. He also was closely connected to the Chinese nuclear weapon establishment and cultivated crucial early exchanges between CAEP and Los Alamos.

Prior to these exchanges, Chinese scientists visited Los Alamos primarily as part of civilian science and technology cooperation within the framework of the 1979 agreements. In March 1979, a Chinese Nuclear Society delegation visited the United States to establish contact with the American Nuclear Society and to visit U.S. universities and DOE national laboratories, including Los Alamos.⁹² Though known primarily for weapons work from the time of the Manhattan Project, Los Alamos was also home to advanced research in fundamental nuclear physics, fusion, and renewable energy technologies. The Chinese Nuclear Society's visit to Los Alamos in April 1979 consisted of tours and briefings centered on nuclear physics and fusion as well as nuclear safety, material safeguards, and waste management. A few months later, Los Alamos received another Chinese delegation on a renewable energy-focused mission.

Reciprocal visits inevitably brought the two countries' nuclear weapon scientists into contact. In an oral history interview, former Los Alamos director Harold Agnew recalls meeting Wang Ganchang, one of the lead scientists of China's nuclear weapon program, during his 1979 U.S. visit. Officially, Wang was the head of the Chinese Nuclear Society delegation that toured the United States in March and April of that year. But back in China, he was second-in-command of the nuclear weapons program. A physicist by training, Wang served as the deputy head of China's Institute of Modern Physics from 1950 and then the Soviet Joint Institute for Nuclear Research at Dubna from 1958. Starting in 1961, he became the deputy head of the Second Ministry of Machine Building's Ninth Institute – predecessor of the CAEP – and then as the director of CIAE.⁹³ When Wang visited the United States in 1979, he was already one of China's most senior nuclear weapon scientists. But to Agnew, Wang was plainly a fellow nuclear physicist. At a reception dinner, Wang asked Agnew what his scientific interests were. Agnew said “defense science.” Wang replied, “Oh, well, that's nice.”⁹⁴

Whereas civilian science and technology exchanges proceeded at an official institutional level from 1979 onward, the earliest exchanges on the weapons side were initially rather informal. In May 1979, Agnew visited Fudan University in Shanghai at the invitation of Yang Fujia, who was the head of the university's Department of Nuclear Science at the time. Agnew connected Yang with the head of the

⁹² Chinese Nuclear Society, “Ta yongyuan huo zai women xin zhong: jinian Wang Ganchang lishizhang danchen 100 zhounian,” *Physics* 36, no. 5 (2007): 357–60.

⁹³ “Wang Ganchang,” China Academy of Engineering Physics, accessed November 19, 2025, <https://www.caep.cn/doc/2020/01/06/499.shtml>.

⁹⁴ Interview with Harold Melvin Agnew, interview by Mary Palevsky, October 10, 2005, 37, <https://special.library.unlv.edu/ark%3A/62930/d19k4649n>.

Los Alamos Physics Division, George A. (Jay) Keyworth, who was invited to Fudan the following year to meet with Chinese scientists from CAEP. When President Reagan took office, Keyworth joined the administration and handed off the exchanges with CAEP to his successor at the Los Alamos physics department, John Browne. In 1983, Keyworth visited China as President Reagan's Science Advisor and met with then de-facto Chinese leader Deng Xiaoping, bringing the linkage between scientific ties and bilateral political relations full circle.

Agnew retired as Los Alamos director and joined the fusion company General Atomics shortly after his 1979 trip, but he maintained his Los Alamos ties – and desire to gain a better understanding of China's nuclear-weapon program. When Yang invited him back to China in 1982, Agnew agreed, but only on the condition that he be taken to the Chinese nuclear test site at Lop Nur, and Yang arranged it. Agnew was allowed to enter the testing tunnels and observe the drilling of the vertical shafts. He even took a rock sample back to Los Alamos – unusual access considering how geological information could help estimate the yields of test detonations based on seismic signals.⁹⁵

Exchanges and reciprocal visits continued through the 1980s. Following the unrest and political uncertainties of 1989, China's nuclear weapon establishment saw a pressing need to better secure the warheads and sensitive materials at defense nuclear sites. That was one of the drivers behind the institutionalized lab-to-lab activities of the next decade. In 1990, the head of the nuclear-weapon program at Los Alamos, John Hopkins, led a lab delegation to Lop Nur and the southwestern sites of the CAEP. Keyworth had introduced Hopkins to Yang when the latter visited Los Alamos in 1989. It was once again Yang who made the visit to Lop Nur possible. In addition to Hopkins and his wife, the delegation consisted of intelligence officials from Los Alamos and DOE who had spent decades analyzing China's nuclear-weapon program from afar.⁹⁶ Among them was the head of intelligence at Los Alamos, Danny B. Stillman. Earlier in his career, Stillman had been the director of a division of the lab that helped U.S. intelligence agencies analyze foreign countries' nuclear programs. He was promoted to that role in 1978 – at the time China began sending official scientific delegations to Los Alamos – and took advantage of opportunities to ask questions of the visiting Chinese scientists.⁹⁷

In 1990, Stillman went on the full tour of China's nuclear weapon sites with Los Alamos intelligence analyst Terry Hawkins and DOE head of intelligence Bob Daniels. Their intelligence background and interest were fully transparent to their Chinese hosts, who deliberately gave them access. Upon

⁹⁵ Interview with Harold Melvin Agnew, 38–39.

⁹⁶ Clay Dillingham, "Behind the Bamboo Curtain," Los Alamos National Laboratory, July 6, 2020, <https://www.lanl.gov/media/publications/national-security-science/0720-behind-the-bamboo-curtain>.

⁹⁷ Steve Coll, "The Man Inside China's Bomb Labs," The Washington Post, May 16, 2001, <https://www.washingtonpost.com/archive/politics/2001/05/16/the-man-inside-chinas-bomb-labs/7d5a0209-fe13-4394-9ff5-6bbd16538f2e/>.

seeing Hawkins and Stillman pace out the test tunnel, the accompanying Chinese general straightforwardly revealed the tunnel's length, effectively disclosing their device yields. Hopkins later recalled, "They wanted to show us what they were doing. In fact, if we didn't ask the right questions, they'd give us hints about what we should ask." The American visitors attributed the openness of the Chinese nuclear weapon establishment to a desire to show off capabilities and initiate collaboration.⁹⁸

Both objectives were accomplished. Visits from 1990 onward gave American visitors, and by extension the U.S. government, unprecedented insight into the Chinese nuclear-weapon program. Danny B. Stillman, who "visited nearly all of China's nuclear weapons facilities" during his nine trips to China as a Los Alamos intelligence official and as a private citizen, would boast, "more Americans have walked on the moon than been to the nuclear facilities and test sites I have visited in China."⁹⁹ The personal relationships he developed eventually allowed him to visit China's nuclear weapon facilities beginning in 1990. Stillman took photographs and notes, gathered names and passed the information on to U.S. intelligence agencies after each trip.¹⁰⁰

The Chinese knew that American visitors like Stillman would relay information back to the U.S. government, and they counted on it. Stillman recalls how his Chinese host repeatedly asked him to pass on their request for assistance in permissive action links – a warhead safety technology that the United States had shared with the Soviet Union as part of Cold War risk reduction. They were also interested in stockpile stewardship – the maintenance of warheads after the cessation of nuclear testing.¹⁰¹ While the U.S. government did not approve the sharing of sensitive technologies like permissive action links, it did approve safety, security, and nonproliferation exchanges with China's nuclear weapon labs in what would become known as the U.S.-China Lab-to-Lab Technical Exchange Program. Interactions between Los Alamos and CAEP during the decade prior paved the way to the program. But the most direct initiators of the program were Yang Fujia, then Los Alamos director Siegfried Hecker, and his Chinese counterpart, CAEP President Hu Side.

In February 1994, Yang, along with other scientists and senior representatives of China's nuclear-weapon program, visited Los Alamos, Lawrence Livermore, and Sandia national laboratories. Hecker made a reciprocal trip to China the following month, meeting with Yang at Fudan and traveling on to Beijing to visit CIAE and the Institute of Applied Physics and Computational Mathematics (IAPCM) – CAEP's applied theoretical research division. His interlocutors from the Chinese nucle-

⁹⁸ Dillingham, "Behind the Bamboo Curtain."

⁹⁹ "Declaration of Danny B. Stillman," Federation of American Scientists, August 15, 2001, <https://sgp.fas.org/news/2001/08/stillman.html>.

¹⁰⁰ Coll, "The Man Inside China's Bomb Labs."

¹⁰¹ Coll.



Siegfried Hecker gives Bill Clinton and Hazel O'Leary a tour of Los Alamos, 1993 · Department of Energy

ar-weapon establishment reaffirmed their desire to cooperate on stockpile stewardship, non-proliferation, and arms control.

Following his trip, Hecker drafted and presented to DOE a white paper proposing their vision of U.S.-China lab-to-lab exchanges. As Los Alamos director from 1986 through 1997, Hecker had spearheaded an analogous U.S.-Russia lab-to-lab program. Conceived after the Soviet collapse to secure Russia's nuclear weapons and sprawling defense nuclear com-

plex, the program brought U.S. and Russian scientists together to prevent nuclear dangers and develop scientific knowledge. Through his interactions with Soviet, then Russian scientists from the 1988 Joint Verification Experiment to the 1992 lab directors' exchange, Hecker came to appreciate what he would later term the "human dimension." Scientists were able to develop respect for each other's scientific work, which made it easier to build the trust necessary to tackle sensitive matters. Hence, lab-to-lab cooperation had irreplaceable value for generating understanding and overcoming mistrust in addition to the technical and scientific fruits.¹⁰²

Hecker's vision was to learn from the U.S.-Russia lab-to-lab program and adapt it to China's nuclear weapon complex. As with Russia, the primary concern was nuclear material safeguards and control. In this regard, what Hecker saw in 1994 during his visits to China's civilian and defense nuclear labs reminded him of what he saw in Russia: the facilities were at times run down, and security measures were lax at best. This primary concern aside, there was a desire on both sides to cooperate over more constructive scientific research and peaceful technology conversion. Therefore, Hecker's initial proposal for lab-to-lab cooperation recommended these areas alongside MPC&A and warhead safety and security.

¹⁰² Siegfried S. Hecker, "Lab-to-Lab Cooperative Threat Reduction," in *AIP Conference Proceedings*, vol. 1898 (Nuclear Weapons and Related Security Issues, Washington, DC, n.d.); J. Weston Phippen, "Doomed to Cooperate," Los Alamos National Laboratory, July 6, 2020, <https://www.lanl.gov/media/publications/national-security-science/0720-doomed-to-cooperate>; Siegfried S. Hecker, ed., *Doomed to Cooperate: How American and Russian Scientists Joined Forces to Avert Some of the Greatest Post-Cold War Nuclear Dangers* (Los Alamos: Bathtub Row Press, 2016).

By mid-1994, the Los Alamos proposal had expanded to include the Lawrence Livermore and Sandia National Laboratories and, in that form, gained support from key people in the Departments of Energy and State. From administration officials' perspective, helping China strengthen nuclear material safeguards and nonproliferation controls while sharing verification technologies leading up to the Comprehensive Nuclear Test Ban Treaty (CTBT) aligned with U.S. policy toward China and broader international security. As such, exchanges with Chinese labs received interagency support from the U.S. government, but with a narrower focus on nonproliferation and arms control and tighter bureaucratic oversight compared to the lab-to-lab program with Russia. Constrictions derived in part from necessary caution not to reveal information that could help China advance its weapons technology, and in part from U.S. export controls and sanctions on China that still had not been fully lifted.¹⁰³ The scope of U.S.-Russian lab-to-lab activities was never fully replicated with China because of the turmoil surrounding the publication of the congressional Cox Report in early 1999.

Nevertheless, fruitful exchanges took place within the boundaries of nonproliferation and arms control. In addition to MPC&A, the cooperative agenda included "atmospheric science related to nonproliferation and treaty verification, monitoring technologies and their application for nuclear materials processing and storage, and technical means to monitor a CTBT." A key U.S. aim was to demonstrate to CAEP that nuclear-weapon scientists and laboratories had important technical roles to play in nonproliferation and arms control, a role that CAEP had come to recognize as China took part in CTBT negotiations.¹⁰⁴ Another key objective was to foster relationships and trust.¹⁰⁵

Since cooperation touched upon non-weapon-related areas, civilian labs like CIAE became involved, particularly in the context of MPC&A work aimed at "[demonstrating] the use of modern techniques for nuclear material protection and accounting to strengthen domestic safeguards against subnational theft."¹⁰⁶ Scientists from the U.S. labs, CAEP, and CIAE conducted meetings and workshops relating to MPC&A techniques,¹⁰⁷ culminating in a joint demonstration at CIAE's Nuclear Materials Safeguards Laboratory. A bi-lingual MPC&A primer was produced as what the participants hoped would be the first in a series of joint nonproliferation and arms control publications.¹⁰⁸

¹⁰³ M. S. Di Capua, "The Cox Report and the US-China Arms Control Technical Exchange Program," in *Cox Committee Report, The: An Assessment* (Stanford: Center for International Security and Cooperation, 1999), 70–72, <https://fsi9-prod.s3.us-west-1.amazonaws.com/s3fs-public/cox.pdf>.

¹⁰⁴ Di Capua, 74.

¹⁰⁵ Nancy Prindle, "The U.S.-China Lab-to-Lab Technical Exchange Program," *The Nonproliferation Review* 5, no. 3 (1998): 111.

¹⁰⁶ Arian L. Pregenzer, "Technical Cooperation on Nuclear Security between the United States and China" (Albuquerque: Sandia National Laboratories, December 2011), 9, <https://www.osti.gov/servlets/purl/1034870>.

¹⁰⁷ Hui Zhang and Tuosheng Zhang, "Securing China's Nuclear Future" (Cambridge: Belfer Center for Science and International Affairs, March 2014), 49, https://www.belfercenter.org/sites/default/files/pantheon_files/files/publication/securingchinasnuclearfutureenglish.pdf; Nathan Busch, "China's Fissile Material Protection, Control, and Accounting: The Case for Renewed Collaboration," *The Nonproliferation Review* 9, no. 3 (2002): 99.

¹⁰⁸ Di Capua, "The Cox Report and the US-China Arms Control Technical Exchange Program," 10.

Beyond MPC&A, U.S. technical experts shared their knowledge in verification, monitoring, and export controls during bilateral workshops. Cooperation in the verification domain was aimed at building a shared understanding and mutual confidence in the CTBT's monitoring technologies. In 1997, the Los Alamos and Lawrence Livermore National Laboratories initiated a project with the IAPCM on applying atmospheric modeling techniques to trace the radionuclides that a nuclear test could release. The techniques also have utility for civilian nuclear emergency response. Following an information exchange workshop, the United States transferred its atmospheric modeling codes to Chinese partners.¹⁰⁹ Additional projects on data handling and analysis as well as on-site inspection simulations were proposed. The latter was supposed to involve the Northwest Institute of Nuclear Technology (NINT) as it was responsible for supporting China's nuclear test diagnostics before the cessation of testing. Post-CTBT, NINT would take on the implementation of technologies for test ban verification and monitoring.¹¹⁰

Meanwhile, in the cooperative monitoring category, the collaboration focused on the remote tracking of fissile material.¹¹¹ A CAEP scientist worked at Sandia National Laboratory on enhancing the Automated Tracking and Monitoring System (ATMS) for nuclear material shipments "to make enhancements for its application in China," and further workshops on the monitoring of fissile material production and storage were planned. Finally, nonproliferation cooperation extended to the export control area, where the objectives were "to strengthen export controls through involvement of the scientific nuclear community, to build technical infrastructure for export control, and to develop relevant technical expertise." Workshops on the role played by U.S. scientists and national laboratories in supporting export controls were well received particularly by CAEP as it sought to carve out a similar role for itself within China's export control system.¹¹²

According to the plans of the bilateral steering committee, the lab-to-lab exchange program past 1999 would have deepened to involve more substantive activities, including a joint MPC&A demonstration at a Chinese fuel cycle facility, a CTBT on-site inspection table-top exercise, technical work related to CTBT seismic verification, and discussions of verification under a Fissile Material Cutoff Treaty.¹¹³ But all these plans were upended by the politics surrounding the Cox Report. Formally titled the "Report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China," it alleged that China had systematically acquired sensitive U.S. nuclear and military technology over roughly two decades, largely through espionage and lax export controls. The congressional scrutiny was initially triggered by unauthorized exports of

¹⁰⁹ Pregenzer, "Technical Cooperation on Nuclear Security between the United States and China," 9.

¹¹⁰ Prindle, "The U.S.-China Lab-to-Lab Technical Exchange Program," 112–13.

¹¹¹ Prindle, 115.

¹¹² Pregenzer, "Technical Cooperation on Nuclear Security between the United States and China," 9.

¹¹³ Di Capua, "The Cox Report and the US-China Arms Control Technical Exchange Program," 75.

U.S. space and computer technology to China by U.S. defense contractors but soon expanded to suspected Chinese theft of U.S. nuclear warhead data from DOE laboratories.

These suspicions originated from classified Chinese documents that the U.S. Central Intelligence Agency received from a “walk-in” spy. While the spy was later determined to have been a double agent directed by the Chinese intelligence services, the documents were judged to contain genuine U.S. nuclear warhead data¹¹⁴ and, as such, triggered espionage investigations by the FBI and DOE. When the House created the Cox Select Committee in 1998, this prior investigative trail provided both the factual backbone and much of the drama for the committee’s narrative about alleged catastrophic security failures at the U.S. weapons labs. A Los Alamos scientist by the name of Wen Ho Lee was investigated on suspicion of espionage and indicted on 59 counts of mishandling classified information. Ultimately, the allegations of the Cox Report regarding Chinese theft of nuclear weapon technology from DOE labs were never substantiated beyond information handed over by the “walk-in,” and Lee was released with the judge’s apology and no espionage conviction. But the damage had been done.

In early 1999, following the espionage allegations, CIAE and NINT signaled they would suspend planned MPC&A and CTBT verification activities with the U.S. national labs.¹¹⁵ As the Cox Report’s espionage allegations circulated in China, CAEP reportedly faced domestic pressure. Those who took the U.S. allegations seriously came to perceive CAEP as too dependent on U.S. technology to fulfill its core national defense mission. It was this reputational injury in particular that made it difficult to resume exchanges even when the public attention surrounding the Cox Report subsided in the United States, and U.S.-China relations improved. In 2004, Hecker returned to China to resurrect the lab-to-lab program. His Chinese counterpart, Hu Side, was in favor of bringing back joint activities between the weapons labs – upon the condition that DOE acknowledge in a formal letter that past cooperation had been legal and mutually beneficial. That letter was prepared but never delivered to the Chinese due to Bush administration officials’ reservations, and exchanges between U.S. and Chinese weapons labs never resumed. However, the lab-to-lab program laid a solid foundation for subsequent civilian nuclear security and nonproliferation engagement.

¹¹⁴ Christopher Cox, “U.S. National Security and Military/Commercial Concerns with the People’s Republic of China” (Washington, DC: U.S. Government Printing Office, 1999), 83–84, <https://www.govinfo.gov/content/pkg/GPO-CRPT-105hrpt851/pdf/GPO-CRPT-105hrpt851.pdf>.

¹¹⁵ Di Capua, “The Cox Report and the US-China Arms Control Technical Exchange Program,” 75.

Chapter 3. Nuclear security and nonproliferation cooperation beyond lab-to-lab

At the intergovernmental level, U.S.-China nuclear security and nonproliferation cooperation had involved civilian labs and regulators as early as the 1990s. As China acceded to the NPT in 1992, the civilian authorities responsible for implementing China's nuclear material control and accounting obligations recognized the inadequacy of the basic system in place.¹¹⁶ Upon Chinese request “for assistance in establishing a state system for nuclear material control and accounting (MC&A) and physical protection” in 1993, the U.S. Nuclear Regulatory Commission dispatched a safeguards specialist on a “2-week lecture-tour” to China to discuss the NRC's regulatory process and responsibilities in this regard. A DOE representative went on the trip also to cover safeguards technology. The Chinese audience for the training included representatives of the Chinese civilian nuclear regulator known as the National Nuclear Safety Administration (C/NNSA), CIAE, and the National Office of Nuclear Material Control.¹¹⁷ In 1997, the NRC's Division of Fuel Cycle Safety and Safeguards conducted another workshop for C/NNSA representatives, with a “primary focus” on safeguards in the context of civil nuclear licensing and inspections.¹¹⁸ These workshops ran parallel to those under the lab-to-lab program.

While controversy surrounding the Cox Report interrupted lab-to-lab exchanges, cooperation in security and nonproliferation was able to resume between DOE and the China Atomic Energy Authority (CAEA) – an entity created to represent the Chinese government in international civil nuclear affairs in a restructuring after the Ministry of Nuclear Industry became CNNC.¹¹⁹ A driver for DOE was the U.S. government's focus on international security initiatives against nuclear and radiological terrorism following the September 11 attacks.¹²⁰ On the Chinese side, the CAEP was no

¹¹⁶ James L. Blaha, “Weekly Information Report - Week Ending September 17, 1993,” September 23, 1993, <https://www.nrc.gov/docs/ML2005/ML20057F125.pdf>.

¹¹⁷ James L. Blaha, “Weekly Information Report - Week Ending August 6, 1993,” August 11, 1993, <https://www.nrc.gov/docs/ML2005/ML20056F241.pdf>.

¹¹⁸ James L. Blaha, “Weekly Information Report - Week Ending July 18, 1997,” July 23, 1997, <https://www.nrc.gov/docs/ML9929/ML992930027.pdf>.

¹¹⁹ Wen L. Hsu, “The Impact of Government Restructuring on Chinese Nuclear Arms Control and Nonproliferation Policymaking,” *The Nonproliferation Review* 6, no. 4 (1999): 156.

¹²⁰ M. O'Brien et al., “Insider Threat Identification and Mitigation (ITIM) Training Workshops for Abrupt and Protracted Theft” (4th Russian International Conference on Nuclear Material Protection, Control and Accounting, Obninsk, 2009), 39, <https://www.osti.gov/servlets/purl/1124912>; Haibin Wang and Yun He, “Zhong Mei heneng guanxi de guoji zhengzhi jingjixue fenxi,” *International Economy and Politics*, no. 6 (2011): 143–55.

longer formally involved, and CIAE took the lead, but representatives of the defense nuclear complex continued to take part in security-oriented cooperative activities.¹²¹ On the U.S. side, the participating DOE labs included but were no longer limited to the three defense laboratories under the National Nuclear Security Administration.

In January 2004, the U.S. DOE and China's CAEA signed a statement of intent on cooperation in nuclear energy, nonproliferation, and counterterrorism. Concrete areas of cooperation included nuclear reactor, fuel, and material design; nuclear power plant safety; nuclear and radiological emergency preparedness; and export controls, in particular the identification of sensitive nuclear and dual-use material, equipment, and technology exports requiring licensing.¹²² In addition, the two sides pledged to continue international nuclear security and safeguards training and consultations, building on prior cooperation in support of IAEA programs.¹²³ Significantly, the bilateral statement of intent named radiological security as an area of cooperation, allowing the parties to implement joint projects on the physical protection and recovery of radioactive sources.¹²⁴ With the statement of intent, cooperation in nuclear security and nonproliferation formally resumed under the 1985 bilateral peaceful use agreement and 1998 U.S.-China Agreement on Cooperation in the Peaceful Uses of Nuclear Technologies (PUNT).¹²⁵ The latter was signed in June 1998 and complemented the 1985 agreement by covering "cooperation in nuclear technology and export control, nuclear and radiological safety and security, and radioactive waste management."¹²⁶

In the MPC&A domain, the U.S. National Nuclear Security Administration and China's CAEA conducted a "second joint demonstration of advanced MPC&A technology" in 2005¹²⁷ that involved "jointly designed and installed physical protection systems" at CIAE,¹²⁸ building on Los Alamos National Laboratory's MPC&A cooperation with CIAE during the 1990s. Cooperation then extended to insider threats. In 2006, the parties "agreed to jointly develop a series of workshops for Chinese personnel on how to identify and mitigate potential threats insiders may pose to Chinese nuclear

¹²¹ Zhang and Zhang, "Securing China's Nuclear Future," 50–52.

¹²² "Statement of Intent between the Department of Energy of the United States of America and the China Atomic Energy Authority of the People's Republic of China Concerning Cooperation in the Fields of Peaceful Use of Nuclear Energy and Nuclear Non-Proliferation and Counter-Terrorism," January 12, 2004, https://www.energy.gov/sites/default/files/pi_iec/098b7ef980003d4a.pdf.

¹²³ "Statement of Intent between the Department of Energy of the United States of America and the China Atomic Energy Authority of the People's Republic of China Concerning Cooperation in the Fields of Peaceful Use of Nuclear Energy and Nuclear Non-Proliferation and Counter-Terrorism."

¹²⁴ Alexander Feldman et al., "U.S.-China Radiological Source Security Project: Continuing and Expanding Bilateral Cooperation," 2009, 2, <https://www.osti.gov/servlets/purl/1122001>.

¹²⁵ "Statement of Intent between the Department of Energy of the United States of America and the China Atomic Energy Authority of the People's Republic of China Concerning Cooperation in the Fields of Peaceful Use of Nuclear Energy and Nuclear Non-Proliferation and Counter-Terrorism."

¹²⁶ "ESTH Topics," U.S. Embassy & Consulates in China, July 20, 2021, <https://china.usembassy-china.org.cn/esth-topics/>.

¹²⁷ Zhang and Zhang, "Securing China's Nuclear Future," 50.

¹²⁸ Pregenzer, "Technical Cooperation on Nuclear Security between the United States and China," 11.

facilities.” The first workshop took place in January 2008,¹²⁹ followed by another in February 2009 that expanded from one to two weeks to focus more on protracted theft and place greater emphasis on practical exercises. CIAE and the U.S. National Nuclear Security Administration jointly developed the workshop course consisting of 20 modules and 12 practical exercises, and China identified facility personnel responsible for nuclear material control and accounting as well as physical protection.¹³⁰ Between 2005 and 2011, U.S. and Chinese experts “conducted more than 15 workshops on nuclear security issues and activities.”¹³¹

In parallel with governmental cooperation, Hecker and his colleagues at Stanford University, where he became a professor in 2005, conducted Track 1.5 exchanges with China on nuclear security and nonproliferation. These exchanges built upon lab-to-lab activities but were animated by post-9/11 concerns surrounding nuclear terrorism as well as regional proliferation issues. By the mid-2000s, several U.S.-China Track 1.5 nuclear dialogues had been initiated. These included a series of U.S.-China Conferences on Arms Control, Disarmament, and Nonproliferation led by the Center for Nonproliferation Studies (CNS) at the Monterey Institute of International Studies and China Arms Control and Disarmament Association, starting from 1998, with support from private foundations and the U.S. State Department; a Dialogue on Arms Control between the Chinese Scientist Group on Arms Control and the Committee on International Security and Arms Control of the U.S. National Academies of Sciences; a China-U.S. Dialogue on Strategic Nuclear Dynamics; and a U.S.-China Strategic Dialogue in Hawaii. The latter devoted limited attention to nuclear security and nonproliferation issues, focusing overwhelmingly on questions related to nuclear weapons and strategic stability.¹³² The Stanford initiative therefore filled a critical gap in the Track 1.5 arena as inter-governmental nuclear security and nonproliferation cooperation ramped up.

From the mid-2000s, Stanford’s Center for International Security and Cooperation (CISAC) spearheaded a U.S.-China Nuclear Risk Reduction program addressing nuclear security and nonproliferation through a series of workshops and seminars. In parallel, Stanford partnered with the China Institute of International Studies (CIIS) to organize annual Conferences on Sino-U.S. Security Relations and Cooperation addressing nuclear and other strategic issues. North Korea topped the nonproliferation agenda. Track 1.5 workshops and seminars addressed the North Korean challenge alongside other regional proliferation concerns. Between 2004 and 2010, Hecker and other Ameri-

¹²⁹ Michael O’Brien et al., “US-China Cooperation: Insider Threat Identification and Mitigation Workshop” (Annual Meeting of the Institute of Nuclear Materials Management, Nashville, 2008), <https://resources.inmm.org/annual-meeting-proceedings/us-china-cooperation-insider-threat-identification-and-mitigation>.

¹³⁰ O’Brien et al., “Insider Threat Identification and Mitigation (ITIM) Training Workshops for Abrupt and Protracted Theft,” 1–3.

¹³¹ Cheryl Pellerin, “Defense, Energy Experts Aid China’s Nuclear Security,” Defense Visual Information Distribution Service, January 27, 2011, <https://www.dvidshub.net/news/514045/defense-energy-experts-aid-chinas-nuclear-security>.

¹³² Yunzhu Yao, “Taking Stock: The Past, Present, and Future of Nuclear Dialogue,” in *Taking Stock: U.S.-China Track 1.5 Nuclear Dialogue*, ed. Brad Roberts (Livermore: Lawrence Livermore National Laboratory, 2020), 11, 13, <https://cgsr.llnl.gov/sites/cgsr/files/2024-08/CGSR-US-China-Paper.pdf>.

cans made seven trips to North Korea as part of the United States' denuclearization engagement. After each trip, Hecker met with his Chinese colleagues in Beijing to assess the North Korean program. Hecker offered his observations and benefitted from Chinese insights. These meetings ultimately informed U.S. government assessments of North Korean nuclear weapon progress.

In the nuclear security domain, nuclear and radiological terrorism became a major focus of CISAC's Track 1.5 dialogues. Initial workshops saw U.S. participants discuss the 9/11 experience and DOE-led nuclear security initiatives in the post-Soviet space to alter Chinese underappreciation of non-state nuclear and radiological threats. U.S. subject-matter experts shared analytical and forensic approaches for evaluating these threats with IAPCM and CNNC. These technical exchanges carried on for nearly two decades,¹³³ during which they complemented governmental initiatives.

During a 2005 visit to IAPCM, Hecker suggested anti-terrorism cooperation in the lead-up to the 2008 Beijing Summer Olympics. The following year, under the Global Threat Reduction Initiative (GTRI), DOE's National Nuclear Security Administration and CAEA initiated a radiological security program with an "initial scope ... focused on securing potentially vulnerable radiological sources in the run-up to the 2008 Beijing Olympic Games." Participants included the Los Alamos, Sandia, and Oak Ridge National Laboratories on the U.S. side, and the State Environmental Protection Administration (SEPA), CIAE, and "other associated provincial government agencies" on the Chinese side.¹³⁴

In late 2006 and early 2007, the two sides met to review the GTRI's radiological security efforts surrounding the 2004 Olympics in Athens and develop a pilot project to demonstrate analogous efforts to secure and remove radiological sources around Beijing.¹³⁵ The task of upgrading physical protection for high-activity sources close to Olympic venues was assigned to the first working group led by Sandia and CIAE. The working group developed plans for upgrading source security and organized training on the analysis of security threats and physical protection systems. Meanwhile, the second working group led by Los Alamos, Oak Ridge, and SEPA focused on removing disused radiological sources and organized training on transport security. Subsequently, Sandia and Los Alamos National Laboratories hosted additional training workshops in the security of radiological sources. In September 2007, the two sides agreed to expand the pilot project to additional Olympic sites in Qingdao and Tianjin. In the end, cooperation led to "physical protection upgrades at 11 facilities at eight sites totaling over 7,000,000 curies" and "the removal of a large amount of disused sources from 22 sites

¹³³ Larry Brandt, Jason Reinhardt, and Siegfried Hecker, "Structuring Cooperative Nuclear Risk Reduction Initiatives with China," January 2017.

¹³⁴ Daniel Chong et al., "China Radiological Security Cooperation in Preparation for the 2008 Beijing Olympic Games" (Annual Meeting of the Institute of Nuclear Materials Management, Nashville, 2008), 2, https://osrp.lanl.gov/Documents/LAURS_Documents%20Page/LAUR-08-3098.pdf.

¹³⁵ Chong et al., 2.

totaling over 32,000 curies,” in addition to the diffusion of radiological security best practices in China.¹³⁶ And it created the precedent based on which the GTRI, CAEA, and SEPA’s successor, the Ministry of Environmental Protection, expanded cooperation in radiological security to other places in China. With the deepening of trust, the U.S. side received increasingly more detailed facility briefings, turning the cooperative mechanism into “an effective confidence building measure.”¹³⁷ Training also expanded to local operators and regulators in “about half of China’s provinces” by 2009.¹³⁸

Parallel to cooperation in radiological security within China, DOE engaged Chinese customs and border protection agencies to cooperate in port monitoring against the illicit trafficking of nuclear and radioactive materials. If the protection, control, and accounting of these materials may be considered the first line of defense, then the monitoring of their illicit trafficking would constitute the “second line of defense” in DOE’s programmatic terminology. In the late 1990s, DOE set up the Second Line of Defense (SLD) program with an initial focus on helping Russia and other states of the former Eastern Bloc monitor the smuggling of nuclear materials.¹³⁹ As SLD partnerships expanded globally after the September 11 attacks, the program morphed into the Office of the Second Line of Defense.¹⁴⁰ When DOE’s National Nuclear Security Administration launched the Megaports Initiative to “deter, detect, and interdict nuclear or other radiological materials smuggled through foreign seaports” in 2003, the office oversaw efforts to train foreign screening personnel and equip them with radiation detection devices. A sustainability program ensured that the partner country could autonomously operate and maintain the equipment.¹⁴¹

U.S.-China cooperation in these areas took place against the background of broader Chinese participation in the United States’ global counterterrorism initiatives in the aftermath of the September 11 attacks.¹⁴² Prior to the Megaports Initiative, Chinese Customs had cooperated in seaport security with the U.S. Bureau of Customs and Border Protection (CBP) under the Container Security Initiative (CSI) responding to concerns that terrorists might “smuggle weapons of mass destruction in the 7 million ocean containers that arrive annually at U.S. seaports.” Announced in January 2002, CSI sought to place CBP staff at foreign seaports to screen for high-risk containers.¹⁴³ Later that year, China accepted the presence of U.S. customs personnel at its largest ports in Shanghai and Yantian,

¹³⁶ Chong et al., 3–6.

¹³⁷ Feldman et al., “U.S.-China Radiological Source Security Project: Continuing and Expanding Bilateral Cooperation,” 3–4.

¹³⁸ Feldman et al., 5.

¹³⁹ U.S. General Accounting Office, “U.S. Efforts to Help Other Countries Combat Nuclear Smuggling Need Strengthened Coordination and Planning” (Washington, DC: U.S. General Accounting Office, May 2002), 6–7, <https://www.gao.gov/assets/gao-02-426.pdf>.

¹⁴⁰ Reema Verma, “20 Years Later: Celebrating the Office of Nuclear Smuggling Detection & Deterrence,” *DNN Sentinel*, February 2020.

¹⁴¹ U.S. General Accounting Office, “Megaports Initiative Faces Funding and Sustainability Challenges” (Washington, DC: U.S. General Accounting Office, October 2012), 5–9, <https://www.gao.gov/assets/gao-13-37.pdf>.

¹⁴² “U.S., China Stand Against Terrorism,” White House, October 19, 2001, <https://georgewbush-whitehouse.archives.gov/news/releases/2001/10/20011019-4.html>.

¹⁴³ U.S. General Accounting Office, “Expansion of Key Customs Programs Will Require Greater Attention to Critical Success Factors” (Washington, DC: U.S. General Accounting Office, July 2003), <https://www.gao.gov/assets/gao-03-770.pdf>.

which together accounted for some 8% of all cargo containers bound for the United States.¹⁴⁴ Co-operation was formalized through a July 2003 Declaration of Principles.¹⁴⁵

On the other hand, partnership under the Megaports Initiative was established by a September 2005 statement of intent, followed by a November Memorandum of Understanding (MoU), between DOE and China's customs and border protection agencies.¹⁴⁶ The U.S. National Nuclear Security Administration agreed to offer DOE-funded technical assistance, including equipment, training, and services, to enhance the detection of trafficking in weapons-usable nuclear and radiological materials at select Chinese seaports.¹⁴⁷ Between February 2006 and May 2007, the U.S. and Chinese counterparts held five rounds of technical talks on the 11 annexes of the MoU on countering nuclear and radioactive smuggling. Agreement on all 11 annexes marked the start of substantive cooperation under the Megaports Initiative.¹⁴⁸ Shanghai's Yangshan Port was selected as the pilot site. In December 2011, the Megaports Initiative pilot project was inaugurated at Yangshan – the fortieth seaport to join the U.S.-led global radioactive smuggling detection network.¹⁴⁹

By then, the Obama administration had launched the multilateral Nuclear Security Summits and bilateral U.S.-China Strategic & Economic Dialogue (S&ED), providing high-level impetus for strengthening counter-nuclear smuggling cooperation.¹⁵⁰ In early 2011, during Chinese President Hu Jintao's visit to Washington, DC, DOE and Chinese Customs signed an additional MoU agreeing to establish a Radiation Detection Training Center in China.¹⁵¹ DOE's National Nuclear Security Ad-

¹⁴⁴ U.S. General Accounting Office, 5–19.

¹⁴⁵ “Memorandum of Understanding among the General Administration of Customs, the General Administration of Quality Supervision, Inspection, and Quarantine of the People's Republic of China and the Department of Energy of the United States of America Concerning Cooperation to Prevent the Illicit Trafficking in Nuclear and Other Radioactive Material,” November 19, 2005, https://www.energy.gov/sites/default/files/pi_iec/098b7ef980003d53.pdf.

¹⁴⁶ “Joint Statement of Intent by the Department of Energy of the United States of America and the Customs General Administration, the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China Concerning Exploration of Cooperation in Nuclear and Other Radioactive Material Detection,” September 2, 2005, https://www.energy.gov/sites/default/files/pi_iec/098b7ef980003d35.pdf.

¹⁴⁷ “Memorandum of Understanding among the General Administration of Customs, the General Administration of Quality Supervision, Inspection, and Quarantine of the People's Republic of China and the Department of Energy of the United States of America Concerning Cooperation to Prevent the Illicit Trafficking in Nuclear and Other Radioactive Material.”

