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TOWARDS A ROBUST AND EFFICIENT NUCLEAR DISARMAMENT VERIFICATION CONCEPT

Gerald Kirchner
Carl-Friedrich von Weizsäcker Center for Science and Peace Research, University of Hamburg, 20148 Hamburg, Germany

ABSTRACT

During the last decades, much effort has been devoted to developing and testing technologies and procedures for nuclear disarmament verification. This paper presents objectives, general principles and approaches for combining these in efficient and robust verification process concepts, which allow gaining high confidence and, at the same time, limit inspection efforts to practically and economically acceptable levels. The 14 step process scheme developed by the International Partnership for Nuclear Disarmament Verification (IPNDV) is used as reference. Examples are given, how evidence of provenance of a treaty accountable item, redundant and diverse choice of chain of custody technologies and absence and presence attribute measurements can be combined as elements of robust and efficient nuclear disarmament verification strategies.

INTRODUCTION

A comprehensive verification regime will presumably become an integral part of a potential future nuclear disarmament treaty. This requirement has triggered research and development efforts on technologies for nuclear disarmament verification including passive and active radiation measurements as well as containment and surveillance technologies [1,2]. Although many of these had been extensively used in nuclear safeguards, their application for disarmament verification is challenged by the requirement not to disclose any sensitive information. This has led to developing information barriers, encryption methodologies and authentication procedures for the measurement devices resulting in quite complex and time-consuming technologies. Moreover, their applicability to nuclear warheads prior to their dismantlement may be questionable due to security and safety restrictions by the nuclear weapon states.

Currently concepts for combining various technologies in a nuclear disarmament verification strategy as robust and efficient as possible are still missing. However, such concepts may become mandatory, if a future treaty calls for the verified destruction of large numbers of nuclear warheads. Inspired by the considerations on a systems approach published by MacArthur et al. [3], objectives and principles which could assist in assigning technologies to particular verification tasks are presented in this paper. A classification scheme is developed for selecting between the various technologies which generally may be available for specific applications.

OBJECTIVES AND GENERAL PRINCIPLES

Major, albeit partially conflicting objectives of nuclear disarmament verification concepts should include gaining high confidence, limiting inspection efforts to a feasible and economically acceptable level, and limiting measurements to those stage(s) of the disarmament process, at which they are most effectively applied. Against this background the following general principles are suggested.

1. If it is verified that an item is being removed from a delivery vehicle, this creates considerable confidence on its military nature.
2. As far as possible, the chain of custody should be established and maintained by containment & surveillance technologies.
3. Intrusive technologies for attribute verification should be applied only if unevitable. This includes any radiation measurements.
4. Absence measurements can be considered as less intrusive, since they show a low risk to disclose sensitive information in case of treaty compliance.
5. Chain of custody technologies should be redundant showing at least two layers of security. If possible, diverse technologies should be applied.
6. Random selection of inspection activities should be excluded only, if fissile material will be readily accessible for undetected diversion without inspectors being present.
7. Notifications on transports should be sent within an agreed time period, so that the location of each warhead is transparent and could be verified.

NUCLEAR DISMANTLEMENT PROCESS

The conceptual scheme of the nuclear disarmament process shown in Fig. 1 has been developed by the International Partnership for Nuclear Disarmament Verification (IPNDV) [4]. Starting with the removal of the nuclear weapon from its delivery system it includes various transport and interim storage steps before and after the dismantlement operations with separation into its principal components (fissile material, high explosives and scrap material) up to their final disposition. The following considerations are based on this generic concept.

CLASSIFICATION OF VERIFICATION ACTIVITIES

At each position of a nuclear dismantlement process, the potentially available verification activities can be categorized in three major groups.

Category (1): Essential activities
It includes verification activities required for gaining or maintaining a high degree of confidence.

Category (2): Supplementary activities
These activities could be used for increasing the level of confidence at specific situations (e.g. for confirming the results of a category (1) activity of a previous inspection).

Category (3): Backup activities
It includes verification activities, which show a high level of complexity and/or intrusiveness, are not applied routinely, but may be required occasionally (e.g. for re-establishing the chain of cusody).

It should be noted that categorization of a specific verification technology may differ at various steps of the dismantlement process.

