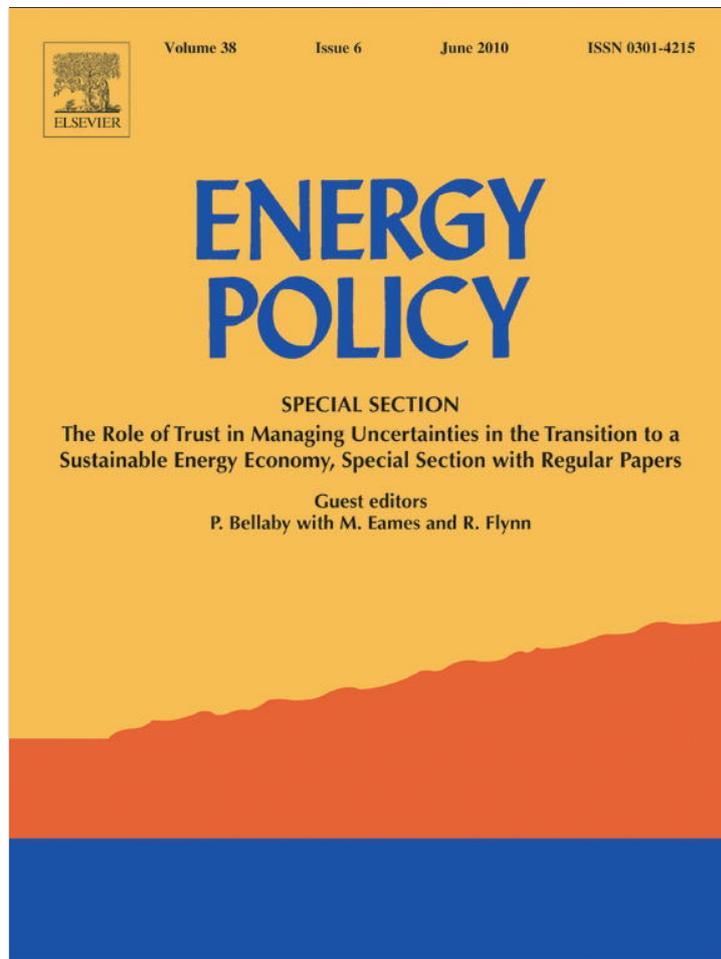


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## Rogue proliferator? North Korea's nuclear fuel cycle & its relationship to regime perpetuation

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### ABSTRACT

North Korea is unlikely to relinquish its nuclear program because of its importance to the perpetuation of the Kim regime. This conclusion arises from the observation that the nuclear program has been a long-term project spanning several decades, culminating in denuclearisation negotiations, which have followed a cyclical pattern in which the North has provoked crises to extract concessions and gain leverage vis-a-vis regional states. It is clear that the nuclear program has great intrinsic value to Pyongyang. First, this paper argues that the sunk costs of previous investment in the nuclear program, as evidenced by the infrastructure for the country's nuclear fuel cycle, create forward momentum favouring continuation of the nuclear program. Second, it argues that the nuclear program solidifies Kim regime rule as an institutional buttress, as a prop for the domestic economy, and as a vehicle for ideological legitimisation. The paper is a unique contribution, which explicitly links the Kim regime's proliferation calculus to the economic and bureaucratic imperatives of regime perpetuation, as well as the sunk cost of previous investment in the nuclear program. It provides a coherent explanation for North Korea's consistent unreliability in negotiations, and offers insights into future prospects of the denuclearisation process.

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### 1. Introduction

The motivations for North Korea's nuclear proliferation are not comprehensible without an understanding of the technical aspects of the nuclear program itself. Observers often refer to nuclear dismantlement as if it were something the North could perform very rapidly. By examining the physical extent of the program, it becomes clear that it is not the case. In a very real way, the physical plant of the program, the nuclear infrastructure, is embedded in the national economy, which becomes clear when considering the numerous complex industrial processes of the North's nuclear fuel cycle. By understanding the technical aspects of the Kim regime's nuclear capability and the motivations for its nuclear proliferation, one can successfully locate the program within the political economy of the DPRK state and evaluate its importance to the institutional maintenance of the North's unique political system.

The paper provides readers with an understanding of integration of North Korea's nuclear program into the political economy of the DPRK state. It aims to demonstrate how North Korea's nuclear fuel

cycle, with its associate bureaucracy, are integral economic survival, political stability and ideological legitimisation of the Kim regime. In this regard, it is a unique contribution to the academic literature, which explicitly links the Kim regime's proliferation calculus to the economic and bureaucratic imperatives of regime perpetuation, as well as the sunk cost of previous investment in the nuclear program. In doing so, it provides a coherent explanation as to why North Korea has consistently proven to be an unreliable negotiating partner, and offers insights into future prospects of denuclearisation negotiations. Using this information, policy-makers should re-evaluate the practicality of a negotiated settlement as an instrument to secure the dismantlement of North Korea's nuclear program, in favour of a strategy for constructive management of Northeast Asian security in light of North Korea's ascension as a nuclear power.

This research focus is important because it comes at a time when the evolution of political dynamics in Northeast Asia is beginning to accelerate. China's growing role as a centre of power is occurring as the United States begins to diminish as a global superpower. In Japan, tension exists between its historic pacifist posture under US protection and pressure from the political right to return Japan to a more active and 'normal' strategic posture. Internationally, the global financial crisis, energy insecurity and climate change are emerging challenges to regional stability, despite the difficulty in calibrating their precise long-term impacts. In this context, old denuclearisation strategies have

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become obsolete. To improve regional political and economic stability, regional states must acknowledge the wide-ranging imperatives driving North Korea's nuclear proliferation. The intellectual task of nesting the technical understanding of North Korea's nuclear fuel cycle within the context of the Kim regime's motivations for proliferation is integral to this objective.

The first section will describe North Korea's nuclear fuel cycle in order to document the physical extent of the nuclear program. The second section addresses the quest for weaponisation of the nuclear program, including miniaturisation, testing and potential delivery systems. The third section explores the domestic political economy considerations driving Pyongyang's nuclear calculus, incorporating economic, institutional and ideological factors. The inescapable conclusion is reached that North Korea is unlikely to relinquish its nuclear program because no suite of incentives on offer from the international community can match its utility in maintaining the rule of the Kim regime.

