Systems Concept for Arms Control Verification

Workshop Report
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Workshop Report: Systems Concept for Arms Control Verification

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The Institute for Nuclear Materials Management (INMM) and the European Safeguards Research and Development Association (ESARDA) jointly held a series of workshops/meetings with the objective of exploring whether lessons learned from the International Atomic Energy Agency's (IAEA) proposed State-Level Concept (SLC) for safeguards could be adapted and utilized to develop a systems approach for arms control— addressing the state as a whole, rather than focus on verification of specific agreements. A systems concept could be applied at two levels: a systems analysis for verifying specific treaty commitments (e.g., limits on total warheads or fissile material), or at a general level to help identify areas where effective verification could provide the greatest confidence and thereby inform the most fruitful avenues for future disarmament efforts.

ESARDA's Verification Technologies and Methodologies (VTM) Working Group (WG) held a workshop in Ispra, Italy in November 2014 to begin the discussion of this approach, and was followed by a meeting at Lawrence Livermore National Laboratory's (LLNL) Center for Global Security Research (CGSR) in July 2015.

The Ispra workshop focused on developing pathway analysis for arms control, drawing upon on the IAEA's acquisition pathway analysis (APA) methodology for safeguarding nuclear materials. A fictitious bi-lateral scenario was developed to facilitate the discussion. One key lesson was that while acquisition pathways in the safeguards context are driven by a single technical verification objective—the timely detection of a significant quantity of direct-use material—there are multiple national security requirements influencing arms control verification objectives. The numerous and sometimes competing security concerns of all treaty parties and stakeholders drives the assessment of priority pathways and detection goals. In particular, an important detection goal, drawing a parallel to safeguards timely detection of significant quantities, is the detection of "militarily significant violations."

The follow-on CGSR meeting used a modified version of the scenario developed for the Ispra workshop to identify and explore factors relevant to the security objectives of stakeholder states, and how those security objectives translated into arms control verification objectives. Political, military, and regional perspectives on the potential role of cooperative measures and agreements in current security challenges were introduced, and a short exercise exploring security and verification drivers in a bilateral treaty context, was conducted.

Application of the Acquisition Pathway Analysis methodology

The State-Level Concept (SLC) seeks to design a safeguards regime that treats the state as a whole rather than as a collection of unrelated facilities and its applicability has been demonstrated[i]. By integrating the decades of experience in developing concepts and technologies for verifying bilateral and multilateral (e.g., START, CTBT) arms control agreements and the knowledge gained from the IAEA's SLC, a broad conceptual systems approach to arms control is being developed that takes into account varying levels of information and risk. It may be possible to provide state-level confidence that commitments are being upheld , by piecing together a broad range of information encompassing declarations, technical monitoring data, and other safeguards-relevant information such as open source, nuclear-related trade, and information from member states' national technical means.

The NPT obligation undertaken by Non-Nuclear Weapons States (NNWS) to not acquire nuclear weapons defines the commitment against which the IAEA evaluates state-level confidence. While the IAEA intends to apply the SLC to states possessing nuclear weapons to the extent relevant to their Voluntary Offer Agreement (VOA) or INFCIRC/66 agreements, these facility or item-specific agreements do not define a basis for state-level confidence.

Safeguards implementation focuses on the acquisition of weapons-usable nuclear material and therefore serves as the endpoint of the APA. A central component is the development of a customized state-level approach (SLA), which describes the process for planning safeguards verification activities within a state. The SLA is comprised of three elements[ii]: (1) analyzing plausible acquisition paths, (2) establishing and prioritizing technical objectives, and (3) identifying applicable safeguards measures to address the technical objectives. An acquisition path is the sequence of technical activities a state can use to obtain weapons-usable nuclear material.[iii] Each path represents the routes material forms traversed and set of processes exploited to obtain the weapons-usable nuclear material. These process steps may involve diversion from declared facilities, misuse of declared facilities, undeclared import of nuclear materials, or the operation of undeclared facilities. Information about a state's nuclear activities is used to constrain the set of possible paths.

To adapt the SLC into a general framework for considering arms control verification challenges, the following steps are being undertaken:

1. Understanding the selection and prioritization of verification objectives, particularly when there is no treaty in place;
2. Extending the IAEA materials-only physical model to encompass the range of facilities and activities in an entire, active nuclear weapons enterprise;
3. Developing a methodology for evaluating and prioritizing pathways;
4. Understanding and identifying detection goals;

5. Identifying the types of verification measures and technologies relevant to arms control, including assessing performance characteristics and tradeoffs; and
6. Identifying the political, legal, financial, and security considerations that influence the usefulness of the approach.