¹⁴⁸ “Zhong Mei jiu ‘Te Daxing Gangkou Jihua’ Hezuo Liangjie Beiwanglu fujian dacheng yizhi,” Ministry of Foreign Affairs of the People's Republic of China, June 6, 2007, https://www.mfa.gov.cn/wjb_673085/zzjg_673183/gjs_673893/xwlb_673895/200706/t20070606_7650545.shtml.

¹⁴⁹ Xinhua News Agency, “Xinhua: China, U.S. Start Megaports Initiative Pilot Project to Boost Cargo Security,” Embassy of the People's Republic of China in the United States of America, December 7, 2011, https://us.china-embassy.gov.cn/eng/zmgx/zxxx/201112/t20111208_4907352.htm.

¹⁵⁰ “Di er lun Zhong Mei Zhanlüe Yu Jingji Duihua kuangjia xia zhanlüe duihua chengguo qingdan,” Ministry of Foreign Affairs of the People's Republic of China, May 26, 2010, https://www.mfa.gov.cn/web/ziliao_674904/zt_674979/ywzt_675099/2010nzt_675437/zmzldh_675481/201005/t20100526_9285601.shtml.

¹⁵¹ “Memorandum of Understanding between the Department of Energy of the United States of America and the General Administration of Customs of the People's Republic of China for Cooperation in Jointly Establishing the Radiation Detection Training Center of China Customs,” January 19, 2011, https://www.energy.gov/sites/default/files/pi_iec/098b7ef98002bde3.pdf; “Fact Sheet: U.S., China Partner to Counter Nuclear Smuggling,” White House, January 19, 2011, <https://obamawhitehouse.archives.gov/realitycheck/the-press-office/2011/01/19/fact-sheet-us-china-partner-counter-nuclear-smuggling>.

ministration agreed to supply training materials and equipment. Chinese Customs would operate the training center. The training curriculum would be determined through consultations within the scope of WMD, radiation protection, radioactive material transport and smuggling, and emergency response.¹⁵² In September 2012, the training center was commissioned in the Chinese port city of Qinhuangdao.¹⁵³

For Chinese Customs, with its lack of radiation detection experience, the center filled a key gap in “nuclear security training and capacity building.”¹⁵⁴ Additionally, since the first Asia-Pacific Workshop in January 2014, the center has become a regional hub for customs training and experience sharing in the area of countering nuclear and radioactive smuggling.¹⁵⁵ By the fourth Nuclear Security Summit in 2016, Chinese Customs and DOE had co-hosted as many as 47 training courses at the Qinhuangdao center. The courses covered radiation detection as well as commodity identification training (CIT) for nonproliferation export controls.¹⁵⁶ Cooperation on the latter was formalized by a separate statement of intent between DOE and Chinese Customs in 2016, which envisioned “the development of GACC trainers and a tailored curriculum of CIT for nonproliferation export control, including developing and supplying accompanying guidelines, materials and toolsets” to “front-line Customs officers.”¹⁵⁷ This separate track built upon two decades of U.S. efforts to help China enhance its export control regulation and enforcement capacity.

As previously noted, the Clinton administration considered China’s institutionalization of nuclear and dual-use export controls to be one of the conditions for implementing the bilateral peaceful use agreement of 1985. The Chinese export control challenge was deeply rooted in its economic reform and opening. In the 1980s, under Deng Xiaoping’s leadership, China began moving toward a mixed market economy with a prominent export focus. Around the same time, the slashing of state defense contracts and subsidies combined with the explicit policies of military-civil integration and military-civilian conversion compelled the country’s defense industry to shift production capacity toward the civilian sector. Enterprises under pressure to survive saw opportunities in the export of nuclear and nuclear dual-use goods and technologies. Chinese authorities, however, lacked experience in imple-

¹⁵² “Memorandum of Understanding between the Department of Energy of the United States of America and the General Administration of Customs of the People’s Republic of China for Cooperation in Jointly Establishing the Radiation Detection Training Center of China Customs.”

¹⁵³ Xinhua News Agency, “China Pledges Further Nuclear Cooperation with U.S. in Customs Control,” People.cn, April 1, 2016, <https://en.people.cn/n3/2016/0401/c90883-9038827.html>.

¹⁵⁴ Bin Zhao, “The Practice and Exploration of Nuclear Security Education and Capacity Building about China Customs” (International Conference on Nuclear Security, Vienna, 2020), <https://conferences.iaea.org/event/181/contributions/15431/contribution.pdf>.

¹⁵⁵ “A/P Region Workshop on Radiation Detection Technology,” World Customs Organization Asia/Pacific, June 27, 2014, <https://www.wcoasiapacific.org/index.php/news/313-asia-pacific-region-workshop-on-radiation-detection-technology>.

¹⁵⁶ Qiaosu Zhang, “Zhong Mei hezuo daji he cailiao feifa fanyun qude jiji chengguo,” Xinhua Net, April 1, 2016.

¹⁵⁷ “Statement of Intent between the Department of Energy of the United States of America and the General Administration of Customs of the People’s Republic of China for Cooperation in the Field of Commodity Identification Training for Nonproliferation Export Control,” March 17, 2016, https://www.energy.gov/sites/default/files/pi_iec/098b7ef9800d4a41.pdf.

menting structured and coordinated controls over growing volumes of exports. After all, Beijing only endorsed nonproliferation in principle in the mid-1980s. It was not until 1992 that China acceded to the NPT. The Chinese government traditionally perceived international export controls as discriminatory and restrictive while its own controls were implemented via internal administrative mechanisms. This system was manageable when the state monopolized most sensitive industries and when export activities were limited. But as China transitioned to a market economy, and free-acting enterprises increasingly exported sensitive, dual-use items, existing control mechanisms became inappropriately rudimentary and opaque.¹⁵⁸ That, in turn, directly impacted Washington's willingness to endorse civil nuclear cooperation with China that would inevitably involve the transfer of nuclear and nuclear dual-use materials, equipment, and technology.

U.S. concerns were based upon reports of unsafeguarded Chinese nuclear and dual-use exports to risky destinations. In the early 1980s, the Chinese National Chemicals Importing and Exporting Corporation (Sinochem) reportedly sold large quantities of heavy water to a West German middleman, Alfred Hempel, who then passed the material onward to Argentina and India. At the time, the United States suspected that Argentina might pursue a covert nuclear weapon program after its defeat in the Falklands War.¹⁵⁹ The U.S. intelligence community judged that a heavy water-moderated plutonium production reactor could help Argentina acquire the weapons-grade nuclear material it needed to produce a bomb and, in that context, became concerned about the unsafeguarded transfer of Chinese-origin heavy water.¹⁶⁰ India, meanwhile, had conducted a "peaceful nuclear explosion" in 1974. That device used plutonium produced in a research reactor supplied by Canada, using U.S.-supplied heavy water. These incidents were not alone. In the same period, China was also suspected of transferring 30-45 tons of enriched uranium to Argentina and another 60 tons to South Africa, which was pursuing nuclear weapon capabilities at the time.¹⁶¹ The Chinese government denied these reports. But there was no doubt about a lack of due diligence in export controls on Beijing's part.

In this context, the Chinese government's endorsement of nonproliferation and acceptance of IAEA safeguards as a condition of future nuclear exports during negotiations with the United States over the 1985 bilateral peaceful use agreement was a major step forward. But the country still lacked a legal and regulatory framework for nuclear export controls and, for a time, refused to join such mul-

¹⁵⁸ Evan S. Medeiros, *Chasing the Dragon: Assessing China's System of Export Controls for WMD-Related Goods and Technologies* (Santa Monica: RAND Corporation, 2005), 10–13.

¹⁵⁹ William P. Clark, "400. Memorandum From the President's Assistant for National Security Affairs (Clark) to President Reagan," Office of the Historian, U.S. Department of State, October 5, 1982, <https://history.state.gov/historicaldocuments/frus1981-88v13/d400>.

¹⁶⁰ Director of Central Intelligence, "Argentina's Nuclear Policies in Light of the Falklands Defeat," SNIE 91-2-82, September 8, 1982, <https://nsarchive2.gwu.edu/nukevault/ebb423/docs/5A.%20argentina%201982.pdf>.

¹⁶¹ Jack Anderson, "CIA Says China Has Sent A-Fuel to South Africa," *Washington Post*, July 23, 1981, sec. B; George Lardner and Don Oberdorfer, "China Was Source of Atomic Fuel for South Africa, U.S. Believes," *The Washington Post*, November 19, 1981, <https://www.washingtonpost.com/archive/politics/1981/11/19/china-was-source-of-atomic-fuel-for-south-africa-us-believes/019e05fb-d053-41e7-bc5b-16cb02045624/>.

tilateral export control arrangements as the Zangger Committee and the Missile Technology Control Regime (MTCR). Its transfers of sensitive nuclear and missile technologies to Pakistan and Iran continued, prompting Washington to pressure Beijing to comply with international export control norms. U.S. pressure proved effective. In 1991, China joined the other members of the UN Security Council to commit to developing more concrete guidelines restricting the sale of conventional weapons to the Middle East and to harmonize their controls over the transfer of CBRN weapons technology to the region.¹⁶² When China continued to export missiles to Pakistan, U.S. sanctions compelled Beijing to pledge compliance with MTCR guidelines,¹⁶³ leading to the cancellation of missile deals with Iran and Syria.¹⁶⁴

In 1996, it was revealed that CNNC had sold 5,000 ring magnets – a critical component of gas centrifuges for uranium enrichment – to Pakistan’s A.Q. Khan Research Laboratory. The CIA claimed that the sale was “probably” approved by the Chinese government. The Department of Defense concurred. However, other U.S. government officials were satisfied, after engaging their Chinese counterparts, that the Chinese Foreign Ministry had no knowledge of the sale, which was a result of China’s defense sector contravening the wishes of policymakers in Beijing to continue aiding a longstanding regional ally.¹⁶⁵ On May 10, 1996, the U.S. State Department announced that no sanctions would be imposed on China and Pakistan over the ring magnet sale. In return, China promised to limit future transfers to safeguarded nuclear facilities only and engage in consultations with the United States on export controls and nonproliferation.¹⁶⁶ To the U.S. administration, the best way to prevent future unauthorized nuclear transfers out of China was working with Beijing to improve its export control regulations and enforcement.¹⁶⁷

As Washington hoped, the ring magnet incident highlighted to Beijing the inadequacy of its export control system based on internal administrative rules and informal control lists, particularly for dual-use items. U.S. officials therefore found a receptive audience as they pressed their Chinese counterparts to formalize their export control regulations.¹⁶⁸ Rounds of U.S.-China high-level meetings in 1996 and 1997 addressed how China might better control its nuclear and dual-use exports.¹⁶⁹ Beijing

¹⁶² Alan Riding, “5 Powers Will Seek Ban On Major Mideast Arms,” *The New York Times*, July 10, 1991, sec. A.

¹⁶³ Deborah A. Ozga, “A Chronology of the Missile Technology Control Regime,” *The Nonproliferation Review* 1, no. 2 (1994): 78.

¹⁶⁴ Ethan Meick, “China’s Reported Ballistic Missile Sale to Saudi Arabia: Background and Potential Implications,” June 16, 2014, 4, https://www.uscc.gov/sites/default/files/Research/Staff%20Report_China%27s%20Reported%20Ballistic%20Missile%20Sale%20to%20Saudi%20Arabia_0.pdf.

¹⁶⁵ Mark Hibbs, “U.S.-China Cooperation Closer as China Scales Back Pakistan Aid,” *Nucleonics Week* 37, no. 42 (October 17, 1996).

¹⁶⁶ Shirley A. Kan, “China and Proliferation of Weapons of Mass Destruction and Missiles: Policy Issues” (Washington, DC: Congressional Research Service, February 22, 2005), 3, <https://www.justice.gov/file/267406/dl?inline>; Norman Kempster, “Nuclear Pledge by China Averts U.S. Sanctions,” *Los Angeles Times*, May 11, 1996, <https://www.latimes.com/archives/la-xpm-1996-05-11-mn-2936-story.html>.

¹⁶⁷ Hibbs, “U.S.-China Cooperation Closer as China Scales Back Pakistan Aid.”

¹⁶⁸ Medeiros, *Chasing the Dragon: Assessing China’s System of Export Controls for WMD-Related Goods and Technologies*, 16–17.

¹⁶⁹ Mark Hibbs, Kathleen Hart, and Wilson Dizard, “U.S.-China Talks on Nuclear Export Controls to Resume in Washington,” *Nuclear Fuel* 21, no. 22 (October 21, 1996).

followed through and took substantive steps to improve the country's domestic export control regulations and enforcement in accordance with U.S. experts' advice.¹⁷⁰ Building on its 1987 Customs Law that granted Customs the authority to inspect exported cargo and enforce controls¹⁷¹ and 1994 Foreign Trade Law that granted the state explicit authority to compile, update, and publish export control lists and issue export licenses,¹⁷² the Chinese government promulgated the Regulations on Nuclear Export Control in 1997, the year China joined the Zangger Committee, and analogous regulations on nuclear dual-use items and technologies in 1998. Apart from explicit control lists, the regulations introduced end-use and end-user controls, including certificates and guarantees, the latter referring to the end-user's guarantee not to divert controlled items from authorized end-uses, for nuclear explosive purposes, or for fuel cycle activities outside IAEA safeguards, and not to retransfer the items to third parties without Chinese government consent. Mirroring U.S. practice, the license is reviewed primarily by the Ministry of Commerce, known before 2003 as the Ministry of Foreign Trade and Economic Cooperation, with interagency consultations involving the CAEA and Ministry of Foreign Affairs.¹⁷³ These improvements in Chinese export control behavior were pivotal to the Clinton administration's certification of China's nonproliferation policies and practices that allowed the 1985 bilateral peaceful use agreement to be implemented. They also marked a significant milestone in China's evolution from a country that explicitly rejected nonproliferation controls to one that embraced public, multilaterally harmonized control lists and export control regulations.

With regulations in place, subsequent cooperation focused on compliance training, administration, and enforcement capacity building. During the October 1997 session of the Joint Commission on Commerce and Trade (JCCT) in Beijing, the U.S. and Chinese governments agreed to initiate dual-use export-control technical exchanges, the first of which took place in 1998. The U.S. bombing of the Chinese embassy in Belgrade caused a brief hiatus.¹⁷⁴ In October 2000, cooperation resumed with the first ever export control seminar for U.S. and Chinese businesses to be jointly organized by the Bureau of Export Administration under the U.S. Department of Commerce and China's Ministry of Foreign Trade and Economic Cooperation.¹⁷⁵ The Bureau of Export Administration would be renamed the Bureau of Industry and Security (BIS) in 2002 whereas the Ministry of Foreign Trade

¹⁷⁰ Mark Hibbs and Michael Knapik, "U.S. Aims for China Certification Timed with Fall Visit by Jiang," *Nuclear Fuel* 22, no. 15 (July 28, 1997).

¹⁷¹ "Zhonghua Renmin Gongheguo Haiguan Fa," China Export Control Information, December 30, 2021, <http://exportcontrol.mofcom.gov.cn/article/zcfg/gnzcfcg/flfg/202111/233.html>.

¹⁷² William Clinton, "Letter to Congressional Leaders on the China-United States Nuclear Cooperation Agreement," The American Presidency Project, January 12, 1998, <https://www.presidency.ucsb.edu/documents/letter-congressional-leaders-the-china-united-states-nuclear-cooperation-agreement>.

¹⁷³ "Regulations of the People's Republic of China on Control of Nuclear Dual-Use Items and Related Technologies Export," China Atomic Energy Authority, July 11, 2017, <https://www.caea.gov.cn/english/n6759372/c6793480/content.html>.

¹⁷⁴ U.S. Department of Commerce Bureau of Export Administration, "BIS Annual Report," accessed November 23, 2025, <https://www.bis.doc.gov/index.php/documents/policy-guidance/926-bis-annual-report-fy-2000/file>.

¹⁷⁵ U.S. Department of Commerce Bureau of Export Administration, "Export Administration Annual Report Fiscal Year 2001," January 2002, <https://www.bis.doc.gov/index.php/documents/policy-guidance/925-bis-annual-report-fy-2001/file>.

and Economic Cooperation was absorbed into the Chinese Ministry of Commerce (MOFCOM). Even in the 2000s, the division within MOFCOM's Science and Technology Department that was responsible for administering dual-use export controls suffered a shortage of staff and expertise. Likewise, Chinese Customs lacked the personnel, equipment, and experience necessary to enforce WMD export controls.¹⁷⁶ Joint training seminars with the U.S. Department of Commerce therefore filled an important gap. Participants included officials from the Chinese Ministry of Commerce as well as Customs and CAEA.¹⁷⁷

In addition to joint training and outreach, BIS and MOFCOM's Department of Science and Technology maintained regular dialogue in export controls under the JCCT. It was through this channel that BIS encouraged MOFCOM's cooperation on the issue of end-use checks for verifying that U.S. export-controlled items had not been diverted from their licensed use in China.¹⁷⁸ In April 2004, BIS and MOFCOM reached an agreement "on procedures to strengthen end-use visit cooperation," which was expected not only to increase confidence in compliance with U.S. controls in China¹⁷⁹ but also to fast-track the processing of licenses for controlled dual-use exports to China.¹⁸⁰

Months earlier, in January 2004, CAEA had signed its Statement of Intent with DOE envisioning cooperation in nuclear and nuclear dual-use export controls, in particular "the development of cooperative exchanges and programs on the licensing of nuclear materials, equipment, technology and related dual-use items, and identifying nuclear and nuclear-related dual-use exports."¹⁸¹ DOE would subsequently sponsor training under its International Nonproliferation Export Control Program (INECP) for Chinese export control licensing and customs enforcement officials, including training in commodity identification and interdiction. DOE and CAEA would also go on to jointly develop technical guides on export-controlled nuclear and nuclear dual-use items to enhance Chinese license evaluation capacity.¹⁸²

In May 2004, China joined the Nuclear Suppliers Group (NSG) with the U.S. government's blessing. Although some lawmakers in Washington raised concerns with the Bush administration's support of

¹⁷⁶ Medeiros, *Chasing the Dragon: Assessing China's System of Export Controls for WMD-Related Goods and Technologies*, 23–24, 32.

¹⁷⁷ Medeiros, 32–33.

¹⁷⁸ Terence P. Stewart, "China's Compliance with World Trade Organization Obligations: A Review of China's 1st Two Years of Membership" (Washington, DC: U.S.-China Security and Economic Review Commission, March 19, 2004), 123, <https://www.uscc.gov/sites/default/files/Research/china%20compliance%20with%20wto%20obligations%20first%20two%20years.pdf>.

¹⁷⁹ U.S. Department of Commerce Bureau of Industry and Security, "Bureau of Industry and Security Annual Report for Fiscal Year 2004," accessed November 23, 2025, <https://www.bis.doc.gov/index.php/documents/policy-guidance/922-bis-annual-report-fy-2004/file>.

¹⁸⁰ U.S. Department of Commerce Bureau of Industry and Security, "Bureau of Industry and Security Annual Report for Fiscal Year 2005," 2, accessed November 23, 2025, <https://www.bis.doc.gov/index.php/documents/policy-guidance/921-bis-annual-report-fy-2005/file>.

¹⁸¹ "Statement of Intent between the Department of Energy of the United States of America and the China Atomic Energy Authority of the People's Republic of China Concerning Cooperation in the Fields of Peaceful Use of Nuclear Energy and Nuclear Non-Proliferation and Counter-Terrorism."

¹⁸² Patricia McNerney, "China's Nonproliferation Practices," U.S. Department of State, May 20, 2008, <https://2001-2009.state.gov/t/isn/rls/rm/105084.htm>.

China's membership – pointing in particular to China's agreement earlier that month to supply Pakistan with a second nuclear reactor – senior officials from the State Department defended the decision. Assistant Secretary of State for Nonproliferation John S. Wolf spoke for the administration as he argued that China was on a positive nuclear nonproliferation trajectory. Beijing had essentially halted its nuclear engagement with Tehran, most notably canceling the sale of two 300MW power reactors and a turn-key uranium conversion plant. It had also been a cooperative member of the Zangger Committee since joining in 1997. To the Bush administration, NSG membership would place China under further pressure to align with international nuclear export control norms¹⁸³ since it implied higher standards predicated on full-scope safeguards. There would continue to be controversy surrounding whether it was appropriate for China to indefinitely grandfather its civil nuclear cooperation with Pakistan, where full-scope safeguards do not apply. But by and large, there were no more reports of Chinese nuclear transfers to unsafeguarded programs – in Pakistan or elsewhere.

As China became a member of the NSG, the U.S. and Chinese governments conducted what the State Department characterized as “the first comprehensive export control talks since the late 1990s.” The talks focused on “general export licensing, implementation, enforcement and industry outreach” and concluded with a nuclear-focused export control workshop in May 2004. A follow-on workshop for technical experts was held in December. Speaking at the opening of the workshop, the deputy head of the Chinese Foreign Ministry's arms control department acknowledged the “close and fruitful dialogue and cooperation on non-proliferation issues” between China and the United States and expressed hope that such cooperation might expand.¹⁸⁴ U.S. participants at the meetings observed a serious willingness on the Chinese part to learn and improve their export control practices. Then Assistant Secretary of State for Arms Control Stephen G. Rademaker recalled regarding the May dialogue that “the Chinese delegation admitted to some shortcomings and proposed to institutionalize regular consultations and exchanges between counterpart agencies.”¹⁸⁵ He noted further that Chinese attendees had “asked thoughtful questions that demonstrated they were listening to and thinking carefully about the issues” in all the export control meetings and workshops.¹⁸⁶ With these developments, export controls increasingly transformed from a hindrance to U.S.-China civil nuclear cooperation and high-technology trade to an item on the cooperative agenda.

¹⁸³ Wade Boese, “Congress Questions U.S. Support for China Joining Nuclear Group,” Arms Control Association, June 1, 2004, <https://www.armscontrol.org/act/2004-06/congress-questions-us-support-china-joining-nuclear-group>.

¹⁸⁴ Zhixian Liu, “Dangqian fang kuosan lingyu mianlin de tiaozhan — Junkong Si Fu Sizhang Liu Zhixian zai Zhong Mei he chukou kongzhi yantaohui shang de fayan,” Ministry of Foreign Affairs of the People's Republic of China, December 15, 2004, https://www.fmprc.gov.cn/wjbxw_673019/200412/t20041215_363924.shtml.

¹⁸⁵ Stephen G. Rademaker, “Remarks to U.S.-China Economic and Security Review Commission,” U.S. Department of State, March 10, 2005, <https://2001-2009.state.gov/t/ac/rls/rm/43277.htm>.

¹⁸⁶ Rademaker.

Thanks to decades of cooperation in MPC&A, radiological security, detection of nuclear and radioactive smuggling, and export controls, the United States and China had established extensive bilateral nuclear security and nonproliferation cooperation when President Barack Obama announced the launch of the Nuclear Security Summit process in 2009. The multilateral initiative to advance nuclear security globally only deepened their partnership. One reflection of the partnership was the joint nuclear security Center of Excellence (COE). At the inaugural Nuclear Security Summit in Washington, DC in April 2010, China announced that its CAEA intended to cooperate with the U.S. National Nuclear Security Administration and Department of Defense (DoD) to establish a Beijing-based COE to “help meet Chinese and regional training needs in all aspects of nuclear material security.”¹⁸⁷ The intent was formalized in early 2011, when the two governments signed the intergovernmental MoU that set out a broad mission for the COE – to promote exchanges, trainings, tests, and demonstrations of “technologies, concepts, and practices” in the areas of “nuclear security and safeguards; nuclear material physical protection, control, and accounting; nuclear detection technology; nuclear measurement; nuclear emergency preparedness and response.”¹⁸⁸ In essence, the COE would upgrade the CIAE facilities where DOE and its Chinese partners had conducted joint nuclear security demonstrations since the days of the lab-to-lab program, but it would serve both Chinese and wider regional needs.¹⁸⁹



Leaders at the 2016 Nuclear Security Summit - Government of Chile

Leaders at the 2016 Nuclear Security Summit - Government of Chile

In November 2011, CAEA established the State Nuclear Security Technology Center (SNSTC) to take responsibility for constructing and operating the COE,¹⁹⁰ complete with a laboratory for destructive and nondestructive analysis and nuclear security equipment testing, a firing range, mock bunker and nuclear processing facility, and transportation security equipment for training. The U.S. National Nuclear Security Administration not only provided equipment but also supported the de-

¹⁸⁷ “FACT SHEET: U.S.-China Clean Energy Cooperation Announcements,” January 19, 2011, 2, <https://web.archive.org/web/20250401093549/https://www.energy.gov/node/206329>.

¹⁸⁸ “Memorandum of Understanding between the Government of the United States of America and the Government of the People’s Republic of China for Cooperation in Establishing a Center of Excellence on Nuclear Security,” January 17, 2011, https://www.energy.gov/sites/default/files/pi_iec/098b7ef98002bf04.pdf.

¹⁸⁹ Pellerin, “Defense, Energy Experts Aid China’s Nuclear Security.”

¹⁹⁰ “National Progress Report on Nuclear Security of the People’s Republic of China,” U.S. Department of State, March 27, 2012, <https://2009-2017.state.gov/documents/organization/246077.pdf>.

velopment of training curriculums and conducted initial trainings¹⁹¹ after the Center opened in March 2016. As “the largest nuclear security center in the Asia-Pacific region,” it had “the capacity to train about 2,000 nuclear security staff” each year.¹⁹²

Aside from the nuclear security COE, the Nuclear Security Summits provided impetus for a separate joint initiative – the conversion of miniature neutron-source reactors (MNSR) from HEU to LEU fuel to reduce proliferation hazards. Coordinated international efforts to convert research and test reactors to lower enrichment fuel date back to 1978, when the United States launched the Reduced Enrichment for Research and Test Reactors, or RERTR, program.¹⁹³ The Soviet Union undertook a similar initiative to develop lower-enrichment research reactor fuel. In the decades prior, the two countries had exported mostly HEU-fueled research reactors to approximately 40 countries in the name of “atoms for peace.” But by the late 1970s and early 1980s, the proliferation implications had become clear.¹⁹⁴ With modest funding, the RERTR program supported the conversion of “twelve foreign reactors and nine domestic reactors” by 1995.¹⁹⁵ The Soviet Union, by the time of its disintegration in 1991, had converted most of the research reactors it supplied internationally from 90% to 36% enriched fuel.¹⁹⁶ Russian research institutes continued to advance replacement fuel development and demonstration in the 1990s.¹⁹⁷

China’s participation in international research reactor conversion efforts may be traced back to the mid-1980s, when scientists from the U.S. Argonne National Laboratory, James Matos and James Snelgrove, visited the Southwest Center for Reactor Engineering Research and Design, the predecessor of the Nuclear Power Institute of China (NPIC), in Chengdu. The information they presented about the RERTR program prompted scientists and engineers at the Chinese institute to study the program as they attempted to reduce the fuel enrichment of the High-Flux Engineering Test Reactor (HFETR) – a 125MW material testing reactor the institute operated and continues to operate in the mountains of Leshan, Sichuan Province.¹⁹⁸ But unlike the United States and the Soviet Union,

¹⁹¹ William Yaegle et al., “An Overview of the Collaboration between the China Atomic Energy Authority and the United States Department of Energy National Nuclear Security Administration to Establish the Nuclear Security Center of Excellence in Beijing, China” (Annual Meeting of the Institute of Nuclear Materials Management, Atlanta, 2016), <https://resources.inmm.org/annual-meeting-proceedings/overview-collaboration-between-china-atomic-energy-authority-and-united>.

¹⁹² Xinhua News Agency, “China-U.S. Nuclear Security Center Goes Online,” China Atomic Energy Authority, March 21, 2016, <https://www.caea.gov.cn/english/n6759374/n6759376/c6793146/content.html>.

¹⁹³ “Research Reactors,” World Nuclear Association, May 21, 2014, <https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/research-reactors>.

¹⁹⁴ Frank Von Hippel, “A Comprehensive Approach to Elimination of Highly-Enriched-Uranium from All Nuclear-Reactor Fuel Cycles,” *Science and Global Security* 12, no. 3 (2004): 137.

¹⁹⁵ A. Travelli, “The RERTR Program Status and Progress” (1995 International RERTR Meeting, Paris, 1995), <https://www.rertr.anl.gov/PRGM/TRAVEL95.html>.

¹⁹⁶ Von Hippel, “A Comprehensive Approach to Elimination of Highly-Enriched-Uranium from All Nuclear-Reactor Fuel Cycles,” 137.

¹⁹⁷ Travelli, “The RERTR Program Status and Progress.”

¹⁹⁸ Feng P. and Yongxi B., “Physical Behaviour of the High Flux Engineering Test Reactor (HFETR),” 1986, 503, *Physical Behaviour of the High Flux Engineering Test Reactor (HFETR)*.

China continued to develop and export HEU-fueled research reactors in the 1980s. In 1984, CIAE commissioned the prototype of the 30kW miniature neutron-source reactor (MNSR) fueled with around 90% HEU and subsequently exported a slightly modified version of the reactor to Ghana, Iran, Nigeria, Pakistan, and Syria from 1989 to 2004.¹⁹⁹

As China gradually embraced nonproliferation norms, the conversion of these and other, larger research reactors to lower enrichment fuel became a priority. In the 1990s, when Washington and Beijing negotiated the implementation of the 1985 peaceful use agreement, U.S. officials objected to China's export of HEU-fueled research reactors to Ghana, Nigeria, and Pakistan and pressed China to refrain from civilian use of HEU. China was open to LEU conversion but preferred to "keep that discussion technical" rather than linking it to the nonproliferation certification necessary for bilateral civil nuclear commerce.²⁰⁰ In February 1995, the U.S. Secretary of Energy and head of the CAEA signed a statement of intent on cooperation under the RERTR program. The U.S. hope was that such cooperation would lead "soon to a Chinese RERTR program that would make the RERTR program global."²⁰¹ Chinese researchers from CIAE and NPIC began participating in international RERTR meetings while observing the LEU norm when designing fuel for new research reactors.²⁰² In 2007, NPIC converted the HFETR and its accompanying critical assembly to LEU, consistent with the aims of the RERTR program, which had been folded into the GTRI. The HEU-fueled MNSR in Shanghai was shut down permanently.²⁰³

At the same time, under an IAEA Cooperative Research Project starting in 2006, CIAE and U.S. DOE researchers worked with MNSR-operating countries to make technical preparations for their conversion to LEU.²⁰⁴ That led to a design that would allow the 90%-enriched uranium fuel to be replaced with 13%-enriched LEU while maintaining reactor performance. As the project concluded in 2010, an MNSR Working Group was established "to coordinate activities related to the conversion of MNSRs to LEU and the return of the HEU to China."²⁰⁵ Over the previous year, Argonne National Laboratory and CIAE had worked out a cost sharing agreement whereby the United States would contribute \$1.7 million toward a Zero Power Test Facility (ZPTF) in China for testing the

¹⁹⁹ Jaci Dickerson, "Conversion of Miniature Neutron Source Reactors from High Enriched Uranium to Low Enriched Uranium" (International Conference on Nuclear Security, Vienna, 2020), <https://conferences.iaea.org/event/181/contributions/15780/contribution.pdf>; "Zhongguo weidui dinonghua zhi lu," China National Nuclear Corporation, May 20, 2016, <https://www.cnncc.com.cn/cnncc/xwzx65/bzqk/2016nqk/2016ndsqq/827237/index.html>.

²⁰⁰ Mark Hibbs, "China Has Far to Go Before U.S. Will Certify, Agencies Now Say," *Nucleonics Week* 37, no. 50 (December 12, 1996).

²⁰¹ Travelli, "The RERTR Program Status and Progress."

²⁰² Luzheng Yuan and Yalun Kang, "Problems Concerned in Fuel Design of CARR" (1998 International RERTR Meeting, São Paulo, 1998), <https://www.rertr.anl.gov/Analysis98/LYuan.pdf>; Feng Peng and Rong Fu, "Reduced Enrichment Neutronic Study on High Power Research Reactor" (1999 International RERTR Meeting, Budapest, 1999), <https://www.rertr.anl.gov/Analysis98/LYuan.pdf>.

²⁰³ National Nuclear Security Administration, "Global Threat Reduction Initiative Strategic Plan," January 2009, 13, <https://www.nrc.gov/docs/ML0907/ML090790171.pdf>.

²⁰⁴ "Conversion of Miniature Neutron Source Research Reactors (MNSR) to Low Enriched Uranium (LEU)," International Atomic Energy Agency, accessed November 23, 2025, <https://www.iaea.org/projects/crp/t12020>.

²⁰⁵ Dickerson, "Conversion of Miniature Neutron Source Reactors from High Enriched Uranium to Low Enriched Uranium."

performance and safety of the MNSR's LEU cores while China bore the cost of actual conversion.²⁰⁶ That agreement was signed in September 2010.²⁰⁷ Under a contract with Argonne National Laboratory that took effect in 2012, CIAE designed the LEU core of the MNSR²⁰⁸ and conducted the zero power test in March 2014 to coincide with the third Nuclear Security Summit.²⁰⁹ In his statement at the summit, Chinese President Xi Jinping highlighted China's commitment to HEU minimization and pledged to convert Ghana's MNSR from HEU to LEU.²¹⁰ Two years later, on the eve of the fourth Nuclear Security Summit in Washington DC, the converted MNSR at CIAE entered full-power operation. The accomplishment was highlighted by the U.S.-China Joint Statement on Nuclear Security Cooperation at the summit, where China committed "to work with the United States to



Ghana's research reactor in Accra, 2013 ·IAEA / Dean Calma

convert its remaining MNSR reactors" and "all remaining Chinese-origin MNSRs worldwide."²¹¹ In addition to Ghana's reactor, the Nigerian MNSR received LEU fuel from CNNC in October 2018 and reached full power with a converted core the following month.²¹²

In many ways, the MNSR episode was the capstone of U.S.-China nuclear security and nonproliferation cooperation and a paradigmatic reflection of cooperative dynamics at the intersection of security and civil nuclear applications.

The issue emerged as a U.S. concern during negotiations toward a bilateral peaceful use agreement but was resolved through quiet technical engagement that avoided politicization. Through visits and exchanges, China became involved in the RERTR and embraced HEU minimization norms. Leveraging prior ties, U.S. and Chinese institutions cooperated to secure weapons-usable material in civilian nuclear applications – first in China, then elsewhere, in a gradual process that succeeded in shaping the nonproliferation standards tied to China's civil nuclear exports.

²⁰⁶ Miles A. Pomper and Ferenc Dalnoki-Veress, "The Little Known Success Story of U.S.-China Nuclear Security Cooperation," Nuclear Threat Initiative, June 10, 2020, <https://www.nti.org/analysis/articles/little-known-success-story-us-china-nuclear-security-cooperation/>.

²⁰⁷ "Zhongguo weidui dinonghua zhi lu."

²⁰⁸ "Zhongguo Yuanzi Neng Yuan weidui dinonghua yanjiu qude zhongyao jinzhuan," China Atomic Energy Authority, March 11, 2014, <https://www.caea.gov.cn/n6760338/n6760342/c6833727/content.html>.

²⁰⁹ "Zhong Mei qianding 'Yuanxing Weidui Dinonghua Zhuanhua' hetong," China Atomic Energy Authority, July 23, 2014, <https://www.caea.gov.cn/n6760338/n6760342/c6833587/content.html>.

²¹⁰ Jinping Xi, "Statement by H.E. Xi Jinping President of the People's Republic of China at the Nuclear Security Summit," Ministry of Foreign Affairs of the People's Republic of China, March 25, 2014, https://www.fmprc.gov.cn/eng/xw/zyjh/202405/t20240530_11340698.html.

²¹¹ Office of the Press Secretary, "U.S.-China Joint Statement on Nuclear Security Cooperation," White House, March 31, 2016, <https://obamawhitehouse.archives.gov/the-press-office/2016/03/31/us-china-joint-statement-nuclear-security-cooperation>.

²¹² Thomas Hanlon, "Nigeria Converts Its Research Reactor from HEU to LEU Fuel," International Atomic Energy Agency, December 20, 2018, <https://www.iaea.org/newscenter/news/nigeria-converts-its-research-reactor-from-heu-to-leu-fuel>.

Chapter 4. Early nuclear safety cooperation

If DOE's cooperative engagement shaped China's nuclear security and nonproliferation practices, the U.S. Nuclear Regulatory Commission helped shape the safety architecture supporting China's civil nuclear development. The U.S. DOE was created just two years prior to the signing of the U.S.-China Science and Technology Agreement. Its creation was the result of the U.S. Congress's 1974 decision to split the Atomic Energy Commission into an executive agency for nuclear research and development and an independent regulatory body for nuclear safety oversight. The latter became known as the Nuclear Regulatory Commission (NRC). In the spirit of the 1979 U.S.-China Science and Technology Agreement, the NRC established its own safety-oriented cooperation with the Chinese government's Science and Technology Commission. At the time, the NRC maintained formal cooperation arrangements with no more than two dozen countries – the overwhelming majority of them close allies of the United States. Common arrangements included the exchange of safety documents, joint safety research, and sharing of licensing decisions and other safety-relevant updates. The NRC also received foreign regulators for training and embedded foreign assignees in its staff to transfer regulatory know-how in practice.²¹³

When the Chinese Nuclear Society first proposed cooperation during a visit to the NRC in 1979, China had not constructed a single civilian nuclear power plant. Nor had it established an independent nuclear safety regulatory body. No bilateral peaceful use agreement had yet been negotiated. As a result, the protocol that the NRC signed with China's State Science and Technology Commission in 1981 was limited in scope,²¹⁴ and the two sides' contributions to joint safety research and technical exchanges were initially highly asymmetric. Nevertheless, the NRC saw benefit in gaining transparency with respect to China's civil nuclear program and safety management. It also valued the opportunity to shape China's civil nuclear safety norms and practices at an early stage by transferring U.S. safety regulatory standards, tools, and approaches.²¹⁵

China, for its part, was eager to borrow from U.S. nuclear safety regulatory experience as it attempted to establish its own NRC equivalent. In November 1984, just one month after the Chinese government set up the National Nuclear Safety Administration (C/NNSA) as the country's independent

²¹³ Leiss, "Science and Technology: Cooperation between the United States and China," 132–33.

