Options for a Verifiable Freeze on North Korea's Missile Programs

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Contents

Glossary of Terms

ASEAN	Association of Southeast Asian Nations
BMD	ballistic-missile defense
CRBM	close-range ballistic missile
DPRK	Democratic People's Republic of Korea (North Korea)
ER	extended range (missile designation)
IAEA	International Atomic Energy Agency
ICBM	intercontinental ballistic missile
INF	Intermediate-range Nuclear Forces Treaty
IRBM	intermediate-range ballistic missile
KN	Korea North (missile designation)
LPE	liquid-propelled engine
MaRV	maneuverable re-entry vehicle (missile designation)
MLRS	multiple-launch rocket system
MRBM	medium-range ballistic missile
MTCR	Missile Technology Control Regime
NTM	national technical means
OSI	on-site inspections
R&D	research and development
RoK	Republic of Korea (South Korea)
RV	re-entry vehicle
SLBM	submarine-launched ballistic missile
SLV	space-launch vehicle
SRBM	short-range ballistic missile
SRM	solid rocket motor
UAV	unmanned aerial vehicle
UN	United Nations
UNMOVIC	United Nations Monitoring, Verification, and Inspection Commission
UNSCOM	United Nations Special Commission on Iraq
UNSCR	United Nations Security Council Resolution
US	United States
WMD	weapons of mass destruction

Executive Summary

Recent developments in US-North Korean diplomacy underscore the difficulty of achieving far-reaching disarmament objectives at a stroke. A verifiable freeze—a reversible halt to certain activities that the concerned parties are able to confirm—can serve as an initial step that promotes trust and creates space for patient, in-depth negotiations, while also providing concrete security benefits.

The freeze approach has been applied during the current round of diplomacy. Around the end of 2017, North Korea informally adopted a freeze on missile flight tests, and in April 2018, it declared a "suspension" of nuclear tests and long-range missile flight tests. After the June 2018 Singapore Summit, it also dismantled some missile- and space-related structures at one facility, notably including a large vertical test stand used for developing powerful liquid-propellant engines. North Korea has recently reversed this last step.

Returning to the idea of a freeze may provide a path around the present impasse in talks. To promote trust and create space for further negotiations, North Korea and its negotiating partners could exchange one or more packages of verifiable, reversible concessions, in addition to the steps already taken along these lines. A verifiable freeze should not only improve the atmosphere for negotiations; it can also provide tangible security benefits to the concerned parties.

This CNS occasional paper identifies and evaluates options for freezing the testing, production, and deployment of North Korean missiles, among other potential steps. These options might be pursued singly, in combination, or sequentially. The paper identifies some of the precedents for these activities and describes both the verification requirements and the security benefits associated with each option.

While it describes these trade-offs, the paper does not offer any single, specific recommendation. Policy makers must supply crucial value judgments, and any freeze agreement must be negotiated, including measures to be extended to the North Koreans. These matters are beyond the scope of the present analysis, but a better understanding of the options for a verifiable freeze of North Korea's missile programs, it is hoped, can provide some of the "raw material" for creative policy making.

Introduction

As the United States and the Democratic People's Republic of Korea (DPRK) engage in negotiations toward the "denuclearization of the Korean Peninsula,"[1] many analysts view a freeze on Pyongyang's missile program as a potential early step. Indeed, North Korea has not tested any ballistic missiles or conducted any space launches since November 2017. It announced the "suspension" of long-range missile flight tests (and nuclear tests) in April 2018; after the February 2019 Hanoi Summit, North Korean Foreign Minister Ri Yong Ho stated that Chairman Kim Jong Un would be willing to commit in writing to a permanent moratorium in return for US concessions.[2] A fortnight later, Vice Foreign Minister Choe Son Hui hinted that DPRK leader Kim Jong Un might reconsider the "suspension" given the lack of progress in the talks.[3]

This would not be the first time North Korea has adopted a freeze on aspects of its nuclear or missile programs as part of US-North Korean nuclear negotiations. Indeed, a September 1999 agreement not to test long-range ballistic missiles or conduct space launches lasted until July 2006. However, the troubled history of past efforts makes clear that establishing a truly sustainable freeze will be no easy matter. The parties must reach specific and verifiable agreements. This paper attempts to aid this process by examining several potential freeze options, their associated verification requirements, and their anticipated contributions to regional and global security.

The architects of a freeze must decide upon a basic framework: which classes of missiles they wish to control and which aspects of their life-cycle they wish to limit. A freeze, for example, might apply narrowly to intercontinental ballistic missiles (ICBMs) or more broadly to all missiles with a range and/or payload that exceeds Missile Technology Control Regime limits. Similarly, a freeze might narrowly apply to the testing of missiles or extend to production and deployment as well. Clarity will be essential on issues such as the status of space-launch vehicles (SLVs) during a freeze, since

[1] Joint Statement of President Donald J. Trump of the United States of America and Chairman Kim Jong Un of the Democratic People's Republic of Korea at the Singapore Summit, June 12, 2018.
[2] Deb Riechmann, Jonathan Lemire, and Foster Klug, "U.S. and North Korea offer contradictory accounts of why the Trump-Kim summit collapsed," *Associated Press,* February 28, 2019.
[3] Choe Sang-Hun, "North Korea Threatens to Scuttle Talks with the US and Resume Tests," *New York Times,* March 15, 2019.

a dispute over this question undid the February 2012 "Leap Day Deal."[4] The more recent restoration of partly dismantled facilities at North Korea's Sohae launch center and activities observed at the Sanum-dong SLV/ICBM production facility might indicate a possible return to space launches in the near future.[5]

The verification regime for a freeze also must be tailored to the realities of negotiations and the particularities of the rapidly evolving North Korean missile program. A flight-testing ban, for example, can be verified unilaterally by national technical means (NTM). However, broader efforts, such as production bans, would require more intrusive measures to provide sufficient confidence, especially given the rapid growth of North Korea's missile complex in recent years and its shift to more indigenous designs, production, and testing. Since North Korea is likely to demand greater concessions before it would agree to more intrusive measures, it will also be important for negotiators to strike an appropriate balance between any concessions offered and the security benefits gained from a freeze. While this study describes the security benefits of freezing different missile-related activities and various trade-offs, it does not make a single, specific recommendation.

In developing a freeze, policy makers can draw from several models for limiting states' ballistic and cruise missile and space-launch programs. These agreements include the post-Gulf-War inspection regimes in Iraq, arms-reductions treaties signed between the United States and the Soviet Union, and voluntary international arrangements aimed at curbing missile proliferation.

This paper begins with an introduction to North Korea's missile complex and a capsule history of its development, including previous missile freezes. It then describes other major missile-limitation efforts and their potential applicability to the DPRK case. It then identifies and analyzes options for freezing North Korean missiles, their verification requirements, and their associated benefits for regional and global security.

[4] The Leap Day Deal was a short-lived understanding between the United States and North Korea, announced on February 29, 2012, that was to have frozen the nuclear facilities at Yongbyon as well as missile and nuclear testing.
[5] Geoff Brumfiel, "Activity At 2nd North Korean Missile Site Indicates Possible Launch Preparations," *National Public Radio,* March 8, 2019.

Background: North Korea's Missile Complex

North Korea began its ballistic-missile program in the 1960s. In the late 1970s or early 1980s, Pyongyang obtained an unknown number of short-range, Soviet-made Scud ballistic missiles from Egypt. North Korea's missile specialists reverse-engineered these systems and sought to enhance their range and performance, establishing a new technological foundation for North Korea's ballistic-missile program. For years, the North Korean program built on this foundation slowly and steadily, through techniques such as clustering Scud-like engines and adding missile stages.[6] On a few occasions, this development was slowed by the North's agreement to missile-testing freezes.[7]

But in the last few years—since the 2011–12 ascent of Kim Jong Un—North Korea's ballistic-missile program has taken a dramatic leap forward, drastically increasing in size and technological complexity and transitioning to more complicated designs, advanced propellants, and new road-mobile launch systems.

A ballistic missile is a guided projectile, powered in early flight, that falls to its target on an elliptical trajectory. Its maximum range is largely a function of its burnout speed (i.e., its velocity at the end of powered flight). Using the terminology currently employed by the US government, most ballistic missiles fall into one of the following categories:

Most ballistic missiles fall into one of the following categories:

- Close-range ballistic missile (CRBM): Up to 300 kilometers (km) in range
- Short-range ballistic missile (SRBM): Up to 300 km—1,000 km in range
- Medium-range ballistic missile (MRBM): 1,000 km—3,000 km in range
- Intermediate-range ballistic missile (IRBM): 3,000 km—5,500 km in range
- Intercontinental-range ballistic missile (ICBM): 5,500 km+ in range

[6] Joseph S. Bermudez, "A History of Ballistic Missile Development in the DPRK," James Martin Center for Nonproliferation Studies, Occasional Paper No. 2, November 1999.
[7] In the 1990s, Israel sought a missile agreement with North Korea to ensure the latter would not export its technology to Syria, Iran, Iraq, or other hostile states in the Middle East. Israel offered North Korea hard currency, trade, foreign investments, and mining assistance; the deal was ready to proceed had the United States not blocked it. The United States was pursuing its own negotiations with North Korea, which culminated in an agreement in 1994, when North Korea pledged to freeze and ultimately dismantle its gas-graphite reactors in exchange for international aid and two new light-water reactors. After North Korea's program restarted in the early 2000s, another agreement was reached in 2005, where the North agreed to give up its entire nuclear program in exchange for energy assistance. After a re-escalation in tensions, in 2006, North Korea conducted its first space launch since 1998

As of 2019, North Korea's known ballistic-missile types consist of:

1. At least two ICBM variants, the Hwasong-14 and -15
2. An ICBM/space-launch vehicle (SLV), the Unha/Taepodong-2
3. Two types of IRBMs, the Musudan and the Hwasong-12
4. Nodong MRBMs based on Scud technology
5. Scud SRBM variants with improvements to range and accuracy
6. At least two types of CRBMs, the KN-02 and KN-SS-X-09
7. A new family of solid-propellant SLBMs and MRBMs, the Pukguksong-1 and Pukguksong-2.

Solid-propellant missile systems like the Pukguksong-2 MRBM enable North Korea to launch more rapidly than previous liquid-propellant systems, reducing opportunities for its opponents to detect or prevent an imminent launch.[8] The need for additional support vehicles for handling toxic liquid propellants also makes a Scud-type mobile-missile convoy larger and more obtrusive than a solid-propellant equivalent. Finally, solid-propellant missiles accelerate more rapidly than liquid-propellant missiles of comparable range. Their shorter boost times would make them less vulnerable to any boost-phase interceptors that might eventually be developed.

