Portal Monitoring Considerations for Treaty Verification Applications

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What Is Portal Monitoring?

Portal monitoring is an arms control verification mechanism that can assist in verification of treaty accountable items (TAIs)[1]. Portal monitor technology spans a wide range of sensors, including radiation detectors, break beams, or weight sensors. Radiation-detecting portal monitors are able to confirm absence/presence of a radiological signature and to track direction of motion of items of interest. Portal monitoring uses measurements from strategically placed sensors (e.g., radiation detectors) to record the entry or egress of TAIs. The implementation of portal monitoring relies on three key elements: perimeter definition, portal location (singular or multiple), and sensor technology. It can be implemented in either time-bound or continuous operations depending on what is allowed under the terms of a given agreement.

[1] TAIs are those items specifically designated in an arms control agreement for accountability related to a given limit or prohibition. Examples could include nuclear warheads/ components, facilities, or delivery vehicles as defined by the relevant agreement.

Figure 1: Vehicle portal monitor (credit: NNSA Nevada Site Office Photo Library); hallway Portal Monitor for Authentication and Certification (PMAC) showing two modules with tamper-indicating enclosure removed (credit: Sandia National Laboratories)

Portal Monitoring Methods and Techniques

Perimeter Definition

The first step in establishing portal monitoring capabilities is defining a perimeter of interest. The perimeter takes into account the inspecting party's objectives, as defined in the agreement, and the physical layout of the area. For example, a perimeter can be drawn at the outermost site boundary, around a building, or around a room. Determining an appropriate perimeter for useful portal monitoring is similar to the practice of the International Atomic Energy Agency in establishing a material balance area in order to track all material entering and leaving that given area and ensure that nuclear material is used only for peaceful purposes. Perimeter boundaries may or may not be visible or tangible (e.g., an infrared boundary, a boundary drawn on paper). A verification regime should consider methods for inspectors to confirm the perimeter boundary's integrity to ensure there are no openings for diversion of TAIs. In the interest of maximizing limited resources (time and cost), it is useful to employ existing host country infrastructure, such as a facility fence line, when possible.

Portal Location

After determining the perimeter of interest, portal locations can be selected. A portal is an intentional, declared opening in the perimeter boundary. The portal is monitored, with fixed or mobile sensors, and can take measurements of any items, people, or vehicles that pass through the portal. It is ideal to have as few portals as necessary to reduce the burden on both parties, and to also use existing host country infrastructure when possible (e.g., use of roads as egress points that already exist at the host site). Care must be taken, however, to have enough portals that host operations are not severely impacted, such as by increasing traffic wait times to an unrealistic level. It may also not be realistic to close host roads in order to create a portal control point.

Sensor Technology and Item Attributes

The final step in establishing portal monitoring capabilities is to consider the sensor technology and what attributes of the particular TAI it is necessary to measure and verify. Portal monitoring technology can range in size and can be unattended or attended by inspectors. The size range for radiation detectors spans from hand-held detectors to portals large enough to monitor whole vehicles and shipping containers. Other sensors could include break-beam technology, video cameras, radiography, radiofrequency identification (RFID) tag scanners, and weight sensors. The verification regime may also supplement technology in an attended monitoring scenario, including visual confirmation of TAI via unique identifiers (UIDs) as they pass through the portal.

To select portal monitoring technology, the inspecting entity should determine their priorities and needs, account for what is allowable in the agreement, and consider the operations, items, and activities occurring within the perimeter. For example, if there is no vehicle traffic through the perimeter, then large vehicle monitors would be unnecessary. The inspecting entity should also consider the amount, frequency, and type of data generated; data post-processing plans; and data transfer from the technology to the inspector (e.g., does the host need to review the data first or should an information barrier be mandated).

An additional concern for sensor selection is how the signal collected by a sensor(s) is mapped to an attribute of a TAI or the absence of an attribute. For example, if TAIs were defined as containing plutonium or uranium, a spectroscopic gamma detector could analyze the spectrum of an item passing through the monitor to determine if that item contains that given attribute. In this case, if the spectrum did not have the characteristics of a plutonium or uranium source, despite its radioactivity, the portal monitor would not record the passage of a TAI through the portal. Some other TAI attributes that could be considered for use in portal monitoring can include when the mass of an item exceeds a designated threshold, item shape (perhaps determined behind an information barrier), and UIDs.

