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Evidence of absence: Verifying the removal of nuclear weapons

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List of acronyms and abbreviations

ALCM	Air-launched cruise missile
CTR	Cooperative Threat Reduction (Program)
HEU	Highly-enriched uranium
IAEA	International Atomic Energy Agency
ICBM	Intercontinental ballistic missile
INF	Intermediate-Range Nuclear Forces (Treaty)
IPNDV	International Partnership for Nuclear Disarmament Verification
NATO	North Atlantic Treaty Organization
NPT	Nuclear Non-proliferation Treaty
NTM	National technical means
PNIs	Presidential Nuclear Initiatives
SLBM	Submarine-launched ballistic missile
SLCM	Sea-launched cruise missile
SSGN	Cruise missile submarine
START	Strategic Arms Reduction Treaty
TEL	Transporter erector launcher
TLAM/N	Nuclear-armed Tomahawk land-attack cruise missile
TPNW	Treaty on the Prohibition of Nuclear Weapons

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1 Executive summary

Removing nuclear warheads from their weapon systems, withdrawing warheads and other weapons from their operational bases, and relocating those warheads to central storage and the dismantlement queue are all steps along the path the elimination of nuclear weapons. This, in fact, is how most of the nuclear reductions have been carried out to date. While some reductions undertaken by Russia and the United States were part of bilateral disarmament treaties, the largest decrease in the number of operational nuclear weapons was a result of unilateral voluntary decisions. The United States and Russia significantly reduced the number of non-strategic nuclear weapons as part of the Presidential Nuclear Initiatives and other unilateral steps. The United Kingdom and France substantially reduced their nuclear arsenals as well.

As a result of all these steps, nuclear weapons are currently deployed in the fewest number of places since the early years of the Cold War. This is a remarkable achievement that can serve as a basis for further progress in nuclear disarmament. The steps that remove nuclear weapons from military bases, weapon systems, territories or entire Sates could be an important tool of building trust and confidence, reducing the role of nuclear weapons in international security, and creating conditions for deeper nuclear reductions. The key premise of this study is that if the result of these steps—the absence of nuclear weapons—can be verified, their value in the nuclear disarmament process would greatly increase.

This study describes an arrangement for verifying the absence of nuclear weapons and infrastructure for their deployment. A framework centred on absence does not require reliable chain of custody, access to sensitive data, or the creation of trusted information barriers, which are among the most complex and daunting problems associated with nuclear disarmament verification. Furthermore, an arrangement to verify the absence of nuclear weapons can employ tools and techniques otherwise unavailable when the presence of nuclear weapons is a possibility.

The core of the verification arrangement proposed in this report draws upon the use of key elements of existing New START arrangements, with modifications that can expand its applicability to a wider range of removal scenarios. This includes inspection provisions that can confirm the physical absence of weapons on missiles at bases, and radiation detection techniques that can determine the non-nuclear status of inspected objects. Adapted procedures with managed access could confirm the absence of weapons in storage facilities or the elimination of the infrastructure for permanent deployment or storage of nuclear weapons. The arrangement could also include procedures to confirm the conversion of nuclear-capable weapon systems.

The proposed arrangement could provide a high degree of assurance in the absence of nuclear weapons within a certain territory or on a class of weapon systems. The implementation of such measures, especially if implemented in combination, could provide the appropriate verification that nuclear weapons have been removed. These measures could be introduced gradually and applied provisionally as a transparency and confidence-building measure. For instance, some nuclear-armed States may want to confirm that old military nuclear facilities have been dismantled, and States in nuclear-sharing arrangements may wish to demonstrate the absence of nuclear weapons formerly deployed on their territory. The arrangement could also be used as part of more formal arms control and disarmament measures, for instance removal of non-strategic nuclear weapons from operational bases or prohibition of nuclear-armed cruise missiles.

It is universally acknowledged that robust verification will be a crucial element of the nuclear disarmament process. An arrangement that verifies the absence of nuclear weapons—as presented in this study—can become a valuable element of the verification toolkit that supports this process and help propel it forward. It could also be key to a range of policy initiatives that would demonstrate that practical disarmament measures are possible in the short- and medium-term, creating the conditions for more comprehensive measures in the long term.

2 Introduction

There has been much progress in nuclear disarmament since 1986 and the height of the Cold War, when the global stockpile reached its peak of more than 70,000 warheads. The most dramatic reductions have been linked to arms control measures involving the United States and Russia; they include the bilateral Strategic Arms Reduction Treaties (START in 1990, New START in 2010) and the Presidential Nuclear Initiatives (PNIs, 1991–92). France and the United Kingdom have also dramatically reduced their nuclear arsenals. Four nuclear-armed States—France, Russia, the United Kingdom and the United States—adhere to a moratorium on fissile material production for weapons; China is believed to have stopped such production as well.[1] A significant amount of weapon-usable fissile material has been eliminated or disposed of.

The record on containing the spread of nuclear weapons, however, is mixed. Today, nine States have nuclear weapons with some continuing to produce fissile material, possibly with a view to expanding their arsenals. It is estimated that there are about 14,500 nuclear warheads in existence, with approximately 9,300 of them in active military stockpiles (the rest are awaiting dismantlement). Of these, some 3,750 warheads are deployed with operational forces.[2] In recent years, progress in nuclear reductions has slowed, owing, in part, to a greater complexity of the issues associated with deeper cuts. Still, nuclear disarmament remains a universally shared goal, even if States differ about the best way to achieve it.

Achieving deeper reductions of nuclear arsenals and eventual elimination of nuclear weapons will require coordinated efforts across many different areas of the nuclear disarmament landscape.

In driving such efforts, States will need to move to establish credible, reliable, and accurate verification techniques and arrangements. This remains one of the key challenges in nuclear arms control and disarmament, as it is universally agreed that robust verification will be an essential element of the nuclear disarmament process. It is well understood that a comprehensive verification system should cover all steps of the nuclear disarmament process, including warhead dismantlement and disposition of fissile materials.[3] However, past verification arrangements have centred on delivery vehicles; warhead elimination to date "has only been carried out under conditions that are strictly controlled and overseen by national authorities."[4] In recent years there have been a number of high-profile international cooperative programs that aimed to address the technical and institutional questions linked to the multilateral verification of warhead dismantlement—the International Partnership on Nuclear Disarmament Verification (IPNDV), the Quad Nuclear Verification Partnership, and the joint U.S.-U.K. project on technical cooperation in arms control among others. Although these projects have made significant progress in addressing the issue, it has also become clear that there are still challenges that must be addressed. Most of these challenges are linked to the sensitive nature of nuclear weapons, which requires protecting the information about weapon design and composition of fissile materials contained in them. Even

[1] Moritz Kütt, Zia Mian and Pavel Podvig, "Global Stocks and Production of Fissile Materials, 2017", in *SIPRI Yearbook 2018: Armaments, Disarmament and International Security* (Stockholm: SIPRI, 2018), pp. 288–94.

[2] Hans M. Kristensen and Robert S. Norris, "Status of World Nuclear Forces", *Federation of American Scientists* (blog), June 2018. Available at https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/.

[3] National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials* (Washington, D.C.: National Academies Press, 2005).

[4] Wyn Q. Bowen, Hassan Elbahtimy, Christopher Hobbs and Matthew Moran, *Trust in Nuclear Disarmament Verification* (Palgrave MacMillan, 2018), p. 56.

the initial step of disclosing the data on the number of nuclear weapons and their locations could presents a significant barrier on the way toward disarmament.

Yet, there are a number of meaningful steps toward nuclear disarmament that do not involve verified dismantlement of nuclear warheads. While the elimination of warheads and weapon-usable fissile material represent the final stage of the process, it is critical to examine other actions along this way that would most likely precede it and that could make the dismantlement arrangements easier to implement. Such actions could include the removal of nuclear warheads from delivery vehicles and withdrawal of warheads and nuclear-capable delivery systems from operational military bases or entire territories. Further steps could include dismantlement of the infrastructure that could support long-term nuclear weapons deployment and elimination or conversion of nuclear-capable delivery vehicles and launchers. This, in fact, is how most of the nuclear reductions have been carried out to date. The key premise of this study is that if the result of these steps—the absence of nuclear weapons—can be verified, their value in the nuclear disarmament process would greatly increase.

This study considers arrangements that would verify the absence of nuclear weapons or nuclear-capable delivery systems or launchers in various nuclear disarmament scenarios. We conclude that the removal of weapons can be done in a verifiable manner and that the process can be designed in a way that avoids dealing with issues of reliable chain of custody, access to sensitive data, or information barriers that are usually among the most complex problems associated with warhead dismantlement and elimination. We believe that it is possible to chart a path toward nuclear disarmament that would rely primarily on gradual withdrawal of nuclear weapons from operations and that would therefore avoid dealing with the warhead dismantlement process and the many technical and political problems associated with it. In the short-term, this approach could be used in a range of nuclear disarmament scenarios, whether as part of a formal treaty or as a measure that builds confidence and reduces the dangers associated with nuclear weapons. These scenarios might include zero-deployed non-strategic weapons in Europe, denuclearization of the Korean Peninsula, or elimination of nuclear cruise missiles.

The next section of the report (Section 3) describes the proposed verification approach in the context of nuclear disarmament, scenarios where it can be used, and then examines various steps that would be involved in the process of nuclear weapons removal. Section 4 considers historical experience with verifying the absence of nuclear weapons or nuclear-capable delivery systems. The final section of the report (Section 5) describes elements of practical arrangements that would verify the absence of nuclear weapons.

It should be noted that the basic outline of the arrangement described here is based primarily on the operational practices and disarmament experience of Russia and the United States. We believe there is no reason why it cannot be applied to other States as well, although some adjustments may be necessary.

3 Verifying absence: overview of the concept

3.1 REMOVAL OF NUCLEAR WEAPONS AND DISARMAMENT

Removal of nuclear weapons has been an essential component of the nuclear disarmament process for a long time. For instance, the United States and the Soviet Union retired an entire class of nuclear weapons under the 1987 Intermediate-Range Nuclear Forces (INF) Treaty by eliminating all ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 kilometres. In another prominent example, the Soviet Union withdrew all nuclear weapons from the Warsaw Pact States, and following the breakup of the Soviet Union, Russia withdrew tactical nuclear weapons from the former Soviet republics.[5] It then arranged the removal of strategic nuclear weapons from Belarus, Kazakhstan, and Ukraine. Under the Presidential Nuclear Initiatives of 1991–1992, the United States removed tactical nuclear weapons deployed in several European States and South Korea. And under those unilaterally reciprocated commitments, the United States and Russia also removed all nuclear warheads from entire classes of delivery platforms, such as surface military ships.

Yet, in none of these cases has the removal of nuclear weapons been fully and directly verified. The withdrawal of weapons have been either verified indirectly, through the withdrawal or elimination of delivery systems, or confirmed by circumstantial evidence. The establishment of verification procedures for confirming the absence of weapons would have significant value, especially in the existing geopolitical environment.

First, verification can contribute to further cooperation by establishing an atmosphere of trust, confidence, and mutual understanding. The presence of credible verification enhances the viability of existing agreements and commitments by ensuring obligations are being upheld. Developing a broad verification toolkit thus expands the spectrum of possibility for disarmament progress, providing tangible reference points that can be drawn upon both to strengthen provisions in existing instruments and shape the contours of future agreements.

