INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

IMAGERY BRIEF

Plutonium, Tritium, and Highly Enriched Uranium Production at the Yongbyon Nuclear Site

North Korea's nuclear arsenal may be growing significantly

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According to Reuters, a US government source stated that North Korea has separated plutonium at the Radiochemical Laboratory at the Yongbyon nuclear site. The Institute has independently confirmed activities inside the main building at the Radiochemical Laboratory. DigitalGlobe satellite imagery dated June 8, 2016 shows no signs of full-power operation at the 5 megawatt-electric (MWe) reactor, although intermittent operation may continue. In 2015, the Institute conducted a comprehensive analysis of the production of separated plutonium, weapon-grade uranium, and nuclear weapons as of the end of 2014; one of the key central estimates was that North Korea had 10-16 nuclear weapons as of the end of 2014.[1] *Since the end of 2014, or during the last 18 months, North Korea has added an estimated 4-6 nuclear weapons to this value, based on additional production of separated plutonium and weapon-grade uranium at Yongbyon, where any contribution of a second centrifuge plant is ignored. Thus, as of June 2016, North Korea has about 13-21 nuclear weapons, where one weapon was subtracted to reflect the underground test in early 2016. The upper bound, or 21 weapons, is greater in fact because it does not include the effect of any weapon-grade uranium produced in a possible second centrifuge plant. Nonetheless, this estimate, despite not being comprehensive, shows that North Korea appears to be significantly increasing its nuclear weapons capabilities.*

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[1] David Albright, "North Korean Plutonium and Weapon-Grade Uranium Inventories," Institute for Science and International Security, January 8, 2015 (revised October 7, 2015), p. 8. http://isis-online.org/uploads/isisreports/documents/North_Korean_Fissile_Material_Stocks_Jan_30_2015_revised_Oct_5_2015-Final.pdf. Summarized findings in this study concerning inventories through 2014 appeared earlier in *Future Directions in the DPRK'S Nuclear Weapons Program: Three Scenarios for 2020* by Albright, published as an ISIS Report, February 26, 2015. http://www.isisonline.org/uploads/isis-reports/documents/North_Korea_Nuclear_Futures_26Feb2015-Master-ISIS_Final.pdf. This same study was simultaneously published by the US-Korea Institute at the School of Advanced International Studies, Johns Hopkins University under its Nuclear Futures Series. http://38north.org/wpcontent/uploads/2015/02/NKNF-Future-Directions-2020-Albright-0215.pdf. Frequently, the Institute's estimate of the number of nuclear weapons as of the end of 2014 has been incorrectly cited to the US-Korea Institute.

Radiochemical Laboratory and Nuclear Waste Facilities

Indications of plutonium separation, or reprocessing activities, at the Radiochemical Laboratory, have reportedly been observed by the United States government. The Radiochemical Laboratory is where North Korea chemically processes discharged irradiated fuel from the 5 MWe reactor and separates plutonium for nuclear weapons.[2] The Institute has independently confirmed activity inside the main building at the Radiochemical Laboratory.

A U.S. official, who spoke on condition of anonymity, told Reuters "They take the spent fuel from the 5 megawatt reactor at Yongbyon and let it cool and then take it to the reprocessing facility, and that's where they've obtained the plutonium for their previous nuclear tests. So they are repeating that process. That's what they're doing."[3] Thus, it is likely that North Korea is reprocessing or has reprocessed spent fuel.

The activity reportedly happening inside the Radiochemical Laboratory has not apparently produced direct signatures visible in commercial satellite imagery. However, some indirect signatures associated with plutonium separation have been visible and continue to be present in recent imagery. DigitalGlobe imagery from June 8, 2016 shows a few vehicles and small trucks at the site (see figure 1). Additionally, one of the three possible waste tanks has been covered with grass. The tanks (or casks) that had been spotted in front of the spent fuel reception building at the Radiochemical Laboratory on April 11, 2016 (see 38North) and May 22, 2016 (see ISIS), are no longer present in the June 8 imagery. Additionally, the coal fired steam generation plant may be active on June 8, 2016 (see figure 2).[4] These last two signatures are important because they are more directly associated with plutonium separation activities at the Radiochemical Laboratory.

As figure 2 shows, a truck is visible at Building 500, an alleged undeclared nuclear waste storage building located south of the Radiochemical Laboratory (see figure 2). This building reportedly has four basement pits for liquid waste storage and six smaller compartments for storage of

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[2] For detailed annotations of the buildings at the Radiochemical Laboratory site see David Albright and Serena Kelleher-Vergantini, "May 2016: Monitoring Activities at the Yongbyon Nuclear Site," May 27, 2016, http://isis-online.org/uploads/isis-reports/documents/Monitoring_Activities_at_the_Yongbyon_Nuclear_Site_May_27_2016_FINAL.pdf.

