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North Korea's Nuclear Weapons Program: Verification Priorities and New Challenges

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North Korea's Nuclear Weapons Program: Verification Priorities and New Challenges

Abstract

A comprehensive settlement of the North Korean nuclear issue may involve military, economic, political, and diplomatic components, many of which will require verification to ensure reciprocal implementation. This paper sets out potential verification methodologies that might address a wide range of objectives. The inspection requirements set by the International Atomic Energy Agency form the foundation, first as defined at the time of the Agreed Framework in 1994, and now as modified by the events since revelation of the North Korean uranium enrichment program in October 2002. In addition, refreezing the reprocessing facility and 5 MWe reactor, taking possession of possible weapons components and destroying weaponization capabilities add many new verification tasks. The paper also considers several measures for the short-term freezing of the North's nuclear weapon program during the process of negotiations, should that process be protracted. New inspection technologies and monitoring tools are applicable to North Korean facilities and may offer improved approaches over those envisioned just a few years ago. These are noted, and potential bilateral and regional verification regimes are examined.

Acronyms and Abbreviations

ABACC	Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
AF	(US-DPRK) Agreed Framework (1994)
CBM	Confidence building measure
CMC	Cooperative Monitoring Center
CRS	Congressional Research Service
CSCAP	Council for Security Cooperation in the Asia Pacific
DOE	Department of Energy
DPRK	Democratic People's Republic of Korea
HEU	Highly enriched uranium
HRGS	High-resolution gamma spectroscopy
IAEA	International Atomic Energy Agency
INFCIRC	Information Circular (IAEA publication)
ISIS	Institute of Science for International Security
JNCC	Joint Nuclear Control Commission
KAERI	Korean Atomic Energy Research Institute
KEDO	Korean Peninsula Energy Development Organization
KEPCO	Korea Electric Power Company
KIDA	Korea Institute for Defense Analyses
LWR	Light water reactor
MWe	Megawatt-electrical
NPT	Nuclear Nonproliferation Treaty
OMV	On-going monitoring and verification
ROK	Republic of Korea
SEM	Scanning electron microscopy
SIMS	Secondary ion mass spectrometry
SSAC	State system of (nuclear materials) accountancy control
TCNC	Technology Center for Nuclear Control
TIMS	Thermal ionization mass spectrometry
UNSC	United Nations Security Council
USGS	U.S. Geological Survey
WANO	World Association of Nuclear Operators
WMD	Weapon(s) of mass destruction
XRF	X-ray fluorescence

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Executive Summary

Over the past two years, the Democratic People's Republic of Korea (DPRK) has advanced its nuclear programs and moved towards acquiring nuclear weapons capabilities. Pyongyang has reversed or nullified all its previous nonproliferation commitments including the Nuclear Nonproliferation Treaty (1975), the Joint Declaration on the Denuclearization of the Korean Peninsula (1992), the IAEA-DPRK Safeguards Agreement (1992), and the U.S.-DPRK Agreed Framework (1994). These unilateral acts are unprecedented.

A solution to the current crisis will require a comprehensive settlement—one that will not be easy to achieve. It will encompass political, security, economic, energy, humanitarian, and verification elements. For verification issues, Pyongyang's full cooperation and transparency will be essential. The new verification system must be rigorous and include both inspectors and technically-based measures.

This paper sets out potential paths, with associated verification, toward the ultimate resolution of the North Korean nuclear issue. Several measures for the short-term freezing of the North's nuclear weapon program are outlined including a number of nuclear CBMs and transparency steps to support future verification activities.

If North Korea commits to freeze all activities covering its current nuclear weapons programs, it would be a turning point for the comprehensive settlement of the North Korean nuclear issue. The North's potential steps to freeze its programs and the International Atomic Energy Agency (IAEA) monitoring plan should be designed as an integral part of the total dismantlement process in North Korea.

Inspection goals and methodologies that the IAEA has enumerated provide the foundation for verifying the dismantlement of the DPRK nuclear program and the return to compliance with the Nuclear Nonproliferation Treaty (NPT). The long-term inspection goals are based on the agency's Program of Work (2001) and more recent communications of July 2003. First, it is necessary to consider the outstanding issues left over from the first attempts to implement international safeguards in the early 1990's:

- Measurement of the 8,017 spent fuel rods removed from the 5 megawatt-electrical (MWe) power reactor to calculate the remaining amount of plutonium, and determine whether those rods are the first core inserted in 1986
- Sampling and analysis of liquid wastes at the reprocessing plant to estimate the total volume of reprocessing activities
- Swipe sampling at the reprocessing plant to determine the time sequence of plutonium separation operations
- Preservation of records of operating history of the 5 MWe reactor and relevant information on the flow of fissile materials

- Location of key components possibly fabricated for the 50 and 200 MWe reactors under construction
- Special inspection on two suspected waste storage sites, one near the reprocessing plant and the other near the IRT-2000 research reactor.

With the passage of time, the inspection requirements for removing the nuclear danger in North Korea have grown more difficult. This paper summarizes recent events in the North to establish the current scope of the problem. The IAEA has updated its approach and has expressed interest in adding several steps to the above methodology:

- A new initial declaration by the DPRK of all nuclear material and facilities in the country
- Comprehensive accounting by North Korea for past production of nuclear material
- A continuous inspection regime, including short-notice inspections
- Neutron and gamma radiation monitoring of nuclear facilities
- Aerial, video, and radiation surveillance
- Nuclear material inventory verification and flow measurement
- Continuing plant design verification
- Sample taking for destructive analysis and non-destructive essay
- Interviews with DPRK personnel.

As the stakeholders in a non-nuclear-weapons Korean peninsula start to convene substantive discussions in the six-party process, other elements must be included. Foremost among these is how to dismantle the weaponization program and any existing nuclear weapons. There are several topic areas:

- Freezing the current reprocessing and enrichment programs.
- Temporary measures to detect undeclared nuclear facilities. This may include a number of procedures like wide area environmental monitoring, managed access to suspected sites, and access to documents and records.
- Dismantlement of weapons and weaponization capabilities. Precedents from dismantlement of the South African program in 1991-1993 are relevant, as well as certain voluntary measures taken by the US and the Russian Federation since the mid-1990's.
- Disposition of the spent fuel rods from the 5MWe reactor, including transporting to another country.
- Dismantlement of the uranium enrichment program. This is especially problematic because so little is known about its actual status; even the location of the program is largely a matter of conjecture.
- Inspection of the reprocessing waste facilities to ascertain the probable amount of plutonium separated prior to 1992 and now, in the most recently claimed activity.
- Additional dismantlement activities called for under the Agreed Framework, which include the 5 MWe reactor, two additional reactors that were under construction, and the reprocessing facility. The decontamination effort will ultimately require financial and technical assistance that have not yet been studied extensively.

Since 1993, the IAEA has established the "strengthened" standard for safeguards based on the Additional Protocol (INFCIRC/540/Corr.) adopted in 1997. The methods developed to implement the Additional Protocol offer many alternatives to verification in North Korea that

were not available at the time of negotiating the Agreed Framework. Environmental monitoring to detect covert enrichment or plutonium production may give the inspectors greater effectiveness. At the same time, processes for analyzing records and intelligence data will help guide inspectors. Furthermore, new remote monitoring technologies can allow certain safeguards to be both more effective and less intrusive than previous procedures; this may smooth the way toward negotiation of a new safeguards agreement between the DPRK and the IAEA. Given North Korea's extensive nuclear programs and records of non-compliance, it is desirable that the North should sign and ratify the Additional Protocol as soon as possible.

Beyond the immediate nuclear weapons issues that receive most attention, the Republic of Korea (ROK) additionally hopes to revive the 1992 Declaration on the Denuclearization of the Korean Peninsula. This paper explores briefly the possibility of a bilateral, North-South, nuclear safeguards regime, noting that it might follow the successful model of cooperation between Argentina and Brazil. Alternatively, a regionally managed threat reduction regime, staffed and sustained by all interested parties (participants of six-party talks plus IAEA) might be an effective and durable solution. The regional inspection regime's charter could be observation of all present and future nuclear agreements for both South and North Korea. The initial task of the regime would be observing the elimination of the North Korean weapons program. Following that phase, the regime could be charged with monitoring of routine international safeguards in cooperation with the IAEA and monitoring compliance with provisions for a non-nuclear Korean peninsula, similar to those contained in the Joint Denuclearization Declaration.

Assuming a successful return of the DPRK to compliance with the NPT, nuclear cooperation measures may be useful between the North and the South. This is particularly true if the current negotiations result in agreement to complete the KEDO reactors. Useful cooperation could include safety culture training, training on inspections and physical protection, and inter-Korean monitoring with IAEA cooperation.

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1. Introduction

Over the past two years, the Democratic People's Republic of Korea (DPRK) has advanced its nuclear programs and defiantly moved towards expanding its nuclear weapons capabilities. Pyongyang has reversed or nullified all its previous nonproliferation commitments including the Nuclear Nonproliferation Treaty (1975), the Joint Declaration on the Denuclearization of the Korean Peninsula (1992), the IAEA-DPRK Safeguards Agreement (1992), and the U.S.-DPRK Agreed Framework (1994). These unilateral acts are unprecedented. Since late 2002, an alarming sequence of events has occurred that has further isolated North Korea from the international community:

- October 2002—North Korea admitted conducting a clandestine program to make highly enriched uranium (HEU) for weapon purposes.
- December 2002—North Korea lifted the "freeze" pursuant to the Agreed Framework (AF) and expelled the International Atomic Energy Agency (IAEA) inspectors from the country.
- April 2003—In trilateral talks in Beijing, North Korea claimed it has nuclear weapons and further to have completed reprocessing the approximately 8,000 spent fuel rods formerly under IAEA monitoring into weapons-grade plutonium.
- August 2003—In six-party talks in Beijing, the North refused to dismantle its nuclear weapons programs and accept early international inspections.

North Korea claims that the United States policy is militarily hostile and the primary motivation for its withdrawal from the Nuclear Nonproliferation Treaty (NPT). The North has increasingly emphasized the deterrent value of nuclear weapons and the wisdom of its military-first policy. At the same time, however, Pyongyang has expressed the desire to negotiate a solution and demanded talks solely with the United States. For its part, the Bush administration avoided direct contacts for over a year prior to the trip to Pyongyang by Assistant Secretary James Kelly in October 2002. North Korea's demand for bilateral talks softened to accept the six-party talks. For the United States, Republic of Korea (ROK), Japan, Russia and China, the goal of the multilateral talks is clear: a complete, verifiable and irreversible elimination of North Korea's nuclear weapons program and the establishment of a Korean peninsula free of nuclear weapons.

In some respects, the current nuclear crisis is a recurrence of the previous one in early 1990s. The first crisis was solved by the AF, which traded the North's plutonium program for proliferation-resistant light water-reactors (LWR) provided by the Korean Peninsula Energy Development Organization (KEDO). U.S. support for the AF has eroded, and the future of the LWR project in Kumho is not bright.

A solution to the current crisis will require a more comprehensive settlement than the AF—one that will not be easy to achieve. It will require a comprehensive approach encompassing political, security, economic, energy, humanitarian, and verification elements. For verification issues, Pyongyang's full cooperation and transparency will be essential. The new verification system must be rigorous and include both inspectors and technically based measures. David Albright of the Institute for Science and International Security emphasized that "verification arrangements must be more central (to an agreement) and the U.S. and its allies have to

scrutinize much more carefully any proposed agreements with respect to their impact on achieving effective verification."[1]

This paper sets out potential paths, with associated verification, toward the ultimate resolution of the North Korean nuclear issue.[2] Several measures for the short-term freezing of the North's nuclear weapon program are outlined including a number of nuclear CBMs and transparency steps to support future verification activities. Assuming an interim agreement is concluded, the paper attempts to define the verification priorities. The paper also examines new inspection technologies and monitoring tools applicable to North Korean facilities. Looking to the long-term, the scope of IAEA safeguards and some proposals aimed at establishing bilateral and regional verification regimes are examined.

