North Korea’s Hwasong 12 Missile Test

S. Chandrashekar, Rajaram Nagappa and N. Ramani
Executive Summary

The available evidence from North Korea’s May 14 2017 launch of the Hwasong 12 missile suggests that it is a two stage missile.

Measurements on the images of the missile are also consistent with an Unha 3 space launcher origin for the Hwasong 12. If this were so it would have a diameter of 2.4 m and use Kerosene and AK 27 as fuel and oxidizer.

A single stage Unha 3 derived Hwasong 12 can also be ruled out based on a performance appraisal of North Korea’s current missile and space capabilities.

The two stages appear to have about the same length. The first stage would be very similar to the Unha 3 booster with a propellant fraction of 84%.

The second stage would also use the same engine as the Unha 3 booster but would be a more optimized stage with a propellant fraction of around 87%.

These stages are consistent with what North Korea has already demonstrated through its space and missile launchings.

Though North Korea has so far not tested a thermonuclear device, the length of the Reentry Vehicle (RV) of 5.25 m suggests that it is intended to carry a thermonuclear warhead.

The predicted range of the Hwasong 12 missile with a warhead weighing 650 Kg launched due east with an azimuth of 90 degrees will be 4385 Km. This should allow North Korea to comfortably target Guam even with a heavier warhead.

With a suitable third stage the Hwasong 12 can be converted into an ICBM that can reach the US mainland. One can expect the test of such a configuration in the near future.

Taken together the successful launch of the Hwasong 12 along with the nuclear weapons testing that North Korea is carrying out indicates that North Korea is well on its way towards developing a nuclear tipped ICBM that can reach the continental United States.
North Korea’s Hwasong 12 Missile Test

S.Chandrashekar, Rajaram Nagappa and N.Ramani

Background

On May 14 2017 North Korea test fired a new Hwasong 12 missile. The launch took place from a location near the city of Kusong at 04 58 hours local time. The launch did not take place using a Transportable Erector Launcher (TEL). The missile appears to have been launched from a pad.

The missile flew a lofted trajectory landing in the Sea of Japan with a range of 787 Km. The altitude reached by the missile was 2111.5 Km. The flight time as reported by Japanese sources was about 30 minutes.

The Korean Central News Agency (KCNA) in its report said that the test “proved to the full” a range of systems, including “guidance and stabilization systems, structural system and pressurization, inspection and launching systems and reconfirmed the reliability of new rocket engine under the practical flight circumstances.” The test “also verified the homing feature of the warhead under the worst re-entry situation and accurate performance of detonation system.”

Images of the missile were released by North Korea’s Rodong Sinmun newspaper. Video footage of the launch was also made available by North Korea.

The Locations of the Launch Site and the Impact Point

The video as well as the images put out have been widely used in evaluating the capabilities of the missile and their political and strategic consequences.

1 All the authors are with the International Strategic & Security Studies Programme, National Institute of Advanced Studies Bangalore, India. For correspondence please contact E Mail chandrashekar.schandra@gmail.com
2 This is 05 27 Seoul time or 20 27 Saturday GMT. See http://asia.nikkei.com/Spotlight/Pyongyang-provocation/North-Korea-fires-missile-days-after-new-South-Korea-leader-pledges-dialogue?page=2
3 A lofted trajectory is chosen in order to test the missile without the missile having to overfly the territories of other neighbouring countries.
4 http://allthingsnuclear.org/dwright/north-koreas-missile-in-new-test-would-have-4500-km-range
5 http://asia.nikkei.com/Spotlight/Pyongyang-provocation/North-Korea-fires-missile-days-after-new-South-Korea-leader-pledges-dialogue
Apart from pictures of the actual launch one of the images shows the North Korean leader Kim Jong Un looking at the planned trajectory of the test launch with the launch and impact points marked.

Based on an analysis of this image the launch site has been identified as close to the city of Kusong with the coordinates 40 04 N Latitude and 125 12 E Longitude. Figure 1 shows this location.