The shift from cloning and modifying older Soviet designs to designing, testing, and fielding a diverse and more sophisticated indigenous arsenal presents new challenges for constructing any type of verifiable missile freeze, expanding the types of weapons that need to be controlled, the types of controls that may be required, and the potential utility of any freeze.

The full dimensions of North Korea's missile complex are extensive but unknown. Indeed, one likely step in any process of verifying a freeze will be for North Korea to submit a declaration of relevant facilities, which could be checked against its negotiating partner's intelligence estimates. A list of known and suspected facilities appears in Table 1.

and tested its first nuclear device in 2006. In 2007, North Korea agreed to close its main reactor in exchange for a $400 million aid package. For more, see: "Israel seeks to keep North Korea from aiding Iran," *New York Times,* June 20, 1993; "S. Korea asks Peres not to visit N. Korea," *Reuters,* June 21, 1993; "Israel Agrees to Suspend Contracts with North Korea," *The Washington Post,* August 17, 1993; "North Korean Ex-Diplomat Says Blackmail Is Part of Regime's Playbook," *Wall Street Journal,* July 8, 2018.

[8] A liquid-propellant missile consists of liquid fuel and oxygen (or any other oxidizer) in a liquid state, stored in different chambers in a missile and combined in the combustion chamber for ignition. Solid-propellant missiles, however, consist of fuel and oxidizer pre-mixed and cast into a case as one homogenous mixture. Solid-propellant missiles are always "fueled" and ready to launch, whereas liquid-propellant missiles may require additional preparation time before launch. Scud-type liquid-propellant missiles, for example, are usually kept mostly fueled, but also require an additional "starter fuel" to be loaded into the missile just before launch.

Table 1

Known or suspected North Korean production facilities for various missile, missile components, and launcher programs.

FACILITY NAME	ROLE (Known/Suspected)	COORDINATES/PROVINCE
July 21 Factory	Candidate for liquid-propellant production	42.534, 130.361 North Hamgyong
July 27 Factory	Candidate for liquid-propellant production	42.522, 130.349 North Hamgyong
January 18 Machine Plant	Suspected production facility for missile components; production facility for heavy diesel engines, probably for mobile launchers	39.554, 125.851 South Pyongan
No. 17 Explosives Factory	Solid-propellant production and casting	39.831, 127.583 South Hamgyong
Magun-po Solid-Fuel Test Stand	Horizontal static test stand	39.801, 127.560 South Hamgyong
February 8 Vinylon Complex	Candidate for solid- and liquid- propellant production	39.854, 127.576 South Hamgyong
Hungnam Fertilizer Complex	Solid-propellant production	39.837, 127.626 South Hamgyong
Chemical Material Institute	Produces wound SRM casings and ablative reentry vehicle material	39.956, 127.558 South Hamgyong
Kusong Ejection Test Stand	Previously an ejection test stand at the Kusong vehicle proving ground	40.010, 125.220 North Pyongan
Tonghungsan Machine Plant	Suspected site for missile component and mobile launcher component production	39.953, 127.546 South Hamgyong
Chamjin Missile Factory	Vertical static test stand, ground testing of RVs, LPE assembly	38.956, 125.573 Pyongyang
Sanum-dong R&D Facility	Missile and space launcher research/development/assembly; older satellite control center also present	39.142, 125.766 Pyongyang
Machine Plant Managed by Jon Tong Ryol	Manufactures light aircraft, but it may also be involved in the production of missiles	39.878, 125.256 North Pyongan
Machine Plant Managed by Ri Chol Ho	Suspected manufacturing site for missile-guidance systems or their components	39.023, 125.708 Pyongyang
Machine Plant Managed by O Mun Hyon	Manufactures CNC machines used in missile program	39.969, 125.265 North Pyongan
Machine Plant Managed by Ri Jong Ok	Missile launcher manufacturing	40.630, 126.431 Jagang
Sinpo South Naval Shipyard	Ejection test stand, submersible test barge, SLBM testing, SSB production, submariner training	40.023, 128.161 South Hamgyong
Nampo Naval Shipyard	Submersible test barge	38.718, 125.394 South Pyongan
No. 26 Factory	Suspected missile component production site	40.957, 126.606 Jagang
Machine Plant Managed by Jong Il Man	Final assembly, modification of mobile launchers	40.204, 127.604 South Hamgyong
Machine Plant Managed by Ho Chol Yong	Final assembly of mobile launchers (tracked vehicles)	40.053, 125.218 North Pyongan
Amnokgang Tire Factory	Tire production for wheeled mobile launchers	41.142, 126.247 Jagang
March 16 Factory	Production and modification of vehicles usable as mobile launchers	39.281, 125.869 North Pyongan
No. 65 Factory	Modification, conversion of mobile launchers	40.611, 126.426 Jagang
Pyongyang General Satellite Control Center	Satellite control	39.042, 125.709 Pyongyang
Sohae Space Launch Center	Vertical static test stand, space launch center	39.659, 124.705 North Pyongan
Tonghae Space Launch Center	Vertical static test stand, space launch center (inactive)	40.855, 129.666 North Hamgyong

FIGURE 1

Known or suspected North Korean production facilities for various missile, missile components, and launcher programs. (Source: CNS analysis)

Production Sites

North Korea's missile-production complex is estimated to include nearly two dozen sites (see Table 1). Its ICBM program alone hosts at least nine such sites. These facilities are scattered all around the country, and many of them are embedded within civilian structures or are underground complexes. The clandestine nature of this geographic spread highlights the complexity of the verification problem, especially when it comes to a production freeze on only certain types of North Korean missile systems. Such facilities will need to be part of any initial declaration, production freeze, and on-site inspection regime.

The complexity and variety of North Korea's missile and related space programs is illustrated in Table 1, on the left, with the roles that known and suspected facilities play.

North Korea's solid-fuel program has expanded since 2017 to include a large manufacturing complex at the Chemical Material Institute to produce wound carbon-fiber casings for their newer generation of solid-propellant missiles. Solid-propellant sites are centered around the greater Hamhung area (see Figure 1), in contrast to the liquid-propellant program, which is spread across the country and includes a series of large underground production complexes, many of which are listed in Table 1.

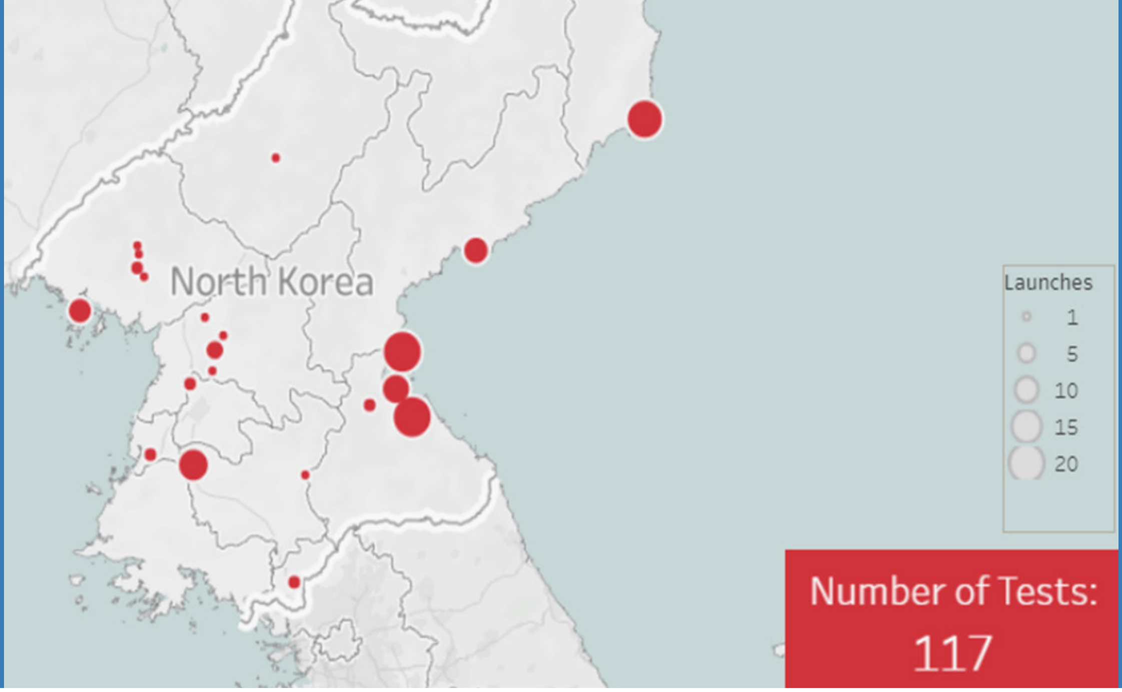


FIGURE 2

North Korean missile flight tests and space launches as of November 2017. (Source: CNS North Korea missile-test database)

Testing Sites

To be confident that missiles will perform reliably, a missile program involves a series of steps culminating in flight tests. So far, North Korea has conducted at least 117 flight tests or space launches over the course of its program, using a wide variety of launch sites (see Figure 2). Another important step in missile development is the ground testing of liquid-propellant engines (LPEs) or solid rocket motors (SRMs). LPE test stands are vertical, while SRM test stands are typically horizontal. North Korea currently has four known sites for ground testing: three for LPEs—the Sohae Vertical Test Stand (also known as Tongchang-ri or Yunsong), which is North Korea's largest known vertical test stand; the Tonghae Vertical Test Stand; the Chamjin Vertical Test Stand; and North Korea's only identified horizontal test stand to date, at Magun-po (see Figure 2). Ground testing for ICBM-class LPEs has taken place at Sohae. The Chamjin Vertical Test Stand has also been used for testing at least one re-entry vehicle by placing it under an LPE's exhaust, to simulate the intense heat of re-entry.

If a testing freeze were to exclude North Korea's shorter-range missile systems, eliminating or modifying larger test stands that are capable of supporting the testing of LPEs or SRMs suitable for longer-range missile systems could help ensure that the development of longer-range systems does not continue. The large test stand at Sohae was partially dismantled starting in July 2017, in keeping with an oral, undocumented agreement at the US-North Korea summit in Singapore in June 2018; it has since been reassembled. The metal structure of the test stand was disassembled, leaving its concrete base in place (see Figures 5 and 6). These changes were detectable in space imagery, making the temporary disassembly an example of a transparency measure verifiable with national technical means (NTM), a concept discussed further below.

