JUNE 2024

Verification of Nuclear Disarmament

Insights from a Decade of the International Partnership for Nuclear Disarmament Verification

10 YEARS OF PROGRESS
IPNDV
INTERNATIONAL PARTNERSHIP FOR
Nuclear Disarmament Verification

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Executive Summary

Since its entry-into-force in 1970, the landmark Nuclear Non-Proliferation Treaty (NPT) has united its Parties around the three pillars of disarmament, nonproliferation, and peaceful uses of nuclear energy. The NPT obligates all states parties "to pursue negotiations in good faith on effective measures relating to…nuclear disarmament." Progress toward nuclear disarmament requires confidence that there will be robust mechanisms through which Parties can verify each other's nuclear disarmament commitments.

In December 2014, U.S. Department of State and the Nuclear Threat Initiative (NTI) launched the International Partnership for Nuclear Disarmament Verification (IPNDV), in partnership with a diverse group of countries, to explore the question of how to multilaterally verify nuclear disarmament. Over the past ten years, the Partners have worked collaboratively to identify technical and procedural challenges associated with the effective verification of future disarmament efforts and develop practical solutions to overcome those challenges. Although work remains to be done, this report affirms the IPNDV's progress by highlighting the most important lessons that the Partners have learned so far about nuclear disarmament verification.

Given the prevailing tensions in the global security environment, the concepts, tools, and technologies that the IPNDV has identified and tested and the capacity that it has built will be a critical resource for future negotiators when the time again is ripe for progress. Whether such progress eventually comes as a revival of traditional nuclear arms control agreements or as a part of a more comprehensive effort, the insights gained through the IPNDV will pave the way to robust verification regimes capable of assuring all countries that nuclear disarmament is advancing as agreed.

The Partners

From its inception, the Partnership has operated on the principle that all countries—with and without nuclear weapons—have a role to play in a collaborative process to identify and develop effective verification measures. For that reason, the Partnership is committed to building and diversifying international expertise and capacity in the field of nuclear disarmament verification. It has brought talented individuals from around the world together in a non-traditional partnership to create a common language, and in so doing, establish building blocks for their shared work.

By promoting an inclusive and cooperative process, the IPNDV has also built trust and transparency among the many technical experts in science, engineering, and nuclear policy who participate in each meeting and the Partner countries they represent. As listed in Table 1, 30 countries and the European Union currently contribute to the work of the Partnership.

Table 1. IPNDV Partners

Argentina	Australia	Belgium	Brazil	Canada	Chile	European Union
Finland	France	Germany	Holy See	Hungary	Indonesia	Italy
Japan	Jordan	Kazakhstan	Mexico	The Netherlands	Nigeria	Norway
Philippines	Poland	Republic of Korea	Romania	Sweden	Switzerland	Turkey
United Arab Emirates	United Kingdom	United States of America				

Trust through Verification

The Partnership has explored the connection between previous verification initiatives and the goals of the IPNDV. Verification of existing nuclear arms control and disarmament agreements has largely focused on delivery vehicles, rather than on the dismantlement and elimination of nuclear warheads. The Partners realized that they would need to identify new approaches, not only for technical goals and procedures, but also for creating a new climate of collaboration among states with and without nuclear weapons.

"Trust but verify" was the Russian proverb invoked by U.S. President Ronald Reagan to guide the eventually successful arms control negotiations at the end of the Cold War. The IPNDV's work is animated by that belief and strives to build "trust through verification."

Collaboratively developing and testing verification approaches can help build a foundation of trust and generate momentum for a sustainable and credible process of nuclear disarmament in the future.

Three Phases Lead to Key Judgment

The IPNDV's three phases of work have each centered on a different theme: "creating a conceptual roadmap" (Phase I); "moving from paper to practice" (Phase II); and "addressing complexities and building confidence" (Phase III). Within each phase, the Partners have collaborated across topical working groups, enabling focused exploration of different aspects of the overarching theme. Across these phases, the Partnership has developed a set of scenarios that provide needed context for its work. The Partnership is currently near the end of Phase III.

At the end of Phase I in November 2017, the Partnership affirmed its key judgment that multilaterally monitored nuclear warhead dismantlement should be possible while successfully managing safety, security, non-proliferation, and classification concerns. Based on the work summarized in this report, that key judgment can be strongly reaffirmed but also extended:

> The Partnership has successfully identified a substantial toolkit of declarations as well as monitoring and inspection processes, procedures, techniques, and technologies (including, as needed, Information Barriers) to verify the reduction and dismantlement of nuclear warheads or limitations on nuclear warheads. Although additional conceptual and technology development work remains to be done, **the Partnership's results should provide a path forward to multilaterally verified nuclear disarmament while effectively managing safety, security, non-proliferation, and classification concerns.**

More specifically, as detailed in this report, the Partnership has:

- Developed a set of verification concepts and models to guide the development and implementation of nuclear disarmament verification mechanisms
- Identified, assessed, and in key instances tested through demonstrations and exercises a broad spectrum of verification measures and technology options for use in meeting future monitoring and inspection requirements
- Identified and tested a set of managed access procedures to ensure that proliferation-sensitive and other sensitive information is effectively protected during nuclear disarmament verification
- Built necessary international capacity as a foundation for multilateral verification, reflecting the recognition that every country has a potential role in the verification of future nuclear disarmament agreements
- Continually adapted its activities to address new issues and problems, thereby carrying forward its founding mission to understand the technical and procedural challenges to the effective verification of nuclear disarmament and develop practical solutions for those challenges.

Through all these activities, the Partnership has advanced the shared NPT goal of nuclear disarmament. A world working on effective nuclear disarmament verification is a world enabling future nuclear disarmament.

Looking Ahead

The Partners have begun to consider subsets of these issues that merit more exploration in the future. The Partners hope to continue refining the verification concepts already identified, including by conducting additional verification technology assessments and exercises, which remain important tools for understanding how to implement verification measures and technologies in increasingly realistic scenarios.

Section I. Introduction to the Partnership and Its Achievements

Phases, Structure, and Process

During the past decade, the Partnership has divided its work into three phases, each building upon the work of the previous phase. At the outset, the Partners focused on "creating a conceptual roadmap" (Phase I), then moved "from paper to practice" (Phase II), and are now "addressing complexities and building confidence" (Phase III). In each phase, the Partners have established Working Groups, led by co-chairs, that have focused on a specific element of the phase's central theme. As their work progressed, the Partners have used in-person and virtual meetings, exercises, and technology demonstrations for developing, testing, and refining verification concepts, evaluating technologies, and building knowledge and capacity. The trajectory of the phases, Working Groups, exercises, and demonstrations reflects the Partners' continuous effort to address the spectrum of challenges in nuclear disarmament verification.

Table 2. Working Groups across the IPNDV's Three Phases

Phase I (2015–2017)	Phase II (2018–2019)	Phase III (2020–2025)
Working Group 1: Monitoring and Verification Objectives *Co-Chairs: the Netherlands, United Kingdom*	Working Group 4: Verification of Nuclear Weapon Declarations *Co-Chairs: Poland, United Kingdom*	**2020–2022** Inspector Task Group *Co-Chairs: Australia, Canada, Germany*
Working Group 2: On-Site Inspections *Co-Chairs: Australia, Poland*	Working Group 5: Verification of Reductions *Co-Chairs: Australia, the Netherlands*	Host Task Group *Co-Chairs: Canada, the Netherlands, United Kingdom*
Working Group 3: Technical Solutions and Challenges *Co-Chairs: Sweden, United States*	Working Group 6: Technologies for Verification *Co-Chairs: Sweden, United States*	Technology Track *Co-Chairs: Germany, Sweden, United States*
		2023–2025
		Limitations Working Group *Co-Chairs: Australia, Norway, United Kingdom*
		Reductions Working Group *Co-Chairs: Germany, the Netherlands*
		Cross-Cutting Concepts Working Group *Co-Chairs: Canada, Germany*
		Technology Track *Co-Chairs: Sweden, United States*

Table 3. Exercises and Technology Demonstrations

Phase I (2015–2017)	Phase II (2018–2019)	Phase III (2020–2025)*
• UK-Norway Information Barrier Demonstration (Norway, November 2015) • Monitoring and Verification Technology Demonstrations (Italy, May 2016) • Monitoring and Inspection Tabletop Exercise (Switzerland, June 2017)	• Dismantlement Tabletop Exercise (Netherlands, June 2019) • High Explosives Detection Demonstration (Netherlands, June 2019) • Belgian Technology Experiment (Belgium, September 2019) • Nuclear Disarmament Verification Exercise—NuDiVe (Germany, September 2019—jointly with France) • Muon Tomography Demonstration (Canada, December 2019)	• Inspection Planning Tabletop Exercise (Virtual, December 2020) • Westend ICBM Base Inspection Tabletop Exercise (Virtual, June 2021) • NuDiVe 2 (Germany, April 2022—jointly with France) • JUNEX 22 Transport-Long-Term Storage Inspection Tabletop Exercise (Belgium, June 2022) • Trusted Radiation Identification System (TRIS) and CORIS360 Demonstrations (Australia, December 2022) • Belgium Technology Experiment—BeCamp 2 (September 2023)

*Exercises and demonstrations to date, with more to be conducted before the end of the phase.

A Central Focus on the Verified Dismantlement of Nuclear Warheads in a Scenario-Based Approach

From the start, the Partnership has focused most heavily on the verification of nuclear warhead dismantlement as the most important, complex, and technically challenging task of nuclear disarmament verification.[1] Dismantlement is essential to achieve the elimination of nuclear warheads, and verification is essential to build confidence both among parties to a disarmament agreement and to the wider community in the credibility of such efforts.

The 14-Step Model of the Nuclear Dismantlement Process

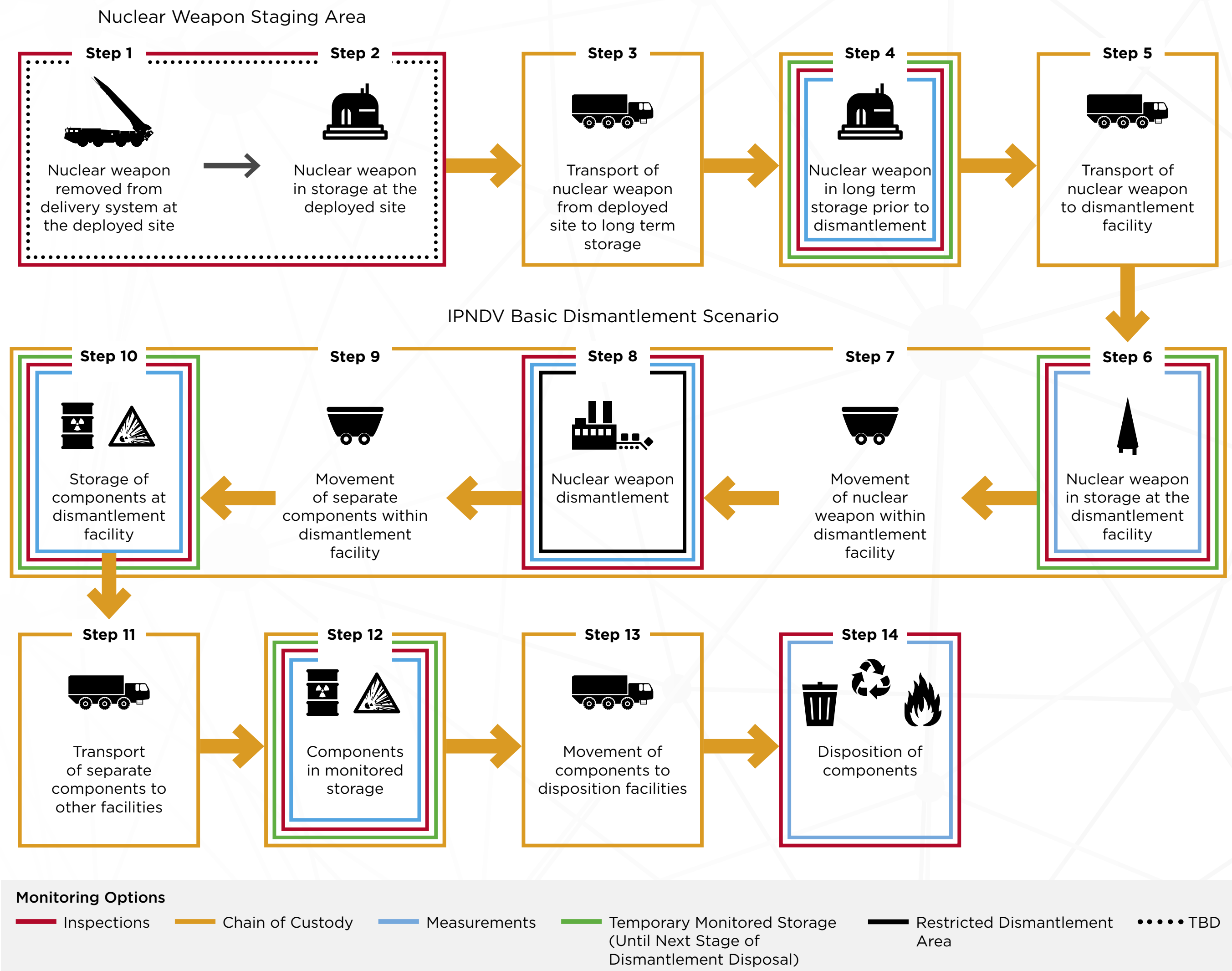
In its analysis of verified nuclear warhead dismantlement, the Partnership recognized the need for a conceptual Model to define the overall nuclear warhead dismantlement process. Depicted in Figure 1 and discussed fully in Section III, the 14-Step Model that the IPNDV developed describes a set of possible dismantlement steps beginning with removing a nuclear weapon from its delivery system at a deployment site and concluding with the disposition of its separated components. The central step of the

[1] See IPNDV, *Phase I Summary Report: Creating the Verification Building Blocks for Future Nuclear Disarmament*, November 2017, https://www.ipndv.org/reports-analysis/phase-1-summary/.

actual physical dismantlement of a nuclear warhead (Step 8) is defined as the physical separation of the two key components of nuclear weapons: the special nuclear material and the high explosives.

This sequence of 14 steps is not prescriptive. Future nuclear disarmament agreements involving the reduction of nuclear warheads might entail only a limited sub-set of these steps. Moreover, given unique national programs, some of these steps may not exist in some countries with nuclear weapons. However, this 14-Step Model has proved a highly valuable analytic framework to help the Partnership define specific verification objectives at each step, identify and assess possible verification measures to achieve those objectives, and explore the role of different technologies for technical monitoring. The Partners have continued to refine, test, and validate the Model during the past decade.

