

HOW SOUTH KOREA COULD ACQUIRE AND DEPLOY NUCLEAR WEAPONS

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INTRODUCTION: WHY STUDYING OPTIONS FOR NUCLEAR WEAPONS IS NECESSARY TO PREVENT FUTURE PROLIFERATION

Political leaders and defense planners in the Republic of Korea (ROK), or South Korea, are cognizant that worsening security in Northeast Asia could lead to additional states, including the ROK, to consider and even develop nuclear weapons. In particular, Korean President Park Geun-hye warned in May 2014 that another nuclear bomb test by North Korea (Democratic People's Republic of Korea or DPRK) would be "crossing a Rubicon" and would make it "difficult for us to prevent a nuclear domino from occurring in this area."¹ She mentioned that there are some leaders in minority political parties in the ROK discussing options for South Korea's acquisition of nuclear weapons. But the preference is still strongly for the ROK to rely on extended nuclear deterrence from the United States and for the ROK Armed Forces to improve their conventional military capabilities in cooperation with the United States. Nonetheless, if the Japanese government decides that it must acquire nuclear weapons, which would also be far from Japan's preference, the ROK would feel pressure to follow Japan. Thus, while South Korea would not be first to acquire these weapons, it would not want to feel vulnerable to a nuclear-armed Japan.

Often nonproliferation analysts avert their gaze and do not want to contemplate too deeply how trusted allies such as South Korea or Japan could plausibly develop

nuclear arms. However, to prevent an awful event, it is useful to study how the external geopolitical and internal domestic political circumstances could transpire to lead to this event and then to examine the consequences if such an action were to occur. This technique of “negative visualization” has a long and distinguished history, having been practiced by Stoics such as the Roman Emperor Marcus Aurelius, in identifying what the practitioners can do and control in order to reduce the likelihood that tragic “Rubicon”-crossing events would happen. President Park herself proposed in an op-ed for the *Wall Street Journal*, a “Northeast Asian Peace and Cooperation Initiative” for China, the ROK, and Japan to work together to resolve the region’s “many quandaries.”² Moreover, the ROK needs to continue to work closely with alliance partners to strengthen non-nuclear defense options, and the United States needs to continue to provide nuclear deterrence commitments to the ROK.

RATIONALES FOR SOUTH KOREA TO CONSIDER ACQUIRING NUCLEAR WEAPONS

Faced with growing threats of nuclear weapons and missile capabilities from North Korea, South Korea clearly needs reliable means to deter the North’s nuclear weapons and effective responses if deterrence fails. Would South Korea develop nuclear weapons to provide deterrence and response capabilities? Different political factions in South Korea have at times doubted U.S. nuclear deterrence assurances or have wanted their own nuclear capabilities to provide for credible deterrence. Other factions have in contrast argued for reconciliation with North Korea and pushed for creating a peninsula free of nuclear weapons.³

Reasons against South Korea acquiring its own nuclear weapons can look compelling, but a different viewpoint on these reasons can argue for South Korea crossing that threshold. Let's examine a few prominent reasons for and against.

First, South Korea has become one of the most globalized nations in the world with one of the largest economies, supplying coveted goods (such as electronic products made by Samsung and LG Corporation) to markets around the world, especially to the United States. This argues against South Korea acquiring nuclear weapons because it would jeopardize its economy due to the resulting international sanctions. On the other hand, South Korea would most likely weather the storm of sanctions considering the precedent of India. In May 1998, India conducted nuclear explosive tests and was then sanctioned. But the sanctions did not last much longer than a year. While India was not producing many coveted goods at that time, its huge population offered an enticing market and, as a democracy, was seen by the United States as an important counter to communist China's rising military strength. In the case of South Korea, it has a tiny population compared to India, but most of its people are relatively wealthy and take part in a vibrant democracy, and as mentioned, many South Korean companies create goods that Americans want to consume. Thus, the sanctions would likely be pro forma and be removed after a period of a few to several months.

Second, South Korea has positioned itself as one of the stalwart defenders of the nuclear nonproliferation regime. South Korea, for example, has applied the Additional Protocol to its Comprehensive Safeguards Agreement and thus opened up its civilian nuclear program to intensive inspections by the International Atomic Energy Agency (IAEA). Also, Seoul hosted the 2012 Nuclear Security Summit and demonstrated

leadership in securing nuclear and other radioactive materials. Moreover, South Korea would not want to risk sanctions on its ability to export nuclear technologies because it has pledged to garner 20 percent or more of the future nuclear export market, estimated to be worth more than \$100 billion in the coming decades. The flipside, however, states that the nonproliferation regime is only good as long as it serves South Korea's national interests. If the Republic of Korea's government determines that its national security requires developing nuclear weapons, it can cite Article X of the Non-Proliferation Treaty (NPT) to exercise its right to leave the treaty in 90 days, similar to what North Korea did in 2003. As to sanctions on nuclear exports, South Korea has smartly embedded its nuclear industry with the United States, France, and Japan, to name a few prominent partners. If these countries want to continue to benefit from partnership with South Korea in the United Arab Emirates or other countries where South Korea has negotiated deals, they would not press too much or hardly at all for sanctions that would also hurt themselves.

Another argument against South Korea's obtaining nuclear weapons is that the ROK would rupture its defense agreement with the United States as well as spark a potential nuclear arms race with Japan or perhaps China. This may be the most powerful argument impeding South Korea's acquisition of nuclear weapons, but there are plausible ways in which it could still happen. Despite the U.S.-stated strategic pivot to the Asia-Pacific region, the fiscal reality is that the United States is increasingly hard pressed to meet the levels of defense spending required to shore up the security of Japan and South Korea. Also, some current and former leaders in those two countries have perceived the Barack Obama administration as downplaying the utility of nuclear weapons, and

President Obama's call for a world free of nuclear weapons has alarmed some defense analysts in Japan and South Korea. If the United States were perceived to not be able to reliably and credibly counter the threats posed by China and North Korea, prudent military planners in Japan and South Korea would want to take steps to have their own nuclear capabilities. Moreover, some ROK officials might rationalize that acquiring nuclear weapons would wake up the United States to the need to work more seriously with the ROK on security matters, namely the denuclearization of North Korea.