North Korea has two submersible ballistic-missile testing barges, one at Sinpo and the other at Nampo. The first such barge appeared during 2014 at Sinpo South shipyard; this barge has supported the development of the Pukguksong-1 SLBM. A submarine for this same purpose is also stationed at Sinpo, as is a land-based ejection test stand.[9] Another such land-based test stand at the Kusong Vehicle Proving Ground has been dismantled.[10]

Missile Operating Bases

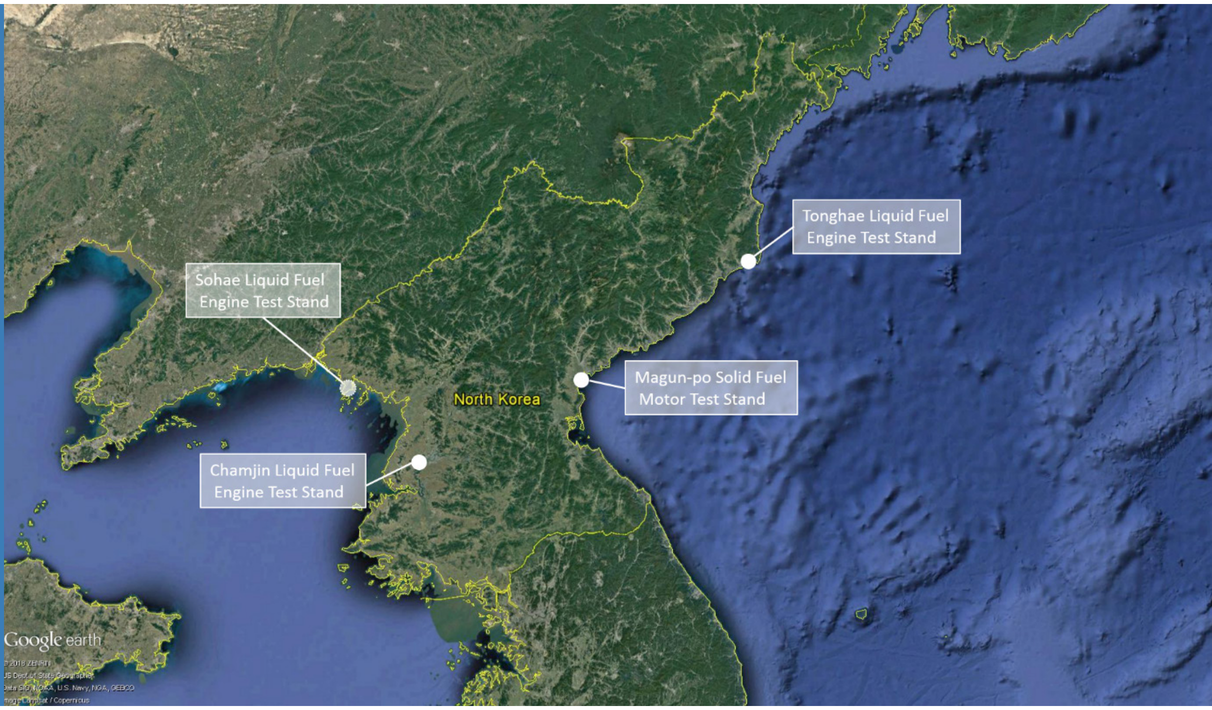
The DPRK has numerous missile operating bases. During a crisis or armed conflict, launch vehicles could disperse from these bases to specially prepared tunnels, bunkers, or other locations where they would remain hidden until ordered to return to their base, to move again, or to launch. Launches would take place at pre-surveyed launch sites anywhere in the surrounding area; essentially any firm, flat surface should be adequate. In recent years, ballistic-missile tests and exercises in North Korea have involved launches from paved roads, from airfields or airports, from a ground-vehicle testing facility, and even from small patches of concrete.

Although they will presumably be addressed in any arms-control or disarmament agreement, North Korea's operating bases are unlikely to be involved in a freeze agreement.

[9] "North Korea Continues Work on Second Barge Used for SLBM Testing," *38 North,* September 28, 2017; "Work Continues on the Submersible Sea-launched Ballistic Missile Test Stand Barge at Nampo," *38 North,* January 16, 2018.
[10] "North Korea Razing Key Missile Test Stand," *38 North,* June 6, 2018.

FIGURE 3

Locations of known liquid- and solid-fuel test stands in North Korea. (Source: Google Earth; CNS analysis)



Precedents for Verification Models

Depending on the scope and ambition of an agreement, verifying a freeze on North Korean missiles may be a considerable challenge, but policy makers fortunately do not start from a blank page. The last several decades offer a number of precedents that can inform the development of alternative verification models.

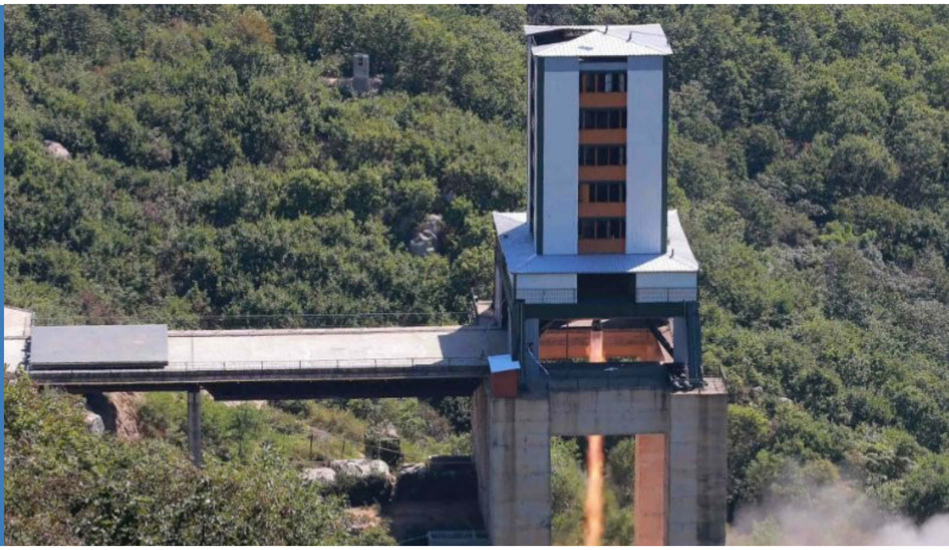


FIGURE 4

Picture released by Korean Central News Agency on September 20, 2016, shows the vertical engine test at Sohae in operation.
(Source: France24, July 24, 2018)

This section introduces and discusses missile-specific arms control and disarmament agreements from recent decades that offer precedents and potential points of departure for the design of a freeze on the North Korean missile program and the associated verification procedures. These range from highly intrusive verification arrangements imposed on a defeated enemy to completely voluntary transparency measures.

The two UN commissions for overseeing disarmament in Iraq—UNSCOM and UNMOVIC—are presented first due to the unprecedented verification mechanisms used and the insights that can be gleaned from the experience of verifying Iraqi missile compliance.

Next, we examine the Intermediate-range Nuclear Forces (INF) Treaty, due to its innovative use of NTM—most notably satellite imagery analysis—as well as due to the complexity of its on-site inspection and verification regime. Many of the verification mechanisms in the INF Treaty are potentially applicable to the North Korean situation; in fact, some INF principles, such as permanent portal monitoring and missile exhibitions, have already been discussed in previous US-DPRK negotiation rounds.

Following the INF discussion, the potential relevance of the bilateral missile guidelines between the United States and the Republic of Korea (RoK) is discussed, as it could serve as a point of reference in negotiations with North Korea.

Finally, this section discusses the Missile Technology Control Regime (MTCR), another potential point of reference.

Other cases, such as the missile-related aspects of the Cooperative Threat Reduction program in the Soviet successor states or the retrieval of missiles from Libya, are not considered here.[11] These undertakings fall into the category of "weapons of mass destruction (WMD) elimination" or disarmament, offering few lessons applicable to a freeze. While the INF Treaty also may be considered a disarmament agreement, it was narrow in scope, addressing some missile systems while excluding others. This approach may offer lessons for a "selective" freeze.

[11] For more information on these cases, see: Paul F. Walker, "Cooperative Threat Reduction in the former Soviet states: legislative history, implementation, and lessons learned," *Nonproliferation Review,* Vol. 23, Nos. 1–2, pp. 115–29; Patrick Terrell, Katharine Hagen, and Ted A. Ryba, Jr., "Eliminating Libya's WMD programs: creating a cooperative situation," *Nonproliferation Review,* Vol. 23, Nos. 1–2, pp. 185–96.

FIGURE 5

Image taken on August 26, 2017, showing the vertical engine test stand prior to partial dismantlement; note the prominent shadow of the test stand's superstructure. (Source: Planet; CNS analysis)

FIGURE 6

Image taken on October 15, 2018, showing the vertical engine test stand partially dismantled. (Source: Planet; CNS analysis)

Monitoring and Verification of Iraq's Missile Program: UNSCOM and UNMOVIC

Verification of the North Korean missile program (and its WMD program as a whole) would require in-depth knowledge of the facilities, materials, manufacturing capability, personnel, and expertise involved. Such a comprehensive verification system for an entire missile program is almost uncharted territory; the main exception is the international inspections regime in Iraq: the UN Special Commission on Iraq (UNSCOM) and its successor, the UN Monitoring, Verification, and Inspection Commission (UNMOVIC).

In April 1991, the United Nations Security Council adopted Resolution 687 (UNSCR 687), ending the first Iraq War. However, there were still many questions about whether Iraq still possessed weapons of mass destruction and delivery systems. Therefore, a new inspectorate, the United Nations Special Commission (UNSCOM), was established with the mandate to remove or destroy all of Iraq's WMD and their means of delivery, such as missiles with a range exceeding 150 kilometers. The IAEA was tasked to do the same for Iraq's nuclear-weapons programIt was not an arms-control agreement, as Iraq did not enter into this arrangement voluntarily; rather, it was a case of "forced disarmament."[12]

Based on its intrusive mandate, UNSCOM had access to valuable information, sensing technologies, and aerial vehicles that allowed it to gain incredible insight into the Iraqi missile program; it also received information from foreign intelligence agencies, export manifests from companies that export WMD-related technologies and equipment to Iraq, and access to Iraq scientists to complement its work. While UNSCOM had discovered and verified the destruction of most of Iraq's materials and components relevant to chemical- or biological-weapons programs and missiles, Iraq provided no full, detailed account of all related activities or unfettered access, as required by the Security Council. Questions remained as to the extent of Iraq's biological weapons and missile programs, and UNSCOM struggled against Iraqi noncompliance and noncooperation.

