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ABSTRACT

North Korea continues to modernize and grow its nuclear weapons arsenal. In this Nuclear Notebook, the authors cautiously estimate that North Korea may have produced enough fissile material to hypothetically build up to 90 nuclear warheads, but has likely assembled fewer than that—potentially around 50. To deliver the warheads, North Korea is enhancing and diversifying its missile force, most recently with new solid-fuel long-range strategic missiles, short-range tactical missiles, and sea-based missiles. The Nuclear Notebook is researched and written by the staff of the Federation of American Scientists' Nuclear Information Project: director Hans M. Kristensen, associate director Matt Korda, research associate Eliana Johns, and program associate Mackenzie Knight. To see all previous Nuclear Notebook columns in the *Bulletin of the Atomic Scientists* dating back to 1987, go to <https://thebulletin.org/nuclear-notebook/>.

KEYWORDS

North Korea; Nuclear Notebook; ballistic missiles; intercontinental ballistic missiles; nuclear weapons; Hwasong

North Korea—also known as the Democratic People's Republic of Korea, or DPRK—has made significant advances over the past two decades in developing its nuclear weapons arsenal. Since 2006, North Korea has detonated six nuclear devices, updated its nuclear doctrine to reflect the irreversible role of nuclear weapons for its national security, and continued to introduce a variety of new missiles test-flown from new launch platforms.

It is widely assumed that North Korea has operational nuclear warheads for its short- and medium-range missiles as well as possibly for its longer-range missiles, although the latter capability has not yet been publicly demonstrated. There is considerable uncertainty about which of North Korea's missiles have been fielded with an active operational nuclear capability. However, it seems clearer from North Korea's public statements and systems-testing that the country intends to field an operational nuclear arsenal capable of holding targets at risk in East Asia, the United States, and Europe.

In 2021, Kim Jong-un announced several key strategic goals for North Korea's nuclear weapons program, proposed as a five-year plan. According to Kim's statement, these goals included: 1) producing “super-sized nuclear warheads,” 2) producing smaller and lighter nuclear weapons for tactical uses, 3) improving precision strike and range capabilities, 4) introducing “hypersonic gliding flight warheads,” 5) developing “solid-fuel engine propelled intercontinental, underwater, and ground ballistic rockets,” and 6) introducing a “nuclear-powered submarine and underwater-launch

nuclear strategic weapon” (KCNA 2021). North Korea appears to have made significant progress on these goals, and has since introduced more demands including the dramatic increase of missile production and “cutting edge strategic weapon engines” (Kim 2023).

Due to the lack of clarity surrounding North Korea's nuclear program, agencies and officials of the US intelligence community, as well as military commanders and independent experts, struggle to assess the program's characteristics and capabilities. As a result, this paper relies upon publicly available information and satellite imagery about North Korea's fissile material production, nuclear posture, and delivery vehicle development, and uses multiple sources of data whenever possible to corroborate conclusions. We cautiously estimate that North Korea might have produced sufficient fissile material to potentially build up to 90 nuclear weapons and might have assembled around 50 warheads for delivery primarily by medium-range ballistic missiles—an increase since our last report in 2022 (Kristensen and Korda 2022).

Research methodology and confidence

After concluding a safeguards agreement with North Korea in 1992, the International Atomic Energy Agency (IAEA) accessed North Korean nuclear facilities for the first time to verify North Korea's nuclear materials declaration. In the years that followed, the IAEA periodically visited North Korea to verify compliance with this safeguards agreement, along with the Agreed Framework and other initiatives, until the inspectors

were finally expelled in 2009. In addition, between 2004 and 2012 North Korea would also occasionally invite unofficial expert delegations to observe its nuclear program and the suspension of activities at Yongbyon. These meticulously documented IAEA inspections and special experts' visits—during which inspectors and experts were able to tour and inspect North Korea's nuclear complex—continue to comprise much of the foundation for the public's understanding of North Korea's nuclear weapons arsenal.

North Korea has also historically used its state-run media outlets, such as the *Korean Central News Agency* (KCNA), the *Rodong Sinmun* newspaper, and *Korean Central Television*, to release videos, images, and statements related to military parades, missile tests, and other new weapon developments. Intentionally or not, North Korean state media often provides insights into key aspects of its nuclear weapons program. However, this information is not considered to be fully reliable given the many well-documented cases of exaggeration and falsification found in previous North Korean propaganda efforts.

Using these resources and other open sources, including commercial satellite imagery and publicly available reports from the IAEA and the UN Panel of Experts on North Korea, analysts at independent organizations have been able to examine industry networks, locate key facilities, and map North Korea's nuclear fuel cycle to generate estimates of fissile material stockpiles and production—all of which are key factors in assessing the size, sophistication, and status of North Korea's nuclear arsenal today.

However, confidence in estimates about North Korea's nuclear capacity is slowly decreasing as we move further away from the last official and unofficial on-site inspections. Without data exchanges or access to key sites, experts are forced to rely more on unofficial sources and satellite imagery to infer the status of North Korea's arsenal. This presents unique challenges and often can lead to a wide range of conclusions about North Korea's fissile material production, weapon stockpiles, warhead designs, and other key factors, which can even be contradictory in some cases. In the sections below, we explain the assumptions used for our estimates.

North Korea's nuclear policy

For decades, North Korea has made numerous statements and signals about its nuclear weapons policy, laying out its nuclear doctrine if deterrence fails. Such statements have more recently been codified in official declaratory policy. In 2013, for example, North

Korea's "Law on Consolidating the Position of Nuclear Weapons State" suggested a no-first-use policy, noting that North Korea's nuclear arsenal would only be used "to repel invasion or attack from a hostile nuclear weapons state and make retaliatory strikes" (KCNA 2013). Kim Jong-un officially declared a no-first-use policy in 2016 following North Korea's fourth nuclear test.

Since 2016, however, North Korean statements and force posture changes have indicated a shift away from this no-first-use policy. Just two months after the policy was declared, the North Korean government issued a statement that North Korea would not be the first to use nuclear weapons "as long as the hostile forces for aggression do not encroach upon its sovereignty" (KCNA 2016b). In 2020, Kim Jong-un stated that North Korea's nuclear deterrent "will never be used preemptively. But if [...] any forces infringe upon the security of our state and attempt to have recourse to military force against us, I will enlist all our most powerful offensive strength in advance to punish them" (38 *North* 2020). Such caveats culminated in September 2022 when North Korea's parliament codified in law North Korea's right to launch nuclear weapons preemptively (Kim 2022). One year later, the North Korean government codified under the country's constitution its right to "deter war and protect regional and global peace by rapidly developing nuclear weapons to a higher level" (Soo-Yeon 2023).

The abandonment of North Korea's no-first-use policy coincides with the country's recent efforts to develop tactical nuclear weapons. Following development and demonstration of new long-range strategic nuclear-capable missiles, the pursuit of tactical nuclear weapons appears intended to provide options for nuclear use below the strategic level and strengthen its regional deterrence posture (KCNA 2022; National Committee on North Korea 2021). According to two analysts, Pyongyang now sees its nuclear weapons as useful not only for retaliation against an attack but also for potentially winning a limited conflict (Mount and Sup 2022). Others have suggested that such a posture might involve some degree of pre-delegating nuclear launch authority down the chain of command (Narang and Panda 2017; 38 *North* 2022). But North Korea's nuclear command and control system is largely unknown, and it seems doubtful that Kim Jong-un would be comfortable with handing over control of nuclear weapons to the military: In April 2024, North Korea conducted the first drill of its "nuclear trigger" system including firing multiple launch rocket system (MLRS) rockets with mock warheads, reportedly to test "Kim's ability to maintain

command and control over nuclear weapons spread across the country in a crisis” (Zwirko 2024).

