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# NUCLEAR ARMS CONTROL

# U.S. May Face Challenges in Verifying Future Treaty Goals

Accessible Version

GAO-23-105698

# GAO Highlights

Highlights of GAO-23-105698, a report to congressional committees

September 2023

# NUCLEAR ARMS CONTROL

## U.S. May Face Challenges in Verifying Future Treaty Goals

## Why GAO Did This Study

New START limits the number of U.S. and Russian strategic delivery vehicles—such as intercontinental ballistic missiles (ICBM)—and the total number of nuclear weapons that each party is allowed to deploy on those vehicles. New START also details a collection of verification measures—such as inspections and the use of satellites—intended to provide confidence that parties are complying with treaty limits. The U.S. has sought to negotiate a New START successor with Russia and aspires to pursue future arms control with China.

The Senate report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2022 includes a provision for GAO to review technologies that could support verification of future nuclear arms control treaties. This report describes (1) U.S. goals and likely verification measures for future nuclear arms control treaties, including a successor to New START; (2) the extent NNSA has planned for or developed verification technologies to support future arms control goals; and (3) challenges stakeholders have identified to implementing verification measures to support future treaties.

GAO reviewed U.S. government plans and reports pertaining to nuclear arms control treaty verification, as well as relevant studies. GAO also interviewed 43 stakeholders, including U.S. government officials, representatives from the Department of Energy's national laboratories, and nuclear arms control experts.

View GAO-23-105698. For more information, contact Allison Bawden at (202) 512-3841 or bawdena@gao.gov.

## What GAO Found

New START, a treaty that limits U.S. and Russian strategic nuclear forces, will expire in 2026. The U.S. has established three goals for a nuclear arms control treaty with Russia to follow New START:

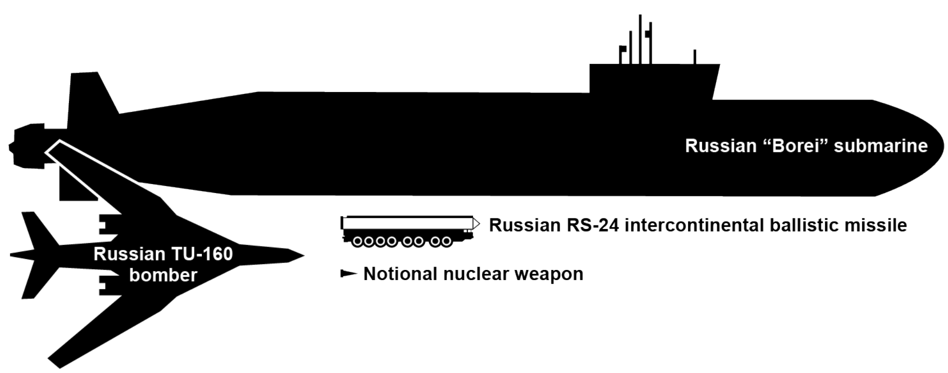
- Retain limits on systems capable of delivering nuclear weapons at intercontinental ranges, or "strategic delivery vehicles";
- Address all nuclear weapons, including nonstrategic nuclear weapons and weapons in storage; and
- Address new and novel Russian delivery vehicles, such as a nuclear-powered and nuclear-armed cruise missile.

According to U.S. officials, the measures for verifying compliance with a New START successor are likely to be similar to those employed for New START, including exchanges of data about deployed strategic delivery vehicles, inspections at relevant bases, and use of satellites. In the long term, the U.S. has aspirational goals—such as nuclear weapons reductions—that may require more extensive verification using more intrusive technologies.

The National Nuclear Security Administration (NNSA) has a plan for developing verification technologies that would support an array of possible treaty scenarios. NNSA's plan groups these technologies into three "approaches" based on increasing levels of intrusiveness and confidence in compliance. Officials stated that technologies in the first, "baseline" approach are largely proven or already used under New START and are ready to support a potential successor treaty. More intrusive technologies—such as devices to measure weapons' radiation signatures—would provide increased confidence in compliance and support longer-term treaty goals but may require 5 to 10 more years of development.

Stakeholders GAO interviewed and studies GAO reviewed noted likely challenges to verifying Russian compliance with future treaties that address U.S. nuclear arms control goals. For example, nuclear weapons are smaller than strategic delivery vehicles and would thus be harder to monitor using satellites. Verifying Russian compliance with limits on nonstrategic nuclear weapons may also be challenging, in part because many Russian nonstrategic delivery vehicles can carry nuclear or conventional weapons, making visual differentiation difficult.

**Size Comparison of Russian Strategic Delivery Vehicles to a Nuclear Weapon**




Sources: GAO analysis of publicly available information; and GAO (icons). | GAO-23-105698

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**Abbreviations List**

| | |
|---|---|
| 3G-TRIS | Third Generation Trusted Radiation Identification System |
| CNS | James Martin Center for Nonproliferation Studies |
| DNN | Office of Defense Nuclear Nonproliferation |
| DNN R&D | Office of Defense Nuclear Nonproliferation Research and Development |
| DOD | Department of Defense |
| DOE | Department of Energy |
| DTRA | Defense Threat Reduction Agency |
| ICBM | intercontinental ballistic missile |
| IPNDV | International Partnership for Nuclear Disarmament Verification |
| NNSA | National Nuclear Security Administration |
| NTM | national technical means |
| OSTP | Office of Science and Technology Policy |
| R&D | research and development |
| SLBM | submarine-launched ballistic missile |
| START | Strategic Arms Reduction Treaty |
| TRL | technology readiness level |

U.S. GOVERNMENT ACCOUNTABILITY OFFICE

441 G St. N.W.
Washington, DC 20548

September 28, 2023

The Honorable Jack Reed
Chairman
The Honorable Roger Wicker
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Mike Rogers
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

Beginning in the 1970s, the U.S. and Russia (then the Soviet Union) entered into arms control agreements that limited the number of vehicles[1] capable of delivering nuclear weapons, prohibited a category of vehicle capable of delivering nuclear weapons, and limited the number of nuclear weapons that could be on certain deployed delivery vehicles.[2] Since the 1980s, when the U.S. and Russia had a combined total of more than 60,000 nuclear weapons, the countries have dramatically reduced the sizes of their respective nuclear arsenals to less than 10,000 nuclear weapons today.[3] Arms control treaties support strategic stability by providing transparency into another party's nuclear force structure and capabilities. These treaties established verification measures—such as

[1]For the purposes of this report, we use the term "vehicle" or "delivery vehicle" to refer to systems capable of delivering nuclear weapons, such as missiles.

[2]Interim Agreement on Certain Measures With Respect to the Limitation of Strategic Offensive Arms, U.S.-U.S.S.R., May 26, 1972, 23 U.S.T. 3463; Treaty on the Elimination of Their Intermediate-Range and Shorter-Range Missiles, U.S.-U.S.S.R., Dec. 8, 1987, 27, I.L.M. 84; Treaty on Further Reduction and Limitation of Strategic Offensive Arms, U.S.-Russ., Jan. 3, 1993, S. Treaty Doc. No. 1, 103rd Cong., 1st Sess. (1993); Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, U.S.-Russ., Apr. 8, 2010, T.I.A.S. No. 11-205 (New START).

[3]For the purposes of this report, we use the term "nuclear weapon" to refer to any device capable of creating a nuclear explosion. This term includes nuclear warheads that can be placed on intercontinental range ballistic missiles (ICBM), submarine-launched ballistic missiles (SLBM) and other missiles. In addition, for this report, we use the term "nuclear weapon" to include nuclear bombs and any other forms of nuclear armaments.

on-site inspections—that have helped instill confidence that parties are complying with treaty limits and terms.

In February 2026, the last of these treaties between the U.S. and Russia—New START—will expire. If a new treaty or other agreement is not reached by then, the U.S. and Russia will lack any negotiated limits on their nuclear weapons and any agreed-upon measures to verify those limits. The resulting loss of transparency and predictability about Russian nuclear forces could motivate the U.S. to take steps to address or hedge against such uncertainty. For example, in its ratification of New START, the Senate said the treaty established predictability so that parties could plan based on reliable data about the other party's arms, thereby avoiding unsupported estimates that could lead to destabilizing strategic competition.[4]

New START entered into force for a 10-year period starting in February 2011, following nearly a year of negotiations between U.S. and Russian officials.[5] In 2020, the U.S. and Russia discussed a potential successor to New START but were unable to complete an agreement. In 2021, the U.S. agreed with Russia on a 5-year extension, the maximum extension permitted under the treaty, to maintain the predictability and transparency that New START provides and to give both sides time to explore future arms control steps. However, Russia ceased implementing some of its treaty obligations in 2022 and, in February 2023, Russia announced that it would suspend its participation in New START, citing U.S. support for Ukraine and other factors. The State Department has determined that Russia's purported suspension is legally invalid and that Russia is in violation of its obligations under the treaty. In March and June 2023, the U.S. responded to Russia's action by ceasing U.S. implementation of certain New START obligations, including verification measures, while pledging to work with Russia to resume implementation of the treaty.[6]

[4]Resolution of Advice and Consent to Ratification, S. Exec. Rept. No. 111-6 (2010).

[5]New START was signed in April 2010, shortly after the Strategic Arms Reduction Treaty (START) expired in December 2009. START, which the U.S. and the Soviet Union signed in 1991, limited each party to 1,600 deployed missiles and heavy bombers and 6,000 nuclear weapons attributed to those delivery vehicles.

[6]The State Department notes that these actions are fully consistent with international law and that they are proportionate, reversible, and meet all other legal requirements.

The Senate Armed Services Committee Report accompanying S. 2792, a bill for the National Defense Authorization Act for Fiscal Year 2022,[7] includes a provision for GAO to review U.S. nuclear weapons treaty verification capabilities.[8] This report describes (1) the goals and likely verification regimes the U.S. has identified for future nuclear arms control treaties,[9] (2) the extent to which the National Nuclear Security Administration (NNSA) has planned for or developed verification technologies to support goals for future nuclear arms control, and (3) challenges stakeholders have identified to implementing verification regimes to support future nuclear arms control treaties.

To conduct this work, we reviewed a variety of official documents on nuclear arms control treaties and verification, including the text of New START, the Senate Resolution of Advice and Consent to Ratification of New START, and Department of State annual reports on Russian compliance with New START. We also reviewed government plans and documents pertaining to nuclear arms control, including NNSA's plan for development of technologies that could support future treaty verification.