Figure 1. 14 Steps of Nuclear Dismantlement



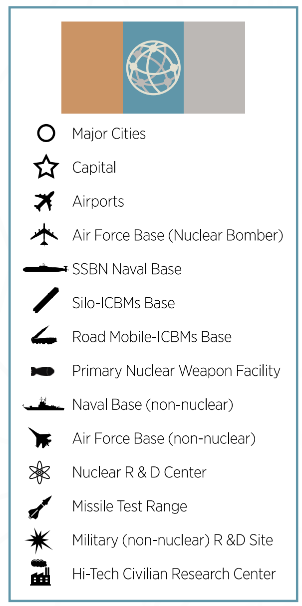
Note: We make the assumption that there will be declarations at each step in the process.

The Ipindovia Scenarios

The 14-Step Model also has been the jumping-off point for the Partnership's exploration of a spectrum of nuclear disarmament scenarios. Initially in Phase I, the Partnership developed a "Basic Dismantlement Scenario" which posited that a country with nuclear weapons had agreed to the verified dismantlement of an unspecified number of nuclear warheads. Phase II both carried forward a modified version of the "Basic Dismantlement Scenario" and also considered a scenario in which an undescribed State "A" had declared all of the nuclear weapons in its stockpile and agreed to keep its total stockpile below an agreed number.

At the start of Phase III, the Partnership took its scenario-based approach a major step forward by setting out a more detailed scenario that described a notional nuclear-weapon state (called Ipindovia, Figure 2) and its disarmament obligations in the context of a multi-party Nuclear Weapons Reduction Treaty (NWRT) with multilateral verification of those obligations. In so doing, the Partnership made a series

Figure 2. Map of Fictional Nuclear Weapon State Used during Phase III



This map has been prepared to support the Phase III work of the International Partnership for Nuclear Disarmament Verification. As a basis for analysis of verification of disarmament obligations, it depicts nuclear-weapon sites, infrastructure, and other relevant sites in a notional nuclear-armed country. For more about the IPNDV, visit: www.ipndv.org.

“Over the past decade, the International Partnership for Nuclear Disarmament Verification has developed solutions to some of the toughest verification challenges, helping make the world safer. Today, the work of this initiative is as important as ever.”

U.S. Secretary of State ANTONY BLINKEN

of assumptions about Ipindovia covering its nuclear arsenal, its deployment of nuclear weapons, and other relevant nuclear-weapon activities and locations. The scenario assumed that Ipindovia was one of several State parties to the NWRT, all of whom had agreed to reduce their nuclear arsenals from 1,000 to 500 nuclear warheads within 20 years of the treaty's entry into force.[2]

As Phase III continued, the Partnership revised the Ipindovia Scenario by developing two additional nuclear disarmament sub-scenarios: one for the limitation of Ipindovia's nuclear arsenal at 500 nuclear warheads; the second for the reductions of Ipindovia's nuclear arsenal to zero nuclear warheads. These two sub-scenarios are the basis for two Working Groups, the Limitations Working Group and the Reductions Working Group as Phase III continues.

A Roadmap to the Report

The following sections discuss key insights from the accomplishments of the IPNDV during the past decade:

- **Section II.** Concept development, or how to build a framework for verification of nuclear disarmament, including verification goals, principles, and objectives; scenario-specific concepts and Models; a scenario-based approach; and building sufficient verification confidence over time
- **Section III.** Building, testing, and refining a nuclear disarmament verification toolkit, including options for declarations as well as monitoring and inspection processes, procedures, techniques, and technologies (PPTT); the application of those options in specific disarmament scenarios; and the importance of "thinking strategically" about nuclear disarmament verification
- **Section IV.** Capacity building through the type of collaborative engagement among countries with and without nuclear weapons that is at the very core of the IPNDV
- **Section V.** Defining an agenda for continuing work on nuclear disarmament verification.

Together, these accomplishments support the following concluding "key judgment":

> The Partnership has successfully identified a substantial toolkit of declarations as well as monitoring and inspection PPTT (including, as needed, Information Barriers) to verify the reduction and dismantlement of nuclear warheads or limitations on nuclear warheads. Although additional conceptual and technology development work remains to be done, the Partnership's results should provide a path forward to multilaterally verified nuclear disarmament while effectively managing safety, security, non-proliferation, and classification concerns.

[2] For details, see *IPNDV Phase III Basic Scenario*, December 2022, https://www.ipndv.org/reports-analysis/ipndv-basic-scenario/.

Section II. Building a Framework for Verification of Nuclear Disarmament

The Partnership has developed a framework for thinking about the entire verification process, which comprises four interrelated components: defining overarching verification goals, identifying verification principles and objectives, developing scenario-specific concepts and models, and building verification confidence.

Defining Overarching Verification Goals

The Partnership identified three overarching goals for nuclear disarmament verification:

- **Goal 1.** To detect and deter violations of a nuclear disarmament agreement. The implementation over time of verification measures also can highlight lack of cooperation by another party that may be an indication of non-compliance.
- **Goal 2.** To allow parties to demonstrate their compliance with the provisions of an agreement, thereby sustaining support for the agreement among all parties and reinforcing their collective interest in maintaining an effective verification regime.

Framework for Verification of Nuclear Disarmament

Overarching Verification Goals → Verification Principles and Objectives → Scenario-Specific Concepts and Models → Building Verification Confidence

- **Goal 3.** To provide assurance to countries not party to a nuclear disarmament agreement that the agreement is effectively implemented. Building such confidence is particularly important, given the obligations of nuclear-weapons states (NWS) to pursue nuclear disarmament under Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).

Identifying Verification Principles

In addition to these broad verification goals, the Partners identified a set of *verification principles* to guide the design and implementation of nuclear disarmament verification regimes.[3] Taken together, these principles focus on how to achieve both the overarching verification goals and the more specific verification objectives of nuclear disarmament agreements. Their application, as the work of the Partnership has repeatedly demonstrated, requires careful balancing among them.

Effectiveness. The verification regime should be able to provide parties to a disarmament agreement with sufficient assurance that non-compliance can be detected (and thus deterred) and that other parties are meeting their obligations under the agreement. Safety and security requirements and the types of limitations of the verification regime likely to be negotiated by parties (including treaty-mandated limits on the number of inspections) make 100 percent effectiveness unattainable.[4] Thus, an important test for effective verification is whether the measures in place can detect militarily significant non-compliance in sufficient time to remedy that non-compliance or to take appropriate actions to offset any advantages gained by the non-compliant party.

Verification Principles

- Effectiveness
- Confidence-building
- Non-proliferation and non-interference
- Cost-efficiency
- Determinacy
- Established locus of authority

[3] For a more complete discussion, see Working Group 1: Monitoring and Verification Objectives, https://www.ipndv.org/working_groups/working-group-1-monitoring-verification-objectives/ and Working Group 4: Verification of Nuclear Weapon Declarations, https://www.ipndv.org/working_groups/working-group-4-verification-nuclear-weapon-declarations/.

[4] For a discussion of verification confidence, Section II in this report.

Confidence-Building. Over time, the effective implementation of a verification regime will build increased confidence among parties by providing a background environment against which possibly non-compliant activities can be more readily detected. Pursuing other related activities can provide transparency and establish working relationships among parties in a way that also builds confidence in the effective implementation of an agreement. Examples of these activities include providing information on national security reviews and nuclear doctrines and capabilities as well as establishing working relations between technical experts, military personnel, and officials of the parties to an agreement.

Non-Proliferation and Non-Interference. The design and implementation of a nuclear disarmament verification regime needs to satisfy the requirements of non-proliferation and non-interference. In this context, *non-proliferation* means ensuring that sensitive information related to the production, design, manufacturing, and transportation of nuclear weapons or nuclear explosive devices is not unintentionally revealed by the verification process. This principle is derived from the obligations respectively of NWS and non–nuclear-weapon states (NNWS) under Articles I and II of the NPT.[5]

Non-interference underlines that any verification regime will need to reflect safety, security, and operational considerations. It is critical to ensure that the elements of the verification regime do not adversely impact the physical safety of nuclear weapons as well as the safety of on-site personnel (including inspectors) and that of the wider population. Similarly, the regime should not compromise the security of nuclear weapons and their component materials (both on-site and in transport). Verification design and implementation must also seek to minimize operational disruptions and the overall burden of verification on the parties to the disarmament agreement.

Non-proliferation and non-interference are intertwined and, together, set boundaries on possible options for nuclear disarmament verification activities. This creates a continuing need to strike a balance between enhanced effectiveness and unacceptable intrusiveness at all stages of the verification process: negotiating verification procedures, developing verification technologies and concepts of operation for their use, planning and conducting monitoring and inspection activities, and reporting the results. Striking that balance sometimes rules out certain verification activities (e.g., directly viewing nuclear warheads), influences the choice of verification technologies (e.g., based on safety and security considerations), and constrains the modalities of the use of certain verification technologies (e.g., most often, requiring Information Barriers to limit information directly provided by radiation measurement of containers with nuclear warheads). Most broadly, balancing effectiveness with non-proliferation and non-interference calls for use of procedures to manage inspectors' access to a given site and how their activities are conducted as part of a nuclear disarmament verification regime—a concept known as "managed access."

Cost-Efficiency. Cost-efficiency is another driving factor to be considered in the design and implementation of nuclear disarmament verification regimes. Verification options must be practically feasible in relation to the amount of time, the number

5 Article I of the NPT obligates NWS not to "…assist, encourage, or induce any non-nuclear weapon State to manufacture or otherwise acquire nuclear weapons or nuclear explosive devices;" Article II obligates NNWS not to "…manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture [of such devices]." Treaty on the Non-Proliferation of Nuclear weapons, 1 July 1968.

“The IPNDV is important to the world because we need to have developed the technologies, techniques, and strategies for dealing with nuclear disarmament well in advance of a treaty being negotiated.”

MICHAEL LANE | Assistant Director, CTBT, Disarmament, and Technology Section, Australian Safeguards and Nonproliferation Office | AUSTRALIA

of personnel, and the level of resources (including technologies' operating costs) they would require. All parties and multilateral verification bodies are motivated to keep the costs and burdens of verification as low as possible without compromising verification effectiveness. Sometimes, more cost-efficient approaches can gather needed verification data; sometimes, nearly the same level of confidence may be possible even without carrying out a given verification activity.

Determinacy. The verification regime needs to balance clarity, simplicity, and flexibility. To help ensure that their interests are safeguarded within the verification regime, parties to a nuclear disarmament agreement will want the regime's specific verification measures to be clearly set out in the agreement's text. This includes defining and ensuring predictability of the mandate and powers of the inspecting entity and the permitted verification rules and procedures to ensure that verification produces similar results in similar cases. In this way, verification can establish shared expectations, predictability, and stability in relations between the parties to an agreement. Nonetheless, some degree of flexibility should be built into the overall verification regime. Such flexibility is important to allow any needed adaptations of specific rules and procedures to new situations and take advantage of the development of new verification technologies, so that—after consultations—adjustments can be agreed. Flexibility also will be essential in responding to unexpected developments in implementing a verification regime.

Established Locus of Authority. Design and implementation of a nuclear disarmament verification regime also requires that a principal locus of verification authority be agreed by the parties. Historically, verification authority has been national (via National Technical Means, e.g., SALT I and the Anti-Ballistic Missile (ABM) Treaty), bilateral (by each of the parties jointly to an agreement, e.g., the START and Conventional Forces in Europe treaties), and multilateral (by a multilateral entity, e.g., the Chemical Weapons Convention). For its part, the Partnership has assumed that the principal locus of authority will be multilateral. However, even in the case of reliance on a multilateral entity, a role for elements of national verification may exist and the ultimate political determination that there is sufficient confidence that other parties are meeting their obligations will be made at the national level.

Defining Verification Objectives

Verification objectives will have a significant impact on the design and implementation of any verification regime. These objectives flow from the overarching objectives of the agreement (its central limits) and are shaped by the principles set out above. The Partnership's work has differentiated three levels of verification objectives and demonstrated the importance of treating separately the objectives of the entity responsible for verification (the inspectors, whether bilateral or multilateral) and of the parties subject to the agreement (the inspected state, or host). Although host and inspector objectives sometimes overlap, differences also shape the specific modalities of any verification regime.[6]

Inspector Objectives

Level 1: Treaty Central Objectives. These comprise the legally binding obligations assumed by parties to a disarmament agreement. For example, in the original Ipindovia Scenario, the treaty central objective is to reduce the arsenal from 1,000 to 500 nuclear warheads and eliminate those warheads through a monitored dismantlement process. These central objectives are taken as a given by inspectors.

Level 2: High-Level Verification Objectives. These flow from the treaty's central objectives and are derived from inspectors' responsibility to confirm compliance with the obligations of the agreement. In the original Ipindovia Scenario, the inspectors' high-level objectives are to confirm the reduction and dismantlement of nuclear warheads and to confirm the absence of any nuclear warheads over the 500 nuclear warhead limit once the initial reductions are completed.

Level 3: Implementation-Specific Verification Objectives. These set out what the inspectors need to achieve to meet the high-level objectives as the parties implement the disarmament agreement. For example, the 14-Step Model used in the Ipindovia Scenario posits that one starting point for reductions could be removing a warhead from a delivery system at a deployment site. Thus, an inspector's implementation-specific objective would be to confirm that a nuclear warhead has been removed from a delivery system.

Host Objectives

Level 1: Treaty Central Objectives. From the host's perspective, the treaty central objectives provide a starting point. At the time of an agreement's entry into force, the host shares those objectives with the inspectors and other parties.

Level 2: High-Level Verification Objectives. The host is focused on demonstrating compliance with its obligations under that agreement. Building

Examples of Host's Implementation-Specific Objectives

- Facilitate the inspection team's conduct of required inspection activities at a given site
- Restrict inspectors' access to that which is specified in the agreement:
  - Do not allow inspectors to view uncovered nuclear warheads
  - Do not allow inspectors to view the interior of nuclear warhead containers
  - Do not allow inspectors' access to facilities unrelated to the specific inspections
  - Protect proliferation sensitive and other sensitive information
  - Ensure safety of personnel, nuclear material, and operations
  - Protect information regarding the physical security of nuclear warheads and their storage sites
  - Protect information about operations at inspected sites not related to the inspection and limit impacts on such operations

[6] For more detailed discussion of verification objectives from the respective perspectives of inspectors and hosts, see Inspector Task Group, "Some Thoughts on Verification Objectives, Declarations, and their Implications from the Perspective of an Inspecting Entity," November 2022; Host Task Group, "Some Thoughts on Verification Objetives, Declarations, and Their Implications from the Perspective of an Inspected State," November 2022.

confidence in its compliance is essential because it builds trust among the parties to an agreement. It also can strengthen the host's international credibility and global political standing. The host also has a high-level objective to ensure that inspectors comply with its safety and security requirements, do not compromise proliferation-sensitive and other sensitive or proprietary information, and that inspections minimally disrupt normal operations at the inspected sites.

