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On January 6, 2016, two days short of Kim JongUn’s birthday, the Democratic Peoples’ Republic of Korea (DPRK) conducted its fourth nuclear test. The test took place at 10:30 AM Local Time (01:30:00 UTC). An analysis of the seismic data from the test, clearly points to the fact that the earthquake (with a magnitude of 4.85 on the Richter scale) was the result of a nuclear test and not due to a natural earthquake. The Preparatory Commission of the Comprehensive Test Ban Treaty Organisation (CTBTO PrepCom) too has classified the event as a man-made event.[2]

North Korea released a statement following the test. The statement claimed that it had conducted a nuclear test and had exploded its first H-bomb. The statement further stated that the test, “fully proved that the technological specifications of the newly developed H-bomb for the purpose of test were accurate and scientifically verified the power of smaller H-bomb.”

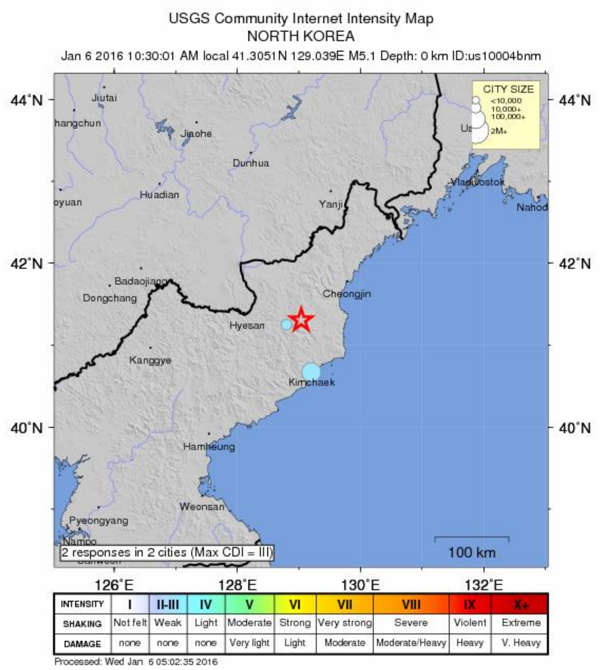

Figure 1: USGS Location Map

Estimating the Test Location

According to the United States Geological Survey (USGS), the **test took place in the mountain ranges about 22 kms east of Sungjibaegam** (See **Figure 1**).[3] The test location is estimated to be **41.305°N 129.039°E.** NORFAR - which is the Norwegian designated National Data Center (NDC) for verifying compliance with the Comprehensive Nuclear Test Ban Treaty - has modelled the seismic data received by the international network of seismic stations. It has estimated (See **Figure 2** below) that North

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[2] “DPRK 2016 Announced Test-Technical Findings”, *Preparatory Commission for the Comprehensive Test Ban Treaty Organization*, available at, https://www.ctbto.org/the-treaty/developments-after-1996/2016-dprk-announced-nuclear-test/technical-findings/

[3] “M5.1 Nuclear Explosion - 22km ENE of Sungjibaegam, North Korea”, *US Geological Service (USGS)*, available at, http://earthquake.usgs.gov/earthquakes/eventpage/us10004bnm#general_summary

Korea conducted the nuclear test around the same mountainous range where the earlier 2006, 2009 and 2013 tests had been conducted.[4]

