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ANALYSIS

A post-launch examination of the Unha-2

BY DAVID WRIGHT AND THEODORE A. POSTOL | 29 JUNE 2009

Article Highlights

- The launch vehicle North Korea tested on April 5, the Unha-2, represents a significant advance over North Korea's previous launchers.
- In particular, it would have the capability to reach the continental United States with a payload of 1 ton or more if Pyongyang modified it for use as a ballistic missile.
- However, if key Unha-2's components were acquired from Russia and elsewhere, North Korea's domestic missile development program may be much more limited than commonly assumed.

North Korea tested a launch vehicle called the Unha-2 from its Musudan-ri launch site in North Hamgyong province on April 5 local time (April 4, 10:30 p.m. Eastern Standard Time). Using information that has become available since the test and information from previous tests, we have conducted a technical analysis that leads to a compelling description of the Unha-2 launcher. This analysis suggests both challenges and potential opportunities.

In particular, our analysis shows that the Unha launcher represents a significant advance over North Korea's previous launchers and would have the capability to reach the continental United States with a payload of 1 ton or more if North Korea modified it for use as a ballistic missile.

On the other hand, the Unha launcher appears to be constructed from components that probably weren't manufactured in North Korea. It's likely that these critical rocket components were acquired from other countries, most notably Russia, although likely without the involvement of the Russian government. If these guesses are true, it could mean that North Korea's indigenous missile capability could be significantly constrained if Pyongyang is denied further access to such components.

The April launch. North Korea announced in February that it was preparing the launch of an "experimental communications satellite" named the Kwangmyongsong 2. No details about this satellite are publicly known, but North Korean reports indicated that it was intended to broadcast patriotic songs from low Earth orbit. This would be similar to what the Iranian Omid satellite did earlier this year, and the first Chinese satellite (Dong Fang Hong 1) did in 1970.

The size and mass of the North Korean satellite aren't known. The Iranian satellite was a cube that measured 40 centimeters on each side with a mass of 27 kilograms; the first Chinese satellite was roughly spherical with a diameter of 1 meter and a mass of 173 kilograms. Photos of the satellite North Korea was said to have used in its 1998 launch attempt show a design resembling the Chinese satellite, although the North Korean satellite is thought have had a much smaller mass. Both satellites resembled the U.S. Telstar 1 communication satellite, which was launched in 1962; it had a diameter of 0.88 meters and mass of 77 kilograms.

For the first time, North Korea announced the launch in advance PDF and listed launch hazard zones for aircraft and ships, indicating the areas where it expected the first two stages of the launcher would return to Earth. This indicated the launcher would have three stages, since the final stage would remain in orbit near the satellite after a successful launch. North Korea also announced that it was joining the Outer Space Treaty, a step that may have been intended to reinforce its claim that it was attempting a satellite launch rather than a ballistic missile test. A successful launch would, of course, provide useful information about technical capabilities that could be used for developing a ballistic missile.

The launch was monitored by a range of U.S. and Japanese land-, sea-, and air-based sensors. While the United States hasn't released information about the launch, information on the launcher and the trajectories of the first two stages has appeared in several public sources.

The launch direction was nearly due east, which is consistent with a satellite launch since it allows the launcher to gain maximum speed from the Earth's rotation. But this direction raised concerns in Japan since it carried the second and third stages of the launcher over the relatively sparsely populated northern end of the main Japanese island of Honshu early in flight.

The locations of the splashdown points of the first two stages reported in the Japanese press and by the Japanese Defense Agency indicate that both stages fell within the announced splashdown zones, suggesting that these stages worked essentially as planned. However, both stages apparently landed near the front edges of those zones, which may suggest that the thrust was somewhat lower than expected or that the guidance system didn't place the launcher on the planned trajectory.

The first stage reportedly fell into the Sea of Japan 540 kilometers from the launch site and 300 kilometers from Japan. The second stage successfully ignited and separated from the first stage, carrying the rocket over Japan at an altitude of about 400 kilometers. The only previous time North Korea had demonstrated the ability to separate and ignite an upper stage was during its unsuccessful August 1998 attempt to place a small satellite in orbit with its Taepodong-1 launcher.