UNSCOM withdrew its personnel from Iraq in late 1998 prior to a wave of punitive US airstrikes. It was disbanded entirely in December 1999, in part because of the deep mistrust between Iraq and UNSCOM. Iraq had accused it of serving as a cover for Western interests and intelligence. The UN Monitoring, Verification, and Inspection

[12] Charles Duelfer, "Arms Reduction: The Role of International Organizations, the UNSCOM Experience," *Journal of Conflict & Security Law,* Vol. 5, No. 1 (June 2000), p. 105.

Commission (UNMOVIC) was given a similar mandate to UNSCOM to disarm Iraq's chemical and biological weapons and missiles with a range of more than 150 km, and to operate a system of ongoing monitoring and verification to check Iraq's compliance with its obligations not to reacquire the same weapons prohibited to it by the Security Council. Meanwhile, the IAEA was tasked to do the same for nuclear weapons. In contrast to UNSCOM, all UNMOVIC staff were United Nations employees in order to dispel concerns about foreign intelligence influence and interference.[13]

UNMOVIC could not enter Iraq until three years after it had been launched, but inspectors used that time to re-establish the basline. It reviewed which sites to visit, what its predecessor UNSCOM had achieved, and it trained its inspectors—including cultural-sensitivity training. As portable technologies improved, UNMOVIC used smaller radiation detectors and other sensors directly in the field. In 2002, before the second Iraq War, the Security Council declared that Iraq was in "material breach" of its obligations and must immediately cooperate with UNMOVIC. Through UNSCR 1441, Iraq was required to provide UNMOVIC access to any site and not impede any of its activities. Three weeks later, and on the threat of "serious consequences" for noncompliance, a UNMOVIC team deployed to Iraq.

Despite Iraq's obstruction of UNSCOM in particular, UNSCOM and UNMOVIC had remarkable success on the whole, satisfying their mandate for Iraq to "unconditionally accept the destruction, removal or rendering harmless, under international supervision, of all ballistic missiles with a range greater than 150 kilometers."[14] Table 2 shows the commission's work supervising, accounting for, and overseeing the destruction of missiles, missile launchers, warheads, engines, propellant (both fuel and oxidizer), facilities, and equipment related to the Iraqi missile program. They also established a program to monitor sales to Iraq of sensitive equipment and to interview scientists and conduct inspections of relevant facilities. Overall, UNMOVIC carried out 731 inspections at ov er 411 sites; almost one third of the inspections were related to the Iraqi missile program.[15]

There are at least superficial similarities between the missile programs of Iraq and North Korea. Both programs began with technology derived from Soviet Scud SRBMs, and then expanded their range, payload capability, and, with varying degrees of success, their

[13] Trevor Findlay, "The lessons of UNSCOM and UNMOVIC," *Verification Yearbook 2003* (VERTIC: 2004).
[14] Charles Duelfer, "Arms Reduction: The Role of International Organizations, the UNSCOM Experience," *Journal of Conflict & Security Law,* Vol. 5, No. 1 (June 2000), p. 105.
[15] Findlay, "The lessons of UNSCOM and UNMOVIC."

Table 2

UNSCOM/UNMOVIC supervised, accounted for, and oversaw the destruction or dismantlement of:

Missiles	817 out of 819 imported missiles and 72 Samoud-2 missiles
Missile launchers	18
Fixed launch sites	56
Missile fuel	20 tons
Missile oxidizer	52 tons
Supergun related	Assorted equipment
Engines	236 Volga engines (Samoud-2)

accuracy. Both also cooperated with other nations to develop more sophisticated missiles. Both countries attempted to hide their missile programs from the international community by importing sensitive technology, circumventing export controls. Like North Korea, Iraq desired a solid-propellant program; it invested a great deal of effort, albeit unsuccessfully, to develop a long-range solid-propellant missile in cooperation with Argentina and Egypt.

However, there are also many key differences in monitoring Iraq compared to North Korea. First, the North Korean program has grown far larger and more successful than Iraq's. North Korea has successfully developed medium-, intermediate-, and intercontinental-range ballistic missiles, which require a more sophisticated program, more developed facilities, and intensive support and infrastructure. North Korea has successfully established both LPE and SRM research, development, and production infrastructures. Second, unlike UNSCOM or UNMOVIC, any future inspectors in North Korea are not likely to be a forced disarmament or with a mandate for unfettered access to the facilities, personnel, or documentation of North Korea's missile program. North Korea has long resisted or avoided entering into agreements that allow inspectors to move around freely, preferring to allow inspectors/observers at specific sites of their own choosing at particular times and under particular conditions.[16] For the foreseeable future, any verification regime in North Korea can be expected to operate under strict conditions and a limited mandate.

Under UNSCR 687, Iraq was prohibited from producing or having missiles with a range exceeding 150 km, while North Korea is

[16] UNSCR 687 (1991), section C, paragraph 8, subparagraph b.

unlikely to voluntarily give up its short- and medium-range systems, which appear to be considered especially important to its national defense requirements. This will constitute a significant challenge for negotiators. In addition, there will be difficulties in distinguishing between missiles that can carry weapons of mass destruction payloads and those that cannot. Except for North Korea's CRBMs, the KN-02 and KN-SS-X-09, all of North Korea's missiles appear to be large enough to carry what is believed to be its smallest nuclear warhead, i.e., the spherical device it displayed in its news media in March 2016.[17]

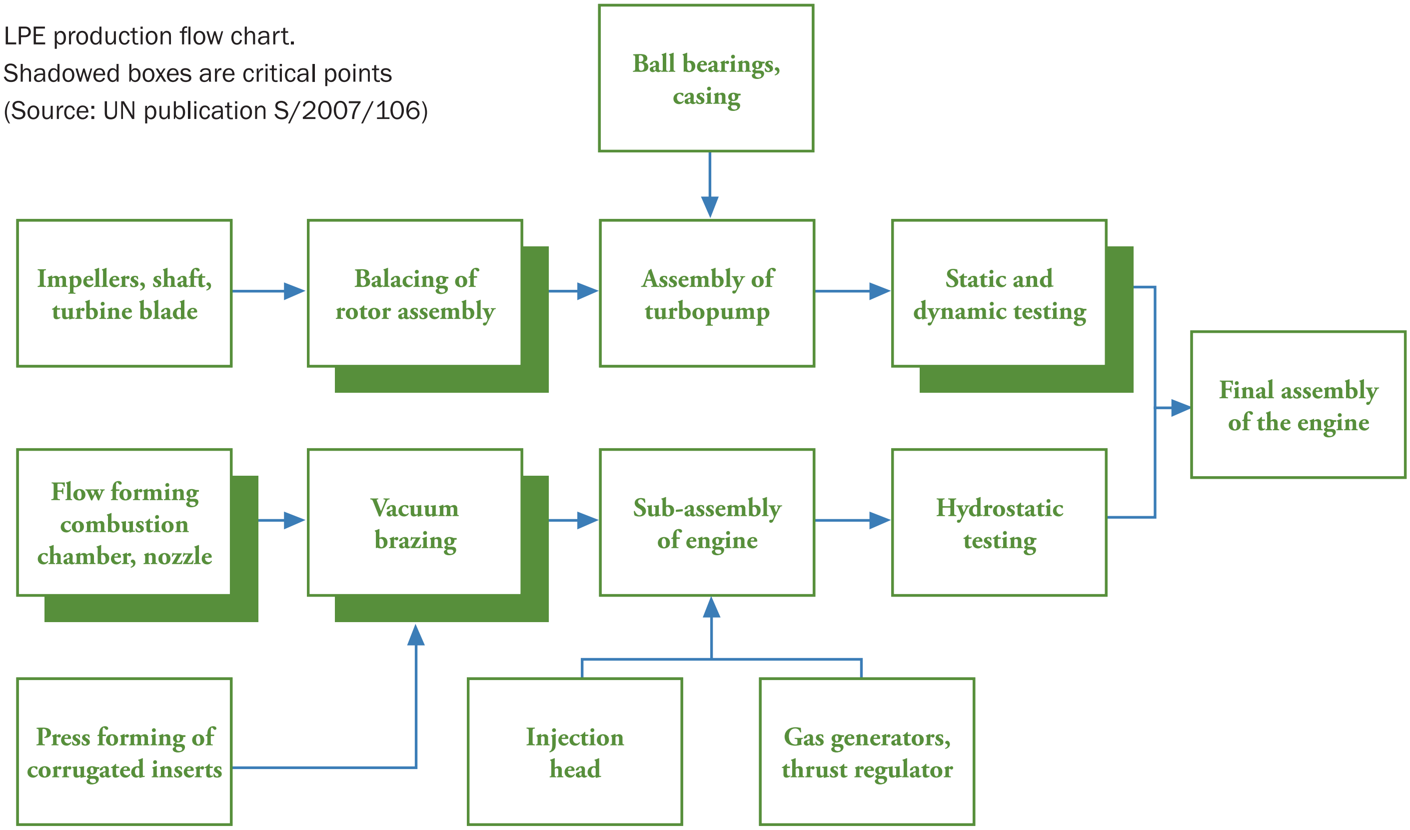
UNMOVIC left Iraq prior to the 2003 Iraq War and never returned. It was officially disbanded in 2007, when UNSCR 687 was reversed since a "democratically elected and constitutionally based Government of Iraq is now in place" in Iraq.[18] However, one of the final reports of the Commission described an improved missile-verification system, which might offer a useful model for North Korea. It specifically focused on the dual-use issue: the problem of distinguishing peaceful space-launch activities from prohibited activities.

Of the first requirements suggested for a future verification regime is the "knowledge and understanding of activities and related equipment."[19] This consists of knowledge of past, present, and future plans and requires inspections of facilities and access to detailed information and personnel associated with the program. The data provided by the inspected state must be in the form of formal declarations and will need to be both "site-based" and "project-based."[20] The role of baseline inspections will be to verify that the data obtained in the field is consistent with declarations made. In that sense, the declarations form a baseline from which inspections and confidence-building measures can start. Another requirement of the verification regime is tracking and identifying imports and exports of sensitive equipment, such as missile parts and their subcomponents. UNSCOM and UNMOVIC had produced a list of missile items deemed too sensitive for importing into or exporting from Iraq.[21] This list included items from the MTCR annex (a list of items, materials, equipment, goods, and technology related to ballistic-missile programs) that should be used to monitor the import and export of sensitive items. A more detailed discussion of the MTCR and its controlled items is discussed below.

[17] Trevor Findlay, "Looking back: The UN monitoring, verification and inspection commission," *Arms Control Today,* Vol. 35, No. 7 (2005), p. 45.
[18] UNSCR 687 (1991), section C, paragraph 8, subparagraph b.
[19] United Nations, S/2003/580 (March 30, 2003).
[20] Ibid. Sites have specific applications whereas projects describe a network of sites and their purpose.

