Gregory S. Jones[1]
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The Implications of North Korea Testing a Boosted Nuclear Weapon

On January 6, 2016 North Korea conducted its fourth nuclear test. The preliminary seismic magnitude was 5.1, giving the test about the same yield as the device that North Korea tested in 2013, implying a yield of 5 to 15 kilotons. North Korea has claimed that this device was a hydrogen bomb (i.e. a two-stage thermonuclear weapon) but this claim has been met with justified skepticism.

The low yield of North Korea's latest test is inconsistent with it being a two-stage thermonuclear device. The first tests of two-stage thermonuclear weapons by the U.S., Soviet Union, China and France all had yields of 1 megaton or more. Even the first British test of this type of weapon which was a partial failure had a yield of 300 kilotons. Before China tested its first two-stage thermonuclear weapon it tested a device that established the general principles of this type of weapon but at a reduced scale.[2] Even this device had a yield of 122 kilotons. It was only after many additional nuclear tests that these five nuclear weapon powers were able to develop two-stage thermonuclear weapons with significantly lower yields.

If North Korea did not test a two-stage thermonuclear device, then what did it test? Without a major release of fission products from this test we are unlikely to know for sure. It is possible that North Korea simply tested an improved implosion fission device similar to the sort of device that was used in its three prior nuclear tests.

Another possibility, one that many others have suggested, is that North Korea tested a boosted fission weapon. Such a device, which uses thermonuclear reactions, might provide North Korea some justification for its claim even if the device was not a true two-stage thermonuclear weapon. However, many experts seem to not fully understand the principles behind boosted fission weapons, their true nature and the broader implications of North Korea possessing such weapons.

The British have revealed a good deal of information regarding boosted fission weapons.[3] These weapons use hollow cores of fissile material. Just before detonation a tritium/deuterium gas mixture is inserted into this hollow space. The detonation of the weapon causes a fusion reaction. The energy output from this fusion reaction is small but this reaction significantly increases the efficiency of the fission reactions in the weapon. Many experts mistakenly believe that this increased efficiency is used to increase the yield of the weapon to produce high yield weapons but that is not usually its purpose. As the British have said, "But there was another way to look at boosting. Instead of using it to *increase* the yield of a warhead of given size and fissile

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[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, this paper is not related to any RAND project and therefore RAND should not be mentioned in relation to this paper. I can be reached at GregJones@proliferationmatters.com

[2] This was China's fifth nuclear test, conducted on December 28, 1966.

[3] Lorna Arnold, *Britain and the H-Bomb*, UK Ministry of Defense, Palgrave, 2001.

content, it could be used to *reduce* the size and fissile content of a warhead while maintaining or even improving the yield."[4] [Emphasis in original]

As the British have pointed out, boosted fission weapons have another important property. Implosion fission weapons that use plutonium are vulnerable to predetonation due to the neutrons from spontaneous fission. Even if such weapons contain only highly enriched uranium, they are still vulnerable to predetonation from neutrons from nearby nuclear detonations, which could be either defensive warheads or nearby "friendly" weapons. Boosted fission weapons do not have this vulnerability and can be used to manufacture what the British termed "immune warheads." Such immune warheads would produce the same yield whether they were manufactured from weapons-grade plutonium or reactor-grade plutonium.

The deuterium required for such weapons can be extracted from ordinary water but tritium only exists in trace amounts in nature and must be produced by either irradiating lithium in nuclear reactors or recovering the tritium produced in the moderator of heavy water nuclear power reactors. When irradiating lithium in a nuclear reactor, each gram of tritium produced results in the loss of 79.3 grams of plutonium, since each neutron that produces a tritium atom could have been used to produce plutonium instead. Further since tritium has a half-life of 12.3 years, each year 5.5% of the tritium will decay away.

Natural lithium consists of two isotopes, lithium 6 and lithium 7. Lithium 6 comprises 7.5% of natural lithium and lithium 7 the other 92.5%. When irradiated by neutrons it is the lithium 6 that produces tritium by the reaction: lithium 6 + neutron = tritium + helium 4. Many experts assume that the lithium must be enriched (i.e. the percentage of lithium 6 increased) in order to produce tritium in a nuclear reactor but there is no need. Since the thermal capture neutron cross section of lithium 6 is 942 barns and that of lithium 7 is 0.045 barns, when natural lithium is irradiated, 99.94% of the neutrons are absorbed by the lithium 6.[5]

In the past tritium has been produced by using plutonium production reactors to irradiate a lithium aluminum alloy containing 3.5 weight percent of lithium. North Korea could be using its 25 MWt plutonium production reactor at Yongbyon which it restarted in 2013 to produce tritium. However, a natural uranium fueled plutonium production reactor has little excess reactivity and since lithium is a strong absorber of neutrons, only a small amount of lithium can be placed into the reactor without making the reactor inoperable. For example the Yongbyon reactor could at most produce about 3 grams of tritium per year by irradiating lithium if it used only natural uranium fuel.

However, North Korea has developed centrifuge enrichment which gives it the option of using enriched uranium fuel in the Yongbyon reactor. If North Korea has replaced the natural uranium

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[4] *Ibid.*, p.177.

