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North Korea's Nuclear Weapons Program

Daniel Wertz and Matthew McGrath
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Introduction

Despite years of international condemnation, diplomacy, and pressure, North Korea has succeeded in developing a relatively small nuclear arsenal, one which is poised for further gradual expansion, in terms of both size and sophistication, in the future. North Korea has conducted four nuclear tests, the most recent of which took place in January 2016. While determining the level of North Korea's technical sophistication is difficult, some experts believe that Pyongyang may have achieved the capability to miniaturize a nuclear warhead to be paired atop a ballistic missile, and may have also developed a boosted-fission weapon that is more sophisticated than a simple fission device. North Korea is also increasing its stockpile of fissile material though both uranium enrichment and plutonium production programs, is developing more sophisticated delivery systems, and has begun to articulate a nuclear posture. In addition, North Korea has a history of proliferating nuclear and missile technology abroad, and the possibility of future nuclear proliferation remains a source of major international concern. The Six Party Talks, which aimed to find a diplomatic solution to North Korea's nuclear program, have not convened since 2008, and Pyongyang has since repeatedly declared that it has no interest in denuclearization.

There are several key technical questions about North Korea's nuclear program that must be addressed in order to assess Pyongyang's current and future capabilities. These include:

- The size of North Korea's current stockpiles of plutonium and highly-enriched uranium (HEU);
- The extent of North Korea's uranium enrichment capacity, and the operability of its plutonium production infrastructure;
- Whether North Korea can produce a nuclear weapon that is small and rugged enough to be paired with a ballistic missile, as well as whether Pyongyang can produce reliable long-range missiles with effective reentry vehicles.[1]
- The extent of North Korea's progress in developing thermonuclear weapons (hydrogen bombs), which Pyongyang already claims to possess and to have tested.[2]

Given the secrecy of North Korea's nuclear program, the answers to these questions are subject to varying degrees of uncertainty. North Korea is reliably estimated to possess approximately 30 to 50 kilograms of plutonium, enough for perhaps six to eight weapons.[3] Estimates of North Korea's current HEU stockpile are more speculative, although one study assesses that Pyongyang has produced enough for 4-8 weapons. The uranium enrichment facility at its Yongbyon nuclear site houses 2,000 or more P2-type centrifuges, but North Korea is assumed by many analysts to have at least one additional clandestine enrichment facility of unknown scale, which makes estimating the country's HEU output difficult.[4] Various branches of the U.S. intelligence community and independent analysts, given a dearth of hard evidence, also differ on whether North Korea has the capability to deliver its nuclear weapons via missile.[5] Finally, while most experts do not believe that North Korea has successfully developed or tested a thermonuclear weapon, some evidence suggests that it is taking steps achieving this capability.[6]

The Plutonium Program

North Korea's gas-graphite 5 MWe experimental nuclear reactor at the Yongbyon nuclear complex began operating in 1986 and has served as the centerpiece of its plutonium production efforts.[7] By 1990, North Korea began operating a reprocessing plant to separate plutonium from spent fuel at the 5 MWe plant, producing up to 10 kilograms of plutonium by 1994 – possibly enough for one or two crude nuclear weapons. In the early 1990s, North Korea also began construction of two larger gas-graphite reactors: a 50 MWe reactor at Yongbyon and a 200 MWe reactor at nearby Taechon.

Plutonium production halted when operations at the 5 MWe plant and reprocessing facility, as well as construction of the larger reactors, were frozen under the Agreed Framework of 1994. However, following the collapse of the Agreed Framework in 2003, North Korea resumed operation of the 5 MWe reactor and began reprocessing spent fuel rods to produce plutonium. (Significant construction at the larger reactor sites did not resume.)[8] After operating for several years, the 5 MWe reactor was shut down and partially disabled in 2008, an action taken as a part of the Six Party Talks process. In the most visible part of this process, North Korea demolished the reactor's cooling tower in June 2008.

