Menzingen Verification Experiment

Verifying the Absence of Nuclear Weapons in the Field

EDITED BY PAVEL PODVIG

Acknowledgments

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About UNIDIR

UNIDIR is a voluntarily funded, autonomous institute within the United Nations. One of the few policy institutes worldwide focusing on disarmament, UNIDIR generates knowledge and promotes dialogue and action on disarmament and security. Based in Geneva, UNIDIR assists the international community to develop the practical, innovative ideas needed to find solutions to critical security problems.

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Acronyms

ICBM	Intercontinental ballistic missile
SLBM	Submarine-launched ballistic missile
START	Strategic Arms Reduction Treaty
NTM	National technical means
INF	Intermediate-Range Nuclear Forces (Treaty)
CFE	Conventional Forces in Europe (Treaty)
NATO	North Atlantic Treaty Organization
WS3	Weapons Storage and Security Systems
WSV	Weapon Storage Vault
GUMO	Main Directorate of the Ministry of Defence
IAEA	International Atomic Energy Agency
ACX	Absence Confirmation Experimental [Device]
keV	kilo electron volt
NGO	Non-governmental organization
OPCW	Organization for the Prohibition of Chemical Weapons
UTC	Coordinated universal time
SAR	Synthetic aperture radar

Summary

The Menzingen Verification Experiment described in this report was designed to test practical procedures for verifying the absence of nuclear weapons at a storage site. The experiment, which was conducted on 8 March 2023, was organized by UNIDIR in partnership with the Swiss Armed Forces, Spiez Laboratory, Princeton University's Program on Science and Global Security, and the Open Nuclear Network. The project was supported by the Governments of the Kingdom of the Netherlands, Norway, and Switzerland.

The experiment modelled an on-site inspection of a nuclear weapons storage site, represented by a former air defence site near Menzingen, Switzerland. In preparation for the experiment, UNIDIR developed a model protocol governing the inspection activities. Together with its partners, it designed procedures to confirm the non-nuclear nature of the inspected items, including radiation measurements with active sources, and arranged for the acquisition of satellite imagery of the site.

The scenario developed for the experiment assumed that the inspection was conducted as part of an agreement that requires the parties to remove all nuclear weapons from storage sites associated with military bases that host nuclear-capable delivery systems. The inspection procedures used in the experiment were modelled on those developed for the Conventional Forces in Europe Treaty and New START.

The Menzingen Verification Experiment demonstrated in practice the viability of the approach to nuclear disarmament based on removing nuclear weapons from their delivery systems. It provided an opportunity to test in practice specific verification procedures and techniques, provided valuable insights into the challenges that can be encountered during an on-site inspection, and identified promising new approaches to verification that can create political space for arms control and disarmament initiatives.

Key results

- A model on-site inspection was carried out at a Swiss Armed Forces facility near Menzingen, Switzerland on 8 March 2023.
- The experiment tested in practice verification arrangements to verify the absence of nuclear weapons at a military site.
- The experiment developed and tested several methods of confirming the non-nuclear nature of inspected items.
- Verification procedures used during the inspection included two types of radiation measurements.
- Satellite images acquired for the experiment supported the inspection activities.
- The experiment provided valuable insights into processes of verifying the absence of nuclear weapons and identified areas for further research.

Participants of the Menzingen Verification Experiment after the post-inspection workshop.

Introduction

This report describes the Menzingen Verification Experiment that was designed to develop and test verification procedures that can be applied to an arms control or disarmament arrangement that removes nuclear weapons from the storage facilities near delivery systems. This arrangement could be applied to those categories of weapons that are normally not mated to their delivery systems. These weapons, non-strategic nuclear weapons in particular, are considered deployed when they are stored at or near the units that operate their delivery systems. The removal of weapons from these storage sites would bring these weapons into a non-deployed state. By creating some distance between nuclear weapons and their means of delivery, this step would increase stability by reducing the risk of misunderstanding or inadvertent escalation in a crisis. Importantly, it could also strengthen the security of nuclear weapons by removing them from areas of potential military action. The transfer of nuclear weapons to a small number of central storage sites would also facilitate their eventual elimination.

Chapter 1 describes the non-strategic nuclear-weapon storage and deployment procedures in the Russian Federation and the United States. It outlines key elements of a zero-deployed arrangement that would remove these weapons from the military bases where they are stored today. The chapter considers the design of the verification system that would rely on the confirmation of the absence of nuclear weapons at a limited number of known sites.

The verification arrangements in an agreement of this kind would certainly provide the parties with an option to conduct on-site inspections to verify the absence of weapons. Chapter 2 introduces a model inspection protocol that would regulate the inspection activities on site and describes the organization of the model inspection that was conducted as part of this experiment.

Chapter 3 provides a detailed account of the actual model inspection that took place at a former military facility near Menzingen, Switzerland, in March 2023. It includes the inspection materials and the inspection report.

The verification of the non-nuclear nature of items that may be found at the inspected site may require radiation measurements. Chapter 4 describes two experimental setups that were used for this purpose during the inspection and contains a detailed discussion of the results.

The experiment explored the possibility of using satellite images to assist on-site inspection activities. Chapter 5 describes the process of acquiring the images and discussed potential uses of satellite data during the verification process.

Finally, the report discusses the key lessons learned during the experiment and suggests directions for further research.

Authors are responsible for their individual contributions. The editor is responsible for the report's conclusions and for ensuring consistency across contributions, as well as for any errors.

1. Non-deployment of nuclear weapons

Pavel Podvig

Introduction

Traditionally, US–Russian nuclear arms control and disarmament has focused on limiting or eliminating nuclear weapons delivery vehicles, addressing strategic delivery systems such as intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs), and long-range bombers. Over time, the goals of the nuclear disarmament process have become more ambitious, and treaties have begun to cover some non-strategic systems and to account more accurately for the number of nuclear warheads. For example, New START, the most recent US–Russian arms control treaty, accounts for the actual number of warheads deployed on strategic delivery vehicles and includes procedures to verify that number.

The decision to suspend participation in New START announced by the Russian Federation in 2023 has ended the practical implementation of the treaty's verification procedures and created further uncertainty around the future of US-Russian arms control. At the same time, both the Russian Federation and the United States have pledged to adhere to the limits set by the treaty at least until its formal end in 2026.[1] If the two States return to bilateral arms control in the future, they are likely to use the current approach to limiting strategic nuclear arsenals, which has demonstrated its effectiveness in the past.

The situation with non-strategic nuclear weapons is different. The limits on delivery systems, which work well for strategic nuclear weapons, are more difficult to implement since most non-strategic systems can be used to deliver conventional as well as nuclear weapons. An alternative approach would be to limit the number of nuclear weapons themselves, but such an arrangement would require the development of verification procedures that account for individual weapons and track them throughout their life cycle. Although researchers have identified a number of ways to address this problem by technical means, there are still issues to be resolved, primarily related to the issue of access to sensitive information about nuclear weapons in the process.[2] There are political challenges as well. When the United States and the Russian Federation briefly discussed a possible freeze of the total number of nuclear weapons in 2020, the Russian Federation said that "the intrusive verification

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1 Foreign Ministry Statement in Connection with the Russian Federation Suspending the Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START)," The Ministry of Foreign Affairs of the Russian Federation, February 21, 2023, https://www.mid.ru/ru/press_service/spokesman/official_statement/1855184/?lang=en; "Russian Noncompliance with and Invalid Suspension of the New START Treaty," United States Department of State, March 15, 2023, https://www.state.gov/russian-noncompliance-with-and-invalid-suspension-of-the-new-start-treaty.

2 Malte Göttsche and Alexander Glaser, eds., *Toward Nuclear Disarmament: Building up Transparency and Verification* (Federal Foreign Office, 2021), https://www.auswaertiges-amt.de/blob/2462108/6dc81f5932e6b96b48b8bc222f4b2e58/towards-nuclear-disarmament-data.pdf; *Everything Counts: Building a Control Regime for Nonstrategic Nuclear Warheads in Europe* (James Martin Center for Nuclear Nonproliferation, 2022), https://nonproliferation.org/op55-every-thing-counts-building-a-control-regime-for-nonstrategic-nuclear-warheads-in-europe.

measures proposed by the American side are unacceptable".[3] While the political positions may change and the technical issues may be resolved, their combined challenge strongly suggests that an approach based on the direct accounting of nuclear warheads will be extremely difficult to implement. It must be noted that none of the past arms control agreements included nuclear warheads in their scope and, with the exception of the United States, none of the nuclear-armed States have revealed information about the number of nuclear weapons in their arsenals, whether strategic or non-strategic.

One way to deal with the issue of sensitive data on nuclear weapons, which includes information on their numbers, types, and design, is to build arms control and disarmament arrangements that do not rely on access to such information. This approach can be based on the solution found in New START. This treaty is the first arms control agreement that can account for actually deployed strategic nuclear weapons. Past treaties limited the number of warheads indirectly, by using agreed counting rules to assign a certain number of weapons to each strategic launcher. New START, in contrast, counts only those ICBM and SLBM warheads that are mated to deployed missiles (a counting rule is still used for weapons assigned to strategic bombers).[4] While both parties retain a certain number of non-deployed weapons that can be deployed on existing launchers, the treaty does not limit non-deployed weapons and does not require the parties to disclose any information about them. This arguably means that the New START reductions are not truly irreversible. However, by concluding the treaty, the United States and the Russian Federation have effectively agreed that the benefits of an arms control agreement and the transparency and verification measures that come with it outweigh this drawback.

The same approach can be extended to other categories of nuclear weapons once we recognize that none of them are deployed in the way that ICBM and SLBM warheads are. Neither non-strategic nuclear weapons nor weapons assigned to strategic bombers are normally mated to their delivery vehicles. In this respect, they are similar to non-deployed ICBM and SLBM warheads, which New START does not limit or account for. At the same time, it would be incorrect to consider them non-deployed because they can be quickly loaded onto their delivery vehicles if they are stored at the same site or in close proximity to it. To consider these weapons non-deployed, one would have to move them away from their delivery systems. Although such removal would not be irreversible, it can have significant benefits for arms control and disarmament.

