

## **“Nuclear developments in North Korea”**

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### **Abstract**

Three years ago, Pyongyang expelled the international inspectors from its Yongbyon nuclear complex and abandoned the Six-Party talks. The crisis atmosphere on the Korean peninsula sparked by Pyongyang's military actions in 2010 turned into diplomatic calm in 2011, but Pyongyang continued to expand its nuclear program. It conducted a second nuclear test in 2009, unveiled a modern, sophisticated uranium centrifuge facility, and rolled out a road-mobile intermediate-range ballistic missile in 2010. Its cooperation in missile technologies with Iran continued and nuclear cooperation is suspected. Beijing protected Pyongyang from crippling sanctions while Washington and Seoul remained reluctant to engage having been burned by Pyongyang's unveiling of its clandestine uranium enrichment program. Prospects for resolution of the North Korean nuclear crisis looked grim. Then, surprisingly in December 2011, just before the death of Kim Jong-il, American and North Korean diplomats nearly reached a deal to return to the negotiating table. Even more surprisingly, the new Kim regime agreed to take initial steps with Washington in February. In this paper, I describe the troubling nuclear developments in 2011 and suggest targets for the upcoming negotiations to further reduce the nuclear risks while the parties resume the long road toward eventual denuclearization and normalization of relations on the Korean peninsula.

### **Setting the political stage**

The end of 2011 marked the third year of diplomatic standoff between North Korea and the United States. In 2009, North Korea attempted its third long-range missile launch. The anticipated United Nations condemnation triggered Pyongyang's expulsion of the international inspectors from its Yongbyon nuclear complex followed by a second nuclear test. The year 2010 was marked by clashes and a dangerous spike in tensions on the Korean peninsula – namely the sinking of the South Korean Corvette, the Cheonan, and the North Korean shelling of Yeongpyeon Island. In contrast, 2011 was a year of diplomatic calm and rapprochement until the death of Kim Jong-il.

I believe there were two major reasons for the diplomatic quiet in 2011. It is important to understand these in order to understand what may still be driving Pyongyang in spite of the transfer of power to young Kim Jong-un. First, and most important, Pyongyang focused on securing a stable external environment in order to concentrate on economic goals for 2012, the centenary of Kim Il-sung's birth, which is planned as a banner year for the regime. Second, South Korea inched away from efforts to put maximum pressure on the North. Tensions remained, notably in the West Sea where both sides continue to build up their military forces, but the overall temperature on the peninsula is lower.

In 2011, Pyongyang agreed to two meetings between North and South Korean nuclear negotiators, a necessary obstacle to overcome to achieve bilateral meetings with Washington. American and North Korean negotiators met three times – in New York in July, Geneva in October, and in Beijing in December – for what Washington called “exploratory” discussions. In Beijing, American and North Korean diplomats apparently came close to halting nuclear activities, but only under the condition that Washington provides food aid. Before the parties could return to brief their capitals, Kim Jong-il died on December 17, throwing the entire process into limbo. Analysts had a field day predicting the fate and direction of the new leadership under the young leader, Kim Jong-un. Opinions varied widely, from predicting renewed provocations to reconciliation. In reality, no one knew what to expect. For now, Kim Jong-il’s death has been followed by remarkable calm in an orderly transition of power.

On February 29, 2012 Washington and Pyongyang announced that at the fourth bilateral meeting held on February 23 and 24 they had reached agreement along the lines of the December meeting – that is, North Korea has agreed to implement a moratorium on long-range missile launches, nuclear tests and nuclear activities at Yongbyon, including uranium enrichment activities in return for nutritional aid.<sup>1</sup> The two sides issued independent statements that differed slightly, but significantly, exposing important unresolved issues before they can get back to the Six-Party negotiating table. Pyongyang also agreed to the return of International Atomic Energy Agency (IAEA) inspectors to monitor the moratorium on uranium enrichment activities at Yongbyon.<sup>2</sup> I welcome the latest agreement. In this paper, I focus primarily on why this agreement was necessary to stop the nuclear crisis in North Korea from getting worse and I offer some suggestions for the negotiating parties as they head to the table.

### **Nuclear developments**

In 2011, Pyongyang revealed very little about its nuclear progress, but all signs pointed to a continuing march toward a more threatening nuclear weapons capability. The most alarming development was a combination of two things: the operation of modern uranium centrifuge facility and the presence of road-mobile intermediate-range ballistic missiles (IRBM). An added source of stress is North Korea’s likelihood of cooperating with illicit nuclear programs of other countries, such as Iran, and the likelihood of it importing and exporting nuclear technologies to expand its own programs or aid those of others.

#### *Yongbyon light-water reactor*

In 2010, North Korea greeted the world with the announcement that they would build an indigenous LWR and enrich uranium domestically to fuel it.<sup>3</sup> During my 2010 visit to

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<sup>1</sup> Statement on “U.S.-DPRK Bilateral Relations.” U.S. Department of State, February 29, 2012, Washington D.C. and “DPRK Foreign Ministry Spokesman on Result of DPRK-U.S. Talks.” Korea Central News Agency (KCNA), February 29, 2012. Pyongyang, North Korea.

