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# Annex:
# North Korea's Long Path to Uranium Enrichment Capacity

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In the early 1990s, the international community had growing nonproliferation concerns about the Democratic People's Republic of Korea (DPRK) developing graphite-moderated, gas-cooled reactors and reprocessing capabilities, which formed a foundation for a significant nuclear weapons program. However, little attention was paid to uranium enrichment—the other path to building the bomb—in part because it was believed to be beyond the North's technical capabilities. That said, there was a provision in the North-South Joint Declaration on the Denuclearization of the Korean Peninsula stating there would be no uranium enrichment facilities on the peninsula. Moreover, while the 1994 Agreed Framework focused primarily on the plutonium program, the agreement also obligated the North Koreans to implement the 1992 deal, including its provisions covering enrichment.

While the international community was largely focused on the North's plutonium production program, increasing signs started to emerge that North Korea was, indeed, working to build a uranium enrichment program as well.

## Tapping Foreign Expertise

There are several indications that North Korea began research and development in uranium enrichment in the late 1980s, including acquisition of key vacuum equipment from European companies that were also involved in uranium enrichment efforts of Iran, Iraq, Libya and Pakistan. However, like in Iran and Libya, the first attempts to master uranium enrichment technology ran into difficulties, leading countries to acquire additional support from Pakistan.

Relations with the Kahuta Research Laboratories (Khan Research Laboratories, KRL) grew in 1993 when Prime Minister Benazir Bhutto visited North Korea to acquire missile technology. North Korea received a substantial boost to enrichment plans after 1997, when Pakistan provided the North two dozen P-1 and P-2 centrifuges and other equipment, including small amounts of uranium hexafluoride (UF6, a compound used in the production of enriched uranium).

This support, which likely took place under the auspices of a government-to-government agreement on missile technology, was acknowledged by former Pakistani President General P. Musharraf in his memoirs.[1] The International Atomic Energy Agency (IAEA) also had information indicating that nuclear cooperation was a part of this agreement,[2] which has recently been confirmed in a history of Prime Minister Bhutto.[3] Some later reports suggest that the actual delivery of centrifuge equipment took place in 2000,[4] but there are also claims that the assistance was provided in 2002 just before the existence of the A.Q. Khan nuclear nonproliferation network was exposed.[5]

In either case, the early 2000s appear to have been an important benchmark in North Korea's uranium enrichment program development. Research and development (R&D) and large-scale manufacturing of centrifuges on an industrial or semi-industrial scale are challenging multi-year tasks. Though Pyongyang received "a starter kit" of a couple of dozen centrifuges, components and other equipment from Pakistan, it had to go through a normal R&D process to develop the technical know-how to establish manufacturing capabilities and to build an actual enrichment plant.

Experienced uranium enrichment developers apply the following "rules of thumb" in the development and fielding of new centrifuges:

- Year One: testing of single centrifuges
- Year Two: tests with centrifuges in small cascades
- Year Three: tests with full-size cascades
- Years Four and Five: gradually building up a small demonstration-scale uranium enrichment plant with 1,000-2,000 centrifuges

## Acquisition of Key Raw Materials

When we look at the receipt of the starting kits and acquisition of relevant equipment, North Korea should have been able to have a demonstration plant by 2005 at the earliest, if it confronted no major obstacles. That should have been preceded by extensive R&D in a location, which remains unknown.

[1] Pervez Musharraf, *In the Line of Fire*: *A Memoir* (London: Simon & Schuster, 2006), 286.
[2] Mohamed ElBaradei, *The Age of Deception: Nuclear Diplomacy in Treacherous Times* (New York: Metropolitan Books, 2011), 174.
[3] Owen Bennett-Jones, *The Bhutto Dynasty: The Struggle for Power in Pakistan* (New Haven: Yale University Press, 2020), 191.
[4] David Albright, *Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies* (New York: Free Press, 2010), 165.
[5] Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb* (Stanford: Stanford University Press, 2012), 246-247.

The receipt of equipment around 2000 coincides with the delivery of UF6 from North Korea to Libya via Pakistan.[6] This was followed by the North's procurement efforts, which have been analyzed in detail by David Albright. He identified procurements from around 2002-2003, which could have been sufficient for manufacturing up to 8,000-12,000 P-2-type centrifuges.

