POTENTIAL IMPACTS OF ACCIDENT AT OR ATTACK ON THE DPRK'S YONGBYON NUCLEAR REACTORS



Recommended Citation

David von Hippel and Peter Hayes, "POTENTIAL IMPACTS OF ACCIDENT AT OR ATTACK ON THE DPRK'S YONGBYON NUCLEAR REACTORS", NAPSNet Special Reports, May 22, 2017, https://nautilus.org/napsnet/napsnet-special-reports/potential-impacts-of-acciden--at-or-attack-on-the-dprks-yongbyon-nuclear-reactors/

David von Hippel and Peter Hayes

May 22, 2017

I. INTRODUCTION

This essay by David von Hippel and Peter Hayes argues that neither attack nor accident at the DPRK's two reactors at Yongbyon would result in significant transborder radiological damage. They conclude that "the United States and its allies control most of the variables that would result in substantial radiological release from the DPRK's small reactors, but any leverage arising from that dominance is offset by the reciprocal threat posed by DPRK retaliation to ROK LWRs, neutralizing the US-ROK threat from the DPRK's perspective."

David von Hippel is Nautilus Institute Senior Associate. Peter Hayes is Director of the Nautilus Institute and Honorary Professor at the Centre for International Security Studies at the University of Sydney.

Acknowledgements: This Special Report is a longer version of "What are the Potential Impacts of a Crisis at North Korea's Yongbyon Nuclear Reactors?" published by the Korea Economic Institute's *The Peninsula.*

The views expressed in this report do not necessarily reflect the official policy or position of the Nautilus Institute. Readers should note that Nautilus seeks a diversity of views and opinions on significant topics in order to identify common ground.

Banner Image Credit: Yongbyon reactors site, GoogleEarth imagery

II. SPECIAL REPORT BY DAVID VON HIPPEL AND PETER HAYES

POTENTIAL IMPACTS OF ACCIDENT AT OR ATTACK ON THE DPRK'S YONGBYON NUCLEAR REACTORS

May 22 2017

Nuclear Tensions on the Korean Peninsula

In spite of the May 10 2017 election of a pro-engagement ROK President,[1] tensions on the Korea peninsula remain high. Although the reactions of United States president Donald Trump to further provocations—nuclear weapons or missile tests, for example, or simply the usual shrill rhetoric and next possible military provocation by the Democratic Peoples' Republic of Korea (the DPRK, or "North Korea") are difficult to predict, in his first few months in office Mr. Trump has already shown a willingness to use or show force as deterrent and a means of persuasion. The US use of cruise missiles in early April to attack a Syrian airfield in retaliation for the Syrian government's chemical weapons use, the use of a huge "Massive Ordnance Air Blast Bomb" in Afghanistan a week later, and the dispatching of the aircraft carrier Carl Vinson and its strike group to the Western Pacific in late April have not escaped the DPRK's notice,[2] and have resulted in further threats on the US and its allies in the region from DPRK media, including threats of attacks with conventional and nuclear weapons. For its part, the DPRK continues to fire missiles into the Sea of Japan although it has not tested a long range missile nor carried out a seventh nuclear test, as many had anticipated earlier this year.

How many nuclear weapons of what types the DPRK possesses, where those weapons are located,

and whether the DPRK already has the technology to make weapons small enough to launch on one of its missiles are all subjects of debate among DPRK-watchers. One thing that is clear is that the plutonium used to make at least many of the weapons in the DPRK's arsenal was, and likely is being, produced in a small "magnox" reactor at the DPRK's Yongbyon Nuclear Scientific Research Center in Pyong'an Province, about 90 km north of Pyongyang. Analysts estimate that the magnox reactor has been reactivated since mid-2016.

A recently-built experimental light-water reactor (ELWR) at the complex also appears complete in satellite photos, although there is no evidence that it has operated as yet. It too could be a source of plutonium for weapons.

