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NUCLEAR DANGERS

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Although North Korea has the bomb, it has no nuclear arsenal to speak of and no nuclear-generated electricity.

North Korea's Choice
Bombs over Electricity

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Nuclear power and nuclear weapons have a common technological foundation. In pursuit of a civilian fuel cycle—making fuel, building reactors to burn the fuel, and dealing with nuclear waste, which might include extracting some valuable by-products of spent reactor fuel—a nation can develop the capability of producing the material necessary for a bomb, either highly enriched uranium or plutonium. Under civilian cover, North Korea developed a fuel cycle ideally suited to harboring a latent capability for weapons production. In fact, although the country now has the bomb, it does not have much of a nuclear arsenal or any nuclear-generated electricity (Hecker, 2010).

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In the 1970s, South Korea was also interested in the bomb, but it gave up those aspirations and, with international assistance, turned its nuclear focus to civilian energy. Today the South Korean nuclear power industry provides nearly 40 percent of the country's electricity, and South Korea is in a position to become a major international exporter of nuclear power plants. The factors that led North Korea to build the bomb and those that led South Korea to forsake it can be instructive for the United States in formulating a policy to restrain Iran's nuclear weapon ambitions, although the political situation there is dramatically different.

North Korea's gas-graphite reactor was ideal for producing plutonium fuel for a bomb.

Building a Dual-Use Nuclear Foundation

North Korea's nuclear story began about half a century ago. In the first phase of nuclear development, Kim Il-sung sent hundreds of students and researchers to Soviet-bloc universities and research centers to cultivate a base of technical expertise. Soviet material and technical assistance, under the umbrella of the Soviet Atoms for Peace program and the Soviet/North Korea 1959 nuclear cooperation treaty, led to the construction of a small research reactor (the IRT-2000) and, in the 1960s, many key nuclear facilities at the nuclear center in Yongbyon.

During the second phase, in the 1970s and 1980s, Pyongyang built an indigenous nuclear capability, driven partly by Kim Il-sung's interest in nuclear weapons and partly by his inability to obtain them from China or the Soviet Union. North Korea used its Soviet-supplied research facilities to train specialists and hone their skills by upgrading the research reactor to achieve higher performance.

Even though North Korea was then receiving minimal foreign assistance, it continued to rely on outside knowledge. Taking advantage of extensive declassified data on the design and operation of the first British reactor at Calder Hall (a dual-use reactor) and its larger progenies, such as Tokai-1 in Japan and Latina in Italy, North Korea was able to reverse engineer Western facilities. The country's first nuclear reactor, a 5-megawatt electric (MWe) gas-graphite reactor, became operational in 1986.

The gas-graphite reactor is well suited to industrializing countries with limited nuclear construction infrastructure and ideal for producing plutonium fuel for a bomb under the guise of generating civilian power.[1] With graphite moderation and carbon dioxide cooling, natural uranium can be used for reactor fuel, obviating the need for technologically demanding enrichment facilities. North Korea has abundant, indigenous supplies of uranium to fuel its reactors.

The gas-graphite reactor produces ample weapons-grade plutonium. And, because the natural uranium fuel is clad with a magnesium alloy that corrodes readily in contact with air and water, the discharged spent fuel rods are difficult to store. Thus North Korea was able to justify reprocessing the spent fuel to extract plutonium, which, in turn, can be used as bomb material.

Again relying on foreign designs, North Korea then copied the design of the Eurochemic reprocessing plant at the Mol-Dessel site in Belgium. Given Mol's international status, its many owners had published a plethora of information about its construction and operation. North Korean engineers used this information to construct the Yongbyon reprocessing plant.[2]

The 5-MWe reactor can produce roughly 6 kilograms (kg) of plutonium per year (about enough for one bomb), but the North Koreans were also building a 50-MWe reactor and a 200-MWe reactor, which together could have produced roughly 300 kg of plutonium per year when completed. The small reactor was well suited to quickly establishing a nuclear arsenal with little capacity for producing electricity; the medium-size reactor appears to be designed for dual use; and the large reactor appears to have been designed primarily for the production of electricity.

However, as the ambitious gas-graphite reactor program progressed in the 1980s, Pyongyang realized that modern light-water reactors (LWRs), which South Korea was acquiring from the West, were much better suited to producing electricity. Hence, in 1985, Kim

[1] The Calder Hall design was code named PIPPA (pressurised pile producing power and plutonium) by the UK Atomic Energy Authority to denote the plant's dual commercial and military role. Early gas-graphite reactors built by various nations were used as plutonium production reactors, sometimes in concert with commercial nuclear power.