Second, a focus on verifying the completion of removal processes essentially seeks to verify the absence of nuclear weapons. This ‘absence’ approach allows avoidance of the fundamental conundrum in nuclear disarmament verification. After all, verifying absence does not require access to nuclear warheads themselves at any stage: production, deployment, storage, transport, or dismantlement. As such, the approach largely avoids issues of access and sensitive information surrounding those armaments (though this is not to say that such an approach avoids issue of access and sensitive information altogether). It should be far more palatable for nuclear-armed States than disarmament approaches focused on verifying ‘presence’—centred on baseline counts and monitoring all stages of the process of moving warheads from operational bases to dismantlement.

Third, verifying absence could be key to policy initiatives that can support a range of approaches to nuclear disarmament. Certainly, the elimination of nuclear warheads remains the common end of the process, which explains why dismantlement has become a focal point for many current disarmament verification programs. An approach based on verifying absence can make the dismantlement arrangements easier to devise and implement. This is because intermediate arms

[5] Joshua Handler, “The 1991-1992 PNIs and the Elimination, Storage, and Security of Tactical Nuclear Weapons”, in *Tactical Nuclear Weapons: Emergent Threats in an Evolving Security Environment*, Alistair Millar and Brian Alexander, ed. (Potomac Books, Inc., 2003), pp. 27–28.

reduction steps are necessary to bridge the gap to warhead elimination. Stockpile consolidation, withdrawal from active service, and removal from States or territories represent such measures. These actions can also utilize "new modes of verification that could be ad hoc, tailored, and adaptable to national and regional circumstances."[6] Across these scenarios then, an arrangement that verifies absence has relevance.

3.2 POSSIBLE REMOVAL SCENARIOS

Verifying the absence of nuclear weapons could help to demonstrate that practical disarmament measures are possible in the short- and medium-term, reinforcing the nuclear disarmament and non-proliferation efforts. This section outlines a number of concrete removal scenarios along this vein. These scenarios could also expand the disarmament conversation beyond the United States and Russia to include the so-called nuclear umbrella States and non-nuclear-weapon States. This capacity-building element would enhance the involvement of all States in nuclear disarmament.

3.2.1 Non-strategic nuclear weapons in Europe

Verified removal of U.S. and Russian non-strategic nuclear weapons from operational bases in Europe could help reduce the danger of conflict and subsequent escalation between NATO and Russia; it could also ease current tensions. While such tactical weapons have been excluded from past bilateral arms control treaties, many experts and officials had sought to target them in the next round of cuts. In fact, in consenting to ratify New START in 2010, the U.S. Senate specified that the United States should "seek to initiate […] negotiations with the Russian Federation on an agreement to […] secure and reduce tactical nuclear weapons in a verifiable manner."[7] One possible measure that could help address the issue of weapons in Europe may involve consolidation of all these weapons at central storage facilities, away from operational bases.[8] The approach described in this report can be used to verify that this consolidation process has been completed.

3.2.2 Denuclearization of the Korean Peninsula

Recent rapprochement between North and South Korea included an April 2018 declaration outlining a "common goal of realizing, through complete denuclearization, a nuclear-free Korean peninsula."[9] While much attention has rightly been focused on North Korea's weapons program, verifying the absence of deployed U.S. weapons in South Korea would probably be part of the denuclearization arrangement as well. As Section 4 details, while removal of U.S. weapons took place in accordance with the 1991–1992 PNIs, it was only in 2005, in the context of the Six-Party Talks, that the United States formally affirmed that it had no nuclear weapons on the peninsula. Yet the issue remains a concern for North Korea, which as a condition for denuclearization in 2016 included calls for the United States to remove nuclear weapons from its bases in South Korea.[10] Demonstration of the absence of nuclear weapons at these bases could be an important confidence-building tool that would help advance the denuclearization talks.

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[6] Nathan E. Busch and Joseph F. Pilat, "South African Rollback: Revisiting Monitoring and Verification Lessons after 20 Years", *Comparative Strategy,* 33.3 (2014), p. 251.

[7] United States Senate, "New START Treaty: Resolution of Advice and Consent to Ratification", 22 December 2010.

[8] Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe", UNIDIR, 2017.

[9] Choe Sang-Hun, "North and South Korea Set Bold Goals: A Final Peace and No Nuclear Arms", *The New York Times*, 27 April 2018. Available at https://www.nytimes.com/2018/04/27/world/asia/north-korea-south-kim-jong-un.html.

[10] Duyeon Kim, "The Panmunjom Declaration: What it wasn't supposed to be", *Bulletin of the Atomic Scientists,* 1 May 2018. Available at https://thebulletin.org/panmunjom-declaration-what-it-wasnt-supposed-be11773.

3.2.3 Elimination of nuclear cruise missiles

Enhanced awareness of the particular risks of nuclear-armed cruise missiles has inspired calls for a global ban on these weapons.[11] These risks were linked, for instance, to the inherent ambiguity of delivery vehicles that could carry both conventional and nuclear warheads, to their technical capabilities (e.g. cruise missiles are meant to avoid detection and impossible to recall once launched), and to the rhetoric by decision-makers surrounding their potential use.[12] The targeting of an entire class of delivery vehicles has precedent in the PNIs and the INF Treaty; the verified removal of nuclear cruise missiles would address their destabilizing effects and help confirm the nuclear-armed States' commitment to arms control and disarmament. Those States that have tested nuclear-capable cruise missiles could demonstrate the absence of warheads on their deployed missiles as a confidence-building measure.

3.2.4 Verification in the context of the Treaty on the Prohibition of Nuclear Weapons

Article 2(1)(c) of the Treaty on the Prohibition of Nuclear Weapons (TPNW) requires each State party to declare, *inter alia,* "whether there are any nuclear weapons or other nuclear explosive devices in its territory or in any place under its jurisdiction or control".[13] That provision specifically addresses weapons owned by another State. The treaty does not require such a declaration to be verified, but it is possible to imagine circumstances in which a State would want to demonstrate to other States parties that weapons previously stationed on its territory have indeed been withdrawn.

3.2.5 Strategic elimination of nuclear weapons

The reduction of the role of nuclear weapons, with a view to their ultimate destruction, has been recognized as an important condition for nuclear disarmament. This process has been described as "strategic elimination of nuclear weapons" to distinguish it from the physical elimination weapons, delivery systems, and weapon materials. According to this concept, "nuclear weapons would be kept in cold storage" as they would no longer be means of national strategy.[14] Verifying absence can allow nuclear-armed States to demonstrate their commitment to this process and push it forward. In the longer term, "strategic elimination" would entail the disposition of nuclear components and materials, the transformation of systems to non-nuclear purposes, the monitoring and regular inspection of converted facilities. Prior to that, however, nuclear-armed States would need to remove weapons from operational deployment, shift them to storage, and consolidate existing stockpiles, which is what the verifying absence arrangement is designed to do.

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[11] Andrew Weber, "Nuclear-Armed Cruise Missiles Should be Banned", Asia Pacific Leadership Network for Nuclear Non-Proliferation and Disarmament and Toda Peace Institute, *Policy Brief No. 12* (May 2018). Available at http://toda.org/files/policy_briefs/T-PB-12_Weber_Cruise-missiles.pdf.

[12] Christine Parthemore, "The Unique Risks of Nuclear-Armed Cruise Missiles", in John Borrie, Tim Caughley and Wilfred Wan, eds., *Understanding Nuclear Weapons Risks,* UNIDIR, 2017.

[13] "Treaty on the Prohibition of Nuclear Weapons", (United Nations General Assembly, July 7, 2017), Article 2(1)(c), http://undocs.org/A/CONF.229/2017/8. The treaty also has provisions that would apply to a nuclear-armed State joining the treaty. In addition to a "time-bound plan for the verified and irreversible elimination" of its nuclear weapons program, the treaty would require the State to "immediately remove [nuclear weapons] from operational status" ("Treaty on the Prohibition of Nuclear Weapons", Article 4(2).). This step in the process could use elements of the approach described in this report.

[14] Lewis A. Dunn, "The Strategic Elimination of Nuclear Weapons: An Alternative Global Agenda for Nuclear Disarmament", *The Nonproliferation Review*, 24:5-6 (2017), pp. 401–435.

3.3 WHAT IS THE REMOVAL OF NUCLEAR WEAPONS?

The removal of nuclear weapons could involve a number of different steps carried out sequentially or in parallel. And each step described below would provide a different level of assurance about weapons absence, with each possibly requiring its own verification arrangement. These steps are a subset of measures that would be required to ensure elimination of nuclear weapons, as illustrated in Table 1.

The starting point for the process is the state in which nuclear weapon systems are deployed in full readiness to be used. For strategic systems that would mean that nuclear warheads are mated to missiles, which are installed in their launchers, while bombs or nuclear ALCMs are loaded in the bomb bay or attached to pylons. Non-strategic systems can be fully deployed as well if bombs are attached to the aircraft that would deliver them and short-range missiles are loaded onto their launchers.

In practice, few nuclear weapon systems are in full readiness. It is the standard mode of peacetime operations only for U.S. and Russian ICBMs, and for most SLBMs.[15] For other systems, peacetime operations would include storing armed weapons, such as missiles or bombs, at the base, ready to be loaded on their launchers—aircrafts or transporter erector launchers (TELs).[16] Other deployment arrangements are possible as well. For example, missiles may be installed in their launchers without nuclear warheads.

The basic weapon removal measure would involve making sure that no nuclear weapons are deployed, meaning that no weapons are mated to delivery systems and ready for immediate use. This could be done in a number of ways. Bombs and other air-delivered nuclear weapons could be moved to a base storage facility, missiles could be removed from their launchers or kept in launchers without nuclear warheads. Launchers could contain only conventional versions of a missile, or, if a missile has interchangeable warheads, only conventional warheads would be installed.

Since in most cases the absence of fully ready nuclear weapons is a normal peacetime operational practice, a meaningful removal of nuclear weapons would have to include withdrawal of warheads and other weapons from the bases that support operations of weapon systems. This is particularly important for non-strategic systems and air-based strategic weapons, but could also be part of the procedure for ICBMs and SLBMs.

The removal of weapons from operational bases would be a fairly strong step in the direction of ensuring the absence of deployed nuclear weapons, even though it is relatively easily reversible. In fact, it appears that this is the operational practice currently adopted by Russia for its non-strategic nuclear systems. Weapons are stored at a relatively small number of central storage facilities, but they can be quickly transferred to operational bases and then deployed on their delivery vehicles.[17]

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[15] Other sea-based weapons, such as SLCMs, would normally be deployed in launchers as well. These weapons, however, may have launch authorization procedures that are different from those of ICBMs and SLBMs, so they probably should not be considered in the same category from the point of view of readiness to launch.

[16] Weapons can also be stored at a different base. This appears to be the case of U.S. nuclear weapons stored at the Incirlik air base in Turkey. Hans M. Kristensen, "Non-Strategic Nuclear Weapons", *Federation of American Scientists, Special Report*, no. 3 (2012). Available at https://fas.org/_docs/Non_Strategic_Nuclear_Weapons.pdf; Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe", UNIDIR, 2017. Available at http://unidir.org/files/publications/pdfs/lock-them-up-zero-deployed-non-strategic-nuclear-weapons-in-europe-en-675.pdf.

[17] Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe".

Table 1: Status of weapons that corresponds to various stages of removal of nuclear weapons from operations and their elimination.