Also in use at Yongbyon are a facility for separating plutonium from spent reactor fuel, and a center for enriching uranium, both of which can produce fissile material usable in nuclear weapons. This set of facilities makes Yongbyon an obvious potential target for an adversary determined to damage the DPRK's nuclear weapons production capability.

At the same time, due in part to the lack of a safety culture in the DPRK in both construction and operation practices, a nuclear accident at one or both of the reactors is not out of the question. Such an accident or attack would likely result in some release of radioactive materials. As such, populations potentially downwind from Yongbyon, and those concerned with their welfare, might reasonably ask "What could be the radiological consequences of an accident at or attack on one of the reactors?" And would the threat of such releases give US policymakers pause before attacking such facilities? And could North Koreans hope to obtain coercive leverage from the risk of accidents in negotiations to settle the nuclear issue?

Background: The DPRK's Nuclear Reactors

Apart from a small research reactor, also located at Yongbyon, that is used occasionally to produced istotopes for medical use, the two operational (or potentially operational) nuclear reactors known to exist in the DPRK are the magnox and ELWR reactors mentioned above (see Figure One).

The magnox reactor uses graphite as a moderator (to slow neutrons produced by the nuclear chain reaction) and cooled with carbon dioxide gas. "Magnox" refers to the magnesium alloy (magnesium/aluminum) cladding material used for the reactor's fuel rods. Construction on the reactor began in 1979, and was completed in 1986.[3] It has a nominal power rating of 5 MWe (megawatts electric), and a thermal power range of 20-25MW, though in fact it is our understanding that it does not generate electricity, but does provide some heat for the Yongbyon complex.[4] By way of comparison, most commercial nuclear reactor units in use around the world are rated at on the order of 1000 MWe, so the DPRK's magnox reactor is small in comparison. The design of the reactor is modeled after the United Kingdom's Calder Hall reactor,[5] though the DPRK reactor is considerably smaller. The magnox reactor uses natural, not enriched, uranium. The reactor core contains about 50 tonnes of uranium.



Figure One: The DPRK's Experimental Light Water Reactor and Magnox Reactor[6]

Note: The ELWR is the white-domed building near the bottom of the picture, while the magnox reactor is the off-white building with the reddish roof and the smokestack located in the upper middle of the image.

The experimental LWR at Yongbyon was revealed in 2010 to a delegation from the United States including Siegfried Hecker of Stanford University. Shortly thereafter, Hecker described his visit in a report that also expressed concerns about the potential safety shortcomings of a DPRK reactor.[7] If those safety concerns are realized, the DPRK LWR could, once commissioned, be vulnerable to accidents causing significant radioactive releases. As described to Hecker by his Korean hosts, and as observed by Hecker and his colleagues, the under-construction DPRK LWR was planned to have (and, we assume, has or will have) a designed heat output of 100 thermal megawatts (MWth), an electricity generation capacity of 25-30 MWe, and a level of enrichment in U_{235} of 3.50 percent, with a mass of uranium in the reactor core of 4 tonnes heavy metal (tHM).

Potential Release of Radioactive Materials from DPRK Reactors as a Result of Accident or Attack

Concerns about the release of radioactive material from damaged reactors, and concerns regarding potential exposure of populations living downwind of the reactors, focuses on the radioactive isotope cesium-137 (Cs_{137}). Cs_{137} can be distributed by prevailing, and is easily dissolved in water and thus can make its way into the tissues of the body, where its decay produces gamma radiation that can cause damage including increasing the probability of the growth of cancers. The Cs_{137} inventory in the DPRK's magnox reactor is about 3.7 PBq, a measure of radioactivity.[8] Our estimate of the potential Cs_{137} inventory in the ELWR reactor core is a maximum of about 9 PBq just before refueling, with up to an additional 40 PBq building up in the reactors' spent fuel pool over 20 years (assuming that spent fuel is not removed for reprocessing or disposal).[9] By way of comparison, the inventory of Cs_{137} in the reactors and spent fuel pools involved in the Fukushima accident totaled nearly 3000 PBq, although only a small fraction of that total was released during the accident.