[3] Jonathan Landay, David Brunnstrom, and Matt Spetalnick, "North Korea restarts plutonium production for nuclear bombs - U.S. official," Reuters, June 8, 2016. http://www.reuters.com/article/us-northkorea-nuclear-usa-exclusive-idUSKCN0YT2I1

[4] The coal plant's main purpose is to provide a source of industrial steam for the plutonium separation activities taking place there. Steam is used to generate heat for nuclear waste minimization and solidification. Thus, the steam is importantly used to address the aftermath of plutonium separation. See David Albright, Olli Heinonen, and Serena Kelleher-Vergantini, "Correlating the Operation of the Coal Plant to Reprocessing Activities at Yongbyon, April 15, 2016, http://isis-online.org/uploads/isis-reports/documents/Correlating_the_Operation_of_the_Coal_Plant_to_Reprocessing_Activities_at_Yongbyon_April_15_2016_FINAL.pdf.

solid wastes.[5] Previously, our Institute noted that a trench had been dug here between March 15 and April 4, 2016. Although the exact purpose of the trench remains unknown, North Korea may be attempting to access the lower portion of the building, where the waste is allegedly stored, to remediate a problem, perhaps a waste leak, or conduct maintenance activities.[6] The purpose of the truck is hard to determine at this time.

5 Megawatt-Electric Reactor and Experimental LWR

North Korea produces plutonium in its 5 MWe reactor at the Yongbyon site. The June 8, 2016 DigitalGlobe image shows no signs of full-power operation at the 5 MWe reactor. Water is not visibly being discharged from the reactor's discharge pipeline, and steam is not visibly venting from the reactor's turbine building (see figure 3). However, the reactor is believed to continue to operate intermittently or at low power. This intermittent or low power operation is believed to have begun in mid-2014.[7]

There appears to be less activity at the reactor site than in previous images. On June 8, 2016, the two large open bed trucks that were visible in previous imagery dated May 22, 2016, are no longer present. In fact, as of June 8, no vehicles or trucks are present at the entrance of the 5 MWe reactor. Only one dark unidentified object, possibly an oil stain, is visible at this location.

A large open bed truck is parked at the entrance of the Experimental Light Water Reactor (LWR). However, no other signatures of significant external activities are visible here. When finished, this reactor could produce significant amounts of weapon-grade plutonium for nuclear weapons.

Amount of Plutonium Being Separated

With more evidence that North Korea has separated plutonium at the Radiochemical Laboratory, it is important to ask: How much plutonium for nuclear weapons could North Korea have produced and separated at Yongbyon since the 5 MWe reactor restarted? The amount of plutonium separated will depend on the amount of plutonium produced in the 5 MWe reactor since it restarted in mid-2013. ISIS previously estimated that the reactor produced roughly 3-4 kilograms of weapon-grade plutonium between the summer of 2013 and the end of the summer of 2014.[8] During this one year period, the reactor appeared to run continuously, although perhaps not at full power. Since mid-2014, the reactor has operated

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[5] David Albright and Kevin O'Neill, *Solving the North Korean Nuclear Puzzle* (Washington, DC: Institute for Science and International Security Press, 2000).

[6] See David Albright and Serena Kelleher-Vergantini, "April 2016: Monitoring Activities at Yongbyon Nuclear Site," April 29, 2016, http://isis-online.org/uploads/isis-reports/documents/Monitoring_Activities_at_Yongbyon_Nuclear_Site_April_29_2016_FINAL.pdf.

[7] As previously noted, the reactor may have been shut down at certain times during this timeframe.

[8] "North Korean Plutonium and Weapon-Grade Uranium Inventories," op. cit., p. 8.

intermittently or at relatively low power, based on analyses of satellite imagery and interviews with government officials who monitor the plant closely. These officials have stated that the reactor has not been shut down during the past two years. Analysis of commercial satellite imagery supports this assessment. During this roughly 21-24 months period of intermittent operation, the 5 MWe reactor could have produced an additional 2.5-4 kilograms of plutonium. In total, the reactor could have produced an estimated 5.5-8 kilograms of weapon-grade plutonium since its 2013 restart.

This amount of plutonium is enough for one to four nuclear weapons, assuming 2-4 kilograms of weapon-grade plutonium per weapon, or a central estimate of 2.5 nuclear weapons equivalent. The number of weapons could increase if North Korea uses weapon-grade uranium in combination with the plutonium, but that scenario is not considered in this report.