Occasionally, North Korea has explicitly mentioned or signaled which targets it would hit with its nuclear weapons. These include US military bases in South Korea, the Asia-Pacific region, Guam, Hawaii, and the continental United States. Knowing that its statements and military activities are being closely followed and analyzed abroad, in 2013 North Korea published a picture of Kim Jung-un and military officials with a map in the background apparently showing missile tracks to several locations in the United States in what was interpreted as a deliberate intent to unnerve the United States (Berkowitz, Karklis, and Meko 2017; Mansourov 2014). A 2016 statement by the Supreme Command of the Korean People’s Army stated that the country would first target South Korea’s Blue House (its seat of government), then “the US imperialist aggressor forces’ bases for invading [North Korea] in the Asia-Pacific region and the US mainland,” in that order (KCNA 2016a). The statement does not explicitly mention nuclear use; however, it is strongly implied that nuclear weapons would be used for at least the second wave of attacks against targets related to the US-South Korean’s conventional invasion force. The January 2021 report of the 8th Congress of the Workers’ Party of Korea noted the goal of “making a preemptive and retaliatory nuclear strike by further raising the rate of precision good enough to strike and annihilate any strategic targets within a range of 15,000 kilometers with pinpoint accuracy” (National Committee on North Korea 2021). In this context, nuclear use (or the threat of nuclear use) with shorter-range missiles could potentially be in an attempt to “decouple” US military support from its regional allies in the Asia-Pacific region, by withholding strikes on US homeland targets during nuclear attacks on regional targets. Whether North Korea’s nuclear posture is advanced enough to support such a complex strategy is unknown. In response to the arrival of a US B-52 bomber in South Korea in October 2023, KCNA reported that US strategic assets deployed in South Korea would be the “first targets of destruction” (Yonhap News Agency 2023).

North Korea has also threatened to launch nuclear weapons in response to more minor provocations, including joint US-South Korean military exercises (Ellyatt 2016). However, despite such occasional inflammatory statements, it appears highly likely that North Korea—as with other nuclear-armed states—would use its nuclear weapons only under extreme circumstances, particularly if the continued existence of the North Korean state and its political leadership were threatened.

North Korea’s nuclear weapons program

Plutonium production operations

The Yongbyon Nuclear Scientific Research Center, located in North Pyongan province, has been called the “beating heart” of North Korea’s nuclear weapons program. At Yongbyon, North Korea produces plutonium at its five megawatt-electric (MWe) graphite-moderated nuclear reactor, which has been operating intermittently since 1986. In July 2021, following several years of inactivity, the IAEA and independent experts detected the discharge of cooling water from the reactor and subsequent steam plumes from the reactor’s hall, signatures which would be consistent with the reactor being operational once again (IAEA 2021; Pabian, Town, and Liu 2021). In April and September 2023, satellite imagery indicated that cooling water discharge had ceased, suggesting that reactor operations had ceased during those times (United Nations 2023, 2024). This could mean that the reactor was undergoing maintenance or that the spent fuel was removed to be sent for reprocessing, which could potentially provide five to eight kilograms of pure plutonium after separation (Heinonen et al. 2023).

The five megawatt-electric reactor could potentially also be used to produce tritium—an element that can be used to boost the yield of fission warheads. Some analysts estimate North Korea could produce up to between seven and 12 grams of tritium per year; enough for one to three boosted fission bombs depending on the design (Yang et al. 2024).

In its August 2021 annual report, the IAEA concluded that the Yongbyon complex’s thermal plant—which supplies steam to the radiochemical laboratory used for plutonium reprocessing—operated for approximately five months, from mid-February 2021 until early July 2021, after a multi-year hiatus (IAEA 2021). The IAEA noted that this timeframe was consistent with the time required to reprocess a complete core of irradiated fuel. Emissions from the thermal plant at the radiochemical laboratory were observed in July 2022 along with activity at the radioactive waste storage facility, which could be a sign of preparations for a reprocessing campaign, maintenance, or treatment of radioactive waste (Makowsky et al. 2022; United Nations 2023).

Since 2010, North Korea has also been in the process of constructing a light-water reactor (LWR) and has engaged in moderate activity at the site for nearly a decade, including construction of new buildings in 2021 and 2022 (Heinonen, Makowsky, and Liu 2022; Makowsky, Heinonen, and Liu 2022a). Between 2020 and 2023, the IAEA and the UN Panel of Experts

reported several tests of the LWR's cooling water system, suggesting the reactor was being prepared for operation (IAEA 2021; United Nations 2023). Then, in October 2023, the IAEA reported increased levels of activity that were consistent with the commissioning of the LWR (IAEA 2023b). Further observation of a heat signature from the power switchyard and sustained warm water discharge from presumed cooling lines in the following months seemed to indicate that the reactor may be in its initial operational phase or undergoing pre-operational testing (IAEA 2023a; Park and Puccioni 2024). Construction around the LWR was observed through satellite imagery throughout 2023 (United Nations 2024). Although the LWR appears to be designed for civilian electricity production, it also has a latent capacity to produce weapons-grade plutonium or tritium that could be used for North Korea's nuclear weapons program.

In May 2022, independent analysts from the James Martin Center for Nonproliferation Studies (CNS) noted the possible resumption of construction at North Korea's long-dormant 50-MWe reactor, which had been paused since 1994 (Lewis, Pollack, and Schmerler 2022). The analysts concluded that, upon completion, the reactor could theoretically produce approximately 55 kilograms of plutonium per year, enough to potentially produce about a dozen new nuclear weapons per year, depending on the design of the warhead. However, analysts from the Stimson Center's 38 *North* project subsequently noted that similar construction efforts at the 50-MWe site are not uncommon, and that the recent trenching activity could be intended to service a nearby underground facility that is unrelated to the reactor itself (Makowsky, Heinonen, and Liu 2022a). Given these uncertainties, it remains unclear whether North Korea has indeed restarted construction on the 50-MWe reactor; given the state of the reactor's apparent disrepair, doing so would likely take several years to complete (Hecker 2010).

Uranium enrichment operations

Assessing the state of North Korea's uranium enrichment operations is more difficult because the operational history and locations of several associated uranium enrichment facilities are unknown. In addition, the associated facilities and their production capacities are harder to detect than those used for plutonium production, as their signatures are less visible through open sources. Much of what is publicly known is based on reports from an unofficial delegation that visited North Korea's uranium enrichment facility at

Yongbyon in 2010. Open-source analysts have also relied on satellite imagery and technical geological methods to estimate the operation and production capacity of North Korea's known uranium mines, uranium mills, and centrifuge facilities (Park et al. 2021).

North Korea produces yellowcake—a type of uranium concentrate powder that, once converted and enriched, is used in reactor fuel—at the Pyongsan uranium concentration plant (also known as the Nam-chon chemical complex) (Bermudez, Cha, and Jun 2021). Since 2020, analysts have observed ongoing mining, milling, and concentration activities including expanded tailings piles at the uranium concentration plant and the uranium mine collocated at Pyongsan (IAEA 2022; Makowsky 2023; United Nations 2024).

North Korea has only one declared uranium enrichment facility—within the Yongbyon nuclear fuel rod fabrication plant—which contained 2,000 centrifuges when it was first revealed to a visiting delegation of experts in 2010. The facility is now estimated to house approximately 4,000 centrifuges after satellite imagery indicated the uranium enrichment hall at the site nearly doubled in size between 2013 and 2014. The enrichment facility at Yongbyon was seen operating regularly throughout 2021, as plumes of steam were observed through satellite imagery as well as the presence of what may have been a liquid nitrogen tank trailer on-site (United Nations 2021b, 2022).¹ The construction of a second, smaller expansion to the uranium enrichment hall was originally noted by analysts from CNS in September 2021 before it was completed in May 2022. This expansion could potentially accommodate approximately 1,000 additional centrifuges, which could increase the plant's overall capacity by 25 percent (Lewis, Pollack, and Schmerler 2021). Ongoing activity at the facility can be observed through satellite imagery, including the recently completed construction of several new buildings in the southernmost section of the site; however, the purpose of these buildings remains unknown (Makowsky, Liu, and Heinonen 2023).

It is widely believed that North Korea has at least one additional clandestine centrifuge facility outside of the known Yongbyon complex. In May 2018, the *Washington Post* first reported the existence of a potential uranium enrichment site at Kangson, just outside of Pyongyang, citing work by the Institute for Science and International Security (Warrick and Mekhennet 2018). In 2022, the United Nations Panel of Experts listed Kangson as a “suspected clandestine uranium enrichment facility” and noted continuous vehicular and construction activities since July 2021 (United Nations 2022). However, independent analysis has raised doubts about the type of activities conducted

at the Kangson complex, suggesting that the site might be used to manufacture components for centrifuges rather than to enrich uranium (38 North 2021; Heinonen 2020). Without more detailed public information or access to the site itself, however, it is not possible to confirm the purpose of the Kangson site nor its potential role in North Korea's nuclear weapons program.