<sup>2</sup> The American statement includes the language “and confirm the disablement of the 5-MWe reactor and associated facilities, whereas the North Koreans state “while productive dialogues continue.” The North Korean statement also adds “Once the six-party talks are resumed, priority will be given to the discussion of issues concerning the lifting of sanctions on the DPRK and provision of light water reactors.” These provisions are not in the American statement.

<sup>3</sup> “N.Korea to Build Light Water Reactor Soon: State Media,” Agence France-Presse, 29 March 2010. The North Korean’s MOFA announced that they would build an indigenous LWR in April 2009 as well, but the 2010 pronouncement was considered more significant.

Yongbyon with Stanford colleagues John Lewis and Robert Carlin, we confirmed that construction had begun on a 25-30 megawatt-electric (MWe) LWR and that the North Koreans had built a modern, sophisticated uranium enrichment facility, ostensibly to provide fuel for the reactor. Commercially available satellite imagery allows us to track progress of North Korea's LWR construction from September 26, 2010 (just prior to our visit) to January 26, 2012 -- as shown in Figure 1. Early images indicate that the construction of this new LWR began in late September 2010, near the site of the destroyed cooling tower of the 5 MWe gas-graphite reactor.

One of the latest available close-up overhead images taken on January 26 (Figure 2) shows that many of the reactor's external structures are almost complete. Much progress has been made on the turbine generator hall; a traveling crane rail was installed and the roof just completed as per a February 3 image. The structure of the turbine pedestal inside the turbine building is already apparent. This is significant; it indicates that North Korea has a turbine design and possibly the ability to manufacture a turbine generator set that will fit within the dimensions of the turbine pedestal now under construction. The reactor building containment dome on the east side of the reactor's containment structure is complete and will be placed on top of the reactor's containment structure once the large internal components of the reactor's core have been inserted.

Using overhead images from Figure 1, a 3-D model (Figure 3) of the LWR was constructed.<sup>4</sup> Our analysis confirms Pyongyang's plan to use this experimental reactor for electricity production. The rapid progress of construction also demonstrates that North Korea still has impressive manufacturing capabilities, in spite of the last two decades of economic downturn. However, we view this progress with alarm given the safety concerns associated with building and operating an LWR. Was the seismic analysis of the reactor site sufficiently rigorous? Did the regulatory authorities have the skills and independence required to license this reactor in such a short time period? And do Yongbyon specialists have sufficient experience with the very demanding materials requirements for the reactor components, including the pressure vessel, steam generators, piping, and fuel-cladding materials? Do the North Korean specialists know how to weld these components to a high quality leak-tight system keeping good quality assurance practices? Will they know how to connect all the electric cables to a high quality control room center that will monitor and control the future operation of the reactor at adequate safety levels? These concerns were greatly exacerbated by the nuclear accident at the Fukushima Daiichi Nuclear Power Plant in March 2011.

#### *Uranium enrichment*

During our November 2010 visit to Yongbyon, we were stunned to find a newly constructed, modern, 2,000-centrifuge uranium enrichment plant.<sup>5</sup> Our visit answered some questions regarding the North's nuclear facilities at Yongbyon, but it raised many more. Though the Yongbyon uranium centrifuge enrichment facility looked complete, we

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<sup>4</sup> See N. Milonopoulos, S. Hecker and R. Carlin in Reference 4 above.

<sup>5</sup> Siegfried S. Hecker (2010) A Return Trip to North Korea's Yongbyon Nuclear Complex. *Center for International Security and Cooperation*, Stanford University, 20 November. Available at: <http://iis-db.stanford.edu/pubs/23035/HeckerYongbyon.pdf>.

were unable to verify that it was operational. We were told that the facility was producing low enriched uranium (LEU) destined for the small, experimental LWR under construction; the facility appeared to house sophisticated centrifuges (apparently of the P-2 or G-2 design) and was sized properly for that reactor's fuel requirements.<sup>6</sup> We also were told that the facility became operational just a few days before our arrival, but we were unable to corroborate that. Whatever its status during our visit, the facility may be fully operational now, more than a year later. They may also have run into the typical difficulties of getting centrifuge cascades to operate smoothly, so we don't know how much LEU has been produced to date, what the current production rates are, and what is the disposition of any LEU that has been produced to date. Although the facility is likely producing LEU for the reactor, it could conceivably be producing highly enriched uranium (HEU) bomb fuel. And if it is configured to do this, the reactor could produce roughly 40 kilograms of HEU annually, enough for one or so bombs.

As far as I know no foreigners have been given access to the facility since our November 2010 visit. Our requests for a return visit have so far been denied. By tracking the construction of the Yongbyon centrifuge plant via overhead imagery, however, we conclude that North Korea must also have an undisclosed, pilot-scale centrifuge facility elsewhere to have made it possible for such recent rapid installation progress at Yongbyon. Figure 4 shows the North's fuel fabrication plant as it existed in June 2009, only a few months after Pyongyang announced it would construct a pilot LWR and produce LEU to power it. (The North Koreans previously denied having a uranium enrichment program.) In Figure 4, Building 4, formerly the fuel rod fabrication building, which houses the centrifuge plant we visited, looks the same as when the IAEA inspectors were expelled in April 2009.

