Can a North Korean ICBM Be Prevented?

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In January 2011, U.S. Secretary of Defense Robert Gates mused that “North Korea will have developed” an intercontinental ballistic missile (ICBM) by 2016, with the caveat that the arsenal would be small with limited operational capability.

Five years later, in 2016, there still is hope that the United States and its Asian allies can prevent North Korea from developing a nuclear-capable ICBM. Pyongyang, however, is not cooperating. North Korea conducted its fourth nuclear test in January, with Kim Jong Un boasting that it had exploded a hydrogen bomb. A month later, it successfully lofted a satellite into orbit using a large, long-range rocket. Then in March, North Korea unveiled a mock-up of a miniaturized nuclear bomb and performed two separate missile-related ground tests. The first test simulated the conditions a warhead would experience during re-entry into the atmosphere to evaluate the thermal protection technologies. The other was a stationary firing of a large, solid-fueled rocket motor.

In April, North Korea tested a previously unseen liquid-propellant engine. In response to Pyongyang’s provocative actions, the UN Security Council enacted the most stringent sanctions to date on North Korea. Perhaps most importantly, China seems to have lost its patience with the Kim regime and has promised to enforce export controls along its heretofore porous border with North Korea. At this point, it is not clear if these actions would be enough to forestall the North’s development of long-range missiles. The international community might need to be more creative and proactive.

North Korea has limited experience developing ballistic missiles. Its Scud and Nodong missiles were likely imported from Russia. The Unha satellite launcher is an indigenous design and was assembled in North Korea, but its main engines were likely imported. If North Korea builds its own ICBM, it will probably rely on engines fabricated elsewhere. If Pyongyang is already in possession of the engines needed for an ICBM, then political restraint, money, and time are the only hurdles standing in the way of a capacity to threaten the U.S. mainland, short of military action by a foreign power. Fortunately, North Korea’s inexperience with missile development will slow its progress, leaving the international community with an extra year or two to identify and implement new policies aimed at slowing Pyongyang’s pursuit of new nuclear delivery capabilities.

Background

North Korean efforts to acquire ballistic missiles likely began in the mid-1970s, when three parallel routes were initiated. One pathway sought to clone the Soviet-designed FROG, or Luna, long-range artillery rocket. The second program explored adapting surface-to-air missiles for use as ballistic missiles. Both approaches were abandoned when it became clear that neither would yield the short- and medium-range ballistic missile systems Pyongyang desired. On the third route, North Korean engineers joined a Chinese initiative to develop a liquid-propellant ballistic missile called the Dongfeng-61 that was to have a range of 600 kilometers. Domestic politics in Beijing caused China to abandon the project in 1978, after just one year.

Having failed to develop the necessary technologies, North Korea turned to foreign sources from which it could import ballistic missile technology. The effort focused on acquiring Soviet-built, short-
range Scud-B missiles and the accompanying support vehicles and equipment. Poor diplomatic relations between Pyongyang and Moscow during the mid-1970s drove North Korea to seek an alternative supplier of Scud-B technology. Egypt proved willing and delivered to North Korea missiles, equipment, and transporter-erector launchers (TELs) sometime between 1976 and 1981.6

The history of North Korean ballistic missile development after the initial acquisition of Scud-B technology has become a source of debate. Conventional wisdom argues that North Korea began the process of reverse-engineering Scud missiles acquired from Egypt and, in April 1984, test-launched a Scud-B, which was rebranded as the Hwasong-5.7 After this initial flight test, North Korea launched up to five additional Hwasong-5 missiles; three of these launches were successful.8 The Hwasong-5 can carry a 1,000-kilogram warhead a distance of 300 kilometers.