Finally, if Japan crosses the threshold to nuclear weapon acquisition, South Korea would feel compelled to follow suit. South Korean leaders would then not want to be vulnerable to both nuclear-armed North Korea and Japan. Imperial Japan subjugated the Korean people to colonial rule from 1910 to 1945, and many South Koreans still feel bitter animosity toward Japan and want to prevent Japanese incursion onto Korean territory or into Korea's national interests.

SCENARIOS FOR SOUTH KOREAN ACQUISITION OF NUCLEAR ARMS

Let's consider three scenarios that would lend South Korea the means to deter, counter, and respond to nuclear threats. The first scenario will be called "enhanced status quo" because it will show that the current status quo has already resulted in South Korea having delivery systems such as missiles and aircraft for nuclear weapons and having a relatively large civilian nuclear infrastructure that would only need to be enhanced a bit to provide the means to extract fissile material for weapons and deploy the first nuclear weapons on available delivery systems. This scenario posits that South Korea would first stockpile separated reactor-grade, but still weapons-usable, plutonium (Pu) and proceed

with enhancing its means to produce larger quantities of weapons-grade or near-weapons-grade plutonium for a potential major breakout if necessary. In parallel to the initial amassing of separated plutonium, the ROK would continue to improve its ballistic and cruise missile systems and perform development and testing to ensure that these systems are nuclear capable. Once South Korea has at least a few bombs' worth of plutonium and has confidence in its missile systems, it could go for a quick breakout that would most likely be used to signal North Korea, China, Japan, and the United States. One plausible purpose of this signaling of these initial "diplomatic" bombs would be to prod Washington as well as Beijing to engage seriously on the denuclearization of North Korea.

If the United States and China failed to act, if Japan acted to breakout or build up its nuclear arsenal if it had already broken out, or if North Korea took steps to increase its nuclear arms, South Korea could leverage its base of a handful of nuclear bombs to keep ratcheting up and implement its potential to make dozens of nuclear warheads annually from near-weapons-grade plutonium produced from its four pressurized heavy water reactors (PHWRs). The initial steps could take place conceivably within a five-year period, and the latter ramp up might require more than five years from the initial start. South Korea would try to do as many preparatory steps in parallel. It would need to be prepared for relatively rapid buildup because of the uncertainty concerning how the other states might respond.

In the second scenario, "encirclement," which would build on the first scenario, South Korea would need to ratchet up its nuclear capability to deal with nuclear threats from Japan and China as well as North Korea. In particular, the assumption is that Japan

has obtained nuclear weapons and is threatening both North and South Korea. Also, although Seoul and Beijing have good political and economic relations, South Korea wants to prevent China from occupying the North in the event of a regime collapse or some catastrophe that would give the People's Liberation Army (PLA) a rationale to cross the Yalu River. Seoul would perceive nuclear weapons as a way to deter Chinese incursion into the Korean Peninsula. Beijing's top priority in the region is stability in the Korean Peninsula because of its concern about a mass exodus of millions of North Korean refugees into Chinese Manchuria. In this encirclement scenario, South Korea would likely perceive the need for longer-range strategic nuclear weapon systems and battlefield-capable tactical systems.

In the third scenario, the wild card will be that Japan and South Korea actually join forces and cooperate against common foes. This scenario could be called "the enemy of my enemy is my friend." Working together, Japan and South Korea could climb the ladder to advanced nuclear weapons faster than their separate efforts. They would aim to counter China and North Korea. The United States might actually welcome such a nuclear alliance because this could reduce the U.S. defense burden, but on the other hand, Washington would worry that this scenario could lead to more aggressive conventional and nuclear arms races in Northeast Asia and a more militarily capable China. Without a doubt, this scenario would result in a major strategic realignment.

Scenario One: Enhanced Status Quo.

In this scenario, South Korean conservatives gain the political ascendancy and argue successfully that engagement policies toward North Korea are bankrupt. They win

the debate that it is time to stop wishing for North Korea to denuclearize because South Korea offers food aid and other means of assistance or because Seoul keeps admonishing Pyongyang to participate in peace summits. Indeed, South Korean conservatives have in recent years become the dominant political force, and some have argued in public for South Korea to consider seriously acquiring nuclear weapons. For example, Chung Mong-jun, former chairman of the ruling Saenuri Party, and Won Yoo-chul, former chairman of the National Assembly's Defense Committee, have been two of the most vocal advocates. Chung Mong-jun raised concern among the Washington nonproliferation establishment at the Carnegie Nuclear Policy Conference in April 2013 when he called for tactical nuclear weapons from the United States to return to South Korea and also insinuated that if U.S. deterrence is not strengthened then South Korea should take matters into its own hands.⁴ In February 2013, a Korea Gallup poll showed that 64 percent of 1,006 respondents replied, "yes" to the question: "Should South Korea have nuclear weapons?"⁵

Many South Korean conservatives believe that North Korea will not negotiate away its nuclear weapons given the recent statements by Kim Jong-un and the Korean Central News Agency, the media voice of the North Korean regime, that North Korea is a nuclear weapon state and has joined this elite club. Moreover, South Korea needs to face the reality that the Kim regime cannot give up its nuclear weapons because then it would not maintain its rule over North Koreans. For decades, starting with the reign of Eternal President Kim Il Sung and even 21 years after his death, North Korean leaders have based their legitimacy on the *Songun*, or military-first, policy. To justify the sacrifices of

the North Korean people, their leaders have to constantly point to the “hostile policy” of the United States and the “American lackeys” in the South.⁶

DPRK rhetoric notwithstanding, North Korea has been building up its nuclear and missile capabilities and has been alarming South Korean military planners.⁷ In January 2015, the South Korean Minister of Defense stated that the ministry’s assessment is that North Korea has made “significant” advances toward making a warhead small enough to fit onto a long-range missile capable of reaching the West Coast of the United States but that North Korea had yet to conduct a test to demonstrate this capability.⁸ The more North Korea builds up these capabilities, the more South Korean military planners would want to counter them.

To make its first nuclear weapons, South Korea would need (1) fissile material, (2) capable warhead designs, and (3) reliable delivery systems for the warheads. South Korea can plausibly and relatively easily acquire all these ingredients. More advanced thermonuclear warheads would require access to heavy hydrogen isotopes of deuterium and tritium. South Korea has these readily available as well.