The non-deployment approach can be particularly productive in the case of US and Russian non-strategic nuclear weapons. This is one of the issues that proved difficult in the past and that will definitely come up again should the United States and the Russian Federation seek to resume their bilateral arms control dialogue. It should also be noted that this approach creates an opportunity to reach a comprehensive agreement that will limit all nuclear weapons, strategic and non-strategic.

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3 "Deputy Foreign Minister Sergey Ryabkov's Interview with the Newspaper Kommersant, Published on September 22, 2020", The Ministry of Foreign Affairs of the Russian Federation, September 22, 2020, https://www.mid.ru/print/?id=1442515&lang=en.

4 Rose Gottemoeller, "Rethinking Nuclear Arms Control," *The Washington Quarterly* 43, no. 3 (July 2, 2020): 146, https://doi.org/10.1080/0163660X.2020.1813382.

Zero-deployed non-strategic nuclear weapons

In the scenario considered here, the Russian Federation and the United States have committed to transfer their non-strategic nuclear weapons to storage facilities that are located away from the bases where their delivery systems are deployed.[5] This can be described as a 'zero-deployed' arrangement since neither party will have its non-strategic weapons available for immediate use.

The focus on the absence of deployed weapons, as opposed to one limiting the total number of non-strategic weapons or their delivery systems, significantly simplifies verification arrangements. Once the existing non-strategic weapon storage and deployment procedures practiced by the Russian Federation and the United States are taken into account, it becomes possible to design a verification procedure that can be tested in practice.

The United States has about 230 non-strategic nuclear weapons, of which about 100 are deployed in Europe. All US non-strategic weapons are variants of the B-61 gravity bomb delivered by aircraft.[6] The Russian Federation is believed to have about 1,800 weapons assigned to a range of non-strategic delivery systems as well as various defence systems.[7] While the weapon storage and deployment arrangements are very different, the Russian Federation's non-strategic nuclear weapons as well as the US weapons in Europe are stored at a small number of known secure sites and are never mated to their delivery systems in peacetime.

US weapons in Europe

The United States and NATO have never officially disclosed the locations or the number of nuclear weapons deployed in Europe. There are six air bases that are believed to host nuclear weapons: Kleine Brogel in Belgium, Volkel in the Netherlands, Aviano and Ghedi in Italy, Büchel in Germany, and Incirlik in Turkey.[8] Nuclear-certified aircraft that can deliver these weapons are deployed at all these bases, except for Incirlik.

Nuclear weapons are deployed in Protective Aircraft Shelters, which are equipped with Weapons Storage and Security Systems (WS3). These systems include vaults where the weapons are actually stored. A Weapon Storage Vault (WSV) is a structure recessed into the floor of the shelter that can contain up to four B-61 bombs (see Figure 1).[9]

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5 Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe" (UNIDIR, 2017), https://www.unidir.org/sites/default/files/publication/pdfs/lock-them-up-zero-deployed-non-strategic-nuclear-weapons-in-europe-en-675.pdf.

6 Hans M. Kristensen and Matt Korda, "United States Nuclear Weapons, 2023," *Bulletin of the Atomic Scientists* 79, no. 1 (January 2, 2023): 28–52, https://doi.org/10.1080/00963402.2022.2156686.

7 Hans M. Kristensen, Matt Korda, and Eliana Reynolds, "Russian Nuclear Weapons, 2023," *Bulletin of the Atomic Scientists* 79, no. 3 (May 4, 2023): 174–99, https://doi.org/10.1080/00963402.2023.2202542.

8 Kristensen and Korda, "United States Nuclear Weapons", 2023.

9 Hans Kristensen, "Kleine Brogel Nukes: Not There, Over Here!," *Federation of American Scientists*, February 12, 2010, https://fas.org/blogs/security/2010/02/kleinebrogel2.

Figure 1. Weapon Storage Vault in a raised position.

Source: USAF

Figure 2. Security perimeter around aircraft shelters with Weapon Storage and Security System (in the upper right corner). Aviano, Italy.

Source: Google Earth

At all bases but Volkel the shelters that contain nuclear weapons are surrounded by a security perimeter that is visible on satellite images (Figure 2). It appears that at least some shelters outside the security fence also have vaults.[10] These, however, are not used for nuclear weapons storage. In principle, aircraft that are assigned nuclear missions could be stationed in 'hot' shelters during peacetime day-to-day operations. In any event, they are likely to be moved there at a heightened state of alert, so bombs can be quickly loaded onto the aircraft. At the highest readiness level, known as a quick-reaction alert, weapons are loaded onto aircraft which stay in shelters awaiting an order to take off. An aircraft on a quick-reaction alert can get into the air in "less than 15 minutes".[11] The time it takes to load weapons stored in a vault onto an aircraft is probably longer.

Russian Federation

Compared to the United States and NATO, the Russian Federation has a much wider range of nuclear-capable delivery systems. This section focuses on air-delivered weapons and on ground-launched road-mobile missiles (whether ballistic or cruise missiles). The key principles of operations, however, remain the same across all nuclear delivery systems.

The Russian Federation has repeatedly stated that in peacetime all of its non-strategic nuclear weapons are "concentrated at centralized storage bases".[12] There are two kinds of facilities that fit that definition—12 large national-level storage sites and about 35 base-level storage facilities.[13] Base-level facilities could contain weapons that are assigned to delivery systems at the base they are co-located with or at other bases in the region. For example, a storage facility known as Kolosovka can store nuclear weapons for all nuclear-capable delivery systems in the Kaliningrad region. Each base-level facility has a 'parent' national-level storage site that stores nuclear weapons assigned to the respective base or region.[14] All weapons that are not mated to their delivery systems are handled by the troops of the 12th Main Directorate of the Ministry of Defence (12 GUMO).

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10 A story about US weapons in Volkel suggests that in 2019 6 out of 11 shelters were used to store nuclear weapons; "US Soldiers Expose Nuclear Weapons Secrets Via Flashcard Apps," Bellingcat, May 28, 2021, https://www.bellingcat.com/news/2021/05/28/us-soldiers-expose-nuclear-weapons-secrets-via-flashcard-apps. Secure vaults are also installed at six bases in Europe from which weapons have been withdrawn; Hans Kristensen, "NATO Steadfast Noon Exercise and Nuclear Modernization in Europe," *Federation of American Scientists* (blog), October 17, 2022, https://fas.org/publication/steadfast-noon-exercise-and-nuclear-modernization.

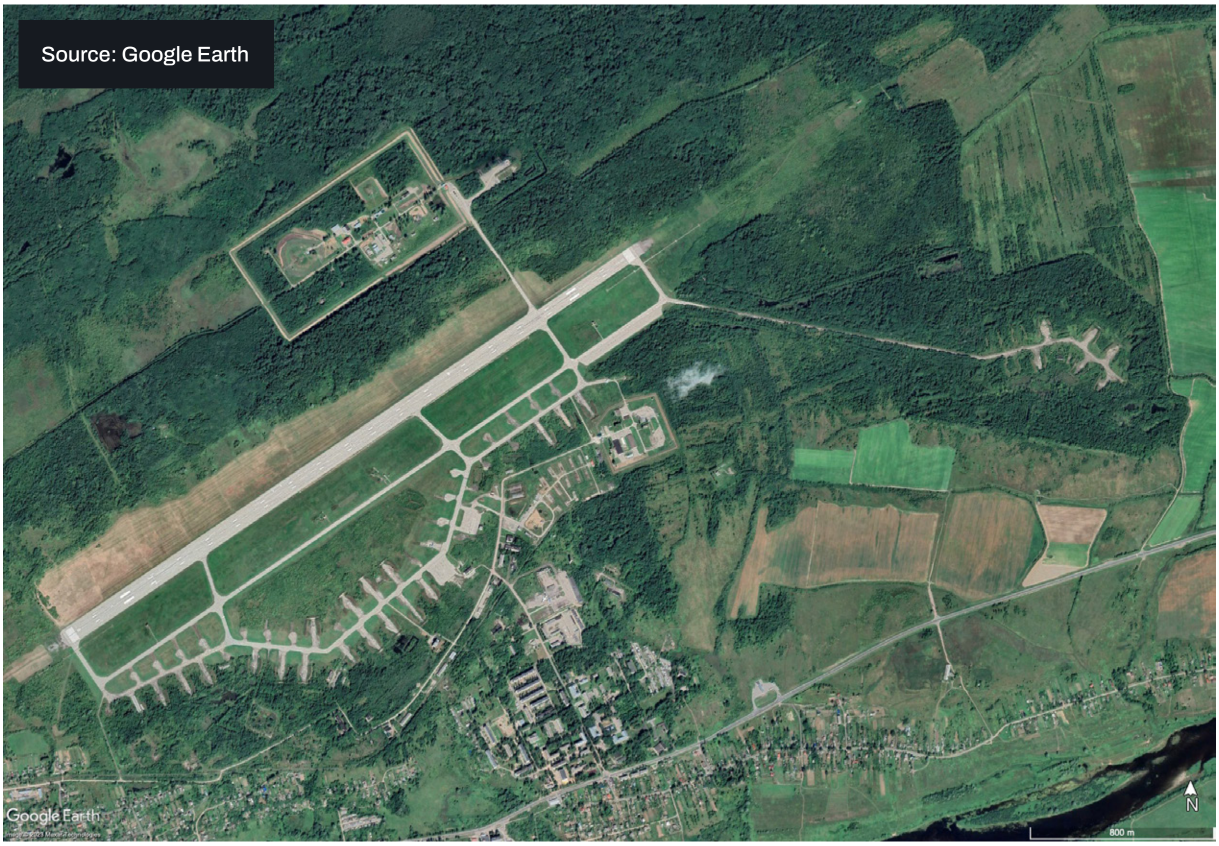
11 "30 Years Past: 20th FW Role in Victor Alert," December 5, 2016, https://web.archive.org/web/20221008203637/https://www.acc.af.mil/News/Features/Display/Article/1020423/30-years-past-20th-fw-role-in-victor-alert; "Safe Skies: 60 Years of NATO Air Policing," NATO, December 10, 2021, http://www.nato.int/cps/en/natohq/news_185683.htm.

12 Statement by Mikhail I. Uliyanov, Acting Head of the Delegation of the Russian Federation at the 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons," May 1, 2015, https://www.reachingcriticalwill.org/images/documents/Disarmament-fora/npt/revcon2015/statements/1May_Russia.pdf.