In the late 1980s, North Korea began to develop a modified Hwasong-5 missile, the Hwasong-6, which is a clone of the Soviet-designed and -built Scud-C. Just as the Scud-C has technological similarities with the Scud-B, the Hwasong-6 uses the same engine, guidance and control systems, and fuel-oxidizer combination as the Hwasong-5. The two versions are identical in length and diameter, but the warhead mass of the Scud-C/Hwasong-6 is approximately 270 kilograms less than that of the Scud-B/Hwasong-5. Furthermore, the Scud-C/Hwasong-6 uses a common bulkhead to fit additional propellant into the airframe, which, when combined with the lighter warhead, increases the range to 500 kilometers.

The limited number of flight tests during development of the Hwasong-5 and -6, the near perfect replication of the Scud-B and -C performance and reliability characteristics, and the rapid deployment of the Hwasong systems cast doubt on claims that they were reverse engineered from a few sample missiles acquired from Egypt or elsewhere. Available evidence argues convincingly that North Korea more likely purchased Soviet-made Scud-B and -C missiles or acquired a licensed production line to manufacture them (see box below).9

### Reverse Engineering: Reality or Myth?

Scud-B missiles exported by North Korea, some as late as 2002,1 are identical in appearance to those produced by Russia. Further, Scud-B missiles said to be of North Korean origin have performance and reliability characteristics that duplicate perfectly those of the Russian versions.2 The tightly compressed timeline associated with the development of a reverse-engineered missile, the immediate success achieved during the initial flight tests of the replicated Scud, and the domestic deployment and foreign sales of newly produced systems prior to the completion of performance and reliability testing conflict with the common view that North Korea established a self-sufficient manufacturing line.

Historical evidence indicates that North Korea would have faced extensive challenges reverse-engineering the missiles. There is no confirmed instance of a country successfully reverse-engineering an entire ballistic missile system. After five years of effort, the Soviet Union’s attempts to copy the German A-4 (V-2) ballistic missile yielded the R-1, which underperformed in comparison to the original. Furthermore, unlike the North Koreans, the Soviets had access to the original design and production documentation, the German manufacturing line, and many of the German engineering experts. Similarly, China tried to reverse-engineer the Soviet-built R-2 and R-5 missiles. Even with access to design and production documents and collaboration with Soviet scientists, China needed more than five years to successfully flight-test prototype missiles, all of which exhibited inferior performance when compared to the original R-2 and R-5. In another example, Iraq’s effort to duplicate the engine used by the Soviet-built SA-2 air defense missile largely failed, despite having used between 50 and 100 reference engines to extract measurements and other key design features. North Korea possessed only a small collection of Scud-B missiles from which to derive the necessary information.

As another hypothetical route to development of the Hwasong-5 and -6, North Korean acquisition of a licensed production line for Scud-type missiles also is belied by available evidence, according to skeptics. The Soviet experience in trying to leverage the German manufacturing equipment for the A-4 missile indicates that replicating a production line can prove difficult. The paucity of flight tests to validate the missiles produced in North Korea is also at odds with experience elsewhere.
Random testing of missiles being produced is one of the hallmarks of any new or even existing manufacturing line.

As with the reverse-engineering hypothesis, some experts argue that North Korea scaled up the Scud-B to create the Nodong, a medium-range missile, in the late 1980s, possibly in collaboration with technicians from the Makeyev Design Bureau, the Soviet company responsible for production of the Scud-B and the developer of submarine-launched ballistic missiles (SLBMs) for the Soviet navy. Media reports that Makeyev scientists were detained in late 1992 en route to Pyongyang are consistent with this hypothesis.