Fissile material and warhead inventory estimates

Because of the prior access to the facilities at Yongbyon, analysts have a reasonable understanding of North Korea's plutonium production capabilities. However, given the uncertainties about the operations at Yongbyon's uranium enrichment facility and the possible existence of a second centrifuge facility, it is unclear how much highly-enriched uranium (HEU) North Korea has produced and how much uranium it might divert to military purposes, including for plutonium production. Still, this amount is known to be growing and it is clear North Korea is investing in the improvement of its fissile material production capabilities.

Throughout the years, many experts have attempted to estimate North Korea's fissile material production, with a wide range of results. In April 2021, former Los Alamos National Laboratory director, Siegfried Hecker, who was given unprecedented access to North Korean nuclear facilities over several years, estimated that North Korea had a plutonium inventory in the range of 25 to 48 kilograms and could produce up to six kilograms per year at full operation (38 North 2021). Hecker also estimated that North Korea had possibly produced 600 to 950 kilograms of HEU as of the end of 2020 (38 North 2021). An assessment published by the Stockholm International Peace Research Institute (SIPRI) suggested a wider range of possibly 230 to 1,180 kilograms of HEU as of the beginning of 2021 (Kütt, Mian, and Podvig 2022, 426), whereas the International Panel on Fissile Materials estimated a slightly smaller range of 400 to 1,000 kilograms of HEU in 2022 (International Panel on Fissile Materials 2022). A report by David Albright of the Institute for Science and International Security suggested that North Korea's fissile material stockpile could range between 56 to 70 kilograms of weapon-grade plutonium and between approximately 1,400 to 2,200 kilograms of HEU as of the end of 2022 (Albright 2023).

A newly-published methodology for modeling North Korea's nuclear fuel cycle uses information gained from the prior access provided to IAEA inspectors and international experts, as well as satellite imagery and open sources, to estimate fissile material production under

different scenarios (Christopher et al. 2023). These scenarios are built around certain assumptions about operational history, facility sophistication, and the existence of other facilities. Depending on the assumptions in the scenarios, as well as accounting for the allocation of fissile materials to different fuel cycle activities and nuclear tests, the model produces high- and low-range estimates of North Korea's potential plutonium and HEU stockpiles.

For the purpose of this notebook, we use this model and incorporate three assumptions about North Korea's fissile material production:

- (1) Five full plutonium reprocessing campaigns have taken place at the radiochemical laboratory since 2003.²
- (2) North Korea could operate up to 8,000 P2-type centrifuges for uranium enrichment, including:
 - a. Up to 4,000 P2-type centrifuges at North Korea's uranium enrichment facility at Yongbyon, with the first 2,000 operating between 2003 and 2015 (some of this output was low-enriched uranium used for the LWR) and an additional 2,000 operating since 2015 (after the observed expansion to the enrichment hall).
 - b. An estimated additional 4,000 P2-type centrifuges at a second clandestine facility (the location of which has yet to be confirmed), which we assume has the same size and uses the same type of centrifuges as the one at Yongbyon and has been operating since sometime between 2006 and 2010.
- (3) North Korea produces very little tritium at its five-megawatt-electric reactor, requiring the use of enriched uranium, but this is a limited capacity.

The size of North Korea's nuclear stockpile also depends on the weapon design and the number and types of launchers that can deliver them. Many experts also estimate that North Korea may have built a smaller number of nuclear weapons than what its stockpile of fissile material may suggest. This is because it is unclear whether North Korea is prioritizing the development and production of higher-yield thermonuclear weapons, lower-yield fission-only weapons, boosted single-stage weapons, or any combination of these designs. More powerful warheads with the high yield demonstrated in the single 2017 advanced design test would consume more fissile material if based on a composite warhead design or would require special hydrogen fuel if based on a two-stage thermonuclear design, whereas lower-

yield single-stage fission weapon designs would require less fissile material. Such assumptions can result in contrasting estimates regarding the number of nuclear weapons North Korea has procured and how many it could assemble in the future.

For example, in 2020, SIPRI researchers Vitaly Fedchenko and Robert Kelley published a report in *Janes Intelligence Review* in which they calculated the size of North Korea's arsenal based on fissile material stockpile estimates from 2018 (Fedchenko and Kelley 2020). Assuming North Korea would allocate four kilograms of weapon-grade plutonium for single-stage plutonium weapons—which is consistent with a Department of Energy statement declassified in 2001—12 kilograms of HEU for single-stage uranium-only devices, and 40 kilograms of HEU for a thermonuclear weapon with a plutonium primary, the Fedchenko-Kelley report concluded that if North Korea committed its HEU to the production of thermonuclear weapons, the country was likely to possess between 10 and 20 warheads. In 2023, a report from the Institute for Science and International Security estimated that a plutonium-only weapon would require four kilograms, a composite weapon would contain two kilograms of plutonium with 10 to 15 kilograms of HEU, and a thermonuclear device would use 3.5 kilograms of plutonium and 80 kilograms of HEU (Albright 2023). Coupled with different assumptions about North Korea's fissile material stockpiles, as well as the possibility that its nuclear weapons arsenal contains a mix of composite core, thermonuclear, plutonium-only, and HEU-only nuclear devices, this resulted in an estimated range of 35 to 63 nuclear weapons (Albright 2023).

Under the assumptions stated above, we estimate North Korea could possess up to 81 kilograms of plutonium and 1,800 kilograms of HEU, which could supply North Korea with enough material to potentially build up to 90 nuclear weapons (if it assembled 48 HEU-only devices and 40 composite weapons by using an estimated 25 kilograms of HEU for the uranium-only design, then two kilograms of plutonium and 15 kilograms of HEU for the composite design). The above assumptions could also produce a lower estimate of North Korea's fissile material stockpile, of approximately 66 kilograms of plutonium and 1000 kilograms of HEU. These lower-end projections mean that North Korea could potentially build up to 20 uranium-only design and 33 composite design weapons if using the same fissile material allocations, for a possible capacity to build up to 53 nuclear weapons.

While North Korea's warhead design and stockpile makeup are unknown, it is possible that most weapons would likely be single-stage fission weapons with yields

possibly between 10 and 20 kilotons of TNT equivalent, akin to those demonstrated in the 2013 and 2016 tests, and a smaller number would be composite-core single-stage warheads with a higher yield. Such an arsenal would also be consistent with the understanding that North Korea has a limited plutonium supply and prioritizes shorter-range nuclear weapons capabilities over long-range strategic weapons.

Under these previously stated assumptions, we cautiously assess that North Korea may have produced sufficient fissile material for a maximum capacity to potentially build up to 90 nuclear weapons, but has likely assembled fewer than that—potentially around 50. Additionally, we estimate that North Korea might be capable of adding sufficient fissile material to produce an additional half-a-dozen nuclear warheads per year—enough to potentially produce a total of up to approximately 130 weapons by the end of the decade.

Nuclear testing and weaponization

After six nuclear tests—including two with moderate yields and one with a high yield—there is no longer any doubt that North Korea can build powerful nuclear explosive devices designed for different yields. North Korea's latest nuclear test, conducted on September 3, 2017, had a yield of well over 100 kilotons and demonstrated that North Korea had managed to design a thermonuclear device or at least one that used a mixed-fuel (composite) design. Photos published at the time of Kim Jong-un standing next to a peanut-shaped warhead model described as a “thermonuclear” design appeared intended to signal development of a two-stage design. Although its visual appearance suggested that it is small and light enough to potentially be delivered by ballistic missiles, it is unknown if the display was a real warhead or a mock-up design. It is also possible that North Korea's reference to a so-called “hydrogen” bomb implied the use of tritium to boost the efficiency of a single-stage fission device, not a two-stage thermonuclear weapon. Such a technology would enable North Korea to use less fissile material in each bomb and further expand its production capacity (Jones 2016).³ However, given tritium's relatively short half-life (12.33 years) and North Korea's low rate of tritium production, the capacity of North Korea to produce boosted or thermonuclear weapons appears to be limited (Yang et al. 2024).

In a May 2021 speech, Kim Jong-un stated that North Korea had developed what he described as “tactical nuclear weapons including new-type tactical rockets.” In the future, he stated, it would be necessary to improve the technology “and make nuclear weapons smaller and

lighter for more tactical uses. This will make it possible to develop tactical nuclear weapons to be used as various means according to the purposes of operational duty and targets of strike in modern warfare” (North Korean Ministry of Foreign Affairs 2021). Although the meaning of “tactical” in Kim’s speech is not clear, it appears to imply a role that is distinct from “strategic” weapons with longer range, and perhaps could be used earlier in a conflict.