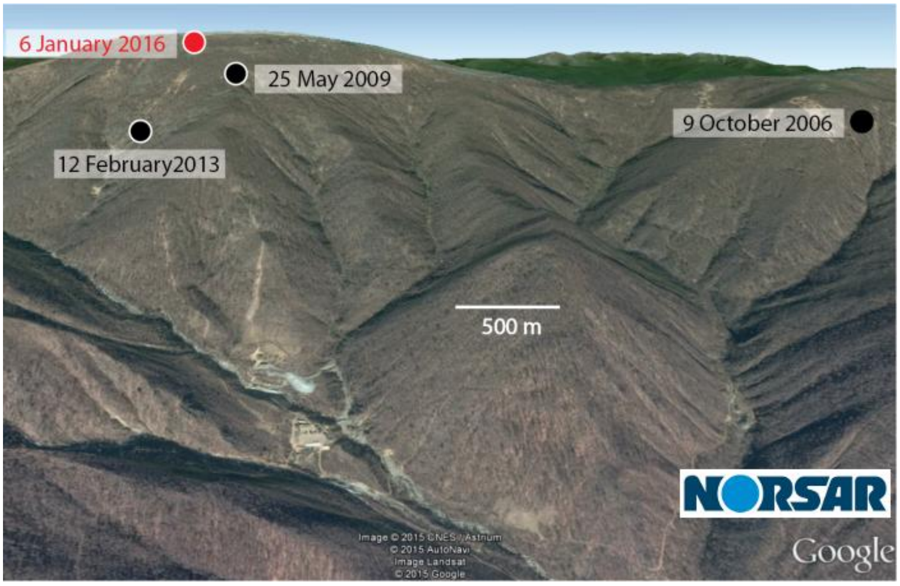

Figure 2: NORSAR - Estimation of Test Location

The fact that the **four tests have been conducted in the same area** is important. Though the NORSAR analysis points to the possibility that the test was conducted a few hundred metres into the mountain range, it can safely be assumed that the **overall geology in the area will be similar**. This is an important fact which will **allow for the comparison of the seismic signals of this test with those of the earlier tests. This comparison will also provide an estimation of the yield of the nuclear weapon test**. The US Geological Survey (USGS) too has put out details of the estimated locations of the four North Korean nuclear tests along with the imagery (**Figure 3**) of the nuclear explosion site.[5]

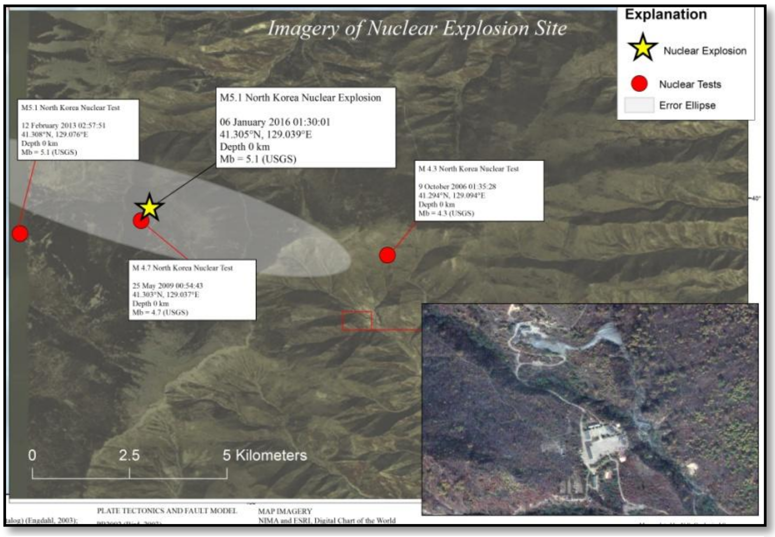

Figure 3: USGS - Estimation of Test Location

[4] "Information on North Korea's nuclear test on 6 January 2016", NORSAR, available at, http://www.norsar.no/norsar/about-us/News/North-Korea-nuclear-test-on-6-January-2016

[5] "Poster of the North Korea Nuclear Explosion of 06 January 2015 - Magnitude 5.1", *US Geological Survey (USGS)*, available at http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2016/20160106.php

From the seismic data, it is clear that North Korea did conduct a nuclear test on January 6, 2016. However to verify whether the test was indeed that of a small Hydrogen bomb as claimed by North Korea would need a closer look at the seismic data and possibly other sources of data such as radio nuclide monitoring.

Though the conduct of a nuclear test by North Korea would be bad news for the international community, a successful hydrogen weapon test would make matters significantly worse. If this claim is true, it represents a very significant yet unexpected leap in the hermit kingdom's nuclear weapons capabilities. As far as India is concerned while North Korea is geographically far away there are implications especially in view of the North Korean Pakistani relationship.

Analysis of the Seismic Data

North Korea has conducted four nuclear tests in 2006, 2009, 2013 and 2016. Comparing the seismic data of the four tests will allow us to get a better handle of the nature of the tests.