Information Portal Monitoring Can Provide

Portal monitoring provides a useful tool for maintaining chain of custody over TAIs, during the inspectors' absence. Chain of custody may be employed during an on-site inspection, such as when the inspectors leave a facility at the end of the day, or in between on-site inspections or provision of periodic declarations. Portal monitoring can therefore be useful to track TAI movements, even in the inspectors' absence.

Advantages of Portal Monitoring

The greatest advantage of portal monitoring is the ability to hold prohibited host activities at risk of detection when inspectors cannot be present in person. Portal monitoring can also be scalable and its technology diverse, making it a flexible and customizable solution to meet inspector needs. Lastly, its level of intrusiveness can also be varied. During negotiations, the parties to an agreement would work together to identify when, how, and how often data from the portals should be transmitted to or otherwise obtained by inspectors. In some situations, only locally stored data may be permitted (for operational security reasons), requiring inspectors to verify data maintained under seal during each inspection at that site.

Technologies Used for Portal Monitoring

The types of technologies that can be used for portal monitoring are vast and diverse, and they will depend on the goals of the treaty. However, a commonly considered approach for verification of nuclear warheads or their components is radiation detection equipment. This equipment can detect and collect count rates, counts above a threshold, and radiation spectra. Additional technology can include vehicle scanners that use radiography to inspect spatial details of the contents of vehicles; break beams to indicate the presence of individuals within a portal, and weight or motion sensors to identify vehicles passing through. It may be important to verify the number of TAIs transported between sites, but this is challenging to do without inspecting the contents of the vehicles involved. For example, one method to account for the number of nuclear warheads in a vehicle passing through a portal monitor could involve the use of emitting tags (like RFIDs) that are logged by the portal monitor. However, these tags would be applied to the nuclear warhead containers rather than being affixed directly to the warheads directly. The automatic logging of tags could serve as an automated notification of TAIs passing through a portal. Additional chain of custody, challenge inspections, or portal monitor sensors may be used to increase confidence that each container with a logged UID truly contains a nuclear warhead.

Aside from technology types, it is also important to identify how the technology will be used. An autonomously operated portal monitoring system would be advantageous because it can provide a persistent remote monitoring option. However, autonomous operation adds significant complexity to false alarm handling and establishing data and equipment trust. Alternately, a portal monitor attended by inspectors could allow for the visual confirmation of UIDs or the number of items traveling through a portal in addition to any measurements made by the portal monitoring equipment.

Portal Monitoring Applications for the Ipindovia Scenario

For the Ipindovia scenario,[2] implementing portal monitoring as part of the overall treaty verification approach is determined by the objective of the agreement: either a limit on the total number of nuclear warheads, or a defined reduction in warheads over time. In either situation, four potential objectives were identified where inspector confidence could be improved by implementing portal monitoring. Table 1 provides more details of how portal monitors would be used for each scenario along with some key characteristics such as their location/positioning, and potential technology options. As with the use of scenarios in all of IPNDV's work, the purpose of the following scenario-based discussion is to illustrate and stimulate thinking about possible applications of portal monitoring as one element of the overall toolkit available for verification in future agreements. Its examples are not intended to predict how future negotiators might or might not make use of this particular tool.

Objective #1: Verify the Total Number of Nuclear Warheads in Ipindovia

Given that all nuclear warheads must undergo recurring maintenance activities during their lifetime, the central production/refurbishment site is the location of great interest for portal

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[2] IPNDV Basic Scenario, December 2022, https://www.ipndv.org/wp-content/uploads/2022/12/Ipindovia-Scenario_Streamlined-to-Circulate_copy-edited-mre_lad_MF-final.pdf.

monitoring. It is of interest in this example, as it supports verification in a limitations scenario where a state is obligated not to exceed a given total number of nuclear warheads. The site consists of three main areas:

(1) A central storage area

(2) A nuclear weapon production/refurbishment/dismantlement and storage area

(3) The non-accountable areas of the overall site

Only the first two locations should contain nuclear warheads or their components. Therefore, portal monitoring would only be an option for use around the perimeter of these two areas within the larger site. The use of portal monitors could verify each transport notification associated with central production site. The notification of movements provides information about the change in the number of nuclear warheads/components at the site, which supports verification of the total declared number of nuclear warheads.