## 2. North Korea's nuclear fuel cycle

The nuclear fuel cycle consists of a number of complex industrial processes through eight specific stages. This analysis demonstrates the resource inputs, industrial hardware and technical expertise necessary to maintain the nuclear program, as well as the geographic dispersion of important nuclear sites. While Yongbyon clearly is the epicentre of the nuclear operation, other important nuclear-related facilities are located around the country. As will be made clear, it is unrealistic to expect hasty dismantlement of the nuclear infrastructure, regardless of any denuclearisation agreement.

### 2.1. Uranium mining and milling

North Korea is endowed with extensive uranium ore deposits, which constitute the prerequisite feedstock of the nuclear fuel cycle. Surveys conducted during the 1970s suggest that North Korea at that time possessed ~300,000 tons of uriferous black shale ore, at concentrations of around 0.2% uranium, located at depths of about 200 m (Hayes 2004). Today, large-scale uranium mine sites in North Korea include Suncheon in South Pyongan province, Kusong, in North Pyongan province, Unggi in North Hamgyong province, Pyongsan in North Hwanghae province, and Pakchon in South Hamgyong province (Nuclear Threat Initiative 2007). North Korean mines use two uranium ore extraction techniques; open cut mining is used when the ore body lies at a shallow depth, while underground mining techniques are employed when the ore deposit is greater than 120 m deep (Hayes 2004; Hore-Lacy 2004, p. 317).

Uranium milling facilities are generally located close to the ore body. North Korea's uranium milling facilities are located at Suncheon, Pyongsan and Pakchon, close to uranium mines in those areas (Global Security 2006a, b). The extracted ore must be milled to concentrate the uranium in a form more practical for industrial processing because of the low concentration of uranium in the ore body (as little as 0.2%). The milling process crushes the ore into a powder, which is then filtered through a strong acid or alkaline solution to leach the uranium from the ore fragments. The leached uranium is precipitated from the solution then dried and heated to produce a concentrate of uranium oxide, known as yellowcake, which contains ~80% uranium. The remainder of the ore is waste tailings consisting of radioactive materials and toxic heavy metals that need to be stored in isolation from the wider environment (Landa, 2004, 1–2). One ton of North Korean uranium ore contains ~1 kg of uranium, which means that 50,000 tons of uranium ore had to be mined and milled to extract the 50 tons of uranium

required for the initial fuel load for the 5 MW(e) reactor at Yongbyon. At peak production in the early 1990s, before the 1994 freeze under the Agreed Framework, North Korea was able to produce about 300 tons of yellowcake annually, from ~30,000 tons of ore (IISS, 2004, p.33).

### 2.2. Uranium conversion and enrichment

#### 2.2.1. Conversion

Ordinarily yellowcake must be processed into uranium hexafluoride, then fed into a uranium enrichment process to increase the proportion of the isotope uranium-235 ( $^{235}\text{U}$ ) in the final fuel load (Makhijani et al., 2004, pp. 32–33). Most reactors operating around the world today require enriched uranium for fuel. However, the 5 MW(e) [MW(e)=megawatts of electric output] reactor at Yongbyon is a gas-cooled graphite-moderated model, based on the UK's Calder Hall plutonium production reactor, which is capable of using fuel fabricated directly from unenriched natural uranium (Hayes, 2004; Kokoski, 1995, p. 12). This was advantageous to the North Koreans because the materials, technology and equipment for uranium enrichment would have had to be imported from abroad (Hecker and Liou, 2007, p. 7). Skipping the enrichment step was not only cheaper and more practical, but also allowed the front end of the fuel cycle to remain an indigenous operation.

North Korea has mastered the processing of yellowcake to uranium dioxide and then into uranium tetrafluoride, which is the precursor step to conversion into uranium hexafluoride, the feedstock for uranium enrichment (Hecker and Liou, 2007, p. 8). A reported export of 2 tons of uranium to Libya from North Korea in 2004 raised concerns that a uranium hexafluoride conversion process had been mastered at Yongbyon, though it is unclear whether the export load was delivered as yellowcake or as uranium hexafluoride. If it was the latter, it means the North has developed the expertise for full uranium conversion and has mastered the prerequisite step for uranium enrichment (Hayes 2004). However, IAEA inspections of the Yongbyon fuel fabrication plant prior to 2003 found no evidence of the equipment needed to produce uranium hexafluoride (Hecker and Liou, 2007, p. 8). The existence of a full conversion process at Yongbyon, or elsewhere in North Korea, remains a matter of debate.

#### 2.2.2. Uranium enrichment

Natural uranium primarily consists of two isotopes:  $^{235}\text{U}$  and  $^{238}\text{U}$ . Of the two, only  $^{235}\text{U}$  is fissile, though it constitutes only 0.7% of the natural uranium load. Uranium must be enriched to ~2–4%  $^{235}\text{U}$  for use as fuel in light water reactors and to over 90% as highly enriched uranium (HEU) for use in nuclear weapons (Makhijani et al., 2004, p. 5). As North Korea does not have any operational light water nuclear reactors, any uranium enrichment activity is likely to be devoted specifically to the production of fissile uranium for nuclear weapons.

There are two enrichment processes currently in commercial use around the world: gaseous diffusion and gas centrifuge, which both use uranium hexafluoride as a feedstock and both use the different molecular weights of  $^{235}\text{U}$  and  $^{238}\text{U}$  to separate the isotopes. Gaseous diffusion requires a massive "cascade" of at least 1200 diffusion stages, where each stage enriches the uranium slightly more to produce 3%  $^{235}\text{U}$  reactor-grade uranium. Over 4000 stages are required to produce highly enriched weapons-grade uranium using this technique (Kokoski, 1995, p. 63). Gaseous diffusion facilities in the United States and Europe are enormous, requiring physical space, equipment and substantial energy inputs that are not available in North Korea. If the North did establish such a facility, its size and energy signature

would make it easily detectable by surveillance satellites. By contrast, gas centrifuge enrichment achieves isotopic separation by rotating the uranium hexafluoride at very high speed in rotating metal cylinders, where centrifugal acceleration causes the isotopes to separate out by weight. A cascade of only ten centrifuges is all that is required to produce reactor-grade uranium, or about 35 centrifuges for highly enriched weapons-grade uranium. However, as the capacity of each centrifuge is very small, thousands of centrifuges are required to produce highly enriched uranium on an industrial scale (Makhijani et al., 2004, pp. 11–13).