FIGURE 7

LPE production flow chart.
Shadowed boxes are critical points
(Source: UN publication S/2007/106)



Another important lesson learned from the UNMOVIC experience is that the introduction of "critical points" may be "less intrusive and more efficient."[22] The idea is similar to material balance areas in nuclear safeguards, which are used to determine the quantity of nuclear material transferred into and out of the area and the physical inventory of nuclear material. In this case, the purpose of critical points are key points in missile programs that can't be avoided or bypassed and involve technologies, processes, or equipment that are necessary for a successful outcome. Monitoring only critical points can provide the required data for verification purposes "just as effectively as a comprehensive monitoring approach."[23] Key critical points in a program may be also points where various steps in the process converge or when significant equipment is used at key locations. Critical points differ according to the objectives of the project. For example, for successfully executing the production of a liquid propulsion system, key critical points could include balancing of the turbopump rotor assembly, vacuum brazing of crucial engine components, and other steps (see Figure 7).

[21] United Nations, S/2001/560 (October 15, 2001).
[22] United Nations, S/2007/106 (February 27, 2007).
[23] Ibid.

The Intermediate-range Nuclear Forces Treaty

The INF Treaty was signed on December 8, 1987, between US President Ronald Reagan and Soviet General Secretary Mikhail Gorbachev and permanently banned all US and Soviet ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 kilometers. This agreement was a milestone in arms control because it eliminated an entire class of delivery systems rather than simply reducing their numbers, and because it was the first treaty of its kind to allow for on-site inspections (OSI) and a rigorous set of verification mechanisms including permanent portal monitoring and the innovative use of NTM. The treaty banned only the missiles and did not place limits on warheads or guidance systems, which were returned to stockpiles or reused with permitted missile systems. Within the INF, conventionally armed ground-launched missiles within the specified range were also banned, as the verification task of distinguishing between a conventionally armed INF system and a nuclear-armed was considered too difficult. In total, 2,962 US and Soviet INF missiles, their launchers, and support equipment were destroyed within three years of the treaty's entry into force.[24]

The INF verification mechanism combined OSIs and cooperative verification measures with the use of NTM, most notably satellite technology. For example, each party could request a certain number of missile exhibitions or parades per year, one missile facility at a time. Upon request, each party would have to open the roofs of any fixed structures at facilities, remove all missiles and their launchers from concealment, and display them out in the open for an agreed-on number of hours. This permitted satellite verification of the numbers and, to some extent, the type of missiles at each base without making the missile force as a whole vulnerable to pre-emptive attacks. In the North Korean case, if certain longer-range missiles were to be banned, missile parades at missile operating bases would enhance confidence that banned missiles have not been relocated. In addition to these parades, the INF introduced a set of OSIs that were designed to reinforce and enhance the information gained through NTMs and to provide additional evidence of compliance in a setting of mistrust between treaty signatories. The Treaty's requirement of ten years of OSIs after the last elimination of banned missiles—instead of five years, which became the norm in later arms-control treaties—reflects the air of mistrust in which the INF treaty was negotiated.[25]

[24] John Russell, "On-Site Inspections Under the INF Treaty: A Post-Mortem," *VERTIC,* August 2001.
[25] Ibid.

A memorandum of understanding was appended to the treaty, declaring the numbers and locations of all treaty-related items. These declarations were the baseline numbers against which compliance would be judged through OSIs and NTM. A treaty database was derived from these declarations and updated every six months. The technical specifications of these missiles required verification through baseline inspections before regular treaty inspections could start. The United States and the Soviet Union used their Nuclear Risk Reduction Centers for continuous communications on all treaty information, notifications, declarations, and updates. The communication demands imposed by the treaty were unprecedented for the United States and the Soviet Union,[26] and their success indicates that a similar arrangement can be realistically envisioned for North Korea. Inspections under the INF Treaty, listed below, were also unprecedented in their intrusiveness and can set a baseline for future inspections of North Korean missile and space-launch vehicle testing, production, and storage facilities.

- Baseline inspections verified the location and number of all initially declared items and allowed the comparison of declarations against parties' own intelligence estimates;

- Elimination inspections verified the complete and irreversible destruction of banned missile and missile launcher types;

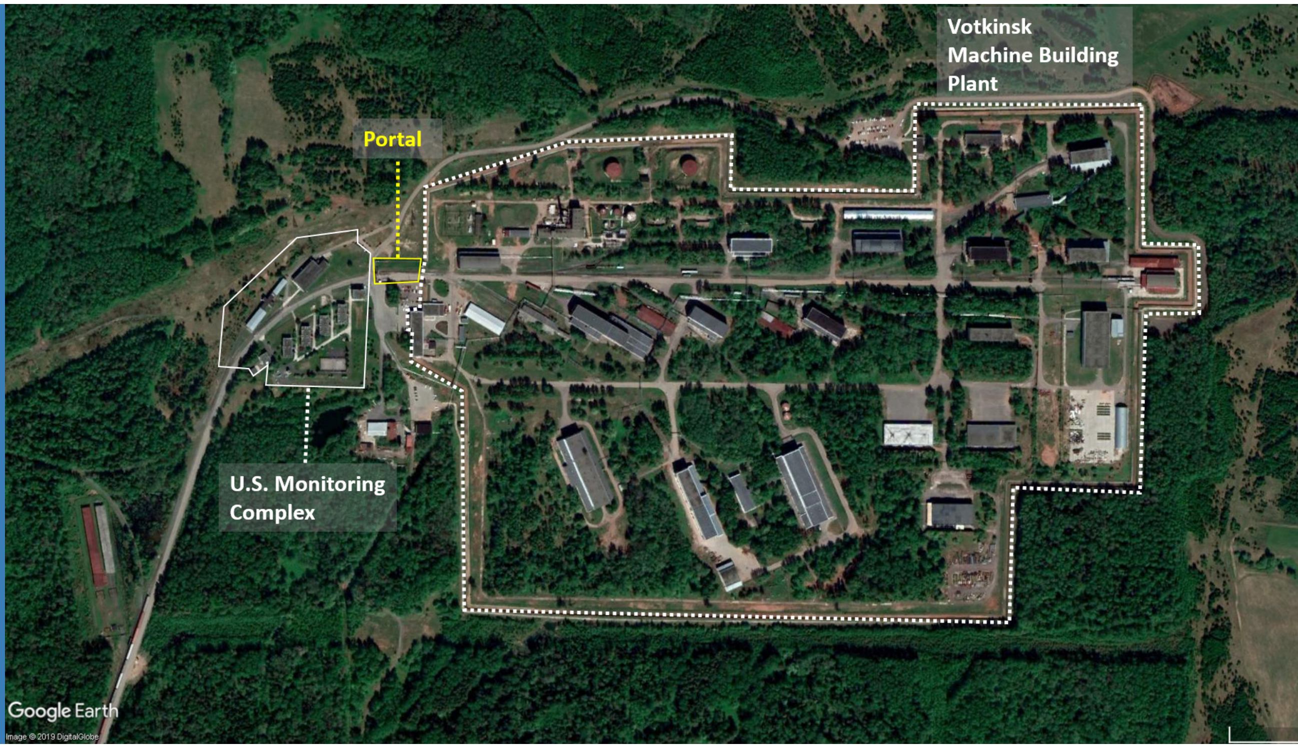
- Closeout inspections confirmed that a facility was free of INF systems;

- Short-notice inspections were meant to ensure compliance with the treaty and as a deterrent against cheating. These inspections continued for thirteen years. For the first three years, each party was allowed twenty inspections per year; for the next five years and the final five years of the period involving inspection activities under the treaty, the parties were allowed fifteen and ten inspections per year, respectively. Only upon arrival at a point-of-entry to the inspected (host) country did the inspectors have to declare which site was to be inspected. The inspected party then had nine hours to transport the inspection team to the site, where the inspection could last up to twenty-four hours. Within one hour of the announcement of the inspection, the inspected party had to cease the movement of any treaty-limited items.

[26] Amy Woolf, Paul Kerr, and Mary Beth Nikitin, *Arms Control and Nonproliferation: A Catalog of Treaties and Agreements,* Congressional Research Service, RL33865 (2018), pp. 7–9.

FIGURE 8

Overhead view of the Votkinsk Machine Building Plant with the adjacent US Permanent Portal Production. Monitoring Facility (Source: Google Earth, CNS analysis)



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- Permanent Production Monitoring of one INF solid-fuel rocket motor production facility on each party's territory, meant to confirm that production of INF missiles had ceased. The United States stationed up to thirty inspectors by the Votkinsk facility in the Ural Mountains (see Figure 7), while the Soviets were permitted to station themselves at a plant in Magna, Utah, though they ultimately chose not to continue implementation of this treaty provision past 2001 for financial reasons. While inspectors could not enter the plants, they could monitor the

FIGURE 9

Diorama depicting the Permanent Portal Production Monitoring Facility, Sandia National Laboratories, Albuquerque, NM. (Source: Martin Pfeiffer)

> perimeter and portals continuously, 24/7, for thirteen years. Both parties could stop, weigh, and measure all vehicles or containers leaving the facility that were large and heavy enough to contain an INF system. The United States could operate approved sensors to verify that the container did not hold a system banned under the treaty.[27] The agreed practices at the portal reflected a carefully negotiated balance of considerations. According to a former US inspector at Votkinsk, the United States employed a CargoScan X-ray machine at the portal. The scanner would be allowed to image a single horizontal "slice" of the container, chosen by the Americans. The inspectors made a practice of selecting the point where they expected a permissible type of SRM inside a container to "turn down," that is, where the sides of the object start curving toward its end; this served as a consistent reference point for measuring the diameter of the SRM in order to confirm its type. The Soviets, in turn, sought to protect sensitive design information by placing a support for the SRM at this point inside the container, obscuring certain details in the scan.[28]

Since baseline declarations were the cornerstone of the INF, and, considering the validity of any declarations is bound to be an issue with the DPRK, it is useful to discuss how confident the United States and the Soviet Union were that the other side was not hiding a number of banned INF missiles. In fact, an air of mistrust clouded the INF negotiations in much the same way it has stalled progress in talks with North Korea. It was necessary for each INF state party to continue using the full extent of its NTM, in combination with the other verification measures, to ensure the compliance of the other side beyond a reasonable doubt.

[27] Ibid.
[28] Interview by member of the study team.

In the DPRK case, similar pressure may be needed to ensure compliance. The systemic analysis of indicators of violations can be holistically examined to deduce noncompliance, as it also did in the Iraq case. A table of these indicators is presented in Section IV, Part E. Complemented with other measures, the DPRK and its negotiating partners may maintain enough confidence necessary to keep an agreement alive. Yet both sides must accept that mistrust will likely persist for some time.

