Taking Stock:
North Korea's Uranium Enrichment Program

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Executive Summary

North Korea's centrifuge program poses both a horizontal and a vertical proliferation threat. It is an avenue for North Korea to increase the number and sophistication of its nuclear weapons and for it to proliferate to others who seek to build their own centrifuge programs. As a result, the priority is finding ways to either stop the program or to delay its progress through a combination of negotiations and sanctions.

Procurement data obtained by governments and information from Pakistan, establish that North Korea is developing centrifuges. However, determining the centrifuge program's status and the locations of its centrifuge facilities is difficult.

Known procurements for North Korea's centrifuge program do not show whether North Korea is able to produce significant amounts of highly enriched uranium. Yet the data support that North Korea has moved beyond laboratory-scale work and has the capability to build, at the very least, a pilot-scale gas centrifuge plant. However, the procurement data do not contain consistent numbers of procured items that would indicate the construction of a 3,000 centrifuge plant, large enough to produce enough weapon-grade uranium for about two nuclear weapons per year.

Faced with uncertainties in assessments of North Korea's centrifuge program, the U.S. intelligence community focused on the significance of the 2007 and 2008 discoveries of traces of highly enriched uranium (HEU) found on North Korean aluminum tubes and operating records for the Yongbyon nuclear reactor. The discoveries raised anew concerns that North Korea had a secret gas centrifuge plant operating by the mid-2000s, contradicting assessments based on procurement data. The enriched uranium particles remain the most direct evidence that North Korea has produced highly enriched uranium. But the reported lack of consensus on their meaning warrants caution in reaching a firm conclusion. Moreover, even if North Korea produced the HEU, without further evidence, that conclusion does not translate to North Korea having a facility able to produce weapon-grade uranium on a significant scale, such as in a plant with 1,000-3,000 centrifuges.

North Korea has stated it intends to build a large enrichment plant this decade, and there is no reason to doubt its intentions. To succeed, North Korea will likely need to overcome several technical challenges. North Korea could also face additional difficulties in completing the plant as a result of actions by the United Nations Security Council and the broader international community.

The most effective way to end the threats posed by North Korea's centrifuge program is through negotiations, even though that route currently looks difficult. If discussions with North Korea resume, negotiators should view the North Korean uranium enrichment program as a priority and focus on obtaining an agreement to verifiably disable and eventually dismantle this program. Until an agreement is implemented, at least involving a declaration and disablement, sanctions affecting North Korea's nuclear program should remain in place.

Given the number of references to uranium enrichment in its announcements over the last two years, North Korea may make its uranium enrichment program a topic of discussion in future diplomatic talks, either seeking to use it as a bargaining chip or arguing that it should continue as a peaceful nuclear

program. It is therefore important for negotiators to prepare now in case the gas centrifuge program becomes a major challenge at the start of any negotiations.

Equally important, negotiators should focus early on obtaining a North Korean commitment that it will halt illicit procurements from abroad for its nuclear programs and end the proliferation of its nuclear technology. The latter is especially important for negotiations to establish in a verifiable manner.

While waiting for negotiations to bear fruit, the United States and its allies will face two interconnected challenges. They must slow down North Korea's centrifuge program, or at least make progress more costly and visible to the international community. In addition, they must ensure that North Korea does not proliferate centrifuge, reactor, or other nuclear technology. A critical part of achieving both goals will be thwarting North Korean illicit nuclear trading activities both for itself and others.

U.N. Security Council Resolutions 1718 and 1874 are particularly useful for disrupting North Korea's ability to procure for its uranium enrichment program and proliferate nuclear goods. Better implementation of these resolutions must be a priority, particularly implementing the May 2010 findings of the panel of experts established by U.N. Security Council Resolution 1874.

North Korea frequently procures for its uranium enrichment program either directly in China or by using it as a transshipment point. China is unlikely to view North Korea's continued illicit procurement for its nuclear program as strengthening Chinese national security interests. Most believe that China views North Korea's nuclear weapons program as destabilizing to the region. Likewise, there is no evidence that the Chinese government is secretly approving or willfully ignoring exports to North Korea's centrifuge program in an effort to strengthen North Korea's nuclear weapons program. Nonetheless, China is not applying enough resources to detect and stop North Korea's illicit nuclear trade. Although China has taken many actions recently to bolster its implementation of trade controls and U.N. Security Council resolutions, it should do more. As China seeks to be a global leader, it should also be willing to shoulder the responsibilities that attend such a status. Preventing nuclear proliferation is one of the most important global responsibilities.

The way forward must focus on moving diplomacy forward, obtaining greater Chinese cooperation, and implementing a robust international regime against North Korea's nuclear proliferation and illicit procurement for its nuclear programs.

Table of Contents

PART 1 – INTRODUCTION AND OVERVIEW

Since mid-2009, North Korea has admitted it has a uranium enrichment program and implied that it will enrich uranium on a significant scale in the near future. After years of denial, North Korea mentioned its uranium enrichment program in public statements as tensions increased following its ballistic missile test in April 2009, its May 2009 nuclear test, and the subsequent imposition of United Nations Security Council sanctions against North Korean trading entities.

Despite its announcements, determining when it may produce significant quantities of highly enriched uranium (HEU) remains challenging. Although North Korea has not provided any concrete information about the actual status of its enrichment effort, its statements and information about its procurements abroad suggest it may be able to bring into operation a large uranium enrichment plant during this decade. But doing so will require North Korea to obtain a range of nuclear-related goods and expertise abroad. It is not self-sufficient in the wherewithal to make enriched uranium, so it seeks a wide variety of products overseas to both develop and build an enrichment plant.

A priority is deepening understanding of North Korea's enrichment program and finding diplomatic and non-military means to inhibit its progress. The resumption of the Six Party Talks is the most direct way to seek a verifiable declaration and disablement of this program. In lieu of successful negotiations, the most effective options to inhibit the program's progress rest on U.N. Security Council resolutions 1718 and 1874. If implemented effectively, they provide mechanisms to prevent North Korea from obtaining vital goods it needs to build and maintain an enrichment facility. Key to successful implementation is greater Chinese cooperation. In addition, improvements in national trade controls need to include greater industry awareness of North Korean smuggling methods and closer industry/government cooperation to detect and thwart its procurement efforts.

North Korean Statements

On June 13, 2009, North Korea announced it would commence uranium enrichment, stating "enough success has been made in developing uranium enrichment technology to provide nuclear fuel to allow the experimental procedure."[1] In September 2009, North Korea announced that experimental uranium enrichment had entered into the "completion phase."[2] On March 29, 2010, North Korea stated that it would produce low enriched uranium for its own light water nuclear power reactor in the "near future in the 2010s."[3] On June 27, 2010, a North Korean Foreign Ministry spokesman said that recent developments underscore the need for the North "to bolster its nuclear deterrent in a newly developed way to cope with persistent" U.S. hostility and its military threat.[4] Could this

[1] KCNA, "DPRK Foreign Ministry Declares Strong Counter-Measures against UNSC' Resolution," June 13, 2009.
[2] KCNA, "DPRK Permanent Representative Sends Letter to President of UNSC," September 4, 2009.
[3] KCNA, March 29, 2010. Full text reproduced by BBC Monitoring Asia Pacific, March 30, 2010. The full sentence follows: "The DPRK will witness the appearance of a light water reactor power plant relying on its own nuclear fuel in the near future in the 2010s in the wake of mass-production of juche iron and Juche-based vinalon cotton." Juche iron and vinalon cotton, a synthetic fiber that serves as North Korea's national thread, were recently displayed prominently in North Korean media as major technological accomplishments. See for example, B.R. Myers, "In North Korea, Juche Iron vs. American Crows," *The New York Times*, April 17, 2010. On June 25, 2010, this statement could not be found in the archives for the date March 29, 2010 on the KCNA English web site, http://www.kcna.co.jp/index-e.htm.
[4] Simon Martin, "N.Korea vows to bolster nuclear deterrent," Agence France Presse. June 27, 2010; see also KCNA, June 28, 2010.

mean that it is now or will soon be producing highly enriched uranium?

Interpreting these elliptic announcements is challenging, but most believe that North Korea is unlikely to be bluffing about pursuing uranium enrichment. Moreover, few believe that if North Korea does build an enrichment plant, the enriched uranium will be strictly for peaceful nuclear uses. More likely, the plant will produce highly enriched uranium for nuclear weapons. Fueling this assessment, North Korea has not demonstrated any capability to build a light water reactor, which requires a range of technological capabilities that are lacking in the country. However, it is unclear whether North Korea can successfully build and operate an enrichment plant to produce significant quantities of highly enriched uranium for nuclear weapons.

North Korea has not officially admitted which enrichment technology it is developing. But it is known to have acquired centrifuge technology and centrifuge-related goods. In the 1990s, it received considerable assistance from the Pakistani engineer A.Q. Khan and his centrifuge associates at the Khan Research Laboratories (KRL). In addition, North Korea has used its own nuclear smuggling networks to procure a range of nuclear and nuclear dual-use goods internationally, often via China, that appear to be for Pakistani-type centrifuges.

The Risk

A North Korean gas centrifuge program poses several risks for the international community. The first is that it could lead to a supply of HEU for use in nuclear weapons. It is unknown how North Korea would seek to use HEU in nuclear weapons, but it would have several options to increase the quantity and quality of its nuclear weapons. Currently, North Korea is limited to roughly one dozen nuclear weapons due to constraints on its plutonium stock.[5] North Korea might simply decide to build a stock of HEU-based fission weapons similar in design to its plutonium weapons. It could also combine both HEU and plutonium in a fission weapon to create a weapon with a greater explosive yield. It could seek to develop two-stage thermonuclear weapons. If North Korea seeks more advanced weapons, it would likely want to conduct more underground nuclear tests.

A growing concern is that North Korea would provide centrifuge equipment, facilities, and technical know-how or even HEU to other countries or groups. It has demonstrated the capability and inclination to provide nuclear goods to customers abroad. North Korea found profitable and suffered few consequences for its proliferation of reactor technology and components to Syria.[6] Its proliferation of centrifuges or the underlying technology and its facilitation of related purchases abroad could also be lucrative. Its international consortium of illicit trading entities and overseas accomplices, combined with ready access to centrifuge technology and its own centrifuge experts, could over time rival the now defunct Khan network in both its sophistication and ability to provide turnkey centrifuge plants.

North Korea has a long history of subterfuge in carrying out its overseas sales. Recently, a United Nations panel of experts, its creation mandated under U.N. Security Council resolution 1874, scrutinized North Korea's illicit, secret exports. Based on an analysis of recent conventional arms exports, the panel of experts concluded that that North Korea "has used a number of masking techniques in order to circumvent the Security Council measures,

[5] ISIS, *ISIS Estimates of Unirradiated Fissile Material in De Facto Nuclear Weapon States, Produced in Nuclear Weapon Programs*, to be published. The ISIS estimate is if North Korea uses 2-5 kg of plutonium per weapon, it has enough plutonium for 6-18 nuclear weapons. The central estimate is 12 nuclear weapons.