Japanese reports state that the second stage splashed down in the Pacific Ocean approximately 3,200 kilometers from the launch site, although one report cites U.S. officials saying that it landed 600-700 kilometers further. The second stage was on a trajectory that reportedly carried it to a maximum altitude of 485 kilometers. (See, for example, this *Chunichi Shimbun* article; this analysis PDF from the Japanese Ministry of Defense; the *Spaceflight Now* article, "North Korean Rocket Flew Further than Earlier Thought"; and this *JoongAng Daily* article.)

The third stage may have separated from the second stage, but it apparently didn't ignite and fell into the Pacific Ocean with the satellite it was carrying, near where the second stage splashed down. If the third stage had ignited, Japanese sensors were in a good position to see it as it passed over Japan.

North Korea's announcement of its launch suggests that it planned for the launcher's engines to burn for a total of 542 seconds, and that it had planned to place the satellite in an orbit of 490 kilometers by 1,426 kilometers. This would require the launcher to reach a speed of 7.88 kilometers per second to insert it into orbit at an altitude of 490 kilometers. Based on our analysis of the launcher, we estimate that the mass of the satellite plus the deployment mechanism and the structure that attached the satellite to the third stage may have been about 300 kilograms.

Analysis of the Unha-2. Combining this information with results of analyses of past tests and computer modeling of the launcher allows us to develop a fairly detailed understanding of the Unha-2. While some uncertainties in missile parameters remain, calculations using this model of the launcher are consistent with all of the known data about the launch and show that it could have placed a satellite with a mass of a few hundred kilograms into orbit at about an altitude of 500 kilometers.

The Unha-2 launcher was expected to be a three-stage variant of the Taepodong-2 missile that North Korea began developing in the 1990s but has never successfully launched. We conclude from our analysis that the second and third stages of the launcher represent significantly more advanced technology than North Korea has launched in the past. We believe that it's extremely unlikely that these technologies were indigenously produced by North Korea.

Pyongyang has released a video showing the launcher shortly before and during launch; these pictures allowed us to determine the relative sizes of the launcher's stages. Assuming the first-stage diameter is 2.4 meters, which is the diameter that has long been discussed for the first stage of the Taepodong-2 missile, fixes the rest of the dimensions. These are shown here PDF. Based on the dimensions of the stages, we can estimate their masses using estimates of the structure mass and the density of the propellant.

Overall, the launcher has a length of roughly 30 meters and a mass of 80-85 metric tons. We believe the first stage uses a cluster of four Nodong engines housed in a single missile casing and sharing a common fuel tank. The Nodong engine is essentially a scaled-up version of the engine used in the Soviet Scud-B missile. This engine is likely of Russian origin.

The video shows the first 20 seconds of the launch. By measuring the distance the launcher moves as a function of time in these videos, we determined the thrust-to-weight ratio of the Unha vehicle at launch. Using estimates of the mass of the Unha launcher, we then estimated the thrust at liftoff generated by the engines.

The sizes and shapes of stages two and three are completely consistent with known stages from other rockets. Both stages appear to use technology that's more advanced than North Korea has used in previous launches. The second stage appears identical to the single-stage Soviet R-27 sea-launched ballistic missile, called the SS-N-6 in the United States, which the Soviet Union first deployed in 1968. There have been reports for years that North Korea had acquired some number of SS-N-6 missiles in the 1990s and was modifying them for use as an intermediate-range missile. Reports also have stated that in 2005 Iran bought 18 SS-N-6 missiles from North Korea.

The SS-N-6 uses liquid fuels (unsymmetrical dimethylhydrazine and nitrogen tetroxide) that are more advanced than those used in the Scud-B; therefore, it has a high thrust for its size. Since it was designed for a submarine, the missile has a compact design with a lightweight aluminum casing; it is reported to have a range of 2,400 kilometers with a 650-kilogram warhead. (For more information about the SS-N-6, see Pavel Podvig's *Russian Strategic Nuclear Forces*.)

North Korea's use of this stage would explain why the Unha-2's second-stage diameter is smaller than the first-stage diameter. The diameter of the first stage is determined in part by the volume of fuel it must carry. Designing a second stage with the same diameter would reduce the structural mass of the second stage compared to a longer, thinner stage. But if North Korea utilized an existing, advanced missile body with a lightweight structure for this stage, this design decision would make sense.

