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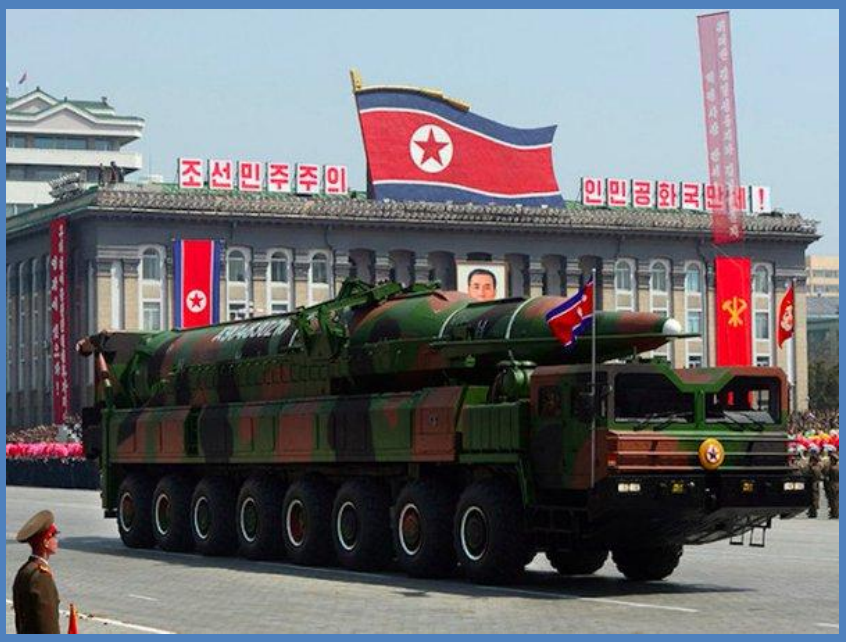

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S.Chandrashekar, Rajaram Nagappa & N.Ramani[1]

Background

The launch of two ICBM's within the space of one month by North Korea has created a major turmoil within the countries of the Asia Pacific Region. These July 2017 flights were preceded by the test of an IRBM in May 2017 as well as the launching of a large number of shorter range ballistic missiles.

North Korea has already conducted five nuclear weapon tests and is presumed to have a reasonable stockpile of fissile materials. The recent spate of missile launches provides visible proof of North Korea's intent to target the US and its allies with nuclear weapons.

The first of the ICBM tests that potentially threaten the US was carried out on July 4 2017. The missile was launched from near the Panghyon Aircraft factory with location 39.87 N 125.27 E. According to reports put out by various agencies tracking the missile the Hwasong 14 was launched on a lofted trajectory with a range of 933 Km landing in the waters between Japan and Korea. The missile reached an altitude of 2802 Km with a flight time of 37 minutes (2220 seconds).

The range of this missile if it were launched on a maximum range trajectory is reported to be at least 7500 Km. This range would bring Alaska and parts of Hawaii within striking distance of the missile. However the US mainland would still be out of reach. Other analysts reporting on this test suggested that it could have a range of up to 9500 Km making at least some US cities vulnerable.

The second test was also a lofted trajectory test carried out on July 28 2017. It was a night launch from a different location reported to be near Mupyong Ni (40.69 N 126.46 E). The missile travelled farther to 998 Km and landed 200 Km west of the Shakitan peninsula of Hokkaido. The missile also reached a higher altitude of 3725 Km with a longer flight time of a little over 47 minutes.

The range of the Hwasong missile launched on July 28 is reported to be between 10400 to 11000 Km. Such a range would enable the Hwasong 14 to target most US cities and make the North Korean threat credible.

The International Strategic and Security Studies Programme (ISSSP) at the National Institute of Advanced Studies (NIAS) carried out an independent assessment of the performance of North Korea's two Hwasong 14 ICBM launches. The results of this assessment are presented in this brief.

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The July 4 Hwasong 14 Launch

North Korea released video footage as well as images of the Hwasong 14 missile soon after the July 4 launch.

They also released information on the range, the flight time and the altitude reached by the missile. These parameters were confirmed by a number of countries independently tracking the missile. These reports also confirmed that it was a two stage and not a single stage missile as some observers had initially suggested.

An examination of the images of the missile launched on July 4 confirmed the fact that the Hwasong 14 was a completely different missile from the Hwasong 12 IRBM which had been launched in May 2017.

Figure 1 provides the images of the two missiles. Even without any measurements it is obvious that the two missiles are quite different.