The INF Treaty was designed to be selective, not simply shuttering all missile-production facilities and operating bases, but rather constraining them in agreed ways. If the terms of the INF Treaty were adapted to the contemporary North Korean missile program, it might allow North Korea to possess missiles with ranges below a certain range. However, the scope of the INF Treaty limitations is less important than the verification precedents that the treaty set. The portal monitoring system, OSI regime, and the use of NTM facilitated by selective displays of missiles may be adaptable to the verification of a freeze on selected aspects of North Korea's missile program.

The US-RoK Bilateral Missile Guidelines

The United States and South Korea have, over several decades, negotiated and periodically updated an agreement on "missile guidelines," limiting the capabilities of RoK missile forces as a condition of bilateral defense-technology cooperation. Until a recent agreement that removed the limit on payloads, the guidelines allowed Seoul to develop and deploy ballistic missiles with a range of up to 800 km and a payload of up to 500 kg. The first set of guidelines were agreed in 1972 but were not officially endorsed as agreements by both states until 1979; these early guidelines limited South Korea's missiles to a 180-km range limit and a 500-kg payload maximum on South Korea's missile arsenal.[29] Significantly for this discussion, in 2001, Washington agreed to increase the missile range to 300 km, matching the export guidelines associated with the MTCR, in exchange for allowing US inspections of missile-development facilities to make sure that South Korea was not secretly working on longer-range missile systems that could contribute to a regional arms race.

[29] Koo Sang-Hoi, "Reminiscence from a Living Witness of the Korean Missile Program, Dr. Koo Sang-hoi," *Shindonga,* February 1999; "South Korea," *Federation of American Scientists,* February 3, 2000; Oh Won-chul, Korean Economic Construction Model (Seoul, CEOI, 1996), p. 560.

The agreement included the following limitations:

1. US inspections of RoK missile-production facilities;
2. Full transparency in South Korea's provision of information at each step of its missile development and prior to research,
3. No RoK research on missile systems with a range greater than 300 km; and
4. Disclosure of information on RoK civilian rocket research.[30]

The United States demanded these extensive verification measures from South Korea because it had found evidence of noncompliance with earlier limits. The guidelines were further revisited in October 2012 as the DPRK's nuclear and missile programs advanced. While the payload limit remained at 500 km, Seoul was allowed ballistic missiles with ranges up to 800 kilometers, covering all North Korea, but without threatening China or Japan. Nonetheless, Seoul could still load warheads weighing up to one metric ton (1,000 kg) on ballistic missiles with shorter ranges.[31] In November 2017, Washington agreed to drop all payload limits from the guidelines.[32] This decision implies a newfound degree of trust, since the substitution of a lightweight payload could extend the range of an otherwise permitted missile beyond the agreed limit.

Some complications might arise if the precise terms of the US-RoK bilateral missile agreement were used as a baseline for an agreement on the control of North Korea's missiles, as the North is likely to refuse more restrictive guidelines than South Korea's. This would mean accepting North Korea's short-range ballistic missiles up to 800 km in range while banning longer-range systems. Doing so would leave Beijing and westerly parts of Japan in range from North Korean soil. However, if North Korea were unwilling to accept verification measures as intrusive as those associated with the US-RoK guidelines, then it might be prepared to accept stricter limits on range and payload instead.

Using the US-RoK guidelines as a point of departure for controlling North Korea's space program could also be difficult. For the most part, United States policy on Seoul's space program has been neither

[30] For a comprehensive account of these negotiations and their outcome, see: Daniel Pinkston, "The New South Korean Missile Guidelines and Future Prospects for Regional Stability," *Strong & Prosperous,* October 25, 2012. See also: Jeffrey Lewis, "ROK Missile Rationale Roulette," *Arms Control Wonk,* October 9, 2012.
[31] Choe Sang-Hun, "U.S. Agrees to Let South Korea Extend Range of Ballistic Missiles," *New York Times,* October 7, 2012.
[32] Byun Duk-kun, "Moon, Trump agree to build up deterrence, urge N. Korea to give up nukes," *Yonhap News,* November 7, 2017.

to support nor obstruct it; the United States has denied requests to export space technology to South Korea, but has not intervened with other suppliers.[33] After two failed launch attempts, South Korea successfully placed a satellite in orbit in January 2013.[34]

North Korea's space-launch program has been a sticking point in previous missile-freeze attempts, as the DPRK is unlikely to give up pursuit of a national space program. However, if North Korean space launches remain unacceptable to the international community in view of their overlap with long-range missile technology, alternative arrangements may be possible to sustain a North Korean space program without a national launch program. Models may include hiring launch services, e.g., in Russia or China, or regional or inter-Korean cooperation on space launches involving North Korean payloads on other states' launch vehicles.

The Missile Technology Control Regime

The MTCR is a voluntary, informal arrangement, dating back to 1986, in which participant states, now numbering thirty-five, agree to adhere to common export-policy guidelines to slow the proliferation of ballistic and cruise missiles, rockets, and unmanned aerial vehicles (UAV) capable of delivering WMD. The guidelines call on each partner country to exercise restraint when considering transfers of equipment, technology, or assistance that would provide or help a recipient build a missile capable of delivering a 500-kg warhead to a range of 300 km or more. The warhead weight limit intends to limit transfers of missiles that could carry a relatively simple nuclear warhead. The MTCR guidelines outline two categories of controlled items. Category I items are highly sensitive in their dual-use nature and are subject to "a strong presumption to deny such transfers." Partner countries have greater flexibility in deciding on transfers of Category II items. Category I items include complete rocket systems including ballistic missiles, SLVs, and UAV systems, production facilities for such systems, and major subsystems, including rocket stages, re-entry vehicles, rocket engines, guidance systems, and warhead mechanisms. Category II items are other less sensitive, dual-use missile components that could be used to develop a Category I system, as well as complete missiles and major subsystems of missiles capable of delivering a payload of any size to a range up to 300 km.

[33] Woolf, Kerr, and Nikitin, "Arms Control and Nonproliferation," pp. 43–44.
[34] Jung-yoon Choi and Barbara Demick, "South Korea Launches Satellite into Orbit," *Los Angeles Times,* January 30, 2013.

The regime does not have the independent means to verify whether states are adhering to its guidelines nor a mechanism to penalize states if they violate them. Membership is generally reviewed on a case-by-case basis, based largely on the strength of the country's export-control laws. The United States supports requests for membership only if the applying country agrees not to develop or acquire missiles that exceed MTCR guidelines, excluding space launch vehicles.[35]

While the MTCR has succeeded in slowing or stopping the missile programs of several states, it has not been able to prevent others from acquiring or developing their own ballistic missiles, in some cases with assistance from states outside the MTCR. As a result, a common critique of the regime is that it does not regulate countries' acquisition or production of missiles and cannot realistically prevent non-partners from exporting their own missiles or technologies. Even participant states do not always honor the guidelines.

Verification under the MTCR is a non-issue, since supplier states are expected to adhere to the guidelines voluntarily. However, the MTCR's periodically updated lists of dual-use equipment—the Equipment, Software, and Technology Annex—can inform missile-related verification regimes by serving as a "menu" for controlled technologies.[36]

Security Benefits of a Missile Freeze

The value of a freeze is often associated with the prospect of in-depth negotiations; the verifiable suspension of certain provocative or threating activities can reduce tensions. However, a freeze on missile-related activities can also provide direct benefits to regional and global security.

North Korea is currently observing an informal missile flight-test freeze, readily verifiable by NTM, which include radars in South Korea and Japan and satellites with infrared sensors in geosynchronous earth orbit. But the absence of a more far-reaching agreement leaves open the possibility for North Korea to continue developing, producing, and deploying a more advanced ballistic-missile arsenal. In 2017, North Korea tested a full suite of new SRBMs, MRBMs, IRBMs, and ICBMs; however, continued testing would be required to improve their reliability and overall performance. In addition to increasing the reliability of their new missile systems, North Korea has shown interest in newer manufacturing methods and

[35] Woolf, Kerr, and Nikitin, *Arms Control and Nonproliferation,* pp. 43–44.
[36] For more information, see the MTCR Annex at http://mtcr.info/mtcr-annex/.

technologies that would greatly increase the sophistication of their missile arsenal. For example, North Korea has sought to develop and test larger-diameter SRM cases, which allow it to replace liquid-propelled missiles with solid-propelled missiles that require less support in the field and can be prepared for launch more rapidly. Advances in materials and manufacturing techniques will allow the development of increasingly long-range solid-propelled missiles. North Korea is also building a new generation of mobile launch vehicles, and has initiated a submarine-launch program.

The main security concerns with North Korea's development of a more advanced and reliable ballistic-missile arsenal include the missile force's ability to achieve four objectives:

1. Carry larger payloads to greater distances;
2. Achieve greater survivability;
3. Overcome ballistic-missile defenses (BMD); and
4. Perform more reliably.

All four North Korean objectives represent threats to other countries; a freeze should therefore be designed to stop progress toward some or all of these goals.

A related objective for North Korea's missile program is to earn export income, which undercuts the international community's broadly shared nonproliferation goals. Since the attractiveness of missile systems to foreign buyers depends largely on the four primary objectives above, this objective need not be considered separately at length.

A particular reason to be concerned about the development (or improvement) of missiles that can carry larger payloads to greater distances is the role of ICBMs targeting the United States. A DPRK arsenal capable of reaching US targets with nuclear weapons might discourage the United States from intervening in a conflict with North Korea in defense of its allies. Similarly, North Korea's ability to launch nuclear weapons against bases in Guam, Japan, and South Korea could threaten the ability of the United States to project military power into the Korean theater of operations.

To make its missile forces more "survivable," i.e., less vulnerable to pre-emptive attack, North Korea can take two main measures. The first is upgrading to solid-propellant missiles to allow land-based forces to launch more rapidly, leaving fewer opportunities to detect them in the field. The second is developing a more diverse and stealthy set of platforms for launchers, particularly by developing ballistic-missile submarines.