[1] See Arms Control Association Press Briefing, "The North Korean Crisis: What's Next?," May 7, 2003. Transcript available at www.armscontrol.org/events/northkorea

[2] In order to focus on verification issues in all aspects, this paper does not include detailed discussions on political and economic inducements for North Korea.

2. North Korea's Nuclear Escalation and Non-compliance

2.1 North Korea's Non-compliance Issues

2.1.1 IAEA-DPRK Safeguards Agreement (1992)

In January 1992, eight years after its joining the NPT, North Korea signed a comprehensive safeguards agreement with the IAEA that required the North to report all nuclear programs to the IAEA and gave the IAEA the right to conduct a range of inspections in North Korea.[3] On 10 April 1992, the NPT safeguards agreement entered into force. The North submitted to the IAEA the initial report on its fissile material inventory, and the IAEA began *ad hoc* inspections in the DPRK. However, due to lack of Pyongyang's cooperation, the IAEA has been unable to implement fully its comprehensive NPT safeguards agreement with the DPRK. Since 1993, the IAEA has not been allowed by North Korea to verify the correctness and completeness of the North's initial 1992 report[4], and the "inconsistencies" between the North's declaration and the IAEA's findings have remained unresolved.

From November1994 to December 2002, the AF between the United States and North Korea had been a tool for implementing safeguards in North Korea, but because of confrontational views between the IAEA and Pyongyang as to the status of the Safeguards Agreement, no tangible progress has been made on key inspection issues. The IAEA was only allowed to monitor the "frozen facilities" pursuant to the AF. To the frustration of the NPT regime, the DPRK has consistently refused to accept the IAEA's requirements for verifying how much plutonium the North had produced prior to 1992.[5]

In late December 2002, Pyongyang's unilateral acts to remove the IAEA's containment and surveillance equipment at the "frozen" nuclear sites and to expel international inspectors put an end to the IAEA's monitoring phase. The IAEA's "continuity of safeguards" has been terminated as well. Since then, the IAEA has not performed any verification activities in the DPRK and cannot therefore provide any level of assurance about the non-diversion of nuclear material for military purposes.

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[3] The 1992 IAEA-DPRK Safeguards Agreement (INFCIRC/403) is based on the comprehensive, full-scope and traditional IAEA Safeguards Agreement Model (INFCIRC/153/Corr.). Before then, in 1977, North Korea had concluded a partial INFCIRC/66-type Safeguards Agreement (INFCIRC/252) for two nuclear research facilities (a Soviet-supplied IRT-2000 research reactor and a critical assembly).

[4] Pyongyang's Initial Inventory Report included: 1) declarations of the nuclear-material inventory of seven facilities subject to safeguards; 2) design information of these seven facilities; 3) a list of locations of nuclear material outside facilities (LOFs); 4) a list of nuclear facilities under construction or planned; 5) a list of scientific institutions; and 6) a list of nuclear facilities related to the nuclear industry. This initial report illustrated that the North had indigenously developed an extensive nuclear program equipped with a full cycle of nuclear fuel except the uranium enrichment. See David Albright, Kevin O'Neill, "Solving the North Korean Nuclear Puzzle," ISIS, 1999, p. 257.

[5] See Director General's Report to the 47th General Conference, "Implementation of the Safeguards Agreement between the Agency and the DPRK Pursuant to the NPT," GC (47)/19, Distributed August 2003; Director General's Statement to the 47th Regular session of the IAEA General Conference 2003, Vienna, 15 September 2003.

2.1.2 U.S.-DPRK Agreed Framework (1994)

The 1994 AF was not perceived by the U.S. or other governments as perfect, but it froze the North's known nuclear programs and thus prevented Pyongyang from acquiring a large supply of separated plutonium. Without the AF, the North could have been able to produce between 500 and 700 kilograms of weapons-grade plutonium by the end of 2001. This would be enough to produce a large number of weapons and might also tempt Pyongyang to export plutonium or nuclear weapons to other countries.[6]

Under the AF, North Korea promised to give up its nuclear program in return for the provision of two 1,000 megawatt-electrical (MWe) light-water reactors and an annual supply of 500,000 tons of heavy fuel oil during the construction of the first LWR unit. The AF commits North Korea to "freeze and eventually dismantle its graphite-moderated reactors and related facilities" under IAEA monitoring. The freeze includes a halt to construction of 50 MWe and 200 MWe reactors and no refueling of the 5 MWe reactor. The AF obligates North Korea to "store and dispose of the spent fuel rods removed from 5 MWe reactor in May 1994 in a safe manner that does not involve reprocessing in the DPRK." The AF commits the North to "consistently take steps to implement the Joint Declaration on the Denuclearization of the Korean peninsula." The AF also articulates Pyongyang's broader responsibilities to adhere to all its obligations of the NPT, including IAEA inspections. Table 1 lists the facilities covered by the AF. Figure 1 contains several photographs of the Yongbyon facilities.

For the Clinton administration, the key policy objective was to prevent North Korea from producing large quantities of nuclear-weapons-grade plutonium.[7] The U.S. priority was to contain the North's present and future nuclear capabilities, rather than to verify immediately Pyongyang's past activities through the IAEA special inspections. Consequently, the AF banned the North's three graphite-moderated reactors, a reprocessing plant, and a fuel rod fabrication factory, but it indefinitely postponed the IAEA's inspections in the country. North Korea would fully implement its IAEA safeguards agreement at a later stage in conjunction with the LWR construction milestones.[8] This compromise of inspection timing and the ambiguity in wording gave the North a pretext later for not accepting the IAEA's inspection requests.

During past eight years, the IAEA and member countries have unanimously urged Pyongyang to accept international inspections much earlier than after "a significant portion of LWR project (turbine generator) is completed." To the contrary, the DPRK countered that it had only to accept inspections just "before the delivery of key nuclear components (reactor, steam generator, primary coolant, etc.)." The prime contractor of the LWR project, the Korea Electric Power

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[6] Joseph Cirincione with Jon B.Wolfsthal and Miriam Rajkumar, *Deadly Arsenals: Tracking Weapons of Mass Destruction*. Washington, DC: Carnegie Endowment for International Peace, 2002, p. 249.

[7] Larry Niksch, "North Korea's Nuclear Weapons Program," CRS Issue Brief for Congress, Updated August 27, 2003, p.11; David Albright and Kevin O'Neill, eds, *op. cit.*

[8] The AF (Article IV, 3) commits North Korea to come into full compliance with its IAEA safeguards agreement (INFCIRC/403) including special inspection, "when a significant portion of the LWR project is completed, but before delivery of key nuclear components." This ambiguous article indicated that the Agency's inspection of Yongbyon nuclear complex would take place at least five years after the start of LWR construction. According to the latest KEDO construction milestones, the "delivery of key nuclear components," deadline of the Agency ad hoc and special inspections, is scheduled in mid-2005, if the LWR project is not interrupted.

Company (KEPCO), determined that the period between "installation of the turbine generator and delivery of key nuclear components" is only two to three months. This technical assessment fueled the debate over when and how the IAEA inspections should be reinstated in North Korea.

At the request of the UN Security Council, the IAEA has maintained a continuous presence of two to three inspectors at the Yongbyon complex to monitor the facilities "frozen" by the AF. The IAEA viewed its monitoring mission as a subset of NPT safeguards activities, which North Korea strongly denied. Notwithstanding this difference of opinion, the IAEA and the DPRK have held regular technical meetings to address the so-called "outstanding issues" alternately in Pyongyang and Vienna. The discussions initially focused on preserving the relevant information on the North's plutonium program. Since the IAEA conveyed its Program of Work to the North in November 2000, the focus has shifted to asking for North Korea's prompt and full cooperation to carry out these inspection activities. However, North Korea did not agree even to discuss the Program of Work at the last technical meeting - the 17th - held in November 2001.

The "outstanding issues" or "inspection requirements" defined by the IAEA are as follows[9]:

- Measurement of the 8,017 spent fuel rods removed from the 5 MWe reactor to calculate the remaining amount of plutonium, and determine whether those rods are the first core inserted in 1986[10]
- Sampling and analysis of liquid wastes at the reprocessing plant to estimate the total volume of reprocessing activities
- Swipe sampling at the reprocessing plant to determine the time sequence of plutonium separation operations
- Preservation of records of operating history of the 5 MWe reactor and relevant information on the flow of fissile materials
- Location of key components possibly fabricated for the 50 and 200 MWe reactors under construction
- Special inspection of two suspected waste storage sites, one near the reprocessing plant, the other near the IRT-2000 research reactor.

[9] KAERI, *North Korean Nuclear Issues and LWR Project*, KAERI/AR-552/99, November 1999, p. 67-86.

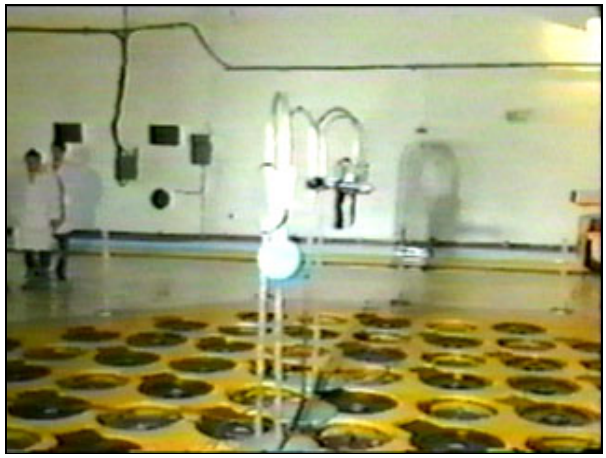
[10] When the 5 MWe reactor was shut down for more than 70 days in 1989, North Korea is suspected by the IAEA of unloading most or all of the first core. Estimates vary, but David Albright suggests that this unloading would have contained about 7-10 kg of weapons-grade plutonium.

Table 1. Yongbyon Nuclear Complex Under the AF

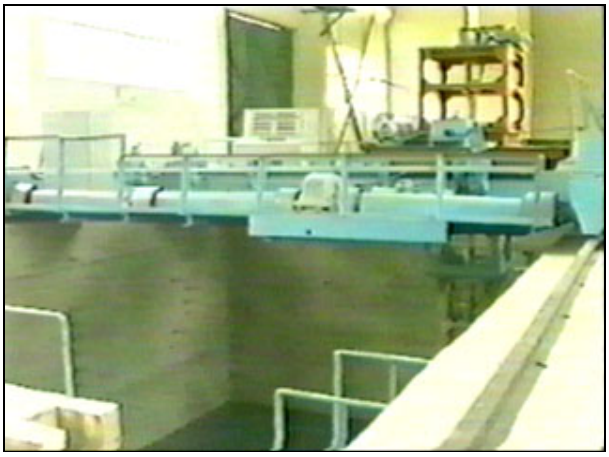
Nonproliferation Milestones	Name of Facility	IAEA Monitoring of the Freeze	IAEA Safeguards Activities	Dismantlement Deadline
Subject to the Freeze and Eventual Dismantlement	**1.** 5 MWe Reactor **2.** 50 MWe Reactor (under construction) **3.** 200 MWe Reactor (under construction, Taechon) **4.** Reprocessing Plant (partially completed, called Radiochemical Laboratory) **5.** Fuel Rod Fabrication Plant	• Frozen since 1994 under the AF • Un-frozen by North Korea's lifting in December 2002 and Reactivated in February of 2003	• North Korea refused to accept IAEA requests to resolve the outstanding issues. Only limited measures were taken. • North Korea argued that the IAEA inspections should begin when a significant portion of the LWR project is completed (mid-2005 expected).	Dismantlement would begin when the first LWR unit is completed and end when the second LWR unit is constructed (LWR supply agreement).
Not-Subject to the Freeze	**6.** Nuclear Fuel Storage Facility **7.** IRT-2000 Research Reactor **8.** Critical Assembly **9.** Subcritical Assembly (Pyongyang)	N/A	• Inspections resumed since January 1996 • IAEA team paid visit to the IRT-2000 reactor and associated Isotope Production Laboratory in January 2002.	N/A
Subject to Special Inspection	Two undeclared suspected waste storage sites—one near the reprocessing plant, the other near the IRT-2000 reactor	N/A	Expected, "when a significant portion of the LWR project is completed, but before the delivery of key nuclear components" (mid-2005)	N/A
Safe Storage and Eventual Shipment Abroad	• 8,017 Spent Fuel Rods discharged from the 5MWe Reactor in May 1992 (estimated to contain 25-30 kgs of Pu 239) • Irradiated, magnesium-clad, natural uranium fuel rods	• Between April 1996 and January 2001, U.S. DOE canning work completed • North Korea refused to accept the IAEA request to take detailed spectral analyses of individual rods during the canning process. Only basic gamma radiation measurement was made to verify that each rod came from the reactor. • Despite North Korea's claims to have completed reprocessing, the status of the remaining spent fuel is currently not confirmed.	North Korea refused to accept the IAEA request to measure remaining plutonium before the canning work started in April 1996.	Shipment to a third party would begin when the first LWR unit is completed, and end by the completion of the second unit (LWR supply agreement).