13 The description of nuclear weapon storage and deployment procedures is based primarily on Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe"; *Рожденные атомной эрой. История создания и развития 12 Главного Управления Министерства Обороны Российской Федерации. т*. 1 (Москва: Наука, 2007), http://elib.biblioatom.ru/text/biryukov_rozhdennye-atomnoy-eroy_t1_2007/go,0; László Becz, Szabolcs Kizmus, and Tamás Várhegyi, *OKSNAR – Fully Assembled State - Soviet Nuclear Weapons in Hungary 1961–1991* (Becz László, 2019). In 2023, the Russian Federation and Belarus reached an agreement to deploy some Russian nuclear weapons in Belarus. Construction of a storage facility appears to be underway, but it is not clear whether weapons will actually be deployed there; see Hans Kristensen and Matt Korda, "Russian Nuclear Weapons Deployment Plans in Belarus: Is There Visual Confirmation?" *Federation of American Scientists*, June 30, 2023, https://fas.org/publication/russian-nuclear-weapons-deployment-plans-in-belarus-is-there-visual-confirmation.

14 For example, the 'parent' national-level storage facility of the Kolosovka site, Vologda-20, is located more than 1,000 km away. In many cases, however, the distance between the sites is smaller; Pavel Podvig and Javier Serrat, "Lock Them Up: Zero-Deployed Non-Strategic Nuclear Weapons in Europe."

Figure 3. Soltsy air base, Russian Federation. The rectangular security perimeter surrounding the nuclear weapon storage facility is seen in the upper left corner of the image. A storage facility on the right side of the image, which is used to store non-nuclear armaments, does not have a similar security perimeter around it.



If nuclear weapons are stored at the base-level facility, the standard weapon deployment procedure appears to include several steps that depend on the specific delivery system and the weapon type. In the Russian Federation's practice, weapons are stored separately from their delivery vehicles.

The base-level storage facilities are located at a distance from airfields or missile bases (Figure 3). If the weapons in question are warheads of ballistic or cruise missiles, each of them is stored in a specialized container, only to be mated with the missile as part of the deployment procedure. Gravity bombs are stored in their containers assembled.

Once the units receive an order to bring nuclear delivery systems to a higher state of readiness, the 12 GUMO units must take the weapons, still in containers, out of storage and load them onto specialized trucks. When this procedure is completed, the trucks deliver the containers to a designated point, where weapons are removed from the containers so that they can be mated with their delivery systems.

In the case of air-delivered weapons, such as bombs or air-launched cruise missiles, this point is normally a designated area of an airbase where the 12 GUMO troops carry out the final assembly of a weapon, if necessary, and prepare it for loading on the delivery aircraft. Fully assembled weapons at the airbase remain in the custody of the 12 GUMO troops until the very moment they are loaded onto an aircraft that is ready to take off, at which point custody is transferred to the flight crew.

Warheads of land-based ballistic and cruise missiles can probably be delivered to the missile base. However, the standard procedure appears to involve transporting the warheads to a designated rendezvous point away from the base where they would be mated with missiles and then loaded on launchers. The 12 GUMO troops apparently have the necessary equipment to conduct these operations in the field.

It appears that the 12 GUMO troops can keep nuclear weapons outside of the storage facility for some time, probably days and maybe even weeks. However, at some point the weapons must be returned to the base-level facility that provides conditions for long-term storage.

A potential arms control arrangement

The verification arrangement described in this report assumes that parties agree to withdraw their non-strategic nuclear weapons to some central storage facilities away from the bases where they are prepared for deployment. In practical terms that would mean that the Russian Federation would transfer all of its weapons to national-level storage sites while the United States would move its weapons either to its national territory or to centralized storage facilities in Europe. The base-level facilities would then be open to inspections to verify that the weapons have indeed been removed. This arrangement could also be broader in scope. For example, it may require removal of nuclear weapons from all facilities in a certain geographical area.

One significant advantage of this arrangement is that it does not require revealing any information about the nuclear weapons. For example, neither side would have to disclose the number of non-strategic weapons, their types, or specific characteristics of individual weapons. This drastically simplifies verification procedures as they do not have to include measures that protect classified information about weapons or their design.

It is also important to emphasize that this arrangement would be different from a disarmament scenario in which parties would agree to eliminate some or all nuclear weapons. In the case of partial disarmament, parties would have to develop a way to declare and count individual weapons and then to verify that the number of deployed weapons does not exceed the agreed limit. While the development of such procedures is possible in principle, it would require addressing a range of difficult issues, from agreeing on a definition of nuclear weapon, to protecting information about weapons.[15]

In the case of complete disarmament, the verification procedure must address the very difficult problem of confirming the absence of nuclear weapons in a State's territory, which would require making virtually any facility subject to a challenge inspection.[16] In contrast, the zero-deployed arrangement could limit verification activities to a small number of known sites.

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15 "IPNDV Working Group 4: Verification of Nuclear Weapons Declarations" (IPNDV, June 2019), www.ipndv.org/wp-content/uploads/2020/04/WG4_Deliverable_FINAL.pdf; Alexander Glaser, "Ceci N'est Pas Une Bombe. Toward a Verifiable Definition of a Nuclear Weapon" (58th Annual Meeting of the Institute of Nuclear Materials Management, Indian Wells, California, USA, July 2017).

16 "State-Wide Verification of Absence of Undeclared Weapons," in "IPNDV Working Group 4: Verification of Nuclear Weapons Declarations."

The key reason why this is possible is that the parties can be assumed to be responsible custodians of nuclear weapons. This means that deployed weapons are stored in conditions that provide proper maintenance, security, and a reasonable degree of readiness. This requires storing them in dedicated facilities, which is indeed the standard practice of the Russian Federation and the United States. As described earlier, apart from ICBM and SLBM warheads, in peacetime neither State keeps nuclear warheads mated to missiles or air-delivered weapons loaded onto aircraft. While it is possible to move weapons outside of their secure facilities or indeed mate them with their delivery systems, this would be done only in extreme circumstances of a crisis.

This means that the approach to the selection of facilities that would be subject to inspection can follow the practice that was accepted in the INF and START/New START treaties. In New START the parties provide a list of declared sites, which includes "site diagrams [...] for each facility at which inspection activities may be conducted".[17] The facilities covered by this obligation are ICBM, SLBM, and bomber bases as well as maintenance facilities. Information about a facility must include its geographic coordinates as well as a site diagram that should depict "structures and locations at which items of inspection may be located".[18]

For the purposes of a zero-deployed agreement, a declared site eligible for inspection would be defined by a security perimeter around the nuclear weapon storage sites. The diagram must identify objects of verification, which are the structures where nuclear weapons might be stored, as well as auxiliary buildings within the perimeter of the declared site.[19] An example of a site diagram for one of the storage sites in the Russian Federation is shown in Figure 4.

It should be noted that START and New START (as well as the INF Treaty) allowed inspections at declared sites and did not have provisions for challenge inspections to verify the absence of undeclared treaty-relevant items or facilities. This approach could be used in the zero-deployed arrangement as well since nuclear-weapon storage facilities have very distinct signatures and their locations are well known. The Russian Federation submitted information about its weapon storage facilities to the United States as part of the Cooperative Threat Reduction programme that improved security at these sites. Even though the United States and NATO have never officially disclosed the locations where nuclear weapons are deployed, these sites are easily identifiable as well. To resolve potential disputes, the agreement could introduce a category of former storage facilities that would be subject to a one-time 'close-out' inspection to confirm the absence of infrastructure for nuclear weapon deployment.[20] Disputes could also be resolved in a bilateral commission that would be established by the agreement. At the same time, the experience of the INF and START/New START treaties suggests that this mechanism is not essential. Despite the absence of a challenge inspection mechanism, neither party has attempted to conceal its facilities that would be subject to inspection.

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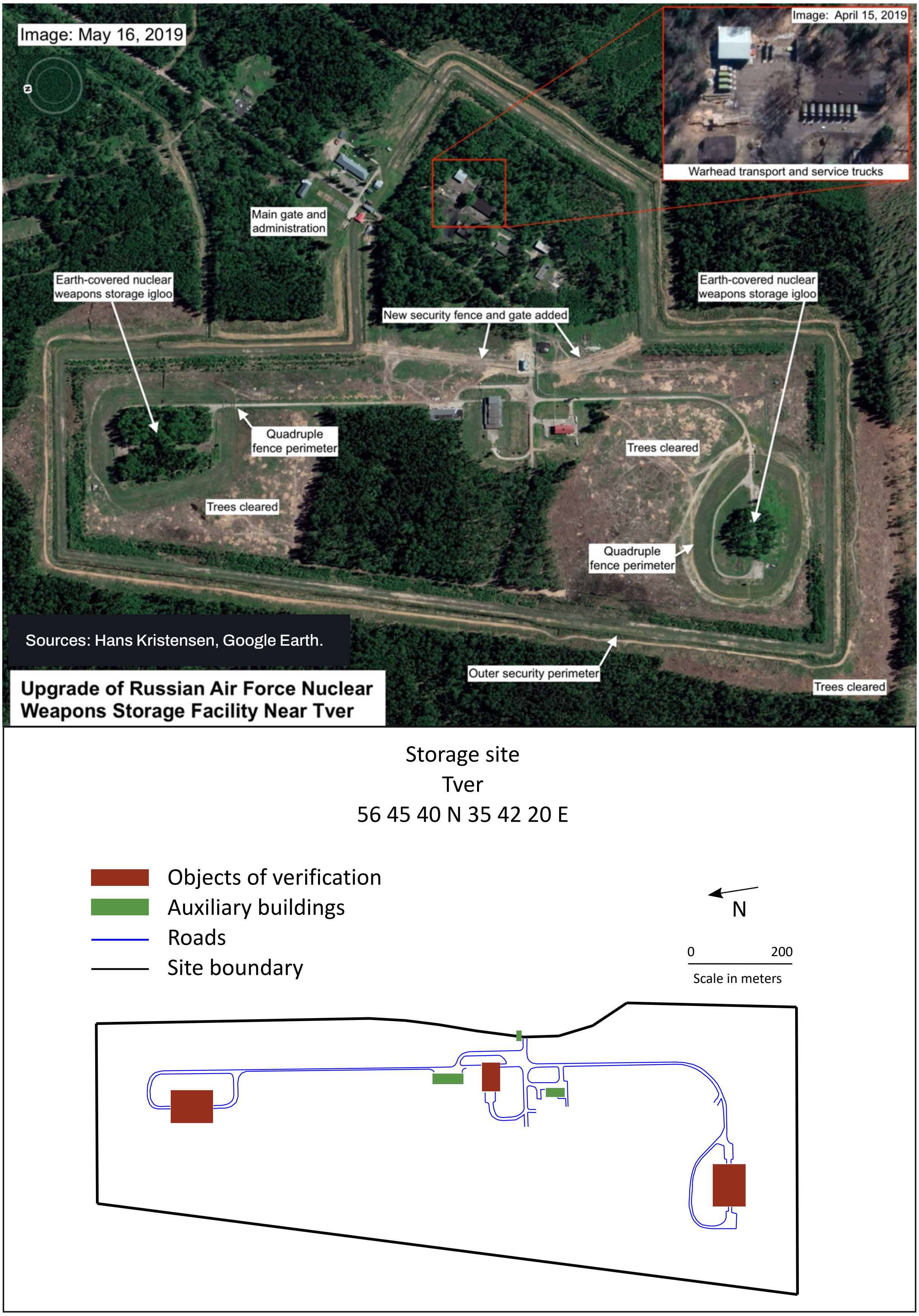
17 Protocol to the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms," 8 April 2010, Part Two, Section I, para 2.

