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International Strategic and Security Studies Programme
National Institute of Advanced Studies
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Summary Overview

North Korea's attempt to launch a satellite into earth orbit failed for the fourth time on April 12 2012.

Details of what happened are still not fully clear. From the limited evidence released to the public the failure happened close to the end of the first stage burnout though the information put out by North American Aerospace Defense Command (NORAD) and South Korea differ to some extent.

The announcement by North Korea of the imminent launch and its notification of the areas of impact of the spent first and second stages triggered widespread international condemnation especially from the US. In their view the space launch is a clever ruse by North Korea for acquiring long range missile capability under an ostensible noble civilian peaceful purpose.

The imminent launch also saw the publication of many articles and reviews about North Korea's missile and space launchers. These drew upon earlier work that many of them had done on the space and missile capabilities of North Korea. These also had the benefit of a more transparent North Korea which allowed the international press access to the launch site and allowed limited video coverage.

At NIAS we thought it a worthwhile exercise to track the North Korean launch effort and if possible make some predictions about the launch. Though the launch has failed we thought it necessary to put out our work in the public domain. This report is the outcome of our work and is based on the assumption that if the North Koreans had been successful what kind of capability would they have created.

Using images of the Unha 2 and Unha 3 launchers available in the public domain we were able to make measurements on the different components of the missile. Using the diameter and lengths obtained from these we were able to translate them into propellant and structural masses. Using other publicly available information on North Korea's missile and space programmes and some expert knowledge available with rocket engineers and designers we could derive the necessary launch vehicle parameters for running a trajectory model developed at NIAS.

The notifications of the impact zones for the first and second stages put out by North Korea helped us anchor our trajectory model more realistically to the first and second stage cutoff velocities and locations of the missile. Through a process of iteration we were able to alter the missile parameters obtained from the images with the shaping of a trajectory that fitted well with the notified impact zones for the first and second stage respectively. A launch azimuth of 171 degrees and an initial pitch angle of 89.2 degrees provided a reasonable fit with the first and second stage impact zones. To achieve this fit some additional weight had to be added to our derived baseline third stage and some marginal changes were also needed for the second stage.

Using this iterated and improved baseline that fitted with the impact zones of the first and second stages we then went to shape the trajectory of the third stage. To achieve the intended 500 km orbit it is necessary to carry out a maneuver after the burnout of the second stage. After this the third stage satellite combination has to coast for a certain time before the third stage rocket motor is ignited. This firing has to happen close to an altitude of 500 km and should take place when the local velocity vector is perpendicular to the radius vector of the third stage. Through a process of iteration once again we were able to inject the third stage with the satellite into an orbit of 506 km perigee and 638 km apogee. The achieved orbit has an inclination of 87.050 degrees and a period of 95.93 minutes.

Though the achieved orbit is not perfectly circular it is reasonably close to the set of possible orbits that North Korea could have achieved if the launch had been successful. The degree to which an achieved orbit matches the parameters of a perfect 500 km circular orbit would give us an idea of North Korean capabilities in mastering the technology of a precise orbit injection to achieve a desired orbit.

The Keplerian orbital elements that are based on a non-rotating earth centered inertial frame of reference have also been derived from the propagation of our trajectory model. For different points in the orbit these orbital elements are relatively constant as they should be.

Some of the key parameters of the achieved orbit are provided below.

Semi major axis of the elliptical orbit **"a"**	6943 Km
Eccentricity of the orbit **"e"**	0.0095
Apogee of orbit	638 Km
Perigee of orbit	506 Km
Inclination of the orbit ***"i"***	87.050
Period of the satellite	95.93 minutes

Since the space launch vehicle can also be used as a missile we also studied the range that could be achieved by the Unha 3 if it is used as a ballistic missile with a standard 1000 kg nuclear payload. The ranges for different launch directions vary from a minimum of 6200 km to a maximum of 7700 km depending on the direction of launch. These ranges are not sufficient to hit any major city in the continental USA which are located over 9000 km away. However the range of the missile is adequate for it to reach targets in Alaska. The Unha 3 missile therefore does pose a threat to the United States

Though the launch has failed the results of this exercise can be matched to the orbital elements realized by North Korea if and when they launch a satellite into a similar orbit. The extent to which the achieved orbit parameters meet those of a near perfect 500 km circular orbit would provide some insight into North Korean capabilities in both the missile and space domains.

Background

A major topic that grabbed international media attention recently related to North Korea's attempted launch of a 100 kg satellite into a 500 km polar orbit. This launch was North Korea's fourth attempt to put a satellite into earth orbit.[1] Three other attempts in 1999, 2006 and 2009 all ended in failure.[2] According to North Korea the current launch is a part of the country's plans to use space for developmental purposes.

North Korea's announcement evoked widespread concern and condemnation from all countries. North Korea's neighbours especially Japan and South Korea were prepared to shoot down the launcher if it strayed into their territory.[3] The US as well as Europe and a host of other countries including North Korea's mentor China have condemned North Korea's actions. There is international unanimity that the space launch was being used as a legal cover for the development of a long range missile by North Korea.[4]

Unlike in the past where North Korea's attempts at space launches have been carefully kept under wraps, there was some effort on the part of North Korea to share information on Unha 3 launch. A media team was taken to the launch site for a view of their launcher.[5] The launch preparations were monitored by satellites and information was constantly updated by the international media.[6] Launch coincided with the 100th birth anniversary of North Korea's founder president Kim Il Sung.[7]

Some investigators have critically examined the information put out by North Korea and other information coming out from the

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1 North Korean statements suggest that the satellite could even be in a sun synchronous orbit. The purpose of the mission appears to be remote sensing applications to manage various resources.

2 According to publicly available information the 1999 launch was based on a Nodong first stage, a Scud derived second stage and a small solid propellant third stage. The 2009 launcher was significantly different involving a new bigger 2.25 m liquid booster stage, a Nodong second stage and a small liquid propellant liquid stage. For a more detailed analysis of the 2nd launch and associated missile parameters see David Wright, "An Analysis of North Korea's Unha - 2 Launch Vehicle", Union of Concerned Scientists, March 30 2009.

3 The ability of any of the neighbouring countries to shoot down the missile in the boost phase or mid-course phase where the altitude is about 500 km is questionable.