The summary of our estimates of radiation release resulting from several scenarios of accident at or attack on the DPRK ELWR was that even in the event of an worst-case attack that caused releases from the reactor AND the spent fuel pool, and which occurred when the spent fuel pool was full (some 20 years from start-up), exposure to individuals exceeding United States Environmental Protection Agency guidelines for long-term radiation exposure would be limited to Yongbyon and small DPRK towns in the vicinity, and would not extend to, for example, Pyongyang or Seoul, even if prevailing winds were in those directions. Given the much smaller inventory of Cs_{137} in the DPRK's magnox reactor, even in the event that the entire inventory was released (presumably because the graphite core burns, although we do not know the likelihood of such an event[10]), the exposure would be less than our estimate for the ELWR.

It is unclear what additional inventories of Cs_{137} a large attack on Yongbyon might release—perhaps from the spent fuel pool storing spent magnox fuel or from reprocessing wastes located at the site, for example—but these quantities would not change our general finding that significant radiation exposure is highly unlikely to occur except in DPRK territory within about 20 kilometers of Yongbyon.

Conclusion

In the event of even a large and targeted attack on Yongbyon, significant radiological consequences will be limited to DPRK territory nearby. The major impacts of the attack or the threat of an attack beyond the local area will therefore be in the response elicited from the DPRK military, the psychological influences on more distant populations, and the effects on policies in the region.

Following an attack on Yongbyon, the possibility of a reciprocal, retaliatory attack by the DPRK, given DPRK rhetoric, would seem substantial. DPRK retaliation could come either in the form of an attack by the DPRK with conventional weapons on ROK military and civilian targets, essentially starting a war, or an attack on one of the ROK's much larger LWRs or spent fuel storage sites, via, for example, missile strikes or invasions by a commando group. Thus, rather than the risk of radiological release making the United States and its allies think twice about attacking the DPRK's nuclear facilities, the real risk that is likely to give the United States and its allies pause when considering an attack on Yongbyon is the risk of North Korean "reciprocal but a-symmetric and escalatory retaliation."

This deterrent effect exists because the risks to populations and economic losses arising from successful North Korean missile bombardment of ROK LWRs or spent fuel sites are much greater to the ROK (including not only radiological exposure, but prospective loss of large fractions of the ROK's power supply) than the consequences of a successful attack on the DPRK's reactors. In short, the United States and its allies control most of the variables that would result in substantial radiological release from the DPRK's small reactors, but any leverage arising from that dominance is offset by the reciprocal threat posed by DPRK retaliation to ROK LWRs, neutralizing the US-ROK threat from the DPRK's perspective.

Similarly, subsequent to an attack on one or both of the DPRK's reactors, even though radiation doses above a threshold for substantial harm would not reach populations in the Republic of Korea—for winds blowing toward the south, as prevail in winter—or in China—for winds blowing toward the north, as prevail in summer—populations in these neighboring countries would certainly be concerned. Thus, the primary predictable impacts of a radiological release—or the threat of a release—from the DPRK's LWR will be psychological, in terms of downwind perceptions and anxiety on the part of exposed or potentially exposed populations, and political, in terms of the policies adopted in anticipation of or as a result of such an event. As such, it is the consideration of the response of ROK and/or Chinese public mobilization in advance of a strike on Yongbyon due to fear

of war—compounded by fear of radiation, even if ill-founded—that would serve as a deterrent to an attack on Yongbyon, rather than consideration of the direct radiological consequences of such an attack.

III. ENDNOTES

[1] See, for example, Choe Sang-hun (2017), "South Korea Elects Moon Jae-in, Who Backs Talks with North, as President", *New York Times*, May 9, 2017, available as https://www.nytimes.com/2017/05/09/world/asia/south-kore--election-president-moon-jae-in.html?_r=0.

