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U.S.-China Energy Technology Cooperation: Civil Nuclear Energy

I appreciate the opportunity to address the U.S.-China Economic and Security Review Commission. My statement is principally based on research I did concerning the Possible Military Implications of the Westinghouse AP1000 sale to China, for the Nonproliferation Education Policy Center (NPEC), published as part of a Research Memorandum in March 2008.[i] I am a Senior Program Manager at Pacific Northwest National Laboratory (PNNL). PNNL is one of five Department of Energy Office of Science multi-program laboratories with a substantial portfolio in national and homeland security programs. Opinions in this statement reflect my personal views alone.

Before addressing the national security implications of the agreement between China and Westinghouse to build four AP1000 nuclear reactors in China, I would like to provide some brief background on the Westinghouse AP1000 nuclear reactor and China's energy program.

Westinghouse AP1000

The AP-1000 reactor is a Generation 3+ reactor, the standard nomenclature for the new generation of reactor designs that follow the Generation III Advanced Light Water Reactors developed in the 1990s.[ii] The reactor plant design is a conventional two loop pressurized water reactor. As such, it is very similar to other operating reactor plants in China. The first AP1000 to be constructed anywhere will be the first of two reactors to be constructed at Sanmen in Zhejiang province in China. Additionally, the AP1000 is likely to be the reactor plant of choice in U.S. over the next few years. Several plants have been ordered by U.S. utilities, of which the first is expected to come on line in 2014.

China's Nuclear Program

China has a fairly advanced civilian nuclear power program that has been aided by technology transfer from France and Russia. Technologies include reactor plant construction and operation, and uranium isotope separation technology, principally centrifuges used for uranium enrichment. These technologies can be assumed to have been assimilated by the Chinese nuclear power industry. China has demonstrated its ability to construct and operate nuclear power plants and uranium enrichment plants.

Currently China has about 8600 MWe of nuclear power, making up a little less than 2% of China's overall electrical generating capacity. About 80% of China's electricity is produced from coal fired plants, with the environmental consequences that that entails. The remaining electrical generation capacity is a combination of oil and gas fired plants, hydroelectric, and wind turbines. As the Chinese economy is rapidly developing, electricity demand is growing very fast. In conjunction with rapidly growing coal, gas, hydro, biomass, and wind power, and an emphasis on demand-side efficiency, China has recently decided to increase its nuclear capacity to about 5% of the total electrical generating capacity by 2020. This will require a very ambitious program including the construction of some 30 reactors over the next 12 years that would produce between 50 and 60 gigawatts of power.

One result of China's ambitious nuclear power expansion program is likely to be the continued requirement for technology and infrastructure assistance from the U.S. and other nuclear industry leaders. Shortly after signing the AP1000 deal with Westinghouse in 2007 for four new reactors at Sanmen and Haiyang, China signed an agreement with Areva to build two new reactor plants in Guangdong province. Westinghouse, Areva, and Russia's Atomstroyeksport will compete for the construction of the additional new reactors that China plans to build.

China began site preparation for the first of the four new AP1000 reactors in February 2008.[iii] Ground breaking occurred in July 2008, and construction will begin in early 2009. This first AP1000 reactor is expected to be operating by 2013, with the other three coming on line in 2014 and 2015.

National Security Implications

In exploring the national security implications of the AP1000 sale, I found only a tenuous link between the technology being provided by Westinghouse, and the Chinese naval nuclear propulsion program. I had some concern that China might be able to reverse engineer some of the components of the AP1000 for use in naval reactors because of China's demonstrated capability for reverse engineering complex technology.[iv] Nevertheless, for a number of reasons, I conclude that the likelihood that reverse engineering will provide China with technology that will improve its nuclear submarine fleet is unlikely.

