A study on roadmap for North Korea's denuclearization

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1. Introduction

With numerous discussions on denuclearization pace, what has become clear after the Hanoi Summit is that denuclearization is a long-term process to look at from the broad perspective. For complete denuclearization, a long-term 'plan of action' instead of 'a mere show' is required. Therefore, this study focuses on a long-term development of North Korea (NK) denuclearization roadmap.

To do this, this paper first analyzes key components of NK nuclear program using new methodology 'FIVE-M'. Then, a link to 'the four phased roadmap' proposed in this paper. The roadmap specifies several action items for key components at each phase.

2. Applied new methodology and proposed phases

In this section, newly used methodology and proposed phases are introduced. This paper analyzes NK nuclear programs systematically and derives key components using 'FIVE-M' methodology. The phases are established based on the previous research.

2.1 'Five-M' methodology

In the military, the Target System Analysis (TSA) methodology is frequently used when analyzing the adversary target system (for example, WMD, TBM system, etc.). In this method, the criterion for dividing types of targets is 'FIVE-O'. Targets fall into one of five target types: Facility, Individual, Virtual, Equipment, or Organization [1]. In this paper, 'FIVE-M methodology is applied, since FIVE-O could not cover nuclear program entirely. The 'FIVE-M' stands for Facility, Individual, Virtual, Equipment, and Material. Previous studies related to the NK nuclear program analysis have focused on nuclear materials and facilities based on the nuclear fuel cycle. The reason why FIVE-M is introduced, is to analyze the nuclear program more systematically, since CVID (Complete, Verifiable, Irreversible Dismantlement) is broad process including scientists, data, and arsenal.

2.2 A four phase approach

The roadmap is based on belief that NK will never give up its nuclear program and its 'peaceful nuclear uses' right (nuclear power plants, medical isotope research and production) until its security is assured. In a previous study [2], written by Stanford University professor Siegfried S. Hecker, such assurance cannot be achieved simply by a promise or an agreement on paper, it will require a substantial period of coexistence and interdependence. Other report [3], written by CARNEGIE endowment for international peace, neither Kim nor the North Korean military will provide a full and complete declaration of the country's holdings at the first stage. Nor will either agree to allow inspections anywhere, anytime. To realistically test NK's intentions mutual confidence must be built through step-by-step progress.

In the Fig. 1, a four phase roadmap is proposed. Each phase does not have a specific timeframe (years). Political considerations will be taken into account whether or not the time frame can be shortened or lengthened. Goal, precondition, scope, IAEA engagement, verification measure will be further explicated by each phase. 'Verification', 'Capping', 'Roll Back', 'Peaceful use only' are the names of each phase.

Time Frame	Short term	Medium term		Long term
Goal	**Verification**	**Capping**	**Roll Back**	**Peaceful use only**
Precondition	Declaration Agreement between stakeholders	Initial verification has been completed Transparency measure clearly developed	Agreement between stakeholders (include proper compensation)	All arsenal taken out of NK Trusting relationship IAEA safeguard AP
Scope	Verification about declaration Initial freeze action	Integrated management and monitoring of key materials / arsenal Additional fissile materials/arsenal production prohibition	Gradual reduce of materials/arsenal	Nuclear power plants (ELWR) Medical isotope research & production
IAEA engagement	Special inspection	IAEA safeguards (CSA)	Additional Protocol + Enhanced measure (like JCPOA)	

Fig. 1. A four phase of NK denuclearization.

Kim Jong-un emphasized "four no" in his 2019 new year's speech. "Accordingly, we declared at home and abroad that we would neither make nor test nuclear weapons any longer nor and proliferate them, and we have taken various practical measures". Although the uncertainty have elevated after Hanoi Summit, if sincere nuclear declaration is made and the stakeholders agree on the verification process, Phase 1 can be presented, "Verification" (short term).

At this phase, verification of the declaration report will be done by IAEA and nuclear-weapon states. As mentioned earlier in the key premise, it is difficult to expect that NK will faithfully report all its nuclear program from the start. Therefore, initial verification phase will focus on reviewing of reported content and developing measures to completely block additional activities within the declared area and facility. As part of the initial confidence building measures, some materials and arsenal may be dismantled or transported offshore.

In phase 2, "Capping" (medium term-1), management and monitoring of all nuclear activities are to be performed within the declared area and facilities. In addition, monitoring and tracking nuclear activities may occur in undeclared facilities. This phase can be shortened or lengthened in accordance with the political situation. With IAEA safeguard (CSA) measures signed, and this in effect, all nuclear activities could be thoroughly controlled in all declared areas. Then, next phase comes in, which specifies plans: "Roll-back (medium term-2).