STATUS OF WEAPONS	EXAMPLES
Weapons are armed and deployed in/on launchers	U.S and Russian ICBMs in silos or on TELs SLBMs installed in launch tubes on a submarine ALCMs or bombs loaded on bombers
Weapons are armed and ready to be deployed, but not in/on launchers	Bombs and/or armed ALCMs stored at an air base[a]
Weapons are unarmed Warheads/bombs are in storage at the base	ICBMs in silos or on TELs without warheads[b] SLBMs in launch tubes without warheads[c] ALCMs stored at an air base with warheads removed[d]
Warheads/bombs are removed from the base	Russia's non-strategic weapons[e]
Warheads and bombs are removed from the base Infrastructure for warhead storage is eliminated	U.S. Barksdale Air Force Base with B-52H strategic bombers[f] Former U.S. and Soviet bases in Europe[g]
Warheads and bombs removed from the base Infrastructure for warhead storage eliminated Delivery vehicles and/or launchers converted	U.S. air bases with B-1B bombers[h]
Warheads and bombs are in dismantlement queue	About 5000 U.S. and Russian retired warheads and bombs[i]
Warheads and bombs are dismantled	Older types of warheads

NOTE: Stages shaded blue are considered in this report.

a. This appears to be the standard peacetime operational status of weapons (bombs and ALCMs) assigned to strategic bombers. It is also the way the United States deploys its non-strategic nuclear weapons in Europe—gravity bombs are stored in vaults located in aircraft shelters. Hans M. Kristensen, "Non-Strategic Nuclear Weapons", *Federation of American Scientists, Special Report*, no. 3 (2012): 17, https://fas.org/_docs/Non_Strategic_Nuclear_Weapons.pdf.

b. China is believed to operate its ICBMs and shorter-range ballistic missiles without warheads. Hans M. Kristensen and Robert S. Norris, "Chinese Nuclear Forces, 2018", *Bulletin of the Atomic Scientists*, vol. 74, no. 4, July 2018, pp. 289–95, doi:10.1080/00963402.2018.1486620. Russia and the United States remove warheads from ICBMs that are undergoing maintenance.

c. UK SLBMs do not have warheads when they transit from/to the United States to pick up or unload missiles. Tamara Patton, Pavel Podvig, and Phillip Schell, "A New START Model for Transparency in Nuclear Disarmament. Individual Country Reports", UNIDIR, 2013, pp. 38–39. Available at http://unidir.org/files/publications/pdfs/a-new-start-model-for-transparency-in-nuclear-disarmament-individual-country-reports-en-415.pdf.

d. ALCMs deployed at U.S. strategic bomber bases normally have their warheads installed. However, the bases have the capability to install warheads on site. It is possible that in Russia ALCMs can be stored separately from their warheads.

e. Russia has repeatedly stated that all its non-strategic nuclear weapons have been removed to central storage facilities. See the discussion in Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe", UNIDIR, 2017. Available at http://unidir.org/files/publications/pdfs/lock-them-up-zero-deployed-non-strategic-nuclear-weapons-in-europe-en-675.pdf.

f. Barksdale Air Force Base is one of the two U.S. bases that have nuclear-capable B-52H strategic bombers. All their nuclear weapons are stored at Minot Air Force Base. The United States is planning to reconstitute the nuclear weapon storage capability at Barksdale. Greg Hilburn, "House Passes Military Pay Raises, Barksdale Nukes Storage", *Monroe News Star*, July 26, 2018. Available at http://www.thenewsstar.com/story/news/2018/07/26/breaking-house-passes-military-pay-raises-barksdale-nukes-storage/840935002/.

g. Almost all these bases have been closed down. However, some bases that hosted U.S. weapons appear to maintain the vaults that were used to store nuclear bombs. The vaults are kept in "caretaker status", so they may not be able to receive nuclear weapons without some upgrade. Kristensen, "Non-Strategic Nuclear Weapons", p. 25.

h. Between 2007 and 2011, all B-1B bombers were converted for non-nuclear missions in accordance with START and New START procedures. "B-1B Lancer", U.S. Air Force, December 16, 2015. Available at http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104500/b-1b-lancer/.

i. Hans M. Kristensen and Robert S. Norris, "United States Nuclear Forces, 2018", *Bulletin of the Atomic Scientists* 74, no. 2 (March 4, 2018), pp. 120–31. Available at https://doi.org/10.1080/00963402.2018.1438219; Hans M. Kristensen and Robert S. Norris, "Russian Nuclear Forces, 2018", *Bulletin of the Atomic Scientists* 74, no. 3 (May 4, 2018), pp. 185–95. Available at https://doi.org/10.1080/00963402.2018.1462912.

Thus, even if nuclear weapons are not permanently deployed at the operational base, they can be reintroduced there if the base retains the infrastructure that can support weapons deployment. This suggests that the weapon storage support infrastructure is in itself a very important capability. One way to limit that capability and ensure the completion of removal activities is to verify that this infrastructure is eliminated so that operational bases cannot store nuclear weapons for an extended period of time.

It should be noted that eliminating the infrastructure for maintaining deployment of nuclear weapons at operational bases would not preclude the possibility of short-term deployment of nuclear weapons at these bases in an emergency. For example, virtually any air base or any base with a suitable landing strip can accept aircraft with nuclear weapons on board. This option would be available as long as a State keeps nuclear weapons and nuclear-capable weapon systems. This is, however, different from a situation in which a base maintains the capability to host weapons permanently.

In an arrangement that does not aim to verify the actual dismantlement of nuclear warheads and weapons, such as the one presented in this study, one can eliminate nuclear capability by focusing on the delivery vehicles and launchers instead. This approach is at the core of traditional arms control treaties such as INF, START, and New START. However, it would be difficult to apply this approach to weapon systems capable of carrying conventional as well as nuclear payloads, which is the case with some modern weapon systems. Nevertheless, in certain cases it might be possible to modify a delivery vehicle or launcher to eliminate its capability to carry nuclear weapons and to do so in a verifiable way. Such conversion would normally be reversible but can still present a significant barrier to deployment of nuclear weapons as resuming nuclear missions would require physical modifications of the delivery vehicles and/or launchers, training of the crews, and certification of the weapon system.

The range of options for removal of nuclear weapons is reasonably broad, as demonstrated by this overview. None of these measures are truly irreversible, but if they are implemented, especially in combination, they could provide a strong level of assurance regarding the absence of nuclear weapons within a certain territory or on a class of delivery vehicles or launchers. It should be noted that reversibility of the withdrawal process does not necessarily mean that nuclear weapons could be easily brought back. The reversibility could also play a certain stabilizing role, providing a hedge that enables progress in disarmament while giving States time to adjust their policies to new political conditions or indeed to work on changing these conditions to make that hedge unnecessary or irrelevant.

This approach deliberately does not address the question of what happens to nuclear warheads and bombs after they are removed from operational bases. This question would become increasingly relevant as the number of deployed nuclear weapons decreases. However, two considerations are in order. First, verifying the absence of nuclear weapons is fully compatible with other approaches to nuclear disarmament. Elements of this approach have already been implemented in the traditional arms control treaties that are focused on elimination of delivery systems, such as the INF Treaty or in START, or as part of unilateral disarmament initiatives, such as PNIs. Neither does it rule out future arrangements that may rely on monitored withdrawal of weapons from operational bases and their elimination under international control.

More importantly, the approach based on gradual withdrawal of nuclear weapons from operational status and verified elimination of the capability to re-deploy them might provide an alternative path toward nuclear disarmament. A situation in which nuclear warheads are consolidated in a small number of storage facilities and measures are taken to verify their absence outside of these facilities would provide a much more favourable environment for addressing the issues of warhead dismantlement, reconstitution capabilities, virtual arsenals, and disposition of fissile materials. Moreover, this approach could be combined with the deferred verification arrangement that provides a mechanism for verified declarations of the amount of fissile material in weapons.[18] In this case, the most difficult issues related to monitored warhead dismantlement, such as authentication, chain of custody, and information barriers, could be almost entirely avoided.

Whether or not the removal of nuclear weapons becomes the central element of the nuclear disarmament process, it is quite likely that it will be an essential element of any future reductions of nuclear arsenals. In fact, this has been demonstrated in the past, although, as the next section details, the process was almost never verified. Adding arrangements to verify the absence of weapons would add an important element to the set of nuclear disarmament verification tools.

[18] Pavel Podvig and Joseph Rodgers, "Deferred Verification: Verifiable Declarations of Fissile Material Stocks", UNIDIR, 2017.

4 Historical verification experience

Each of the removal steps outlined above has been previously pursued under a range of treaty obligations and State commitments. As mentioned however, there is limited direct verification experience attached to these activities. In some instances, proxy measures centring on delivery vehicles, fissile materials, and/or support facilities have substituted for verification of removal activities of nuclear warheads and/or weapons. In others, no formal verification processes were outlined or implemented at all. Despite this, past removal scenarios contribute to a foundation for verifying absence. They reveal the varied—if limited—means through which verification has been executed, the steps in the removal process to which such procedures have been applied, and the corresponding standard of proof for confirmation of those activities. By exploring case examples, this section highlights the degree to which verifying absence can reduce the spectrum of uncertainty for the facilitating steps in the nuclear disarmament process.

4.1 ABSENCE OF WEAPONS

4.1.1 The Cuban missile crisis

The removal of nuclear weapons from Cuba following the Cuban Missile Crisis provides probably the first example of removal of nuclear weapons carried out as part of an agreement that was partially verified. When the United States and the Soviet Union reached an agreement on withdrawal of missiles from Cuba, the initial assumption was that the absence of missiles (but not the nuclear warheads) would be verified by the United Nations.[19] However, Cuba objected to any inspection of its territory,[20] and the verification was instead done by U.S. national technical means (NTM)—watching from air and sea as ships entered and left Cuba.

What the United States did not know was that some Soviet nuclear weapons remained in Cuba after the ballistic missiles were removed. U.S. President John F. Kennedy had not requested that all nuclear weapons be removed, only that all *offensive* weapons be removed, which was understood by both sides to mean weapons capable of reaching the United States. Nearly one hundred Soviet short-range tactical nuclear weapons were left behind. The Soviet Union eventually removed all nuclear weapons, but it was done without any verification.[21]

The arrangement that ended the Cuban crisis also included a commitment by the United States to remove its ballistic missiles from Turkey. That withdrawal was completed by the end of April 1963.[22] This part of the arrangement was not disclosed at the time and no verification measures were expected or implemented, although presumably the Soviet Union was able to confirm, through national technical means or otherwise, that the missiles were removed.

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[19] Message From Chairman Khrushchev to President Kennedy, "Foreign Relations of the United States, 1961–1963, Volume XI, Cuban Missile Crisis and Aftermath - Foreign Relations of the United States, 1961–1963, Volume XI, Cuban Missile Crisis and Aftermath - Historical Documents - Office of the Historian", pp. 279–283, accessed September 24, 2018. Available at https://history.state.gov/historicaldocuments/frus1961-63v11/pg_279.

[20] Letter From Fidel Castro to Chairman Khrushchev, National Security Archive, The George Washington University. Available at https://nsarchive2.gwu.edu//nsa/cuba_mis_cri/19621028caslet.pdf.

[21] James M. Lindsay, "TWE Remembers: Secret Soviet Tactical Nuclear Weapons in Cuba (Cuban Missile Crisis, a Coda)", *Council on Foreign Relations* (blog), October 29, 2012. Available at https://www.cfr.org/blog/twe-remembers-secret-soviet-tactical-nuclear-weapons-cuba-cuban-missile-crisis-coda.

[22] Ibid.