4 For a historical perspective of development and motivation see Daniel A Pinkston, "The North Korean Ballistic Missile Programme", February 2008 available from http://www.StrategicStudiesInstitute.army.mil/

5 A media team has already visited the site and there is a video on the net put out by BBC where engineers are seen working on the missile. Some images on the vehicle put out on the Internet are from this video. See http://www.bbc.co.uk/news/world-asia-17650517

6 Nick Hansen, "Preparing for the April DPRK Launch: A timeline for the next three weeks", http://38north.org/2012/03/nhansen0329/

7 38 North, " North Korea Begins Launch Pad Preparations for April Rocket Launch: A 38 North Exclusive", http://38north.org/2012/03/tongchang0329/

media to assess the performance of North Korea's launcher.[8] These include mapping the impact zones where the spent first and second stages fall as notified by North Korea as well as a comparison between the 2009 failed Unha 2 launch and the current Unha 3 launch.

The Launch of April 12 2012

North Korea carried out the launch on April 12, 2012. According to NORAD the launch was unsuccessful and the first stage of the missile fell into the sea about 165 Km west of Seoul.[9] Another source based on South Korea's tracking of the launch differs from this estimate of the impact point of the failed launcher. According to this source the failed rocket landed just a little bit away from the notified impact zone put out by North Korea for the first stage impact. This would suggest that the failure happened towards the end of the first stage operation.[10]

Figure 1 provides an overview of the information on the launch and where the missile fell into the sea. The differences between NORAD and South Korea on the impact location are clearly captured in this figure. If the NORAD data is more correct the impact happened about 245 km south of the launch site. If the South Korean data is right the impact happened much further down south at about a distance of 410 km from the launch pad. Since this is just a little bit above the front part of the impact zone for the first stage put out by North Korea (marked ABCD) this would imply that the failure occurred just before the burnout of the first stage. If the NORAD data is more correct the failure must have happened a few seconds earlier.[11] This aspect will be touched upon later after we have run a trajectory that fits the missile path with the provided first and second stage impact points.

Inputs for Evaluation of the Launch Trajectory

Though the launch was a failure it may be still worthwhile to find out what kind of a vehicle has been engineered by North Korea. It may also be important to know whether the inferences we make about North Korea's capabilities are consistent with the visual and inferred evidence that has now become available. There is now a reasonable base of information and data on North Korea's space launcher. The notification of the impact zones for the spent first and second stages provides some additional anchor points for fixing the parameters and trajectory of the space launch. As mentioned earlier some work along these lines is already going on. The International Strategic & Security Studies Programme (ISSSP) at the National Institute of Advanced Studies (NIAS) thought it worthwhile to investigate North Korea's space launcher in some more detail to see whether we can come up with a more informed evaluation of North Korea's capabilities and if possible make some predictions about the orbit of the satellite that

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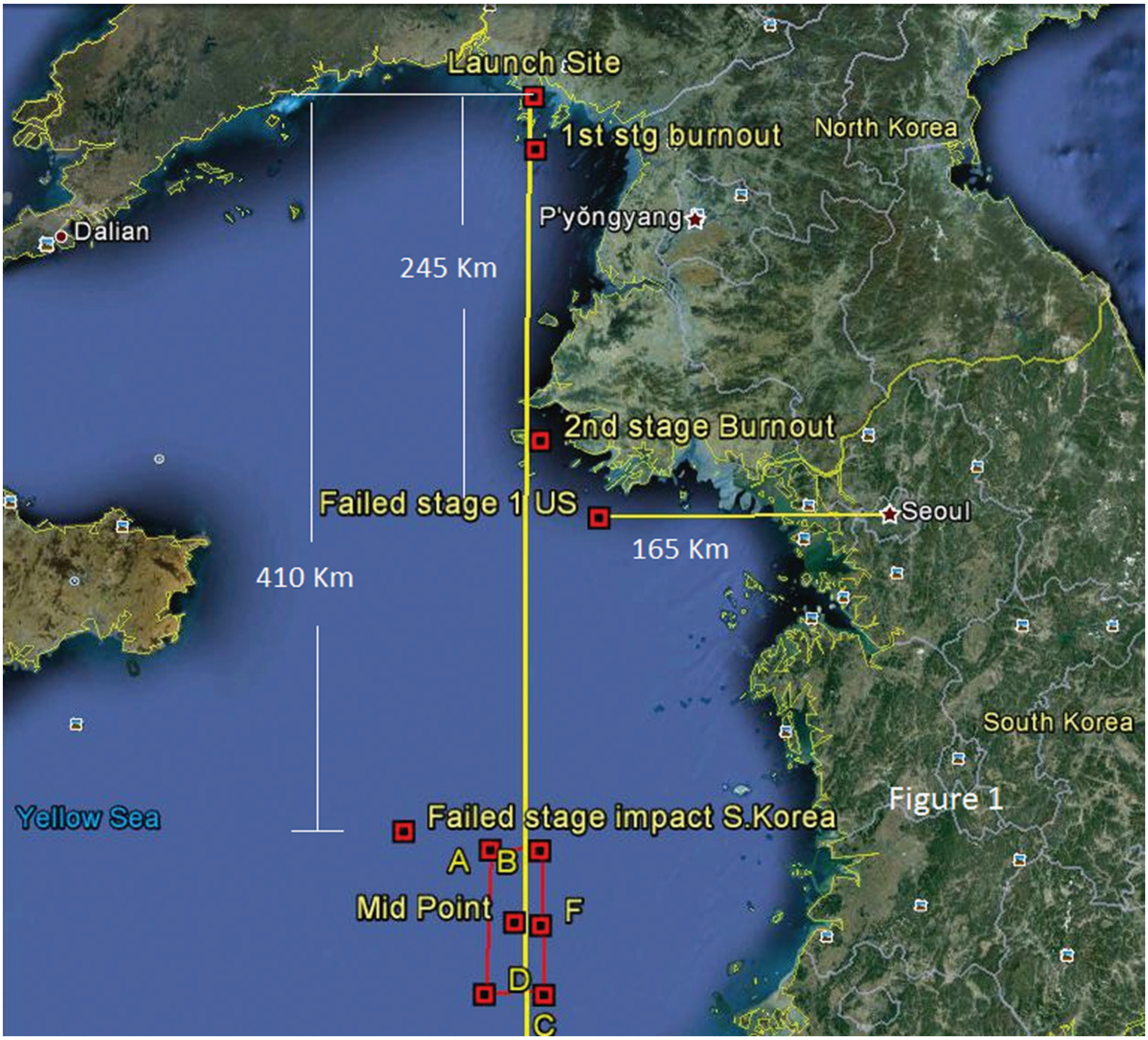
8 David Wright has put out a number of interim reports on the launch of North Korea's Unha 3 launch vehicle prior to the actual launch. These include David Wright "North Korea's Launch: Threading the Needle", April 1, 2012 http://allthingsnuclear.org/post/20309447404/north-koreas-launch-threading-the-needle, and "A Comparison of North Korea's Unha 2 and Unha 3", April 8, 2011 http://allthingsnuclear.org/post/20730991602/a-comparison-of-north-koreas-unha-2-and-unha-3

9 http://www.northcom.mil/News/2012/041212.html

10 Jonathan's Space Report No. 657 http://www.planet4589.org/space/jsr/jsr.html

11 For the NORAD data to fit, the velocity of the missile at failure would be about 1.44 Km per second. For the South Korean data to be correct the velocity would be closer to the velocity required of the first stage of 2.1 Km per second.