Another image shows the North Korean leader in front a screen showing the trajectory of the missile plotted on a Google Earth kind of rendition.

The impact point as seen in this image is off the coast of Russia. US officials claimed that the missile landed in Russian waters about 60 miles (108 Km) south of the Vladivostok Region.

In contrast to the US statement that the missile landed within the EEZ of Russia, the Russian Defense Ministry said that the missile posed no danger and landed about 500 Km off the Russian coast.

Based on a detailed scrutiny of the image Jonathan McDowell estimates the impact point to be close to 41.6 N & 134.6 E which is about 150 Km from the Russian coast or about 260 Km from Vladivostok.
This would suggest that the impact point was within the Russian EEZ.\(^7\) This photo is reproduced as Figure 2 below.

![Figure 2](image)

**Missile Performance - Assessments in the Public Domain**

Based on the information put out by North Korea and a study of the images a number of assessments have been made about the capabilities of the Hwansong 12.

One assessment suggested that the Hwasong 12 missile was an extended version of the single stage Musudan missile that North Korea had tested earlier with a range of 3700 Km \(^8\)

Another assessment said that the Hwasong 12 is a two stage missile. If such a missile were flown on a maximum range trajectory the realized range would be about 4800 Km.\(^9\)

**NIAS evaluation of the Hwasong 12**

This evaluation of the May 14 North Korean missile test will fit various missile parameters to the reported range, altitude and time of flight of the missile using a trajectory model. The simulation uses the Quo Vadis software developed by NIAS.

Images of the Hwasong missile available in the public domain are analyzed along with measurements on a few images. This data is used along with available information on North

---

\(^7\) [https://twitter.com/planet4589/status/863930056275632128](https://twitter.com/planet4589/status/863930056275632128)

\(^8\) The results of the simulation exercise indicate that in order for a single stage Hwasong 12 Musudan-derived missile to fit the trajectory data it would have to be a very advanced stage. Whether North Korea can develop such a capability given its known capabilities is highly doubtful. Ralph Salversberg, “A Quick Technical Analysis of the Hwansong 12 Missile”, 19 May 2017 at [http://38north.org/2017/05/hwasong051917/](http://38north.org/2017/05/hwasong051917/)

\(^9\) [http://allthingsnuclear.org/dwright/north-koreas-missile-in-new-test-would-have-4500-km-range](http://allthingsnuclear.org/dwright/north-koreas-missile-in-new-test-would-have-4500-km-range)
Korean missile and space capabilities to estimate the initial missile parameters that are needed to run the trajectory model. The missile parameters are then be progressively refined via the trajectory model to fit the realized range, altitude and time of flight of the Hwasong 12. Such an approach provides a realistic assessment of the missile’s true capabilities.

**Measurements on flight images of the Hwasong 12**

A sample set of three images of the missile in flight were selected for measurements from the available images put out by various entities immediately after the launch.\(^\text{10}\) The results of the measurements are provided in **Table 1**.

<table>
<thead>
<tr>
<th>Image</th>
<th>L/D Ratio(^\text{11})</th>
<th>W/h ratio %</th>
<th>Engine ratio %</th>
<th>Tankage ratio %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image 1</td>
<td>9.60</td>
<td>22.08 %</td>
<td>12.50 %</td>
<td>65.42 %</td>
</tr>
<tr>
<td>Image 2</td>
<td>9.80</td>
<td>22.45 %</td>
<td>11.56 %</td>
<td>65.99 %</td>
</tr>
<tr>
<td>Image 3</td>
<td>9.81</td>
<td>22.35 %</td>
<td>11.37 %</td>
<td>66.28 %</td>
</tr>
<tr>
<td>Average 2 &amp; 3</td>
<td>9.80</td>
<td>22.40 %</td>
<td>11.47 %</td>
<td>66.14 %</td>
</tr>
</tbody>
</table>

Based on the measurements as well as on the quality of the three images the average of images 2 & 3 is used as the best estimates for further work. These images are reproduced in **Figure 3**.

