

## Verification of Denuclearization in the DPRK and Potentially in a Larger Zone including the ROK and Japan\*

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Final, 27 April 2019

The key building blocks of the 1992 ROK-DPRK Joint Declaration of the Denuclearization of the Korean Peninsula were:

1. No nuclear weapons
2. No nuclear reprocessing or uranium enrichment facilities
3. A joint nuclear control commission to verify these commitments

Unfortunately, the agreement did not come into force. The following year, it was displaced by a confrontation between the DPRK and the IAEA over the DPRK's refusal to allow the IAEA access to evidence relating to the DPRK's declaration of the amount of plutonium it had separated before placing its reprocessing plant under safeguards, which led through a series of deals and confrontations to where we are today.

Nevertheless, the above commitments plus the elimination of the DPRK's stocks of fissile materials (plutonium and highly-enriched uranium [HEU]) would be the key elements of a future denuclearization agreement. The purpose of this paper is to explain this and discuss the verification of such an agreement and then the possibility of a larger denuclearization agreement in which South Korea and Japan too would be included.

**Denuclearization of the DPRK.** Politically, even in a best-case scenario, it will take at least a decade before North Korea has sufficient trust to go all the way to full denuclearization. A step-by-step process will be required. At each step, the DPRK will have to be rewarded with economic and security benefits. A first stage might be a verified halt to the production of fissile materials (highly enriched uranium and separated plutonium), i.e. an expanded version of Kim Jong Un's offer at the Hanoi Summit. A second stage – probably broken down into steps – could focus on the elimination of existing stocks, including in weapons.

*A halt to fissile material production* would require the verified permanent disablement of the DPRK's Yongbyon reprocessing plant – perhaps by pouring concrete into its tanks and pipes; the verified destruction of all of its gas centrifuges; and destruction of the conversion facilities in which uranium oxide is turned into uranium hexafluoride for enrichment and then back into uranium metal or oxide after enrichment. To maximize the chances of catching clandestine enrichment, it would be critical also to place uranium mines and mills and any uranium recovered in the mills under international safeguards.

*Elimination of fissile materials.* This would require first an unverified declaration of the DPRK's total stocks of HEU and plutonium and then verified disposal of agreed fractions. HEU could be blended down to LEU under safeguards and the LEU either used in the DPRK's Experimental LWR or sold. The task of disposing of the DPRK's

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\* Session on Regional Security in Northeast Asia, Joint ROK-Japan Workshop, "From Peace Korean Peninsula to North East Asia Nuclear Weapon Free Zone, Sejong Institute, Seoul, ROK, 1-2 June 2019.

plutonium could be undertaken by another country with a safeguarded plutonium program – perhaps Japan. It is not obvious that there would be an advantage in verifying that warheads were actually being dismantled since all plutonium and HEU is potentially weapon useable and therefore should be eliminated whether or not it comes from warheads.

**Verification.** Verifying the denuclearization of the DPRK would be an extensive process because its program has not been subject to IAEA verification except for brief periods with coverage limited to its gas-cooled reactor, fuel fabrication facilities and reprocessing plant, all in the Yongbyon nuclear complex.

It would be necessary for the DPRK to declare the history of its nuclear program, starting with uranium mining and milling, through enrichment or irradiation and reprocessing. This would allow consistency checks:

- The volume of the residues from the separation of the uranium from ore and the concentrations of the uranium decay products in these “mill tailings” could potentially be measured to determine how much uranium they originally contained;
- The depleted uranium from uranium enrichment could be assayed to determine the amount of U-235 that had been extracted;
- The uranium residues from the reprocessing of irradiated natural uranium fuel could be assayed to determine the amount of uranium had been irradiated and how much of the U-235 it originally contained had been fissioned, which would allow calculation of how much plutonium the fuel contained before reprocessing; and
- The fractions of certain trace impurities in the graphite of the Yongbyon plutonium-production reactor that had been converted by neutron absorption could be measured as second approach to determining the total amount of plutonium that the reactor had produced.

These activities could be carried out as part of internationally-funded cooperative decommissioning and cleanup efforts.

At this point, it is estimated that North Korea could have produced enough plutonium and HEU for tens of nuclear weapons but the uncertainties in these estimates are more than a factor of two. The above approaches would narrow these uncertainties considerably but perhaps not enough to rule out the possibility that North Korea was holding back fissile material sufficient for one or two weapon. That situation would be better, however, than the current one in which North Korea has a large and growing weapons stockpile. If North Korea opened up to academic exchanges, business investments and the like and, if openness to challenge inspections were part of the verification agreement, it would be difficult to keep the existence of hidden weapons secret for more than a decade or so.

**A denuclearized zone, including the US, ROK and Japan?** The focus above has been on the nuclearization of the DPRK but the 1992 Denuclearization Agreement was reciprocal between the DPRK and ROK and the ROK’s nuclear establishment has been insisting in its negotiations with the US that it have the same rights to reprocess and enrich as Japan.

*No nuclear weapons.* The DPRK has made clear that it would like to see constraints on the US as well. During the Korean War and during times of tension since, the US has made nuclear threats against the DPRK, including implicitly via flights of long-range bombers near the DPRK and port visits of nuclear-capable submarines to the ROK and Japan. Prior to 1992, the US had up to 1000 nuclear weapons in South Korea.