Figure 1



North Korea would have put into space if the launch had been successful.

To carry out any analysis of the trajectory of a space launch the starting point has to be data on the various basic parameters of the launch vehicle.[12] This starting point used for our analysis of the Unha 3 launch were the images available in the public domain of North Korea's Unha 2 launcher used for the April 2009 space effort. These images were used to make measurements of the different components of the missile. These measurements made in pixels were converted into physical lengths by making the assumption that the second stage of the Unha 2 launcher is a Nodong derivative whose diameter we had validated earlier as being close to 1.33 m. The procedures for converting these lengths into propellant and stage weights are reasonably well-known and the group at NIAS has used such approaches on

[12] These include data on propellant masses and structural weights of the different stages, the specific impulses of the propellant combinations used in each stage, information on the thrust of the rocket engines used in different stages as well as data on the weight of the payload.

other similar studies.[13] The image used to make the measurements is in Figure 2.

Based on the assumption that the second stage diameter is 1.33 m – a reasonable assumption since the second stage has to be a Nodong variant – the diameters of the booster stage and the third stage can be estimated as 2.25 m and 1 m respectively. The tank lengths, which are important for determining the amount of propellant, are 12m, 6.5 m and 2.4 m for the first, second and third stages respectively.[14] The overall length of the vehicle which includes the satellite works out to be about 28 m.

Annexure 1 provides the details of these weight estimates for the different stages based on our image measurements. Our estimates are also compared with the estimates put out David Wright after North Koreas launch of Unha 2 in 2009[15]. Our estimate of the weight of the first stage at 56.5 tonnes is lower than Wright's estimate of about 66 tonnes. Our estimate of the second stage mass is 10.2 tonnes. This matches well with Wright's estimate of 10.1 tonnes. Our estimate of the third stage mass is 1.450 tonnes as compared to Wright's estimate of 1 tonne. Our analysis assumes the payload shroud mass as 400 kg (Wright's value) and a satellite mass of 100 kg. Following Wright our trajectory also assumes that the shroud is jettisoned at 180 seconds after liftoff during the second stage burn.

As we were progressing with our work some more information on North Korea's space launcher became available. Based on this Wright has made available a comparison of the launcher used in 2009 with the 2012 launcher. This figure **(Figure 3)** is reproduced from Wright.[16] As we can see there is an almost perfect match between the two images. In the second image some people are seen working on the missile. There is also another image available of the satellite part of the missile enabling a comparison of the diameters of the second and third stages.[17] These images are consistent with a 1m diameter third stage, a 1.33 m diameter second stage and a 2.25 to 2.35 m diameter of

Figure 2

[13] S.Chandrashekar et al, "An Assessment of Pakistan's Ballistic Missile Programme - Technical and Strategic Capability", National Institute of Advanced Studies, Report No. R 5-06, 2006.

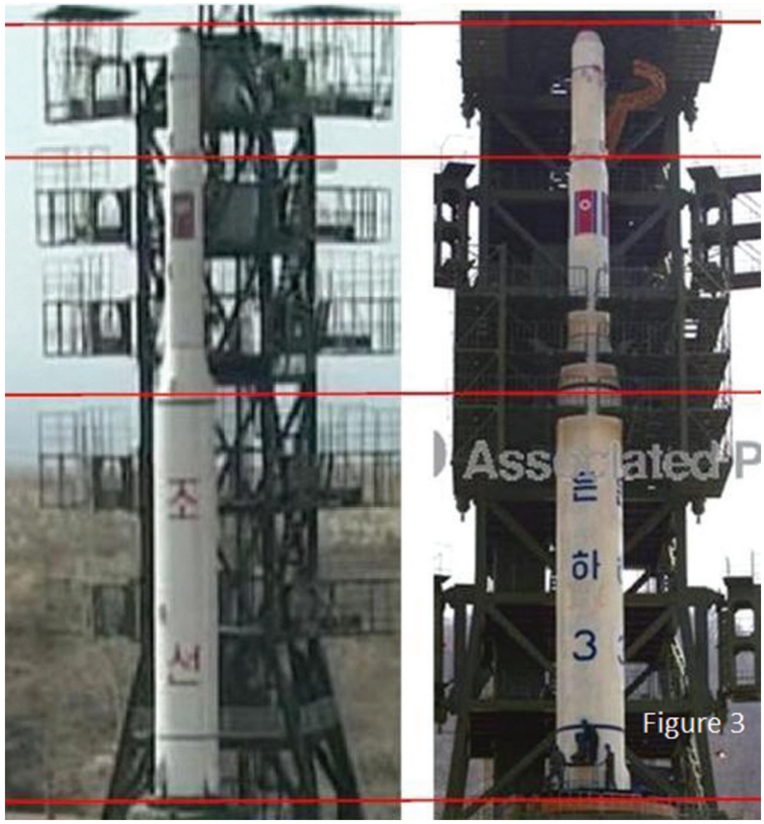
[14] This is based on the assumption that all three stages use liquid propellants.

[15] See Reference 2 p7

[16] David Wright, "A Comparison of North Korea's Unha-2 and Unha-3", April 8, 2012, http://allthingsnuclear.org/post/20730991602/a-comparison-of-north-koreas-unha-2-and-unha-3

[17] http://english.peopledaily.com.cn/102774/7780643.html

Figure 3



Unha-2 (April 2009) **Unha-3 (April 2012)**

the first stage. Therefore using an image of the earlier Unha 2 launch **(Figure 2)** to size the current launcher is consistent with the visual evidence.

Simulating the Trajectory of the Unha 3

We will use the launcher parameters derived from our measurements of the Unha 2 launcher as the baseline for computing the trajectory. Using the information on the impact zones of the spent first and second stages of the launch we will try to model the actual trajectory that North Korea may choose to launch a 100 kg satellite into a 500 km near polar orbit.

The coordinates for the impact area of the spent first and second stages are available.[18] The midpoint of the impact area of the first stage is 35 33 47 North Latitude and 124 41 23 E Longitude and the midpoint of the impact area of the second stage is 17 16 23.5 North Latitude and 124 17 50.25 E Longitude respectively. These midpoints are located at distances of 456 km and 2490 km from the launch site respectively. These midpoints will be used to shape and fine tune the trajectory of the Unha 3 launcher.