4.1.2 Post-Soviet States

At the time of its breakup, the Soviet Union had an estimated 35,000 nuclear weapons across its constituent territories. This included at least 22,000 tactical weapons designed for battlefield use, and 3,200 strategic nuclear warheads in Ukraine, Kazakhstan, and Belarus.[23] All of these would be removed from the Warsaw Pact countries and the successor States and returned to Russia over the course of the following years.[24] There were no multilateral verification arrangements in the withdrawal process and Russia released little information about its progress. In February 1992, for instance, Ukraine complained it had "no information" about the status of tactical nuclear weapons removed from its territory.[25] Russia announced the completion of the removal and transport processes in Warsaw Pact countries and former Soviet territories only after the fact.[26]

The presence of strategic nuclear weapons in Belarus, Kazakhstan and Ukraine complicated the denuclearization process, as those items fell under START provisions. While the START treaty did not enter into force until 1994, the 1992 Lisbon Protocol—accompanied by letters of intent—brought these three countries into the START framework and committed them to eliminate their treaty-accounted strategic launchers within a seven-year period. However, the verification procedures of START—explored later—centred on delivery vehicles; it was assumed that warheads were removed in the process. The Lisbon Protocol did not entail discussion about how warhead removal might take place in the former Soviet territories, let alone how that process might be verified.

The post-Soviet cases illustrate practical considerations in verifying removal. Sticking points concerned external access to the process (Ukraine for instance pushed for the involvement of international experts) and resources (including financial responsibility for transport and compensation for weapons return). Bilateral agreements, including the Massandra Accords with Ukraine, left Russia unilaterally responsible for transport and warhead disassembly, yet one outcome was an information deficit that surfaced between the weapons owner and the host State.[27] The transport process was not a complete black box. The removal of weapons and weapons-usable materials from Ukraine was reported to the United States through the Cooperative Threat Reduction Program; in addition, the United States was involved in the 1994 Trilateral Statement and Annex, which allowed Ukrainian experts to monitor the process of warhead shipment to Russia.[28] Still, a number of post-Soviet States expressed concerns about the whereabouts of their withdrawn weapons.[29]

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[23] Graham Allison, "What Happened to the Soviet Superpower's Nuclear Arsenal? Clues for the Nuclear Security Summit", *Faculty Research Working Paper Series*, Harvard Kennedy School, August 2012.

[24] Including under the 1991 Agreement on Joint Measures with regard to Nuclear Weapons.

[25] L. Gak, "Denuclearization and Ukraine: Lessons for the Future", *The Nonproliferation Review,* 11.1 (2004), p. 118.

[26] An interview with Belarus' First Defence Minister confirmed the process in that country. See Joshua Handler, "The September 1991 Presidential Nuclear Initiatives and the Elimination, Storing and Security Aspects of TNWS", in T. Susiluoto, ed., *Tactical Nuclear Weapons: Time for Control*, UNIDIR, 2002, pp. 107-132.

[27] Olli-Pekka Jalonen, "Captors of Denuclearization? Belarus, Kazakhstan, Ukraine, and Nuclear Disarmament", Tampere Peace Research Institute, 1994, p. 57.

[28] Steven Pifer, "The Trilateral Process: The United States, Ukraine, Russia and Nuclear Weapons", Brookings Institution, May 2011. Available at https://www.brookings.edu/wp-content/uploads/2016/06/05_trilateral_process_pifer.pdf.

[29] For instance, Belarus noted that "little information exists concerning the location and method of destruction". See M. D. Skootsky, "An Annotated Chronology of Post-Soviet Nuclear Disarmament 1994-1994", *The Nonproliferation Review*, Spring-Summer 1995, p. 69. This was true beyond weapons. The presence of weapons-grade materials at Degelen Mountain in Semipalatinsk was not disclosed to Kazakhstan for some time after it gained independence. See also E. Harrell and D. E. Hoffman, *Plutonium Mountain: Inside the 17-Year Mission to Secure a Dangerous Legacy of Soviet Nuclear Testing* (Cambridge: Harvard University, August 2013); D. Sholk, *The Denuclearization of Kazakhstan*

4.1.3 U.S. weapons in Europe and South Korea

The post-Soviet context marked a situation in which newly independent States acquiesced to the return of nuclear weapons stationed on their territories. Yet the withdrawal process from a State or territory can also be an entirely unilateral decision by the nuclear-armed State.[30] For instance, as part of the President Nuclear Initiatives, George H. W. Bush in 1991 pledged to “bring home and destroy all of our nuclear artillery shells and short-range ballistic missile warheads.”[31] For the United States, this involved its tactical nuclear weapons deployed in Europe and South Korea. The subsequent detachment of warheads, removal from weapon systems, and/or consolidation of its stockpiles lacked any verification mechanisms—even the limited and irregular means present in the post-Soviet cases.

In December 1991, South Korean President announced that the United States had completed withdrawal of weapons from South Korea. At the time, the United States did not officially confirm that information, but did not deny it either.[32] Subsequently, U.S. Assistant Secretary of State for Arms Control Stephen Rademaker stated in an interview that the United States had completed dismantlement of the warheads formerly stationed in South Korea in 2003, in accordance with the PNIs.[33] The Joint Statement of the Fourth Round of Six-Party Talks in 2005 also included an affirmation by the United States that it had “no nuclear weapons on the Korean Peninsula.”[34] These seem to echo the post-Soviet cases wherein announcements after the fact by government or military officials stand as the standard of proof for any such process.

Some information concerning the removal of U.S. nuclear weapons deployed overseas was incomplete. While the U.S. Department of Energy provided information on the numbers of warheads withdrawn and eliminated under PNIs, there were discrepancies. For instance, the number of Lance missile warheads claimed destroyed exceeded the number first declared to exist by U.S. officials in 1991.[35] In other cases, information has been absent altogether. The United States did not confirm the removal of deployed weapons in Greece and the United Kingdom, nor the consolidation of stockpiles in Germany. These removals were revealed by independent researchers.[36]

The PNIs are not the only instance of unverified nuclear weapons removal.[37] It is notable that Rademaker in the aforementioned interview noted “considerable concern” regarding the

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(1991-1995), INAF 912, 30 April 2013. Available at https://isd.georgetown.edu/sites/isd/files/JFD_Sholk_Denuclearization.pdf.

[30] Nuclear weapons were routinely transferred to and from various bases before, but that was done largely as part of a change in deployment plans, rather than as a result of a commitment to remove the weapons. See Robert S. Norris, William M. Arkin and William Burr, “Where They Were. Appendix B”, *Bulletin of the Atomic Scientists* 55, no. 6 (November 1999), pp. 66–67. Available at https://doi.org/10.1080/00963402.1999.11460395.

[31] George H. W. Bush, Address to the Nation on Reducing United States and Soviet Nuclear Weapons, 27 September 1991. Available at https://bush41library.tamu.edu/archives/public-papers/3438.

[32] Hans M. Kristensen and Robert S. Norris, “A History of US Nuclear Weapons in South Korea”, *Bulletin of the Atomic Scientists,* 73.6 (2017), p. 352.

[33] “Press Roundtable at Interfax: Stephen G. Rademaker, Assistant Secretary of State for Arms Control”, 6 October 2004. Available at https://2001-2009.state.gov/t/isn/rls/rm/37275.htm.

[34] Joint Statement of the Fourth Round of the Six-Party Talks, Beijing, 19 September 2005. Available at https://www.state.gov/p/eap/regional/c15455.htm

[35] Joshua Handler, “The September 1991 Presidential Nuclear Initiatives”.

[36] Hans M. Kristensen, “U.S. Nuclear Weapons Withdrawn from the United Kingdom”, *Federation of American Scientists*, 26 June 2008. Available at https://fas.org/blogs/security/2008/06/us-nuclear-weapons-withdrawn-from-the-united-kingdom

[37] In an interesting early case, U.S. intelligence was not aware of the removal of Soviet tactical warheads from Cuba following the Cuban Missile Crisis. See https://nsarchive2.gwu.edu/NSAEBB/NSAEBB449/.

fulfilment of PNI commitments by the Russian side.[38] The lack of precise accounting has arguably undermined the disarmament activity itself. When North Korea outlined its denuclearization policy in July 2016, it specified as a basic condition that the United States publicly disclose its nuclear weapons in South Korean bases and remove and verify their absence.[39] The value of removal verification mechanisms even in unilateral contexts is readily apparent, especially in light of shifting global dynamics and the evolving proliferation threat.

4.2 ELIMINATION OF NUCLEAR-CAPABLE SYSTEMS

4.2.1 The INF Treaty

The United States and Russia have extensive experience with treaties dealing with delivery vehicles as a means to reduce warheads. Unlike the withdrawal processes discussed above, legal instruments in this removal step have encompassed elaborate verification systems that centre almost exclusively on delivery vehicles. The first of these was the 1987 INF Treaty, in which both sides committed to the elimination of all ground-launched and cruise missiles, nuclear and conventional, with a range between 500 and 5,500 kilometres (it became a multilateral treaty following the breakup of the Soviet Union).

The INF Treaty was a ground-breaking arms control and disarmament instrument, both in terms of substance and procedure. It included two long protocols, one focused on procedures governing the elimination of the relevant missile systems and one focused on the on-site inspections at the heart of its verification system. It was the first arms control instrument to contain verification mechanisms beyond national technical means.

The INF's extensive system of on-site inspections (at all missile operating bases, support facilities other than production facilities and elimination facilities) comprised the bulk of the instrument. Baseline inspections allowed the creation of an inventory that would become the reference point for elimination procedures. Continuous portal monitoring, missile elimination and base close-out inspections allowed each side to verify that the other side was upholding their obligations. Base close-out procedures in particular have applicability to the arrangement presented in this study. In addition, the treaty is also one of the few to implicitly require the elimination of nuclear infrastructure, as it specified that no "support structures or support equipment shall be possessed" three years after its entry into force.[40] The elimination of these structures took place *in situ*, with the process again subject to verification through on-site inspection.

4.2.2 START and New START

The inspection-based verification model created by the INF Treaty inspired what is arguably the most successful arms control and disarmament instruments to date; the Strategic Arms Reduction Treaties (START in 1991, New START in 2010). Both of them committed the United States and Russia to reduce their strategic nuclear missile launchers and associated warheads. Again, both treaties verified only limits in launchers, rather than the number of warheads possessed by each State.

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[38] "Press Roundtable at Interfax: Stephen G. Rademaker, Assistant Secretary of State for Arms Control", 6 October 2004. Available at https://2001-2009.state.gov/t/isn/rls/rm/37275.htm.
[39] "DPRK Government Denounces U.S., S. Korea's Sophism about 'Denuclearization of North'", KCNA, 6 July 2016.
[40] Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of their Intermediate-Range and Shorter-Range Missiles, 8 December 1987 (signed), Article IV. Available at https://fas.org/nuke/control/inf/text/inf.htm.

Figure 1

An aerial view of the Royal Air Force Greenham Common, United Kingdom in 1989. The base was used for deployment of nuclear ground-launched cruise missiles. It was closed in 1993 and subsequently designated as public parkland. The site was subsequently used to film scenes for one of the "Star Wars" movies. Source: U.S. Department of Defense via picryl.com.

The 1991 START expanded the verification toolkit by adding new dimensions to the INF model. Baseline information was predicated on data exchanges and notifications and confirmed by 12 types of on-site inspections (including at ICBM bases, submarine bases, and air bases). These inspections made assumptions about the number of nuclear warheads on missiles, a practice changed in New START—when the United States and Russia shared the actual number of warheads deployed at individual bases (and allowed counting on a selected missile), and also expanded the identifier system on missiles and streamlined inspection procedures.

The New START verification provisions also reflected a number of compromises. The carrying capacity of heavy bombers, for instance, was ignored in favour of a system that counted each as one warhead. Meanwhile, heavy bombers located at repair or production facilities were exempt—as they were considered non-deployed. That the treaty set limits only on deployed strategic warheads (and not inactive stockpiles) meant that storage sites remained outside the realm of inspections as well. And while the treaty included limits on the number of deployed warheads and delivery vehicles, verification covered only the reduction in the number of launchers.