[6] Albright, *Peddling Peril* (New York: Free Press, 2010).

including false description and mislabeling of the content of the containers, falsification of the manifest covering the shipment, alteration and falsification of the information concerning the original consignor and ultimate consignee, and use of multiple layers of intermediaries, shell companies, and financial institutions."[7]

Since the passage of resolution 1874 in 2009, the panel of experts did not learn of any official allegations about North Korea receiving or providing proscribed nuclear-related or ballistic missile-related items, technology, or know-how. Nonetheless, its review of several government, International Atomic Energy Agency (IAEA), and private assessments indicated continuing North Korean involvement in nuclear and ballistic missile related activities in certain countries, including Iran, Syria, and Myanmar.[8]

Potential customers of centrifuge technology remain hard to identify with certainty. But the reclusive military regime in Myanmar may have already benefited from North Korean largesse in this area.[9] Syria is a potential customer, as it contemplates its future nuclear options. North Korea could provide equipment or cooperate with Iran's centrifuge effort. It is already suspected of working with Iran on nuclear-related procurements. If Iran obtains nuclear weapons, other Middle Eastern customers could emerge. Lastly, surprises could develop. Would Venezuela buy centrifuges from North Korea? Would criminal elements or terrorists groups seek this technology from North Korea, and would it be willing to sell to them?

At some point, a failing regime or new leadership in North Korea might decide to sell HEU to a foreign customer. Elements in a collapsing North Korea might seek to profit from the ensuing chaos. But even if the regime remains in power, it could decide to sell HEU to the highest bidder, particularly if it masters centrifuges and manages to produce HEU well in excess of its need for its own nuclear weapons.

Earlier ISIS Assessment

Available information supports a start date for North Korea's gas centrifuge program in the early 1990s.[10] During the remainder of the 1990s, North Korea appears to have concentrated on acquiring model centrifuges and learning the complex processes to produce centrifuge components and the centrifuge feed gas uranium hexafluoride.

In the early 2000s, North Korea acquired large quantities of raw aluminum tubes, or "pre-forms," with specifications that matched those used for the outer casing of a P2 centrifuge, a type that A.Q. Khan is known to have supplied North Korea. In addition, it acquired a wide range of other centrifuge-related equipment and materials, leading many to conclude that North Korea was planning or taking steps to build a gas centrifuge plant. According to a European intelligence official familiar with the estimates, North Korea had in the early 2000s a definitive plan to set up a centrifuge plant of about 3,000 centrifuges, which is enough to produce at least 50 kilograms of weapon-grade uranium per year or enough for 2-3 nuclear weapons per year.

According to a fact sheet distributed by the CIA to Congress on November 19, 2002, the CIA had just learned of "clear evidence indicating that North Korea had begun constructing a centrifuge facility." The CIA assessed that this plant could produce annually enough HEU for two or more nuclear weapons per year when it is finished, and

[7] Panel of Experts, *Report to the Security Council from the Panel of Experts established Pursuant to Resolution 1874 (2009)*, May 2010, paragraph 5.
[8] Panel of Experts, op. cit. paragraph 5.
[9] David Albright, Paul Brannan, Robert Kelley and Andrea Scheel Stricker, *Burma: A Nuclear Wannabe; Suspicious Links to North Korea; High-Tech Procurements and Enigmatic Facilities*, January 28, 2010.
[10] *Peddling Peril*, op. cit.

it could be fully operational "as soon as mid-decade."[11]

Surprisingly, little substantiating information surfaced after this assessment. Firm evidence to support the existence or schedule of the construction of a large-scale centrifuge plant did not emerge. Evidence of ongoing, large-scale procurements of sensitive centrifuge equipment and materials likewise remained missing. Given North Korea's limited capabilities, it would have been expected to seek many sensitive items for the plant from abroad,

Faced with a growing lack of evidence of any such plant, many U.S officials started to downplay the worst-case conclusions in the CIA's factsheet. Intelligence community officials expressed uncertainty about the actual scale of the facility, particularly after the Iraqi weapons of mass destruction (WMD) fiasco and general loss of faith in CIA assessments about WMD. By the end of 2003, intelligence officials were expressing doubts about the quality of the underlying evidence of a sustained North Korean effort to build a centrifuge plant. One senior Pentagon nuclear expert, who accepted that North Korea appeared to be buying for a centrifuge plant, questioned whether North Korea knew how to build and operate a centrifuge plant.[12]

In 2004, additional U.S. intelligence officials downplayed the original assessment. One former State Department official stated that there were disagreements over the projected schedule for the completion of the centrifuge plant.

The aluminum tubes sought or procured by North Korea were easy to obtain internationally at that time. By themselves, they were not a reliable indicator of the existence, status, or construction schedule of a gas centrifuge plant. Without other information about the procurement of more sensitive centrifuge components or other concrete information about a centrifuge plant, projections of the construction of a large-scale plant and its possible completion date came to be viewed critically. One knowledgeable, former senior U.S. official said: "The idea that I can tell you that by mid-decade they are going to be producing a couple bombs' worth of HEU is simply bad tradecraft."[13]

In addition, U.S. officials may have oversold a supposed admission by North Korean officials about having a centrifuge program. During a confrontation in Pyongyang in October 2002 with U.S. officials, North Korean officials allegedly admitted to having a centrifuge program. The former senior official mentioned directly above said regarding the admission, "The notion that they admitted to the HEU isn't as clear-cut in the transcript as in the oral tradition that the meeting seemed to foster."[14] Regardless, North Korean officials were never reported to have said in this meeting that they were building a large-scale plant.

Skepticism continued to grow. One senior U.S. official knowledgeable about the intelligence on North Korea's nuclear program said in January 2007 that there had not been evidence in the last few years of procurements for a large-scale North Korean centrifuge program.[15] In early 2007, Christopher Hill, then Assistant Secretary of State, expressed the view of skeptics while speaking at the Brookings Institution in Washington: "A number of countries have seen that North Korea made certain purchases of equipment which is entirely consistent with a highly enriched uranium program." But he added that such a program would "require a lot

[11] A shorter version of this fact sheet is on the web site of the Federation of American Scientists at November 2002 National Intelligence Estimate on North Korea, or www.fas.org/nuke/guide/dprk/cia111902.html.
[12] Interview, December 16, 2003.
[13] Joel Wit, "Enhancing U.S. Engagement with North Korea," *The Washington Quarterly*, Spring 2007.
[14] Ibid.
[15] Interview, January 7, 2007.

more equipment than we know that they have actually purchased" and "production techniques that we are not sure whether they have mastered."[16]

A Director of National Intelligence (DNI) unclassified report from August 2007 echoed Hill's doubts, "We continue to assess with high confidence that North Korea has pursued efforts to acquire a uranium enrichment capability, which we assess is intended for nuclear weapons. All Intelligence Community agencies judge with at least moderate confidence that this past effort continues. The degree of progress towards producing enriched uranium remains unknown, however."[17]

The Section 721 Unclassified Report to Congress, covering the period January 1 to December 31, 2008, gave a nuanced assessment: "Although North Korea has halted and disabled portions of its plutonium production program, we continue to assess North Korea has pursued a uranium enrichment capability at least in the past. Some in the [Intelligence Community] have increasing concerns that North Korea has an ongoing covert uranium enrichment program."[18]

Faced with a dearth of additional procurement data or any specific information about a centrifuge plant, some officials went so far as to say that construction never started or did not progress very far. Most, including ISIS, concluded by 2007 that this plant was unlikely to have been built in the 2000s, but that nonetheless, North Korea was maintaining a gas centrifuge development program. A small-scale centrifuge development program involving a few tens of centrifuges in nondescript facilities is extremely difficult to detect, let alone characterize.

A February 2007 ISIS report laid out three alternatives to the CIA assessment, which had posited the completion of a large centrifuge plant in the 2000s:[19]

- The reclusive, totalitarian state sought to acquire everything it could for a centrifuge program, despite its inability to actually build a functioning facility. The items may have been placed in storage and plant construction never progressed significantly.
- North Korea bought the centrifuge goods for someone else.
- The scale-up stalled, despite initial preparations that could have even included partially constructing the plant. A reason offered by U.S. intelligence officials in March 2007 is that after the United States confronted North Korea about the enrichment program in October 2002, North Korea scaled back its efforts.

New information eliminates the second possibility in which North Korea bought these centrifuge goods for another country. That does not mean, however, that in other cases North Korea did not buy sensitive goods for other countries. A recent example is a North Korean entity's purchase for Myanmar of dual-use equipment usable in missile or centrifuge programs.[20] The equipment included a grinder

[16] All Hill quotes in this paragraph are from The Associated Press, "Questions Over North Korea's Alleged Uranium Program Could Undo Disarmament Deal," March 1, 2007.

[17] *Unclassified Report to Congress on Nuclear and Missile Programs of North Korea*, Office of the Director of National Intelligence, August 8, 2007.

[18] *Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions, Covering 1 January to 31 December 2008*, Office of the Director of National Intelligence.

[19] Albright, *North Korea's Alleged Large-Scale Enrichment Plant: Yet Another Questionable Extrapolation Based on Aluminum Tubes*, ISIS, February 23, 2007.

[20] *Burma: A Nuclear Wannabe*, op. cit. This report stated that the equipment could have ended up in Myanmar itself or been transshipped to North Korea or elsewhere. We learned after publishing our report that Japanese

and a magnetometer, which have the precision and strength to make ring magnets for gas centrifuges.

Another possibility discounted in the earlier ISIS report is that North Korea managed to hide the completion of a centrifuge plant for several thousand centrifuges from foreign intelligence services. This possibility certainly occurred to intelligence analysts in the mid-2000s, although they undoubtedly had little incentive to reveal U.S. intelligence weaknesses by admitting this possibility publicly. In this case, the October 2002 U.S. confrontation with North Korea might have driven the centrifuge plant construction further underground. However, the lack of any detection of significant procurements remained a powerful counter-argument to this possibility.

Before assessing North Korea current and future efforts to produce HEU, it is worth reviewing available information about North Korea's past centrifuge program. A considerable amount of information exists about North Korea's procurement for its centrifuge program from Pakistan or by its own nuclear smuggling entities. There is little information on any centrifuge sites or the program itself.

Procurements from A.Q. Khan

Reports date North Korea's first attempts to pursue gas centrifuge technology to the 1980s. IAEA inspectors have stated that North Korea explored gas centrifuges in the 1980s but had abandoned its effort because of technological limitations.[21] Yet North Korea's sale of a ballistic missile to Pakistan in the early 1990s provided an opportunity to gain access to A.Q. Khan's extensive centrifuge program and his experts. It was Khan Research Laboratories (KRL) that was responsible for producing the 1,500 kilometer-range Ghauri missile, a replica of the Nodong missile, which Pakistan purchased from North Korea.

The journalist Shyam Bhatia has alleged in his book that help on gas centrifuges was facilitated by Benazir Bhutto in 1993.[22] Although he is subject to Pakistani charges of bias as an Indian journalist, Bhatia was Bhutto's Oxford University classmate, and he met with her regularly afterwards. He wrote that Bhutto told him in a confidential interview the following: shortly after she became Pakistan's prime minister for the second time in the autumn of 1993, she carried CDs containing sensitive centrifuge data to North Korea. A key part of her 1993 visit was to negotiate with North Korea's founder, Kim Il Sung, for missile assistance.[23] Khan had told her that Pakistan could obtain this much-needed missile technology if it provided North Korea with centrifuge technology. The data were either a sweetener or intended as payment for the missile technology.