Obtaining Fissile Material

Acquiring fissile material would require South Korea to have facilities for either uranium enrichment or reprocessing of spent nuclear fuel. The former could produce highly enriched uranium (HEU) that could initially power a relatively easy-to-make gun-type nuclear explosive such as the one first made during the Manhattan Project for the Hiroshima bomb. HEU could also power more advanced implosion-type nuclear explosives. South Korea does not have enrichment facilities. Although the Korean

nuclear industry has expressed interest in developing enrichment capabilities, the financial incentives for South Korea venturing into enrichment are not apparent for the foreseeable future given the relative glut of cheap enriched uranium on the world market. In addition, South Korea would likely not get U.S. permission to build an enrichment facility. A clandestine facility could not be ruled out, but reprocessing seems to be a more promising immediate pathway as argued herein.

Reprocessing would separate plutonium from spent fuel; the plutonium could power first-generation implosion-type bombs or second-generation pure fission weapons that make use of levitated plutonium pits surrounded by neutron reflectors made of beryllium. Later, South Korea could use its plutonium in more advanced boosted fission and thermonuclear bombs. Notably, these more advanced weapons could use HEU in combination with plutonium or by itself. By the time the ROK went down the thermonuclear pathway, it would be many years into an open breakout scenario and would then be overt about building an enrichment facility.

Plutonium is more desirable to South Korea for a few other reasons. Because plutonium is more efficient in terms of the amount of material needed to achieve a certain explosive yield as compared to HEU, South Korean weapon designers would most likely prefer this fissile material for their first nuclear bombs. Such material is more amenable for use in compact or miniaturized warheads. Moreover, the ROK would likely choose the plutonium pathway because it has many tons of plutonium already resident in spent nuclear fuel, and it has been acquiring expertise in reprocessing. Thus, the enhanced status quo scenario focuses on plutonium.

Spent fuel could be acquired from either South Korea's pressurized water reactors (PWRs) or PHWRs. While South Korea presently has much more PWRs with 19 operable and several more under construction or planned, the four PHWRs are much more useful for acquiring weapons-usable plutonium. Due to the design of a PHWR, it does not burn up as much nuclear fuel as a PWR. A lower burnup means that the isotopic composition of the plutonium in the spent fuel is better suited for nuclear explosives. That is, the higher the fraction of the fissile isotope plutonium-239, the better the material will be for weapons purposes. Fissile Pu-241 is also useful for weapons purposes but is less desirable than Pu-239 because it is more reactive and emits more radiation, which is a consideration during the handling and fashioning into an explosive. In particular, a PHWR with a typical burnup of 7,500 megawatt-day/ton results in a plutonium mix of 66.6% Pu-239, 26.6% Pu-240, and 5.3% Pu-241 for a total fissile content of 71.9%. A PWR with a typical burnup of 53,000 megawatt-day/ton results in a plutonium mix of 50.4% Pu-239, 24.1% Pu-240, and 15.2% Pu-241 for a total fissile content of 65.6%.⁹ Thus, in terms of the portion of Pu-239 and total fissile content, PHWR spent fuel is more weapons-usable than PWR spent fuel.

These "reactor-grade" plutonium mixtures are weapons-usable, as officially stated by the U.S. Department of Energy.¹⁰ According to former nuclear weapon designer Dr. Richard Garwin, it is wrong to rule out the use of a plutonium mixture that has less than 85% fissile content. His calculations show that even a fissile content of about 66% is weapon-usable and has a "bare" critical mass of about 13 kilograms as compared to about 10 kilograms bare critical mass for weapons-grade plutonium (Bare means a sphere of this material by itself in a vacuum without being surrounded by a neutron reflector that

would reduce the critical mass). He outlines in a 1998 article the relatively simple engineering steps that would be needed to be able to use reactor-grade plutonium of 66% or greater fissile content. He also points out that Pu-240 would add to the fissile yield because high-energy neutrons, produced during the fission of Pu-239 and Pu-241, can fission Pu-240. Thus, he argues that the explosive yield of a reactor-grade plutonium bomb would be comparable to a weapons-grade plutonium bomb because of approximately the same number of fissions in each bomb, assuming similar number of critical masses.¹¹

Moreover, there should be no doubt because the United States demonstrated via a nuclear test during the Cold War that reactor-grade plutonium is usable in nuclear explosives and will produce powerful nuclear yields.¹² Also, it is believed that India demonstrated during its May 1998 tests that it used reactor-grade plutonium. The Indian PHWRs were the likely source of that fissile material for at least one of the tests.¹³ The Indian PHWRs and the Korean PHWRs are both derived from Canadian-designed PHWRs known as CANDUs. The currently stockpiled spent fuel at the dry cask storage facility at Wolsong could provide about 26,000 kilograms of reactor-grade, but still weapons-usable, plutonium for South Korea.¹⁴ Assuming a conservative estimate of about six kilograms plutonium for a first-generation fission device, the ROK has up to 4,330 bombs' worth of plutonium at this site. South Korea could also use its PHWRs without too much effort to make near-weapons-grade, often called fuel-grade, plutonium with a content of about 10 to 11 percent Pu-240 and at least 85 percent fissile isotopic content in the overall plutonium mixture.

The CANDU design is proliferation-prone from the standpoints of nuclear material diversion and relative ease in making near-weapons-grade or fuel-grade plutonium. The CANDU can be fueled with natural uranium, low enriched uranium, or even mixtures of various fissionable and fissile materials. South Korea has fueled its CANDUs or PHWRs with natural uranium fuel. The CANDU is designed so that it is refueled while operating. Thus, the plant does not have to shut down to refuel, and there is no outward signal that the plant is refueling. In contrast, a PWR would have to shut down to refuel, and an inspector could witness this activity by noting that there would be no steam plume leaving the cooling tower. Consequently, if South Korea decided to make nuclear weapons and wanted fissile material, it could keep its PHWRs operating while removing and then diverting the spent fuel. Secondly, a CANDU uses heavy water as a moderator and coolant. The heavy water does not absorb as many neutrons as light water, so there would be more neutrons available to convert the uranium-238 atoms in the natural uranium fuel to plutonium-239. Natural uranium has more than 99 percent of its atoms as uranium-238, providing for numerous targets for the neutrons to hit and result in conversion to plutonium. To optimize for near-weapons-grade plutonium production with a very large percentage of plutonium-239, the operator of the PHWR would want to remove irradiated fuel on the order of about once a month.

