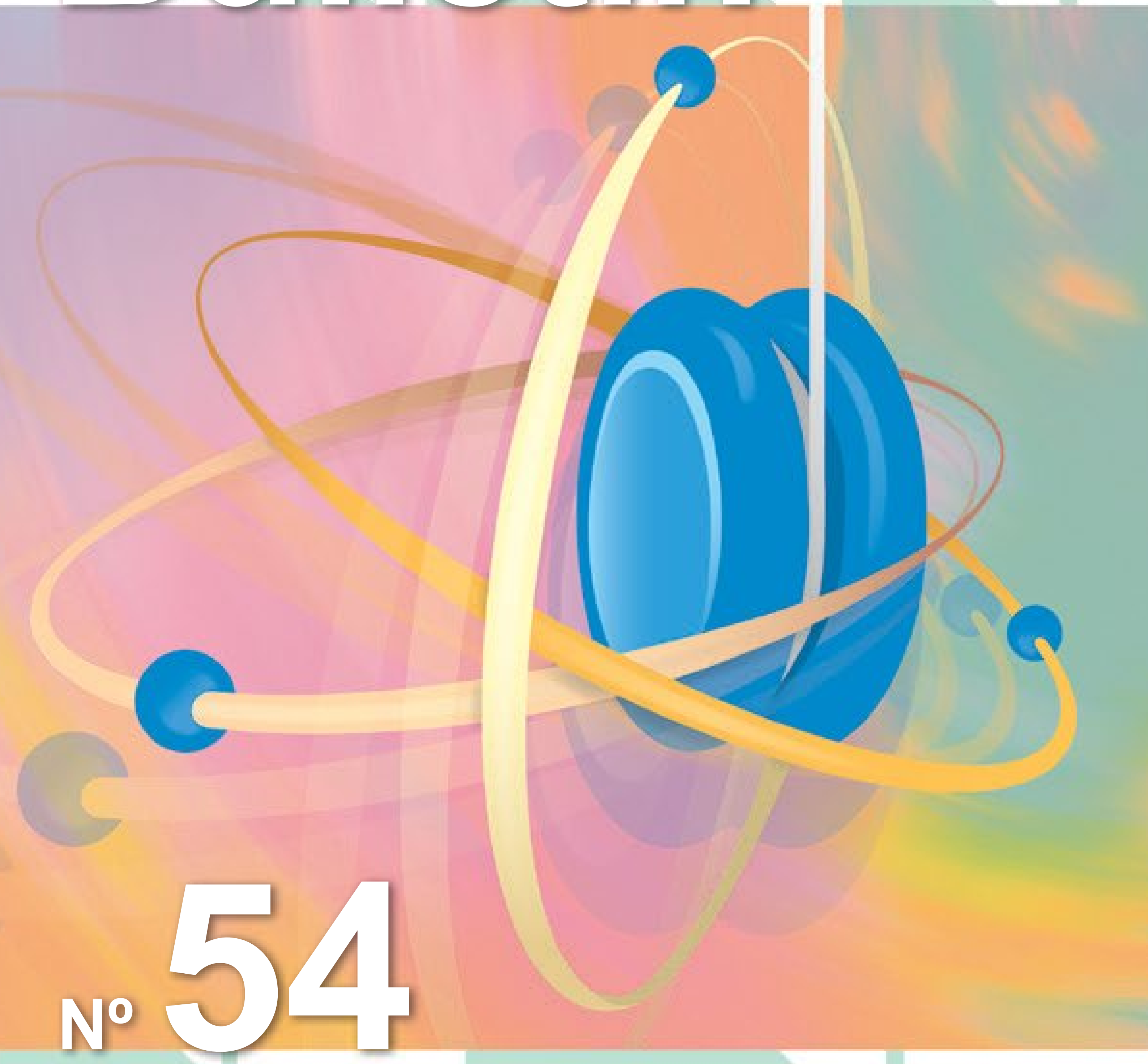
ISSN 1977-5296

ESARDA

European Safeguards Research and Development Association

Bulletin



Nº 54

June 2017

ISSN 1977-5296

Number 54

June 2017

Editor

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The publication is authorized by ESARDA.