²¹⁴ Leiss, 135.

²¹⁵ Qingshan Tan, "U.S.-China Nuclear Cooperation Agreement: China's Nonproliferation Policy," *Asian Survey* 29, no. 9 (September 1989): 881.

regulator, a delegation led by C/NNSA head Jiang Shengjie visited the NRC and met with its chairman, commissioners, and senior staff to discuss the broadening of cooperation.²¹⁶ The two countries' conclusion of a peaceful use agreement the following year provided further impetus to expand bilateral exchanges that had been largely "formal and infrequent" up to that point.²¹⁷ Consequently, the 1986 NRC-C/NNSA agreement amending and extending the 1981 protocol identified more concrete fields and forms of cooperation.²¹⁸

By that time, senior NRC leadership and staff had begun traveling to China regularly to exchange views with the Chinese safety regulator and "help train Chinese nuclear specialists in safety-related areas."²¹⁹ Meanwhile, C/NNSA personnel were receiving on-the-job training via extended six-month assignments at the NRC and participation in the NRC's staff training courses.²²⁰ The assignees often assumed senior posts within the C/NNSA after returning from their temporary assignments at the NRC.²²¹ The exchanges – aimed formally at capacity transfer – thus strengthened people-to-people ties that facilitated the deepening of cooperation. More substantively, the safety knowledge that C/NNSA trainees gained from their time at the NRC helped them review and license China's first civilian reactor for power generation. This first unit of the Qinshan nuclear power plant, with construction start in 1985 and commercial operation in 1994, is a 300MW PWR of indigenous design derived from naval propulsion.²²²

Since the C/NNSA was formed just months before the start of construction at Qinshan, the Chinese regulator required technical assistance in performing oversight. The Qinshan reactor's safety review therefore became a focal point of early assistance that the NRC offered to the C/NNSA. Apart from the temporary assignees, teams of Chinese regulators visited the NRC and spent weeks at a time consulting technical staff in the Office of Nuclear Reactor Regulation on how to perform

²¹⁶ T. A. Rehm, "Weekly Information Report - Week Ending November 16, 1984," November 23, 1984, <https://www.nrc.gov/docs/ML2009/ML2009J497.pdf>.

²¹⁷ Victor Stello, "Response to BNL Offer to Help NRC in Nuclear Safety Cooperation w/ People's Republic of China," February 21, 1986, <https://www.nrc.gov/docs/ML2020/ML20203L518.pdf>.

²¹⁸ "Protocol between the State Scientific and Technological Commission of the People's Republic of China and the Nuclear Regulatory Commission of the United States of America on Cooperation in Nuclear Safety Matters," in *Bilateral, Regional and Multilateral Agreements Relating to Co-Operation in the Field of Nuclear Safety* (Vienna: International Atomic Energy Agency, 1990), 83–89, <https://www-pub.iaea.org/MTCD/Publications/PDF/Pub850Web.pdf>.

²¹⁹ Stello, "Response to BNL Offer to Help NRC in Nuclear Safety Cooperation w/ People's Republic of China."

²²⁰ T. A. Rehm, "Weekly Information Report - Week Ending November 28, 1986," December 3, 1986, <https://www.nrc.gov/docs/ML2021/ML20214U730.pdf>.

²²¹ "Arrangement Country Administrators and Other Country Contacts," March 30, 1989, <https://www.nrc.gov/docs/ML2024/ML20248K228.pdf>.

²²² Michael F. L'Annunziata, "Co-Operation in Development through Fellowships and Training," *IAEA Bulletin* (Vienna: International Atomic Energy Agency, 1991), 20.

the Qinshan reactor's safety assessment.²²³ Meanwhile, NRC staff traveled to China to assist with the C/NNSA's technical safety evaluation.²²⁴

The great importance that China's political leaders attached to the country's first civilian nuclear power project, particularly in the safety dimension, elevated visits and exchanges beyond the technical working level. In 1987, NRC Chair Lando Zech met with Vice Premier Li Peng during his visit. The latter was a hydroelectric engineer by training who rose through the ranks of China's state-monopolized power sector to become the lead government official overseeing China's nuclear power development.²²⁵ The meeting gave Zech an opportunity to share his candid views regarding China's limited nuclear safety regulatory capacity and suggest how best to improve safety at Qinshan. Li welcomed Zech's suggestions. He also praised the NRC's cooperation with the C/NNSA and expressed his hope that such cooperation would continue.²²⁶ Years later, Zech would describe his trip as "an enjoyable and rewarding experience" that "provided an excellent opportunity to exchange views on a variety of nuclear safety and regulatory licensing issues" that the two countries both faced.²²⁷ Three months after his conversation with Zech, Li became China's acting Premier, then Premier – the head of the Chinese government – and served for ten years in that role.

Close cooperation between the NRC and the C/NNSA over Qinshan's safety licensing and discussions addressing the broader safety agenda continued until mid-1989,²²⁸ when the Tiananmen Square incident prompted the U.S. government to put bilateral nuclear cooperation on hold.²²⁹ It was not until spring 1991 that Congress "agreed to the renewal of the overall U.S.-China Agreement on Science and Technology" under which nuclear safety cooperation took place. Even then, cooperation did not immediately resume. In October 1991, the U.S.-China protocol on nuclear safety cooperation was allowed to lapse. Yet there was no pause in China's civil nuclear program. In December 1991, China commissioned the Qinshan reactor while two French-supplied reactors were under construction at Daya Bay and were scheduled for operation in 1993 and 1994. China was expected to engage Westinghouse to import reactors for a third plant. In these circumstances, the NRC and the U.S. executive branch acted upon the belief "that the protection of the public health and safety [was]

²²³ T. A. Rehm, "Weekly Information Report - Week Ending February 27, 1987," March 4, 1987, <https://www.nrc.gov/docs/ML2021/ML2021J866.pdf>; T. A. Rehm, "Weekly Information Report - Week Ending May 6, 1988," May 11, 1988, <https://www.nrc.gov/docs/ML2015/ML20154D193.pdf>.

²²⁴ Nuclear Regulatory Commission, "1989 NRC Annual Report" (Washington, DC: U.S. Government Printing Office, 1989), 114, <https://www.nrc.gov/docs/ML2005/ML20056B553.pdf>.

²²⁵ Mark Hibbs, "International Analysts Assert Chinese Nuclear Plans Unrealistic," *Nucleonics Week* 39, no. 3 (January 15, 1998).

²²⁶ Peng Li, *Li Peng bedian riji (xia): qibu dao fazhan* (Beijing: Xinhua Publishing House, 2004).

²²⁷ Lando W. Zech, "Congratulates Recipient on Appointment as Director General of Natl Nuclear Safety Admin," April 20, 1989, <https://www.nrc.gov/docs/ML2024/ML20247P526.pdf>.

²²⁸ John C. Hoyle, "Weekly Information Report - Week Ending September 23, 1988," September 28, 1988, <https://www.nrc.gov/docs/ML2015/ML20155B395.pdf>; James L. Blaha, "Weekly Information Report - Week Ending March 17, 1989," March 22, 1989, <https://www.nrc.gov/docs/ML2024/ML20247B922.pdf>.

²²⁹ Nuclear Regulatory Commission, "1989 NRC Annual Report," 114.

paramount and that all cooperative efforts to help assure this should be supported.”²³⁰ Responding positively to the C/NNSA’s interest in further cooperation, the NRC drafted a renewed protocol that was signed upon Chairman Ivan Selin’s visit to China in January 1993. With that, full exchanges resumed.

Although the Chinese regulator had learned to perform reactor safety assessments, its capacity was strained against rapid newbuilds, especially with the simultaneous introduction of multiple foreign reactor designs, including the French M310 PWR, Canadian CANDU, and Russian VVER.²³¹ The NRC knew from experience the challenge of reviewing and maintaining safety oversight in relation to a large number of reactor designs. Its cooperation with the C/NNSA thus became animated by the concern that the C/NNSA’s meager staff of fewer than 200 regulators might not be able to cope with the workload.²³² NRC staff continued offering safety advice to help the C/NNSA exercise oversight at Qinshan and Daya Bay.²³³ In addition, the NRC shared with the C/NNSA its regulatory approaches such as probabilistic risk assessment²³⁴ as well as computer codes for analyzing reactor accidents upon Chinese request.²³⁵ The NRC’s practice was to share only publicly available codes, in consultation with the executive branch.²³⁶ It benefited in turn by receiving user feedback and identifying bugs in the codes.²³⁷

Other cooperation targeted Chinese regulatory shortcomings in facility inspections, emergency preparedness, nuclear material safety and security, and radiation protection, at times involving Chinese regulators beyond the C/NNSA. For instance, prior to 2003,²³⁸ the Ministry of Public Health was responsible for regulating health and safety related to the use of radiation for medicine and agricul-

²³⁰ Harold R. Denton and Ronald D. Hauber, “Forwards Commission Proposed Renewal of Protocol between NRC & Natl Nuclear Safety Admin for Cooperation in Nuclear Safety Matters & Recommends Positive Commission Action,” December 17, 1992, <https://www.nrc.gov/docs/ML2012/ML20126E775.pdf>.

²³¹ James L. Blaha, “Weekly Information Report - Week Ending May 6, 1994,” May 12, 1994, <https://www.nrc.gov/docs/ML2007/ML20070S166.pdf>.

²³² Shirley Ann Jackson, “Trip Report on Visit to Canada and the People’s Republic of China,” October 18, 1996, <https://www.nrc.gov/docs/ML2013/ML20137Z993.pdf>.

²³³ Ivan Selin, “Remarks by Ivan Selin Chairman, U.S. Nuclear Regulatory Commission before the Ninth Pacific Basin Nuclear Conference,” May 2, 1994, <https://www.nrc.gov/docs/ML0037/ML003708682.pdf>; Qitao Huang, “Expresses Appreciation for Strong Support for Cooperation between Natl Nuclear Safety Admin & NRC,” July 28, 1997, <https://www.nrc.gov/docs/ML2021/ML20216G246.pdf>.

²³⁴ Nuclear Regulatory Commission, “Summary of Meetings and Site Visits,” July 29, 1996, 13, <https://www.nrc.gov/docs/ML2013/ML20137Z784.pdf>.

²³⁵ Janice Dunn Lee, “Visit of Vice Minister Song, China State Environmental Protection Administration, August 18, 2000,” August 15, 2000, <https://www.nrc.gov/docs/ML0037/ML003748118.pdf>.

²³⁶ Janice Dunn Lee, “Invitation to China to Participate in Camp,” October 25, 2000, <https://www.nrc.gov/docs/ML0037/ML003762970.pdf>.

²³⁷ Jinjun Feng et al., “Application of TRACE V5.0 P2 to China Domestic PWR LBLOCA Analysis” (Washington, DC: Nuclear Regulatory Commission, July 2013), xi, <https://www.nrc.gov/docs/ML1321/ML13213A077.pdf>.

²³⁸ Gregory B. Jaczko, “Trip to the People’s Republic of China and South Korea,” January 22, 2007, 3–5, <https://www.nrc.gov/docs/ML1102/ML110260152.pdf>.

ture,²³⁹ so the NRC engaged the Ministry of Public Health to cooperate in radiation protection²⁴⁰ while building C/NNSA capacity.²⁴¹

During his visit to China in spring 1993, NRC Commissioner Forrest J. Remick suggested to the C/NNSA that they dispatch assignees to the NRC's regional offices to gain experience working with NRC inspectors.²⁴² The C/NNSA was eager to learn more about the NRC's inspection program,²⁴³ which subsequently became the subject of many discussions and briefings as Chinese delegations visited the NRC.²⁴⁴ The exchange of inspectors would also become a major form of cooperation between the two agencies in the 2000s and 2010s.

Also in 1993, NRC Chairman Ivan Selin advised the Chinese authorities during his visit to strengthen their emergency preparedness procedures. At the time, nuclear emergency response in China fell within the responsibilities of municipal and local governments rather than the C/NNSA.²⁴⁵ Therefore, the NRC invited delegations including the Vice Governor of Guangdong Province, where the Daya Bay Nuclear Power Plant was just entering operation, and "representatives from various governmental and utility organizations" sponsored by CNNC's Emergency Response Office, to tour the NRC's Emergency Operations Center and observe U.S. nuclear power plants' emergency exercises.²⁴⁶

In the meantime, the C/NNSA took greater responsibility in emergency preparedness upon itself, as per the recommendation of an IAEA team that conducted an in-country review of China's nuclear safety program in 1994.²⁴⁷ Thereafter, visits to the NRC's Emergency Operations Center and the observation of U.S. nuclear power plants' emergency exercises became routine items on visiting C/NNSA delegations' agendas.²⁴⁸ In the early 2000s, the C/NNSA received funding to establish its

²³⁹ Nuclear Regulatory Commission, "Summary of Meetings and Site Visits," 13.

²⁴⁰ Shirley Ann Jackson, "Expresses Appreciation for Time Taken from Busy Schedule to Meet during Recent Visit to China," September 9, 1996, <https://www.nrc.gov/docs/ML2013/ML20138F323.pdf>.

²⁴¹ Selin, "Remarks by Ivan Selin Chairman, U.S. Nuclear Regulatory Commission before the Ninth Pacific Basin Nuclear Conference," 8–9.

²⁴² Nuclear Regulatory Commission, "1993 NRC Annual Report" (Washington, DC: U.S. Government Printing Office, 1993), 159–60, <https://www.nrc.gov/docs/ML2002/ML20024J235.pdf>.

²⁴³ James L. Blaha, "Weekly Information Report - Week Ending December 10, 1993," December 16, 1993, <https://www.nrc.gov/docs/ML2005/ML20058P098.pdf>.

²⁴⁴ James L. Blaha, "Weekly Information Report - Week Ending April 14, 2000," April 20, 2000, <https://www.nrc.gov/docs/ML0037/ML003705780.pdf>.

²⁴⁵ Nuclear Regulatory Commission, "1989 NRC Annual Report," 9–10.

²⁴⁶ Nuclear Regulatory Commission, "1993 NRC Annual Report," 159–60.

²⁴⁷ Ivan Selin, "Remarks by Ivan Selin Chairman, U.S. Nuclear Regulatory Commission Before the American Chamber of Commerce," July 27, 1994, <https://www.nrc.gov/docs/ML0037/ML003710638.pdf>; International Atomic Energy Agency, "The Annual Report for 1994" (Vienna: International Atomic Energy Agency, July 1995), 151, <https://inis.iaea.org/records/qrcss-v7h79/files/32042399.pdf>.

²⁴⁸ James L. Blaha, "Weekly Information Report - Week Ending October 4, 1996," October 9, 1996, <https://www.nrc.gov/docs/ML2012/ML20128N985.pdf>; John W. Craig, "Weekly Information Report - Week Ending August 18, 2000," August 22, 2000, <https://www.nrc.gov/docs/ML0037/ML003743367.pdf>; Janice Dunn Lee, "Visit of China CAEA Vice Chairman Xu, Yuming," June 4, 2002, <https://www.nrc.gov/docs/ML0217/ML021720585.pdf>.

own Emergency Operations Center, which they modeled after the NRC's.²⁴⁹ By 2002, every operating Chinese nuclear power plant had conducted its own emergency drills.²⁵⁰

Hence, two decades after the signing of the U.S.-China protocol on cooperation in nuclear safety matters, initially formal and infrequent exchanges focused on ensuring the basic safety of China's first civilian reactors had grown into a broad and multifaceted regulatory partnership spanning reactor safety review, inspections, emergency preparedness, nuclear material safety and security, and radiation protection. In 2002, Director of the NRC's Office of International Programs Janice Dunn Lee wrote in response to a request for information by the U.S. Department of State that the Commission's bilateral objectives in pursuing cooperation with China were, inter alia, to "foster an understanding of the U.S. approach to nuclear safety" and assist China in "the development of sound regulatory and safety practices." She also noted that by facilitating contact with China's nuclear safety regulator, the NRC-C/NNSA protocol "provided a dialog with China at times when [the] two nations' relations were strained."²⁵¹ These included periods immediately after the 1989 Tiananmen Square crackdown and after the release of the Cox Report alleging Chinese espionage at U.S. nuclear weapon laboratories,²⁵² which, together with the Wen Ho Lee affair, terminated exchanges between U.S. and Chinese nuclear labs in 1999. Nuclear safety cooperation between the two countries remained resilient in part because both sides subscribed to the mantra popularized after Three Mile Island and reinforced by Chernobyl that "a nuclear accident anywhere is a nuclear accident everywhere,"²⁵³ and in part because cooperation was mutually beneficial.

Prior to the conclusion and implementation of the U.S.-China nuclear technology and nuclear energy agreements in 1998,²⁵⁴ the NRC managed one of the most resilient governmental channels for contact with the Chinese civil nuclear enterprise. Though an independent regulatory agency, the NRC routinely interacted with the executive branch, particularly the White House, the Department of State, and the Department of Energy, to coordinate its exchanges with Chinese counterparts. The United States government gained valuable transparency with respect to China's civil nuclear program and successfully shaped its safety standards and practices. In the 15 years prior to 2002, more than two dozen Chinese regulators served temporary assignments at the NRC ranging from several

²⁴⁹ Kevin Burke, "Visit of Commissioner Jeffrey S. Merrifield, U.S. Nuclear Regulatory Commission (March 3-10, 2001)," May 2001, 2, <https://www.nrc.gov/docs/ML0310/ML031040436.pdf>.

²⁵⁰ Lee, "Visit of China CAEA Vice Chairman Xu, Yuming."

²⁵¹ "Regulatory Cooperation NRC-NNSA Protocol in Nuclear Safety Matters," September 24, 1998, <https://www.nrc.gov/docs/ML0209/ML020990091.pdf>.

²⁵² Cox, "U.S. National Security and Military/Commercial Concerns with the People's Republic of China."

²⁵³ M. H. Fontana and D. R. Patterson, "Foreword," in *Proceedings of the Americal Nuclear Society/European Nuclear Society Topical Meeting*, vol. 2 (Thermal Reactor Safety, Knoxville, 1980), ii, https://digital.library.unt.edu/ark%3A/67531/metadc1056887/m2/1/high_res_d/5206840.pdf.

²⁵⁴ Shirley Ann Jackson, "Meeting with Leon Fuerth, National Security Advisor to the Vice President," August 14, 1996, <https://www.nrc.gov/docs/ML2013/ML20137Z964.pdf>.



Li Ganjie and NRC Chair Allison Macfarlane renew a bilateral nuclear safety arrangement, July 2013 · U.S. Nuclear Regulatory Commission

months to a year to learn U.S. regulations and safety culture via hands-on experience.²⁵⁵ They then returned to senior positions within the C/NNSA. The NRC therefore considered the assignee program “an excellent mechanism for developing top quality and long-lasting relationships with key personnel in foreign regulatory agencies,” including the C/NNSA.²⁵⁶

Since the Chinese government is especially technocratic, technical personnel often rise through the ranks to become high-level government decisionmakers, lending further significance to these relationships. Li Peng was one example. Another

is Li Ganjie, a graduate of Tsinghua University’s nuclear reactor engineering and safety programs who entered the C/NNSA as an engineer in 1989.²⁵⁷ As the head of the C/NNSA, Li oversaw extensive contact between the Chinese regulatory agency and the NRC and traveled regularly to the NRC’s events in Washington.²⁵⁸ He led the C/NNSA until 2016 before becoming the Minister of Ecology and Environment. After brief tenures as the Governor and Party Secretary of Shandong Province, Li became the youngest member of the Chinese Politburo and now heads the Chinese Communist Party’s United Front Work Department.

On the technical working level, early bilateral cooperation laid the foundation for subsequent nuclear safety exchanges where the NRC learned from the C/NNSA as well as the other way around. The U.S. regulator remained the transferor of safety knowledge for the most part but occasionally found itself in a position to benefit from the Chinese regulator’s oversight experience vis-à-vis new reactor technologies that China deployed ahead of the United States. One such technology was the high-temperature gas-cooled reactor (HTGR). Unlike traditional pressurized water reactors (PWRs), HTGRs use helium as the coolant and graphite as the neutron moderator. Rather than fuel rods, small spheres – or “pebbles” – of graphite encasing tiny uranium particles form a “pebble bed” that cycles through the reactor core. China began researching HTGR technology in the 1970s and

²⁵⁵ Lee, “Visit of China CAEA Vice Chairman Xu, Yuming.”

²⁵⁶ Nuclear Regulatory Commission, “Commissioners Meeting: Briefing on International Activities,” August 14, 2001, 12, <https://www.nrc.gov/docs/ML0122/ML012270284.pdf>.

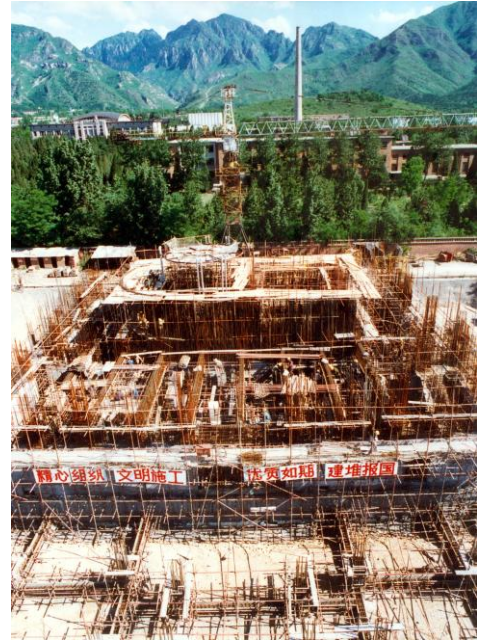
²⁵⁷ CPC News, “Li Ganjie dangxuan Shandong Sheng shengzhang,” July 21, 2020, <http://renshi.people.com.cn/n1/2020/0721/c139617-31791705.html>.

²⁵⁸ Ganjie Li, “Invitation Letters Re: 15th Annual Regulatory Information Conference (RIC) in Washington, DC on 04/16-18/2003,” January 23, 2003, <https://www.nrc.gov/docs/ML0302/ML030270367.pdf>; Nuclear Regulatory Commission, “RIC 2005 Program and Schedule,” January 25, 2005, <https://www.nrc.gov/docs/ML0818/ML081830271.pdf>.

worked with German entities to deploy the pebble bed concept domestically. Tsinghua University took the lead with key R&D, conceptual design, and feasibility study for a prototype reactor, the HTR-10, between 1986 and 1990 after the Chinese government designated the technology a priority under the 863 State High-Tech Development Plan. The reactor was approved for construction in 1995²⁵⁹ and reached criticality in 2000.

In spring 2001, NRC Commissioner Jeffrey S. Merrifield made his first visit to China. Apart from the usual discussions surrounding probabilistic safety assessment and emergency preparedness,²⁶⁰ Merrifield was taken on a tour of the HTR-10 prototype reactor and associated fuel fabrication at Tsinghua University's Institute of Nuclear Energy Technology (INET). At the time, the NRC expected to "soon be asked to review" a pebble bed modular reactor for licensing. Merrifield was impressed by the Chinese reactor and expressed his hope that the C/NNSA and INET would share the reactor's safety information with the NRC.²⁶¹ Soon, the C/NNSA shared its final safety analysis report (FSAR) for the HTR-10 with the NRC, which was able to consider how it would approach reviewing the same technology while gaining transparency into the Chinese approach.²⁶²

Within six months of Merrifield's visit, the NRC sent another delegation to spend three days in Beijing – two at the C/NNSA and one at Tsinghua INET, during a trip aimed at gaining familiarity with HTGR technology. Discussions with Chinese partners focused on the "design, safety review and initial operational experience of the HTR-10." Staff from China's Nuclear Safety Center and from the C/NNSA who were involved in reviewing the HTR-10 participated in the meetings.²⁶³ There was a lot to discuss. After all, HTGR technology differs from PWR technology in every respect, and its safety is enhanced via robust graphite fuel pebbles and passive cooling. The NRC team was particularly curious about the "safety review framework" that was used for the HTR-10's safety



Construction of China's HTR-10 high-temperature gas-cooled reactor ·IAEA

²⁵⁹ Institute of Nuclear Energy Technology, Tsinghua University, "10MW High Temperature Gas-Cooled Reactor Test Module," February 2001, <https://www.nrc.gov/docs/ML0310/ML031000231.pdf>.

²⁶⁰ Burke, "Visit of Commissioner Jeffrey S. Merrifield, U.S. Nuclear Regulatory Commission (March 3-10, 2001)," 2.

²⁶¹ Jeffrey S. Merrifield, "A Letter from Commissioner Merrifield Expressing Appreciation for Meeting during Recent Visit to Beijing," April 4, 2001, <https://www.nrc.gov/docs/ML0110/ML011070475.pdf>.

²⁶² Jon R. Johnson, "Chinese National Nuclear Safety Administration (NNSA) Report, 'FSAR of 10 MW High Temperature Gas-Cooled Experimental Reactor' November, 2000," July 3, 2001, <https://www.nrc.gov/docs/ML0215/ML021570036.pdf>.

²⁶³ Ashok C. Thadani, "Summary of the NRC Delegation Visit to China and Japan on Safety Aspects of High-Temperature Gas-Cooled Reactor Design and Technology," December 6, 2001, <https://www.nrc.gov/docs/ML0310/ML031050596.pdf>.

licensing. That included questions about the “significant safety issues that were identified and resolved” as well as the tests, inspections, and reviews that were associated with the HTGR’s unique features – like its pebble fuel, high-temperature materials, and passive heat removal system.²⁶⁴ C/NNSA and INET teams delivered presentations on HTGR licensing, which the NRC appreciated for helping “to broaden [its] understanding of the challenges that lie ahead.”²⁶⁵ Cooperative safety research with INET “related to its HTR-10 reactor safety experiments” followed.²⁶⁶ In 2004, the NRC signed a “revised cooperative research agreement” with the C/NNSA designating INET as its Chinese counterpart in exchanges regarding HTGR technology.²⁶⁷ Then Westinghouse was selected to supply four AP1000 reactors to China with technology transfer. China became the first country in the world to construct the U.S. Generation III+ PWR. Joint safety review and inspections with the C/NNSA allowed the NRC to foresee regulatory challenges with the AP1000 in the United States. Before the AP1000 episode can be discussed in greater depth, however, it is necessary first to contextualize the energy track of U.S.-China civil nuclear cooperation.

²⁶⁴ Amy Cubbage, “E-Mail from A. Cubbage to F. Akstulewicz, Y. Orechwa and U. Shoop, Regarding China and Japan Trip: Draft Agendas for Planned Itinerary,” August 9, 2001, <https://www.nrc.gov/docs/ML0311/ML031190058.pdf>.

²⁶⁵ Janice Dunn Lee, “10/01/01 Ltr to Dr. Zhao Yimin, China from Janice Dunn Lee, Expressing Appreciation for Visit to the National Nuclear Safety Administration & the Institute of Nuclear Energy Technology,” October 1, 2001, <https://www.nrc.gov/docs/ML0127/ML012760172.pdf>.

²⁶⁶ Nuclear Regulatory Commission, “Semiannual Update of the Status of New Reactor Licensing Activities,” December 2003, <https://www.nrc.gov/docs/ML0333/ML033380831.pdf>.

²⁶⁷ Nuclear Regulatory Commission, “Semiannual Update of the Status of New Reactor Licensing Activities,” June 2004, 17, <https://www.nrc.gov/docs/ML0411/ML041190618.pdf>.

Chapter 5. Setting the scene for civil nuclear commerce

Shortly after the conclusion of the bilateral science and technology agreement in 1979, the U.S. DOE and Chinese State Planning Commission signed a Memorandum of Understanding for Bilateral Energy Agreements. As a follow-on to Schlesinger's late-1978 visit, the MoU served as the basis for cooperation in subsequent decades in areas ranging from fossil fuels to renewables and nuclear power.²⁶⁸

The prospect for civil nuclear commerce with China was attractive to U.S. industry. On March 28, 1979, unit 2 of the Three Mile Island Nuclear Generating Station in Pennsylvania suffered a core meltdown. While the reactor's containment structure prevented a significant radiation release, this most serious civil nuclear accident in the United States marked the start of the U.S. nuclear industry's decline. The following few decades saw no new domestic nuclear power plant orders while "more than 100 reactors," including "all ordered after 1973," were cancelled.²⁶⁹ In these circumstances, the U.S. nuclear industry turned to the global market. China was seen as a promising export destination.

In December 1978, upon the signing of a long-term economic cooperation agreement between China and France, Deng Xiaoping announced that China planned to purchase two power reactors from the French vendor Framatome.²⁷⁰ In the early 1980s, China also explored commercial deals for new-builds with U.S., British, and German companies, and technical and commercial negotiations over the Qinshan and Daya Bay nuclear power plant projects were conducted with Westinghouse and General Electric.²⁷¹ Meanwhile, Ebasco and the Tennessee Valley Authority (TVA) sought to sell to China two sets of surplus PWR equipment from a U.S. nuclear power plant project that was cancelled after Three Mile Island.²⁷²

Although the Reagan administration supported the liberalization of technology exports to China and appreciated the importance of allowing U.S. companies to compete for the burgeoning Chinese nuclear energy market, U.S. policy at the time dictated that transfers of U.S. nuclear material and sales

²⁶⁸ U.S.-China Economic and Security Review Commission, "2014 Report to Congress," 206.

²⁶⁹ Mark Holt, "Nuclear Energy Policy," Congress.gov, October 15, 2014, <https://www.congress.gov/crs-product/RL33558>.

²⁷⁰ Peng Li, *Li Peng bedian riji (shang): qibu dao fazhan* (Beijing: Xinhua Publishing House, 2004), 21.

²⁷¹ State Council Information Office of the People's Republic of China, "Guanyu Zhong Mei maoyi pingheng wenti," State Council of the People's Republic of China, March 1997, https://www.gov.cn/zhengce/2005-05/26/content_2615746.htm.

²⁷² Li, *Li Peng bedian riji (shang): qibu dao fazhan*, 38–39, 110, 118.

of U.S. civil nuclear equipment could take place only within the framework of a bilateral agreement on the peaceful use of nuclear energy in which nonproliferation safeguards were embedded. In fall 1981, U.S. Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs James L. Malone went to China to negotiate such an agreement. Initial talks stalled over China's refusal to accede to the NPT and accept IAEA safeguards on U.S. transfers.²⁷³ In the early 1980s, China not only stood outside the NPT regime but was skeptical of nonproliferation as a principle. It was also making unsafeguarded nuclear transfers to countries that the United States believed were developing nuclear weapons or were at high risk of doing so.

According to the Atomic Energy Act, DOE could, with the State Department's concurrence, issue nuclear technology export authorizations under its Part 810 authority even without a bilateral peaceful-use agreement in place. But the State Department was reluctant to grant its concurrence for Part 810 export authorizations pending clarifications about China's nonproliferation policy.²⁷⁴ Meanwhile, transfers of U.S.-origin nuclear material and equipment were completely off the table without a bilateral peaceful use agreement in place. Ebasco was therefore unable to secure an export license for its PWR equipment. Its plan to accept interning staff from the Shanghai Nuclear Engineering Research and Design Institute (SNERDI) was likewise scrapped due to U.S. government restrictions. As the State Department prohibited U.S. companies from participating in the project at Daya Bay,²⁷⁵ in March 1984, a closed-door meeting of the Chinese State Council's nuclear power small group decided to focus on procuring France's 900 MW reactor while continuing perfunctory engagement with Westinghouse and TVA to maintain negotiating leverage against the French.²⁷⁶ Other U.S. companies were contracted only to assist in the evaluation of non-U.S. bids for the Daya Bay project.²⁷⁷ Similarly, when German and French companies were invited to bid for a third Chinese nuclear power plant project in February 1985, U.S. companies were excluded.²⁷⁸

It was not until July 1985, upon Chinese President Li Xiannian's visit to Washington, that China and the United States formally concluded their bilateral peaceful use agreement.²⁷⁹ Both sides made compromises to facilitate the accord. Senior Chinese leaders made public pledges and private commitments to refrain from proliferation, effectively endorsing nonproliferation in principle,²⁸⁰ even

²⁷³ Bernard Gwertzman, "U.S. and China Discussing Export of Nuclear Technology," *The New York Times*, June 2, 1982, sec. A.

²⁷⁴ Michael Knapik, "Approval of Technology Transfers Should Follow Signing of U.S.-China Accord," *Nucleonics Week* 26, no. 30 (July 25, 1985).

²⁷⁵ Li, *Li Peng bedian riji (shang): qibu dao fazhan*, 72.

²⁷⁶ Li, 205–6, 238, 240.

²⁷⁷ Li, 238, 240; Li, *Li Peng bedian riji (xia): qibu dao fazhan*, 489.

²⁷⁸ James Martin Center for Nonproliferation Studies, "China Nuclear Chronology," Nuclear Threat Initiative, March 2013, https://www.nti.org/wp-content/uploads/2021/09/china_nuclear_3.pdf.

²⁷⁹ Li, *Li Peng bedian riji (shang): qibu dao fazhan*, 351–53.

²⁸⁰ Associated Press, "U.S. and China Sign Technology Pacts," *The New York Times*, January 13, 1984, sec. A; Li, *Li Peng bedian riji (shang): qibu dao fazhan*, 311.

though China remained outside the NPT and continued to perceive certain Treaty provisions as unacceptably discriminatory.²⁸¹ Beijing also met Washington's safeguards and advance consent de-



The Reagans with Li Xiannian and Lin Jiamei, July 1985 · White House

mands half-way by agreeing to consult regarding “visits” and “exchanges” before undertaking any reprocessing or further enrichment of U.S.-origin nuclear material. The compromise effectively kicked the advance consent issue down the road. The thinking was that the construction of a U.S. reactor would take years, and reprocessing would not come up as an issue until the reactor had produced a substantial quantity of spent fuel in any case. That allowed the Reagan administration to claim there would

be “sufficient time to observe PRC actions under the agreement before sensitive issues” like reprocessing arose.²⁸² Under this compromise, China did not have to immediately acknowledge U.S. consent rights, nor did the United States have to relinquish them.

Endorsing these compromises upon the initialing of the agreement in Beijing in 1984, President Reagan affirmed optimistically that the agreement would “permit American firms and experts to help China meet the ambitious energy goals of its modernization program,” bring a “new dimension of peaceful cooperation” to the bilateral relationship, and advance the two countries’ “shared desire to prevent the proliferation of nuclear explosives in the world.”²⁸³ More discussions regarding the agreement’s nonproliferation monitoring provisions and China’s nonproliferation policy followed.²⁸⁴ When the agreement was formally signed in July 1985, both sides were eager for its implementation, assuming the U.S. Congress’s expedient review and approval. Following a morning meeting with congressional leadership on July 25, the Chinese delegation departed from Washington, and a small group led by Vice Premier Li Peng split from the delegation to visit the Braidwood nuclear power plant near Chicago, where they were met by the CEO of Westinghouse and Commonwealth Edison

²⁸¹ Li, *Li Peng hedian riji (shang): qibu dao fazhan*, 159, 319.

²⁸² U.S. General Accounting Office, “Nuclear Agreement: Cooperation Between the United States and the People’s Republic of China” (Washington, DC: U.S. General Accounting Office, November 27, 1985), 1, <https://www.gao.gov/products/nsiad-86-21br>.

²⁸³ Ronald Reagan, “Remarks at a Signing Ceremony for Four United States-China Agreements,” Ronald Reagan Presidential Library & Museum, April 30, 1984, <https://www.reaganlibrary.gov/archives/speech/remarks-signing-ceremony-four-united-states-china-agreements>.

²⁸⁴ Li, *Li Peng hedian riji (shang): qibu dao fazhan*, 279, 344; U.S. General Accounting Office, “Nuclear Agreement: Cooperation Between the United States and the People’s Republic of China,” 1.

and accompanied by Secretary of Energy John Herrington.²⁸⁵ Li sensed the eagerness of the U.S. executive branch and industry to initiate civil nuclear commerce. Indeed, new safety regulations after Three Mile Island had delayed the construction of reactors in the United States such as the Westinghouse PWRs that the Chinese delegation toured at Braidwood.²⁸⁶

However, Li had underestimated congressional resistance to the peaceful use agreement due to lingering nonproliferation concerns. When the agreement was submitted for congressional review in July 1985, the U.S. Congress imposed further nonproliferation conditions that delayed its implementation. The main condition was the requirement of a presidential certification regarding China's nonproliferation credentials. In 1987, when U.S. and Chinese negotiators of the peaceful use accord worked out concrete arrangements for the visits and exchanges previously agreed to, the Reagan administration said it would submit the required certification to Congress once the arrangements went through interagency review.²⁸⁷ But then China's sale of anti-ship missiles to Iran, among other reasons for Washington to question China's nonproliferation commitments, led the administration to introduce restrictions on high technology exports to China.²⁸⁸ That delayed the agreement's implementation to 1989, when Congress imposed sanctions on China in the aftermath of the June 4 Tiananmen Square crackdown. These sanctions further prejudiced U.S.-China civil nuclear commerce pending China's progress on human rights.²⁸⁹

Despite the delay in the agreement's formal implementation, the existence of an agreement allowed the U.S. executive branch to approve limited cooperation. In 1985, the U.S. State Department gave DOE its concurrence to approve U.S. companies' applications to export civil nuclear technology, though not material and equipment, to China. A key license was granted for Mitsubishi Heavy Industries to manufacture the pressure vessel for the Qinshan reactor using a Westinghouse design.²⁹⁰ While the reactor was derived from China's indigenous naval propulsion engineering, Chinese planners opted to purchase its main vessel and coolant pump from abroad to guarantee fabrication quality.²⁹¹ Westinghouse also received a broad Part 810 authorization to export reactor and fuel technologies to China. Rather unusually, the authorization had no expiration date, allowing Westinghouse to benefit from it well into the 2000s.²⁹² About a dozen other U.S. companies, including Bechtel, Combustion Engineering, Ebasco, and General Electric had also submitted applications to

²⁸⁵ Li, *Li Peng hedian riji (shang): qibu dao fazhan*, 354.