\(^{10}\) All the images released are from images and video footage provided by the Korean Central News Agency (KCNA).

\(^{11}\) L/D ratio is the length of the missile measured in pixels divided by the diameter of the missile in pixels.
A close scrutiny of the images revealed no obvious evidence of two separate stages. The cable carrying raceway appears to be continuous going all the way down to the engine. The separation of the warhead and its interface with the missile is clear.

**What is the diameter of the Hwasong 12?**

These measurements by themselves have no value unless we can find a way to estimate the diameter of the Hwansong 12 missile.

A Musudan derived single stage missile with a 1.5 diameter stage can be ruled out on the grounds that realizing such an advanced stage would be beyond North Korea’s current capabilities.

The other possibility is that it is a new booster with or without a second stage that could be a part of a future ICBM. If this were so, it is likely that it is based on the booster stage of the Unha 3 space launcher. This pedigree would make the diameter of the Hwansong 2.4 m.

The length of the engine part of the missile which can be measured on the images works out to be 2.7 m if a 2.4 metre diameter booster stage is assumed for the Hwansong 12. This is the value reported by South Korea based on the analysis of the debris from the first Unha 3 launch in 2012. This measurement provides a reasonable basis to indicate that the Hwansong 12 missile is derived from the Unha 3 space booster stage and has a diameter of 2.4 m.

The overall length of the missile based on our measurements and using a diameter of 2.4 m would be 23.53 m with a warhead length of 5.27 m.

---

12 The origins of the Musudan and its pedigree have been the subject of extensive debate. One version is that it is derived from the Soviet R 27 SLBM with a submerged engine. This version therefore provides the Musudan with advanced capabilities. See Ralph Salversberg and James Kiessling, “North Korea’s Musudan Missile: A Performance Assessment” available at http://38north.org/2016/12/musudan122016/ The other version is that the Musudan is an adapted second stage derived from the Unha 3 launcher with a Nodong pedigree. In this version the performance of the Musudan is not as good as a missile derived from the R 27 SLBM. See Markus Schiller, Robert H Schmucker, “Explaining the Musudan New Insights on the North Korean SS-N-6 Technology” available at http://www.armsocontrolwonk.com/files/2012/05/Explaining_the_Musudan_Schiller_Schmucker_v1.2.pdf

13 See Reference 8.

14 While other diameters are possible they appear to be unlikely unless there is concrete evidence to suggest that this is so.

15 This is based on an analysis of the recovered first stage debris of the Unha 3 by South Korea. An English translation of South Korea’s report has been put out David Wright. See” North Korean Long-range Missile Debris Survey” Ministry of Defense, (English translation by D. Wright revised 1/27/13) available at http://www.ucsusa.org/assets/documents/nwgs/SK-report-on-NK-rocket-debris-analysis-translation-1-18-13.pdf
The Unha 3 booster stage uses a propellant and oxidizer combination of Kerosene and AK 27 (73% RFNA + 27% N2O4). This is consistent with the orange coloured fumes seen in all images of the launch.\textsuperscript{16}

From the image measurements the propellant mass and stage mass can be worked out based on the Unha 3 pedigree assumption.\textsuperscript{17} This can be done both for a single stage configuration as well as a two stage configuration.

**Trajectory Simulation Results for a Single Stage Hwasong 12**

For a single stage configuration the length of the stage for a 2.4 m diameter missile from image measurements is 18.26 m. Using the Unha 3 data as a baseline, this translates into a propellant mass of 67300 Kg and an inert mass of 12820 Kg. The sea level specific impulse and thrust are 228 seconds and 1260 Kilo Newtons respectively. With these starting parameters the Quo Vadis trajectory software was used to iteratively fit the realized range, altitude and time of flight.