Level 3: Implementation-Specific Objectives. The host has a detailed set of unique implementation-specific objectives that flow primarily from its high-level verification objectives but may vary depending on the specific treaty obligation and verification activities. These host implementation-specific objectives often are in tension with those of the inspectors. They also can be expected to drive the inclusion of managed access procedures to govern implementation of verification measures provided by a particular nuclear disarmament agreement. As the name suggests, such procedures manage inspectors' access to a given site and how they conduct their activities.

Developing Scenario-Specific Concepts and Models

The Partnership has developed several other more scenario-specific nuclear disarmament verification concepts that provide a foundation for thinking about nuclear disarmament verification generally. These other concepts can inform the design and implementation of the more specific verification regimes discussed in Section IV of this report.

Four Disarmament Contexts. The scope, subject, mix of elements, and implementation modalities of any verification regime will depend heavily on what is termed the disarmament context. The Partners have identified the following four broad disarmament contexts:

1. **Reduction of the Number of Nuclear Warheads.** A verification regime in this context focuses on confirming that a state has reduced its overall stockpile of nuclear warheads by the agreed-upon number.
2. **Reduction of the Number of Nuclear Warheads to Zero.** Reduction to zero entails verification of the elimination of all of a state's nuclear warheads. A key question in this context is how an end-state of zero impacts the verification regime, including regulation of nuclear-weapon related facilities and infrastructure (including, e.g., personnel and training).
3. **Limitation of the Number of Nuclear Warheads.** In this context, parties agree to limit their total number of nuclear weapons arsenals to a common upper limit declared to exist when the agreement enters-into-force. Verification focuses on determining the total number of nuclear weapons in each parties' arsenal and confirming that it does not exceed the agreed-upon common upper limit during the period the agreement is in force.
4. **Maintenance of Zero Nuclear Warheads.** After a party's nuclear arsenal has reached zero, verification focuses on determining the absence of clandestine residual nuclear warheads at former nuclear-weapon related facilities or other sites and the absence of the clandestine production of new nuclear warheads at former or clandestine production facilities. This context also requires consideration of how to regulate ongoing peaceful nuclear activities in states that had formerly possessed nuclear weapons.

Until now, the Partnership's work has explicitly addressed verification in the first three contexts. However, many of the concepts and the overall verification toolkit developed are relevant in the fourth context.

“One of the most interesting aspects of the IPNDV is the evolving scenario and the processes, procedures, technologies, and techniques that go along with it. This makes the work more realistic and approachable to those who are new to the nuclear disarmament verification community.”

HOJUNG DO | Researcher, Korea Institute of Nuclear Nonproliferation and Control | REPUBLIC OF KOREA

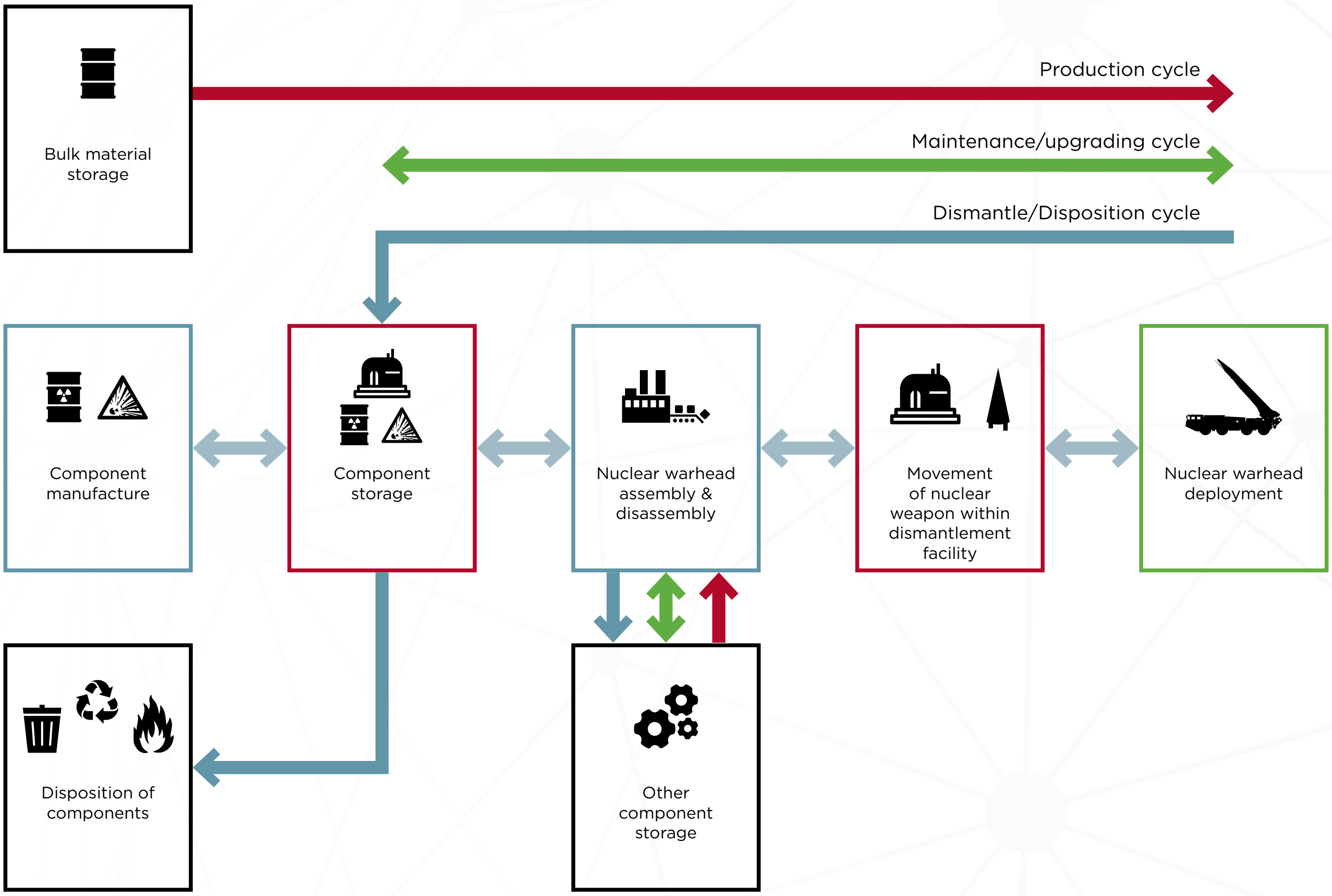
Grouping the Activities within the 14-Step Model of the Nuclear Warhead Dismantlement Process. Several of the specific steps in the 14-Step Model involve similar functional activities and can be grouped together. Importantly, initialization of a nuclear warhead into the overall nuclear dismantlement process can take place at any step of this Model. Specific types of activities occurring at various steps of the model include:

- Removal of a nuclear warhead from a delivery vehicle
- Short- or long-term storage of a nuclear warhead as it progresses through the dismantlement process and later storage of the components derived from a dismantled nuclear warhead prior to their disposition
- The actual physical dismantlement of a nuclear warhead and its separation into its components
- Movement of nuclear warheads and separated components within given sites as well as their transport between sites
- The disposition of the special nuclear material (SNM) and high explosives (HE) from a nuclear warhead by means that ensure they are no longer capable of being used in a nuclear weapon.

Complementing the 14-Step Model with a Nuclear Weapon Enterprise Model. Nuclear weapon dismantlement is one activity within a broader nuclear weapon enterprise. Building on the Ipindovia Scenario and the 14-Step Model (Figure 1), the Partnership also developed a model of the nuclear enterprise in a nuclear possessing country (Figure 3). This Model places the nuclear warhead dismantlement process into a broader set of ongoing nuclear weapons-related activities. It depicts the various flows of nuclear materials, warheads, and weapons and the wider set of nuclear production, refurbishment, and deployment activities underway. As with the 14-Step Model, it is intended as an analytic aid, not a rigid one-size-fits-all prescription.

An understanding of the broader enterprise is particularly important for thinking about verification of the absence of undeclared nuclear warheads or their production within the nuclear enterprise in the Limitations Scenario. Defining the nuclear enterprise also is important for developing a systems approach to verification and for identifying potential diversion pathways and responses to them.

Figure 3. Nuclear Enterprise Model with Functional Activities



The Verification of "Absence." At least three distinct but related dimensions of "absence" are of concern for nuclear disarmament verification:

1. The absence of undeclared nuclear warheads or nuclear weapons components at declared sites.
2. The absence of undeclared nuclear warheads or nuclear warhead components at non-declared sites.
3. The absence of any undeclared nuclear weapons-related facilities or activities.

Verifying absence in any of these three dimensions would be a requirement in the Reductions (especially to zero) Scenario and in the Limitations Scenario.

Closely related, the Partnership's work has highlighted the distinction between verifying the *correctness* and the *completeness* of declarations. The former refers to confirming that what a state has declared to be the case is the case (e.g., the number of nuclear warheads in a given storage facility) and the latter refers to confirming that no other nuclear warheads, facilities, or activities exist that should be declared under an agreement that have not been declared.

Identifying Potential Diversion Pathways. Design and implementation of a nuclear disarmament verification regime also needs to account for potential diversion pathways. These are potential ways that a Party to an agreement could attempt to clandestinely withhold nuclear warheads and/or their

Diversion Pathway Attractiveness and Risk: A Working Proposition

- Greatest risk for activities involving assembled nuclear warheads—no further assembly-processing needed
- Less risk for nuclear warhead components (e.g., pit)—need other components or reassembly
- Least risk for materials (e.g., separated SNM)—need remanufacturing and reassembly

components from treaty accountability or otherwise clandestinely produce nuclear warheads in violation of the agreement. Those pathways will be scenario dependent.

For example, in the Reductions Scenarios, the analysis so far suggests that while diversion risks are present at all points in the process of nuclear warhead dismantlement, the relative risk is likely greater of swapping a "real" warhead with a simulated warhead at some point during the nuclear warhead dismantlement process. For the Limitations Scenario, the risk is likely greater of retention of excess non-declared nuclear warheads or undeclared production activity, although both of these pathways also would be of concern in the Reductions Scenario, especially reduction to zero. Most broadly, the attractiveness of different diversion pathways (or conversely their risk) likely varies with whether nuclear warheads, nuclear warhead components, or nuclear warhead materials are being diverted.[7] An effective verification regime will need to consider all credible diversion pathways regardless of assessments of their relative risk.

Building "Sufficient" Verification Confidence Over Time

In any verification effort, absolute, 100% confidence is unattainable. Some uncertainty is unavoidable.[8] This judgment has informed the Partnership's thinking about the design and implementation of nuclear disarmament verification regimes. It applies across the different disarmament contexts as well as to the more scenario-specific verification results. It also applies to assessments of the expected effectiveness of more detailed monitoring and inspection activities. Given such uncertainties, absolute 100% confidence also is unattainable in the irreversibility of nuclear disarmament. This is so whether irreversibility is measured ultimately by the verified disposition of fissile material from dismantled nuclear warheads[9] or by the inability of a party to reverse its disarmament commitments without that reversal being detected before it had achieved major strategic benefits.[10]

Practical and technical limitations are one reason why absolute 100% verification confidence cannot be achieved. In practice, the magnitude of the inspection burden and the resources available in money and personnel will place limits on the conduct of on-site inspections. In the Ipindovia Reductions Scenario, for example, it would be impractical for inspectors to individually verify the status of each of many hundreds of nuclear warheads in each of the parties to the agreement as it moves through the dismantlement process. Or, for verifying absence in the Limitations Scenario, given that nuclear warheads are relatively small, the number of locations in which a declared warhead could in theory be hidden will exceed likely limits on the number of permitted annual inspections of suspect sites. There also will

7 See, "Thinking about Potential Diversion Options," Working Briefing, Reductions Working Group, October 2023.

8 For a discussion of verification confidence see "Thinking about Verification Confidence: Insights from IPNDV Exercises," Working Paper, Concepts Working Group, July 2023.

9 On origins of the term *irreversibility*, its usage, and the limitations of irreversibility see, IPNDV, "Food-for-Thought Paper: Achieving Irreversibility in Nuclear Disarmament," Working Group 1: Monitoring and Verification Objectives, January 2018, https://www.ipndv.org/reports-analysis/food-thought-paper-achieving-irreversibility-nuclear-disarmament/.

10 Ibid., p. 8 on "adequate irreversibility."

Factors Influencing Verification Confidence

- Magnitude of inspection requirements
- Number and duration of permitted inspections
- Extent of host cooperation
- Composition of inspection teams
- Effectiveness of monitoring/inspection activities in a multi-layered approach
- Understanding and effectiveness of monitoring/inspection technologies
- Coverage of potential diversion pathways
- Robustness of statistical sampling strategies
- Robustness of responses to unexpected or disruptive contingencies

be technical limitations linked to the effectiveness of specific monitoring technologies, for example, for detecting the presence of SNM. Not least, the need to balance the principles set out above of effectiveness and non-proliferation and non-interference underlies this judgment that absolute 100% confidence is unattainable.

In thinking about levels of verification confidence, the work of the Partnership also suggests it is important to take into account perceptions of the level of confidence attained through specific monitoring and inspection activities. For example, perceptions that the effectiveness of a given verification technology is less than it actually is can result in lower verification confidence than would otherwise be justifiable. Perceptions on the part of officials and decision makers will be especially important. Knowing this possibility, the Partnership is exploring how to communicate verification outcomes (and their basis in monitoring and inspection activities) in a manner that accurately reflects what has been achieved.

Implications of Verification Uncertainty. Given verification uncertainty, the Partnership has concluded that verification confidence needs to be thought of as the cumulative result of many separate monitoring and inspection activities that occur across an extended period of time. In effect, nuclear disarmament verification should be viewed as a *confidence-building process*. Many different factors can both positively and negatively affect the level of confidence attained, ranging from the magnitude of verification requirements to the effectiveness of specific monitoring and inspection activities.

Second, the objective should be to achieve *sufficient* confidence. This limitation applies in verification of each specific dismantlement step as well as the overall dismantlement process; to verification of limitations, reductions, and absence; and to the verified irreversibility of nuclear disarmament overall. What is "sufficient" confidence is ultimately a subjective political determination that will be made by each State individually on its own grounds.[11] However, as also just noted, it is important to ensure that credible verification outcomes are communicated in a manner that the results are understood by the various audiences so that sufficient confidence can be attained, including other parties to an agreement, publics, and especially officials and decision makers.