Cover designed by Laura Spirito,
(JRC Ispra in Italy),

Printed by
IMPRIMERIE CENTRALE, Luxembourg

ESARDA Bulletin

European Safeguards Research and Development Association

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International Engagement in Arms Control Verification Using a Systems Approach

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Abstract:

A series of exercises and targeted meetings held by the European Safeguards Research and Development Association (ESARDA) Verification Technologies and Methodologies Working Group and the Institute of Nuclear Materials Management (INMM) Nonproliferation and Arms Control Technical Division provided valuable insight into how a systems approach could help identify nonproliferation and arms control verification requirements. International experts from nuclear weapons states and non-nuclear weapons states, with a wide-range of expertise in nuclear safeguards, arms control verification, radiation detection, political science, and defense studies, participated in the discussions. It was demonstrated that with a systems approach, it is possible to design a transparent state-level systems framework to define arms control verification objectives, processes, and timescales for an effective verification regime based on the strategic goals of a treaty, while taking into account restrictions from different security environments. This approach was also shown to be an effective mechanisms for international and technical engagement on such complicated issues. Possible future research activities could include: (1) increased efforts to link the material and weapons sectors of the nuclear weapons complex; (2) further attention on how to satisfy the competing needs for effective verification and protection of national security; (3) greater consideration on how to define the treaty-controlled items so that declarations can be verified effectively; (4) continued testing of a systems approach to analyze the pros and cons of possible verification regimes, to conduct a form of sensitivity analysis and provide feedback and a better understanding of confidence levels that could be achieved; and (5) possible ideas of how to engage in substantive dialogue in a broad international environment, such as the on-going International Partnership for Nuclear Disarmament Verification (IPNDV), while taking into account the range of weapons and verification experience and the need to uphold NPT Article VI.

Keywords: verification, arms control, systems approach

1. Introduction

Establishing a method to systematically identify verification options for nuclear weapons control agreements could significantly contribute to future development of an effectively verifiable treaty [1]. A transparent presentation of a nation's nuclear defense complex would allow for the definition of potential cheating pathways and aid in the development the verification requirements for declarations/data exchanges and an inspection regime. The increased transparency could foster confidence and improve communication between potential stakeholders.

The application of a systems approach, such as the International Atomic Energy Agency's (IAEA) State Level Concept (SLC) used for safeguards implementation [2,3], to arms control agreements could help build a framework for a verification architecture that would be useful for structuring the analysis of options. A series of technical meetings, over the course of 2014 and 2015, were held to determine whether it was possible to design such a framework to achieve high-confidence arms control verification. The key challenges were to:

- leverage the more than 50 years of IAEA verification lessons-learned to build a high-confidence, coherent and comprehensive picture of a State's compliance;
- develop a systems framework that integrated the material and weapons enterprise – utilizing a broad range of information from cooperative technical monitoring data (declared), national technical means (undeclared), open source, and state & international trade controls; and
- facilitate cooperation between nuclear weapons states and non-nuclear weapons states.

International experts from nuclear weapons states (NWS) and non-nuclear weapons states (NNWS), with a wide-range of expertise in, *inter alia*, nuclear safeguards, arms control verification, radiation detection, political science, and defence studies, participated in exercises and discussions to test the feasibility for using a systems approach and identify knowledge gaps. In order to make the effort less abstract, two fictitious countries and a hypothetical treaty were devised and used during two exercises. An effort was made to represent some real-world complexity without making it too difficult, so relatively simple physical models of national nuclear weapons enterprises could be created. By formulating a scenario that incorporated more than the technical aspects of verification, it was possible to look at the state-as-a-whole and consider the additional factors that influence national security decision-making.

Two constraints that were NOT applied during the exercises: (1) the declaration of security-sensitive information was not restricted because a country could make a future decision that it was in its interest to declassify information or share it under conditions deemed advantageous; and (2) the verification requirements focused only on the country to be monitored/verified without consideration of the acceptability of the same requirements being imposed on the verifier. These conditions would not likely to be true in reality but significantly simplified the conditions for the purpose of an exercise.