We interviewed a nongeneralizable selection of 43 relevant "stakeholders," which we use to refer collectively to individuals we selected for interview based on their status as (a) government officials working in nuclear arms control policy and technology development; (b) national laboratory representatives developing verification technologies; or (c) recognized experts in the field, including individuals involved in negotiating START and New START, or who serve or served as nuclear arms control experts for nongovernmental think tanks. We identified these stakeholders by contacting government agencies and nongovernmental organizations with nuclear arms control experience and asking them to identify other knowledgeable stakeholders. We reached out to these other knowledgeable stakeholders and interviewed those who responded and were willing to speak with us.

[7]S. Rep. No. 117-39 (2021).

[8]For the purposes of this report, we use the term "verification" to refer to both (1) the monitoring of a party's activities related to treaty limits through, for example, use of satellite imagery and on-site inspections; and (2) the verification of a party's compliance with treaty limits, which relevant agencies determine based on deliberations and outcomes of monitoring.

[9]For the purposes of this report, we define "verification regime" as the collection of cooperative and noncooperative verification measures that treaty parties use to gain confidence that parties are complying with treaty terms.

In addition, we reviewed studies that were recommended to us by stakeholders and conducted a literature search of studies—including government-produced studies and scholarly articles—pertaining to New START and the verification of nuclear arms control treaties since 2017. We used professional judgment to identify a selection of 38 studies for further review based on their relevance to our objectives. We identified challenges associated with the establishment and implementation of a possible New START successor treaty through (1) our interviews with stakeholders and (2) reviews of the relevant studies.[10] Additional details of our scope and methodology can be found in appendix I.

We conducted this performance audit from February 2022 to September 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

# Background

## New START Limits

New START limits each party's strategic delivery vehicles and nuclear weapons on those delivery vehicles. Specifically, the treaty limits each party to

[10]Throughout this report, we will say "several" when referring to a point made by five or more stakeholders or five or more studies, and "some" when referring to a point made by three to four stakeholders or three to four studies. If fewer than three stakeholders or studies made a given point, we will cite the specific number. Challenges we identified based on interviews we conducted and studies we reviewed are not generalizable to stakeholders we did not interview or studies we did not review for our report.

- 700 deployed strategic delivery vehicles—including submarine-launched ballistic missiles (SLBM), intercontinental ballistic missiles (ICBM), and nuclear-capable heavy bombers;[11]
- 1,550 nuclear weapons deployed on or counted for these strategic delivery vehicles;[12] and
- 800 deployed and nondeployed SLBM launchers, ICBM launchers, and nuclear-capable heavy bombers.[13]

New START does not limit all types of weapons. For example, the treaty does not address strategic nuclear weapons that are in storage but could be deployed on strategic delivery vehicles—nuclear weapons estimated to number in the thousands between the U.S. and Russia combined. In addition, the treaty does not limit nonstrategic nuclear weapons or their delivery vehicles. Nonstrategic nuclear weapons are nuclear weapons deployed on delivery vehicles with shorter ranges than strategic nuclear delivery vehicles. Russia in particular is believed to have up to 2,000 nonstrategic nuclear weapons, according to the 2022 Nuclear Posture Review.[14]

[11]For the purposes of this report, we use the term "strategic delivery vehicle" to refer to systems capable of delivering nuclear weapons at intercontinental ranges, namely ICBMs, SLBMs, and heavy bombers. A deployed strategic delivery vehicle means either (1) a bomber that has been equipped for nuclear armaments and is not for testing purposes or located at a repair or production facility or (2) an ICBM or SLBM that is contained in or on a deployed launcher. A deployed launcher is one that is not for testing or training purposes and is not located at a space launch facility.

[12]Some missiles may hold more than one nuclear weapon. For example, each U.S. ballistic missile submarine can carry up to 20 SLBMs, with each SLBM bearing multiple reentry vehicles, which can deliver nuclear weapons to different targets. Under New START counting rules, each reentry vehicle counts as one nuclear weapon. In contrast, although nuclear-capable bombers may also carry more than one weapon, each is counted as having a single nuclear weapon. The counting approach differs because missiles are deployed with a set number of reentry vehicles that can be counted on inspection, but bombers may carry a range of nuclear weapons and typically are not loaded until needed, so there is no specific number to verify upon inspection.

[13]Launchers are the missile tubes (such as a missile silo or launch tube on a submarine) or vehicles (such as for mobile ICBMs) that hold a missile. A launcher without a missile counts only as a nondeployed launcher; once loaded with a nuclear missile, it counts as (1) a deployed missile and (2) a deployed launcher. For example, a missile silo containing an ICBM would count as a deployed ICBM (1 of 700) and a deployed launcher (1 of 800), but if the ICBM were removed from the silo, the silo would then count only as a nondeployed launcher (1 of 800).

[14]According to the 2018 Nuclear Posture Review, the U.S. nonstrategic nuclear force consisted of a relatively small number of B61 gravity bombs.

## Verification Regime under New START

In order for treaty parties to have confidence that their counterparts are complying with treaty terms, the parties agree to the use of certain cooperative and noncooperative verification measures. Collectively, these measures are known as a “verification regime.” The New START verification regime does not involve counting all items limited under the treaty. Instead, it comprises a combination of verification measures that have enabled the U.S. to assess Russian compliance with the treaty and that provide transparency into Russian intercontinental-range nuclear forces and operations.

The verification regime detailed in New START includes the following measures:

- **National technical means (NTM)**. NTM consist of various technical means to collect information, including through satellites capable of providing high resolution imagery. NTM constitute noncooperative measures that have served as the foundation for arms control verification for decades, according to two experts we interviewed, including a former nuclear arms control treaty negotiator, as they allow monitoring of the strategic delivery vehicles at ICBM bases, submarine bases, and airfields. New START prohibits the parties from interfering with NTM and from using concealment measures to impede compliance verification by NTM.
- **Biannual data exchanges**. Twice per year, the U.S. and Russia are to exchange data on the number and locations of deployed strategic delivery vehicles and deployed and nondeployed launchers. For example, in 2022, Russia declared that it had 540 deployed strategic delivery vehicles, with 1,549 nuclear weapons on those deployed vehicles.[15] Additionally, both parties are to detail the total number of nuclear weapons across different types of deployed strategic delivery vehicles, as well as a total number of deployed strategic nuclear weapons at each declared location.
- **Ongoing notifications**. The treaty calls for the parties to notify each other of certain activities, such as when the status changes for deployed strategic delivery vehicles and launchers. For example, a notification is required if an ICBM is removed from a silo, at which

[15]The Department of State, *Report to Congress on the Implementation of the New START Treaty* (2023).

point it would no longer count against limits on deployed strategic delivery vehicles.[16] Incoming and outgoing notifications for U.S. treaties and agreements, including New START, are managed by State's National and Nuclear Risk Reduction Center.

- **Inspections**. The treaty allows U.S. and Russian teams to conduct 10 on-site inspections per year at bases to spot check declared information on deployed strategic delivery vehicles.[17] Inspections do not involve directly counting all delivery vehicles or nuclear weapons limited by the treaty at the base. Instead, inspections serve as spot checks that information included in data exchanges and notifications is accurate. The random selection of declared bases and deployed delivery vehicles for inspection helps to deter cheating. Over time, inspections help build each party's confidence in the accuracy of the information provided by the other party.

  Inspection teams can visit on short notice any declared site with deployed strategic delivery vehicles.[18] Once an inspection team is on site, the host party is to provide the team with a detailed list of the exact number of nuclear weapons affixed to each delivery vehicle at the site, among other things. The inspection team can then select and visit a single delivery vehicle, such as an ICBM, and visually confirm that the number of weapons on that delivery vehicle matches the number on the detailed list provided by the host party.[19]

  For security purposes, inspectors never directly see or interact with nuclear weapons. Instead, the host party covers the nuclear weapons to shield them from view. Then, to confirm the number of weapons on an ICBM or SLBM, inspectors count the number of "bumps" created by the weapon points. Inspectors then compare the number of

[16]Other types of notifications include when ICBMs and SLBMS will be test launched or eliminated, when heavy bombers will be involved in major exercises, and 32-hour advance notification of the arrival of an inspection team to a host country.

[17]Teams may also conduct eight additional on-site inspections of declared locations with nondeployed launchers and missiles.

[18]An inspecting party must provide 32 hours advance notice to the host party before an inspection team arrives at an official point of entry in the host country. Upon arrival, the inspection team has 4 hours to notify the host party of which declared site the team wants to visit for inspection purposes. At that time, the host party has a maximum of 24 hours to transport the inspection team to the selected site.