The role these scientists were to play in North Korea is not known with certainty. They might have been sent to aid in the design of a larger missile and help commission a production line, but this conflicts with the history of events in North Korea. Indeed, North Korea is believed to have attempted a flight test of the Nodong in 1990, although scorch marks left on the launch pad suggest the launch failed badly. Moreover, Pyongyang initiated discussions with possible foreign buyers of the Nodong in 1991 and hosted delegations from Pakistan and Iran in May 1993, where they witnessed a successful launch of a Nodong. Although one cannot discount the possibility that the Makeyev experts detained in 1992 were preceded by others, the rapid pace of development; a flight-test program limited to two firings, one of which failed; and the confidence Iran and Pakistan indicated by their commitment to make the purchase suggest otherwise. So too does the basic design of the Nodong. As noted by German missile experts Robert Schmucker and Markus Schiller, the Nodong’s dimensions are identical to those of the nuclear version of the Scud-B, not the conventional version. The nuclear version of the Scud-B is roughly 20 centimeters longer than the version designed to carry a conventional, high-explosive warhead. The additional length is found at the base of the nuclear warhead, where it is connected to the missile’s airframe. The Nodong shares this feature with the nuclear Scud-B, but North Korea never had access to that version of the missile.

Available evidence from the North Korean program, when combined with the history of missile development elsewhere, indicates that arguments offered by skeptics of the reverse-engineering process are likely correct. If this is the case, North Korean engineers accumulated very little experience designing, developing, and producing new missiles indigenously prior to the mid-1990s. Recent satellite launches, which employ a three-stage rocket of domestic design, albeit with engines of Soviet design and likely Russian manufacture, indicate that North Korea has begun the process of establishing the skills needed for indigenous design, development, and assembly of more-capable missiles. Yet, contrary to popular concerns, these satellite launch activities will not provide North Korea with a shortcut for developing a viable and reliable long-range ballistic missile.

ENDNOTES


2. Ibid., p. 24.


Satellite Launch Rockets

Mock-ups of the large rockets North Korea would eventually use in its attempts to loft satellites into low-earth orbit were first spotted by U.S. intelligence in February 1994 at the Sanum-dong research center outside Pyongyang. A little more than four years later, in August 1998, North Korea used the Taepo Dong-1, a three-stage rocket launched from Musudan-ri. The launch failed shortly after the third stage separated from the second.

Eight years after the Taepo Dong-1 firing, in July 2006, North Korea launched a much larger rocket, the Taepo Dong-2. The rocket exploded just 42 seconds into its flight; its intended mission therefore remains a mystery, as does its configuration. There are no publicly available photographs or videos of the launch. Then, on April 5, 2009, North Korea attempted to boost a small satellite into orbit using a three-stage Unha-2 rocket from the Musudan-ri launch facility. It failed after second-stage burnout, with remnants of the satellite and third stage of the rocket falling into the ocean roughly 3,200 kilometers from the launch site.

North Korea again attempted a satellite launch on April 12, 2012, using the Unha-3, a slightly modified version of the Unha-2. The new rocket was fired from the Sohae facility, situated on the western shores of the Korean peninsula. It failed roughly 100 seconds into first-stage operation. Finally, on December 12, 2012, the Unha rocket successfully placed a satellite into orbit, although the satellite did not operate as designed. North Korea successfully repeated the launch in February 2016, when it placed the Kwangmyongsong-4 satellite into orbit. The new satellite reportedly weighed 200 kilograms, about twice as much as the previous one. The satellite continues to orbit the Earth at an altitude of roughly 500 kilometers.

With the exception of the Taepo Dong-2 test-fired in July 2006, which exploded too soon after liftoff to determine its trajectory and mission, all of the large rockets launched by North Korea were designed to maximize performance as a satellite launcher. In each case, the Taepo Dong-1 and Unha rockets flew on trajectories fully consistent with a satellite launch. Furthermore, all employed low-thrust engines in the upper stages, which would not provide sufficient power if the rocket were to fly on a ballistic missile trajectory. Gravity losses resulting from the long-burning, low-output engines would rob the Unha rocket of 1,000 kilometers or more of range if used as a surface-to-surface missile.

The Unha-2 or -3 could serve as a springboard for the development of an ICBM, but the history of long-range missile development by other countries, including the Soviet Union, the United States, China, and France, indicates that satellite launch activities have limited impact on missile programs. No country has converted a satellite launch rocket into a long-range ballistic missile. China ran parallel programs, but it still conducted a full set of flight tests to validate the performance and reliability of the long-range missiles that are part of the Dongfeng series. Nonetheless, North Korea could attempt to transform the Unha rocket into a long-range missile.

