38 NORTH

# A New ICBM for North Korea?

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**December 22, 2015**

## Executive Summary

The intercontinental ballistic missile (ICBM) displayed by North Korea during the military parade in October appears quite different from the versions seen in 2012 and 2013, but a close examination reveals as many similarities as differences. The missile has been shortened and simplified, with two stages instead of three and a blunt warhead replacing the narrow triconic design. The underlying technology is mostly the same—a blend of North Korean engineering and Cold War leftovers from the Soviet Union—but the structural design has been substantially improved. There is reason to suspect that the new structural technology was illicitly obtained from Ukrainian sources. The overall effect is that the missile's performance is largely unchanged (and remains quite marginal for an ICBM), but the potential reliability has been substantially improved. However, such a substantial design change late in the missile's development will likely delay its entry into service until 2020 or beyond.

Examination of external features such as fuel ports and separation motors indicates that the lower stages use the same engines as the 2012/2013 model. These are most likely a cluster of Scud-type engines for the first stage and a second stage based on the Soviet R-27 submarine-launched ballistic missile (SLBM). There is no evidence to suggest that the most recent model incorporates new engines such as those of the R-29 SLBM. However, the propellant tanks for both stages have been lengthened substantially, and the third stage has been removed.

The missile's structure, of which the propellant tanks are an integral part, has been substantially improved. The new model does not show the extensive riveting seen on earlier models and on debris from the 2012 Unha-3 launch. This apparent alteration suggests the addition of a machined isogrid structure common on modern missiles, reducing the weight and extending the range of the KN-08. There is evidence that North Korea is seeking expertise in this area from previously unknown sources. In June 2012, Ukraine reportedly sentenced two North Korean

diplomats who had attempted to photograph secret documents from the Yuzhnoue Design Bureau relating to the construction of improved fuel tanks.[1]

Finally, the triconic warhead of 2012/2013 has been replaced by a short, blunt reentry vehicle. This design is easier to develop and is more likely to survive reentry, at the cost of being less accurate and more vulnerable to missile defenses. It would also allow for a lighter warhead package, perhaps as little as 400 kg.

With a light warhead, the new KN-08 would have a range of roughly 9,000 km, enough to cover the US west coast. This is roughly the performance expected from the 2012/2013 model, but that design was a complex three-stage system that was unlikely to function reliably in wartime. The new design is simpler and more reliable, and thus a more credible threat. But with a major redesign four years into the development process and no flight testing so far, our estimate for initial operational capability slips to 2020 or beyond. While North Korea appears to be making progress towards a road-mobile ICBM, progress has been slower than we expected—a threat postponed, but not prevented.

**Figure 1. The KN-08 missile in 2013 (top) and 2015 (bottom).**

Photos: KCNA.

[1] "N. Koreans convicted of trying to steal rocket technology from Ukraine," *Yonhap News*, June 9, 2012, http://english.yonhapnews.co.kr/national/2012/06/09/91/0301000000AEN20120609000700320F.HTML.

## Introduction

On October 10, the 70th anniversary of the Workers' Party of Korea (WPK), North Korea threw a party, and we were all invited—invited to watch, at least, as the North paraded an array of impressive-looking missiles and other armaments. Most of these were nothing new, and not really all that impressive under their carefully painted skins. But the big attention-getter was an updated inter-continental ballistic missile (ICBM), similar in some respects to the missile paraded in 2012 and 2013. Similar, but not identical. We have been watching for years for signs of progress on this program; but is this what we have been looking for?

First, let's deal with the obvious: These are not real missiles, because nobody puts real missiles on parade when they have perfectly good mock-ups they can use, and any real missile development program will accumulate plenty of mock-ups. So until the North Koreans manage to flight-test this missile, we can't be sure how much of what we are seeing is real and how much is disinformation. But as the development of the missile proceeds, the value of disinformation at this scale diminishes. Our satellites will see the missile's real form in pre-operational exercises, and we will be able to observe its performance in flight tests, well before it enters operational service. So while we should always acknowledge that the North may have a few more surprises in store, it is worth trying to understand the implications if this "new" missile really is what it appears to be.