Estimating the amount of plutonium separated during the last three years is complicated by the absence of public information on the amount of fuel that North Korea has unloaded from the 5 MWe reactor. The first indications of fuel being unloaded after the 2013 restart dates back to the end of 2014, but these indications were ambiguous (see here). Moreover, North Korea's fuel re-loading strategy for the reactor may have changed in the last several years. North Korea may no longer operate the reactor for a period of time, shut it down, and then unload all the fuel in the core before reloading fresh fuel, as it has done in the past. Instead, North Korea may be capable of refueling the reactor online. This entails unloading part of the fuel in the core and replacing that portion with fresh fuel while the reactor continues to operate, e.g. is online. This type of on-line fuel reloading was part of the original design of this reactor.

In any case, the Radiochemical Laboratory is oversized for the fuel discharges of the 5 MWe reactor. It was built to handle not only spent fuel from the 5 MWe reactor but also from a 50 MWe reactor North Korea never completed. The plant is thus capable of processing all the irradiated fuel in the 5 MWe reactor core within 3 to 6 months.[9] If reprocessing in the Radiochemical Laboratory started near the beginning on this year, North Korea could have finished separating most of the estimated 5.5-8 kilograms of plutonium produced in the 5 MWe reactor since it restarted in 2013. It could certainly finish reprocessing all this plutonium during this summer.

In estimating the number of nuclear weapons North Korea has produced, the key plutonium value is the amount separated (see below). While the plutonium is in irradiated fuel, it cannot be used in nuclear weapons.

[9] *Solving the North Korean Nuclear Puzzle,* op. cit.

Suspect Isotope Separation Plant

On June 8, 2016, several signatures of external activity are visible at a site ISIS identified as a possible isotope separation facility, located east of the fuel fabrication facility.[10] The exact purpose and operational status of this new facility remains unknown. However, based on analysis of suspect hot cells inside this building, it is suitable for separating tritium from irradiated targets. This tritium could be used in thermonuclear weapons, which North Korea has said it intends to develop.

As figure 4 shows, a small extension has been added to the main building at this site. Construction material and a truck are visible outside the building. Additionally, the June 8 image shows the presence of possible water ponds. One set of ponds is located immediately south of the main building, while a smaller set of ponds is visible southeast of the smaller building at the site.

North Korea may have earlier extracted small amounts of tritium at the Isotope Production Laboratory. This aged facility is located at the north end of the Yongbyon site near the small IRT reactor.

Centrifuge Plant

No significant external activity was visible at North Korea's uranium enrichment facility on June 8, 2016. This site is part of a larger complex, parts of which are located outside the Yongbyon site, to make weapon-grade uranium for nuclear weapons.

The Yongbyon centrifuge plant could have made enough weapon-grade uranium in 2015 and the first half of 2016 for 2.6 to 6.5 nuclear weapons equivalent, rounded to 3-7 nuclear weapons equivalent (central estimate), assuming that only weapon-grade uranium were used in a nuclear weapon.

Estimated Total Additional Nuclear Weapons Production from Plutonium and Weapon-Grade Uranium at Yongbyon

In 2015, the Institute conducted a comprehensive estimate of the amount of separated plutonium, weapon-grade uranium, and numbers of nuclear weapons in North Korea. The central estimate was that North Korea had 10-16 nuclear weapons, as of the end of 2014.[11]

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[10] See David Albright and Serena Kelleher-Vergantini, "Yongbyon: A Better Insight into the Status of the 5MWe Reactor," April 29, 2015, http://isis-online.org/isis-reports/detail/yongbyon-a-better-insight-into-the-status-of-the-5mwe-reactor/10#images; "Update on North Korea's Yongbyon Nuclear Site," September 15, 2015, http://isisonline.org/uploads/isisreports/documents/Update_on_North_Koreas_Yongbyon_Nuclear_Site_September15_2015_Final.pdf.

[11] Albright, "North Korean Plutonium and Weapon-Grade Uranium Inventories," op. cit.

Although a comprehensive update is not done in this report, it is useful to consider a partial update, based on recent activities at the Yongbyon Plant and on central estimates only.

Since the end of 2014, North Korea likely further increased its stocks of separated weapon-grade plutonium and weapon-grade uranium. How much more could it have produced and how many more nuclear weapons could it have built, based only on activities at Yongbyon? As discussed above, separated plutonium is considered because only in that form can the plutonium be used in nuclear weapons. So, even though the reactor produced plutonium since 2013, its separation was within the last year and thus adds to the total separated plutonium stock that existed at the end of 2014.