A militarized version of the satellite launch rocket would require a significant redesign, including new second and third stages. If done with existing options available to North Korea, the resultant missile could deliver a 1,000-kilogram warhead to a range of 10,000 kilometers. The transformation, however, would entail many challenges. First, the new missile would have to be flight-tested along a ballistic missile trajectory to include a warhead that survives re-entry into the atmosphere at speeds of roughly seven kilometers per second. A single flight test would not be sufficient; a series of tests...
would be required to verify the reliability and performance of the missile operating under a variety of conditions. If North Korea succeeded in developing an ICBM based on the Unha rocket, it would find that the ICBM would be too cumbersome for deployment on mobile platforms. In principle, Unha-based ICBMs could be placed in silos, but unlike China, Russia, and the United States, North Korea is small, making it more difficult to hide silo locations from U.S. surveillance satellites. Furthermore, the long preparation and fueling times would leave the missile exposed to pre-emption for extended periods. Nonetheless, North Korea could pursue this option as a more feasible alternative to developing a mobile ICBM. Western observers would receive advance notice of a new capability because the flight trials would take several years and would be detected by intelligence agencies.

The Musudan

The Musudan, as it is named by U.S. intelligence agencies, had been rumored to be under development in North Korea since the mid-2000s. Some reports contend that the missile was initially deployed by North Korea as early as 2003, with others suggesting 2006. The missile reportedly appeared in a military parade in April 2007, but no photographs were made public. In October 2010, a handful of Musudan mock-ups carried on TELs were unveiled during a parade broadcast by state-run television. The mock-ups show a missile similar in appearance to the Soviet-era R-27 (SS-N-6, Serb) submarine-launched ballistic missile (SLBM) although the North Korean version is longer. Other minor differences, such as the change in the position of the cable duct that runs along the missile’s outer frame, are visible.

The technologies used by the Soviet R-27 are quite sophisticated relative to the Scud missiles North Korea has maintained and operated for the past three decades. The R-27 airframe and propellant tanks are made using a chemical etching process to provide it with considerable strength while remaining lightweight. It is unclear if North Korea has the technical knowledge, experience, and industrial infrastructure to replicate the processes needed to fabricate the airframe. Even if Pyongyang’s production engineers have mastered the etching process, additional structural elements would be needed to accommodate the added length of the Musudan and to ensure that the missile, which was designed to be housed in the relatively benign, temperature-controlled environment of a submarine launch tube, survives the rigors of deployment on a road-mobile TEL. Finally, the R-27 engine is a closed-cycle, high-pressure system, very different from and far more advanced than the low-pressure, open-cycle engines North Korean engineers have employed to date. If North Korea has struggled to replicate the Scud or Nodong engines, it would be almost impossible for it to master production of the R-27’s main engine.

Although mock-ups of the Musudan have been seen on numerous occasions, there is no public evidence that North Korea has conducted test flights of this missile. Yet, reports continue to suggest that the Musudan has been deployed to missile bases in Yangdok in South Pyongan province and Sangnam-ri, in North Hamgyong province. The Musudan missiles showcased during parades in Pyongyang are not copies of the original R-27 design, suggesting that North Korea has incorporated some changes. Like any new system, it therefore must be flight-tested to validate reliability and performance. Without undertaking the necessary developmental tasks, including flight trials, North Korea must accept considerable risk that it will not work if launched.