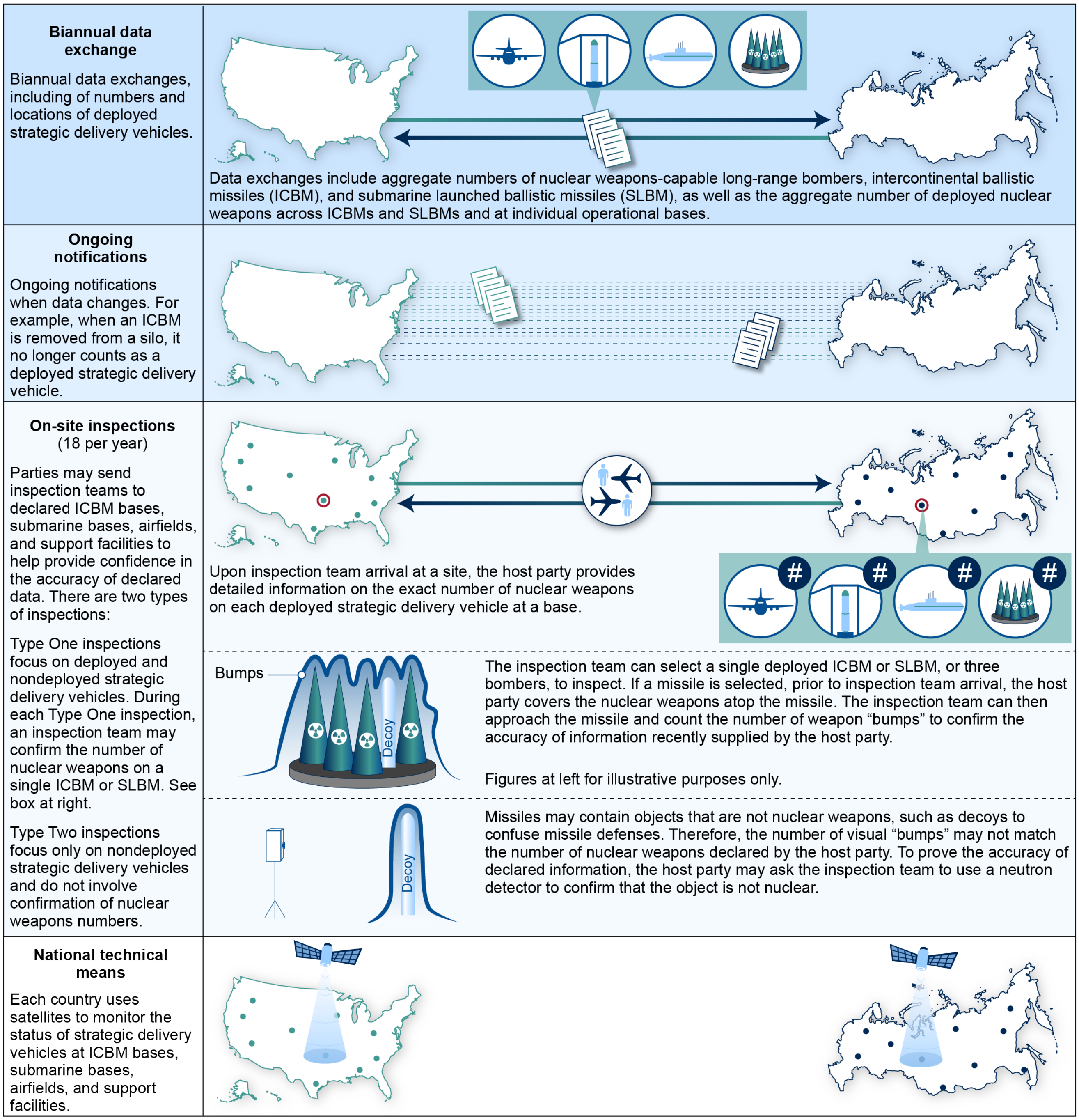
[19]For inspections of deployed strategic delivery vehicles at declared air bases, three nuclear-capable heavy bombers can be inspected and, if nuclear weapons are loaded on those bombers at the time, the number of those nuclear weapons can be confirmed. Bombers are typically not loaded with nuclear armaments until needed, however.

"bumps" against the number of weapons declared by the host party to be on that missile. In some cases, a missile might show a "bump" that is not a nuclear weapon; the bump could instead be instrumentation or a decoy to confuse missile defenses. As a result, the number of "bumps" might exceed the number of declared weapons. A host party may request that inspectors use simple radiation detection equipment—in this case, a neutron detector—to measure this undeclared object to confirm it is not nuclear; otherwise, the inspection team could claim that the host country had not provided accurate information.

When declared nuclear weapon numbers for a particular strategic delivery vehicle are confirmed as accurate, the inspection team gains confidence that declared data about all delivery vehicles and associated nuclear weapons at that site are also accurate. Because inspection locations are not shared with the host party until shortly before arrival of an inspection team, and because the inspection team can select any strategic delivery vehicle on site to inspect, inaccurate declarations and cheating are at risk of detection.

See figure 1 below for details on measures of the New START verification regime.

Figure 1: Verification Measures under New START




Sources: GAO analysis of Department of State information; Map resources and GAO (illustration). | GAO-23-105698

Note: The sites identified on the maps of the U.S. and Russia are notional to illustrate the concept of inspections and use of national technical means; they do not denote actual sites in either country.

## Federal Agencies' Nuclear Arms Control Roles and Coordination

- State leads development and analysis of U.S. arms control policy and serves as the lead U.S. negotiator for nuclear arms control agreements. In addition, according to State officials, State leads interagency working groups that support treaty implementation and that assess international treaty compliance, including Russian compliance with New START. Each year, State issues a compliance report based on the deliberations of these working groups.
- Within the Department of Defense (DOD), the Defense Threat Reduction Agency (DTRA) manages U.S. teams that inspect Russian sites, as called for under New START. DTRA also escorts Russian inspection teams that visit U.S. sites. DOD's Office of the Undersecretary for Policy develops and coordinates DOD policy and positions in arms control negotiations, such as for a successor to New START.[20]
- NNSA, a separately organized agency within the Department of Energy (DOE), conducts research and development (R&D) in support of nuclear arms control verification. NNSA's Office of Defense Nuclear Nonproliferation (DNN) supports research and development of arms control verification technology through two suboffices: the Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D) and the Office of Nonproliferation and Arms Control. According to NNSA officials, DNN R&D manages technologies in the early stages of development, from the conceptual phase to initial prototyping, whereas the Office of Nonproliferation and Arms Control brings technologies to maturity, including by refining concepts in more applied settings. These two suboffices within DNN generally partner with DOE and NNSA national laboratories and production facilities to conduct arms control technology research and development through individual projects.

  NNSA's expenditures on projects to develop verification technologies and capabilities for each office has generally been under $10 million

[20]In addition, the DOD's Office of the Undersecretary of Defense for Acquisition and Sustainment provides oversight of DOD's implementation of and compliance with arms control agreements.

per year, but expenditures have increased in recent years (see table 1).

**Table 1: National Nuclear Security Administration (NNSA) Expenditures, by Program, on Nuclear Arms Control Verification Research and Development Projects, Fiscal Years 2017 to 2022**

**Dollars in millions**

| NNSA program | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Office of Defense Nuclear Nonproliferation Research and Development | 7.8 | 9.1 | 1.1 | 0.0 | 8.5 | 18.3 |
| Office of Nonproliferation and Arms Control | 3.9 | 4.1 | 3.7 | 4.0 | 4.4 | 5.4 |

Source: NNSA. | GAO-23-105698

In addition, since fiscal year 2022, NNSA has identified the need for increased funding to support verification-related efforts within DNN R&D and the Office of Nonproliferation and Arms Control. For instance, in the fiscal year 2023 budget request, DNN R&D cited the need for increased funding to expand research and development and improve vulnerability assessments of verification technologies. In addition, in the fiscal year 2024 budget request, the Office of Nonproliferation and Arms Control cited the need for increased funding to expand NNSA's base of verification expertise and construct a user facility to support development of more advanced verification technologies.

# The U.S. Has Identified Goals and a Likely Verification Regime for a New START Successor and Has Aspirational Longer-Term Arms Control Treaty Goals

## U.S. Goals for a New START Successor Include Limits on a Broader Scope of Weapons, Likely Using a Similar Verification Regime

The U.S. has established three specific goals it seeks to achieve through a nuclear arms control treaty or agreement with Russia to follow New START:[21]

- **Retain limits on strategic delivery vehicle**s. The U.S. seeks to retain limits, analogous to those under New START, on delivery vehicles with intercontinental range, including ICBMs, SLBMs, and nuclear-capable heavy bombers.
- **Address all nuclear weapon**s. The U.S. seeks to address all nuclear weapons, including those not limited previously, such as nuclear weapons in storage and nonstrategic nuclear weapons.[22]
- **Address new and novel Russian delivery vehicle**s. In March 2018, Russian President Putin announced the development of four new intercontinental range, nuclear-armed delivery vehicles, including a nuclear-armed and nuclear-powered cruise missile and a nuclear-armed and nuclear-powered autonomous underwater vehicle.[23] One

[21]Under Secretary of State Bonnie Jenkins, *Remarks to the 17th Annual NATO Conference on Weapons of Mass Destruction Arms Control, Disarmament, and Nonproliferation,* Copenhagen, Denmark (Sept. 6, 2021).

[22]In 1988, the U.S. and the Soviet Union entered into the Intermediate-Range Nuclear Forces Treaty, which required destruction of all U.S. and Soviet (and later Russian) ground-launched ballistic and cruise missiles with ranges from 500 to 5,500 kilometers. The treaty did not address intermediate-range nuclear weapons launched from the sea or air. The treaty resulted in the elimination of nearly 2,700 nonstrategic missiles by the implementation deadline in 1991. The U.S. withdrew from the treaty in 2019 after determining that Russia was violating terms of the treaty by producing a prohibited ground-launched cruise missile.

[23]Two of the other announced systems—a hypersonic glide vehicle and an intercontinental ballistic missile with a large nuclear weapon payload—would fall under New START definitions, according to State Department information.

of the U.S. goals for a New START successor treaty is to address these novel Russian delivery vehicles.

According to State officials we interviewed, the overall verification regime that would support the successor to New START would likely be similar to the current verification regime under New START. In other words, such a regime would likely include the same core measures—NTM, data exchanges, notifications, and inspections—without introducing other more advanced verification technologies. DOD officials agreed that the verification regime that would support a New START successor would include the current verification regime under New START but that a successor verification regime would also require additional techniques and more advanced verification technologies to address nondeployed nuclear weapons.

However, according to several stakeholders we interviewed, agreeing to a successor to New START could be difficult for a number of reasons. First, overall relations and trust between the U.S. and Russia have been deteriorating since Russia's annexation of Crimea in 2014, and the deterioration was exacerbated by Russia's further invasion of Ukraine in 2022. Relations further declined in February 2023, when President Putin announced suspension of Russian participation in New START, including inspections and data exchanges.[24] According to these stakeholders, the current state of relations diminishes near-term prospects that the U.S. and Russia could negotiate a successor to New START.

Second, some stakeholders, including a former nuclear arms control treaty negotiator, noted that differences in U.S. and Russian arms control priorities may make future negotiations difficult. These differences include Russia's desire to restrain future U.S. antiballistic missile systems, which Russia sees as a threat to its strategic capabilities but which the U.S. sees as critical to defending itself and its allies, according to the 2022 Missile Defense Review.[25] From the U.S. perspective, Russia's large estimated stockpile of nonstrategic nuclear weapons threatens U.S.

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[24] As stated above, the State Department has determined that Russia's suspension is legally invalid and that Russia is in violation of its obligations under the treaty.