In April 2013, several years after the Six Party Talks collapsed, North Korea announced its intention to rebuild and restart the disabled reactor.[9] Analysis of satellite imagery indicated that by September of that year, North Korea had restarted operations.[10] However, satellite imagery has indicated that the reactor has since been operating only sporadically, due to aging infrastructure and problems with the reactor's new cooling system.[11] If operating at full capacity, the reactor would be able to produce up to six kilograms of plutonium annually, although it would take two to three years before the reactor's irradiated fuel could be discharged and another six to twelve months before plutonium could be separated from the spent fuel.[12] Alternatively, one analysis suggests that the retooled 5 MWe reactor could be used for the production of isotopes including tritium, an important component in boosted-fission and hydrogen bombs.[13]

North Korea's experimental light water reactor (LWR) at Yongbyon may provide a second route for plutonium production. In 2009, Pyongyang announced that it would construct a light-water reactor in conjunction with its uranium enrichment plans;[14] the following year, a team of U.S. experts was shown the 25 to 30 MWe reactor under construction.[15] Exterior construction of the reactor appears to have finished in early 2014, but the facility is not yet operational.[16] While Pyongyang has publicly stated that the LWR is intended for energy production, one report speculates that if the reactor were configured for producing weapons-grade plutonium and commensurate modifications were made to the Yongbyon reprocessing plant, North Korea could eventually produce up to about 20 kg of plutonium a year.[17]

Siegfried Hecker, the former director of Los Alamos National Laboratory, estimated after North Korea's second nuclear test that the country had a stockpile of 24-48 kg of plutonium, based on the assumption that each of the first two tests used 6 kg of plutonium. After North Korea's second nuclear test, David Albright and his colleagues at the Institute for Science and International Security have estimated that North Korea possesses 34-56 kg of plutonium, assuming the use of 2-4 kg per test for North Korea's initial two nuclear tests.[18] (It is unknown whether the fissile material used for North Korea's two subsequent nuclear tests was plutonium or highly enriched uranium.) In 2008, as part of the Six Party Talks disablement process, North Korea declared that it possessed about 30 kg of separated plutonium – if one adds the approximately 8 kg separated in 2009 and subtracts 2-6 kg for the second nuclear test, this leaves 32-36 kg of plutonium in Pyongyang's declared stockpile.[19]

Uranium Enrichment

North Korea began receiving centrifuge-related equipment and know-how from the A.Q. Khan network beginning in the mid-to-late 1990s.[20] By the late 1990s, U.S. policymakers began to suspect the DPRK was acquiring uranium enrichment technology and the U.S. confronted North Korea about this issue during a 2002 meeting in Pyongyang. After this encounter, the U.S. delegation stated that North Korea admitted to having a uranium enrichment program, while North Korea subsequently denied any such admission or the existence of an enrichment program.[21] Even as the Six Party Talks process led to the disablement of North Korea's 5 MWe reactor in 2008, the DPRK continued to deny the existence of a highly enriched uranium program.[22] Documents submitted as part of North Korea's 2008 declaration of its nuclear program did not include a reference to uranium enrichment, but reportedly contained traces of highly enriched uranium.[23]

Following its second nuclear test in 2009, North Korea announced that it would commence enriching uranium, and that "enough success has been made in developing uranium enrichment technology" to produce fuel for its experimental light-water reactor.[24] In 2010, a U.S. delegation visited a newly-built enrichment facility at Yongbyon, which it described as a "modern, small industrial-scale" facility that, unlike other North Korean nuclear facilities, was "ultra-modern and clean."

The chief process engineer at the enrichment facility told the delegation that it was operational, enriching uranium to an average level of 3.5% (a low level of enrichment standard for light-water reactor fuel), and contained 2,000 centrifuges with a capacity of 8,000 kg separative work units per year.[25] Based on this output level and North Korea's historical involvement with the A.Q. Khan network, analysts believe that North Korea's centrifuge design is based on the second-generation Pakistani P2 model.[26] In 2013, satellite imagery revealed that the centrifuge facility had been expanded with a new roof covering roughly twice the area of the previous one, hypothetically allowing the building to house up to 2,000 additional centrifuges.