Publicly, however, Bhutto consistently said that Pakistan paid for missile technology and did not obtain it in exchange for centrifuge technology.[24] She was assassinated in late 2007, shortly before Bhatia's book was published. In one interview, however, she may have hinted that Bhatia was correct. When asked about payments for missile

investigators had determined that the end user of the equipment was Myanmar.

[21] According to a senior official close to the IAEA interviewed in August 2010, North Korean officials reported this to then IAEA Director General Hans Blix during his May 1992 trip to North Korea. This visit was intended to lay the basis for applying safeguards under the Nuclear Non-Proliferation Treaty (NPT) to North Korea's nuclear program. North Korea signed the NPT in 1985 but it did not finalize a safeguards agreement until January 1992.

[22] Shyam Bhatia, *Goodbye Shahzadi, A Political Biography of Benazir Bhutto* (New Delhi: The Lotus, Rolli Books, 2008).

[23] "Benazir Reveals Plot to Kidnap A.Q. Khan and ISI Links to Nuclear Black Market," *South Asia Tribune*, Issue no. 83, March 14-20, 2004.

[24] See for example, "Bhutto Says Pak Paid N. Korea for Missile Tech," *The Times of India Online*, February 10, 2004.

technology, she said that Pakistan made "installments of computer disks."[25]

Under the cover of its missile sales to KRL, North Korea appears to have received training in making centrifuges during the early to mid-1990s. Based on A.Q. Khan's statements, the North Korean missile experts started arriving at KRL in 1993 and 1994. They instructed KRL centrifuge engineers and technicians in manufacturing key missile parts. But North Korean trainers worked mainly in two workshops that were also producing centrifuge components and assembling and testing centrifuge subassemblies and whole centrifuges for the adjacent enrichment plant. They became interested and started asking about centrifuges. Khan has admitted that the North Korean missile experts likely gained access to sensitive areas of the workshops and acquired instruction in centrifuge manufacturing—at the time KRL was focused on the P2 centrifuge.[26] Pakistan's best centrifuge manufacturing engineers and technicians likely instructed the North Koreans in manufacturing and assembly procedures of the P2 centrifuge.

According to a senior North Korean defector, Hwang Jang-yop, who was the architect of the regime's Juche ideology and close to leader Kim Jong Il, North Korea and Pakistan formalized the sale for centrifuges in 1996. Hwang heard from Jun Byung Ho, a high ranking, highly decorated official who was secretary of the Workers Party department of arms and munitions industry and a Director General in the Second Economic Committee, that in 1996, Pakistan agreed to supply help on "developing enriched uranium nuclear weapons."[27] (see Figure 1) This agreement is believed to refer to Khan's provision of centrifuge documents and P1 and P2 centrifuges. However, the shipment of the centrifuges was delayed for several years, even after North Korea made the necessary payments. Jun Byung Ho himself complained to Khan in mid-1998 about the delay in the delivery of the centrifuges and associated documentation.

Figure 1: Jun Byung Ho, member of North Korea's National Defense Commission. Photo credit: Yonhap

Pakistani President Pervez Musharraf confirmed in his autobiography that North Koreans were regular visitors to top-secret centrifuge facilities at the Khan Research Laboratories.[28] He added that they received regular coaching on centrifuge technology and that Khan provided North Korea about 20 P1 centrifuges, four P2 centrifuges, and measuring equipment that would permit trial enrichment.[29] KRL engineers also provided centrifuge control equipment and produced centrifuge-related software for the North Koreans. According to a senior U.S. official, North Korea received centrifuge manuals from KRL, and KRL experts went to North Korea, possibly training North Koreans there on

[25] Benazir Reveals Plot to Kidnap A.Q. Khan," op. cit.
[26] *Peddling Peril*, op. cit., pp. 161-162.
[27] "Highest Ranking DPRK Defector in ROK Offers Observations on DPRK's Nuclear Program," *The Daily*, Seoul, April 24, 2005 (translated from Korean). See also, Stephanie Ho, "North Korea Pursuing Two Paths Towards Nuclear Weapons," VoaNews.com, June 21, 2004. The English spelling of Jun Byung Ho varies, where some use Chun instead of Jun, or alternatively Chun Byong-ho or Jon Pyong Ho.
[28] Pervez Musharraf, *In the Line of Fire* (New York: Free Press, 2006), p. 296; the breakdown of the number of each type is from a U.S. official.
[29] Ibid.

centrifuges.[30] A North Korean plane picked up the P1 and P2 centrifuges from KRL in about 2000 after delivering more missile components to KRL.[31]

North Korea approached KRL for assistance in producing uranium hexafluoride, which is the feed gas for centrifuges and is difficult to make. In the 1990s, North Koreans brought a sample of uranium hexafluoride to Pakistan and asked KRL to analyze it. KRL experts tested the sample and found that it was not pure enough for use in centrifuges. Uranium hexafluoride must be highly purified to ensure that contaminants do not interfere in the enrichment process or damage a centrifuge. To assist North Korea, KRL provided a sample of pure uranium hexafluoride that North Korea could compare to the material it would make. In addition, KRL provided a flow-meter for taking important measurements during centrifuge testing. This flow-meter was subject to trade controls under nuclear supplier guidelines and was potentially difficult for North Korea to obtain. In addition, if supplier states detected North Korea's attempts to procure this piece of equipment, they could have a strong, early indication of a North Korean centrifuge effort.

Questions remain whether Pakistan and North Korea cooperated in obtaining restricted goods for their centrifuge programs. In the missile area, such cooperation is known to have occurred. In 1997, while living in Islamabad, Kang Thae Yun, Khan's chief liaison and the North Korean representative to Pakistan reporting to Jun Byung Ho, brokered a deal with a Russian company to buy maraging steel for both Pakistan and North Korea, reportedly for their missile programs.[32]

Additionally, it remains unclear who in North Korea is responsible for the centrifuge program. KRL transferred centrifuge technology and equipment to North Korean missile and aerospace engineers in a sale overseen by Jun Byung Ho, the primary managing executive in North Korea's military and defense industry and since 1990 a member of North Korea's highest ruling body, the National Defense Commission. Could the centrifuge program be run by North Korea's military industry, in particular its missile and aerospace industry? Given the nature of centrifuges, with their rapid rotation and high-specification components, the aerospace or missile industry is a credible place to develop centrifuges. For example, the U.S. centrifuge program depended on U.S. aerospace companies. Likewise in Europe, many centrifuge technologies used in early URENCO centrifuges, such as maraging steel and flow-forming equipment, came from missile industries. In any case, the atomic establishment would likely make the uranium hexafluoride.

North Korea lost direct access to KRL in the early 2000s. Under U.S. pressure, Musharaff ordered the North Koreans out of KRL and removed Khan from his position as head of KRL in early 2001. By this time, North Korea had received centrifuge designs, centrifuges, important training, and instruction manuals. Overall, North Korea received an impressive starter kit from Khan and his colleagues.

However, Musharraf had to admit in his autobiography that he was naïve in thinking that his actions could stop Khan's proliferation activities. Likewise, he was mistaken if he believed he could end North Korean cooperation with Khan and his rogue transnational network, which, at the time, was focused on a large, highly profitable sale of centrifuges to Libya.

[30] Interview, January 7, 2005.
[31] The Associated Press. July 4, 2008; and Haq Nawaz, "Kidwai Comes Out with Guns Blazing," *The Nation*, July 5, 2008.
[32] Dexter Filkins, "N. Korea Aid to Pakistan Raises Nuclear Fears," *The Los Angeles Times*, August 23, 1999. Kang left Islamabad in the summer of 1998 after his wife was gunned down under mysterious circumstances.

Suspicious Work with the A.Q. Khan Network in the Early 2000s

North Korea's involvement with Khan appears to have gone beyond being only customer and missile technology supplier. Pyongyang looked set to join the Khan network as a nuclear supplier to Libya's gas centrifuge program.

In the spring of 2004, Pakistani government officials told the IAEA that North Korea was the source for 1.6 tonnes of uranium hexafluoride that the Khan network sent Libya in February 2001 for use in centrifuges then being supplied by the network. A subsequent U.S. Department of Energy (DOE) technical assessment concluded that North Korea had likely produced the uranium hexafluoride for Libya.[33] This assessment included the detection of minute amounts of plutonium on the uranium hexafluoride shipping canister. DOE analysts concluded that the plutonium was produced in North Korea in Yongbyon's gas-graphite reactor.

Over the next two years, the IAEA uncovered indications that North Korea intended on becoming Libya's main supplier of uranium hexafluoride, in essence becoming a full-fledged state member of the Khan network, and not just a customer. The demise of the network in 2003 and 2004 ended its activities.

Lack of uranium hexafluoride was shaping up as a key bottleneck in the Khan network's operation to provide Libya with a centrifuge plant. Despite many attempts, Libya had failed to acquire its own facilities to make uranium hexafluoride.[34] To run its centrifuge plant, Libya would need 30-40 tonnes of uranium hexafluoride per year. It was unclear how Libya would have produced or acquired such a large quantity.

As an interim step, the Khan network agreed to provide Libya with 20 tonnes of uranium hexafluoride.[35] But diverting uranium hexafluoride from Pakistan was not easy. With Khan removed from KRL, obtaining enough uranium hexafluoride was unlikely.

The cylinder of 1.6 tonnes of uranium hexafluoride was part of this commitment. Libyan officials told IAEA investigators that they were unaware of the uranium hexafluoride's origin in North Korea. They denied any nuclear cooperation with North Korea, although they freely admitted cooperation on missiles.[36] Khan evidently took steps to hide North Korea's role. The canister arrived in Libya from Pakistan in a cargo plane bringing a wide variety of centrifuge equipment. The Libyans did not know that an earlier flight brought the cylinder to Pakistan from North Korea.

Bank records obtained by the IAEA added to the suspicions that North Korea provided this material. Libya sent its payment for this delivery of uranium hexafluoride through a route established by the Khan network. Although the available bank information did not show that a payment went to North Korea, payments went to a company that is linked to North Korea, implying that North Korea sold something to Libya.[37]

Deepening North Korea's involvement, evidence emerged that the Khan network was outfitting North Korea with equipment to produce uranium hexafluoride. With North Korea seemingly interested in developing secret uranium conversion capabilities for its own gas centrifuge program, North Korea may have decided to fund

[33] Glenn Kessler, "North Korea May Have Sent Libya Nuclear Material, U.S. Tells Allies," *The Washington Post*, February 2, 2005.
[34] Interview with senior official close to the IAEA, June 11, 2004.
[35] Director General, *Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya*, GOV/2004/33, May 28, 2004, par. 20.
[36] Interview with senior official close to the IAEA, May 24, 2004.
[37] Interview with senior official close to the IAEA, April 1, 2005.

the construction of these conversion facilities by supplying uranium hexafluoride to Libya. A senior U.S. intelligence official said that North Korea may have been willing to give a little to get a little.