China, Russia, the United States, and other countries would not deploy a strategic weapon without first verifying its capabilities. Even Iraq, in the midst of its war with Iran in the 1980s, conducted 10 flight tests of a modified Scud-B, the al-Hussein missile, over approximately two years before firing them on Tehran and other cities. That North Korea has not test-flown the Musudan hints that Pyongyang either does not possess R-27 missiles and its major components or that it is willing to accept very poor reliability of the modified missile. The April test-firing of what appears to have been a pair of main engines from the R-27 at the vertical stand at the Sohae facility suggests that Pyongyang possesses some Soviet-made R-27 engines. If North Korea has such engines, its limited experience developing missiles indigenously and the typical imperfections contained in any new missile design will present challenges. Without flight-testing Musudan missiles, North Korea would run the risk that fewer than half of those missiles would reach their assigned targets.

North Korean ICBMs
During an April 2012 military parade in Pyongyang, North Korea unveiled a three-stage missile carried on a 16-wheel TEL. A more detailed and slightly modified mock-up appeared in another military parade a year later. Dubbed the KN-08 and sometimes referenced as the Hwasong-13, the missile is very likely powered by liquid-propellant engines, as evidenced by the small fueling and draining ports positioned along the airframe’s length. Engineering reconstructions of the missile by Western experts suggest that the KN-08 first stage employs a cluster of four Scud engines with four small steering engines used to control the missile’s flight. The second stage is powered by the main and steering engines of the R-27, if indeed North Korea has them. Steering engines, which are also employed by the Unha rocket, are likely found on the third stage. If this reconstruction is accurate, the KN-08 could have a range of 7,500 to 9,000 kilometers when carrying a warhead and re-entry vehicle weighing between 500 and 700 kilograms. In principle, it could reach the west coast of the United States.

There is little doubt that North Korea has ambitions to field a viable ICBM fleet. The KN-08 and KN-14 currently are experimental prototypes. North Korea has tested nosecone replicas under Scud engine exhaust, simulating re-entry by placing a nosecone replica under the exhaust plume of a Scud engine to simulate re-entry conditions. Such tests, however, are not a substitute for testing under real conditions. Further, the dimensions and geometry of the nosecone tested do not match those of any of North Korea’s long-range missile mock-ups.

During a 2015 parade, North Korea unveiled what appears to be a two-stage, long-range missile, subsequently identified as the KN-14. The KN-14 mock-up shares many of the external features found on the Soviet R-29R SLBM. The R-29R (SS-N-18 Mod 1, Stingray) is a product of the Makeyev Design Bureau, the Russian entity with which North Korea allegedly has worked in the past. It is unclear, however, when and how the R-29R would have been transferred from Russia to North Korea because the missile is still deployed on Russia’s Delta III (667BDR) submarines and was test-fired by the Russian navy as recently as October 2012. It is difficult to imagine that Russia would export a strategic weapon that is currently serving on active duty. The range-payload capabilities of KN-14 are unknown or highly speculative.

Regardless of the authenticity or success of the re-entry technology test, the fact that it was performed indicates that North Korea is pursuing the engineering activities needed to develop a functional ICBM. North Korea will need more than a handful of years of additional developmental actions, including multiple flight tests, before it has a viable, long-range nuclear capability. Satellite launches using the Unha rocket are not a substitute for KN-08 or KN-14 tests. Unha flights will contribute to the development of an ICBM but not decisively.

As with the Musudan, North Korea could elect to use an unproven missile under emergency conditions. The failure rate of first- and second-generation, long-range missiles developed by other countries during initial flight trials was greater than the success rate, and each of those countries had far more experience designing and developing ballistic missiles prior to their respective long-range missile flight trials than North Korea now does. It is safe to assume that the KN-08 and KN-14 will not succeed more than half the time without test flights. More likely, only one-third to one-quarter of all launches under emergency conditions will succeed. One or two test launches would improve North Korea’s odds of success but not substantially.

Latest Developments

In addition to its quest to develop a long-range nuclear strike capability, North Korea has initiated two new programs aimed at diversifying its strategic delivery options.