Given the sophistication of the Yongbyon enrichment facility and the speed with which it was constructed, many analysts suspect that the country has a second clandestine uranium enrichment facility.[27] The scale and fissile material output of such a facility is difficult to assess and could vary based on North Korea's capacity to manufacture key components domestically.[28] The existence of such a facility would complicate any future efforts to verifiably denuclearize North Korea, particularly if the country were capable of manufacturing centrifuges domestically.

Estimates of North Korea's overall enrichment capacity and highly enriched uranium stockpiles are highly speculative, hinging on a number of factors. These include:

- The scale and operational history of any clandestine enrichment facility;
- Whether the Yongbyon enrichment facility is used to produce light-water reactor fuel or weapons-grade uranium;
- Whether North Korea faces any technical or material barriers to operating its centrifuges efficiently; and
- The number of centrifuges currently installed at the Yongbyon enrichment facility.

David Albright and Christina Walrond argue that a credible upper bound for North Korea's production of weapons-grade uranium is 17 kg per year per 1,000 centrifuges dedicated to producing highly enriched uranium rather than reactor fuel. A lower bound, assuming a less efficient enrichment process and operational difficulties, is 4 kg per year per 1,000 dedicated centrifuges.[29] (A uranium-based weapon would likely require 15-25 kg of weapons-grade uranium.)[30] It is possible that North Korea may begin installing more advanced centrifuges in the future, which would increase its output of HEU.

Weaponization and Tests

To date, North Korea has conducted four underground nuclear tests at its Punggye-ri testing site. The first two tests were in 2006 and 2009, and likely used plutonium-based devices and had yields of under 1 kiloton and 2-7 kilotons, respectively.[31] (For comparison, the plutonium-based weapon dropped on Nagasaki in 1945 had a yield of 21 kilotons.) The yield for the third test was higher – one expert estimated it to be roughly between 5 to 15 kilotons – while an initial estimate from South Korea's National Intelligence Service estimated the fourth test at 6 kilotons.[32] The fissile material used for the third test is not known with certainty since North Korea sealed the test site to prevent any telltale gases from escaping. Analysts believe that uranium or plutonium could have plausibly been used. However, many believe the third test more likely used a uranium-based device because Pyongyang had a limited stockpile of plutonium and a potentially growing supply of highly enriched uranium.[33]

One possible reason for the low yield in the first two nuclear tests is that North Korea may have tested relatively sophisticated implosion devices that only required a small amount of plutonium in order to quickly develop a miniaturized nuclear warhead capable of pairing with its medium-range Nodong missiles. In 2008, as part of a declaration of its past nuclear activities, North Korea reported that its first nuclear test used only 2 kg of plutonium; if true, this would indicate a relatively advanced weapon design.[34] Some analysts believe that North Korea could have received warhead designs from the A.Q. Khan network in addition to centrifuges.[35] Alternatively, A.Q. Khan has alleged that North Korea developed advanced warhead designs as early as 1999, although experts question the truthfulness of his testimony.[36]

After North Korea's third nuclear test in 2013, the Korea Central News Agency announced that it had tested a "smaller and light A-bomb unlike the previous ones, yet with great explosive power" in an apparent claim that its nuclear weapons could be miniaturized.[37] Subsequent assessments by U.S. officials and nongovernment experts on North Korea's progress toward miniaturization have been mixed.[38] Admiral Bill Gortney, the head of NORAD and U.S. Northern Command, has publicly given an assessment that North Korea has the ability to mount a miniaturized warhead atop an ICBM, but a National Security Council spokesman subsequently said that "we do not think they have that capability."[39] It may be possible that North Korea has made enough progress toward miniaturization and other technical challenges to mount a warhead on its medium-range Nodong missile, but not on longer-range missiles.[40] (Additionally, neither North Korea's KN-08 road-mobile ICBM nor its Musudan intermediate-range ballistic missile have been flight-tested, and they may not yet be operational, regardless of the country's progress on miniaturization; the Taepodong-2 ICBM may also lack military effectiveness in the absence of a hardened launch site.)[41]

