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What I found in Yongbyon and Why It Matters

Siegfried S. Hecker

On November 12, 2010, during my most recent visit to the Yongbyon nuclear complex, North Korean scientists showed me and my Stanford University colleagues, John W. Lewis and Robert Carlin, a small, recently completed, industrial-scale uranium-enrichment facility and an experimental light-water reactor (LWR) under construction. Although I had long ago concluded that North Korea has a uranium enrichment program, despite Pyongyang's vehement denials, I was stunned by the sight of 2,000 centrifuges in two cascade halls and an ultramodern control room.

These findings raise troubling questions about how North Korea's program got this far and the nature of the threat it poses. Moreover, in the wake of recent military altercations between the two Koreas, what we saw highlights the necessity of a careful review of what we know about the nation's nuclear program—and what we don't—so we can prevent a further nuclear buildup and forestall the potential export of fissile materials and technology.

Unlike what was widely reported in the news media, we did not discover secret North Korean facilities.

Pyongyang showed them to us because it wanted the world to know, and it chose us to report its nuclear advances because they trusted us to do so accurately. This trust came from a long association with North Korea's diplomats and professionals through non-official, non-governmental (Track II) visits.

I made my first visit to North Korea in January 2004 at the request of Lewis, who had a long relationship with North Korea. We were invited at the time because Pyongyang wanted to show that they had reprocessed the spent fuel that had been stored, per agreement, under international safeguards for eight years. Yongbyon technical specialists showed us key nuclear facilities that had been frozen during the U.S.–North Korea Agreed Framework, but restarted because of a 2002 altercation with the Bush administration that prompted Pyongyang to withdraw from the Nuclear Nonproliferation Treaty. Their goal was to send a message to Washington that they had the bomb; they went so far as to show me and let me hold a sealed glass jar with a 200-gram plutonium metal sample. Since then, I have returned to North Korea each year—seven visits in all, including four to Yongbyon – and Pyongyang used my most recent visit to tell the world about its LWR and enrichment program.

Pyongyang has seriously pursued LWRs for more than 25 years. In 1985, it struck a deal with Moscow to provide two LWRs, but the deal fell through with the demise of the Soviet Union. The



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1994 Agreed Framework was an attempt to replace its indigenous gas-graphite reactors with LWRs, which are good for electricity but less suitable for bombs. Shortly after the North's April 2009, long-range rocket launch and the predictable UN condemnation that followed, Pyongyang announced it would build its own LWR. In November, our Foreign Ministry host told us "no one believed us when we announced this in 2009, including you, Dr. Hecker."

Pyongyang's interest in building LWRs for electricity represents a major shift in its nuclear strategy, and I believe this interest is genuine. Pyongyang appears prepared to abandon its plutonium program by shutting down its 5 Megawatt-electric (MWe) gas-graphite reactor, give up on external assistance for an LWR, and proceed with its own program, beginning with the small, experimental 25 to 30 MWe reactor before proceeding with larger power reactors. Although it is technically possible that the LWR will be used to produce bomb-grade plutonium, such a scenario is unlikely. Plutonium from an LWR is much less suitable for bombs than the plutonium already produced in the 5 MWe reactor. If Pyongyang wanted more plutonium bomb fuel, it would simply restart that reactor, not build an LWR. Yet construction of the experimental LWR raises different concerns: can they do it safely, and will the enrichment program lead to additional weapons or export? The answers to both questions are troubling.

I have serious concerns about the design and whether North Korea can operate an LWR safely. I was told that a new team of young engineers, rather than their experienced gas-graphite reactor engineers, designed the LWR. To our knowledge, Yongbyon specialists have no experience in dealing with key LWR design and safety issues. For example, many of the reactor components, such as the pressure vessel and steam generator, require radiation-resistant steels and stringent fabrication and welding specifications so as to withstand intense, long-term radiation environments. The rest of the world has developed strong technical and regulatory links to deal with these challenges, particularly after the Three-Mile Island accident. North Korea has never been part of such collaborations. Moreover, we found they have little experience with uranium oxide fuels and Zircaloy cladding materials, which are typical for LWRs. We found the concrete work for the reactor of most immediate concern. The foundation appeared insufficiently robust and the containment shell was being poured in small sections from a small concrete mixer, not in keeping with nuclear-grade concrete pouring requirements. These concerns will increase dramatically if Pyongyang proceeds with plans for larger power reactors. Operating LWRs with inadequate construction and operational safety standards and practices poses risks beyond the North's borders.