According to the calculations of Thomas Cochran and Matthew McKinzie, every year until the decommissioning of the PHWRs, South Korea could make about 2,500 kg or 416 bombs' worth of near-weapons-grade plutonium (with a Pu-240 content of about 10 percent) from the four PHWRs at the Wolsong Nuclear Power Plant assuming 6 kilograms of weapons-grade plutonium per bomb and assuming an operational mode of

1,500 to 2,000 MW-day/ton burnup.¹⁵ For more sophisticated weapon designs, the ROK might have available upwards of 830 bombs' worth of plutonium in this operational mode.¹⁶ But as Cochran and McKinzie point out, this scale of operations would require four to five times the domestic natural uranium fuel production capacity that the ROK presently has and would need a reprocessing capacity that is two to three times that of the relatively large-scale commercial plant at Rokkasho in Japan. Therefore, they argue that the ROK would reasonably reduce the scale to fit within its current fuel production capacity. That would still result in approximately 500 kilograms of plutonium, enough for several dozen to somewhat more than 100 bombs' worth of material. Even a more modest production rate of 150 kilograms of plutonium annually, which is well within the capabilities of the four PHWRs, would generate 25 to 50 bombs' worth of material depending on the level of sophistication of the weapons' designs.

Cochran and McKinzie notably highlight that the ROK imports all its natural uranium for producing fuel for these reactors because the ROK has had very limited supplies of natural uranium. Consequently, the ROK would have to make sure that it had available sufficient supplies of this material before embarking on a nuclear weapons program. Typically, fuel manufacturing states do purchase the raw material in advance and because uranium is a dense material, hundreds to thousands of tons can be stockpiled without taking up much space. South Korea, however, would have to be careful not to appear to purchase too much natural uranium in a limited time period so as to provide a telltale sign. Because of this concern, the ROK would likely keep its initial weapons' material production program at a lower level within the capabilities of existing stockpiles of natural uranium.

To ensure continuing supplies of natural uranium after the onset of the weapons program, the ROK would mine newly discovered uranium deposits on land and accelerate deployment of seawater extraction methods. Regarding the former source, Stonehenge Metals Limited presently owns 100 percent of the rights to four uranium projects in South Korea. The lead project, known as the Daejon Project, has inferred uranium resources of about 30 million kilograms (30,000 tons) of U_3O_8 with an average grade of 320 ppm in the ore bodies.¹⁷ Seoul would likely move to nationalize the uranium resources in the event of a breakout to a nuclear weapons program. South Korea has also invested significant research and development (R&D) into seawater extraction of uranium.¹⁸ The world's oceans contain at least several hundreds of years of uranium based on current demand, but the concentration of uranium is very diffuse. Recently, an international team of researchers led by U.S.-based Oak Ridge National Laboratory announced a potential major breakthrough that the group claims "can extract five to seven times more uranium at uptake rates seven times faster than the world's best absorbents."¹⁹

Shifting the PHWRs to low burnup operations is an essential step, but the ROK would also need a reprocessing facility to separate the plutonium from the spent fuel. While South Korea in early 2015 does not have a reprocessing facility, it has made significant strides in developing a prototype pyroprocessing facility at the Korea Atomic Energy Research Institute (KAERI) in Daejon. The stated rationale for pyroprocessing is to remove the fissionable materials from spent fuel and thus reduce the radioactivity and volume of the high level waste that would have to be stored underground. The Korean government anticipates fierce public opposition to a permanent high level waste facility

and wants to present a technological method that would show to the public that the amount of waste to be stored would be minimized.

Pyroprocessing would under normal operations not separate out pure plutonium from other fissionable materials in spent nuclear fuel. But it would remove the plutonium and other fissionable materials from the protective barrier of highly radioactive fission products inside spent fuel. The plutonium would be mixed in with transuranic materials such as americium, curium, and neptunium. While this mixture would not be desirable for a militarily useful weapon, it could be susceptible to theft or diversion if adequate physical protection measures are not in place because the mixture would not be highly radioactive and could be handled. The main concern from the proliferation standpoint is that South Korea could divert enough material into a Plutonium Uranium Redox EXtraction (PUREX) type reprocessing facility or could misuse the pyroprocessing facility in order to extract plutonium from the mixture. This plutonium could then be used for making nuclear weapons.

Safeguarding pyroprocessing is challenging due to the nature of the process, it is extremely hard to measure and track the amounts of plutonium. While the International Atomic Energy Agency is working on a safeguards method for pyroprocessing, the most often discussed scenario is to couple the pyroprocessing facility with fast neutron reactors. These reactors make use of high-energy, or fast moving, neutrons to cause fission of plutonium and other transuranic fissionable materials. Uranium enriched to 20 percent or more in the fissile isotope uranium-235 could also be used to fuel these reactors. If the fast reactors were just used to burn up transuranic materials, they could help reduce the amount of these materials that would have to be stored or that could be

diverted into weapons programs. But these reactors can also be run in a breeder mode to produce more plutonium, especially plutonium that can be weapons-grade. Consequently, safeguarding fast reactors adds to the challenge of ensuring that the combined system of pyroprocessing plus fast reactors is not furthering a nuclear weapons program.

At KAERI in Daejeon, a small-scale research facility could provide a relatively small amount of initial plutonium for breakout into a nuclear weapons program. This is the HANARO research and isotope production reactor and an associated hot cell facility. HANARO is rated at 30 MWth, but the Korean regulatory authority has downgraded the operational power to at most 26MWth. The reactor uses heavy water, but instead of natural uranium fuel, it is fuelled with 19.75 percent U-235. If the reactor were fuelled with natural uranium, it could make upwards of 8 kilograms plutonium annually assuming the power limitation of 26 MWth and 300 days of full power operation. However, due to the far fewer number of target U-238 atoms in the 19.75 percent U-235 core versus a 0.7 percent U-235 natural uranium core, this reactor would not be able to make more than 0.55 kg of plutonium annually.²⁰ While placing natural or depleted uranium target material in the irradiation channels and around the core could produce some more plutonium, it is likely that this would not be much more than a few more kilograms of plutonium annually. Although the HANARO reactor might provide some starter plutonium for a weapons program, the annual amount would not be enough for the first bomb, but it might supply enough after another year or two of operations assuming that natural or depleted uranium target material were inserted in the reactor. Notably, the hot cells have been used to extract radioisotopes for medical, industrial, and research purposes. These hot cells could also provide a means to extract some plutonium. Of

course, this assumes that South Korea would break out of its safeguards commitments, but given the basis of this scenario in which South Korea feels under serious threat to its supreme national interests, safeguards commitments are the least of its worries. The important finding from this analysis of the HANARO facility is that the four PHWRs at Wolsong would be the preferred production route for near-weapons-grade plutonium.