[2] The Mol reprocessing plant (60 metric tons/year capacity) was commissioned in 1966 and operated jointly by 12 OECD countries, which formed the Eurochemic Corporation—the first international reprocessing plant. North Korea extended this design to a capacity of 110 metric tons/year, with room for future expansion to 220 metric tons/year.

Il-sung asked the Soviets to build two LWRs to meet the North's growing demand for electricity.

Ready to Deal but Retaining a Hedge

With the demise of the Soviet Union, North Korea's hopes of getting Soviet-supplied reactors crashed, but by that time Pyongyang had expanded its gas-graphite program. By 1992, North Korea had overcome initial start-up problems with its 5-MWe reactor, built an extensive fuel-fabrication facility, and demonstrated its reprocessing plant. It had also made significant progress on the construction of the 50-MWe reactor and had broken ground on the 200-MWe reactor. Pyongyang was thus prepared to launch the next phase of its program, building an actual bomb. However, because of drastic changes in the country and in the outside world, it chose not to build a nuclear arsenal.

The sudden end of the cold war brought about an equally abrupt end to the billions in foreign aid, guaranteed markets, and "friendship prices" Pyongyang had enjoyed from the Soviet bloc. Concurrently, China was moving quickly to open its economy to the West in support of its own agenda. As North Korea watched, both Russia and China recognized and reached out to its archrival, South Korea.

In response, Pyongyang began to seriously explore accommodation with the West, especially the United States, to get much needed assistance to reverse its economic deterioration; industrial capacity had dropped to a mere fraction of what it had been a decade earlier. Pyongyang realized that better relations with the international community and economic improvement could diminish its need for the bomb and potentially provide nuclear-generated electricity to help power its economy.

In 1992, Pyongyang opened the window to its nuclear program and allowed inspectors from the International Atomic Energy Agency (IAEA) into Yongbyon. But the window was quickly closed when inspectors uncovered discrepancies between their nuclear measurements and Pyongyang's declarations. In early 1994, after a few tense years, intense negotiations in Geneva led to the Agreed Framework,[3] which changed North Korea's nuclear trajectory dramatically.

Pyongyang was ready to trade its gas-graphite reactor program for the promise of two 1,000 MWe LWRs to be supplied by the United States and constructed at the Sinpo site, originally dedicated to two similar-sized reactors that had been promised by the Soviets. Operation of the 5-MWe reactor, fuel-fabrication plant, and reprocessing facility were halted and monitored by IAEA inspectors, and construction of the two larger gas-graphite reactors came to a stop. The spent fuel rods, which contained an estimated 20 to 30 kg of plutonium from the 5-MWe reactor, were repackaged by an American technical team and stored temporarily in a cooling pool for eventual removal from North Korea.

However, actual reconciliation between Washington and Pyongyang proved to be difficult. Washington considered the Agreed Framework primarily a nonproliferation agreement, whereas North Korea placed greater value on its relationship-building aspects. Although the relationship between Pyongyang and Washington under the Agreed Framework was rocky almost from the start, it did result in considerable cooperation and dialogue. However, because of congressional opposition to the agreement, which led to a lack of funding, the United States quickly fell behind in its commitments. In addition, a complicated procurement process slowed the project further.

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Perhaps concerned about the prognosis for the Agreed Framework, but unwilling to completely abandon all hope, North Korea restarted a uranium enrichment program in the late 1990s; the program appears to have been shelved earlier in the decade when plutonium operations proved to be successful.[4] To secure badly needed revenue, and possibly

[3] Under the Agreed Framework signed by the United States and North Korea on October 21, 1994, in Geneva, North Korea agreed to freeze its existing nuclear program. In addition to the United States supplying LWRs and delivering 500,000 metric tons of heavy fuel oil annually, the two sides agreed to move toward full normalization of political and economic relations and work together for peace and security on a nuclear-free Korean peninsula. See Arms Control Association link: *http://www.armscontrol.org/factsheets/agreedframework*.