- **Other Declared Nuclear Facilities**: Pyongsan Uranium Mining and, Soonchun Uranium Mining, Pyongsan Uranium Milling, Packchon Uranium Milling (suspended in 1992)
- **Suspected HEU Program Sites**: Academy of Science, Yeongjeodong, Hagap, Mt. Chunma
- **Suspected Underground Reactor or Plutonium Separation Plant**: Kumchangri (Visits by U.S. teams in 1999 and 2000 found it to be an empty tunnel complex.)

5 MWe reactor in Yongbyon



Top of the 5 MWe reactor core



Spent fuel pond for the 5 MWe reactor

Fuel fabrication plant

Photos taken in May 1992 by the IAEA

Figure 1. Yongbyon Complex

2.2 North Korea's Escalatory Steps and the IAEA Reaction

In response to the North's alleged HEU program, the IAEA requested detailed information and offered to hold a senior-level meeting either in Pyongyang or in Vienna, but it was to no avail. In response to North Korea's notification to lift the "freeze," the IAEA offered to have an urgent meeting of technical experts to "discuss practical arrangements involved in moving from the freeze to normal safeguards operations." However, on December 22, 2002 the DPRK started to cut seals and disable surveillance cameras at the 5 MWe reactor, the spent fuel pool and the reprocessing plant. On December 27th North Korea ordered the IAEA inspectors to leave the country, and on December 31st the two inspectors left the Yongbyon sites. Blaming the IAEA resolution adopted by the Board of Governors on January 6, 2003, the DPRK announced its withdrawal from the NPT effective January 11, 2003. No agreed statement on the matter has been issued by the NPT states parties, or by the NPT depository states (US, UK and Russia), or

by the UN Security Council (UNSC).[11] On 12 February 2003, the IAEA Board of Governors referred the North's non-compliance issue to the UNSC.[12]

2.3 IAEA's Potential Approaches

The IAEA determined that it would take three to four years to carry out all the activities required to verify the correctness and completeness of the North's initial report on nuclear material inventory. The IAEA's technical views on the "entire verification process" in the DPRK are based on its practical experience with South Africa in early 1990s. It took two years for the IAEA to conclude its inspection activities verifying South Africa's past nuclear activities, including its previous dismantlement of six nuclear weapons and uranium enrichment facilities.

The IAEA attempted to discuss a timetable of inspections with North Korea in 2001. The IAEA's Program of Work reportedly consists of three baskets[13] and stipulates necessary steps to be performed by North Korea.[14] In the absence of the North's response to this work program, the IAEA asked Pyongyang to take "two initial concrete steps" at the 16th technical meeting in May 2001. The two concrete steps were to inspect the isotope production laboratory associated with the IRT-2000 research reactor and some of the canned spent fuel rods in a cooling pond in Yongbyon. North Korea only accepted the IAEA team's "visit" to the isotope production laboratory in January 2002. The results of this visit were not available, but the Director General reported the visit as a good step to the next Board of Governors in March 2002.

Notwithstanding the termination of nuclear monitoring in North Korea, Director General ElBaradei has stated that the IAEA remains committed to continuing to work with the DPRK and all concerned parties, with a view to securing full safeguards compliance by North Korea through peaceful means.[15] At the 47th General Conference 2003, the Director General stated that the August six-party talks were clearly a step in the right direction towards a comprehensive resolution of the Korean crisis. Hoping that the dialogue would continue, he expected that any future settlement would ensure the return of the DPRK to the NPT regime, that the IAEA would be given the necessary authority and resources, and that it would be provided with all available information to be able to fulfill its responsibilities under the NPT in a credible manner. Especially, he stressed the need for the IAEA to be consulted at an early stage about verification requirements to ensure a greater degree of confidence in the nature of the North's nuclear weapons program.

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[11] IAEA,"Fact Sheet on DPRK Nuclear Safeguards," 8 January 2003, www.iaea/org/Press/Focus/Iaea/Dprk/fact-sheet.

[12] UN Security Council has studied and deliberated on the matter, but no substantive discussions took place. China and Russia are opposed to the UN Security Council's active involvement in the issue. The ROK is also reluctant to deal with the issue at UN, saying that would escalate the current crisis.

[13] The 3 baskets approach consists of inspecting 1) facilities not-subject to the freeze, 2) facilities subject to the freeze, 3) other facilities, in time order. The program of work would require three to four years to conclude and each basket could overlap the next basket's beginning.

[14] For more information, see Dan Pinkston, "The Status of North Korea's Nuclear Inspections," Research Story of the Week, February 26, 2002, available at cns.miis.edu/pubs/week/020226.htm.

[15] Despite the North's withdrawal of the NPT in January 2003, the IAEA has confirmed through its resolutions that the DPRK is a party to the NPT and the IAEA-DPRK safeguards agreement (INFCIRC/403) remains binding and in force.

The IAEA views North Korea as a complex situation for the implementation of safeguards, given the number and sophistication of the facilities in question, including reprocessing and, possibly, enrichment and weaponization. Based on its past experience, the IAEA has worked on developing the safeguards approaches for future verification work in North Korea.[16] The IAEA's potential approaches remain hypothetical so long as neither the scope of access nor the breadth of the IAEA's potential is defined. Unless the IAEA has full information about or unfettered access to the DPRK's nuclear programs, it would be difficult to tailor a national approach and facility approaches. In general terms, the IAEA indicated that potential approaches might include the following measures:

- A new initial declaration by the DPRK of all nuclear material and facilities in the country
- Comprehensive accounting by North Korea for past production of nuclear material
- A continuous inspection regime, including short-notice inspections
- Neutron and gamma radiation monitoring of nuclear facilities
- Aerial, video, and radiation surveillance
- Nuclear material inventory verification and flow measurement
- Continuing plant design verification
- Sample taking for destructive analysis and non-destructive essay
- Interviews with DPRK personnel.

For verification requirements and time frame, Director General ElBararei has emphasized the following sequence of events:[17] 1) North Korea's taking measures to freeze its active nuclear weapons programs, 2) North Korea's measures to implement the IAEA safeguards agreement, 3) IAEA's verification activities on the North's plutonium program, 4) IAEA's verification activities on the North's HEU program, and 5) full application of the Additional Protocol in the DPRK.

At the present stage, an Iraqi-type UN inspection regime is not envisioned in North Korea. The UN inspection regime in Iraq was a highly intrusive and coercive system that goes beyond full implementation of IAEA safeguards agreement and the Additional Protocol.

[16] Deputy Director David B. Waller responded to U.S. Senator Richard D'Amato's enquiry on the IAEA's views on the verification of nuclear disarmament and non-proliferation in the DPRK. His letter dated on 23 July 2003 was printed for the use of the hearing (China's Proliferation Practices and the North Korean Nuclear Crisis) before the U.S.-China Economic and Security Review Commission, held on July 24, 2003, Washington D.C. Copy of the letter is available at www.uscc.gov.

[17] Interviews with ROK officials in August 2003.

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3. Verification Priorities for a Nuclear-free Korean Peninsula

3.1 Freeze of the Current Nuclear Weapons Program

3.1.1 Six-Party Talks and Interim Measures

The first round of six-party talks (August 27-29, 2003 in Beijing) revealed differing views of the six participants on how to end the North Korean nuclear program. The U.S., ROK, China, Japan, and Russia demanded the North's complete dismantlement of its nuclear weapons program, but Pyongyang insisted that Washington first agree to a legally binding non-aggression pact. Because the U.S. and North Korea took tough positions, only some guiding principles and requirements behind verification issues were sketched in that meeting.

It was purported that U.S. Assistant Secretary of State James Kelly said North Korea must freeze its nuclear weapons programs, promise to completely eliminate nuclear weapons, and immediately admit international inspectors before the U.S. would discuss security assurances and economic incentives sought by Pyongyang.[18] Rejecting the American disarmament demands, the North Korean top delegate Kim Yong Il said that Pyongyang would not give up its "nuclear-deterrent force" or even allow inspections without first receiving guarantees that the U.S. would not attack. He went on to say that unless the U.S. stops its hostile policy, North Korea would have no choice but to declare its possession of nuclear weapons, conduct a nuclear weapon test, and demonstrate the capability of delivering nuclear weapons.[19] In this confrontation, the ROK Deputy Foreign Minister Lee Soo-hyuck proposed a "comprehensive and step-by step approach" that calls for the U.S. and the DPRK to make concessions simultaneously. The ROK delegate urged the North to halt plutonium reprocessing, state its willingness to abandon the nuclear weapons program, and agree to a moratorium on missile launches.

In preparation for the multilateral forum,[20] the U.S. reportedly outlined a three-phase approach to its allies, the ROK and Japan. The American plan is said to call for North Korea to take the following measures[21]:

1. Provide a list of all of its nuclear facilities, halt activities at the sites, and allow inspectors to monitor them and rejoin the NPT

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[18] Gordon Fairclough, "U.S., North Korea Take Hard Lines as Talks Begin", *Wall Street Journal*, August 28, 2003.
[19] Yuri Kageyama, "North Korea Makes Bold Nuclear Claims", *Washington Post*, August 28, 2003
[20] In parallel with the six-party talks, the U.S. vigorously pursues the Proliferation Security Initiative (PSI) with 10 like-minded countries to interdict exports of weapons of mass destruction by proliferators, especially North Korea. This international coalition is planning a range of measures and conducted military exercises off Australia in September 2003 to interdict the North Korean sea and air traffic. In his UN General Assembly speech on September 23, 2003, President Bush highlighted the U.S.-led PSI and called on the United Nations to pass an "anti-proliferation resolution" urging nations to adopt more stringent measures to curb the spread of weapons of mass destruction.
[21] Gordon Fairclough, "U.S. is Likely to Stay Firm in Talks with North Korea," *Wall Street Journal*, August 25, 2003

2. Give unfettered access to inspectors from the IAEA and experts from five permanent members of the UNSC and cooperate in the removal from North Korea of all fuel rods and reprocessed plutonium
3. Complete all steps required for a complete, verifiable, and irreversible elimination of its nuclear programs and address other concerns of the U.S., such as human rights, missile development, and chemical and biological weapons.

The extreme positions between the U.S. and the DPRK on initial steps have proved to be a major stumbling block. North Korea's tough statements on its nuclear capabilities do not permit prediction of when Pyongyang will be willing to move forward to accept the dismantlement of its nuclear weapons program. At this stage, North Korea's return to the *status quo ante* without compensation appears extremely difficult, if not impossible.[22]

First and foremost, the U.S., ROK, and Japan must consolidate and tighten their short-term objectives: a halt to the North's current nuclear weapons program and return to a state of compliance with the existing arrangements.[23] The six-party talks should work out a proposal for North Korea to take a series of interim measures without further delay. The five parties should continue to press for the North to declare that it would give up its nuclear weapons programs. They should persuade North Korea that only these measures would defuse the heightened tensions and promote positive trends in the multilateral forum. As soon as Pyongyang moves forward to accept these initial measures, the six-party talks would be able to embark upon substantive negotiations on all elements of the verification process.