Objective #2: Verify Number of Nuclear Warheads at a Single Facility or Site Subject to the Agreement

The utility and acceptability of portal monitoring as an option to verify the numbers of nuclear warheads at a single facility or site depends on the site and the operational activities underway at it. For instance, portal monitoring around a central storage site for nuclear warheads would assist in accounting for transportation of those warheads to and from that site, and of the verification of the number of warheads in storage. By contrast, there would be little verification value from deploying portal monitors at facilities like silo-based intercontinental ballistic missile (ICBM), submarine, or nuclear bomber bases. First, the geometry of establishing portal monitors to detect nuclear material within large vehicles like ballistic missile submarines or heavy bombers is likely not possible. Second, safety and security requirements mean that nuclear warheads are not routinely moved on and off such facilities with high frequency. Thus, in thinking about possible uses of portal monitoring it is important to recognize that operational realities will bound its use in any verification regime.

Objective #3: Verify the Absence of Undeclared Nuclear Warheads Subject to the Agreement

In addition to Objectives 1 and 2, portal monitoring or inspections can be used to verify that formerly declared sites (those that were formerly used for nuclear weapons-related activities but have since been decommissioned for such use) are not receiving undeclared nuclear warheads. This would be particularly so if elements of infrastructure needed for safe and secure storage remained for example. Portal monitoring at such sites could be a cost-effective way to verify that nuclear warheads do not enter these bases, and reduce or eliminate the need for inspectors to visit those locations.

Objective #4: Maintain Continuity of Knowledge During a Dismantlement Inspection Activity

During an inspection to confirm the dismantlement of nuclear warheads, strategically placed portal monitoring can provide confidence to inspectors that all nuclear material from such warheads remains within the accountable perimeter of the facility. This form of portal monitoring maintains the "continuity of knowledge" of all parts of the dismantled warheads until a new chain of custody is established through documentation; template matching; and/or the application of UIDs, tags, and tamper-indicating seals on the special nuclear material (SNM) storage containers. The use of portal monitoring was exercised in the German-French Nuclear Disarmament Verification Exercises (NuDiVe) held in 2019 and 2022.

It is important to acknowledge that some sites are too cumbersome to monitor for very little gain. For example, in the Ipindovia scenario, the Arendy Research Station, the diversity and dual-use nature of the facility's research would generate so much nuclear data on non-treaty-relevant research activities. The volume of non-treaty relevant data would be difficult to process in a timely and helpful manner and could actually decrease confidence through false alarms.

Challenges and Considerations for Implementing Portal Monitoring

Limitations of Portal Monitoring

Portal monitoring can only be effectively applied to facilities declared to contain TAIs that regularly move in and out of a location. In addition, to address the concern of potential undeclared facilities in the host country, other verification methods would need to be used in tandem. In addition, when establishing a portal monitoring system, it may be impacted by existing host infrastructure (or lack thereof) in the country, potentially including access to utilities such as power and communications. The agreed-upon level of intrusiveness as defined in the agreement can also affect the placement of the perimeter and portal monitors.

Technical Challenges of Portal Monitoring

While the option of portal monitoring is an important verification option, several key limitations should be understood. First, when collecting data from portal monitors, it is necessary to avoid collecting too much or too little data. A balance between what is useful and what can reasonably be analyzed will need to be identified. Second, false alarms from the monitoring equipment can be generated, such as a count rate alarm from unrelated radioactive material (e.g., naturally occurring radioactive material, individuals treated with medical radionuclides) passing through a portal; both parties should establish a process for handling false alarms, so they do not greatly undermine confidence. Third, the impact of shielding material or container type on detection probabilities should be considered. A final challenge for portal monitoring technology is defining characteristic differences in the detection signatures between TAIs and non-accountable items, or different TAI types without giving away sensitive information about the items. These and other limitations need to be duly considered when developing a portal monitoring strategy or solution.

Some General Questions to Consider When Assessing the Use of Portal Monitoring as a Verification Option

- How do differing timelines for the refurbishment of nuclear weapons and thus, their movement between sites in a given state impact portal monitoring?