Using the baseline configuration derived from the images and some assumptions on thrust and specific impulses based on empirical knowledge and evidence available in the public domain we will run our trajectory model and shape the cutoff velocities at the burnout of the first and second stages so that the spent

[18] See Reference 8

stages land reasonably close to the midpoint of the impact areas specified by North Korea. From this trajectory of the first two stages of the launch we will then proceed to shape the trajectory of the third stage so as to put a 100 kg satellite into a 500 km near polar orbit.[19]

The initial pitch angle of the missile after liftoff as well as the azimuth were varied so that the impact points of these stages was close to the midpoint of the zones notified by North Korea. **Through a process of iteration we also determined that the weight of the third stage had to increase by about 500 kg for the impact zone criterion to be met by the launcher**. An initial pitch angle of 89.20 degrees[20] with an azimuth angle of 171 degrees provides a reasonable fit for the first stage and second stage impact zones respectively. **The impact point for the first stage from our trajectory is shown in Figure 1.** The impact point for the spent first stage from our trajectory simulation lies close to the **point F** in the figure. This is located to the right of the midpoint of the impact zone and almost at the edge of this zone but still well away from the South Korean coast. The impact point of the failed launch as per information put out by NORAD and South Korea respectively are also shown.

First stage failure of Unha 3

Since we now have a trajectory for the first stage splash down we can try and make some inferences about the failure of the first stage. If the information put out by NORAD is correct the impact of the first stage which failed occurred downrange at a distance of 245 km downrange of the launch site. To achieve this range the launcher when it failed must have been travelling close to about 1.44 km per second. **From our trajectory model this would have happened at an altitude of 45 km and about 92 seconds after liftoff.**

If the South Korean estimate of the impact of the first stage is used the impact happens at a distance of about 410 km down range of the launch site. Since this is only about 50 kilometers away from the midpoint of the projected impact zone specified by North Korea the failure must have happened just before the burnout of the first stage at a velocity close to about 1.9 to 2 Km per second. **From our trajectory model the failure must have occurred at an altitude of 66 km and between 105 and 107 seconds after launch.** This failure seemed to have happened just before the burnout of the first stage. If the South Korean data is correct the failure could have taken place close to the separation of the first and second stages.

In either case as pointed out by Wright the failure happened well after the maximum dynamic pressure point indicated as Qmax in the technical literature where the vehicle goes through the regime of maximum stress.[21] The problem does not appear to be a structural

[19] North Korea's spokesman and press releases also talk of a sun synchronous orbit with an altitude of 500 km. This may require an additional maneuver of the 3rd stage before the coasting and ignition of the third stage. Our initial focus is an orbit without this additional maneuver.

[20] A vertical liftoff has a pitch angle of 90 degrees. This has to be pitched down to reach different targets. A pitch down from 90 degrees to 89.20 degrees will result in the first stage impacting the sea at a distance of 456 km down range of the launch site.

[21] The Qmax or the maximum stress regime for this launcher with our trajectory occurs at an altitude of 11 km and a velocity of 507 metres per second. The failure happened well after crossing this threshold.

breakup problem arising out of this event. We can also see from **Figure 1** that the burnout of the second stage happens well before the impact of the spent first stage

Achieving Orbit - Unha 3

After matching the impact points and the velocities of the first stage and second stage we then went on to fit the trajectory that would put the third stage and the satellite into a 500 km near circular orbit. Since the velocity after second stage burnout is known we can size the third stage suitably so that it can provide the velocity required to achieve a circular 500 km orbit. These revised parameters of our configuration which are modified from our original values are in Annexure 2. The second and third stages differ somewhat from our starting configuration.[22] These changes have come about in trying to fit the vehicle parameters with the splashdown points of the first and second stages as well as to provide the required additional velocity that the third stage should provide to put the satellite into orbit. In order to achieve a 500 km circular orbit after the burnout of the second stage the launch vehicle has to carry out a pitch down maneuver, coast for a certain time period and somewhere near the highest point of its trajectory which should be close to 500 km, fire the third stage motor when the local velocity vector is perpendicular to the radius vector. Such an operation will move the third stage close to the 500 km required orbit. Through an iterative process of changing the pitch down maneuvering angle after the second stage burnout and varying the coasting period we were finally able to achieve a 506 km by 638 km orbit – which is fairly close to the 500 km circular orbit specified by the North Koreans.[23] **Figure 4** which is a plot of the vehicle velocity versus range for the three stages provides an overview of the launch from liftoff.

A more detailed time line of events based on the trajectory run is provided as Annexure 3. A brief description of the salient elements of the trajectory is provided below.

Five seconds after a vertical liftoff the launch vehicle pitches down to 89.20 degrees and heads almost south at an azimuth of 171 degrees with respect to the launch site location. The first stage burns for a little over 108 seconds and at burnout the launcher achieves a velocity of 2105 meters per sec at an altitude of 71 km. The first stage separates out and falls downrange of the launch site at a distance of 457 km at a point close to the point F marked in Figure 1

The second stage ignites immediately after the first stage burnout and propels the rocket to an altitude of 314 km and a velocity of 4199 meters per second. The second stage burns for about 104 seconds. The shroud protecting the satellite is released 180 seconds after liftoff at about the midpoint of the second stage burn. The second stage separates and falls downrange of the launch site at a distance of 2475 km. The second stage impacts the ground after 1258 seconds well after the satellite has been injected into orbit. The impact is at 17.4 degree latitude and 124.18 degree longitude well within the

[22] There is an increase of about 500 kg needed to the third stage to account for the impact zones of the first and second stages. A large part of this increase is the amount of propellant needed in the third stage to provide the additional velocity to put the satellite into orbit.

[23] Even a small change in velocity could create an elliptical rather than a circular orbit. The closer the achieved orbit is to a circular orbit of 500 km altitude the more precise would the injection.