I am also concerned that North Korea's enrichment program might lead to the development of additional weapons or the export of fissile materials. What we saw at the Yongbyon enrichment facility points to Pyongyang's interest in highly-enriched uranium (HEU), which can be produced with slightly reconfigured centrifuge cascades and used as bomb fuel. As we entered the newly renovated building, the chief process engineer told us "we did not want to show you this facility, but our superiors told us to do so." From the second-floor control room we were amazed at the sight of three rows of pairs of centrifuges in the high-bay halls extending 50 meters in both directions. In the modern control room with blinking LEDs and flat-panel monitors, we were told that 2,000 centrifuges in six cascades were operating, producing low-enriched uranium (LEU) for the LWR under construction. We were hurried past the control room and through what they called the recovery room, which allowed us to see some of the uranium hexafluoride gas handling systems and tanks. Because of the hurried pace and limited access, we are not certain that the centrifuges were operational, but what we saw was not inconsistent with a partially or fully operational facility. I was able to get the chief process engineer to tell us enough to conclude that the centrifuges are of a second-generation, P-2, design with a capacity of 4 separative work units (SWUs)/year per machine. The 8,000 SWU/year total capacity is sufficient to produce approximately 2 tons of LEU/year, consistent with the requirements of the small LWR, but could also be reconfigured to make roughly one bomb's worth of HEU/year. We know that North Korea has indigenous uranium ore and all of the chemical know-how and equipment to make the necessary feed material. But, I believe that North Korea is not able to produce key high-performance materials and components domestically to build 2,000 centrifuges.

This is significant because it gives us insight into how Pyongyang got this far—and what they might plan to do next. At Yongbyon, we were told that construction of the centrifuge facility began in April 2009 and that it was completed days before we arrived. But what we saw demonstrates without a doubt that Pyongyang has pursued enrichment for many years. The claim that they just started the centrifuge program for their new LWR program is not credible. In retrospect, over the years there has been plenty of evidence, but no smoking gun, of Pyongyang's uranium enrichment efforts. Former Pakistani President Pervez Musharraf claimed in his memoir that A.Q. Khan, the father of the Pakistani bomb, delivered 20 P1 and four P2 centrifuges to North Korea about 10 years ago. Concurrently, North Korea operated an extraordinarily far-reaching illicit international network through which it procured specialty materials such as high-strength aluminum, maraging steel, and specialty epoxy, along with components such as ring magnets, bearings, vacuum pumps, valves, and flow meters. Prior to his 2004 house arrest in Pakistan, Kahn not only supplied North Korea with a centrifuge starter kit, centrifuge controls, and software, but also trained some of the country's technical specialists at the Khan Research Laboratories.

Now that we have the smoking gun, I believe that Pyongyang combined its own centrifuge experience, which most likely began in the 1980s, with reciprocal visits of Khan's specialists to North Korean facilities, which provided the hands-on training to help Pyongyang master centrifuge operations in a relatively short time. I believe that North Korean specialists built the centrifuges and successfully incorporated them into working cascades in a clandestine facility of unknown size that served as the prototype for the Yongbyon plant. The clandestine facility was almost certainly dedicated to making HEU for bomb fuel rather than LEU for reactors because the gas-graphite reactor in use before Pyongyang decided to build an LWR uses natural uranium fuel, which does not require enrichment.

How does the revelation of uranium enrichment change the security risk? Pyongyang already had the bomb, but not much of a nuclear arsenal. A 25-year pursuit of the plutonium route to the bomb, interrupted by the Agreed Framework and some of the Six-Party agreements, yielded a plutonium inventory of roughly 24 to 42 kilograms. Following the termination of the Agreed Framework in late 2002, Pyongyang built plutonium bombs and demonstrated the first one in 2006. Pyongyang's continued attempts through the Six-Party process to bargain for an LWR were unsuccessful. In 2009, it greeted the Obama administration with a long-range rocket launch, a second nuclear test and a different reality—it would keep the roughly four to eight nuclear weapons that we estimate it has and it will build its own LWRs.

Pyongyang can ratchet up the current nuclear threat if it greatly expands HEU production at undisclosed sites, increases the size of its nuclear arsenal substantially, or conducts more tests to enhance its sophistication. Increased centrifuge capacity also heightens the export threat. Hence, the immediate response by the international community should be to limit Pyongyang's nuclear buildup. Pyongyang's categorical denial of any enrichment activities during a time when they surely existed will make diplomatic reengagement more problematic. Yet there are few options but to reengage. Whereas the long-term objective remains denuclearization of the Korean peninsula, we must first prevent Pyongyang from expanding its arsenal or exporting its nuclear technologies.

Specifically, I advocate what I call the three no's: No more bombs, no better bombs (which means no nuclear testing), and no export, in return for one yes—U.S. willingness to seriously address Pyongyang's fundamental security concerns. Since our ability to monitor uranium enrichment is limited, it would require greater cooperation from Pyongyang and a more intrusive inspection regime to have adequate confidence that it is not producing HEU clandestinely. Likewise, the export threat is much greater because HEU has a weak radiation signature and is difficult to detect. Preventing exports requires close cooperation from the international community, especially from China. So far, no one has been able to figure out how to convince Beijing that Pyongyang's nuclear program seriously threatens what China says it wants to preserve—peace and security in Northeast Asia and the world at large.

For the one yes, we do not really know what Pyongyang wants, but it surely will seek in exchange for cooperation on the nuclear front normalization of relations with the United States, along with

energy and economic aid. An appropriate starting point might be a policy based along the lines of the October 2000 Joint Communiqué between Washington and Pyongyang, which stated that neither government would have hostile intent toward the other and confirmed the commitment of both to make every effort to build a new relationship free from past enmity. We can also be sure that the right to have LWRs will be on Pyongyang's list. But it will not be possible to accept uranium enrichment without much greater cooperation and transparency in North Korea

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