To further illustrate its pursuit of “tactical” nuclear weapons, North Korea in March 2023 released images of Kim Jong-un inspecting new, small nuclear warheads called the Hwasan-31 and pictured alongside technology for mounting the warhead on ballistic missiles (see Figure 1). Posters in the background also seemed to imply the intention to mount this new warhead on eight different types of ballistic and cruise missiles, including the KN23, KN24, KN25, Hwasal, and Haeil (Zwirko 2023a). The number and size of the warheads in the images seemed to imply that North Korea is seeking to standardize designs for a lightweight warhead that

could be fitted atop various kinds of missiles, although this will be highly challenging. There is also no way to know for sure if these warheads reflect actual designs, if they match any of the devices detonated in North Korea’s nuclear explosive tests, or if they would require substantial modification to be fitted on a missile.⁴

Although North Korea has demonstrated significantly improved missile capabilities and more powerful nuclear tests, some US and South Korean officials have occasionally expressed doubt that North Korea actually possesses the technology needed for a warhead to function and survive delivery on a long-range missile. At the Eighth Congress of the Workers’ Party of Korea in 2021, Kim Jong-un discussed the development of multiple independently targetable reentry vehicles (MIRVs), which would be even more technically challenging (KCNA 2021). Some analysts estimate that North Korea’s satellite launch-vehicle tests in February and March 2023 could have been used to validate technologies for achieving such a MIRV capability (Nouwens et al. 2024; Panda 2022b). Employment of short-range



Figure 1. Different nuclear warhead designs displayed by North Korea. (Credit: Federation of American Scientists).

warheads would be less difficult, and during a nuclear drill of tactical systems in 2023, North Korean state media reported the testing of an air-burst test capability, confirming the “reliability of the operation of nuclear explosion control devices and detonators fitted in a nuclear warhead” (Ji 2023).

North Korea has conducted all six of its nuclear tests at the Punggye-ri test site in North Hamgyong province, which consists of a large mountain complex with several underground tunnels. North Korea partially disabled the complex in May 2018 by destroying three tunnel entrances and several nearby buildings; this was done as a confidence-building measure in advance of a planned meeting between Kim Jong-un and Donald Trump (Talmadge 2018). However, the underground site itself was not destroyed and could therefore be reconstituted if necessary.

After an extended period of inactivity, North Korea has begun reconstituting the Punggye-ri test site. Satellite imagery since March 2022 has revealed the construction of new buildings and renovation of older ones; movement of lumber, equipment, and personnel; new excavation activity; and the creation of a new portal into the mountain test site (Bermudez, Cha, and Jun 2022; Lewis and Schmerler 2022; Makowsky, Heinonen, and Liu 2022b; United Nations 2024). This substantial new construction effort led both US and South Korean officials to suggest in 2022 that North Korea may be preparing to conduct a seventh underground nuclear test (BBC 2022; Kang 2022). So far this has not happened.

Potential land-based nuclear-capable missiles

Over the past decade, North Korea has developed a highly diverse ballistic missile force, including missiles in all major range categories. The UN Panel of Experts assessed in its 2024 report that North Korea’s ballistic missile program has made advancements in the past year on performance—including improved maneuverability and precision, survivability, and preparedness (United Nations 2024).

In addition to the uncertainties surrounding North Korea’s nuclear warheads (see section “North Korea’s nuclear weapons program”), it is unclear how many operational delivery vehicles North Korea possesses and how many of those would be assigned a nuclear mission. Moreover, it is highly challenging to assess which of North Korea’s missile systems have been deployed and what their operational status is. North Korean state media occasionally implies that specific systems are operational, but since many of North Korea’s missile bases are hidden within mountain

ranges, it is difficult to verify these statements. Also, some of the ballistic missile types North Korea has flight-tested or displayed might be research projects intended to develop future ballistic missile technology and signal such aspirations to its adversaries, rather than demonstrations of operational missiles.

To ensure completeness, this section analyzes all of North Korea’s known land-based ballistic missiles and offers some hypotheses about which missiles are most likely to have a nuclear role. The inclusion of a missile in this section does not necessarily mean it has or is believed to have a nuclear role. (See Table 1).

Short-range missiles

For decades, the bulk of North Korea’s missile arsenal comprised old liquid-fueled variants of the Soviet-era R-17 Scud short-range ballistic missile (SRBM), which North Korea received from Egypt in the 1970s and subsequently reverse engineered (Pinkston 2008). The initial North Korean versions of these missiles were known as the Hwasong-5 (Scud-B) and Hwasong-6 (Scud-C). The US Air Force’s National Air and Space Intelligence Center lists the missiles’ ranges at 300 and 500 kilometers, respectively, and estimated in 2021 that North Korea had fewer than 100 launchers for the combined Hwasong-5 and -6 arsenal (National Air and Space Intelligence Center 2020, 21). Throughout the 1980s and 1990s, North Korea iterated on these designs to increase their range, eventually developing the medium-range Hwasong-7 (Nodong) and Hwasong-9 (KN04).

Aside from the Toksa (KN02)—a solid-fueled precision SRBM based on the Soviet OTR-21 Tochka—all North Korean SRBMs were relatively inaccurate and used liquid fuel until roughly 2017, when it became clear that North Korea sought to increase the accuracy and readiness of its nuclear-capable SRBMs.

In 2017, North Korea flight-tested modernized versions of its Hwasong-5 and Hwasong-6, each of which were equipped with maneuverable reentry vehicles designed to evade regional missile defense systems like the Terminal High Altitude Area Defense (THAAD) system, which the United States deploys in South Korea (James Martin Center for Nonproliferation Studies 2024; Panda 2017). These modernized missiles were designated by the United States as the KN21 and KN18, respectively.

Over the past five years, North Korea has prioritized the production of a new generation of solid-fuel dual-capable missiles and has placed particular emphasis on its SRBMs. While liquid-fuel missiles are more efficient and can be throttled by slowing the chemical reaction