Second, it's not really a new missile. There are enough similarities to indicate that this is at least part of the same family as the 2012/2013 design. The missiles seem to share the designation Hwasong-13, but is now being called the Hwasong-14. For clarity, however, let's fall back on Cold War tradition to call the old version the "KN-08 Mod 1" and the new version "KN-08 Mod 2." North Korea probably considers the Mod 1 to be obsolete and intends Mod 2 for operational use, but that's one more thing we can't say with any certainty.

And a third curious detail: the DPRK only paraded four missiles this time, compared to six in previous years. They can presumably make as many mock-ups as they want, but they were only able to import six Chinese-made heavy-duty chassis.[2] If they are having maintenance problems on the parade ground already, they may have difficulty deploying the missile in the field later.

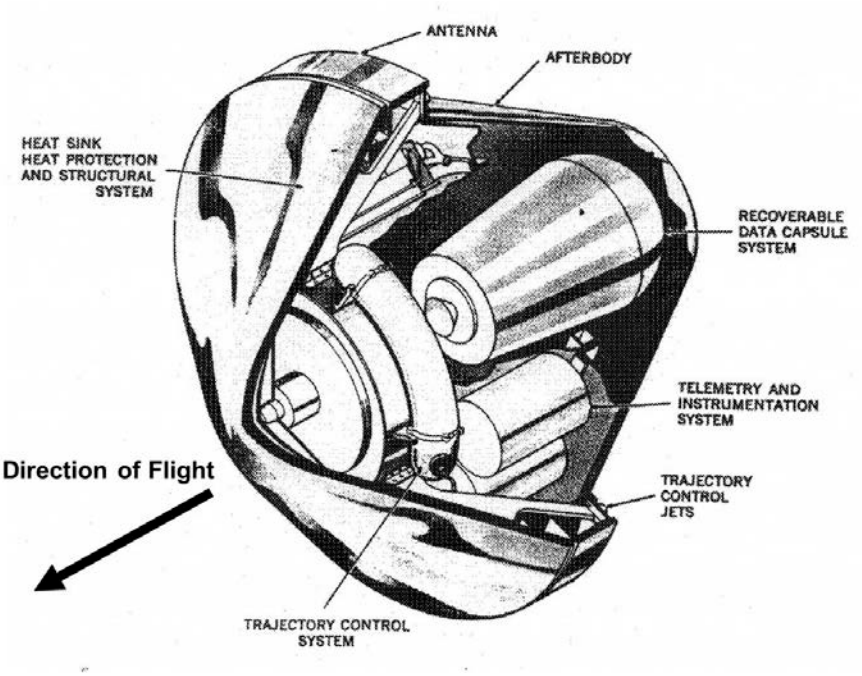
## A New Reentry Vehicle

Now, on to the differences in the missile itself. Let's start at the front, which is about a meter and a half shorter than the Mod 1, and much less pointy. That indicates a major change in the design of the reentry vehicle (RV), which is a critical element of ICBM technology that North Korea

[2] "Report of the Panel of Experts established pursuant to resolution 1874 (2009)," S/2013/337, United Nations Security Council (June 11, 2013), available from www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/s_2013_337.pdf.

has never demonstrated. The previous triconic warhead was a compromise between simplicity and performance, something a team of aspiring missile-builders could hope to get right the first time and which would still be fast and accurate enough to reach a small and well-defended target. The new RV is much blunter. That reduces the concentrated heat loads, allowing for a very simple and robust design. It's probably lighter as well. But it also means the missile will be much less accurate, and much slower at the end of its flight.