Third, it is important to adopt a risk management approach in the design and implementation of a nuclear disarmament verification regime. Such an approach would seek to reduce the attractiveness of different diversion pathways for a State that might contemplate cheating. In so doing, a risk management approach also would take into account

[11] On sufficient confidence, in addition to "Thinking about Verification Confidence: Insights from IPNDV Exercises," also see the discussion related to confidence in absence in Working Group 4 Deliverable, "Verification of Nuclear Weapon Declarations," March 2020, WG4_Deliverable_FINAL_copyedits___CORRECTED_031120_AB.docx.

“Looking back, what I’m most struck by is how smoothly each of the phases built on the last; we’ve taken what we’ve learned and applied it further, steadily growing our understanding without any big hiccups. The collaboration has worked very well.”

AMBASSADOR LEWIS DUNN | U.S. Ambassador to the 1985 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons | UNITED STATES

that the attractiveness of different potential diversion pathways—or their relative risk from the perspective of the inspecting entity—is dynamic. Attractiveness and risk of any given pathway could vary depending on the specific agreement, whether it is early or later in treaty implementation, the pace of treaty implementation, and the overall set of operational nuclear activities still underway during treaty implementation.

Inspection-Monitoring Confidence. As reflected in the listing above of factors influencing verification confidence, several more specific types of verification confidence are directly linked to the inspection and monitoring process. Sufficient confidence that the inspectors can carry out their required tasks within the time allotted is especially important. Confidence is needed, as well, in the reliability of technical monitoring technologies in terms of ability to produce the specified results on a consistent and long-term basis, their authentication and defense against tampering, the technology’s statistical error rate, and the adequate protection of proliferation or other sensitive security information. More broadly, confidence is needed in how the data collected by the various monitoring and verification techniques are handled, stored, managed, and processed. All these factors also need to be considered in the design and implementation of nuclear disarmament verification regimes and the development of supporting technologies.

Section III. Building, Testing, and Refining a Nuclear Disarmament Verification Toolkit

Based on the preceding conceptual framework, the Partnership has developed a substantial toolkit of options for the verification of nuclear disarmament. That toolkit comprises declarations as well as monitoring and inspection PPTT. Through analytic work, exercises, and technology demonstrations, it has applied, tested, and refined that toolkit as well as identified some guidelines for its implementation.

This section first describes the toolkit's elements and then describes its application in two different contexts: reductions (whether to a given number or to zero) and limitations (with a particular focus on verification of absence). In each case, the discussion highlights some propositions regarding both the design and implementation of nuclear disarmament verification regimes as well as some judgments concerning how well the challenges of nuclear disarmament verification can be met. This section

Building, Testing, and Refining a Nuclear Disarmament Verification Toolkit

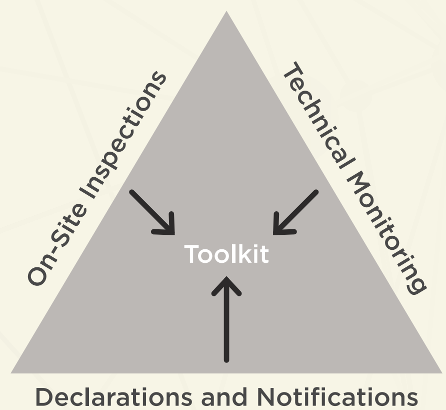
- Declarations, Monitoring, and Inspection Options
- Supporting Technologies
- Applying the Verification Toolkit: Reductions and Limitations
- Importance of Thinking Strategically

concludes with an emphasis on the importance of thinking strategically to inform all the activities involved in the design or implementation of any nuclear disarmament verification regime, including thinking in terms of a multi-State, multi-warhead, multi-site, multi-year verification process as well as developing a systems approach for allocating verification resources.

The Verification Toolkit: Declarations, Monitoring, and Inspection Options

The verification toolkit developed by the Partnership comprises options for three different sets of measures, as reflected by the accompanying graphic. Declarations and notifications—the formal provision of information about activities covered by a nuclear disarmament agreement—are the foundation of any nuclear disarmament verification regime. Their primary *purpose* is to provide information needed for the effective implementation of verification measures, including facilitating the detection of non-compliance by establishing the baseline of declared items, facilities, and activities subject to an agreement. The specific content of declarations will be the subject of negotiations between the parties to an agreement and should be included in the agreement.[12]

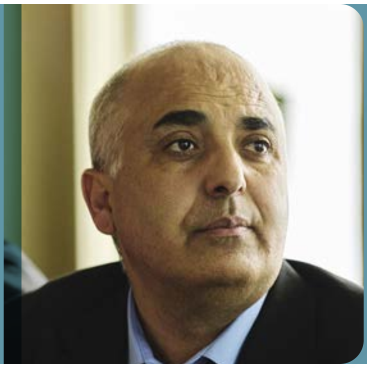
The Verification Toolkit Elements



Types of Declarations. During negotiations and prior to entry into force (EIF) of an agreement, the parties would exchange information needed as a basis for the negotiations in an *Initial Declaration*.[13] Information could include, for example, aggregate inventory data on all nuclear weapons holdings as well as deployment status, including the locations, status, and general operations of all treaty-relevant sites/facilities on the territory of parties subject to the agreement.

[12] After EIF, negotiations may possibly take place between a verification body established by that protocol and a host state to develop site- and facility-specific arrangements based on the verification protocol for inspections at those sites.

[13] On declarations, see Report of Declarations Working Group; "Some Thoughts on Verification Objectives, Declarations, and their Implications from the Perspective of an Inspecting Entity," Report of Inspector Task Group.



“One thing that makes the IPNDV unique is the different skills and expertise at the table. This helps us explore each step of disarmament verification from a variety of perspectives so we can identify challenges and develop a strong set of technical solutions.”

GHAOUTI BENTOUMI | Research Scientist, Canadian Nuclear Laboratories | CANADA

In addition, three other declarations and recurring notifications are the basis of the verification regime, with their specific elements dependent on an agreement's central objectives. These are:

- **Baseline Declaration.** Provided immediately after EIF, the Baseline Declaration builds on the Initial Declaration to provide comprehensive information about the items, facilities, and related activities and their status as defined in the agreement. It also contains additional, more detailed information necessary to prepare for and conduct verification activities, including for example, facility and site design information. The information to be exchanged in this declaration is typically identified within the specific provisions of the governing agreement. The Baseline Declaration sets the starting line for verification. (Depending on the state of the negotiations, some of the information included below in the Baseline Declaration could be provided as part of an Initial Declaration.)
- **Periodic Declarations.** Periodic declarations update the Baseline Declaration and provide the verification body and other parties with the most up-to-date and comprehensive information on a recurring basis, capturing the cumulative set of changes that have occurred over a period of time (e.g., one year, six months, etc.) for treaty-accountable items.
- **Notifications.** Notifications provide more time-sensitive information of changes that affect the accuracy of baseline information and occur in between issuance of periodic declarations. These notifications address day-to-day activities such as the movement of treaty-accountable items from one location to another location for deployment, maintenance, storage, or dismantlement. They also provide essential information that may trigger planning for and implementation of inspections under the agreement, for example, plans to remove a nuclear warhead from its delivery system or from storage at an operational nuclear base and initialize it into the dismantlement process. The specific changes covered, the detailed information to be provided, and the timing of such notifications would also be defined in the disarmament agreement.

In addition, at the beginning of each inspection, the inspecting entity would be provided with updated information not previously provided through declarations or notifications on the specific site being inspected. For example, accountable items may be moved while inspectors are in transit to an inspection site, before the expiration of a notification timeline.

Monitoring and Inspection Options. The Partnership has identified a comprehensive set of possible monitoring and inspection options that could be used to confirm the information contained within the above types of declarations and notifications. These monitoring and inspection options are listed in Table 4 below. Possible application of these technical monitoring and inspection options are discussed later in Section IV.

Table 4. Monitoring and Inspection Options

❑ Visual confirmation of information and applicable documentation provided about the characteristics and status of sites and items subject to the agreement
❑ Visual observation of treaty implementation activities, including specific inspection-related activities determined by the agreement to be carried out by the host
❑ Use of unique identifiers (UIDs) and tamper-indicating tags and seals to sustain chain of custody of containerized nuclear warheads being monitored
❑ Visual confirmation of UIDs, tamper-indicating tags and seals, and locations against applicable documentation
❑ Accompanying movement of accountable items, for example, nuclear warheads being moved within a declared site
❑ Use of radiation detection equipment, most often with an Information Barrier system, to confirm the presence or the absence of SNM
❑ Use of radiation detection equipment with an Information Barrier system to measure the attributes of nuclear warheads to compare against a previously made template for that type of nuclear warhead
❑ Use of radiation, spectroscopic, and x-ray techniques to confirm presence or absence of HE
❑ Use of perimeter portal monitoring systems to detect unauthorized ingress or egress from specified areas subject to the agreement, whether on an ad hoc or a continuous basis and possibly with an Information Barrier system
❑ Use of Closed-Circuit TV (CCTV) and other monitoring systems to detect unauthorized activity in a location or area
❑ Periodic reviews of the data provided by perimeter portal monitoring and other monitoring systems
❑ Measurement of the physical dimensions of treaty-defined facilities, with comparison of those measurements to information on design specifications

Managed Access Provisions. The Partners' analytic work and exercises (including the NuDiVe) have demonstrated the value of incorporating "managed access" procedures in monitoring and inspection activities in any particular nuclear disarmament agreement. As the name suggests, such procedures manage inspectors' access to a given site and how their activities are conducted. They are rooted in the principle of non-proliferation and non-interference discussed in Section III. This includes the host's interest in protecting proliferation-sensitive and other sensitive information and ensuring safety and security at sites subject to monitoring and inspection as well as the inspectors' interest in not violating their NPT obligations and in complying with nuclear safety and security requirements. The specific provisions would be defined by the nuclear disarmament agreement.

At the same time, the host country's overall goal of demonstrating its compliance with an agreement will shape its recourse to managed access, while also creating a need to facilitate the overall monitoring and inspection process. Managed access procedures should not preclude activities necessary to verify an agreement, and, if access cannot be provided, the host shall make every reasonable effort to meet inspector requirements by alternative means. In turn, use of managed access procedures will be an important part of both inspector and host planning prior to any inspection.

Examples of Managed Access Provisions

- Use of specially designated areas for some inspection activities
- Authorization for specified activities to take place outside of inspectors' field of view
- Restrictions on what inspectors can observe, from what locations, for how long, and by how many inspectors
- Permitted use of shrouds, covers, and other means to protect sensitive information
- Equipment to be used only by inspected Party at request of inspectors
- Restriction on direct physical contact with treaty-accountable items
- Inspectors escorted at all times

The Verification Toolkit: Supporting Technologies

Through a sustained, continuing, and in-depth set of activities, the Partnership has identified and evaluated a set of nuclear disarmament verification technology options to support monitoring and inspection activities. These options have been developed principally within the framework of reductions under the 14-Step Model. They also provide a technology resource for verified nuclear warhead limitations as described above in the Limitations Scenario.

Technology Demonstrations and Campaigns

- Information Barrier Systems
- Dismantlement monitoring
- Detecting presence of HE
- Detecting presence or absence of SNM
- Confirming nuclear warhead via template matching
- Portal monitoring

As part of this work, the limitations and readiness for use of specific technologies have been assessed. In that regard, it has been useful to distinguish technologies and methodologies that need extensive development from technologies and methodologies that may need less additional development or reengineering for use in nuclear disarmament verification. In addition, consideration has been given to the requirements for Information Barriers to protect proliferation-sensitive and other sensitive information when using some verification technologies.

Complementing its analytic work, as described in Section II, the Partnership also has carried out practical activities, including technology development by Partner countries, demonstrations and experiments, and measurement campaigns. These activities have ranged across different verification technologies, strengthened understanding of specific technology options among technical and non-technical experts, and helped to identify next steps to fill technology gaps.

A Verification Technologies Snapshot. Table 5, following page, highlights a selection of technology options to support the monitoring and inspection process. Drawn from a more complete set of technologies assessed by the Partnership, two indicators have been used in choosing which technology options to include in this table. First, the technology or equipment is readily in use today in other applications or has been otherwise demonstrated. Second, depending on the actual use requirements, the extent of additional development or reengineering required for use for nuclear disarmament verification, even if significant in certain instances, would not make impractical their eventual adoption. Whether an Information Barrier system would be required for use is also noted. That requirement could in turn impact the fielding of those technologies.[14] Depending on the specific technology listed, there also may be important operational issues that would impact its effectiveness in a nuclear disarmament application, e.g., sensitivity to shielding, the constraints arising out of the container with HE or time required for use. These operational issues would need to be reflected in any eventual choice among specific technology options.

The Partnership has also identified and evaluated other technologies that would require more extensive development. Their use is not to be precluded but would require considerably more time and effort to develop and bring to the field. For all the listed options as well as the full set of verification technologies assessed, their authentication and certification for use would raise other implementation challenges that would need to be overcome.

Information Barrier Systems. As indicated by Table 5, the need for an Information Barrier system stands out as one of the recurrent requirements in design

Table 5. Selected Potential Verification Technology Options*

Monitoring-Inspection Requirement	Technologies	Need for Information Barrier
Maintain Chain of Custody of Containerized Nuclear Warhead Being Monitored	Unique Identifier (UID)—intrinsic/applied to confirm Treaty-Accountable Item (TAI)	✗
	Tamper Indicating Tags/Seals	✗
	Radiation-hardened Radiofrequency Identification (RFID)—unique RFID assigned to container	✗
	Container Integrity Assessment Systems—detect tampering with container	✗
	Laser 3-D Container Identification—“fingerprint” of container	✗
Maintain Chain of Custody in Locations, Sites, Facilities Subject to the Agreement	Video-CCTV/3D	May be needed**
	Radiation (Non-Spectroscopic) Portal Monitors—detect movement of radiation emitting device into or out of an area	May be needed
	Tamper Indicating Tags/Seals—detect opening/ tampering with room	✗
	Accelerometers—detect movement of object of interest	✗
	Change detection systems—laser/optical to confirm changes in status of room between inspections	May be needed

14 For the full set of technologies assessed by the Partnership see Technology Track, “Technology Table — Chain of Custody,” January 2022, https://portal.ipndv.org/file-post/technology-table-chain-of-custody/; “Technology Table — Nuclear Weapon, High Explosives, or Special Nuclear Material in a Container,” January 2022, https://portal.ipndv.org/file-post/technology-table-nuclear-weapon-high-explosives-or-special-nuclear-material-in-a-container/.