Moreover, on September 4, 2009, North Korea's permanent representative to the United Nations announced that his country's "experimental uranium enrichment has successfully been conducted to enter into completion phase."<sup>7</sup> That success could only have been achieved at a different facility, because Building 4 could not have been readied in time. To house the 2,000 centrifuges we saw, the building was totally gutted and retrofitted with a clean, modern heating and air conditioning system; the exterior was refurbished and covered with a new blue metal roof. Given that we were told in November 2010 that the facility became operational only days before our arrival, it is clear that the "experimental" uranium enrichment work had to have been conducted elsewhere.

The overhead images in Figure 5 show that a number of buildings at the fuel-fabrication plant were either retrofitted or newly constructed between June 2009 and November 2011. The building with the blue roof, Building 4, houses the centrifuge plant; the one on the lower left is believed to be a recreational building. We are not certain what the other buildings contain, but equipment had to be housed for UF<sub>4</sub> and UF<sub>6</sub> production, and an entirely new equipment had to be installed to make uranium oxide (UO<sub>2</sub>) fuel pellets for

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<sup>6</sup> Yongbyon officials claimed an annual throughput capacity was 8,000 separative work units (the measurement of the separation during the enrichment process), indicating that the centrifuges were second generation, or so-called P-2 s; first generation centrifuges, by comparison, produce an annual throughput capacity of about 2,000 separative work units (Hecker, 2010).

<sup>7</sup> <http://www.kcna.co.jp/item/2009/200909/news04/20090904-04ee.html>

the light water reactor. In addition, either zircaloy tubing or stainless steel tubing must be produced to clad the light water reactor fuel and fuel assemblies, which are very different from those previously used at Yongbyon.

Figure 6 is a rough schematic of the interior layout of the Building 4. In the November 2010 visit, we observed approximately 2,000 centrifuges, divided into six cascades, from the second-floor observation platform identified in the diagram. Figure 7 is a 3-D model of the outside of the centrifuge hall. Unless Pyongyang allows access to this facility, however, the world will not know if it is fully operational or much else about its sophistication or that of other undisclosed centrifuge facilities.

The Yongbyon centrifuge facility could not have been constructed from scratch and made operational in only 18 months, between April 2009 and November 2010, as Pyongyang has claimed. It is likely that the North had one full cascade (about 340 centrifuges) operational at a separate site long before it moved into the renovated Yongbyon fuel fabrication building and revealed their centrifuge program in November 2010. The size of any clandestine program is likely constrained, but constrained or not, North Korea may be producing some HEU now, and may have been doing so for some time.

### *Plutonium*

The Yongbyon plutonium facilities remained dormant in 2011. The 5-MWe plutonium production reactor, operational since 1986, was shut down in July 2007 and has not been restarted. The reprocessing facility ceased operations in 2009, but remains in stand-by status. Presently, North Korea is not producing any plutonium and there is no plutonium in the pipeline. The key facilities could be reactivated if necessary; it would take approximately six months to do so.<sup>8</sup> I estimate that North Korea has roughly 24 to 42 kilograms (approximately four to eight bombs' worth) of plutonium today.

The decision to pursue uranium enrichment instead of plutonium production is puzzling – *if* Pyongyang simply wants to make more bomb fuel.<sup>9</sup> The missing piece of the puzzle, however, is that Pyongyang has long sought LWRs for electricity production, first from the Soviet Union and then from the United States<sup>10</sup> – and this type of reactor fuel requires enrichment, which, in turn, opens the door to the weapons option since the centrifuge facilities needed for the reactors can also be converted to produce weapon-grade HEU bomb fuel. Thus, choosing the uranium route provides Pyongyang with a viable dual-track option – LEU for nuclear electricity with LWRs and HEU for the second route to the bomb to augment its small plutonium bomb inventory.

### *Nuclear weapons and delivery systems*

Pyongyang has the bomb but not much of a nuclear arsenal. We have reasonable confidence in the number of bombs – roughly four to eight – because plutonium

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<sup>8</sup> If reactivated, the reactor is capable of producing only six kilograms of plutonium, roughly one bomb's worth, per year.

<sup>9</sup> Plutonium is used in all states with nuclear weapons. China switched from HEU to plutonium early on in its program, and Pakistan has begun to employ plutonium in addition to HEU.

<sup>10</sup> See Siegfried S. Hecker, Chaim Braun, and Robert L. Carlin, "North Korea's Light-Water Reactor Ambitions," *Journal of Nuclear Materials Management*, Vol. 39, No. 10 (Spring 2011).

inventories are easy to assess, but we simply don't know their sophistication. Since it has shut down its plutonium facilities, Pyongyang apparently is not planning to increase the number of plutonium bombs significantly.

We assume the North is working on missile-capable nuclear systems, but employing miniaturized nuclear warheads is severely handicapped by the country's lack of nuclear test experience. North Korea's first nuclear test in October 2006 was only partially successful; its yield was estimated at less than one kiloton. Initial estimates of the yield of the second test in 2009 were 2 to 4 kilotons. This estimate has been revised upward to 4.6 kilotons in a recent analysis.<sup>11</sup> Consequently, the North may be able to design a Nagasaki-like bomb with a yield of up to 20 kilotons, but delivery is likely to be restricted to aircraft, boat, or van. For North Korea to gain enough confidence to mount a miniaturized design on a missile, it will have to test again. Hence, the technical and military driving forces for additional tests are high, even if, as Pyongyang surely knows, the political risks are also high. Satellite imagery captured in 2011 showed preparations for what possibly could be another test tunnel, which is located near the two previous tests in the Kilju region.<sup>12</sup> Hence, the nuclear test moratorium agreed to in the February statements is particularly important to halt Pyongyang's drive toward more sophisticated, smaller nuclear weapons that could be mounted on their missiles. If Pyongyang breaks the test moratorium, it will almost certainly be a test of a miniaturized design, but we don't know if it will be with plutonium or HEU.