Table 1. North Korea's potentially nuclear-capable missiles, 2024.*

Class and range	North Korean designation ^a	US designation ^a	Type	Year first displayed	Description and status
<i>Land-based missiles</i>					
<i>Short-range (<1,000 km range)</i>					
	Hwasong-5	Scud-B	SRBM	1984	Reverse engineered liquid-fuel Scud launched from 4-axle wheeled TEL. In 2020, NASIC estimated fewer than 100 Hwasong-5 and – 6 launchers.
	Hwasong-6	Scud-C	SRBM	1990	Improved Hwasong-5 with longer range launched from 4-axle wheeled TEL. In 2020, NASIC estimated fewer than 100 Hwasong-5 and – 6 launchers.
	?	KN21	SRBM	2017	Upgraded Hwasong-6 variant with separating maneuverable warhead. Status unknown; may have been superseded by newer solid-fueled SRBMs.
	?	KN18	SRBM	2017	Upgraded Hwasong-5 variant with terminal maneuverability. Status unknown; may have been superseded by newer solid-fueled SRBMs.
	?	KN25	SRBM	2019	Solid propellant “super-large” 600 mm MRLS.
	Hwasong-11A/Ga/가^b	KN23	SRBM	2018	Next-generation solid-fueled SRBM resembling the USA’s ATACMS system. Successfully flight-tested dozens of times from wheeled, tracked, rail-based, underwater, and silo-based launchers.
	Hwasong-11B/Na/나	KN24	SRBM	2019	Next-generation solid-fueled SRBM resembling Russia’s Iskander-M and South Korea’s Hyunmoo-2B systems.
	Hwasong-11D/Ra/라	?	SRBM	2022	Compact variant of the Hwasong-11A with likely shorter range.
<i>Medium-range (1,000–3,000 km range)</i>					
	Hwasong-7	Nodong/Rodong	MRBM	1993	Single-stage, liquid-fueled MRBM launched from 5-axle wheeled TEL. In 2020, NASIC estimated fewer than 100 Hwasong-7 launchers.
	Hwasong-9^c	KN04/Scud-ER	MRBM	2016	Single-stage, liquid-fueled, extended-range Scud variant launched from 4-axle wheeled TEL.
	Pukguksong-2	KN15	MRBM	2017	Two-stage, solid-fueled MRBM launched from tracked TEL. Land-based version of Pukguksong-1 SLBM.
	Hwasong-12A/Ga/가 [†]	?	MRBM	2021	Conical maneuverable reentry vehicle carried by a shortened Hwasong-12 booster.
	Hwasong-12B/Na/나 ^d	?	MRBM	2021	Wedge-shaped HGV carried by a shortened Hwasong-12 booster. Renamed from Hwasong-8.
	Hwasal-1	?	LACM	2021	North Korea’s first operational cruise missile. Flight tested from a wheeled TEL. One variant includes a “Ra-3” suffix.
	Hwasal-2	?	LACM	2021	LACM with similar design to Hwasal-1 but with an updated propulsion system and longer range.
<i>Intermediate-range (3,000–5,500 km range)</i>					
	Hwasong-12	KN17	IRBM	2017	Single-stage, liquid-fueled IRBM launched from 6-axle wheeled TEL.
	Hwasong-16A/Ga/가 [†] (unconfirmed)	?	IRBM	2024	Solid-propellant IRBM with conical maneuverable reentry vehicle (likely to be the same glider as the Hwasong-12A).
	Hwasong-16B/Na/나 [†]	?	IRBM	2024	Solid-propellant IRBM with wedge-shaped glide vehicle (likely to be the same glider as the Hwasong-12B).
<i>Intercontinental (5,500+ km range)</i>					
	Hwasong-14	KN20	ICBM	2017	North Korea’s first operational ICBM. Two-stage, liquid-fueled, launched from 8-axle wheeled TEL.
	Hwasong-15	KN22	ICBM	2017	Two-stage, liquid-fueled ICBM launched from 9-axle wheeled TEL.
	Hwasong-17^e	KN28	ICBM	2020	Two-stage, liquid-fueled ICBM launched from 11-axle wheeled TEL. Largest ICBM to date, could eventually be capable of carrying MIRVs and penetration aids.
	Hwasong-18	?	ICBM	2023	Three-stage, solid-fueled ICBM launched from a 9-axle wheeled TEL (same launcher as Hwasong-15).
<i>Sea-based missiles</i>					
	Pukguksong-1	KN11	SLBM	2014	North Korea’s first SLBM, featuring a two-stage, solid-fuel design and a relatively short range (approximately 1,250 km).
	Pukguksong-3	KN26	SLBM	2017	Improved Pukguksong-1 design with longer range and new fairing.
	Pukguksong-4/Sh/사 ^f	?	SLBM	2020	Similar design with likely wider diameter and reduced length.
	Pukguksong-5/Sh/사	?	SLBM	2021	Similar length as Pukguksong-3 but with new, ogival nose cone; could eventually be capable of carrying MIRVs and penetration aids.
	Unknown (possibly Pukguksong-6)	?	SLBM	2022	Name not yet formally announced but appears to be a member of the Pukguksong family of SLBMs. Longer than all previous Pukguksong-type missiles, but with similar nose cone to Pukguksong-5.
	Hwasong-11/Sh/사	?	SLBM	2021	Appears to deviate from traditional Pukguksong SLBM design, instead bearing similarities to KN23 SRBM.
	Pulhwasal-3–31	?	SLCM	2024	“Strategic” submarine-launched cruise missile capable of flight for more than two hours.
	Haeil (–1, –2, –5–23)	?	UUV	2023/2024	Three variants of what North Korea describes as a “nuclear-capable underwater attack drone” with the purpose of creating radioactive tsunamis. Claimed to have undergone more than 50 shakedown tests between 2021 and 2023.

Abbreviations used: ICBM: intercontinental ballistic missile; IRBM: intermediate-range ballistic missile; LACM: land-attack cruise missile; MRBM: medium-range ballistic missile; SLBM: submarine-launched ballistic missile; SLCM: sea-launched cruise missile; SRBM: short-range ballistic missile; UUV: unmanned underwater vehicle.

Notes:

*The status and capabilities of North Korea’s missiles come with significant uncertainty. The inclusion of missiles in this table does not necessarily mean the authors conclude that they are all equipped with nuclear warheads or assigned a nuclear mission. Several may have been intended as prototypes, technology demonstrators, or early iterations that have been or will be superseded by newer missiles. Systems that we assess to be operational are highlighted in **bold**.

^aFor overviews of names and designations for North Korean missiles, see: Matt Korda’s “The More You Know About North Korean Missiles” and “The Hwasong That Never Ends” lists on Arms Control Wonk <https://www.armscontrolwonk.com/archive/1203680/the-more-you-know-about-north-korean-missiles/>.

^bNorth Korea has recently begun to assign Hangul suffixes to many of its missiles. These suffixes can be considered akin to A, B, C, etc. given their respective placements in the Hangul alphabet. For example, North Korea refers to the KN23 as the Hwasong-11가 (transliterated into English as “Ga”). Because “Ga” is the first letter of the Hangul alphabet, this system can be considered as “Hwasong-11A.”

^cThe 1,000-km range Scud-ER is sometime called an SRBM, but the US Air Force’s National Air and Space Intelligence Center lists it as an MRBM.

^dThis missile was previously designated the Hwasong-8 by North Korean state media; however, it was renamed between September 2021 and July 2023.

^eThis missile was previously assumed to be designated the Hwasong-16; however, it was revealed at North Korea’s “Self-Defence Exhibition” in October 2021 that it is called the Hwasong-17. It is unclear which missile—if any—currently holds the Hwasong-16 designation.

^fOne of North Korea’s new suffixes is 사 (transliterated into English as “Sh”), which North Korea has recently begun to assign to its newer sea-based missiles. According to South Korean navy officials, this is likely because it refers to 수상용, which means “for use in water.” Source: Kim, Jeongmin. 2021. “FYI: South Korean navy chief said before that the consonant ‘사’ in Pukguksong names likely refers to ‘수상용,’ which means ‘for use in water.’ (i.e. Pukguksong-4사, and the new 5사 today).” Tweet, January 14. <https://twitter.com/jeongminkim/status/1349909227960102913>.

between the fuel and oxidizer as needed, solid-fuel missiles have several distinct military advantages over liquid-fuel ones: Solid propellant is safer and not as corrosive as liquid propellant, requires less maintenance, and can safely handle off-road transportation conditions (Schilling 2016). Moreover, solid-fuel missiles are pre-cast and therefore do not require a lengthy fueling process prior to launch. This means that in a wartime scenario, solid-fuel missiles can simply be rolled out of their hiding places and launched within minutes—in contrast to liquid-fuel missiles that could be vulnerable to a preemptive strike during their prolonged fueling process. This vulnerability could be exacerbated by the presence of support vehicles and fuel trucks that would not be necessary for solid-fuel missiles and make liquid-fuel missiles easier to spot via aerial reconnaissance or satellites.

Since 2019, North Korea has successively unveiled new types of more accurate, solid-fueled SRBMs with indigenous designs that may ultimately replace older Hwasong-5s and -6s, as well as their modernized versions (the KN21 and KN18). These missiles, which include the KN23 (Hwasong-11A), KN24 (Hwasong-11B), KN25, Hwasong-11C, and Hwasong-11D, have collectively been tested approximately 70 times since the beginning of 2019 (James Martin Center for Nonproliferation Studies 2024). These missiles appear to bear several similarities to conventional US, South Korean, and Russian missiles, such as the ATACMS, Hyunmoo-2B, or Iskander SRBMs. North Korea has explicitly claimed in official statements that many of its solid-fuel SRBMs are nuclear-capable. For example, in April 2024, North Korea conducted a “combined tactical drill simulating nuclear counterattack,” in which they simultaneously launched four KN25 missiles “tipped with simulated nuclear warheads” (KCNA 2024b). The drill was significant both as an apparent test of the KN25’s “tactical” nuclear capability and as the first test of North Korea’s “Nuclear Trigger” nuclear weapon management system with the KN25 (Van Diepen 2024).

Except for the Hwasong-11C, North Korea has explicitly tied all its new-generation solid-fuel SRBMs to its nuclear program. North Korea has stated that this variant can carry 2.5- and 4.5-metric ton warheads. These are much heavier payloads than would be needed for carrying a nuclear weapon and could therefore indicate a conventional role (Voice of Korea 2021a; KCNA 2024c).

Some of these SRBMs, including the KN23 and possibly the KN24, can conduct “pull-up” maneuvers in their terminal phase of flight, therefore complicating the abilities of North Korean adversaries to track the missiles during their descent.