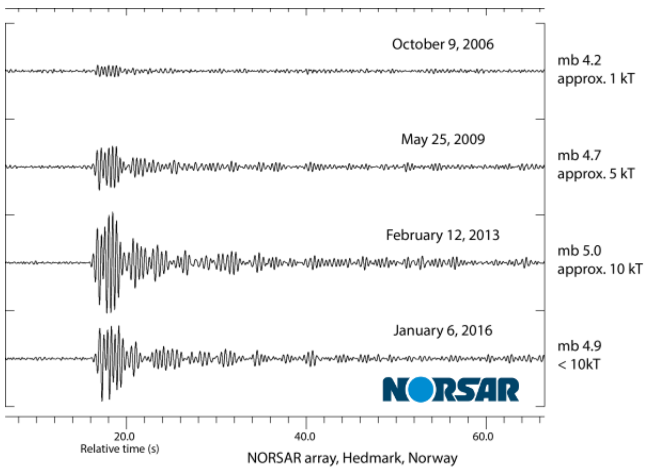

Figure 4: NORSAR Seismic Data for all four DPRK Nuclear Tests

Figure 4 has been put out by the Norwegian NORSAR which provides the magnitude (mb), along with the probable yield of the North Korean nuclear tests.[6]

This establishes the fact that the first test in October 2006 with a yield of ~1kT was a fizzle. This was followed by the second test in May 2009. Though there are differences over the exact yield of the test with estimates ranging from 2.4 kT to 5 kT it is considered to be a success. The third and the fourth tests in February 2013 and January 2015 have yields around 10 kT.

Importantly the seismic signatures generated from the 2013 and 2016 tests are quite similar. This point is confirmed by the seismic data recorded at the Mudanijang Seismic data station in China (**Figure 5**) shared by the Incorporated Research Institutions for Seismology (IRIS).[7]

[6] "Information on North Korea's nuclear test on 6 January 2016", NORSAR, available at http://www.norsar.no/norsar/about-us/News/North-Korea-nuclear-test-on-6-January-2016

[7] Alex Hukto, "Seismic recordings of vertical ground motion at IRIS-USGS (IU) station MDJ of the 2013 and 2016 seismic events", Special Event: 2016 North Korean nuclear test, *Incorporated Research Institutions for Seismology (IRIS)*, January 5, 2016, available at https://ds.iris.edu/ds/nodes/dmc/specialevents/2016/01/05/2016-north-korean-nuclear-test/

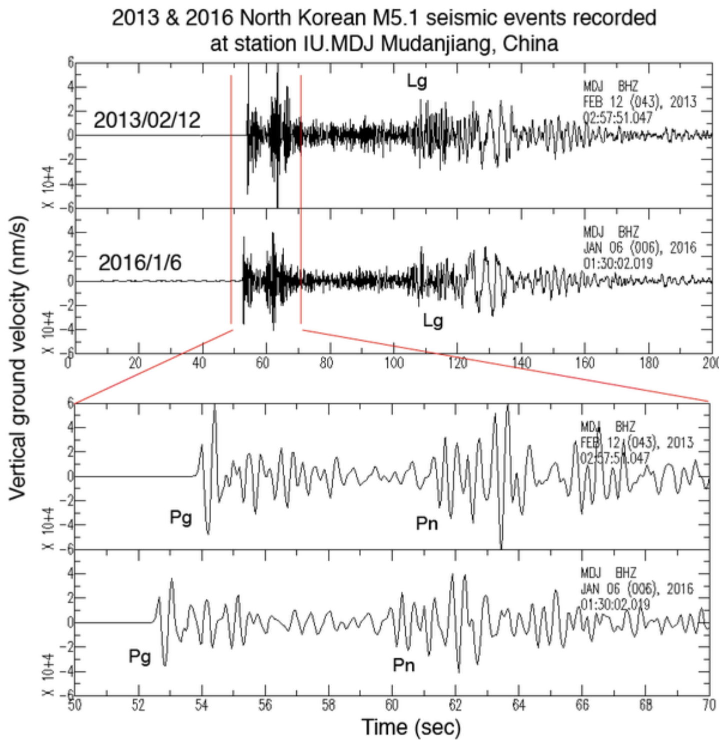

Figure 5: IRIS - Comparison of Seismic Data of 2013 and 2016 North Korean Test

Since all the tests were conducted in the same general region quite close to each other the overall geological conditions under which the tests were conducted would be similar. Given the similarities in the seismic signatures of the 2013 and 2016 tests, it would be logical to conclude that the **yield of the 2013 and the 2016 nuclear tests will be close to each other. While this confirms that a nuclear device was tested, additional evidence is needed to confirm that it was a thermonuclear device.**

The figure below has been shared by Andy Frassetto of the Incorporated Research Institutions for Seismology (IRIS).[8] This also confirms the similarities between the 2016 test and the 2013 test.