[25] In 2022, the Department of Defense issued its Nuclear Posture Review and Missile Defense review as part of its National Defense Strategy. U.S. Department of Defense, *2022 National Defense Strategy of the United States of America—Including the 2022 Nuclear Posture Review and the 2022 Missile Defense Review* (Washington, D.C.: Oct. 27, 2022).

interests and NATO allies, according to the 2022 Nuclear Posture Review.[26] Limiting these weapons has been a U.S. goal for many years.[27]

Prior administrations have recognized the importance of including nonstrategic nuclear weapons in an agreement with Russia. For example, the 2010 Nuclear Posture Review Report set an objective for the U.S. to engage with Russia—once New START was in force—to pursue additional nuclear force reductions and to include nonstrategic nuclear weapons in those reductions.[28] In addition, the previous administration entered into discussions with Russia on a successor agreement to New START that would have considered nonstrategic nuclear weapons.

## The U.S. Has Other Longer-Term Treaty Goals, Including Engaging China in Nuclear Arms Control

### The U.S. Seeks to Engage China in Preliminary Arms Control Discussions, but an Agreement Is Unlikely in the Near Term

The U.S. seeks to engage China in preliminary discussions that could lead to future nuclear arms control negotiations. However, the U.S. has not specified goals for an arms control treaty with China. In 2021, the Secretary of State said that the U.S. seeks to pursue nuclear arms control with China to reduce the dangers associated with China's expansion and modernization of its nuclear forces.

According to State officials, however, sustained nuclear dialogue and arms control discussions have not occurred yet. According to these

[26]According to the 2022 Nuclear Posture Review, Russia has an active stockpile of up to 2,000 nonstrategic nuclear weapons. In contrast, the U.S. has an estimated 230 nonstrategic nuclear weapons, according to the Congressional Research Service. See Congressional Research Service, *Nonstrategic Nuclear Weapons* (Washington, D.C.: Mar. 7, 2022).

[27]In its ratification of New START, the Senate called on the President to address the disparity in the number of U.S. versus Russian nonstrategic nuclear weapons by negotiating for verifiable reductions in the number of such weapons in Russia. Resolution of Advice and Consent to Ratification, S. Exec. Rept. No. 111-6 (2010).

[28]In answering a question for the record as part of the Senate Resolution of Advice and Consent to Ratification, the then Secretary of State explained that nonstrategic nuclear weapons were not included as part of New START negotiations because the treaty would have taken much longer to complete and would have added significantly to the time before a successor agreement could enter into force after START expired in December 2009. Resolution of Advice and Consent to Ratification, S. Exec. Rept. No. 111-6 (2010).

officials, as well as several stakeholders we interviewed and studies we reviewed, a formal nuclear arms control agreement between the U.S. and China is unlikely in the near future for several reasons.

First, according to some stakeholders and studies, China is not interested in limits on its nuclear forces until it attains some degree of nuclear force parity with the U.S.[29] According to the 2023 Annual Threat Assessment of the U.S. Intelligence Community, China is developing hundreds of new ICBM silos and is reorienting its nuclear posture for strategic rivalry with the U.S.[30] However, China has significantly fewer nuclear weapons than the U.S. and is unlikely to achieve numerical parity for many years.[31]

Second, some stakeholders noted that, in contrast to the long history of arms control negotiations between the U.S. and Russia and the Soviet Union, China and the U.S. have no history of nuclear arms control negotiations. These stakeholders also said that China does not prioritize the kind of transparency measures included in nuclear arms control agreements, such as New START. By contrast, the U.S. and Russia (and previously the Soviet Union) have had about 50 years of such experience.

For these reasons, several stakeholders told us it would be more feasible for future negotiations to be preceded by preliminary U.S.-China discussions that could build Chinese confidence in the benefits of arms control and transparency. For example, one State official said that establishing a form of crisis communication line could be a productive first step in confidence building.

NNSA officials told us there are no known technological verification challenges unique to China. As a result, they believe that the verification

[29]According to a DOD assessment, China's operational nuclear weapon stockpile surpassed 400 weapons in 2021. According to State's most recent public disclosure, the U.S. stockpile consisted of 3,750 nuclear weapons as of September 2020. See U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China, Annual Report to Congress, 2022* and State Department, *Transparency in the U.S. Nuclear Weapons Stockpile: Fact Sheet* (Oct. 5, 2021), accessed June 28, 2023, https://www.state.gov/transparency-in-the-u-s-nuclear-weapons-stockpile.

[30]Office of the Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community* (Feb. 2023).

[31]According to DOD's assessment, if China continues its current pace of nuclear expansion, it will likely have a stockpile of 1,500 nuclear weapons by 2035. See U.S. Department of Defense, *Military and Security Developments.*

measures NNSA has developed or is developing to support a treaty with Russia would likely be applicable to any verification regime for a future treaty with China.

## Longer-Term Treaty Goals Are Aspirational and Would Require a More Extensive Verification Regime

The U.S. also has longer-term aspirational goals to reduce the role of, and ultimately eliminate, nuclear weapons worldwide. Notably, under the 1970 Treaty on the Non-Proliferation of Nuclear Weapons, parties agreed to pursue negotiations on a treaty on general and complete disarmament, including nuclear disarmament.[32] In August 2022, at a review conference for the treaty, the U.S. and Russia supported the pursuit of deeper, irreversible, and verifiable reductions in their nuclear arsenals consistent with that goal.[33] Another treaty, the Treaty on the Prohibition of Nuclear Weapons, which entered into force in 2021—but to which no nuclear weapons state, including the U.S., is party—specifically prohibits the development, testing, production, manufacturing, acquisition, possession, or stockpiling of nuclear weapons.

However, confirming deep nuclear arms reductions and weapon elimination may require far more extensive verification regimes and more intrusive technologies than those used under New START, or those envisioned under a New START successor. For example, to verify reductions and actual elimination of weapons, future treaty parties may need to perform verification measures on additional stages in the nuclear weapons life cycle, such as weapons dismantlement.

While a treaty to significantly reduce and verifiably eliminate nuclear weapons is seen as a longer-term, aspirational goal, efforts are underway to conceptualize frameworks for verified nuclear weapons dismantlement and reductions. For instance, the International Partnership for Nuclear Disarmament Verification (IPNDV)—an initiative with participation from 31 partner countries with and without nuclear weapons and the European Union—created a notional 14-step nuclear weapon dismantlement model.

[32]Article VI of the treaty states that “Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.”

[33]Final Draft Document*, 2020 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons* (New York: 25 August 2022). Russia ultimately blocked consensus on the final draft document due to references to the war in Ukraine.

This model describes verification activities beyond those employed in New START or likely to be employed in a successor treaty or agreement. (See app. II for a description and illustration of this model.)

# NNSA's Plan Identifies Proven Technologies to Support a New START Successor and Includes Developing More Intrusive Verification Technologies

## NNSA's Plan Identifies Proven Technologies to Support Verification for a New START Successor

NNSA has a plan to develop technologies that could be used to support verification of future U.S. nuclear arms control treaty goals. Under this plan, NNSA has identified technologies that it believes are suitable and ready to support a likely regime for verifying U.S. goals under a New START successor treaty or agreement.

Specifically, in March 2021, NNSA submitted a *Nuclear Verification Plan* to Congress that includes a toolbox of verification options and associated technologies to support an array of possible future nuclear arms control treaty scenarios.[34] NNSA developed the *Nuclear Verification Plan* independently but in coordination with other agencies and national laboratories, according to officials.[35] NNSA's plan groups verification

[34]National Nuclear Security Administration, *Nuclear Verification Plan* - Report to Congress (Washington, D.C.: Mar. 2021).

[35]Specifically, NNSA officials said that NNSA obtained State and DTRA input during routine coordination meetings about New START compliance; briefed the intelligence community on how the plan's approaches might provide additional verification confidence; and worked with national laboratory experts to identify candidate technologies for development. In addition, NNSA officials stated that neither State nor other agencies dictated what verification technologies NNSA should develop to support U.S. treaty goals. Instead, technology concepts emerge at NNSA, and NNSA communicates these concepts to State and other agency partners through arms control-related interagency efforts. State officials we interviewed confirmed this point and said that, while the readiness of NNSA's technologies would inform what verification options State might propose in treaty negotiations, NNSA is primarily responsible for setting its own technology development timelines and priorities. According to NNSA, its investments in the *Nuclear Verification Plan* also build the core subject matter expertise needed to support future negotiations.

technologies into three categories, or “approaches,” based generally on increasing levels of intrusiveness and confidence in compliance:

- **Baseline approach**. This approach includes verification technologies generally derived from New START, including the use of radiation detectors during inspections to confirm that objects are not nuclear weapons. However, this approach applies these technologies to support verification of a potentially larger scope of nuclear weapons than is covered under New START—such as weapons in storage.
- **Additional approach**. This approach would build upon the baseline approach primarily by introducing technologies to positively confirm the presence of a nuclear weapon through direct measurements of radiation signatures. Directly measuring weapons could support verification of multiple U.S. nuclear arms control goals, according to NNSA’s *Nuclear Verification Plan* and NNSA officials. For example, direct measurement could support verification of weapons in storage. It could also support verification of weapon dismantlement by helping confirm that objects presented for dismantlement are nuclear weapons, or confirm that special nuclear material and high explosives have been separated. Measurement technologies in the additional approach are primarily “passive” technologies, meaning they detect and evaluate radiation emanating from nuclear weapons but do not send energy into the weapons during measurement (the radiation detector used in New START inspections is a passive technology). Directly measuring nuclear weapons is considered highly intrusive, according to NNSA officials.
- **Stretch approach**. This approach would build upon the additional approach, including by adding “active measurement” technologies. In contrast to passive measurement technologies, active measurement technologies send radiation (neutrons or X-rays) into a nuclear weapon to derive information about its material composition and geometric configuration. Active measurement could support, among other things, the verification of limits on different types of nuclear weapons—such as those designed for nonstrategic missiles or bombs—by helping inspectors discern weapon types based on their unique radiation signatures or other attributes.

According to NNSA officials, the technologies included in the baseline approach in NNSA’s *Nuclear Verification Plan* are largely proven and are ready to support a likely verification regime for a New START successor. Officials characterized the baseline approach as the least intrusive—and thus most politically feasible—of the approaches in the *Nuclear Verification Plan*, as the baseline approach includes proven technologies that are already deployed under New START or similar technologies that are commercially available.