²⁸⁶ Li, 358.

²⁸⁷ "U.S., China Agree on Visitation Rights, Clearing Way for Nuclear Exports," *Nuclear Fuel* 12, no. 13 (June 29, 1987).

²⁸⁸ Michael Knapik, "WPPSS Still Looking to Sell WNP-5 to China, Asks NRC for Export License," *Nuclear Fuel* 14, no. 3 (February 6, 1989).

²⁸⁹ Mark Holt, Paul K. Kerr, and Mary Beth D. Nikitin, "U.S.-China Nuclear Cooperation Agreement," Congressional Research Service, August 18, 2015, https://www.congress.gov/crs_external_products/RL/PDF/RL33192/RL33192.25.pdf.

²⁹⁰ Knapik, "Approval of Technology Transfers Should Follow Signing of U.S.-China Accord."

²⁹¹ Li, *Li Peng hedian riji (xia): qibu dao fazhan*, 459.

²⁹² Daniel Horner, "China, U.S. Resolving Dispute That Blocked Technology Exports," *Nuclear Fuel* 28, no. 18 (September 1, 2003).

DOE.²⁹³ Some applications had been pending for several years before they were approved.²⁹⁴ From 1985 to 1989, DOE approved 38 license applications for the transfer of nuclear technology to China.²⁹⁵

Equipped with its broad Part 810 authorization, Westinghouse explored a partnership with NPIC based on the AP600 – an advanced passively safe PWR it designed with DOE support. Up to that point, NPIC had focused only on naval propulsion R&D. It was established as part of China’s submarine propulsion program in the 1960s and constructed its research and prototype reactors in the mountains of Sichuan Province at a time when China shifted its defense industry to its southwestern hinterland in anticipation of military conflict with the United States and the Soviet Union. However, with Deng Xiaoping’s call for military-to-civilian conversion in the 1980s, electricity generation became the primary task of the nuclear industry. Excluded from nuclear power developments along the southern and eastern coasts, NPIC sought to recast itself as the promoter of advanced PWR technology.²⁹⁶ In 1987, NPIC established an “advanced reactor technology development small group” with the goal of developing an advanced Chinese PWR – the AC600 – that would utilize passive cooling like Westinghouse’s AP600.²⁹⁷ They invited Howard Bruschi, the lead architect of the AP600, to lecture in Chengdu. He went and reportedly found himself in a conference room with broken windows, where he lectured to a roomful of Chinese engineers wrapped in their heavy winter coats.²⁹⁸ Bruschi laid out the vision of a partnership that was formalized in an agreement of intent on technical cooperation and exchange between NPIC and Westinghouse.²⁹⁹ That, however, was in 1989, and politics soon intervened to prevent the agreement from taking effect.

Nevertheless, Westinghouse did not cease its exploration of business partnerships in China. In the early 1990s, its representatives went to SNERDI to continue discussions about the development a 600MW advanced Chinese PWR.³⁰⁰ These discussions had reached a “fairly advanced stage” by late 1992, but U.S. government restrictions continued to impede any joint projects.³⁰¹ Westinghouse had to go to great lengths to secure State Department permission even to invite Chinese experts to visit the company’s headquarters in Pittsburgh to negotiate a potential reactor sale in the event that government restrictions were lifted. And Bechtel had to negotiate with DOE over several months to

²⁹³ Knapik, “Approval of Technology Transfers Should Follow Signing of U.S.-China Accord.”

²⁹⁴ “Rep. Edward Markey (D-Mass.) Has Asked DOE to Hold Up Issuing Approval,” *Nucleonics Week* 26, no. 35 (August 29, 1985).

²⁹⁵ “Congress Passes New China Sanctions,” *Nuclear Fuel* 14, no. 24 (November 27, 1989).

²⁹⁶ Personal conversation with Chaim Braun.

²⁹⁷ Feng Lu, *Xin buo* (Beijing: Renmin University of China Press, 2020).

²⁹⁸ Personal conversation with Chaim Braun.

²⁹⁹ Lu, *Xin buo*.

³⁰⁰ “Shanghai hedian chanye dashiji,” Shanghai Municipal Nuclear Power Office, accessed November 22, 2025, <https://www.smnpo.cn/hdds/1662308.htm>.

³⁰¹ Shahid-ur-Rehman Khan, “Official Says China Will Develop 600-Mw Reactor for Third World,” *Nucleonics Week* 33, no. 51 (December 17, 1992).

convey that its subcontract for the CANDU reactors to be built in China only included civil work within its scope.³⁰²

In the decade after the conclusion of the U.S.-China peaceful use agreement in 1985, the U.S. domestic nuclear industry continued to decline. In the 1990s, U.S. nuclear energy companies began lobbying hard for export restrictions to be lifted so they could chase after the Chinese nuclear energy market – then estimated to be worth \$55 billion over the next 30 years. These industry appeals finally won the sympathy of the Clinton administration, which prioritized the improvement of relations with Beijing in its own foreign policy agenda.³⁰³ In February 1995, Secretary of Energy Hazel O’Leary led a trade delegation to Beijing to explore how obstacles to bilateral civil nuclear commerce might be overcome, but obstacles continued to arise. The revelation in 1996 that CNNC sold 5,000 ring magnets – a potentially critical part of gas centrifuges – to Pakistan’s unsafeguarded uranium enrichment enterprise angered the U.S. Congress³⁰⁴ and forced the administration to delay its non-proliferation certification.³⁰⁵

Subsequently, the U.S. State Department led talks with Chinese officials to seek to address the non-proliferation issues raised by the incident and secure Beijing’s reaffirmation of its commitment to cease further unsafeguarded nuclear transfers.³⁰⁶ Talks with CNNC, the State Science and Technology Commission, and Chinese Foreign Ministry focused on plugging the holes in China’s nuclear and dual-use export control system to allow the President to certify China’s nonproliferation credentials and permit the implementation of the 1985 peaceful use agreement.³⁰⁷ The final piece of the puzzle was Iran. In the 1990s, the Clinton administration increasingly prioritized the Iranian nuclear and missile proliferation threat in its Middle East security policy. It therefore applied pressure on Beijing to limit its nuclear transfers to Iran when information surfaced about its readiness to assist Iran in developing uranium conversion and, according to some reports, uranium enrichment. Unlike Pakistan, Iran was party to the NPT. Initially, Beijing insisted upon its right to export uranium conversion equipment to Iran under safeguards,³⁰⁸ but under U.S. pressure, it agreed in mid-1997 to cancel the deal.³⁰⁹ In October, the Chinese Foreign Minister sent U.S. Secretary of State Madeleine Albright a secret letter pledging to refrain from initiating new nuclear transfers to Iran.³¹⁰

³⁰² Mark Hibbs, “U.S. Vendors Now Scrambling for Chinese Reactor Orders,” *Nucleonics Week* 37, no. 43 (October 24, 1996).

³⁰³ Kathleen Hart, “U.S. Officials Urge Nuclear Vendors to Pursue Growing Asian Markets,” *Nucleonics Week* 36, no. 19 (May 11, 1995).

³⁰⁴ Kathleen Hart, “Administration’s Decision on China’s Nuclear Sales Angers Congress,” *Nuclear Fuel* 21, no. 11 (May 20, 1996).

³⁰⁵ Mark Hibbs, “China Said Aiding Kahuta Project; U.S. Credits, NPT Status on Line,” *Nucleonics Week* 37, no. 6 (February 8, 1996).

³⁰⁶ Mark Hibbs, “U.S., China Aim to Relaunch Nuclear Cooperation Agreement,” *Nucleonics Week* 37, no. 38 (September 19, 1996).

³⁰⁷ Hibbs, Hart, and Dizard, “U.S.-China Talks on Nuclear Export Controls to Resume in Washington.”

³⁰⁸ Hibbs, “China Has Far to Go Before U.S. Will Certify, Agencies Now Say.”

³⁰⁹ Hibbs and Knapik, “U.S. Aims for China Certification Timed with Fall Visit by Jiang.”

³¹⁰ Kan, “China and Proliferation of Weapons of Mass Destruction and Missiles: Policy Issues.”

This combination of improvements in China's export control policies and practices paved the way for President Clinton's certification in 1998 that allowed the 1985 peaceful use agreement to be implemented. Clinton's letter to Congress states, "The Government of the People's Republic of China has made substantial strides in joining the international nonproliferation regime, and in putting in place a comprehensive system of nuclear-related, nationwide export controls, since the nuclear cooperation agreement was concluded in 1985." In view of China's "clear and unequivocal assurances to the United States that it is not assisting and will not assist any non-nuclear-weapon state" in acquiring nuclear explosive devices, the administration perceived "no legal bar" to bilateral cooperation in the peaceful use of nuclear energy.³¹¹ What President Clinton omitted in his letter was how desperately the U.S. civil nuclear industry needed the China market in the mid-to-late-1990s. Indeed, a Westinghouse-led industry coalition of major U.S. reactor vendor companies warned the administration that the industry would die, and all the American jobs it sustained would disappear, if restrictions on civil nuclear commerce with China were not lifted. Many of the companies in the coalition had donated generously to President Clinton's re-election campaign.³¹²

The implementation of the 1985 peaceful use agreement allowed U.S.-manufactured nuclear equipment to be exported to China, which in turn unlocked U.S. export financing as the U.S. Export-Import Bank required U.S. content as a condition for providing loans.³¹³ Senior Westinghouse representatives rushed to Beijing to negotiate reactor sales.³¹⁴ In January 1999, the NRC issued its first license for Westinghouse to export reactor components to China beyond the Canadian CANDU project at Qinshan. The CAEA conveyed assurances to the U.S. Department of State that the export would be subject to the terms of the newly implemented 1985 peaceful use agreement.³¹⁵ But then China's appetite for nuclear construction appeared to wane. The new Chinese Premier, Zhu Rongji, was much less supportive of nuclear power than his predecessor, Li Peng, and his policy of shuttering heavily subsidized industrial enterprises led to lower power demand projections.³¹⁶ Moreover, the policymakers in Beijing seemed to lean increasingly toward procuring a standardized PWR design with full technology transfer rather than continuing to sign individual turnkey contracts with Western vendors.³¹⁷ Westinghouse could in theory supply such a standardized design, but as it moved toward a deal, additional disagreements surfaced between the U.S. and Chinese governments. These disagreements pertained to the wording of assurances China would have to provide against the re-transfer of U.S.-origin civil nuclear technology to third parties as a prerequisite for the U.S. State

³¹¹ Clinton, "Letter to Congressional Leaders on the China-United States Nuclear Cooperation Agreement."

³¹² Mark Hibbs, "Vendors' Report to Clinton Claims Only China Can Save U.S. Industry," *Nucleonics Week* 38, no. 33 (August 14, 1997).

³¹³ Hibbs, "U.S. Vendors Now Scrambling for Chinese Reactor Orders."

³¹⁴ Mark Hibbs, "U.S.-China Deal Rumored Reason Westinghouse Staying a U.S. Firm," *Nucleonics Week* 39, no. 14 (April 2, 1998).

³¹⁵ "CHINA/U.S.: Westinghouse Gets Export License," *Nucleonics Week* 40, no. 4 (January 28, 1999).

³¹⁶ Mark Hibbs, "EU-China Fuel Retransfer May Snag on Slumping Sino-U.S. Relations," *Nuclear Fuel* 24, no. 11 (May 31, 1999); Mark Hibbs, "With Demand Below Projections, China May Drop Nuclear Projects," *Nucleonics Week* 40, no. 8 (March 4, 1999).

³¹⁷ Mark Hibbs, "Beijing Orders Nuclear Sector to Revamp PWR Development Plan," *Nucleonics Week* 41, no. 1 (January 6, 2000).

Department to sign off on any additional export authorizations – or for any authorizations already issued to remain valid.³¹⁸ U.S. concerns were prompted by China’s reverse engineering of French, German, and Japanese components for the indigenous 300MW reactor it built at Qinshan, which it subsequently exported to Pakistan.³¹⁹ At this point, all exports to Pakistan were under IAEA safeguards, consistent with China’s 1996 promise, but IAEA safeguards target the diversion of nuclear materials and misuse of nuclear facilities, not the reverse engineering of reactor component technology. Nor did Chinese assurances under the 1985 peaceful use agreement to refrain from retransferring U.S.-origin nuclear material and equipment apply to technology per se. Chinese reluctance to give these assurances arose from a concern that they would prevent Chinese entities from transferring even indigenously developed technology to future partners since a technology’s origin was more ambiguous than the origin of tangible nuclear material or equipment.³²⁰

The “breakthrough” came in September 2003, when Beijing agreed in a compromise to provide case-by-case assurances not to retransfer specific U.S. technologies approved for export to China under Part 810 authorizations.³²¹ The two countries then established “a process for determining what nuclear technologies require government-to-government nonproliferation assurances and set forth procedures for exchanging the assurances.” Finally, the door to full-fledged civil nuclear commerce was open. One of the first U.S. entities to benefit from the resolution of the retransfer issue was in fact the Massachusetts Institute of Technology (MIT), which had signed a memorandum of understanding with Tsinghua University to cooperate on high-temperature gas-cooled pebble-bed reactor.³²² The more commercially significant deal, however, would be Westinghouse’s sale of AP1000 reactors to China with full technology transfer.

³¹⁸ Michael Knapik, “U.S. Tries to Jump-Start Negotiations with China Over Part 810 Assurances,” *Nuclear Fuel* 25, no. 10 (May 15, 2000).

³¹⁹ Mark Hibbs and Margaret L. Ryan, “Technology Retransfer Stalemate Is Looming Over U.S.-China Accord,” *Nucleonics Week* 40, no. 26 (July 1, 1999).

³²⁰ Knapik, “U.S. Tries to Jump-Start Negotiations with China Over Part 810 Assurances.”

³²¹ Horner, “China, U.S. Resolving Dispute That Blocked Technology Exports.”

³²² Mark Hibbs, “U.S.-China Accord Regulates Third-Party Technology Transfers,” *Nucleonics Week* 44, no. 38 (September 18, 2003); Andrew C. Kadak, “Testimony before the U.S.-China Economic and Security Review Commission: China’s Energy Policies and Their Environmental Impacts,” U.S.-China Economic and Security Review Commission, August 13, 2008, <https://www.uscc.gov/sites/default/files/8.13.08Kadak.pdf>.

Chapter 6. The AP1000 deal: broadening cooperation along the energy and safety tracks

The Chinese nuclear industry had gained some familiarity with Westinghouse's AP technology by the early 2000s. As detailed previously, the U.S. vendor had engaged NPIC and SNERDI in the 80s and 90s to negotiate partnerships involving the AP600 – the predecessor of the AP1000. In 1997, Westinghouse and CNNC signed an agreement for Chinese engineers to take part in AP600 development.³²³ The company had also established its bona fides through the provision of technical services to Chinese nuclear power plants. When the core barrel of the Qinshan Unit 1 reactor suffered damage in 1998, Westinghouse managed the repair and replacement³²⁴ and fixed the design flaw that caused the damage.³²⁵ The company also formed a joint venture with CNNC's Research Institute of Nuclear Power Operation to introduce its reactor inspection robots to Qinshan. In 2003, it won further contracts to provide engineering design services to Qinshan and transfer core design know-how to SNERDI.³²⁶ These contracts as well as the reputation of U.S. civil nuclear technology put Westinghouse on a level playing field with the French and Russian PWR vendors who successfully secured reactor deals in China during the decades when U.S. vendors were absent.

That was important as China began preparing for the tender competition to select a Generation III PWR technology for import and indigenization.³²⁷ Generation III refers to a class of reactors featuring enhanced safety and efficiency as well as longer operating lives compared to the second-generation reactors from which they evolved. Three designs fit the bill – Westinghouse's AP1000, France's EPR, and Russia's upgraded VVER. But only the AP1000 reactor used entirely passive safety systems needing no external power to maintain critical safety functions such as core heat removal in the case of an accident. This put the Westinghouse reactor in a separate category of Generation III+ technology. Whereas the French and Russian vendors already had a number of domestic

³²³ Wenjie Su, "Xiwu Dianqi jingbiao Zhongguo hedian xiangmu yu bozhe daodi shengsuan jihe," Sina Finance, September 15, 2005, <https://finance.sina.cn/sa/2005-09-15/detail-ikknsesi2689753.d.html>.

³²⁴ National Nuclear Safety Administration, "The National Report under the Convention on Nuclear Safety of the People's Republic of China" (Beijing, September 2001), 5, <https://nnsa.mee.gov.cn/english/resources/national/201805/P020180524578087023329.pdf>.

³²⁵ Burke, "Visit of Commissioner Jeffrey S. Merrifield, U.S. Nuclear Regulatory Commission (March 3-10, 2001)," 5.

³²⁶ Su, "Xiwu Dianqi jingbiao Zhongguo hedian xiangmu yu bozhe daodi shengsuan jihe."

³²⁷ Zhongxi Qi, "Zhongguo hedian zizhuhua yituo xiangmu xuanyong Meiguo Xiwu sandai jishu," The Central People's Government of the People's Republic of China, March 1, 2007, https://web.archive.org/web/20250312012458/https://www.gov.cn/jrzq/2007-03/01/content_538780.htm.

and overseas orders lined up, Westinghouse needed to win the Chinese tender in order to translate its AP1000 design from blueprint to reality, particularly due to the lack of an active domestic market. That meant Westinghouse was more amenable than the others to China's demand for full, rapid technology transfer.³²⁸ The economic value of the deal was huge. China's Vice President told his U.S. counterpart Dick Cheney during an April 2004 meeting that China planned to build 24 to 30 nuclear power plants by 2020. Each plant would be worth billions of dollars.³²⁹ The U.S. government, represented by the Departments of Commerce, Energy, and State, worked with the Chinese government to support Westinghouse's bid starting from 2004, when China formally announced its tender competition.³³⁰ This time, it was China's turn to ask the U.S. government for export control assurances. Decisionmakers in Beijing were concerned Washington might exploit export controls to unduly interfere with the sale and technology transfer deal.³³¹ These concerns were only assuaged when those parts of the U.S. government with export control authority offered joint written assurances they would not do so.³³²

It was then up to the Chinese side to make their technology selection. To China, AP1000 technology was "mature, advanced, and reliable."³³³ Its passive safety, modular design, and smaller footprint led to expectations that construction would be simpler and more economical than with the French EPR. Intragovernmental meetings in Beijing eventually led to a senior expert vote that decided in favor of the AP1000. In November 2006, more than two years after the tender competition was announced and one-and-half years after Westinghouse submitted its bid, China's State Council and Politburo endorsed the decision to establish the State Nuclear Power Technology Corporation (SNPTC) – a new majority-state-owned nuclear company – to take charge of the import and indigenization of AP1000 technology. SNERDI would be subsumed under the SNPTC.³³⁴ Prior to the start of commercial negotiations, Howard Bruschi was once again invited to China as the lead architect of the AP1000 and retired Senior Vice President of Westinghouse. Bruschi outlined Westinghouse's strategic partnership with Chinese industry based on key complementarities – while Westinghouse held the technological advantage, China boasted a large nuclear workforce as well as equipment manufacturing and power plant construction capabilities, all of which U.S. industry had lost.³³⁵ But China's

³²⁸ Mark Hibbs, Jenny Weil, and Ann MacLachlan, "Westinghouse Wins China Contract; Chinese Look at next Expansion," *Nucleonics Week* 47, no. 51 (December 21, 2006).

³²⁹ Charles Hutzler, "China and U.S. Are Close To Ending Nuclear Dispute," *The Wall Street Journal*, September 2, 2004, <https://www.wsj.com/articles/SB109408266751307547>.

³³⁰ U.S. Department of Energy, "U.S.-Chinese Agreement Provides Path to Further Expansion of Nuclear Energy in China," U.S. Department of State, December 16, 2006, <https://2001-2009.state.gov/p/eap/rls/prs/77962.htm>.

³³¹ Hutzler, "China and U.S. Are Close To Ending Nuclear Dispute."

³³² Li Hongbing, Zhu Yue, and Ma Ke, "Zhongguo yinjin Xiwu hedian jishu juece shi mo," *Caijing*, April 11, 2011, <https://news.caijingmobile.com/article/detail/326455>.

³³³ Qi, "Zhongguo hedian zizhuhua yituo xiangmu xuanyong Meiguo Xiwu sandai jishu."

³³⁴ Zhaobo Chen and Fengtao Li, "Qinli Zhongguo yinjin disan dai hedian jishu shimo," *China Economic Weekly*, no. 13 (2014).

³³⁵ Li, Zhu, and Ma, "Zhongguo yinjin Xiwu hedian jishu juece shi mo."

greatest source of negotiating leverage, which it exploited skillfully to press for equipment localization and technology transfer, was the promise of reactor orders for its vast market.

In December 2006, China selected Westinghouse to supply four AP1000 units and transfer the reactor technology.³³⁶ The finalization of the deal coincided with the first U.S.-China Strategic Economic Dialogue (SED) aimed at fostering mutually beneficial trade and investment. Energy and environment were among the areas in which the two countries set out to explore crosscutting cooperation. The AP1000 deal therefore dovetailed with several priorities on the U.S.-China intergovernmental economic agenda, including the U.S. desire for high-technology exports that would help balance bilateral trade while advancing mutual energy and environmental objectives.³³⁷ U.S. Secretary of Energy Samuel Bodman signed an MoU with the head of the Chinese National Development and Reform Commission to reaffirm the U.S. government's blessing for the reactor's export to China³³⁸ and touted the deal as "a multi-billion dollar commitment by the Chinese that should create some 5,500 jobs" across 13 U.S. states and provide benefits for energy security and environmental stewardship in both countries.³³⁹ Both sides were pleased with the deal, and the commercial contracts were signed within months.

For Westinghouse, the deal represented an opportunity to finally construct its AP1000 plant as well as a chance to expand commercial opportunities beyond it. In 2008, Westinghouse announced that it was working with SNPTC and SNERDI to jointly develop a larger AP reactor.³⁴⁰ According to an earlier agreement with Westinghouse, China could claim intellectual property rights to any reactor design it developed on the basis of the AP1000 as long as the reactor power was above 1350 MWe; Westinghouse would have the right to participate in the reactor's sale in the U.S. and Japanese markets.³⁴¹ The design China developed in subsequent years became known as the CAP1400. As it inherits the AP1000's passive safety feature, the reactor is considered a Generation III+ design. In 2013, Westinghouse and SNPTC announced a further joint venture to develop "a global supply chain" for AP1000 reactors and "a plan to develop a small modular reactor" based on Westinghouse technology, to be marketed globally.³⁴² As for China's AP1000 projects, unfortunate delays resulted

³³⁶ Hibbs, Weil, and MacLachlan, "Westinghouse Wins China Contract; Chinese Look at next Expansion."

³³⁷ Wang and He, "Zhong Mei heneng guanxi de guoji zhengzhi jingjixue fenxi," 153.

³³⁸ "Memorandum of Understanding between the Government of the United States of America and the Government of the People's Republic of China Concerning Cooperation in the Area of Advanced Pressurised Water Reactor Nuclear Power Projects in China and Related Technology Transfer," Department of Energy, December 16, 2006, https://www.energy.gov/sites/default/files/pi_iec/098b7ef980003d3b.pdf.

³³⁹ Samuel W. Bodman, "Statement by U.S. Secretary of Energy Samuel W. Bodman on Reaching Agreement on Civilian Nuclear Energy with China," U.S. Department of State, December 16, 2006, <https://2001-2009.state.gov/p/eap/rls/rm/77965.htm>; U.S. Department of Energy, "U.S.-China Clean Energy Cooperation," January 2011, 8, <https://www.energy.gov/node/266881>.

³⁴⁰ Chunlin Hou, "Nuclear Regulations in China, Status of Sanmen NPP Construction and Experience Gained at NRC," April 20, 2010, 15, <https://www.nrc.gov/docs/ML1029/ML102990200.pdf>.

³⁴¹ Chen and Li, "Qinli Zhongguo yinjin disan dai hedian jishu shimo."

³⁴² Jane Nakano, "The United States and China: Making Nuclear Energy Safer," The Brookings Institution, July 2013, 14, https://www.brookings.edu/wp-content/uploads/2014/01/USChina-Making-Nuclear-Energy-Safer_JNakano.pdf.

from incomplete design and subpar equipment fabrication. Many follow-on AP1000 projects were postponed as planners increasingly favored CNNC and CGN's indigenous Generation III reactor, the HPR1000. Nevertheless, by 2018, all four AP1000 units in China had been connected to the grid. More localized AP1000 reactors, designated the CAP1000, have been approved in recent years and are under construction.



Haiyang Nuclear Power Plant units 1 and 2, 2024 · WPTO

At the end of the day, both countries drew concrete benefits from their cooperation over the AP1000. Shortly after China launched AP1000 construction, the United States began building analogous AP1000 reactor units at the Vogtle and VC Summer nuclear power plants in Georgia and South Carolina, respectively. Since China's AP1000 projects stayed ahead of U.S. projects in schedule, U.S. construction benefited significantly from prior Chinese experience. Through its “lessons learned program,” Westinghouse relayed “design, fabrication and construction related information” from the projects in China to its Pittsburgh headquarters to inform Vogtle's progress.³⁴³ Engineers from Vogtle traveled regularly to the Sanmen Nuclear Power Plant, where two of China's four AP1000 units were under construction, to observe equipment installation, testing, and startup and to “gain lessons learned” on site.³⁴⁴ Equally significantly, some safety tests for a new reactor design only needed to be performed for the first one or several units, and tests successfully completed at China's Sanmen and Haiyang nuclear power plants therefore were “credited” for Vogtle, meaning the same tests no longer needed to be performed.³⁴⁵ The design changes that were reviewed when they were applied to Chinese AP1000 plants also rolled into the design for Vogtle.³⁴⁶

In these and other respects, the AP1000 deal exemplified how U.S.-China civil nuclear commerce benefited from bilateral nuclear safety cooperation and vice versa. On the one hand, decades of NRC-C/NNSA exchanges fostered Chinese appreciation for U.S. civil nuclear technology's safety advantage. Among the six senior Chinese nuclear experts who petitioned the State Council to import and indigenize Generation III PWR technology and thereby paved the way to the AP1000 deal, two

³⁴³ Michael R. Johnson, “Foreign Trip Report on United States Nuclear Regulatory Commission Staff Visit to China for Meetings with the National Nuclear Safety Administration of China and Visits to AP1000 Manufacturing and Construction Sites,” April 20, 2010, <https://www.nrc.gov/docs/ML1033/ML103340208.pdf>.

³⁴⁴ Mike Tyndall, “Exchange Program with Sanmen Nuclear Power Station Results in Valuable ‘Lessons Learned,’” *Vogtle 3 and 4 - Fall/Winter 2016 - Community Magazine*, 2016.

³⁴⁵ Multi-National Design Evaluation Programme (MDEP) AP1000 Working Group, “Design-Specific Technical Report,” May 5, 2021, 2, https://www.oecd-nea.org/mdep/documents/AP1000_TR_LessonsLearnt_ImplementationCP_FPOT_FINAL.pdf.

³⁴⁶ “Technical Session - TH25: Practical Experience in Executing a 10 CFR Part 52,” March 10, 2022, 52, <https://www.nrc.gov/docs/ML2214/ML22140A232.pdf>.

had served in senior positions of the C/NNSA.³⁴⁷ In 2004, soon after China began considering AP1000 technology, the NRC delivered its first workshop on AP1000 design certification to an audience of “approximately 75 engineers and regulators” from Chinese utility operators and the C/NNSA. These workshops served to familiarize Chinese stakeholders with the AP1000’s unique passive safety systems and increase confidence in the NRC’s AP1000 safety review.³⁴⁸

The day after the U.S. and Chinese governments signed the MoU affirming the AP1000 deal, the C/NNSA reached out to the NRC to request “extensive cooperation and assistance” across the “design review, construction, and inspection” of the reactors. The NRC staff reviewed the request and, deeming the cooperation to be “of mutual benefit,” proposed a non-binding memorandum to establish a cooperative framework.³⁴⁹ Since the NRC was the first to review and certify the AP1000 design, the C/NNSA sought design knowledge and regulatory insights from cooperation with the U.S. regulator. The NRC, meanwhile, recognized that as AP1000 construction would commence at Chinese sites first, issues encountered during the Chinese regulatory process could usefully inform its own oversight activities as AP1000 license applications were submitted by U.S. licensees. In concrete terms, the NRC expected that its staff “would benefit from access to the AP1000’s first-of-its-kind engineering and design changes, and Quality Assurance (QA) oversight of vendors and construction activities, well in advance of when those activities could occur domestically” in the United States.³⁵⁰

Signed at the second U.S.-China SED in May 2007, the Memorandum of Cooperation on Nuclear Safety for the Westinghouse AP1000 Nuclear Reactor between the NRC and C/NNSA ended up establishing a Steering Committee to “meet annually to discuss the specific cooperative programs” across “nuclear safety review and inspection for the siting, design, manufacturing, construction, commissioning, and operation phases.”³⁵¹ With that, existing forms of cooperation were animated by a project-oriented mission. NRC assistance was crucial to the C/NNSA’s ability to exercise effective regulatory oversight vis-à-vis China’s AP1000s during safety review, where the Chinese regulator’s main target was to ensure that the “review scope and depth” of the construction permit application for Sanmen were “equivalent to that of COL application of AP1000 in the USA,” and that nuclear safety regulations were equivalent.³⁵² That required the C/NNSA to develop deep familiarity with

³⁴⁷ Zigao Zhao, “Hedian Zai Jujiao,” China Nuclear Energy Association, May 9, 2012, <https://www.china-nea.cn/site/content/10732.html>.

³⁴⁸ William M. Dean, “Weekly Information Report - Week Ending August 6, 2004,” August 11, 2004, <https://www.nrc.gov/docs/ML0422/ML042250026.pdf>.

³⁴⁹ Janice Dunn Lee, “Proposed Plan for Cooperation with China on the AP1000,” April 30, 2007, <https://www.nrc.gov/docs/ML1034/ML103400265.pdf>.

³⁵⁰ Lee.

³⁵¹ “Memorandum of Cooperation on Nuclear Safety for the Westinghouse AP1000 Nuclear Reactor between the Nuclear Regulatory Commission of the United States of America (USNRC) and the National Nuclear Safety Administration of the People’s Republic of China (NNSA),” May 23, 2007, <https://www.nrc.gov/docs/ML2116/ML21161A330.pdf>.

³⁵² National Nuclear Safety Administration, “Safety Review Progress and Status of AP1000 in China,” February 9, 2009, <https://www.nrc.gov/docs/ML1029/ML102990129.pdf>.

the NRC's review documents. However, the language barrier posed a challenge as the C/NNSA attempted to unpack these documents. The challenge was compounded by the fact that the Chinese regulator was not given enough time "to read all of the review documents carefully"³⁵³ even as it relied "heavily" on the NRC's review of the AP1000 to draw its own licensing conclusions.³⁵⁴

To assist with the AP1000's safety review in China, NRC staff visiting China from 2007 to 2009 offered trainings to C/NNSA regulators related to the AP1000's design and design certification review.³⁵⁵ Presentations on the NRC's and C/NNSA's respective reactor licensing processes were incorporated into the AP1000-themed meetings and workshops.³⁵⁶ The NRC then continued offering technical support to the C/NNSA throughout the construction and commissioning of the Chinese AP1000 units – by sending staff to Beijing to conduct AP1000



AP1000 technical training in China · U.S. Nuclear Regulatory Commission

workshops and answering the safety-related questions that came up. C/NNSA delegations' visits to the NRC continued with a similar focus on learning in preparation for China's AP1000 construction and commissioning.³⁵⁷ The NRC would instruct its staff to answer technical questions that the C/NNSA shared in advance as per its "bilateral support" commitment.³⁵⁸

Adding to these customary exchanges, forms of cooperation that were previously only envisioned materialized within this expanded framework. One was China's participation in the NRC's program for sharing computer codes for safety analysis. The NRC benefits from the international user feedback it collects.³⁵⁹ Another cooperative activity was the exchange of inspectors. Nuclear safety regu-

³⁵³ National Nuclear Safety Administration.

³⁵⁴ Jeffrey Jacobson and Eileen McKenna, "Combined Quick-Look and Final Trip Report," February 26, 2009, <https://www.nrc.gov/docs/ML1033/ML103330277.pdf>.

³⁵⁵ Dale E. Klein, "Letter to Ganjie from Klein, Regarding Recent Cooperation on AP1000 Project," April 30, 2009, <https://www.nrc.gov/docs/ML1029/ML102940445.pdf>.

³⁵⁶ Joelle L. Starefos, "NRC Foreign Trip Report on the AP1000 Design and Design Certification Review Training Program Presented in China from August 6-17, 2007," October 29, 2007, <https://www.nrc.gov/docs/ML1101/ML110130097.pdf>; Stephen Koenick, "U.S. Nuclear Regulatory Commission Foreign Trip Report on the Training Workshop – NRC's Regulatory Review of the AP1000 Reactor Design Presented in China October 20–31, 2008," December 2, 2008, <https://www.nrc.gov/docs/ML1103/ML110390357.pdf>.

³⁵⁷ National Nuclear Safety Administration, "Safety Review Progress and Status of AP1000 in China."

³⁵⁸ "Support for China Questions and Forthcoming Meeting with the Chinese National Nuclear Safety Administration Staff (TAC Q00214)," January 8, 2009, <https://www.nrc.gov/docs/ML1029/ML102990126.pdf>.

³⁵⁹ Brian W. Sheron, "Agreement on Nuclear Reactor Safety Research between the U.S. Nuclear Regulatory Commission and the National Nuclear Safety Administration of the People's Republic of China," December 7, 2009, <https://www.nrc.gov/docs/ML1031/ML103120767.pdf>; Jinjun Feng et al., "Application of TRACE V5.0 P2 to Natural Circulation Reactor Safety Analysis" (Washington, DC: Nuclear Regulatory Commission, October 2012), <https://www.nrc.gov/docs/ML1321/ML13213A077.pdf>.

lators not only have to review reactor designs but also must inspect component manufacturing, plant construction, and pre-commissioning tests. Component manufacturing is inspected during so-called vendor inspections. With the AP1000 deal, the U.S. and Chinese reactor supply chains intersected, bringing component manufacturing issues to the fore. During his January 2008 visit to Beijing, NRC Chairman Dale Klein expressed his concern to C/NNSA head Li Ganjie “over counterfeit and sub-standard equipment produced in China for use in reactors in the United States and worldwide.” The two agencies therefore agreed to establish a vendor inspection program for Chinese nuclear equipment manufacturers³⁶⁰ and conduct “joint observations of vendor inspections” along the AP1000 supply chain in both countries.³⁶¹ These joint activities fostered the regulators’ mutual learning and confidence in AP1000 reactor components’ quality assurance.³⁶²

While vendor inspections ensure component manufacturing quality, construction inspections verify that the plant is built to its licensed design according to a set of Inspections, Tests, Analyses, and Acceptance Criteria, or ITAAC. In early 2010, the NRC and C/NNSA launched a construction inspector exchange program. At the time, the Chinese construction inspection program was still “in the early stages of development” and “not formally documented.”³⁶³ Interested in learning more about the NRC’s construction inspections and ITAAC,³⁶⁴ the C/NNSA sent inspectors to the United States to observe the NRC’s construction oversight;³⁶⁵ its assignees at NRC headquarters worked with NRC staff on the development of inspection programs, gaining on-the-job experience.³⁶⁶ In return, the NRC sent its regional inspectors to China to observe the AP1000’s construction.³⁶⁷ The inspectors also had the mission of advising on-site C/NNSA staff in developing their inspection plans based on NRC practice.³⁶⁸

As the Chinese AP1000s approached commissioning, the two regulatory agencies shifted their focus toward the commissioning process. In 2013, the Steering Committee agreed upon a “detailed plan” to “exchange inspectors during pre-operational phases and testing of the AP1000,”³⁶⁹ thus extending

³⁶⁰ James Martin Center for Nonproliferation Studies, “China Nuclear Chronology.”

³⁶¹ Glenn Tracy, “Foreign Trip Report on United States Nuclear Regulatory Commission Staff Visit to China for Meetings with the National Nuclear Safety Administration of China and Visits to AP1000 Manufacturing and Construction Sites,” December 1, 2009, <https://www.nrc.gov/docs/ML1033/ML103340206.pdf>.

³⁶² Lee, “Proposed Plan for Cooperation with China on the AP1000.”

³⁶³ Bradley J. Davis, “Trip Report – International Exchange with China’s National Nuclear Safety Administration at the Sanmen Nuclear Project Construction Site,” July 7, 2010, <https://www.nrc.gov/docs/ML1036/ML103640247.pdf>.

³⁶⁴ Koenick, “U.S. Nuclear Regulatory Commission Foreign Trip Report on the Training Workshop – NRC’s Regulatory Review of the AP1000 Reactor Design Presented in China October 20–31, 2008.”

³⁶⁵ “The United States of America Fifth National Report for the Convention on Nuclear Safety,” September 2010, 161.

³⁶⁶ “Semiannual Status Report on the Licensing Activities and Regulatory Duties of the United States Nuclear Regulatory Commission,” 2010, 34, <https://www.nrc.gov/docs/ML1029/ML102920223.pdf>.

³⁶⁷ Tracy, “Foreign Trip Report on United States Nuclear Regulatory Commission Staff Visit to China for Meetings with the National Nuclear Safety Administration of China and Visits to AP1000 Manufacturing and Construction Sites.”

³⁶⁸ Davis, “Trip Report – International Exchange with China’s National Nuclear Safety Administration at the Sanmen Nuclear Project Construction Site.”