The primary difference between the early generation Chinese reactors and the AP1000 is the passive safety design attributes. Westinghouse describes these attributes as:

" •No reliance on AC power
•Automatic response to accident condition assures safety
•Long term plant safety assured without active components (natural forces only)
•Containment reliability greatly increased by passive cooling
•In severe accidents, reactor vessel cooling keeps core debris in vessel
•Large margin to safety limits
•Defense in depth-active non-safety systems provide additional first line of defense"[v]

The passive safety systems include passive safety injection, passive residual heat removal, and passive containment cooling. The natural forces referenced include gravity, natural circulation, and compressed gas.[vi] There appears to be no application of these passive safety design technologies to submarine reactors. For large surface ship reactors the techniques might be used to simplify some design features of emergency core cooling fill systems. In these cases, the technologies provided are conceptually very simple, and would replace systems that are only for emergency core cooling in case of an accident that caused a loss of reactor coolant. Thus, these passive safety systems would not confer any additional military advantage.

In reviewing the AP1000 design, I concluded that the most likely advanced component that might be applicable to China's nuclear submarines would be the Westinghouse canned motor reactor coolant pumps. Previous reactor installations provided by Russia and France used shaft seal pumps. Although the AP1000 reactor coolant pumps will be much larger than what would be suitable for a naval reactor, there is some possibility that China could, with significant engineering, downscale the design to improve the reactor coolant pumps for submarines. The military significance of improved reactor coolant pumps would be that they could potentially diminish the noise signature of Chinese submarines, thereby making them less detectable. According to Westinghouse, canned motor reactor coolant pumps have been used in U.S. naval reactors for many years.[vii] The Westinghouse contracts with the pump manufacturer, Curtiss-Wright, include the supply of pump hardware and oversight of some localized manufacturing of the reactor coolant pumps with China's State Nuclear Power Technology Corporation.[viii] The national security implications of this technology transfer are mitigated by the fact that technologies applicable to sound quieting in submarines involve much more than the reactor coolant pumps. Consequently, the national security risk associated with the transfer of AP1000 reactor coolant pump technology to China is likely to be small.

Another technology attribute that might provide advantages to China's naval reactor program could be the digital instrumentation and control (I&C) system designed for the AP1000. The AP1000 I&C system uses a microprocessor-based, distributed digital system to perform plant protection functions and safety monitoring, as well as plant control functions. This system is advertised to improve reliability of the control systems, while ensuring that the operator knows the status of the plant continuously.[ix] The improved reliability of the software, electronics, and sensors in these systems could potentially be reverse engineered for application to naval reactors to improve reactor reliability.

However, digital I&C systems are not new to China's nuclear power industry. For example, the Russian supplied VVER-91 (VVER-1000) reactors have modern digital Siemens-Areva I&C systems. Therefore, the new technology gained from the AP1000 I&C systems is likely to be marginal. Additionally, the reliability advantages of a digital I&C system are not completely clear- cut. The U.S. Nuclear Regulatory Commission (NRC) and other national regulatory authorities have been concerned about the potential that undetected software malfunctions in a digital I&C system could lead to safety or reliability problems.

Most of the design elements of the AP1000 reactor are extensions of previous designs, and appear to be either the same as previous designs, or refinements, rather than technological breakthroughs. For example, the fuel bundles are standard 17x17 matrices of fuel rods that have been used in a number of reactor designs in the U.S. and Europe. The fuel element manufacturing technology is conventional, and well known.

Large commercial reactors such as the AP1000, VVER1000, GE's Advance Boiling Water Reactor, and Areva's EPR are an order of magnitude larger than a typical naval reactor. Many of the design, safety, and control mechanisms of the AP1000 are driven by the large size of the core. For example, the complex control and safety shutdown mechanisms consisting of control rods, gray rods, and boron dissolved in the reactor coolant are necessary to ensure proper flux distribution, to manage axial fuel burnout, and to compensate for such phenomena as xenon stability issues. These issues are simpler to manage in a smaller core such as for a naval reactor.