A missile with a propellant fraction of a little over 93% (inert mass of 4820 Kg as compared to the starting inertial mass of 12820 Kg) with a pitch angle of 89.13 degrees and an azimuth of 70 degrees matches the altitude of about 2111 Km and the range of 787 Km. The time of flight is about 1970 seconds which is a bit more than the reported flight time of “about 30 minutes”. This flight time is however not inconsistent with the reported data.

As we can see these results are quite similar to what has been reported by Salversberg where a Musudan (Russian R 27 SLBM) pedigree is assumed for a single stage Hwansong missile.\textsuperscript{18}

A missile with these parameters would be very difficult for North Korea to develop given its current capabilities. A single stage Hwansong 12 missile can therefore be ruled out for the May 14 2017 launch.

The Hwansong 12 is therefore a two stage missile.

It may be worthwhile to explore the possibility that some of the images released by North Korea could provide some indicators as to whether this is indeed so.

**A Two Stage Hwasong 12 Missile**

\textsuperscript{16} Red Fuming Nitric Acid (RFNA) may also be used along with UDMH as fuel. This can also provide similar coloured fumes.  
\textsuperscript{17} The Unha 3 launcher parameters that provide a good fit with the realized trajectory and orbit are available in S.Chandrashekar, N. Ramani & Arun Viswanathan, “An Analysis of North Korea’s February 2016 Successful Space Launch”, available at \url{http://isssp.in/wp-content/uploads/2016/04/North-Korean-Feb-2016-Successful-Space-Launch.pdf}  
\textsuperscript{18} See reference 12
One of the images of the Hwansong 12 does provide an indication that the cable raceway is not continuous and does seem to have a break.\textsuperscript{19} Figure 4 provides a blow up of this part of the missile.

Based on the measurements and a diameter of 2.4 m the stage lengths for the two stages of the missile were estimated. The estimated length for the first stage is 8.75 m while the length of the second stage works out to be 8.60 m. The two stages of the Hwansong 12 thus appear to have almost the same length.\textsuperscript{20}

From these lengths and using the data from the Unha 3 flights\textsuperscript{21} the propellant masses and inert masses were worked out. The propellant mass for stage 1 is 32250 Kg with an inert mass of 6140 Kg. The second stage propellant mass works out to be 31700 Kg with an inert mass of 6035 Kg. The specific impulse and thrust assumed for the first stage are the same as those derived from the Unha 3 launch of 2016.\textsuperscript{22} The second stage specific impulse is taken as 260 seconds. The thrust of the second stage is assumed to be 10% higher than the first stage to take care of vacuum conditions of the second stage operations.

\textsuperscript{19} A study of one of the images using Envi enhancement software does suggest a break in the cable. The interface can also be seen. The image shown however is the raw mage without filtering.

\textsuperscript{20} These lengths are also not consistent with a single stage missile. The debris analysis of the Unha 3 first stage revealed an oxidizer tank length of 7.5 m and a fuel tank length of 3.9 m with an intertank interface of 0.9 m. The equal lengths from the interface therefore would be consistent only with a two stage missile.

\textsuperscript{21} This is based on the reconstruction of the trajectory of the Unha 3 launch vehicle in 2016. See Reference 18.

\textsuperscript{22} See Reference 18
Using a trial and error iterative process we systematically varied various missile parameters to arrive at a good fit with the range, altitude and time of flight of the missile that has been reported by various agencies tracking the missile. Table 2 provides the missile parameters as well as the performance details of the missile that matches well with the tracking data.