The third stage appears to be very similar, if not identical, to the upper stage of the Iranian Safir-2 launch vehicle, which placed a small satellite in orbit in February. This appears to be a concrete indication of cooperation between the Iranian and North Korean programs. Based on an analysis of the Iranian Safir-2 launcher, this stage appears to use the small steering motors from the SS-N-6 for propulsion. Therefore, the Unha-2 appears to use a third stage with liquid rather than solid fuel, unlike the Taeopdong-1 launcher.

The SS-N-6 steering engines have a relatively small thrust--the maximum thrust of the pair of engines is less than 15 percent of the thrust of the main SS-N-6 engine. Thus, this stage can accelerate a relatively small stage and small satellite into orbit, but it wouldn't have enough thrust to accommodate a much heavier payload.

Ballistic missile capability. North Korea has conducted two nuclear tests, but it isn't thought to have designed a nuclear warhead that could be delivered by a missile. Such a first-generation plutonium warhead could have a mass of 1,000 kilograms or more.

If the Unha-2 was designed to launch a relatively lightweight satellite, its structure may not allow it to carry a 1,000-kilogram warhead. If it could, we estimate that it could have a range of 10,000-10,500 kilometers, allowing it to reach Alaska, Hawaii, and roughly half of the lower 48 states. If a 1,000-kilogram payload were instead launched by the first two stages of this missile, it would have a range of 7,000-7,500 kilometers. This would allow it to reach Alaska and parts of Hawaii, but not the lower 48 states. (It's worth noting that North Korea already has a missile capability against Japan with its Nodong missile, which is believed to have a range of 1,000-1,300 kilometers with a 700-1,000-kilogram payload.)

Although nothing is known about the Unha-2's guidance-and-control system, it's likely derived from the SS-N-6, which we expect would be used to control the SS-N-6 steering motors during the second and third stages. Due to both higher reentry speeds and the longer range of the Unha-2, such a guidance system probably would produce inaccuracies of roughly 10 kilometers or more. North Korea hasn't demonstrated a reentry heat shield for a missile of this range. The reentry heating increases rapidly with the reentry speed of a missile, so a 10,000-kilometer range missile would require a much better heat shield than that developed for the Nodong missile. Since heat-shield techniques and materials have been developed for more than 40 years, North Korea should be able to develop an adequate heat shield, although the heat shield could be a major source of missile inaccuracy.

To develop a launcher with greater satellite-launch capability or a missile with longer range, there are several steps North Korea might take if it had the technical capability. For example, it could replace the third stage of the Unha-2 with a stage that has a higher thrust and a shorter burn time. It also could improve the thrust of the first stage by using more advanced propellants and decreasing its structural weight by making the body out of lightweight materials such as aluminum alloys.

That said, gaining substantially more capability would require North Korea to build a significantly larger missile. For example, China launched its first satellite on the Long March 1 launcher, which was similar in size and capability to the Unha-2 but had a more advanced first stage. However, for its first intercontinental ballistic missile (the Dong Feng-5), China developed a much larger missile, with a first-stage diameter of 3.35 meters (compared to 2.4 meters for the Unha-2) and an overall mass of 183 metric tons--twice the mass of the Unha-2. This missile was able to carry 3 tons to a range of 12,000 kilometers. It also was modified to become the Long March 2 space-launch vehicle, which was able to place more than 1 ton into low Earth orbit--a much greater capability than the Unha-2.

Limits on North Korea's missile development. While Pyongyang has demonstrated the ability to launch rockets of increasing range over the past 20 years, this progress may have depended strongly on foreign assistance and technology. If true, North Korea may face important limits on its program.

The general assumption for many years was that in the late 1980s North Korea successfully reverse engineered the Soviet Scud missile and began producing its own version. Following that, it was thought to have scaled up the Scud engine to produce a larger engine to power the Nodong missile. But there's growing evidence that North Korea received significant technical assistance from Soviet/Russian missile designers--although not necessarily with the involvement of the Soviet/Russian government--and that its missile program may rely in large part on rocket engines and other key components that it acquired from Russia.

First, press accounts in the early 1990s reported that dozens or hundreds of Russian missile experts attempted to travel to North Korea; some were stopped in Russia, but others reportedly began working in North Korea. These experts were said to have come from the Makeyev Missile Design Bureau in Russia, which produced the Scud-B and extended-range Scud-C missiles, the SS-N-6, and other liquid-fueled missiles. This was at a time when Russia was facing severe economic distress and North Korea was reportedly offering high salaries and good money for missiles and technology.