³⁶⁹ Nuclear Regulatory Commission, “2013 New Reactor Program,” March 2014, 5, <https://www.nrc.gov/docs/ML1405/ML14055A176.pdf>.

the exchange program beyond construction inspections. Exchanges of information and inspectors lent both regulatory agencies insight into the other's commissioning program.³⁷⁰ From 2010 onward, nearly 20 NRC inspectors served rotational assignments at Sanmen³⁷¹ to observe the AP1000 reactors' construction, pre-operation, and startup testing, thus gaining familiarity with plant systems and layout and deriving oversight lessons.³⁷² The U.S. inspectors who returned from their months-long rotational assignments at Sanmen incorporated their first-hand insights into the NRC's AP1000 training courses and leveraged these insights to refine the NRC's own inspection plans and procedures.³⁷³

In the four decades after 1981, when the bilateral nuclear safety cooperation protocol was signed, the NRC-C/NNSA partnership gradually evolved from unidirectional assistance to mutual learning. When it comes to nuclear safety management, the United States has no doubt remained ahead in experience and methodology. Apart from training that the NRC has offered to the C/NNSA, transfer of U.S. knowledge in risk-informed nuclear safety management to Chinese nuclear operators, engineers, and researchers has taken place through workshops under DOE's Peaceful Uses of Nuclear Technology (PUNT) framework,³⁷⁴ and U.S. industry has transferred best practices in quality assurance³⁷⁵ and nuclear power plant operation to Chinese industry.³⁷⁶ That said, mutual learning has increased in the last two decades. Parallel with AP1000 cooperation, the two countries explored collaborative opportunities in the safety of high-temperature gas-cooled reactors and liquid metal reactors,³⁷⁷ with China being one of the few countries in the world to operate prototypes of both. In May 2010, visiting NRC Chairman Gregory Jaczko secured the C/NNSA's commitment to "further cooperation" on HTGR data, positioning the NRC to regulate the advanced reactor concept that China was ahead in deploying.³⁷⁸ The NRC expected Chinese operational data to help it validate ex-

³⁷⁰ Jigen Li, "Letter to China's NNSA Regarding AP1000 Design Issues-July/August 2013 Visit," November 26, 2013, <https://www.nrc.gov/docs/ML1327/ML13274A523.pdf>.

³⁷¹ "Technical Session - TH25: Practical Experience in Executing a 10 CFR Part 52," 25.

³⁷² Lauren A. Nist and Omar R. Lopez-Santiago, "10 CFR Part 52 Construction Lessons-Learned Report," January 16, 2024, <https://www.nrc.gov/docs/ML2332/ML23325A202.pdf>.

³⁷³ Victor M. McCree, "Construction Reactor Oversight Process Self-Assessment for Calendar Year 2017," April 27, 2018, 10, <https://www.nrc.gov/docs/ML1805/ML18059A247.pdf>; Margaret M. Doane, "Construction Reactor Oversight Process Self-Assessment for Calendar Year 2018," April 21, 2019, <https://www.nrc.gov/docs/ML1903/ML19037A311.pdf>; "Strategic Programmatic Overview of the New Reactors Business Line," September 24, 2015, <https://www.nrc.gov/docs/ML1527/ML15272A030.pdf>.

³⁷⁴ Office of the Spokesperson, "U.S.-China Strategic & Economic Dialogue Outcomes of the Strategic Track," U.S. Department of State, June 7, 2016, <https://2009-2017.state.gov/r/pa/prs/ps/2016/06/258146.htm>; "Events," Socio-Technical Risk Analysis (SoTeRiA), accessed November 23, 2025, <https://soteria.npre.illinois.edu/events/>.

³⁷⁵ Jeffrey Jacobson, "Combined Quick-Look and Final Trip Report," November 13, 2008, <https://www.nrc.gov/docs/ML1033/ML103340204.pdf>.

³⁷⁶ Clarion Energy Content Directors, "Exelon Signs Nuclear Consulting Service Contract in China," Power Engineering, November 14, 2011, <https://www.power-eng.com/nuclear/exelon-signs-nuclear-consulting-service-contract-in-china/>; "Exelon to Provide Nuclear Services to CNNC," World Nuclear News, November 14, 2011, <https://world-nuclear-news.org/Articles/Exelon-to-provide-nuclear-services-to-CNNC>.

³⁷⁷ James E. Lyons and Jennifer L. Uhle, "Foreign Trip Report," April 23, 2009, <https://www.nrc.gov/docs/ML1031/ML103120766.pdf>.

³⁷⁸ Gregory Jaczko, "Trip Report for Visit to: Beijing, China, May 23-25, 2010," August 12, 2010, <https://www.nrc.gov/docs/ML1102/ML110260168.pdf>.

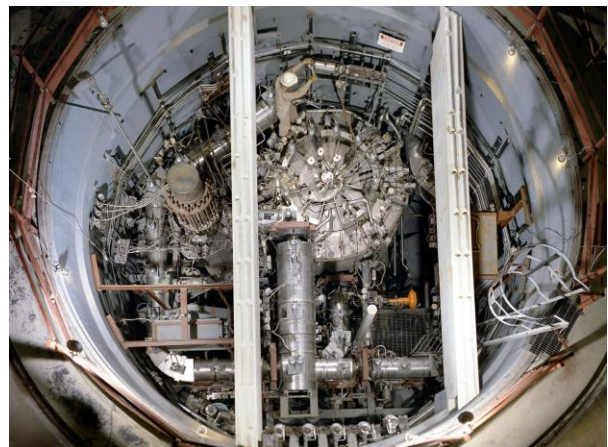
isting safety models while the C/NNSA could benefit from NRC insights and recommendations as it reviewed its larger HTGR.³⁷⁹ Collaboration over the liquid metal reactors, meanwhile, proceeded along the DOE track, as did most U.S.-China collaboration on advanced reactor R&D.

³⁷⁹ Gregory B. Jaczko, “China Letter from Chairman Jaczko Re Biannual U.S.-China Strategic and Economic Dialogue (S&ED),” April 26, 2010, <https://www.nrc.gov/docs/ML1011/ML101130521.pdf>.

Chapter 7. Cooperation in advanced fission energy

If the Westinghouse AP1000 is considered a Generation III reactor, then advanced reactors like HTGRs and liquid metal reactors would be considered Generation IV – referring to a class of “revolutionary” reactor concepts, most of which depart from traditional light-water-reactor (LWR) technology. Through innovations such as a fast neutron spectrum and metal fuel, these reactors could allow fissile material breeding, fuel recycling, and waste transmutation while achieving safety advances. Despite their civil nuclear programs’ convergence on LWRs, both China and the United States have a long history of exploring and developing non-LWR technologies.

In the 1940s, the Oak Ridge National Laboratory (ORNL) began researching nuclear aircraft propulsion, leading to the demonstration of a small reactor fueled with uranium dissolved in molten salt.³⁸⁰ That morphed into a Molten Salt Reactor Experiment that achieved first criticality in 1965. Rather than circulating liquid coolant through solid fuel, the reactor used uranium dissolved in molten salt as both fuel and coolant. It also operated experimentally on uranium-233 – a fissile uranium isotope that could be bred from thorium, unlike the uranium-235 isotope that could only reach higher-than-natural concentrations through enrichment.³⁸¹ But then the experimental reactor was shut down. Ultimately, the liquid-fueled molten-salt reactor became just one among many non-LWR prototypes that the United States explored in succession. Like the homogeneous reactor and lead-bismuth reactor that were abandoned in its favor, the molten salt reactor program was terminated in 1973 to free up the AEC’s budget for the sodium-cooled fast breeder.³⁸²



The Molten-Salt Reactor Experiment at Oak Ridge, c. 1964 · Oak Ridge National Laboratory

³⁸⁰ Murray W. Rosenthal, “An Account of Oak Ridge National Laboratory’s Thirteen Nuclear Reactors” (Oak Ridge: Oak Ridge National Laboratory, March 2010), 28–29, <https://info.ornl.gov/sites/publications/files/Pub20808.pdf>.

³⁸¹ “Time Warp: Molten Salt Reactor Experiment—Alvin Weinberg’s Magnum Opus,” Oak Ridge National Laboratory, June 1, 2016, <https://www.ornl.gov/blog/time-warp-molten-salt-reactor-experiment-alvin-weinbergs-magnum-opus>.

³⁸² Rosenthal, “An Account of Oak Ridge National Laboratory’s Thirteen Nuclear Reactors,” 29, 33.

Sodium as a reactor coolant provides high thermal conductivity and a very high boiling point, allowing operation at near atmospheric pressure, which enhances inherent safety. It also has advantageous properties in terms of neutronic interactions, providing an excellent neutron economy and a fast spectrum that enables both efficient breeding of fissile material and transmutation of high-activity radioisotopes. The United States pursued sodium-cooled fast breeders at what is today Idaho National Laboratory. It was there that the world's first Experimental Breeder Reactor, or EBR-I, fueled by uranium and cooled by a sodium-potassium alloy, was brought online in 1951. While the amount of electricity generated by the reactor was minuscule, it proved the concept of a reactor that could breed fissile plutonium from non-fissile uranium-238 while producing power. A scaled-up EBR-II went critical in the 1960s and operated until the 1990s. Its spent metallic fuel was recycled on-site, demonstrating one of the most attractive features of the sodium-cooled fast breeder concept, namely, the more efficient use of fissionable material.

The world's first HTGR to generate electricity was also built in the United States – in the 1960s, at the Peach Bottom Nuclear Generating Station near Harrisburg, Pennsylvania. After serving its demonstration mission, it was permanently shut down in 1974 due to lack of economic viability.³⁸³ A larger commercial HTGR at Fort St. Vrain, Colorado, was built in the 1960s and 70s, but it, too, was decommissioned in the 1990s.

Like the United States, China explored non-LWR technologies allowing fissile material breeding in the early years of its civil nuclear program as it feared a domestic uranium deficit. In 1970, Premier Zhou Enlai instructed the Second Ministry of Machine-Building – as China's nuclear ministry was called – to develop nuclear power generation separate from its original defense mission. The Shanghai Institute of Nuclear Research – predecessor of what is today CAS's Shanghai Institute of Applied Physics (SINAP) – set out to develop a molten-salt reactor capable of breeding uranium-233 from thorium. A zero-power experimental reactor fueled by a combination of uranium and thorium was constructed and experimentally operated. But in July 1973, after two years of tests, plans to construct a full-scale thorium molten-salt reactor were abandoned due to obstinate challenges ranging from the lack of suitable structural alloys to the difficulty of reprocessing the highly radioactive molten salt fuel to extract the bred U-233.³⁸⁴ The Chinese civilian nuclear power program then pivoted to PWR technology as recommended by the chief engineer of China's naval propulsion program.

³⁸³ Bruce K. McDowell et al., "High Temperature Gas Reactors: Assessment of Applicable Codes and Standards" (Richland: Pacific Northwest National Laboratory, October 2011), 4–5, <https://doi.org/10.2172/1031438>.

³⁸⁴ N. Abrate et al., "Status of Molten Salt Reactor Technology" (Vienna: International Atomic Energy Agency, 2023), 235–37, https://www-pub.iaea.org/MTCD/Publications/PDF/STI-DOC-010-489_web.pdf.

That, in turn, led to China's indigenous PWR first constructed at Qinshan and subsequently exported to Pakistan.³⁸⁵

Even as their nuclear power programs became defined by LWRs, neither China nor the United States abandoned their non-LWR research. In the United States, a series of DOE programs and initiatives in the 2000s renewed the development of advanced reactors and fuel cycles to mitigate the economics, waste, and proliferation challenges associated with nuclear energy and unleash its potential to contribute to energy security and sustainability. These were the objectives of the Generation IV Nuclear Energy Systems Initiative and Advanced Fuel Cycle Initiative (AFCI) and, after 2006, the Global Nuclear Energy Partnership (GNEP). In the early 2000s, under the Generation IV Nuclear Energy Systems Initiative, DOE and its international partners identified the six most promising advanced reactor concepts, each offering its own combination of safety, economics, fuel utilization, and proliferation resistance advantages, and sought to advance the research and development of these concepts toward commercial adoption.³⁸⁶ A key objective was the development of suitable fuels and structural materials at national labs.³⁸⁷ The AFCI, meanwhile, aimed to develop advanced fuel and spent fuel reprocessing technologies that, together with advanced reactors, promised to “reduce the volume and long-term toxicity of high level waste from spent nuclear fuel, reduce the



China Experimental Fast Reactor under construction, 2004 · Petr Pavlicek / IAEA

long-term proliferation threat posed by civilian inventories of plutonium in spent fuel, and provide for proliferation-resistant technologies to recover the energy content in spent nuclear fuel.”³⁸⁸

China adopted its official policy of pursuing a closed nuclear fuel cycle in 1983 – a decision that was in part encouraged by other countries’ fast breeder and reprocessing programs.³⁸⁹ Between 1990 and 2010, CIAE designed and constructed an experimental sodium-cooled fast reactor – the China Experimental Fast Reactor (CEFR) – with

³⁸⁵ Yajie Wang, “Hedian wangshi —— Zhongguo shou zuo hedianzhan jianli shi mo,” Shanghai Nuclear Engineering Research & Design Institute Co., LTD., August 16, 2019, <https://www.snerdi.com.cn/newsdetail?id=7009>; “Peng Shilu: jianfu lishi shiming de Qinshan hedian,” China National Nuclear Corporation, March 2, 2022, <https://www.cnnc.com.cn/cnnc/xwzx65/zt25/hgylbq/1165625/1165629/1234746/index.html>.

³⁸⁶ “Office of Nuclear Energy, Science and Technology,” Princeton Plasma Physics Laboratory, 2004, 75–76, 79, https://fire.pppl.gov/us_pres_bud_ne_jus_fy04.pdf.

³⁸⁷ “Office of Nuclear Energy, Science and Technology,” 80.

³⁸⁸ “Office of Nuclear Energy, Science and Technology,” 18.

³⁸⁹ Matthew Bunn, Hui Zhang, and Li Kang, “The Cost of Reprocessing in China” (Boston: Belfer Center for Science and International Affairs, January 2016), 9, <https://dash.harvard.edu/server/api/core/bitstreams/7312037d-cbd2-6bd4-e053-0100007fdf3b/content>.

significant Russian assistance.³⁹⁰ The plan was to develop follow-on demonstration and commercial units that could operate on mixed-uranium-plutonium-oxide (MOX) fuel, burning the plutonium extracted from the spent fuel of China's indigenous PWRs. Meanwhile, Tsinghua University continued to concentrate on the HTGR, and other non-LWR concepts were explored by institutes under the Chinese Academy of Sciences. Thus, by the mid-2000s, China was in effect pursuing the same advanced reactor concepts as the United States and, under some concepts, leaping ahead in deploying prototype reactors based on non-U.S. foreign technologies. Its R&D followed the same priority on high-temperature reactors and sodium-cooled fast reactors like the U.S. DOE.³⁹¹

When the Bush administration announced the Global Nuclear Energy Partnership in February 2006, these technical complementarities formed a natural basis for cooperation. At its core, the GNEP was a global energy security initiative. One of its aims was to establish a multinational program offering developing countries that agreed to forgo proliferation-sensitive fuel-cycle capabilities reliable access to nuclear fuel. Another was to demonstrate and deploy advanced reactor and fuel cycle technologies making nuclear power uranium-efficient, low-waste, and proliferation-resistant. More specifically, the program envisioned developing “new proliferation-resistant recycling technologies,” particularly pyroprocessing and fast reactors for burning recycled nuclear fuel, in partnership with “established fuel-cycle countries” while designing and deploying “small scale nuclear reactors” to ease nuclear energy access for developing countries.³⁹² Hence, while building directly upon the preceding Generation IV Nuclear Energy Systems Initiative and AFCI, the GNEP represented a more comprehensive strategic vision that the administration could champion domestically and internationally in the name of bolstering U.S. and global energy security, sustainable development, and nonproliferation.

It also expanded the United States' cooperation with other countries in advanced civil nuclear R&D. Within the first 18 months of the GNEP's announcement, the United States had formalized bilateral agreements with a number of “established fuel-cycle countries” to cooperate over advanced fast reactor and reprocessing technologies.³⁹³ China was eager to participate in the program from the start.³⁹⁴ On April 20, 2006, two months after the GNEP's announcement, U.S. President George W. Bush and Chinese President Hu Jintao met at the White House, where they jointly affirmed their

³⁹⁰ Mi Xu, “Fast Reactor Development for a Sustainable Nuclear Energy Supply in China,” 2009, https://www-pub.iaea.org/MTCD/Meetings/PDFplus/2009/cn176/cn176_Presentations/plenary_session_1/FRP-01.Xu.pdf.

³⁹¹ National Research Council, *Review of DOE's Nuclear Energy Research and Development Program* (Washington, DC: The National Academies Press, 2008), 31, <https://doi.org/10.17226/11998>.

³⁹² U.S. Department of Energy, “Department of Energy Announces New Nuclear Initiative Global Nuclear Energy Partnership to Expand Safe, Clean, Reliable, Affordable Nuclear Energy Worldwide,” 2006, <https://www.nrc.gov/docs/ML1214/ML12142A232.pdf>.

³⁹³ Paul Lisowski, “The Global Nuclear Energy Partnership,” U.S. Department of Energy, 2007, 9, 13, <https://www.energy.gov/sites/prod/files/NEAC0207-global-partnership.pdf>.

³⁹⁴ Personal conversation with Chaim Braun.

countries' desire to expand cooperation in advanced fuel cycle R&D.³⁹⁵ Like the AP1000 deal, joint research of advanced civil nuclear technologies fit under the clean energy rubric of the bilateral SED framework. Ahead of the second SED, on May 21, 2007, U.S. Energy Secretary Samuel W. Bodman and Chairman of the Chinese National and Development Reform Commission (NDRC) Ma Kai issued a joint statement with senior energy officials from France, Japan, and Russia endorsing the GNEP and broader civil nuclear cooperation.³⁹⁶ As successive SEDs reiterated the two countries' common concern for energy security and sustainability,³⁹⁷ advanced fission energy collaboration appeared a natural imperative. Cooperation was formalized with the signing of the U.S.-China Bilateral Civil Nuclear Energy Cooperative Action Plan (hereafter, "Action Plan") in September that year.³⁹⁸

Formally, the Action Plan represented a "programmatic commitment" and was not legally binding,³⁹⁹ but it set up a senior Steering Committee convening the U.S. DOE, NRC, and State Department with the Chinese NDRC, CAEA, C/NNSA, CNNC, Ministry of Science and Technology, and Foreign Ministry. Under bilateral agreements on the peaceful uses of nuclear energy and technology, this group held the requisite authority to implement the cooperative action plan across its three phases. Areas of cooperative R&D mirrored the GNEP's objectives. For each area, a working group was charged with developing detailed proposals during Phase I, to be implemented in Phases II and III from 2009 onward. The technical work for fast reactors and reprocessing was led by Idaho and Argonne National Laboratories on the U.S. side and CIAE on the Chinese side while Oak Ridge and NPIC took the lead with respect to materials and grid-appropriate reactors.⁴⁰⁰ Additional working groups were envisioned to advance modeling and simulation as well as "global assured nuclear fuel supplies and services."⁴⁰¹

In 2008 and 2009, working groups met and outlined an ambitious cooperative agenda focused on advanced fuels and materials, fast reactor technology, spent fuel reprocessing and waste management, and safeguards and physical protection. The fuels and materials working group set out to develop cladding and casting technology for metallic fuels, which are more suitable for fast reactors and pyroprocessing than traditional oxide fuels. While the United States had far more experience

³⁹⁵ C. Channy Wong, John W. Herczeg, and Zhijun Qin, "An Overview of the US-China Cooperative on Advanced Fuel Cycle Research" (The 8th International Topical Meeting on Nuclear Thermal-Hydraulics, Operation and Safety (NUTHOS-8), Shanghai, China, 2010), 3.

³⁹⁶ "United States - China: Bilateral Civil Nuclear Energy Cooperative Action Plan," September 18, 2007, https://media.nti.org/pdfs/1a_1_1.pdf.

³⁹⁷ "The First U.S.-China Strategic Economic Dialogue December 14-15, Beijing Fact Sheet," U.S. Department of the Treasury, December 15, 2006, <https://home.treasury.gov/news/press-releases/hp205>; "Fact Sheet: Second Meeting of the U.S.-China Strategic Economic Dialogue," U.S. Department of the Treasury, May 23, 2007, <https://home.treasury.gov/news/press-releases/hp417>.

³⁹⁸ Wong, Herczeg, and Qin, "An Overview of the US-China Cooperative on Advanced Fuel Cycle Research," 3.

³⁹⁹ "United States - China: Bilateral Civil Nuclear Energy Cooperative Action Plan," 2.

⁴⁰⁰ Blythe J. Lyons et al., "United States-China Cooperation on Nuclear Power: An Opportunity for Fostering Sustainable Energy Security" (Washington, DC: Atlantic Council, 032009), 20, https://www.files.ethz.ch/isn/104035/2009_03_USChinaNuclearPower.pdf; Wong, Herczeg, and Qin, "An Overview of the US-China Cooperative on Advanced Fuel Cycle Research," 4.

⁴⁰¹ "United States - China: Bilateral Civil Nuclear Energy Cooperative Action Plan," 5.

with metallic fuels, CIAE's infrastructure for fast neutron irradiation testing made joint R&D attractive. The reprocessing working group, meanwhile, saw benefit in the joint development of a simplified pyroprocessing technique with higher efficiency in fissile material recovery and reduced waste generation. Here, too, the United States held the knowledge advantage yet sought to leverage CIAE's radiochemistry laboratory and hot cells for joint experiments. For the fast reactor technology working group, the main task was to exchange information to better understand core design and safety analysis of sodium-cooled fast reactors, as well as commissioning, operation, and maintenance. American experience with sodium-cooled fast reactors came from the EBRs. China's experience after 2010 would come from the CEFBR. Finally, the safeguards working group extended existing cooperation in safeguards technology R&D from traditional to advanced reactors.⁴⁰²

In hindsight, the working groups' technical proposals were perhaps overly ambitious, especially as the GNEP's continuity hinged upon politics in Washington. In 2009, newly elected President Barack Obama reversed the Bush administration's policy of supporting domestic nuclear spent fuel reprocessing, undermining the GNEP's central focus on the commercialization of advanced fuel recycling.⁴⁰³ To critics of the GNEP, advanced pyroprocessing mitigates neither the poor economics of plutonium recycling nor the attendant proliferation risks.⁴⁰⁴ In 2010, the GNEP was formally transformed into the International Framework for Nuclear Energy Cooperation (IFNEC) with a maximally generic mission statement.⁴⁰⁵ With that, the GNEP vision was largely abandoned. But cooperation under the U.S.-China bilateral Action Plan continued. New working groups for Spent Fuel Storage and Repository Sciences and Nuclear Safety Enhancement were created, reflecting a shift in focus to spent fuel and waste disposal as well as safety management.⁴⁰⁶ Accordingly, the existing separations technology working group adapted its agenda to focus on the management of iodine and tritium that escape as gaseous wastes during spent fuel reprocessing. In 2012, the two sides identified a set of "potential joint projects on iodine and tritium management for solid spent fuel" and envisioned developing a multi-year plan around the 2014-2015 timeframe.⁴⁰⁷

⁴⁰² Wong, Herczeg, and Qin, "An Overview of the US-China Cooperative on Advanced Fuel Cycle Research," 4–7.

⁴⁰³ Office of Nuclear Energy, U.S. Department of Energy, "Notice of Cancellation of the Global Nuclear Energy Partnership (GNEP) Programmatic Environmental Impact Statement (PEIS)," Federal Register, June 29, 2009, <https://www.federalregister.gov/documents/2009/06/29/E9-15328/notice-of-cancellation-of-the-global-nuclear-energy-partnership-gnep-programmatic-environmental>.

⁴⁰⁴ "Advancing Technology For Nuclear Fuel Recycling: What Should Our Research, Development, And Demonstration Strategy Be?" (Washington, DC: U.S. Government Printing Office, 2009), <https://www.govinfo.gov/content/pkg/CHRG-111hhrg50172/html/CHRG-111hhrg50172.htm>.

⁴⁰⁵ International Framework for Nuclear Energy Cooperation, "History," International Framework for Nuclear Energy Cooperation, accessed November 14, 2025, https://www.ifnec.org/ifnec/jcms/g_5150/history.

⁴⁰⁶ Chinese Academy of Sciences and U.S. Department of Energy, "Cooperation in Nuclear Energy Sciences and Technologies First Executive Committee Meeting Report," October 22, 2012, 11, https://ia802900.us.archive.org/19/items/sovereignwealthus_337/DOE%20_%20China%20MSR%20Collaboration.pdf.

⁴⁰⁷ Jason Schulthess and Douglas Hamelin, "Separations and Waste Forms Research and Development FY 2013 Accomplishments Report" (Idaho Falls: Idaho National Laboratory, 2013), 8, <https://web.archive.org/web/20250204204730/https://inldigitallibrary.inl.gov/sites/sti/sti/5960998.pdf>.

Other existing working groups with responsibilities in fast reactor technology, fuels, and materials, also continued to advance joint research activities. These included the development of a model for the CEFR's safety analysis and use of the CEFR for irradiation testing.⁴⁰⁸ The latter was a particular priority for DOE because the United States had lost its domestic fast-neutron-spectrum irradiation capability.⁴⁰⁹ Elsewhere at the time, Japan's experimental fast reactor, Joyo, was under restoration following an incident that had severely damaged components inside the reactor vessel;⁴¹⁰ France's Phénix had been shut down in 2009; and India's Fast Breeder Test Reactor was outside IAEA safeguards. China's CEFR emerged as the best alternative fast-spectrum neutron irradiation facility available apart from Russia's BOR-60. Consequently, in September 2014, DOE and the Chinese National Energy Administration signed a formal statement of intent to conduct joint irradiation testing on advanced fuels and materials at the CEFR.⁴¹¹

In parallel with joint R&D led by national laboratories, commercial cooperation on sodium-cooled fast reactors proceeded between Bill Gates's U.S.-based reactor company, TerraPower, and CNNC. At a Seattle trade and investment seminar in September 2015, the two parties signed an MoU on joint development of Traveling Wave Reactor (TWR) technology,⁴¹² with the eventual aim of establishing a joint venture.⁴¹³ Unlike a conventional reactor that requires periodic refueling with enriched uranium and external reprocessing should fuel recycling be desired, a TWR is loaded with mostly fertile material such as uranium-238, which absorbs neutrons from fission reactions to convert into fissile plutonium-239 and then itself fissions, releasing more neutrons to "breed" more plutonium. As this breeding-burning wave travels through the reactor core, most of the initially non-fissile uranium is consumed. Thus, the reactor can operate for a long period of time without refueling. Uranium tails and waste normally associated with plutonium extraction through reprocessing would be reduced. Further, a fuel cycle based on the TWR would drastically reduce the need for proliferation-sensitive enrichment and reprocessing infrastructure. Whereas fast reactor concepts that envision plutonium breeding normally require the periodic extraction of spent fuel and separation of weapons-usable plutonium, this proliferation risk is mitigated with the TWR because plutonium is consumed directly in the core as it is bred.

⁴⁰⁸ Argonne National Laboratory, "Status of the SAS4A/SASSYS-1 Safety Analysis Code" (Argonne: Argonne National Laboratory, 2017), 2, <https://publications.anl.gov/anlpubs/2018/08/145562.pdf>.

⁴⁰⁹ U.S. Department of Energy, "Final Versatile Test Reactor Environmental Impact Statement Summary," May 2022, S-3, <https://www.energy.gov/sites/default/files/2022-05/final-eis-0542-versatile-test-reactor-summary-2022-05.pdf>.

⁴¹⁰ Masahide Hara et al., "Completion of 'Joyo' Experimental Fast Reactor Upper Core Structure Replacement," *Mitsubishi Heavy Industries Technical Review* 53, no. 4 (December 2016): 65.

⁴¹¹ "Meilijian Hezhongguo Nengyuan Bu he Zhonghua Renmin Gongheguo Guojia Nengyuan Ju guanyu zai Zhongguo Shiyuan Kuaidui kaizhan lianhe fuzhao shiyan de yixiang shengming," September 4, 2014, https://www.energy.gov/sites/default/files/pi_iec/098b7ef98009faab.pdf.

⁴¹² "CNNC Signs Nuclear Agreement with TerraPower," China National Nuclear Corporation, September 23, 2015, https://en.cnncc.com.cn/2015-09/23/c_1022863.htm.

⁴¹³ "TerraPower, CNNC Team up on Travelling Wave Reactor," World Nuclear News, September 25, 2015, <https://world-nuclear-news.org/Articles/TerraPower,-CNNC-team-up-on-travelling-wave-reactor>.

TerraPower was spun out of the company that first patented the TWR design.⁴¹⁴ In the early 2010s, it sought to deploy its first TWR overseas due to the financing and regulatory burdens associated with U.S. deployment. The company explored partnerships in several countries with experience in sodium fast breeders.⁴¹⁵ To TerraPower, China was an ideal location for first-of-a-kind TWR deployment because it offered the world's largest nuclear energy market and was where nuclear energy "would make the most difference on the emissions front." Equally importantly, China was able and willing to take the risk of "actually trying out these new reactors." TerraPower's motive was "to keep the United States in the game" and pave the way for U.S. domestic deployment of TWR technology once it was proven in China.⁴¹⁶

Export controls and safeguards proved to be major hurdles. China had repeatedly pressed the U.S. government to allow the transfer of nuclear fuel material knowhow under the GNEP-framed bilateral Action Plan. Such knowhow was unclassified but sensitive enough to merit special export control considerations. Parts of the U.S. government were inclined to discourage cooperation that might contribute to China's fast reactor program due to security and nonproliferation concerns.⁴¹⁷ However, the Obama administration at the time was seeking to reset the U.S.-China relationship with clean energy and climate cooperation as a pillar.⁴¹⁸ In November 2009, President Obama and President Hu Jintao announced a list of seven initiatives to advance clean energy cooperation. These included, inter alia, a U.S.-China Clean Energy Research Center, a U.S.-China Renewable Energy Partnership, and a U.S.-China Energy Cooperation Program that envisioned "[leveraging] private sector resources for project development work in China across a broad array of clean energy projects."⁴¹⁹ The administration saw cooperation in clean energy technologies as being integral to broader climate diplomacy vis-à-vis China leading up to the Paris Climate Agreement.

This general policy thrust framed the desire of certain U.S. government agencies to facilitate joint projects in advanced fission energy. Starting in the late 2000s, TerraPower worked with the U.S. Department of State, DOE/NNSA, the NRC, and Chinese counterpart agencies to facilitate a government-level deal that would permit the export of TWR technology to China.⁴²⁰ This work paid off in 2013, when the U.S. and Chinese governments finalized an agreement authorizing joint TWR devel-

⁴¹⁴ "TerraPower, CNNC Team up on Travelling Wave Reactor."

⁴¹⁵ Victoria Baghdjian, "TerraPower Seeking Partners for Demonstration TWR," *Nucleonics Week* 53, no. 39 (September 27, 2012).

⁴¹⁶ John Gilleland, "The Status of Advanced Nuclear Technologies" (U.S. Government Publishing Office, May 17, 2016), <https://www.congress.gov/114/chr/CHRG-114shrg22127/CHRG-114shrg22127.pdf>.

⁴¹⁷ Mark Hibbs, *The Future of Nuclear Power in China* (Washington, D.C.: Carnegie Endowment for International Peace, 2018), 38, https://carnegieendowment.org/files/Hibbs_ChinaNuclear_Final.pdf.

⁴¹⁸ Merritt T. Cooke, *Sustaining U.S.-China Clean Energy Cooperation* (Washington, DC: Wilson Center, 2013), 6–8, https://www.wilsoncenter.org/sites/default/files/media/documents/event/US_China%20Cooperatin%20in%20Clean%20Energy.pdf.

⁴¹⁹ Office of the Press Secretary, "U.S.-China Clean Energy Announcements," The White House, November 17, 2009, <https://obamawhitehouse.archives.gov/the-press-office/us-china-clean-energy-announcements>.

⁴²⁰ Lee McIntire, "Taking the Next Steps for TWR Prototype Development," TerraPower, 2015, <https://www.terrapower.com/news/taking-the-next-steps-for-twr-prototype-development>.

opment, deployment, and technology transfer.⁴²¹ The agreement entered into force in 2014, though parts of the U.S. government remained concerned about the national security sensitivities surrounding the transfer. Additional questions were raised about the application of safeguards to the U.S.-designed reactor to be built in China. The United States preferred that IAEA safeguards be applied under China's voluntary-offer agreement. But technical and financial questions surrounding the safeguards arrangement turned out not to be trivial.⁴²²

While these issues were being worked out, the commercial relationship continued to advance. In 2017, CNNC and TerraPower set up a 50-50 joint venture, Global Innovation Nuclear Energy Technology, to complete the TWR design and commercialize the technology while sharing intellectual property.⁴²³ Agreement was reached to build a prototype TWR in the Chinese city of Cangzhou.⁴²⁴ However, less than a year after the finalization of these arrangements, the U.S. government drastically tightened its controls on the export of nuclear technology to China, introducing a presumption of denial for non-light-water advanced reactor technology. These tightened restrictions forced the project off track. TerraPower announced that it would seek alternative partners,⁴²⁵ though the company's president Christopher Levesque remarked that the project's billion-dollar price tag "limits potential partners to wealthy nations that are already funding nuclear energy" and that "those countries also need to have agreements with the U.S. government that permits the sort of partnership that TerraPower has with China."⁴²⁶ TerraPower Chairman Bill Gates judged further that U.S.-based reactor construction was only possible with "funding and regulatory changes."⁴²⁷ In essence, the TWR project was dead, and TerraPower shifted its focus to other sodium-cooled fast reactor designs.

The 2018 shift in U.S. policy regarding civil nuclear cooperation with China also affected DOE's joint research and development in advanced fission energy with the Chinese Academy of Sciences (CAS). The centerpiece of cooperation along that parallel track was the technology of molten-salt reactors. As recounted previously, both China and the United States pursued molten salt reactor R&D prior to convergence on LWRs. In the early 2000s, the Generation IV Nuclear Energy Sys-

⁴²¹ Office of Nonproliferation and International Security, Department of Energy, "Proposed Subsequent Arrangement," Federal Register, December 18, 2013, <https://www.federalregister.gov/documents/2013/12/18/2013-30080/proposed-subsequent-arrangement>.

⁴²² Material provided by Mark Hibbs.

⁴²³ Xinhua News Agency, "China Calls for Stronger Cooperation with US in Next-Generation Nuclear Power Technology," China National Intellectual Property Administration, November 9, 2017, https://english.cnipa.gov.cn/art/2017/11/9/art_2706_164933.html.

⁴²⁴ Jay Greene, "Trump's Tech Battle With China Roils Bill Gates Nuclear Venture," The Wall Street Journal, January 1, 2019, <https://www.wsj.com/articles/trumps-tech-battle-with-china-roils-bill-gates-nuclear-venture-11546360589>.

⁴²⁵ Carl O'Donnell, "Bill Gates' Nuclear Venture Hits Snag amid U.S. Restrictions on China Deals: WSJ," Reuters, January 2, 2019, <https://www.reuters.com/article/technology/bill-gates-nuclear-venture-hits-snap-amid-us-restrictions-on-china-deals-wsj-idUSKCN1OV1R6/>.

⁴²⁶ Greene, "Trump's Tech Battle With China Roils Bill Gates Nuclear Venture."

⁴²⁷ Bill Gates, "What I Learned at Work This Year," GatesNotes, December 29, 2018, https://web.archive.org/web/20220626172909/https://www.gatesnotes.com/About-Bill-Gates/Year-in-Review-2018?mod=article_inline.

tems Initiative identified molten-salt reactors as one of the six most promising advanced reactor concepts. Compared to PWRs, reactors using molten salt as a coolant or as a solvent for liquid fuel operate at higher temperatures with lower coolant pressure, which together support the efficient generation of electricity and industrial heat. The properties of molten salt also confer inherent safety advantages – from negative reactivity feedback to radionuclide retention in accident scenarios. When the reactor is liquid-fueled, an online reprocessing setup could continuously remove fission products and minor actinides that interfere with fission, making molten-salt reactors particularly advantageous for a thorium fuel cycle where uranium-233 is bred from thorium-232 mixed into the fuel. Uranium 233 is a fissile material like the uranium-235 commonly used in small concentrations in the fuel of commercial PWRs.

For China, thorium utilization was an appealing prospect given the relative scarcity of its uranium reserves and the abundance of thorium, particularly around its massive rare earth deposits in Bayan Obo, Inner Mongolia.⁴²⁸ It was largely for these reasons that the Shanghai Institute of Nuclear Research conducted thorium fuel cycle research from the 1960s onward. Apart from advancing the molten-salt reactor concept, the institute also conducted thorium and uranium-233 separation experiments and “explored reprocessing of thorium fuel from high-temperature gas-cooled reactor with Tsinghua University.” Small-scale research on the thorium fuel cycle continued up to the late 1990s. Then all work stopped as researchers shifted to other areas including nuclear physics, nuclear medicine, radiation protection, and dosimetry, and the Shanghai Institute of Nuclear Research was renamed the Shanghai Institute of Applied Physics (SINAP).⁴²⁹

By 2010, China’s overwhelming dependence on imported uranium had become incongruent with its nuclear energy scaling ambitions. The prospect of thorium utilization prompted renewed interest in the molten-salt reactor concept. Apart from freeing China’s long-term nuclear energy growth from the constraints of uranium access, molten-salt reactors were also expected to enable innovative hybrid energy solutions via high-temperature hydrogen production and offer a safe, water-free inland nuclear power deployment option.⁴³⁰ In 2010, CAS developed the Project on Future Advanced Nuclear Fission Energy as one of four “strategic technology pilots” under its State Council-endorsed “Innovation 2020” plan⁴³¹ – a project that included R&D related to thorium molten-salt reactors (TMSR) and accelerator-driven systems (ADS) – the latter for transmuting radioactive waste. The

⁴²⁸ Hai-Dong She et al., “The Occurrence and Distribution of Thorium in the Giant Bayan Obo REE-Nb-Fe Polymetallic Deposit, China,” *Ore Geology Reviews* 186 (2025).

⁴²⁹ BerkeleyNUC, “Thorium Fueled Molten Salt Reactor Research in Shanghai Institute of Applied Physics, Kun Chen,” YouTube, January 20, 2015, https://www.youtube.com/watch?v=_enjvYHePUY.