18 Ibid., Annex on Inspection Activities, Part Four.

19 See Chapter 2 for details.

20 Pavel Podvig, Ryan Snyder, and Wilfred Wan, "Evidence of Absence: Verifying the Removal of Nuclear Weapons" (UNIDIR, 2018), https://www.unidir.org/sites/default/files/publication/pdfs/evidence-of-absence-verifying-the-removal-of-nuclear-weapons-en-722.pdf.

Figure 4. Satellite image and a site diagram of the Tver storage site in Russia.[21]



21 The satellite image with annotations is taken from Hans M. Kristensen, "Russia Upgrades Western Nuclear Weapons Storage Sites," *Federation of American Scientists*, July 24, 2019, https://fas.org/blogs/security/2019/07/russia-upgrades-western-nuclear-weapons-storage-sites.

Conclusions

The zero-deployed arrangement outlined here has several important benefits. It offers a path for extending nuclear arms control to non-strategic weapons. Its implementation would be fairly straightforward as it would not require radical changes in current practices and policies regarding these types of weapons. This means that the necessary steps could be taken relatively quickly as soon as a political window for an arms control agreement opens. Even though the zero-deployed arrangement may not prevent re-deployment of weapons in time of crisis, once nuclear weapons are separated from their means of delivery, such re-deployment would be a deliberate and highly visible step. By creating a distance between the peacetime posture and the situation in which non-strategic weapons are prepared for use, the arrangement could be a stabilizing factor in a crisis and reduce the risks of misunderstanding or accident.

The non-deployment of non-strategic nuclear weapons also opens a path towards a broader arms control agreement that would encompass all nuclear weapons, strategic and non-strategic. For example, a new arms control treaty could follow New START by setting a limit on the number of all deployed nuclear weapons. This approach would avoid many complications resulting from the difficulty of accounting for non-strategic weapons and their means of delivery. At the same time, it would provide a range of options for making arms reductions irreversible. This could be done by reducing the number of sites where non-strategic weapons can be deployed and by converting or eliminating their delivery systems.[22]

Reducing the number of sites where nuclear weapons are deployed or stored would have clear benefits for nuclear security. Even though these sites are normally well protected, there have been known security breaches at some of them.[23] Particularly problematic are situations where nuclear-weapon storage facilities are located near an area of active armed conflict.[24] Consolidating nuclear weapons at a small number of sites is the most reliable way of making sure that they are safe and secure.

Consolidation could also become a starting point for the verifiable elimination of nuclear weapons. It is important to note that this process, like consolidation itself, does not require knowledge of the number or type of nuclear weapons that have been brought to the site. It would involve securing the perimeter of the storage facility, declaring the amounts of fissile materials contained inside, and accounting for the materials that are released during the dismantlement process.[25]

In the end, nuclear arms control and disarmament is a complex process shaped primarily by political considerations. The development of new approaches to disarmament and verification can contribute to this process by providing practical steps that can create space for political initiatives. The zero-deployed arrangement could be one of these steps that can support efforts to include non-strategic nuclear weapons in the arms control process.

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22 Ibid.

23 Hans Kristensen, "US Nuclear Weapons Site in Europe Breached," *Federation of American Scientists* (blog), February 4, 2010, https://fas.org/blogs/security/2010/02/kleinebrogel.

24 Robyn Dixon, "Wagner Rebellion Raises Doubts about Stability of Russia's Nuclear Arsenal," *Washington Post*, July 5, 2023, https://www.washingtonpost.com/world/2023/07/05/russia-putin-nuclear-strike-nato.

25 Pavel Podvig and Ryan Snyder, "Watch Them Go: Simplifying the Elimination of Fissile Materials and Nuclear Weapons" (UNIDIR, August 2019), https://doi.org/10.37559/WMD/19/NuclearVer01; Tamara Patton and Alexander Glaser, "Deferred Verification: The Role of New Verification Technologies and Approaches," *The Nonproliferation Review* 26, no. 3–4 (2019), https://doi.org/10.1080/10736700.2019.1629072.

2. Organization of the experiment

Pavel Podvig, Eleanor Krabill

Introduction

This chapter describes the model verification arrangement that was designed to guide the inspection conducted as part of the Menzingen Verification Experiment. On-site inspections have been a standard element of arms control and disarmament agreements since the late 1980s, when they were included in the US–Russian Intermediate-range Nuclear Forces (INF) treaty, or even earlier if the safeguards administered by the International Atomic Energy Agency are included. Subsequently, on-site inspections were an essential part of all agreements between the Russian Federation and the United States—from the treaties that limited strategic nuclear armaments, such as START and New START, to those that dealt with fissile materials, such as the agreement that shut down plutonium production reactors. On-site inspections were also included in the verification regimes of multilateral treaties outside the nuclear field, such as the Conventional Forces in Europe (CFE) treaty or the Chemical Weapons Convention among others.

The role of on-site inspections in verification arrangements depends on the specific obligations included in the agreement that these arrangements are part of. It is important to understand, however, that on-site inspections are only one element of the verification mechanism that provides parties with confidence regarding compliance with obligations. This mechanism can be defined as "a set of national and cooperative activities, tools, procedures, analytical processes, and fundamentally, judgments about what is happening with regard to specific activities defined in an agreement".[1] On-site inspections play at least two roles in this process. First, they complement information obtained by national technical means, data exchanges, or notifications.[2] More importantly, though, as an inherently cooperative activity, on-site inspections provide a unique opportunity to assess the degree of cooperation of the parties with the verification procedures. This, in turn, provides an essential contribution to the assessment of compliance with the obligations assumed by the parties.

Indeed, on-site inspections rarely, if ever, uncover direct violations. In most cases of suspected or actual non-compliance, it was the unwillingness of the inspected party to cooperate with verification activities, provide clarifications and additional information that has been the most reliable indicator of a violation. The opposite is true as well—verification arrangements provide parties with a mechanism for positively demonstrating their commitment to comply with their obligations. From this point of view, on-site inspections have a special role to play, as they bring parties into direct contact, providing them with the best opportunity to judge intentions and the degree of cooperation with verification activities.

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1 "Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks. Overview," Cultivating Confidence Verification Series (Nuclear Threat Initiative, July 2014), 5, http://www.nti.org/media/pdfs/VPP_Overview_FINAL.pdf.

2 Amy F. Woolf, "Monitoring Mobile Missiles: Lessons from US–Soviet Arms Control," in *Exploring Options for Missile Verification*, ed. Pavel Podvig (UNIDIR, 2022), https://doi.org/10.37559/WMD/22/Misver/01.

To play this role effectively, verification arrangements need to be designed accordingly. First, they must provide a sufficiently high level of confidence that a violation would be detected. The value of this requirement, however, is not in the detection of violations, but in demonstrating compliance. Equally important is the presence of a clear and efficient consultation and dispute resolution mechanism that allows parties to discuss their concerns, address points of disagreement, and provide clarifications and additional information. This mechanism is essential if verification is understood as a cooperative rather than adversarial process.[3]

The model verification arrangement presented in this chapter outlines key elements of a mechanism that can support the removal of nuclear weapons from the storage sites located close to their delivery systems, as described in Chapter 1 of this report. It builds on the experience of previous arms control agreements, notably the CFE treaty, which provided a general framework for the verification arrangements, and New START, which provided a template for the radiation measurement procedures.[4] These procedures were adapted for the purposes of the zero-deployment arrangement considered in this report. The resulting documents, the model Protocol on Inspection and the Annex on Equipment and Procedures, are included in this report as Appendix A.

The basic premise of the inspection is that it is conducted at one of several declared sites. Although the zero-deployed arrangement assumes that nuclear weapons are withdrawn, the site may still retain the infrastructure to support the storage of weapons. This includes the security perimeter around the site, protected storage facilities, and various support systems. The maintenance of these features at a state's declared sites means that the withdrawal of weapons is not irreversible. It is possible to design a verification arrangement that would verify the dismantlement of this support infrastructure, but the procedures in this case would be somewhat different.[5]

It is important to note that this experiment did not attempt to replicate all elements of an on-site inspection. Accordingly, the model Protocol and the Annex include only those provisions that were relevant for the experiment. For example, the CFE Treaty and New START procedures include detailed steps for verifying the accuracy of geographic coordinates of the inspected site. In this experiment, the verification was done by reading the coordinates off a smartphone of the in-country escort. In another example, this experiment did not include procedures for checking the operability of the radiation measurement equipment or any authenticating procedures. These elements of the inspection activity have been extensively tested in practice or in other experiments.

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3 Nick Ritchie, "Constructing Verification: Power, Politics and Discourse," in *Verifying Disarmament in the Treaty on the Prohibition of Nuclear Weapons*, ed. Pavel Podvig (UNIDIR, 2022), https://doi.org/10.37559/WMD/22/TPNW/01.