This new generation of solid-fuel SRBMs can apparently be launched from several different types of platforms, including wheeled transporter erector launchers (TELs), tracked TELs, silo-based launchers, underwater launchers, and rail-based launchers. North Korea has also announced its intention to expand the Railway Mobile Missile Regiment—created at the Eighth Congress of the Workers’ Party of Korea in January 2021—into a brigade, which could eventually consist of nine launchers with 18 missiles (Voice of Korea 2021b). Given that North Korea has an extensive cross-country rail network that frequently travels through mountains, rail-mobile launchers would enable North Korea to move missiles around the country rapidly and increase the survivability of its second-strike force.

The sophisticated testing program for these newer systems indicates that North Korean missile troops are becoming significantly more practiced at conducting salvo launches and lowering the time intervals between missile launches (Dempsey 2020). As an illustration of this new capability, in June 2022, North Korea test-launched eight SRBMs from multiple different locations in less than an hour. This constituted the largest number of North Korean ballistic missiles launched on a single occasion (Yonhap News Agency 2022). In March 2024, North Korea conducted another salvo drill, firing six KN25 dual-capable SRBMs simultaneously, followed by another KN25 to simulate a probable nuclear airburst (Van Diepen 2024).

Medium- and intermediate-range missiles

North Korea is developing a new generation of medium- and intermediate-range missiles with improved accuracy, readiness, and maneuverability. For decades, North Korea operated its relatively inaccurate, liquid-fuel Hwasong-7 (Nodong) and Hwasong-9 (KN04) medium-range ballistic missiles (MRBMs). These missiles—carried by five- and four-axle wheeled TELs, respectively—were derived from the early-generation Hwasong-5 and -6 and had relatively poor accuracy. Partially for this reason, some analysts have suggested that the Hwasong-7 is one of the most likely missiles to have an operational nuclear capability (Albright 2013; Center for Strategic and International Studies 2021; James Martin Center for Nonproliferation Studies 2006).

Between 2010 and 2016, North Korea was also developing a liquid-fuel intermediate-range ballistic missile (IRBM)—the Hwasong-10 (Musudan)—with an estimated range of more than 3,000 kilometers. The missile suffered several test failures in 2016, however, and its

design was not mirrored in North Korea's newer generation of regional missiles—indicating that the missile has likely been superseded and is no longer in development (James Martin Center for Nonproliferation Studies 2024).

In 2017, North Korea unveiled two new regional ballistic missiles: the Pukguksong-2 (KN15) and the Hwasong-12 (KN17). The Pukguksong-2 is a two-stage, solid-fuel MRBM carried in a canister on a road-mobile caterpillar-type TEL. The missile appears to be a modification of the submarine-launched Pukguksong-1 (KN11). The first two flight tests in 2017 demonstrated a range of up to 1,200 kilometers (Wright 2017b, 2017c). The Hwasong-12 is a single-stage, liquid-fuel, intermediate-range ballistic missile carried on a six-axle road-mobile TEL with a detachable firing table. Several tests, including one in January 2022 after a nearly five-year hiatus, have indicated that the missile could reach targets as far as 4,500 kilometers if flown on a normal trajectory (Japanese Ministry of Defence 2022a; Wright 2017e).

North Korea appears to be developing two variants of the original Hwasong-12 that are significantly more maneuverable than the original design. One missile carries a wedge-shaped boost-glide vehicle, and another missile carries a conical maneuverable reentry vehicle. The former system was originally designated by North Korean state media as Hwasong-8 but was apparently changed to Hwasong-12Na (equivalent to Hwasong-12B, as “Na” is the second consonant in the Hangeul alphabet) between September 2021 and July 2023; The new designation was confirmed in July 2023 by an image from the Russian Defense Minister's visit to North Korea (Lewis 2023). Given this confirmation, we can speculate that the missiles with conical reentry vehicles tested in January 2022 are “Hwasong-12Ga” (equivalent to Hwasong-12A), although this designation is unconfirmed. While both gliders appear to be carried by modified by Hwasong-12 boosters, they are assessed to have shorter ranges than the original Hwasong-12 IRBM.

North Korean state media reported that the Hwasong-12Na was the first North Korean missile to use a “fuel ampoule,” which involves placing pre-fueled, liquid-fueled missiles in temperature-controlled canisters to facilitate faster launches (DPRK Today 2021; Xu 2021). North Korea says it plans to transition all liquid-fueled missiles into ampoules (DPRK Today 2021).

In 2024, North Korea debuted a solid-fuel IRBM capability by revealing two variants of a new two-stage missile design, featuring what appeared to be the same two types of gliders as those carried by the Hwasong-12. Launches of the two variants were conducted in January

and April 2024. Given that the variant carrying the wedge-shaped boost-glide vehicle was confirmed by state media as the Hwasong-16Na (equivalent to Hwasong-16B), the variant launched in January carrying the conical maneuverable reentry vehicle is likely to be the Hwasong-16Ga (equivalent to the Hwasong-16A); this would also match the designation pattern for the Hwasong-12 (KCNA 2024a; Van Diepen 2024; Lewis 2024). During the April test, the Hwasong-16B demonstrated a pull-up maneuver and lateral maneuvering capability. Both tests were reportedly conducted at limited speed and range, making it difficult to assess whether either glider will be successful at the intermediate range (Xu 2024).

Intercontinental ballistic missiles

The most dramatic of North Korea's recent developments has been the display and test launch of large intercontinental ballistic missiles (ICBMs), including the country's first solid-fuel ICBM. North Korea has revealed several types of missiles in this range category over the years, three of which are likely to be currently operational: the Hwasong-15, Hwasong-17, and Hwasong-18 (see Figure 2).

Achieving an ICBM capability to target the US homeland has long been a strategic goal for North Korea. North Korea's first intercontinental-range missiles were the Taepodong-1 (TD01) and Taepodong-2 (TD02), test flown in 1998 and 2006, respectively. However, these missiles were better suited as space launch vehicles and were unlikely to realistically function as nuclear-capable ICBMs. As a result, we assess that neither variant is currently operational as a North Korean military system.

North Korea next demonstrated its commitment to developing an ICBM capability in 2012, when it displayed the Hwasong-13 (KN08) during a parade. The Hwasong-13 was a three-stage, liquid-fuel ICBM, but it was never flight tested. A two-stage version of the Hwasong-13 was subsequently displayed at a parade in 2015 but also was never tested. Given North Korea's development of more sophisticated systems since then, we assess that the Hwasong-13 is not currently an operational system and the design has likely been superseded by the newer designs.

North Korea reached a turning point in 2017 with test launches of what would become its first operational ICBM theoretically capable of delivering nuclear warheads to the continental United States: the Hwasong-14 (KN20). North Korea conducted the first two test launches of the two-stage, liquid-fueled Hwasong-14 in July 2017. According to the National Air and Space