The first project was initially detected in late 2014 by Joseph Bermudez and the 38 North website when they spotted equipment commonly used to develop an SLBM at a navy yard in Sinpo, North Korea, on commercially available satellite imagery. Months later, on May 9, 2015, North Korea aired photographs of Kim Jong Un witnessing first hand a test of a sea-launched missile. Photographs from the test show a missile emerging from underwater and its main engine igniting, although the engine did not operate for more than a few seconds. Shutting down the engine shortly after ignition is a common practice when the primary test objective is focused on the launch-tube ejection system. Prudently, North Korea did not use a submarine for the test, instead electing to employ a submergible barge with a launch tube, towed by a surface ship. From its outward appearance, the missile appears to be a variant of the Musudan, although the exhaust plume seen in the photographs is not consistent with the propellant combination employed by the R-27 and the
presumed Musudan.

Additional tests of the system have been reported in the media, a clear indication that North Korea aspires to develop an SLBM capability. If North Korea pursues the engineering steps at a healthy pace, it could have an operational system in about five years. Historically, however, projects undertaken by other countries to develop an SLBM have encountered unanticipated technical challenges that extended the timeline, sometimes more than doubling or tripling the development schedule. North Korea's limited experience developing missiles domestically likely will prolong the developmental program beyond what other countries have encountered. The added time needed by North Korea to operationalize the capability provides the Japanese, South Korean, and U.S. navies a cushion in time to hone their respective anti-submarine warfare skills to be able to confidently detect and track North Korea's underwater systems.

The second developmental effort appears to be focused on mastering the production of large, solid-propellant rocket motors. In late March 2016, North Korea released photographs of Kim attending a ground test of such a motor. Although the size of the motor is difficult to determine using the available pictures, it is likely about 1.25 meters in diameter and roughly three meters long. Its size indicates that it is designed to be the upper stage of a larger missile.

Several possibilities for its planned use come to mind. North Korea might be attempting to develop a solid-fueled version of the Nodong missile, much like what Iran has attempted to do with the two-stage, medium-range Sajjil. Solid-fueled missiles are easier to deploy on road-mobile platforms than liquid-fueled missiles are, and they require less logistical support for mobile operations. Because they do not require fueling prior to launch, they can be fired more quickly than their liquid-propellant counterparts. Moreover, the greater density of solid propellants reduces the overall size of the missile, which is preferable for mobile deployment.

If this is what North Korea has in mind, it will require many years to perfect and field a medium-range missile powered by a solid propellant. Iran has been developing the Sajjil for more than a decade, with an initial ground test of the first-stage motor taking place in 2005. Flight tests began in 2008. Yet, technical difficulties appear to have slowed the Iranian effort, as it has not launched a Sajjil since 2011. North Korea will likely encounter many challenges as well, suggesting that it will not begin deploying a mature design to the military before 2022 at the earliest.

The upper-stage motor might also be intended for use as the third stage of a militarized version of the Unha rocket. The current configuration of that rocket is optimized for satellite launches, not as a ballistic missile. North Korea might seek to replace the second and third stages of the Unha with higher-thrust, shorter-action time stages that would improve the range capabilities of the rocket by avoiding the gravity losses, and thus range reductions, resulting from the use of underpowered stages. The modification would require flight testing, although the flight trials could be shortened marginally because of North Korea's experience working with the first stage, which is not likely to undergo significant modifications. Even so, a flight-test program would likely take at least two years and more likely three to five.

In the near to medium term, North Korea will not benefit hugely from using solid-propellant technologies. In the longer term, however, the strategic significance could be consequential. Mastering the technology would enable Pyongyang to field reliable and capable long-range missiles on road-mobile launch platforms, making them more difficult to destroy before they are fired. On the other hand, mastering the art of producing a solid-propellant motor is expensive and time consuming. North Korea will struggle mightily to produce a flight-proven, solid-fueled ICBM before 2030.