The Ispra 2014 workshop focused on the best ways to verify compliance with a fictitious treaty therefore only considered steps (2), (3), and (4) above. The workshop exercise concentrated on identifying a broad range of potential cheating pathways for a proposed treaty of a sophisticated nuclear weapons state. The group considered how to evaluate the most likely pathways and the time in which any illicit activities should be detected. The means to quantitatively or qualitatively measure the degree of "attractiveness" and the "timeliness" for detection were considered.

When evaluating "attractiveness" factors of weapons acquisition pathways for arms control, much can be learned from previous analysis of attractiveness measures used within the safeguards community. In 2011, the Generation IV International Forum Proliferation Resistance & Physical Protection (PR&PP) Expert Group[iv] proposed potential attractiveness measures for safeguards. Those measures were divided into intrinsic and extrinsic factors, which represented both the inherent attractiveness of the pathway with no verification and pathway attractiveness when verification is implemented, respectively. In the safeguards context, the intrinsic measures included *Proliferation Technical Difficulty*, *Proliferation Cost*, *Proliferation Time*, and *Fissile Material Type*. Extrinsic measures include the *Detection Probability* and *Detection Resource Efficiency*. When applied in an arms control context, these same measures were broadly considered to remain suitable with minor modifications and emphases. For example, states possessing nuclear weapons are assumed to already possess the knowledge and capability to build their stockpiles so *Technical Difficulty* may only be relevant to pathways involving new capabilities or significant modifications to current arsenals. Additional factors not included in the PR&PP list may be relevant in the arms control context. For example, an extrinsic risk factor includes both the detection probability and the (difficult to quantify) political consequence of getting caught. Different pathways may have varying severity of consequences should non-compliance be detected.

In safeguards context, the IAEA has a well-defined timeliness goal of detecting the diversion of one significant quantity (SQ) of unirradiated direct-use material within four weeks (8 kg Pu or 25 kg HEU). However, in the arms control context, such a concrete determination of timeliness does not exist. For example, the U.S. considers a treaty as effectively verifiable if there is sufficient confidence that a militarily significant violation can be detected in time to respond and offset the threat posed by the violation[v]. In different situations and for different countries, the timeliness goal could vary broadly.

The workshop participants concluded that the concept of timeliness and significant quantity could be transferrable to an arms control context but would largely be driven by security and political considerations rather than be established by more technical drivers. One of the biggest differences between safeguards and arms control verification objectives is that the latter's requirements will vary from treaty to treaty. Safeguards objectives are technical and concrete, and for all intents and purposes are non-shifting targets.

The difficulty of how to identify and prioritize the arms control verification objectives and the corresponding pathway analysis endpoints in the absence of an overarching agreement, was highlighted. The verification objectives in a systems analysis can either be specified by treaty commitments, or if applied in a broader context, identified by strategic concerns. Consequently the follow-on CGSR meeting was designed with a pre-established agreement allowing exploration of the political, legal, and security influence on verification objectives, and how a *state's security objectives* (SSOs) can be used to develop the verification objectives that define the endpoints of the acquisition paths.

Perspectives that influence the systems approach

As stated above, the CGSR workshop explored how political, defense and regional perspectives influence arms control verification requirements. The general discussion of military/defense perspectives highlighted that:

- Few states have only one adversary and future regional agreements will require participation of multiple interested parties.
- While P5 verification may focus on the nuclear enterprise, regional verification may focus much more on delivery systems and understanding intent – nuclear doctrine and concepts of operations (CONOPS).
- The focus of verification is on latency and timelines. Monitoring that focuses on the detection of patterns and deviations from patterns is more important than precision.
- Deemphasizing irreversibility may facilitate initial engagement in commitments by providing states the flexibility to recalibrate their activities to their security environment.

Political perspectives challenged some of the conventional wisdom on arms control verification. One view held that verification gets harder as stockpiles get smaller, requiring more intrusive verification measures for confidence because small-scale cheating would be more significant. However, this can be countered by the view that any security environment conducive to deep reductions and small stockpiles would most likely be cooperative and significantly more transparent leading to verification requirements less stringent than currently envisioned. Another emphasis was on irreversibility. For disarmament verification, irreversibility would increase the latency time to breakout, but it is also possible that reversibility may enable deeper reductions to reserve arsenals by alleviating certain security concerns, in addition to deterring cheating because of the potential for a fast response. However, there was not general consensus on this point.

A regional perspective on verification highlighted the difficulties of reaching arms control agreements in current conflicts. For example, lessons drawn from agreements between Argentina and Brazil suggest that symbolic gestures and transparency efforts may be of great benefit. In the regional conflicts, rather than focusing on state-level confidence, limited steps such as transparency on civilian nuclear activities and separation of civilian and military fuel cycles may help provide a basis for dialog. It was suggested that constructing an exercise that uses the systems framework to discuss verification objectives and priorities might be useful in augmenting current bilateral Track 2 discussions in South Asia.