4 The applicability of the CFE treaty arrangements to nuclear disarmament verification was first considered by the International Partnership for Nuclear Disarmament Verification; "IPNDV Working Group 4: Verification of Nuclear Weapons Declarations" (IPNDV, June 2019), https://www.ipndv.org/wp-content/uploads/2020/04/WG4_Deliverable_FINAL.pdf.

5 Pavel Podvig, Ryan Snyder, and Wilfred Wan, "Evidence of Absence: Verifying the Removal of Nuclear Weapons" (UNIDIR, 2018), https://www.unidir.org/sites/default/files/publication/pdfs/evidence-of-absence-verifying-the-removal-of-nuclear-weapons-en-722.pdf.

This experiment focused on the following key procedures:

- verification of the site lockdown;
- confirmation of the accuracy of the site diagram;
- inspection of objects of verification (storage facilities);
- confirmation of the non-nuclear nature of items by a visual inspection; and
- radiation measurements to confirm the non-nuclear nature of items.

The following sections provide a description of these procedures and discuss details of their implementation.

Pre-inspection activities

Notification

The general sequence of an on-site inspection would follow the practice established in earlier treaties. Provisions of the CFE Treaty are especially useful as they provide for the possibility of conducting inspections in States that would normally host nuclear weapons belonging to another State. In the CFE Treaty these States are referred to as "host" and "stationing" States respectively. In this case, the escort team can include representatives of both States. The CFE Treaty provision can also be adapted to provide non-nuclear States with an option to conduct inspections independently (Protocol, Section I.1.A–D).

At the time of the initial data exchange, the parties identify points of entry that would be used by inspectors to enter the inspected country (Protocol, Section I.1.N). Typically, there is more than one site that can be accessed from a given point of entry. Before initiating the inspection, the inspecting party submits a notification of intent to inspect, which specifies the point of entry and the time of arrival, but not yet the specific site that will be inspected (Protocol, Section IV). The site selected for inspection is designated after the inspectors arrive at the point of entry (Protocol, Section VII). Once the site is designated, the inspected party must arrange travel for the inspectors to the site within the agreed period of time. The times included in the model Protocol on Inspection are taken from the CFE Treaty. These values are notional and can be adjusted as necessary for the purposes of the agreement. It is, however, reasonable to assume that the time between the notification of the intent to inspect and the arrival of the inspectors at the site will be tens of hours.

Lockdown

Once the facility to be inspected is designated, the inspected party must implement certain restrictions at the designated site to ensure that no nuclear weapons are removed from the site or moved from secure to temporary storage within the base. In New START, which served as a model for this requirement, these measures include a ban on the removal of closed vehicles or covered objects that are "large enough to contain an item of inspection";[6] movements within the inspected site should be limited as well. These restrictions must be implemented no later than one hour from the designation of the site to be inspected (Protocol, Section VII.3).

6 "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," April 8, 2010, Annex on Inspection Activities, Part Seven, Section I.

It should be noted that items of inspection in New START, defined as a heavy bomber, an ICBM or SLBM, are large objects, which makes a lockdown easier to monitor. This is not the case with nuclear weapons, which are normally much smaller items. The model Protocol on Inspection restricts movements of “containers and vehicles large enough to contain a special armament” without specifying the size of items covered by this prohibition. Although this may seem to create an ambiguity that could complicate verification, in practice it is unlikely to change the effectiveness of the inspection.

First, in the zero-deployed arrangement an item of inspection is, in effect, not a single weapon or a container, but rather all nuclear weapons that could be stored on site. Removal of these weapons would involve movement of at least several vehicles or aircraft, which would be rather difficult to conceal. Indeed, it has been demonstrated that the movement of security convoys that accompany transfer of nuclear weapons can be detected by satellites.[7]

Another factor to consider is the inspection timeline. As described earlier, the time between the notification of the intent to inspect and the designation of the site for the inspection, when the lockdown restrictions come into force, can be at least several hours. This period of time can be used to begin preparations for an inspection at all sites that can be accessed from the point of entry designated in the notification. Indeed, this has been the normal practice in START and New START, in the Russian Federation as well as in the United States. For example, the Russian Federation is known to have moved mobile missiles outside of their base after receiving a notification.[8] In the United States, pre-inspection preparations also begin before the specific site is designated. It is assumed that if the inspected party is in violation of its obligations, it will begin the removal of weapons from all potentially affected sites as soon as it receives the notification.

Even though the New START experience suggests that the effectiveness of the lockdown restrictions is somewhat limited, this provision still plays a role as it gives the parties an additional opportunity to demonstrate and assess their compliance with treaty obligations. For example, even though the removal of mobile missiles from their bases was not a violation of the New START treaty provisions, this activity certainly influenced US assessment of the Russian Federation’s commitment to its arms control obligations.

In practice, the inspecting party will have the ability to constantly monitor movements at the site it designated for the inspection, regardless of the specific inspection date. It can also select the time for the inspection to ensure favourable monitoring conditions during the period of time between the notification of the inspection and the arrival of inspectors at the site. Normally, monitoring would be done by national technical means, but the inspecting party can also task commercial satellites to create uncertainty about the exact observation window. As a result, the inspected party can never have sufficiently high confidence in its ability to conceal movements of equipment at the base during the lockdown period.[9]

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6 “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,” April 8, 2010, Annex on Inspection Activities, Part Seven, Section I.

7 See, for example, Hans M. Kristensen, “Urgent: Move Us Nuclear Weapons Out of Turkey,” *Federation of American Scientists*, October 16, 2019, https://fas.org/blogs/security/2019/10/nukes-out-of-turkey.

8 Rose E. Gottemoeller, Negotiating the New START Treaty (Amherst: Cambria Press, 2021), 130.

9 See the discussion in Chapter 5.

Inspection procedures

Accuracy of the site diagram

After arriving at the inspected site, the inspectors receive a briefing, during which the escort team explains the safety and administrative procedures and provides the inspectors with an updated site diagram and, if necessary, describes changes or modifications at the site. The diagram must show the boundary of the site, its geographic coordinates, roads, and all buildings and structures located within the perimeter (Protocol, Section VII.5).

According to the original design of the experiment, each building and structure must be assigned one of two categories: objects of verification and auxiliary buildings. By designating a building as an object of verification, the inspected party declares that this is a structure that can be used to store nuclear weapons and therefore can be selected for an indoor inspection. Normally, these would be dedicated nuclear weapon storage bunkers or aircraft shelters with Weapon Storage and Security System that includes Weapon Storage Vaults inside. The buildings that cannot be used for nuclear weapon storage would be marked as auxiliary. These could be small structures, office and support buildings, or buildings with limited access.

Once the inspectors receive the site diagram, they have the right to verify its accuracy (Protocol, Section VII.8). In the process, they can move around the site to ensure that all structures and buildings are reflected accurately on the diagram and that the buildings that are marked as auxiliary cannot be used to store nuclear weapons. It is possible that the inspectors determine that some auxiliary buildings could be used for nuclear weapon storage. For example, nuclear weapons could be temporarily placed in a large hangar or garage within the site's perimeter. In this case, the inspectors can ask for clarification and request a close visual examination of the building in question. The model Protocol on Inspection prepared for this experiment assumed that the inspectors would have the right to request a close visual examination of two auxiliary buildings (Protocol, Section VI.11). The escort team can provide the necessary clarification and grant access to the building. However, the escort team can also refuse access, in which case the inspectors would have the right to document the challenge by taking photographs of the building's exterior and taking necessary measurements (Protocol, Section VI.17). These materials would then be included in the inspection report and considered by the Joint Implementation Commission. The Commission may decide to leave the classification of the building unchanged or to designate the building as an object of verification that is eligible for inspection during subsequent inspections of the site.

Inspecting objects of verification

Once the inspectors have checked the accuracy of the site diagram, they can select some of the buildings identified as objects of verification for inspection (Protocol, Section VII.9). Once the building is selected, the host should be allowed to prepare it for inspection, for example by shrouding sensitive items (Protocol, Section VI.13). During that period, the escort team must provide inspectors with the opportunity to observe that no items are removed from the building, for example by allowing them to observe the entrance to the selected building from a distance (Protocol, Section VII.10).

After the escort team has completed the preparation of a selected building, they provide the inspectors with a floor plan of the interior showing the dimensions of the interior space as well as any objects that may be located inside.

In its simplest form, when the object of verification is empty, the inspection would consist of a visual inspection of the interior space. The inspectors would also check the accuracy of the floor plan to confirm the absence of hidden doors or areas that are large enough to contain nuclear weapons. If inspectors detect any inconsistencies with the floor plan, they can ask for a clarification. If the host cannot provide one, the inspection team can register an anomaly in the inspection report.

In practice, the inspected building may not be completely empty, as it is likely to contain items that the inspected party would claim to be non-nuclear. These items could be support equipment, training munitions, containers, or other similar items. Some of these items might be sensitive objects that the inspected party has the right to cover (Protocol, Section VI.13). Accordingly, the Protocol on Inspection should include procedures that can confirm the non-nuclear nature of objects that may be present in the inspected building. For this purpose, each object that can be found in the inspected building (or in the open area of the site) should be assigned a category that determines the method that the inspectors can use to confirm its non-nuclear nature.

During the inspection, the inspectors will have the right to verify the position of items as shown on the floor plan and, if necessary, perform measurements to confirm that these items are correctly categorized. Once the accuracy of the floor plan and the categories of the items have been checked, the inspectors have the right to select several items for further inspection using a method that corresponds to their assigned category. The model Protocol on Inspection assumed that the inspectors could select up to three items to be so examined (Protocol, Section VI.14).

Confirming the non-nuclear nature of items

Confirmation of the non-nuclear nature of an item can present a number of challenges, especially in those cases where the item has classified or otherwise sensitive characteristics that may preclude an intrusive close-up inspection.

The approach to examining non-nuclear objects developed in this experiment assumed that the parties would negotiate a set of procedures, each of which would be associated with a category of items to which it could be applied. The agreed procedures could range from a visual inspection of the interior of a container to confirm that it is empty, to elaborate radiation measurements that may involve active radiation sources to confirm the absence of fissile materials.

The development of these inspection procedures can take advantage of the fact that the arrangement discussed here will verify the absence of *deployed* nuclear weapons, rather than the absence of nuclear weapons of some unknown type or design. This means that the parties can make certain assumptions about the items that should not be present at the inspected site. This does not mean that the parties need to share this knowledge or agree on a common definition of a nuclear weapon (or any definition at all). Rather, the specific assumptions that they make about each other's weapons would be expressed in their readiness to accept certain verification procedures.