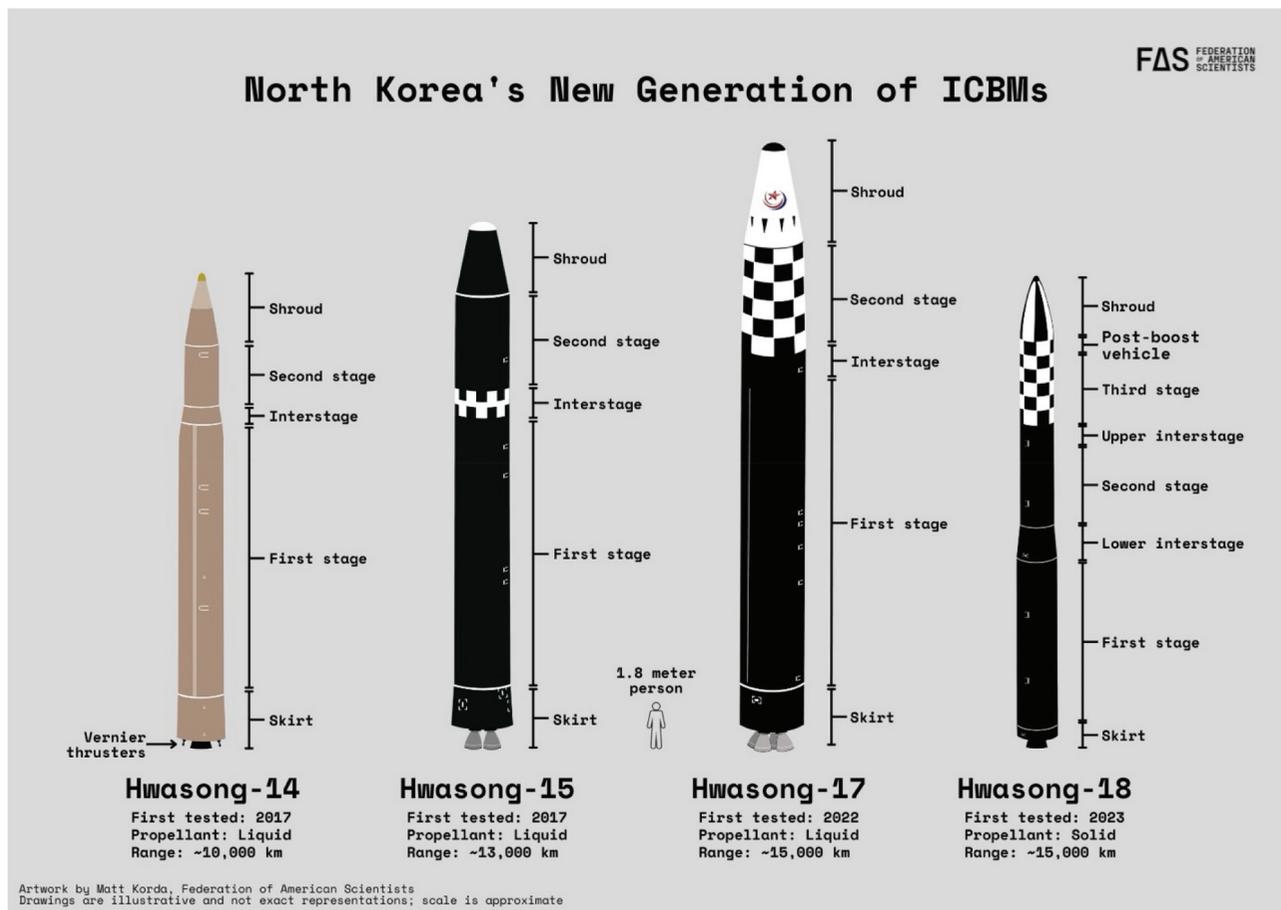


Figure 2. North Korea's new generation of intercontinental ballistic missiles. North Korea has demonstrated significant progress over the past decade in developing increasingly capable intercontinental ballistic missiles. (Credit: Matt Korda, Federation of American Scientists).

Intelligence Center and independent analysts, the second test demonstrated that the missile could, if flown on a normal trajectory, have a range of over 10,000 kilometers (National Air and Space Intelligence Center 2020, 27; Wright 2017a). These tests, however, did not demonstrate a functioning ICBM reentry vehicle. Notably, North Korea has not paraded the Hwasong-14 since 2018 and did not include it at its October 2020 and February 2023 military parades that featured other ICBMs (NK News 2020). Combined with its development of newer, more sophisticated systems, this leads us to assess that the North Korean military does not currently operate the Hwasong-14.

On November 29, 2017, North Korea launched a newer ICBM with an even longer range: the Hwasong-15 (KN22). The two-stage, liquid-fuel missile was launched from a nine-axle transporter erector on a highly lofted trajectory to nearly 4,500 kilometers, which indicates a maximum range on a normal trajectory with a light payload of approximately 13,000 kilometers, sufficient to potentially target most of the

United States (Wright 2017c). The National Air and Space Intelligence Center lists the range of the Hwasong-15 to be upwards of 12,000 kilometers (National Air and Space Intelligence Center 2020, 29). However, it is important to note that heavier payloads—including nuclear warheads—would significantly decrease the missile's range. Hwasong-15 ICBMs were displayed during North Korea's October 2020 military parade (NK News 2020), but not in the February 2023 military parade.

The Hwasong-17 (KN28) ICBM was first displayed at the October 2020 parade (Panda 2021). The two-stage, liquid-fuel missile was shown on an 11-axle TEL, and independent analysts assessed that the missile was significantly larger than other North Korean ICBMs, with a diameter possibly ranging between 2.4 and 2.5 meters and a length of roughly 24 to 25 meters (Elleman 2020; La Boon 2020; Lewis 2020).

On March 24, 2022, North Korea conducted a test launch that it claimed was the first test of the Hwasong-17. However, an *NK News* analysis of the launch video

released by North Korea suggested that the missile may have been tested on March 16 but failed, and that the missile tested may have been a Hwasong-15 instead—an assessment confirmed to the *Washington Post* by an unnamed US official (Ye Hee Lee 2022; Zwirko 2022). It appears instead that the first successful test-flight of the Hwasong-17 took place on November 18, 2022, making the missile the largest road-mobile, liquid-propellant missile ever tested (Panda 2022a). North Korea claims to have successfully flight tested the Hwasong-17 again in March 2023 (KCNA 2023d). During a February 2023 missile parade, North Korea displayed at least 11 Hwasong-17 ICBMs on 11-axle TELs (Panda 2023b).

During the same missile parade, North Korea revealed the most significant recent advancement in its ICBM capabilities: its first three-stage solid-fuel Hwasong-18 ICBM. The country demonstrated substantial progress on solid rocket motors in December 2022 with its first static test of a solid-fuel engine (Johnson 2023). State media announced that North Korea conducted the first successful flight test of the Hwasong-18 on April 13, 2023, after which Kim Jong-un said that the missile will “greatly reinforce the components of our strategic deterrent, rapidly increase the utility of the nuclear counterattack posture and innovate the practicality of the offensive military strategy” (Zwirko 2023b).

North Korea conducted a total of three flight tests of the Hwasong-18 in 2023, the second and third occurring on July 12 and December 18, respectively (Panda 2023a; United Nations 2024). The third launch took place over three kilometers away from the concrete pad where the first two launches were conducted, demonstrating the relative mobility of the missile (United Nations 2024). Three consecutive successful launches and state media’s reference to the third launch as a “launching drill of an ICBM unit” likely indicate that the Hwasong-18 ICBM is in the process of being integrated into the armed forces (KCNA 2023a).

Several US and South Korean officials have stated that North Korea has not yet publicly demonstrated an operationally functioning reentry vehicle that can protect a warhead during reentry through the Earth’s atmosphere when delivered at intercontinental range in a normal trajectory. However, many experts assess that there is no significant barrier to building a working reentry vehicle, and that doing so is likely to be within North Korea’s growing technological capabilities (Hecker 2017; Wright 2017h).

North Korea’s ability to deploy large numbers of heavy long-range missiles depends on its ability to procure or indigenously produce launchers for those missiles. In the past, North Korea has sourced its heavy

launchers from Russian, Belarusian, and Chinese companies, and imported them under the guise of civilian applications (Hanham 2012; Schiller 2012). In particular, the Chinese WS51200 lumber truck forms the basis for many of North Korea’s TELs.

Recently, North Korea has had apparent significant success with its indigenous production of heavy launchers for its longer-range missiles. In October 2020, the country displayed a new 11-axle TEL for its new Hwasong-17 ICBM, which the UN Panel of Experts suggested was manufactured inside North Korea (United Nations 2021a, Annex 10). At least 11 of the launchers were visible during North Korea’s February 2023 military parade, suggesting a substantial production capability (Panda 2023b). If North Korea can now mass-produce heavy launchers for its ICBMs, there would be significantly fewer constraints on the number of long-range missiles that the country can operate.

At the same time, these types of heavy, wheeled launchers would be limited to traveling on high-grade roads. For North Korea’s liquid-fueled ICBMs, the launchers would also have to travel in a convoy with fuel trucks, support vehicles, and possibly a loading crane—all of which would make it significantly easier for adversarial reconnaissance to spot the systems well in advance of launch. (See also Figure 3).

Sea-based nuclear-capable missiles

Over the past decade, North Korea has worked to develop an increasingly sophisticated sea-based nuclear deterrent. Since its first flight test of a nascent submarine-launched ballistic missile (SLBM) capability in 2015, North Korea has publicly shown nearly 10 different sea-launched delivery systems that it has characterized as nuclear-capable, including ballistic missiles, cruise missiles, and unmanned underwater vehicles.

Submarine-launched ballistic missiles

The majority of North Korea’s SLBMs are part of the Pukguksong family of missiles (also spelled as Pukkuksong and Bukkeukseong), or “Polaris.” As of mid-2024, at least five versions of Pukguksong missiles have been developed, although most of these variants have likely not been deployed. Given the iterative designs, lack of recent tests, and scarcity of launch platforms, we assess that the earliest variants were likely intended to validate key technologies needed to develop more sophisticated missiles. North Korea’s family of sea-based ballistic missile designs demonstrate progression toward a deployable missile (Table 2).