Application of the methodology

At CGSR exercise the framework shown in Figure 1 was proposed to develop verification priorities for two states in a hypothetical bilateral scenario. By structuring the approach it was hoped that, for the purpose of the exercise, the group could quickly to assess the verification priorities taking into account attractiveness measures for the pathways and the establishment of detection goals. Each group was asked to step through the framework to identify the factors that influence each framework element for a hypothetical state.

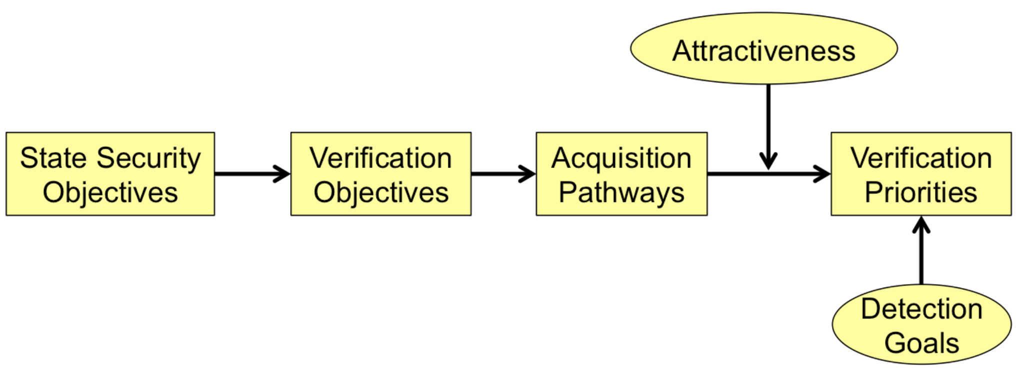

Figure 1. Framework for developing the systems concept.

The Scenario. Two hypothetical regional nuclear-armed competitors, *Trenzalia* and *Azaria*, with a history of ethnic conflict and border disputes have agreed to a treaty limiting total nuclear forces, including strategic and tactical, deployed and non-deployed, at existing levels for a period of 10 years. Specifically, the hypothetical treaty capped each type of delivery system, the number of deployed and total (deployed and non-deployed) warheads, and prohibited the development, testing, and deployment of new types of warheads and delivery systems.

In the scenario, Trenzalia, the larger power, is a moderately-advanced industrialized state with regional military and economic dominance and growing global influence. Azaria is a newly industrialized, ascending power with a recently developed nuclear capability. Both states have first-generation nuclear arsenals and weapons complexes but with different types of capabilities to meet their strategic needs.

Trenzalia's nuclear arsenal consists of fixed-site Short-Range Ballistic Missiles (SRBMs), fixed-site Intermediate Range Ballistic Missiles (IRBMs), and gravity bombs for its strategic bombers. Its SRBMs are forward-deployed and in range of Azaria's arsenal, whereas its IRBMs are currently out of reach of Azaria's capabilities. Trenzalia has dual-use strategic bombers co-located with conventional air forces at three air bases. Its warheads are a mix of 1-stage HEU gun-type and boosted Pu implosion types.

Azaria's nuclear arsenal consists of fixed-site SRBMs, mobile SRBMs, and gravity bombs. Its SRBMs are in range of Trenzalia's SRBMs and bombers. Its bombers are located at two air bases out of range of Trenzalia's SRBMs but within range of its IRBMs and bombers. Its warheads are all 1-stage HEU gun-type devices.

Additional details on the political context, tables of declared arsenals, and diagrams of enterprise facilities were provided to workshop participants.

The Exercise. Specific questions were posed to the groups:

- What are the security objectives of your state and your perceived risks and objectives of the other state?
- What are your state's key verification objectives with regard to the other state?
- Using the enterprise map of the other state, what are the acquisition pathways and key verification points that contravene your verification objectives?
- For each verification objective, what attractiveness factors help prioritize which pathway to monitor?
- What are the detection goals for the verification objectives and specified pathways?

Due to the limited time for the exercise, participants were asked to evaluate the verification objectives, pathways, and detection goals as applied to the other state **without** consideration of how reciprocal verification would impact their own state. Identification of potential technical verification methods was deferred for future discussion.

Results. Each state developed very different approaches for addressing the elements of the framework. Azaria emphasized the assessment of its political objectives and developed a strategic doctrine and national security strategy, and then used this information to analyze its own strategic and tactical weaknesses.

This was essential towards defining their verification objectives. Trenzalia took a more technical approach by developing technical verification objectives based on its security objectives, and analyzing Azaria's enterprise to identify key acquisition pathways and verification priorities.

