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North Korea's Sixth Nuclear Test: Was It a Hydrogen Bomb?

On September 3, 2017 North Korea conducted its sixth nuclear test. North Korea claimed that this device was a hydrogen bomb (i.e. a two-stage thermonuclear nuclear weapon). The day before, North Korea had primed the world for this claim by releasing photos of Kim Jong-un inspecting a peanut shaped mockup of a relatively small two-stage nuclear weapon. The development of such weapons has been a primary goal of the five major nuclear powers and if North Korea has tested such a device, it represents a major advance.

However, North Korea has made this claim before, in January 2016, after its fourth nuclear test. At the time, the low yield of this test (around ten kilotons) led to widespread skepticism of this claim. North Korea's sixth nuclear test had a substantially higher yield which makes the claim more plausible. However, simple fission devices using large amounts of nuclear material (plutonium or highly enriched uranium—HEU) can also produce devices with yields equal to or even greater than the yield of North Korea's sixth test.

This paper will examine the types of nuclear devices that North Korea might have tested. It will show that while a test related to the development of a two-stage thermonuclear device is a possibility, so is a simple fission implosion weapon, perhaps using large amounts of nuclear material. The paper will also examine the type of nuclear weapon that North Korea could mount on its Hwasong-14 ICBM and concludes that such a weapon would be a simple fission weapon with a yield of ten to thirty kilotons, weighing about 500 kilograms and having a diameter of about 0.6 meters. Finally the paper will discuss a problem that North Korea must resolve before it can reliably deliver any kind of nuclear weapon using its ICBM.

Yield of the Nuclear Test

The U.S. Geological Survey has reported that the North Korean sixth nuclear test had a body-wave magnitude of 6.3.[2] Since North Korea's prior nuclear test in September 2016 had a body-wave magnitude of 5.3, this test was a full magnitude larger which would make the yield 32 times larger. Since the September 2016 test was estimated to have a yield around 15 kilotons, this test would have had a yield of around 500 kilotons.

Most estimates of the yield have been significantly smaller. NORSAR (Norwegian Seismic Array) initially found the body-wave magnitude to be only 5.8 and the yield to be about 120 kilotons.[3] NORSAR recently revised its estimate to a body-wave magnitude of 6.1 and a yield of

[1] This paper is the product of the author's personal research and the analysis and views contained in it are solely his responsibility. Though the author is also a part-time adjunct staff member at the RAND Corporation and a faculty member of the Pardee RAND Graduate School, this paper is not related to any RAND project or the Pardee RAND Graduate School and therefore these organizations should not be mentioned in relation to this paper. I can be reached at GregJones@proliferationmatters.com

[2] "M 6.3 Explosion-22km ENE of Sungjibaegam, North Korea," U.S. Geological Survey, September 3, 2017. Link

[3] "Large nuclear test in North Korea on 3 September 2017," NORSAR, September 3, 2017. Link

250 kilotons.[4] The Lianxing Wen Research Group at the University of Science and Technology of China estimated the yield to be 108.3 kilotons with an uncertainty range of plus or minus 48.1 kilotons, i.e. about 110 kilotons with a range between 60 kilotons and 160 kilotons.[5] I will examine the possible types of nuclear weapons that could produce this range of yields.

Two-Stage Thermonuclear Devices

A MIRV type two-stage thermonuclear device well represents not only the yield of this test but is close to the size of the mockup shown by the North Koreans. A good example is the French TN-70 warhead which had a yield of 150 kilotons, weighed 200 kilograms and was used as a MIRV on the French M4 submarine-launched ballistic missile. However, it would represent quite an advance if this were North Korea's first two-stage thermonuclear device. France first tested a two-stage thermonuclear device in 1968. It took the French at least five more high-yield nuclear tests before they were able to perfect their first two-stage thermonuclear warhead, the TN-61. This weapon weighed about 700 kilograms and had a yield of one megaton. Based on photos it was clearly much larger than the mockup shown by the North Koreans. France needed to conduct a number of additional tests before the TN-70 was ready for deployment in 1985. Therefore it seems unlikely that North Korea could have tested such a sophisticated device. If it did it, could only have done so with very substantial outside assistance, probably from Russian nuclear scientists.