One example of this approach is the New START procedure used to confirm the non-nuclear nature of inspected objects. The treaty gives the inspecting party the right to use radiation detection equipment to measure the total neutron count in the vicinity of the inspected object, which is then compared to the separately measured neutron background.[10] This procedure relies on certain assumptions about nuclear weapons, namely on the presence of a certain mass of plutonium. By agreeing to use passive neutron detection the parties effectively acknowledged that they had confidence that the other party's weapons contain a certain amount of plutonium.

The relative simplicity of passive neutron detection has made this technique the verification method of choice for many proposals that have approached the issue of nuclear disarmament verification.[11] However, this method also relies on the assumption of the absence of shielding or neutron-absorbing material around the inspected item. The New START procedure is designed to deal with items that are "located on the front section" of a deployed missile or "located on or in the heavy bomber", which guarantees the absence of shielding that could mask the radiation emitted by the fissile material in a warhead.

When an item is placed in a storage or transport container, the absence of shielding material cannot be taken for granted. Indeed, the New START inspection protocol explicitly specifies that "the use of containers shall not be permitted while conducting the [radiation detection] procedures [described in the protocol]".[12] This suggests that a different technique must be used to examine containers that may be found at the inspected site.

It is, however, possible to develop an approach that would confirm the absence of a nuclear weapon in a closed container. First, the parties can agree that sufficiently small containers cannot have a nuclear weapon inside them. As noted earlier, even if the parties do not explicitly exchange information about their nuclear weapons, they would normally have a good understanding of their dimensions and can define the notional 'small container' accordingly. For example, during an inspection at a NATO storage site in Europe one can assume that containers smaller than the dimensions of the B-61 gravity bomb can be considered non-nuclear.

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10 "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," 8 April 2010, Annex on Inspection Activities, Part Five, Section VI; see also Alexander Glaser, "Ceci N'est Pas Une Bombe. Toward a Verifiable Definition of a Nuclear Weapon" (58th Annual Meeting of the Institute of Nuclear Materials Management, Indian Wells, California, USA, July 2017).

11 James M. Acton, Thomas D. MacDonald, and Pranay Vaddi, "Revamping Nuclear Arms Control: Five Near-Term Proposals" (Carnegie Endowment for International Peace, December 2020), 14, https://carnegieendowment.org/files/Acton_McDonald_Vaddi_Arms_Control.pdf; Keir Allen et al., "Selection and Deployment of Verification Technologies. Lessons Learned from the Quad Nuclear Verification Partnership and the LETTERPRESS Simulation" (Quad Nuclear Verification Partnership, March 2019), 12, https://quad-nvp.info/wp-content/uploads/2020/06/QUAD-Selection-and-deployment-of-verification-technologies_-March-2019.pdf.

12 "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," Annex on Inspection Activities, Part Five, Section VI, para 16(l).

Larger containers may require an additional procedure to confirm the absence of nuclear weapons inside. The simplest one is a visual inspection of the interior of the container to confirm that it is empty. Of course, this type of inspection can be applied only to those containers that the host is willing to open. Some other containers could allow a visual inspection of a different kind. A closed container may have a window that shows whether or not it contains a weapon.[13] A container may have special markings that show, for example, that it is a training mock-up. Training versions of weapons that are stored without containers also normally have distinct markings or colour coding.[14]

A visual inspection could probably be applied only to those containers that the inspected party considers non-sensitive. Others may require application of a different procedure. Passive neutron measurements can be an effective technique for closed containers that are large enough to contain a nuclear weapon but not sufficiently large to contain significant shielding. While each party would make its own assumptions about the fissile material content of the other party's weapons and the effectiveness of shielding materials, it should be possible to agree on a common size limit for containers that can be examined with passive neutron measurements without revealing those assumptions.

If the parties have concerns about shielding, they can negotiate a procedure that uses active radiation sources to confirm the absence of shielding in an inspected item. Since none of the items that may be found at the inspected site is expected to contain fissile materials, the use of active sources should not present a safety problem. There is a range of techniques that use active gamma-ray or neutron sources to verify the absence of fissile materials in the possible presence of shielding.[15] Typically, these methods would require some understanding of key characteristics of a nuclear weapon, such as the type and amount of fissile material used. However, it may be possible to develop a protocol that would not depend on these kinds of assumptions, as long as the inspection procedures are agreed in advance.[16]

Testing this approach to verifying the non-nuclear nature of inspected items was one of the central elements of this verification experiment. The model Protocol on Inspection contained an Annex on Equipment and Procedures that defined the categories of items and the procedures that can be used to inspect them. It should be noted that the category definitions used in this experiment were notional as they reflected the availability of items to be examined rather than a judgment about the applicability of any particular method of examination.

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13 A similar procedure is apparently used to verify whether a nuclear-capable Tomahawk missile is equipped with a nuclear or inert warhead; see Joby Warrick and Walter Pincus, "Missteps in the Bunker," *The Washington Post*, September 23, 2007, http://www.washingtonpost.com/wp-dyn/content/article/2007/09/22/AR2007092201447.html.

14 "US Soldiers Expose Nuclear Weapons Secrets Via Flashcard Apps," Bellingcat, May 28, 2021, https://www.bellingcat.com/news/2021/05/28/us-soldiers-expose-nuclear-weapons-secrets-via-flashcard-apps.

15 Eric Lepowsky, Jihye Jeon, and Alexander Glaser, "Confirming the Absence of Nuclear Warhea ds via Passive Gamma-Ray Measurements," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 990 (February 21, 2021), https://doi.org/10.1016/j.nima.2020.164983; D. L. Chichester et al., "Active Neutron Interrogation as a Method for Verification of the Absence of Special Nuclear Material in Arms Control Dismantlement," *Proceedings of the INMM & ESARDA Joint Annual Meeting*, August 2021, https://resources.inmm.org/sites/default/files/2021-09/a143.pdf.

16 Pavel Podvig and Ryan Snyder, "Verifying the Non-Nuclear Nature of Objects," *Proceedings of the 60th Annual Meeting of the Institute of Nuclear Materials Management*, Palm Desert, CA, July 2019.

The first category, Category A, was defined to include items that can be inspected visually (Annex, Section VII.3). The inspectors can check dimensions or markings or other distinguishing features of the item. They can also request access to the interior of the container unless its dimensions are below the agreed threshold. The inspectors can dispute the categorization of the inspected item if, for example, they believe that the hidden volume in the container is too large. If that is the case, the inspectors can request the escort team to make a photographic record of the challenged structure and register it in the inspection report.

Items in Category B would be relatively small, closed containers that can be examined with passive techniques—passive neutron measurements follow the protocol described in the START and New START treaties.[17] Category C was introduced to include items that require radiation measurements with active radiation sources to confirm their non-nuclear nature. In this experiment the active interrogation procedure was represented by the method developed by the Princeton University team.[18] Specific procedures that were used during the inspection are described in Chapter 4 of this report.

Finally, Category D was introduced to include items similar to the Weapon Storage and Security System vault. It was assumed that the vault would be raised above ground and covered by a soft cover. The inspection would include verifying the dimensions of the item and requesting the escort team to demonstrate that there are no objects secured within the vault.

In the case of an actual agreement these definitions and procedures would be subject to negotiations between the parties. The purpose of this experiment was to test the conceptual approach to verifying the absence of deployed nuclear weapons.

Inspection report

Once the visual inspection of the object of verification and the examination of the non-nuclear items selected for detailed inspection are completed, the inspection team prepares an inspection report (Protocol, Section IX). The report should describe the activities performed by inspectors and include all documents related to the challenges raised during the inspection. The inspectors submit the report to the Joint Implementation Commission which will then consider the challenges. If the parties agree, they will make the necessary adjustments to their practices.

In addition, the inspection team would provide a detailed account of the inspection to its national authorities who will combine it with the information available through other channels, such as national technical means or with the data obtained by intelligence, to reach a conclusion about the inspected party's compliance with its obligations. As noted earlier, the experience of conducting on-site inspections and the degree of cooperation of the inspected party provide the most valuable inputs to the compliance evaluation process.

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17 See Alexander Glaser, "Ceci N'est Pas Une Bombe."

18 Lepowsky, Jeon, and Glaser, "Confirming the Absence of Nuclear Warheads via Passive Gamma-Ray Measurements."

3. The on-site inspection

Pavel Podvig, Vivienne Zhang

Overview

This chapter provides an account of the on-site inspection that was the central part of the Menzingen Verification Experiment. The experiment modelled an on-site inspection designed to verify the absence of nuclear weapons at a military facility.

In preparation for the experiment, UNIDIR developed a detailed script based on the Protocol on Inspection described in Chapter 2 of this report. These documents were based on the work of the expert workshop held in Geneva in April 2022. The Swiss Armed Forces provided the site for the experiment as well as the logistical support for the experiment. The Armed Forces College in Lucerne provided a venue for the pre-inspection and post-inspection workshops that took place on 7 March 2023 and 9 March 2023 respectively. Lucerne was also identified as the point of entry for the purposes of the inspection.

Site preparation

The site selected for the inspection is a former air defence site known as the Bloodhound Missile Station BL-64 ZG, located near Menzingen, canton Zug. Although the station is no longer active, it is still managed by the Swiss Army, making it a suitable facility for the experiment.

The territory of the site is measured approximately 0.6 km by 0.4 km, which is comparable to that of secured areas of most active weapon storage sites. It includes 16 open launch pads, 32 hardened bunkers, a number of buildings and roads. The satellite image of the site and the view of the bunkers are shown in Figure 1. Each bunker is about 4x7 m in size, protected by a hardened door.