The positive experience stemming from the INF and START treaties led the United States and Russia to expand discussion beyond launchers and delivery vehicles. In the 1990s, the sides discussed mutual inspections of dismantled warhead storage sites and agreed during preparations for the failed START III negotiations to include "measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads."[41] But neither

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[41] Anatoly Dyakov, "Nuclear Warheads and Weapons-Grade Materials", in Natalia Bubnova, ed., *Nuclear Reset: Arms Reduction and Nonproliferation* (Moscow: 2012), pp. 237–8; "U.S., Russia to Inspect Plutonium Storage", Washington

came to fruition. The START cases thus underline both the sensitivity of warhead dismantlement and the utility of alternative approaches with non-warhead related objectives.

4.2.3 Sea-based weapon systems

In addition to the withdrawal and elimination of tactical nuclear weapons deployed overseas, President Bush, as part of the PNIs, also pledged to remove all warheads from naval ships, attack submarines, and naval aircraft. Some of these would be eliminated, the others stored centrally. President Gorbachev later reciprocated.[42] These were, however, political commitments that contained no intrinsic monitoring or verification mechanisms. The only monitoring mechanism in place was the annual declarations about the number of deployed nuclear sea-launched cruise missiles (SLCMs) that the United States and Russia committed to provide when they signed the START Treaty. While the treaty was in force, both sides routinely submitted declarations that confirmed that no nuclear SLCMs were deployed at sea.[43] However, this reporting mechanism did not contain any verification measures and the exchange was discontinued when START expired in 2009. Nevertheless, this mechanism does represent a model for minimal verification (in a national context) for future reciprocal action.[44] Subsequent U.S. action to reduce its non-strategic naval nuclear weapons have lacked even that. This has been true across different steps of the disarmament process: from the denuclearization of its surface fleet in 1994, the withdrawal of nuclear-armed Tomahawk land-attack cruise missiles (TLAM/N) to surface sites, and the consequent retirement of those TLAM/Ns in 2010.[45]

4.3 OTHER REMOVAL SCENARIOS

Under a host of circumstances, many of the objectives associated with nuclear weapons removal have been achieved, including the withdrawal of warheads from a territory, the elimination of nuclear-capable weapon systems, and the destruction of nuclear infrastructure. As discussed, the level of verification for these activities has fluctuated greatly, though as a totality past cases have contributed to a useful toolkit that can contribute to the verification of absence. A final category of relevant experience involves North Korea. While any removal activities currently remain hypothetical, the longstanding crisis on the peninsula provides some insight as to the complexities of the nuclear disarmament process, as well as the need to disaggregate the process into steps in order to make verification more feasible—both politically and technically.

The 2005 Joint Statement of the Six-Party Talks provided momentum that brought verification to forefront of the agenda. In July 2008, the Heads of Delegation outlined measures that would "include visits to facilities, review of documents, interviews with technical personnel and other measures unanimously agreed upon", with the IAEA to provide consultancy and assistance as necessary.[46] Yet further discussions—meant to take place in the Working Group on

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Post, 16 March 1994. Available at http://articles.orlandosentinel.com/1994-03-16/news/9403160512_1_plutonium-inspection-agreement-warhead.

[42] There would be a second round of cuts from Bush and Boris Yeltsin.

[43] Pavel Podvig, "Do Russian Attack Submarines Carry Nuclear Weapons?", *Russian Strategic Nuclear Forces*, September 15, 2006. Available at http://russianforces.org/blog/2006/09/do_russian_attack_submarines_c.shtml.

[44] Susan J. Koch, "The Presidential Nuclear Initiatives of 1991–1992", *Center for the Study of Weapons of Mass Destruction Case Study 5*, National Defense University Press, September 2012, p. 22.

[45] Nuclear Posture Review [Extract from the 1995 Annual Defense Report]. Available at https://fas.org/nuke/guide/usa/doctrine/dod/95_npr.htm; Hans M. Kristensen, "U.S. Navy Instruction Confirms Retirement of Nuclear Tomahawk Cruise Missile", *Federation of American Scientists*, 18 March 2013. Available at https://fas.org/blogs/security/2013/03/tomahawk/.

[46] Press Communique of the Heads of Delegation Meeting of the Sixth Round of the Six-Party Talks, 12 July 2008. Available at https://www.mofa.go.jp/region/asia-paci/n_korea/6party/press0807.html.

Denuclearization—stalled after the United States circulated a discussion paper that demanded "verification of all related information, personnel, facilities or materials", with full access to all materials, at any sites related to the nuclear program, or to any site upon request to confirm absence of undeclared materials, equipment, and activities; and full access to records and personnel.[47] North Korea withdrew from all talks in April 2009.

The April 2018 Panmunjom Declaration, in which North and South Korea committed themselves to the denuclearization of the Peninsula, has refocused attention on verification. So far, North Korea has not committed to any verification measures. One of the most visible disarmament steps—dismantlement of the nuclear test site at Punggye-ri—was only shown to a handful of foreign journalists, who watched from afar. It is, however, generally accepted that denuclearization will have to include verified dismantlement of warheads as well as elimination of weapon materials and weapon-related infrastructure. This process could take a long time—some have suggested that a verified denuclearization process in North Korea would take up to 15 years.[48] Verified consolidation of nuclear weapons in storage facilities could be a measure that would help prepare their subsequent elimination.

[47] "Verification Measures Discussion Paper", reprinted in *Global Fissile Material Report 2009*, Appendix 4A: U.S. Proposal for Verification of North Korea's Denuclearization. Available at http://fissilematerials.org/library/gov08a.pdf; Glenn Kessler, "Far-Reaching U.S. Plan Impaired N. Korea Deal", *Washington Post*, 26 September 2008. Available at http://www.washingtonpost.com/wp-dyn/content/article/2008/09/25/AR2008092504380.html.

[48] Siegfried S. Hecker, Robert L. Carlin and Elliot A. Serbin, "A Technically-Informed Roadmap for North Korea's Denuclearization", 28 May 2018. Available at https://cisac.fsi.stanford.edu/sites/default/files/hecker_carlin-serbin_denuc_rlc.pdf.

5 Potential practical arrangements for verifying the absence of nuclear weapons

As detailed earlier, the range of steps linked to the removal of nuclear weapons is reasonably broad. Accordingly, designing practical arrangements that aim to verify removal activities—by confirming the absence of nuclear weapons—must be similarly varied, and tailored to each need. As mentioned, the New START model in particular provides many of the tools necessary to verify absence, and will serve as the foundation for much of the discussion to follow. It is worth emphasizing that there is no ready verification procedure that can be utilized in every situation. Given different types of nuclear weapons present in existing arsenals (as well as limited information about stockpiles) it may well be necessary to develop new verification technologies. New START tools and procedures, however, provide a basis that can guide these efforts.

5.1 CHARACTERISTICS OF A NUCLEAR WEAPON

In discussing practical arrangements, it is important to emphasize that verification procedures would have to establish the absence of nuclear warheads or weapons, rather than components of a nuclear charge or fissile materials. This consideration should help set certain boundaries regarding the kinds of objects targeted by inspection activities. Specifically, this should allow inspectors to make general assumptions about the mass and size of inspected objects as well as about the type of fissile material that can be present. Verification procedures would not require any information about design of a warhead or its specific attributes, yet assumptions about this information would help define procedures in a way that would ensure confidence in the outcome of the inspection.

It should be possible to make a number of assumptions about nuclear weapons for the purpose of verifying their absence. To begin, the number of different types of weapons in any arsenal is limited, and in some cases their general characteristics are reasonably well known. For example, the United States arsenal includes 11 warhead designs, which can be considered modifications of seven basic weapon types. The modernization plan would further reduce that number to five designs—three ballistic missile warheads, one gravity bomb, and an air-launched cruise missile warhead.[49] The United Kingdom has only one type of warhead, for use in its SLBMs. France is converting its force to a structure that will include only two types of warheads, down from the current three.[50] Useful assumptions can also be made about types of weapons in other nuclear-armed States, even if the information is not as readily available.

It should also be possible to make assumptions about the fissile material used in weapons. Fundamentally, only three types of nuclear explosive devices exist. A pure fission device derives all of its explosive energy from the fission of chain-reacting fissile material, whether plutonium or highly enriched uranium (HEU). A boosted fission device incorporates small amounts of deuterium and tritium that "boost" the overall yield of the explosion by speeding up the fission chain reaction with the release of large numbers of neutrons. And a thermonuclear weapon uses one of these

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[49] Hans M. Kristensen, "NNSA's New Nuclear Stockpile Stewardship and Management Plan", *Federation Of American Scientists* (blog), November 16, 2017. Available at https://fas.org/blogs/security/2017/11/ssmp2017/.

[50] Hans M. Kristensen and Robert S. Norris, "Worldwide Deployments of Nuclear Weapons, 2017", *Bulletin of the Atomic Scientists* 73, no. 5 (3 September 2017), pp. 289–97. Available at https://doi.org/10.1080/00963402.2017.1363995.

two fission explosions as a "primary" to create the conditions for the ignition of a quantity of thermonuclear fuel that contributes significantly to the explosive yield.[51] It may be possible to assume that the weapons in active arsenals have a two-stage thermonuclear design with plutonium-based primaries, with a smaller likelihood for HEU-based fission-only weapons. For example, in START and New START the United States and Russia were confident in assuming that all weapons on strategic delivery systems contain a certain amount of plutonium. Accordingly, verification procedures relied on a gross neutron count to determine whether an object was nuclear or non-nuclear. Had the parties expected the presence of HEU-only weapons, they would have selected a different procedure because such weapons emit too few neutrons to be identified as nuclear objects with these methods.[52]

Figure 2

Nuclear bomb "28" that was deployed by the Soviet Union between 1969 and 1980. The red protection cap on the body most likely covers the socket for the cable that connects the bomb with the arming system on board the aircraft. A nuclear warhead of a cruise missile is on the background. Photo: Michael Jerdev, 2015. Reproduced with permission.

The approximate size and weight of a weapon expected to be located at a specific facility can also be estimated with some certainty. Fundamentally, a storage facility adjacent to a bomber airbase would not be expected to contain ICBM warheads (although some storage facilities may contain several types of warheads and bombs). Beyond that, the dimensions of most gravity bombs or ballistic or cruise missile warheads are very well known (see, for example, Figure 2). For warheads,

[51] Theodore B. Taylor, "Verified Elimination of Nuclear Warheads", *Science & Global Security*, Volume 1, 1989, pp. 1–26.
[52] Alex Glaser, "Ceci N'est Pas une Bombe", 58th Institute of Nuclear Material Management Annual Meeting, Indian Well, CA, July 2017.

these are normally determined by the interface with the delivery system, such as a missile. Also relevant for verifying absence, it can be assumed that warheads and bombs would be stored in a form that does not require any on-site assembly operations, for example, as fully assembled gravity bombs, ballistic missile re-entry vehicles, or nuclear warheads of cruise missiles. This should provide reasonable guidance about the size of nuclear warheads relevant for most situations.