**Figure 2. US Mark 2 Reentry Vehicle, as used on Jupiter, Thor and Atlas missiles.**




The United States used such reentry vehicles in its first long-range missiles, as shown in figure 2. These were replaced with triconic warheads as soon as we learned to make them work reliably, and the Soviets used triconic designs from the start. Blunt RVs were too inaccurate to be of military use even when equipped with large thermonuclear warheads. Perhaps more importantly, they are slow enough to be engaged by ordinary surface-to-air missiles as they descend toward their targets. If North Korea is planning on fielding such warheads, they are playing it very safe technologically, but they are limiting themselves to a system that can be used only against large, undefended targets.

Strangely, it is not entirely clear which way the reentry vehicle is facing. Some Soviet submarine-launched ballistic missiles (SLBMs) incorporated a backward-mounted warhead section for more efficient packaging in a very tight space, and used thrusters to reorient the RVs after boost. The KN-08 Mod 2 reentry vehicle has two to four visible thruster packs for separation, at least, and a ring of apertures around the base of the spherical cap could be additional thruster ports. The appearance is vaguely similar to a Soviet-style reversed warhead

package, and we know North Korea has worked with ex-Soviet SLBM designers. But this would require a more complicated deployment maneuver, and the North Koreans have no reason to do that here—the missile could easily be a bit longer if they need more room for the RV.

A more likely explanation is that the KN-08 uses a forward-facing RV to simplify deployment, and that the spherical cap is just an aerodynamic fairing. Blunt RVs are good for slowing down at the end of a flight, not so much for building up speed at the beginning. The apertures at the base of the cap would then be for separation mechanisms to jettison the fairing when it is no longer needed. Indeed, the ability to remove the fairing may be of value even before launch, allowing access to the warhead section for maintenance and/or launch preparation.[3]

However the RV is oriented, it will have adequate internal volume for the early-generation compact fission warhead North Korea is likely to field. The mass of the warhead is likely to pose a greater challenge than its dimensions—the KN-08 Mod 2 has plenty of space for a large warhead, but may not have much throw-weight. North Korea has conducted three nuclear tests, with the stated goal of miniaturizing its nuclear weapons. According to a North Korean defector, North Korea was attempting to develop a nuclear warhead that weighed approximately 500 kilograms. That is consistent with the experience of Pakistan, which received an early nuclear weapon design from China and worked to reduce its weight. The initial Chinese-design that ended up in Libya reportedly had a mass of approximately 500 kilograms, while other reports suggest that plans for a second Pakistani design were found in Switzerland with a mass of about 200 kilograms. We should probably anticipate that North Korea is capable of building a fission device that weighs between 300-700 kilograms, with another hundred kilograms or so needed for shielding.

**Changes to the Upper Staging**

The KN-08 Mod 1 was a three-stage missile, with a third stage of substantially smaller diameter than the first and second, substantially similar to (but shorter than) the upper stage used successfully on Iranian and North Korean satellite launch vehicles (SLVs). The first and second stages of the Mod 1 were of the same diameter, with a clear interstage region or engine bay between them. For the KN-08 Mod 2, the third stage appears to have been either eliminated or replaced by something that maintains the same diameter over most of the missile's length. What isn't clear is what may have replaced it.

One possibility is simply that the third stage has been reshaped to fit inside the new forebody. Conveniently for this interpretation, the cylindrical section of the KN-08 Mod 2 is just long enough for the unmodified first and second stages of the Mod 1 with a reasonable interstage section beneath the third stage. In this hypothesis, the third-stage fuel and oxidizer tanks would fit neatly in the conical section, almost to the base of the RV, holding almost as much propellant

[3] Note that some nations prefer to store missiles and warheads separately for security reasons.

as the original. Conical tanks are slightly harder to manufacture than cylindrical tanks, but they would be more compact and efficient in this geometry.

However, it seems more likely that the third stage has been removed entirely, with the first two stages lengthened to compensate. Two-stage missiles will generally offer inferior performance to three-stage designs, especially with light warheads, but two stages mean fewer chances for things to go wrong. Stage separation is one of the more common failure points for large rockets, and North Korea's track record in three-stage rocketry is only one success out of four attempts.