North Korea claimed that its fourth nuclear test, which took place in early January 2016, successfully tested a "smaller H-bomb."[42] A month before the test, Kim Jong Un claimed that North Korea was "a powerful nuclear weapons state ready to detonate self-reliant A-bomb and H-bomb to reliably defend its sovereignty and the dignity of the nation," according to the Korean Central News Agency.[43] Nuclear experts and South Korean government sources quickly expressed strong doubt about the possibility that North Korea had tested a two-stage hydrogen bomb, citing technical barriers and pointing out the inconsistency between the test's low yield and the expected yield of even a fizzled thermonuclear test.[44] Several analysts raised the possibility that North Korea had tested a boosted fission device, which would use a small amount of fusion fuel to increase the yield of a fission reaction – designs for such weapons can be significantly less complex than those for two-stage thermonuclear bombs, which have an exponentially higher yield.[45] However, some analysts also pointed out that this possibility remained speculative, and that the test could have involved a simple fission device.[46]

Nuclear Proliferation to Other Countries

According to a 2014 Defense Department report to Congress, "One of our gravest concerns about North Korea's activities in the international arena is its demonstrated willingness to proliferate nuclear technology."[47] There are several examples of demonstrated or suspected North Korean nuclear cooperation with foreign countries, as well as a history of North Korean missile proliferation to other countries. Additionally, U.S. officials have warned that North

Korea may be more willing to sell fissile material or complete nuclear weapons (as opposed to only nuclear technology or equipment) as the size of its arsenal grows.[48] Pyongyang has indicated that its willingness to abide by international nonproliferation principles is dependent on "the improvement of relations with hostile nuclear states" and recognition of the DPRK as a nuclear power.[49]

The best-documented case of North Korean proliferation of nuclear technology concerns Pyongyang's cooperation with Syria in the construction of the al-Kibar nuclear reactor in the early-to-mid 2000s. This reactor, built with North Korean technical assistance, had a design very similar to that of North Korea's 5 MWe reactor at Yongbyon.[50] Several North Korean scientists were reportedly present at the facility when it was destroyed by an Israeli airstrike in 2007.[51] In a prior instance of nuclear proliferation, North Korea likely collaborated with the A.Q. Khan network to send uranium hexafluoride to Libya prior to Tripoli's 2003 decision to dismantle its WMD programs.[52]

Additionally, North Korea is suspected of having engaged in nuclear cooperation with Iran, in light of the two countries' extensive collaboration on the development of ballistic missiles and a 2012 agreement between Pyongyang and Tehran to cooperate on science and technology.[53] There have been multiple media reports alleging various forms of nuclear cooperation between Iran and North Korea, but they have tended to rely only on anonymous sources and remain unconfirmed.[54] U.S. officials have not publicly confirmed any instances of North Korean nuclear cooperation with Iran.[55] Because of this uncertain evidence, various analysts have expressed sharply different views on the extent of nuclear cooperation between the two countries.[56]

Several analysts have also expressed concern over the possible proliferation (or use) of North Korean nuclear weapons arising from internal instability or a collapse scenario. In such a contingency North Korean nuclear weapons, fissile material, or nuclear scientists could escape from established chains of custody, and preventing their diversion to other states or non-state actors would be a complex and difficult task for the global community.[57]