### 2.2.3. Highly enriched uranium (HEU)

It is unclear whether the North has progressed to an operational industrial-scale uranium enrichment program today. There is no smoking gun to prove its existence and the evidence that does exist is largely circumstantial. In 1998, claims surfaced that there was a secret enrichment plant located in underground facilities at Kungchang-ri, 160 km north of Pyongyang (Corera, 2006, pp. 92–93). Subsequent inspections of the site in 1999 and 2000 appeared to refute this, ascertaining that the facility in question had not housed any enrichment activities (Milton and Kampani, 1999). The Central Intelligence Agency (CIA) and the US Department of Energy are believed to have documentary evidence including contracts, banking and shipping receipts documenting North Korea's overseas procurement of materials and components destined for the HEU program (Niksch, 2006, p. 98). North Korea reportedly bartered missile technology for centrifuge enrichment equipment with Pakistan in the late-1990s through the network of Abdul Qadeer Khan, the chief scientist behind Pakistan's nuclear program. Khan reportedly visited Pyongyang at least thirteen times between 1997 and 2002, the alleged period in which the North Korean HEU program expanded. The circumstantial evidence is damning, but there is no direct proof in the public record that Pyongyang acquired centrifuge technology from this source (Corera, 2006, pp. 92–93; Niksch, 2006, pp. 105–106).

During a trilateral meeting held in Beijing in October 2002, the Americans accused the North of conducting a clandestine HEU program. At a meeting on October 4, DPRK First Vice Minister Kang Sok-ju stated in reply that North Korea was forced to reinforce its “military-first” policy by modernising its military to the maximum extent possible. Kang cited North Korea's inclusion in President Bush's “axis of evil,” the preventive war doctrine outlined in the 2002 US National Security Strategy, and the targeting of North Korea by American nuclear weapons as mitigating factors. Charles Pritchard, who was a member of the American negotiating team, recalled that Kang did not explicitly admit to a HEU program:

While there was no precise, irrefutable statement—a smoking gun—many factors led all eight members of the US delegation to reach the conclusion that Kang had effectively and defiantly admitted to having an HEU program. Kang acknowledged that we said that his country had begun a uranium enrichment program for the production of nuclear weapons. Immediately following that statement, he declared that the DPRK was in fact prepared to manufacture even more developed weapons; he then said that the DPRK needed to be on equal footing with the United States if it was to discuss the issue of denuclearisation (Pritchard 2007, p. 38).

According to Pritchard, the US team arrived at a consensus on the meaning of Kang's remarks through a cumbersome process in which the three Korean linguists in their group were isolated and asked to recreate Kang's statement from memory, or from any notes that they

took during the meeting. They then created a final text by consensus that they felt accurately re-created Kang's statement. Clearly the Kang “admission” was far from unambiguous.

A CIA intelligence estimate circulated in the US Congress in November 2002 alleged that North Korea had been working on a uranium enrichment program for several years. The estimate stated that the regime had been attempting to secure “centrifuge-related materials in large quantities” and was constructing an enrichment plant at an undisclosed location (CIA, 2002). The Bush administration extrapolated a worst-case scenario of a HEU program from “sketchy data” that did not warrant such an extreme conclusion (Harrison, 2005, p. 1000). Evidence of limited centrifuge acquisition by North Korea does not support the notion that the North obtained the thousands of centrifuges necessary to conduct an industrial-scale HEU process. There is a significant difference between assembling a small-scale centrifuge program with a few dozen centrifuges and operating a large-scale production plant involving the manufacture of thousands of complete centrifuges (Hecker, 2009; Albright, 2007, p. 1). The best estimate from the evidence at hand is that the North has a small HEU effort that has not progressed beyond an embryonic phase.

### 2.3. Fuel fabrication

As noted above, the fuel fabrication facility at Yongbyon houses processes for the production of fabricated reactor fuel from yellowcake. At the end of the conversion process, uranium tetrafluoride is furnace-moulded into metallic uranium ingots. In the final stage of fabrication, the uranium tetrafluoride ingots are melted into an aluminium alloy. The extruded mixture is then machined into fuel rods 50 cm long and 3 cm in diameter. The rods are then clad in magnesium–zirconium alloy (magnox) cladding, after which they are ready for insertion into the reactor. The 5 MW(e) reactor at Yongbyon requires a full load of ~8000 fuel rods (IIS, 2004, p.36). The North currently has around 2000 magnox-clad fuel rods in storage, which were fabricated for the 5 MW(e) reactor prior to 1994 but remain ready for use, along with ~12,000 unclad fuel rods that were manufactured for use in the 50 MW(e) reactor (Hecker, 2009).

During a visit to Yongbyon in December 2006, Sigfried Hecker (2006, p. 7) was told by Yongbyon nuclear center Director Ri Hong-sop that a section of the fabrication facility had been under repair but would be ready to resume operation sometime in 2007. IAEA inspectors verified on 17 July 2007 that the fuel fabrication facility had been disabled in accordance with the 2007 nuclear freeze agreement (Lee and Choi, 2007). In fact, the facility was abandoned because the industrial equipment used to convert uranium oxide into uranium tetrafluoride has been excessively corroded and cannot be used (Hecker, 2009). According to Ri however, the reactor was being operated with the spare fuel rods from the previous inventory described above. There was no hurry to recommence production as enough fuel rods had already been produced to service the 5 MW(e) reactor, while no extra fuel was needed for the incomplete 50 MW(e) and 200 MW(e) reactors. To manufacture new fuel rods the fabrication facility will need to undergo substantial repairs.