[4] North Korea most likely experimented with uranium enrichment technologies in the 1980s in parallel with its plutonium program. For example, it attempted to purchase vacuum system components from Germany. In the late 1990s, Pyongyang is reported to have acquired centrifuge technology from Pakistan's A.Q. Khan (Musharraf, 2006). Additional evidence, including the purchase of aluminum tubes suitable for centrifuge rotors from Russia and attempted purchase from Germany, is discussed by Zhang (2009).

maintain the expertise of its idle nuclear workers, North Korea began to look into exporting nuclear technologies to Syria, Libya, and perhaps Iran, much as it had done with its missile technologies (Miller and Richter, 2008; Sanger and Broad, 2005).

The long-range missile test in April 2009 surprised the Obama administration.

Exercising the Hedge by Building the Bomb

Although beset by years of delays and almost derailed by the 1998 missile crisis that was saved by the Perry process,[5] the Agreed Framework was finally derailed by the change of U.S. administrations. Pyongyang suffered a major strategic setback when the Bush administration opposed both the terms of the Agreed Framework and efforts to achieve political accommodation. In late 2002, the United States accused North Korea of violating the agreement by pursuing the uranium enrichment path to the bomb.

Pyongyang used the occasion to exercise its hedge by building the bomb. It expelled IAEA inspectors, withdrew from the Nuclear Nonproliferation Treaty, reprocessed the spent fuel rods that had been previously packaged and stored, and restarted its reactor to make more plutonium. In 2003, for the first time, Pyongyang told the Americans it had manufactured nuclear weapons and that it would continue to strengthen its "deterrent."

The years 2003 to 2009 were characterized by intermittent disarmament discussions punctuated by provocative weapons-related actions. Pyongyang returned to the negotiating table under the Six-Party talks and signed the Joint Statement on the denuclearization of the Korean peninsula on September 19, 2005. However, the United States concurrently imposed financial sanctions, which convinced Pyongyang that its relationship with the United States had not fundamentally changed. Pyongyang then chose to demonstrate its nuclear capabilities with a nuclear test in October 2006.

Although the nuclear test was only partially successful, it changed Pyongyang's negotiating strategy, especially after the Bush administration relented and agreed to hold bilateral discussions. At this point, Pyongyang insisted that it be treated as a nuclear state and that the negotiations focus on mutual disarmament rather than on unilateral denuclearization.

After surprising the Obama administration with another long-range missile test in April 2009, North Korea responded to the predictable United Nations Security Council (UNSC) condemnation by once again walking away from all nuclear negotiations and conducting a second nuclear test in May. UNSC Resolution 1874 condemned the test and tightened sanctions.

Nevertheless, this test, which was much more successful than the first, appeared to embolden North Korea and strengthen its diplomatic hand. By the summer of 2009, Pyongyang signaled Washington that it was, once again, ready to talk; but since then it has skillfully dragged out its return to the Six-Party talks, trying to shape the conditions and the agenda under which it returns.

In retrospect, had the United States expeditiously implemented the terms of the Agreed Framework and built the LWRs as planned, Pyongyang would have traded a nuclear fuel cycle that was primarily geared to making weapons-grade plutonium for an LWR fuel cycle that is much less suitable for making bombs and much easier to monitor and control. Although we believe Pyongyang explored uranium enrichment as a potential alternative for making nuclear weapons in case the Agreed Framework fell apart,[6] the Bush administration's decision to confront Pyongyang in October 2002 proved to be disastrous.

Although the confrontation had the intended effect of killing the Agreed Framework negotiated by the Clinton administration, the United States was unprepared to deal with North Korea walking out, building the bomb, and then demonstrating it. In effect, the United States had traded the risk of North Korea developing a

[5] As a result of a congressionally mandated commission headed by former Secretary of Defense William J. Perry, Pyongyang's second-ranking official, Vice Marshal Jo Myong-rok, visited the White House in October 2000. The two sides issued a Joint Communiqué that pledged "neither would have hostile intent toward the other and confirmed the commitment of both governments to make every effort in the future to build a new relationship free from past enmity." Combined with Secretary of State Madeline Albright's meeting with Kim Jong-il in Pyongyang a couple of weeks later, it dramatically changed the security relationship and nearly resolved both nuclear and political issues.

[6] In addition to the evidence presented above, traces of HEU contamination were found on items that North Korea turned over to the United States in an attempt to prove it had no such activities (Kessler, 2008).

highly enriched uranium bomb, which was many years away, for the risk of a plutonium bomb, which took only months to develop. Today, there is still no convincing evidence that North Korea has been able to advance beyond the exploratory stage of uranium enrichment.