⁴³⁰ BerkeleyNUC, “ORNL-SINAP FHR CRADA Colloquium, Kun Chen and David Holcomb,” YouTube, March 16, 2015, <https://www.youtube.com/watch?v=HG7fObYNzU0>.

⁴³¹ “Gao zhiliang wancheng chuangxin san qi mubiao, qidong shishi ‘Chuangxin 2020,’” Chinese Academy of Sciences, 2011, https://www.cas.cn/zt/hyzt/2011ndgzhy/2010gzhy/201101/t20110127_3068306.html.

TMSR project was formally launched in January 2011, with the long-term goal of building a pilot TMSR based on Chinese intellectual property by 2030.⁴³² In May, a TMSR Research Center was set up at SINAP, successor to the Shanghai Institute of Nuclear Research. The research plan and budget for the first five years of the TMSR project was approved by CAS in September.⁴³³

International collaboration was an integral part of CAS's "Innovation 2020" plan under which the Project on Future Advanced Nuclear Fission Energy was conceived.⁴³⁴ The TMSR project envisioned indigenous R&D but also foresaw the need for international collaboration.⁴³⁵ CAS Vice President Jiang Mianheng was a key promoter of collaboration with DOE on the Chinese side. A U.S.-educated scientist, Jiang received his PhD in electrical engineering from Drexel University in 1991. He is also the son of former Chinese president Jiang Zemin. In fall 2010, months before CAS formally approved the TMSR proposal,⁴³⁶ Jiang led a delegation to visit the Oak Ridge National Laboratory to seek a TMSR research partnership.⁴³⁷

At the time, there was a sentiment among U.S. thorium advocates that sharing the technology with foreign countries would help maximize its chances of deployment, ultimately to the United States' benefit.⁴³⁸ Most of the intellectual property associated with Oak Ridge National Laboratory's pioneering molten-salt-reactor work dating back to the days of the Atomic Energy Commission was already in the public domain. While DOE was investing hundreds of millions of dollars in advanced reactor R&D,⁴³⁹ only modest resources were being devoted to the molten-salt reactor concept. Over the previous decade, the DOE Advanced Reactor Concepts program funded only "early phase, small-scale investigations" into molten-salt reactor technology.⁴⁴⁰ In 2010, the program selected fast-spectrum molten-salt reactors as "a transformational reactor concept for light-water reactor (LWR)-derived heavy actinide disposition."⁴⁴¹ Oak Ridge developed the pre-conceptual design for a Small

⁴³² Qimin Xu, "Weilai hedianzhan anquan 'bu tiaoshi,'" *Wen Hui Bao*, January 26, 2011, https://web.archive.org/web/20110207004255/http://whb.news365.com.cn/yw/201101/t20110126_2944856.htm.

⁴³³ Xiaohan Yu, "TMSR Project of CAS," 2012, <https://thoriumenergyalliance.com/wp-content/uploads/2020/02/TMSR-CAS-1.pdf>.

⁴³⁴ "Gao zhiliang wancheng chuangxin san qi mubiao, qidong shishi 'Chuangxin 2020.'"

⁴³⁵ Qimin Xu, "Xu Hongjie: cong Shanghai guangyuan dao xin yi dai heneng, shizhong wei guojia weilai zhuoxiang," *Chinese Academy of Sciences*, June 22, 2021, https://www.cas.cn/xzfc/202106/t20210622_4794152.shtml.

⁴³⁶ Yu, "TMSR Project of CAS."

⁴³⁷ Kirk Sorensen, "China Initiates Thorium MSR Project," *Energy from Thorium*, January 30, 2011, <https://energyfromthorium.com/2011/01/30/china-initiates-tmsr/comment-page-1/#comments>.

⁴³⁸ Orrin G. Hatch, "S.3680 - Thorium Energy Independence and Security Act of 2008," *Congress.gov*, 2008, <https://www.congress.gov/bill/110th-congress/senate-bill/3680/text>.

⁴³⁹ U.S. Department of Energy, Office of Nuclear Energy, "Next Generation Nuclear Plant," April 2010, https://www.energy.gov/sites/prod/files/4.4_NGNP_ReporttoCongress_2010.pdf; Steven Chu, "Statement of Secretary Steven Chu, U.S., Department of Energy, before the Committee on Science and Technology, U.S. House of Representatives," 2010, <https://www.energy.gov/node/230725>.

⁴⁴⁰ David E. Holcomb et al., "Fluoride Salt-Cooled High-Temperature Reactor Technology Development and Demonstration Roadmap" (Oak Ridge: Oak Ridge National Laboratory, 2013), xv, 1, <https://www.osti.gov/servlets/purl/1107839/>.

⁴⁴¹ Xin Huang, "Zhongguo zheng yinling quanqiu rongyandui yanfa," *Chinese Academy of Sciences*, January 7, 2019, https://www.cas.cn/cm/201901/t20190107_4676006.shtml.

modular Advanced High-Temperature Reactor⁴⁴² and proceeded to work on a larger Advanced High Temperature Reactor.⁴⁴³ Complementing these efforts, in 2011, DOE's Nuclear Energy University Programs (NEUP) awarded \$7.5 million to MIT, UC Berkeley, and the University of Wisconsin at Madison to "develop the path forward to a test reactor and ultimately a commercial high-temperature salt-cooled reactor."⁴⁴⁴

These invested sums paled in comparison to the Chinese government's \$350 million allocation to CAS to pursue the initial phase of its TMSR research. It became clear, even by resource commitments alone, that China would become the next leader in molten-salt reactor technology.⁴⁴⁵ Oak Ridge National Laboratory's 2013 roadmap on FHR technology stated frankly that while the United States had "the most experience with FHR technologies as a result of its historic and long-term investments in advanced nuclear reactors (in particular MSRs)" and had been "pursuing FHR technology development on a small scale for the past decade," CAS's huge investment meant that China would "soon surpass US capabilities" and would "almost certainly succeed in bringing FHRs to market independent of external partnering." To the authors of the roadmap, "the remaining question for the United States is whether to partner with China, helping to direct a joint development path; to fund a competing development program; or to back away from FHR technology and eventually become dependent on imported technology for key aspects of the US energy infrastructure."⁴⁴⁶

The choice among these alternatives was clear. The U.S. government had no funding to set up a competing program, and technological dependence was only a rhetorical option. By partnering with CAS to construct a prototype molten-salt reactor, Oak Ridge hoped to leverage Chinese programmatic resources to advance FHR technology, thereby facilitating U.S. commercialization. Since the construction of a test reactor was "the single most expensive step in the commercialization of FHRs," Oak Ridge researchers reasoned, "development of FHRs for the US market can rapidly advance if knowledge and information developed by the Chinese program is available to researchers, designers, and regulators."⁴⁴⁷ Like TerraPower, the team of U.S. FHR researchers saw cooperation with China as a shortcut to the deployment of advanced reactor technology in the United States.

⁴⁴² S. R. Greene et al., "Pre-Conceptual Design of a Fluoride-Salt-Cooled Small Modular Advanced High Temperature Reactor (SmAHTR)" (Oak Ridge: Oak Ridge National Laboratory, December 2010), <http://www.osti.gov/servlets/purl/1008830/>.

⁴⁴³ D. E. Holcomb et al., "Core and Refueling Design Studies for the Advanced High Temperature Reactor" (Oak Ridge: Oak Ridge National Laboratory, September 30, 2011), <http://www.osti.gov/servlets/purl/1025857/>.

⁴⁴⁴ "MIT Wins \$7.5M DOE Grant to Develop a New Generation of Advanced Reactors," Nuclear Science & Engineering at MIT, October 1, 2011, <https://web.archive.org/web/20111001010243/http://web.mit.edu/nse/news/2011/advanced-reactors.html>.

⁴⁴⁵ David Lague and Charlie Zhu, "SPECIAL REPORT-The U.S. Government Lab behind China's Nuclear Power Push," Reuters, 2013, <https://web.archive.org/web/20150416231944/https://www.reuters.com/article/2013/12/20/breakout-thorium-idINL4N0FE21U20131220/>.

⁴⁴⁶ Holcomb et al., "Fluoride Salt-Cooled High-Temperature Reactor Technology Development and Demonstration Roadmap," 121.

⁴⁴⁷ Holcomb et al., 126.

The thinking was typical in the context of broader U.S.-China clean energy cooperation. As articulated contemporarily by the U.S.-China Economic and Security Review Commission, “China is a global leader in clean energy investment, and Chinese funding could be used to boost technologies that are not cost effective in the short run.”⁴⁴⁸

The TMSR was one such technology over which the two countries aligned. In keeping with the administration’s general policy of encouraging cooperation in clean energy technologies, the State Department and DOE viewed joint R&D in advanced reactors favorably. CAS, meanwhile, sought to leverage the momentum of the AP1000 deal and replicate its technology transfer arrangement, though the arrangement that eventually came to be was confined to pre-commercial R&D. Following his visit to Oak Ridge, in November 2010, Jiang Mianheng met with U.S. Under Secretary of Energy Steven Koonin to discuss an expanded cooperation framework between DOE and CAS.⁴⁴⁹ That meeting led to a January 2011 DOE-CAS protocol for cooperation in energy sciences⁴⁵⁰ formally governed by the 1979 U.S.-China Science and Technology Agreement.⁴⁵¹ In Jiang’s vision, CAS’s collaboration with DOE should concentrate on a few strategic programs⁴⁵² – such as joint R&D on molten-salt reactors and hybrid energy systems. In mid-2011, Jiang met with visiting Oak Ridge director Thomas Mason and Assistant Secretary of Energy Peter Lyons in Beijing to negotiate collaborative arrangements in both areas.⁴⁵³ Whereas Oak Ridge would collaborate with SINAP on molten-salt reactors, Idaho National Laboratory would partner with CAS on hybrid energy systems. A CAS delegation visited Idaho National Laboratory in June 2011, followed by a visit to Oak Ridge in November.⁴⁵⁴ It was during this flurry of exchanges that the DOE-CAS MoU on Cooperation in Nuclear Energy Sciences and Technologies was drafted and finalized.⁴⁵⁵

⁴⁴⁸ U.S.-China Economic and Security Review Commission, “2014 Report to Congress,” 203.

⁴⁴⁹ Zhong guo ke xue yuan guo ji he zuo ju, “Jiang Mianheng huijian Meiguo Nengyuan Bu Fu Buzhang Steven Koonin,” Bureau of International Cooperation, Chinese Academy of Sciences, 2010, https://web.archive.org/web/20200430030311/https://www.bic.cas.cn/gjhzdt/201011/t20101108_3004498.html.

⁴⁵⁰ “Jiang Mianheng fangwen Meiguo bing yu Nengyuan Bu qianshu hezuo yidingshu,” Chinese Academy of Sciences, 2011, https://www.cas.cn/xw/ldhd/201101/t20110124_3066595.shtml.

⁴⁵¹ “Protocol between the Department of Energy of the United States of America and the Chinese Academy of Sciences for Cooperation in Energy Sciences,” January 18, 2011, https://www.energy.gov/sites/default/files/pi_iec/098b7ef98002befd.pdf.

⁴⁵² “Jiang Mianheng Li Jinghai chuxi Zhong Mei nengyuan hezuo qingkuang baogao,” Chinese Academy of Sciences, March 25, 2011, https://www.cas.cn/xw/ldhd/201103/t20110325_3094921.shtml.

⁴⁵³ “Jiang Mianheng huijian Meiguo Nengyuan Bu Zhuli Buzhang Peter Lyons yixing,” Bureau of International Cooperation, Chinese Academy of Sciences, June 10, 2011, https://www.bic.cas.cn/gjhzdt/201106/t20110610_3285629.html; “Jiang Mianheng huijian Meiguo Xiangshuling Guojia Shiyanshi zhuren,” Chinese Academy of Sciences, May 16, 2011, https://www.cas.cn/xw/ldhd/201105/t20110516_3133163.shtml.

⁴⁵⁴ Chinese Academy of Sciences and U.S. Department of Energy, “Cooperation in Nuclear Energy Sciences and Technologies First Executive Committee Meeting Report,” 38–39.

⁴⁵⁵ Chinese Academy of Sciences and U.S. Department of Energy, 3, 40.

Signed in December 2011, the MoU designated a co-chaired executive committee and technical coordinators who would go on to steer collaboration⁴⁵⁶ under three working groups. Apart from the Molten Salt Coolant Systems Working Group and Nuclear Hybrid Energy Systems Working Group, there was also a Nuclear Fuel Resources Working Group co-chaired by scientists at SINAP, Oak Ridge, and UC Berkeley, with the task of pursuing uranium extraction from seawater.⁴⁵⁷ Research in this area was initiated almost simultaneously by DOE and CAS in 2010 and fit appropriately under the theme of uranium resource sustainability.⁴⁵⁸

Early exchanges took the form of working group meetings, workshops, and technical information exchanges.⁴⁵⁹ A shift toward deeper collaboration took place in 2014, when Oak Ridge National Laboratory and SINAP entered into a Cooperative Research and Development Agreement, or CRADA⁴⁶⁰ as a follow-on to the 2011 DOE-CAS MoU, focusing specifically on molten-salt reactors.⁴⁶¹ That agreement was envisioned to “enable Chinese access to US expertise on the broad set of technologies necessary to design and operate an FHR test reactor while the United States would gain access to the information generated by the extensive, ongoing and planned FHR materials, components, and systems R&D efforts.”⁴⁶² At the time, CAS was pursuing both a solid-fuel molten-salt reactor prototype – to use uranium TRISO fuel pebbles designed for the HTR-PM high-temperature gas-cooled reactor – and a liquid-fuel molten-salt reactor prototype – to operate on “sufficient thorium to demonstrate separation technology.”⁴⁶³ SINAP planned to collaborate with Oak Ridge on the former – for which the technology was considered more mature, and no reprocessing or fissile material separation was involved – before shifting its focus to a liquid-fuel design.⁴⁶⁴ Nevertheless, both sides understood that “nearly all of the technology developed” jointly under the CRADA would apply to the solid- as well as liquid-fuel paths.⁴⁶⁵

Under the first phase of the 10-year CRADA, the focus was on building essential testing infrastructure – such as Oak Ridge National Laboratory’s liquid salt loop for heat transfer testing – and vali-

⁴⁵⁶ “Memorandum of Understanding between the Department of Energy of the United States of America and the Chinese Academy of Sciences on Cooperation in Nuclear Energy Sciences and Technologies,” 2011, 2–3, https://www.energy.gov/sites/default/files/pi_iec/098b7ef980045aed.pdf.

⁴⁵⁷ Chinese Academy of Sciences and U.S. Department of Energy, “Cooperation in Nuclear Energy Sciences and Technologies First Executive Committee Meeting Report,” 41; Yu, “TMSR Project of CAS.”

⁴⁵⁸ Zhifang Chai and Guozhong Wu, “Preface,” *Science China Chemistry* 56, no. 11 (November 2013): 1493–94, <https://doi.org/10.1007/s11426-013-4991-9>.

⁴⁵⁹ Chinese Academy of Sciences and U.S. Department of Energy, “Cooperation in Nuclear Energy Sciences and Technologies First Executive Committee Meeting Report,” 43.

⁴⁶⁰ BerkeleyNUC, “ORNL-SINAP FHR CRADA Colloquium, Kun Chen and David Holcomb.”

⁴⁶¹ Oak Ridge National Laboratory, “ORNL, Shanghai Institute of Applied Physics Cooperate on Salt-Cooled Reactors,” Oak Ridge Today, 2015, <http://oakridgetoday.com/tag/cas/>.

⁴⁶² Holcomb et al., “Fluoride Salt-Cooled High-Temperature Reactor Technology Development and Demonstration Roadmap,” 153.

⁴⁶³ BerkeleyNUC, “ORNL-SINAP FHR CRADA Colloquium, Kun Chen and David Holcomb.”

⁴⁶⁴ BerkeleyNUC.

⁴⁶⁵ David Holcomb and Kun Chen, “ORNL-SINAP FHR CRADA Colloquium,” UC Berkeley Nuclear Engineering, 2015, <https://nuc.berkeley.edu/ornl-sinap-fhr-crada-colloquium/>.

dating key components. Technical challenges to the deployment of molten-salt reactors at scale needed to be resolved, including managing tritium release, scaling up lithium enrichment, designing salt chemistry control systems for larger reactors, and developing qualified fuels, materials, and instrumentation. A robust safety and licensing approach was equally critical.⁴⁶⁶ China leveraged the CRADA to obtain access to “U.S. advanced reactor capabilities, facilities, and experience,” such as the Oak Ridge National Laboratory’s “expertise in fuels, materials, instrumentation and controls, design concepts, and modeling and simulation” as well as “experience in the design, construction and operation of the Molten Salt Reactor Experiment.” Meanwhile, Oak Ridge expected to benefit “through access to the information and experience produced by the large and rapidly advancing Chinese program.”⁴⁶⁷ The lab also believed that future Chinese molten-salt reactors would require U.S. special-material components, which would give U.S. manufacturers “the opportunity to compete in future salt-cooled reactor markets” and benefit commercially from participating in China’s “nuclear renaissance.”⁴⁶⁸

That said, funding was the critical CAS contribution in the collaborative arrangement. It was not uncommon for DOE’s advanced reactor technologies program to “leverage and expand R&D investments” via international collaboration.⁴⁶⁹ In the mid-2010s, Oak Ridge researchers sorely needed the funding CAS had at its disposal for molten-salt reactor experiments as there had been no substantial increase in the availability of U.S. government funding beyond modest university grants. Whereas Oak Ridge had constructed a fluoride salt test loop using internal funding, the loop had never been turned on due to competing demands on the lab’s budget. Chinese funding would allow that test loop to be turned on, and in return, SINAP would “participate in the experimental program.”⁴⁷⁰ By 2014, CAS had secured additional funding from the China National Energy Administration, which had selected the TMSR project as one of its “Major National Energy R&D projects,” and from Shanghai’s local government, which had initiated a “TMSR major innovation project,” beyond the central government’s original \$350 million allocation.⁴⁷¹ That allowed CAS to mount what it claimed was “the world’s largest national effort on thorium” employing “430 scientists and engineers” in 2014 – a number that rose to 700 in 2015.⁴⁷² It also allowed CAS to cover the cost of the CRADA with Oak Ridge to the tune of \$5 million per year out of the budget for its TMSR pro-

⁴⁶⁶ Holcomb and Chen.

⁴⁶⁷ Oak Ridge National Laboratory, “ORNL, Shanghai Institute of Applied Physics Cooperate on Salt-Cooled Reactors.”

⁴⁶⁸ Oak Ridge National Laboratory; Rosalind Reischer, “Fourth Generation Reactor Technology Development in China,” Nuclear Newswire, August 25, 2016, <https://www.ans.org/news/article-1868/fourth-generation-reactor-technology-development-in-china/>.

⁴⁶⁹ Holcomb and Chen, “ORNL-SINAP FHR CRADA Colloquium.”

⁴⁷⁰ BerkeleyNUC, “ORNL-SINAP FHR CRADA Colloquium, Kun Chen and David Holcomb.”

⁴⁷¹ BerkeleyNUC.

⁴⁷² “China-US Partnership May Produce Advanced Nuclear Reactors by 2030,” Physics Today, October 19, 2015, <https://physicstoday.aip.org/news/china-us-partnership-may-produce-advanced-nuclear-reactors-by-2030>.

gram.⁴⁷³ In 2015, CAS signed a separate cooperative research agreement with MIT on molten-salt reactors, under which it provided \$2.1 million to the U.S. institution for “an initial series of four research activities, and potentially others to be added in the future, to address issues related to their test reactor projects.” These activities included the study of molten-salt reactor materials and radiation safety, power cycles, effluent control, and modeling to support design, licensing, and operation.⁴⁷⁴

In October 2015, the lead researcher of the SINAP TMSR program, Xu Hongjie, visited Oak Ridge to attend its “celebratory workshop” marking the fiftieth anniversary of the first molten-salt reactor experiment.” While there, he presented China’s ambitious plans including the construction of a 10MW solid-fuel reactor and a 2MW liquid fuel thorium reactor by 2020, aiming for commercial operation by 2030.⁴⁷⁵ The representatives of U.S. molten-salt reactor companies including TerraPower, Flibe, and Terrestrial Energy who were in the audience were reportedly startled by the sophistication and pace of China’s program despite their familiarity with its contours. To those who viewed China as a competitor in civil nuclear technology, the SINAP-Oak Ridge collaboration was “a dangerous, even treacherous, form of technology transfer.”⁴⁷⁶ The FHR team at Oak Ridge held the opposite view – namely, that the technology was still “at a pre-commercial level of maturity,” and joint work approved by DOE was focused on “open science rather than specific technology to a commercial reactor.” In this view, most historical U.S. intellectual property on molten-salt reactors had been released into the public domain, and new joint research with CAS was likewise “intended to be openly available and published in the scientific literature.” According to Oak Ridge National Laboratory’s FHR lead, David Holcomb, scientific collaboration would end, and commercial competition would emerge, only “after SINAP’s higher-power test reactor” completed operational testing, thus marking the technology’s commercial maturity.⁴⁷⁷ In one way or another, the parties navigated the intellectual property and export control issues to continue their scientific collaboration, with the approval of both the U.S. and Chinese governments. Outside the caveats of pre-commercial science and government approval, Oak Ridge, in Holcomb’s own words, was “trying to help [Chinese researchers] succeed.”⁴⁷⁸ And succeed they did. In October 2023, SINAP’s 2MW prototype TMSR reached criticality in the desert of Gansu Province. Two years later, in November 2025, SINAP announced that

⁴⁷³ BerkeleyNUC, “ORNL-SINAP FHR CRADA Colloquium, Kun Chen and David Holcomb”; Oak Ridge National Laboratory, “ORNL, Shanghai Institute of Applied Physics Cooperate on Salt-Cooled Reactors.”

⁴⁷⁴ Nuclear Reactor Laboratory, Massachusetts Institute of Technology, “MIT Enters into Joint Nuclear Research Agreement with Shanghai Institute of Applied Physics,” MIT Nuclear Reactor Laboratory, 2015, <https://nrl.mit.edu/mit-enters-into-joint-nuclear-research-agreement-with-shanghai-institute-of-applied/>.

⁴⁷⁵ “China-US Partnership May Produce Advanced Nuclear Reactors by 2030.”

⁴⁷⁶ Richard Martin, “China Details Next-Gen Nuclear Reactor Program,” MIT Technology Review, October 16, 2015, <https://www.technologyreview.com/2015/10/16/165755/china-details-next-gen-nuclear-reactor-program/>.

⁴⁷⁷ BerkeleyNUC, “ORNL-SINAP FHR CRADA Colloquium, Kun Chen and David Holcomb.”

⁴⁷⁸ BerkeleyNUC.

it had achieved thorium-to-uranium conversion at the reactor.⁴⁷⁹ But by then, the United States was no longer trying to help China succeed in its advanced fission reactor development. Following its 2018 policy shift, the U.S. government began to treat China as a rival in the race toward dominance over advanced nuclear technologies.

⁴⁷⁹ Wenhan Zhao, “Wo guo shixian tu ji rongyandui yanfa tupo,” Xinhua, November 1, 2025, <http://www.xinhuanet.com/photo/20251101/2b9aded50ca4452e80aaf8a7f48d4b12/c.html>.

Chapter 8. From cooperation to rivalry

Beginning with an interagency policy review led by the National Security Council, the first Trump administration moved in October 2018 to tighten U.S. controls on civil nuclear cooperation with China. The U.S. DOE announced new guidance for transfers under 10 CFR Part 810 that aimed to prevent diversion of U.S. civil nuclear technology “for military or other unauthorized purposes,” and established a presumption of denial for any transfer involving China General Nuclear (CGN),⁴⁸⁰ which had been indicted in 2016 alongside a U.S. consultant for violating the Atomic Energy Act’s authorization requirements.⁴⁸¹ In parallel, the NRC updated its licensing posture for exports under 10 CFR Part 110, embedding the executive branch’s security judgments into its licensing process.⁴⁸² A presumption of approval was preserved for amendments to pre-2018 authorizations and for equipment supporting ongoing AP1000 and CAP1000 projects, subject to end-user vetting, but meaningful collaboration on advanced reactor development was no longer possible.

Administration officials framed the policy revision as a national-security response to China’s “military-civil fusion” strategy and associated risks of diversion and intellectual-property theft. In an apparent reference to CGN’s acquisition of U.S. nuclear expertise without DOE authorization, Energy Secretary Rick Perry stated that the United States “cannot ignore” evidence of efforts to obtain U.S. civil nuclear technology outside established channels.⁴⁸³ Then Assistant Secretary of State for international security and nonproliferation Christopher Ford articulated the administration’s broader concerns as he urged a “coalition of caution” to slow U.S. civil nuclear transfers to China.⁴⁸⁴ These concerns ranged from China’s supposedly unsafe and “predatory” civil nuclear exports to “security implications” referring to the risk that China might divert civil nuclear technology to its defense sector through military-civil fusion. Civil nuclear cooperation with China, Ford claimed, rested upon “the integrity of end-use assurances, licensing conditionality, ‘deemed export’ controls, and other mechanisms designed to prevent the diversion of materials or technology to unapproved purposes,

⁴⁸⁰ “DOE Announces Measures to Prevent China’s Illegal Diversion of U.S. Civil Nuclear Technology for Military or Other Unauthorized Purposes,” Department of Energy, October 11, 2018, <https://www.energy.gov/articles/doe-announces-measures-prevent-chinas-illegal-diversion-us-civil-nuclear-technology>.

⁴⁸¹ “U.S. Nuclear Engineer, China General Nuclear Power Company and Energy Technology International Indicted in Nuclear Power Conspiracy against the United States,” U.S. Department of Justice, April 14, 2016, <https://www.justice.gov/archives/opa/pr/us-nuclear-engineer-china-general-nuclear-power-company-and-energy-technology-international>.

⁴⁸² “U.S. Policy Framework on Civil Nuclear Cooperation with China for Exports Pursuant to 10 CFR 110,” Nuclear Regulatory Commission, October 2, 2025, 110, <https://www.nrc.gov/about-nrc/ip/export-import/us-pol-frame-civil-nuc-coop-china>.

⁴⁸³ “DOE Announces Measures to Prevent China’s Illegal Diversion of U.S. Civil Nuclear Technology for Military or Other Unauthorized Purposes.”

⁴⁸⁴ Christopher Ashley Ford, “A New Approach to Civil Nuclear Cooperation Policy,” U.S. Department of State, February 26, 2019, <https://2017-2021.state.gov/a-new-approach-to-civil-nuclear-cooperation-policy/>.

and especially to non-peaceful ones,” yet China’s military-civil fusion had “deliberately [undermined] this system of assurances.”⁴⁸⁵

This fundamental rationale has driven a series of U.S. government controls on nuclear and nuclear dual-use transfers to China. As an extension of the 2018 policy framework under which the U.S. DOE and NRC placed transfers to CGN under a presumption of denial, in August 2019, the U.S. Department of Commerce added four entities under CGN to its Entity List restricting dual-use exports. As the basis for that measure, it alleged that all four entities had “engaged in or enabled efforts to acquire advanced U.S. nuclear technology and material for diversion to military uses in China.”⁴⁸⁶ Then, in 2021, the NRC suspended its general license for exporting radioactive material and deuterium to CGN entities.⁴⁸⁷ These steps served as a prelude to broader nuclear nonproliferation controls announced by the NRC and the Department of Commerce vis-à-vis China in August 2023. The justification for the 2023 measure, once again, was China’s policy of military-civil fusion.⁴⁸⁸ The first Trump administration’s restrictive policies therefore persisted into the Biden administration under the framing of preventing military diversion.

There is no doubt that China could benefit militarily from U.S. civil nuclear transfers because nuclear technology is inherently dual use. But this risk is not new. Nor is China’s military-civil fusion. As a matter of fact, previous U.S. administrations had always recognized the likelihood that U.S. nuclear and dual-use transfers to China might be diverted to its military R&D. A 1985 technical memorandum by the U.S. Congressional Office of Technology Assessment on energy technology transfers to China warned, “We know enough about the organization of Chinese R&D, and China’s considerable science and technology capabilities, not to be careless about dual-use transfers ... [U.S.] controls are costly, not welcomed by the Chinese, and certainly do not completely rule out the possibility of diversions.” With respect to civil nuclear technology in particular, the memorandum notes that China’s “naval reactor program could get an unintended assist” from U.S. transfers.⁴⁸⁹ Nevertheless, the

⁴⁸⁵ Christopher Ashley Ford, “Competitive Strategy Vis-a-Vis China: The Case Study of Civil-Nuclear Cooperation,” U.S. Department of State, June 24, 2019, <https://2017-2021.state.gov/competitive-strategy-vis-a-vis-china-the-case-study-of-civil-nuclear-cooperation/>.

⁴⁸⁶ Industry and Security Bureau, “Addition of Certain Entities to the Entity List, Revision of Entries on the Entity List, and Removal of Entities From the Entity List,” Federal Register, August 14, 2019, <https://www.federalregister.gov/documents/2019/08/14/2019-17409/addition-of-certain-entities-to-the-entity-list-revision-of-entries-on-the-entity-list-and-removal>.

⁴⁸⁷ Industry and Security Bureau, “Order Suspending General License Authority To Export Radioactive Material and Deuterium to China General Nuclear (CGN), CGN Subsidiaries, or Related Entities,” Federal Register, October 1, 2021, <https://www.federalregister.gov/documents/2021/10/01/2021-21342/order-suspending-general-license-authority-to-export-radioactive-material-and-deuterium-to-china>.

⁴⁸⁸ Industry and Security Bureau, “Expansion of Nuclear Nonproliferation Controls on the People’s Republic of China and Macau,” Federal Register, August 14, 2023, <https://www.federalregister.gov/documents/2023/08/14/2023-17243/expansion-of-nuclear-nonproliferation-controls-on-the-peoples-republic-of-china-and-macau>; Nuclear Regulatory Commission, “Order Suspending General License Authority To Export Special Nuclear Material, Source Material, and Deuterium for Nuclear End Use to the People’s Republic of China,” Federal Register, August 14, 2023, <https://www.federalregister.gov/documents/2023/08/14/2023-17394/order-suspending-general-license-authority-to-export-special-nuclear-material-source-material-and>.

⁴⁸⁹ U.S. Congress, Office of Technology Assessment, *Energy Technology Transfer to China—A Technical Memorandum* (Washington, DC: U.S. Government Printing Office, 1985), 10, 42.

Reagan administration proceeded with the conclusion of a civil nuclear cooperation agreement with Beijing as it judged that the agreement's benefits to U.S. economic and security interests would outweigh the risks.

This judgment essentially held firm over the next three decades. The Clinton administration committed to a cooperative course based on its view that civil nuclear cooperation with China was beneficial to U.S. economic interests in terms of civil nuclear exports and security interests with respect to nonproliferation. Post-2000, the economic case for civil nuclear commerce with China remained compelling, especially as trade rebalancing became a U.S. priority. Cooperation was increasingly seen as part of the U.S.-China partnership in energy and climate security. Meanwhile, China became a U.S. partner in various nuclear security initiatives revolving around nonproliferation and counterterrorism. These considerations in addition to traditional justifications such as transparency and influence with respect to China's nuclear nonproliferation behavior grounded Washington's desire to maintain cooperation despite clear knowledge of the dual-use risks.

For instance, despite knowing the risk that Westinghouse's reactor coolant pump technology, if transferred to China, could advance the latter's submarine propulsion, the George W. Bush administration gave its blessing for the AP1000 sale and technology transfer deal, and the Obama administration renewed the bilateral peaceful use agreement a decade later. The Nuclear Proliferation Assessment Statement that the State Department submitted to Congress in 2015 alongside the renewed peaceful use agreement clearly notes that U.S. civil nuclear transfers could benefit Chinese naval propulsion R&D and that China's "civil-military integration ... requires close scrutiny of all end users of U.S. technology under the proposed Agreement."⁴⁹⁰ But the administration at the time nevertheless determined that the peaceful use agreement should be renewed as guardrails were sufficient and cooperation was mutually beneficial. In short, successive U.S. administrations that promoted civil nuclear cooperation with Beijing had always had their eyes wide open with respect to the associated dual-use risks. The first Trump administration's policy revision was fundamentally driven by a broader shift in U.S.-China relations and Washington's policy beliefs and priorities.

In December 2017, the first Trump administration released its National Security Strategy labeling China a "revisionist power" determined to promote a state-led economic model and advance authoritarian governance while expanding its military power and geopolitical influence at the expense of U.S. interests. The Strategy claimed that prior U.S. policy of economic and technological engagement with China was rooted in the faulty assumption that China would liberalize through the course

⁴⁹⁰ "Nuclear Proliferation Assessment Statement," in *Message from the President of the United States Transmitting the Text of a Proposed Agreement for Cooperation between the Government of the United States of America and the Government of the People's Republic of China Concerning Peaceful Uses of Nuclear Energy, Pursuant to Subsections 123 b. and 123 d. of the Atomic Energy Act of 1954, as Amended* (42 U.S.C. 2153(b), (d)) (Washington, DC: U.S. Government Publishing Office, 2015), 54.

of its peaceful rise; as China defied that expectation, the United States' China policy must shift toward strategic competition.⁴⁹¹

This view gained wide bipartisan support in Washington. In February 2018, *Foreign Affairs* published an article by Kurt Campbell and Ely Ratner expounding a similar critique of the longstanding U.S. policy of engagement toward China. Campbell had been Assistant Secretary of State for East Asian and Pacific Affairs under the Obama administration while Ratner had been a deputy national security advisor to Joe Biden as Vice President. In their article titled "The China Reckoning," they argue,

Neither carrots nor sticks have swayed China as predicted. Diplomatic and commercial engagement have not brought political and economic openness. Neither U.S. military power nor regional balancing has stopped Beijing from seeking to displace core components of the U.S.-led system. And the liberal international order has failed to lure or bind China as powerfully as expected ... That reality warrants a clear-eyed rethinking of the United States' approach to China.⁴⁹²

In this sense, Campbell and Ratner believed that the first Trump administration's National Security Strategy "took a step in the right direction." The specific concerns they highlighted with respect to Chinese behavior largely echoed the Strategy. One critical concern related to Beijing's pursuit of industrial policies involving forced technology transfers and unfair subsidies. In the language of the 2017 National Security Strategy, the United States must defend its "national security innovation base" as China exploited "access to the U.S. innovation economy, including America's world-class universities," to build up its economic and military advantage.

In this vein, in March 2018, the Office of the United States Trade Representative under the Executive Office of the President released the findings on an investigation into "China's acts, policies, and practices related to technology transfer, intellectual property, and innovation." The investigation found that China had leveraged foreign investment restrictions and discriminatory technology licensing procedures to pressure U.S. companies to transfer proprietary technologies to Chinese entities. In addition, the report charged that China directed or unfairly facilitated outbound investment to obtain U.S. technology, supported by cyber intrusion and IP theft. The Chinese military's hacking of Westinghouse to steal technical designs and sensitive email communications was cited as a specific

⁴⁹¹ President, *National Security Strategy of the United States of America* (Washington, DC: White House, 2017), <https://trumpwhitehouse.archives.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf>.

⁴⁹² Kurt M. Campbell and Ely Ratner, "The China Reckoning," *Foreign Affairs*, February 13, 2018, <https://www.foreignaffairs.com/china/china-reckoning>.

example. Meanwhile, the AP1000 deal itself was framed as an instance of forced technology transfer.⁴⁹³

As with the dual-use risks of nuclear technology transfer, the U.S. government had had its eyes wide open to the IP risks inherent in civil nuclear cooperation with China. A December 2015 report released by an independent advisory subcommittee under DOE's Office of Nuclear Energy reviewing U.S.-China collaboration names IP loss as "the principal pitfall." The report recognizes that "the Chinese are masters of absorbing IP and furthering it through their vast array of institutes and RD&D programs to rapidly bring it to commercialization while eventually pushing out foreign partners."⁴⁹⁴ Nonetheless, it concludes based on input obtained from DOE, NRC, national laboratories, universities, and nuclear industry that the risks to commercial IP were manageable:

U.S. commercial companies appear to have a good grasp of the risks associated with IP control when collaborating with Chinese entities. In the major programs, e.g., the AP1000 deployment projects, proper treatment of IP holds a prominent place in project reviews. For the larger companies, very thorough procedures are in place to carefully monitor and control where the IP is used. In addition, the Department of Commerce's International Trade Administration (ITA) has excellent training and software tools to help smaller companies understand and manage the risks of IP when cooperating with the Chinese.⁴⁹⁵

In the grand scheme of things, the report argues that "continued close cooperation with China in commercial nuclear energy" will "benefit U.S. companies" and "further U.S. policy interests." Indeed, it could not have been otherwise. No nuclear technology could have been legally transferred to China without the U.S. government's explicit blessing in the form of DOE authorizations, if not export licenses from the NRC and Department of Commerce. Major deals like the AP1000 sale and technology transfer agreement enjoyed endorsements from the highest levels of the U.S. government in full knowledge of China's transparently aggressive localization and technology indigenization plans. In fact, the U.S. government had a policy interest in seeing China indigenize U.S. civil nuclear technology for export because it would "[bring] along U.S. government export control protocols."⁴⁹⁶

The larger calculus favoring civil nuclear cooperation with China shifted not because new legal and technical facts had come to light but rather because Washington had adopted a new set of policy

⁴⁹³ Office of the United States Trade Representative, "Findings of the Investigation into China's Acts, Policies, And Practices Related to Technology Transfer, Intellectual Property, and Innovation under Section 301 of the Trade Act of 1974," March 22, 2018, 166–67, <https://ustr.gov/sites/default/files/Section%20301%20FINAL.PDF>.

⁴⁹⁴ NEAC International Subcommittee, "Report on Review of U.S./China Collaboration," December 2015, 3, <https://www.energy.gov/ne/articles/neac-international-subcommittee-report-december-11-2015-meeting>.

⁴⁹⁵ NEAC International Subcommittee, 5.