Second, North Korea isn't believed to have conducted the level of missile testing that typically is seen for reverse engineering or developing a successful indigenous production capability, either for its Scuds or Nodongs. In addition to conducting relatively few tests, the success rate of those tests was very high. (See Robert Schmucker's presentation at the 12th Multinational Conference on Theater Missile Defense, "Third World Missile Development--A New Assessment Based on UNSCOM Field Experience and Data Evaluation.") This is especially surprising given the difficulty other countries have had in developing these technologies. For example, the history of the Iraqi Scud program shows that Baghdad was unable to successfully develop key components such as turbopumps and combustion chambers, and instead built its missiles using components that it had acquired from abroad.

Third, recent analysis has shown that the velocity curves for Soviet Scuds and Iranian Scuds, which were likely purchased from North Korea, are essentially identical. (See Schmucker and Markus Schiller's presentation at the 2008 Symposium on Missile Defense/Theatre Missile Defense.) This wouldn't be expected if the Scuds had been reverse engineered and strongly suggests that these missiles were either Soviet-made or were manufactured with Russian help and equipment and to Russian specifications.

Some analysts have speculated that Soviet missile producers may have transferred large numbers of Scud-C missiles to and through North Korea after the 1987 Intermediate Nuclear Forces Treaty restricted the Soviet Union from deploying these missiles. The small number and high success rate of Nodong missile tests further suggests that the Nodong engine was an existing engine supplied by Russian engineers.

Analysis of the Taepodong-1 and Unha-2 launchers strongly suggests that they may be designed and built around components of Soviet missiles. The apparent lack of testing of these components by North Korea suggests that they aren't indigenously produced systems but are existing components that North Korea has been able to combine to build multistage launchers. The Taepodong-1 appears to have used PDF a modified Nodong missile for the first stage; a modified engine from a Soviet surface-to-air missile for the second stage; and the engine from a solid-fueled Soviet SS-21 tactical missile for the third stage. As noted above, the second stage of the Unha-2 appears to be a modified SS-N-6 missile, which was produced by the Makeyev bureau in the 1960s.

It's possible that North Korea learned, with significant Russian assistance, to manufacture Scuds and Nodongs and is therefore not limited in its number of these missiles, assuming it can acquire the necessary materials. But this is much less likely for the SS-N-6, which is a far more advanced system due to its use of highly optimized rocket motors, very energetic propellant, and a complex airframe fabricated from aluminum alloy.

None of this evidence is conclusive, but because it has important policy implications, it should be a high priority for the United States to assess it and work with Russia to determine what technical assistance and components North Korea may have received.

Final thoughts. If North Korea isn't able to build some key rocket components, then its missile program may rely on combining existing components in clever ways. It has shown that it's capable of doing so, as well as building missile bodies. The result is launchers with the potential to launch significant payloads to U.S. territory.

But if North Korea's missile program relies on foreign components, then this could significantly limit what steps North Korea may be able to take in the near term to increase the capability of its launchers. Moreover, if North Korea's missile program depends on a stockpile of components that it has acquired from abroad, then this would imply that North Korea's domestic missile development program is much more limited than is commonly assumed, and that North Korea understands it has a dead-end program if its supply of these components is limited.

In that case, North Korea may have a much higher incentive to negotiate its missile program away than is commonly assumed. This view is consistent with past experience, including Israel's reported success in reaching an agreement to buy North Korea's missile program in the early 1990s in return for money and help with mining technology (a deal that was apparently shelved at the request of the United States, which was negotiating the Agreed Framework); the interest in missile negotiations North Korea expressed to the United States late in the Clinton administration; and the missile flight test moratorium that North Korea observed for seven years starting in 1998.

Article with full links can be found at: http://www.thebulletin.org/web-edition/features/post-launch-examination-of-the-unha-2

Author Bios

David Wright

A physicist, Wright codirects the Union of Concerned Scientists' (UCS) Global Security Program. His expertise is in national missile defense, space weapons, and U.S. nuclear weapons policy. As a primary organizer of the International Summer Symposiums on Science and World Affairs, he helps create an international community of scientists working on arms control and security issues. He has also worked for many years on projects that train technical arms control experts in other countries, especially Russia and China. In 2001, the American Physical Society awarded him with the Joseph A. Burton Forum Award for his arms control research and work with international scientists.