One piece of evidence was that the network used funds from Libya in 2002 to manufacture "centrifuge-related equipment" and shipped it to North Korea.[38] If North Korea was buying from the network, the payment should have gone from North Korea to the network, not flow from Libya.[39] What was North Korea to provide with this equipment? Suspicion fell on equipment to make uranium hexafluoride for Libya.[40]

Confirming this shipment of equipment was difficult. The network moved the goods on a circuitous route through many countries and international trade zones, making recreation of the actual route nearly impossible. Nonetheless, the equipment did move through at least two transit points in Asia known to be used to transfer items to North Korea.

Another suspicious piece of information came from Pakistan. The Pakistani government said that it was missing ten uranium hexafluoride transport canisters from the same batch as the one found in Libya.[41] Moreover, it concluded that someone had transported them all out of Pakistan, and the most likely destination was North Korea. Pakistan bought all these canisters for use in Khan's centrifuge program. Khan and his associates might have sent the cylinders to North Korea as part of its effort to supply uranium hexafluoride to Libya.

In spite of the evidence, the IAEA did not make a definitive public determination of the status of North Korea's uranium hexafluoride production capability or its relationship to the Khan network. If the effort to build a North Korean uranium hexafluoride plant fell apart after the busting of the Khan network, it could help explain delays in a North Korean centrifuge plant, which would require similar quantities of uranium hexafluoride as the Libyan program. North Korea may have needed several more years to establish that capability on its own.

Developing the Gas Centrifuge

With its starter kit from Pakistan, North Korea was well positioned to develop gas centrifuges (see Figure 2). It would need to operate single centrifuges, enrich uranium, and run centrifuges in cascades. However, little information is available about these activities. North Korea could have used its more numerous P1 centrifuges in tests of single machines and small cascades while it tried to establish the industrial infrastructure to build centrifuges.

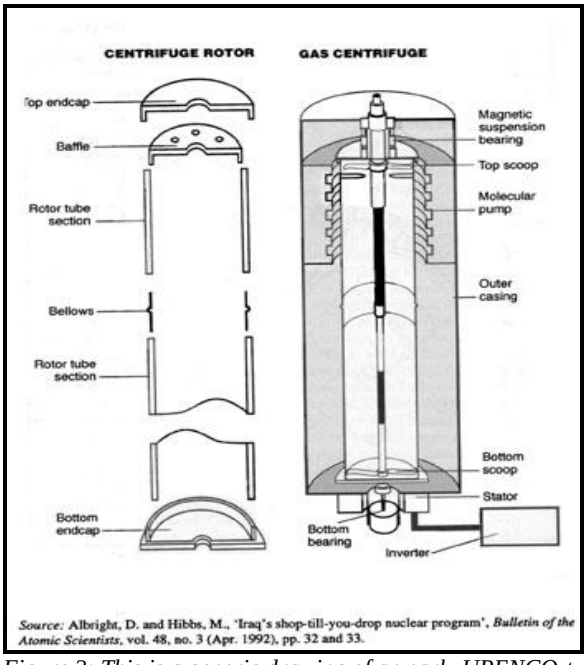

Figure 2: This is a generic drawing of an early URENCO-type centrifuge. In the North Korean case, information suggests that the rotor tubes and the bellows are made in one, longer piece.

[38] Interview with senior official close to the IAEA, April 15, 2005.
[39] Interview with senior official close to the IAEA, April 1, 2005.
[40] Interview with senior official close to the IAEA, April 1, 2005.
[41] Interview with senior official close to the IAEA, April 1, 2005.

The North Korean centrifuge program did not move rapidly. With an official commencement date of 1996 to 1998, the program spent several years on laboratory scale development.[42] A key question is: how skillful were the North Koreans in mastering the centrifuge technology acquired from Khan? Iran has encountered numerous difficulties in duplicating Khan's centrifuges, despite all the assistance it received from the Khan network.[43] Some experts believe that North Korea is more technically adept than Iran. It acquired missile technology and ended up selling it to Iran. The guidance systems mastered by North Korea are viewed to be at the same technological level as gas centrifuges. Nonetheless, duplicating gas centrifuges remains a challenging and slow task.

Japanese officials stated during an interview in 2005 that they assessed North Korea had already tested prototype cascades. Similarly, South Korean officials stated in late 2005 in interviews that North Korea was likely pursuing small-scale enrichment but had encountered difficulties in building a large plant.[44] These officials attributed part of the delay to North Korean difficulties in procuring key items abroad due to international scrutiny.

Asia scholar Selig Harrison obtained indirect confirmation of small-scale development activities on a 2004 visit to Pyongyang. A senior North Korean foreign ministry official, Li Gun, told him that North Korea had a laboratory studying lightly enriched uranium, in an apparent break from long-standing denials of such a program.[45] In an interview, Harrison added that based on his visit he believed that North Korea had some enrichment effort, but he did not believe that they were close to having a plant large enough to make highly enriched uranium.[46]

North Korea's larger challenge was obtaining the capability to produce and operate several thousand centrifuges. There is a significant difference between creating a small-scale centrifuge program involving a few dozen or hundred centrifuges and building and operating a comprehensive, large-scale production plant containing thousands of complete centrifuges. To obtain the needed equipment, materials, and know-how, North Korea turned to its experienced smuggling networks.

Nuclear Smuggling by Nam Chongang Trading Company

North Korea has faced Western sanctions for decades. In response, its military and nuclear programs created their own smuggling networks to obtain sensitive goods. One North Korean entity would play a key role in seeking goods for North Korea's centrifuge program – Nam Chongang Trading Company (NCG), headquartered in the Mangyong district of Pyongyang.[47] NCG has come to symbolize the sophistication and determination of North Korea's smuggling and nuclear proliferation operations.

[42] Interview with knowledgeable European officials, August 2010.
[43] For a discussion of that assistance see Peddling Peril, *op cit*., chapters 4 and 9. For the problems in the Iranian centrifuge program, see various reports at http://isis-online.org/countries/category/iran/.
[44] Interview with South Korean officials, November 10, 2005.
[45] Quoted in "S. Korea: North's Nuke Plans Not an Issue," The Associated Press. September 1, 2005. For a slightly different version, see Selig Harrison, "Did North Korea Cheat?" *Foreign Affairs*, Volume 84, No. 1, January/February 2005, p. 107.
[46] Interview with author, May 28, 2004. See also "Did North Korea Cheat?"op. cit.
[47] The name of the company varies. For example, some references call it Nam Chongang High-Tech Engineering Corporation. It is common for such trading companies to change their names. The address is from an invoice dated September 18, 2002 to NCG from a German company. The full address was Senkujia Dong 11-2 Mangyong District, Pyongyang, DPRK.

NCG became known in intelligence circles as an enterprise that buys and sells a wide range of illicit and legitimate wares, including missile and nuclear-related goods. Subordinate to North Korea's General Bureau of Atomic Energy, NCG would also play a key role in outfitting a secret nuclear reactor in Syria, which was bombed by Israel in September 2007. Its presence in Myanmar has elevated suspicions about a secret nuclear program there.

During the 2000s, the man behind NCG's purchases was Yun Ho Jin, a pleasant, former senior North Korean diplomat (see Figure 3). *The Wall Street Journal* reported that Yun is believed to be the husband of the daughter of National Defense Commission member Jun Byung Ho.[48] With Jun backing a centrifuge program back home and Yun buying for it overseas, this pair has reportedly played a leading role in the development of North Korea's centrifuge program.

Figure 3: A still image from a 1992 IAEA video of a tour of DPRK nuclear sites given to the IAEA. Yun is seen here at Pyongyang's airport while he escorts IAEA officials. To view the full IAEA video, see:IAEA Director General Hans Blix Tours North Korean Nuclear Sites.

[48] Jay Solomon, "North Korean Pair Viewed as Key to Secret Trade," *The Wall Street Journal*, August 31, 2010.

Yun's career shadowed North Korea's growing sophistication in illicit nuclear trade from the 1980s until today. In the 1980s and 1990s, Yun was based in Vienna at North Korea's Mission to the IAEA. While at the Vienna mission, Yun was part of North Korea's strategy to use its embassies and missions as bases to procure Western goods and technologies.[49] In the 1980s, the Korea Lyongaksan Import Corporation, headquartered in Pyongyang's Potonggang District, was one of the main importers for North Korea's military industries, disguising itself as an importer for its civilian industries. Such trading companies were the communist nation's procurement "backbone" for circumnavigating long-standing sanctions on its nuclear and military industries. Despite sanctions, North Korean entities had an easy time importing items for the country's nuclear and military programs. Yun organized North Korean trade delegation visits to Europe to negotiate a range of purchases from European companies. Several of these purchases are believed to have ended up at the Yongbyon nuclear center; some were sent to the center's uranium fuel fabrication plant, according to a senior IAEA official who saw the equipment when he was involved in monitoring the site in the 1990s.

To reduce the visibility of its activities to Western intelligence agencies, North Korea went to pains to hide payments to suppliers even back in the 1980s. In one case, a German supplier received funds through a Kuwaiti bank, which listed the client as International Monetary and Exchange Co. When the payment was received at its bank, the supplier found no address for this company, which he believed was aimed at hiding the payment's true origin.

Yun also worked through German and Swiss trading companies, which would in turn contact suppliers for North Korea. One of the most notorious was the Swiss trading company Kohas,

[49] *Peddling Peril*, op. cit., see chapter seven.

which became one of North Korea's lead procurement fronts in the late 1980s. In 2006, the U.S. Treasury Department sanctioned Kohas for links to Korea Ryongwang General Corporation, a follow-on company to the Lyongaksan Corporation.[50] It turned out that about half of Kohas's shares were owned by Korea Ryongwang.

Yun left Vienna in the mid-to-late 1990s. When he started to work for NCG is unclear, but his shift away from diplomatic quarters signaled a new North Korean strategy to conduct significant illicit business for its nuclear program. North Korea's procurement entities had encountered more difficulties as Western governments learned of the clandestine role of North Korean missions in Europe. As a result, Western intelligence agencies were closely monitoring North Korean missions for signs of illicit procurements. It was at this time that Yun went to NCG, basing himself in Beijing and Dandong, China.

A company like NCG would be far less visible to foreign intelligence surveillance. And Yun was careful. In letters to one key German intermediary, who procured over one million dollars worth of equipment for NCG, he wrote: "I want to discuss certain matters with you by mail and not by phone. That is because letters are more reliable in a certain sense."[51] By 2001, Yun was buying a range of items in Germany and other European countries. He sought out small, private companies that placed orders for him with major suppliers.

Suppliers sent equipment either to NCG in Pyongyang, or if a North Korean destination worried a supplier, Shenyang Aircraft Corporation, a large Chinese operation that assembles fighter planes for the Chinese military. This company has cooperated with Airbus and Boeing, providing a civilian sheen if any authorities raised questions about a supplier's export to Shenyang. Conveniently, Shenyang had a subsidiary in the Chinese city of Dandong, across the river from North Korea, known as Shenyang Aircraft Industry Group Import &Export Co., Dandong Branch. The United States established that this subsidiary was often just a transit point on the equipment's journey from China to North Korea.[52]

To further disguise his purchases, Yun created a new company in Dandong located about 300 meters from the North Korean border. He chose a name that, to most, would be confused with the legitimate Shenyang Aircraft subsidiary in Dandong. He added "Ltd" at the end and changed the placement of "Dandong," arriving at Shenyang Aircraft Group Dandong Import and Export Co. Ltd. Without permission, he also used the Shenyang Aircraft logos. The sole purpose of Yun's new company was to funnel equipment, including centrifuge goods, to North Korea. As of April 2010, this company still existed, although it was dealing with such goods as clothing and textiles.