⁴⁹⁶ NEAC International Subcommittee, 3.

beliefs about China and a new framing of nuclear innovation as a national security priority. In parallel with a dramatic revision of its strategic approach to engagement with China,⁴⁹⁷ the first Trump administration re-framed nuclear energy as an instrument of U.S. “energy dominance.” In contrast to the Obama administration’s framing of civil nuclear cooperation with China in terms of global clean energy development and climate change mitigation, the “energy dominance” framing presupposes a far less collaborative approach to nuclear innovation. Between 2019 and 2020, the U.S. DOE developed a strategy of “restoring America’s competitive nuclear energy advantage” to “assure U.S. national security.”⁴⁹⁸ The State Department, for its part, took a page out of the Russian playbook and introduced strategic “Nuclear Cooperation MoUs” aimed at locking in 50-100-year civil nuclear partnerships with key countries – a “new approach” specifically designed to compete against Russia and China in civil nuclear exports.⁴⁹⁹ In this context, Washington became less tolerant of U.S. transfers benefiting China’s nuclear R&D, whether it was civilian or military. Therefore, in addition to concerns about military diversion, the 2018 policy revision also aimed explicitly to blunt China’s ability to engage in “direct economic competition with the United States” in the civil nuclear domain.⁵⁰⁰

The Biden administration left the first Trump administration’s policy in place as it continued to leverage technology restrictions as an instrument of strategic competition with China, though it sought to narrowly tailor the scope of these restrictions and coordinate them with allies. National Security Advisor Jake Sullivan, for instance, highlighted the need to revive U.S. domestic manufacturing, particularly in strategic industrial sectors, and described a “small yard and high fence” approach limiting China’s access to “a narrow slice of technology” that “could tilt the military balance.”⁵⁰¹ Nuclear energy technologies received a strategic designation from the executive branch. The U.S. National Science and Technology Council’s list of critical and emerging technologies named “advanced nuclear energy technologies” and “nuclear energy systems” explicitly in its 2022 and 2024 updates.⁵⁰² In his November 2024 remarks titled “Understanding the Past and Navigating the Future of Civil Nuclear Energy,” Assistant Secretary of State C.S. Eliot Kang framed U.S. civil nuclear leadership as a na-

⁴⁹⁷ White House, “United States Strategic Approach to the People’s Republic of China,” May 26, 2020, <https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/05/U.S.-Strategic-Approach-to-The-Peoples-Republic-of-China-Report-5.24v1.pdf>.

⁴⁹⁸ “Restoring America’s Competitive Nuclear Energy Advantage: A Strategy to Assure U.S. National Security” (Washington, DC: U.S. Department of Energy, 2020), <https://www.energy.gov/articles/restoring-americas-competitive-nuclear-energy-advantage>.

⁴⁹⁹ Ford, “A New Approach to Civil Nuclear Cooperation Policy.”

⁵⁰⁰ “U.S. Policy Framework on Civil Nuclear Cooperation with China,” Department of Energy, October 11, 2018, <https://www.energy.gov/nnsa/articles/us-policy-framework-civil-nuclear-cooperation-china>.

⁵⁰¹ Jake Sullivan, “Remarks by National Security Advisor Jake Sullivan on Renewing American Economic Leadership at the Brookings Institution,” The White House, April 27, 2023, <https://bidenwhitehouse.archives.gov/briefing-room/speeches-remarks/2023/04/27/remarks-by-national-security-advisor-jake-sullivan-on-renewing-american-economic-leadership-at-the-brookings-institution>.

⁵⁰² Fast Track Action Subcommittee on Critical and Emerging Technologies, “Critical and Emerging Technologies List Update,” February 2024, <https://bidenwhitehouse.archives.gov/wp-content/uploads/2024/02/Critical-and-Emerging-Technologies-List-2024-Update.pdf>; Fast Track Action Subcommittee on Critical and Emerging Technologies, “Critical and Emerging Technologies List Update,” February 2022, <https://bidenwhitehouse.archives.gov/wp-content/uploads/2022/02/02-2022-Critical-and-Emerging-Technologies-List-Update.pdf>.

tional-security priority, emphasizing strategic competition with Russia and China in global civil nuclear exports. He also linked nuclear energy to U.S.-China competition in artificial intelligence, arguing that China's expanding nuclear power generation capacity could sustain military AI applications and enhance its military capabilities.⁵⁰³ This outlook reinforced the competitive framing established under the first Trump administration.

The second Trump administration unsurprisingly continued the policies of the first. Executive orders issued in May 2025 on "reinvigorating the nuclear industrial base" and "deploying advanced nuclear reactor technologies for national security" sought to restore U.S. nuclear industrial and technological leadership.⁵⁰⁴ These orders linked nuclear energy deployment to military and AI dominance as well as U.S. industrial and export competitiveness against adversaries. Continued restrictions on nuclear commerce with China were consistent with this wider agenda of protecting America's strategic advantage and rebuilding domestic industrial capabilities. Additional restrictions emerged amid the renewed U.S.-China trade war. In June 2025, Reuters reported that the Commerce Department had suspended existing licenses for exports of parts and equipment to Chinese nuclear power plants, alongside restrictions affecting other industrial sectors.⁵⁰⁵ These suspensions coincided with disputes over Chinese rare-earth export controls and added uncertainty to nuclear commerce already constrained by the 2018 framework.

The consequences of Washington's new restrictive approach toward civil nuclear cooperation began to emerge immediately after the adoption of the new export control framework in 2018. The most immediate impact was an end to most ongoing cooperation in advanced fission energy under the Bush-era Action Plan and subsequent DOE-CAS MoU. Commercially, TerraPower was forced to terminate its cooperation with CNNC. Approvals on dozens of Part 810 authorization applications for nuclear technology transfers were suspended. Equally consequential were the dampening effects of the policy revision on U.S.-China nuclear security and nonproliferation cooperation. The third U.S.-China Nuclear Security Dialogue held in April 2018 became the last in which the two sides reaffirmed their commitment to the NSS's cooperation agenda.⁵⁰⁶ Thereafter, while technical, working-

⁵⁰³ C.S. Eliot Kang, "Understanding the Past and Navigating the Future of Civil Nuclear Energy," U.S. Department of State, November 13, 2024, <https://2021-2025.state.gov/understanding-the-past-and-navigating-the-future-of-civil-nuclear-energy>.

⁵⁰⁴ Donald J. Trump, "Reinvigorating the Nuclear Industrial Base," The White House, May 23, 2025, <https://www.whitehouse.gov/presidential-actions/2025/05/reinvigorating-the-nuclear-industrial-base>; Donald J. Trump, "Deploying Advanced Nuclear Reactor Technologies for National Security," The White House, May 23, 2025, <https://www.whitehouse.gov/presidential-actions/2025/05/deploying-advanced-nuclear-reactor-technologies-for-national-security>.

⁵⁰⁵ Karen Freifeld and Fanny Potkin, "Exclusive: US Suspends Licenses to Ship Nuclear Plant Parts to China, Sources Say," Reuters, June 6, 2025, <https://www.reuters.com/business/aerospace-defense/us-suspends-licenses-ship-nuclear-plant-parts-china-sources-say-2025-06-06>.

⁵⁰⁶ Bureau of International Security and Nonproliferation, "The United States and China Hold Third Nuclear Security Dialogue," U.S. Department of State, April 17, 2018, <https://2017-2021.state.gov/remarks-and-releases-bureau-of-international-security-and-nonproliferation/the-united-states-and-china-hold-third-nuclear-security-dialogue/>; "The Third China-United States Nuclear Security Dialogue," Ministry of Foreign Affairs of the People's Republic of China, April 18, 2018, https://www.fmprc.gov.cn/eng/wjlb/zzjg_663340/bmdyys_664814/xwlb_664816/202406/t20240606_11401528.html.

In broader context, export controls became an integral dimension of the U.S.-China strategic technological competition as Washington leveraged its control lists to target Chinese companies like Huawei and to deny them access to U.S. technologies. On December 1, 2018, Chief Financial Officer of Huawei Technologies Co., Ltd., Meng Wanzhou, was detained in Vancouver on a provisional U.S. extradition request alleging fraud tied to Iran-related sanctions evasion. China detained two Canadian citizens in retaliation. Meng's detention came just less than a month after Iran sanctions re-imposed after the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA) entered full effect. The Chinese Foreign Ministry attributed Meng's detention to the United States' "unilateral sanctions against Iran outside the UN Security Council framework ... in contravention of international law" and characterized it as a "highly political act of technology bullying" by the United States to persecute Chinese technology companies.⁵⁰⁹ Hence, as the Meng Wanzhou affair evolved into an irritant in U.S.-China relations, it also further divided the two countries on sanctions and export controls with respect to Iran.

Partners in Rivalry



The IR-40 heavy water research reactor at Arak, Iran, in 2012 · Wikimedia Commons

with the Atomic Energy Organization of Iran. In 2017, Beijing's Foreign Ministry announced that Chinese entities had signed the first commercial contract to undertake the work of reactor redesign and modification.⁵¹¹

Then the United States withdrew from the JCPOA, effectively ending U.S.-China coordination over the Arak project, though the relevant sanctions waivers were not immediately terminated.⁵¹² China continued to work with the Iranians.⁵¹³ In 2020, Washington erected a further barrier to the project by withdrawing the waivers

that previously allowed non-Iranian entities to continue working on the reactor.⁵¹⁴ For a time, Chinese interlocutors in Track 1.5 dialogues with the United States “showed interest in resuming” the reactor conversion project, but Biden-era U.S. efforts to revive it ultimately met with a passive response from Beijing.⁵¹⁵

U.S.-China civil nuclear technology ties as well as nuclear security and nonproliferation cooperation had always been contingent on good bilateral relations. Mistrust that impacted the overall relationship – for instance, following the 1989 Tiananmen Square crackdown and the 1999 release of the Cox Report – jeopardized nuclear cooperation. However, in these previous episodes, basic scientific exchanges tended to escape the curtailments that affected more sensitive collaborations. That changed with the latest downturn in U.S.-China relations. Starting from the first Trump administration, the U.S. government has adopted a more cautious posture toward science and technology cooperation with China on account of technology diversion and foreign influence concerns.

Proponents of more stringent restrictions believe that China has unfairly exploited the U.S. system of open scientific innovation to pilfer sensitive intellectual property and channel U.S.-funded research toward Chinese economic and military advancement. These concerns are not unfounded, nor are they new in the context of U.S.-China science and technology cooperation. Under the Bob Stump National Defense Authorization Act for Fiscal Year 2003, Congress had required that the

⁵¹¹ Chenxi Sun, “Waijiao Bu: Zhongguo he Yilang jiang zhengshi qianshu Alake zhongshuidui gaizao shoufen shangye hetong,” Xinhua Net, April 20, 2017, http://www.xinhuanet.com/politics/2017-04/20/c_1120846038.htm.

⁵¹² Pomper and Gogna, “US-China Areas of Cooperation: Nonproliferation and Nuclear Security,” 48–49.

⁵¹³ Maryam Sinaiee, “Iran Prepares To Revive Arak Nuclear Reactor, With Chinese Help Or Alone,” Iran International, March 19, 2021, <https://old.iranintl.com/en/world/iran-prepares-revive-arak-nuclear-reactor-chinese-help-or-alone>.

⁵¹⁴ Richard Stone, “U.S. Move Imperils Effort to Reduce Weapons Risk from Iranian Reactor,” Science, May 29, 2020, <https://www.science.org/content/article/us-move-imperils-effort-reduce-weapons-risk-iranian-reactor>.

⁵¹⁵ Pomper and Gogna, “US-China Areas of Cooperation: Nonproliferation and Nuclear Security,” 52.

Secretary of State monitor the implementation of the U.S.-China Science and Technology Agreement, ensure compliance with restrictions on military and dual-use technology transfers, and report biennially to Congress, with Defense, Commerce, and CIA input, regarding the Agreement's benefits to China's economy, military, and industrial base.⁵¹⁶ The reporting requirement was only repealed in 2016.⁵¹⁷ The last report from 2016 states,

Science and technology engagement with the United States continues to be highly valued by the Chinese government. This enables [the Department of State] and other federal agencies to use ongoing dialogues and cooperation to encourage the Chinese to support democratic and meritocratic principles and to adopt appropriate protection of intellectual property, scientific merit review processes, and transparent publishing of scientific data. Accordingly, engagement under the S&T Agreement likely has positively influenced the foreign and domestic policies of China. Cooperative activities also accelerated scientific progress in the United States and provided significant direct benefit to a range of U.S. technical agencies.⁵¹⁸

Less than two years later, the sharp deterioration of U.S.-China relations turned this assessment on its head.

In June 2018, the White House Office of Trade and Manufacturing Policy released its report entitled “How China’s Economic Aggression Threatens the Technologies and Intellectual Property of the United States and the World.” In addition to reinforcing the March 2018 findings of the Office of the United States Trade Representative with respect to China’s commercial technology-seeking practices, the June 2018 report elaborated on what it dubbed “information harvesting” by China to obtain “technologies and IP from America’s national security innovation base.”⁵¹⁹ Specific channels named by the report included open-source collection, U.S.-based Chinese nationals acting as “non-traditional information collectors,” and talent recruitment. Chinese students in the United States and Chinese nationals employed by “U.S. national laboratories, innovation centers, incubators, and think tanks” are described as potential agents of the Chinese government in acquiring dual-use technologies to “serve Beijing’s military and strategic ambitions.”⁵²⁰ The report cites, in particular, how Chinese nationals formerly employed by U.S. national laboratories moved back to China to continue their research, reportedly contributing to Chinese advancements in areas ranging from hypersonic

⁵¹⁶ “Bob Stump National Defense Authorization Act for Fiscal Year 2003,” Pub. L. No. 107–314, 116 Stat. 2458 (2002), <https://www.congress.gov/bill/107th-congress/house-bill/4546/text>.

⁵¹⁷ Blevins and Sutter, “U.S.-China Science and Technology Cooperation Agreement.”

⁵¹⁸ U.S. Department of State, “Implementation of Agreement between the United States and China on Science and Technology,” 2016, <https://web.archive.org/web/20200806151134/https://fas.org/irp/world/china/docs/scitech-2016.pdf>.

⁵¹⁹ Office of Trade and Manufacturing Policy, *How China’s Economic Aggression Threatens the Technologies and Intellectual Property of the United States and the World* (Washington, DC: White House, 2018), 13.

⁵²⁰ Office of Trade and Manufacturing Policy, 13–16.

glide vehicles and submarines to passenger jets and nuclear power reactors.⁵²¹ A 2019 Senate report entitled “Threats to the U.S. Research Enterprise: China’s Talent Recruitment Plans” presented more detailed findings from an investigation into this brain drain and IP leakage from DOE laboratories.⁵²² This investigation and others compelled DOE to act.

The following year, DOE issued an order banning employees of the Department and national laboratories from participating in activities sponsored by high-risk foreign governments, including the government of the PRC.⁵²³ The order followed measures rolled out by DOE in 2018 to restrict sensitive foreign research collaborations.⁵²⁴ These restrictions chilled joint research in basic sciences. One example in high-energy physics was DOE’s abrupt withdrawal of funding for U.S. institutions to participate in the Jiangmen Underground Neutrino Observatory (JUNO) – a \$330 million follow-on to the Daya Bay Neutrino Experiment. U.S. focus turned instead to the Deep Underground Neutrino Experiment (DUNE) at Fermilab’s Long-Baseline Neutrino Facility (LBNF). China’s Institute of High Energy Physics was a partner in the U.S. experiment, but collaboration at the LBNF has since been curtailed.⁵²⁵

When it comes to scientific collaboration and talent recruitment, restrictions cut both ways. A 2022-2023 HEPAP study found that “barriers to international participation in the U.S. [particle physics] program have increased over the last decade because of research security concerns, visa issues, and more restricted access to the national laboratories,” undercutting the ability of U.S. institutions to conduct scientific research and recruit foreign talent.⁵²⁶ The report goes on to illustrate: “An excellent example concerns those from China who are stuck either in the U.S. for fear of not being able to return to the U.S. or stuck in China with delays in visa processing. Some have been subjected to undue investigations from the leftover impacts of the U.S. Department of Justice’s China Initiative.”⁵²⁷ The U.S. Justice Department launched the China Initiative in 2018 to investigate ties between U.S.-based university researchers and the Chinese government and prosecute those who failed

⁵²¹ Stephen Chen, “America’s Hidden Role in Chinese Weapons Research,” South China Morning Post, March 29, 2017, <https://www.scmp.com/news/china/diplomacy-defence/article/2082738/americas-hidden-role-chinese-weapons-research>.

⁵²² Permanent Subcommittee on Investigations, Committee on Homeland Security and Governmental Affairs, United States Senate, “Threats to the U.S. Research Enterprise: China’s Talent Recruitment Plans,” 2019, <https://www.hsgac.senate.gov/wp-content/uploads/imo/media/doc/2019-11-18%20PSI%20Staff%20Report%20-%20China's%20Talent%20Recruitment%20Plans%20Updated2.pdf>.

⁵²³ “DOE O 486.1A, Foreign Government Sponsored or Affiliated Activities,” U.S. Department of Energy, September 4, 2020, <https://www.directives.doe.gov/directives-documents/400-series/0486.1-BOrder-a>.

⁵²⁴ Dan Brouillette, “Memorandum for Heads of Departmental Elements,” December 14, 2018, https://osp.unc.edu/wp-content/uploads/sites/1202/2022/06/osp_DOE-December-2018-Memo.pdf.

⁵²⁵ Ryan Woo, “Inside the Underground Lab in China Tasked with Solving a Physics Mystery,” Reuters, October 16, 2024, <https://www.reuters.com/science/inside-underground-lab-china-tasked-with-solving-physics-mystery-2024-10-16>.

⁵²⁶ 2023 HEPAP International Benchmarking Subpanel, *The Path to Global Discovery: U.S. Leadership and Partnership in Particle Physics* (Washington, DC: U.S. Department of Energy Office of Science, Office of High Energy Physics, 2023), 5, https://science.osti.gov/-/media/hep/hepap/pdf/Reports/2024/International_Benchmarking_HEPAP_2023.pdf.

⁵²⁷ 2023 HEPAP International Benchmarking Subpanel, 87.

to disclose such ties. The initiative was terminated under the Biden administration over criticism that it lowered the bar for prosecution and promoted racial profiling. By then, prosecutions of U.S.-based academics had already resulted in convictions, chilling collaborative academic research⁵²⁸ and intimidating U.S.-based scientists of Chinese descent. As a result, the “reverse brain drain” referring to the departure of Chinese-descent scientists from their U.S. institutions accelerated.⁵²⁹

Fifty years after people-to-people exchanges in science and technology aided diplomatic normalization, U.S.-China relations as well as science and technology cooperation once again stand at a crossroads. In the past decade, the Science and Technology Agreement has faced challenges even in its routine five-year renewals. In 2018, when the agreement was due for extension, the United States sought to introduce amendments⁵³⁰ to “address concerns about China’s approaches to technology, innovation, and practices,” including IP theft and forced technology transfer. The parties negotiated for months, during which the agreement was extended on a temporary basis, before agreeing upon amendments to the IP annex. When the agreement was once again due for extension in 2023, the Biden administration sought additional amendments. This time, the parties failed to agree on new terms and, after two temporary six-month extensions, allowed the agreement to lapse.⁵³¹

It was only in December 2024 that the protocol to amend and extend the agreement was concluded. The U.S. State Department declared that the new agreement limited cooperation to basic research, avoiding critical and emerging technologies, to “[ensure] that any federal science and technology cooperation with the PRC under the [Science and Technology Agreement] benefits the United States and minimizes risks to U.S. national security.”⁵³² In an April 2026 article, Jake Sullivan, former national security advisor under President Biden, writes that the agreement “promotes shared standards on issues such as intellectual property protections and reciprocal access to certain databases and scientific field sites,” and the renewal of the agreement in December 2024 “shows that ample room remains for the two countries to collaborate on scientific endeavors that benefit humanity even as they pursue competitive policies.”⁵³³

⁵²⁸ Didi Tang, “US Tensions with China Are Fraying Long-Cultivated Academic Ties. Will the Chill Hurt US Interests?,” AP News, December 23, 2023, <https://apnews.com/article/china-us-academic-cooperation-science-nih-investigation-44bfd9f18a5f76d8889aa5a30ea165eb>; Eric Tucker, “US Drops Name of Trump’s ‘China Initiative’ after Criticism,” AP News, February 23, 2022, <https://apnews.com/article/business-china-asia-beijing-race-and-ethnicity-c0cb26411f08f82d2ceda30f399d7003>.

⁵²⁹ Yu Xie et al., “Caught in the Crossfire: Fears of Chinese–American Scientists,” *Proceedings of the National Academy of Sciences* 120, no. 27 (July 2023).

⁵³⁰ “Protocol Between the United States of America and China Amending and Extending the Agreement of January 31, 1979, as Amended and Extended,” September 18, 2018, <https://www.govinfo.gov/content/pkg/GOVPUB-S-PURL-gpo219866/pdf/GOVPUB-S-PURL-gpo219866.pdf>.

⁵³¹ Blevins and Sutter, “U.S.-China Science and Technology Cooperation Agreement.”

⁵³² “Amendment and Extension of the U.S.-PRC Science and Technology Agreement (STA),” U.S. Department of State, December 13, 2024, <https://2021-2025.state.gov/amendment-and-extension-of-the-u-s-prc-science-and-technology-agreement-sta>.

⁵³³ Jake Sullivan, “The Tech High Ground: What It Will Take to Gain the Advantage over China,” *Foreign Affairs*, April 15, 2026, <https://www.foreignaffairs.com/united-states/tech-high-ground-jake-sullivan>.

Nevertheless, lawmakers in Washington continued to raise objections against what they perceived to be militarily sensitive research collaborations between U.S. and Chinese institutions. In 2025, the House Select Committee on the Chinese Communist Party released reports finding that Pentagon-funded research had involved Chinese military-affiliated scholars and that partnerships between U.S. and Chinese academic institutions were feeding STEM talent to China's defense complex. Members of Congress called for the Justice Department to restore the China Initiative.⁵³⁴ In December 2025, the Select Committee released an additional report alleging "a pervasive and deeply troubling pattern" of DOE-funded collaborations with Chinese defense research institutions in dual-use emerging technologies, nuclear science, and explosion science. Citing cases of collaboration linking U.S. universities and national laboratories with CAEP, the report finds that DOE-supported research "likely advanced the PRC's strategic weapons development," particularly its nuclear weapon modernization.⁵³⁵ The extent to which the second Trump administration will respond to these concerns with further restrictions remains to be seen.

⁵³⁴ Didi Tang and David Klepper, "China and the US Have Long Collaborated in 'Open Research.' Some in Congress Say That Must Change," AP News, October 13, 2025, <https://apnews.com/article/united-states-china-academic-research-congress-53ee311ea07f6ceccce4a7fe99f0857d>.

⁵³⁵ Select Committee on China, Senate Select Committee on Intelligence, and House Permanent Select Committee on Intelligence, "Containment Breach: The U.S. Department of Energy's Failures in Research Security and Protecting Taxpayer-Funded Research from Foreign Exploitation," December 2025, https://web.archive.org/web/20251217190727/https://chinaselectcommittee.house.gov/sites/evo-subsites/selectcommitteeontheccp.house.gov/files/evo-media-document/doe_report_containment_breach_final-v2-compressed.pdf.

Chapter 9. Reassessing U.S.-China nuclear cooperation

The downturn in U.S.-China relations has entailed a reassessment of cooperation across many domains. Nuclear cooperation is particularly complex due to the importance of globally coordinated nuclear governance and the dual-use applications of nuclear technology. A responsible reassessment of U.S. nuclear cooperation with China is one that rests upon reasonable judgments about its past, present, and future. The central judgment relevant to the past concerns whether nuclear cooperation with China has harmed or benefited U.S. interests. Meanwhile, the critical question related to the present is whether cooperation is still worth reviving given current U.S. strategy and global responsibility. Contingent upon an affirmative answer to this question, plotting the path to future cooperation will require judgments about the priority areas and modes – as well as the limits and guardrails – of engagement.

Taking stock of the past

There is a widespread view in the United States that China has unfairly exploited U.S. openness to cooperation to leap ahead in science and technology to the detriment of U.S. strategic interests. In the civil nuclear domain at least, this view understates Washington's historical agency in steering cooperation toward fair and mutual benefit while overstating the role of cooperation in enabling China to catch up in civil nuclear capabilities.

This historical review shows that U.S. interests drove and benefited from decades of cooperation with China in nuclear science, technology, and governance. Exchanges between U.S. and Chinese nuclear scientists and high-energy physicists contributed, by Washington's design, to political rapprochement and diplomatic normalization, to the ultimate benefit of U.S. Cold War strategy from the 1970s onward. The U.S. government deliberately loosened restrictions on dual-use technology transfers to China during this period to strengthen China as a counterweight to the Soviet Union. Engagement during the 1980s and 1990s surrounding the bilateral civil nuclear agreement, coupled with technical capacity-building assistance, helped align China with global nuclear safety, security, and nonproliferation norms. Beijing became an IAEA member state, accepted voluntary safeguards, acceded to the NPT, instituted export controls, and curtailed unsafeguarded nuclear transfers as well as general nuclear ties with countries of proliferation concern to the United States, all in accordance

with Washington's expectations. The Chinese civil nuclear enterprise adopted U.S. safety and security practices, reducing the chances of radiological accidents as well as nuclear and radiological security threats with global harm. China also collaborated with the United States to reduce the global threat of nuclear terrorism and regional proliferation.

At the same time, energy and climate security became shared strategic objectives advanced by civil nuclear cooperation. China responded to U.S. appeals to become a "responsible stakeholder" in global energy and environmental security by developing clean energy technologies, including nuclear energy, to reduce fossil fuel consumption.⁵³⁶ The GNEP and Ten-Year Energy and Environment Cooperation Framework the two countries signed at the tail-end of the Bush administration fit under this framing. Subsequently, the Obama administration hoped to make climate a linchpin of the U.S.-China cooperative agenda.⁵³⁷ In this context, bilateral nuclear energy cooperation supported the U.S. government strategy of enlisting China's contribution to global climate action. This strategy worked as China became a clean energy leader. In other words, Washington steered the agenda and terms of cooperation to serve U.S. interests.

What confounds this assessment is the fundamental fact that China's civil nuclear industry has risen to world class while America's nuclear industry has been in decline for several decades. And this comes at a time when there exists rare bipartisan support for the reversal of that decline as a strategic national security priority. Such support results from a unique convergence – nuclear energy now cuts across U.S. partisan agendas of reindustrialization, energy dominance, strong national defense, technological advancement, and climate action. Both the U.S. government and private industry are eager for nuclear energy to satisfy the surging electricity demands of AI datacenters – another central arena of U.S.-China competition. Some therefore perceive prior U.S. civil nuclear cooperation with China as a strategic mistake that strengthened a technological and industrial competitor.

It is politically convenient to attribute America's civil nuclear decline to the naïve policies of successive American administrations that allowed China to steal America's technological edge. The implication of such a view is that China has little homegrown advantage beyond stolen American IP and that the United States can reclaim its edge simply by denying China access to U.S. civil nuclear technology, now that it has its eyes wide open. The present review of U.S.-China nuclear cooperation paints a very different picture of what drove the decline of U.S. industry and what allowed China to catch up.

⁵³⁶ Robert B. Zoellick, "Whither China: From Membership to Responsibility?," U.S. Department of State, September 21, 2005, <https://web.archive.org/web/20051104060212/http://www.state.gov/s/d/rem/53682.htm>.

⁵³⁷ Cooke, *Sustaining U.S.-China Clean Energy Cooperation*, 6–8.

The atrophy of the U.S. civil nuclear industry began in the 1970s, before significant nuclear commerce or technology transfer between the United States and China. After leading the world in nuclear technologies, industrial supply chains, and power reactor construction, the U.S. nuclear industry began to decline as the construction of new reactors slowed and then came to a halt. The March 1979 Three Mile Island nuclear accident turned a slowing industry into one with virtually no new reactor orders for decades. U.S. nuclear companies were eager to enter the Chinese market but were blocked by the lack of a bilateral civil nuclear agreement. China launched its commercial nuclear industry with the help of French rather than U.S. technology transfer. It later purchased reactors from Russia and Canada. American industry pushed the U.S. government for permission to enter the competition for China's nuclear market and was willing to trade technology for market access to keep the industry alive. It was during this period that Combustion Engineering transferred its System 80 PWR technology to South Korea – an arrangement that led to complex U.S.-South Korean IP disputes decades later.

When Westinghouse signed the deal to sell the AP1000 reactor and to transfer related technology to China in 2007, its aim, as in its earlier international bids, was winning orders to keep its nuclear reactor business alive, not to surrender its competence to a foreign competitor. For China, the AP1000 deal added an advanced lineage to the multiple foreign reactor designs it had acquired and domestic reactor designs it had developed. It was an important addition, but not an indispensable one for China's domestic nuclear energy scaling. To Westinghouse, on the other hand, the deal with China represented the most promising opportunity to advance its first-of-a-kind reactor from engineering design to construction. The U.S. government endorsed the deal, which aligned with the policies of both the Bush and Obama administrations. Both administrations favored clean energy and nuclear governance cooperation with China. But neither was naïve about the attendant IP and dual-use technology diversion risks.

Indeed, the United States granted reactor export authorization only after nonproliferation guardrails had been negotiated over the previous two decades, and the technology transfer agreement was negotiated to exclude the surrender of IP rights for the AP1000 to China. Technology transfer gave China the ability to construct the indigenized CAP1000 domestically with Westinghouse involvement, not the right to export it in competition against Westinghouse. Only an upscaled reactor with significant Chinese design input could be exported, and even then, Westinghouse would either enjoy the right to participate in the export project or receive compensation for its technology. Neither the demand for technology transfer nor subsequent design indigenization for export is a uniquely Chinese expectation and practice. Among U.S. allies, France's PWR lineage began with Westinghouse technology transfer, and South Korea's indigenous PWR design originated from the System 80 reactor design by Combustion Engineering, which later became part of Westinghouse. In contrast to

France and South Korea, China has not exported a U.S. PWR derivative, or, for that matter, any commercial power reactor to markets where U.S. nuclear companies seek to compete for business. Nor would such export necessarily harm U.S. interests. Apart from the commercial benefits that would accrue to Westinghouse as a technology partner, a driver behind the U.S. government's endorsement of Westinghouse's technology transfer was the expectation that the incorporation of U.S. technology into China's advanced reactor lineage would embed U.S. technology controls into Chinese civil nuclear exports.⁵³⁸ By all accounts, the United States put itself in a position to benefit from Westinghouse's partnership with SNPTC. The decline in U.S. civil nuclear competitiveness has little to do with Chinese IP appropriation or export competition.

Nor is there evidence of forced technology transfer. While technology transfer was a condition of the tender competition in which Westinghouse participated against the French and Russian state nuclear companies, the condition was transparent, and Westinghouse's participation was voluntary. China also did not deny its market to the French and Russian vendors who were unwilling to transfer technology to the degree Westinghouse did. Technology transfer was a commercial decision Westinghouse made to take advantage not only of the Chinese market but also of Chinese supply chains. To Westinghouse, China was a potential reactor development and export partner with whom it could explore third-country markets. Promoters of the AP1000 sale and technology transfer deal like Howard Bruschi envisioned it as a path toward maximizing U.S. and Chinese industry complementarities, not competition. That vision does not appear misguided even from today's hindsight. A joint U.S.-China civil nuclear offering did not materialize due to geopolitics, but it still may.

In the meantime, Westinghouse has drawn concrete benefits from its AP1000 deal with China. These benefits include lessons related to design completion, manufacturing, construction, commissioning, and oversight. Although the terminology of "technology transfer" implies handing over a complete and mature technology to the recipient, the AP1000 design was in many ways incomplete when the Sanmen and Haiyang projects began. China was not just a passive recipient of mature U.S. technology. Rather, the Chinese projects helped elevate the AP1000 to a higher readiness level. The U.S. Vogtle project continued to benefit from Chinese lessons until the completion of the two reactors there in 2023 and 2024. The absence of such lessons would likely have made



Vogtle plant with the future units 3 and 4 construction site at left, 2011 · Charles C. Watson Jr.

⁵³⁸ NEAC International Subcommittee, "Report on Review of U.S./China Collaboration," 3.

the delays and cost overruns at Vogtle even worse. Moreover, had there been no AP1000 export to China, Westinghouse would not be able to point to any export experience as it now seeks to market the AP1000 to U.S. allies.

Even as the United States aggressively promotes the construction of new AP1000 reactors domestically and in allied countries in efforts to reclaim global civil nuclear leadership, China remains the leading customer of the Westinghouse AP1000 worldwide. Despite the 2018 policy revision, Westinghouse's export of AP1000 equipment and components to China continued to enjoy a presumption of approval until the second Trump administration again made it an issue in the trade war with China in June 2025.⁵³⁹ Chinese industry has continued to award contract scope for these new reactor units to Westinghouse,⁵⁴⁰ providing a predictable and lucrative source of business for U.S. industry. Beijing has continued to seek expanded commerce. When Westinghouse CEO Patrick Fragman visited China in September 2023 to attend the signing ceremony for the Xudapu CAP1000 units' instrumentation and control contracts, the head of the Chinese nuclear safety regulator met with him "to urge Westinghouse to play a positive role in facilitating the rollback of U.S. sanctions on China's civilian nuclear sector," as reported by the regulator.⁵⁴¹ The Chinese civil nuclear market, currently the world's fastest-growing, is still open to U.S. nuclear companies if they are permitted to do business within U.S. export control boundaries.

Although advanced fission energy research, development, and deployment are often framed as areas of U.S.-China technology competition, the efforts by the two countries have been more complementary than competitive. The U.S.-initiated GNEP benefited from Chinese contributions to fast reactor research. TerraPower had its only real chance to deploy the Traveling Wave Reactor in China. As with the AP1000, technology transfer in the TerraPower deal did not imply the handover of a proven reactor design and mature know-how. In fact, the Traveling Wave Reactor was at an even lower technology readiness level than the AP1000 and would have required far more significant Chinese input to bring to deployment. In the case of molten-salt reactors, Chinese contributions did materially benefit U.S. R&D activities. In particular, the ORNL-SINAP CRADA helped preserve FHR knowledge at Oak Ridge and lay the foundation for its commercialization in the United States – in no small part by funding the startup of molten salt experimental facilities allowing ORNL to "recapture" previous experience with liquid salt loops while enabling experiments⁵⁴² for demonstrating

⁵³⁹ Freifeld and Potkin, "Exclusive: US Suspends Licenses to Ship Nuclear Plant Parts to China, Sources Say."

⁵⁴⁰ Kamen Kraev, "Westinghouse To Supply Instrumentation Systems For Xudabu-1 And -2 Nuclear Plants," Nucnet, September 28, 2023, <https://www.nucnet.org/news/westinghouse-to-supply-instrumentation-systems-for-xudabu-1-and-2-nuclear-plants-9-4-2023>; "Cameco and Brookfield Complete Acquisition of Westinghouse Electric Company Creating a Powerful Platform for Strategic Growth," Cameco, November 7, 2023, https://www.cameco.com/sites/default/files/2024-03/2023_11_07_Westinghouse_Acquisition_Closing.pdf.

⁵⁴¹ "Zhonghua Renmin Gongheguo Guojia He Anquan Ju 2023 nian bao" (Beijing, May 5, 2024), 74, https://nnsa.mee.gov.cn/ztzl/haqbg/haqnb_1/202405/P020240531579488725688.pdf.

⁵⁴² Graydon Yoder et al., "Start-up Operation Experience with a Liquid Fluoride Salt Forced Convection Loop" (Oak Ridge, August 2023), 1.

molten-salt reactor components and supporting commercialization. Meanwhile, former U.S. participants in the CRADA that received SINAP funding to carry out molten-salt reactor research went on to co-found Kairos Power, a company that is now leading U.S. FHR commercialization efforts. Since the first Trump administration's crackdown, DOE has severed ties with SINAP; U.S. researchers and national laboratories that cooperated with SINAP on FHR development have grown reticent to acknowledge previous cooperation publicly. Nevertheless, the cooperative legacy is real.⁵⁴³ Had there been no cooperation, U.S. advanced reactor R&D would likely have lagged further for lack of resources to maintain the necessary infrastructure and talent.

Of course, there is no doubt that China has benefited enormously from cooperation with the United States. Scientific exchanges with the U.S. experimental high-energy physics and magnetic fusion communities facilitated China's induction into these internationally collaborative fields; U.S. capacity-building assistance informed China's nuclear safety, security, and nonproliferation policy and architecture. U.S. technology transfers aided China's civil nuclear program, particularly its transition to passively safe, Generation III+ PWRs and its exploration of advanced fission reactor concepts.

However, China's civil nuclear progress today is not a result of U.S. technology transfer alone, and the United States could not have stifled China's civil nuclear ambitions by withholding cooperation given China's indigenous capability and diverse foreign partnerships. Before the implementation of its civil nuclear agreement with the United States, China had secured the transfer of PWR technology from France and constructed indigenized units of the French-design reactor. Russia had sold its large power reactors to China under a legacy deal from the 1980s, transferred centrifuges to Chinese uranium enrichment plants, and committed to helping CIAE construct its experimental fast reactor. China had also acquired CANDU heavy water reactor technology from Canada and high-temperature gas-cooled reactor technology from Germany. Had the United States withheld technology transfers and R&D collaboration, China would still have developed a competent, well-rounded civil nuclear program over time, albeit one less transparent to the United States, less complementary to the U.S. nuclear industry and technology advancement, and less robustly shaped by U.S. standards of nuclear governance. This governance framing is uniquely salient in the U.S.-China civil nuclear partnership. Beyond transactional benefits, both countries came to appreciate the global responsibilities that make cooperation indispensable, whether in nuclear safety, security, and nonproliferation or in global energy and climate security. Even though the United States has reconsidered its commitment to global responsibility in recent years, it should not regret previous cooperation with China to advance global governance objectives because Americans ultimately benefit from a better governed world.