North Korea could have tested a two-stage thermonuclear weapon similar to the first two-stage thermonuclear devices used by the five major nuclear powers. Such a device would have been physically much larger than the mockup shown in the North Korean photos. However, the first successful two-stage thermonuclear tests of all five major nuclear powers involved devices with yields greater than one megaton, which is significantly higher than even the high-end yield estimate of the North Korean test. Apparently it is easier to design a high-yield two-stage thermonuclear device, than a lower-yield, compact device. Therefore it is improbable that North Korea tested a full yield two-stage thermonuclear device.

The first two British two-stage thermonuclear devices had yields of 300 kilotons and 200 kilotons, which is within the uncertainty range of the North Korean test. However, these tests involved partial failures as they were intended to produce yields of at least one megaton. It is unlikely that North Korea would have conducted this test at its current nuclear test site if it had been expecting a yield greater than one megaton. Therefore, the first British two-stage thermonuclear tests do not provide examples of the type of nuclear device that North Korea might have tested.

A more intriguing possibility is illustrated by the Chinese nuclear program. In December 1966, six months before it tested its first two-stage thermonuclear device with a yield of 3.3 megatons, China tested a device which it said established the principles of a two-stage thermonuclear

[4] "The nuclear explosion in North Korea on 3 September 2017: A revised magnitude assessment," NORSAR, September 12, 2017. Link

[5] "North Korea's 3 September 2017 Nuclear Test Location and Yield: Seismic Results from USTC," Lianxing Wen's Geogroup, University of Science and Technology of China. Link

device.[6] It had a yield of 122 kilotons, similar to the yield estimates for the North Korean nuclear test. The debris from the Chinese test contained enriched lithium, which supports the Chinese description of this test. Therefore there is a very real possibility that the sixth North Korean nuclear test was related to the development of a two-stage thermonuclear device, even if it was not a full yield device. However, there are other possibilities that simply involve pure fission implosion devices without any need to hypothesize a two-stage thermonuclear device.

Fission Implosion Devices

Various sorts of pure fission devices can produce yields within the range of uncertainty of the sixth North Korean nuclear test. In the early 1950s the U.S. fielded an improved version of the Nagasaki nuclear weapon, known as the Mark 6. Its maximum yield was 160 kilotons.[7] Shortly thereafter the U.S. fielded a somewhat smaller and lighter pure fission weapon, known as the Mark 5. Its maximum yield was 120 kilotons. The first French nuclear test had a yield of 60 to 70 kilotons which is within the low end of the uncertainty range of the North Korean test. Therefore, pure fission designs similar to these weapons could have been used by North Korea for its nuclear test.

Nor do these weapons represent the maximum possible yield from a pure fission weapon. By putting large amounts of HEU into an implosion weapon, yields of up to a megaton are possible. The U.S. first tested such a weapon in 1952 as the King shot in the Ivy test series. It had a yield of 500 kilotons. This weapon was large and heavy, being about the size of the Nagasaki weapon but smaller, lighter versions are possible. The U.S. deployed this device as the Mark 18 bomb between 1953 and 1956.

In May 1957 the British tested a pure fission device[8] known as Orange Herald (Small) which was 30 inches (0.8 meters) in diameter and weighed about 2000 lb. (900 kilograms).[9] It had a yield of 720 kilotons and was the largest yield pure fission weapon ever tested. One source says that this device used 117 kilograms of HEU.[10] To produce 720 kilotons would require the complete fissioning of the U-235 contained in about 46 kilograms of 90% enriched uranium. The reported HEU content of the device would imply an efficiency of about 39%. If the King device had the same efficiency, then it contained about 82 kilograms of 90% HEU. These weapons used approximately four to six times as much HEU as a nominal pure fission weapon and there were safety concerns regarding accidental criticality. Therefore, it is unlikely that North Korea would actually deploy such devices given its limited nuclear material stocks, but it certainly could have used such a device to produce a high yield test.