2. Workshops and Exercises

The initial exercise objective was to determine whether acquisition pathway analysis (APA) could be used to help define the objectives for a future regime by analyzing potential diversion (cheating) pathways and potential treaty verification measures to be applied in a nuclear weapons state. This exercise was hosted by the European Safeguards Research and Development Association (ESARDA) at the Verification Technologies and Methodologies Working Group Meeting, held at the Joint Research Centre, Ispra, Italy, in autumn of 2014 [4]. The model bilateral treaty between the two fictitious nuclear weapons states in the exercise limited the total number of warheads deployed and stockpiled. It was determined that any undeclared warheads above the initially declared total of 1,970 (in the fictitious state that maintained six types of nuclear warheads, deployed across three types of delivery platforms) and any warheads deployed above the maximum of 500 would constitute cheating.

The participants worked to identify cheating pathways and potential verification mechanisms for only one of the states, with a nuclear weapons enterprise including all stages of a nuclear fuel cycle and weaponization facilities (including a stockpile of military fissile material; warhead components production facilities; warhead production, maintenance, and dismantlement facilities; different types of storage depots; military bases; and delivery vehicles).

The exercise allowed the group to explore the parallels between using an acquisition pathway analysis (APA) approach for arms control verification, as compared to IAEA safeguards applications. The general impressions from applying the APA methodology in this new context are outlined in Table 1.

During this first exercise, the group quickly discovered that national security concerns and a country's defence posture greatly influenced the identification of the likely cheating pathways and the type of cheating deemed the most important. To take this additional perspective into account, a second short exercise was held by the Institute of Nuclear Materials Management (INMM) at Lawrence Livermore National Laboratory, during the summer of 2015 [5]. At this

Acquisition Pathway Analysis (Components	IAEA Safeguards	Arms Control Verification
(Physical) Model	Many different facility types and potential pathways	More complex due to consideration of both civilian fuel cycle and military domain (material, production, warhead storage, deployed warheads), larger number of path families
Accountable items	Nuclear Material R&D (Additional Protocol) Well-defined (one Significant Quantity)	**Multiple**, depending on treaty limits – Overall number of warheads – Overall number of delivery systems – Dismantlement
Path attractiveness/path prioritization	Formalized (time, cost, difficulty) Different for each country Path Relevance is clearer	Formalized (time, cost, difficulty, **military significance**) **Non-technical factors** (strategic/ military considerations)
Verification measures	Defined in treaty/agreement	**Undefined unless treaty under consideration**
No of proliferators	Many but state-by-state evaluation	Bi- or multi-lateral – treaty dependent
Application	Establish and prioritize technical objectives	Help define verification measures need for a specific treaty or identify priorities to achieve confidence
Applicability	Formalized, mathematical modelling approach, State level	Basis for systematic, structured analysis, dialogue, State-level or sub-set

Table 1: Comparison of the use of Acquisition Pathway Analysis (APA) in the context of IAEA safeguards and arms control verification.

meeting, a simpler scenario was developed for the two fictitious neighbouring countries and an exercise was structured to take national security objectives into account, while developing a verification regime for each country. Representatives from political science and defence studies, as well as safeguards, arms control experts from nuclear and non-nuclear weapons states were invited to consider a scenario that encompassed the whole nuclear enterprise (e.g. materials, weapons and delivery vehicles). A formal exercise framework (Figure 1) was imposed to focus the participants on national objectives and priorities.

During this second exercise, the model treaty limited the total nuclear forces to the existing levels for 10 years, including strategic and tactical nuclear weapons. All types of delivery systems and the total number of warheads (including deployed and non-deployed) were capped. The development, testing, and deployment of new types of warheads and delivery systems was prohibited.

The same fictitious neighboring countries used in the first exercise were reconfigured to represent different levels of development, capabilities, and populations. The larger state, with a population of 200 million, was a moderately advanced industrialized state with regional military and economic dominance, and ambitions for broader global influence. It had a sophisticated nuclear weapons enterprise consisting of civilian and military nuclear fuel cycles and a total of 322 nuclear warheads. The smaller ascending power, with a population of 100 million, was newly industrialized with a modest conventional force. It recently developed its nuclear capability as a primitive nuclear deterrent. Its nuclear enterprise consisted of both civilian and military nuclear fuel cycle and had possession of a total of 110 warheads.

Detailed nuclear enterprise models were provided to the exercise participants, so that they would spend their time considering verification for key pathways rather than attempting an APA exercise in a short period of time. Figure 2 is the examples for the larger fictitious state (named "Trenzalia").