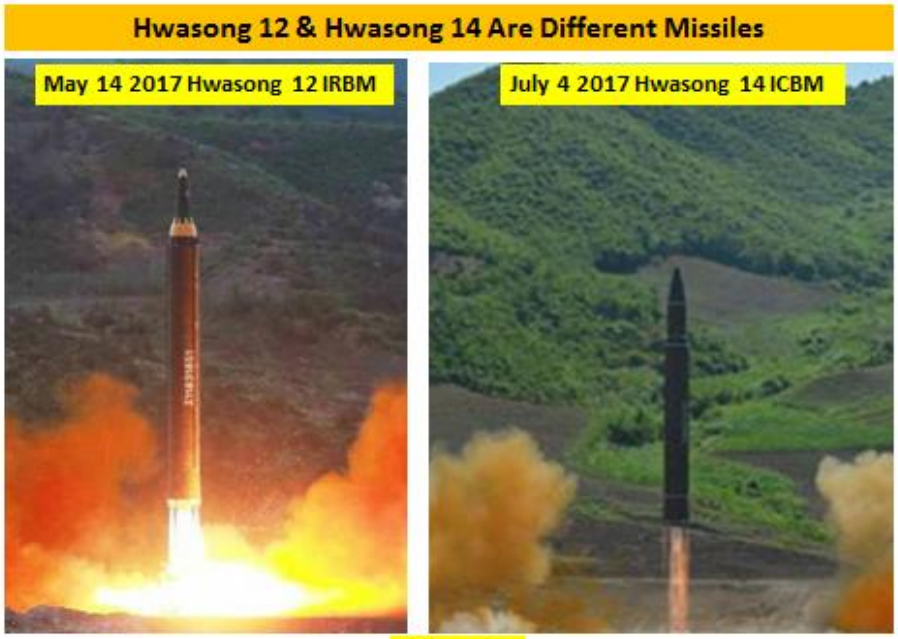

Figure 1

Based on measurements on the images of the Hwasong 14 missile, the diameter of the booster stage was estimated to be about 2 m. The diameter of the upper stage was estimated to be 1.5 to 1.6 m.

The overall length of the missile is about 20.5 m with the re-entry vehicle, second stage and first stage having lengths of 3.75 m, 2.75 m and 14 m respectively.

The measurements on the images were used to initially size the missile. A propellant mass of 33400 Kg with an inert mass of 6400 were the estimates derived for the first stage. A propellant mass of 3200 Kg with an inert mass of 500 Kg were the initial estimates for the second stage. Typical thrust values and

specific impulse values from earlier studies on North Korea's satellite and missile launches along with the location of the known launch site were then used for trajectory simulation studies of the July 4 launch. The payload for the initial trajectory was assumed to be 150 Kg which would be the bare structure of the re-entry vehicle without a payload.

Using the NIAS developed Quo Vadis Trajectory simulation model a series of trajectory runs were carried out to realize the actual trajectory flown by the Hwasong 14. **The missile parameters that provide a close match to the realized trajectory are provided in Table 1.**

Table 1

First Stage Parameters	Value
Propellant Mass Stage 1 (kg)	33400
Inert Mass Stage 1 (kg)	6400
Stage Mass	39800
Fuel Fraction	0.84
Thrust Sea Level (Newtons)	770000
ISP Sea Level (seconds)	229
Burn time Computed (seconds)	97.41
Area of Cross Section (m^2)	3.14
Second Stage Parameters	
Propellant Mass Stage 2 (kg)	3200
Inert Mass Stage 2 (kg)	500
Stage Mass	3700
Fuel Fraction	0.86
Thrust (Newtons)	58000
ISP Vacuum (seconds)	265
Burn time Computed (seconds)	143.38
Area of Cross Section (m^2)	1.77
Payload Mass Kg	325
Lift Off Weight (Kg)	
Missile Trajectory Parameters	
Initial Pitch Angle (degrees)	89.23
Azimuth (degrees)	75
Range (Km)	931
Altitude (Km)	2800
Time of Flight (seconds)	2237
Impact Latitude Longitude	40.00 N 136.2E

As we can see from **Table 1** the realized range of the configuration used in Quo Vadis is 931 Km which is close to the realized range of 933 Km reported by various tracking agencies. The realized altitude is 2800 Km which is also close to the reported 2802 Km altitude. The flight time from the trajectory model is 2237 seconds which is quite close to the reported flight time of 37 minutes (2220 seconds). The payload

that provides this fit with the realized trajectory has a mass of 325 Kg. Whether this mass is adequate to accommodate a nuclear warhead is still an open question. The missile is launched near vertically with a pitch angle of 89.23 at an azimuth of 75 degrees. The impact point of the missile is consistent with the data put out by agencies tracking the missile.