[6] JPRS Report: Science & Technology, China, "Selections from 'China Today: Nuclear Industry', Part I," JPRS-CST-88-002. January 15, 1988, pp. 40-42.

[7] Robert S. Norris and Hans M. Kristensen, "U.S. Nuclear Warheads, 1945-2009," *Bulletin of the Atomic Scientists*, July/August 2009.

[8] The British attempted to boost this device using a small amount of thermonuclear material but concluded that the boosting was unsuccessful. Lorna Arnold, *Britain and the H-Bomb*, UK Ministry of Defense, Palgrave, 2001, p. 147.

[9] Richard Moore, "The Real Meaning of the Words: a Pedantic Glossary of British Nuclear Weapons," UK Nuclear History Working Paper, Mountbatten Centre for International Studies, March 2004.

[10] Nuclear Weapon Archive. Link Walker describes Orange Herald (Small) a little differently. He says that it was 45 inches (1.1 meters) in diameter, 2,500 lb. (1,100 kilograms) and used "up to" 120 kilograms of HEU. See: John Walker, *British Nuclear Weapons and the Test Ban 1954-1973*, Ashgate, 2010.

Though not strictly a pure fission device, a boosted device is another but not very likely possibility.[11] Boosting uses a small fusion reaction involving tritium and deuterium to enhance the efficiency of the fission reactions in a nuclear device. Usually boosting is used to produce smaller lighter nuclear devices with yields in the low tens of kilotons but it is possible to use boosting to increase the yield instead.

The key ingredient for any boosted device is tritium, which must be produced by irradiating lithium in a nuclear reactor. Since tritium is radioactive and decays away, tritium production is an ongoing process. North Korea's plutonium production reactor at Yongbyon would be a likely source of tritium. However, this reactor was shut down in 2007 and restarted only in 2013. The reactor has operated intermittently and is not thought to have operated at all since the end of 2015. Therefore North Korea cannot have produced much tritium and probably does not have sufficient tritium to have produced a large yield boosted nuclear device.

ICBM Warhead

Almost all of the high yield nuclear weapon options discussed above are too large and heavy to be carried on North Korea's Hwasong-14 ICBM. Therefore it is of interest to examine what type of nuclear warhead this missile could carry. Unless North Korea has suddenly developed a two-stage thermonuclear device similar to the French TN-70, the most reasonable possibility is a small lightweight pure fission warhead.

Table 1 shows examples of lightweight simple fission implosion weapons developed by other nuclear weapon states. The U.S. Mark 7 and the British Red Beard represent one class of light-weight nuclear weapons that an early nuclear power such as North Korea might develop. The French AN 51/52 and the U.S. Mark 12 represent close to the lower limit of simple implosion fission weapons that have been developed and deployed. The AN 51/52 was the warhead of the French short-range Pluton ballistic missile and was also used as a tactical bomb. It was in service into the 1990s.

Table 1

Lightweight Fission Implosion Weapons

Device	Weight	Diameter	Yield in Kilotons
Mark 7	1,700 lb. (770 kg)	30 in (0.76 m)	8-60
Red Beard	2,000 lb. (900 kg)	28 in (0.71 m)	15
AN 51/52	1,000 lb. (455 kg)	24 in (0.6 m)	8-30
Mark 12	1,200 lb. (550 kg)	22 in (0.56 m)	12

The AN 51/52 and the Mark 12 represent reasonable examples of the type of weapon that North Korea may have already developed, with a weight of about 500 kilograms, 0.6 meters in

[11] For more on boosted devices see: Gregory S. Jones, "The Role of Boosting in Nuclear Weapon Programs," July 25, 2017. Link

diameter and a yield of 10 to 30 kilotons. Such a weapon is a likely candidate for the warhead of North Korea's Hwasong-14 ICBM. This weapon design is fully consistent with the yields produced by North Korea's prior nuclear tests. Note that weapons of this size and weight are required for the primary of a two-stage thermonuclear device.[12] Therefore, if North Korea has developed any kind of two-stage thermonuclear device, then it must have developed a small lightweight fission implosion device.