Finding a German Buyer: Optronic GmbH

In 2001 or 2002, Yun managed to recruit at least one small German company, Optronic GmbH, in the Swabian town Koenigsbronn-Zang. Through this company, Yun bought a range of items for North Korea, including vacuum pumps, dial gauges, generators, gas masks, steel rotors and plates, and compressors. Although much of this equipment appeared for general use, some could have been for North Korea's centrifuge program.

[50] U.S. Department of Treasury, "Swiss Company, Individual Designated by Treasury for Supporting North Korean WMD Proliferation," JS-4144, March 30, 2006.
[51] Quoted in "Atom Smuggling: The North Korea Connection," by Georg Mascolo, *Der Spiegel*, 39/2003, September 22, 2003, translated from German.

[52] German customs investigation of Hans Werner Truppel, July 18, 2003.

In another case, Optronic sought equipment that was clearly for a centrifuge program.[53] It bought key raw aluminum tubes for North Korean gas centrifuges in quantities large enough for thousands of centrifuges. Optronic purchased the first order of tubes from the metals trader Jakob Bek GmbH in Ulm, which in turn bought the tubes from British Aluminum Tubes Limited.

German authorities learned of the aluminum tube order in September 2002, exposing NCG as well. Hans Werner Truppel, the head of Optronic, approached German customs officials about whether he needed permission to export the tubes to NCG in North Korea. Later, he changed his story and said the end user was Shenyang Aircraft, although in this case, it was likely the phony Shenyang company created by Yun.

In either case, the officials told him not to export the tubes because of suspicions that the obscure North Korean company was actually providing the tubes to the North Korean nuclear program.[54] Despite the order, Truppel did so anyway in April 2003. By the time the authorities learned about his action, the tubes were at sea on the French container ship *Ville de Virgo* bound for China. German authorities contacted the owner of the ship, who agreed to off-load the tubes at the nearest port. The ship docked at Alexandria, Egypt on April 12, 2003, and authorities were waiting at the dock.[55] The tubes were soon on their way back to Germany. The authorities meanwhile had arrested Truppel. In 2004, a Stuttgart court convicted him of violating export control laws and sentenced him to four years in prison.

Authorities showed the seized tubes to Horst Puetter, a URENCO centrifuge expert with long experience investigating Iraq's and Iran's gas centrifuge programs for the German government and the IAEA. He determined that the tubes appeared as if they would be finished into an outer casing of a P2 centrifuge. Documents seized during the official investigation showed that the North Koreans intended to acquire 220 tonnes of aluminum tubing from Truppel, enough for about 4,000 P2 centrifuges. During the same period, North Korea successfully obtained 150 tonnes of aluminum tubing with these same dimensions through an unknown agent, possibly NCG or a company affiliated with the Khan network. This tubing came from a Russian company and was enough for 2,700 centrifuges. In total, Yun sought enough aluminum tubes for 6,700 centrifuges, an amount that would imply North Korea wanted to build a large centrifuge plant.

After being discovered, Yun disappeared from Germany. He undoubtedly sensed that the authorities were increasingly alert to his business. Little was done to stop NCG, and it continued to operate. It did not even change its name.

NCG has mainly operated in China, according to one senior European intelligence official. An official German customs investigation report shows that in 2003, Yun listed NCG's address as located in the Chaoyang district of Beijing.[56] This district is the city's prime commercial, entertainment, and shopping area, and in 2002, it contained the headquarters of more than 8,000 foreign companies, attracted by China's rapid economic growth.[57] Many of these companies sell high-precision equipment and industrial materials that Chinese companies cannot make.

A North Korean company like NCG could blend in easily in China. Many North Koreans receive

[53] German customs investigation of Truppel, op. cit.
[54] "Atom Smuggling: The North Korea Connection," op. cit.
[55] Joby Warrick, "N. Korea Shops Stealthily for Nuclear Arms Gear," *The Washington Post*, August 15, 2003.
[56] German customs investigation of Hans Werner Truppel , op. cit.
[57] "Chaoyang District," *Beijing This Month*, March 2002. This publication is sponsored by the Information Office of the Beijing Municipal Government.

their education and advanced training in China and own companies there.[58]

With so much economic opportunity, NCG thrived in China. Unlike in Germany, it has faced few obstacles from Chinese government authorities, which only recently created modern trade controls and has not implemented them effectively or comprehensively.

NCG's *modus operandi* remained buying from other traders, who then bought items from suppliers, according to a European intelligence official who has tracked NCG for years. In China, it can effectively buy dual-use equipment from suppliers throughout the world, even those in Europe and the United States, particularly if those suppliers have subsidiaries in China. When NCG buys an item from another company in China—either a domestic company or a foreign subsidiary—the transaction would appear as a domestic sale. NCG can then smuggle the items to North Korea's nuclear or military programs, or to a proliferant state such as Syria.

In July 2009, the U.N. Security Council imposed sanctions on NCG, along with seven other entities and five individuals, including Yun Ho Jin. NCG is believed to remain active in China, but it may have since changed its name. After being designated by U.N. sanctions, other North Korean entities substituted their names with others or replaced their names altogether. For example, Green Pine Associated Co. replaced Korea Mining Development Trading Corporation. Green Pine is an entity under the control of the General Bureau of Surveillance of the Korean Peoples' Army, and is responsible for about half of North Korea's arms and related materiel exports.[59]

Yun has disappeared, according to European intelligence sources. Yet, there is little reason to believe that North Korea has reduced its efforts to evade sanctions to acquire nuclear-related goods. Likely, they have just become more sophisticated.

Known Centrifuge-Related Procurements of Dual-Use Goods

Reviewing North Korea's known or attempted procurements can shed light on its gas centrifuge program. Because North Korea has depended heavily on procurement from abroad for its centrifuge program, such an assessment provides insight into the program's status and timeline as well as details about the centrifuges themselves. But such an assessment has not identified the location of the program inside North Korea. As discussed earlier, it is difficult to develop construction timelines based solely on discoveries about procurement. Nonetheless, procurement data are valuable in understanding a gas centrifuge program and the networks and entities that seek necessary goods.

Early Procurements

Prior to the CIA assessment in the fall of 2002, North Korea had procured at least a dozen sensitive items associated with a gas centrifuge plant from Russian, European, and Japanese suppliers, according to a senior U.S. official.[60] The aluminum tube order established that North Korea acquired or sought some items in quantities large enough for a centrifuge plant containing several thousand centrifuges.

In addition to the aluminum tubes obtained by NCG, North Korea acquired ring magnets for use in an upper bearing of a centrifuge, epoxy resins used in assembling centrifuge parts (sold commercially as Araldite), and a range of equipment important to operating centrifuges individually or in cascades, such as vacuum pumps, valves, specialized uranium hexafluoride

[58] Interview with knowledgeable European officials, August 2010.
[59] Panel of Experts, op. cit.
[60] Interview, January 7, 2005.

resistant oils, and power supplies or their subcomponents. North Korea may have also acquired a flow-forming machine usable to make centrifuge rotors, although the available information is divided on whether North Korea acquired this machine tool prior to 2003 (see figure 4). In addition, a German company sold an electron beam welder to North Korea that could have been used in a centrifuge program.[61]

The CIA factsheet stated that North Korea also acquired "equipment suitable for use in uranium feed and withdrawal systems."[62] The statement seems to imply that North Korea did not buy feed and withdrawal systems; instead, it bought subcomponents of such a system such as vacuum pumps, valves, pipes, autoclaves, cold-traps, or control equipment. Such systems could be bought in their entirety on the black market, for example, from Friedrich Tinner, a key Swiss agent of the Khan network.[63] By the early 2000s, he had sold several small feed and withdrawal systems to Pakistan and Libya. But no evidence has emerged that North Korea bought anything from Tinner. There remain suspicions that North Korea bought centrifuge goods from Khan's associates in South Africa, which concentrated on feed and withdrawal systems, piping, and other ancillary equipment associated with a centrifuge plant.[64]

However, important items were missing that are critical to successfully building a centrifuge plant. There were no reports of procurements of maraging steel suitable for use in rotating centrifuge rotors or bellows, measuring equipment for magnets, specialized machine tools such as rotor balancing equipment,[65] and enough frequency converters for a large plant. In addition, there were few reports about the training of North Koreans in operating specialized machine tools.

Figure 4: A P2 centrifuge rotor assembly, showing a bellows in the middle of the tube and the pin of the bottom bearing, provided to Libya by the Khan network and subsequently sent to the United States. North Korea likely received several such assemblies and may now be producing them. Photo credit: NHK.

Subsequent Procurements

North Korea's pace of procurements appeared to slow after 2003 or 2004, partially due to increased scrutiny of its illicit trade efforts. In the mid-2000s, according to one senior intelligence official, only one additional procurement emerged that could be tied to North Korea's centrifuge program. It was specialized oil resistant to uranium hexafluoride. Such oil is necessary to use in vacuum pumps and centrifuge bearings exposed to uranium hexafluoride.

Although North Korea may have become more careful in hiding its overseas procurements, Western governments should have detected some procurements, given the large number of items that North Korea would need to procure abroad for a centrifuge plant. According to a knowledgeable European intelligence official, intelligence agencies should have detected at least the "tip of the iceberg" of many procurement efforts if North Korea had made substantial progress in finishing a centrifuge plant during the mid-2000s. Yet, they did not.

[61] Interview with knowledgeable German official, February 11, 2008.
[62] 2002 CIA Factsheet, op. cit.
[63] *Peddling Peril*, op. cit.
[64] *Peddling Peril*, op. cit.
[65] Interview with South Korean officials, op. cit.

Procurements in late 2000s

After 2007, NCG secretly procured goods that were very likely intended for a uranium enrichment program.[66] In the late 2000s, Western intelligence agencies detected North Korean procurements that appeared to be for the manufacture of centrifuges. From 2007 to 2009, North Korea entities obtained state-of-the-art computer numerically controlled (CNC) machines via China needed to make centrifuge parts, according to a European intelligence official. (During this period, North Korea was seeking sophisticated equipment for missile, nuclear, and conventional military uses, such as radar and unmanned aerial vehicles). North Korea purchased spare parts for centrifuge-related equipment and bought more specialized epoxy for use in assembling centrifuges.

Figure 5: President Ahmadinejad during his tour of the Natanz complex in 2008. In the center of the image is a pressure transducer. Iran has recently sought large numbers of pressure transducers overseas suspected for it gas centrifuge uranium enrichment program. North Korea reportedly also acquired them. Photo credit photo archive of the web site of the President of Iran, www.president.ir.