3.1.2 Taking Measures to Freeze Current Nuclear Weapons Programs

If North Korea commits to freeze all activities covering its current nuclear weapons programs, it would be a turning point for the comprehensive settlement of the North Korean nuclear issue. The North's potential steps to freeze its programs and the IAEA's monitoring plan should be designed as an integral part of the total dismantlement process in North Korea. The "new freeze" initially means to re-establish the freeze at Yongbyon sites pursuant to the 1994 AF. The DPRK freeze decision should be accompanied by its immediate return to the NPT, including the

[22] Quoting the press reports, Larry Niksch summarized what the North had proposed in detail to the U.S. in the April trilateral talks in Beijing: In return for the American 1) resumption of heavy oil, 2) supply of energy, presumably electricity, 3) facilitating the completion of LWR project, 4) removal of North Korea from the list of terrorist countries, 5) establishment of full diplomatic relations with Pyongyang and provision of extensive financial aid, and 6) legal security guarantee against both a nuclear attack and conventional attack on the North, North Korea would 1) declare the end of its nuclear program, 2) allow renewed IAEA inspections but limit them to Yongbyon, 3) continue its moratorium on long-range missile testing and cease the export of missiles and missile technology, and 4) dismantle its nuclear program. North Korea's detailed proposal for package solution was based on restoring major elements of the 1994 AF, which was reportedly rejected by the U.S. in the August six-party talks in Beijing. See L. Niksch, *op. cit.*, p 2.

[23] In June 2003, the Council on Foreign Relations (CFR) recommended the U.S. government to develop an interim measures to quickly test North Korea's intentions to stop its nuclear program. In exchange for Pyongyang's freeze of its nuclear reactors and reprocessing facilities including the admission of IAEA inspectors and accounting for and turning over all spent fuel rods, as well as any plutonium separated from those rods, the report calls for the U.S. to provide assurances that it would not attack North Korea and agree not to object to foreign assistance by other countries for so long as the interim agreement remains in effect. See Morton I. Abramowitz, Eric Heginbotham, and James T. Laney, "Meeting the North Korean Nuclear Challenge," Independent Task Force Report, Council on Foreign Relations, June 2003.

readmission of IAEA inspectors and their monitoring equipments to the nuclear sites. The freeze should be applied simultaneously to any uranium enrichment facilities and all claimed activities of the weaponization program. The IAEA's on-going monitoring work would be essential in verifying the North Korean freeze of all active nuclear weapons programs.

North Korea's plutonium infrastructure is the most advanced component of its nuclear complex.[24] As soon as the North reports on its recent activities at the plutonium production facilities, the IAEA inspectors would need to quickly establish the location and condition of the previously monitored spent fuel rods, as well as the operational status of the 5 MWe reactor and the reprocessing plant. They should also confirm the cessation of the construction of the 50 MWe and 200 MWe reactors. In particular, while supervising the shutdown of the 5 MWe reactor, the IAEA inspectors need to pay attention to the unloading and safe storage of about 50 tonnes of new fuel and any other fuel loaded since early 2003. At the fuel rod fabrication plant, the IAEA should re-establish monitoring and examine the North's fresh fuel inventories. Some experts suggest that the two controversial suspected waste sites that were not included under the 1994 freeze, should be frozen this time.[25] Jon B. Wolfsthal of Carnegie Endowment for International Peace examined how a freeze of North Korea's plutonium program might be reconstituted and verified, and presented a number of methods to implement the freeze. His suggested measures include visual clues, physical clues, sampling, and timing analysis.[26]

The North Korean uranium enrichment program is believed to be at least two years from beginning the production of significant amounts of HEU for weapons uses. It is believed that North Korea was in the process of manufacturing and testing centrifuges and constructing a centrifuge enrichment facility.[27] A high degree of uncertainty remains concerning the location of the enrichment site and the current status of centrifuge-based enrichment facilities. When the North makes a detailed declaration, it is expected that one of three reported sites, 1) the North Korean Academy of Science near Pyongyang, 2) the Hagap region in Chagang Province, and 3) the City of Yeongjeodong near the Chinese border, will be included.

The North Korean freeze should be applied to all aspects of its centrifuge program.[28] North Korea must grant IAEA inspectors access to its secret enrichment facilities and give practical information on its procurement efforts and financial resources. The IAEA inspection team needs

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[24] Jon B. Wolfsthal, "Estimates of North Korea's Unchecked Nuclear Weapons Production Potential," Available at www.ceip.org/files/nonprolif/countries/. Wolfsthal estimates that North Korea's plutonium program, if left unchecked, could provide Pyongyang with enough separated plutonium to produce as many as six nuclear weapons, possibly by the end of 2003, and as many as 200 by 2010.

[25] David Albright, "Refreezing Yongbyon: Developing an Effective Approach," ISIS, July 2003. Prepared for a series of workshops in the summer of 2003.

[26] See "Freezing and Reversing North Korea's Plutonium Program," Working Papers Number 38, Carnegie Endowment for International Peace and the Nautilus Institute for Security and Sustainability, June 2003.

[27] The CIA unclassified report to the Congress released on November 19, 2002 confirmed that North Korea was constructing a plant that could produce enough weapons-grade uranium for two or more nuclear weapons when fully operational – which could be as soon as mid-decade. The report assessed that North Korea had embarked on the effort to develop a centrifuge-based uranium enrichment program about two years ago. Transcript available at.www.ceip.org/files/nonprolif/countries/

[28] Fred McGoldrick, "The North Korean Uranium Enrichment Program: A Freeze and Beyond," Working Papers Number 38, Carnegie Endowment for International Peace and the Nautilus Institute for Security and Sustainability, June 2003.

to survey all reported locations to provide confidence that the North's enrichment activities have definitely ceased. The IAEA inspectors will tag and seal all items subject to the freeze. Containment and surveillance devices will be installed at appropriate locations. For enrichment facilities under construction, the IAEA could establish an initial photographic baseline to document the status of each facility's construction.

3.1.3 Temporary Measures To Detect Undeclared Nuclear Facilities[29]

During the six-party talks, a progression of freeze steps may be proposed, each needing some verification. It is possible that the individual steps will fall short of returning to full IAEA safeguards in one comprehensive agreement. That is, there may be a series of stages through which parties will gradually decrease nuclear tensions. These steps will need some degree of confirmation, although not necessarily 100% verification, so that the process can continue.

Verification processes adopted during the multilateral talks as confidence-building freezes may not be like a full-scope IAEA safeguards agreement. To commit to full safeguards early in the talks may be an unlikely strategy for the North, although the U.S. and the ROK would greatly desire that level of concession early in the process. The question is thus: what kind of confidence building monitoring might be practical if North Korea agrees to freeze some activities during the multilateral talks?

Some of the approaches developed by the IAEA for the Additional Protocol may provide guidance. However, this is not to suggest that the DPRK would sign and implement the Additional Protocol during the six-party talks. There are two reasons why this may be unlikely. First, the Additional Protocol builds on a complete set of traditional safeguards measures. That system of IAEA safeguards is in disarray in the DPRK and must be implemented anew. Second, both the full-scope safeguards agreement and the Additional Protocol are complex agreements that require detailed technical disclosures to negotiate. It is hard to imagine an integrated safeguards process proceeding on the technical level, while the highly sensitive political level is unresolved. Therefore, these temporary verification measures are designed especially for detecting undeclared nuclear facilities and will probably not be based on a firm IAEA-DPRK strengthened safeguards system.

There are three levels of measures that the Additional Protocol may suggest as temporary confidence building steps to support progress in the six-party talks:

1. **Wide Area Environmental Sampling**
   North Korea may agree to freeze nuclear activities in certain provinces or may state that certain provinces are nuclear-free. Samples of water, soil and air from the associated watershed or downwind can build confidence that the freeze is in place. Certain freshwater seaweeds concentrate heavy metals and retain long-term traces of prior activity, so biotic sampling can be a powerful tool. Chemical tests for fluorine compounds could be sensitive to reprocessing and enrichment activity. Noble gas monitors, sensitive to Krypton-85 for example, could detect

[29] This section's main idea is a result of discussions with Dr. John Olsen of the Cooperative Monitoring Center, Sandia National Laboratories, September 2003.

on-going reprocessing activities. All of these techniques are tested and ready. While the lack of a detected signal may not be conclusive, it will still be a step toward effective verification.

2. Complementary Access

Under the Additional Protocol, inspectors would be able to ask for access to facilities connected to or related to declared nuclear facilities. While actual access for nuclear and chemical sampling (swipes) may be more than the North will grant as negotiations are still ongoing, perhaps the preliminary step of perimeter monitoring would be possible. That is, inspectors would not enter a suspected facility, but merely place radioactivity monitors around it, pending later inspection. If the monitored facility were actually operating, eventually the radiation levels would fluctuate as equipment was serviced or malfunctioned. On the other hand, if the radiation on the perimeter were constant and at a low level, it could mean either that the activity was frozen, or that the facility was not a nuclear operation.

3. Records and Documentation

The Additional Protocol calls for comparison of import and shipping records for consistency with declarations. This can be conceived as a multistage process, wherein North Korea can progressively allow greater disclosure as the talks develop. For example, suppose that the DPRK discloses import documents that suggest they might have manufactured a certain number of centrifuges for uranium enrichment. A thorough inspection progress would aim at locating the centrifuges, measuring every aspect of the related facility, examining operational documents, and placing all nuclear materials under full safeguards. This cannot occur in one step. A preliminary step that might be acceptable to North Korea and also build confidence with other parties might be to merely allow an inspection team to walk through a facility. The result might be qualitative agreement between documents and machinery, but not an exhaustive evaluation. That is, North Korea would still have some bargaining power, while the US and ROK would gain confidence that they were getting control of parameters of the discussion.

These measures suggested by the Additional Protocol could support the six-party talks process. Yet, they fall far short of "effective verification" or "safeguards compliance." Moreover, they might arise in an ad hoc manner without the full legal authority of a DPRK-IAEA safeguards system. Therefore, the IAEA might choose not be the implementing party. The six-party process might delegate these measures to specially appointed teams of nuclear experts from the other five parties. The IAEA, U.S. Department of Energy laboratories, and the Korean Atomic Energy Research Institute/Technology Center for Nuclear Control (KAERI/TCNC) could provide technical assistance and personnel for the ad hoc teams.[30]

3.2 Verification Priorities and New Challenges

Achieving the denuclearization of the Korean peninsula hinges upon how soon and by what manner to disarm North Korea and effectively verify it. According to John R. Bolton, U.S. Undersecretary of State for Arms Control and International Security,[31] the U.S. government was discussing internally what a complete, verifiable, and irreversible dismantlement of the North's

[30] The task of observing "partial freezes" during the six-party talks could form the foundation for a new institution for multilateral verification on the Korean peninsula.

[31] *Arms Control Today*, Volume 33, Number 4 (May 2003)

nuclear programs would mean in practice and had received some international consultation as well. The undersecretary added that while the U.S. government did not have a final package yet, its thinking was well advanced on the kind of verification that would be required. At the August 2003 six-party talks, the U.S. delegation stressed its guidelines on verified dismantlement and what the DPRK should do first to start a negotiated solution on the current crisis. North Korea vehemently rejected the U.S. suggestions. ROK, Japan, Russia, and China also urged North Korea to make a decision to eliminate its nuclear weapons programs, but detailed and concrete proposals on verified dismantlement were too premature to be announced.

Given the North's intransigence and complexities of the issues concerned, verification issues are critical and will require time to resolve. The sequencing of any deal will probably include phased steps of verification. During the freeze or possible "partial freeze" by the North, the six-party talks and the international community should seek to identify the entirety of verification priorities to be implemented in the mid and long-term. The multilateral forum must also determine what type of verification organization ought to be in place for the denuclearization of the Korean peninsula.[32] In this context, it is advisable to invite the IAEA Department of Safeguards to relevant meetings in conjunction with the six-party talks.

As it was a decade ago, today's question is how to freeze and eventually dismantle the North's active nuclear weapons programs. The next issue is how to effectively verify its past nuclear activities. Pyongyang's admission to having an HEU program as well as its defiant claims on the possession of nuclear weapons and reprocessing of spent fuel rods cannot be left without response. Thus, identifying new verification priorities becomes of paramount importance. Given North Korea's lack of cooperation[33] and its numerous underground facilities, the most difficult part of the verification activities would be to detect undeclared nuclear facilities. The rest of this section outlines five prominent verification priorities and new inspection challenges in dismantling the North's extensive nuclear weapons programs.