North Korea's indigenously-modified WS51200 ICBM transporter-erector-launcher (TEL) variants FAS

Many of North Korea's TELs are based on the Chinese WS51200 Lumber truck. North Korea imported six of the vehicle chassis in 2011 and indigenously added erectors and other specialized equipment to launch ICBMs. The Hwasong-14 is launched from a slightly modified version with the original 8 axles. Newer variants for the Hwasong-15 and -18 contain an additional 9th axle and modified cabs. The Hwasong-18 TEL includes a canisterized erector-launcher.

Figure 3. Evolution of North Korea's missile launchers. (Credit: Federation of American Scientists).

Table 2. North Korea's evolving sea-based ballistic missiles.

Missile	Date first shown	Date of most recent flight test	Iterative design notes
Pukguksong-1	May 2015	August 2016	North Korea's first SLBM, featuring a two-stage design, elliptical nose cone, and relatively short range (approximately 1,250 kilometers). Later versions included grid fins.
Pukguksong-3	April 2017	October 2019	Incremental improvement on Pukguksong-1, with a similar diameter but longer length, implying increased range (maximum range estimated to be between 1,900 and 2,500 kilometers). Also includes a shorter, blunter fairing.
Pukguksong-4	October 2020	N/A	Iterative design with similar fairing and diameter (or possibly slightly wider) to the Pukguksong-3, with slightly reduced length. Paraded version included the suffix "人," implying its status as a sea-launched system.
Pukguksong-5	January 2021	N/A	Similar design and diameter to Pukguksong-4, but longer with a new, ogival nose cone. Paraded version also included the suffix "人."
Pukguksong-6? (not confirmed)	April 2022	N/A	North Korea's longest, widest SLBM to date, featuring a similar nose cone design to the Pukguksong-5.

Abbreviations used: SLBM: submarine-launched ballistic missile.

North Korea is clearly iterating upon its SLBM design, especially with regards to the airframe length and diameter, motor size, and nose cone shape. We assess that rather than deploying multiple Pukguksong variants, North Korea eventually intends to settle upon a standardized SLBM design. As with other North Korean missiles, speculations about a multiple reentry vehicle capability seem premature at this stage.

North Korea also appears to have developed a "new type" of smaller SLBM which appears to bear similar characteristics to North Korea's newer SRBM designs, particularly the KN23 (Xu 2021). The missile, which name has not been officially announced, was revealed during North Korea's "Self-Defence 2021" exhibition in October 2021 and flight-tested the following week to

a range of nearly 600 kilometers. North Korea subsequently announced that the test demonstrated the missile's "flank mobility and gliding skip mobility" (Naenara 2021). The same type of missile may have also been tested on May 7, 2022; however, it is unclear whether the test was successful (Japanese Ministry of Defence 2022b).

The rapid development of North Korea's sea-based missile program has not yet been matched by its development of launch platforms. Until late 2023, North Korea only had a single submarine that could launch ballistic missiles—the Gorae-class (Sinpo) experimental submarine with a single launch tube, known as 8.24 *Yongung* (Naenara 2021). In September 2023 North Korea commissioned a redesigned variant of its legacy

Romeo-class submarine—named the *No. 841 Hero Kim Kun Ok*—that can accommodate up to 10 vertical-launch ballistic missiles (four large-diameter missiles and six smaller missiles). The submarine is referred to by North Korean state media as a “tactical nuclear attack submarine,” referring to its ability to launch nuclear-capable missiles, rather than to its method of propulsion (diesel-electric) (KCNA 2023b). During the launch of the *No. 841 Hero Kim Kun Ok*, Kim Jong-un noted the need to “push forward with the nuclear weaponization of the Navy in the future,” indicating that such a deployment had not yet taken place (KCNA 2023b). In his speech, Kim Jong-un also announced “the plan to convert all existing medium-sized submarines into attack submarines equipped with tactical nuclear weapons” (Rodong Sinmun 2023). Throughout the first half of 2024, satellite imagery indicated that a new construction campaign to build additional submarines had begun (Liu, Makowsky, and Ragnone 2024). The addition of several mobile nuclear-capable sea-based delivery systems to North Korea’s arsenal would complicate efforts to continuously track North Korea’s nuclear launchers.

Submarine-launched cruise missiles

North Korea is developing a new submarine-launched cruise missile, known as Pulhwasal-3-31. The system has been labeled a “strategic cruise missile”—implying a nuclear-capable status—and the Korean state media press release described the test taking place in the context of the “nuclear weaponization of our navy” (Rodong Sinmun 2024). During a test in January 2024, the two missiles reportedly flew for just over two hours (Rodong Sinmun 2024). Although the “Pulhwasal” designation would suggest that the missile is part of the same family as North Korea’s land-based Hwasal-1 and Hwasal-2 cruise missiles, North Korean state media has not yet released high enough resolution images of the Pulhwasal-3-31 to confirm the technical similarities.

Other sea-based weapons

North Korea appears to be developing an underwater weapon system, the mission of which has been described by North Korean state media as “stealthily infiltrat[ing] into operational waters and mak[ing] a super-scale radioactive tsunami through [an] underwater explosion to destroy naval striker groups and major operational ports of the enemy” (KCNA 2023c). While this description sounds like Russia’s “Poseidon” unmanned underwater vehicles (UUV), the weapon system itself bears

significant differences. Notably, it is not nuclear-powered, does not travel at high speeds, and likely has a much shorter range, therefore limiting its utility to a retaliatory weapon rather than a first-strike system.

The system, called “Haeil,” is apparently under continuous development, and North Korea claims that it underwent more than 50 shakedown tests between 2021 and 2023, with several tests lasting for dozens of hours at a time (KCNA 2023c). There are at least three known variants of the Haeil system—Haeil-1, Haeil-2, and Haeil-5-23—however, it remains unclear which of these, if any, will ultimately be deployed. It is possible that all Haeil variants that have been publicly displayed are technology demonstrator programs, and that a future version will have a different designation.

The Haeil was notably one out of eight delivery systems included in a graphic promoting a common warhead, known as the “Hwasan-31.” Developing interoperable warheads is rife with challenges, however, given necessary differences in sizes, shapes, masses, centers of gravity, and many other technological factors. It therefore seems unlikely that the Haeil UUV would carry the exact same warhead as North Korea’s tactical SRBMs and strategic cruise missiles.

Land-attack cruise missiles

North Korea appears to be developing a series of land-attack cruise missiles (LACMs)—the Hwasal-1 and Hwasal-2—that have been tested at least a dozen times as of mid-2024. Although North Korea has described these LACMs as “strategic weapons,” it has also indicated that the missiles have been deployed with units that have been tasked with carrying out tactical nuclear strikes (KCNA 2023c).

Despite the apparent connection to North Korea’s nuclear program, it is likely that these missiles also have conventional strike roles. In January 2021, for example, Kim Jong-un stated that the cruise missiles’ conventional warheads are “the most powerful in the world” (Rodong Sinmun 2021). And, in April 2024, North Korea claimed to have tested a “super-large” warhead for the Hwasal-1 Ra-3 (an apparent variant of the Hwasal-1 that may be slightly longer than the original design) which, based on Kim Jong-un’s previous statement and the type of test conducted (a flight test evaluating the “power” of the warhead), is likely to be conventional (*Voice of Korea* 2024).

North Korean state media has released images of the missiles, indicating that they might include a terminal guidance system and could be launched from TELs carrying five missiles (Xu 2021). The Hwasal-2 appears to feature a longer air intake than the Hwasal-1.

Notably, during the first tests, South Korean news sources subsequently reported that neither South Korea nor the United States was aware of the LACM launches until after the announcement in North Korean state media (Lee and Park 2021). Given that these systems are designed to circumvent radars and missile defense systems by flying at lower altitudes on maneuverable trajectories, they could offer North Korea a new and unique capability to attack regional targets.

Notes

1. Liquid nitrogen is used as part of the uranium enrichment process, particularly within the context of cold trapping uranium hexafluoride.
2. According to the IAEA, five reprocessing campaigns have taken place since the 1994 Agreed Framework. Each lasted for four to five months in 2003, 2005, 2009, 2016, and 2021. The steam plant operated for a shorter period of around two months in 2018, but the duration and timing of activities were indicative of waste treatment or maintenance (IAEA 2022).
3. For an insightful review of North Korea's hydrogen bomb claim, see Kelley and Hansen (2016).
4. For assessments of North Korean warhead designs and production capacity, see Albright (2017), Hecker (2017), Jones (2017), and Kelley and Hansen (2016).

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