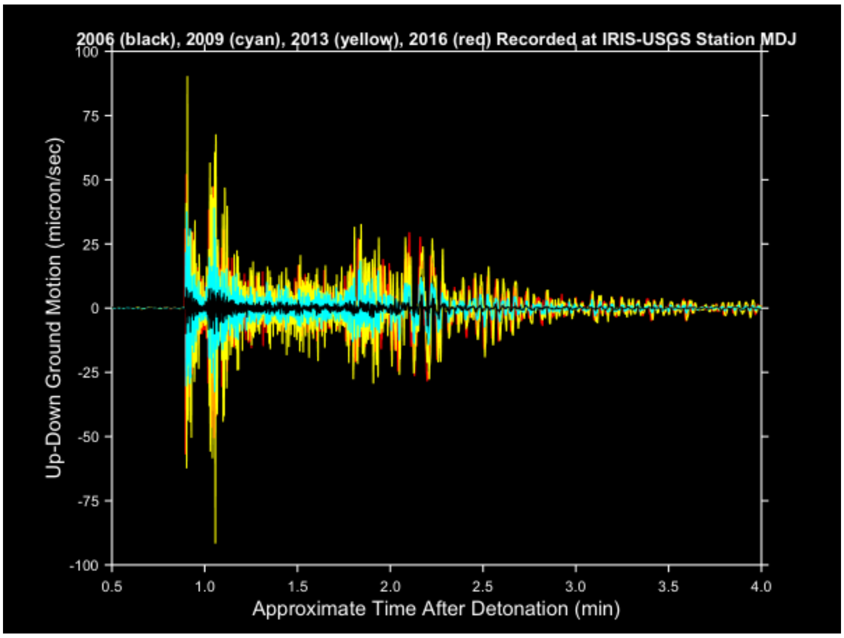

Figure 6: IRIS - Comparison of seismic data for all four DPRK Nuclear Tests

[8] Andy Frassetto, "Seismic recordings of vertical ground motion at IRIS-USGS (IU) station MDJ of the 2006, 2009, 2013 and 2016 seismic events", Special Event: 2016 North Korean nuclear test, *Incorporated Research Institutions for Seismology (IRIS)*, January 5, 2016, available at https://ds.iris.edu/ds/nodes/dmc/specialevents/2016/01/05/2016-north-korean-nuclear-test/

Verification by Radionuclide Monitoring

While expert opinion around the world seems to be veering towards the view that the 2016 test was indeed that of a fission device, from a purely technical point of view one cannot rule out the possibility that the test was that of a small thermonuclear device.

Seismic data provides useful information on the possible conduct of a nuclear weapon test and allows for estimation of its yield. However, the smoking gun which establishes beyond all doubt that a nuclear weapon was tested and enables an analysis of the nature of the weapon tested is radionuclide monitoring.

In case of a nuclear explosion about 10% of the nuclear radiation is released in the days and weeks following the blast as a result of the subsequent decay of the fission products. In case of an underground nuclear test, these radionuclides escape into the atmosphere either immediately after the test or seep out from cracks in the days/weeks following the test. This is popularly known as Venting.

Radionuclide monitoring in case of a nuclear explosion monitors radioactive noble gases like Xenon and Argon. Four Xenon isotopes, namely (Xe-131m, Xe-133m, Xe-133, Xe-135) which are produced from the nuclear explosion and one isotope of Argon (Ar-37) which is produced as a result of reaction of neutrons with calcium in surrounding bedrock are monitored to establish that a nuclear weapon test had indeed taken place.

Detection of Argon isotope is far harder than that of the Xenon isotopes. This is because there is more copious production of xenon isotopes per kT fission yield than that of argon from fusion reactions. The redeeming feature is that background levels of argon in the atmosphere are exceedingly low relative to xenon levels. The capability for post-test atmospheric sampling and measurement has been established only recently. There is so far no prior experience of its detection in nuclear tests. As a result, confirmation of the DPRK claim of having tested a thermonuclear device will have to await successful detection of Argon.