While Azaria emphasized political objectives and derived their security objectives from them, Trenzalia, presumably satisfied with the status quo, started with security objectives. Each group developed the following set of verification priorities.

- Azaria, as the weaker state with a more limited arsenal and inferior delivery capabilities, currently relies on a hybrid- retaliation strategy. Its priorities were to deter preemptive attack and coercion, and in the long term revise the regional status quo. Its verification priorities focused on understanding and detecting changes to deployment patterns that might signal preemptive attack (e.g., bomber movements and exercises), and to identify the development of new delivery systems, particularly mobile systems, that put the survivability of its arsenal and targeting capabilities at risk.
- Trenzalia's security concerns focused on deterring Azarian aggression in the future. Its verification objectives centered on detecting new Azarian capabilities or postures that threaten the existing strategic balance. Specific objectives included detecting the development of new delivery systems and the enhanced research and production capacities for future arsenal growth, particularly as the treaty did not constrain stockpiles of nuclear material.

A key lesson that can be derived from the exercise is that each state's approach was heavily influenced by the perspectives of the experts/decision-makers included in the discussion. The Azaria team members' strong focus on strategic security, led to the identification of a specific set of acquisition pathways that need to be monitored in order to meet its security objectives in accordance with its national security strategy. Azaria's strategy was to accede to the treaty to cap development of Trenzalian capabilities, while it develops its own economy, conventional forces, and weapons complex (in compliance with the treaty) to improve its long-term strategic position. In this specific scenario the treaty did not necessarily represent an improved political dialogue. The ongoing strategic risks thus highlight the need for greater verification confidence.

The Trenzalia's more technical approach following the proscribed framework, developed longer lists of verification objectives and pathways to monitor in order to address all of the potential cheating risks. It focused on the ability to detect the further development or modernization of Azaria's capabilities, being that Tranzalia was confident in its present day military superiority.

Lessons Learned. The most effective implementation of a systems approach will require close collaboration across diverse backgrounds and perspectives, and clear understanding of specific treaty verification objectives. It was clear that even thought the acquisition path analysis is expanded beyond the material enterprise, additional elements (research & development, human capital and enterprise capacity development, and detecting general enterprise activity patterns) need to be integrated into the overall analysis. That said, these elements will also impact strategic considerations and may require different frameworks for analysis. [The APA framework needs to be expanded to incorporate these elements.]

Because the nuclear arsenals and security concerns of the two fictitious states were not directly matched, the verification goals and approaches varied significantly. This also illustrated how, even with specified treaty limits, such an assessment cannot be conducted based on the technical aspects of the enterprise alone but is strongly influenced by strategic requirements.

While the exercise unrealistically deferred consideration of reciprocal verification measures, concerns were still frequently raised about how reciprocity might impact overall security objectives. However, the discussions also suggested that if direct reciprocity on verification measures is not assumed, there might be the potential for creative verification solutions tailored to the specific concerns of each state. For example, in this scenario Azaria might request the ability to monitor Trenzalia's deployment patterns and delivery systems. While Azaria, as the weaker state may feel that reciprocal monitoring of its deployments may put its deterrent at risk, it may offer in exchange the ability to monitor its R&D and infrastructure development.

Summary and next steps

The systems concept can provide a framework for understanding how technical analysis and verification solutions can support high-level state security objectives and be effectively used when there are multiple stakeholders. There is a need for close collaboration between the stakeholders, in particular those with strategic, political, and technical perspectives. The systems approach clearly provides a common framework and enables focused discussions between all the stakeholders. It was noted that there is the potential for creative verification solutions when states with different security environments engage and that a systematic approach could potentially help identify creative solutions to support progress on arms control measures. Demonstrating the value of the systems concept will require further detailed development of acquisition pathways and analysis of the ability of current technical solutions to address verification challenges. It was generally agreed that working on a case study would provide a good way to further develop the methodology and should be undertaken as a next step.

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[i] IAEA. 2013. Conceptualization and Development of Safeguards Implementation at the State Level, *GOV/2013/38*

[ii] Cooley, J. N. 2011. Progress in Evolving the State-Level Concept, *Seventh INMM/ESARDA Joint Workshop Future Directions for Nuclear Safeguards and Verification.*

[iii] The APA is based on the IAEA's physical model, developed during the Programme 93+2, which identifies and characterizes all possible components of each stage of the nuclear fuel cycle. Liu, Z. and Morsy, S. 2001. Development of the physical model, *IAEA-SM-367/13/07*

[iv] Generation IV International Forum PR&PP Expert Group, *Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems, Rev 6* (2011)

[v] Woolf, A. 2011. Monitoring and Verification in Arms Control, *Congressional Research Service R41201*.