If this configuration with a payload mass of 325 Kg is launched on a maximum range trajectory along an azimuth of 90 degrees the range of the missile is about 7800 Km. However in order to reach the US the Hwasong 14 has to be launched in a north eastern direction. At an azimuth of 35 degrees the realized range of the missile is 7284 Km. Such a missile can reach all of Alaska as well as parts of Northern Canada. It however cannot reach the US mainland or any of its major cities.

The July 28 Launch of the Hwasong 14

Almost immediately after the July 4 launch North Korea launched another Hwasong 14 ICBM. As mentioned earlier this missile flew farther (998 Km), higher (3725 Km) and longer (47 minutes and 12 seconds or 2832 seconds). It was clear that North Korea was telling the world that they did indeed have a missile that could go farther than what it had demonstrated in the July 4 launch.

A video of the launch and images of the missile put out by North Korea made it clear that the July 28 lunch was a Hwasong 14 missile very similar to the one flown on July 4.

Figure 2 provides a comparison of the two missiles. It is clear that the two missiles are the same.

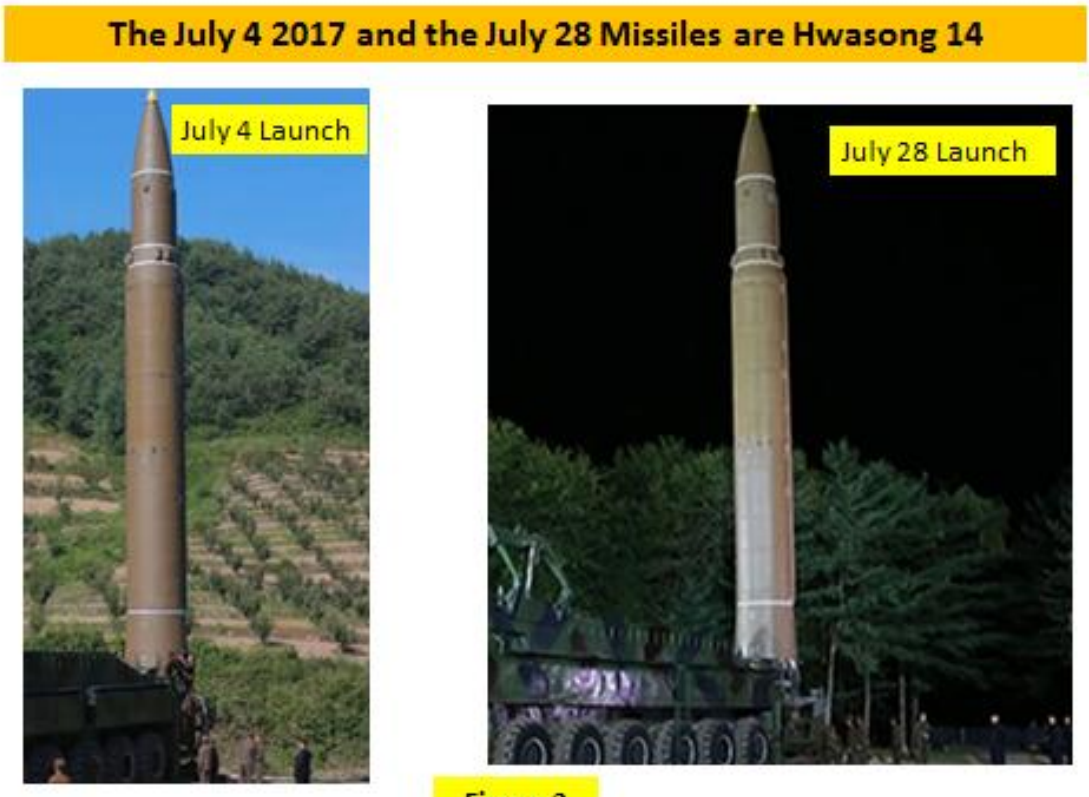

Figure 2

The July 28 launch was also from a new launch site near Mupyong Ni demonstrating that North Korea could launch missiles quickly from a number of different locations within the country.

The improvement in the performance of the July 28 launch could have been achieved most easily by

- Reducing the mass of the payload
- By loading more propellant into the second stage without adding to the inert weight of the stage
- By improving the specific impulse of the second stage

It is unlikely that the performance improvement evident in the July 28 flight was a result of a significant increase in the specific impulse. This option can therefore be ruled out in this case.