North Korea did not launch another long-range rocket in 2011. None of its three previous attempts (in 1998, 2006, and 2009) were entirely successful. Not surprisingly, it continues to expand its missile program. Commercial satellite imagery indicates that a second long-range missile launch pad, under construction for 10 years and located at Tongchang-ri near the northwest border with China, is essentially complete (Harlan, 2011). It is considerably more sophisticated and capable than the country's first launch site, located at Musudan-ri on the east coast. There are no indications that another launch is imminent.

In October 2010, North Korea publicly exhibited, for the first time, a road-mobile intermediate-range ballistic missile at a military parade in Pyongyang. Dubbed the "Musudan" by US intelligence services, the IRBM can travel an estimated 3,000 to 5,000 kilometers, apparently farther than any other missile in the North Korean arsenal.<sup>13</sup> Although never flight-tested, the missile represents a big step forward for Pyongyang, because it is road mobile and, hence, difficult to find. In June 2011, then-Defense Secretary Robert Gates expressed concern that North Korea had also been developing a

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<sup>11</sup> J.R. Murphy, B.C. Kohl, J.L. Stevens, T.J. Bennet, and H.G. Israelsson, "Exploitation of the IMS and Other Data for a Compressive Advanced Analysis of the North Korean Nuclear Test," *2010 Monitoring Research Review: Ground-Based Nuclear Explosion Monitoring Technology*, Science Applications International Corporation, p. 456-465. Another recent analysis claims a minimum yield of 5.7 kilotons (E. Rougier, H.J. Patton, E.E. Knight, and C.R. Bradley, "Constraints on burial depth and yield of the 25 May 2009 North Korean test from hydrodynamic simulations in a granite medium," *Geophysical Research Letters*, Vol. 38, L16316 (30 August 2011).

<sup>12</sup> "North Korea Prepared to Detonate Third Nuclear Device, South Says," *Global Security Newswire*, 19 April 2011, available at [http://gsn.nti.org/gsn/nw\\_20110419\\_5975.php](http://gsn.nti.org/gsn/nw_20110419_5975.php).

<sup>13</sup> "North Korea Rolls out Ballistic Missiles," *Global Security Newswire*, 13 October 2010, available at [http://gsn.nti.org/gsn/nw\\_20101013\\_1452.php](http://gsn.nti.org/gsn/nw_20101013_1452.php).

road-mobile intercontinental ballistic missile (ICBM).<sup>14</sup> Nick Hansen provides an assessment of the North's ballistic missile program along with its connections to Iran's missile programs in this book.<sup>15</sup>

#### *Nuclear cooperation, imports, and exports*

Though 2011 cast little light on North Korea's nuclear relationships with outside countries, there is certainly cause for increased concern, considering developments like the Musudan and the new uranium enrichment facilities at Yongbyon. North Korea has a history of being a quick study (it became self-sufficient for the entire plutonium fuel cycle after initial help from the Soviets) and enterprising (Pyongyang almost certainly built a plutonium production reactor for Syria).<sup>16</sup>

North Korea has historically relied on importing key materials and components for its uranium centrifuge program. We believe it still does not have all the requisite capabilities today and has to rely on imports to expand its program. The centrifuge facility we were shown in 2010 apparently benefited from imports from Europe, Russia, Japan, and the A. Q. Khan network prior to 2003. It also profited from training and consultation with Pakistani enrichment specialists in the Khan Research Laboratories (KRL).<sup>17</sup> Today, the most likely acquisition route for key materials and components is through China.<sup>18</sup>

Over the past 10 years, North Korea has developed a uranium export business, supplying Libya with 1.8 metric tons of uranium hexafluoride before Muammar Qaddafi terminated the program in 2003.<sup>19</sup> The reactor built for Syria by North Korea at Dair Alzour also would have provided a lucrative fuel export business for North Korea had it not been bombed by Israel in 2007.<sup>20</sup> In 2011, Pyongyang may have continued to export nuclear technologies, knowhow, and precursor materials like uranium hexafluoride or, potentially, HEU itself to dangerous states. None of these are easy to detect or easy to stop. The footprint for uranium centrifuge activities is small, detection is difficult, and Pyongyang could claim exports are for civilian applications.

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<sup>14</sup> In June 2011, then-U.S. Secretary of Defense Robert Gates noted, "With the continued development of long-range missiles and potentially a road-mobile intercontinental ballistic missile and their continued development of nuclear weapons, North Korea is in the process of becoming a direct threat to the United States," available at <http://www.iiss.org/conferences/the-shangri-la-dialogue/shangri-la-dialogue-2011/speeches/first-plenary-session/qa/>. Also available at <http://www.thedailybeast.com/articles/2011/06/21/robert-gates-interview-his-lingering-concerns-about-u-s-supremacy-nuclear-proliferation-and-more.html>.

<sup>15</sup> Hansen, Nick. "North Korean-Iranian Cooperation in Ballistic Missile Development," Pacific Basin Nuclear Conference (PBNC – this volume), 2012, Busan, Republic of Korea.