NCG has also procured computerized control equipment used to run a plant composed of centrifuge cascades. The equipment is dual-use, also used in the petrochemical industry, but it was the same as those acquired by Iran to run its centrifuges.[67] NCG also acquired pressure transducers, which are used to measure the vacuum pressure in centrifuges (see Figure 5).

Undetected were large-scale procurements like those for the aluminum tubes in 2002. Such procurement efforts may not have happened, or intelligence agencies may have missed them.

Nonetheless, known procurements confirm North Korean intentions to pursue the development of gas centrifuges, and they demonstrate its determination and skill at acquiring vital equipment abroad. Unfortunately, this collection of known procurements continues to provide only a partial picture of the actual status or accomplishments of North Korea's centrifuge program.

These procurements do not show whether North Korea is able to produce significant amounts of highly enriched uranium. Yet the data support that North Korea has the capability of building, at the very least, a pilot plant; it supports that North Korea has moved beyond laboratory-scale work. But according to one knowledgeable analyst, consistent numbers of items are not seen being procured that would indicate the construction of a 3,000 centrifuge plant.[68]

HEU Contamination

Faced with great uncertainties in assessments of North Korea's centrifuge program, the U.S. intelligence community intensely focused on the significance of the 2007 and 2008 discoveries of traces of HEU found on the aluminum tubes North Korea procured in Russia in the early 2000s and operating records for the Yongbyon

[66] Interview with knowledgeable European intelligence officials, August 2010.

[67] Interview with knowledgeable European intelligence officials, August 2010.

[68] Interview with knowledgeable European intelligence official, August 2010.

nuclear reactor.[69] North Korea gave these items to the United States during a Six Party Talks accounting of North Korea's nuclear programs.

The discoveries raised anew concerns that North Korea had a secret gas centrifuge plant operating by the mid-2000s, contradicting assessments based on its procurement data. The U.S. intelligence community, however, differed over the significance of the HEU traces. Were they produced inside North Korea? Or did this HEU originate from Pakistan's centrifuge program and inadvertently contaminate the tubes and records? North Korea had imported Pakistani centrifuges and other Pakistani equipment such as uranium hexafluoride transport cylinders, which originated in the Pakistani nuclear complex where HEU was made. Or were they outliers that were impossible to assign a place of origin? According to a U.S. official, the data did not lead to a consensus judgment about their significance.

HEU Traces

In 2007, U.S. nuclear laboratories discovered the traces of highly enriched uranium in smelted aluminum tubing and on the surface of other tubes. These tubes were reportedly the ones obtained by North Korea that had the dimensions matching the outer casing of the P2 centrifuge. North Korea had admitted to the United States that it had acquired aluminum tubes from a Russian supplier, but it denied ever using the tubes in a gas centrifuge program. Under U.S. prodding, North Korean officials reportedly took U.S. officials to a missile facility where North Korea handed over samples of the tubes in an attempt to explain what had become of them.

[69] Glenn Kessler, "Uranium Traces Found on N. Korean Tubes," *The Washington Post*, December 21, 2007; James Rosen, "North Korean Tubes Found To Be Contaminated with Uranium Traces," FOX News.com, December 22, 2007; and Glenn Kessler, "New Data Found on North Korea's Nuclear Capacity," *The Washington Post*, June 23, 2008.

The next year, U.S. nuclear laboratories found traces of HEU, at least one enriched up to weapon-grade, on 18,000 pages of operating records for the five megawatt-thermal reactor at Yongbyon. North Korea provided these records to U.S. monitors as part of its declaration of its plutonium production at the Yongbyon nuclear site. The high level of enrichment increased support for excluding Pakistan as the source of the HEU. The reason for this was that such high levels of enriched uranium were unlikely to be found on Pakistani centrifuges. Almost all centrifuges in Pakistan would have traces of enriched uranium that is far below weapon-grade, which is at least 90 percent uranium 235. Only about two percent of Pakistani centrifuges enriched uranium from roughly 60 to 90 percent, so the chance was small that the roughly two-dozen P1 and P2 centrifuges that North Korea had acquired from Khan would have been involved in enriching up to 90 percent. However, other equipment came from Pakistan that could have carried weapon-grade uranium contamination, and many North Koreans were at the centrifuge workshops at Khan Research Laboratories . In addition, Pakistanis from the nuclear program are suspected to have visited North Korea. So, while the presence of weapon-grade uranium could be significant, by itself, it does not exclude Pakistan as the source.

Further controversy surrounding the meaning of the HEU traces quickly emerged. One complication was that the U.S. laboratories found only a small number of particles on the aluminum and the paper records. Although analysis based on a small number of particles is legitimate, it is often subject to greater scrutiny and doubt.

One finding about the enriched uranium was intriguing. The enriched uranium lacked uranium 236, an isotope of uranium that is found in uranium that has been irradiated in a reactor, recovered from irradiated fuel, and then enriched. This meant that HEU from Russia,

China, or for that matter the United States were unlikely to be the source of the HEU, since they recycled reactor uranium into their enrichment plants that produced HEU, and thus, their HEU contained tiny amounts of uranium 236. North Korea, however, would be expected to use fresh uranium in any centrifuge program. It had reprocessed irradiated reactor fuel at Yongbyon but is not believed to have recovered the uranium for reuse. But the lack of uranium 236 did not eliminate Pakistan. Although Pakistan obtained considerable quantities of uranium from China that contained uranium 236, it had also produced HEU free of any uranium 236 for many years. This uranium could have been domestically produced or possibly even imported from North Korea and then enriched at the Khan Research Laboratories. The main suspects for the HEU particles remained contamination from Pakistan or from a centrifuge program in North Korea.

Age of Particles?

In a potential breakthrough, the U.S. laboratories determined the age of one HEU particle to be 3.5 years, originating sometime in 2004.[70] Since Pakistani assistance had ended earlier, the finding could possibly eliminate Pakistan as a source of the HEU. Yet the analysis was not so clear.

In 2008, according to a knowledgeable U.S. official, the intelligence community agreed only that the HEU particles found on the aluminum and in the paper records had been "processed" in North Korea. However, U.S. intelligence agencies differed over the interpretation of processing. Did processing mean new production of HEU, or simply that the HEU underwent a chemical reaction? Portions of the intelligence community took it to mean that North Korea produced the HEU 3.5 years earlier, evidently in a secret enrichment plant. Other agencies stated that the definition of processing is vague and includes exposing the HEU to air and is not the same as its production, as assumed by others. Under the latter condition, the HEU could have still originated in Pakistan and arrived in North Korea on goods from Pakistan's facility that was involved in making HEU. Moreover, some considered that one HEU particle an "outlier" and simply unexplainable as to its origin or why it was discovered on the tubes or the documents.

But how did the HEU get on the tubes and on the paper, whatever its origin? North Korea is unlikely to have provided the United States with smelted tubes that actually were part of functioning centrifuges. And the operating records were at the Yongbyon nuclear center, the plutonium site. The results remain difficult to interpret. One possibility is that equipment or individuals from the Pakistani centrifuge program were at the Yongbyon site, leaving traces of HEU. North Korean personnel then could have picked up some of this HEU who then transferred it onto the documents and tubes. Another possibility is that personnel from Yongbyon went to view these contaminated tubes at a different site, where they inadvertently picked up minute traces of the Pakistani HEU and brought them back to Yongbyon and contaminated the documents. There are many other possibilities, but they all suggest a connection, perhaps indirect, between the facility holding the tubes and the Yongbyon site.

In addition, the plutonium contamination on the uranium hexafluoride shipping container found in Libya in 2004 also suggests a point of intersection between the plutonium program at Yongbyon and a facility to make or store uranium hexafluoride. One intersection is a uranium conversion facility that makes both uranium hexafluoride and uranium metal for reactor fuel. Since both are made from uranium tetrafluoride, producing both in the same facility is practicable.

[70] Glenn Kessler, "White House Voices Concern On North Korea and Uranium," *The Washington Post*, January 8, 2009.

The enriched uranium particles remain the most direct evidence that North Korea could have enriched uranium up to weapon-grade. But the reported lack of consensus on their meaning warrants caution in reaching any conclusion about their significance. In addition, even if North Korea produced the HEU, that conclusion does not translate to North Korea having a facility able to produce weapon-grade uranium on a significant scale.

Centrifuge Facilities

Learning the locations of North Korean centrifuge sites has proven elusive. The 2002 CIA assessment reportedly included evidence for a large construction project, although the CIA did not appear to have identified a definite location. The following discusses the facilities necessary to build a uranium enrichment program, including a centrifuge plant, and available information about such potential facilities in North Korea.

Any discussion of such sites is complicated because North Korea has hundreds of secret underground facilities, many of which could house gas centrifuge facilities. In addition, gas centrifuge facilities have few physical signatures, making them difficult to detect, even if a facility is not underground.

In order to pursue a gas centrifuge uranium enrichment program, North Korea would need to establish a range of capabilities to build a gas centrifuge plant. In particular, it would need to develop a prototype centrifuge and create an industrial infrastructure to research, develop, test, build, and operate gas centrifuges. It may build a dedicated centrifuge manufacturing and assembly facility, or it could use its military industrial facilities to make most of the centrifuge parts. The creation of this infrastructure would depend on domestic or overseas acquisition of a wide variety of goods, including raw materials, equipment, and parts. The program would also need to recruit and train a competent staff.

R&D Facilities

To operate a gas centrifuge program, North Korea would need to have established research and development facilities. These workshops would support the development of prototype centrifuges, undoubtedly P1 and P2 centrifuges obtained from Khan Research Laboratories. In addition to testing single machines, North Korea would need to build experimental cascades ranging from a few to tens of centrifuges. Know-how for this stage of development likely was provided by KRL. The two-dozen centrifuges that North Korea received from Khan likewise would be invaluable during this phase.

A media report from 2000 may be relevant to this stage of North Korea's centrifuge development. The Japanese newspaper *Sankei Shimbun* reported on June 9, 2000 that Chinese sources had indicated there was an enrichment plant located inside a mountain, known as Mount Chonma. ISIS was unable to confirm this information. If true, however, this plant could have been built to utilize the initial centrifuge aid from KRL.

Centrifuge Manufacturing Sites

Since North Korea bought only a limited number of centrifuges from Khan, it would thus need to establish a sophisticated manufacturing infrastructure to make centrifuge components. Each P2 centrifuge has about 100 components, and therefore a 3,000-centrifuge plant would require the manufacture and assembly of 300,000 high precision parts. ISIS was not able to locate any reporting on where North Korea might make or assemble centrifuge parts. One possibility, although a dubious one, would be the reported missile facility where U.S. monitors received the samples of the aluminum tubes.

In addition to importing high precision, computer controlled equipment to make centrifuge components, North Korea makes its own computer-controlled machine tools that could be part of a centrifuge manufacturing complex. It is known to have three major manufacturing companies that make machine tools for domestic use and foreign export, Ryonha Machinery Joint Venture Corporation in Pyongyang, the Kusong Machine-Tool Plant in North Pyongan Province, and the Huichon Machine Tool Factory in Huichon city. North Korean media announced in recent years that the Kusong Machine Tool Plant had recently undergone modernization.[71] Figures 6 and 7 show Ryonha machine tools on display at the Three Revolutions Exhibition, a technological museum in Pyongyang. U.S. officials assessed that some of the North Korean machine tools are capable of making high precision centrifuge components. They are able to achieve a level of precision similar to machine tools that Iraq acquired in the late 1980s for its centrifuge manufacturing complex.[72] The reliability of these domestically produced machines is unknown.

