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Spin-On for the Renaissance? The Current State of China's Nuclear Industry

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Summary

China's nuclear industry has undergone rapid growth in recent years and is projected to further expand in the coming decades. Accounting for almost 40 percent of all nuclear reactors either under construction or that have been approved globally, the expansion of China's nuclear capacities has largely been driven by increasing demands for energy to support continued economic growth. Constraints include human resources, fuel supply, and the extent to which China can develop indigenous nuclear power capacities. The role of civil-military integration in this industry is yet to be determined partly as a result of the deliberate decision by Beijing to keep its nuclear weapons segment separate from its civilian operations.

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BACKGROUND

While China's nuclear industry dates back to the early 1950s, it was largely focused on the development of the country's nuclear weapons capability. It was not until the late 1970s and early 1980s, with the changing international security environment and the decision by the Chinese leadership under Deng Xiaoping to shift from war preparations to economic construction, that the peaceful use of nuclear energy was put on the agenda. Beginning with the construction of the 300 MWe pressurized water reactor (PWR) in Qinshan in the mid-1980s, the Chinese nuclear power industry has gradually taken off. By mid-2010, 12 nuclear reactors are in operation, including power plants in Daya Bay, Tianwan, and Lingao.

In 2009, China increased its investments in nuclear power infrastructure by almost 75 percent. Two 1,250 MWe nuclear units in Sanmen (Zhejiang province), two 1,250 MWe nuclear power plants in Haiyang (Shandong province), and two 1,600 MWe units in Taishan (Guangdong province) were all started. Construction of 20 of 24 approved power plants is now underway.

Beijing has planned for up to 30 new reactors by 2020, which would raise the percentage of nuclear-generated electricity from the current 2.4 percent in the total electricity mix to about 5 percent, which would represent an increase from 9.1 GWe (2009) to more than 80 GWe over the next decade. However, this still falls far short of the average 15 percent in industrialized countries. It is estimated that China may need as many as 300 new nuclear power plants and a projected 400 GWe by 2050 to keep up with the country's energy needs.

The Chinese government has designed a three-phase strategy to greatly expand its nuclear industry and meet its ever-growing energy needs: 1) continued development of third-generation nuclear power; 2) expansion of nuclear plants from coastal regions to the interior; and 3) technological innovation, nuclear safety, and strategic planning to enable the development of an independent indigenous nuclear power industry that will be both internationally competitive and capable of meeting domestic needs. Beijing could spend more than 1 trillion yuan (\$US147 billion) in the next decade on nuclear energy.

China's current operational nuclear reactors and those under construction are primarily based on two PWR designs: the CPR-1000 and AP1000. In July 2007, Westinghouse Electric Company (now owned by Toshiba) signed contracts with China's State Nuclear Power Technology Corporation, Sanmen Nuclear Power Company, and China National Technical Import and Export Corporation to provide four AP1000 nuclear power plants to China. AP1000s are third-generation reactors that could enable China to acquire advanced technologies in the field. According to Westinghouse, the AP1000, featuring passive safety systems, is "the safest, most advanced, yet proven nuclear power plant currently available in the worldwide marketplace."

In addition, development of high-temperature and fast breeder reactors appears to be a high priority. Beijing is giving priority to research and development in next-generation technologies such as fast breeder reactors like the China Experimental Fast Reactor (CEFR) and high-temperature gas-cooled reactors. CEFR is capable of producing 23 MWe of power and could be operating soon. In addition, China seeks to reprocess civilian spent fuel and to recycle plutonium in MOX fuel for its light water and fast breeder reactors. Chinese scientists also have tested a new fusion reactor, the Experimental Advanced Superconducting Tokamak, which is the world's first fully superconducting tokamak device.

CHALLENGES

Notwithstanding Beijing's commitment to expanding the country's nuclear industry and the significant progress made over the past decade, the country faces numerous challenges moving forward. These include indigenization, human resources, and management of fuel supply and waste.

Indigenization

Achieving self-sufficiency and competency in nuclear design and engineering has been a major goal of the Chinese government, which encourages reliance on and promotion of China's own technologies in developing nuclear power projects. Localization in the development of nuclear

engineering, design, and components remains an important goal for the Chinese nuclear industry. This could become a critical issue in the country's nuclear industry development since dependence on outsourced nuclear components and technologies could subject China to export controls and intellectual property rights restrictions imposed by foreign suppliers.

Despite more than three decades of development and the successful construction and operation of a number of major nuclear power plants with a fairly high percentage of indigenous designs and components, China's nuclear industry remains hamstrung by its inability to design and manufacture key components for nuclear reactors, such as pressure vessels, primary coolant pumps, and turbine parts, which have to be provided by foreign suppliers either as part of the reactor contract or imported from abroad. Even where joint ventures have been established, the Chinese side does not necessarily receive the core technologies. While the Chinese government has made major investments to expand the country's nuclear energy capacities, relatively fewer resources have been allocated for nuclear R&D.