North Korea's Nuclear Posture and Future Program Goals

North Korea's nuclear program could be poised for steady expansion in the near- to mid-term future. One recent assessment of North Korea's nuclear program estimates that Pyongyang could have anywhere from 20 to 100 nuclear weapons by 2020, depending on factors including its number of deployed centrifuges, its technical proficiency in producing fissile material, and its ability to procure necessary foreign goods for its programs. The study gives a mid-range estimate that North Korea will be able to produce approximately 50 weapons by 2020.[58] A closed-door analysis by Chinese nuclear experts, reported on by the *Wall Street Journal*, estimates that North Korea could produce over 75 weapons by the same date.[59] As North Korea's nuclear arsenal increases in size, it may also become more sophisticated, with further progress toward miniaturization, higher yields, and reliability possible with additional nuclear testing.[60] Additionally, over the next several years North Korea may make progress toward the development of a thermonuclear weapon, its claims to have already tested one notwithstanding.[61]

Under Kim Jong Il, Pyongyang may have viewed its nuclear weapons program at least partially as a political or diplomatic tool to be leveraged at the negotiating table in order to obtain concessions or foreign assistance.[62] However, the DPRK's line on negotiating over its nuclear program has hardened considerably in recent years. North Korea has repeatedly declared that its nuclear program is not "a bargaining chip to be exchanged for something else," and has announced its intent to expand its nuclear forces "qualitatively and quantitatively until the denuclearization of the world is realized."[63] In 2012, North Korea revised its constitution to declare itself a "nuclear state," and in 2013 adopted a law declaring itself "a full-fledged nuclear weapons state."[64]

This law has provided some clarity into Pyongyang's official nuclear posture, indicating that nuclear weapons will be used for "deterring and repelling the aggression and attack of the enemy against the DPRK and dealing deadly retaliatory blows at the strongholds of aggression" – indicating intent for both battlefield use and strategic use against civilian targets. The law indicates that the DPRK considers both nuclear weapons states and their allies to be potential targets for its nuclear weapons, and does not include a "no first use" stance. It also articulates a highly centralized command and control structure, stating that the country's nuclear weapons may only be used upon "a final order of the Supreme Commander of the Korean People's Army" (i.e. Kim Jong Un).[65]

One expert cautions that while this declaratory policy may indeed signal a relatively more transparent North Korean nuclear strategy, it could also be "understood as political rhetoric employed to mimic US statements or as an aspirational objective of KPA planners."[66] A different analyst, noting that North Korea's conventional forces have been successful at deterrence, argues that Pyongyang's posturing is "intended to compel its adversaries to change their policies towards the DPRK, not to deter unprovoked external attack."[67] Other explanations for North Korea's new doctrine point to its role in legitimizing the rule of Kim Jong Un, and in internally justifying cutbacks to conventional forces in order to redirect resources into the civilian economy.[68]

Several analysts have suggested that as North Korea's stockpile of nuclear weapons grows, the country's nuclear strategy may become more ambitious.[69] A relatively small arsenal, as Pyongyang currently possesses, could be used to shape the actions of outside powers due to their fear of the risks of instability, or to deter a full-scale invasion through the threat of possible retaliation against major population centers. A more sizeable arsenal with greater survivability and more advanced delivery mechanisms could increase the credibility of assured North Korean retaliation against large-scale attacks, and enable more effective access-denying strikes against U.S. or ROK military bases.[70] Further in the future, if North Korea amasses a significantly larger nuclear arsenal and develops more sophisticated command and control mechanisms, Pyongyang could also adopt a posture of asymmetric escalation, credibly threatening tactical nuclear weapons use in order to deter lower-threshold strikes.[71] Such a posture, if put into operational practice rather than employed as a rhetorical bluff, could greatly increase the risks of inadvertent nuclear use or unintended escalation.[72]