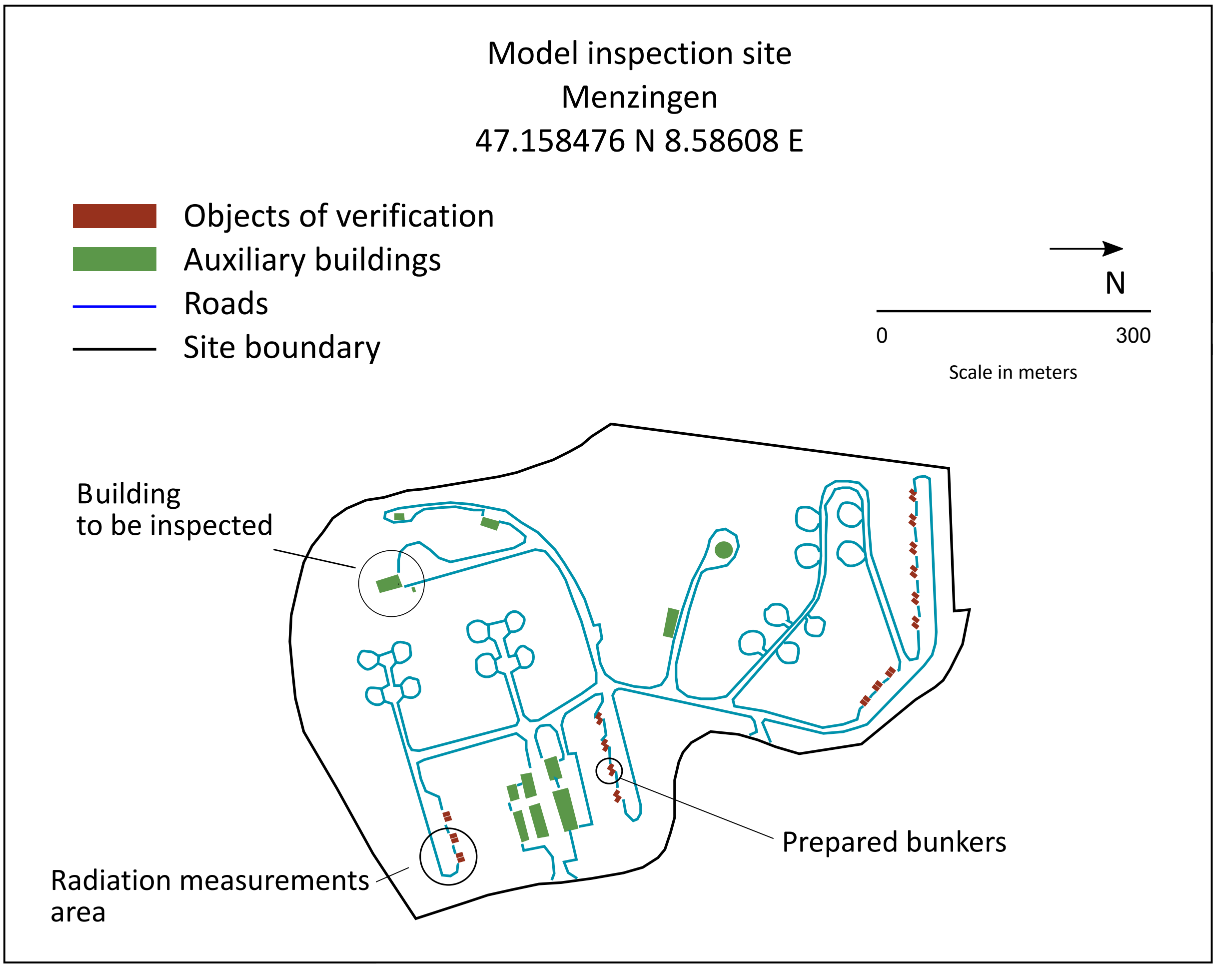
According to the inspection protocol, the inspectors have the right to request inspection of two buildings that are designated as objects of verification. The inspection script specified that the inspectors would request an inspection of two bunkers, No. 212 and No. 213, located in the ‘inspected bunkers’ area shown in Figure 2.

Four bunkers, Nos. 201, 202, 204, and 205, located in the radiation measurements area of the site (see Figure 2) were prepared for radiation measurements. The initial preparation of the bunkers included the placement of containers according to the script developed for the experiment. The containers were placed in the bunkers by the Swiss Armed Forces team on 3 March 2023. Additional preparations included placing radiation sources in some of the containers prepared for radiation measurements. The sources were delivered to the site and installed in the containers by the Spiez Laboratory team on the day of the inspection, 8 March 2023.

The experiment participants were divided into three groups of six: the inspectors, the hosts, and the observers. In order to facilitate access to various facilities at the site, the host group was led by representatives of the Swiss Armed Forces.

Figure 1. Satellite image of the Menzingen site and storage bunkers.

Figure 2. Site diagram with areas prepared for the experiment.



Inspection activities

Notification and arrival at the site

The inspecting party informed the inspected party of its intent to conduct an on-site inspection in an email message sent at 13:00 CET on 6 March 2023. The notification contained the following information required by Section IV.1 of the model Protocol on Inspection:

(A) the point of entry/exit to be used – Lucerne;
(B) the estimated time of arrival at the point of entry/exit – 12:00 CET 7 March 2023;
(C) the means of arrival at the point of entry/exit – train;
(D) the time interval between the arrival at the point of entry/exit and the designation of the inspection site – 20 hours;
(E) the language to be used by the inspection team – English;
(F) the language to be used for the inspection report prepared in accordance with Section IX of the Protocol – English; and
(G) the full names of inspectors and transport crew members, their gender, date of birth, place of birth and passport number.

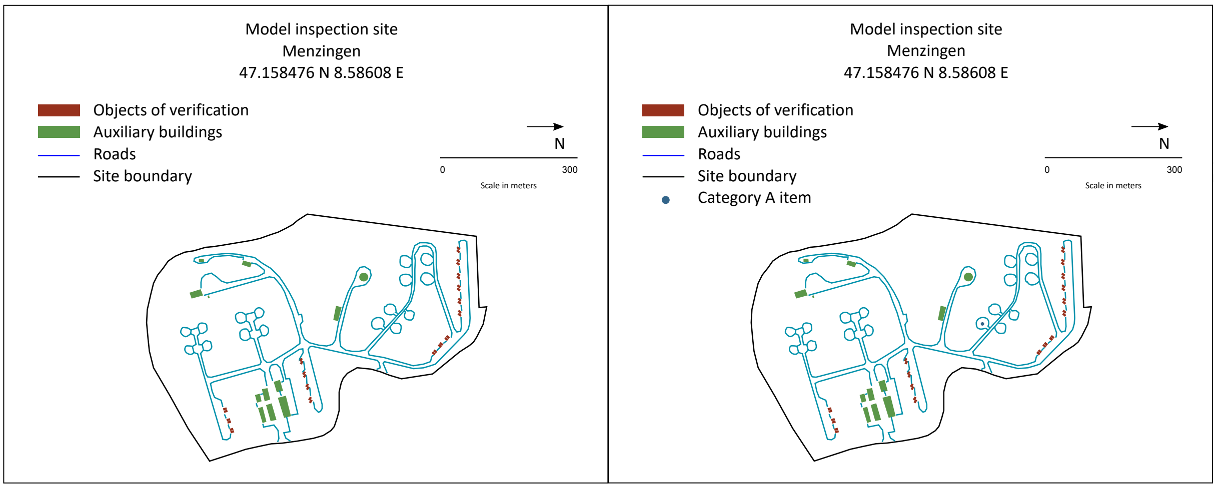
Although it was known that the inspection would take place at the Menzingen site, the initial notification did not include that information.

At 8:00 CET on 8 March 2023 the inspection team met the escort team at the agreed meeting point at the Lucerne train station. The inspection team formally informed the escort team of its intent to inspect the site listed in the declaration submitted by the inspected party during the initial data exchange as Menzingen.

The escort team provided two Mowag Duro light transport vehicles and accompanied the inspectors to the designated site.

At 10:10 CET, after a security check by Military Police, the inspection team was escorted to the briefing facility. The escort team provided a safety and security briefing and provided the inspectors with an updated site diagram. Figure 3 shows the site diagram submitted during the initial data exchange and the site diagram provided at the site. These documents were included in the inspection report as Attachment 1. The escort team explained that the updated diagram showed a training model of the BL-64 missile installed in one of the open launch pads. It is the Category A item appearing right of the centre of the in the updated diagram.

Figure 3. The site diagram submitted during the initial data exchange (left) and the site diagram provided by the escort team at the site (right). Included in the inspection report as Attachment 1.



Normally, the inspectors would verify the geographic coordinates of the site using the equipment provided by the inspected party and the procedure specified in the Protocol on Inspection. This step was not included in the inspection scenario. Instead, the inspectors verified the accuracy of the site coordinates using smartphones of the Swiss Army members of the escort team.

Accuracy of the site diagram

After receiving the updated site diagram, the inspection team formed two sub-teams, Sub-team North and Sub-team South. The teams selected their areas of responsibility for the purpose of verifying the accuracy of the site diagram. The inspectors and the escort team agreed to conduct the inspection on foot.

The goal of this stage of the inspection was to confirm that the site diagram correctly reflected the status of the site and that the buildings and structures were properly categorized.

Confirming the status of a building

In some cases, a visual inspection of the exterior of the building was sufficient to confirm that it was correctly classified as an auxiliary building not suitable for nuclear weapon storage.

One example is the building at Location 6 (Figure 4), inspected by Sub-team South. At the request of inspectors, the escort team identified it as a radio transmission building. The visual inspection of the exterior confirmed that it was not suitable for nuclear weapon storage, largely because of the narrow entrance door and a set of stairs.

In one case, the inspectors were granted access to the interior of the building they examined. When Sub-team North was inspecting the building at Location 1 (Figure 4), it identified an open door with a long narrow corridor with steps up and down behind it. The escort team identified this building as a power station and marked it as auxiliary. With the consent of the escort team, the inspectors examined the interior of the building using a flashlight. The inspection showed an empty room with a large fuel tank. The inspectors concluded that the building was not suitable for nuclear weapon storage.

A similar procedure was used at Location 5, where Sub-team North inspected a row of buildings marked as auxiliary. The escort team clarified that these buildings are garages. Some of these buildings were in scaffolding, apparently undergoing roof repairs. A visual inspection of one of the garages with a flashlight, conducted with the consent of the escort team, showed a largely empty hall with some construction material inside. The inspectors concluded that these buildings could in principle be used to store nuclear weapons and reflected this conclusion in the inspection report.

While examining the building at Location 11, Sub-team South requested access to a small structure located next to the examined bunker. The escort team granted full access to the interior of the structure, which turned out to be a toilet.