The final discussion session was held at the 8th INMM–ESARDA Joint Workshop at Jackson Hole, Wyoming, in October 2015 [6], was not directed towards any specific scenario, but instead focused more on application of systems engineering approaches and the complications that protection of sensitive national security information introduces into the process.

3. Key insights

The group of experts participating in the workshops demonstrated that It is possible (although complicated) to create a state-level systems framework to define objectives, processes, and timescales for an effective verification regime based on the strategic goals of an arms control treaty, while still considering restrictions from different security environments. The use of exercises, with fictitious states and model treaties, effectively focused the discussion on the application of a systems approach beyond IAEA safeguards, and provided the specific security and verification objectives needed to carry out such an assessment. This context directly influenced the assessment of pathway attractiveness, timeliness, detection goals, and level of effective verification. Finding the balance between intrusiveness and transparency was a recurrent theme and the need for flexibility was stressed. The verification technology required to find solutions will have to be treaty-specific, but advance work can be done so that various technical options can be ready for consideration in the context of actual negotiations.

The range of viewpoints brought by nuclear weapons state and non-nuclear weapons state experts illustrated how a diversity can spur new research directions. By mixing safeguards, arms control, international relations and political science experts it was possible to challenge the group to adjust their usual focus and methods to a different domain.

During the first exercise, most the participants brought extensive international safeguards experience, which drove

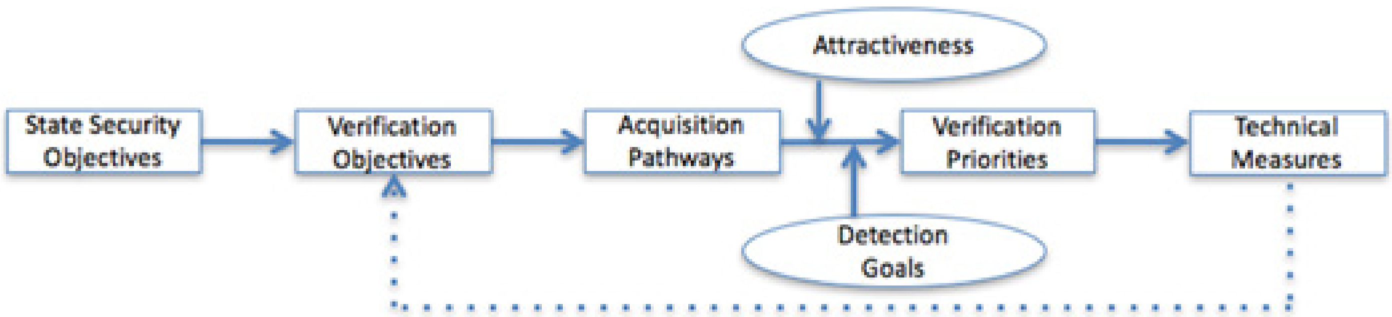

Figure 1: Framework used to explore the usefulness of a systems approach to development of a treaty verification regime.