Monitoring-Inspection Requirement	Technologies	Need for Information Barrier
Confirm Absence of SNM—in Container, in Room	Passive Gamma Detection	May be needed
	Passive Gamma-ray Imaging	May be needed
	Passive Neutron Counting	May be needed
	Active Neutron Techniques	May be needed
Confirm Presence of SNM—Nuclear Warhead, Nuclear Components in Container	Passive Gamma Detection	✓
	Passive Gamma-ray Imaging	✓
	Passive Neutron Counting	✓
	Active Neutron Techniques	✓
	Radiation Templates Matching	✓
Confirm Absence/ Presence of HE—in Container, in Room	Raman Explosive Identification System	✓
	Fast Neutron Interrogation System	✓
	Active Neutron Techniques	✓
	Compton Backscattering Cameras (X-ray)	✓
	Nuclear Resonance Fluorescence	✓
	X-ray Computed Tomography	✓

* These technologies are illustrative and selected from the wider set identified and evaluated by the Partnership because in many instances they would likely require limited or moderate development or reengineering for use in nuclear disarmament verification. Actual methods selected for use are situation dependent.

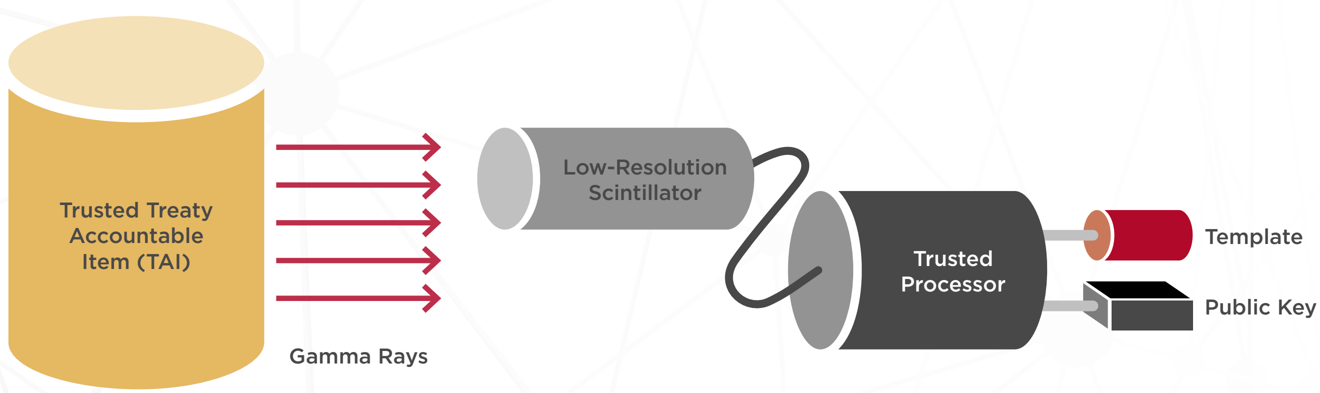
** Depends on the content of the data produced by the system.

and implementation of specific technology-based monitoring and inspection processes for nuclear disarmament verification. This need arises from the somewhat divergent goals of the inspecting and inspected parties in a nuclear disarmament monitoring regime. On the one hand, the inspecting party is most concerned with conducting accurate and reproducible measurements that provide confidence and assurance in inspecting classified/sensitive items. On the other hand, the inspected party must protect highly sensitive nuclear warhead design information or other sensitive information to address non-proliferation and security concerns. In this tension between competing goals, the requirement to protect the classified information of the inspected party will be paramount to any verification regime.

The work of the Partnership over the past decade has complemented other international initiatives in helping to understand the underlying logic necessitating Information Barrier systems and their limitations. Its discussions also have helped Partners to better understand that Information Barriers are not a single monolithic technology that protects sensitive information but a combination of Technology (hardware and software), physical and encryption mechanisms, and procedures (administrative controls). Its discussions also have focused on approaches to the development of systems that could be used in future nuclear disarmament verification, including identification of both overall design considerations (e.g., the importance of simplicity and the value of joint development by inspectors and host) and more specific design considerations (e.g., for different design elements from equipment certification to measurement system authentication to system maintenance).

This focus on Information Barrier systems is continuing, and future discussions will draw on technical studies of selected Information Barrier systems being conducted outside of the Partnership for use in one or more of specific nuclear disarmament monitoring and inspection applications. One example of this technology development work, depicted schematically in Figure 4, is the TRIS being developed at Sandia National Laboratories. The "trusted processor" is divided into two sides, one that handles processing of sensitive information, and the other that acts as an Information Barrier—providing only a non-sensitive "yes-no" conclusion of whether the declared item matches the template created earlier from the trusted reference item.[15]

Figure 4. Trusted Radiation Identification System



Applying the Verification Toolkit: The Reductions Scenario

Through both its analytic studies and a continuing series of exercises, the Partnership has applied and tested its verification toolkit in a Reductions Scenario, including reductions to zero. The following discussion begins by setting out some assumptions that have guided the Partnership's analysis. Building on the more generic discussion above, it then describes more specific elements of declarations and their verification and PPTT options for monitoring and inspecting the nuclear dismantlement process. In doing so, several

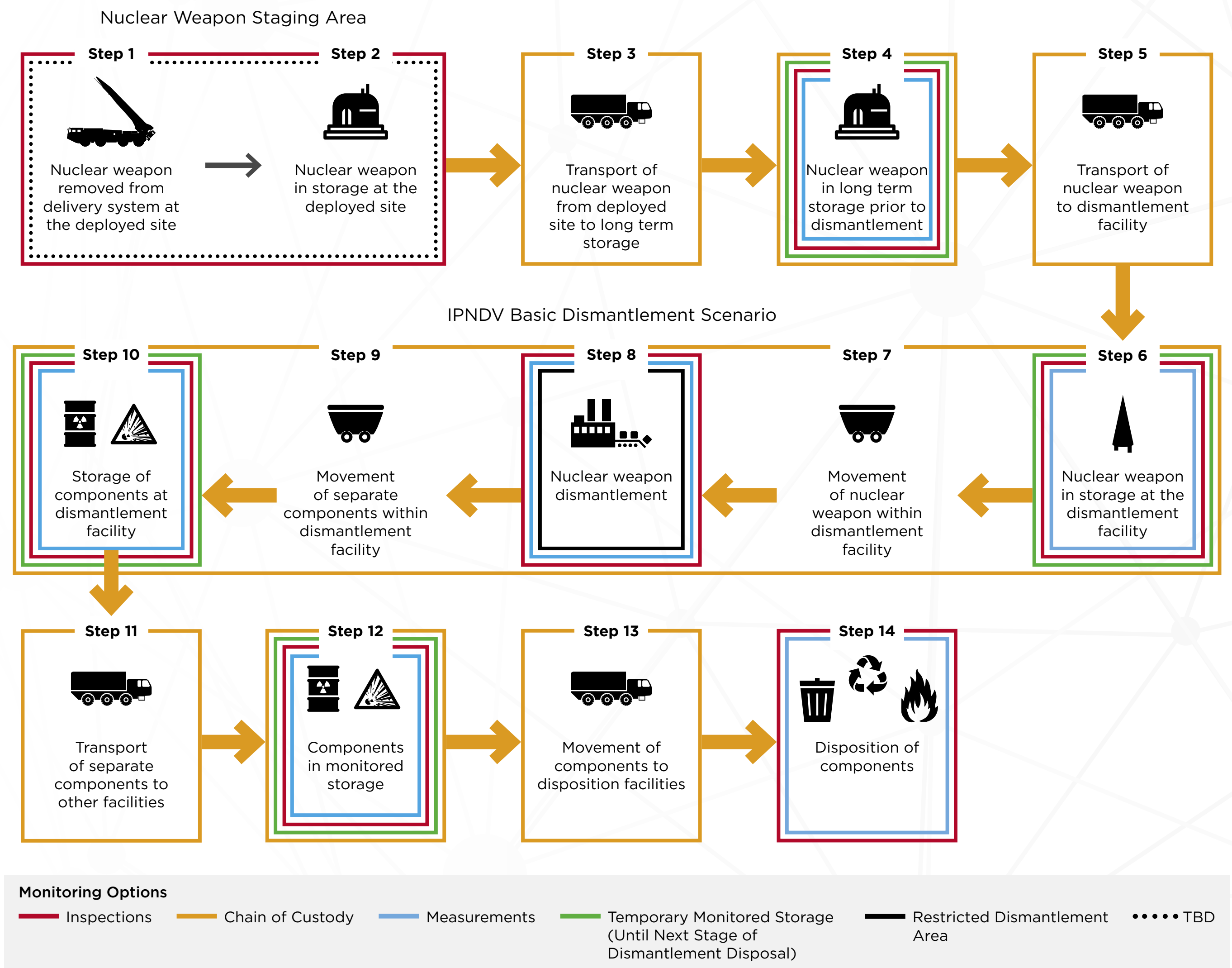
[15] For an earlier discussion of the basic concept, see P. B. Merkle, T. M. Weber, J. D. Strother et al., "Next Generation Trusted Radiation Identification System," Proceedings of the INMM 51st Annual Meeting, 11–16 July, Baltimore, MD, USA, 2010.

comparable activities are grouped and discussed together, e.g., storage, transport, etc. Whether or not an inspecting entity would choose to implement all the possible PPTT options for a given activity—and how often—would depend on the overall quotas of inspections under an agreement as well as overall inspection strategy. This sub-section then sets out some propositions about verification of nuclear disarmament reductions based on the series of exercises carried out by the Partnership. It concludes with some questions about what might change if the end point of that reductions process were not a residual number of nuclear weapons but rather zero nuclear weapons.

Some Assumptions in the Partnership's Analysis. To guide its work in a manner consistent with the set of verification principles set out initially, the Partnership has made the following assumptions:

- Reductions would take place within the framework of the 14-Step Model (Figure 5).
- Dismantlement of a nuclear warhead is defined as the separation of the SNM from the HE.

Figure 5. 14 Steps of Nuclear Dismantlement



Note: We make the assumption that there will be declarations at each step in the process.

- To protect proliferation-related and other sensitive information, there would be no direct visual observation by inspectors of an uncovered nuclear warhead; the inside of containers for nuclear warheads; the actual physical dismantlement of a nuclear warhead; and the SNM, HE, and other components directly derived from such a disassembled nuclear warhead.
- The nuclear disarmament agreement would set out the specific procedures, equipment, and other requirements for monitoring and inspections.
- Absence measurements would be allowed as provided for in the nuclear disarmament agreement.
- Inspections would be subject to managed access procedures that protect sensitive information and information not related to the inspection but ensure that inspectors can accomplish their tasks.
- The use of radiation detection technologies to confirm the presence or absence of a nuclear warhead or of separated SNM or HE would entail use of an Information Barrier system (unless otherwise determined).
- Verification would be conducted by a multilateral entity, with inspectors from both countries with and without nuclear weapons that are parties to the treaty or agreement.

Declarations and Notifications in a Reductions Agreement. Submitted after the EIF of a nuclear reductions disarmament agreement, the *Baseline Declaration* contains the specific information to be verified. Its specific content, as noted above, would be specified in the agreement and would be defined by the specific objectives of that agreement. (As noted above, the agreement also would include an obligation to periodically update the information provided by the Baseline Declaration.)

Illustrative Baseline Declaration: Reductions Scenario

- Number and type of warheads currently in Ipindovia and their status (total aggregate/per location, deployed/non-deployed, active/inactive, reserve/maintenance, in storage prior to dismantlement/dismantled)
- The location and types (with site diagrams) of all operational nuclear weapon bases and storage sites as well as nuclear production/refurbishment facilities and nuclear sites within them (with site diagrams)
- Unique identifying characteristics for containerized nuclear warheads

Periodic updates support general inspection planning, while *incident-driven notifications* may trigger specific inspections. Examples range from plans to move nuclear warheads subject to the agreement to plans for dismantling nuclear warheads subject to the agreement. The timing of how often periodic updates would be required as well as when notifications would be provided would be set out in the agreement.

Illustrative Periodic Notifications: Reductions Scenario

- Plans to remove a nuclear warhead from its delivery system as a step to dismantlement
- Plans to remove nuclear warheads subject to the agreement from storage or from an operational nuclear base
- Movement of nuclear warheads subject to the agreement within or between sites
- Plans for the dismantlement of one or more nuclear warheads
- Notification of breaches of chain of custody or unexpected issues that cause deviations in procedures or issues with monitoring and verification equipment

Baseline Inspection Options: Reductions Scenario

- Visual observation with managed access
- Possible use of radiation measurement equipment
- Measurement and photos by host on behalf of inspectors of items subject to the agreement
- Confirmation of UIDs
- Confirmation of site diagrams

Baseline Inspections in a Reductions Agreement Verification Regime. The use of baseline inspections is an important means to confirm the data provided in the Baseline Declaration, including site diagrams. Inspections would be permitted at every declared facility where nuclear warheads subject to the agreement are located. On any given site, more specific PPTT options could include visual observation with managed access, selective use of radiation measurement equipment to confirm the presence of nuclear warheads, and measurement and photos taken by the host on behalf of the inspectors.[16]

Options for Monitoring and Inspecting Nuclear Warhead Dismantlement in a Reductions Agreement Verification Regime. Following baseline inspections, the verification objective at Step 1 in the 14-Step Model would be to confirm that a nuclear warhead had been initialized into the dismantlement process (as declared) and to establish chain of custody over that warhead. Visual observation combined with inspection technologies such as tags and seals are the core of the PPTT options at this step. The set of PPTT would provide multiple layers of verification security.

Initialization could take place, however, at later steps in the 14-Step Model. In particular, a nuclear warhead identified for dismantlement could be removed from storage at a deployment site (Step 2) or at a long-term storage site (Step 4). Under most conditions, the same set of PPTT options would apply to achieve the given objectives. For example, in the case of initialization of nuclear warheads that had been in storage at a deployment site or in storage at a long-term central storage facility, it would be possible for inspectors

Initialization at Deployment Site Verification Options (Step 1)

- Observe delivery system/mated warhead prior to removal from delivery system
- Observe the process of removal of warheads subject to inspection from a delivery system or from storage at a deployment site
- Confirm that storage containers to be used for the removed warheads do not contain a nuclear warhead
- Observe process, under managed access, of placing of warheads by inspected state into container for transport
- Observe application of UIDs by host on container
- Confirm UIDs are associated with storage containers and ensure the container with warhead is sealed with tamper indicating seals

[16] In addition, separate from the baseline inspections, there could be exhibitions of treaty-accountable items by the host.