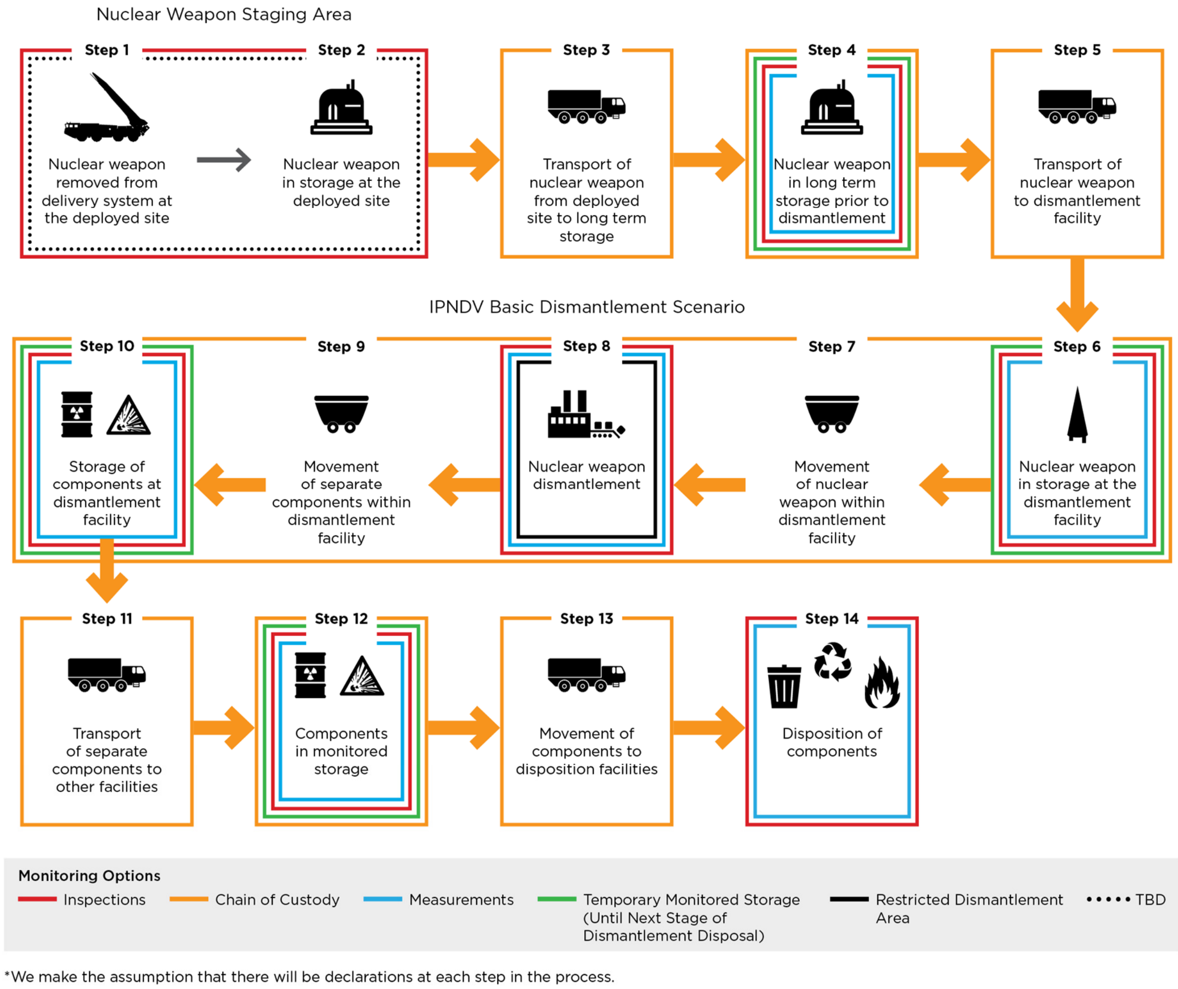

Figure 1: The IPNDV disarmament process scheme [4]

APPLICATION TO THE DISARMAMENT PROCESS

In the following an example is given, how the principles and categories given above could be combined into an efficient and robust verification system. It is assumed that (1) the treaty accountable items, which are scheduled for being eliminated, are deployed initially, and (2) that the initial declaration of the possessor state specifies that they include plutonium as fissile material.

For this generic example the various transport and storage steps before and after the physical dismantlement of the IPNDV process scheme (Fig. 1) have each combined in a single step. Step 14, the disposition of the fissile material, is excluded, since its verification requirements are determined by future national decisions on the use of the dismantled plutonium. The resulting simplified process scheme is shown in Fig. 2. It also indicates the primary verification objectives at the various steps of the process.