Following the UN reprimand in April 2009, North Korea declared that it would pursue uranium enrichment to fuel LWRs that it would build itself. In September 2009, it declared success, although it is technically not possible to succeed in such a short time. The announcement appears to be politically motivated to allow Pyongyang to now justify enriching uranium. However, we believe that North Korea is not technically prepared to enrich uranium beyond the laboratory scale or to build its own LWR.

Ironically, while the United States and the international community were trying to keep North Korea from importing nuclear materials, Pyongyang was engaged in exporting nuclear technologies. It appears to have exported uranium hexafluoride, a precursor to highly enriched uranium, to Libya for Muammar Gaddafi's covert centrifuge program. From 2001 to 2007, it also built a plutonium production reactor for Syria; the facility was destroyed by an Israeli air attack before it became operational. What is most disturbing, however, is that North Korea was never taken to task for these egregious actions and today may be cooperating with Iran, with which it has had a robust exchange of missile technologies.

The Price of Keeping the Bomb

North Korea enters the next round of Six-Party negotiations with a handful of bombs, which we believe are of primitive design and have not been miniaturized to fit on top of a missile (Hecker, 2010). We estimate that, even though its plutonium-producing reactor became operational 24 years ago, North Korea has only 24 to 42 kg of plutonium, enough for four to eight bombs. That reactor is now shut down, and although the fuel-fabrication and reprocessing plants are functional, there is no new plutonium in the pipeline. North Korea appears ready to give up the Yongbyon plutonium-production complex, apparently believing that the political value of its few bombs is sufficient to keep the United States out and to provide negotiating leverage.

Pyongyang does not appear ready to give up its nuclear weapons, which it believes are necessary to secure the regime's survival domestically and internationally. In addition, the power and prestige of the bomb are believed to be diplomatic levers that strengthen North Korea's negotiating position. Pyongyang views the bomb as a diplomatic equalizer with South Korea and Japan, its much more prosperous and powerful, but non-nuclear rivals.

Without nuclear weapons, North Korea would receive scant attention from the international community. But what price did Pyongyang pay for getting the bomb, and how much more is it willing to pay to keep it?

Pyongyang's economic system and military-first policy, in which nuclear weapons are a key element, have resulted in a state of abject poverty in contrast to its free-market southern neighbor. Choosing to build the bomb cost North Korea the opportunity to produce much needed nuclear electricity for its energy-starved country. Unless it has much more electric power than it now has, North Korea cannot effectively rebuild its industries.

While the international community was trying to keep North Korea from importing nuclear materials, Pyongyang was exporting nuclear technologies.

Construction of the two larger indigenous reactors, which could have delivered substantial electricity, was terminated by the Agreed Framework. Having lain dormant and unprotected since then, these larger reactors are now unsalvageable. Construction of the two LWRs promised as part of the Agreed Framework was terminated when the agreement collapsed, and there is not much to be salvaged. Although the Yongbyon reactor supplied small amounts of electricity and heat to the local town, the total amount of electricity it produced during its entire lifetime is equivalent to just 23 days of operation of one modern LWR.

The pursuit of nuclear weapons has cost North Korea much more than electricity. Its entire economy has suffered because of international sanctions and isolation following the missile launches and nuclear tests. North Korea has one of the highest political risk factors in the world, making it difficult to attract foreign capital and

foreign aid. Moreover, recent cutbacks in economic support from South Korea have led to further isolation and economic impoverishment.

By building the bomb, North Korea also effectively terminated its production of medical isotopes. The county has not been able to acquire the fresh highly enriched uranium fuel necessary to operate the small Soviet-supplied research reactor that used to produce medical isotopes.[7] Yongbyon's technical specialists, although trained and competent, are now cut off completely from the global scientific community—including in areas such as nuclear safety and nuclear safeguards. University and civilian research facilities suffer from a chronic lack of electricity to run their equipment and train their people, thereby wasting the country's precious, limited human capital.

South Korea has realizable ambitions of becoming a leading exporter of nuclear power plants.

North Korea's nuclear choice and current economic status provide a stark contrast to the situation in South Korea, which seriously explored the development of nuclear weapons in the 1970s but gave up its pursuit because of heavy U.S. pressure and guarantees of increased U.S. security measures (Oberdorfer, 2001). As part of South Korea's drive to become an international economic powerhouse, it began to build a robust nuclear power program, initially with Western technology and assistance.