Movement within a Site Verification Options (Steps 2, 4, 8, 10, 12, and 14)

- Confirm that transport vehicle is empty
- Confirm tags, seals, and UIDs on containers against applicable documentation
- Visually check storage containers, including for consistency with declared design criteria and with previously acquired photos of containers
- Observe, under managed access, the loading of warheads for transportation
- If possible, maintain continuous visual observation in the convoy of the warhead transport vehicle throughout its travel
- Confirm the removal of the warhead container from the transport vehicle and its placement in storage

again to observe the overall process with managed access, including use of UIDs, tags, and seals.

Within the nuclear dismantlement process, *movement within a site* (possible at multiple steps) of nuclear warheads or nuclear warhead components has been addressed separately in the IPNDV from *transport between sites*. This distinction reflects the heightened security concerns that are associated with the transport on open roads, over possibly long distances, of the items in question. In particular, notification of transport between sites almost certainly will take place only after transport has been completed and the specific PPTT used will need to reflect that limitation.

More specifically, regarding *movement within a site*, the objective would be to establish and/or maintain chain of custody on nuclear warheads, for example, in Step 1 or 2, after removal from a delivery vehicle and prior to its placement in short-term storage. Once again, an extensive set of possible visual inspection activities, complemented by technical measures, are the core of the PPTT options. Potential options include being present to observe the loading under managed access of containerized nuclear warheads for intra-site movement into the transport.

By contrast, security considerations considerably constrain the PPTT options available to confirm chain of custody during the *transport between sites* of nuclear warheads or components. Relying on visual checks (including of tags, seals, and UIDs) made some time prior to and sometime after any transport has been completed would provide only a single layer of verification security rather than the multiple layers for movement within a site. One way to buttress the PPTT for transport between sites would be to periodically undertake radiation measurement of selected containers after their transport to storage.

Storage of highly sensitive items takes place across the nuclear dismantlement process, initially of nuclear

Transport between Sites Verification Options (Steps 3, 5, 11, and 13)

- Prior to and/or after shipment, visually check storage containers, including for consistency with declared design criteria and with previously acquired photos of containers
- Prior to and/or after shipment, confirm tags, seals, and UIDs on containers against applicable documentation
- After shipment confirm information provided in applicable notifications
- Periodically measure radiation of container after transport has occurred

Short or Long Storage Verification Options (Steps 2, 4, 6, 10, 12)

- Visually check storage site for diversion pathways, including for consistency with declared design information; apply seals as appropriate
- Confirm placement or check tags, seals, and UIDs on containers as documented
- Visually check storage containers, e.g., for consistency with declared design criteria
- Radiation detection measurement to confirm that storage containers contain a nuclear object
- Perimeter Portal Monitoring (PPM)

warheads, then of separated components from dismantled nuclear warheads, and ultimately of SNM and HE from dismantled and processed components. A multilayer set of PPTT monitoring and inspection options is available to confirm chain of custody. In particular, radiation detection measurements can be used during inspections to confirm the presence of a nuclear object. In addition, for storage other than at operational nuclear deployment sites, perimeter portal monitoring is a PPTT option, either ad hoc during inspections or possibly on a continuous basis during and between inspections.

The actual *dismantlement of nuclear warheads* is the centerpiece of nuclear disarmament as envisaged by the Partnership. As made clear by the assumptions set out above, this step most highlights the tension discussed earlier in this report between the principle of effectiveness and those of non-proliferation and non-interference, safety, and security: inspectors

Dismantlement Verification Options (Step 8)

- Observation to confirm/re-confirm the physical integrity of the dedicated dismantlement area and to check for consistency with declarations
- Review applicable documentation and confirm tags and seals, including any UIDs applied to warhead containers, prior to dismantlement
- After dismantlement, confirm placement of tags and seals, including any UIDs applied to containers with components
- Perimeter portal monitoring and use of CCTV, with periodic review of surveillance data
- Measurements with agreed equipment to confirm/re-confirm the physical integrity of the designated dismantlement area, no SNM and/or HE presence
- Before dismantlement, attribute/template measurements using radiation detection techniques with an Information Barrier to compare templates against containerized items to be dismantled to confirm containers declared to contain a nuclear object do contain such an object
- After dismantlement, attribute/template measurements using radiation detection techniques with an Information Barrier to compare templates against a container declared to contain SNM components from a dismantled nuclear warhead to confirm containers do contain such a nuclear warhead
- Attribute/template measurements using HE detectors to confirm presence of HE in containers after dismantlement

will not be able to directly observe the actual dismantlement of a nuclear warhead and may be required to rely on technical measurements with Information Barrier systems.

Within these limitations, however, a comprehensive set of monitoring and inspection PPTT options exists. This set again provides options for visual observation and checks by inspectors, for example, to confirm the integrity of the actual area in which a warhead is to be dismantled prior to and after dismantlement. But even more so than in other steps, it includes a robust set of options for technical activities that could be implemented by inspectors, again prior to and after the actual nuclear warhead dismantlement. These technical measures are designed to build confidence that unauthorized ingress or egress from the area has not occurred as well as more indirectly that dismantlement has occurred.

The final activity in the 14-Step Model of nuclear dismantlement in the Reductions Scenario is the *disposition* of the components and of the SNM derived from those components of dismantled nuclear warheads. At this step in the dismantlement process, protecting classified information would again be an important consideration. In particular, it is necessary to ensure that during the process of disposition, inspectors are not able to determine the classified shapes or isotopic composition of specific nuclear weapons. Once rendered unclassified by processing as part of this step, different ways of disposing of the SNM exist, including its hand-off to International Atomic Energy Agency (IAEA) safeguards. The Partnership is focusing only on the verification aspects of disposition and not on the specific disposition options.

Many of the same PPTT options would be relevant to verification of disposition. These include both visual observation and checking by inspectors and use of different technology-based measures.

Verifying Nuclear Dismantlement in a Reductions Scenario: Additional Considerations from Exercises. Beginning in Phase III (2020), the Partnership conducted a series of nuclear disarmament verification tabletop exercises to test and assess the PPTT for the verified dismantlement of nuclear warheads described above. Two Partners, France and Germany, cooperated to organize an on-site nuclear disarmament verification exercise (NuDiVe) to follow-up an earlier one conducted in 2019 at the end of Phase II. These exercises covered in varying levels of detail almost all the activities set out in the 14-Step Model. The tabletop exercises offer additional insights into planning and implementing an effective nuclear dismantlement verification regime for reductions.

The exercises *validated the generic conceptual processes and procedures* set out above. They also contributed to *validating the set of inspection technologies identified* by the Partnership as well

Disposition Verification Options (Step 14)

- Confirm tags, seals, and UIDs on containers as documented
- Visually check storage containers, including for consistency with declared design criteria
- Visually check site for diversion pathways, including for consistency with declared design information; seal as appropriate
- Attribute/template measurements using radiation detection techniques with an Information Barrier to confirm presence of SNM and HE
- Perimeter portal monitoring and use of CCTV—continuous

“Bringing together the technical and policy worlds is one of the most important parts of the Partnership, so we can all learn to speak the same language when we’re talking about nuclear monitoring and verification.”

ERIN CONNOLLY | **Contractor, National Nuclear Security Administration, U.S. Department of Energy** | **UNITED STATES**

as their potential contributions to verification of nuclear warhead dismantlement according to the 14-Step Model. The exercises also tested different types of managed access procedures. At the same time, the exercises highlighted issues related to the more *detailed implementation of the PPTT* as well as the need for flexibility in planning and use of specific inspection technologies. Sometimes, tensions will surface between using specific verification technologies and the time constraints inherent in any inspections process. More study is needed about how to coordinate, integrate, and prioritize the discrete verification PPTT options across the different steps of the 14-Step Model. In turn, unpredictable but inevitable contingencies (e.g., weather conditions, equipment failure) also can disrupt procedures and require limited on-the-spot adaptations of the inspection process.

At a different level, the exercises also underscored the *centrality of maintaining chain of custody* over treaty-accountable items (nuclear warheads and their components in the basic Ipindovia Scenario or any of its sub-variants) and reliance on t*wo-layers of verification security*. With two independent PPTT, a single point of failure in chain of custody can be avoided because a second layer will provide needed back-up. Challenges exist, however, to always meeting this test, including because of time constraints on inspections (e.g., impacting the use of radiation measurement technologies to confirm the presence of SNM).

As the series of exercises continued, they increasingly made clear the impact of *numbers and time* on monitoring and inspection planning and implementation. Both the annual quotas for inspections as well as the number of possible sites to visit and nuclear warheads being dismantled mean that any inspection entity will need to make choices with regard to what to inspect, how, and how often. Given an inability to inspect everything, a need to develop and rely on a *sampling strategy* exists. Possibilities identified ranged from using simple random selection to more sophisticated mathematical strategies. The impact of numbers and time, moreover, will grow as the numbers of warheads and sites subject to any agreement grow.

Closely related, the exercises made clear that the time required to carry out specific monitoring and inspection activities also will limit what can be done during any given inspection. Thus, thinking through the overall *phasing and ordering of discrete inspection activities* to be carried out during a single inspection as well as using robust and efficient PPTT will be essential to inspection planning and implementation. This need for phasing and ordering also underscores the importance of focusing on verification as a multi-warhead, multi-site, multi-year undertaking.

Quite differently, in the discussions that accompanied the exercises, it was noted that the very process of implementing inspections over an extended period of time would increase inspectors’ insights into the normal activities underway in the inspected country. Against that backdrop, it would become easier over time to detect anomalous behavior or activities that could be indications of non-compliance with an agreement.

Most broadly, the exercises also repeatedly demonstrated the *shared interest of both inspectors and hosts in effective verification* of nuclear disarmament. Even so, they also revealed differences in the perspectives of inspectors and hosts on specific issues, from the scope and content of declarations to the implementation of different PPTT. Greater host circumspection often reflected the need to protect sensitive information and the overriding demands of ensuring the safety and security of nuclear weapons. In that regard, however, exercises repeatedly demonstrated that multilateral verification of nuclear disarmament, with participation of both personnel from countries with and without nuclear weapons, can be made to work while protecting sensitive information.

Implications of Reductions to Zero. The focus of the Partnership's work on verification of reductions until recently has been on reducing nuclear warheads from one number to a lower number. As greater attention is focused on reductions to zero nuclear warheads, the sets of options for monitoring and inspection PPTT will continue to provide the basic verification toolkit. At the same time, additional analysis will be needed on how an end point of zero nuclear warheads could impact the choice and implementation of PPTT monitoring and inspection options and the resultant overall verification regime during the process of reductions to zero.

At one level, it could do so at the margin, for example, creating a heightened requirement for continuous perimeter portal monitoring of storage or dismantlement sites to increase confidence that nuclear warheads have not been clandestinely diverted. It could do so more fundamentally, for example, by creating a new or at least greatly increased need to include verification of absence within a reductions verification regime. Again, the purpose would be to increase confidence that no undeclared nuclear warheads have been retained or no undeclared production of nuclear warheads is occuring within declared activities or at a clandestine site.

At a different level, over time, reductions to zero will entail reduced activity ultimately resulting in a cessation of activity across Ipindovia's nuclear weapons enterprise. To take a few examples, deployment bases will be closed; movement and transport of nuclear warheads will decline; maintenance, refurbishment, and other activities at R&D and production sites and facilities first will decline and ultimately those sites will be shut down if not disassembled. These changes would need to be declared under the treaty and monitored by the inspection body. In some cases, these changes would call for specific additional types of inspections, for example, close-out inspections of a shutdown base or facility. Overall, this process of change over time would impact the design, burden, and implementation of the verification regime.

Suffice it now only to identify this issue. As the Partnership's work on reductions to zero continues, this will become an important area for future analysis.

Applying the Verification Toolkit: The Limitations Scenario

Initially in Phase II and now in greater detail in Phase III, the Partnership has also addressed nuclear disarmament verification in what it has termed the Limitations Scenario. To recall, in the Limitations Scenario, Ipindovia is obligated to declare all the nuclear warheads in its stockpile and to maintain that stockpile at an agreed common limit of no more than 500 nuclear warheads for a 20-year time period. As in the discussion of applying the verification toolkit in the Reductions Scenario, this section begins with some assumptions that have guided the analysis. It then turns to a discussion of declarations as well as monitoring and inspection options. However, given that the work of the Partnership until now has focused considerably more detailed attention on the Reductions Scenario, the following discussion provides only an initial introduction to verification of limitations.

Assumptions in the Partnership Analysis. Given that verified nuclear dismantlement is not involved, only some but not all of the assumptions that guide the Partnership on verification of limitations are the same as for reductions. Assumptions include:

- Ipindovia's nuclear deterrent comprises the full set of deployed nuclear weapons described in the Basic Scenario.
- Ipindovia has an active nuclear deterrent and nuclear weapons enterprise, with:
  - Operational movements of nuclear submarines and road-mobile ICBMs (making them possibly inaccessible for extended periods of time and, therefore, not available for inspection)
  - The transport of nuclear warheads from deployment sites to storage
  - The replacement and refurbishment of all warheads twice over the 20-year period.
- To protect proliferation-related and other sensitive information, inspectors would make no direct visual observation of the nuclear warhead (to be presented to inspectors in a container) or the internal configuration of nuclear warhead containers.
- The nuclear disarmament agreement would set out the specific procedures, equipment, and other requirements for monitoring and inspection activities.
- Inspections would be subject to managed access procedures that protect sensitive information but ensure that inspectors can accomplish their tasks.
- If used, radiation detection technologies would entail using an Information Barrier system unless otherwise determined.
- Verification would be conducted by a multilateral entity, with inspectors from countries with and without nuclear weapons.

Given the above assumptions, three challenges stand out in the Limitations Scenario. First, it will be necessary to keep track of individual warheads in an active nuclear weapons program in which movement of nuclear warheads from one location to another occurs as well as the refurbishment and replacement of nuclear warheads over the duration of the agreement. Second, as part of that process, some warheads are likely to be unavailable for inspection at different times. Third, verification of absence of any undeclared "excess" warheads over and above the agreed common limit or undeclared production of warheads will be especially important.