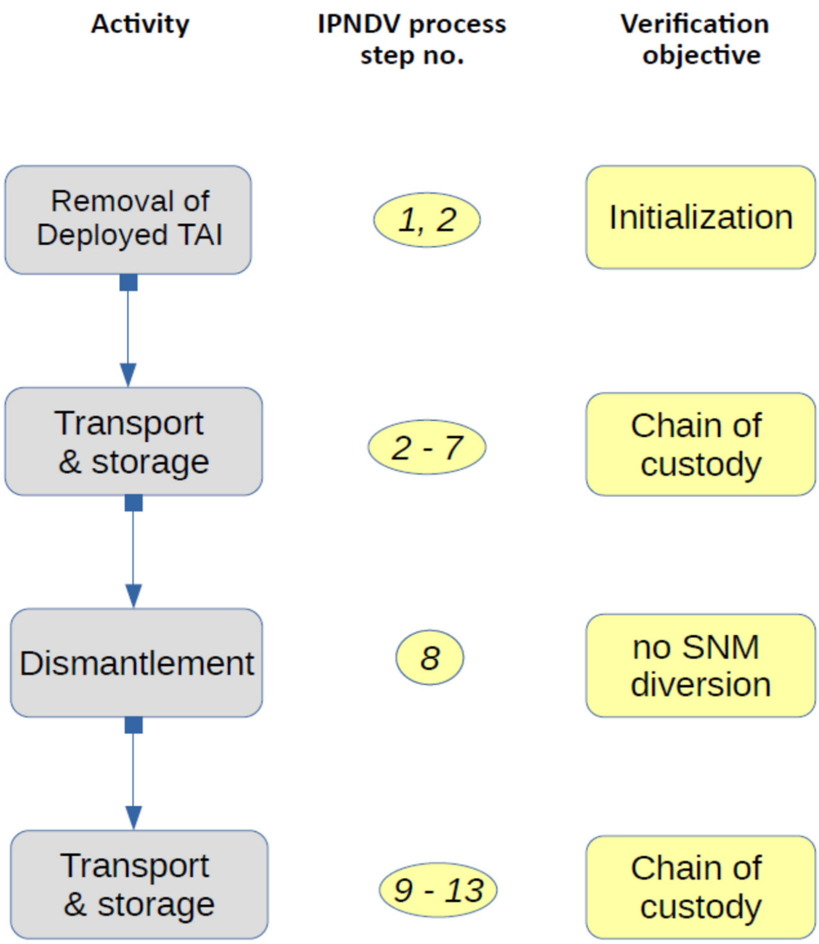

Figure 2: Simplified scheme of the IPNDV disarmament process

An efficient and robust verification system for the disarmament process considered could include the following elements.

Process steps 1-2: Removal from delivery vehicle and initialization

(1) *Essential activities*

- Provenance:
  Visual observation of the removal of an item from its delivery vehicle provides confidence in its military nature.
- Containment & surveillance provisions:
  Activities include the application of tags, seals and UIDs on the TAI container.

(2) *Supplementary activities*

- Neutron flux density measurements:
  They provide additional confidence that the item removed from the delivery vehicle contains fissile material.
  Neutron flux density measurements are a robust, moderately intrusive technology, which has been applied for verifying the INF treaty. If required, it can be operated with a simple

information barrier, which will indicate whether the detected neutron signal exceeds the ambient background with a defined statistical confidence.

- Template recording:
  Recording and storing the neutron energy distribution of the containerized warhead establishes a template for future confirmation of its presence. It provides a diverse Chain of Custody (CoC) technology.
- Additional CoC technologies:
  There are various technologies (e.g. 3D laser identification of the container, accelerometers), which are redundant and diverse to tags, seals and UIDs. The 3D laser scanning technology requires a reference measurement to be taken before or after containerization of the warhead.

(3) Backup activities

- Template attribute measurements:
  Compared to neutron flux density measurements these are more laborious and intrusive. Additional requirements include declarations down to a detail, which allow distinguishing the item analyzed from other warhead types present at the possessor state's territory, and trusted reference templates for each of those types.

Process steps 2-7: Transport and storage

(1) *Essential activities*

- Notification of transports of the treaty accountable items between sites:
  This allows inspectors having an almost continuous knowledge both of the location of each TAI and of the inventories of each interim and long-term storage area.
- Surveillance technologies:
  At the storage areas an additional layer of security can be established by surveillance technologies (e.g. CCTV, accelerometers) and perimeter monitoring of dedicated storage areas.
- On-site inspections:
  Their objectives include verification of the inventories of stored treaty accountable warheads at inspected sites and of the CoC of the stored containers. Inspections may be realized randomly.

(2) *Supplementary activities*

- Short notice on-site inspections:
  Analogously to IAEA safeguards, there may be the option of performing unpredictionably scheduled short notice inspections, probably randomly.