Reliable information about the weight of nuclear weapons is more difficult to obtain. Some sources suggest that weapons in the current U.S. arsenal have an average mass of a few hundreds of kilograms.[53] Other information suggests that the weapons could be lighter. According to a Soviet estimate from the 1980s, the weight of the 100-kt W76 warhead deployed on U.S. Trident II SLBM is approximately 92 kg, about 62 kg from the nuclear charge and the rest from the re-entry vehicle body and electronics. During the Cold War, the lightest warheads deployed on Soviet ballistic missiles were those of R-29R and R-39 SLBMs with the total weight in the range of 100–130 kg.[54] Smaller and lighter weapons, for example, artillery shells or demolition munitions, had been developed in the United States and the Soviet Union, but these have been withdrawn from active service. Weapons of earlier generations and single-stage weapons are likely to have less efficient designs, so they are unlikely to be significantly lighter even with smaller yields.

These numbers are only estimates, of course, and cannot be applied to all situations. It should be noted, though, that nuclear-armed States should be able to have reasonably good understanding of the range of possibilities they will encounter and adjust their verification procedures accordingly. Importantly, since these procedures would be designed to confirm the absence of weapons, development of the detection techniques would not require disclosing information about weapon design. This means that experts from nuclear-armed States should be able to contribute to that development without sharing any sensitive information.

5.2 NEW START VERIFICATION ARRANGEMENTS

It is possible that procedures for confirming weapons absence can be based upon existing arrangements, including those used for the New START treaty agreed to by Russia and the United States in 2010. Many of these arrangements were, in fact, included in the first START treaty, but New START introduced a number of additional elements.

While New START follows many of the same definitions and counting rules to identify treaty-limited items as the earlier treaty, it added inspection provisions to verify the number of warheads deployed on land- and sea-based ballistic missiles. This was a significant advancement over old START inspections that were only used to confirm that these missiles carried no more re-entry vehicles than the number of warheads attributed to them. START procedures did not aim to establish how many warheads a missile could carry or to verify the actual number of weapons deployed.[55]

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[53] Alex Wellerstein, "Kilotons per Kilogram", *Restricted Data: The Nuclear Secrecy Blog* (blog), December 23, 2013. Available at http://blog.nuclearsecrecy.com/2013/12/23/kilotons-per-kilogram/; Steve Fetter et al., "Detecting Nuclear Warheads", *Science & Global Security* 1, no. 3–4 (1990), pp. 225–53.

[54] These warheads had yields of 50 kt and 75 kt respectively. Pavel Podvig, "How Many Warheads?", *Russian Strategic Nuclear Forces* (blog), May 17, 2007. Available at http://russianforces.org/blog/2007/05/how_many_warheads.shtml.

[55] Amy F. Woolf, *Monitoring and Verification in Arms Control* (Congressional Research Service, 2011), p. 21. Available at https://www.fas.org/sgp/crs/nuke/R41201.pdf; Amy F. Woolf, *The New START Treaty: Central Limits and Key Provisions,* (Congressional Research Service, February 5, 2018), p. 14. Available at https://crsreports.congress.gov/product/pdf/R/R41219. Technically, the New START procedures allow parties to verify

New START procedures require parties to report the actual number of warheads deployed on its ICBMs and SLBMs and the number of warheads deployed on operational launchers at each ICBM or SLBM base. The weapons associated with heavy bombers are accounted for differently, with parties reporting the number of deployed bombers; each is then counted as a single warhead toward the treaty limit.

The main element of the New START verification regime is its ability to confirm the accuracy of those declared numbers of deployed warheads. For this purpose, the treaty allows parties to conduct up to ten inspections at ICBM, submarine, or heavy bomber bases each year. For an inspection, the host party is required to report the number of warheads deployed on individual launchers located at the inspected base. Inspectors then designate one launcher for inspection and count the number of warheads deployed on the missile contained in that launcher. Because inspected sites and launchers are randomly selected on short notice, parties have a good chance of detecting any effort to deploy extra warheads, thereby deterring such attempts.[56]

Should a State choose to take all nuclear warheads off its missiles, for instance at an ICBM or submarine base, and move them to storage, the basic New START verification arrangement can be used, without modification, to verify that such removal has taken place. This practice, in fact, would not be unprecedented. In the 1970s the Soviet Union removed warheads from virtually all its UR-100/SS-11 missiles due of safety concerns when the missiles reached the end of their service life. In the 1990s, as part of the PNIs, the United States and Russia took older ICBMs off alert, with warheads likely taken off these missiles long before they were removed from their silos. Similarly, all warheads deployed on ICBMs located in Belarus, Kazakhstan and Ukraine were transferred to Russia by November 1996, even if the process of removing missiles from silos took considerably longer.[57] According to START accounting rules these warheads were counted as deployed, but under New START the missile bases in those countries would have been listed as having zero deployed warheads. Furthermore, it is also possible to imagine scenarios in which missiles will be operationally deployed without warheads. For example, China is believed to operate its ICBMs in this manner, and some de-alerting proposals call for the removal of warheads from all ballistic missiles. In these cases, New START appears to provide a ready solution for verifying the absence of warheads on ballistic missiles.

Another important element of the New START verification system is the provision that allows inspectors to use radiation detection equipment to confirm the non-nuclear status of certain objects.[58] The treaty itself does not rely on this capability to make a distinction between nuclear and non-nuclear warheads that can be deployed on a missile, as warheads on missiles are counted against the treaty limit regardless of whether they are nuclear or conventional. Nevertheless, the treaty contains a detailed description of the procedure that would allow that distinction to be made.

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that the number of warheads on an individual missile does not exceed the declared number. However, in practice they provide high confidence in the fact that the parties declare the actual number of deployed warheads.

[56] Amy F. Woolf, *The New START Treaty: Central Limits and Key Provisions, p. 14.*

[57] *Рожденные атомной эрой. История создания и развития 12 Главного Управления Министерства Обороны Российской Федерации. т. 1* (Москва: Наука, 2007), p. 304. [*Born by the atomic era. History of creation and development of the 12th Main Directorate of the Ministry of Defence of the Russian Federation*. Vol. 1 (Moscow: Nauka, 2007), p. 304]. The first time all three States reported having no START-accountable deployed strategic weapons was in the 31 January 2002 START Treaty Memorandum of Understanding.

[58] Annex on Inspection Activities to the Protocol to the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, Part Five, Section VI.

The New START annex on inspections outlines procedures to confirm the number of warheads deployed on ICBMs and SLBMs.[59] At the discretion of the inspected State, the missile can remain in its silo, launch tube, or launcher for inspection. In some cases, preparation of the missile for inspection requires considerable effort. For example, in order to gain access to the warhead section of Russia's liquid-fuel SLBMs, a fuelled missile must be removed from the launch tube and transferred to a dedicated on-shore facility, where it can be inspected. This illustrates that even if inspections involve complex and time consuming operations, the parties are willing to implement them.

During the inspection, the inspecting party may request radiation measurements of an object located in the front section of the missile or on a heavy bomber that the host party has declared to be a non-nuclear object. The allowed measurements are taken with one neutron detector, which simply counts the number of emitted neutrons that hit it. The treaty includes a procedure for calibrating the detector and making sure measurements are unaffected by the natural neutron background. Radiation from the actual object is measured with the detector placed in its vicinity—between seven centimetres and two meters from its surface. The object is deemed non-nuclear if the neutron count is comparable to the background.[60]

Technically, it might be possible for the host State to shield the inspected object, so the detector would not register the neutron count that corresponds to a nuclear weapon. One preventive measure implemented in New START is to prohibit placing objects removed from an aircraft in a container. The inspected item can, however, be covered by a soft cover to protect potentially sensitive information.

New START pre-inspection restrictions address another concern in verifying removal, which is how to ensure that weapons are not temporarily removed from an operational base undergoing inspection. There are three moments of crucial importance in this pre-inspection: (1) the time for the designation of the inspection site; (2) the moment the inspection team arrives at the inspection site; and (3) the moment that procedures of designation of weapon systems are completed.

Once the time for the designation of an inspection site is declared, no more than one hour may elapse at the designated ICBM base, submarine base, or air base, before certain restrictions are implemented. These include not removing from the inspection site any item of inspection, any containers and closed vehicles large enough to contain an item of inspection, and any covered objects large enough to contain or be an item of inspection.[61] In addition, no work may begin that is associated with the removal of an item of inspection, the installation or removal of re-entry vehicles or front sections of deployed ICBMs or SLBMs, or the installation or removal of armaments on heavy bombers. No silo doors of silo launchers of ICBMs, hatches of SLBMs, hatches of converted launchers of SLBMs, or hatches of launchers installed on cruise missile submarines (SSGNs) may be opened that were closed at the time the pre-restrictions were

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[59] Ibid., Part Six, Section II.

[60] The threshold used in this case is called the comparison number. To calculate this number the value of the square root of the average background radiation is multiplied by four. This number is then added to the average background radiation value. See Annex on Inspection Activities, Part Five, Section IV, subparagraph 14 (e) (iv).

[61] Annex on Inspection Activities, Part Six, Section I, p. 57. An item of inspection is defined as a heavy bomber located within the boundaries at the following inspection facilities: air bases, storage facilities of heavy bombers, and conversion and elimination facilities of heavy bombers. At any inspection facilities other than these, an item of inspection is an ICBM, SLBM, first stage of an ICBM or SLBM that is maintained, stored, or transported in stages, or a mobile launcher. See Protocol to the Treaty Between the United States of American and the Russian Federation on Measures for the Further Reduction of Strategic Offensive Arms, Part Five, Section V, para. 10.

implemented. Lastly, no ballistic missile submarines or SSGNs may be moved from within the waters of the submarine base, nor may they be moved into a dry dock.[62]

The restrictions placed on the movement of items within or out of the inspected base reflect an understanding that the item of inspection would be a rather large object, such as a missile or a missile stage. Even though there are no specific arrangements that would allow the inspectors to verify that no vehicle large enough to contain an inspection item has left the base after the designated one-hour window, presumably the movement of large vehicles can be monitored by national technical means. At the very least, the host party should expect that the base is monitored and any attempt to remove a large object would be detected. Since nuclear warheads are much smaller than launchers, monitoring their movement would be more difficult. However, if the host State attempts to remove a large number of nuclear weapons from the base, this attempt is likely to be visible through national technical means as well.[63]

5.3 NO DEPLOYED WEAPONS

New START procedures can be applied with almost no modification to verify the absence of deployed nuclear weapons. They can, for example, verify that a launcher does not contain a missile or that no bombs are loaded on an aircraft. The procedure for confirming the nuclear nature of objects deployed on ICBMs and SLBMs can confirm the absence of a nuclear payload on these missiles if they were only allowed to carry conventional warheads. The same procedure could presumably be applied in verifying the absence of nuclear warheads deployed on shorter-range ballistic missiles installed in their launchers. This is also true for other weapon systems, such as SLCMs, missile defence and air-defence interceptors or coastal defence missiles, as long as they are deployed in launchers.[64]

Torpedoes on submarines or surface ships could present a challenge, as would any system that allows one launcher to launch multiple weapons from a stock of them stored on board.[65] Without some degree of access that allows an inspection team to knowingly select a particular missile on short notice for inspection, as is done for ICBMs and SLBMs, confidence in the absence of weapons would not be very high. But an inspection protocol could be developed that allows for managed access to, for instance, the torpedo compartment to select a random missile for inspection. The New START procedures may need some modification depending on the weapon system, but there is no reason they cannot be adapted for all of them.

Another modification of the New START procedures could involve a different radiation measurement technology. If the inspecting side has reason to believe that the inspected party has weapons that cannot be measured by passive neutron emission, another technique is probably needed. Here it may be possible to use a broad range of techniques to confirm the non-nuclear nature of an object, which could be rather aggressive when necessary. For the purposes of the subsequent discussion we will assume that inspectors have the capability to determine whether

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[62] Annex on Inspection Activities, Part Six, Section I, p. 57.