[2] See, for example, Junko Ogura and Susannah Cullinane (2017), "North Korea threatens to sink US aircraft carrier", CNN.com, April 24, 2017, available as http://www.cnn.com/2017/04/23/politics/uss-carl-vinson-japan-us-drills/.

[3] See, for example, Nuclear Threat Initiative (NTI, 2017), "Yongbyon 5MWe Reactor", last updated January 30, 2017, and available as http://www.nti.org/learn/facilities/766/.

[4] Other sources suggest that the DPRK"s magnox reactor does produce, or at least has produced, electricity. See for example Chaim Braun, Siegfried Hecker, Chris Lawrence, and Panos Papadiamantis (2016), *North Korean Nuclear Facilities After the Agreed Framework*, dated May 27, 2016, and available as http://cisac.fsi.stanford.edu/sites/default/files/khucisacfinalreport_compressed.pdf.

[5] An early description of the Calder Hall reactors is provided in Kenneth Jay (1956), *Calder Hall: The Story of Britain's First Atomic Power Station*. Harcourt Brace and Company, New York, 1956.

[6] Credit: GoogleEarth, May 14, 2017

[7] Source: "Redefining denuclearization in North Korea" by Siegfried S. Hecker, 20 December 2010, *Bulletin of the Atomic Scientists*, available at http://thebulletin.org/redefining-denuclearization-north-korea-0.

[8] A petabecquerel, or 10^{15} Bq, represents a rate of radioactive decay equal to 1 disintegration per second. 37 billion (3.7 x 1010) Bq equals 1 curie (Ci). See, for example, US Nuclear Regulatory Commission (2013), "Becquerel (Bq)", available as http://www.nrc.gov/reading-rm/basic-ref/glossary/becquerel-bq.html. Our estimate assumes an entire reactor core that is ready for refueling, that is, has been subjected to an average of 635 MW-days/tU of "burnup", a value reported as the average burnup for the DPRK magnox reactor by Jooho Whang and George T Baldwin (2005) in the Sandia National Laboratory Report *Dismantlement and Radioactive Waste Management of DPRK Nuclear*

Facilities (available as https://www.osti.gov/scitech/servlets/purl/957471/), although other sources suggest that burnup in this reactor could be higher, which would increase its maximum Cs_{137} inventory.

[9] See David F. von Hippel and Peter Hayes (2014), *Illustrative Assessment of the Risk of Radiological Release from an Accident at the DPRK LWR at Yongbyon*, dated 6 May 2014, and available as https://nautilus.org/napsnet/napsnet-special-reports/illustrative-assessment-of-th--risk-of-radiological-release-from-an-accident-at-the-dprk-lwr-at-yongbyon-2/.

[10] In a 1957 accident at the Windscale plutonium production facility in the UK, some of the graphite moderator did catch on fire, though that reactor was cooled with air, not CO_2 as the DPRK's magnox reactor is. Similarly, in the 1986 Chernobyl disaster, the graphite moderator of that water-cooled reactor burned, contributing to the atmospheric dispersion of radioactivity in the core. We do not know whether an attack on the DPRK's magnox reactor could cause a substantial fraction of the graphite core to burn, though we suspect that some organization has probably analyzed such an event. Our point here is that even *if* the graphite core were to burn and the entire Cs_{137} inventory in the reactor core was released, the event would be insufficient to exceed radiological risk thresholds even tens of kilometers from Yongbyon.

IV. NAUTILUS INVITES YOUR RESPONSE

The Nautilus Asia Peace and Security Network invites your responses to this report. Please send responses to: nautilus@nautilus.org. Responses will be considered for redistribution to the network only if they include the author's name, affiliation, and explicit consent.

View this online at: https://nautilus.org/napsnet/napsnet-special-reports/potential-impact-of-accident-at-or-attack-on-the-dprks-yongbyon-nuclear-reactors/

Nautilus Institute
608 San Miguel Ave., Berkeley, CA 94707-1535 | Phone: (510) 423-0372 | Email: nautilus@nautilus.org