3.2.1 Nuclear Weapons and Weapon Components

If North Korea's claims to possess nuclear weapons turn out to be true,[34] it would present new challenges, including how to deal with the problem of securing nuclear weapons, weapon components, weapon-usable plutonium, and uranium metal, while dismantling all facilities involved in the weaponization program. On the premise that Pyongyang abandons its nuclear arsenal as part of a general agreement, the best option would be to transfer all North Korean

[32] IAEA's prime role to verify the implementation of safeguards agreement by the DPRK remains unchanged. But verifying the North's nuclear weapons and dismantlement goes beyond the Agency mandate. David Albright and Corey Hinderstein asserted that the Bush administration officials prefer "IAEA plus 5 nuclear weapons states" inspection formula in the North Korean context. See "Cooperative Verified Dismantlement of Nuclear Programs: An Eye Toward North Korea," Institute for Nuclear Materials Management (INMM) 44th Annual Meeting (Phoenix, AZ), June 1, 2003.

[33] In May 1992, when the ad hoc inspections first got underway, the IAEA enjoyed a high level of cooperation from the DPRK. At the end of the Agency's first visit, North Korea offered a standing invitation to IAEA inspectors to visit any site in North Korea, even if that site was not included in the initial report. However, this cooperation disappeared quickly as problems developed. See David Albright, Kevin O'Neill, eds, *op. cit.*, p. 18.

[34] The CIA unclassified report to Congress released on November 19, 2002 states that the U.S. has assessed since the early 1990s that North Korea has one or possibly two nuclear weapons using plutonium it produced prior to 1992.

nuclear weapons, as well as plutonium or HEU metal that has been stockpiled for planned nuclear weapons, to one of the five nuclear-weapons states.[35] There is a precedent for transferring nuclear warheads to a nuclear-weapons state. In the mid-1990s, Ukraine, Belarus, and Kazakhstan transferred about 8,000 former Soviet nuclear warheads deployed in their territories to Russia. In return, the three countries received security assurances from Russia, the United Kingdom, and the United States. For political and geographical reasons, either Russia or China might be a good destination for the North Korean nuclear weapons and fissile material.

The South African case is a good precedent for international supervision of nuclear de-weaponization. South Africa developed and possessed nuclear weapons (six by its admission), but then voluntarily disarmed. It dismantled all its nuclear weapons before acceding to the NPT as a non-nuclear weapon state in July 1991. South Africa accepted IAEA verification to confirm the termination of its nuclear weapons program. Further, the Pretoria government extended a standing invitation to the IAEA for visits "anywhere, any time, any place—within reason." During a five-month period, the IAEA team carried out inspections at a number of South African facilities and locations that had been declared to be involved in the former nuclear weapons program.[36]

The IAEA's work to verify the correctness and completeness of South Africa's inventory of nuclear material and facilities was no easy task, since the exercise had to go back more than 20 years in history. The verification of the HEU output of the pilot enrichment plant against the uranium inputs, depleted uranium outputs, and in-process gas losses posed a particularly difficult problem. Over a period of 21 months, the IAEA tried to establish a correlation between the operating records of the plant and declared outputs. In September 1993, the IAEA General Conference decided to give a positive verdict concerning South Africa. The IAEA verdict included the completeness of the dismantling and destruction of the hardware of the nuclear devices, reassignments of dual-use equipment and facilities to peaceful civilian uses, and the destruction of the two underground test shafts.[37] By 1994, South Africa had dismantled the entire associated weapon infrastructure under international inspection, and all its nuclear plants and all previously produced enriched uranium were placed under IAEA safeguards.[38]

Another useful precedent is that of Russia and the United States voluntarily putting excess HEU from their weapons programs under IAEA safeguards in the mid-1990s. Monitoring of Russian Federation and U.S. storage facilities includes both on-site inspection and remote monitoring.

After nuclear weapons and fissile material are removed from North Korea, the next goal would be to dismantle the weaponization program itself. As soon as the North begins dismantlement

[35] Another option is to let the North to dismantle its nuclear warheads, but it is not perceived practical in terms of international concerns about its nuclear ambitions, let alone a complicated process of verified dismantlement.
[36] Adolf von Baeckmann, Gary Dillon, and Demetrius Perricus, "Nuclear Verification in South Africa," *IAEA Bulletin*, Volume 37, Number 1 (1995).
[37] Waldo Stumpf, "Birth and Death of the South African Nuclear Weapons Programme," Presentation given at the Conference "50 Years After Hiroshima" held in Castiglioncello, Italy, September 1995.
[38] Joseph Cirincione, Jon B. Wolfsthal, and Miriam Rajkumar, *op. cit.*, p. 359.

activities, IAEA inspectors and experts from the five nuclear-weapon states[39] need to focus on a long-term dismantlement of facilities that were involved in the North's weaponization program. A high-explosive test site in the Yongbyon complex should be destroyed.[40] Verification priorities relating to the DPRK nuclear weaponization program could be as follows[41]:

1. Obtain information regarding the dismantling program and the destruction of design and manufacturing information
2. Assess the information provided by North Korea with respect to the timing and scope of the weaponization program
3. Interview North Korean authorities and technical staff responsible for the production phase of the nuclear weaponization program
4. Visit facilities previously involved in or associated with the weaponization program to confirm that they are no longer being used for weapons purposes
5. Verify that all non-nuclear components of the devices, all laboratory and engineering facilities, and all weapons-specific equipment have been decommissioned and dismantled.

3.2.2 Disposition of the Spent Fuel Rods Unloaded from the 5 MWe Reactor

After removing the nuclear weapons, nothing is more urgent than shipping the spent fuel rods out of North Korea. Since it takes a relatively short period of time to transform spent fuel into weapon-usable fissile material, the spent fuel rods provide a powerful means of blackmail as long as Pyongyang holds them.[42] In spite of the North's recent claims, there is no hard evidence to indicate that all the spent fuel rods have been reprocessed at the Yongbyon reprocessing plant or possibly at an undeclared facility. If it turns out that North Korea had successfully separated plutonium from the spent fuel during the IAEA monitoring hiatus, immediate measures should be taken to put that plutonium under the IAEA safeguards.

All accessible spent fuel rods and pieces were kept in 360 canisters manufactured by NAC Corporation of Atlanta, Georgia. The canisters are constructed of stainless steel, filled with inert argon cover gas with 2% oxygen, and equipped with a pressure relief valve. Between April 1996 and January 2001, the U.S. Department of Energy had carried out the canning work of all the 8,017 declared spent fuel rods, including about 700 damaged rods, and periodic maintenance activities.[43] Canning the fuel allowed the IAEA inspectors to monitor the spent fuel more easily and minimized further escape of radioactive contaminants.

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[39] To avoid the spread of sensitive information about the design of North Korea's nuclear weapons, a special effort of the five nuclear-weapon states needs to be formed. Some suggest concluding an agreement with North Korea to facilitate the dismantlement activities.

[40] North Korea is believed to have conducted about 70 high-explosive tests prior to 1992. In March 1986, a U.S. satellite detected the residue of experimental high-explosive detonations, although the North claimed the tests were for civilian purposes. See Don Oberdorfer, *The Two Koreas: A Contemporary History* (New York: Basic Books, 2001), p. 250.

[41] IAEA and outside experts may wish to follow the Iraqi or South African model, but these intrusive measures will require intensive negotiations with North Korea.

[42] Chun Yung-woo, "North Korean Nuclear Issue: Current Status and a Roadmap for a Solution", March 31, 2003.

[43] Mark Mohr, "Yongbyon Spent Fuel Experience," US-DPRK Next Steps Workshop sponsored by the Nautilus Institute for Security and Sustainability and the Carnegie Endowment for International Peace, Washington, DC,

When the 1994 AF was concluded, no concrete agreement had been worked out between the DPRK and the U.S. on where the canisters were to be ultimately sent and who would pay the costs of transport, reprocessing, and disposal of radioactive wastes. Transporting the remaining spent fuel rods to a foreign reprocessing plant as soon as possible would allow a more accurate, and potentially cheaper analysis of the fuel's plutonium content. This course of action could ease the IAEA's inspection and verification task.[44]

For technical reasons, an attractive location to send the fuel is the Sellafield plant in the United Kingdom, where Magnox fuel is routinely reprocessed. For example, the Tokai-1 nuclear power plant in Japan was a Magnox reactor that operated from 1965 to 1998. During this period, the fuel was sent by ship to Sellafield for reprocessing.[45] Alternately, Russia and China would be good destinations, because both countries have facilities to reprocess spent fuel removed from the graphite-moderated reactors. Both Russian and Chinese locations would entail lower transportation costs.[46]

3.2.3 Dismantlement of the Illicit HEU Program

The North's HEU program presents different issues and other challenges. It may be relatively straightforward to verify the activities and facilities that North Korea has declared. The real challenge will be in detecting undeclared uranium enrichment facilities. Uranium enrichment facilities are relatively easy to conceal and difficult to detect. For instance, a cascade of gas centrifuges, which can produce enough HEU for four nuclear bombs per year can be installed in a space of 60 by 60 meters, and could be located underground. This means that it is extremely difficult to detect small-scale uranium enrichment activity through satellites without other intelligence. Moreover, even if on-site inspection were allowed, it would be difficult for inspectors to detect all enrichment facilities if they are dispersed through the country and unless they are completely declared.[47] Other detection methods are available however, including 1) power line sensors, 2) analysis of heavy metals in water and soil, and 3) fluorine compounds in environment. Wide area environmental sampling techniques and methods are discussed in Section 4.2 of this paper.

If North Korea disavows its uranium enrichment program while it is still under construction,[48] it could be dismantled either prior to the onset of verification activities or concurrent with verification. In the North Korean case, there is no reason not to take the concurrent disarmament

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January 27, 2003. Mohr estimated that the DPRK spent fuel disposition program by the U.S. required approximately $34 million to date and would require $2 million per year for continuing operations.

[44] David Albright and Kevin O'Neill, eds., *Solving the North Korean Nuclear Puzzle* (Washington, DC: Institute of Science for International Security Press, 2000), pp. 239-240

[45] Michael May, *et al*., *Verifying the Agreed Framework,* UCRL-ID-142036. Center for Global Security Research, Lawrence Livermore National Laboratory and Center for International Security and Cooperation, Stanford University, April 2001, p. 74.

[46] KAERI, "North Korean Nuclear Issues and LWR Project," KAERI/AR-552/99, November 1999.

[47] Chun Yung-woo, "North Korean Nuclear Issue: Current Status and a Roadmap for a Solution", March 31, 2003.

[48] If the North's uranium enrichment facilities had been operating, the inspection and dismantlement would be complicated. The IAEA has experience in safeguarding operating centrifuge enrichment facilities in Japan and Western Europe. The Agency also inspected enrichment facilities that had been shut down in South Africa and Australia.

and verification approach. David Albright and Corey Hinderstein suggested a "cooperative verified dismantlement" which requires that North Korea voluntarily dismantle its uranium enrichment program in cooperation with the IAEA or a new verification organization.[49] In a cooperatively verified dismantlement process, the verification organization would be required to exercise extensive rights that could go beyond the IAEA Model Additional Protocol. The process of dismantling a gas centrifuge and its verification could be accomplished in about a year, and the core effort might require five to ten specialists and a budget of several million dollars a year.

The main steps in dismantling the gas centrifuge facilities are as follows: 1) initial meeting of the DPRK and the verification organization, 2) North Korea's declaration of its centrifuge program, 3) joint tour of main facilities in the centrifuge program, 4) an agreed understanding of the centrifuge program, 5) North Korean plan for dismantlement, 6) verification organization's plan, 7) North Korea's dismantlement of its centrifuge program, 8) verification organization's activities, 9) verification of the production of any enriched uranium, 10) conversion of the program to non-centrifuge use,[50] 11) on-going monitoring, and 12) verification organization's conclusion.