Concern for the security implications arising from a growing North Korean nuclear arsenal has led to calls for the United States to prioritize negotiating a "cap and freeze" on North Korea's nuclear arsenal, under which North Korea would agree to a moratorium on nuclear tests and fissile material production at Yongbyon. Advocates of this approach argue that it would not mean abandoning the long-term U.S. goal of complete denuclearization, and would slow down or halt advancements in an otherwise unconstrained nuclear program. However, critics argue that such an approach could legitimize North Korea as a nuclear state, that Pyongyang could seek to simply pocket foreign concessions and then walk away from its obligations, and that North Korea would be unlikely to acknowledge or halt operations at any covert uranium enrichment facility.[73]

[1] Jeffrey Lewis, "North Korea's Nuclear Weapons: The Great Miniaturization Debate," *38 North*, February 5, 2015, http://38north.org/2015/02/jlewis020515/

[2] See "DPRK Proves Successful in H-bomb Test," Korean Central News Agency, January 6, 2016.

[3] Mary Beth Nikitin, "North Korea's Nuclear Weapons: Technical Issues," Congressional Research Service, April 3, 2013, https://www.fas.org/sgp/crs/nuke/RL34256.pdf

[4] Joel Wit and Sun-young Ahn, "North Korea's Nuclear Futures: Technology and Strategy," *U.S.-Korea Institute at SAIS*, February 2015, http://38north.org/wp-content/uploads/2015/02/NKNF-NK-Nuclear-Futures-Wit-0215.pdf

[5] Thom Shanker, David E. Sanger, and Eric Schmitt, "Pentagon Finds Nuclear Strides by North Korea," *New York Times*, April 11, 2013, http://www.nytimes.com/2013/04/12/world/asia/north-korea-may-have-nuclear-missile-capability-us-agency-says.html?pagewanted=all

[6] "N. Korea May Be Readying for Thermonuclear Weapon Tests: S. Korean Military," *Yonhap News Agency*, January 3, 2016.
http://english.yonhapnews.co.kr/news/2016/01/03/0200000000AEN20160103000700315.html

[7] An IRT-2000 research reactor, constructed in the early 1960s, may have also produced a small amount of plutonium. The IRT 2000 reactor has barely operated since 1994. In 1992, North Korean officials had told the IAEA that technicians had separated 300mg of plutonium from the reactor via hot cells in 1975. While the facility was under IAEA safeguards after 1978, one analyst estimates that the reactor could have produced up to 4 kg of plutonium while operational at declared power levels and load factors. Jared S. Dreicer, "How Much Plutonium Could Have Been Produced in the DPRK IRT Reactor?," *Science & Global Security*, Vol. 8 (2000), pp. 273-286.

[8] In 2010, a North Korean technician told U.S. scientist Siegfried Hecker that the 50 and 200 MWe reactors "have become ruined concrete structures and iron scrap." Siegfried Hecker, "A Return Trip to North Korea's Yongbyon Nuclear Complex," Stanford University Center for International Security and Cooperation, November 20, 2010, http://iis-db.stanford.edu/pubs/23035/HeckerYongbyon.pdf

[9] "DPRK to Adjust Uses of Existing Nuclear Facilities," *KCNA*, April 2, 2013.

[10] "North Korea Restarting its 5 MW Reactor," *38 North*, September 11, 2013, http://38north.org/2013/09/yongbyon091113/; "More Evidence that North Korea has Restarted its 5MWe Reactor," *38 North*, October 2, 2013, http://38north.org/2013/10/yongbyon100213/; David Albright and Robert Avagyan, "Steam Venting from Building Adjacent to 5 MWe Reactor: Likely Related to Reactor Restart," Institute for Science and International Security, September 11, 2013, http://isis-online.org/isis-reports/detail/steam-venting-from-building-adjacent-to-5mwe-reactor-likely-related-to-reac/10

[11] "Nuclear Safety Problems at North Korea's Yongbyon Nuclear Facility?" *38 North*, April 7, 2014, http://38north.org/2014/04/yongbyon040714/; "North Korea's Yongbyon Nuclear Facility: Sporadic Operations at the 5 MWe Reactor But Construction Elsewhere Moves Forward," *38 North*, July 24, 2015, http://38north.org/2015/07/yongbyon072415/