Technologies in the baseline approach include

- the passive neutron detector used during New START inspections, which is intended to confirm that an object is not nuclear;
- tamper-indicating devices, such as seals—also used under New START—to detect and deter tampering with the inspection area or inspection equipment; and
- a commercially available gamma radiation detector—not currently used under New START—to confirm that an object is not nuclear, albeit using some additional radiation detection functionality (see app. III for additional information on NNSA's technologies).

In its plan, NNSA generally assessed the baseline approach technologies at a high level of maturity.[36] Officials stated that NNSA and the national laboratories involved in developing the relevant technologies demonstrated the use of the technologies in treaty-like scenarios during a 2021 baseline approach exercise. As a result of this exercise, NNSA and the national laboratories concluded that the technologies are ready to support a likely verification regime for a New START successor treaty. However, officials stated that NNSA ultimately must wait for a treaty negotiation process to define a specific concept of operations around which to fully mature and assess the readiness of a technology for a specific treaty application. Officials stated that exercises such as the 2021 baseline approach exercise nonetheless enable NNSA to refine its understanding of technologies' suitability for likely treaty applications.

[36]NNSA's *Nuclear Verification Plan* included initial assessments of the maturity of each technology associated with baseline, additional, and stretch approaches. NNSA included these assessments to provide a general picture of the technologies' development status to Congress, according to officials. Officials stated that NNSA's assessments thus provide a general approximation of technology maturity rather than reflect the results of a formal technology readiness assessment. In NNSA's plan, each technology is assigned a technology readiness level (TRL) of one through nine (nine being the most mature) in order to communicate commonly understood levels of technical maturity. TRLs are a common measure of technical readiness that indicate increasing levels of technical maturity based on demonstrations of capabilities. TRLs should reflect the results of tests using prototypes of appropriate scale and fidelity, and in environments that best approximate those in which the technology is expected to be used. For the purposes of this report, we will characterize technologies as "low" maturity (TRLs one through three), "medium" maturity (TRLs four through six), and "high" maturity (TRLs seven through nine).

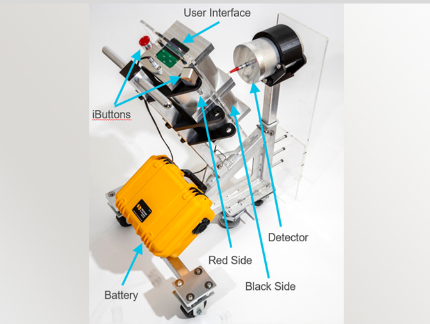
## NNSA Expects Some More Intrusive Technologies to Be Mature by 2025, but Others May Take Longer

NNSA officials stated that they expect some of the key technologies categorized under the additional approach to be mature by 2025. In its *Nuclear Verification Plan*, NNSA estimates that stretch approach technologies, however, may require 5 to 10 more years of research and development. According to NNSA officials, the additional and stretch approaches are major conceptual leaps because they envision more intrusive verification through the direct measurement of nuclear weapons—something that has not been included in the verification regime of other strategic arms control agreements.

Technologies categorized under the additional approach range from low to high maturity, according to NNSA's initial assessments. Officials stated that NNSA will further assess these technologies' suitability for treaty-specific applications during a planned multilaboratory exercise in late 2024 to test the readiness of the additional approach. By 2025, officials stated, they expect some additional approach technologies to be technologically mature enough to be proposed in treaty negotiations for a New START successor.

Some of the technologies in development under the additional approach include the following:

**Third Generation Trusted Radiation Identification System (3G-TRIS)**




**Prototype of 3G-TRIS radiation detection system with labeled components.**

3G-TRIS is a passive radiation detection system to confirm the presence of a nuclear weapon during inspections. 3G-TRIS uses "template matching," which measures the radiation signature emanating from an inspected object and compares it with a reference signature (the "template") from a known weapon. Sandia National Laboratories is developing 3G-TRIS in coordination with the National Nuclear Security Administration (NNSA).

Sources: NNSA and Sandia documentation; and interviews with NNSA officials and Sandia representatives; and Sandia National Laboratories (photo). | GAO-23-105698

- **Technologies to confirm nuclear weapon presence**. The additional approach includes two passive radiation detection technologies that NNSA is developing to measure and thereby confirm the presence of known nuclear weapon types. The first technology is the Third Generation Trusted Radiation Identification System (3G-TRIS), which measures the gamma signature emanating from nuclear material in an inspected object and compares it with a previously measured signature, such as from a known nuclear weapon. If the two signatures substantially match, inspectors would gain confidence that the inspected object is in fact a nuclear weapon. (See the sidebar on this page for additional details.)

  The second technology is the Plutonium and Highly Enriched Uranium Mass Attribute Measurement System, which measures gamma and neutron radiation signatures emitted by an inspected object to determine whether the levels meet thresholds that may be indicative of a nuclear weapon. NNSA assessed these technologies to be at medium and low maturity, respectively, as of July 2023.

- **Technologies to confirm the presence and absence of high explosives**. The additional approach also includes two radiation detection technologies to support verification of nuclear weapon dismantlement by detecting the presence and absence of high explosives from measured objects.[37] One of these technologies is the Portable Isotopic Neutron Spectroscopy device, which sends neutrons into an object to detect the presence of elements indicative of high explosives. The other is the Neutron Ratio Meter, a device intended to assess whether high explosives are collocated with an object containing nuclear material.[38] NNSA assessed these technologies to be at high and medium maturity, respectively, as of July 2023.

- **Technologies that maintain information security**. Details about nuclear weapon design are highly sensitive and closely protected by nuclear weapon states. NNSA officials stated that information security—which refers to the ability to confirm that a weapon

[37]Detecting the absence of high explosives in a nuclear weapon is one of the methods to verify weapon dismantlement, as outlined in NNSA's *Nuclear Verification Plan*. High explosives are contained inside nuclear weapons and perform different functions, including initiating the nuclear chain reaction.

[38]The Neutron Ratio Meter measures the slow-to-fast neutron ratio of neutrons emitted passively from an object before and after the object is dismantled. If the ratio decreases by an appreciable amount postdismantlement, then the inspector has evidence that high explosives are indeed absent.

measurement technology does not reveal sensitive weapon design information beyond what the treaty parties agreed to share—is thus a key criterion used to assess verification technologies' maturity.[39] Some technologies that NNSA is developing include capabilities to protect sensitive design information. For example, 3G-TRIS would protect sensitive radiation signatures from observation by inspectors by keeping the signatures under encryption, with the decryption key held by the host party. Another technology, the Modular Reprogrammable Information Barrier, is a stand-alone device that would obscure certain information derived by other measurement technologies. According to NNSA officials, information security capabilities are generally still nascent.

NNSA has not selected specific technologies to perform the verification measures included in the stretch approach, according to NNSA officials. Selecting and maturing technologies for the stretch approach may require 5 to 10 more years, according to NNSA's plan. NNSA has identified some concepts for stretch approach technologies, however. For example, according to NNSA's plan, NNSA is developing active neutron measurement and imaging techniques that would provide higher-fidelity measurements of objects' contents. Such techniques would support high-confidence confirmation that a declared object is a nuclear weapon, or support confirmation that dismantled components originated from a specific weapon.[40] NNSA assessed these technologies to be at low maturity, as of July 2023.

[39]NNSA has identified several arms control specific criteria that, according to officials, NNSA may use to assess laboratory progress maturing technologies. Some of these criteria include performance, information security, hazard level, cost, and ease of use. NNSA has included these criteria in technology development guidance for the laboratories. Officials stated NNSA may use these criteria more universally in performance assessments in the future, including in the planned additional approach exercise in late 2024.

[40]NNSA officials cited IPNDV's notional 14-step nuclear weapon dismantlement model in the context of developing stretch approach concepts for verifying weapon dismantlement.

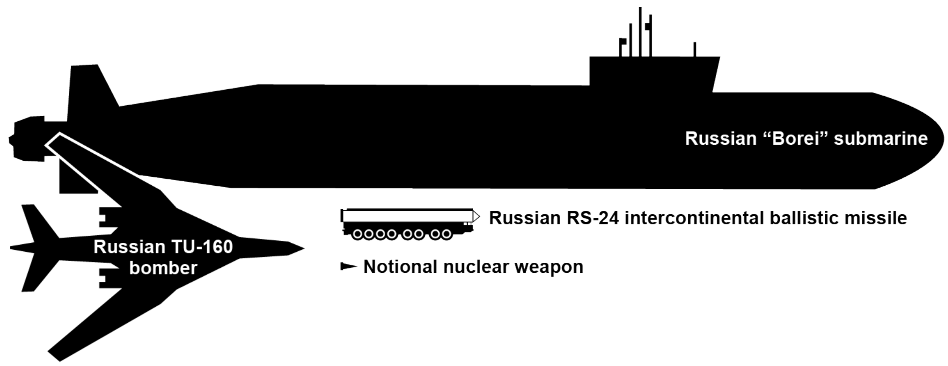
## Stakeholders Have Identified Operational Challenges to Implementing a Verification Regime for Any Future Treaty Addressing All Nuclear Weapons

According to studies we reviewed and stakeholders we interviewed, the U.S. would likely face operational challenges in implementing verification regimes to support U.S. near- and longer-term nuclear arms control treaty goals, including addressing all nuclear weapons. These operational challenges include the limitations of NTM, Russian weapon storage and movement, unique aspects of nonstrategic nuclear weapons, and challenges in the feasibility of using technology to verify nuclear arms control limits.

**NTM may be less capable of monitoring and helping verify compliance with nuclear weapon limits**. According to some studies we reviewed and stakeholders we interviewed, NTM may face challenges in monitoring nuclear weapons under future treaties. NTM have been foundational to verifying limits under nuclear arms control treaties pertaining to the numbers and locations of strategic nuclear delivery vehicles, such as ICBMs and heavy bombers, according to two stakeholders and one government study we reviewed.[41] Strategic delivery vehicles are relatively large, and NTM, which consist primarily of imaging satellites, can monitor the status and movement of these systems. Nuclear weapons are far smaller by comparison, making them harder to monitor through NTM, including while in storage and during transport, according to some stakeholders we interviewed and studies we reviewed. (See fig. 2 below for a size comparison.) According to these sources, NTM would, therefore, likely be less capable in monitoring numbers and locations of Russian weapons than in monitoring strategic delivery vehicles, as is done under New START.