It is not always possible to collect samples of xenon isotopes to carry out an analysis in the case of underground tests. In the case of North Korea, samples were successfully collected following the 2006 nuclear test. However, this was not possible following the 2009 nuclear test. In the aftermath of the 2013 test, the collection was very faint. It was not enough for a conclusive analysis of the test. This could be due to variety of reasons ranging from sealing of the shaft due to molten sand and rock, measures taken by North Korea leadership to prevent venting, prevailing atmospheric conditions at the time and following the test, the speed with which the collection of samples are done or because of the existence of ambient

Xenon gases around monitoring stations like the Yellowknife radionuclide monitoring station in Canada.[9]

In addition, there is a time gap between the actual test and the time when the radionuclide stations detect the fission products. In case of the 2013 DPRK nuclear test, the Xe-131m and Xe-133 were detected 55 days after the test.[10] NORSAR states that it can take upto 60 days for the fission products to reach the nearest radionuclide stations located in South Korea, China, Eastern Russia among others.[11]

While the monitoring of the noble gas isotopes would provide evidence of the fission nature of the device it may still not be adequate to state with certainty whether a boosted fission or a thermonuclear was tested. The thermonuclear nature of the device can only be established by radionuclide monitoring of Argon in the atmosphere or backed up by an On-Site Inspection.

For a boosted fission or a full-fledged thermonuclear test, one can also look for presence of residual tritium or heavy hydrogen or lithium in the device. Alternatively, other radionuclides produced by neutrons from the fusion reactions can provide a trace. However, almost all of the latter type are particulates and even if vented settle down close to Ground Zero. They are very easily detected in On-Site Inspection, an option not available in DPRK.

To confirm fusion reactions, one has to look for residual tritium or deuterium which are gases. There may well be a large fraction remaining unused in the test. At the high temperatures that develop, these could form solid compounds with other elements. **Prospects for detection of the thermonuclear nature of a test by sampling atmospheric air for these at a distance appear low**.

It is possible that if the test is completely contained there will no venting taking place. In such a situation it is unlikely that radionuclide monitoring will provide convincing evidence that North Korea had indeed tested a thermonuclear or a boosted fission device. Thus it may not be possible to establish with absolute certainty that North Korea did indeed conduct a thermonuclear test.

[9] Lisa Kokaji and Nobuo Shinoharab, "Radiochemical Verification Technologies for the Detection of Nuclear Explosions: Recent Developments in Radionuclide Monitoring with the Comprehensive Nuclear-Test-Ban Treaty", *Journal of Nuclear and Radiochemical Sciences*, Vol. 14, No.1, 2014, pp. R1-R9.

[10] "CTBTO detects radioactivity consistent with 12 February announced North Korean nuclear test", *Preparatory Commission for the Comprehensive Test Ban Treaty Organization*, April 23, 2013, http://ctbto.org/press-centre/press-releases/2013/ctbto-detects-radioactivity-consistent-with-12-february-announced-north-korean-nuclear-test/

[11] "Information on North Korea's nuclear test on 6 January 2016", NORSAR, http://www.norsar.no/norsar/about-us/News/North-Korea-nuclear-test-on-6-January-2016

In the absence of conclusive proof from radionuclide monitoring we will have to look basically at the seismic data to come to some conclusion about the veracity of the North Korean claim that they had carried out a thermonuclear test.

Did North Korea Test a Thermonuclear Device?

Only Radionuclide monitoring can conclusively establish the nature of the North Korea test including the type of device tested. In order to establish or disprove the North Korean claim of having tested a thermonuclear device, Argon-37 has to be detected by the international radionuclide monitoring stations. As mentioned in the above paragraphs, detection of Argon-37 is an uphill task.

In the past, other nuclear weapon states have conducted thermonuclear tests with yields in the hundreds of kilotons. A comparison of the first underground thermonuclear tests conducted by the major nuclear weapon states and their corresponding magnitude on the Richter scale is given in the Table below.

Table 1: Comparison of Underground Thermonuclear Tests

Country	Underground Test Yield (kT)	Date of Test	Magnitude (Richter Scale)
United States	1000 kT	Jan. 19, 1968	6.30
Former Soviet Union	1001 kT	Oct. 14, 1970	6.6 - 6.8
China	660 kT	May 21, 1992	6.5

From the above Table it is clear that these tests have generated seismic signatures with a magnitude that is above 6.3 on the Richter scale. This is significantly (about 10 to 50 times) larger than the magnitude of the January 2016 test.

Nevertheless, it is important to recall that these countries also conducted other thermonuclear tests with smaller yields. As Sharon Squassoni points out, the US has a B-83 warhead in its stockpile with variable yields ranging between the low kiloton to 1.2 megaton.[12] However, designing such an advanced warhead is hard and would require more testing.