3.2.4 IAEA Special Inspection of the Two Suspected Nuclear Waste Sites

Since April 1993, the UNSC has been reluctant to fulfill the commitment implicit in its 31 January 1993 declaration. This declaration states that the proliferation of all weapons of mass destruction constitutes a threat to international peace and security and that UNSC members "will take appropriate measures in the case of any violations notified to them by the IAEA." If North Korea's violations continue unchecked, they would undermine not only the effectiveness of the NPT safeguards system in deterring proliferation, but also the enforcement authority of the UNSC.[51]

One key objective of the special inspections request by the IAEA in 1993 was to gain access to two suspected, camouflaged underground waste storage facilities, one near the reprocessing plant and the other near the IRT-2000 research reactor. The first site is a building with a hidden basement that is connected to the Radiochemical Laboratory by a trench that might contain pipes. The two sites might contain waste leftover from separating plutonium. The IAEA intended to inspect these sites and take samples of any waste to find new evidence of the amount of separated plutonium.[52] Gaining access to these waste storage sites would probably help ascertain how much, if any, plutonium North Korea produced before the start of IAEA inspections in 1992. If North Korea reprocessed some or all of the existing 8,017 spent fuel rods in 2003, it may create complications for uncovering the history of the North's past activities. For example, if North Korea recently transferred liquid wastes from the reprocessing plant to the suspected

[49] David Albright and Corey Hinderstein, "Cooperative Verified Dismantlement of Nuclear Programs: an Eye Toward North Korea," *op. cit*.
[50] This conversion option will not be economically attractive and responsibility for the costs remains to be decided. Aluminum tubes, if any, could be easily converted for civilian uses.
[51] David Fisher, "The DPRK's violations of its NPT Safeguards Agreement with the IAEA," in IAEA, *History of the IAEA,* Vienna: IAEA, 1997.
[52] David Albright and Kevin O'Neill, *op cit.*

waste storage sites, this would change the contents of those sites and greatly complicate efforts to use those materials to reconstitute North Korea's past nuclear history.[53]

Because Pyongyang maintains a hostile attitude towards special inspections, access to these so-called "military facilities" will continue to be a central issue in verifying Pyongyang's past nuclear activities. Unless the two camouflaged sites are thoroughly inspected, the "ancestry" of the North's plutonium program will remain unresolved.

3.2.5 Dismantlement Milestones Contained in the Agreed Framework

Amid the current crisis, the future of KEDO LWR project in Kumho is uncertain. According to Larry Niksch's analysis, the Bush administration is expected to decide whether to suspend or terminate the project by the end of 2003.[54] However, this impasse does not mean an indefinite delay of implementation by North Korea of the nonproliferation obligations contained in the AF. Even if the AF is officially declared as nullified and the LWR project terminates, the nonproliferation milestones contained in the AF should be incorporated into a new agreement to be devised by the participants in the six-party talks. The dismantlement of the plutonium program would not pose major technical problems, but how the dismantlement will take place and who will assume costs of the decommissioning and subsequent "clean-up" has to be decided.

In addition, the future of the IRT-2000 reactor and associated hot cells (which were not included in the AF dismantlement list) must be decided. The North admitted that in 1975 it extracted a minute amount of plutonium from these hot cells. Since 1977, the small-scale research reactor has been placed under IAEA safeguards, but the IAEA's suspicions concerning this small reactor remain unresolved. The worst-case scenario is that over the past 30 years the North could have separated up to 4 kg of plutonium produced in this reactor.[55]

There are three stages of decommissioning the North's graphite-moderated reactors and related facilities:[56]

Stage 1 (safe storage with surveillance)
The outer contamination barrier is kept, but the mechanical opening systems (valves, plugs, etc.) are permanently blocked and sealed. All spent fuel rods are removed and liquid flow is blocked. Access to the containment building is allowed, subject to monitoring and surveillance procedures. Stage 1 would be sufficient to achieve the basic nonproliferation goal and effective nuclear monitoring.

Stage 2 (restricted site release: cocooning)
The outer contamination barrier is reduced to a minimum size and all parts except the core and shields are dismantled. The contamination barrier is reinforced by physical means. After

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[53] Jon B. Wolfsthal, *op. cit.*
[54] Larry Niksch, *op. cit.*, p. 4. On November 21, 2003, the Executive Board of KEDO decided to suspend the LWR project in the DPRK for a period of one year, beginning on December 1, 2003. The future of the project will be assessed and decided by the Executive Board before the expiration of the suspension period.
[55] David Albright and Kevin O'Neill, *op cit.*
[56] Michael May, et. al., *op. cit.*, 74-76; KAERI, *op. cit.*, 49-52.

decontamination to acceptable levels, the containment building and the nuclear ventilation system are modified or removed.

Stage 3 (unrestricted site use: greenfield)
All materials, equipment, and parts of the plant are removed. In all remaining parts, contamination has been reduced to acceptable levels. The site is released for unrestricted use.

The 5 MWe reactor had operated for eight years prior to the freeze in 1994 and was reactivated in February 2003. In the decommissioning process, emphasis should be placed on removing and destroying critical reactor components such as control rod drives. The empty core of the reactor could be filled with concrete to avoid handling the radioactive graphite core blocks, which is time-consuming and presents a radiological risk to workers. While "cocooning" and "greenfield" would require considerable time and costs, it would be relatively easy to bring the 5 MWe to Stage 1 (safe storage with surveillance). At the beginning of Stage 1, some critical pipes and the reactor vessel could be cut apart. The steam generators, refueling machines, and control rod dives could be removed and destroyed to provide assurance that the Stage 1 decommissioning can not be reversed.

Given the enormous costs and time-consuming nature of the Stage 2 and 3 processes,[57] one viable option is to store the 5 MWe reactor with surveillance (Stage 1) for several decades. At a time when the radioactive level is drastically lowered and advanced decommissioning technology is readily available, Stages 2 and 3 could be carried out. For nonproliferation purposes alone, Stage 1 is sufficient, and Stages 2 and 3 could be delayed indefinitely. During the extended period of Stage1, international monitoring efforts and anti-pollution measures should be in place.

The two gas-graphite reactors currently under construction could be easily taken to advanced stages of decommissioning. Finding and destroying nuclear-related equipment and components that North Korea has possibly manufactured for them is of particular concern. Destruction techniques are not difficult and costs should be manageable. One task could be to dispose of a large quantity of nuclear-grade graphite from the nearly completed 50 MWe reactor, the existence of which North Korea has acknowledged.

In 1992, IAEA inspectors estimated that the Yongbyon reprocessing plant (Radiochemical Laboratory) to be 80% complete. One reprocessing line was complete and the other had 40% of its equipment installed. By 1994, the second separation line was nearly complete, but not all instrumentation had been installed. The inspectors confirmed that one of two lines has been tested and contaminated.[58] The Radiochemical Laboratory, if completed, is believed to have the capacity to separate all the plutonium from the North's three gas-graphite reactors. As in the nuclear reactor case, decommissioning a reprocessing plant is a very long, complicated, and

[57] KAERI, *op. cit.*, estimates that completing three stages of one reactor would require more than $100 million. Moreover, because North Korea have no facilities, a third country should be involved in disposition program of radioactive wastes from the decommissioning of 5 MWe reactor.
[58] Sharon A. Squassoni, "North Korea's Nuclear Weapons: How soon an Arsenal ?," CRS Report for Congress, April 23, 2003, p. 5.

expensive process. The radioactive waste tanks and contaminated concrete would be the most time-consuming parts to dismantle.

Because North Korea has no experience in nuclear decommissioning, it may be sensible to find a western company to do the project management and provide technology. A decision might be required on the scope of international involvement and assistance in the North's dismantlement activities.

Entirely dismantling the North's three gas-graphite reactors and reprocessing plant is not crucial. Stage 1 (safe storage with surveillance) is a sustainable solution. However, if the nuclear decommissioning is conducted in a reckless manner, all of North Korea could be an environmental disaster zone. Therefore, dismantlement that goes beyond Stage 1 should be considered as a long-term South-North cooperation project, largely separate from the immediate priorities of nonproliferation on the Korean peninsula. Table 2 summarizes the elements in verification phases for North Korean nuclear facilities.

Table 2. Verification Task Time Frames in North Korea

Short Term	Mid Term	Long Term
1. North Korea's official declaration to give up nuclear weapons programs and admission of international inspections • Return to the NPT and implementation of IAEA safeguards agreement • Implementation of 1992 Joint Declaration **2. Freeze all DPRK nuclear weapons programs** • Re-freeze the plutonium program pursuant to the AF • Freeze the illicit HEU program • Freeze the nuclear weaponization program • Shut down the 5 MWe reactor and unload the 50 tons of spent fuel rods (agreement of storage needed) **3. Verify the North's Expanded Declaration and it's Claims of Nuclear Activities** • Confirm the status of all existing nuclear programs and newly declared facilities • Investigate the reprocessing of all spent fuel rods • Location of separated Pu • Status of nuclear weapons and weapon components • Location of facilities **4. Take temporary measures to detect undeclared nuclear facilities** • Wide area environment sampling techniques and methods • Complementary access for perimeter monitoring • Expanded records and documentation	**1. Shipping nuclear weapons and weapon components, if any, abroad** • An NPT nuclear weapon state(s) as the potential destination **2 Dispose of the 8,000 spent fuel rods.** • Transferring the spent fuel to a third country (UK, Russia or China) • IAEA's measurements of remaining plutonium **3. Dismantle the HEU program** • Concurrent dismantlement with the verification work **4. IAEA special inspection (or survey visit) on two suspected waste storage sites** • Early freeze or survey visit needs to be considered **5. " Stage 1" of the dismantlement of graphite-moderated reactors and related facilities** • Safe storage with surveillance (monitoring and anti-pollution measures put in place) • Critical components cut apart **6. Application of the IAEA Integrated Safeguards** • North Korea's ratification of Additional Protocol and new inspection techniques and methods applied **7. (Under special circumstances) Iraqi-type UN inspection regime** • UN Security Council resolutions	**1. "Stage 2 and 3" of dismantlement of graphite-moderated reactors and related Facilities** • Assistance to North Korea's environmental clean-up **2. South-North Korean nuclear cooperation** • Assistance to the North's technical framework of the state system of nuclear materials accountancy control (SSAC) • Cooperation for North Korea's nuclear export control and physical protection infrastructure in preparation for the LWR plant operation • South-North Korean Nuclear Cooperation Agreement **3. Wide range of nuclear CBMs and transparency** • If LWR project is completed, a wide number of projects to be carried out • Remote monitoring to be in place

4. New Inspection Technology and Key Tools

4.1 IAEA Strengthened Safeguards System

Since 1997, the IAEA has established the "strengthened" standard for safeguards based on the Additional Protocol (INFCIRC/540/Corr.) adopted in 1997. Given North Korea's extensive nuclear programs and records of non-compliance, it is imperative that the North should sign and ratify the Additional Protocol as soon as possible.[59] In the past, the IAEA inspectors' rights of access have been limited, and in practice the IAEA was not able to exercise its rights to conduct special inspections. The IAEA inspections have focused on the North's declared nuclear material, and the IAEA's access has been limited to strategic points in declared facilities.

Under the Additional Protocol, the DPRK would provide the IAEA with broader information covering all aspects of its nuclear fuel cycle-related activities, including research and development and uranium mining. The North should also grant the IAEA broader access rights and enable it to use the most advanced verification technologies. When fully implemented, the Additional Protocol, in combination with the IAEA-DPRK safeguards agreement, will allow the IAEA to draw safeguards conclusions both on the non-diversion of declared nuclear material and the absence of undeclared nuclear material and activities in the DPRK.

The IAEA has developed the "strengthening measures" for a new safeguards system, including advanced technology and equipment to complement nuclear material verification activities at safeguarded facilities. The IAEA would mobilize these strengthening measures and technology to locate undeclared activities in combination with intelligence and export-import records. The most recent technological advances in environmental sampling, analysis and remote monitoring provide the IAEA with more powerful yet unobstrusive means of verifying states' declarations. The IAEA is also evaluating the use of commercial satellite imagery for providing safeguards-relevant information that can complement other information sources. These new technologies and key tools should be integrated into mid and long-term nuclear monitoring of North Korea.