[5] In countries that possess two-stage thermonuclear weapons such as the U.S., enriched lithium is produced for the secondaries of these weapons. Where enriched lithium is being produced anyway, it is likely to be used for tritium production since enriched lithium has minor advantages over natural lithium for this purpose. Using enriched lithium reduces the number of targets elements required and thereby the number of neutrons captured in the aluminum that is used as part of the lithium target element. This would increase the amount of tritium produced by one or two percent. See: R. Nilson, "Conversion Ratio Incentive for Using Black Mint in an E-N Load," HW-63668, General Electric, Richland Washington, January 28, 1960.

fuel at Yongbyon with uranium fuel enriched to 0.95%, the reactor would be able to produce about 17 grams of tritium per year by irradiating lithium while still producing about 5 kilograms of plutonium per year.[6]

Sources are not clear as to how much tritium is required for each nuclear weapon. The only official statement is that it is less than 20 grams.[7] In the past the most authoritative statement on this issue suggested that on average about 4 grams were used for each weapon.[8]

The current U.S. program to produce tritium at the Watts Bar 1 reactor allows one to produce a more up-to-date estimate. It is planned to produce on average about 1,130 grams of tritium per year to support the current U.S. nuclear arsenal.[9] Such a production rate would maintain a total tritium inventory of 20,100 grams.[10] The U.S. apparently maintains a five year tritium reserve, which would mean that only three-quarters of the tritium stockpile is actually contained in weapons. It has been estimated that the current U.S. nuclear weapon stockpile is 4,650.[11] This gives an average of 3.2 grams of tritium for each weapon. This number is similar to the older 4 grams estimate and therefore a reasonable estimate for the average tritium per weapon is between 3 and 4 grams. Therefore, with 0.95% enriched fuel North Korea could be producing enough tritium each year for roughly five nuclear weapons. If North Korea were to use fuel with a higher enrichment, the tritium production could be even higher, at the expense of lost plutonium production.

No source has indicated the size and fissile material content of boosted fission weapons but they are likely significantly less than implosion fission weapons. Pakistan has claimed to have equipped small short-ranged ballistic missiles with nuclear warheads. If this claim is true, then it is likely that Pakistan is using boosted fission warheads since such warheads are smaller and lighter than the smallest implosion fission weapons fielded by the U.S. For example, Pakistan's Nasr missile has a warhead that is only about 400 kilograms in weight and no more than 16 inches in diameter.[12] If North Korea has tested a boosted fission device then it may be able to produce weapons of a similar size and weight.

Such small light-weight nuclear weapons could be easily carried on ballistic missiles and indeed the weapon's light weight might make it possible for North Korea to extend the range of its

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[6] R.D. Carter and W.A Blyckert, "Final Report on E-N Conversion Ratio Data Production Test IP-350-C, HW-73615, General Electric, Richland Washington, December 18, 1962.
[7] *Restricted Data Declassification Decisions: 1946 to the Present*, RDD-7, U.S. Department of Energy, Office of Declassification, January 1, 2001, II.C.17.
[8] See footnote 3 in: J. Carson Mark, Thomas D. Davies, Milton M. Hoenig, and Paul Leventhal, "The Tritium Factor as a Forcing Function in Nuclear Arms Reduction Talks," *Science*, Vol. 241, No. 4870, September 2, 1988.
[9] "Supplemental Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor," Public Scoping Meeting, October 20, 2011, National Nuclear Security Administration, Department of Energy, slide 8.
[10] The total inventory is found by multiplying the annual production rate by the half-life of tritium and dividing by ln2. With an inventory of this size the annual production rate would be counter balanced by the annual decay of the total tritium inventory.
[11] Hans M. Kristensen and Robert S. Norris, "US nuclear forces, 2014," Bulletin of the Atomic Scientists, Vol. 70, No.1, January/February 2014.
[12] In contrast, the smallest implosion fission weapon fielded by the U.S., the Mark 12, had a weight of 550 kilograms and a diameter of 22 inches.

current missiles. South Korea, Japan and perhaps Guam could now be under threat from nuclear-armed North Korean ballistic missiles. Having such small and light-weight nuclear warheads would help simplify North Korea's task should it wish to develop the capability to target the U.S. with nuclear weapons.

The reduced fissile material requirements of boosted fission weapons means that North Korea may be able to significantly increase the number of nuclear weapons it can produce from a given amount of fissile material. Over the next few years, as North Korea increases its tritium stocks, it may be able to increase its nuclear arsenal by 50% or more even if it is producing fissile material at a much lower rate.

Pakistan's possible possession of boosting technology raises the concern that it received this technology from China in violation of China's NPT obligations and that Pakistan may have passed it on to North Korea. Even if North Korea did not receive this technology from Pakistan but only developed it indigenously, there is still the danger that North Korea could pass the technology on to other countries seeking to acquire nuclear weapons. Boosted fission weapons may now become the norm for all nuclear weapons armed countries. Since this technology can use reactor-grade plutonium just a readily as weapons-grade plutonium, there can no longer be any doubt regarding the weapons usability of this plutonium.

Bottom line, if North Korea has tested a boosted fission weapon, then it can now produce small light-weight nuclear weapons that can be easily carried on ballistic missiles. South Korea, Japan and perhaps Guam could now be under threat from North Korean nuclear-armed ballistic missile attack and North Korea's task of developing the capability to conduct nuclear strikes on the U.S. could be simplified. Further since such weapons can use less fissile material to produce the same yield, over the next few years, North Korea's nuclear arsenal may increase by 50% or more. Furthermore, North Korea could provide boosted fission weapon technology to any country seeking to acquire nuclear weapons, making boosted fission weapons the norm. If North Korea has tested a boosted fission weapon then it is a development is almost as ominous as if North Korea had tested a hydrogen bomb.