[41]Congressional Research Service, *Monitoring and Verification in Arms Control* (Washington, D.C.: Dec. 23, 2011).

**Figure 2: Size Comparison of Russian Strategic Nuclear Delivery Vehicles to a Nuclear Weapon**




Sources: GAO analysis of publicly available information; and GAO (icons). | GAO-23-105698

**Russia stores nuclear weapons in many places and moves them frequently**. Two former officials involved in past nuclear arms control treaty negotiations who we interviewed, as well as a study by the James Martin Center for Nonproliferation Studies (CNS), indicated that a verification regime for a treaty that addresses all nuclear weapons could face challenges due to the significant dispersal and movement of nuclear weapons across Russia.[42] For example, Russia stores, refurbishes, and moves its nuclear weapons among more facilities—and more frequently—than the U.S.[43] The two former officials told us that the large number of facilities and the frequency of movement could further challenge U.S. ability to track the weapons using NTM, which, as stated above, would already be challenged by the weapons' small size.

According to CNS, Russia also ships nuclear weapons primarily by rail and road in a manner to look like normal rail and road traffic, making discernment more difficult. The two former officials, as well as CNS, indicated that these practices could also challenge agreement on inspections. This is because the disparity in the number of nuclear weapon locations could mean that the U.S. would need to inspect far more facilities than Russia to gain confidence in declared weapon

[42]Miles A. Pomper et al., "Everything Counts: Building a Control Regime for Nonstrategic Nuclear Warheads in Europe" (James Martin Center for Nonproliferation Studies: 2022).

[43]Russia has an estimated 46 nuclear weapon storage facilities that likely store strategic and nonstrategic nuclear weapons, according to a 2017 United Nations report. Most U.S. nuclear weapons are stored at far fewer locations, according to DOD officials. See Pavel Podvig and Javier Serrat, *Lock them Up: Zero-deployed Non-strategic Nuclear Weapons in Europe* (United Nations Institute for Disarmament Research: 2017).

numbers. Increased U.S. inspections could entail a substantial logistical effort, while also potentially raising Russian concerns about bearing an unequal inspection burden.

**Nonstrategic nuclear weapons pose unique verification challenges.** According to several stakeholders we interviewed and government documents and studies we reviewed, aspects of Russia's nonstrategic nuclear weapons—of which Russia has up to an estimated 2,000[44]—could create unique challenges to the verification regime for a treaty that addresses all nuclear weapons. These unique challenges include the following:

- **Many of Russia's nonstrategic nuclear delivery vehicles are dual capable**. Many of the delivery vehicles, such as missiles, for Russia's nonstrategic nuclear weapons are dual-capable, meaning they can use either nuclear or conventional weapons, according to some studies we reviewed. For example, the Iskander short-range ballistic missile can be equipped with either a conventional or nuclear weapon.[45] Such dual capability introduces verification challenges. For example, two studies we reviewed and two stakeholders we interviewed stated that NTM would be challenged to visually differentiate between nuclear and conventionally-armed delivery vehicles, such as the Iskander. Inspectors might be similarly challenged to detect whether delivery vehicles were loaded with nuclear weapons without using intrusive methods.
- **Russia has many types of nonstrategic nuclear delivery vehicles**. According to the Department of Defense, Russia has several different types of nonstrategic nuclear delivery vehicles, including cruise missiles, short-range ballistic missiles, hypersonic missiles, and gravity bombs.[46] This variety of delivery vehicles could present certain challenges for a future verification regime. For example, a 2021 study by the White House Office of Science and Technology Policy (OSTP) noted that some launchers of nonstrategic nuclear weapons, such as

[44]U.S. Department of Defense, *2022 Nuclear Posture Review* (Washington, D.C.: Oct. 27, 2022).

[45]According to reports, Russia has used Iskander missiles loaded with conventional weapons in the war in Ukraine.

[46]U.S. Department of Defense, *2018 Nuclear Posture Review* (Washington, D.C.: Feb. 2018). According to CNS, Russia has an estimated 26 different types of nonstrategic missiles alone. The U.S., by contrast, has only one type of nonstrategic nuclear weapon, the B-61 gravity bomb.

launch systems on ships and torpedo tubes on submarines, may require new verification methodologies.[47]

- **Nonstrategic nuclear delivery vehicles are often collocated with conventional delivery vehicles**. According to the same OSTP study, Russia may consider inspections of sites where Russia deploys nonstrategic nuclear delivery vehicles to be unacceptably intrusive. This is because Russia often collocates nonstrategic nuclear delivery vehicles with conventional delivery vehicles at the same sites and, according to OSTP, Russia may therefore find inspections of these sites to be too disruptive to other Russian military operations.
- **Nonstrategic nuclear weapons may be difficult to outwardly distinguish from strategic weapons**. According to some studies, Russia likely comingles many of its strategic and nonstrategic nuclear weapons in storage. Two studies noted that verifying a limit on nonstrategic nuclear weapons specifically—or verifying limits on different types of weapons, as outlined in NNSA's *Nuclear Verification Plan*—could require differentiating between weapons by using intrusive technologies to assess the weapons' unique (and highly sensitive) design characteristics.

**Challenges in the feasibility of using technology for arms control verification**. A verification regime to support the U.S. goal to address all nuclear weapons may include inspections of nuclear weapon storage and production facilities and direct weapon measurement. Several studies we reviewed and stakeholders we interviewed indicated that such a verification regime would likely be challenged by several factors, including

- **Russian aversion to verification technologies**. Russia has historically been averse to using technologies to support arms control verification, according to some stakeholders we interviewed, including two former officials involved in past nuclear arms control treaty negotiations. U.S.-Russian laboratory-to-laboratory collaboration historically helped to address this reluctance by developing some basis for mutual trust and technology development, according to

[47]Office of Science and Technology Policy [OSTP], *Nuclear Arms Control Verification Challenges and Opportunities for Limiting Nondeployed Warheads and Nonstrategic Nuclear Weapons* (Washington, D.C.: Sept. 2021). OSTP was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976 to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of issues that require attention at the highest levels of government. OSTP leads interagency science and technology policy coordination efforts across the federal government.

national laboratory representatives and a study we reviewed.[48] However, according to the same study, the cessation of nearly all laboratory collaboration in recent years undermines the prospects that Russia will be amenable to using new verification technologies in the near future.

- **Potential effect of measurement on nuclear weapon safety**. Several NNSA officials and national laboratory staff said it would be challenging to convince Russia that nuclear weapon measurement technologies do not negatively affect sensitive weapon components (such as high explosives, electronics, or special nuclear materials) and thus jeopardize the weapon's safe functioning. NNSA officials stated that safety considerations stemming from direct weapon measurements have been a long-standing concern on the U.S. side as well. For example, laboratory staff described extensive steps they have taken to validate the safety of several of NNSA's verification technologies, especially prior to testing measurement technologies on U.S. nuclear weapons at the Pantex Plant.[49] NNSA officials stated that further validating safety will be part of the planned exercise in 2024.
- **Security of nuclear weapon design information and access to facilities.** Nuclear weapon measurement technologies are purposefully designed to assess certain weapon attributes. However, according to some studies we reviewed and several NNSA officials and laboratory representatives we interviewed, it would be a substantial challenge to demonstrate that technologies for passively or actively measuring nuclear weapon attributes—either Russian or U.S. weapons—do not reveal sensitive design information beyond what the treaty parties agreed to share. As indicated previously, NNSA officials stated that information security capabilities remain nascent. Laboratory representatives also stated that, regardless of whether inspections included direct measurement of nuclear weapons, they believe it is questionable whether Russia or the U.S. would ever allow inspectors into one another's weapons research and

[48]Noah C. Mayhew, "Back to the Future: Reviving U.S.-Russian Lab-to-Lab Cooperation," *Arms Control Today* (Nov. 2021).

[49]Specifically, from 2011 through 2018, NNSA conducted two multilaboratory "campaigns" that involved testing the safety of nuclear weapon measurement technologies on U.S. stockpile weapons at the Pantex Plant (Pantex assembles and disassembles nuclear weapons, among several other weapons-related missions). Laboratory representatives told us that the exercise taught them how difficult it would be to give potential future treaty parties confidence that nuclear weapon measurement technologies would not jeopardize safety of the weapon.

production facilities, given concerns about the vulnerability of other highly sensitive information.

## Agency Comments

We provided a draft of this report to NNSA, State, DOD, and the intelligence community for review and comment. NNSA and the intelligence community provided technical comments, which we incorporated, as appropriate. State and DOD did not have any comments on the report.

We are sending copies of this report to the appropriate congressional committees, the Administrator of NNSA, the Secretary of State, the Secretary of Defense, the intelligence community, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact us at (202) 512-3841 or bawdena@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

Allison Bawden
Director, Natural Resources and Environment

# Appendix I: Objectives, Scope, and Methodology

This report describes (1) the goals and likely verification regimes the U.S. has identified for future nuclear arms control treaties, (2) the extent to which the National Nuclear Security Administration (NNSA) has planned for or developed verification technologies to support goals for future nuclear arms control, and (3) challenges stakeholders have identified to implementing verification regimes to support future nuclear arms control treaties.

For all three objectives, we identified and interviewed a nongeneralizable selection of 43 relevant "stakeholders," which we use to refer collectively to individuals we selected for interview based on their status as (a) U.S. government officials from NNSA, the Department of State, the Department of Defense, and the intelligence community; (b) representatives of three U.S. national laboratories and one site involved in developing arms control verification technologies, including those at Los Alamos National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratories, and the Y-12 National Security Complex; and (c) recognized experts on nuclear arms control.

We identified these stakeholders by first contacting government agencies and nongovernmental organizations with nuclear arms control experience and asking them to identify other knowledgeable stakeholders. We then selected for interview those agency officials and laboratory representatives that stakeholders cited as knowledgeable and who are currently working in nuclear arms control policy and technology development. We interviewed a total of 13 officials and 22 laboratory representatives who fit these criteria. We also selected for interview experts that stakeholders cited as experts and who had previous experience supporting START or New START negotiations; had authored studies in nuclear arms control publications; or who held relevant positions in government, academic, or nongovernmental institutions. We interviewed eight experts who fit these criteria. The views of stakeholders we interviewed are not generalizable to stakeholders we did not interview for this report.