Using the results of the baseline model derived from the July 4 test we could explore the various options available to North Korea to demonstrate a longer range missile.

One obvious approach is to reduce the payload to only the heat shield of the reentry vehicle. Trajectory runs with the payload reduced to 150 Kg were not by themselves sufficient to match all the observed performance parameters of the July 28 test.

If one retained the same payload mass and increased only the propellant carried by the second stage without adding to its inert mass, the propellant fraction becomes greater than 92 %. Such an advanced stage may be difficult for North Korea to achieve based on its current capabilities. This option can also therefore be ruled out.

It appears obvious from the above that in addition to reducing the payload mass, some propellant also had to be added to the second stage without increasing the inert weight of the stage.

By reducing the payload from 325 Kg (baseline of the July 4 flight) to 150 Kg and by increasing the propellant mass of the second stage from 3200 Kg (baseline of July 4 flight) to 3650 Kg we were able to match the range, time of flight and the altitude realized by the July 28 flight of the Hwasong 14.

This option requires that the second stage has a propellant fraction of 88% which is a much more realistic possibility for North Korea to realize.

Table 2 provides details of the Hwasong 14 configuration that closely matches the range, time of flight and the altitude realized by the flight of July 28 2017.

Table 2

First Stage Parameters	Value
Propellant Mass Stage 1 (kg)	33400
Inert Mass Stage 1 (kg)	6400
Stage Mass	39800
Fuel Fraction	0.84
Thrust Sea Level (Newtons)	770000
ISP Sea Level (seconds)	229
Burn time Computed (seconds)	97.41
Area of Cross Section (m^2)	3.14
Second Stage Parameters	**Value**
Propellant Mass Stage 2 (kg)	3650
Inert Mass Stage 2 (kg)	500
Stage Mass	4150
Fuel Fraction	0.88
Thrust (Newtons)	58000
ISP Vacuum (seconds)	266
Burn time Computed (seconds)	164.16
Area of Cross Section (m^2)	1.77
Payload Mass Kg	150
Lift Off Weight (Kg)	
Missile Trajectory Parameters	**Value**
Initial Pitch Angle (degrees)	89.30
Azimuth (degrees)	66
Range (Km)	1002
Altitude (Km)	3720
Time of Flight (seconds)	2836
Impact Latitude Longitude	42.90 N 138.19E

The main differences between the two flights are

- The payload has been reduced from 325 Kg in the July 4 flight to 150 Kg in the July 28 flight.
- The propellant loading of the second stage has increased from 3200 Kg in the July 4 flight to 3650 Kg in the July 28 flight.

These changes are marginal and would pose no special problems to North Korea.

Can the Hwasong 14 reach the US mainland?

Table 3 provides details of the range of the Hwasong 14 for different warhead masses launched in different azimuth directions from the launch site used for the July 28 launch.

Table 3

Warhead Mass (Kg)	Azimuth (degrees)	Range (Km)	Coverage
150 Kg	0 to 40 degrees	10560 – 12700 Km	All of continental US covered
200 Kg	20 to 40 degrees	9940 – 10650 Km	San Diego, LA, SF up to Chicago covered
250 Kg	40 degrees	9375 Km	West Coast up to LA covered
300 Kg	40 degrees	8454 Km	Portland, Seattle - 500 Km short of SF
325 Kg	40 degrees	8075 Km	Can reach Portland

It is clear from Table 3 that the ability of the Hwasong 14 to threaten the US mainland is critically dependent on the mass of the warhead.

With a warhead of 300 to 325 Kg a few major cities in the US can be reached.

A warhead with a mass of 250 Kg can reach the whole of the west coast up to LA.

If this mass can be reduced even further a significant part of the US then comes within reach of North Korean missiles.

The reports on the range of the Hwasong 14 put out after the July 28 test seem to suggest that North Korea can build a nuclear warhead that weighs between 150 to 250 Kg. How realistic is this assumption is still an open issue. Our own view is that North Korea may still need a few more nuclear weapon tests before they can reach a 150 to 250 Kg Re-entry Vehicle.

North Korea has so far conducted five nuclear weapon tests.

The last of the tests had a reported yield of 30 KT and could have been a Boosted Fission test.

With two launches of the Hwasong 14 North Korea has demonstrated its capability to reach the US mainland. Its next step may to signal that it has the knowhow to miniaturize its nuclear warhead.

One can expect that North Korea will not only continue to demonstrate long range missile capability but also go ahead and conduct a few more nuclear weapon tests as it strives to develop a smaller warhead to place on top of its reliable ICBM.