When the basic level of trust is established through the second phase and NK enters the NPT regime again, the arsenal is dismantled gradually, and fissile material is transferred to abroad or converted for peaceful use. From this point on, additional protocol should be concluded and enhanced verification measure beyond additional protocol (like JCPOA in Iran) should be applied for irreversible and effective denuclearization.

The last "Peaceful use only" (long-term) phase is a goal and remains questionable as to whether it is feasible. This is too risky for the nuclear capability remains in NK. Peaceful use will be possible when denuclearization willingness is genuine and strong enough to turn North Korea into a normal state.

3. The roadmap

The NK nuclear program consists of Pu, HEU, H-Bomb programs and weaponization (sophistication of arsenal). In order to identify the key components and elements, each program are analyzed using FIVE-M. The result is presented in Fig. 2.

Fig. 2. North Korea nuclear program with FIVE-M.

'Facility' category is related to the production and reprocessing of fissile material (Pu, HEU), and the material production plants- which are essential for hydrogen bomb, and nuclear test site. 'Individual' refers to nuclear scientists, engineers, and arsenal experts. 'Virtual (commonly known as cyber)' covers intangible technical information. It include electronic files, servers, simulators, application, etc. 'Equipment' is nuclear arsenal itself. 'Material' is fissile material (Pu, HEU inventory), deuterium and Lithium-6. Now, we will connect the key components analyzed by FIVE-M with the denuclearization four phases. The result is presented in Fig. 3.

3.1 Facility

There are six key components. Pu program (Reactor, Reprocessing), HEU program (Enrichment), H-Bomb program (Deuterium/Li-6D), weaponization (Test Site). The exact number of facilities heavily depends on the present of hidden sites. Phase 1 will focus on identifying the exact material inventory and hidden site through operational history review and environment sampling. Verifiable nuclear freeze may proceed in parallel. In phase 2, monitoring of declared facilities and facility characterization analysis for D&D planning are carried out. Actual dismantlement will be implemented for phase 3. Before this point, the decision about decommissioning options (DECON, SAFSTOR, ENTOB) should be made.

3.2 Individual

Nuclear scientists, engineers, and arsenal experts are key players in the NK nuclear program. The exact number is unknown. Most of them have high royalty to the regime, work in isolation and secrecy (classified research). They are disconnected from the public awareness.

It is different from the case of the former Soviet Union and Iraq. They have specific area of cooperation and trust that already existed.

Fig. 3. A four phase roadmap for NK denuclearization.

Joint research related to space flight and history (FSU), historical ties of western educated scientists and policymakers (Iraq) are the examples. However, the situation is fundamentally different compared with NK and it will take a longer time to build confidence. Moreover, there is presumed to be a "Huge difference in the technological level" between NK and other countries and, as a consequence, "less eagerness on both sides" to work together. [4]

They should cooperate with the technical measures for denuclearization at each phase. Trust Building measure should be taken through the all phases.

3.3 Virtual (Technical information)

During phase 1, relevant information should be provided to the inspector. Actual protection must be done from phase 2, including not only physical protection but also cyber security measures for servers and application. The weaponization related data have to be destroyed completely in phase 3.

3.4. Equipment (Nuclear arsenal)

Nuclear arsenal must be accurately reported and verified. All arsenal must be kept in one venue for dismantling and monitoring in phase 2. Irreversible dismantling must be achieved in phase 3. Core components should be taken out of the country. This process will be carried out by the nuclear weapon states for nonproliferation.

3.5 Material (Pu, HEU inventory)

For both fissile materials, the most important thing in phase 1 is to know the exact amount of inventory. Operation history review, report and document review, nuclear archaeology (by environment sampling) is carried out. Drilling and environmental sampling is also required for the Punggye-ri nuclear test site to determine past consumption in tests. In phase 2, a thorough accountancy of the declared material via the safeguard (CSA) should be undertaken. Remote monitoring of undeclared HEU program is required at all phases. As part of trust building, gradual withdrawals of excess inventory can be planned and implemented in phase 2, and at the end of Phase 3, all excess inventory should be taken out of the country. There could be a debate about phase 4, Down-blending the HEU and using it as commercial fuel for our nuclear power plants (like "Megatons to Megawatts" project) could be a symbolic project.

4. Conclusions

The process of developing a phased roadmap requires many assumptions. Phases could be omitted or added depending on the political situations. This study is conducted at the level of establishing the denuclearization phase and linking the key components of the NK nuclear program to form a roadmap with large frame.

As for future work, technical action items with periodic expectations should be listed for each phase. It is necessary to specify actual 'plan of action' like JCPOA in Iran.

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