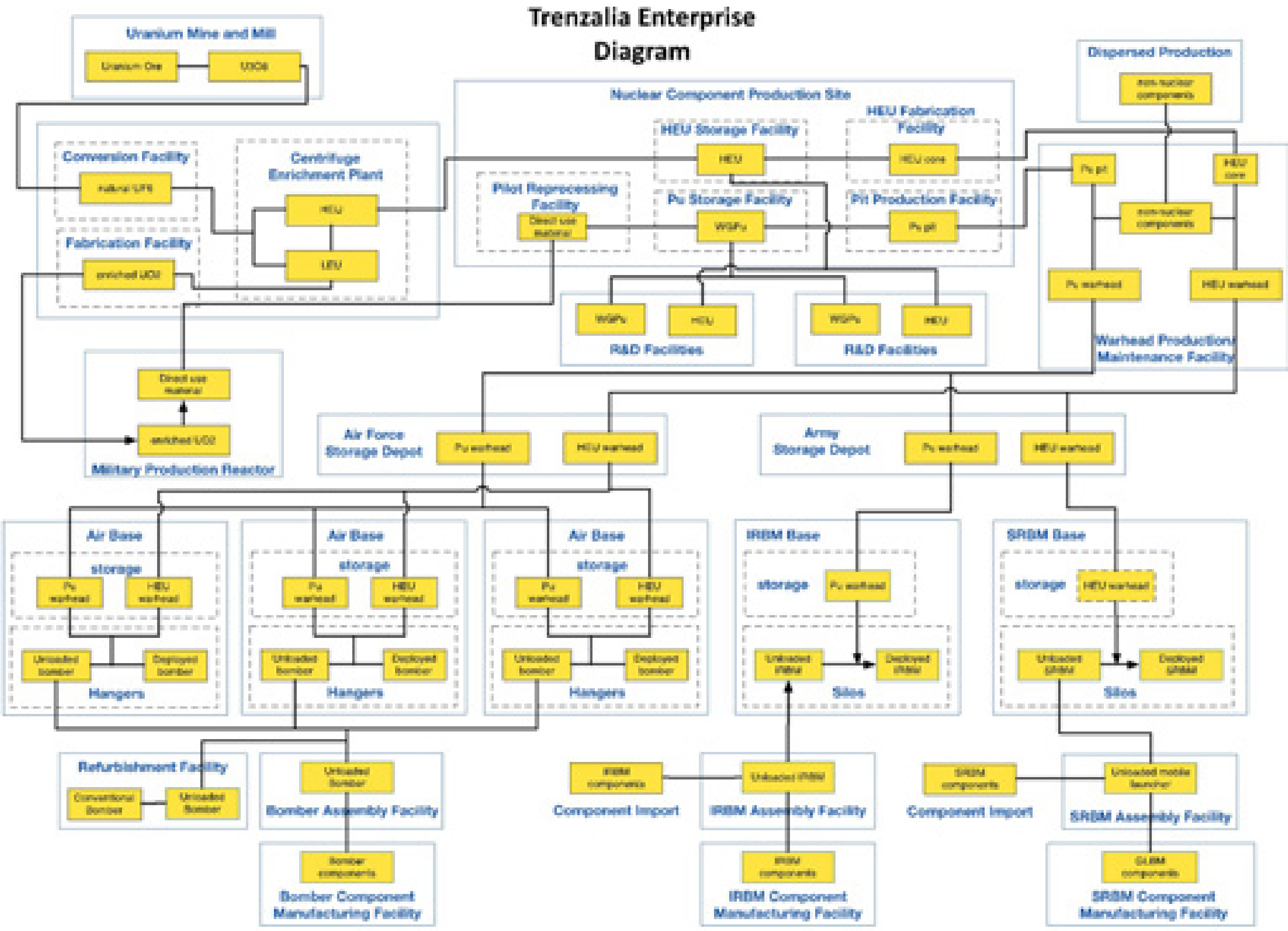

Figure 2: Nuclear enterprise model for the larger power with a moderately advanced industrialized state, with regional military and economic dominance.

the group into detailed of APA analysis with efforts to define attractive pathways and timeliness goals, as is currently done by the IAEA. As the effort bogged down, it was clear that the state-level approach would need to be modified to fit into this different arms control context. In applying safeguards in NNWSs, the goal is to prevent and detect the diversion of clearly defined materials for the whole state, however, in NWSs with a Voluntary Offer, safeguards are applied only in volunteered facilities in the complex, so the whole enterprise has not been considered. In the arms control context, depending on the definition of the treaty accountable items (TAI), the cheating pathways across the whole military and civilian complex must be taken into account, so, it will be necessary to link the materials and weapons sectors of that nation's nuclear weapons complex. So, when planning for the verification of items such as weapons or weapons components, the State's security and defense objectives will have a significant influence.

Defining clear metrics to evaluate pathway "attractiveness" and "timeliness of detection" for possible cheating must also be modified in this context. The metrics used by the IAEA provide a good basis for further work, but new or revised metrics would be dependent on the objectives of the treaty and the security situation of the countries involved. For example, the technical difficulty of cheating might not be the issue if a functioning facility exists but "stealth" or "denial and deception" to hide prohibited activities could be a credible cheating scenario. Maintenance and operational costs could be considered as obstacles to cheating for a particular pathway, however, if those costs were already included in the national budget, it might not have an influence on the attractiveness of exploiting the pathway.