[63] Normally, using national technical means for verification implies the use of reconnaissance satellites—a capability that is not yet widely available. At the same time, States may have other options that they could use to monitor movements of objects at a base.

[64] As discussed before, the effectiveness of New START inspection procedures to confirm the nuclear nature of an inspected object is based on the assumption that nuclear warheads deployed on the designated weapon system contain significant quantities of plutonium.

[65] It appears that multiple SLCMs could be launched from torpedo tubes on both U.S. and Russian submarines. See Valerie Thomas, "Verification of Limits on Long-range Nuclear SLCMs", *Science & Global Security*, Volume 1, 1989, pp. 27–57.

an inspected object is non-nuclear and could be operationally deployed with any of the weapon systems at the inspected base.

5.4 ABSENCE OF WEAPONS IN A STORAGE FACILITY

As discussed, New START only allows the inspection of warheads that are mated to delivery vehicles and deployed in their launchers. Modifying its procedures to confirm that no warheads are deployed on any delivery vehicle is therefore insufficient to cover the full range of scenarios. Even in the case of ICBMs, detached warheads could be stored in a base-level facility.[66] In fact, in most circumstances—including for bombers and all other non-strategic systems—there exists a separate facility, vault, or something similar that contains weapons capable of being deployed. To some extent, the weapons stock on a ship presents the same problem.

Confirming the absence of weapons on a certain base then requires the inspection of these storage facilities as well. Once again, New START procedures could be adapted for this purpose, and used to confirm that no non-deployed warheads are hidden in the room requiring inspection. At an operational base, such rooms would be those holding bombs or warheads that are held in reserve to be deployed on delivery vehicles—for example, warheads for SLCMs or short-range ballistic missiles. It is also possible that the base-level storage would contain armed delivery vehicles, such as cruise or ballistic missiles with warheads. Granting an inspection team access to these facilities through some measure of managed access may be necessary.

One obvious aspect of this inspection arrangement would be confirming that nuclear warheads are not present inside objects large enough to contain them, and the cooperative process we assume here should facilitate this. That is, any State aiming to assure another that it does not possess nuclear warheads should not complicate this judgement by leaving open the possibility that it is concealing nuclear warheads in containers able to hide them. As discussed earlier, inspectors would generally have a good understanding of the types of warheads that can be stored at a particular facility.

Visual inspection may be sufficient in some cases if no objects large enough to contain warheads that the inspected State was known to possess are found. If these warheads are known to contain plutonium, existing New START radiation detection procedures should also allow to verify the non-nuclear nature of objects.

As discussed earlier, in those cases when the parties have a reasonable expectation of non-plutonium weapons to be present, a different inspection procedure may have to be developed. Given that inspections are never supposed to encounter a nuclear object, this procedure can involve rather intrusive methods. These could include, for example, the use of active interrogation techniques currently under investigation, involving the utilization of neutron and gamma ray sources to confirm the nuclear nature of objects.[67]

Of further reassurance may be the pre-inspection restrictions discussed earlier, specifically the allowable one-hour window that prohibits the movement of items of inspection. In New START, such items at ICBM or submarine bases include missiles or anything covering or containing objects large enough to be a missile. Yet the possibility remains that something as small as a warhead could be smuggled out. An agreement could be reached that the movement of all objects would

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[66] Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe".

[67] See for example Michael C. Hamel, J. Kyle Polack, Marc L. Ruch, Matthew J. Marcath, Shaun D. Clarke & Sara A. Pozzi, "Active neutron and gamma-ray imaging of highly enriched uranium for treaty verification", *Scientific Reports*, Volume 7(1):7997, 2017, pp. 1–10. It is worth mentioning here that active interrogation may have limited success if there are no constraints on the shielding of the object. However, the scenarios considered here assume that these constraints exist and the ability of the host to introduce shielding is either limited or detectable.

stop upon arrival of inspectors at the base—similar to missiles under new START—but even then a violation is possible. Still, such activity would have to occur prior to every inspection, increasing the chances that it would be observed at some future time by inspectors. Confidence in using national technical means to observe this activity may also be high, and this capability would very likely deter any smuggling attempt if it were also anticipated by the inspected State.

The focus on storage facilities presumes the lack of an off-base facility that exists to support long-term nuclear weapons deployment. While the transport of warheads to a temporary location (e.g. a forest, tent, or storage area away from the base) is possible, maintaining a facility to support the long-term deployment away from a military base would come with significant challenges and a high chance of being discovered over time.

5.5 INFRASTRUCTURE TO SUPPORT LONG-TERM DEPLOYMENT

After verifying the absence of weapons on delivery vehicles and at storage facilities, confirming that no infrastructure is present to support their long-term deployment is the next challenge. The absence of this infrastructure would provide high confidence that weapons are not being temporarily smuggled from the base or to another area of the base inaccessible to inspectors.

Because nuclear weapons are dangerous and potentially very valuable, there are certain systems that a State would want to have in place to support long-term deployment regardless of whether they are party to any treaty to limit them. The challenges of providing this support will likely accumulate if a State does this covertly while agreeing to a cooperative process to assure other States of their absence, as considered here.

For instance, diversion of warheads to avoid discovery by an inspecting State would likely create records associated with that movement, with a limited number of people informed about the purpose of the covert stockpile. Poor recordkeeping would jeopardize accountability over the stockpile—the severity of consequences for the State if one of its nuclear weapons went missing and was used would be incalculable.[68] Infrastructure to handle off-base deployment includes a workforce to handle nuclear weapons in an operational military context; the lack thereof would suggest a level of negligence that would increase the chances of an accident (or provides evidence that nuclear weapons are absent). The State would also have to provide security, surveillance, and maintenance for the stockpile, as well as the ability to mate warheads to delivery vehicles.[69] These challenges reflect the assumption made in the previous section that no off-base facility to support the long-term deployment of nuclear weapons is likely to exist.

On bases accessible to inspectors, there are various signs of long-term deployment linked to the facility itself. One indication may be the existence of a security perimeter that would surround the warhead storage facilities. Another is the presence of military units that are trained and certified to handle nuclear weapons. Although the presence of personnel or of the physical security infrastructure does not prove that the nuclear weapons are deployed at a certain base, if strongly fortified barriers with hardened doors and windows, locks and keys to control access, perimeter fences, etc., were found, this suggests a desire to protect access to something considered extremely important. If such signs were then discovered alongside other indications tailored to meet the security needs of nuclear weapons intended for possible deployment, for example, particular monitoring and detection systems, alarm systems, or electronic access control, evidence could mount that the needed infrastructure does exist. It should also be noted that these systems

[68] Richard L. Garwin, "Technologies and procedures for verifying warhead status and dismantlement", in Nicholas Zarimpas, ed., *Transparency in Nuclear Warheads and Materials: The Political and Technical Dimensions*, pp. 151–164, Stockholm International Pease Research Institute (New York: Oxford University Press, 2003).

[69] Ibid., p. 152.

deployed by different States have many common features. For example, U.S. Cooperative Threat Reduction (CTR) Program (known as the Nunn-Lugar program) provided the necessary equipment to many nuclear sites in Russia, including nuclear warhead and nuclear material storage sites run by the Russian Navy, and warhead storage sites run by Russia's Strategic Rocket Forces and the 12th Main Directorate, a branch of the Russian Ministry of Defence responsible for warhead security and maintenance.[70]

These U.S.-Russia cooperative efforts in nuclear security provide important details for verifying the absence of infrastructure to support the long-term deployment of nuclear weapons, and can be useful for inspecting States—who presumably know what their own nuclear weapons require—in making judgments about what those of other States require. The periodic maintenance that nuclear weapons require, likely due to their specific fissile material and weaponization aspects, suggest that they cannot simply be transported to a clandestine location permanently without substantial support infrastructure following them. This potentially includes specific types of maintenance, transport, and associated equipment, as well as a particular climate control system over time in order for them to be deployed for possible use. Whether certain aspects of the CTR program may need to be broadened and made more transparent to provide assurance that no supporting infrastructure for long-term deployment exists, this cooperative process may provide a good basis for building the confidence necessary to confirm it.

5.6 CONVERSION OF NUCLEAR-CAPABLE WEAPON SYSTEMS

Confirming that weapon systems are not capable of deploying nuclear weapons is another element in verifying the absence of deployed weapons. This approach would become possible if there is a conversion process that is verifiable and considered irreversible to an inspecting State.

The New START process for converting a heavy bomber equipped for nuclear armaments to one equipped for non-nuclear armaments is outlined in the treaty's Protocol. The process may be carried out using any of the following procedures: "(a) All weapons bays and all external attachments for pylons shall be modified so as to render them incapable of employing nuclear armaments; (b) All internal and external launcher assemblies shall be modified so as to render them incapable of employing nuclear armaments; or (c) Other procedures that are developed by the Party carrying out the conversion."[71] After completing the conversion, the bomber must be moved to the viewing site at the same facility, and the inspecting party has 30 days to conduct an inspection and verify that these procedures have been completed.[72]

Similar provisions for conversion of heavy bombers were included in the START treaty as well. The United States used these procedures to convert all its B-1B bombers to non-nuclear missions, which allowed it to exclude all aircraft of this type as well as their bases from the treaty limits. Specific procedures implemented by the United States included two steps that were described by the U.S. Air Force as follows:[73]

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[70] This effort was part of the Materials Protection and Cooperation Program (MPC&A). See Mary Beth D. Nikitin and Amy F. Woolf, "The Evolution of Cooperative Threat Reduction: Issues for Congress", *Congressional Research Service Report R43143*, June 13, 2014.

[71] Protocol to the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, Part Three, Section V, para. 3.

[72] Ibid., para. 4.

[73] B-1B bombers did not have nuclear missions after 1994, but for the purpose of the treaty the conversion was carried out during the 2007-2011 period. "B-1B Lancer", U.S. Air Force, December 16, 2015. Available at http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104500/b-1b-lancer/.

- During the first step a metal cylindrical sleeve was welded into the aft attachment point of each set of B-1 pylon attachments. This prevented installing B-1 Air Launched Cruise Missile pylons.
- During the second step two nuclear armament-unique cable connectors in each of the B-1 weapons bays were removed. This prevented the pre-arm signal from reaching the weapons.

Under New START, the United States also converted a portion of its B-52 bomber fleet to conventional-only capabilities, presumably using a similar procedure.[74] By 2018, the United States had used this option to convert 41 of its B-52 bombers, with 42 aircraft of this type remaining accountable under New START.[75]

One problem with the conversion procedure is that even if it can be done in a verifiable way, in most cases the conversion is reversible. Indeed, in New START Russia expressed concerns about the manner in which the United States implemented the conversion of its heavy bombers (as well as SLBM launchers).[76] It might in fact be difficult to come up with a technical procedure that would guarantee irreversible denuclearization of any specific weapon system. However, if conversion is accompanied by other measures, such as removal of weapons from the operational base, it should be possible to achieve fairly high confidence in the absence of nuclear capability in most cases.

Another example of an arrangement that verified the absence of nuclear-capable weapon systems at a certain base was an agreement involving aircraft deployed at the Sevastopol base that Russia leased from Ukraine. A condition of the lease was that all aircraft deployed there had to be non-nuclear.[77] To verify the absence of nuclear-capable aircraft, the parties developed a procedure that allowed Ukraine to inspect Su-24 aircraft based in Sevastopol. According to a protocol of an inspection published in the Ukrainian press (Figure 3), the procedure involved visual inspection of the aircraft as well as checks of the seals that presumably prevent installation of essential arming equipment. It was also suggested that inspectors had access to the armament depot at the base.[78] The Russia-Ukraine agreement provides an example of a cooperatively developed and implemented procedure to verify the absence of the nuclear capability of a class of weapon systems.