**Table 2**

<table>
<thead>
<tr>
<th>First Stage Parameters</th>
<th>Initial Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant Mass Stage 1 (kg)</td>
<td>32250</td>
<td>32250</td>
</tr>
<tr>
<td>Inert Mass Stage 1 (kg)</td>
<td>6140</td>
<td>6140</td>
</tr>
<tr>
<td>Stage Mass</td>
<td>38390</td>
<td>38390</td>
</tr>
<tr>
<td>Fuel Fraction</td>
<td>0.84</td>
<td>0.84</td>
</tr>
<tr>
<td>Thrust Sea Level (Newtons)</td>
<td>126000</td>
<td>1260000</td>
</tr>
<tr>
<td>ISP Sea Level (seconds)</td>
<td>228</td>
<td>228</td>
</tr>
<tr>
<td>Burn time Computed (seconds)</td>
<td>57.23</td>
<td>57.23</td>
</tr>
<tr>
<td>Area of Cross Section (m²)</td>
<td>4.52</td>
<td>4.52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Stage Parameter</th>
<th>Initial Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant Mass Stage 2 (kg)</td>
<td>31700</td>
<td>31700</td>
</tr>
<tr>
<td>Inert Mass Stage 2 (kg)</td>
<td>6035</td>
<td>4635</td>
</tr>
<tr>
<td>Stage Mass</td>
<td>37735</td>
<td>36335</td>
</tr>
<tr>
<td>Fuel Fraction</td>
<td>0.84</td>
<td>0.87</td>
</tr>
<tr>
<td>Thrust (Newtons)</td>
<td>1386000</td>
<td>1386000</td>
</tr>
<tr>
<td>ISP Vacuum (seconds)</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Burn time Computed (seconds)</td>
<td>58.31</td>
<td>58.31</td>
</tr>
<tr>
<td>Area of Cross Section (m²)</td>
<td>4.52</td>
<td>4.52</td>
</tr>
<tr>
<td>Payload Mass Kg</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Lift Off Weight (Kg)</td>
<td>76275</td>
<td>74875</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Missile Trajectory Parameters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Pitch Angle (degrees)</td>
<td></td>
<td>89.26</td>
</tr>
<tr>
<td>Azimuth (degrees)</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>Range (Km)</td>
<td></td>
<td>787</td>
</tr>
<tr>
<td>Altitude (Km)</td>
<td></td>
<td>2105</td>
</tr>
<tr>
<td>Time of Flight (seconds)</td>
<td></td>
<td>1969</td>
</tr>
<tr>
<td>Impact Latitude Longitude</td>
<td></td>
<td>41.15 N 134.14 E</td>
</tr>
</tbody>
</table>

A trajectory with a pitch down angle of 89.26 degrees after a vertical liftoff launched at an azimuth of about 70 degrees provides a good match with the trajectory details put out by the various tracking agencies.

As we can see from Table 2 the range matches well with the reported range of 787 Km. The altitude reached in our trajectory run using Quo Vadis is 2105 Km which is not very far from the
reported altitude of 2111.5 Km. The trajectory realized flight time of 1969 seconds while not inconsistent with the reported flight time of “about 30 minutes” could be considered to be on the higher side. It is however possible that the agencies reporting on the time of flight did not track the missile all the way to its impact point. 23

The reconstructed trajectory of the Hwasong 12 missile using a Google Earth rendition is shown in Figure 5.

![Figure 5](image)

Range of the Hwasong 12 Missile

Using the missile parameters derived from the reconstruction of the realized Hwasong 12 trajectory the maximum range of the missile was estimated. The range of the missile with a 650

---

23 The trajectory runs suggest that for a 150 Kg Reentry Vehicle with a 2.4 m diameter it takes about 160 seconds to hit the ground from an altitude of about 10 Km. It is possible that the tracking data may not cover the last part of the missile flight just before it impacts the ground. This could account for much of the difference in the flight time.
Kg Nuclear warhead launched at an azimuth of 90 degrees works out to be 4385 Km. This missile can comfortably reach the US base at Guam from a suitable location in North Korea.

The Hwasong 12 can be the first two stages of a North Korean ICBM. With a suitable third stage it would be possible for North Korea to reach the US mainland.