### 2.4. Burn-up: reactor operation

The 5 MW(e) reactor at Yongbyon is a gas-cooled, graphite-moderated design capable of producing up to 25 MW of thermal output. The reactor core consists of 300 tons of graphite blocks, vertically cut with between 801 and 812 fuel channels. Each channel holds 10 fuel rods stacked vertically on top of one another, giving the reactor capacity for about 8000 fuel rods in

total. A further 300 tons of graphite encase the graphite blocks containing the fuel rod channels, which reflect neutrons back into the core. A steel pressure vessel encloses the entire core structure to contain cooling gas and limit the release of radioactive particles. Pressurised carbon dioxide is blown through the core to keep it cool. A large machine located at the top of the core is used to load and remove fuel rods. If operating at full power for 300 days/year, the reactor could produce  $\sim 7.5$  kg of weapons-grade plutonium every year, reprocessed from the spent fuel (Global Security, 2006a, b).

IAEA inspectors verified on 17 July 2007 that the 5 MW(e) reactor had been shut down in accordance with the 2007 nuclear freeze agreement (Lee and Choi, 2007). On 27 June 2008, the reactor's cooling tower was demolished as a gesture of goodwill to indicate compliance with agreements reached in the Six Party talks and by early 2009,  $\sim 90\%$  of disablement work under the agreement was complete (KCNA, 2009). In response to international condemnation of its April 2009 rocket launch, the DPRK announced its intention to permanently withdraw from the Six Party talks, restore the Yongbyon facilities to full operation and recommence reprocessing plutonium from the stockpile of spent fuel rods at the site (IAEA, 2009, p. 3). For the reactor to resume production at optimal levels, a new cooling system would have to be built, which could take between six months to one year. Alternatively, the reactor could run without a cooling system at very low power levels, though the rate of plutonium production would also be quite low (Hecker, 2009).

North Korea has two other incomplete larger reactors that have been under construction for some time. Construction at both sites ground to a halt under the Agreed Framework and following the hiatus both require significant extra repairs for construction to resume (Albright and Brannan, 2007, pp. 1–2). The site for the 200 MW(e) reactor is located at Taechon, about 20 km from Yongbyon. According to the International Atomic Energy Agency (2008, p. 3), no work has been done at this site since 2002. The Yongbyon site also houses North Korea's first nuclear reactor, the IRT-2000 research reactor built in the 1960s. This reactor was utilised for medical isotope production and other research projects but has been used only sparingly since 1991 due to fuel supply constraints (Mansourov, 1995, p. 26).

### 2.5. Spent fuel storage and reprocessing

Spent fuel freshly removed from a reactor emits a substantial amount of heat and radiation. Used fuel is thus unloaded into a storage pond where the water traps radiation and absorbs heat. Fuel must remain in temporary water storage for periods ranging from six months to several years, allowing sufficient time for short-lived isotopes such as the volatile iodine-131 to degrade (Betti, 2000, p. 366). The Yongbyon facility contains a spent fuel storage pond located next to the 5 MW(e) reactor (Hecker, 2004, p. 4). Prior to April 2009, over three-quarters of the 8000 fuel rods had been removed from the reactor under the nuclear freeze agreement, though removal had slowed to only 15 fuel rods per week, dragging out the estimated date of full dismantlement to 2011 (Hecker 2009).

Once the spent fuel has cooled and unstable fission products have decayed, the fuel can be removed from storage and reprocessed. Spent fuel contains  $\sim 96\%$  of its original uranium, with a reduced content of  $^{235}\text{U}$  isotopes (less than 1%). Waste products make up 3% of spent fuel, while the remaining 1% is plutonium. Reprocessing separates the uranium and plutonium from the waste products. The separated uranium is recyclable at the conversion stage of the cycle, while separated plutonium can be used for nuclear weapon production (Betti, 2000, p. 366).

The Purex method (plutonium–uranium extraction), employed extensively in the nuclear industry worldwide, is used to reprocess spent fuel at Yongbyon. Spent fuel is transported by lorry in lined casks from the storage pond to the reprocessing facility, which has become known as the “radiochemical laboratory,” where the fuel has its cladding removed mechanically (Niksich, 2006, p. 8). Next, the de-cladded rod is dissolved in nitric acid and then mixed with various organic liquids, before passing through a series of mixer-settler tanks where plutonium and uranium are selectively precipitated from the remaining fission products. Using a similar process, the plutonium–uranium mixture then passes through more mixer-settler tanks to separate the plutonium from the uranium. The separated plutonium is purified into plutonium oxide powder in a series of glove boxes, which are small radiation-insulated chambers in which radioactive materials can be handled safely. Plutonium metal ingots are smelted from this powder, which can later be melted and cast into components for nuclear weapons. A series of tanks are located adjacent to the radiochemical laboratory for storage of liquid and solid radioactive waste (IISS, 2004, p. 36).

IAEA inspectors toured the radiochemical laboratory during their inspection regime between 1992 and 1994. The facility was operational at this time and had a peak capacity to reprocess  $\sim 220$ –250 tons of spent fuel per year, if operated continuously for 300 days, which was of sufficient capacity to reprocess all the spent fuel from the 5 MW(e) and 50 MW(e) reactors. Operations at the facility were frozen under the Agreed Framework, but were recommenced in 2003 when reprocessing began on the 8000 fuel rods stored in the temporary storage pond at Yongbyon. A second reprocessing campaign extracted plutonium from fuel burnt in the reactor between February 2003 and March 2005 (Hecker and Liou, 2007, p. 8). IAEA inspectors verified on 17 July 2007 that the Radiochemical Laboratory had been shut down in accordance with the 2007 nuclear freeze agreement.

### 2.6. North Korea's plutonium stockpile

Calculations of the size of North Korea's plutonium stockpile are highly uncertain because of the lack of verifiable data concerning reprocessing efforts. In theory the 5 MW(e) reactor is capable of producing 0.9 g of plutonium per day. If the reactor runs at an average capacity of 85% over a year, the amount of plutonium produced would range between 5.5 and 8.5 kg. A more realistic estimate assuming the reactor operates at 60% capacity over a year would yield between 4 and 6 kg of plutonium (Global Security, 2006a, b). Reprocessing activities have yielded a total estimated plutonium stock of  $\sim 46$ –54 kg, of which between 28–50 kg is processed and ready for use in nuclear weapons (Albright and Brannan, 2007, p. 1; Norris and Kristensen, 2005).