To turn the KN-08 into a two-stage missile, the first-stage propellant tanks would have to be stretched by three to four meters, with the second stage being similarly stretched and pushed forward until its oxidizer tank fills the conical region. This also would be a very good match for the observed mock-up. It probably would not deliver quite the same performance as the Mod 1, but if it can still reach targets in the contiguous United States, the improved reliability might be seen as a worthwhile trade.

**A New First Stage**

Some commentators initially believed that the Mod 1 and Mod 2 missiles shared the same first stage. There are, in fact, a number of similarities, but a close examination of the missile reveals that the first stage of the KN-08 Mod 2 is significantly longer than that of the KN-08 Mod 1.

Each North Korean missile contains a number of externally visible elements that offer clues to the configuration. A careful examination of the location of features such as draining ports, structural markings, and apparent separation planes suggests that the new first stage is roughly 10.5 meters long, more than 3 meters longer than the first stage of the KN-08 Mod 1.

The base section, containing the engines, is largely unchanged. There is, in particular, no evidence to suggest that this is secretly the first stage from a Russian R-29 SLBM, as others have suggested. With a submerged engine design, the propellant drain port would have to be much lower on the missile. And there is no evidence that the DPRK has ever acquired the R-29 missile or the technology needed to build it. But while the engines may remain the same as in the Mod 1, the fuel and oxidizer tanks have been stretched. The elongated first stage is now nearly optimal for a two-stage missile, which is probably not a coincidence.

**No More Rivets**

The KN-08 Mod 1, especially in its 2013 parade incarnation, had an extensively riveted skin. So too did the Unha SLV, North Korea's only unambiguously real and successful long-range rocket. For the missiles we get to see parade mock-ups, but for the Unha we got to fish an entire rocket stage out of the ocean. And at least in 2012, it looked like the state of the art in North Korean

metallurgy wasn't up to building an all-welded or intricately machined rocket body; they needed the rivets.

Which makes it somewhat surprising that the KN-08 doesn't seem to have any. It is also annoying to those of us trying to figure out how the missile is put together; the rivet lines are what told us where the engine bays, interstage regions and propellant tanks were. Indeed, there is less external detail all around. As noted, there is a bit of external hardware visible on the reentry vehicle, like propellant discharge ports for the first and second stages, and a few features that look like stage-separation thrusters. There might be a stage separation joint, partially hidden by the clamps holding the missile to the transporter. Even the cable raceway is now a single unbroken run, unless there is a break we can't see hidden under the clamp.

**Figure 3. Comparison of surface detail on KN-08 Mod 1, Unha-3 and KN-08 Mod 2 (left to right).**

Photos: Left and middle: 38 North; Right: Korean Central Television footage crop.

One possibility is that this mock-up simply was not built to show that level of detail. That would be surprising, as the 2013 mock-ups revealed great detail. Perhaps the North Koreans are concerned we are learning more than they wish to reveal. Another possibility is that their engineers have started using flush rivets, which would not be visible through a layer of camouflage paint. That would make more sense for a jet plane, spending its career flying at high speeds through the atmosphere, than for a rocket that ascends as quickly as possible into the airless void above, but even such a small gain as a smooth skin might appeal to engineers trying to increase the performance of a marginal ICBM. The same logic may apply to other features—a smooth and featureless skin means less drag. Stage separation, for example, might be accomplished using linear shaped charges inside the missile's fuselage, a technique the US mastered in the 1960s.

The most worrisome prospect is that the new mock-ups don't show any rivets because North Korean engineers have improved their machining and welding skills to the point where they no longer need them. If the KN-08 Mod 2 uses the sort of machined isogrid structure common on more modern US and Russian missiles, the tanks and structures will be significantly lighter and

the missile would be able to fly significantly farther. Improved propellant tank design would allow more of the missile's propellant to be used, rather than left in dead spots. This is a technology North Korea hadn't mastered in 2012, but they may have learned something new in the past few years. There is evidence they have been looking for technological assistance.