Table 3

The range of activities and types of facilities that would be required of North Korea to improve its missile program. *Source: CNS analysis*

IMPROVEMENTS	ACTIVITIES REQUIRED	FACILITIES REQUIRED	PROGRAM STATUS AS OF EARLY 2019
Range/payload	• Develop more powerful LPEs	• LPE R&D facilities • LPE test facilities • LPE production facilities	• LPEs for missiles of all ranges have already been developed; improvements are likely to be incremental only
Survivability	• Develop more powerful SRMs	• SRM R&D facilities • SRM test facilities • SRM production facilities	• CRBMs and MRBMs with SRMs already flight-tested • SRBMs, IRBMs, ICBMs with SRMs not flight-tested • SRM production facilities recently expanded, modernized
	• Develop more diverse, stealthy platforms	• Submarine R&D facilities • Shipyards	• Submarine program at early stage
BMD penetration	• Develop maneuvering RVs	• R&D facilities • Production facilities	• One known flight test on SRBM in 2017
	• Expand missile force	• Missile production facilities • Mobile launcher production facilities	• SRM production facilities recently expanded, modernized • New mobile launchers under production for SRBMs and MRBMs • Limited numbers of imported/modified longer-range mobile launchers • Submarine program at early stage
Reliability	• Conduct ground tests • Conduct flight tests of missiles	• Missile test facilities	• Testing of new LPEs for IRBMs, ICBMs has been limited • Fully realistic testing of ICBM RVs has not taken place • Testing of new SRMs for SLBMs, MRBMs has been limited

The ability to overcome missile defense systems may depend on qualitative advances, such as maneuvering re-entry vehicles (MaRVs). It may also involve larger numbers of launchers and missiles, allowing "saturation" of defenses through large salvoes, i.e., multiple simultaneous launches. North Korea has demonstrated salvo launches on several occasions in recent years, mostly with short-range ballistic missiles, and flight-tested a Scud SRBM with a MaRV in 2017.

The reliability of a missile depends to a large extent on opportunities for testing, both in engine tests on the ground and in flight tests. In particular, the introduction of new missile types without flight-testing makes for a highly questionable capability. North Korea's deployment of Musudan IRBMs without flight-testing around 2006–07 appears to have been a historical first. While the presence of the Musudan force could not be disregarded, its poor record in flight-testing in 2016 illustrates the liabilities of this unorthodox approach. This experience makes it less likely that North Korea will ever again deploy any entirely un-flown missile type.[37]

The security benefits of any provision in a missile freeze agreement depends on the current status of the relevant aspects of the missile program. In some cases, the value of a particular provision may have declined on account of milestones already achieved within the North Korean missile program. In other cases, the relevant aspects of the program are still in progress or not yet begun. Table 3 describes the status of the program across the four areas of improvement identified earlier.

The greatest security benefits from a freeze are naturally found in those areas where the program appears to be relatively immature. These include, notably:

- The absence of tested SRMs in the SRBM, IRBM, and ICBM categories (primarily affects survivability);

Currently, the largest missiles for which North Korea has been able to develop SRM cases are the Pukguksong-1 SLBM and Pukguksong-2 MRBM. North Korea also possesses solid-propellant CRBMs—the KN-02 and KN-SS-X-09—although these missiles do not appear capable of carrying nuclear payloads (because of their small diameters). Preventing North Korea from developing larger-diameter SRM cases would ensure that any North Korean IRBMs and ICBMs remain liquid-fueled, limiting their survivability.

Furthermore, although North Korea has exhibited what appeared to be solid-propellant SRBMs in a parade, it is not known to have flight-tested any yet.

- The relatively recent expansion of production facilities for SRMs (affects survivability and BMD penetration);

The renovation of North Korea's solid-propellant production facilities near Hamhung and the establishment of new production facilities at a nearby R&D center that has developed new SRM case technology are recent developments. The Pukguksong-1 and Pukguksong-2 may not yet have entered full-scale production; if they have, the planned numbers may not yet have been achieved.

[37] One recent study notes that there is no fixed number of tests needed to ensure a system's reliability since it is up to the end-user to determine performance and reliability requirements. However, an examination of previous such development efforts indicated that new missile types were flight-tested an average of sixteen times before achieving "consistent improvement in reliability." See: Michael Elleman, "Why a Formal End to North Korean Missile Testing Makes Sense," *38 North,* February 26, 2019.

- The relatively recent development of locally produced mobile launchers for SRBMs and MRBMs (affects BMD penetration);

An armored-vehicle-production facility at Kusong appears to have developed a new family of mobile missile launchers suitable for SRBMs and MRBMs, including the Pukguksong-2, working in conjunction with a production line for large diesel engines established at the January 18 Machine Plant. These new mobile launchers may not yet have entered full-scale production; if they have, the planned numbers may not yet have been achieved.

- The early stage of the ballistic-missile submarine program (affects survivability and BMD penetration);

A single ballistic-missile submarine (SSB) with a single vertical launch tube is present at the Sinpo South Naval Shipyard, where it has been used for SLBM testing. It appears to lack significant operational capabilities, but one or more larger, more capable SSBs may be under production inside the nearby construction halls.

- Limited flight-testing for SRBMs with a maneuvering RV (affects BMD penetration);

A single Scud SRBM with a MaRV was flight-tested once in 2017; no other tests of this type of RV have been reported. A joint DPRK-Syrian program to develop this type of RV appears to have been cancelled over a decade ago.

- Limited flight-testing for newer types of SLBMs, MRBMs, IRBMs, and ICBMs (affects reliability).

Pukguksong-1 SLBMs, Pukguksong-2 MRBMs, Hwasong-12 IRBMs, Hwasong-14 ICBMs, and Hwasong-15 ICBMs all made their initial appearance in recent years, and have only limited flight-test records. In April 2018, North Korea pledged to "suspend" further ICBM flight tests, but has offered no similar assurances about other types of missiles, at least in public.

An additional complicating factor is North Korea's space-launch program. While North Korea has not conducted a space launch since February 2016, it has made no public pledges to discontinue the program. The dual-use character of this technology means the space program could provide opportunities to test LPEs or SRMs suitable for ICBMs, but under civilian cover.

Missile Freeze Options and Verification Requirements

North Korea's Air Force is no match for that of the United States or South Korea. As a result, Pyongyang can be expected to rely on missiles to deliver any nuclear weapons against US or allied targets. Limiting the growth of this missile arsenal, therefore, is as or perhaps more important than limiting any future improvement in the quality of Pyongyang's nuclear arsenal per se.

Nonetheless, any effort to freeze or limit North Korea's military arsenal will not be taken in isolation. Negotiators will have to weigh the trade-offs of any security benefits obtained from freezing its delivery systems (missiles) vs. potential broader freezes or cuts to its nuclear weapons and nuclear complex as well as the costs of any political, economic, or military concessions offered in return. North Korea is likely to demand greater concessions for the more intrusive measures required for deeper freezes.

In general, the most attractive forms of verification involve existing capabilities only, in the form of NTM, and create no added burden of intrusiveness. If a particular goal for verification cannot be achieved this easily, then it may be possible to negotiate transparency measures to supplement the use of NTM. If still more information or confidence is required, then it may be necessary to establish on-site inspections or monitoring. These measures are relatively time-consuming to negotiate, and therefore may be less suitable for early-stage agreements.

In addition, the security benefits of a freeze are not necessarily equal for the United States and its regional allies. For example, a testing freeze on ICBMs would relieve only the United States from a direct threat to its homeland. Japan and South Korea would still fall within the range of North Korean missiles; their own security gains would be limited to the greater freedom of action the United States would have under these circumstances. Given the complexity of such trade-offs, this paper does not offer a single proposal for a verifiable missile freeze, but instead a menu of options for policy-makers to consider. As part of the ongoing dialogues between North Korea and other countries, particularly South Korea, the United States, and China, opportunities may arise to freeze and ultimately to roll back its missile program, as well as other programs of concern. Options for a negotiated freeze are described in this section.

Three main options are discussed below: a freeze on missile testing; a freeze on deployment of new missiles; and a freeze on the production of certain missiles, launchers, and platforms. These options may be considered individually, jointly, or sequentially as negotiations progress. In addition, a further set of options is presented with broader goals in mind. These additional options may play a supporting role in building confidence in a freeze.

Freeze on Missile Testing

A freeze on ballistic-missile flight-testing can be verified with high confidence through NTM. The rocket plume from a launch will be detected by infrared sensors in orbit as soon as a rocket booster passes through cloud cover (if any). Surface-based radars will also detect the flight. Electronic listening posts also may detect the broadcast of telemetry from a missile being flight-tested. This form of verification is ideal, since it involves capabilities already in place, and does not involve any intrusive measures.

A freeze on the ground testing of LPEs or SRMs can also be verified through NTM, although cloud cover may interfere. As long as there is not excessive cloud cover, infrared sensors will capture tests at North Korea's open-air test stands. In the absence of cloud cover, imagery satellites can also capture activity at these sites, including burn scars on the ground after a test. Radar satellites can capture activity at these sites, and are immune to cloud cover, but since they are relatively scarce, they may not be available for this purpose at all times.

Additional assurance of the absence of ground tests could be gained by requesting the partial or complete dismantlement of all of North Korea's known test stands. Dismantlement can be confirmed with imagery or radar satellites; no presence on the ground is required, although OSIs may be useful to build confidence.

Freeze on New Missile Deployment

A freeze on deployment of new types or additional numbers of missiles would be significantly harder to verify than a freeze on testing; however, the INF Treaty has detailed protocols on verifying the deployment freeze and even dismantlement of missiles, which could be adapted to new settings. North Korean cooperation through transparency measures will be essential to monitoring any freeze on deployment, especially given the road-mobile nature of North Korea's missile launchers.

First, a declaration on the numbers, types, and locations of deployed missiles would be required, along with notice of any change to those numbers. It is notoriously difficult to verify the accuracy of any declaration. This raises the need for baseline inspections. As discussed in the INF section, it will be necessary to use both NTM and extensive OSIs to ensure that the DPRK's declarations are valid.

A second option is a periodic parade of missiles, along the lines of the arrangement that existed under the INF Treaty, which used satellite imagery for some verification instead of OSIs. In the DPRK case, the negotiating partner could request a certain number of "parades" each year from each North Korean base with controlled missile types. With a few hours' notice, North Korea would have to open the roofs of any deployment structures, remove all missiles and launchers from concealment, and display them in the open for a certain number of hours to allow imagery satellites to confirm the numbers and types. This option can also be used in verifying dismantlement projects for any obsolete or outdated missile stocks or for intermediate and intercontinental ballistic missiles.

These types of arrangements will be demanding to negotiate. A deployment freeze could therefore not be put in place quickly, and should probably not be seen as an early step.

Freeze on Missile/Launcher/Platform Production

A total freeze on production at particular facilities for making missiles, launchers, ballistic-missile submarines, or their key components will be easier to verify than a selective freeze. If North Korea agrees to halt all such production, then NTM should be sufficient to confirm the absence of activity at specific facilities, perhaps supplemented by confidence-building site visits.[38] However, this approach will require a declaration of all production facilities. Some sort of challenge-inspection provisions will be desirable in order to rule out suspected sites. The difficulty of reaching such an arrangement with North Korea may dictate that, at least initially, a declaration consistent with intelligence assessments should be considered acceptable.