If the UN Security Council provides the IAEA with a mandate for both on-sight inspections and an ongoing monitoring and verification (OMV) system,[60] highly intrusive procedures and technologies could be employed to detect the presence of prohibited equipment, materials, and activities in the DPRK. The UN inspection regime's procedures and techniques could include: 1) unannounced inspections of known locations, 2) unannounced inspections of previously un-inspected locations, 3) examining of records, equipment, materials and products, 4) sampling of materials and work surfaces, 5) interviews of personnel in the workplace, 6) overhead imagery

[59] By the end of September 2003, 78 countries had signed and 37 had ratified the Additional Protocol. Each member state may negotiate an Additional Protocol specific to its situation. Full text of the Model Protocol (INFCIRC/540) is available on the IAEA web site (www.iaea.org).

[60] "Report of the Director General of IAEA in Connection With the Panel on Disarmament and Current and Future Ongoing Monitoring and Verification Issues", S/1999/127, 9 February 1999. IAEA's special responsibilities under the UNSC Resolution 687 (1991) and subsequent resolutions are distinguished from the regular work of its safeguards inspectors. The UNSC resolutions charged the IAEA with uncovering and dismantling Iraq's clandestine nuclear program and developing and implementing a plan for the ongoing monitoring and verification of Iraq's obligations under the resolution.

analysis, and 7) environmental monitoring, including aerial and land-based radiation surveys and sampling of waterways, vegetation, air, and soil.

4.2 Environmental Sampling

The collection of environmental samples at or near a nuclear site, combined with ultra-sensitive analytical techniques, such as mass spectrometry, particle analysis, and low-level radiometric techniques, can reveal indicators of past and current activities in locations handling nuclear materials. Environmental sampling was introduced in 1993-1996 period as one of the strengthening measures that can be applied under an IAEA comprehensive safeguards agreement. The Additional Protocol adds to the impact of environmental sampling and analysis through the provision that samples can be collected beyond the strategic points defined in facilities, when the IAEA deems it necessary to confirm the absence of undeclared nuclear material and activities. Samples are received, screened, and analyzed at the IAEA Clean Laboratory located at Seibersorf near Vienna.[61]

For the North Korean case, its extensive weapon programs are likely to leave "nuclear fingerprints" in nature. To detect undeclared activities, wide-area water monitoring could be conducted across the North. This could be accomplished using a system that draws raw water through a filter for one hour, the equivalent of testing a large volume of water. Laboratory analysis of the filter is able to find even minute traces of materials in the water with pinpoint accuracy. Air sampling stations could be set up at various points and samples of vegetation be tested for tritium, an isotope of hydrogen. Finding tritium in waterways or the air may indicate reactor operations.

Proliferation-prone nuclear facilities would not fail to leave traces that could be detected by the methods of environmental sampling. Uranium enrichment facilities involve thousands of processing units. The plants are physically large, difficult to start up, and difficult to reconfigure (for example, from a declared LEU plant to undeclared HEU production). Uranium stock in such a plant must be converted to UF_6 gas for the process and returned to solid metal afterward. The residues are large in quantity and, because they are depleted in U-235, leave a distinctive signature. A nuclear reactor for producing plutonium also releases radioactive isotopes. After use in a power reactor, up to 0.9% of the original U-238 might be converted to plutonium. Frequent change-out of fuel elements in a clandestine production reactor offers opportunities for frequent releases of isotopes to the environment. Operation of graphite or heavy water reactors adds distinct signatures as well. These reactors are attractive to proliferators because they can operate with natural uranium fuel. Plutonium reprocessing plants release distinctive traces. Chopping up the fuel rods and dissolving the metal in nitric acid releases noble gases like krypton and argon that are hard to trap and provide strong evidence. Even in a modern reprocessing plant that takes stringent environmental measures, minute traces can be detected in the environment.[62] Table 3 summarizes critical types of nuclear signatures in the environment.

[61] Pierre Goldschmidt, "The IAEA Safeguards System Moves into the 21st Century," IAEA Bulletin, 41/4/1999.
[62] N.A. Wogman, M. S. Wigmosta, D. W. Swindle, and P. W. Krey, "Wide-area aquatic sampling and analysis for the detection of nuclear proliferation," Journal of Radioanalytical and Nuclear Chemistry, Vol. 248, No. 3 (2001), pp. 611-615.

The IAEA Clean Laboratory[63] has summarized recent advances in environmental sampling for safeguards and analytical techniques to screen and measure environmental samples. Table 4 introduces available analytical techniques of environmental sampling for safeguards.

Table 3: Tracking Nuclear Signatures in the Environment

1. **Enrichment of Uranium Leaves Traces in the Environment**
   - **Direct signatures**
     - Inevitable small releases will put product uranium in soil, stream beds, and plants
     - Concentration occurs naturally; freshwater seaweed concentrates uranium 1000-fold
   - **Indirect signatures**
     - The enrichment method will release its own byproducts (ex: fluorine gases like $U_2O_2F_2$)
     - Vegetation can concentrate the releases

2. **A Reactor for Producing Plutonium Releases Various Radioactive Isotopes**
   - **All reactors** release tiny quantities of radioactive gases that is detectable
   - **Near to site** (up to few km): radioactive gases
   - **Remote from site**
     - longer lived isotopes of iodine and various metals deposit on waterways and the plants and animals that use the water
     - evidence lasts many years in river deposits
     - seaweeds and invertebrates can concentrate some isotopes by 10,000-fold or more

3. **Reprocessing to Separate Plutonium Releases Distinctive Traces**
   - **Opening the fuel assemblies** releases radioactive gases (iodine, krypton, and hydrogen) different from those released in reactor operations
   - **Chemical separation** of the Pu from the uranium fuel involves various industrial chemicals; traces of certain chemicals could arouse suspicions.
   - **Long-term storage** before reprocessing and careful filtering can reduce emissions, but seaweeds and certain invertebrates can reconcentrate the releases.

[63] David L. Donohue, "Key Tools for Nuclear Inspections: Advances in Environmental Sampling Strengthen Safeguards," *IAEA Bulletin*, 44/2/2002

Table 4. Analytical Techniques of Environmental Sampling for Safeguards

See Reference 63.

1. **High-resolution Gamma Spectrometry (HRGS)** is used for the initial radiometric screening of samples when they are first received. This screening can be performed without removing the samples from their bags or bottles, reducing the chances of cross contamination.

2. **Radioisotope or X-ray Tube-excited X-ray Fluorescence (XRF) Spectrometry** can detect sub-microgram amounts of uranium in environmental samples. This information is used to decide how to handle the samples safely in the laboratory as well as in choosing the detailed analysis methods to be applied.

3. **Scanning Electron Microscopy with Electron-excited X-ray Fluorescence Spectrometry (SEM/XRF)** measures the elemental composition of micrometer-sized particles removed from environmental samples. In particular, the uranium/plutonium and the americium/plutonium ratios are of interest in samples taken inside glove boxes or hot cells.

4. **Thermal Ionization Mass Spectrometry (TIMS) with Ion-counting Detection** is used to measure sub-nanogram amounts of uranium or plutonium in the samples (so-called "bulk analysis"). Bulk analysis gives an average composition of the sample, regardless of the physical form of the elements present, and complements the information obtained from "particle analysis" methods such as SEM/XRF.

5. **Secondary Ion Mass Spectrometry (SIMS)** is used to measure the isotopic composition of micrometer-sized particles. The isotopes uranium-235 and uranium-238 are of greatest interest because they reveal the enrichment of uranium, showing whether it is intended for use in reactor fuel or nuclear explosives.

4.3 Remote Monitoring of Nuclear Activities

Remote monitoring is the collection of data and images by sensors (radiation, motion, video, etc.) and the transmission of that data from the point of collection to another location for evaluation. The control center could be within the facility being monitored or it could be on the other side of the world. Sensors are combined and integrated into a system to monitor and report a specific activity of interest while ignoring unrelated activity. Data can be collected continually or only when activity occurs.[64] There are three elements in any remote monitoring system: 1) sensors to measure observable quantities, 2) communication links, and 3) data storage and analysis systems. Modern transparency technologies for international nuclear safeguards are

[64] Michael Vannoni, Kent Biringer, and Lawrence Trost, *Verifying Missile Proliferation in Northeast Asia*, SAND 2003-1148C, (Albuquerque, NM. Sandia National Laboratories, April 2003).

tending toward integrated sensor systems, Internet accessibility, and improved software analysis.[65]

The real-time transmission of authenticated and encrypted data acquired by remote monitoring systems could reduce the frequency of inspector visits to a monitored facility, increase the capability for data review and evaluation, and facilitate the remote detection of and rapid response to an event. For the facility and inspected state, remote monitoring for safeguards purposes could be less intrusive on facility operations than on-site inspections. Following field tests of remote monitoring systems at several types of nuclear facilities around the world, the IAEA is preparing to incorporate remote monitoring into its safeguards applications on a case-by-case basis.[66]

As a new safeguards technology, remote monitoring complements hands-on nuclear material accountancy and offers several advantages, such as reducing the frequency and amount of inspection, reducing exposure of inspectors to hazardous environments, reducing intrusion on facility operation, and increased cost-effectiveness. Remote verification may be an alternative in some applications, should North Korea not accept extensive on-site verification.[67]

Remote monitoring of nuclear facilities also affords an effective way to provide South-North transparency with low intrusiveness. These technologies could permit a limited stream of agreed-upon information to flow over secure Internet or telephone lines to provide assurance of safety and nonproliferation. Simple sensors could verify that a facility remained closed, or that operations from a facility were safe, or that spent fuel remained in a storage pond. Motion or radiation detectors could trigger video cameras so that events could be analyzed quickly without personnel actually being on-site.[68] In this context, Yoon Wan-ki asserted that if confidence builds, remote verification could be applied to complement certain on-site inspections and facilitate inter-Korean nuclear transparency measures. He suggested that, with the consent of the IAEA, the ROK should provide the DPRK with remote monitoring data from existing surveillance and seals for all its nuclear facilities, including its fuel fabrication plant and research reactors, without any conditions. At a later stage, the ROK can ask for the North's safeguards data, including remote monitoring, as South-North relations improve.

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[65] John N. Olsen and Charles D. Harmon, "Technology Development for Nuclear transparency Applications," Third Annual JNC International forum on the Peaceful use of Nuclear Energy, Tokyo, Japan, February 21-22, 2001.

[66] Pierre Goldschmidt, "The IAEA Safeguards System Moves into the 21st Century," IAEA Bulletin, 41/4/1999.

[67] Yoon Wan-ki (KAERI), "TECATOM: Technical Atomic Energy Community in East Asia and Pacific," Paper submitted to the CMC of Sandia National Laboratories, April 2003. Yoon also proposed to establish TECATOM in East Asia and the Pacific to promote nuclear transparency based on the concept and applicability of remote monitoring.

[68] John Olsen, "Activities to Further Nonproliferation and Encourage Confidence Building Measures on the Korean Peninsula," CMC, Sandia National Laboratories, August 2000.