David Albright and Paul Brannan (2007, p. 1) speculate that a plutonium stock of this size is sufficient to make between 5 and 12 nuclear weapons, based on the assumption that each bomb contains 4–5 kg of plutonium. They further conjecture that North Korean engineers may use more plutonium per weapon, perhaps 6 kg or more, to reduce the size of their weapons to configure onto a ballistic missile, in which case the separated plutonium stock would only be sufficient for 4–8 weapons (Albright and Brannan, 2007, p. 1). Sigfried Hecker estimates the North's plutonium stockpile between 40 and 50 kg, from 6–8 nuclear bombs that could be fashioned of similar size to that exploded in the October 2006 nuclear test (Hecker, 2006, p. 4). Mary-Beth Nikitin arrives at the slightly lower figure of 4–7 nuclear weapons, based on a plutonium stockpile of 30–50 kg, assuming 6 kg per weapon and subtracting 5–6 kg for the 2006 nuclear test (Nikitin, 2009, p. 4).

As these estimates demonstrate, attempting to calculate the size of a nuclear arsenal from a poorly quantified stockpile of fissile material is a complicated exercise. The precise amount of plutonium required to fashion a nuclear bomb depends on several variables: the desired yield, the design of the bomb, and the sophistication of the technology and the process (Pritchard, 2007, p. 133). These variables are themselves dependent on the technical capabilities of the scientists and engineers involved. Designers with advanced technical competencies could build a bomb with a 1 kton yield from ~1 kg of plutonium. Less competent technicians might require 3 kg of plutonium to manufacture a bomb of the same yield (Norris and Kristensen, 2005). Assuming that the reactor and associated facilities can be brought back online, North Korea could be capable of separating ~8 kg of plutonium by October 2009 with existing stocks of reactor fuel and another 6 kg of plutonium per year for the next four years (Hecker, 2009). Significant future growth of its plutonium stockpile will only be possible if the 50 MW(e) and 200 MW(e) reactors are brought online, or if the HEU program can be developed to operate at an industrial scale (Nikitin, 2009, p. 6). These figures indicate that North Korea does not have the capacity to rapidly expand its nuclear arsenal.

### 3. Weaponisation

This section analyses Pyongyang's efforts to weaponise its nuclear capability through testing, describing potential delivery systems as well as efforts to miniaturise an operational warhead through nuclear tests.

#### 3.1. Delivery systems

Suitable delivery systems must exist to carry strategic nuclear warheads to high-cost targets where maximum damage and casualties can be inflicted. North Korea possesses Scud-C, Nodong and Taepo-dong ballistic missile systems capable of delivering warheads to targets in South Korea and Japan. The Scud-C is considered the best short-range missile available on the market to states not allied with the US, with a range of ~500 km, more than enough to hit targets in South Korea. The North is thought to have an inventory of around 600 Scud-C missiles (Scobell and Sanford, 2007, pp. 113–114). The Nodong is a medium-range ballistic missile with a range of 1000 km. It is estimated that the North has an inventory of ~1–200 Nodong missiles, many of which may be deployed at suspected sites at Shino-ri, Chongju and Pyong-pukto (Scobell and Sanford, 2007, pp. 113–114). Pyongyang has also unveiled a new short-range missile called the Toksa KN-02, which is a version of the Russian Tochka SS-21 Scarab missile. It has a limited range of only 120 km, but is far more accurate than other short-range missiles in its inventory (International Crisis Group, 2009, p. 5).

The Taepo-dong I missile system has a longer range of up to 2300 km, consisting of a three-stage conglomeration of a Scud-C short-range missile mounted on a Nodong rocket, with a small third-stage booster to deliver the final payload (Norris and Kristensen, 2005; Cumings, 2004, p. 80). The Taepo-dong I was first tested on 31 August 1998, when a prototype was launched from a test facility at Musudan-ri with the stated intention of placing a small satellite into orbit. The three rocket stages separated successfully but the final booster stage exploded, destroying the satellite (Scobell and Sanford, 2007, p. 105). A Taepo-dong II three-stage rocket has also been developed, which uses a missile similar to the Chinese DF-3 or CSS-2 rockets as the base stage instead of a Nodong missile, increasing range to between 3500 and 6000 km (Cumings, 2004, pp. 80–81). It is clear

from a number of failed tests that both the Taepo-dong I and II rockets are still under development and are not ready for deployment. On 5 April 2009 the DPRK again launched a multi-stage rocket for the ostensible purpose of placing a satellite into orbit, which foreign observers believed to be a clandestine long-range rocket test (KCNA, 2009). Though ultimately described as a failure, the final stage of the rocket did manage to fly 2700 km before splashing down in the Pacific Ocean, a more successful result than previous tests (Yonhap, 2009). These missiles also lack a reliable re-entry vehicle within which to house nuclear warheads and they re-enter the atmosphere en route to their target (Hayes and Bruce, 2009). Until these technical issues have been rectified, the Taepo-dong missiles cannot be considered as an operational delivery system for a strategic nuclear weapon (Paal, 2009).

#### 3.2. Miniaturisation & testing

Miniaturisation is the next technological milestone for the North's nuclear scientists, in order to produce a nuclear warhead that is deliverable atop a missile. This is a substantial technical challenge that is likely to require additional nuclear tests. Such tests are likely to be smaller in magnitude, due to the reduced size of the weapon, as well as the need to use as little fissile material as possible to achieve the necessary scientific goals. North Korea could extract enough plutonium from reprocessing spent fuel already in storage for two new nuclear devices, which would allow them to conduct a third test without any net loss from their plutonium stockpile (Hayes and Bruce, 2009).

On 9 October 2006 the Korea Institute of Geoscience and Mineral Resources in South Korea detected seismic activity equivalent to a 3.58 magnitude earthquake emanating from Musudan-ri in North Korea's North Hamgyong province (Chosun Ilbo, 2006). The North announced shortly afterward that it had successfully tested a nuclear weapon, hailing it as "a historic event as it greatly encouraged and pleased the KPA and people that have wished to have powerful self-reliant defence capability" (KCNA, 2006). An estimate released by John Negroponte, the then US Director of National Intelligence, confirmed that the October 9th nuclear test had indeed taken place but that its yield was quite low, reported at under 1 kton (kt), perhaps even as low as 0.2 kt (Kang and Hayes, 2006). A test yield of less than 1 kt is considered to be a failure. A successful test of a simple plutonium device should normally produce a blast in the realm of 5–20 kt (Chanlett-Avery and Squassoni, 2006, p. 2).