While KAERI has not yet used its Pyroprocessing Integrated DEMonstration (PRIDE) facility with irradiated materials, its experience to date with surrogate materials and its R&D work alongside U.S. researchers at Idaho National Laboratory give KAERI's researchers the essential knowledge and some work with this technique. The ROK has also requested to the United States that packages of pyroprocessed material be made in advance of operating the ROK's experimental fast reactor, which the ROK wants to bring online by 2028. Making packaged pyroprocessed fuel would give Korean technicians even further useful experience. The PRIDE facility could handle about 10 tons of material per year. This capacity would not allow for extensive production of plutonium annually from the PHWRs given the several hundred tons of irradiated material from these reactors, but it could provide a smaller scale means to extract the first few bombs' worth of fissile material while KAERI is building a bigger reprocessing facility.

To ensure much greater production capacity, the ROK would likely want to build a dedicated reprocessing facility for the PHWRs that could use the well-proven aqueous PUREX method. As Cochran and McKinzie point out, the ROK could first make a "Simple, Quick Processing Plant," which could only require four to six months to build.²¹ Considering that the PHWRs have much lower burnup than PWRs and thus roughly an

order of magnitude greater amount of spent fuel to be reprocessed, this simple plant would likely generate on the order of about one kilogram of plutonium per week or about 50 kilograms per year. In parallel, the ROK could build a facility on the scale of the Rokkasho Reprocessing Plant, which can reprocess up to 800 tons of irradiated fuel annually, but such a plant would take considerably longer than six months to build. (Also, given the technical struggles that Japan has had with operating the complex Rokkasho plant, the ROK might not want to go down this road. But Japan had successfully operated a pilot scale reprocessing plant at Tokai that could process about 200 tons per year—plenty for the ROK’s needs.) Nonetheless, the simple facility would still provide the ROK with more than enough plutonium to make its first few handfuls of nuclear bombs.

Acquiring Materials for Advanced Nuclear Weapons

South Korea already has the essential elements for making advanced nuclear weapons. Such weapons would include boosted fission warheads and thermonuclear warheads. Two essential ingredients for these warheads are deuterium and tritium, the two isotopes of heavy hydrogen. Deuterium is a stable isotope found in water. South Korea has a large plant that can produce about 400 tons per year of heavy water run by Korea Electric Power Corporation (KEPCO) Nuclear Fuel Limited in Daejeon.²² Korea’s HANARO research reactor and four PHWRs at Wolsong routinely make tritium when the heavy water in these reactors absorbs neutrons. South Korea has to remove the tritium from the water in order to prevent too much worker and public exposure to this radioactive substance. The Wolsong Tritium Removal Facility can process 100 kg per hour of tritiated heavy water feed to produce 99% pure tritium. The recovered tritium is then made available for various commercial applications.²³ However, this large amount

of tritium would provide South Korea with what would be needed to power boosted fission warheads and even more advanced thermonuclear warheads.

For thermonuclear warheads, South Korea would need to also acquire or manufacture the chemical lithium-6 deuteride. As mentioned, South Korea already has lots of deuterium. Lithium-6 occurs at the portion of 7.6 percent of natural lithium. Column exchange separation processing can be used to separate this isotope.²⁴ In 2012 South Korea made a major deal with Bolivia to acquire abundant supplies of lithium for production of lithium-ion batteries.²⁵ South Korea could conceivably divert some of this lithium into an isotope separation plant in order to obtain the needed lithium-6 for thermonuclear weapons.

Designing Nuclear Warheads

Essential components for any successful nuclear warhead design include high-speed electronic triggers to signal the detonations of high-energy conventional explosives, the ability to shape the high-energy explosives, and of course, the capacity to manufacture reliable high-energy explosives. Advanced computers would also be helpful but not necessary given the fact that the earliest nuclear warheads did not require such computers; nonetheless, South Korea has very advanced computers. The other components are truly necessary, and South Korea has them available and could most likely readily adapt their non-nuclear applications to nuclear weapons use.

High-speed electronic triggers such as krytrons or sprytrons can operate in voltage ranges of two to 20 kilovolts and “can draw currents ranging from 10 to 100 kilo-amps. Pulse neutron tubes, used to precisely control the initiation of fission chain reactions,

require voltages of 100 to 200 kilovolts, and currents in the ampere range. These currents must be turned on rapidly and precisely, timing accuracies of tens to hundreds of nanoseconds are required.”²⁶

Subject to export controls, krytrons were illegally acquired by Iraq, Pakistan, and North Korea for their nuclear weapons programs. David Albright, for example, cites a statement from A.Q. Khan, who headed Pakistan’s nuclear black market, acknowledging that Pakistan received technical assistance from North Korea in acquiring and developing these electronic triggers.²⁷ Krytrons have non-nuclear defense and civilian applications. For example, in 1976, the Agency for Defense Development (ADD) in the Republic of Korea purchased krytrons for the stated purpose of developing laser-range finders and identifiers for the South Korean Air Force. The ADD said that there were no other intended applications. The ADD, however, at that time had also been ordered by President Park Chung-hee to work on creating a nuclear weapons program. More recently, in 1994, South Korea hosted an international conference in Daejeon, South Korea where a group of Japanese researchers presented a paper describing the use of a krytron for X-ray photography, which requires very high-speed switches. Thus, there is evidence that South Korea has had access to krytrons. However, the extent of South Korea’s capability to manufacture these particular devices is not clear from open literature. More advanced types of this technology might be developed and manufactured in South Korea.