Eventually, however, the South developed an impressive indigenous capability in a transparent way in cooperation with Western suppliers, the Nuclear Suppliers Group, and the IAEA.[8] Today, South Korea has 20 modern LWRs that produce nearly 40 percent of its electricity. It has a strong nuclear research establishment in the Korean Atomic Energy Research Institute (KAERI) and its industrial nuclear-supply infrastructure.

South Korea has realizable ambitions of becoming one of the world's leading exporters of nuclear power plants. A recently awarded $20.4 billion contract to build the first four power plants in the United Arab Emirates is an example of its growing global role (Coker, 2009). In addition, in cooperation with the industrial giant Daewoo, KAERI just signed a contract to build a research reactor for Jordan. South Korea today has too much to lose economically to pursue the nuclear weapons option. In fact, it tries to be especially transparent and compliant so as not to jeopardize its export business.[9]

We draw the contrast between the North and the South not to suggest that North Korea could have done as well if it had simply pursued nuclear electricity and an expanded economy instead of bombs, but to demonstrate that North Korea could have much to gain by trading its military program for a civilian program. As it is, North Korea has gotten very little in return for its huge investments in its nuclear program. Even its remarkable technical accomplishments have been negated by international sanctions and isolation. Giving up the bomb and developing civilian nuclear power could help lift its economy and its people out of poverty.

Lessons Learned and a Path Forward

The North has paid a heavy price for choosing the military over the civilian route to nuclear power because its existential security concerns were never resolved by diplomatic means. Once the bomb had been built and demonstrated, it propped up the regime both internally and externally, and the country toughened its negotiating position. Ironically, today the regime may be protecting itself against imagined external enemies while the primary threats are internal and economic—a situation perhaps not unlike that of the Soviet Union in the 1980s.

The security concerns of the South, on the other hand, were taken care of by the U.S. alliance, which not only keeps U.S. troops on South Korean soil, but

[7] During a visit to Yongbyon in February 2008, Ri Hong-sop, former director of the Yonbyon Nuclear Center, told Hecker that Russia refused to supply new fuel in the 1990s because North Korea could not afford to pay. Now international sanctions preclude all purchases of HEU.

[8] In 2004, South Korean scientists from the KAERI, however, conducted experiments in laser isotopic enrichment of various elements including uranium. These experiments were conducted without informing Korean Ministry officials or IAEA safeguards inspectors. This activity was stopped and fully reported to the IAEA later in 2005.

[9] South Korea is exploring a spent-fuel reprocessing option using pyroprocessing for its nascent breeder reactor program and for the reprocessing and volume reduction of their accumulated spent power-plant fuel. The effort is convincingly civilian this time because of the transparent manner in which South Korea is pursuing reprocessing.

Figure 1 Satellite image of the night sky over North and South Korea. Source: MailOnline, 2010.

for several decades also kept nuclear weapons stationed there. By moving toward a democratic government, gearing its economy for export, and providing 40 percent of its electricity from commercial nuclear power, South Korea has become an economic powerhouse.

The next Six-Party negotiations must balance the disincentives the parties can bring to bear on North Korea if it chooses to keep the bomb—namely further international sanctions and isolation—with incentives for greater security and economic development. To develop effective incentives, the United States should review its diplomatic record with North Korea. Instead of remaining fixated on denuclearization, Washington should realize that, in spite of its inconsistent and often contradictory policies during the past 20 years, diplomacy has left Pyongyang with only a handful of bombs, instead of the 100 or more it might have had by now, and essentially no significant nuclear-generated electricity (Figure 1).

Washington still considers the Six-Party talks and the September 19, 2005, Joint Statement primarily a denuclearization agreement, much as it considered the Agreed Framework. Pyongyang, however, views all of these agreements through the lens of resolving more than 60 years of hostilities on the Korean peninsula. Thus, although denuclearization must remain the final goal, we must approach it in combination with Pyongyang's need for security and economic recovery.

Trading in its weapons-oriented nuclear program for one that can deliver electricity and nuclear medicine would be an important step in that direction. Since this will take some time, however, Washington should focus now on managing the greatest risks—namely stopping all nuclear exports and keeping North Korea from building more and better bombs—as part of an overall understanding to ending all nuclear weapons activities.

Finally, we hope that the stark contrast between North and South Korea in nuclear direction and the consequences of those choices will also give Iran pause as it pushes ahead with its nuclear ambitions; at the same time, that contrast could also inform U.S. policy toward Iran. Although Pyongyang has demonstrated that a handful of bombs can protect its regime from the United States, that protection has been bought at an enormous price.

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