To return to the initial question as to whether North Korea tested a thermonuclear device, the short answer is, "We don't know as of yet". Only Radionuclide monitoring will be able to conclusively determine whether a thermonuclear device was tested and this will happen over the next few weeks.

[12] Sharon Sqassoni, "Why even a failed test makes North Korea's nuclear arsenal scarier", *Reuters Blog*, January 8, 2016, available at, http://blogs.reuters.com/great-debate/2016/01/08/why-even-a-failed-test-makes-north-koreas-nuclear-arsenal-scarier/

Can North Korean missiles reach the United States?

Regardless of the type of the nuclear device tested, the very fact that North Korea conducted a successful nuclear test is dangerous. With four nuclear tests, Pyongyang is moving towards the capability to successfully miniaturize a nuclear warhead which would be deliverable by long-range nuclear missiles. If so, can North Korea target their main perceived enemy, the United States?

In this context it is important to take a closer look at the North Korea's successful launch of a remote sensing satellite and placing it in a sun synchronous orbit on December 12, 2012 on the Unha launch vehicle. The North Korean success is more important given that they did not use a Nodong engine for the second stage of the Unha but developed an engine and stage specifically for the satellite mission. The successful Unha launch is indicative of a substantial domestic S&T capability. A December 2013 report by ISSSP NIAS on North Korea's successful space launch analysed this capability in greater detail.[13]

Though the North Korean Unha is designed as a space launcher, it can be suitably modified into a ballistic missile. Trajectory analysis using the NIAS trajectory modelling software – *Quo Vadis* – shows that a due North East launch of the Unha (**Figure 7** below) from a suitable location with a 1000kg payload (sufficient to carry a nuclear warhead) can reach all of Alaska and some parts of northern Canada.

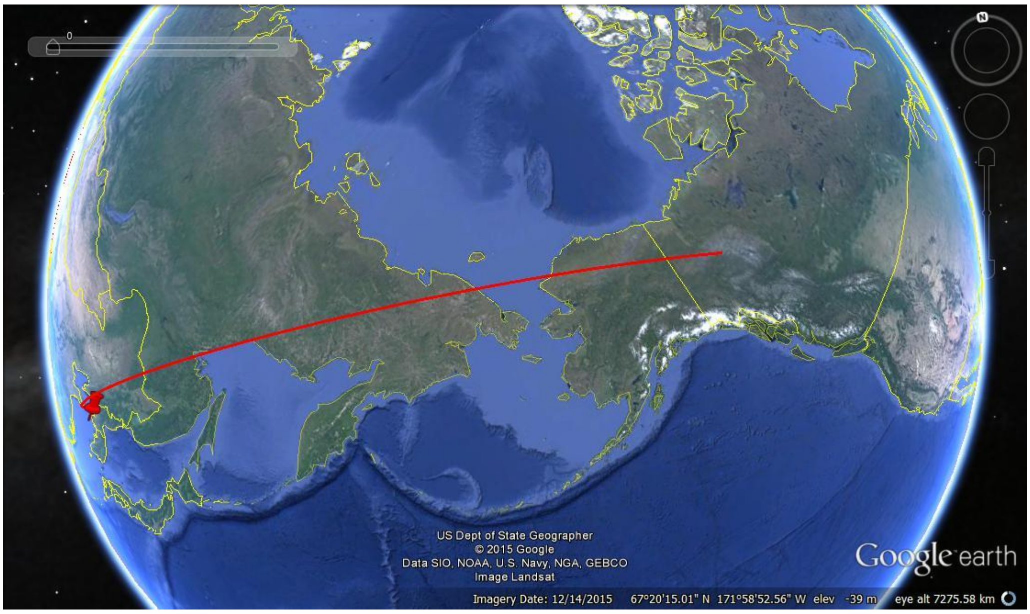

Figure 7: ***Quo Vadis*** **Trajectory Simulation with 1000kg Payload; Azimuth 25 degrees**

[13] S.Chandrashekar, N.Ramani, Rajaram Nagappa and Soma Perumal, "North Korea's Successful Space Launch" International Strategic and Security Studies Programme (ISSSP), National Institute of Advanced Studies, Bangalore, NIAS Report No. R-20/2013, December 2013, available at http://isssp.in/north-koreas-successful-space-launch/

With further reduction of the mass of the payload to say 800kg and launching at an Azimuth of 40 degrees, a North Korean ballistic missile (See **Figure 8** below) will just be able to reach parts of western coast of the continental United States including the states of Washington, Oregon and northern parts of California.