[12] "North Korea Restarting its 5 MW Reactor," *op. cit.;* Albright and Avagyan, "Steam Venting from Building Adjacent to 5 MWe Reactor," *op. cit.*

[13] David Albright and Serena Kelleher-Vergantini, "Update on North Korea's Yongbyon Nuclear Site," Institute for Science and International Security, September 15, 2015, http://isis-online.org/uploads/isis-reports/documents/Update_on_North_Koreas_Yongbyon_Nuclear_Site_September15_2015_Final.pdf

[14] "DPRK Foreign Ministry Declares Strong Counter-Measures against UNSC's 'Resolution 1874'," *KCNA*, June 13, 2009.

[15] Hecker, "A Return Trip to North Korea's Yongbyon Nuclear Complex," *op. cit.*

[16] "North Korea's Yonbyon Nuclear Facility: Restart of the 5 MWe Reactor?," *38 North*, January 28, 2015, http://38north.org/2015/01/yongbyon012815/

[17] David Albright, "Future Directions in the DPRK's Nuclear Weapons Program: Three Scenarios for 2020," U.S.-Korea Institute at SAIS, February 2015, http://38north.org/wp-content/uploads/2015/02/NKNF-Future-Directions-2020-Albright-0215.pdf

[18] Albright and Brannan (2007) estimate a stockpile of 28-50 kg of plutonium, and Albright and Walrond (2012) add that North Korean reprocessing of the last reactor core from the 5MWe reactor in 2009 yielded about an additional 8 kg of plutonium. See David Albright and Paul Brannan, "The North Korean Plutonium Stock, February 2007," Institute for Science and International Security, February 20, 2007, http://isis-online.org/uploads/isis-reports/documents/DPRKplutoniumFEB.pdf; Albright and Walrond, "North Korea's Estimated Stocks of Plutonium and Weapon-Grade Uranium," Institute for Science and International Security, August 2012, http://isis-online.org/uploads/isis-reports/documents/dprk_fissile_material_production_16Aug2012.pdf

[19] Albright and Walrond, "North Korea's Estimated Stocks," *op. cit.*, pp. 8-10.

[20] David Albright and Paul Brannan, "Taking Stock: North Korea's Uranium Enrichment Program," *Institute for Science and International Security*, October 8, 2010, http://isis-online.org/uploads/isis-reports/documents/ISIS_DPRK_UEP.pdf

[21] Don Oberdorfer and Robert Carlin, *The Two Koreas*, Third Ed. (Basic Books, 2013), pp. 366-372.

[22] Testimony of Ambassador Christopher R. Hill, "The North Korean Six-Party Talks and Implementation Activities," Hearing before the Senate Committee on Armed Services, 110th Congress, 2nd Session, July 31, 2008, http://2001-2009.state.gov/p/eap/rls/rm/2008/07/107590.htm

[23] Mary Beth Nikitin, "North Korea's Nuclear Weapons: Technical Issues," Congressional Research Service, April 13, 2013, pp. 11-12, http://fas.org/sgp/crs/nuke/RL34256.pdf

[24] "DPRK Foreign Ministry Declares Strong Counter-Measures against UNSC's 'Resolution 1874'," *KCNA*, June 13, 2009.