Figure 4

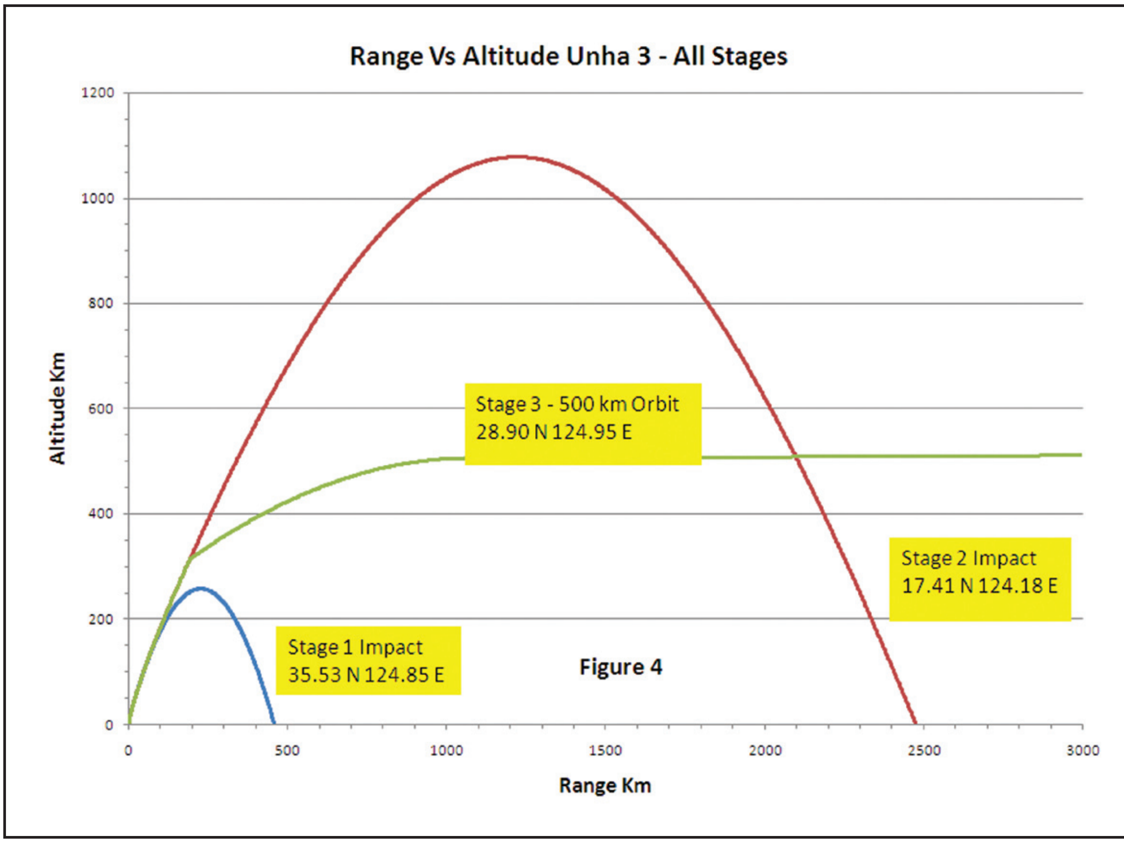
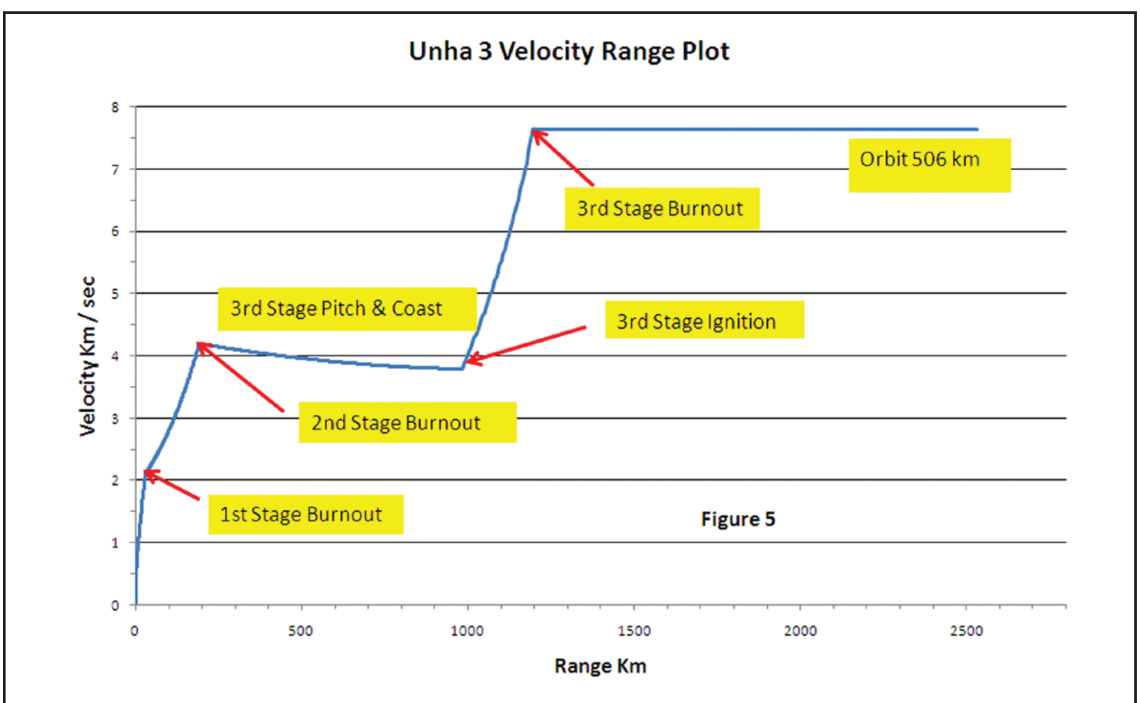