Table 5. Examples of Monitoring Systems

See Reference 64

Function	Sensor Type	Example	Purpose
Tracking Systems	Commercial Transport Tracking System	Portable, GPS-linked device determines/broadcasts location	Monitor location of patrol, vehicle, or cargo; record route taken
Seals	Passive Seals	Tape, wire, fiber-optic cable, plastic shrink-wrap, other means of sealing doors or containers	Reveal whether a sealed item or room has been opened since closure
	Active Seals	Seals linked to audible/visual alarm or radio transmitter	Provide immediate alert of tampering with sealed item
Access Control Systems	Alarmed Fences	Standard security fence with pressure-sensitive wires linked to alarm, camera or transmitter	Provide visible access barrier, intrusion warning
	Buried Fiber-Optic Cable	Pressure-sensitive buried cable linked to alarm, camera, or transmitter	Detect people or vehicles crossing a line of control
	Personal Entry Identifiers	Code locks, magnetic badges, hand geometry readers, other ID devices	Limit access to authorized people
Detectors	Metal Detectors	Walk-through and hand-held magnetic sensors	Locate concealed weapons or other metallic items
	Chemical Detectors	Detection of traces of specific chemicals on vehicles, people, or cargo	Locate concealed drugs, ammunition, or explosives
	Portable X-Ray Machines	Standard airport baggage viewers	Identify contents of bags and small boxes
Unattended Ground Sensors	Seismic, Magnetic, Acoustic Sensors	Transmitter activated by vibration, ferrous metal, or sound waves	Detect people, weapons, or vehicles
	Infrared and Microwave Break-Beam Devices	Alarm or transmitter activated when line-of-sight beam interrupted	Detect people or vehicles crossing a line of control
Aerial or Satellite Imagery	Visual Photography	Standard photography, variable resolution and quality	Provide video or still photography, real time or recorded
	Infrared, Radar, Multi-spectral Imagery	Infrared Camera Synthetic Aperture Radar	Image through darkness, clouds, vegetation; detect objects, terrain not visible to the human eye
Tags	Bar Codes	Adhesive tape with readable bar code; bar code scanner	Identify individual pieces of equipment; facilitate inventory
	Reflective Particle Tag	Metallic particles suspended in polymer coating form unique pattern on equipment	Identify individual pieces of equipment

5. Bilateral and Regional Verification Regimes

5.1 Joint Nuclear Control Commission

North Korea's return to normalcy will include its commitments to implement the Joint Declaration on the Denuclearization of the Korean peninsula. The 1992 Joint Declaration calls for a joint inspection agency—the Joint Nuclear Control Commission—for conducting inspections of "particular subjects chosen by the other side and agreed upon between the two sides." The JNCC is tasked with matters "related to the exchange of information for the verification of the denuclearization of the Korean peninsula," as well as organizing the composition and operation of inspection teams. The JNCC was expected to complement IAEA safeguards activities, but negotiations failed to reach an agreement on the nature and scope of a bilateral inspection regime, and implementation has been stalled since January 1993.

Despite the failure of the JNCC as an implementing mechanism of the Joint Declaration, the need to revitalize a bilateral inspection regime remains. Several workshops were held to model the JNCC on the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (known by its Spanish initials ABACC).[69] In the current crisis, some stressed the need to revitalize the JNCC. However, it is not plausible that the moribund JNCC could or should play a leading role in future inspection activities on the Korean peninsula. Pyongyang would probably continue to marginalize Seoul's role in nuclear issues.

Given the ROK government's interests, the need to establish a bilateral inspection agency like the JNCC could be raised in the six-party talks. Pending an agreement on a new inspection regime, an incremental approach to revive the JNCC would be desirable. In this regard, a study conducted by the Korea Institute for Defense Analyses (KIDA) and the Cooperative Monitoring Center (CMC) suggests an option that may be applicable if inter-Korean relations improve.[70] Assuming that the DPRK may be more willing to enter into a bilateral inspection regime than the IAEA safeguards system, the ROK could make its continued support of the KEDO project and rebuilding of the North's electrical infrastructure conditional on a renewed and active inter-Korean denuclearization agreement and JNCC. The JNCC could follow the operational mode of ABACC.

If the JNCC is not actively involved in the entire verification process in North Korea, an alternative option will be to transform its role into implementing nuclear confidence building and transparency measures on the Korean peninsula. The JNCC could be tasked with "particular subjects" of nuclear safety, physical protection and export control.

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[69] For example, KAERI /TCNC and KIDA co-hosted a workshop on "Nuclear Confidence Building in the Korean Peninsula" in July 23-24, 2001, See *North Korean Nuclear Issues and LWR Project (III)*, KAERI/AR-626/2002, pp. 89-96.

[70] Michael Vannoni, Kim Tae-woo, et al., *Inter-Korean Military Confidence Building After 2003*, SAND2003-2892. Albuquerque, NM: Sandia National Laboratories, August 2003, 74-75.

5.2 Korean Peninsula Nuclear Verification Regime

Any solution to the North Korean nuclear crisis will likely be a comprehensive settlement with military, economic, political, and diplomatic components. Under such an agreement, while North Korea would address nuclear weapons, ballistic missiles, and conventional forces issues, the international community would offer the North security assurances and substantial economic aid in exchange.[71]

The Nuclear Energy Experts Group of the Council for Security Cooperation in the Asia Pacific (CSCAP) discussed a proposal to establish a Korean Peninsula Nuclear Verification Regime at its meeting in Las Vegas, NV in May 2003. Assuming that the DPRK agrees to dismantle its nuclear weapons programs and freeze its long-range missile programs under international scrutiny, a regionally managed threat reduction regime,[72] staffed and sustained by all interested parties (participants of six-party talks plus IAEA) could be an effective and durable solution.

The regional inspection regime's charter could be observation of all present and future nuclear agreements for both South and North Korea. The initial task of the regime would be observing the elimination of the North Korean weapons program. Following that phase, the regime could be charged with monitoring of routine international safeguards in cooperation with the IAEA and monitoring compliance with provisions for a non-nuclear Korean peninsula, similar to those contained in the Joint Denuclearization Declaration. The detailed responsibilities of the regional verification regime could be as follows:

1. Monitor refreezing/dismantling of the DPRK nuclear weapons facilities and removing fissile material

2. Achieve compliance with NPT
   - Resolving the past history of the Yongbyon reprocessing plant (the IAEA retains the lead responsibility)
   - Administering and conducting all normal safeguards activities on the peninsula
   - Implementing the Strengthened Safeguards System on the peninsula.

3. Implement Dismantlement and Reduction Terms
   - Receiving, dismantling and safeguarding any nuclear weapon components that the DPRK possesses. Nuclear-weapons states (P-5) must take the lead until the materials can be placed under normal safeguards supervision.
   - Freezing the facilities for developing and producing long-range missiles.

4. Confirm provisions similar to the 1992 South-North Denuclearization Agreement
   - Subsuming roles envisioned for the JNCC under the 1992 Joint Declaration in mutual inspections and IAEA interaction

[71] Brad Glosserman, "A Verification Regime for the Korean Peninsula," the Nautilus Institute, Policy Forum Online, June 18, 2003.

[72] John Olsen, A Multilateral *Threat Reduction Regime for Korean Peninsula: A Strategy for Success after the Current Impasse is Overcome*. Albuquerque, NM: CMC, Sandia National Laboratories, September 2003.

- Inspecting and freezing the HEU program and safeguarding or removing any material
- Instituting comparable verification of non-enrichment and non-reprocessing compliance in the ROK.

5. Verify mutual reductions or redeployment of conventional forces and other elements of the comprehensive settlement.

The location of this regional verification institution could be in Vladivostok, Russia or in Shenyang, China. For political and geographical reasons, Beijing would also be a good place to host the regional inspection agency. A permanent management staff might number 10 persons supported by 20 secretarial and clerical staff. The Inspectorate Division might need about 25-30 inspectors from the six-party countries and the IAEA for the combined nuclear industries of South and North Korea.[73] Considering the Iraqi experience, short-notice inspections and support for rapid air transport to all portions of the Korean peninsula may be critical.[74]

[73] Olsen estimates 25-30 inspectors would be appropriate for the Korean Peninsula Nuclear Verification Regime. He suggests 3-5 inspection experts each from China, ROK, Japan, Russia, China, DPRK and the U.S. including 6 inspectors from IAEA's Tokyo center.

[74] Stan Fraley, *Comments on Regional Verification of a Denuclearized Korean Peninsula*, Albuquerque, NM: Sandia National Laboratories, July 25, 2003.

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6. Nuclear CBMs and Transparency on the Korean Peninsula

Despite increased inter-Korean exchanges in economics, culture, sports, tourism, and other areas, nuclear matters have remained highly political issues for the DPRK. In the midst of nuclear escalation in May 2003, Pyongyang attempted to nullify the 1992 Joint Declaration on the Denuclearization of the Korean Peninsula. Although North Korea has never implemented it, the Joint Declaration was a significant CBM for both nonproliferation goals and the peaceful uses of nuclear energy. The Declaration goes beyond the NPT by prohibiting the possession of nuclear reprocessing and uranium enrichment facilities, and the deployment of nuclear weapons on the Korean peninsula.

Against this backdrop, it is not opportune to assert the applicability of nuclear CBMs and transparency on the Korean peninsula.[75] As long as the North employs a strategy of nuclear breakout, any nuclear CBMs or transparency would not be practical. At this stage, it is more desirable to devise well-defined precursor measures to promote an atmosphere to facilitate the North's full compliance with the international arrangements. Any prospective verification work could be tied to and accompanied by a number of CBMs. This means that nuclear CBMs and transparency would support the six-party talks and subsequent meetings. On North Korea's part, it needs to understand how verification work would be implemented and how it would meet its national interests. The ROK government's openness and active engagement are needed now more than ever.

In this context, the following measures proposed by the KIDA-CMC Study[76] deserve consideration:

1. Sponsor DPRK participation in regional and international technical meetings.
   Because the North lacks experience in safe operation of nuclear facilities, the ROK should encourage North Korean involvement in international safety cooperation. Foremost of them is the World Association of Nuclear Operators (WANO). Non-governmental discussions can also be useful in aligning North Korea in "safety culture" of Northeast Asia. For example, the Nuclear Energy Experts Working Group of CSCAP has conducted several tours of nuclear facilities in Northeast Asia, Canada, and the U.S., and currently exchanges real-time safety information about member institution operations through a website. The North's participating in CSCAP meetings would be a good start.

2. Develop a group of North Korean nuclear engineers as inspectors.
   Since the early 1990s, the ROK TCNC has accumulated extensive experience in safeguards and strengthened cooperation with the IAEA. The ROK can share with the North its experience of establishing the TCNC with its focus on nuclear accounting and control, physical protection, and export control of nuclear technology. TCNC expertise and technologies could be offered to the North for training its prospective inspectors. The

[75] Nuclear CBMs are intended to defuse heightened tensions, establish precedents for cooperation, and build experience for the denuclearization of the Korean peninsula. The CMC of the Sandia National Laboratories defines the term "nuclear transparency," as "a cooperative process of providing information to all interested parties so that they can be independently assess the safety, security, and legitimate management of nuclear materials."
[76] Michael Vannoni, Kim Tae-woo, *et al.*, *op. cit.*, pp. 71-77.

North has demonstrated its interest in nuclear material control procedures by participating in IAEA-sponsored regional safeguards and physical protection training courses as recently as December 2002.

3. Establish inter-Korean monitoring within the context of the IAEA.
   If the JNCC enters into operation, it could sign an agreement for joint implementation of safeguards with the IAEA as the ABACC did in 1993. Under the IAEA safeguards agreement, the IAEA does not provide information and data collected during an inspection to the inspected state, nor does it provide data about other states. Therefore, such a bilateral agreement, operating in coordination with the IAEA, would provide a high level of transparency on both Koreas' operation of nuclear facilities. Moreover, a broader application of remote monitoring could be discussed further, if conditions permit.

7. Conclusions

As Leon V. Sigal of Social Science Research Council poignantly pointed out, "the verification of any arms control agreement is a political question in technical guise." This would be particularly so for any potential accord with North Korea to dismantle its weapons of mass destruction (WMD) programs.[77] Notwithstanding all differing views on reciprocal and comprehensive arrangements, the international community should make every effort to put "an effective verification regime" into place on the Korean peninsula.

On the assumption that North Korea will continue to wield its nuclear weapons capability as a political and military tool, this paper has outlined a framework of objectives to be realized in future verification work in the DPRK. It has summarized advanced inspection technologies and key tools applicable in the North Korean case. Of particular note is a proposal to establish a Korean Peninsula Nuclear Verification Regime. Potential nuclear CBMs and transparency to support the new verification work on the Korean peninsula are also suggested.

This paper's interim measures and mid- and long-term verification priorities represent a wide range of imperatives for a nuclear-free Korean peninsula. The six-party talks and subsequent meetings would determine the applicability of these options. The multilateral forum should continue to define its goals and act upon them. In this forum's context, the U.S., ROK, Japan, Russia, and China should take an increasingly common approach on disarming the DPRK. The future verification work in North Korea will be extremely challenging and time-consuming.

[77] Leon V. Sigal, "Verifying a Missile Accord with North Korea," in Trevor Findlay and Oliver Meir, editors, *Verification Yearbook 2002*. London: VERTIC, 2002.

About the Author

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