This analysis does not include the additional contribution post-2014 of a possible second centrifuge plant to the weapon-grade uranium stock. Moreover, this report does not fully address the uncertainties in estimating the production of separated plutonium and weapon-grade uranium in North Korea, as was done in the Institute's earlier comprehensive estimate of nuclear explosive materials and nuclear weapons as of the end of 2014. Nonetheless, this report provides a rough indication of the potential growth in North Korea's nuclear weapons stockpile during the last 18 months or since the end of 2014.

Considering only activities at the Yongbyon site, North Korea may have produced enough additional nuclear explosive material for roughly another 5.1-9 nuclear weapons equivalent from the end of 2014 until now (central estimate). Not all of this material would likely end up in weapons. If 70 percent did so, then the increase would amount to about 3.6-6.3 nuclear weapons, rounded to 4-6 weapons. Adding this range to the end of the 2014 estimate of 10-16 weapons results in an estimate of approximately 14-22 nuclear weapons as of June 2016. One weapon should be subtracted from this total to reflect the underground test in early 2016, resulting in a final estimate of 13-21 nuclear weapons as of today. It should be noted again that the upper bound, or 21 weapons, is expected to be greater in a comprehensive estimate because this report does not include the effect of any weapon-grade uranium produced in a second centrifuge plant. Nonetheless, this exercise, despite not being comprehensive, shows that North Korea could be significantly increasing its nuclear weapons capabilities. Most of this increase since 2014 can be attributed to the production of weapon-grade uranium.

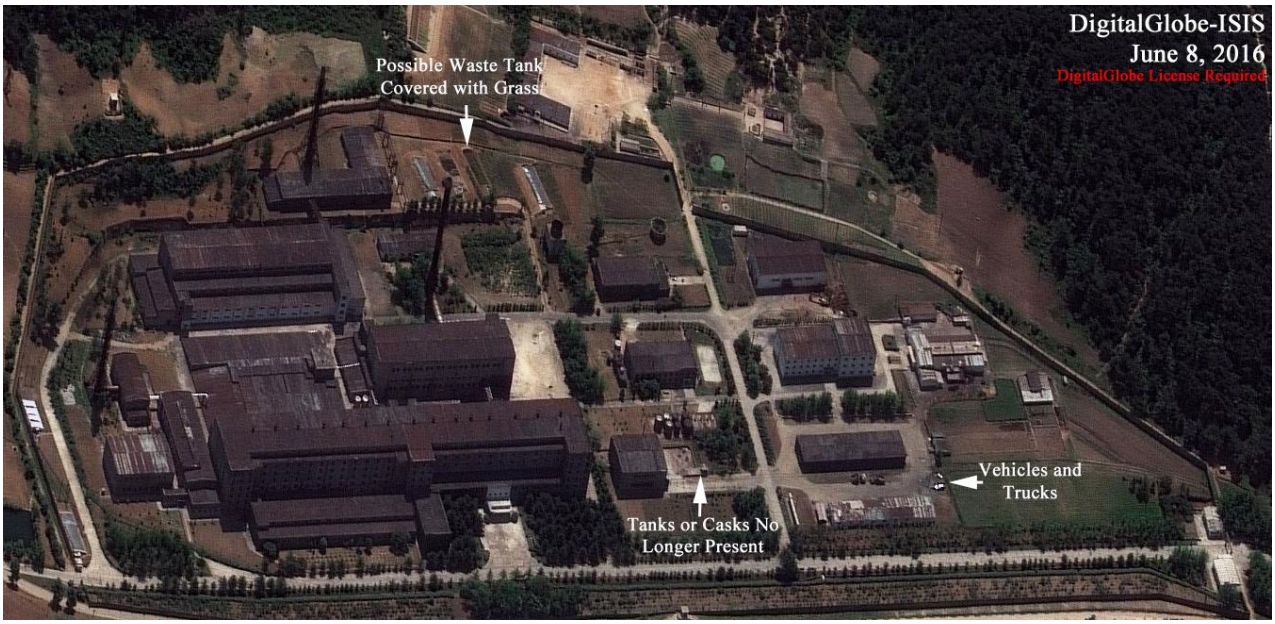

Figure 1. DigitalGlobe imagery showing North Korea's Radiochemical Laboratory on June 8, 2016.

Figure 2. DigitalGlobe imagery showing Building 500 and the coal fired steam generation plant on June 8, 2016.

Figure 3. DigitalGlobe imagery showing North Korea's 5 MWe and LWR reactors on June 8, 2016.

Figure 4. DigitalGlobe imagery showing the possible isotope separation facility at Yongbyon on June 8, 2016.

Figure 5. DigitalGlobe imagery showing the fuel fabrication facility at Yongbyon on June 8, 2016.