Between 2003 and 2008, several additional procurement efforts could have resulted in the acquisition of raw materials for several thousand more centrifuges. According to Albright, further acquisitions were identified by the end of 2010 and in early 2016, but there is no evidence of procurements of maraging steel, which is needed to manufacture P-2 centrifuge rotors. In the early 2000s, a European manufacturer shipped several UF6 containers of various sizes to North Korea using a North Korean ship.[7]

After the first North Korean nuclear test, United Nations Security Council Resolutions (UNSCR) 1718 (2006) and 1874 (2009) prohibited, *inter alia*, the procurement of nuclear-related items, including the transfer to or from the Democratic People's Republic of Korea of services and assistance related to the "provision, manufacture, maintenance or use" of the proscribed items. To monitor and enforce the resolutions, UNSCR 1874 established a Sanctions Committee (the Committee), which is supported by a Panel of Experts (POE).

The Committee took stock of North Korea's known nuclear and enrichment programs in its reports from 2012 and 2013; subsequent reports monitored key nuclear installations in the Yongbyon Nuclear Scientific Research Center using commercial satellite imagery, but they do not provide tangible information on the North's progress in acquiring nuclear-related equipment and materials or in uranium enrichment.

Like many other countries, North Korea likely relies increasingly on its own industrial infrastructure to produce the necessary items for its nuclear program, as it has done with the development of ballistic missiles. Recent advanced missiles, for example, have used carbon fiber, which could also be utilized in manufacturing centrifuges. To this end, North Korea may use lower strength and quality materials, which would result in lower enriched uranium production rates.

## North Korean Statements

In 2002, DPRK officials acknowledged in their bilateral talks with the US the existence of a uranium enrichment program, which the North subsequently denied in August 2003. As requested by the participants of the Six Party Talks, the IAEA started monitoring the shutdown of the Nuclear Fuel Fabrication Plant, the 5 MWe Experimental Nuclear Power Plant, the

[6] IAEA, *Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya*, GOV/2004/33, June 1, 2004, Annex 1, paragraph 20, https://fas.org/nuke/guide/libya/iaea0504.pdf.
[7] Author interview with an engineer of the European company.

Radiochemical Laboratory (reprocessing plant) and the 50 MWe Nuclear Power Plant (under construction) located at Yongbyon, and the 200 MWe Nuclear Power Plant (under construction) in Taechon. The monitoring mandate did not, however, cover other safeguard implementation issues such as North Korea's uranium enrichment activities.

On April 14, 2009, the DPRK informed the IAEA of its decision to cease all cooperation immediately with the Agency and requested that its personnel remove all of its monitoring equipment from the facilities. Two days later, the Agency's inspectors departed from the country, and since then has used satellite imagery, open-source information and information received from its member states to monitor the nuclear activities of North Korea. Since ending its presence in North Korea in 2009, the IAEA Secretariat has provided annual written reports on its relevant nuclear findings in North Korea.

In April 2009, North Korea announced that it would "make a decision to build a light water reactor power plant and start the technological development for ensuring self-production of nuclear fuel as its first process without delay."[8] In June 2009, it declared that uranium enrichment would commence on an experimental basis.[9] This was followed in September 2009 with a statement that "[e]xperimental uranium enrichment has successfully been conducted to enter into completion phase."[10] In August 2016, *Kyodo News* reported North Korean statements that it had been producing highly enriched uranium necessary for nuclear arms and power, but no information on quantities of enriched uranium and the locations of these activities was provided.

In November 2010, a US delegation was invited to visit Yongbyon, where the group was shown a Uranium Enrichment Plant (UEP). The North Korean hosts told the US delegation that construction of the facility had started in April 2009, and that it contained approximately 2,000 centrifuges. According to the delegation's head, Dr. Siegfried Hecker, they appeared to resemble the Pakistani's P-2 centrifuge design installed in six cascades with a capacity of 8, 000 separative work units (SWUs) per year. The team was also told that the installation was operational and was configured to produce low-enriched uranium (LEU) for the Experimental Light Water Reactor (ELWR) under construction at Yongbyon.

## Conclusion

In light of the timing of the transfer of technologies from Pakistan, the DPRK's procurement efforts, limited intelligence information and other information including satellite imagery, North Korea should have at least three locations associated with uranium enrichment: 1) an early R&D

[8] "UNSC Urged to Retract Anti-DPRK Steps," *KCNA*, April 29, 2009.
[9] "DPRK Foreign Ministry Declares Strong Counter-Measures against UNSC's 'Resolution 1874,'" *KCNA*, June 13, 2009.
[10] "DPRK Permanent Representative Sends Letter to President of UNSC," *KCNA*, September 4, 2009.

facility at an unknown location; 2) an active Uranium Enrichment Plant at Yongbyon; and 3) a possible additional enrichment plant at an unidentified location.

*This annex supplements "New Evidence Suggests Kangson Is Not A Uranium Enrichment Plant," by Olli Heinonen, published on 38 North, December 18, 2020, https://www.38north.org/2020/12/kangson201218/.*