<sup>16</sup> There is little chance that North Korea has done this anywhere else. Additionally, reactors are difficult to hide and are vulnerable to foreign intervention, as was demonstrated by Israel's destruction of the Syrian reactor in 2007.

<sup>17</sup> Siegfried S. Hecker, Chaim Braun, and Robert L. Carlin, "North Korea's Light-Water Reactor Ambitions," *Journal of Nuclear Materials Management*, Vol. 39, No. 10 (Spring 2011): pp. 18-25.

<sup>18</sup> David Albright and Paul Brannan, *Taking Stock: North Korea's Uranium Enrichment Program*, The Institute for Science and International Security, 8 October 2010.

<sup>19</sup> International Atomic Energy Agency Board of Governors General Conference, "Application of Safeguards in the Democratic People's Republic of Korea," GOV/2011/53-GC(55)/24, 2 September 2011, pg. 10, Sec. 50.

<sup>20</sup> International Atomic Energy Agency Board of Governors, "Implementation of NPT Safeguards Agreement in the Syrian Arab Republic," GOV/2011/30, 2 May 2011, pgs. 1-9. <http://www.iaea.org/Publications/Documents/Board/2011/gov2011-30.pdf>

Virtually all North Korean missiles are copies or derivatives of Soviet missiles. More than 20 years ago, Pyongyang turned from import to export, becoming the major supplier of missiles and the means to manufacture them to the most unstable parts of the world. Their export business has slowed down considerably,<sup>21</sup> but it appears that North Korea is now collaborating closely with Iran's missile establishment.<sup>22</sup> Nuclear cooperation between North Korea and Iran, including the export and import of sensitive nuclear and missile technology, could greatly benefit both countries – reactor, plutonium, and weapons technologies from North Korea to Iran; centrifuge technologies and missile technologies in both directions.<sup>23</sup>

### **Current state of diplomacy and path forward**

The centrifuge revelations in 2010 complicated an already gridlocked diplomatic Six-Party process, particularly reinforcing the hardliners' stance in Washington and Seoul against diplomatic engagement with Pyongyang. At the same time, events in Libya reinforced Pyongyang's conviction that ceding ground on the nuclear front is dangerous and possibly fatal. This diplomatic standoff allowed Pyongyang valuable time during which it threatened to strengthen its deterrent in both quantity and quality – implying it will build more bombs and smaller ones that can be missile delivered. The revelation of its uranium centrifuge program may have been intended as a signal that they now also have the capability to go the HEU route, which is difficult to track, for making bomb fuel. The nuclear test site preparations demonstrate they were prepared to conduct another nuclear test to develop smaller and better bombs. The display of the Musudan road-mobile missile threatened a means of delivering a small nuclear warhead that would be difficult to detect.

Despite these negative developments, in February North Korea and the United States agreed on a moratorium on nuclear and missile testing and suspension of the enrichment plant in Yongbyon. These steps are welcome and important to keep Pyongyang from enhancing its nuclear capabilities in the short term and making the nuclear crisis worse. Three years of diplomatic standoff did just that. At the end of 2008, North Korea had enough plutonium for a handful of bombs. Its only nuclear test left the international community unconvinced of its nuclear prowess. In 2009, Pyongyang conducted a successful nuclear test erasing any doubt that it can field a Nagasaki-like bomb. In 2010, it displayed its uranium enrichment capability, its determination to construct an indigenously-designed, LEU-fueled LWR in addition to rolling out the Musudan.

North Korean – U.S. negotiating history and the fact that the two sides issued statements with somewhat different language suggest that this negotiation will be difficult and drawn out as well. Both sides reaffirmed their commitment to the September 19, 2005 Joint

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<sup>21</sup> Joshua Pollack, "Ballistic Trajectory: The Evolution of North Korea's Ballistic Missile Market," *Nonproliferation Review*, Vol. 18, No. 2 (July 2011): p. 411-429.

<sup>22</sup> See *Iran's Nuclear and Missile Potential: A Joint Threat Assessment by U.S. and Russian Technical Experts*, (East-West Institute, May 2009), available at <http://docs.ewi.info/JTA.pdf>; Also see Mark Fitzpatrick, ed. *North Korean Security Challenges: A net assessment*, A IISS Strategic Dossier (London: The International Institute for Strategic Studies, July 2011): p. 179-182.

<sup>23</sup> These concerns were previously expressed by Siegfried S. Hecker in 2009 (Foreign Policy) and have been reinforced by the recent IAEA report by the Board of Governors (IAEA Board of Governors, 2011b).



Statement (for realizing the denuclearization of the entire Korean peninsula) and recognized that the 1953 Armistice Agreement is the cornerstone of peace and stability on the Korean Peninsula until the conclusion of a peace treaty. But they have different views of what denuclearization means and what will be required to verify and monitor it. In 2008, North Korea did not deliver a correct and complete declaration of nuclear facilities and materials as it had promised to do. Pyongyang has repeatedly accused Washington and its allies of not holding up their end of various agreements.