In June 2012, Ukraine reportedly arrested two North Korean diplomats for attempting to photograph secret documents at Ukraine's Yuzhnoue Design Bureau. The UN Panel of Experts has noted that the documents "would have provided the Democratic People's Republic of Korea with information on advanced technologies and new forms of technological processes for the design of missile systems, liquid-propellant engines, spacecraft and missile fuel supply systems and associated computer programmes."[4]

Yuzhnoye is an ex-Soviet rocket builder that wound up on the Ukrainian side of the post-Cold War border, which has had some luck in various joint ventures building satellite launch vehicles for international customers, but has lately fallen on hard times. Yuzhnoye has not built ICBM-class engines in almost 30 years, but they have been the place to go for state-of-the-art integrated rocket fuel tanks and structures at a discount price, and now their engineers and technicians aren't getting paid regularly.

The names of the two documents being photographed were "Methods for predicting the capability of capillary intakes in fuel tanks of motor assemblies for spacecraft" and "Hydrodynamic processes in fuel tanks of spacecraft." It is hard to pin down the exact content from translated titles, and we don't know what else the North Koreans might have had access to before they were caught, but it is probably safe to assume that they have learned a bit about how to build better tanks and airframes for the KN-08: how to make them lighter all around and allow less residual propellant in the tanks, with no need for rivets.

**What's "Under the Hood"**

We can try to put all of this together and figure out just what sort of missile the KN-08 Mod 2 is, but the lack of detail will require a certain amount of guesswork as to what has changed.

One thing that probably hasn't changed is the first-stage engines. The base of the vehicle, including the flared skirt and the propellant discharge port 1.6 meters up the side, looks just like it did in 2013 (minus the rivets). So we can reasonably assume that, except for stretching the tanks, the first-stage configuration is the same as it was before, with four modified Scud engines burning relatively low-energy kerosene and nitric acid propellants. The first stage, provided it has enough thrust to fly at all, is generally the least important to a missile's overall performance, so it would make sense to keep as much already-developed hardware there as possible.

[4] "Report of the Panel of Experts established pursuant to resolution 1874 (2009)," 25.

If this were a three-stage missile, we would expect that the second stage would remain unchanged as well. This fits the dimensions of the mock-up quite well. In this hypothesis, the only things that have changed are the third stage and the reentry vehicle. The third stage would use the same propulsion and guidance hardware as before, but the propellant tanks would have to be squeezed into the conical volume at the front of the missile.

The problem with this hypothesis is that, after a substantial redesign of the third stage, the missile's performance would remain almost unchanged. And why do such a redesign if it doesn't get you anything? Even the new blunt-body RV would have fit perfectly well under a fairing shaped to the old design.

It is far more likely that the reason we can't see a third stage is because there isn't one. Instead, the propellant tanks for the first and second stages have been stretched. This would normally rob the missile of some of its already-marginal performance, but as noted, we have reason to believe that the North Koreans and their friends have managed to improve the structural design with a significant reduction in dry mass and residual propellants. The second stage will necessarily have undergone a more substantial redesign, as it has to incorporate the guidance system previously located in the third stage. Again, we will assume an improved structural design. There is no need for a post-boost propulsion system, as the missile can accommodate only a single warhead and the small vernier engines of the second stage can handle post-boost velocity trim. And we assume a blunt, forward-facing RV, as anything else would add complexity but no real gain.

A few other possibilities have been considered but are deemed highly unlikely. The North Koreans could improve the performance of the missile somewhat by using common-bulkhead propellant tanks, or submerging the upper-stage engines in the propellant of the stage below. But these are complex and somewhat dangerous ways of squeezing a bit more propellant into a missile, when the same result could be accomplished by simply making the missile a bit longer. For SLBMs that can be crucial, but the KN-08 lives on an overgrown truck and the Mod 2 could easily grow by another two meters.