Even in the best case, not all missile-production facilities are likely to be included. The two parties are likely to reach restrictions only on missiles greater than a certain range, so as not to impinge on North Korea's legitimate defense requirements. The 300-km range limit associated with MTCR guidelines may provide a useful point of

[38] For more, see Leon Sigal, "Verifying a Missile Accord with North Korea," *Verification Yearbook 2002,* VERTIC, 2002.

reference; this figure is also the upper limit of the CRBM category used by the US government. Since North Korean CRBMs appear to be too small to carry nuclear warheads, this may be an attractive option.

Other potential reference points include the 500-km lower limit of the INF Treaty, or the 800-km limit under the present version of the US-RoK missile guidelines. A 500-km limit would exclude the production of additional missiles capable of reaching either Japan or the Beijing area from North Korean soil.

If a single facility produces both permissible and forbidden types of missiles, verification will become a substantially more complex task. The portal monitoring system pioneered under the INF Treaty for the Votkinsk facility provides a point of comparison for understanding the general requirements, although the specific details are likely to differ. North Korea's willingness to accept the standing presence of foreign inspectors at the Yongbyon nuclear facility in the past suggests that they are possibly open to re-entertaining the idea of continuous portal monitoring at one or more of their production facilities. Facilities producing liquid-propellant engines and solid rocket motors would be main candidates for such a portal-monitoring system, as those are critical points that cannot be bypassed in the production of North Korea's larger missiles.

Given the complexity of negotiating and implementing on-site monitoring arrangements, a selective prohibition of this type within any single facility would not be a realistic first step.

Verified Dismantlement of Obsolete Missile Systems

In addition to a deployment freeze, North Korea's negotiating partner can seek the verified dismantlement and elimination of some missile stocks, especially with obsolete or outdated missiles. This would be a valuable confidence-building exercise. Additionally, satellite verification of missile parades can also assist in confirming the destruction of these stocks. The INF Treaty's protocols on elimination procedures provide guidance on this issue. OSIs to verify dismantlement may also be necessary and can be discussed along the lines of the INF Treaty, Articles IX and X.

Freeze on Exports and Assistance

Verifying the transfer of missiles will be difficult, and their expertise even more so, as these transfers are usually inferred after the fact, such as in the case of the Pakistani Ghauri MRBM, which closely resembles the North Korean Nodong MRBM.[39] Nonetheless, it is important to have clear prohibitions outlined in any missile-control agreement. The monitoring of exports of missiles and their components will largely depend on intelligence agencies, as it does now. A further ban on the production of missiles would give the international community greater confidence about an export freeze. Still, in order to attempt to verify that North Korea is not exporting missile technology and expertise, it would be necessary to maintain the intensive monitoring of North Korean vessels, cargo aircraft, and other export activities.

Cooperative Opportunities in Space Launches

Although North Korea's news media has been silent on the subject of space launches since late 2017, it seems unlikely that North Korea will be eager to accept limitations on its space program over the long term. It is safe to assume that North Korea will want to maintain at least the "perception of parity" in space capabilities with South Korea.[40] Were it to insist on developing and operating its own satellites, the DPRK would rely on foreign launch services, which would send DPRK satellites into orbit without having to fly over Japan.[41]

Additionally, foreign satellite companies could assist North Korea in developing remote-sensing satellites for environmental management and disaster monitoring and relief. Satellite imagery can be very useful in helping North Korea address its nutrition problems by improving the management of land and crops, especially in times of natural disasters. Projects in Nigeria, Vietnam, Egypt, Kazakhstan, and many others show the utility of satellite cooperation in urban mapping, land management, irrigation and water use, crop production, and road and railway development, to name a few.[42]

North Korea can similarly gain access to these services without maintaining a launch capability and even without building and owning its own satellites. Instead, North Korea can build partnerships to acquire such data from other countries and then develop its own domestic expertise in using that data. In fact, North Korea has already received access to low-resolution Landsat imagery and has a Landsat

[39] Sharon Squassoni, "Weapons of Mass Destruction: Trade Between North Korea and Pakistan," Congressional Research Service, RL31900, November 28, 2006.
[40] David Wright, "North Korea's Missile Program," *Union of Concerned Scientists,* 2009, p. 17.
[41] Many countries have developed their own satellites that have been launched from other countries, including Algeria, Egypt, Kazakhstan, Nigeria, Pakistan, South Korea, Vietnam, and many others. For more, see Union of Concerned Scientists Satellite Database, www.ucsusa.org/satellites.
[42] Wright, "North Korea's Missile Program."

interpretation center funded and equipped by the UN Development Program and China.[43] This creates a plethora of opportunities for further expansion in sharing satellite data and services.

One approach would be to set up a consortium that works with North Korea to develop its technical satellite expertise and to design, build, and launch a satellite, as well as set up the ground stations needed for operation. Even if using North Korean launch capabilities, at least it would be better monitored as part of an international project and ideally launched from a location that does not antagonize Japan, such as Russia or China.

Another option would be a group of countries to buy or heavily subsidize a small geosynchronous satellite for North Korea for communications or remote sensing. These satellites can be built using commercially available components to keep costs minimal. Lastly, North Korea can be integrated into regional space organizations to support its satellites and space-exploration programs. Some of these organizations are the Asia-Pacific Space Cooperation Organization, the Satellite Technology for the Asia-Pacific Region Program, and the Association of Southeast Asian Nations Subcommittee on Space Technology and Applications.

[43] Ibid.

Conclusions

Designing a freeze on the North Korean missile program will require policy makers to evaluate trade-offs and make value judgments; actually implementing a freeze will require reaching and carrying out an agreement with the North Korean authorities. For these reasons, we offer no single recommendation, but instead seek to clarify some of the trade-offs involved.

As a rule, the more intrusive verification measures are, the less acceptable they will be to the North Koreans, and the more expensive for the parties responsible for their implementation. At the same time, the more intrusive these measures are, the greater security benefits they provide.

There are at least two ways to approach the options described here. One approach is to try to optimize the trade-offs by selecting and pursuing the single “best available” option. Another approach is to consider the options as a sequence of steps that can be pursued cumulatively as trust improves, relaxing some of the constraints associated with intrusive verification measures.

The passage of time without any freeze on the testing, production, and deployment of missiles also will tend to erode some of the security benefits of negotiating a freeze at a later date; a freeze is always most beneficial at the earliest possible date. Even in the absence of wider security benefits, however, a verifiable freeze on these types of activities can always contribute to the general reduction of tensions.

A brief discussion of the trade-offs associated with each freeze option follows.

Freeze on Missile Testing

The current freeze on flight tests is minimally intrusive, and primarily helps to prevent North Korea from improving the reliability of its current missile force, improving its survivability by developing new types of solid-propellant missiles, or improving its ability to penetrate BMD by improving its MaRV capabilities. Adding a freeze on ground testing, preferably with the dismantlement of ground test facilities to improve verifiability, would help to reinforce most of these benefits.

FIGURE 10

Freeze options portrayed as a cumulative sequence.

Freeze on New Missile Deployment

As described above, a freeze on new deployments of missiles to operational bases would involve much more intrusive verification measures than a freeze on testing, potentially involving the types of declaration, inspections, and displays associated with the INF Treaty. One major benefit would be to prevent North Korea from improving its ability to penetrate BMD by launching larger salvoes. To the extent that recently tested classes of missiles are not yet deployed, however, this type of freeze could also prevent North Korea from extending the effective range of its missile arsenal or improving its survivability by deploying solid-propellant missiles.

Freeze on Missile/Launcher/Platform Production

A production freeze that shutters particular facilities can be verified with NTM, much like a freeze on ground testing, and is therefore not necessarily highly intrusive. A freeze on the production of new missiles, launchers, and/or platforms could have many of the same benefits as a freeze on new missile deployment.

A selective freeze on production, allowing the facilities in question to continue operating while not producing certain systems, would be significantly more intrusive and challenging to negotiate. A full-time on-site presence, perhaps similar to the portal-monitoring arrangements established under the INF Treaty, might be required.

Verified Dismantlement of Obsolete Missile Systems

Verifiably dismantling obsolete systems, either on its own or in conjunction with a production or deployment freeze, would help to assure that North Korea could not improve its ability to penetrate BMD by launching larger salvoes. If dismantlement takes place at one or more designated sites that are not otherwise sensitive, the intrusiveness of verification measures would be limited.

Freeze on Exports and Assistance

A freeze on North Korean missile exports and assistance does not address the immediate security benefits emphasized in this paper, although it would contribute to global nonproliferation objectives. It would not require highly intrusive measures on North Korean soil. Efforts to inspect North Korean cargoes abroad have been an occasional source of tension, but this would not represent a fundamentally new development. All-source intelligence appears to be the most viable means of verifying such a commitment.

Cooperative Opportunities in Space Launches

This option can be considered a "sweetener" to help remove justifications for the continued development of technology applicable to ICBMs inside North Korea. Although it might be expensive for participants, it would not have its own verification requirements. Combined with other measures, it could help to prevent the enhancement of the reliability of North Korean ICBMs and the development of more survivable types.

Appendix A: Classification of North Korean Missile Systems

The table below presents the known North Korean missile systems by range and fuel type. Missiles denoted with an asterisk are systems that are still in development and likely will require more kinds of testing in the future.

The type designations and ranges below are based on the definitions and assessments of the US Air Force's National Air and Space Intelligence Center, supplemented with other public sources of information.[44]

Table 4

List of North Korea's missile systems by range and propellant type.

TYPE	FUEL TYPE	NAME	APPROX. MAX. RANGE (km)
CRBM	Solid	KN-SS-X-09	190
		KN-02 (Toksa)	120
SRBM	Liquid	Hwasong-5 (Scud B)	300
		Hwasong-6 (Scud C)	500
		KN-18* (MaRV Scud)	500
MRBM	Liquid	Scud ER	1,000
		No-dong	1,300
MRBM	Solid	Pukguksong-1 (SLBM)	2,000
		Pukguksong-2	2,000
IRBM	Liquid	Hwasong-10 (Musudan)	3,000
		Hwasong-12	3,000
ICBM/SLV	Liquid	Taepodong-2 (Unha SLV)	12,000
		Hwasong-13 (KN-08)	12,000
		Hwasong-14	10,000
		Hwasong-15	13,000

[44] "Ballistic and Cruise Missile Threat 2017," Defense Intelligence Ballistic Missile Analysis Committee and National Air and Space Intelligence Center, June 2017.

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