What comes next? For now, the moratorium on missile tests, nuclear tests, and uranium enrichment at Yongbyon in return for nutritional aid is sufficient to get Pyongyang and Washington reengaged in the diplomatic process to move toward the September 19, 2005 agreement. These actions should constrain Pyongyang from making significant additional progress in its nuclear weapon program. Much remains to be done, of course, to achieve eventual denuclearization. The six parties must address broader political, security and economic issues in North Korea and Northeast Asia once they return to the Six-Party negotiating table. I will return to the principal nuclear issues discussed above and focus on what could be done to lower the security risks on the Korean peninsula.

*Uranium enrichment.* Although a clandestine uranium enrichment facility is highly likely, we do not know how large and how sophisticated such a facility (or facilities) may be – and if these facilities are producing LEU or HEU, or both. It is unlikely, however, to house a large number of centrifuges because I believe North Korea must still import some of the key materials and components (such as high-strength maraging steel and aluminum alloys). Since it is highly unlikely that Pyongyang will admit the existence of such facilities (and even less likely to allow access), the most important near-term step is for the IAEA or the U.S. technical team<sup>24</sup> to get access to the Yongbyon centrifuge facility. Access will likely be a major point of contention in the next round of discussions; Washington will argue for full access and intrusive inspection, Pyongyang will likely try to keep inspectors stationed outside the centrifuge hall with no access claiming that it, like all other centrifuge plant operators in the world, has a right to protect its proprietary technologies. Washington should press to get access at least as intrusive as what the IAEA currently has at other centrifuge facilities it inspects, including those at Iranian plant in Natanz and the Brazilian enrichment plant in Resende.

The greatest risk posed by North Korea's centrifuge program is that it may allow it to produce large quantities of HEU that could greatly increase the number of nuclear weapons it could field. I do not believe this is currently possible. Highly enriched uranium does offer the simplest and most assured route to a primitive bomb – the so-called gun assembly used for the Hiroshima device. However, Pyongyang has already demonstrated a simple plutonium bomb, so there is no obvious benefit of a simple HEU bomb, unless they build many of them (which they cannot do with plutonium since they have no more plutonium being produced). Highly enriched uranium can also be used for a more sophisticated, miniaturized nuclear warhead, but such a design would have to be tested before Pyongyang could have any confidence to mount one on a missile.

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<sup>24</sup> A U.S. technical team was allowed access to most of the Yongbyon nuclear facilities from September 2007 to April 2009 to monitor North Korea's progress in disabling its Yongbyon plutonium facilities per agreements struck in 2007.

Information on such design(s) was distributed to various clients of the A.Q. Khan network and may also be available to North Korea.<sup>25</sup>

It is important, therefore, to stop Pyongyang from importing large quantities of key centrifuge materials and components to prevent it from building large additional centrifuge facilities now that it has apparently mastered the art of manufacture and operations. Whereas previous supply routes for such materials and components likely originated in Europe and Russia or via the A.Q. Khan network in Pakistan and Malaysia, the most likely routes today go through the enormous and ill-controlled Chinese industrial sector. It should be our first order of discussion with China to help shut down such potential routes. Additionally, as part of the moratorium process Washington should also attempt to place all LEU that may already have been produced at Yongbyon under IAEA safeguards to prevent potential subsequent conversion to HEU in undeclared North Korean enrichment facilities.

*The light-water reactor.* There is no mention in the February statements of the fate of the experimental LWR being constructed at Yongbyon. The North Korean statement hints at the potential prospect that it may be willing to abandon that project since it asks for the provision of an LWR. The Agreed Framework had provisions for two modern, commercial LWRs of 1,000 MWe (compared to the Yongbyon experimental LWR designed for 25 to 30 MWe). The LWR issue need not be addressed at this time. Even if North Korea continues with the construction of the experimental LWR, it will take at least a couple of additional years before it can become fully operational. Moreover, as long as operation of the centrifuge plant remains suspended, the reactor cannot be fueled.

In the longer term, it could well be that a provision of a modern, moderately-sized LWR may be the best way of keeping Pyongyang from completing and operating its own reactor with questionable safety credentials. An LWR reactor could be provided with guaranteed fuel supply and take-back arrangements. This, in turn, would eliminate the need for North Korea to have its own enrichment and reprocessing facilities. Pyongyang was prepared to accept this kind of arrangement a few years ago. It will be more difficult to get Pyongyang to agree to give up its modern centrifuge plant now that it has shown the world that it can build one.

It is currently politically impossible to consider providing an LWR unless it is part of a bargain in which Pyongyang agrees to give up its nuclear weapons and consents to intrusive monitoring and verification. If such a bargain can be worked out, Washington and its partners can consider revisiting the KEDO arrangement.<sup>26</sup> Alternatively, either China or Russia could supply a moderate size LWR for North Korea. Another possibility

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<sup>25</sup> International Atomic Energy Agency Board of Governors, "Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya," GOV/2004/59, 30 August 2004, available at <http://iaea.org/Publications/Documents/Board/2004/gov2004-59.pdf>. David Sanger reported in "Nuclear Ring Reportedly Had Advanced Design," *The New York Times*, 15 June 2008 that the Khan network possessed electronic blueprints for an advanced nuclear weapon design.