Electronic technology does not stand still especially in South Korea. In 1976, the Korean government founded and began funding the Korea Electrotechnology Research Institute (KERI), which is involved in numerous R&D projects, including advanced electrical grids, medical devices, high voltage direct current energy technologies, and

nano-technologies. This government-supported research institute has hundreds of Ph.D. and master's level researchers with access to high quality manufacturing and testing facilities.²⁸ Conceivably, under the scenario being considered, the Korean government could task a small portion of these researchers with developing high-speed, high-voltage, high-current switches for nuclear weapons.

Another essential component of nuclear weapons is high-energy conventional explosives that can be shaped into forms that result in implosion shock waves. These shock waves would squeeze plutonium or HEU into super-critical dense shapes necessary for detonating a fission chain reaction. South Korea has world leading manufacturing capability for these types of explosives. In particular, Hanwha Corporation, which is headquartered in Seoul, can make the nuclear-weapon-usable high-energy conventional explosives HMX and RDX, which have been used to trigger nuclear explosions by rapidly compressing fissile material, as well as other high-energy conventional explosives.²⁹ While Hanwha presently manufactures these types of explosives for non-nuclear military applications, it would not take much effort to retool for nuclear weapon applications. Hanwha was founded in 1952 and was then called the Korea Explosives Company. In 1974, the government designated it as "a national defense firm."³⁰ This was during the time of the Park Chung-hee administration. Hanwha also manufactures explosives and related technologies for commercial applications as well as for the defense sector. This company is recognized as a global leader in its field and can reliably manufacture high quality explosives.

Combining the essential components together, the South Korean government could assign a highly trained group of Korean engineers (of which Korea has many) to

design reliable nuclear warhead designs. They would likely first simulate their designs on advanced computers. Then once they have promising designs, they could potentially use explosive test facilities at Hanwha's testing facilities for conventional explosives to test how surrogate nuclear material such as depleted uranium would behave in the designs. A successful run of non-fissile material tests would give further confidence that the designs work.

Then the government would be faced with a decision to conduct one or more nuclear tests. For fission weapons or even boosted fission weapons such tests might not be needed, especially with the confidence that would result from a set of successful non-nuclear tests. It would be next to impossible to hide the seismic signals from nuclear tests given the extensive detection network operated by the Comprehensive Test Ban Treaty Organization. At this point in the development, the government could decide to be content with doing a series of subcritical tests or to declare its nuclear capability with nuclear yield tests. Plausibly, South Korea would want to signal to North Korea and possibly other states that it had this capability, and Seoul would likely announce that it had left the Non-Proliferation Treaty citing supreme national interests.

Leveraging Strategies and Deployments for the First Nuclear Bombs

The first few nuclear bombs could be considered "diplomatic" bombs that would be directed toward announcing South Korea's arrival in the nuclear-armed club.³¹ A major motivation could be to signal the United States that Washington needs to seriously engage in denuclearizing North Korea. If this is one of the South's major motivations for pursuing nuclear weapons, it will then have to be willing to bargain away its new nuclear arsenal in exchange for denuclearizing the North. In this sense, these weapons would be

diplomatic nuclear bombs. Another motivation would be to signal to Japan and China that South Korea is nuclear-armed or at least nuclear-capable with essentially a bomb-in-the-basement if it pursues trading away its newly acquired nuclear arms.

Assuming that the diplomatic ploy vis-à-vis North Korea does not pan out, then the South would most likely move to build up its nuclear arsenal with the types of capabilities that would deter the North and would provide battlefield capabilities against the North. This action would help fuel a nuclear arms race in East Asia that the ROK would then further respond to, spiraling to more nuclear arms to the other states. North Korea, in particular, would feel compelled to respond with further buildup putting pressure on Japan and South Korea and potentially leading to China to ramp up, then pressuring India and Russia. More Russian and Chinese nuclear arms could push the United States to consider more arms depending on the amount of buildup and types of arms deployed, or at least to halt additional nuclear arms reductions.

What would the ROK's nuclear weapon systems consist of? Seoul might consider a back-to-the-future strategy in which it could reproduce or emulate the types of nuclear weapons the United States had deployed in and around the Korean Peninsula during the Cold War. In recent years, some South Korea political leaders have called for the redeployment of U.S. tactical nuclear weapons, for example.

In 1957 Secretary of State John Foster Dulles convinced President Dwight Eisenhower to approve stationing of U.S. nuclear weapons in South Korea. The United States first deployed in January 1958 280-mm nuclear cannons and Honest John nuclear-tipped missiles. In 1959, the United States positioned a squadron of nuclear-armed Matador cruise missiles with up to a 1,000-kilometer range in South Korea. "By the mid-

1960s Korean defense strategy was pinned on routine plans to use nuclear weapons very early in any new war. As a 1967 Pentagon war game script put it, ‘The twelve ROKA and two U.S. divisions in South Korea had ... keyed their defense plans almost entirely to the early use of nuclear weapons.’³²

By the 1980s, the United States had a multi-pronged nuclear use plan for U.S. forces in Korea. According to scholar of modern Korea, Bruce Cumings, based on a briefing by a former commander of U.S. Forces in Korea:

The United States planned to use tactical nuclear weapons in the very early stages of the outbreak of war, if large masses of North Korean troops were attacking south of the DMZ. This he contrasted with the established strategy in Europe, which was to delay an invasion with conventional weapons and then use nuclear weapons only if necessary to stop the assault... The ‘Air-Land Battle’ strategy developed in the mid-1970s called for early, quick deep strikes into enemy territory, again with the likely use of nuclear weapons, especially against hardened underground facilities ... Neutron bombs—or ‘enhanced radiation’ weapons—might well be used if North Korean forces occupied Seoul, in order to kill the enemy but save the buildings.³³

However, today and for the foreseeable future, an early-use tactic could result in the North’s use of nuclear weapons. In the Cold War, the North was not nuclear-armed. Nonetheless, the South would likely consider or even decide to deploy nuclear weapon systems that can provide multiple roles such as air defense against swarms of North Korean aircraft, ground defense against massive tank formations, mining of harbors, mining parts of the DMZ, and striking the North’s missile bases and aircraft bases. The neutron bomb option could be appealing especially in a situation in which Seoul or other densely populated South Korean cities are evacuated and the South then wants to kill off occupying North Korean forces. Therefore, strategic deterrence alone in which the South could hold at risk the North’s leadership would arguably not be sufficient in a scenario in

which the North continues to build up its nuclear arms and the South perceives the need to have its own nuclear arms because it cannot rely exclusively on the United States.