Figure 6: A Ryonha vertical machining center. Photo taken in the Heavy Industry Hall at the Three Revolutions Exhibition.

[71] KCNA, "Kim Jong Il Gives Field Guidance to Kusong Machine-Tool Plant," March 27, 2009.
[72] Interviews with senior official close to the IAEA, January 2007 and August 2010.

Figure 7. A Ryonha computer-numerically-controlled turning center. Photo taken at the Heavy Industry Hall of the Three Revolutions Exhibition

It is not surprising that North Korea would seek to both acquire and make computer-numerically-controlled (CNC) machine tools. Foreign made machine tools would be more reliable and capable, being equipped with more modern features than North Korean ones. Besides performing more capably, these imported machines could be reverse engineered in an attempt to improve North Korea's own domestically produced machine tools.

Centrifuge Plant

Building a centrifuge plant poses many unique challenges, but Khan Research Laboratories's aid would have been enormously helpful. It provided design documentation, likely designs of cascades, feed and withdrawal systems, control equipment, and piping arrangements. Khan has claimed he did not provide cascade designs to make weapon-grade uranium to North Korea, apparently limiting the transfers to designs of cascades to make low enriched uranium. However, Khan's claim should be dismissed as serving his own interests of avoiding culpability, particularly given the lack of any supporting evidence. In addition, cascades that make low enriched uranium and those that make weapon-

grade uranium are similar, and the Khan network did not hesitate to provide these designs to its other customers. Given North Korea's overriding interest in producing materials for nuclear weapons, North Korea likely requested and received these designs as well.

Even with the design information, scaling up operations and building a centrifuge plant would pose significant challenges to North Korea. As discussed earlier, procurement of necessary materials and equipment abroad is a time consuming and difficult task. Manufacturing several thousand centrifuges and then installing them, along with all the piping and other equipment, poses many significant obstacles. Getting the production technology to work can take time, as both KRL and Iran have discovered.

ISIS interviewed numerous officials from Japan, South Korea, European countries, and the United States. No one provided a confirmed location of a centrifuge plant. Some suggested that the facility could be inside a mountain. A South Korean newspaper, quoting an unnamed South Korean government source, reported in early 2009 that North Korea was operating an enrichment plant near the village of Sowi-ri located several miles upstream of the Yongbyon nuclear site.[73] South Korean officials contacted by ISIS, who were aware of the press report and intelligence on the issue, stated that they had no hard evidence of such a centrifuge plant.

ISIS did not learn of an enrichment plant near the village of Sowi-Ri, but it did learn of a possible facility near Sowi-Ri that was suspected several years ago of housing a small-scale uranium metal fabrication plant. The size and characteristics of the plant suggested that it would make HEU metal and would not be capable of making the large amounts of natural uranium metal needed for the Yongbyon gas-graphite reactor.

[73] Agence France Presse, "N. Korea Running Secret Nuclear Plant: Report," February 17, 2009.

This information remains unconfirmed, but if determined to be true, it could imply the existence of a centrifuge plant elsewhere. In following up on this information, however, ISIS recently learned from an intelligence source that the Sowi-Ri site, whatever its purpose, has been observed as largely dormant over the last few years. As the source put it, Sowi-Ri has "gone cold."[74]

Uranium Hexaflouride (UF_6) Production

Based on information about North Korean/Pakistani cooperation, North Korea likely built laboratory-scale or prototype production units in the 1990s to make kilogram quantities of uranium hexafluoride. It also may have been building a larger production plant by the early 2000s.

One suspect site that could make both uranium tetrafluoride and uranium hexafluoride is in North Pyongsan province. ISIS has learned that this site may have processed uranium tetrafluoride for the fuel fabrication plant at the Yongbyon site in the 1980s and 1990s. A defector's information also implies that the site may have produced uranium hexafluoride.[75]

[74] Interview, May 3, 2010.

[75] Bradley K. Martin, *Under the Loving Care of the Fatherly Leader* (New York: St. Martin's Press, 2004), p. 438. Kim Dae-ho worked at the Atomic Energy April Industry, a uranium conversion plant that was involved in vanadium processing. He apparently developed vanadium poisoning. The reference to vanadium implies that Pyongan may have used the dry hydroflour process to recover uranium and convert it into uranium hexafluoride as opposed to the wet solvent extraction process. (The solvent extraction process does not have a step at the end that removes vanadium and molybdenum, so no exposure to vanadium would have occurred if that method was used). The use of the dry hydroflour process implies that two products could have been produced at this site, uranium tetrafluoride and uranium hexafluoride. In the dry process the uranium tetrafluoride comes off first, and if this is all that they sought, then the operation would have stopped. The vanadium extraction would not have

One candidate for this site is the Pyongsan uranium concentrate plant, although no confirmation is available. A still photograph from an IAEA video of a May 1992 tour of North Korea's nuclear sites given to then Director General, Hans Blix, shows the Pyongsan uranium concentrate plant (see Figure 8). This ground image matches the satellite image of an industrial plant in Pyongsan city (see Figure 9)[76].

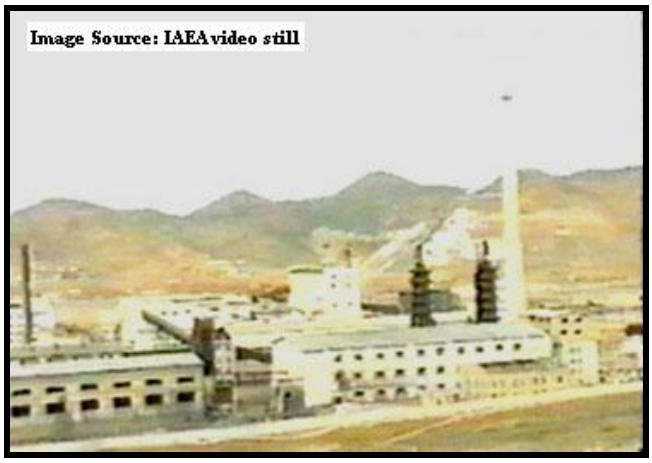

Figure 8: Still image of the "Pyongsan uranium concentrate plant" from a 1992 IAEA video tour of North Korean nuclear sites given to then Director General Hans Blix

Figure 9. DigitalGlobe satellite image from March 23, 2006 on Google Earth showing an industrial plant in Pyongsan city (38.317602, 126.433151). Based on the location of buildings and stacks, ISIS assesses that this is the same site seen in the IAEA video.

Although intelligence agencies likely know more about suspected centrifuge plants in North Korea, ISIS has found little of substance about where North Korea pursues it centrifuge development. Even which organization is responsible for the centrifuge program—the atomic energy establishment or the military aerospace industry—remains unknown. Determining answers to these and other questions about North Korea's centrifuge program is critical.

occurred because this process only happens after uranium hexafluoride is produced.

[76] Pyongsan plant located at 38.317602, 126.433151.

PART 2 – FINDINGS AND RECOMMENDATIONS

North Korea's centrifuge program poses both a horizontal and a vertical proliferation threat. It is an avenue for North Korea to increase the number and sophistication of its nuclear weapons and for it to proliferate to others who seek to build their own centrifuge programs. As a result, the priority must be finding ways to either stop the program or to delay its progress.

Status of centrifuge programs

Procurement data and Pakistani information establish North Korea's development of centrifuges. With few intelligence breakthroughs and no international monitoring, however, determining the centrifuge program's status is difficult. Likewise, the locations of North Korea's centrifuge activities remain unknown and significant portions may be underground.

A.Q Khan and his associates provided significant help to North Korea's centrifuge program. However, North Korea suffered a setback when President Musharraf expelled North Korea missile and centrifuge experts from Khan Research Laboratory in about 2000 or 2001. Then, it likely suffered a further setback when the Khan network was disrupted in 2003 and 2004. These setbacks may have contributed to delays in the North Korean centrifuge program in the mid-2000s.

The evidence supports North Korea's assertion about having finished the experimental phase of its centrifuge program. In addition, it is probably moving to enrich uranium on a larger scale. The existence of a pilot scale plant appears possible, but determining its exact operational status or location remains uncertain.

The evidence is mixed on whether North Korea is producing enriched uranium on a significant scale today, for example, in a plant with about 3,000 P2 centrifuges. Procurement data tend to support the view that such a plant is not finished and that completion awaits the procurement of additional equipment overseas. In addition, as the cases of Iran and Pakistan have shown, bringing a centrifuge plant into operation can take time as the operator works out problems in operating several thousand centrifuges. The HEU traces are ambiguous on this question, although some believe that they demonstrate the existence of an operational centrifuge plant. Even if the HEU traces originated in North Korea, though, they could have come from small-scale research and development work on operating gas centrifuges with uranium hexafluoride, and not necessarily from an existing plant with many centrifuges making HEU on a scale necessary to produce enough for nuclear weapons.

Jun Byung Ho's past and possibly on-going involvement in the centrifuge program lends credibility to the view that the centrifuge program is a high priority for the regime. On North Korea's National Defense Commission, Jun Byong Ho could be a powerful proponent of producing HEU for nuclear weapons and in a position to guarantee that sufficient resources are allocated to finishing and operating a centrifuge plant.

Unless North Korea's plans are disrupted or it voluntarily gives up those plans, the available evidence does not contradict North Korea's assertion that it could finish a large gas centrifuge plant in the 2010s (interpreted as this decade) and that it would produce weapon-grade uranium for nuclear weapons. Given the level of uncertainty, however, ISIS cannot exclude the possibility that an enrichment plant could already be producing significant amounts of HEU or be capable of doing so in the near term. The more plausible situation, however, is that North Korea is not yet operating a full-scale plant able to produce enough HEU for nuclear weapons and

will need a few to several more years before it can do so.

North Korea maintains that it is working on gas centrifuges to produce low enriched uranium for a nuclear power reactor. However, the same centrifuges can be used to make highly enriched uranium for nuclear weapons.[77] The latter purpose appears more likely, particularly since nuclear weapons can be made with one tenth the number of centrifuges required to make low enriched uranium for a standard-sized power reactor. With sanctions in place, few believe that North Korea will be able be build a centrifuge plant large enough to provide enriched uranium to operate a power reactor. The only possible civilian justification is to produce enriched uranium for its Russian-supplied research reactor at Yongbyon. But this requirement is miniscule, and would likely be an afterthought to the use of a centrifuge plant to make HEU for nuclear weapons, and it could also serve as an excuse to maintain its centrifuge program during any future diplomatic negotiations.

Whatever North Korea has accomplished in building centrifuges, it faces an ongoing, fundamental problem. It is not self-sufficient in making and operating centrifuges. It acquired a vital starter kit from the A.Q. Khan network, and it has acquired key equipment and materials abroad and appears to be continuing its overseas procurements. North Korea will undoubtedly need additional equipment and materials to build and operate large numbers of centrifuges successfully. Once it finishes a plant, it will need to buy spare parts and new equipment to update its centrifuge plant. North Korea will face an ongoing need to acquire equipment, materials, and technology abroad for many years.