<sup>26</sup> The Agreed Framework negotiated in three substantive sessions (July 1993, August 1994, and September/October 1994) produced an agreement to construct two modern 1000 MWe LWRs in North Korea as part of a consortium eventually known as the Korean Peninsula Energy Development Organization (KEDO).

for long-term consideration in a weapon-free Korean peninsula is to help Pyongyang convert its HEU-fueled IRT-2000 research reactor to LEU fuel to produce medical isotopes that North Korea's medical community could use and/or sell to neighboring countries. An even better solution may be to have South Korea build a version of its world-class research and isotope production reactor, the HANARO Reactor, for North Korea to produce medical isotopes. Seoul has just signed a deal to build such a reactor for Jordan.

*The Yongbyon plutonium production complex.* Our visit to Yongbyon confirmed the fact that the 5-MWe reactor and the reprocessing facility were not operational and a key building in the fuel fabrication facility used for fuel rod fabrication for that reactor was converted into the centrifuge hall.<sup>27</sup> The chief engineer told us that these facilities are in stand-by, but they could be reactivated. One of the first orders of return to Six-Party negotiations should be to have Pyongyang take the steps necessary to permanently shut these facilities. These steps should involve permanently disabling the core of the reactor (that can be done by a number of means), selling the roughly 14,000 natural uranium metal fuel rods (which make up more than one full core load of new fuel) and dismantling the front end of the plutonium reprocessing facility so that it would no longer be able to accept spent fuel.<sup>28</sup> These actions will effectively and irreversibly shut Yongbyon's plutonium production facilities. To date, the facilities have been frozen several times, but never permanently taken out of commission. Eventually, Pyongyang must address the decommissioning and decontamination of the buildings and site.

*Nuclear weapons and delivery systems.* The nuclear test and long-range missile launch moratorium was the most critical step to take. Another positive step would be for Pyongyang to agree to permanently destroy the test tunnel that has been prepared for a third nuclear test, and completely abandon the test site. It is also imperative that North Korea not share its nuclear testing facilities or data with Iran. In due time, a complete declaration of fissile materials and nuclear weapons inventories must be put on the negotiating table. In the longer term, Pyongyang must declare its entire nuclear program and be willing to have its dismantlement be monitored and verified. Likewise, and accounting of the number of Musudan road-mobile missiles and other long-range missiles must be addressed.

*Nuclear exports and imports.* North Korea's exports of nuclear technologies or fissile materials can destabilize other parts of the world, like the Middle East. In our discussions with Pyongyang diplomats, we were told that they are prepared to discuss halting all "horizontal and vertical" proliferation – meaning no export and limiting the size of their own arsenal. The export issue must be addressed early once negotiations resume. It will be one of the most difficult to address because it is difficult to verify and shutting down exports potentially represents a significant loss income of foreign currency for the regime.

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<sup>27</sup> Although the North Korean February 29 statement, unlike the American statement, did not mention monitoring the 5-MWe reactor during the moratorium, there is no reason for concern since the reactor would require at least six months to reactivate and its operation could easily be monitored from satellite imagery.

<sup>28</sup> It is not advisable to dismantle the entire reprocessing facility because North Korea has not processed and treated the waste from its prior plutonium reprocessing campaigns.

In summary, although I expect the negotiations to be difficult and drawn out, the process has begun. At this point, the most important first steps have been taken by the new Kim regime – a moratorium on those actions that represented the greatest and most immediate threat in return for nutritional aid. It is difficult to predict which twists and turns the process of negotiations will take, but at least the process of negotiations has resumed. The steps that I outline above are ones that I believe will enhance the security of South Korea and the United States, and should be acceptable to the other parties. It will be up to the negotiators to determine what it takes to address Pyongyang’s concerns – food aid alone won’t suffice. Washington will have to address Pyongyang’s fundamental insecurity and future energy and economic needs. Washington and Seoul will have to overcome domestic politics to do so. The young North Korean leader will have to be willing to seek a better future for his destitute people.

## Figures



Figure 1 – A time sequence of overhead images of the light water reactor site tracking its development from September 2010 to November 2011



Figure 2 – Images of Yongbyon nuclear facilities and light water reactor as of January 26, 2012



Figure 3 – Three-dimensional model of the light water reactor based on latest satellite images

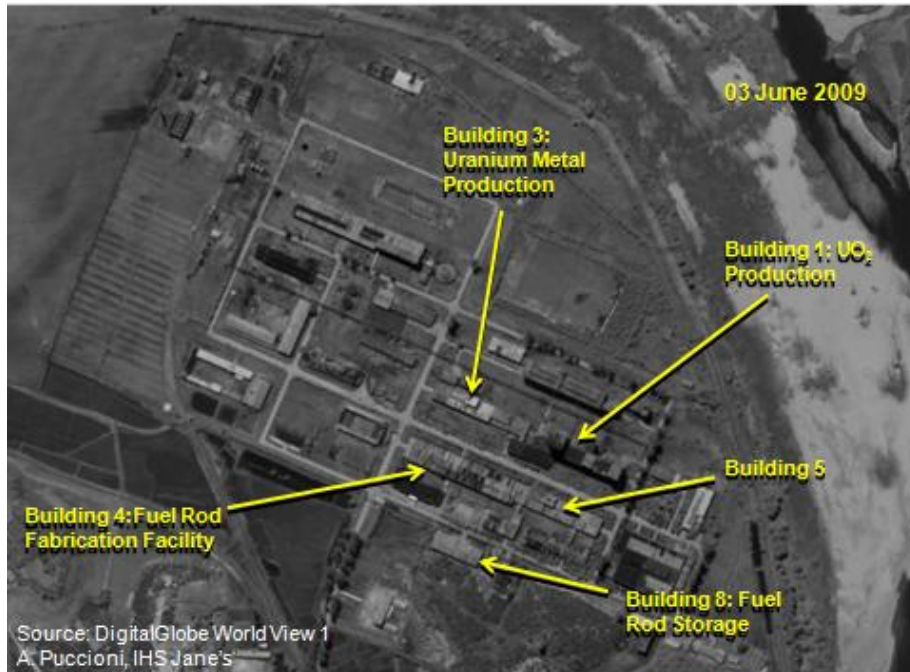


Figure 4 – June 3, 2009 image of the fuel fabrication plant at the Yongbyon nuclear complex