As already noted, we do not see any evidence to support the hypothesis that this is actually an ex-Soviet SLBM, whether the R-29 or otherwise. Nor is there any evidence to suggest that this is a solid-fuel missile, and the presence of fuel discharge ports argues strongly against that hypothesis.

Diagrams of the missile's outer mold line, and the postulated interior configurations, are shown in figures 4 and 5, below.

**Figure 4. Exterior details of the KN-08 Mod 1 and Mod 2 missiles.**

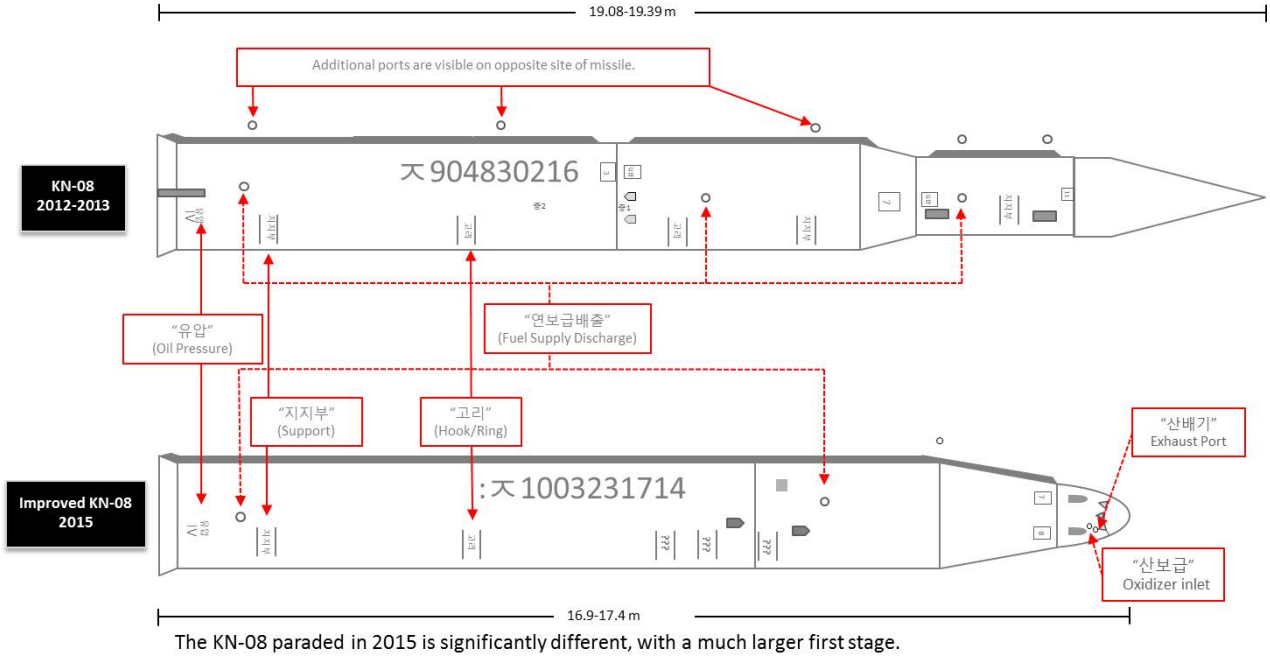



Image: David Schmerler.