North Korea has several ways to acquire needed goods. It continues to exploit weaknesses in trade control regimes and Security Council sanctions. North Korean trading entities continue to target China to obtain necessary goods.

North Korea's cooperation with Iran poses a special challenge. Missile cooperation with Iran is ongoing, and nuclear cooperation may also be occurring. In addition, suspicions are growing that North Korea and Iran are cooperating on buying sensitive dual-use items for one other's military and nuclear programs. This cooperation could provide North Korea with centrifuge technology and facilitate the procurement of key goods for its centrifuge project.

Seeking negotiations

The most effective way to end the threats posed by North Korea's centrifuge program is through negotiations, even though re-establishing the Six Party talks currently looks difficult. If discussions resume, as they should, negotiators should view the North Korean uranium enrichment program as a priority. It should receive at least the same priority as the plutonium program. If North Korea does not resume production of plutonium, which halted a few years ago, the enrichment program should become a higher priority, given concerns that North Korea may be seeking to make HEU on a significant scale.

Given the number of references to uranium enrichment in its announcements over the last two years, North Korea may well make its uranium enrichment program a topic of discussion in future diplomatic talks. It may seek to use it as a bargaining chip, or it may try to insist that it should continue as a peaceful nuclear program. It is important for negotiators to prepare in case the gas centrifuge program becomes a major challenge at the start of any negotiations.

Like the case of plutonium production at Yongbyon, the immediate U.S. goal should be

[77] A.Q. Khan did this in Pakistan. See *Peddling Peril*, op. cit., chapter one.

the shutdown and disablement of North Korea's centrifuge program, accompanied by declarations about the program's status and accomplishments. Any agreement should require monitoring of enriched uranium and defined procedures to verify quantities of this material. The possible involvement of the North Korean missile and aerospace program in the centrifuge effort may complicate negotiations, which in the past involved the North Korean foreign ministry and the Atomic Establishment. If indeed the centrifuge program is run outside the Atomic Establishment, the North Korean military or the entity that controls the centrifuge program may also need to participate directly in the negotiations and the implementation of any disablement or dismantlement steps.

But reducing sanctions aimed at thwarting North Korean nuclear and missile programs and North Korean proliferation should not be a condition for North Korea to resume negotiations.[78] Given the long, secret history of North Korea's centrifuge program, which has been critically dependent on foreign supply, sanctions remain an important bulwark against North Korean illicit nuclear procurement. These sanctions make it more difficult for North Korea to obtain abroad direct-use and dual-use goods suitable for North Korea's nuclear and missile programs. Any such sanctions should be reduced or removed only after North Korea abandons its centrifuge and other nuclear weapons efforts in a verifiable manner. Even then, a priority remains effective national trade controls on direct use and dual-use goods in supplier states, such as China.

Equally important, the negotiators should focus early on obtaining a North Korean commitment that it will halt illicit procurements abroad for its nuclear programs and end proliferation of its nuclear technology. Although North Korea reportedly committed to the latter in a secret agreement between U.S. and North Korean negotiators in 2008, during negotiations under the Six Party Talks, the agreement contained no mechanism to verify North Korea's adherence to this commitment. North Korea needs to make its commitment to ending illicit procurement and proliferation abroad unambiguous and verifiable.

Inhibiting progress on centrifuges and preventing proliferation

While waiting for negotiations to bear fruit, the United States and its allies will face two interconnected challenges. They must focus on slowing down North Korea's centrifuge program or at least making progress more costly and visible to the international community. In addition, they must ensure that North Korea does not proliferate centrifuge, reactor, or other nuclear technology. A critical part of achieving both goals is thwarting North Korean illicit nuclear trading activities.

Accomplishing these goals requires a combination of actions, most of which are already embodied in U.N. Security Council resolutions. They include bans on the import or export of a wide variety of nuclear and nuclear-related goods, improved national export or trade controls combined with more effective implementation, strict financial controls, cargo interdictions, self-restraint and detection efforts on the part of industry and financial entities, and intelligence and diplomatic coordination. China's cooperation is essential to achieving more effective implementation of these methods. Discussing the upcoming imposition of new U.S. sanctions against North Korea on August 2, 2010, State Department Special Advisor for Nonproliferation and Arms Control Robert Einhorn stressed that the United States wants China to "…be a stakeholder in the international

[78] This report focuses on those sanctions implemented to disrupt procurement of goods that further North Korea's WMD and missile programs. They supplement and strengthen national and international trade control regulations. Other sanctions, such as the sanctions on luxury items, are outside the scope of this paper.

system…and not take advantage of the restraint of other countries."[79]

UN Security Council Resolutions 1718 and 1874

Adopted by the U.N. Security Council after North Korea's first nuclear test in 2006, resolution 1718 banned the transfer or procurement by North Korea of a wide range of goods and technologies related to the manufacture of nuclear weapons. After North Korea's second test in May 2009, the U.N. Security Council passed resolution 1874, which strengthened resolution 1781, and specifically called on member states to conduct interdictions at their discretion on suspicious cargoes going to or coming from North Korea. These resolutions are particularly useful in disrupting North Korea's ability to procure for its uranium enrichment program. Given North Korea's dependence on foreign supply for its nuclear programs, better implementation of these resolutions must be a priority.

The full implementation of these resolutions remains a challenge. A recent review of the implementation of the resolutions by the U.N. panel of experts created by resolution 1874 identified several deficiencies in their implementation.[80] The panel found that sanctions have hurt North Korea's conventional arms trade, including high volume missile equipment. However, their impact on both the transfer and importation of nuclear-related goods remains uncertain and inadequately understood. Nonetheless, as mentioned earlier, the panel was concerned about continued North Korean involvement in nuclear and ballistic missile related activities in certain countries, including Iran, Syria, and Myanmar. It noted that it was looking into suspicious activity in Myanmar by NCG.

The panel reported its findings and made a number of recommendations relevant to thwarting North Korea's centrifuge program:

- **Financial measures**: North Korea's ability to purchase materials illicitly overseas is made possible by transferring money through other countries' banks. North Korea uses a "broad range of techniques to mask its financial transactions, including the use of overseas entities, shell companies, informal transfer mechanisms, mixing illicit transactions with legitimate business activities, cash couriers, and barter arrangements."[81] Nonetheless, North Korea must, in most cases, continue to rely on the international financial system to conduct its financial operations. The panel recommends extra vigilance to assure that financial transactions and services do not contribute to North Korea's banned activities. To that end, all member states should adopt and implement the non-proliferation and anti-money laundering and combating the financing of terrorism principles and guidelines published by the Financial Action Task Force.

- **Designation lists**. There is a lack of a comprehensive list of North Korean individuals and entities believed by member states to be in violation of Security Council resolutions. Member states should provide more information to the oversight committees of the U.N. Security Council resolutions regarding individual names and entities, including aliases, to assist them in guiding member

[79] Chico Harlan, "US to Strengthen Sanctions Against N. Korea Amid Concerns of Chinese Influence," *The Washington Post*, August 2, 2010. http://www.washingtonpost.com/wp-dyn/content/article/2010/08/02/AR2010080201697.html?hpid=topnews

[80] Panel of Experts, op. cit.

[81] Panel of Experts, op. cit., paragraph 8.

states in preventing North Korea from engaging in proscribed activities.

- **Shipping vulnerabilities**. The panel found that North Korea is adept at exploiting shipping vulnerabilities by air or sea. Falsifying cargo descriptions and co-packing containers of banned equipment with innocuous materials are just two examples of such strategies. Particularly concerning is that under traditional maritime protocols, the ultimate port of origin or destination is often not included in information provided to transshipment ports. Further, the increasing flight distance of modern cargo aircraft has reduced the incidence of refueling stops where cargo inspections could theoretically occur. It will become increasingly important for countries commonly targeted for transshipment to adequately scrutinize cargo passing through their ports and for every country to closely monitor air traffic originating from North Korea, even if the aircraft never lands.

- **Need for better reporting.** The panel found that many member states are not reporting about their implementation and enforcement of the resolutions. It listed obtaining complete national implementation reports and compliance reports as a priority. It recommended that states should include in their compliance reports all relevant information about the prevention of illicit exports from their territories.

China's Special Role

As discussed earlier, North Korea frequently procures for its uranium enrichment program either from China or by using it as a transshipment point. China's trade control laws need to be better implemented, making it more difficult for North Korean smuggling entities to acquire vital direct use and dual-use goods for a centrifuge program.

A related concern is that China does not place enough of a priority on counter-proliferation intelligence. According to Western intelligence officials, Chinese intelligence agencies do not allocate enough resources to understanding and detecting illicit nuclear trade conducted by North Korea and Iran inside China. In addition, the government has not done enough to investigate the export violations of which it is aware.

China is unlikely to view North Korea's continued illicit procurement for its nuclear program as strengthening Chinese national security interests. Likewise, there is no evidence that the Chinese government is secretly approving these exports to North Korea's centrifuge program in an effort to strengthen North Korea's nuclear weapons program. Most believe that China views North Korea's nuclear weapons program as destabilizing to the region.

China is not applying enough resources to detect and stop North Korea's illicit nuclear trade. Although China has taken many actions to bolster its implementation of trade controls and U.N. Security Council resolutions, it should do more. China should launch an initiative against illicit activities by North Korea and, for that matter, Iran. With separate U.N. Security Council resolutions against Iran and North Korea, China should focus its efforts on both countries.

China does not view North Korea's or Iran's nuclear efforts with the same level of concern as does the United States. Nonetheless, since China seeks to be a global leader, it must take action to shoulder the responsibilities that attend such a status.

EPILOGUE

Despite the existence of so many tools to thwart North Korea's nuclear ambitions, success is not certain. Disagreements remain over when to reduce sanctions in the process of achieving diplomatic successes. North Korea, with some support internationally, wants to condition the resumption of negotiations on an end to sanctions, an approach it also took during the last round of successful Six Party Talks. But those sanctions principally involved U.S. unilateral ones. This time the sanctions are from the United Nations Security Council and are unlikely to disappear without significant progress on nuclear disablement or even disarmament after talks have begun.

Another unknown is whether the current regime will survive the upcoming transition in leadership, or emerge willing to negotiate away its nuclear assets. But new leadership could also be more determined to expand and improve its nuclear arsenal and to proliferate its nuclear technology. With such uncertainty, there are few choices but to focus on moving diplomacy forward, obtaining greater Chinese cooperation, and implementing a robust international regime against North Korea's illicit nuclear procurement and proliferation to others.

A NOTE ON SOURCES

This report has resulted from projects at ISIS that stretch back over a decade. It includes both published information and confidential sources. An important source has been journalists, who have contributed important information and insights into this difficult subject. During the last decade, government officials and experts from at least five countries have contributed information that was used in this report. These individuals acted with official approval but nonetheless prefer to remain anonymous. The country source for the information is given when possible. Unfortunately, this report could only be written by relying on confidential sources. Despite the obvious limitations of confidential sourcing, the report is able to make this new information available to the public.