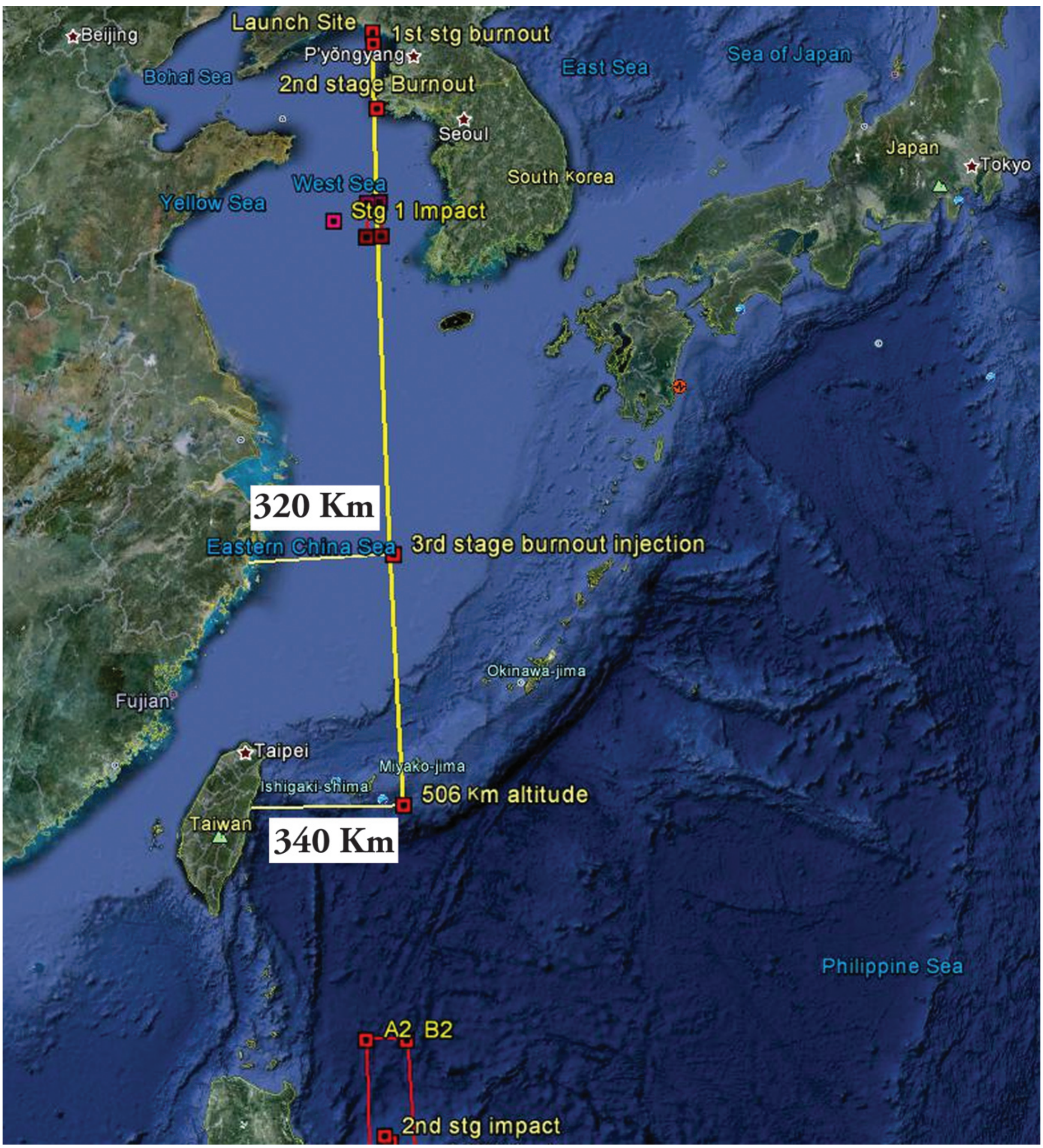
Figure 5



second stage impact zone notified by North Korea.

After the second stage burnout the launcher performs a further pitch down maneuver to 29.75 degrees with respect to the launch site and then coasts for a period of 222 seconds. 432 seconds after liftoff the third stage ignites and burns for about 44 seconds. At burnout the third stage with the satellite has a velocity of 7638 meters per second enough to put it into orbit. The satellite is injected into earth orbit at an altitude of 506.6 km at a location with Latitude 28.902 N and Longitude of 124.954. The injection happens at a distance of 1196

Figure 6



km from the launch site. **Figure 5** depicts the overall sequence of the firing of the three stages in terms of a velocity range profile.

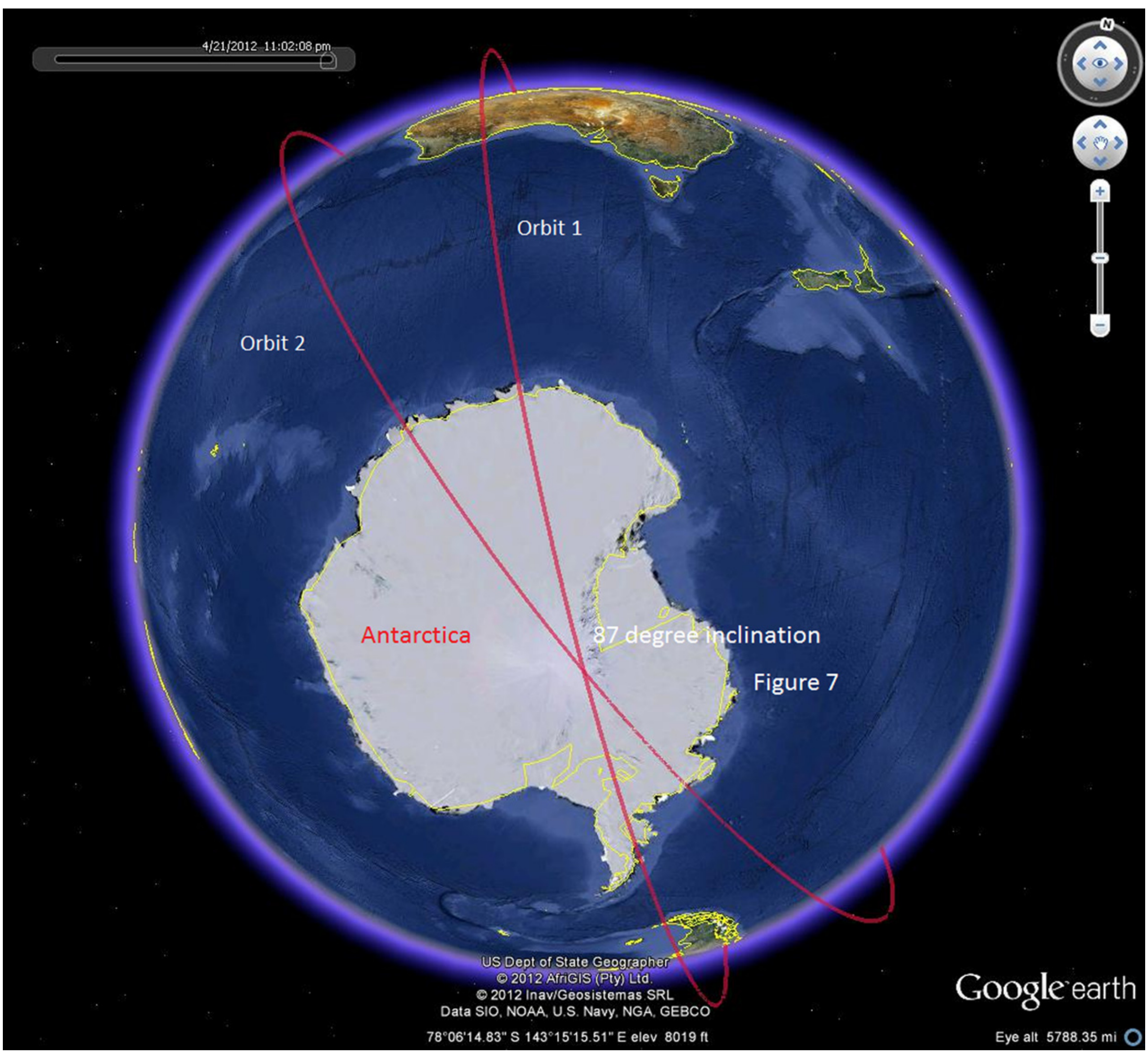
The overall trajectory and the major events in the trajectory are seen in geographic detail in Figure 6 using Google Earth. The injection of the satellite happens about 320 km off the China coast between Ningbo and Fujian. The satellite passes about 340 km east of Taiwan as it goes on to complete its first orbit.