Uncertain ICBM Nuclear Delivery Capability

Though a nuclear weapon of the AN 51/52 or Mark 12 class could easily be carried on North Korea's Hwasong-14 ICBM, there are still uncertainties as to whether this missile can reliably deliver any kind of nuclear warhead. North Korea's two tests of the Hwasong-14 used very lofted trajectories so that missiles impacted west of Japan. The reason often given for this type of trajectory is to avoid overflying Japan but there could be another reason. There have been no reports of North Korea using any ships to observe the missile near its impact point and therefore the lofted trajectory may be used so as to allow North Korea to track and receive telemetry from the missile over a greater portion of its trajectory. Even so the impact points are roughly 600 kilometers away from the North Korean coast. Due to the curvature of the earth, the missile will become unobservable for the last tens of kilometers of the trajectory.

The problems that can result from not being able to track a ballistic missile over its entire trajectory is illustrated by the first long-range ballistic missile—the German V-2 during World War II.[13] In 1942 and 1943 the Germans successfully tested V-2 missiles from Peenemunde on the German Baltic coast. The missiles were fired over 300 kilometers northeastward over the Baltic Sea. The Germans tried tracking the missile using radars positioned along the Baltic coast but the missile traveled at too high a velocity for the radar of that era. The missiles carried bags of dye to allow the Germans to determine where the missile had impacted. The Germans believed that the tests were completely successful.

However, after Peenemunde was bombed in August 1943, the Germans moved the missile test site to Blizna in Poland. The missiles fired from this location traveled north and impacted in Poland, where the final part of the missile's trajectory could be observed. It was only then that the Germans discovered that most of the missiles were breaking up on reentry. The missile had to be redesigned to strengthen it to withstand reentry.

A similar problem may already be occurring with the North Korean Hwasong-14. The second North Korean test of this missile occurred at night, making the missile's reentry visible from Japan. Video of the reentry seemed to show the warhead breaking up.[14] If so, then this missile cannot yet deliver a nuclear warhead. Indeed, until North Korea can test its long-range missiles to full range and can observe the reentry using ships near the impact point, North Korea can have no assurance that it can strike the U.S. using nuclear weapons.

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[12] For example, the first successful British two-stage thermonuclear test, Grapple X with a 1.8 megaton yield, used a Red Beard primary. See: Lorna Arnold, *Britain and the H-Bomb*, UK Ministry of Defense, Palgrave, 2001, p. 160.
[13] R. V. Jones, *The Wizard War: British Scientific Intelligence 1939-1945*, Coward, McCann & Geoghegan, Inc., New York, 1978, p.445.
[14] Michael Elleman, "Video Casts Doubt on North Korea's Ability to Field an ICBM Re-entry Vehicle," 38 North, July 31, 2017. Link

Conclusions

North Korea's sixth nuclear test on September 3, 2017, had a significantly higher yield than did its prior tests. However, it is unlikely that this test was that of a full-yield two-stage thermonuclear weapon, i.e. a hydrogen bomb. The most likely possibilities are either a pure fission implosion device or a device that established the principles of a two-stage thermonuclear device, similar to China's 122 kiloton test in December 1966. If radioactivity was released from this test, it may be possible to tell which of these two possibilities is correct.

At any rate, regardless of the type of nuclear device used in this most recent test, it is unlikely that North Korea's Hwasong-14 ICBM has the capability to carry it. Rather, the most reasonable possibility for an ICBM warhead appears to be a small, lightweight pure fission implosion weapon in the AN51/52 or Mark 12 class. Such a weapon would weigh about 500 kilograms, be about 0.6 meters in diameter and have a yield of 10 to 30 kilotons.

Until North Korea can test its long-range missiles to full range and can observe the reentry using ships near the impact point, North Korea can have no assurance that it can strike the U.S. with nuclear weapons.