Mating Warheads to Delivery Vehicles

South Korea already has several types of weapon systems that could be modified without too much effort to deliver nuclear warheads. Since the late 1970s, the ROK has been moving forward with acquiring and developing ballistic and cruise missiles as a counter to North Korea as well as obtaining modern fighter-bomber aircraft with aircraft types that can be nuclear-capable. While the United States for many years was opposed to the ROK having long-range missiles and kept the range and payload limited to 300 kilometers and 500 kilograms, South Korea has been able to argue that it needs longer-range missiles for its own defense. In October 2012, Seoul received U.S. agreement to allow the ROK to make ballistic missiles with ranges and payloads that would exceed the Missile Technology Control Regime guidelines of 300 km range and 500 kg payload. The new range and payload limits are 800 kilometers and 500 kilograms and shorter-range missiles can carry up to 2,500 kilograms payload. The agreement also allows the ROK to possess drones that can carry up to 2,500 kilograms of weapons and reconnaissance equipment.³⁴ The new range limitation was expressly intended to give the South the capability to hit all potential targets in the North but not pose a significant threat to China or Japan.

In the late 1970s, South Korea reverse engineered the U.S. Nike-Hercules surface-to-air missile. The Nike-Hercules was originally designed and intended for air defense roles. This missile was equipped with either a high explosive conventional fragmentation

warhead or a nuclear warhead. The first nuclear warhead was the W7 with two yields in the X1 and X2 models: 2 kilotons or 40 kT. This was soon replaced by the boosted fission warhead designated W31 with variable yields of 2 kT, 20 kT, and 40 kT.³⁵

While mostly for a surface-to-air role, the Nike-Hercules could also be employed in a surface-to-surface mode, delivering either conventional or nuclear warheads against enemy targets on the ground. For example, a nuclear-armed Nike-Hercules could be directed against enemy tank formations. North Korea has been investing in more advanced T-72 Soviet-based tanks to replace its aging tanks. A nuclear-armed South Korea would consider potential use of tactical nuclear arms to stop North Korean tanks from crossing the DMZ. For air-based targets, the nuclear-armed Nike-Hercules was intended to strike against swarms of aircraft such as Russian bombers launched from Cuba against the Southern United States. For South Korea, this air defense weapon could help defend against swarms of North Korea fighter-bomber aircraft.

The ROK's decades long experience with mastering missile technology via reverse engineering as well as indigenous technologies has resulted in Hyunmoo ballistic and cruise missiles. The Hyunmoo-1 and 2 ballistic missiles and the Hyunmoo-3 cruise missiles could carry upwards of 500 kg warheads. The Hyunmoo-1 has a range of only 180 km while the Hyunmoo-2 has a longer range of 500 km with the 2B variant. It is a two-stage rocket with the first stage based on the Nike-Hercules. The missile uses an inertial guidance system. With the new extended range missile agreement, the ROK will further boost the capabilities of these delivery systems to 800 km.

The Hyunmoo-3 cruise missile is patterned after the U.S. Tomahawk cruise missile. The Hyunmoo-3C variant has a reported extended range of 1,500 km. With a

global positioning system (GPS) guidance system, the ROK could have precision strike capabilities to target the North's command and control with either conventional explosives or low-yield nuclear weapons. High-precision strike thus allows the ROK to try to limit the collateral damage by permitting lower yields to achieve the intended mission. Indeed, the ROK Air Force has recently admitted that the Hyunmoo-3C has GPS guidance and "can fly through a window to hit a target."³⁶

For a first-generation or somewhat more advanced plutonium implosion weapon, the ROK could use gravity bombs coupled to nuclear-capable F-15 and F-16 aircraft. In particular, the ROK has received from the United States 61 F-15K Slam Eagles and 180 F-16s. Both types of aircraft have the range and payload to strike targets throughout North Korea. But in recent years, the ROK Air Force has expressed concern that the upgraded version of the F-15 built by Boeing would not have adequate stealth capabilities to penetrate North Korean airspace. Consequently, South Korea decided not to purchase these newer planes but also turned down Lockheed Martin's highly stealthy F-35 due to the high cost.³⁷ Instead, South Korea has been trying to develop its own advanced stealth fighter-bomber designated the KF-X. This plane's development, however, has experienced significant technical difficulties, and it is unclear whether the ROK can successfully develop the KF-X without substantial foreign assistance. Since 2009, the ROK has been upgrading the capabilities of its KF-16s, which are the Korean variant of the F-16.³⁸

Scenario Two: Encirclement.

In this scenario, South Korea has to contend with not just nuclear threats from North Korea but has to deter Chinese and Japanese nuclear forces. In effect, South Korea would be encircled by nuclear-armed states. The ROK would have more perceived need for a secure second-strike nuclear force to deal with threats from more than one nuclear-armed state.

Some South Korean defense analysts have expressed deep concern about how to deter China from encroaching onto the Korean Peninsula in the event of a collapse of the North Korean regime.³⁹ This is not farfetched because the PLA did cross the Yalu River into North Korea to save the Kim Il Sung regime during the Korean War. One of Beijing's greatest fears is that millions of North Korean refugees would flood into Manchuria. Thus, China highly values stability on the Korean Peninsula to such an extent that it has not pushed Pyongyang very hard on denuclearizing. Ironically, this stance might spark the very development China would not want: South Korea with nuclear arms.

Because South Korea has a relatively small land area (about the size of Virginia), it would likely move toward deployment of nuclear weapons at sea on submarines. The submarines would not necessarily have to be nuclear-powered. There would have to be at least one submarine continuously at sea. Because submarines require major overhauls every decade or so and periodic maintenance every year, the ROK would want more than one nuclear-armed submarine. Also, due to concerns about anti-submarine warfare, the ROK would want more than one submarine at sea. Perhaps the ROK's submarine requirements could be set at a minimum of four or five advanced ships and could eventually climb even higher depending on arms race scenarios and military assessments. The point is that once the ROK ventures down the nuclear-armed submarine path, it

could find itself feeling naval service pressure for more and more such ships. However, reliable and stealthy submarines would help buttress the ROK's second-strike capability.