[25] Hecker, "A Return Trip to North Korea's Yongbyon Nuclear Complex," *op. cit.*

[26] Siegfried Hecker, "Redefining Denuclearization in North Korea," *Bulletin of the Atomic Scientists*, December 20, 2010, http://thebulletin.org/redefining-denuclearization-north-korea-0

[27] Director of National Intelligence James R. Clapper testified before Congress in 2011 that "Based on the scale of the facility and the progress the DPRK has made in construction, it is likely that North Korea has been pursuing enrichment for an extended period of time. If so, there is clear prospect that DPRK has built other uranium enrichment related facilities in its territory, including likely R&D and centrifuge fabrication facilities, and other enrichment facilities. Analysts differ on the likelihood that other production-scale facilities may exist elsewhere in North Korea." James R. Clapper, "Statement for the Record on the Worldwide Threat Assessment of the U.S. Intelligence Community for the House Permanent Select Committee on Intelligence," February 10, 2011.

[28] Experts have disagreed on North Korea's capacities in this regard. See Choe Sang-hun, "North Korea Learning to Make Crucial Nuclear Parts, Study Finds," *New York Times*, September 23, 2013; David Albright and Olli Heinonen, "In Response to Recent Questionable Claims about North Korea's Indigenous Production of Centrifuges," *Institute for Science and International Security*, October 18, 2013, http://isis-online.org/isis-reports/detail/in-response-to-recent-questionable-claims-about-north-koreas-indigenous-pro/

[29] Albright and Walrond, "North Korea's Estimated Stocks," *op. cit.*, pp. 22-25.

[30] Albright and Walrond estimate that a crude North Korea fission device using only uranium would require 15 to 25 kg of weapons-grade uranium. Albright separately writes that the warhead design that China reportedly transferred to Pakistan in the early 1980s required 25 kg of weapons-grade uranium, and that Pakistan further miniaturized the design in the 1980s and 90s. The A.Q. Khan network

reportedly sold this weapon design to Libya, and analysts speculate that it may have sold the design to North Korea as well. Albright and Walrond, "North Korea's Estimated Stocks," *op. cit.,* p. 25; David Albright, "North Korean Miniaturization," *38 North*, February 13, 2013, http://38north.org/2013/02/albright021313/

[31] Frank V. Pabian and Siegfried S. Hecker, "Contemplating a Third Nuclear Test in North Korea," *Bulletin of the Atomic Scientists*, August 6, 2012, http://thebulletin.org/contemplating-third-nuclear-test-north-korea

[32] Verification Science Interview with Paul Richards, "Seismic Detective Work: CTBTO Monitoring System 'Very Effective' in Detecting North Korea's Third Nuclear Test," *CTBTO Spectrum*, No. 20 (July 2013), http://www.ctbto.org/fileadmin/user_upload/pdf/Spectrum/2013/Spectrum20_web.pdf; Choe Sang-hun, "South Korea Doubts North's Claim It Detonated Hydrogen Bomb," *New York Times*, January 6, 2016.

[33] Graham T. Allison Jr., "North Korea's Lesson: Nukes for Sale," *New York Times*, February 12, 2013, http://www.nytimes.com/2013/02/12/opinion/north-koreas-lesson-nukes-for-sale.html

[34] Albright and Walrond, "North Korea's Estimated Stocks," *op. cit.*, p. 9.

[35] See Bruce Klingner, "Going Beyond 'Strategic Patience:' Time to Get North Korean Sanctions Right," Testimony before the U.S. House of Representatives Foreign Affairs Subcommittee on Asia and the Pacific, hearing on "The Shocking Truth about North Korean Tyranny," March 26, 2014. This analysis is partially predicated on the A.Q. Khan network's sale to Libya of detailed instructions on how to produce a Chinese-designed miniaturized nuclear warhead; China had reportedly transferred the weapons design to Pakistan in the early 1980s. See Joby Warrick and Peter Slevin, "Libyan Arms Designs Traced Back to China," *Washington Post*, February 15, 2004.

[36] R. Jeffrey Smith and Joby Warrick, "Pakistani Scientist Depicts More Advanced Nuclear Program in North Korea," *Washington Post*, December 28, 2009; Albright, "North Korean Miniaturization," *op. cit.*

[37] "KCNA Report on Successful 3rd Underground Nuclear Test," *KCNA*, February 12, 2013.

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