These examples suggest that verifying the absence of nuclear capability of aircraft, whether strategic or non-strategic, has been demonstrated in practice. It is not clear, however, whether the same approach would be possible for ballistic or cruise missiles. It may well be that for missiles verification for such conversion is impossible. At the same time, knowledge about the arming, safing, and fuzing functions of nuclear weapons may allow for some meaningful measures.

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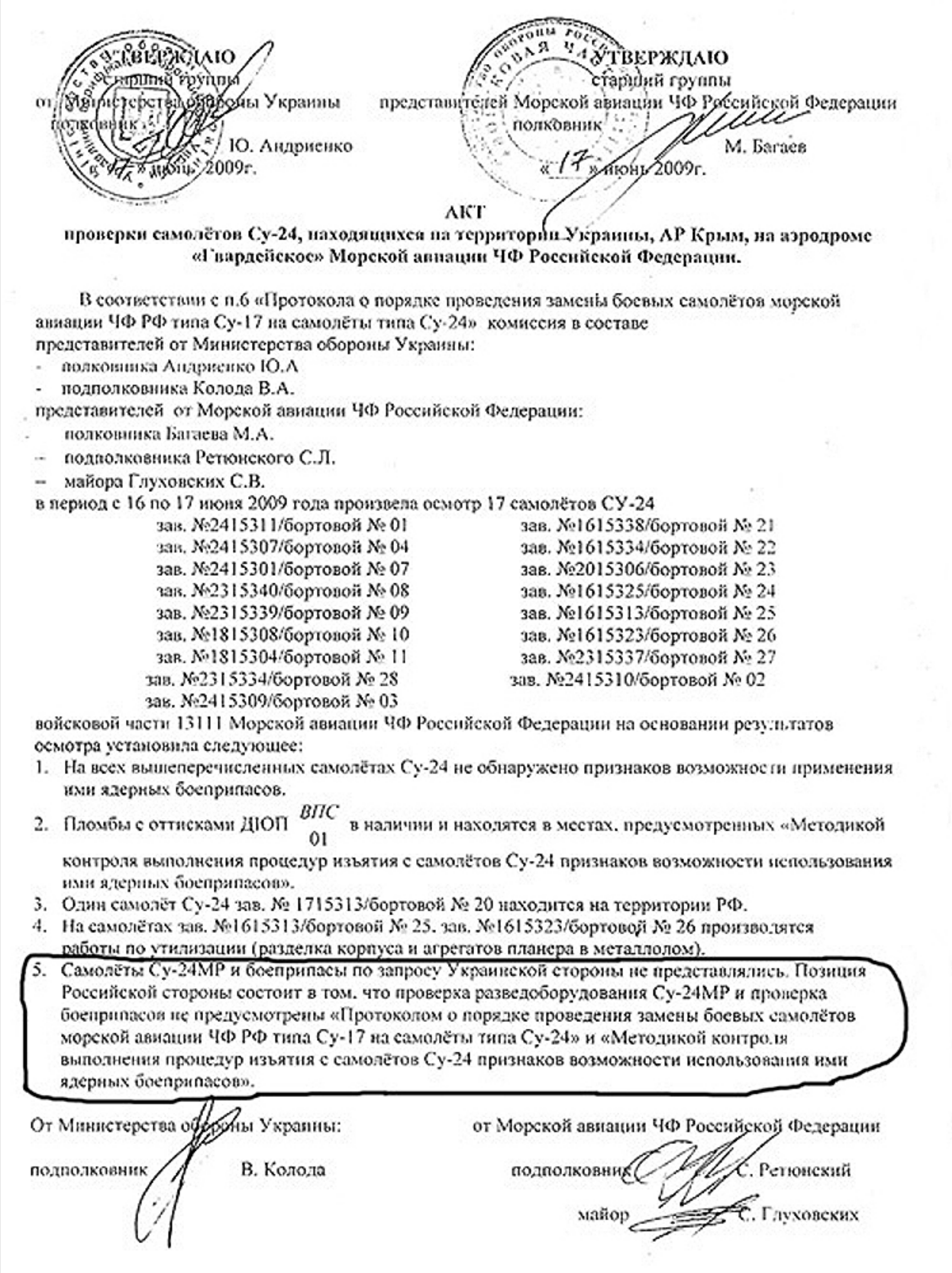
[74] "AFGSC completes first New START bomber conversion", Air Force Global Strike Command, Official United States Air Force Website, September 17, 2015.
[75] Hans M. Kristensen and Robert S. Norris, "United States Nuclear Forces, 2018", *Bulletin of the Atomic Scientists* 74, no. 2 (March 4, 2018), p. 121. Available at https://doi.org/10.1080/00963402.2018.1438219.
[76] The Ministry of Foreign Affairs of the Russian Federation, "Comment by the Information and Press Department on the Latest Data Regarding the Aggregate Numbers of US Strategic Offensive Arms Published by the US Department of State", February 27, 2018. Available at http://www.mid.ru/foreign_policy/news/-/asset_publisher/cKNonkJE02Bw/content/id/3100658.
[77] Igor Sutyagin, "Atomic Accounting. A New Estimate of Russia's Non-Strategic Nuclear Forces", (RUSI, November 2012), p. 29. Available at https://rusi.org/sites/default/files/201211_op_atomic_accounting.pdf.
[78] "Обновление ЧФ РФ: есть неудобные вопросы", *Bagnet.org*, October 26, 2010. Available at http://www.bagnet.org/news/ukraine/77563. [Modernization of the Russian Black Sea Fleet: There are a few inconvenient questions].

Figure 3



УТВЕРЖДАЮ
старший группы
от Министерства обороны Украины
полковник
Ю. Андриенко
«17» июнь 2009г.

УТВЕРЖДАЮ
старший группы
представителей Морской авиации ЧФ Российской Федерации
полковник
М. Багаев
«17» июнь 2009г.

АКТ
проверки самолётов Су-24, находящихся на территории Украины, АР Крым, на аэродроме «Гвардейское» Морской авиации ЧФ Российской Федерации.

В соответствии с п.6 «Протокола о порядке проведения замены боевых самолётов морской авиации ЧФ РФ типа Су-17 на самолёты типа Су-24» комиссия в составе
представителей от Министерства обороны Украины:
- полковника Андриенко Ю.А
- подполковника Колода В.А.

представителей от Морской авиации ЧФ Российской Федерации:
- полковника Багаева М.А.
- подполковника Ретюнского С.Л.
- майора Глуховских С.В.

в период с 16 по 17 июня 2009 года произвела осмотр 17 самолётов СУ-24

зав. №2415311/бортовой № 01	зав. №1615338/бортовой № 21
зав. №2415307/бортовой № 04	зав. №1615334/бортовой № 22
зав. №2415301/бортовой № 07	зав. №2015306/бортовой № 23
зав. №2315340/бортовой № 08	зав. №1615325/бортовой № 24
зав. №2315339/бортовой № 09	зав. №1615313/бортовой № 25
зав. №1815308/бортовой № 10	зав. №1615323/бортовой № 26
зав. №1815304/бортовой № 11	зав. №2315337/бортовой № 27
зав. №2315334/бортовой № 28	зав. №2415310/бортовой № 02
зав. №2415309/бортовой № 03	

войсковой части 13111 Морской авиации ЧФ Российской Федерации на основании результатов осмотра установила следующее:

1. На всех вышеперечисленных самолётах Су-24 не обнаружено признаков возможности применения ими ядерных боеприпасов.
2. Пломбы с оттисками ДІОП ВПС/01 в наличии и находятся в местах, предусмотренных «Методикой контроля выполнения процедур изъятия с самолётов Су-24 признаков возможности использования ими ядерных боеприпасов».
3. Один самолёт Су-24 зав. № 1715313/бортовой № 20 находится на территории РФ.
4. На самолётах зав. №1615313/бортовой № 25, зав. №1615323/бортовой № 26 производятся работы по утилизации (разделка корпуса и агрегатов планера в металлолом).
5. Самолёты Су-24МР и боеприпасы по запросу Украинской стороны не представлялись. Позиция Российской стороны состоит в том, что проверка разведоборудования Су-24МР и проверка боеприпасов не предусмотрены «Протоколом о порядке проведения замены боевых самолётов морской авиации ЧФ РФ типа Су-17 на самолёты типа Су-24» и «Методикой контроля выполнения процедур изъятия с самолётов Су-24 признаков возможности использования ими ядерных боеприпасов».

От Министерства обороны Украины:
подполковник В. Колода

от Морской авиации ЧФ Российской Федерации
подполковник С. Ретюнский
майор С. Глуховских

A protocol of an inspection of Su-24 aircraft based at the Gvardeyskoye naval aviation base of the Black Sea Fleet of the Russian Federation, dated 17 June 2009. The protocol, signed by the Russian and Ukrainian officials certifies that the inspection of 17 inspected Su-24 aircraft "did not discovered features that would allow them to use nuclear armaments." Source: "Обновление ЧФ РФ: Есть неудобные вопросы [Modernization of the Black Sea Fleet: There are some inconvenient questions]." Bagnet.org, October 26, 2010. http://www.bagnet.org/news/ukraine/77563. Reproduced with permission.

6 Conclusions

One conclusion of this study is that the approach to disarmament that relies on verifying the absence of nuclear weapons, whether on a territory or on a class of weapon systems, should have a place in the nuclear disarmament toolbox.

Verifying the absence should not be considered a substitute for a more comprehensive nuclear disarmament steps, such as elimination of weapon systems and dismantlement of warheads. However, it could be a highly significant intermediate step in that process and could provide a viable path to reductions of nuclear arsenals.

In most cases, removal of weapons can be done in a verifiable way and a combination of different measures could provide a high degree of certainty in the absence of weapons. At the same time, further research is required to explore technical methods that could increase confidence in the verification.

The existing New START arrangements could provide a strong foundation for the verification procedures that would confirm the absence of weapons in a range of situations. However, these procedures may have to be adapted to different scenarios.

Verification of the absence of nuclear weapons can be introduced gradually and applied provisionally in a number of scenarios as a transparency and confidence-building measure. For example, some European States could choose to demonstrate the absence of nuclear weapons on their territory. South Korea and the United States can implement some of these measures to improve the prospects for the denuclearization of the Korean Peninsula. Signatories to the TPNW can also consider implementing some of the verification provisions described here to demonstrate the absence of weapons on their territories.

It is also possible that the removal of nuclear weapons and associated verification measures will become part of legally binding arrangements, such as zero-deployed non-strategic nuclear weapons in Europe or an arrangement that would prohibit nuclear-armed cruise missiles.

To sum up, implemented separately or, as it is more likely, in combination with other arms control and disarmament measures, verified removal of nuclear weapons could help reduce the role of nuclear weapons in international security and facilitate nuclear disarmament.

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Evidence of absence: Verifying the removal of nuclear weapons

Credible, reliable, and accurate verification techniques and arrangements are an essential element of the nuclear disarmament process. This study outlines a possible arrangement for verifying the removal of nuclear warheads from delivery vehicles or launchers, and the withdrawal of nuclear bombs and warheads from States, territories or operational military bases. These activities, which have long been conducted as a part of nuclear arms control and disarmament measures, are meaningful steps that can pave the way for the elimination of nuclear warheads—the end stage of nuclear disarmament. An agreed procedure that allows the removal of nuclear weapons to be verified would be a valuable additional disarmament tool and may help create conditions for more comprehensive disarmament measures.

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