The participants found that the detection goals for diversion or production of significant quantities of TAIs are greatly influenced by the perceived stability in a region. Increased transparency with lower-confidence verification of the exact numbers of TAIs might be acceptable between countries with a trusted stable relationship. However, if each state has only a low number of weapons, accurate verification of numbers and locations of TAIs is likely to be a very strong requirement for treaty ratification.

An effort was made during the second exercise to simulate an environment where national security was highlighted as part of the scenario. The two fictitious states were better defined (so there was no need to create this) and the participants were split into two groups. Each side went through the process outlined in Figure 1 and determined its own national security and verification objectives. With this additional information, the analysis of the different cheating pathways would be considered in the context of strategic and/or defense advantage. For example, if deterrence were the objective, having an undeclared (and undetected) cache of weapons would not provide much benefit. However, if the objective was to gain a strategic advantage for a certain area of a disputed border, it would be important to detect cheating with respect to the number and locations of weapons.

The imbalance between the two-hypothetical nuclear capable states during the exercise illustrated how the security objectives would drive the focus of a verification regime. The more capable state was interested in maintaining its advantage and therefore required verification that no new capability could be achieved without detection in the smaller state. So, the pathway analysis focused on the material and weapons production sectors of the complex. The less capable state was less concerned about improvements in the neighbor's already powerful nuclear weapons capability than it was about the numbers and location of weapons near its borders, so its focus was on the verification of numbers and locations of the TAIs.

Ultimately, finding the balance between the degree of intrusiveness and allowable transparency must be achieved to provide confidence in treaty compliance. A nation's security requirements and the protection of sensitive information and facilities will constrain the final verification regime. Protection of nuclear weapons knowledge (including materials, facilities and processes) are crucial to national security and are governed by the Nuclear Non-proliferation Treaty (NPT) Article I (if nuclear and non-nuclear weapons states are involved). Using an iterative process, verification measures could be developed to provide sufficient confidence in compliance in a way that would couple existing technical capabilities with operational and security requirements. It could also help point the way for future technology R&D programs.

Greater details on the scenarios and results of the technical discussions can be found in an upcoming book [7].

4. Future Research

Further development is needed but the authors believe that a clear and transparent framework provides an effective mechanism for international and technical engagement on these complicated issues. In particular, continued research can be done to advance implementation of an acquisition pathway analysis methodology in nuclear weapons states. Increased efforts to link the material and weapons sectors of the nuclear weapons complex are essential. More consideration should be given on definition of treaty-controlled items and the "significant quantity" of these items. Further work to refine metrics for pathway attractiveness, detection probabilities, and detection goals will depend on the items to be verified, related pathways and the security objectives of a state.

Continued testing of a systems approach and validating the framework would help to analyze the pros and cons of possible verification regimes by allowing for sensitivity analysis, to better understand high priority pathways and the confidence levels that non-compliance would be detected. Further work would also help bound the potential for using modeling and simulation to evaluate effective verification options and the potential impacts on the design of future declarations.

A clear benefit from the series of ESARDA/INMM expert meetings was the development of a cadre of international technical experts gaining familiarity and experience with these issues. The majority of the activity was carried out during professional society meetings rather than directly-funded research programs. Based on the positive experience of working across a diverse community in an international environment, continuing substantive dialogue, in venues such as the on-going International Partnership for Nuclear Disarmament Verification (IPNDV), should be encouraged. The inclusion of broader international technical expertise (outside of the NWS) creates opportunities for innovation. The framework described in this paper, could provide a structure to guide complicated and sensitive discussions that facilitates engagement across a broad range of weapons and verification expertise in support Article VI of the NPT. It also has the potential for structuring regional dialogue on sensitive issues.

5. Acknowledgements

The authors would like to thank ESARDA and INMM for hosting the technical meetings and all those who participated and shared their expertise and idea. The authors would like to acknowledge Cliff Chen (Lawrence Livermore National Laboratory) and Keir Allen (Atomic Weapons Establishment) for their significant contributions to this effort.

6. Disclaimer

The views in this chapter do not represent the views of any governments, institutions or professional organizations. This work performed under the auspices of U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. LLNL-CONF-731157, LLNL-PRES-731448.

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KJ-BB-17-054-EN-N