Human Resources

Another major challenge facing China's nuclear industry is the development and retention of human resources. To successfully execute its ambitious nuclear power expansion plans, China needs to recruit, train, and retain sufficient numbers of qualified engineers, technicians, and government personnel to design, build, and maintain the country's growing numbers of nuclear power plants, and oversee and review nuclear technology transfers and facility and materials safety. For example, it is estimated that more than 13,500 engineers, technicians, and operators will be needed to staff the current and planned nuclear power plants for China Guangdong Nuclear Power Company alone. While China's nuclear weapons programs over the years have bred a generation of managers, scientists, technicians, and support staff, and some of them have in turn contributed to the country's civilian nuclear industry, it is becoming imperative that new generations of talent be found, trained, and retained. It is also crucial that R&D

in nuclear science and engineering be ever more closely integrated with and translated into production techniques and processes.

Fuel Supply

As a nuclear weapons state, China has developed and mastered the key nuclear fuel cycle technologies, from uranium prospecting, mining, and purification to conversion, enrichment, and fuel element fabrication. Facilities in Chengdu (Sichuan province), Lanzhou (Gansu province), and Hanzhong (Shanxi province) provide uranium enrichment for civilian purposes. Fabrication of PWR fuel is undertaken at facilities in Sichuan and Inner Mongolia. Since the late 1990s, China has decommissioned some of its aging weapons-grade fissile material production facilities, including the Lanzhou uranium enrichment plant, the plutonium production complex at Guangyuan (Sichuan province), and the country's original plutonium production center in Jiuquan (Gansu province).

One of the issues related to the expansion of civilian nuclear power plants is whether there is a sufficient amount of uranium and reprocessed spent fuel to supply the growing number of reactors and how this would affect future supplies of Chinese military plutonium and highly enriched uranium. China's rapidly expanding nuclear power plants require an increasing amount of uranium that its domestic production and reserve cannot meet. China's current uranium reserves are estimated to be at 70,000 tons, with annual production standing at 840 tons. In recent years, China has reached out in search of uranium supplies and has signed major agreements in Africa and Australia. Some of China's older facilities reportedly supporting a military nuclear fuel cycle have been decommissioned and new ones coming online mainly produce low-enriched uranium suitable for nuclear power plants.

NUCLEAR WEAPONS MATERIALS

China is believed to have stopped producing weapons-grade highly enriched uranium and military plutonium, although it retains a stockpile sufficient for future expansion of its nuclear arsenal should the need arise. However, while China con-

tinues a de facto moratorium on fissile materials production, it will not make public commitments to such a moratorium but would pursue or support a legally binding treaty such as the proposed Fissile Material Cut-off Treaty. Publicly available non-governmental estimates of China's stocks of weapons-grade materials are 17–26 tons of uranium and 2.3–3.2 tons of plutonium. Current estimates of Chinese stockpiles would allow upward growth from around 200 nuclear warheads to about two to three times that number.

CONCLUSIONS

China's nuclear industry has evolved over the past three decades from its previous focus on nuclear weapons development. It has become a critical component in the country's overall strategic goals for the coming decades of clean and secure energy, protection of the environment, and finding catalysts for scientific research and technological innovation.

The Chinese government has committed extensive resources to support the industry's development goals: 1) participation in nuclear power plants supplied with foreign-made Generation III reactors and relevant technologies; 2) improve China's existing Generation II reactors based on imported models and technologies, with continued international cooperation; and 3) design and introduce indigenous Chinese reactors with a high percentage of local components, including core components manufactured in China.

One of the rationales for Chinese defense industry reforms in the early 1980s was to turn "swords into ploughshares, and build better swords." In re-

cent years, the focus has shifted to civil–military integration (CMI), where better application of both civilian and military technologies can be implemented. However, since its inception, China's civilian nuclear sector has largely been separated from its nuclear weapons programs, and the extent to which effective CMI can be carried out is yet to be determined, especially whether technologies and advancements in the civilian sector can benefit nuclear weapons development.

Unlike the civilian space, shipbuilding, and IT sectors where important progress has been made in CMI sectors, evidence remains scant so far that technological innovation, expertise, and experiences from the civilian side have a spin-on effect on China's nuclear weapons modernization, at least as of this writing. Where potentially such CMI does exist, such as reactors for nuclear submarines, foreign suppliers remain bound by the export control regulations of their home governments in restricting transfer of critical technologies. At the same time, increasing demand for fuel to power newly-built reactors means that trade-offs may have to be made in regard to meeting civilian versus military requirements should China decide to expand its existing nuclear arsenal.

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