To describe the goals and likely verification regimes the U.S. has identified for future nuclear arms control treaties, we reviewed New

START and related documents,[1] including the Senate Resolution of Advice and Consent to Ratification[2] and State's recent classified and unclassified annual reports on Russian compliance with New START. We also reviewed public statements made by senior State officials and interviewed other State officials. During discussions with experts and other stakeholders, we asked questions about the prospects for a successor to New START and for verification regimes that might support such a successor. To further our understanding of New START, its verification measures, and prospects for a successor to New START, we attended a week-long course provided by the Defense Threat Reduction Agency on the implementation of the treaty.

To describe the extent to which NNSA has planned for or developed verification technologies to support U.S. goals for future nuclear arms control treaties, we reviewed NNSA plans and documents and spoke with officials from NNSA, State, and representatives from U.S. national laboratories involved in nuclear arms control. In particular, we reviewed NNSA's 2021 *Nuclear Verification Plan* to Congress, which details three approaches NNSA has identified for developing verification technologies. We also reviewed technology program plans for the two relevant offices in NNSA's Office of Defense Nuclear Nonproliferation (DNN)—the Office of DNN Research and Development (DNN R&D) and the Office of Nonproliferation and Arms Control. We also reviewed other plans and studies, including a 2021 study by the White House Office of Science and Technology Policy on challenges associated with verifying nuclear weapons and nonstrategic nuclear weapons.[3]

To further understand the technology used under New START and technologies NNSA is developing to support potential future treaties, we visited four U.S. national laboratories and sites, including Los Alamos National Laboratory, Sandia National Laboratories, Oak Ridge National Laboratory, and the Y-12 National Security Complex. We spoke with laboratory representatives about the technology maturation process, criteria they use to determine technologies' maturity, and recent and future exercises to test the technologies. We selected these laboratories

[1]Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, U.S.-Russ., Apr. 8, 2010, T.I.A.S. No. 11-205.

[2]S. Exec. Rept. No. 111-6 (2010).

[3]Office of Science and Technology Policy, *Nuclear Arms Control Verification Challenges and Opportunities for Limiting Nondeployed Warheads and Nonstrategic Nuclear Weapons* (Washington, D.C.: Sept. 2021).

because NNSA officials identified them as some of the primary laboratories and sites involved in the development of nuclear weapons and nuclear weapons verification technologies. Findings we collected from the selected national laboratories and sites are not generalizable to other national laboratories and sites.

To describe challenges to implementing regimes for verifying compliance with future goals for nuclear arms control, we interviewed knowledgeable stakeholders. We asked stakeholders questions about New START; about potential successor treaties or agreements; and about associated challenges, such as challenges to establishing treaties and verifying treaty limits. In addition to interviews with stakeholders to identify challenges, we reviewed studies that (1) stakeholders recommended to us and (2) we identified through a literature search we conducted with a staff librarian.

We conducted searches using multidisciplinary databases that include peer-reviewed studies, government reports, think tank publications, and conference papers, such as in ProQuest, Taylor & Francis, and Ebsco. We limited our search to articles published from January 2017 through February 2023 and used variations on the search terms “Nuclear Arms Control,” “New START,” “Russia,” “China,” “nonstrategic,” “non-strategic,” or “tactical.” Two analysts independently reviewed the search results and selected the most significant and relevant studies for review. We reviewed a total of 38 studies, including studies from the National Academies of Science, the Bulletin of the Atomic Scientists, the James Martin Center for Nonproliferation Studies, the Carnegie Endowment for International Peace, and the Center for Strategic and International Studies Project on Nuclear Issues, among others.

Based on our interviews with stakeholders and reviews of relevant literature, two analysts identified challenges associated with establishing a New START successor and implementing a verification regime. To do so, the two analysts used their professional judgment to compile independent lists of challenges that were frequently cited across interviews the team conducted and studies the team reviewed or were cited as being important for future verification regimes.[4] The two analysts then met to discuss and reconcile their respective lists of challenges,

[4]Throughout this report, we say “several” when referring to a point made by five or more stakeholders or five or more studies, and “some” when referring to a point made by three to four stakeholders or three to four studies. If fewer than three stakeholders or studies made a given point, we cite the specific number.

come to agreement on a final selection of relevant challenges, and group the challenges into the four categories discussed in the final section of this report. Given our methodology, we may not have identified all possible challenges regarding implementing future verification regimes. However, given the multiple, credible sources that we relied on, we believe our selection captures many of the key challenges the U.S. may face.

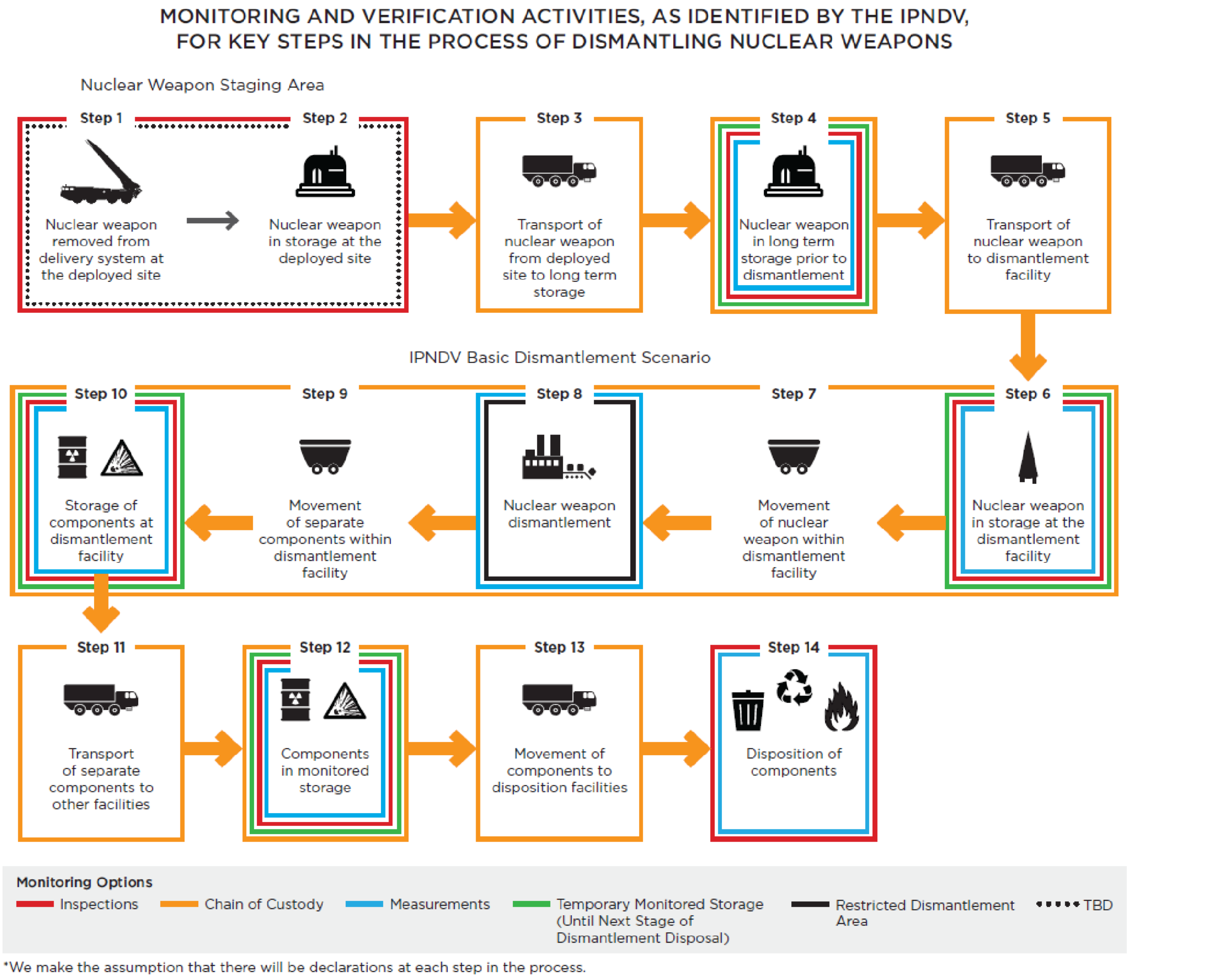
We conducted this performance audit from February 2022 to September 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

# Appendix II: The International Partnership for Nuclear Disarmament Verification 14-Step Framework for Weapon Dismantlement

The International Partnership for Nuclear Disarmament Verification (IPNDV) is an ongoing initiative that includes 31 countries with and without nuclear weapons, and the European Union. According to the IPNDV, the parties involved are working together to identify and develop practical solutions to the technical and procedural challenges associated with effectively verifying nuclear disarmament. The IPNDV began in 2014, when the U.S. Department of State announced it would lead the IPNDV in cooperation with the Nuclear Threat Initiative.[1]

[1]The Nuclear Threat Initiative is a nonprofit, nonpartisan global security organization focused on reducing global nuclear and biological threats.

**Figure 3: International Partnership for Nuclear Disarmament Verification 14-Step Framework for Nuclear Weapon Dismantlement**




Source: International Partnership for Nuclear Disarming Verification (IPNDV) (includes icons). | GAO 23-105698

# Appendix III: Examples of Technologies to Support Nuclear Arms Control Verification

In March 2021, the National Nuclear Security Administration (NNSA) submitted a *Nuclear Verification Plan* to Congress that identifies a "toolbox" of verification technologies to support an array of possible future nuclear arms control treaty scenarios.[1] NNSA's plan groups verification technologies into three categories, or "approaches," based generally on increasing levels of intrusiveness and confidence in compliance.

NNSA officials characterized the baseline approach as the least intrusive and most technologically straightforward of the approaches in NNSA's plan, as it relies on commercially available technologies, or mature technologies already used to support New START.[2] The additional and stretch approaches contain more intrusive technologies that NNSA has assessed at different levels of maturity. However, according to NNSA officials, NNSA ultimately must wait for the treaty negotiation process to define a specific concept of operations around which to fully mature and assess the readiness of a technology for a specific treaty application.

Figure 4 describes examples of technologies in the baseline approach, as well as NNSA's assessments of the technologies' respective maturity as of July 2023.