The ROK Navy (ROKN) has made significant investments and advancements in its submarine capabilities in the past ten years. It has upgraded its submarine fleet to acquire more advanced 1,800-ton displacement air independent propulsion ships that can stay submerged for two weeks in an ultra-quiet mode to prevent detection. These Type 214 class submarines, also known as the Won-il class, have the ISUS 90 combat battle management system, which can track up to 300 targets. These submarines carry cruise missiles for ship-to-land precision strike capability and have a deep diving depth of 400 meters with speeds upwards of 20 knots. The submarine can reportedly travel from Korea to Hawaii roundtrip without refueling. The launch in August 2013 of the Kim Jwa-jin submarine in this class was accompanied by patriotic fanfare and a pointed message by President Park Geun-hye, who said, "I will not tolerate any kind of attempts at damaging our national interests and maritime sovereignty." This ship was specifically named for a Korean independence fighter. The previous ship in this class was also named after another independence fighter. The naming and rhetoric seem directed at Japan and appear to show that the ROK will never again be humiliated by colonial subjugation.⁴⁰

The ROKN has plans for even more advanced submarines that might have vertical launch capability to allow ballistic missiles to be carried and fired. This 3,000-ton displacement ship will have even more capability to stay submerged longer than two weeks. It is reported that this submarine will have an even longer operational range than the Type 214 class. According to a report published by the Nuclear Threat Initiative, this submarine will have effects on Korea's strategic environment because the projected

capabilities seem well suited to targeting China and Japan.⁴¹ The first of this class is planned for 2018, but the schedule might slip.

While South Korea has in the past few years been working on extending the range of its ballistic and cruise missiles, the current extended ranges would likely not be sufficient to strike targets in China and Japan. The distance between Seoul and Beijing is 955 kilometers and between Seoul and Tokyo is 1,155 kilometers. South Korea might want even longer-range missiles to threaten Chinese targets beyond Beijing, which is relatively close to South Korea. As mentioned earlier, the Hyunmoo-3C cruise missile has a range of 1,500 kilometers and thus could hold at risk Tokyo, but the Hyunmoo-2 ballistic missiles are yet to go beyond 500 kilometers. To make longer range ballistic missiles, South Korea could try to leverage its emerging space launch capabilities that have been recently demonstrated in a successful satellite launch.⁴²

As mentioned in the first scenario, the ROK Air Force has nuclear capable fighter planes, but to ensure that the F-15s and F-16s could hit targets outside the Korean Peninsula, the ROK will need air refueling tanker planes as well as early warning aircraft to give advanced warning of enemy fighter interceptors. The ROK has already been moving in this direction with the acquisition of four aerial tankers from 2017-2019. The goal is to have the endurance of the KF-16 increased by 70 minutes and the F-15K by 90 minutes.⁴³ For early warning capabilities, in 2011 and 2012, the ROK Air Force obtained four Peace Eye aircraft from Boeing based on the Boeing 737 AEW&C aircraft. The ROK is also planning on placing more reconnaissance satellites in orbit that could help with surveillance, targeting, and early warning

Scenario Three: The Enemy of My Enemy is My Friend.

In this scenario, Japan and South Korea decide to cooperate in a mutual defense pact to acquire nuclear weapons. For similar reasons, they both feel growing nuclear and missile threats from North Korea. For different reasons, they fear nuclear-armed China with increasingly advanced conventional and asymmetric warfare capabilities.

Admittedly, this scenario might strike many defense analysts as farfetched given the historical and present day animosity between Japan and the ROK. But if both feel abandoned by the United States or at least feel that the U.S. defense posture is weakening, then mutual vulnerability might conceivably drive Seoul and Tokyo to help each other develop a nuclear deterrent. Leaders in both countries would, nonetheless, have to worry that they would not be double-crossed and that one of them would take a significant lead in nuclear weapons development that could create a coercive vulnerability against the relatively weaker state. Thus, this scenario envisions that the two nations would have a pact that would stipulate enough sharing and cooperation to ensure near nuclear parity. Each state would have its own separate nuclear command and control.

One of main advantages of such a nuclear development partnership is that each country can benefit from existing capabilities that the other does not have. In particular, Japan could offer use of PUREX reprocessing facilities as well as the Monju breeder reactor. Korea could bring to the table its advanced cruise and ballistic missiles as well as its source of tritium for advanced nuclear weapons. However, each nation would not want to solely rely on the other long-term for such critical capabilities. For instance, while Japan's lending reprocessing assistance to South Korea would kick start the Korean

nuclear weapons program, the ROK would also want to have its own reprocessing facility as a backup in case of being cut off by Japan.

Depending on how the security environment unfolds in Northeast Asia, the United States might, behind closed doors, welcome Japan and South Korea developing nuclear weapons. While this would be a huge blow to the nonproliferation regime, Washington might have little choice in its Northeast Asian allies taking such a drastic action if North Korea further advances its nuclear capabilities and if Seoul and Tokyo have governments that cannot tolerate increasing vulnerability. Also, if China makes substantial nuclear advancements and if the United States cannot afford adequate power projection and extended deterrence capabilities in the region, this scenario might offer a plausible worst-case means for Japan and South Korea to deter nuclear attacks. But, of course, the major concern is that this would stimulate nuclear arms races throughout the region and even globally considering the likely reactions by India, Pakistan, and Russia.

CONCLUSION

It is not the intention of these scenario exercises to argue for South Korea's acquisition of nuclear weapons. On the contrary, by examining plausible potential developments in the foreseeable future, the intention is to urge political leaders and defense officials in South Korea, Japan, China, and the United States to work together to resolve the region's "many quandaries" in the words of President Park Geun-hye. And in the case of North Korea, which has been modernizing its nuclear forces, the solution is not for the ROK and Japan to further worsen the security environment by developing their own nuclear arms. Nuclear acquisition by these states would likely stimulate nuclear

arms races and would increase the likelihood of these weapons in war. While denuclearizing North Korea is an extremely tough problem and all concerned countries need to redouble their efforts on this front, for the time being the option that provides the best practical assurances to the ROK and Japan is for the United States to continue to demonstrate its resolve to provide conventional and nuclear extended deterrence.

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