**Figure 5. Estimated design of the KN-08 Mod 2 missile.**

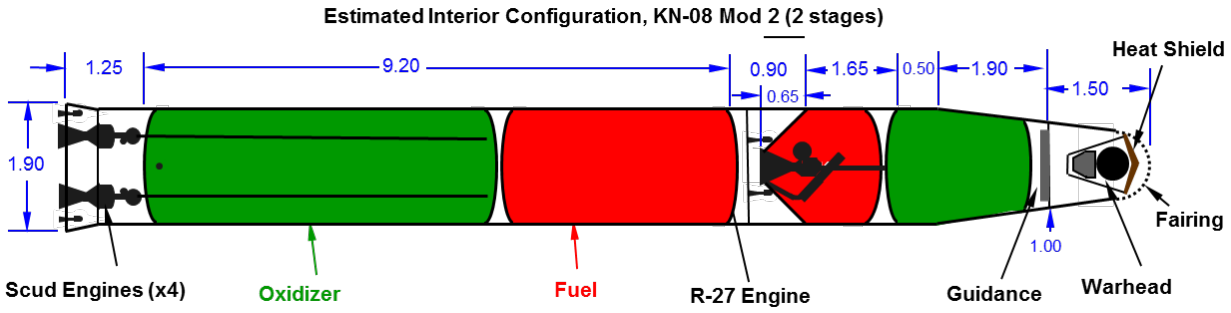



Image: John Schilling.

## What's the Bottom Line?

The most important question is: "Does this change the threat posed by the KN-08 missile?" The simplest answer is: "not by much."

There is very little performance impact. Figure 6, below, shows range-versus-payload curves for both the original KN-08 Mod 1 missile and the Mod 2 configuration discussed here. The new version offers slightly less range with the lightest warheads, though somewhat more with heavier

loads. But the differences are small, within the margin of error of the calculations given how little we know about the Mod 2 design. And the use of a blunt-body RV will allow the North Koreans to reduce the warhead weight while maintaining adequate protection against reentry heating, which should recover some of the lost performance. So the KN-08 Mod 2 probably will not fly any farther than we expected the Mod 1 to reach.