Theodore A. Postol

A physicist, Postol is professor of science, technology, and national security policy at MIT. His expertise is in ballistic missile defense technologies and ballistic missiles more generally. Prior to coming to MIT, he worked as an analyst at the Office of Technology Assessment and as a science and policy adviser to the chief of naval operations. In 2001, he received the Norbert Wiener Prize from Computer Professionals for Social Responsibility for uncovering numerous false claims about missile defenses.

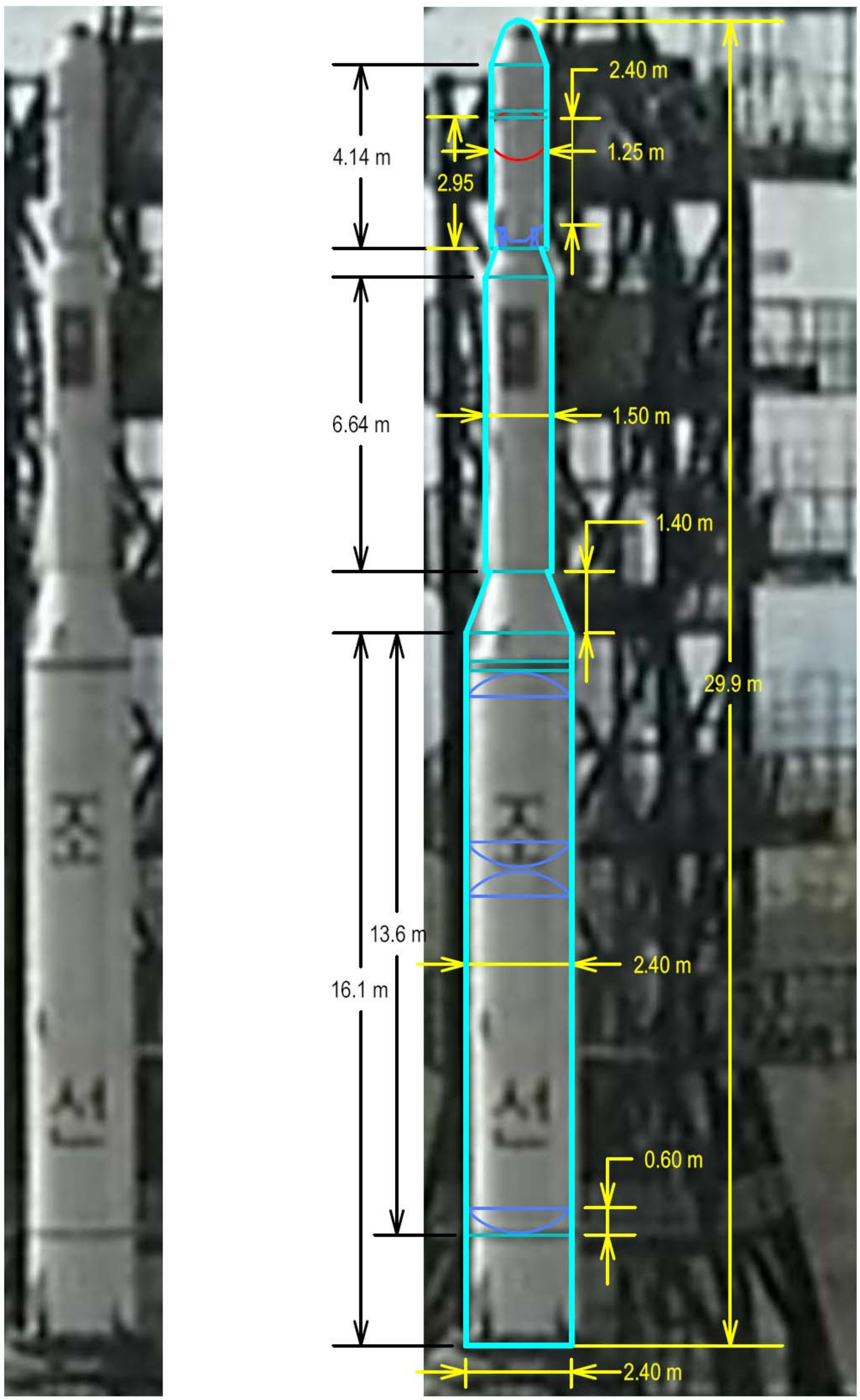

Figure 1. The Unha-2 Launcher
Courtesy of David Wright and Theodore A. Postol