One should remember that exploding a nuclear device is a complex technical undertaking, a multi-faceted process in which there is considerable scope for malfunction and error. There are several possible reasons why the weapon achieved such a small yield. The device itself may have suffered from poor machining of manufacturing defects; the explosive charges used to compress the plutonium and start the chain reaction may not have detonated simultaneously; the charges may have been incorrectly shaped; the amount of plutonium used may have been insufficient; or the neutron initiator or neutron reflector may have malfunctioned (Kang and Hayes, 2006). The test was not a complete failure, despite the compromised yield caused by a malfunction in one particular part of the process. The scientists involved would have learnt a great deal from the test, leading to technical improvements in weapon design. The test was successful in that nuclear criticality was achieved, which by itself is a substantial technical achievement for a first-time test (Park and Lee, 2008, p. 276).

Through April 2009, rumours grew that the DPRK would conduct a second nuclear test sometime in the second half of

2009. As it happened, the test occurred on 25 May, well ahead of the expected timeframe. This blast was much more powerful than the 2006 test, registering a magnitude of 4.52 on the Richter scale, with an estimated yield of ~20 kt, putting it on par with the American atomic bomb that levelled Nagasaki in 1945 (Kirk, 2009; CTBTO, 2009). This test was necessary for the North to overcome the failure of the first test and unambiguously confirm its nuclear capability. The successful second test demonstrates clearly to the world that the North's nuclear program has made substantial technical progress since October 2006. The second detonation created a significant explosion and left no doubt in the minds of foreign observers that the DPRK was now a nuclear power.

#### 4. Proliferation motivation: domestic political economy

It is clear that the nuclear program has great intrinsic value to Pyongyang. In general, states seek to develop and maintain nuclear weapons for a number of reasons. For Kurt Campbell (2004, p. 20), these motivations are five-fold: a response to changes in US foreign policy; a breakdown of the global nonproliferation regime; erosion of regional security; domestic imperatives; and the increasing availability of nuclear technology. In the context of North Korea, Victor Cha (2002, p. 211) has divided Pyongyang's nuclear motivations variously as "shields," "swords" and "badges." If the North's nuclear capability is intended as a shield, it is a product of the Kim regime's feeling of chronic insecurity and as such has been developed as a deterrent. If it is a sword, the nuclear capability has been built for aggressive purposes and will comprise a key component of an offensive war plan with the goal of reuniting the Korean peninsula on Pyongyang's terms. If it is a badge, the nuclear program is a symbol of international prestige that affords North Korea a greater diplomatic weight in the international arena than what it otherwise would enjoy.

Scott Sagan (1996/1997, p. 55) has used a different categorization, which acknowledges the political economy dimension of nuclear proliferation. First, states build nuclear weapons to increase their security against foreign adversaries, particularly if their enemies also maintain a nuclear capability. Second, nuclear weapons acquisition, or restraint of nuclear weapons development, can provide a normative symbol of a state's identity. Finally, nuclear weapons can be used as political tools to advance parochial domestic political and bureaucratic interests. It is this potential driver of North Korea's nuclear development, which is informed most closely by an analysis of the North's nuclear fuel cycle. Other motivations do play a role in informing Pyongyang's proliferation calculus, including issues of national security, systemic maintenance, and ideological legitimacy. However, on its own, the North's long history of nuclear development provides enough evidence to suggest to the international community that the dismantlement of the nuclear program may be an unrealistic goal.

##### 4.1. Systemic maintenance

Ultimately, the choice facing the regime is one of system maintenance versus system transformation. The regime can use the nuclear program perpetuate the *Songun* system and preserve the status quo. Alternatively, to relinquish the nuclear program would remove it as the foundation of the *Songun* system and would necessitate widespread political and economic reform.

The scale of systemic reform is likely to be staggering. It will require land redistribution and decollectivisation, marketisation, industrial restructuring and legal reform, while millions of

workers may be forced to change employment or become unemployed (Noland, 2002, p. 182). The general population would experience the process as one of the great social upheaval, a development that would have great political implications. Social controls, including the rationing system, information controls, and travel restrictions would have to be loosened (Park, 2008). Reform will further open North Korea to foreign information and ideas, which are likely to undercut political restrictions and allow an opportunity for alternative political mobilisation, creating challenges to regime control linked to popular discontent at the pace and scope of change (Kang and Rigoulot, 2001, p. 186; Snyder, 2000, p. 519).

The collapse of the Soviet Union serves as a warning to the North Korean leadership about the dangers of reform. The Soviet communist system proved to be inelastic and incapable of change, so when Mikhail Gorbachev attempted political and economic reform the system could not accommodate evolution and rapidly imploded (Kotkin, 2001, p. 2). Because the functionality of state institutions was so dependent upon established routines, the inertia and transaction costs of change were so high that rapid transformation became impossible when new circumstances arose that required a new *modus operandi* (Pei, 1994, p. 205; Kaminski, 1991). Once marketisation penetrated the operations of state institutions, the incentives for state officials to pursue opportunist ventures outside the formal system increased at the same time as political reforms weakened the monitoring and enforcement capacity of the Party, resulting in a massive exodus of officials from the Party (Kalyvas, 1999, pp. 338–339; Teague and Tolz, 1995, p. 21). The Kim regime undoubtedly fears that reform of this nature could lead to a similar regime termination in North Korea. Because of these dangers, the regime is likely to view the costs of nuclear proliferation for systemic maintenance as preferable to the high risk of systemic implosion inherent in economic and political reform.

The Kim regime's choice to proliferate nuclear weapons is not without cost. Internally, nuclear development necessitates the diversion of resources away from non-military investments in industry, agriculture, infrastructure and social services. Indeed, the privileged position of the military within the wider *Songun* system itself necessitates a form of social triage, in which certain segments of the population are excluded from access to food and services in order to prioritise the provision of the military. Externally, the North's proliferation activities have drawn widespread international condemnation, invited a strengthened (though still ineffective) economic sanctions regime, and alienated the country from its historic allies. Yet for the regime, this cost calculation is relative; the leadership values the maintenance of its power above all other considerations.