- What are the trade-offs for drawing certain perimeters at certain facilities?
    - How does perimeter size, number, and location of portals affect inspector and host confidence in compliance?
- What are the trade-offs for using different portal monitor technologies/detection methods?
    - How does the efficiency of detection effect inspector confidence?
    - How will portal monitoring data be transferred to the inspecting entity?
    - How much data are expected?
    - When and at what frequency should data be released, processed, and evaluated?
    - What infrastructure may be necessary to transmit large data sets?
- What additional information is required to support portal monitoring use?
    - How does portal monitoring fit into the larger monitoring and verification strategy?
- Can a portal monitoring system distinguish between TAIs and non-accountable items that also have a radiological signature?
- How should both parties handle false positive alarms?
- How should both parties address portal monitoring technology that is broken?
    - How do inspectors verify that the portal monitoring is working correctly?
- For vehicle portal monitors, how important is it to determine the number of items in a vehicle? How feasible is this?

Table 1: Characteristics of Portal Monitoring for Different Verification Scenarios[3]

Scenario Verification Objective	Related Facility/ Activity	Portal Monitor Role	Portal Monitor Location/ Positioning	Technical Objectives	Technical Options	Operational Considerations
1. Verify total number of nuclear warheads in Ipindovia	Central production site includes production, storage, and dismantlement facilities	Supporting confirmation of notifications at the only facility that every TAI will visit	Vehicle Portal Monitor on primary entrance and exit from dismantlement and storage facilities	Detect containerized SNM as part of a nuclear warhead **and** Detect direction of movement **and** Detect undeclared entry/exits of warheads **and** Distinguish number of items in a vehicle during transport **and** Distinguish accountable and non-accountable items (components, waste stream)	Advanced portals with information barrier—gamma and neutron Radiography or visual: container size and shape	The most intrusive use of portal monitors will require host confidence in handling of sensitive information collected R&D at a facility includes use of nuclear material. Portal Monitor locations should be chosen to limit need to discriminate accountable and non-accountable items Is there a continuous inspector presence or is monitoring performed remotely?

[3] This table is meant to highlight the main considerations for portal monitoring usage for each objective and the main distinctions between them. In many cases, it is assumed that portal monitoring would only be a part of the full monitoring and verification regime.

2. Verify number of nuclear warheads subject to the agreement at a single facility or site	Nuclear warhead accounting occurring before and/or after transportation from one facility to another	Aids in verification of the number of warheads at a declared facility by confirming notifications of warheads entering and exiting	Vehicle portal monitor at entrance and exit to the storage facility of the declared site and land perimeter of declared site	Detect containerized SNM as part of a nuclear warhead **and** Detect direction of movement **and** Detect undeclared entry/exits of warheads **and** Distinguish number of items in a vehicle	Two portal monitors with gamma and neutron detection **or** one portal monitor (with gamma and neutron detection) and two break beams **Note:** UIDs and tags increase confidence in notifications[4]	Frequency of data exchange and notification timeline will impact efficacy Ability to distinguish false alarms is key to confidence in regime
3. Verify absence of undeclared nuclear warheads subject to the agreement	Facilities declared not to contain nuclear warheads	Detect radiation signatures in and out of the facility to alert inspectors to potential undeclared activity	Vehicle entrances	Detect anything above a threshold quantity of nuclear material **And maybe**: Detect direction of movement depending on site	Spectroscopic information Two portal monitors or one portal monitor and break beam if directionality is a priority	Can use more intrusive technologies to ensure detection of uranium-based items of concern Need no or only limited information barrier Response to alarms is critical; could involve secondary inspection for items flagged initially

[4] To distinguish the number of items through portal monitoring, UIDs would require more intrusive parameters, such as emitting a signal.

						Technical options depend on site priority and amount of site traffic This scenario includes a larger traffic stream, which may raise false alarm frequency from nuisance sources
4. Maintain continuity of knowledge during a dismantlement inspection activity	Dismantlement facility and other temporary verification inspections	Monitor internal boundary during sensitive activities	Corridors and doorways within a facility	Detect any radiation with a high probability (nuclear warhead, SNM components) in a prompt manner	Simple neutron and gamma detection Occupancy sensor Visual observation of inspectors	Nothing should be moving during this time Detectors have to be brought into the space—if it is staying in facility, maintain authentication and certification confidence Assume nuclear warhead/components will go through portal monitor and set it off, increase confidence through test sources

About IPNDV the International Partnership for Nuclear Disarmament Verification

The International Partnership for Nuclear Disarmament Verification (IPNDV) convenes countries with and without nuclear weapons to identify challenges associated with nuclear disarmament verification and develop potential procedures and technologies to address those challenges. The IPNDV was founded in 2014 by the U.S. Department of State and the Nuclear Threat Initiative. Learn more at www.ipndv.org.