Illustrative Initial and Baseline Declaration: Limitations Scenario

- Total number, types, and locations of nuclear warheads currently in Ipindovia and their status (deployed/non-deployed; active/inactive; reserve/maintenance; in storage; assigned for refurbishment/dismantlement)
- The location and types (with site diagrams) of all operational nuclear weapon bases and storage sites
- The location and types of nuclear warhead production/refurbishment facilities and nuclear sites within them (with site diagrams)
- Unique identifying characteristics of containerized nuclear warheads and delivery systems along with photographs of delivery systems and containers

Declarations and Notifications in a Limitations Agreement. Under the Limitations Scenario, the verifying entity must be able to determine a total number of nuclear weapons in Ipindovia. Thus, verifying the absence of undeclared nuclear warheads, including any undeclared production, in Ipindovia as a whole would be a key objective. Doing so entails a focus on first, verifying that all nuclear warheads in Ipindovia have been declared; second, that no undeclared nuclear-weapons-related facilities exist; and third, that no nuclear warheads exist outside of declared locations.

The Initial Declaration made during negotiations followed by the *Baseline Declaration* after EIF again would provide the verification starting point. They would provide as comprehensive a picture as possible of Ipindovia's overall nuclear enterprise, from production to deployment to replacement-refurbishment-dismantlement. Other information would include photographs of objects to be inspected as well as site diagrams. (This information is consistent with that required for verification of reductions.)

In addition, *periodic updates and incident-driven notifications* would provide information about changes in status, typified by moving, converting, refurbishing, or eliminating nuclear warheads subject to the agreement as Ipindovia operates and sustains its overall nuclear weapons enterprise. These updates and incident-driven notifications would provide the basis for both recurring data confirmation inspections and short-notice inspections. Timeliness of both periodic updates and notifications would be specified in the agreement and would depend on the specific changes to be reported as well as security considerations.[17]

Illustrative Periodic Notifications: Limitations Scenario

- Movement of nuclear warheads from
  - Deployment bases to central storage
  - Central storage to deployment bases
  - Central storage to refurbishment facility
- Refurbishment facility to central storage
- Movement of nuclear warheads and delivery vehicles between bases

Baseline Inspections in a Limitations Scenario. Baseline inspections would again be used to determine the accuracy and completeness of the data provided in the Baseline Declaration. Based on historical experience, the initial period after EIF would likely see a large number of inspections as compared to the ongoing implementation of the agreement in later years. Inspection cost, concerns about non-interference, and the numbers of sites/warheads possibly subject to inspection would constrain detailed verification of all the information provided, especially in a short period of time.

At the least, the goal should be to check the UIDs on all available nuclear warheads (recalling that warheads deployed on submarines at sea would not be available for inspection). In addition, further inspection activities would be conducted for a reasonable sample of treaty-accountable items to confirm the declared data more comprehensively. The more specific options for monitoring and inspection PPTT are comparable to those that are available for baseline inspections in the Reductions Scenario. However, given the need to verify absence, the initial baseline inspections will be extremely important in establishing a background against which to detect anomalous behavior.

Options for Monitoring and Inspecting Declared Sites and Steady-State Activities in a Limitations Regime. Visual observation with managed access will be the principal monitoring and inspection

[17] For example, the Limitations Working Group currently assumes that there would be monthly notifications of the movement during the previous month of nuclear warheads between sites.

Baseline Inspections Options: Limitations Scenario

- Visual observation with managed access to confirm baseline data
- Possible use of radiation measurement equipment
- Measurement and photos by host on behalf of inspectors of items subject to the agreement
- Possible confirmation of UIDs on delivery vehicles and nuclear warhead containers
- Confirmation of site diagrams
- Exhibitions and displays of items subject to the agreement by host

option for declared sites for purposes ranging from confirming the number of warheads on a delivery vehicle to visually checking UIDs on delivery vehicles. Radiation measurement techniques also are an option whether to confirm numbers of nuclear warheads loaded on given systems or the non-nuclear nature of items loaded on delivery systems and located at declared sites. In addition, given the ongoing movement within Ipindovia's nuclear posture, monitoring and inspecting delivery vehicles will remain a very important tool for keeping track of nuclear warheads and nuclear warhead numbers.

As in the case of verification of reductions, however, time and numbers will affect the monitoring and inspection process. It would not be possible to visually check, let alone measure, everything everywhere during an inspection visit. The monitoring and inspection regime will likely have to depend on using sampling strategies, including statistical methods to randomly select what to inspect, in choosing how to allocate limited inspection quotas, time, and resources. That said, over time, repeated visits will increase the amount of information collected through inspections, provide a better understanding of steady-state operations, and help to identify anomalies of potential verification concern.

In addition, in the Limitations Scenario, Ipindovia may decide to dismantle and eliminate some nuclear weapons. The same set of PPTT options used to verify dismantlement in the Reductions Scenario would apply.

Verification PPTT Options for Declared Sites and Activities: Limitations Scenario

- Visual observation and checking with managed access to confirm that items satisfy declared criteria
- Visual observation to confirm number of warheads and/or confirm empty launchers
- Visual observation to confirm facilities empty
- Visual observation to confirm heavy bomber loadings, structures
- Use radiation measurement equipment to confirm presence of nuclear warhead
- Visually check UIDs
- Confirm site diagrams
- Confirm non-nuclear status using radiation detection equipment
- Visually check items being inspected with previously provided/taken photographs

Options for Verification of Absence of Undeclared Warheads and Undeclared Production. Inspectors would need to verify absence of nuclear warheads in a number of specific situations under the Limitations Scenario. These include confirming absence of undeclared warheads on declared sites; confirming absence of any undeclared warheads on an undeclared site; and confirming absence of undeclared production (whether at a declared site or an undeclared site) and associated undeclared nuclear warheads.

The Partnership's analysis of possible options for monitoring and inspection PPTT for confirming absence of non-declared nuclear warheads begins from the fact that the relatively small size of a nuclear warhead means that the range of locations in which *a non-declared nuclear warhead* could be located is in principle practically limitless. In practice, safety, security, and environmental requirements would limit the potential locations usable for storing non-declared warheads. Nonetheless, the number of plausible locations still would be too large to be able to inspect every possible suspect location for the presence of undeclared warheads.

In turn, specific safety, security, and operational requirements for nuclear weapons would limit the number of locations at which *undeclared production* outside of an existing production facility could occur. But the number of possible locations again would make it difficult to address all such undeclared production locations via inspections.

Given the above constraints, key to verification of absence is on the one hand, ensuring that no location is formally exempted from inspections and on the other hand, acceptance that in practice there would be limits on what sites could be inspected. This approach is summed up by the concept of "everything at risk at all times." Through it, effective deterrence of undeclared activities can be achieved.

Implementing this concept would require that the monitoring and inspection regime include a *quota system for "challenge-type" inspections*—whether aimed at undeclared items on declared sites, undeclared items at other sites, or undeclared nuclear weapons production at a declared or an undeclared locations. For Ipindovia as an inspected party, such a quota system would need to be coupled to procedural and legal safeguards that would limit the risk of frivolous or deliberately disruptive inspections. For the inspecting entity, using a number of specific parameters linked to the "suitability" (e.g., because of security, proximity to military locations with delivery vehicles, infrastructure) of any given site in Ipindovia being part of undeclared retention or production of nuclear warheads would avoid unrealistic inspection burdens. For the inspecting party, recourse to

Verification Options for Absence of Undeclared Warheads: Limitations Scenario

- "Everything at risk at all times"
- Challenge-type inspections (with quotas, procedural and legal safeguards, and managed access) of
  - Suspect areas on declared sites
  - Undeclared locations
- Measurement with radiation detection equipment to confirm absence of SNM
- Reliance on national and other multilateral measures: open source, national technical means, and commercial satellite imagery

statistical methods and random sampling strategies likely would also partly underlie its use of such a quota system for "challenge-type inspections."[18]

Nonetheless, verification of the absence of nuclear warheads or undeclared production at undeclared locations will not be practicable or feasible without significant help from unilateral means of monitoring. National and other multilateral measures, including but not limited to national technical means of states parties and access to commercial satellite imagery by a multilateral inspection entity, will be necessary to supplement information yielded by declarations and inspections as well as to help direct inspection activities to sites of most concern.

Insights from a Tabletop Exercise. As in its work on verification of reductions, the Partnership refined its analysis of limitations through a tabletop exercise conducted in December 2018 based on the verification mechanism of the Conventional Forces in Europe (CFE) Treaty. (The CFE verification regime included quota inspections to detect undeclared activities.) This exercise reinforced the conclusion that it should be possible to credibly, practically, and effectively verify the absence of undeclared items or activities in a state. At the same time, as discussed initially in this report, absolute certainty that no undeclared nuclear warheads exist is not attainable.

The Importance of "Thinking Strategically" in Refining the Verification Toolkit

The importance of "thinking strategically" about nuclear disarmament verification stands out as a cross-cutting conclusion from the Partnership's work over the past decade on verification of reductions and limitations of nuclear warheads. By way of concluding this section of the report, some key next steps in "thinking strategically" are briefly summarized.

Focus on a Multi-State, Multi-Warhead, Multi-Site, Multi-Year Process. There is a need to focus explicitly on the verification of either nuclear warhead reductions or nuclear warhead limitations as a multi-State, multi-warhead, multi-site, multi-year process—as it would be. Doing so has been implicit in the Partnership's concept of building verification confidence through a continual set of monitoring and inspection activities carried out over time. An explicit focus going forward on this dimension would provide a framework for thinking through the challenges of allocating monitoring and inspection resources in an overall verification strategy, whether, for example, annual quotas of inspections among sites, what is to be done with available time on-site in any given inspection, and how to most effectively integrate different specific monitoring and inspection PPTT.

Develop and Test a Systems Approach. Developing a systems approach is needed to inform judgments about how best to use limited monitoring and inspection resources in verification of nuclear reductions or limitations.19 As now being pursued by the Partnership's work, a systems approach would define Ipindovia's full nuclear weapons enterprise as a series of sub-systems representing key capabilities: deployed nuclear weapons; supporting nuclear weapons infrastructure, and operations and processes involving nuclear warheads (including operational warhead movement among the sub-systems) covered by the Reductions and Limitations Scenarios. It also would set out from the perspectives of both the host and the inspectors how various sub-systems of the enterprise should operate under treaty requirements, possible identification and assessment of diversion

[18] On random sampling and ways to enhance its effectiveness, see "Paper 2. Evaluating Confidence in Compliance: Methods to Evaluate Random Selection Approaches and Confidence Building Statistics," in Working Group 4, Verification of Nuclear Weapons Declarations.

[19] For the Partnership's ongoing work on the elements and application of a Systems Approach, see Systems Approach to Nuclear Disarmament Verification: https://portal.ipndv.org/file-post/systems-approach-to-nuclear-disarmament-verification/; Systems Approach Paper from 2021 (ITG): https://portal.ipndv.org/file-post/systems-approach-paper-draft-10-2/.

> "In a time when geopolitical tensions are on the rise, the Partnership is clear evidence that countries do have shared goals, and when we can identify them, there are opportunities to work together."
>
> **SCOTT ROECKER | Vice President, Nuclear Materials Security, Nuclear Threat Initiative | UNITED STATES**

pathways within each of the sub-systems for clandestine access to nuclear warheads, and sub-system specific verification objectives and associated monitoring and inspection means to counter such pathways. Such a systems approach would directly support decision making regarding how to distribute verification resources, including as an input into a statistical approach.

Efficient and Effective Uses of Technology. The work of the Partnership, as highlighted above, has identified many potential verification technologies. Thinking strategically also would assess at which step(s) of the dismantlement process each verification technology could be used most efficiently and how technologies could be combined most effectively.

Assess and Test a Statistical Approach. In nuclear disarmament verification, a gap between possible verification "targets" and available monitoring and inspection resources needs to be taken as a given. Analysis and exercises have emphasized that a statistical approach will be an essential element of making resource allocation choices to build verification confidence over time. As a next step, therefore, the Partnership has begun to explore in detail using a statistical approach to determine how to use a limited set of inspections to provide increasing confidence that in the Limitations Scenario, Ipindovia's active nuclear weapons enterprise remains below the 500 nuclear warhead limit.

Identify Priority Gaps in the Verification Toolkit. "Thinking strategically" about nuclear disarmament verification also should help shape future priorities for conceptual and technological initiatives to fill gaps identified in the verification toolkit set out in this section. The type of work just described on a systems approach and a statistical approach are two examples. More detailed work on the requirements for Information Barriers and how to meet them in support of technical monitoring either of reductions or limitations is another. Section V below comprises a discussion of future analytic, exercise, and technology assessment-development priorities.

Section IV. Capacity Building through the Partnership

The belief that all countries, both with and without nuclear weapons, have a stake and a role to play in the verification of nuclear disarmament is fundamental to the Partnership. An effective verification regime not only serves the interest of parties to future agreements but also enhances global security and order in the interest of all countries. Multilateral verification also is needed to build confidence and provide assurance to countries without nuclear weapons in the nuclear disarmament process. Given the complexity of nuclear disarmament verification, moreover, drawing on the expertise of a group of concerned countries through the type of international process represented by the Partnership has been and remains essential to sustained progress. For multilateral nuclear disarmament verification to succeed in the future, however, it also is essential to continue to build national and international analytic and technical capacity to support the verification process. The Partnership has done and continues to do so in several different ways.

Joining Together for Cooperative Problem Solving. The Partnership *working group process* has brought together a diverse group of experts to address challenges and solutions to nuclear disarmament verification. The virtual and in-person meetings of the Working Groups have built capacity as experts exchanged ideas and worked together to build the conceptual and technical verification toolkit set out above. That cooperative effort is evidenced in the Partnership and working group reports and papers produced by the Partners during the past 10 years. Sustaining and advancing this work during the COVID-19 pandemic through virtual meetings demonstrated the commitment of the Partners to cooperative problem solving and led to important substantive accomplishments.

Capacity Building through Exercises and Technology Demonstrations. The series of verification exercises carried out by the Partnership and Partner countries also have been essential to the Partnership's knowledge- and capacity-building role. By participating in exercises, individual experts are able to apply and test the verification approaches and concepts that have been developed by them on paper. One result has been a deepened understanding of approaches to nuclear disarmament verification. Participation in technology demonstrations has offered an opportunity for Partner countries not only to test their own technologies and systems but also to interact with and learn more about the technologies of others. In turn, exercises and demonstrations have helped to identify gaps in knowledge and technical capabilities, leading to efforts to address both. Not least, the exercises and demonstrations have strengthened trust, goodwill, and community among the Partners.

Encouraging National Initiatives. In addition, the Partnership process has encouraged *parallel national efforts* to address nuclear disarmament verification to provide analytic and technical inputs into that process. In that regard, national initiatives by Partners to assess and demonstrate specific nuclear disarmament verification technologies have been especially important. Other national initiatives involved designing and executing exercises to help test propositions developed in the Partnership working group process. These activities both helped build national capacity and contributed to the Partnership knowledge base.