Preventing an ICBM

Activities over the past five years and perhaps much longer suggest that North Korea is edging toward the goal of creating a nuclear-armed ICBM. Underground nuclear tests, satellite launches, and the launching of Nodong missiles demonstrate capabilities, a key pillar of a deterrence posture.
Unveiling mock-ups of the Musudan, KN-08, and KN-14 during military parades and showcasing a mock-up of a small nuclear device are more suggestive than real for now.

It should be remembered, however, that North Korea placed mock-ups of the Taepo Dong-1 and -2 rockets in the open for U.S. intelligence satellite to see in 1994. Four years later, North Korea launched a Taepo Dong-1 rocket in an attempt to orbit a small satellite. It took a dozen years before a Taepo Dong-2 was test-launched and 18 years until the Unha, a variant of the Taepo Dong-2, successfully lofted a satellite into orbit. It seems reasonable to project that North Korea could test-launch a KN-08 or KN-14 before 2020 and have it available for emergency operations. In other words, it could be available for use if the Kim regime’s hold on power is directly threatened by a foreign government.

More-recent revelations, including ground tests of re-entry technologies and solid-propellant motors, appear to serve as a warning to Pyongyang’s adversaries that North Korea is serious about its pursuit of a viable strategic deterrent capacity. These tests also provide preliminary technical data to support full development of the capability. The strategic significance of these tests is incremental at best. Yet, North Korea undeniably is inching forward and will likely succeed in fulfilling its ambitions over the long term.

The United States and the international community have a limited capacity to inhibit North Korea’s aspirations to build an ICBM. Two immediate actions, however, could impede Pyongyang’s endeavors with regard to long-range missiles. First, if North Korea can be dissuaded or prevented from flight-testing the KN-08 or KN-14 or a variant of the Unha that has been optimized for ballistic missile missions, the reliability of any of these missiles will remain marginal. If North Korea fields only a dozen or so ICBMs of marginal reliability, the U.S. national missile defense system has a more than decent chance of blocking an attack. Dissuading Pyongyang could come in the form of negotiations or coercion. Prevention would be more difficult, as it could require military action. Ashton Carter and William Perry proposed a similar option in a 2006 op-ed, which argued for destroying a North Korean missile on the launch pad.25 Today, somewhat less-provocative measures are possible, including the use of Aegis Standard Missile-3 interceptors to destroy a missile in the boost, or ascent, phase of flight. Such steps, however, carry greater risk today than in 2006 because North Korea now has nuclear weapons. Nonetheless, the option deserves careful study.

Second, strict adherence to trade sanctions would slow North Korea’s development of large, solid-fueled motors that could be used for long-range missiles. If North Korean engineers and motor producers are unable to establish a reliable and consistent supply of basic solid-propellant ingredients—for example, high-quality aluminum powder and ammonium perchlorate or a similar oxidizer component—from the same manufacturer, they will be severely challenged to master the production of large motors. Iran’s efforts to develop fully the Sajjil medium-range missile appears to have been hampered by UN sanctions that disrupted its supply line of ingredients.26 How much sanctions will set back North Korea’s solid-fuel program depends primarily on China’s willingness to enforce them along its border with North Korea.

Another variable is North Korea’s determination to gain an ICBM capability. If Pyongyang is determined to achieve that goal and is willing to accept the likelihood its long-range missiles will suffer from a high failure rate, the success of either of these two policy options, or anything less than the fall of the Kim regime, will likely be minimal.

ENDNOTES


5. Ibid., p. 130.


9. Ibid., p. 146.


15. In defiance of U.N. sanctions, North Korea attempted to launch a missile on April 15. The flight test failed a few seconds after ignition, when the missile exploded. The missile is widely presumed to have been a Musudan, but no direct evidence has been made available to the public. If it was the Musudan, this would represent its first launch attempt. The cause of the failure is not known. See, Michael S. Schmidt and Choe Sang-Hun, “North Korea Ballistic Missile Launch a Failure, Pentagon Says,” *The New York Times*, April 15, 2016.


23. Elleman, “Prelude to an ICBM?”


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