**Findings & Conclusions**

Based on this analysis of the Hwasong 12 missile we can make the following inferences:

- A single stage Hwasong 12 missile that is either derived from the Musudan (with a Russian R 27 heritage) or based on indigenous development seems to be beyond North Korea’s current missile and space launch capabilities.
- Measurements on the images especially of the engine part of the missile suggest that the Hwasong 12 could have been derived from North Korea’s Unha 3 launch vehicle which has a diameter of 2.4 m and uses Kerosene and AK 27 as fuel and oxidizer.
- A single stage Unha 3 derived Hwasong missile can also be ruled out. It would be difficult if not impossible for North Korea to currently build such an advanced stage.
- The Hwasong 12 is therefore a two stage missile. It is likely that both the stages use the same kind of engine that has been used for the Unha 3 booster.
- The two stages could be approximately about the same length.\(^{24}\) The length of the two stages taken together is about 18.26 m.
- The length of the Reentry Vehicle is about 5.25 m. This length would suggest that it would carry a possible future thermonuclear warhead.
- The first stage would be very similar to the Unha 3 booster with a propellant fraction of 84%.
- The second stage would also use the same engine as the Unha 3 booster but would be a more optimized stage with a propellant fraction of around 87%.
- Such an optimized second stage with a Nodong pedigree has already been flown on two successful Unha 3 launches. It is reasonable to assume that such capabilities can be extended to realize the larger diameter second stage for the Hwasong 12.
- In order to match the reported tracking data the mass of the Reentry vehicle assumed is about 150 Kg.\(^{25}\) This would suggest that North Korea only tested the shell of the RV without any other mass.

\(^{24}\) In principle there could be a number of possibilities for sizing the two stages. However configured they have to provide the required velocity at the desired altitude to provide the realized range, altitude and time of flight. Taken together they also need to have a total length of 18.25 m.

\(^{25}\) The Salversberg and Kiessling simulation of the trajectory (reference 11) also uses 150 Kg as the mass of the Reentry Vehicle.
• The use and shaping of the lofted trajectory may have been dictated by several other considerations as well. It is possible that North Korea did not want to provide advance information about the flight to other countries that would enable them to monitor those locations and recover debris.
• The successful test of this missile does enable North Korea to reach certain targets with a fission device. North Korea has so far conducted five nuclear tests. Coupled with the development of missiles such as Hwasong 12 the tests should enable North Korea to develop a lighter warhead with a fission device. Such a warhead could have a mass of 650 to 700 Kg.
• The predicted range of the Hwasong 12 missile with a warhead weighing 650 Kg launched due east with an azimuth of 90 degrees will be 4385 Km. This should allow North Korea to comfortably target Guam even with a heavier warhead.
• Unlike the other missiles tested by North Korea so far, the Hwasong 12 appears to be the most likely candidate for the yet to be demonstrated North Korean ICBM. If this two stage missile can be integrated with another third stage it may result in a missile that can reach the US with a nuclear payload. There are a number of potential third stages that can emerge out of the Unha 3 launcher programme or from the other missile stages that North Korea has been developing. One could expect to see the test of a missile with such a configuration soon.
• Most probably such a third stage could be liquid fueled since North Korea’s experience with solid fueled missiles has not been very good. It is also likely that the third stage of such an ICBM would be based on the well proven Scud Nodong pedigree of Kerosene and RFNA rather than any other yet to be proven fuel oxidizer combination.
• The length of the warhead tested which is about 5.25 m also suggests that North Korea does intend to fit such an ICBM with a thermonuclear weapon. Though there is no clarity as too whether North Korea has carried out a successful boosted fission test it may well do so in the future before embarking on a thermonuclear weapon development programme.
• Taken together the successful launch of the Hwasong 12 along with the nuclear weapons testing that North Korea is carrying out indicates that North Korea is well on its way towards developing a nuclear tipped ICBM that can reach the continental United States.

---

26 With five nuclear weapon tests North Korea may be in a position to build such a fission warhead.
27 Several sources seem to suggest that the yield of the fifth nuclear test was about 30 KT. This yield value may not be inconsistent with a boosted fission test.