An International Resource. In at least three different ways, the Partnership also has been a resource for international capacity building for nuclear disarmament verification. As members of the "Group of Governmental Experts (GGE) to further consider nuclear disarmament verification issues" established by the United Nations General Assembly, experts from Partner countries contributed *insights from the Partnership to the discussions within the GGE* both in individual interventions and in more

“The IPNDV has proven that dialogue between nuclear and non-nuclear weapon states is necessary to come up with innovative disarmament verification solutions. As long as this dialogue continues, we are getting better prepared for the day when these solutions will be used.”

DR. IRMIE NIEMEYER | Head of Nuclear Safeguards and Security, Forschungszentrum Jülich | GERMANY

“The IPNDV has managed to maintain a teamwork approach with diverse voices and diverse players toward a common problem, which is how we build trust, capacity, and understanding of verification challenges.”

MALLORY STEWART | Assistant Secretary, Bureau of Arms Control, Deterrence, and Stability, U.S. Department of State | UNITED STATES

formal working papers. In that regard, the report of the GGE highlighted the value of learning lessons from the Partnership as well as the value of exercises as a way to build capacity in nuclear disarmament verification.[20] In turn, the Partnership's work has been highlighted through extensive outreach activities within academic and professional communities, as exemplified by periodic panels at the annual meeting of the Institute for Nuclear Materials Management and at a meeting of the European Safeguards Research and Development Association.

In addition, the IPNDV website (www.ipndv.org) *houses papers and reports* on a broad set of nuclear disarmament verification issues. Many of these papers break new ground in thinking about the conceptual challenges of verification and in suggesting responses to them. Other papers speak to the different elements of a verification toolkit. Of special note, the website includes an interactive infographic that helps visitors visualize the steps, tools, and technologies conceptualized by the Partners.

The Partnership serves as an international resource for countries, members of non-governmental organizations (NGOs) and civil society, and experts and interested individuals in the wider public of countries learning and thinking about nuclear disarmament verification. The Partnership is a *compelling model of how states with and without nuclear weapons can cooperate* to build the foundations for future multilateral nuclear disarmament verification. The results of that cooperation also serve as a partial proof-of-principle of multilateral verification.

[20] See Final Report of the Group of Governmental Experts to Further Consider Nuclear Disarmament Verification, A/78/120, June 23, 2023, pp. 16, 23, https://meetings.unoda.org/GGE-NDV/group-governmental-experts-nuclear-disarmament-verification-2022.

Section V. Defining an Agenda for Continuing Work on Nuclear Disarmament Verification

The preceding sections describe the accomplishments of the IPNDV during the past decade in addressing and developing solutions to the challenges of nuclear disarmament verification. Against that backdrop, this section sketches some options for future work. Work has already begun by the Working Groups to address some of these options; others could be addressed prior to the conclusion of Phase III in 2025. Given resources, what follows should be regarded as a "menu" of options for future work.

Refining Verification Concepts

Developing concepts and approaches for nuclear disarmament verification remains central to the IPNDV. Several possible options for future work already have been identified.

Verification of Absence. As noted above, verification of the absence of undeclared nuclear warheads, undeclared nuclear warhead production, or undeclared related activities would be essential to verification of limitations or reductions of nuclear warheads in a disarmament agreement. The Partners have begun to focus greater attention on this challenge. Going forward, a central focus will be how to implement in practice the basic principle of "everything at risk at all times." This would include detailed analysis of a possible "challenge inspection" regime and its implementation over time.

Multi-State, Multi-Warhead, Multi-Site, and Multi-Year Verification. The Partnership's work has highlighted the importance of approaching verification from a multi-state, multi-warhead, multi-site, and multi-year point of view. An inspection entity will need to allocate a limited number of annual inspections, of different types, in pursuit of its objectives. In so doing, that entity will need to make choices and trade-offs regarding what to inspect, when, and how often. Both analysis of those choices and trade-offs as well as exercises (described below) are an option to take forward the existing IPNDV work.

Systems Approach. The IPNDV has identified the value of a systems approach for allocating most effectively available inspection resources, including making the trade-offs that are inherent in verification of nuclear disarmament. Current work focuses on defining the different processes and sub-systems that make up the "nuclear weapons enterprise" in Ipindovia, how those elements interact, what diversion pathways for non-compliance are inherent in them, and PPTT options to counter such diversion pathways. Completing that work is one next step. Once completed, a possible further step would be to use that systems approach in a deeper dive exploring how to allocate monitoring and inspection options to reduce the risk of diversion in the Reductions and Limitations Scenarios.

Building Verification Confidence. Many different factors, as summarized above, can contribute to building verification confidence. Against that background, one next step now underway is to explore in-depth how the make-up or composition of inspection teams can affect the confidence of officials and publics in the results of inspections. Another next step could be to distinguish among confidence on the part of different "audiences" (e.g., inspectors, an inspection entity, officials in parties to an agreement as well as among States not Party to it, and among experts and publics) and to think through what confidence factors are most important for which specific audience. In particular, it is important to think through how best to explain to government officials the verification processes and technologies identified and assessed by the IPNDV as well as their uses, limitations, and results.

Verification of Disposition. Within the 14-Step Model, it is envisaged that disposition of the SNM from dismantled nuclear warheads would involve processing to render the material unclassified. So far, the IPNDV has focused only limited attention on the issues associated with the verification of such processing. In particular, unlike for the other steps in the 14-Step Model, the possible PPTT for monitoring and inspecting disposition remain to be fully identified, refined, and tested. This option would seek to do so.

Applying Diversion Pathways Analysis. Work now underway to understand possible diversion options and more extensive diversion pathways that might be used to violate a nuclear disarmament agreement could be extended in several ways. One option would be to assess how the PPTT identified by the IPNDV could be most effectively used to shut down such pathways as well as the practicalities of doing so.

“There’s no shortage of work to be done on disarmament verification because there are always more angles to consider. We can apply the toolkit in increasingly complex and realistic scenarios to keep expanding our understanding and building capacity.”

MICHAEL EDINGER | Foreign Affairs Officer, Office of Multilateral and Nuclear Affairs, U.S. Department of State | UNITED STATES

Another option would be to assess the implications of ongoing diversion pathway analysis for allocating inspection resources in a multi-state, multi-warhead, multi-site, multi-year verification process.

Data Management, Data Security, and Data Control Issues. Several of the exercises conducted by the IPNDV have identified the importance of data management, data security, and data control as part of the monitoring and inspection regime. An initial next step would be to explore more fully what types of data-related issues could arise. In turn, more specific questions that could be analyzed in the future range from how to protect the data generated during an inspection to what data will be available to officials and publics after an inspection.

Verification Technology Assessment and Use

Building on its continuing assessment of technologies for use in support of nuclear disarmament verification, reflected in Table 5 above, several possible options for future IPNDV work stand out. The Partners also need to engage with other work underway in parallel by outside entities.

The Next “Technology Campaign.” Led by Belgium, the Partnership has carried out two technology assessment campaigns that allowed individual Partners to test different types of radiation measurement technology. The most recent campaign in September 2023 focused on three

"themes": measurements to establish a nuclear warhead template as a basis for later measurement of containerized nuclear warheads; measurement to confirm the absence of SNM; and possible active neutron interrogation of containers with a nuclear object. The results will be shared beyond the IPNDV. Continuation of this ongoing series of technology campaigns, as well as work within the Technology Track to address remaining verification technology gaps, is one possible next step. As determined by the Technology Track, it could carry forward the above themes or address new issues.

"No Radiation Measurement" Options. As shown by Table 5 above, two categories of monitoring and inspection technologies assessed by the Technology Track address detecting the absence or presence of SNM using different types of radiation detection or measurement techniques. Given the constraints on use of such technologies, the possibility also has periodically been raised of assessing options that would not rely on radiation measurements for monitoring and inspecting different steps in the 14-Step Model of nuclear dismantlement. Such options would rely instead on using combinations of tags, seals, and UIDs to sustain chain of custody over containerized nuclear warheads to be dismantled, visual inspection of relevant sites subject to managed access procedures, and reliance on Perimenter Portal Monitoring (PPM). This analysis would do so.

Engaging Non-IPNDV Work on Verification Technologies. Depending on the specific scenario, as discussed above, using radiation measurement technologies may require using an Information Barrier. In addition, developing and using verification technologies will require that the authentication and certification of inspection equipment be addressed to provide confidence to both the inspected State and the inspecting entity that such equipment provides only the information agreed and that it has not been tampered with. In parallel with the IPNDV, the U.S. Department of State has sponsored work in each area. Going forward, the Partnership can both shape that work and leverage its results as part of its overall answer to the challenges of nuclear disarmament verification.

Nuclear Disarmament Verification Exercises

Since Phase I, exercises have proved an effective means to develop, refine, evaluate, and test concepts and approaches for nuclear disarmament verification. Future work by the Partners should again make use of

Credit: Forschungszentrum Jülich / Tobias Schlößer

“The exercises have been very helpful in building mutual understanding across disciplines. They create a rare opportunity for diplomats to engage in practical technical issues, and for technical experts to consider the policy perspective.”

NICO VAN XANTEN | Senior Strategy Advisor, Authority for Nuclear Safety and Radiation Protection | THE NETHERLANDS

exercises for those purposes. Several possible options for future exercises can be identified and serve to illustrate this basket.

Verification of Absence Exercise. An exercise could be used to evaluate and test the results of analytic work, referenced above, on the verification of absence. Using the Ipindovia Limitations Scenario, for example, an exercise could focus on the one hand, on how an inspecting entity could allocate and implement challenge inspections over a three-year period and on the other hand, on how a country seeking to retain undeclared warheads could seek to defeat such an inspections process. Lessons would be drawn for implementation of the “everything at risk at all times” principle.

Implementing a Multi-State, Multi-Warhead, Multi-Site, Multi-Year Inspection Process. This exercise could focus on the choices and trade-offs involved in implementing the PPTT options in a multi-state, multi-warhead, multi-site, and multi-year process. Within the framework of either the Ipindovia Reductions or Limitations Scenario, it could posit that a Planning Cell of the inspection entity had begun planning for implementing inspection quotas for years 1–3 of the NWRT. In addition to exploring choices and trade-offs, this exercise could consider the implications of different choices and trade-offs for verification confidence.

Technology Development Five-Year Priorities. In this option, the IPNDV technical and policy experts could jointly explore technology development priorities in light of the IPNDV scenarios. One way to do so would be to posit that a future group of technical and policy experts had been convened to assess priorities for developing technologies to support nuclear disarmament verification. Specifically, their responsibility would be to develop a list of possible priorities for verification technology development over the ensuing five-year period, the logic behind such a list, the challenges to implementing those priorities, and ways to overcome those challenges.

Restoring Chain of Custody. The IPNDV has identified sustaining chain of custody in the dismantlement process over nuclear warheads and SNM as the backbone of effective verification. The Partners also have acknowledged that disruptive contingencies outside the control of either the inspectors or the host country may result in breaches of chain of custody. This exercise would posit specific breakdowns of chain of custody then explore responses by the inspectors and host country.

Integrating PPTT in a Cohesive Verification Regime. As highlighted above in the discussion of “thinking strategically,” additional thought is needed regarding how to integrate different monitoring and inspection PPTT into an overall effective verification regime. One possible approach would combine analytic work within the Working Groups and Technology Track with specific verification exercises.

Section VI. Key Judgment: Enabling Multilateral Verification of Future Nuclear Disarmament

This report has described the work of the Partnership in the decade since its creation. At the end of Phase I, the Partnership affirmed in November 2017 as a key judgment that multilaterally monitored nuclear warhead dismantlement should be possible while successfully managing safety, security, non-proliferation, and classification concerns.[21] It did so again at the end of Phase II. Based on the work summarized in this report, that key judgment can be strongly reaffirmed but also extended:

[21] *Phase I Summary Report: Creating the Verification Building Blocks for Future Nuclear Disarmament*, November 2017, p. 4, https://www.ipndv.org/reports-analysis/phase-1-summary/.

“The IPNDV’s consistent and effective work will undoubtedly aid in our collective fight to reduce current nuclear dangers and facilitate future arms control and disarmament efforts.”

AMBASSADOR BONNIE JENKINS | U.S. Under Secretary of State for Arms Control and International Security | UNITED STATES

The Partnership has successfully identified a substantial toolkit of declarations as well as monitoring and inspection processes, procedures, techniques, and technologies (including, as needed, information barriers) to verify the reduction and dismantlement of nuclear warheads or limitations on nuclear warheads. Alhough additional conceptual and technology development work remains to be done, the Partnership’s results should provide a path forward to multilaterally verified nuclear disarmament while effectively managing safety, security, non-proliferation, and classification concerns.

More specifically, in achieving this result, the Partnership has successfully:

- Developed a set of verification concepts and models to guide the development and implementation of nuclear disarmament verification regimes
- Identified, assessed, and in key instances tested through demonstrations and exercises a broad spectrum of verification measures and technology options for use in meeting monitoring and inspection requirements in either the dismantlement of nuclear warheads as part of a process of nuclear reductions or limitations on the number of nuclear warheads
- Identified and tested a set of managed access procedures to ensure that proliferation-sensitive and other sensitive information is effectively protected during nuclear disarmament verification
- Built necessary international capacity as a foundation for multilateral verification and reflecting a recognition that every country has a potential role in the verification of future nuclear disarmament agreements
- Continually adapted its activities to address new issues and problems, thereby carrying forward its decade-long founding goal and mission to understand the technical and procedural challenges to the effective verification of nuclear disarmament and to develop practical solutions for those challenges.

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Learn more at www.IPNDV.org

The IPNDV website is home to numerous reports and educational resources that capture the knowledge and analysis produced by the Partnership over a decade of working group meetings, exercises, and technology demonstrations.

Reports and analysis

Dismantlement Interactive

Information about related initiatives

The **International Partnership for Nuclear Disarmament Verification (IPNDV)** is an ongoing initiative that includes 30 countries with and without nuclear weapons. Together, the Partners are identifying challenges associated with nuclear disarmament verification and developing potential procedures and technologies to address those challenges.

The IPNDV is working to identify critical gaps and technical challenges associated with monitoring and verifying nuclear disarmament. To do this, the Partnership assesses monitoring and verification issues across the nuclear weapon lifecycle.

The IPNDV is also building and diversifying international capacity and expertise on nuclear disarmament monitoring and verification. Through the Partnership, more countries understand the process, as well as the significant technical and procedural challenges that must be overcome. At the same time, the Partnership is highlighting the importance of verification in future reductions of nuclear weapons.

For more information, **visit www.ipndv.org**.

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