With respect to construction engineering, the design of the AP1000 reactor is a conventional pressurized water reactor, so construction techniques such as welding, pipe manufacture, and pressure vessel manufacture are little different from earlier nuclear power plant construction projects. The AP1000 uses modular construction to permit parallel construction activities, which saves construction time. China already has the capability to perform modular construction, such as is used in modern shipbuilding. Therefore, there would likely be no additional construction related technology from the AP1000 construction project that would advance China's naval reactor program.

I also looked at whether the infrastructure that China would develop to support their commercial reactor program could lead to a situation in which China could rapidly and massively increase its nuclear weapons arsenal. China is likely to continue to expand its enrichment capacity to try to accommodate its growing requirements for LEU fuel for its expanded nuclear power plant building program. Needed enrichment capacity for its naval reactors program is small by comparison with its power reactor needs. Even if China decided to begin to produce HEU for a new naval reactor design, the enrichment capacity requirements would be small in comparison to the overall enrichment requirements for power reactors.

The subject of China's Nuclear Weapons program deserves brief mention in the context of enrichment requirements. The Chinese government announced in November 1989 that it was ceasing production of HEU for military uses and that it would use its enrichment facilities exclusively for civilian applications.[x] Although never announced, it is likely that weapons grade plutonium production also ceased by 1991. Albright and Hinderstein have estimated that China has roughly 21 metric tons of HEU and about 2.8 metric tons of weapons plutonium.[xi] Because of the small size of China's nuclear weapons force, estimated to be in the neighborhood of 200 to 400 weapons, the amount of HEU and weapons plutonium that China has produced, and which is presumably stockpiled, is far greater than was needed for this number of nuclear weapons. The existing stocks of HEU and plutonium would therefore likely be sufficient to support a substantially greater number of nuclear weapons. Therefore it is unlikely that the increase in enrichment capacity that will be required for the expanding commercial power reactor fleet will increase the risk of a sudden surge to parity with the U.S. or Russia in nuclear weapons production.

Conclusion

The U.S. national security implications of the Westinghouse AP1000 sale to China appear to be minimal. China may derive some incremental technological advances as a result of the deal by reverse engineering some of the technologies provided. But alternative sources of technology that may be available from Westinghouse competitors would likely provide similar benefits. There appears to be no smoking gun concerning the application of AP1000 technology to the development of Chinese naval reactors, or expansion of its nuclear weapons capacity.

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[i] http://www.npec-web.org/

[ii] Westinghouse Electric Company: http://www.ap1000.westinghouse nuclear.com/A4.asp

[iii] http://news.xinhuanet.com/english/2008-02/26/content_7674512.htm

[iv] China's mastery of nuclear power plant simulators is one example of this capability. China had relied on other countries to provide these simulators. However, because of the re-rating of some reactors China needed to update the simulators. According to the deputy general manager of China National Nuclear Corporation (CNNC), China has mastered the technology, and has now developed indigenous reactor simulators. http://china-nuclear-power.co.uk/chinanuclearpower.aspx

[v] Matzie, Regis A., "The AP1000 Reactor Nuclear Renaissance Option," Tulane Engineering Forum, September 26, 2003

[vi] Westinghouse Electric Company: http://www.ap1000.westinghousenuclear.com/A2.asp

[vii] Westinghouse Electric Company: http://www.ap1000.westinghouse nuclear.com/A3.asp

[viii] http://files.shareholder.com/downloads/CW/369059092x0x137155/2e9d80d2-72fa-4c2a-be6a-b8cb6eed19bd/269140.pdf

[ix] Nuclear Regulatory Commission; www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/chapter7.pdf

[x] Nuclear Threat Initiative, China Profiles, http:www.nti.org/db/china/uenrich.htm

[xi] Albright, David and Corey Hinderstein, "Chinese Military Plutonium and Highly Enriched Uranium Inventories," Institute for Science and International Security, June 30, 2005