⁵⁴³ Colin Jones, "How America Gave China an Edge in Nuclear Power," *The New Yorker*, December 18, 2025, <https://www.newyorker.com/news/the-lede/how-america-gave-china-an-edge-in-nuclear-power>.

On the debit side, growing U.S.-China rivalry has accentuated for Washington policymakers the strategic security risks associated with U.S. IP leakage to China, particularly to Chinese military end-users. U.S. officials have cited China's military-civil fusion as a reason to be concerned about China's technology diversion for military benefits. Two separate issues are involved. One is the transfer of proprietary U.S. civil nuclear technologies. The other is collaboration in fundamental research, which may include joint basic scientific inquiry and collaborative development of pre-commercial, non-proprietary technologies. Concerns about China's military-civil fusion practice cut across these two issues.

Nuclear technologies are inherently dual use regardless of whether an explicit military-civil fusion program exists. The defense-civilian divide is porous even within the U.S. nuclear enterprise. Recent U.S. administrations have highlighted the risk that Chinese entities might divert U.S. technology for military purposes, but this is not a new revelation. U.S. policymakers have been aware of the dual-use implications of nuclear technology transfers to China and implemented guardrails against diversion since transfers were first contemplated in the 1980s.

Chinese espionage and other attempts to circumvent U.S. export controls pose different challenges. In 2014, the U.S. Justice Department charged Chinese military hackers for stealing confidential information from Westinghouse. In 2017, Allen Ho, a U.S. citizen who helped CGN enlist U.S. nuclear experts to advise its SMR and advanced fuel programs, was sentenced to 24 months in prison and a \$20,000 fine after pleading guilty to the charge of "conspiracy to unlawfully engage or participate in the production or development of special nuclear material outside the U.S., without the required authorization from the U.S. Department of Energy (DOE)."⁵⁴⁴ These illicit activities require enforcement action. However, conflating economic espionage and export control violations with military diversion is unhelpful for formulating effective U.S. policy responses. In the Westinghouse case, the charges were related to "economic espionage" for "commercial advantage"⁵⁴⁵ rather than espionage for military technology advancement. Similarly, CGN's export control violation did not, even by the U.S. government's own account, result in the diversion of U.S. IP to Chinese military end-users. Then Assistant Secretary of State Christopher Ford publicized the concern that CGN might divert stolen U.S. know-how to the development of maritime reactors for the Chinese military under Beijing's policy of military-civil fusion. Yet he acknowledged that the SMR and advanced fuel programs CGN was attempting to advance through illegally obtained U.S. know-how were not military

⁵⁴⁴ "U.S. Nuclear Engineer Sentenced to 24 Months in Prison for Violating the Atomic Energy Act," U.S. Department of Justice, August 31, 2017, <https://www.justice.gov/archives/opa/pr/us-nuclear-engineer-sentenced-24-months-prison-violating-atomic-energy-act>.

⁵⁴⁵ "U.S. Charges Five Chinese Military Hackers for Cyber Espionage Against U.S. Corporations and a Labor Organization for Commercial Advantage," U.S. Department of Justice, May 19, 2014, <https://www.justice.gov/archives/opa/pr/us-charges-five-chinese-military-hackers-cyber-espionage-against-us-corporations-and-labor>; "Attorney General Eric Holder Speaks at the Press Conference Announcing U.S. Charges Against Five Chinese Military Hackers for Cyber Espionage," U.S. Department of Justice, May 19, 2014, <https://www.justice.gov/archives/opa/speech/attorney-general-eric-holder-speaks-press-conference-announcing-us-charges-against-five>.

in nature and “might have been eligible for cooperation under the existing U.S. ‘123 Agreement’ with China, had CGN actually sought to strike agreements with U.S. firms and go through proper licensing procedures.”⁵⁴⁶

Formulating an effective response requires identifying the actual challenge, distinguishing between economic espionage and export control circumvention, on the one hand, and the diversion of U.S. civil nuclear transfers to military purposes, on the other. The cases of Westinghouse and CGN illustrate the former, to which the response is simple: espionage should be answered with more vigorous counterespionage, and export control violations should be met with more vigorous enforcement. Narrowing the field of legitimate cooperation, on the other hand, is not an effective solution. Chinese espionage activities will continue even if legitimate civil nuclear cooperation is halted altogether; similarly, curtailing established channels of civil nuclear transfer does little to prevent future unauthorized transfers that bypass those channels – as CGN allegedly attempted to do.

With respect to research collaboration related to basic science or pre-commercial technology advancement, security risks and guardrails have been more challenging to define than in the case of technology transfers requiring DOE’s Part 810 authorization. In the 1980s, the Reagan administration issued National Security Decision Directive (NSDD) 189 to establish a U.S. “national policy for controlling the flow of science, technology, and engineering information produced in federally-funded fundamental research at colleges, universities, and laboratories” as it perceived that “the acquisition of advanced technology from the United States by Eastern Bloc nations for the purpose of enhancing their military capabilities [posed] a significant threat to [U.S.] national security.”⁵⁴⁷ The directive framed the dilemma in succinct terms. It acknowledged, on the one hand, that “the strength of American science requires a research environment conducive to creativity, an environment in which the free exchange of ideas is a vital component,” and on the other hand, that U.S. science and technology leadership was “an essential element” in the country’s “economic and physical security.” The administration’s policy as spelled out by the directive was to minimize restrictions on “the products of fundamental research” as a general rule while classifying research sensitive to national security.⁵⁴⁸ Classification authority is assigned to federal government agencies, but the directive itself does not offer uniform, detailed guidance as to how the line between classified and unclassified fundamental research should be drawn.

When China replaced the Eastern Bloc as the United States’ primary technological rival, Washington policymakers faced the same dilemma as during the Reagan administration. In some ways, balancing

⁵⁴⁶ Christopher Ashley Ford, “Chinese Technology Transfer Challenges to U.S. Export Control Policy,” U.S. Department of State, July 11, 2018, <https://2017-2021.state.gov/remarks-and-releases-bureau-of-international-security-and-nonproliferation/chinese-technology-transfer-challenges-to-u-s-export-control-policy/>.

⁵⁴⁷ President, *National Policy on the Transfer of Scientific, Technical and Engineering Information* (Washington, DC: White House, 1985).

⁵⁴⁸ President.

open science against national security had become more challenging since the 1980s as U.S. national security had grown more multifaceted, and the technology landscape had grown more complex. In 2018, DOE began implementing a “risk matrix” to “establish clear policy guidance on what areas of international scientific research collaboration pose potential risks to U.S. national interests.”⁵⁴⁹ However, for university researchers, there continued to be an “absence of clear, coherent, consistent federal policy guidance regarding research and education interactions with China.”⁵⁵⁰ Under the first Trump administration’s crackdown, many university collaborations that were previously encouraged became suspect to the point of triggering legal prosecution. The crackdown caused fear, confusion, compliance fatigue, and productivity erosion among U.S. scientific researchers.⁵⁵¹ An unfortunate effect has been an accelerated exodus of U.S.-based scientists, particularly those of Chinese descent.

U.S. withdrawal from research collaborations with China has not advanced U.S. scientific leadership, at least in nuclear and high-energy particle science. In late 2025, JUNO – the neutrino detector facility built after the Daya Bay Neutrino Experiment – delivered its first physics results. DOE had withdrawn support for U.S. involvement.⁵⁵² The U.S. DUNE at LBNF is now expected to cost around ten times the Chinese experiment and double its original cost estimate when its first phase comes online around 2030.⁵⁵³ In magnetic fusion, the decoupling with China most recently manifested through the total absence of U.S. scientists at the October 2025 IAEA fusion conference in Chengdu. DOE reportedly discouraged U.S. scientists from attending.⁵⁵⁴

Historically, U.S. cooperation with China in nuclear and high-energy physics, nuclear energy science, technology deployment, and governance served U.S. strategic interests as defined by Washington. The United States did not lose its competitive edge because it gave away too much in previous cooperation. Nor did China build its progress solely, or even primarily, upon U.S. know-how, whether it was legally or illegally acquired. The U.S. government has neither determined, nor released evidence showing, that China has materially breached the terms of the bilateral peaceful use agreement against military diversion, demonstrating that guardrails against the diversion of U.S. nuclear technology transfers to military purposes have remained effective. In open science, Chinese talent recruitment has accelerated a reverse brain drain from the United States. But so has misguided U.S.

⁵⁴⁹ Brouillette, “Memorandum for Heads of Departmental Elements.”

⁵⁵⁰ Richard Lester et al., *University Engagement with China: An MIT Approach* (Cambridge: Massachusetts Institute of Technology, 2022), III, https://global.mit.edu/wp-content/uploads/2022/11/FINALUniversity-Engagement-with-China_An-MIT-Approach-Nov2022.pdf.

⁵⁵¹ Hoover Institution, “Critical Issues in the US-China Science and Technology Relationship,” YouTube, November 14, 2024, https://www.youtube.com/watch?v=FMLUv_JImyk.

⁵⁵² Nannan Zhang, “JUNO Experiment Delivers First Physics Results Two Months After Completion,” Chinese Academy of Sciences, November 20, 2025, https://english.cas.cn/Special_Reports/2025q4/202601/t20260122_1146380.shtml.

⁵⁵³ Adrian Cho, “Trying to Stay Ahead of Competition, U.S. Pares down Troubled \$3 Billion Neutrino Experiment,” *Science*, March 29, 2022, <https://www.science.org/content/article/trying-stay-ahead-competition-u-s-pares-down-troubled-3-billion-neutrino-experiment>.

⁵⁵⁴ Raymond Zhong et al., “Clean, Limitless Energy Exists. China Is Going Big in the Race to Harness It,” *The New York Times*, December 13, 2025, <https://www.nytimes.com/2025/12/13/climate/china-us-fusion-energy.html>.

policy. Formulating approaches to mitigate genuine IP and dual-use risks deriving from scientific collaboration while avoiding unintended harm to America's own innovation potential requires carefully re-thinking the rules and boundaries of exchanges.

Present and future cooperation: interests, paths, and boundaries

If the history of cooperation offers any lessons, it is that joint endeavors must serve the interests of both countries. U.S.-China nuclear cooperation has done so over the years and, on balance, has benefited global nuclear governance. However, Washington is increasingly concerned that China is seeking to challenge the United States on the global stage; its approach toward China has evolved accordingly from engagement to decoupling and competition. Both the Trump and Biden administrations have framed U.S. strategic interests in terms of great-power competition. The Biden administration emphasized the need for like-minded allies and partners to face up to the China challenge while President Trump has set U.S. dominance in energy and innovation as top strategic goals. The views of most Democratic and Republican policymakers in Washington have converged toward recognizing the strategic importance of nuclear technology dominance for U.S. national security in both economic and military terms. Recognition that China has caught up with the United States in most nuclear technologies and has moved far ahead in construction of new nuclear power plants is fueling U.S. anxiety. Meanwhile, a more general reappraisal of U.S. global responsibility in areas ranging from climate security to nuclear governance has undercut prior normative justifications for U.S. civil nuclear cooperation with China. Regardless of past benefits, the present question is whether any justifications for cooperation still exist.

According to the National Security Strategy released by the current Trump administration in December 2025, U.S. policy toward China continues to be based on the imperative formulated in 2017 to reverse “more than three decades of mistaken American assumptions about China.” One such assumption relates to China’s power relative to that of the United States: “What began as a relationship between a mature, wealthy economy and one of the world’s poorest countries has transformed into one between near-peers, even as, until very recently, America’s posture remained rooted in those past assumptions.” Another mistaken assumption, according to the 2025 Strategy, is that engagement with China “would facilitate China’s entry into the ‘so-called ‘rules-based international order.’”⁵⁵⁵ Indeed, the current administration is reconsidering not only the aim of integrating China into the international order, but its commitment to that order altogether. The rest of the Strategy

⁵⁵⁵ President, *National Security Strategy of the United States of America* (Washington, DC: White House, 2025), 19.

places minimal emphasis on the United States' global responsibilities and instead frames nuclear energy solely as an instrument of U.S. energy dominance enabling American re-industrialization and innovation in emerging technologies. Nuclear research merits investment under the Strategy primarily because it represents one of several key “military and dual-use” technologies in which the United States must further its lead over its competitors. Notably absent is any reference to nuclear governance as it relates to global security and nonproliferation. Climate responsibility is rejected as a “disastrous” ideological construct that “[threatens] the United States” and “[subsidizes] U.S. adversaries.”⁵⁵⁶ In this zero-sum, dominance-oriented conception of U.S. strategic interests with respect to energy and technology innovation, U.S.-China civil nuclear cooperation has become difficult to justify in its traditional mode – involving R&D collaboration and technology transfer – and via traditional appeals to mutual technological benefit and global governance responsibility.

Although present U.S.-China strategic rivalry demands a rethinking of prior modes, objectives, and boundaries of interaction, it has not eliminated all cooperative opportunities and benefits. The United States still stands to gain from cooperation with China in civil nuclear science, technology, commerce, and governance.

The second Trump administration recognizes the importance of U.S. scientific and technological leadership. The White House Office of Science and Technology Policy's July 2026 report, *Science: A New Golden Age*, proposes reforms to strengthen the U.S. scientific research enterprise, to direct scientific efforts toward strategic priorities, to rebuild the industrial and workforce capabilities needed to translate discoveries into technological advancement, and to mobilize national scientific resources for promoting AI-driven innovation. This vision prescribes an expanded role for federal direction and mobilization of the national scientific base because the previous “laissez-faire” approach can no longer ensure that U.S. scientific excellence translates into technological leadership when competitors pursue state-driven innovation strategies often benefiting from the “unguarded openness” of the U.S. scientific enterprise. But even as the report cautions against unilateral openness, it acknowledges that the values of open and transparent research are “central to scientific progress.”⁵⁵⁷ No country commands all the knowledge and infrastructure needed to advance across the scientific frontier.

The U.S. scientific community has highlighted the need to maintain an open fundamental research environment to avoid weakening “the foundations of American science, technology, and innovation.” It has also highlighted the benefit to the United States of continued scientific engagement with China within appropriate boundaries and guardrails. At a high level, the rationale for engage-

⁵⁵⁶ President, 14.

⁵⁵⁷ Michael Kratsios, “Science: A New Golden Age,” The White House, July 2026, <https://www.whitehouse.gov/science>.

ment is laid out in a 2022 report by the MIT China Strategy Group: “The United States and China are the world’s largest producers of scientific knowledge, and researchers in the two countries collaborate with each other more than any other international pairing. Although China has almost certainly been the greater beneficiary until now, U.S. science and innovation stand to benefit increasingly as China’s investment in science and technology continues to grow.”⁵⁵⁸ According to the OECD, China’s total R&D expenditure approximately matched that of the United States in 2024 when adjusted for purchasing power.⁵⁵⁹ The National Science Board reports that China accounted for 31% of worldwide science and engineering publications in 2024, compared with 12% for the United States. China also remained the largest foreign partner for U.S. authors in scientific publication co-authorship.⁵⁶⁰

In the nuclear domain, China has displayed increasing openness to international scientific cooperation. Since 2024, it has offered international researchers access to over a dozen experimental facilities ranging from research reactors and underground nuclear-waste research facilities on the fission side to tokamak devices on the fusion side.⁵⁶¹ Potential gains from cooperation therefore increasingly include U.S. access to Chinese experimental infrastructure and the knowledge generated through its use. It is possible to realize these gains as long as the U.S. government works with U.S.-based researchers and institutions to clearly define the boundaries and guardrails of joint scientific work consistent with U.S. interests.

Beyond basic science, there is significant space for technology cooperation. Current U.S. government restrictions on collaboration with China in civil nuclear innovation are based on at least three assumptions: first, that advanced civil nuclear technologies like SMRs and advanced reactors have foreseeable commercial and military potential; second, that these technologies are strategically crucial for powering the growth of AI and other emerging technologies; and third, that the United States has an innovation advantage over China, which it can best protect by limiting collaboration with China. All three assumptions are subject to debate and should be reassessed.

⁵⁵⁸ Lester et al., *University Engagement with China: An MIT Approach*, 12.

⁵⁵⁹ Organisation for Economic Co-operation and Development, “OECD Overall R&D Growth Stable; Government R&D Budgets Decline and Reorient towards Defence,” OECD, March 31, 2026, <https://www.oecd.org/en/data/insights/statistical-releases/2026/03/oecd-overall-rd-growth-stable-government-rd-budgets-decline-and-reorient-towards-defence.html>.

⁵⁶⁰ National Science Board, Committee on National Science and Engineering Policy, and National Science Foundation, “Science and Engineering Indicators 2026: The State of U.S. Science and Engineering,” May 4, 2026, <https://ncses.nsf.gov/pubs/nsbsep20261/executive-summary>.

⁵⁶¹ Xinhua, “China to Open 10 Major Scientific Facilities to International Academia in 2026,” The State Council of the People’s Republic of China, March 25, 2026, https://english.www.gov.cn/news/202603/25/content_WS69c3e7f2c6d00ca5f9a0a199.html; People’s Republic of China, “Implementation of the Treaty on the Non-Proliferation of Nuclear Weapons in the People’s Republic of China,” Ministry of Foreign Affairs of the People’s Republic of China, April 21, 2026, https://www.fmprc.gov.cn/eng/wjb/zzjg_663340/jks_665232/kjfywj_665252/202604/t20260423_11898080.html.

For decades, the U.S. civil nuclear industry has championed the vision of a “nuclear renaissance” in which SMRs and advanced reactors enable rapid nuclear energy scaling. However, a fourth-generation reactor concept has yet to come close to domestic commercialization despite a proliferation of reactor engineering startups making ever more optimistic claims about near-term deployment. Much the same can be said about the periodic interest of the military in the application of nuclear energy systems beyond nuclear propulsion. For example, the idea of powering military installations with nuclear energy systems was dismissed upon the termination of the Army Nuclear Power Program in the 1970s for lack of rationale and viability. Only in the last decade has DoD revived the idea under Project Pele and, more recently, the Janus Program, based on highly optimistic assumptions about the revolutionary potential of advanced reactor technologies for military applications. However, most of these technologies are still far from commercial viability. Their near-term military potential is speculative at best.

Contrary to narratives linking the nuclear power race to AI competition, most advanced reactor technologies are not mature enough to power strategic AI scaling in the near term in either the United States or China. According to the IEA’s 2025 projections, natural gas and renewables will dominate U.S. electricity generation for datacenters well past 2030 even under optimistic assumptions about SMR deployments. China is projected to rely on renewables and coal. Although nuclear growth will be more significant there than in the United States, the additional nuclear capacity is expected to come mainly from traditional large PWRs that China knows how to build, rather than from new SMRs and advanced reactors.⁵⁶²

Significantly, the nuclear energy race does not need to be zero-sum. U.S. advanced reactor companies seeking demonstration or commercial deployment opportunities could benefit from access to the Chinese market as well as Chinese financing, project management efficiency, and civil construction competence for first-of-a-kind prototypes. With respect to reactor concepts that China is ahead in developing or deploying, the United States could benefit from Chinese transfer of data, know-how, and supply chain experience. Notwithstanding the U.S. advantage in capital-driven innovation, technologies that are more than a decade away from commercialization require advancement through open science before private and proprietary R&D investments make sense. In this regard, collaborative fundamental research would help advance pre-commercial concepts far more than autarkic practices.

The Trump administration’s National Security Strategy (NSS) correctly recognizes the growth of Chinese capabilities in recent decades. To borrow the language used in the NSS to describe U.S. objectives, China has achieved “energy dominance,” established robust civil nuclear supply chains, and

⁵⁶² Thomas Spencer et al., *Energy and AI* (Paris: International Energy Agency, 2025), 88.

begun leading nuclear technology innovation “from a position of strength.” Energy-wise, China’s total installed power generation capacity is more than triple that of the United States, and it is rapidly growing. China reported adding more than 500 GW of power generation capacity – some 40% of the United States’ total installed capacity – in 2025 alone.⁵⁶³ Renewables account for most of the growth, but the country’s nuclear power capacity is set to overtake that of the United States by the end of the decade. Continued, rapid nuclear construction is enabled by a robust domestic supply chain for uranium processing and reactor component manufacturing. Supply chains for several advanced reactor technologies and SMRs have been developed, and demonstration units are operational. These include the HTR-PM, the 210MWe high-temperature gas-cooled reactor whose prototype at Tsinghua University was once a focus of potential U.S. cooperation. One of the two 600MWe demonstration sodium-cooled fast reactors is also now operational. In Hainan Province, the 125MWe demonstration SMR based on PWR technology is nearing commercial operation. The thorium molten-salt reactor project is proceeding toward larger-scale demonstration after SINAP’s TMSR prototype became operational. In the civil nuclear arena, the U.S. strategy of technology denial simply has been ineffective.

The era when the United States could realistically expect to constrain China’s civil nuclear development through technology denial has long passed. The Chinese government continues to support nuclear technology innovation, including for fusion energy, with generous state investment. China’s state-owned nuclear companies have access not only to a full-fledged domestic civil nuclear innovation base but also to diverse non-U.S. civil nuclear technology partners and multilateral fora such as the Generation IV International Forum for advanced fission energy systems. In short, U.S. restrictions on technology collaboration do little to slow China down, but they do much to prevent the United States from catching up faster.

China’s leading position in deploying most advanced civil nuclear technologies is a reason for the United States to embrace rather than withdraw from technology collaboration, provided that strong guardrails against IP leakage and military diversion are in place. U.S. advanced reactor developers seeking demonstration or commercial deployment opportunities could benefit from access to the Chinese market as well as Chinese financing, project management capabilities, and civil construction expertise for first-of-a-kind reactor projects. For reactor concepts that China has advanced further toward commercialization, the United States could benefit from Chinese data and experience in operation and supply chain development. China modernized its own civil nuclear manufacturing base in part by exposing domestic enterprises to foreign technology and industrial practices. Current U.S. efforts to rebuild advanced nuclear manufacturing could profitably draw on a similar strategy.

⁵⁶³ “Guojia Nengyuan Ju fabu 2025 nian quanguo dianli tongji shuju,” National Energy Administration, January 29, 2026, <https://www.nea.gov.cn/20260129/6874f211acd0417eab7ac10c3061a7c2/c.html>.

Idaho National Laboratory's 2025 report, *Potential Cost Reduction in New Nuclear Deployments Based on Recent AP1000 Experience*, concludes based on Chinese data that "successful transfer of lessons learned from [first-of-a-kind] executions of the AP1000" resulted in "a ~50% reduction in schedule" in subsequent Chinese AP1000 construction and that "a larger, industry-wide, coordinated effort to gather and share construction lessons learned" can substantially speed up future U.S. AP1000 construction for domestic nuclear power scaling.⁵⁶⁴ Just as Westinghouse benefited in the past from Chinese reactor construction experience, so can the depleted U.S. civil nuclear industry today benefit from Chinese project management know-how, civil construction competence, and in-house heavy manufacturing capacity. The United States cannot replicate China's state-owned nuclear industry, but it can learn from China's experience in supporting the civil nuclear industry through consistent policy planning, workforce development, and strategic industry investment.

The road to a nuclear renaissance in the United States will be long and arduous. It will require a renewed partnership between U.S. industry and government to rebuild domestically all aspects of the nuclear reactor and nuclear fuel supply chain, including the workforce. Much of the U.S. forging and heavy manufacturing capacity for making reactor pressure-vessels and other components of nuclear steam supply systems has been lost. As a consequence, most U.S. reactor vendors count on manufacturers in allied countries such as South Korea and Japan to fabricate their forgings and heavy components. The U.S. uranium enrichment enterprise experienced a similar decline from the 1980s onward as the release of Cold War-era fissile material stockpiles exacerbated market oversupply during decades of weak demand and U.S. investments in more efficient centrifuge technology were terminated. As a result, today the United States depends heavily on purchases of foreign enriched uranium. This dependence has become particularly problematic following Russia's full-scale invasion of Ukraine. While Washington lawmakers have formally prohibited imports of Russian enriched uranium, they have chosen to allow waivers until the end of 2027 due to the lack of adequate alternative supply.

The second Trump administration has recognized these challenges and sought to address them, most notably through the May 2025 executive orders focusing on domestic deployment, supply-chain investment, regulatory reform, and export promotion. The administration set an ambitious goal of expanding U.S. nuclear generating capacity from approximately 100 GW to 400 GW by 2050, with more immediate objectives in terms of capacity uprates and new plant construction.⁵⁶⁵ More recently, under the Genesis Mission, DOE has initiated efforts to apply AI to reactor engi-

⁵⁶⁴ Ryan Spangler et al., "Potential Cost Reduction in New Nuclear Deployments Based on Recent AP1000 Experience," June 12, 2025, 38, https://sai.inl.gov/content/uploads/29/2025/06/M3_SAI-AP1000_Lessons_Rev6-nocomments-002.pdf.

⁵⁶⁵ Donald J. Trump, "Ordering the Reform of the Nuclear Regulatory Commission," The White House, May 23, 2025, <https://www.whitehouse.gov/presidential-actions/2025/05/ordering-the-reform-of-the-nuclear-regulatory-commission>; Trump, "Reinvigorating the Nuclear Industrial Base"; Trump, "Deploying Advanced Nuclear Reactor Technologies for National Security."

neering, licensing, manufacturing, and construction.⁵⁶⁶ Congress, for its part, has enacted the International Nuclear Energy Act of 2025, which aims to help sustain domestic suppliers by expanding overseas nuclear power demand and enabling U.S. exports.⁵⁶⁷

These initiatives could strengthen U.S. civil nuclear capabilities, but the United States will not regain self-sufficiency in any segment of the civil nuclear supply chains anytime soon. It will take years for the United States to become self-sufficient in uranium conversion and enrichment, even with the investment and financing assistance of U.S. allies. Despite ongoing efforts by Centrus to restore U.S. uranium enrichment capacity, the company's first new centrifuge cascades are not expected to come online only before 2029, and it will be much longer before the plant will be able to meet U.S. needs. Meanwhile, full reactor delivery capability depends on training a skilled workforce not only for heavy nuclear manufacturing but also for megaproject management and civil construction.

China is not the reason behind these challenges facing the U.S. nuclear industry, and cutting civil nuclear ties with China will not assist in overcoming them. To the contrary, China offers a source of industrial learning and supply assurance. The two countries are already interdependent in nuclear supply. For example, Chinese enriched uranium is filling the supply gap for some U.S. utilities subject to the Russian uranium ban. In the long term, the U.S. ability to continue investing in domestic fuel cycle capacity will depend on high global market prices and demand for uranium fuel. Much of that demand will come from China. At the same time, oversupply from China could once again depress global prices and frustrate U.S. capacity investment. Strengthening the robustness of U.S. nuclear fuel supply involves more than domestic reindustrialization. It requires global coordination.

While global nuclear governance is not addressed in the current U.S. National Security Strategy, it remains critical to U.S. economic and security interests. The International Nuclear Energy Act, which became law in December 2025, recognizes that U.S. civil nuclear leadership includes leadership in safety, security, and nonproliferation. Historically, the accidents at Chernobyl and Fukushima heightened safety anxieties worldwide. Waves of anti-nuclear sentiment in the United States and abroad triggered by these accidents undermined support for new plant construction while hastening plant retirements. Lapses in nuclear safety in any country, including China and recipients of Chinese civil nuclear exports, could undermine public confidence and support for nuclear deployment in the United States. Therefore, the wellbeing of the U.S. nuclear industry depends on continued international cooperation to foster the adoption of nuclear safety best practices globally. Cooperation with

⁵⁶⁶ "Genesis Mission National Science and Technology Challenges," U.S. Department of Energy, accessed September 14, 2026, <https://www.energy.gov/undersecretaryforscience/genesis-mission/genesis-mission-national-science-and-technology-challenges>.

⁵⁶⁷ "International Nuclear Energy Act of 2025," Pub. L. No. 119–60, § 8366, 139 United States Statutes at Large 1889 (2025), <https://www.govinfo.gov/content/pkg/PLAW-119publ60/pdf/PLAW-119publ60.pdf>.

China on nuclear safety would help protect the conditions for American nuclear rebuilding and exports to succeed.

Similarly, nuclear and radiological security, nonproliferation, and export controls require the harmonization of rules and joint international monitoring of illicit activities. The most recent Chinese white paper on nuclear security released in 2019 reaffirmed Beijing's commitment to international cooperation with respect to nuclear security and highlighted the U.S.-China Nuclear Security Dialogue and the Nuclear Security COE as success cases.⁵⁶⁸ However, the pandemic interrupted in-person exchanges, and institutional turnover as well as evolving U.S. strategic priorities reduced the degree of bilateral nuclear security engagement.⁵⁶⁹ Although China expressed a desire to revive the process after the pandemic, U.S. government policy was less clear about how nuclear security should fit within its broader approach of competition and cooperation vis-à-vis Beijing.⁵⁷⁰

A significant global expansion of nuclear power will heighten worldwide nuclear security and nonproliferation governance challenges. Nuclear facilities and materials requiring physical protection will multiply. HALEU and plutonium for advanced reactors will further challenge the boundaries between military and civilian fissile materials, and emerging technologies will empower potential malicious state and non-state actors. To meet these challenges, the United States and China will have strong incentives to work together and in concert with other key stakeholders to coordinate and reinforce nuclear security and nonproliferation standards, norms, and best practices. Regardless of how strategic interests may shift, the United States and China will continue to share a common responsibility for ensuring that dual-use nuclear technology is judiciously governed and controlled.

In recent years, the United States has cited the opacity of the Chinese nuclear enterprise, particularly the indistinct programmatic and organizational separation between its defense and civilian elements, as a reason to scale back engagement. However, transparency is best advanced through engagement, as demonstrated by the history of exchanges involving U.S. and Chinese laboratories across the civil and defense nuclear domains. Prior U.S. administrations recognized transparency as one of the top benefits of cooperation. This benefit remains a compelling justification for reviving engagement, if only to equalize the transparency balance – in the absence of engagement, the U.S. nuclear enterprise is far more transparent to China than the other way around.

Closed-fuel-cycle technologies represent a consequential area of potential engagement. Both the United States and China are actively pursuing civilian fast reactors and spent fuel recycling. The as-

⁵⁶⁸ Xinhua News Agency, “Zhongguo de he anquan,” Central People's Government of the People's Republic of China, September 3, 2019, https://www.gov.cn/zhengce/2019-09/03/content_5426832.htm.

⁵⁶⁹ Pomper and Gogna, “US-China Areas of Cooperation: Nonproliferation and Nuclear Security,” 51.

⁵⁷⁰ Pomper and Gogna, 46.

sociated production and separation of plutonium can increase inventories of weapons-usable material. Previous cooperation navigated the dual-use question by focusing on fast reactor safety, waste management and disposal, and joint advancement of technologies like the Traveling Wave Reactor that do not involve conventional plutonium separation. Since the first Trump administration curtailed advanced-reactor cooperation, China has constructed large sodium-cooled fast reactors with Russian technical support, but the United States has been deprived of cooperative channels to gauge whether the Chinese fast reactor program is intended purely for closing the civilian fuel cycle or for building up a weapons-grade plutonium stockpile. Continued engagement related to civilian fast reactors and alternative closed-fuel-cycle technologies such as accelerator-driven systems can offer a channel of assurance in this regard, even if discussions are constrained to safety, security, and technical nonproliferation safeguards.

The question of how to revive U.S.-China collaboration in civil nuclear science, technology, and governance is as much a question about boundaries and guardrails as it is about paths toward mutual benefit. Traditionally, cooperation started with joint research in open and basic science. Today, basic science remains the path of least risk for restoring prudent collaboration between U.S. and Chinese universities and laboratories. For example, in fields distinguished by high collaborative need and low dual-use sensitivity such as high-energy physics and magnetic fusion, restrictions should be scaled back. The U.S. government should take responsibility for providing guidance to universities on how to reduce collaboration risks. MIT's November 2022 report on university engagement with China advances useful principles in this regard.⁵⁷¹ The same principles could apply to fission energy technologies at a pre-commercial stage of maturity and with few sensitive military applications. If adopted, this approach would enable the United States to benefit from the significant resources China has invested in advanced fission energy research that does not involve proprietary IP.

The U.S. government's approach to commercial civil nuclear innovation should be similarly risk informed. Rather than imposing blanket restrictions on entire technology categories, it should calibrate controls according to a technology's readiness level and its commercial and strategic significance. Technologies at a high readiness level are more likely to become the basis for near-term commercial competition and may also have greater military relevance, warranting stronger intellectual property protections and safeguards against diversion. By contrast, excessive restrictions on technologies at lower readiness levels are more likely to constrain U.S. ability to benefit from Chinese research and development, particularly in areas where China has established a technological lead.

When it comes to technology and intellectual property transfer, clear boundaries, stringent guardrails, and robust enforcement can substantially reduce the risks of IP leakage and military diversion.

⁵⁷¹ Lester et al., *University Engagement with China: An MIT Approach*.

Even so, no system of controls can eliminate diversion risks entirely because nuclear technology is inherently dual use. Policymakers must therefore recognize the inherent national security tradeoffs involved in pursuing the benefits of scientific, technological, and commercial openness. Policies that impose greater costs than the risks they mitigate ultimately undermine rather than strengthen American competitiveness and security. For instance, MIT's 2022 report warns against "the dangers of overreach" as U.S. authorities respond to research-security risks. Citing the wrongful prosecution of an MIT professor of Chinese descent under the China Initiative, the report points out how government efforts to solve a genuine problem can become more damaging than the problem itself.⁵⁷² If the U.S. national security innovation base seeks to benefit from the higher-quality science generated through international collaboration, it is inevitable that China will derive benefits from the same collaboration. Likewise, if the United States wishes to attract scientific and engineering talent from China, it is certain that talent and knowledge will continue to flow in both directions, with some ultimately contributing to Chinese innovation in strategically significant fields. Eliminating these reciprocal benefits and limiting cooperation to zero-risk scenarios are not realistic objectives. It is much more pragmatic to ensure that, in each case, the expected gain to the United States outweighs the loss in security and strategic advantage.

This lesson extends beyond research security and applies equally to nuclear governance, where the costs of severing cooperation can be exceptionally high. Washington's reassessment of the costs and benefits of engagement with China, even if valid, cannot diminish the enduring importance of cooperation on nuclear safety, security, and nonproliferation. As China becomes a leading nuclear technology innovator and supplier in the global market, it will increasingly shape international nuclear norms and practices. Whether these norms and practices emerge through cooperation or confrontation will profoundly affect the future of the global nuclear order.

Fortunately, the institutional foundations for renewed cooperation have not disappeared. At the governmental level, the legacy of prior security and nonproliferation collaboration could serve as the basis for resumption of engagement and constructive dialogue. China has maintained the nuclear and radiological security monitoring infrastructure set up with the help of the United States. The Nuclear Security COE in Beijing continues to serve as a hub of cooperative technical activities and continuing Track 2 dialogue related to nuclear security.⁵⁷³ And legacy working groups provide a pathway for reviving technical nuclear security and nonproliferation exchanges. In November 2023, the Chinese Foreign Ministry and U.S. State Department held their first nuclear security and non-

⁵⁷² Lester et al., 8.

⁵⁷³ "Zhong Mei he anbao er gui duihua huiyi zai Guojia He Anbao Jishu Zhongxin chenggong juban," State Nuclear Security Technology Center, accessed January 13, 2026, https://coechina.org/publication_detail/702.html.

proliferation dialogue in five years.⁵⁷⁴ U.S. and Chinese diplomats exchanged views on nuclear security, nonproliferation, and export control, among other issues, paving the way to an agreement between the U.S. and Chinese leaders later that month, during Chinese President Xi Jinping's visit to San Francisco, to continue "ongoing working-level consultations" in these "key areas."⁵⁷⁵ In October 2024, the PUNT working group responsible for the safety and security of radioactive sources also resumed in-person meetings.⁵⁷⁶ In addition, many long-standing Track 2 dialogues that were interrupted during the COVID pandemic are now being revived and hold promise for rebuilding prior relationships among former government officials and experts while also bringing together a new generation of U.S. and Chinese specialists from diverse fields relevant to peaceful nuclear use, nuclear security, and nonproliferation.

To be sure, it may prove difficult to restore cooperation in some areas. Export controls, for example, have become deeply intertwined with broader strategic competition, including in emerging dual-use technologies. Yet even here, both countries have a shared interest in compartmentalizing nuclear nonproliferation and counterterrorism controls from disputes over semiconductors, critical minerals, and other strategic technologies.

Guardrails are not simply restraints on cooperation – they are what make cooperation politically sustainable. As the United States and China are likely to remain strategic competitors for the foreseeable future, prudent boundaries on cooperation will be necessary. But competition need not become the organizing principle for every aspect of the relationship. The challenge for policymakers is to define boundaries that preserve those forms of engagement whose benefits outweigh their risks. In an era of strategic rivalry, success will depend less on building ever higher walls than on knowing precisely where walls are needed, where bridges remain indispensable, particularly in nuclear governance, where the United States and China are doomed to cooperate.

⁵⁷⁴ Shizuka Kuramitsu, "China, U.S. Hold Rare Arms Control Talks," Arms Control Association, December 2023, <https://www.armscontrol.org/act/2023-12/news/china-us-hold-rare-arms-control-talks>.

⁵⁷⁵ "China and the United States Hold Consultations on Arms Control and Non-Proliferation," Ministry of Foreign Affairs of the People's Republic of China, November 8, 2023, https://www.fmprc.gov.cn/eng/xw/wjbxw/202405/t20240530_11343770.html; "Readout of President Joe Biden's Meeting with President Xi Jinping of the People's Republic of China," White House, November 15, 2023, <https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2023/11/15/readout-of-president-joe-bidens-meeting-with-president-xi-jinping-of-the-peoples-republic-of-china-2>.

⁵⁷⁶ "Zhong Mei Heping Liyong He Jishu Hezuo Xieding di wu gongzuo zu 2024 nian huiyi zai Jing zhaokai," National Nuclear Safety Administration, November 1, 2024, https://nnsa.mec.gov.cn/ywdt/gzdt/202411/t20241101_1093278.html.



nonproliferation.org



Middlebury College
Center for Nonproliferation Studies