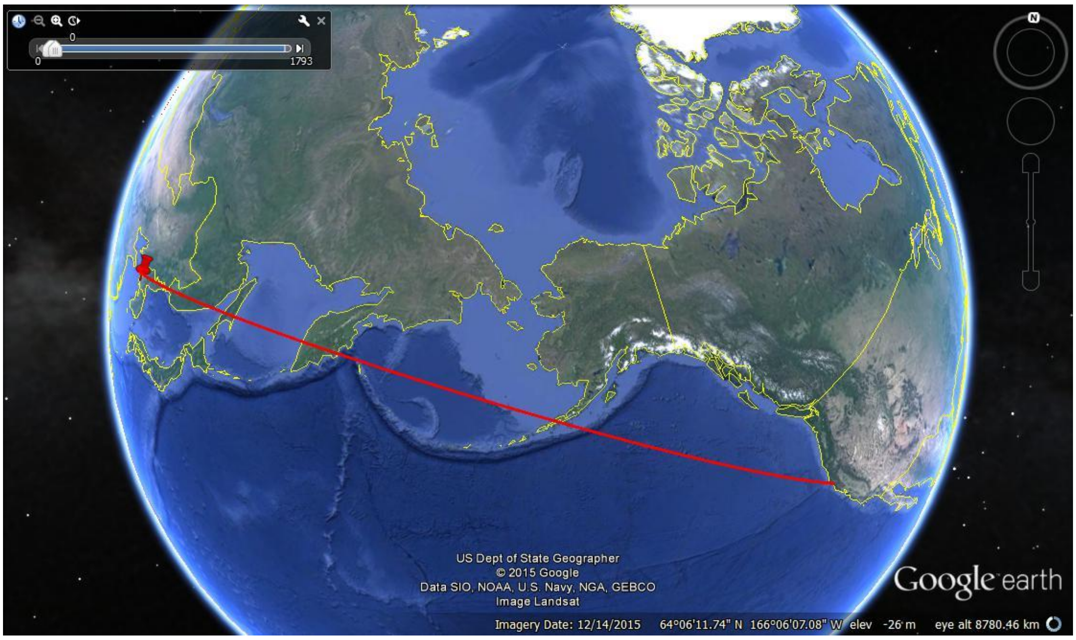

Figure 8: Quo Vadis Trajectory Simulation 800kg Payload; Azimuth 40 Degrees

The successful test provides North Korea with the wherewithal to miniaturize its nuclear warheads. In combination with its advances in space and missile capabilities, Pyongyang might well be on its way to achieving the capability to target the continental United States with nuclear weapons delivered by long-range missiles.

International Implications of the North Korean Test

The test is an indicator that Beijing does not have complete control over the actions of its North Korean ally. China would also be obviously concerned about a nuclear neighbor whose behavior is difficult to manage. Given this situation China would have doubts about North Korea's role as a friendly buffer state between China and US dominated South Korea. This development would strengthen the US position vis-à-vis the China-Korea-US dynamic.

Implications of the North Korean Test for India

Though North Korea is geographically far away from India its growing nuclear weapon capabilities are of direct concern. This arises largely because of the close coupling of the Pakistani and North Korean missile and nuclear weapons programmes. There is no doubt that the Ghauri missile is a copy of the North Korean Nodong missile.[14] There is also

[14] S. Chandrashekar, Arvind Kumar, Rajaram Nagappa, "Assessment of Pakistan's Ballistic Missile Programme: Technical and Strategic Capability", International Strategic and Security Studies Programme (ISSSP), National

evidence that Pakistani nuclear scientists have visited North Korea and had discussions with them.

Pakistan had tested nuclear devices in 1998. All of them were Uranium based devices which are more difficult to miniaturize. Though Pakistan has a major Plutonium based weapons development programme for miniaturization, the fact that it has not tested a Plutonium based device does not lend credibility to its miniaturization claims.

In light of the links between North Korea and Pakistan it is likely that the North Korean Plutonium based tests serve as surrogate tests for the Pakistani miniaturization drive. This has direct security implications for India.

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Institute of Advanced Studies, Bangalore, NIAS Report No. R-5/2006, 2006, available at http://isssp.in/an-assessment-of-pakistans-ballistic-missile-programme-technical-and-strategic-capability/