Figure 5 – The fuel fabrication plant in November 2010, with annotations identifying newly constructed buildings on the site between June 2009 and November 2011

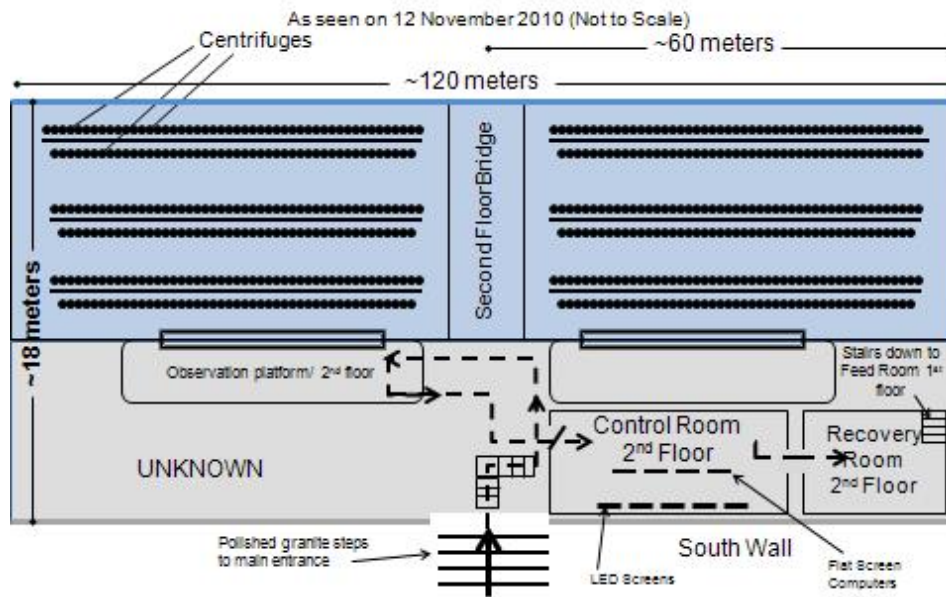


Figure 6 – A rough schematic of the floor plan for the cascade hall at the uranium enrichment centrifuge facility (Building 4) in Yongbyon, as of Nov. 12, 2010.

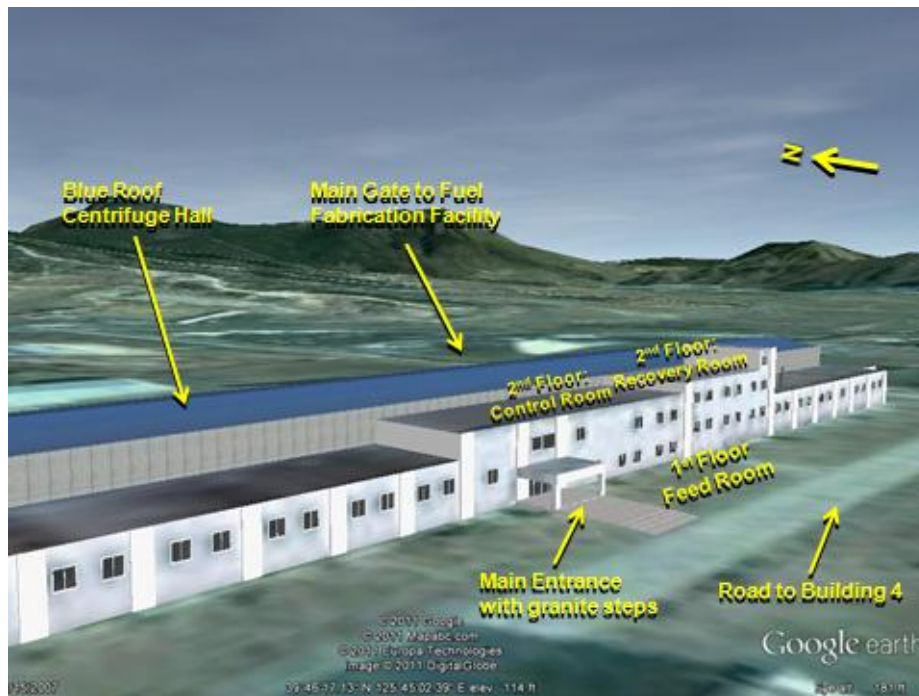


Figure 7 – Three-dimensional model of Building 4 (the new uranium enrichment centrifuge plant) in the fuel fabrication plant, created using the latest satellite images.



Figure 8 – Side View of the Musudan IRBM missile and MAZ-547A TEL as featured in the 10 Oct 2010 military parade in Pyongyang. Source: (KCNA-Yonhap News)

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