Post Injection Orbit

Our trajectory model allows us to continue to track the satellite position and velocity even after injection. This data can be exported into Google Earth also. **Figure 7** provides this orbit as it seen from over the South Pole. From this image we can predict the inclination approximately.[24] The inclination of the orbit as obtained from this Google Earth Projection is about 87 degrees.

The altitude of the satellite increases slowly after injection till the apogee height of 638 km

Figure 7



[24] This is the point where the two tracks of the orbit that are seen in the image intersect

is reached. This occurs about 3274 seconds after launch at 34.065 S Latitude and 67.095 W Longitude. **Figure 8** provides the altitude variation of the achieved orbit with time. We can see that the apogee is about 638 km and the perigee about 506 km. The approximate period of the satellite orbit is 95.93 minutes.

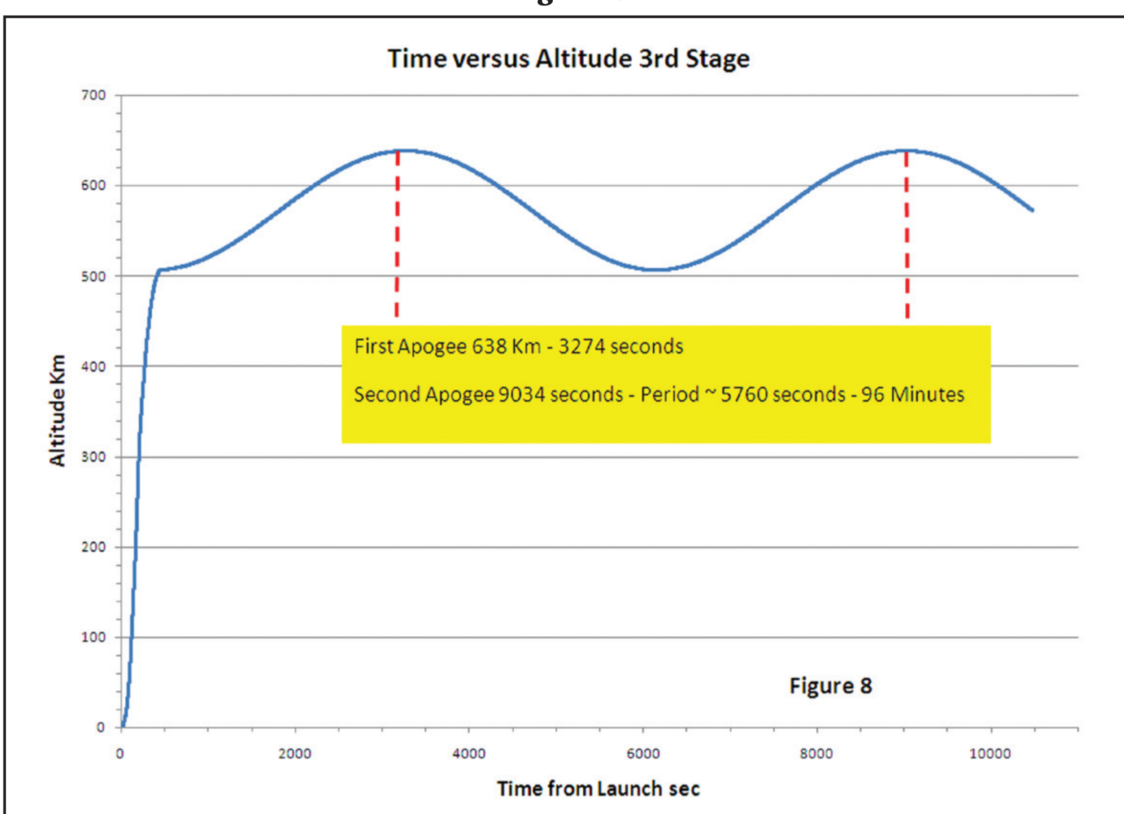
The Keplerian Orbital Elements of the Unha 3 Launch

To check the validity of our trajectory and orbit model we converted the orbital parameters into Keplerian orbital elements. Since Keplerian elements need an inertial frame of reference our ECEF rotating frame of reference had to be converted back into an Earth Centre Inertial (ECI) frame of reference. For any point in the orbit the conversion into Keplerian elements should give the same values for the various orbital elements except for some small second order effects.

The following are the major orbital elements for any elliptical orbit around the earth

- **Semi-major axis measured in Kilometers and represented by symbol "a" which is half the value of the major axis of the elliptical orbit.**
- **Eccentricity is a measure of the deviation of the orbit from a circular orbit denoted by "e".**
- **Inclination measured "*i*" in degrees is the angle between the equatorial plane of the earth and the orbital plane of the satellite.**
- **Right ascension of the ascending node Ω is the longitude where the satellite**

Figure 8



crosses the equatorial plane as it moves from south to north

- **Argument of the perigee "ω" is the angular distance between the Right Ascension point of the satellite as it crosses the equator and the perigee of the orbit**
- **Time from perigee passage denoted by "τ" is the time elapsed from the last perigee point.**
- **Perigee, apogee as well as period of the orbit are other parameters derived from these elements**

We carried out these conversions at different locations within the achieved orbit. These conversions do provide a stable and relatively invariant set of orbital elements for these locations validating our trajectory and orbit model. Table 1 provides the realized Keplerian orbital elements at different points in the orbit. As we can see they are consistent and fairly close to each other.

From Table 1 we can see that the orbital elements are consistent for these various locations in the orbit. An orbit with perigee of 506 km, an apogee of 638 km, an inclination of 87.050 degrees and a period very close to 96 minutes describes this particular orbit.

This is only one of the many possible orbits for the Unha 3 launch. Even after restricting the set of possible orbits through the impact point constraints on the launch there are many possible trajectories. If and when North Korea conducts another launch we could verify to what extent these projections hold. In the ideal case where North Korea can control the injection parameters very closely the orbit would be very close to a 500 Km circular orbit. The extent to which the achieved orbit meets this ideal would give us some idea of North Korea's capabilities in this difficult and arduous technology.