##### 4.2. Institutional momentum

Generally, in nuclear states, the institutional actors typically include the state's nuclear establishment, which maintains all facilities related to the nuclear fuel cycle, and important units within the military bureaucracy (Sagan, 1996/1997, p. 64). Nuclear research has a long history in North Korea, beginning in December 1952 when Kim Il-sung established the Atomic Energy Research Institute as a branch of the North Korean Academy of Sciences to commence research into the use of radioactive isotopes in agriculture, industry and medicine. In 1956, the USSR established the Joint Institute for Nuclear Research located at Dubna, outside of Moscow, to facilitate cooperation in nuclear science among countries within the communist bloc. As a founding member of the institute, North Korea sent over 300 nuclear specialists and more than 150 advanced specialists to

Dubna during the period of Soviet-DPRK nuclear cooperation (Szalontai, 2006, p. 3; Mansourov, 1995). At the same time, Pyongyang established indigenous nuclear physics departments at Kim Il-sung National University and Kim Ch'aek Industrial College, which conducted basic nuclear research and were responsible for the refinement of new ideas in the field emanating from abroad (Mansourov, 1995, p. 2).

Today the Second Natural Science Institute is responsible for nuclear weapons research and development, in collaboration with the Academy of Sciences and the Second Economic Committee's Fifty Machine Industry Bureau. The Nuclear Chemical Defence Bureau in the Ministry of People's Armed Forces manages the research and development of defensive measures against nuclear, chemical and biological attack (Nuclear Threat Initiative, 2005; Pinkston, 2003, p. 9). The Yongbyon complex employs ~3000 personnel, along with additional number associated with other nuclear facilities around the country (Niksich, 2006, p. 9). The Nuclear-Chemical Defence Bureau, an organ of the Ministry of People's Armed Forces reporting directly to Kim Jong-il, exercises command and control of the nuclear inventory (Scobell and Sanford, 2007, p. 16).

These institutions have a powerful vested interest in self-perpetuation and are likely to be active acquiring more resources to expand their role. For example, the fledgling bureaucracy established in the United States during the 1940s to run the Manhattan Project acquired a large pool of resources—including funding, personnel, and physical plant—which gave it a strong incentive to fulfil its mission to perfect a nuclear weapon. Once this task was achieved, the continued existence of this bureaucracy was contingent on the use of the weapon it had created and the continued manufacture of further weapons to augment the existing stock (Beckman et al., 2000, p. 95). It is estimated that over 3000 personnel are employed at Yongbyon, along with an additional number associated with other nuclear facilities around the country (Niksich, 2006, p. 9). Dismantlement of these institutional structures would be extremely difficult because once established, institutions take on a life of their own.

#### 4.3. Domestic economy

Possession of nuclear weapons can dramatically alter the prestige and diplomatic clout of a country. Nuclear proliferation represents a demand for a state to be treated as a major power in regional or global politics, often above and beyond what would otherwise be the case. For the leaders of nuclear-armed states, possession gives them greater leverage in their relations with other countries and allows them to be bolder in the pursuit of their national interests (Cha, 2002, p. 227). North Korea's use of ambiguous nuclear blackmail and overt nuclear posturing has certainly succeeded in attracting the attention of its powerful neighbours in Northeast Asia. The brandishing of the nuclear card is often used by nuclear weapon states as a signal in international diplomacy that their vital interests are engaged, or that a particular policy position is absolute and immovable (Beckman et al., 2000, p. 187).

North Korea has consistently brandished the nuclear card in denuclearisation negotiations since the Agreed Framework in 1994, using coercive bargaining tactics featuring deliberate, directed provocations put pressure on the US and regional states to provide material inducements as a *quid pro quo* to pull back from the brink (Lim, 2006). These deliberate “pinpricks” fall short of war but are serious enough to raise concerns about possible escalation (Cha, 2003, p. 72). Once the provocation has been executed, Pyongyang often issues new demands, or restates previous claims as conditions for a return to negotiations.

Coercive bargaining is integral to the systemic maintenance of North Korea's unique political system. In 1998, Kim Jong-il consolidated his grip on power through the introduction of *Songun* (military-first) politics, which is based on the idea of making North Korea a “strong and powerful country.” The *Songun* system remains dependent on the external inputs to keep it viable. The Kim regime has used coercive bargaining tactics to secure the international largesse that fulfils these input requirements. The nuclear capability gives the regime the bargaining leverage it needs to plug holes in its economy with inputs of aid from the international community. North Korea derives approximately one-third of its revenues from international aid (Haggard and Noland, 2007, pp. 5–13).

International largesse comes in a variety of forms: food aid, energy supplies, fertilizers, development assistance and direct cash payments. Food aid from international donors has been extensive since 1995 (Nanto and Chanlett-Avery, 2008, p. 33; Manyin and Nikitin, 2008, p. 10; Pollack, 2005, pp. 147–148). Under the *Songun* system, it is generally diverted wholesale for military use, strengthening the position of the KPA as the vanguard institution of the state. The KPA subtracts a portion for its own provisions then on-sells the remainder for profit through the entrepreneurial economy (Park, 2008). However, rather than using humanitarian assistance as an addition to supply, the regime used it as balance-of-payments support, offsetting aid by cutting commercial food imports and allocating savings to other priorities. In addition, as aid shipments are distributed by the military, they become a rent-seeking commodity as they are diverted from formal distribution channels to be sold for huge profit by the military on the private market.

By late 2008, with the signing of the September 19 agreement, negotiations had reached a point where the North was being asked to take significant steps toward nuclear dismantlement, steps that would cut into sections of its nuclear capability that it had no intention of giving up. The nuclear program had matured in a technical sense from the development stage to the cusp of a full-fledged nuclear deterrent. Further progress in denuclearisation negotiations would degrade the North's operational nuclear capability, in return for, on paper, much less than that was offered as compensation under the Agreed Framework. This, of course, presented Pyongyang with a dilemma. Without the Six Party Talks as a forum to extract international largesse, the regime had to develop a new plan for its economic survival. In December 2008 the regime instituted a new mobilisation campaign, based on a revival of the *Chollima* movement, to reconsolidate the totalitarian political order and turn the DPRK into a “strong and prosperous country” by 2012, in time for the centenary of Kim Il-sung's birth (Toloraya, 2009). North Korea's provocative and escalatory behaviour since late-2008 indicate that Pyongyang has decided to go it alone.