(3) *Backup activities*

- Template measurements:
  If the chain of custody of a treaty accountable item is questioned, presence of the fissile material could be verified by comparing its radiation signature with the template measurement taken as part of the initialization operations.
- Fast track dismantling:

Alternatively, the affected container could be given priority for dismantlement with attribute measurements being performed after separation (see below).

Process step 8: Dismantlement

Obviouly this process step presents specific challenges: the chain of cusody will be broken, dismantlement will be performed without any presence of inspectors, it will require considerable time, various containers declared as fissile materials, high explosives and other materials, respectively, will result from the operations. The concept developed by the International Partnership for Nuclear Disarmament Verification combines absence and presence measurements of fissile material with containment and surveillance measurements at non-sensitive areas. Attribute analyses may be significantly more effective after dismantlement or even work only then, depending on the technology.

(1) *Essential activities*

- Verification of the Chain of Custody:
  This activity needs to be performed upon container arrival. It may be considered to do this randomly.
- Containment & surveillance:
  These technologies can be applied to verify that not any fissile material is entering or leaving areas not accessible to inspections during the dismantlement operations. Combining CCTV, radiation monitoring and sealing should provide high levels of confidence and can establish two layers of security if required (e.g. overnight).
- Absence measurements:
  Absence measurements complement the containment & surveillance provisions for gaining confidence that there is no diversion of fissile material.The rooms used for the dismantlement operations need to be checked before the warhead container enters and after dismantlement is complete as well as the containers involved except those declared to hold the fissile material.
  Both gamma and neutron measurements should be performed to impede intentional shielding of radiation signals. Since absence measurements do not disclose sensitive information, more intrusive technologies could be applied if required for analyzing the HE and scrap containers.

(2) *Supplementary activities*

- Attribute measurements:
  Provenance, neutron emission, chain of custody combined with absence measurements already give confidence that the dismantled item is a nuclear warhead as declared and that no fissile material has been diverted.
  If inspectors wish to get additional confirmation that the fissile material is weapons grade, its isotope vector could be measured gamma-spectrometrically. Such analyses could be performed randomly.
- Other presence measurements:
  Confirming the presence of high explosives after dismantlement could be attractive for verifying the military nature of the dismantled item. Again, such analyses could be performed randomly.

Process steps 9-13: Fissile material transport and storage

Most of the potential activities and their assignment to one of the three categories (essential, backup, supplementary) are identical with those suggested for the transport and storage steps of the assembled warhead (steps 2-7 of the IPNDV process scheme) listed above. However, radiation templates recorded before its dismantlement do not reflect the actual configuration of the fissile material, but need to be recorded again when the containers enter this sequence of storage and transport steps.

(1) *Essential activities*

- Containment & surveillance provisions:
  Application of tags, seals and UIDs on the fissile material containers.
- Notification of all fissile material container transports between sites:
  This allows inspectors having an almost continuous knowledge both of the location of each container and of the inventories at each interim and long-term storage area.
- Surveillance technologies:
  At the storage areas an additional layer of security can be achieved by surveillance technologies like CCTV and perimeter monitoring of dedicated storage areas.
- Routine on-site inspections:
  Objectives of on-site inspections include verification of inventories at storage sites inspected and of the CoC of stored fissile material containers. Inspections may be realized randomly.

(2) *Supplementary activities*

- Template recording:
  Recording and storing the neutron or gamma energy distribution of the fissile material containers creates templates for future verifying its identity and inventory. It provides a diverse CoC technology.
- Short notice on-site inspections:
  Analogously to IAEA safeguards, there may be the option of performing unpredictionably scheduled short notice inspections, probably randomly.

(3) *Backup activities*

- Template measurements:
  If the chain of custody of a fissile material container is questioned, its presence and inventory could be verified by comparing its neutron or gamma radiation signature with the template measurement taken after dismantlement.

DISCUSSION

To a large extent the nuclear disarmament verification concept presented above relies on combining information on provenance with providing a trusted Chain of Custody. Radiation measurements are scheduled only as backup or even supplementary activities, since it seems to be uncertain whether these will be accepted by nuclear weapon states [5]. The general – less sensitive – exception is given by the requirement of using radiation measurements for verifying the absence of fissile materials at potential diversion pathways for the dismantlement process (step 8 of the the IPNDV process scheme).

In practice, construction details and use of real facilities may have a major impact on the choice of verification activities, in particular whether there are non-treaty related nuclear wahead maintenance and storage activities [6]. However, our concept may be useful as generic guidance for developing and testing more detailed and refined verification procedures.

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