*No reprocessing.* All three countries are involved in reprocessing. North Korea has a military reprocessing plant at Yongbyon. Japan, is the only state not possessing nuclear weapons that reprocesses. As a result of its civilian reprocessing program, Japan has larger stocks of separated nuclear-weapon-usable plutonium than China. And the ROK's Atomic Energy Research Institute (KAERI) has been interested in reprocessing ever since General Park's short-lived nuclear-weapon program in 1970. As a result of KAERI's insistence that the ROK be given the same right to reprocess as Japan in the negotiations that resulted in the ROK's 2015 Agreement of Nuclear Cooperation with the United States, KAERI is currently carrying out a ten-year Joint Fuel Cycle Study on reprocessing with the US Idaho National Laboratory, with actual separation of plutonium being carried out only in the US. The joint study is to be completed in 2021, at which point negotiations with the US over reprocessing in the ROK could resume. India demonstrated in 1974 that even reprocessing for a fast-neutron reactor research and development program such as KAERI proposes can yield enough plutonium for a nuclear-weapon program.

In the 1960s, the United States Atomic Energy Commission, believing that there was very little natural uranium in ore grades high enough to economically support nuclear reactors exploiting primarily the fission energy in U-235 (0.7% of natural uranium) promoted sodium-cooled breeder reactors that would convert the abundant isotope U-238 (99.3% of natural uranium) into chain-reacting plutonium as the energy source of the future. After India's 1974 nuclear test, the Carter Administration reviewed the economics and concluded that water-cooled reactors with no plutonium recycle would be less costly for the foreseeable future. Forty-two years later, that conclusion has become even stronger with the cost of natural uranium contributing only \$.002 to the cost of a kilowatt hour from a light-water reactor. Today, only five states (the others beside Japan being China, France, India and Russia) are committed to continuing separating plutonium. (The UK expects to complete its existing commitments and end in 2021.)

Abandoning reprocessing would have economic and environmental benefits in addition to strengthening the nonproliferation and anti-terrorism regimes by reducing the number of locations where directly weapon-usable separated plutonium could be found.

*No (national) uranium enrichment.* In 2010, the DPRK revealed that it had a uranium-enrichment facility. We don't know whether it is producing weapon-grade or low-enriched uranium.

Japan is one of only three states not possessing nuclear weapons with active *national* enrichment programs. The others are Brazil and Iran. Germany and the Netherlands enrich but in partnership with the UK in the multinational consortium, Urenco. Brazil, Iran and Japan's programs are all dwarfed by the programs of the large enrichers: China, France, Russia and Urenco and can't compete with them even in their own home markets.

Brazil's program is under the control of its navy and probably persists primarily because of the navy's interest in nuclear submarines. Japan and Iran at the moment appear to be maintaining their small enrichment programs primarily to assert their rights to enrich.

The ROK does not enrich but has argued that, as a nuclear-power-plant exporter, it should have the right to do so. This too became an issue in the negotiation of the ROK's 2015 agreement of cooperation with the US and was left unresolved to future negotiations.

Currently, the large suppliers of enrichment services have excess capacity. As a result, their competition has driven the price of enrichment services down to the point where they are not able to recoup their investments in new capacity.

*Multinational control.* Possession of an enrichment plant big enough to support a single large power reactor puts a country within weeks of producing enough HEU for a weapon. The existence of Urenco shows that multinational control is possible. The only enrichment plant operating in the United States today is owned by Urenco. If in the future, an economic argument can be made for enrichment capacity in the Korea's and Japan, it should be put under multinational control.

**A joint verification commission.** The 1992 agreement on the denuclearization of the Korean Peninsula included a joint verification commission. There are two precedents for a such a commission: Euratom and ABACC.

*Euratom* was created in 1957 with an original membership of six West European countries (Belgium, France, Germany, Italy, Luxembourg, and the Netherlands). That was only 13 years after the end of World War II in Europe and one purpose was to assure that Germany not have an independent nuclear program. Euratom established a safeguards and inspection system in 1960 well before the Nonproliferation Treaty of 1970. Since 1973, most Euratom inspections have been done jointly with the IAEA, however, Euratom safeguards have not faded out. As of 2018, Euratom had 130 full-time inspectors. Apparently, the Europeans still want to monitor each other's nuclear programs as well as being monitored by the IAEA whose findings are "safeguards confidential."

*ABACC*, the Argentine-Brazil Agency for Accounting and Control of Nuclear Materials, was established in 1991 as the culmination of a trust-building process, starting in 1985 after both countries had freed themselves from military governments. In 1991, Argentina and Brazil also agreed to IAEA safeguards and, as is the case in Europe, IAEA and ABACC inspections are done jointly. ABACC inspectors are part-time with their primary jobs in their national nuclear industries. They provide transparency between Argentina and Brazil.

The ROK and DPRK could follow these models as part of the process of verifying denuclearization on the peninsula and, on terms agreeable to all, Japan could join in as well.

In this largely technical discussion, the difficult political parts of the negotiations have been ignored including the guarantees and incentives the DPRK will require to fully denuclearize and how it will be able to trust those guarantees. If the political challenges

can be overcome, however, a good approximation to full denuclearization appears technically feasible.