#### 4.4. Ideological legitimization

During the Kim Il-sung era *Juche* was the dominant ideational paradigm of the regime. Kim Il-sung saw *Juche* as the independent creative adaptation of Marxism-Leninism to the unique realities of Korea. Though commonly translated as meaning “self-reliance,” *Juche* can be better understood as implying “self-standing,” an interpretation that the regime can self-manage the economy regardless of whether outside assistance is available (Kim, 2001, p. 386). North Korea had long-established trade and aid relationships with the Soviet Union and other communist bloc countries, as well as Western-aligned European countries and Japan (Kim, 2001, p. 386). Such activities were acceptable under *Juche* if they helped to plug holes in the planning matrix and consolidated the

overall economy. However, when these relationships broke down in 1991 and the economy collapsed, *Juche* philosophy began to look like a hollow shell that no amount of reinterpretation could salvage.

Kim Jong-il's answer was to consolidate the national ideology with *Songun* politics. Given the relative decline in the North's conventional military capability, the nuclear program thus became a symbol of the military component of the new legitimising paradigm. *Songun* politics and *Juche* have a symbiotic relationship, with each providing meaning for the other. *Songun* politics on its own would be unsustainable because of the excessive economic hardship that the military's priority resource allocation imposes on the people (Park and Lee, 2008, pp. 275–276). Similarly, the famine rendered *Juche* practically and philosophically bankrupt as a means of facilitating national self-reliance. However, together they provide the regime with a self-sustaining ideological and organisational structure that legitimises the channelling of vast resources into the military and by extension the indigenous nuclear program. The technological achievement embodied in the nuclear program boosts Kim Jong-il's nationalist credentials and brings prestige to his leadership, which in turn strengthens the relationship between Kim and the military.

The regime is increasingly leaning on hyper-nationalism to legitimise itself as the other facets of its ideology slide into irrelevance. Brian Myers argues that the basis for North Korean nationalism is a race-based moralist worldview in which the Korean people are viewed to be inherently morally superior to all other peoples (Myers, 2006). This inherent goodness is one of the reasons that Korea has been the perennial victim of rapacious foreign powers, allowing the regime to ascribe evil actions to foreign powers alone. Unlike other facets of North Korean ideology such as *Juche* and Kimism that have been undermined by real-world events, North Korea's race-based nationalism is grounded upon an irrational myth that is much harder to disprove, making it extremely resilient and maintainable in both good times and bad.

## 5. A question of leverage

The other five regional states—South Korea, China, Russia, Japan and the United States—have few viable options available to negotiate or compel North Korea to denuclearise because they lack leverage over Pyongyang. The bargaining dynamics are clear: the international community cannot offer North Korea any bargain of equal value to the nuclear program, *in the context of systemic maintenance and regime perpetuation*. In denuclearisation negotiations, Western analysts mistakenly believe grand bargain proposals are benign, despite the likelihood that they would lead to rapid systemic changes within North Korea. Externally, multi-lateral and bilateral engagement has been unsuccessful, as regional actors have too much incentive to hedge agreements in favour of their own interests.

Similarly, compellence through the threat or use of force is unrealistic because *the threat of violence against North Korea does not appear to be plausible*. If nonproliferation solutions are to incorporate military action, the threat of violence must be credible (Brams, 2003, pp. 139–140). American hardliners have an inflated confidence in the capacity of the US military to act decisively in the Korean theatre. The estimated cost of military action is too high to justify the desired gain and the outcome is subject to unacceptable uncertainty (Pinkston et al., 2005, p. 10; Bandow, 2003; Saunders, 2003). Furthermore, unity among regional states is vital if military options are to achieve their desired goals and clearly, regional states are far from unanimous

in backing the use of military force. Consequently, the threat of violence against North Korea is not credible enough to enforce North Korea's compliance.

Failing the use of force, compelling denuclearisation may involve regional states placing North Korea under malign economic and political stress. For this to succeed, the Kim regime must be pressured to the point of unbearable strain but again, regional states have failed to agree on a containment strategy and some, including China and Russia, have proven unwilling to apply the pressure necessary to force the regime to relent. North Korea has little trade, outside of that with China, which the international community can embargo, while sanctions have been ineffective in squeezing the North Korean economy (Noland, 2008, p. 5; Lankov, 2006).

## 6. Conclusion

There is a long history of nuclear development and investment in nuclear infrastructure in North Korea, dating back to the 1950s. This infrastructure and its associated institutions are extensive and have become entrenched in the country's political hierarchy, to such a degree that nuclear proliferation has become heavily entwined with the maintenance of the *Songun* system and the political economy of the DPRK state. The nuclear program has great value in this regard at three levels: first, it provides the pretext to divert the nation's resources to the military. In this way, it helps to legitimise the privations that ordinary citizens bear in order for the military to be the privileged recipient of state resources. Second, nuclear weapons development serves the narrow bureaucratic interests of institutions within the DPRK state. In general, the vested institutional actors include the state's nuclear establishment, which maintains all facilities related to the nuclear fuel cycle, and important units within the military bureaucracy. Third, the nuclear program is the defining symbol of North Korea's unique anti-American nationalism. The regime has painted itself into a corner through its rampant use of virulent anti-American, anti-imperialist propaganda, which is the only legitimate ideational pillar the regime has left. From a technical and political analysis of North Korea's nuclear program, one can therefore suggest that the Kim regime will not relinquish its nuclear program, because no suite of incentives offered by the international community can match the utility of the nuclear program for propping up the *Songun* system and perpetuating Kim regime rule. North Korea's unwillingness to dismantle its nuclear program, combined with the failure of the denuclearisation strategies of regional states, will ultimately force the region to adapt to the reality of a nuclear DPRK.

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