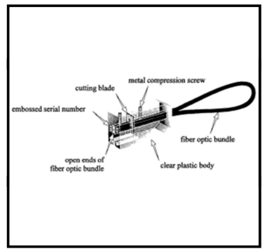
[1]National Nuclear Security Administration, *Nuclear Verification Plan,* Report to Congress (Washington, D.C.: Mar. 2021).

[2]New START is a treaty between the U.S. and Russia for the reduction and limitation of strategic nuclear weapons. The formal title of this treaty is the Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, U.S.-Russ., Apr. 8, 2010, T.I.A.S. No. 11-205.

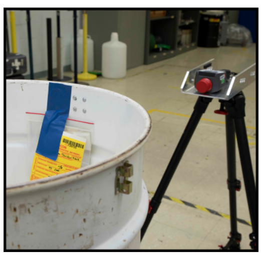
**Figure 4: Examples of Technologies the National Nuclear Security Administration (NNSA) Has Identified to Support Nuclear Arms Control Verification under Its Baseline Approach**

The baseline approach supports verification of a larger scope of nuclear weapons than covered under New START[a], such as weapons in storage, using relatively simple technologies largely borrowed from New START. These technologies are mature and ready to support a likely verification regime for a New START successor, according to NNSA officials.

**Passive neutron detector:** A passive radiation detection device to confirm nuclear weapon absence.[b] The device currently used under New START is a simple neutron radiation detection device that is intended to confirm that an object is not nuclear.




**Tamper-indicating loop seal:** A loop seal that indicates tampering by enabling inspectors to photograph and compare a randomly generated fiber optic pattern before and after sealing. If the pattern remains the same, this provides confidence tampering has not occurred. Seals are used under New START to deter parties from tampering with inspector equipment stored in host country facilities between inspections.



**Passive gamma detector:** A commercially available, passive radiation detection device to confirm nuclear weapon absence. NNSA's currently selected device is gamma based and may supplement the neutron-based device currently used under New START.

Sources: NNSA and laboratory documentation; interviews with NNSA officials and laboratory staff; Sandia National Laboratories (top) and Y-12 National Security Complex (bottom image). | GAO-23-105698

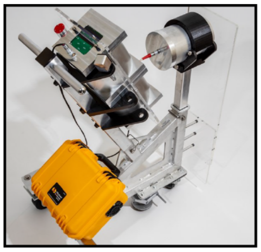
[a]New START is a treaty between the U.S. and Russia for the reduction and limitation of strategic nuclear weapons. The formal title of this treaty is the Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, U.S.-Russ., Apr. 8, 2010, T.I.A.S. No. 11-205.

[b]Verification technologies may be used to detect the absence or presence of nuclear weapons. Under New START, treaty inspectors may confirm weapon absence by using a radiation detection device to scan and confirm that extraneous "bumps" on the end of shrouded missiles are in fact not nuclear weapons. According to NNSA's 2021 *Nuclear Verification Plan*, future treaties may use technologies to confirm the presence of a nuclear weapon, such as by scanning and measuring special nuclear materials and high explosives inside the weapon.

Figure 5 describes examples of technologies in the additional approach, as well as NNSA's assessments of the technologies' respective maturity as of July 2023.

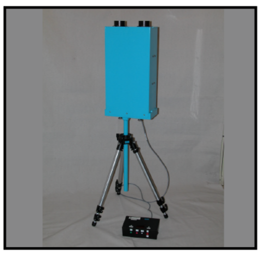
**Figure 5: Examples of Technologies the National Nuclear Security Administration (NNSA) Has Identified to Support Nuclear Arms Control Verification under Its Additional Approach**

The additional approach builds upon the baseline approach primarily by including technologies to confirm nuclear weapon presence, such as measuring radiation signatures to confirm a declared object is a nuclear weapon. NNSA officials stated they expect some additional approach technologies to be mature by 2025.

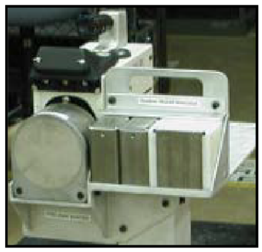


**3rd Generation Trusted Radiation Identification System (3G-TRIS):** A passive radiation detection system to confirm nuclear weapon presence. 3G-TRIS would measure the gamma signature of an inspected object and compare it with a digitally signed reference signature (e.g., from a known nuclear weapon). If the two signatures substantially match, inspectors would gain confidence the inspected object is in fact a nuclear weapon. Assessed at medium maturity.

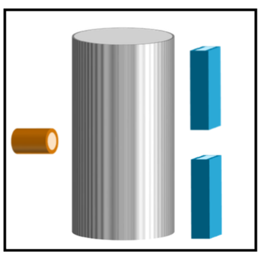
**Portal Monitor for Authentication and Certification (PMAC):** A passive radiation detection system to confirm nuclear weapon movements into and out of nuclear facilities. The portal would indicate the detection of radioactive sources and the direction of travel as they pass by. According to laboratory representatives, the simplicity of PMAC's technology enabled NNSA to use it as a proof of concept for validating that a verification device does not reveal sensitive weapon design information beyond what treaty parties agreed to share. Assessed at medium maturity.



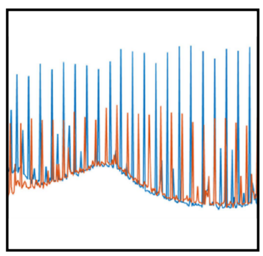
**Neutron Ratio Meter (NRM):** Neutron Ratio Meter (NRM): A passive radiation detection system to confirm nuclear weapon dismantlement by detecting the absence of high explosives. The NRM would measure the ratio of slow to fast neutrons emitted from the inspected object before and after dismantlement, and compare the ratios with predetermined thresholds, such as those from a known nuclear weapon. Ratios serve to obscure sensitive radioactivity counts while enabling inspectors to confirm whether high explosives have been removed from the object. Assessed at medium maturity.



**Portable Isotopic Neutron Spectroscopy (PINS):** An active radiation detection system to help confirm nuclear weapon dismantlement by confirming the absence of high explosives. The device would use a neutron source to excite atomic elements inside the inspected object, enabling inspectors to confirm whether high explosives have been removed from the object. PINS is widely used to evaluate old munitions like chemical rounds. Assessed at high maturity.



**Plutonium and Uranium Mass Attribute Measurement System (PUMA):** A passive radiation detection system to confirm nuclear weapon presence. PUMA would measure neutron and gamma radiation emitted from an inspected object and compare the measurements with preestablished threshold amounts, thereby giving inspectors confidence the object contains enough plutonium or highly enriched uranium to be considered a nuclear weapon. The current concept uses commercially available radiation detection devices coupled with detection algorithms that are still in development. Assessed at low maturity.



**Radio frequency fingerprinting:** A technique for analyzing radio frequencies emanating from electronic inspection equipment. The inspecting party would first determine the equipment's unique radio frequency "fingerprint" and then periodically analyze the equipment to confirm no unauthorized changes had been made to its electronics (the image depicts slight variations in radio frequencies between two different copies of the same radiation detection device). This would support chain of custody and provide confidence that tampering has not occurred. Currently in the concept phase and assessed at low maturity.

Sources: NNSA and laboratory documentation; and interviews with NNSA and laboratory staff; Sandia National Laboratories (L column), Pantex Plant (R1), Los Alamos National Laboratory (R2) and Argonne National Laboratory (R3) (images). | GAO-23-105698

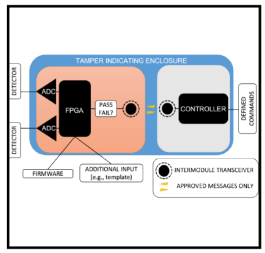
Figure 6 describes examples of technologies in the stretch approach, as well as NNSA's assessments of the technologies' respective maturity as of July 2023.

**Figure 6: Examples of Technologies the National Nuclear Security Administration (NNSA) Has Identified to Support Nuclear Arms Control Verification under Its Stretch Approach**

The stretch approach builds upon the additional approach by adding higher fidelity measurements to support possible limits on nuclear weapons by type. Maturing technologies for the stretch approach may require 5 to 10 more years, according to NNSA.

**Active neutron measurement and imaging techniques:** Technologies that would actively interrogate inspected objects to confirm nuclear weapon presence and dismantlement. According to NNSA officials, while the fundamental science and engineering is mature, these technologies' ability to detect a significant amount of sensitive information raises information security concerns that require further development for treaty-specific applications. Still in the concept phase, with no technology option yet selected. Assessed at low maturity.

**Radiation-based imaging with information barrier:** A passive radiation detection system to confirm nuclear weapon presence. A current prototype would operate a passive gamma radiation detector behind an information barrier in the form of a rotating cylindrical mask. The mask would scramble sensitive radiation image data derived from the inspected object, while still allowing inspectors to use the data to make statistical assumptions about the distribution of nuclear material in the object or its similarity to a known weapon (a model is depicted at left). Still in the concept phase, with no technology option yet selected. Assessed at low maturity.




**Modular Reprogrammable Information Barrier (MRPIB):** An information barrier to hide sensitive nuclear weapon information collected by radiation detection systems. MRPIB would provide a trusted platform for collecting and analyzing sensitive data to arrive at a simple "pass/fail" message viewable by inspectors to confirm treaty compliance. MRPIB is being designed to allow for a variety of potential measurement capabilities to be implemented using the same information barrier hardware (shown on the left is a conceptual illustration of the MRPIB hardware). Such a capability is intended to assuage host party concerns about revealing sensitive nuclear design information to inspectors, while simultaneously helping build inspector confidence in the authenticity of the data collected and the analysis performed. Assessed at low maturity.

Sources: NNSA and laboratory documentation; and interviews with NNSA and laboratory staff; Y-12 National Security Complex (top L) and Sandia National Laboratories (bottom L and R images). | GAO-23-105698

# Appendix IV: GAO Contacts and Staff Acknowledgments

## GAO Contacts

Allison Bawden, (202) 512-3841 or BawdenA@gao.gov

## Staff Acknowledgments

In addition to the contacts named above, William Hoehn (Assistant Director), Dave Messman (Analyst in Charge), David Wishard, Antoinette Capaccio, Cindy Gilbert, Cynthia Norris, John Ortiz, and Sara Sullivan made key contributions to this report.

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