The Unha 3 Performance as a Long Range Missile

One of the major concerns expressed by the international community in response to North Korea's announcement to launch a satellite was that it was cover for achieving Long Range Missile Capability. The US is particularly concerned that this Satellite Launch Vehicle with some minor modifications could pose

Table 1

Orbital Elements Derived From Different Locations in Orbit

Orbital Parameter	**Location 1**	**Location 2**	**Location 3**
Time since launch (seconds)	1064 sec	3864 sec	6064 sec
Semi- major axis **"a"** (Km)	6943.236 Km	6943.18 Km	6953.152 Km
Eccentricity **"e"**	0.009499	0.009587	0.009496
Orbit inclination **"*i*"** (degrees)	87.050 deg.	87.050 deg.	87.050 deg.
Right Ascension of Ascending Node **Ω** (degrees)	308.578 deg.	308.578 deg.	308.577 deg.
Argument of the perigee **"ω"** (degrees)	145.755 deg.	145.827 deg.	145.812 deg.
Time since Perigee Passage **"τ"** (seconds)	394.360 sec	395.237 sec	395.053 sec
Perigee altitude (Km)	506.280 Km	506.177 Km	506.219 Km
Apogee altitude (Km)	638.192 Km	638.196 Km	638.084 Km
Period (minutes)	95.93328 min	95.93227 min	95.93153 min

Table 2
Range of Unha 3 Missile

Launch Site	Payload (Kg)	Direction	Azimuth (degrees)	Max Range (Km)
39.66 N 124.705 E	1000 Kg	Due North	0 degrees	6766 Km
39.66 N 124.705 E	1000 Kg	Due East	90 degrees	7726 Km
39.66 N 124.705 E	1000 Kg	Due South	180 degrees	6787 Km
39.66 N 124.705 E	1000 Kg	Due West	270 degrees	6180 Km

a threat to some if not all parts of the United States. To check the validity of this assertion we also ran a missile trajectory for the Unha 3 with a 1000 Kg payload.[25] Table 2 provides details of the performance of the missile launched from its current launch site (39.66 N 124.705 E) in different directions with a nuclear payload of 1000 Kg.

From Table 2 we can see that the range of the Unha 3 if used as a missile will be between 6200 to about 7700 Km depending on the direction of launch.

Distances from the launch site to the major US cities of San Francisco, New York and Washington are about 9000 Km, 10900 Km and 11000 Km respectively. These are all well beyond the maximum range of the Unha 3 and therefore do not pose a threat to the majority of the US states.

However the Unha 3 could reach most parts of Alaska with a 1000 kg payload. At an azimuth of about 36.5 degrees (launch in a North-eastern direction) the maximum range of the Unha 3 missile would be about 7300 Km putting all of Alaska within reach. Anchorage which is about 6000 km from the launch site can be comfortably reached. **The Unha 3 does pose a threat to Alaska and therefore to the United States.**

Conclusions

Though North Korea has failed for the fourth time in attempting a satellite launch there is now enough information to evaluate the space launcher performance assuming that the launch was successful. Based on the notified impact zones for the first and second stages this analysis works out a possible trajectory for the launch attempt. It also provides the details of the orbit arising from such a launch. The validity of the analysis and the predictions will be known if and when North Korea repeats the effort and places a satellite in orbit. The range of the Unha 3 launcher if used as a missile cannot reach the continental United States. It can however comfortably reach all parts of Alaska and therefore does pose a threat to the US.

[25] This is based on the assumption that a nuclear weapon and other elements to go with it in a warhead can be built within a 1000 Kg payload.

Annexure 1

Table 3
Missile Parameters Used First Set

Parameter	Our Estimates from Image	David Wright 2009 Launch Estimates[26]
Stage 1		
Propellant mass 1st stage kg	49731	60000
inert mass stage 1 kg	6781	5900
Stage mass kg	56512	65900
Fuel fraction	0.88	0.91
Thrust Newtons	1145654	1097600
Isp vac sec	255	252
Burn time computed sec	108.59	120
Cross section Area sq m.	3.98	NA
Stage 2		
Propellant mass stage 2 kg	8695	9000
Inert mass stage 2 kg	1534	1100
Stage mass kg	10230	10100
Fuel fraction	0.85	0.81
Thrust Newtons	210000	206010
Isp vac sec	255	255
Burn time computed sec	103.58	110
Cross sectionArea sq m	1.39	NA
Stage 3		
Propellant mass stage 3 kg	1178	800
Inert mass stage 3 kg	276	200
Stage mass Kg	1455	1000
Fuel fraction	0.81	0.8
Thrust Newtons	93000	52920
Isp vac sec	265	270
Burn time computed sec	33	40
Cross section Area sq. m.	0.79	NA
Other Elements		
Satellite mass kg	100	100
Shroud mass kg	400	400
Shroud release sec after liftoff	180	180
Lift off weight Kg	**68697**	**77500**

[26] See Reference 2 p 7

Annexure 2

Table 4
Final Values Used for Trajectory

Parameter	Final Values used for trajectory
Stage 1	
Propellant mass 1st stage kg	49731
Inert mass stage 1 kg	6781
Stage mass kg	56512
Fuel fraction	0.88
Thrust Newtons	1144002
Isp vac sec	255
Burn time computed sec	108.74
Area of cross section sq m	3.98
Stage 2	
Propellant mass stage 2 kg	8695
Inert mass stage 2 kg	1784
Stage mass kg	10479
Fuel fraction	0.83
Thrust Newtons	210000
Isp vac sec	255
Burn time computed sec	103.58
Area of cross section sq m	1.39
Stage 3	
Propellant mass stage 3 kg	1600
Inert mass stage 3 kg	354
Stage mass Kg	1954
Fuel fraction	0.82
Thrust Newtons	93000
Ispvac sec	260
Burn time computed sec	44
Area of cross section sq m	0.79
Other Elements	
Satellite mass kg	100
Shroud mass kg	400
Shroud release sec	180
Lift off weight Kg	**69445**

Annexure 3

Table 5

Major Events Unha 3 Space Launch (Simulation Model)

Time (seconds)	Event	Altitude (Km)	Range (Km)	Velocity (Km/sec)
0	Vertical Lift off	0	0	0
5 sec	Pitch Down	0.086	0	0.035
51 sec	Maximum Q	11.13	2.17	0.507
109 sec	Burn out stage 1	71.19	29.8	2.105
109 sec	Ignition stage 2	71.19	29.8	2.105
180 sec	Shroud separation	223.642	125.70	3.112
212 sec	Stage 2 Burnout	314.019	191.705	4.199
212 sec	Pitch down & coast	314.019	191.705	4.199
433 sec	3rd Stage Ignition	503.667	983.167	3.792
478 sec	Orbit injection	506.561	1196	7.638
3272 sec	Apogee of orbit	638.216	18800	7.493
6155 sec	Perigee of orbit	506.221	2210	7.637