**Figure 6. Estimated performance of the KN-08 Mod 1 and KN-08 Mod 2 missiles.**

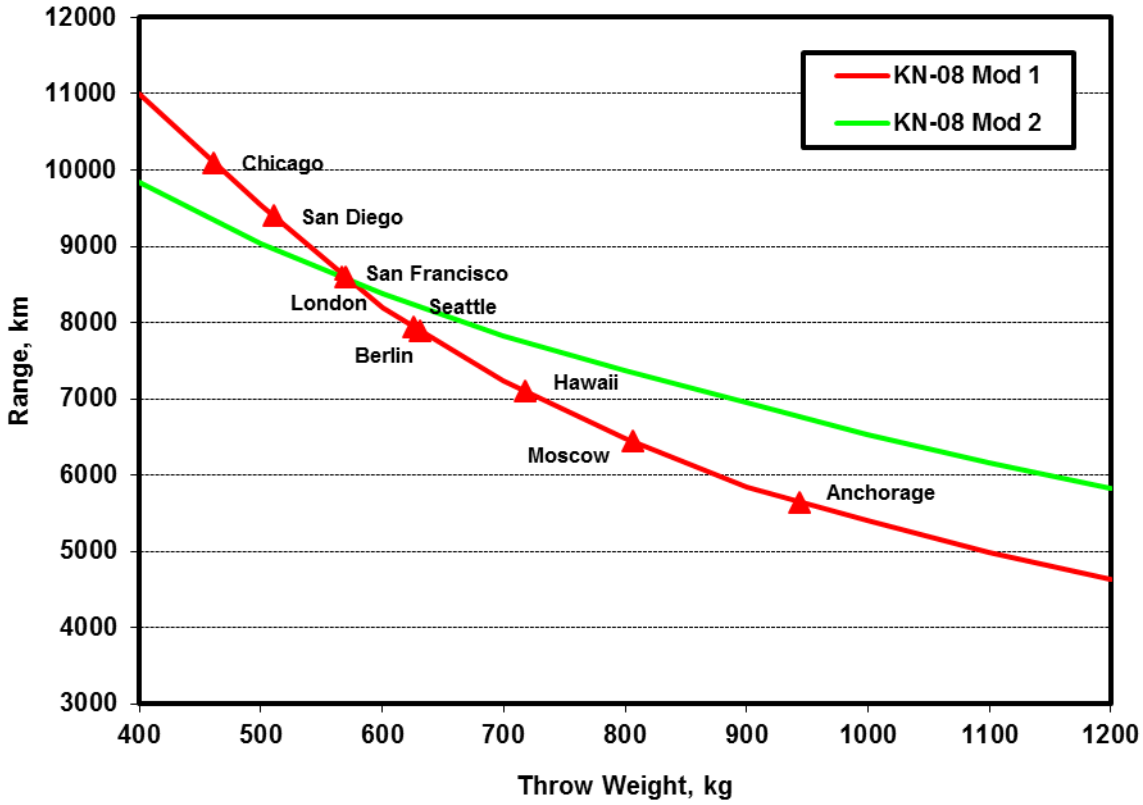



Image: John Schilling/38 North.

This should not come as any surprise. The North Koreans have a fairly limited technology base for building long-range rockets, and they are further constrained by the need to carry this rocket on a heavy-duty truck. There is no magic to change the basic engineering realities here. However the North Koreans tinker with the shape of the missile or the number of rivets, any rocket they can fit onto a WS-51200 transporter using their existing engine technology will be a very marginal ICBM capable of reaching Pacific Rim targets out to the US west coast, but no farther, and then only with lightweight warheads. If they eventually develop better engines, we will have to reevaluate this estimate.

The KN-08 Mod 2 will probably be less accurate than we expected for the Mod 1. The error ellipse will be at least 5 km crossrange and 10 km downrange, and achieving even that level of performance will require multiple calibration tests of the RV. It will also be more vulnerable to

interception, particularly if the intended recipient can deploy missile systems like Patriot or THAAD in the target areas. ICBM warheads are typically too fast to be shot down by such missiles, but blunt RVs slow quite a bit as they descend.

The biggest advantage of the Mod 2, particularly for the two-stage version we expect, will be increased reliability. We had previously estimated, based on the performance of other North Korean multistage rockets, that the KN-08 Mod 1 would work only 30-40 percent of the time in early operation. With the more robust design, the Mod 2 could have a 50-60 percent reliability at its initial operational capability. The North Koreans may have decided to trade a bit of performance to get a missile that is more likely to reach its target than to fall back on North Korean soil. It is even possible that the performance has increased slightly, though there is little room for major gains in this design.

But perhaps the most important change in the threat is that it has been postponed. While this may be a simpler and more robust configuration, and one which retains key elements of the Mod 1, it is also a substantial design change relatively late in the development process. This means that design work has not proceeded as far or as fast as we might have feared, and that some work already completed has been tossed out and will need to be redone. Just as telling is the lack of any flight tests for any version of the KN-08, or even of the related single-stage Musudan missile. North Korea seems to have been slow to resume their engine ground testing after an overhaul of their test facilities.

We had previously estimated that the KN-08 would enter very limited operational service no earlier than 2018 and most likely in 2021. It is now unlikely that the KN-08 Mod 2 could enter service before 2020, and most likely not until 2023. Given the major design changes on the missile, flight testing will probably not begin for two to three years, and a substantial flight test campaign will be required before production can begin.[5] North Korea appears to be making progress towards developing a road-mobile ICBM, but it is slow progress and the end result will likely be a missile of modest reliability and limited performance.

[5] The design of the KN-08 Mod 2 began in approximately 2013, and the changes are substantial enough to require more than two years of design work. Ground testing will also be required, and an upgrade of North Korea's test facilities in 2014-2015 will have interfered with such tests until quite recently. Two to three years of additional development and ground testing is a conservative estimate. North Korea's past record suggests that at least three flight tests will be required to demonstrate success on a vehicle of this complexity, with a year or so between tests to incorporate the lessons learned. With a proven design in hand establishing a production line and testing manufacturing processes will likely take another one to two years.