In those cases where the inspectors did not detect inaccuracies or omissions in the site diagram, they normally did not record their confirmation activity in the inspection report. For example, when Sub-team South examined the cluster of eight launch pads in the southern part of the site, all launch pads were empty as declared, thus no mention of the confirmation was needed in the report.

Similarly, at this stage the inspectors did not closely examine those structures that were marked as objects of verification (bunkers). At the same time, they noted that the bunkers around Location 12 are arranged in pairs and numbered, from West to East, as 219/218, 216/215, 213/212, and 210/209.

Structures not on the site diagram

In a number of cases, the inspectors discovered structures that were not marked on the site diagram. The course of action in these cases depended on the nature of the structure.

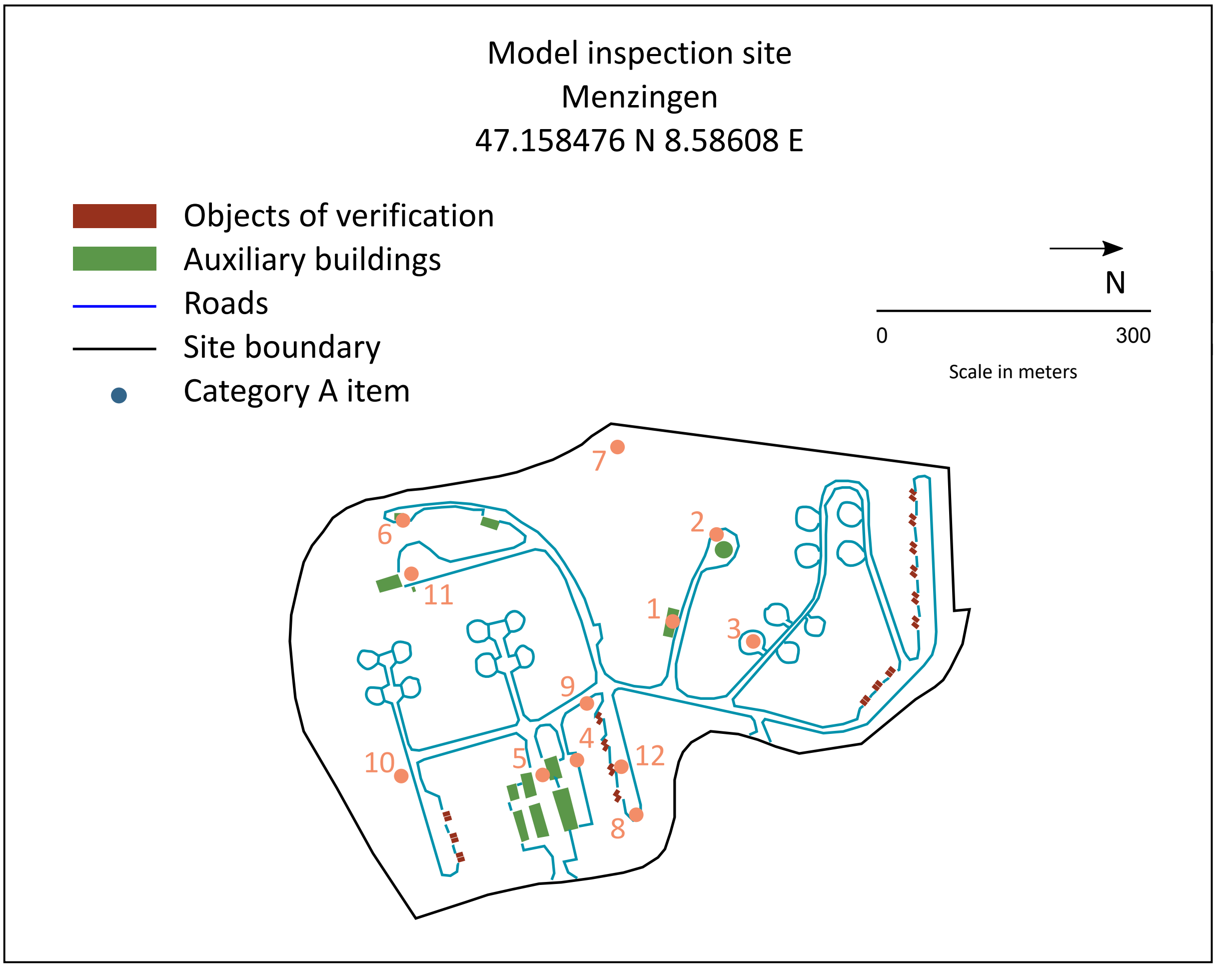
Among the structures that were examined but not mentioned in the inspection report were features like a barbeque area and other similar small structures.

In examining the area at the southern part of the site, Sub-team South discovered an unmarked forest road with freshly distributed soil close to the bunkers in the area (Location 10). The escort team explained this as the site of recent tree cuttings and granted approval for inspectors to examine the cuttings. The feature was included in the inspection report, but because of its temporary nature no request to add it to the site diagram was made.

The inspectors identified several structures that in their view should be added to the site diagram. In some cases, they did not believe a request to access these structures was warranted. Thus, Sub-team South located a bunker labelled '01' at Location 9. The escort team explained that it is a 12-person shelter for site personnel. A similar situation was encountered at Location 4, where Sub-team North identified a possible semi-underground nuclear shelter labelled ‘Bierhalle’ at its entrance, and at Location 7, where the inspectors detected a structure identified as a guard station. Requests to add these structures to the site diagram were included in the inspection report.

There were several larger buildings that were not reflected on the site diagram. Sub-team South discovered a building at the end of the line of bunkers, at Location 8. The building appeared taller and narrower than the individual bunkers. A request for clarification was made, and the escort team explained the building to be for transportation support functions. The inspectors' access to the building was not granted, therefore they could not confirm that the building is not suitable for nuclear weapon storage. A corresponding record was added to the inspection report.

Figure 4. Site diagram with inspected objects and structures. Included in the inspection report as Attachment 2.



A documented challenge

At two locations, inspectors formally challenged the classification of buildings. One of these buildings was shown on the site diagram, while the other was not.

At Location 2, Sub-team North identified a bunker that was not marked on the site diagram. The escort team explained that the bunker is part of the launch control system and declined the request to grant access to the bunker. The inspectors believed that the situation required a formal challenge and asked to document the location and dimensions of the bunker. With the consent of the escort team, the inspectors took a photograph of the bunker doors showing the measured length of the bunker's door. The photo was taken with a non-Internet-enabled instant camera which was approved by the escort team (Figure 5). Although the quality of the photo was less than optimal, it confirmed the presence of the bunker at the location and allowed inspectors to conclude that the bunker is identical to those that are marked on the site diagram as objects of verification.

Figure 5. Photo of the bunker at Location 2 taken by an instant camera. Included in the inspection report as Attachment 3.

Figure 6. Photo of the entrance to the bunker at Location 11. Included in the inspection report as Attachment 4.

Another challenge was issued at Location 11, where Sub-team South identified an underground structure that resembled the bunkers that are used for nuclear weapon storage. The inspectors observed an air vent on top and an exhaust window on the east side of the bunker. Inspectors officially challenged the classification of the bunker as an auxiliary building. The escort team granted access for photography and measurement.

The inspectors measured the dimensions of the doors and took photos of the bunker's exterior and the space behind the doors. Upon request and approval from the escort team, these dimensions were compared to those of other bunker doors. The photograph of the entrance to the bunker was added to the inspection report as Attachment 4 (Figure 6).

Inspection of objects of verification

Once the verification of the site diagram is completed, the Protocol on Inspection allows the inspecting party to select up to two buildings that were designated on the site diagram as objects of verification and to conduct an inspection inside these buildings. At 11:30 CET the inspectors notified the escort team of the intent to inspect two bunkers marked 212 and 213 as objects of verification for inspection. The bunkers are located at Location 12.

At 13:00 CET, the escort team provided the inspectors with floor plans of the selected bunkers. As described earlier, these bunkers were prepared in advance by placing a number of items inside. The arrangement inside Bunker 213 and the floor plans are shown in Figure 7.

For this part of the inspection, the inspectors also formed two sub-teams. One of them inspected the bunkers, while the other conducted radiation measurements; for logistical purposes these tasks were carried out in parallel. However, in normal circumstances the radiation measurements would follow the inspection of the objects of verification.

The inspectors began with Bunker 212. The floor plan showed three Category A items and one Category D item located inside. The inspectors examined the floor and walls of the room and detected no visual signs of hidden rooms or spaces. They also noted that the floor plan was correct, with the exception of a small object, on the right-hand wall between the radiator and the generator, that was not on the plan. The escort team explained it to be a hygrometer. The two narrow elongated Category A items along the walls were confirmed to be heating radiators. The larger Category A item located along the wall above the radiator on the right-hand side was identified as a power generator that was turned on. At the request of the inspectors the escort team opened the lid of the generator to expose its interior.

The Category D object in the middle of the bunker was supposed to be a replica of a Weapon Storage Vault in the raised position. In this experiment the vault was represented by a wooden structure with different dimensions. In accordance with the Protocol on Inspection, the structure was fully covered by a tarpaulin.

Following the procedure described in the Protocol on Inspection, the inspectors measured the item to confirm its dimensions and requested the escort team to push inside the tarpaulin on both sides to demonstrate that the space underneath was empty. It appeared that there was not enough room for a warhead under the tarp; the inspectors concluded that the item is indeed a non-nuclear Category D item.

The inspectors also asked the escort team to uncover the bottom part of the item. Although this procedure was not included in the Protocol, for the purposes of the testing new procedures, the request was granted and revealed the absence of empty space under the item, indicating that it is not an actual Weapon Storage Vault. With consent of the escort team, the inspectors also took photos of the bottom part of the item and the floor beneath it.

The inspectors also measured the dimensions of the bunker's double door to compare them with those of buildings identified during the earlier stage of the inspection. The width of the individual doors was 97 cm and 213 cm, the height was 260 cm, and the depth was 22 cm. The inspectors also made a note of the ramp at the bunker's entrance. This information was noted in the inspection report, so it could later be used to resolve questions regarding the function of various buildings.

After inspecting Bunker 212, the inspectors moved to Bunker 213, which contained four Category A items, one Category B item, and one Category C item (Figure 7). Similar to the previous bunker, the floor and walls appeared to be made of solid concrete with no detectable visual signs of hidden rooms or spaces.

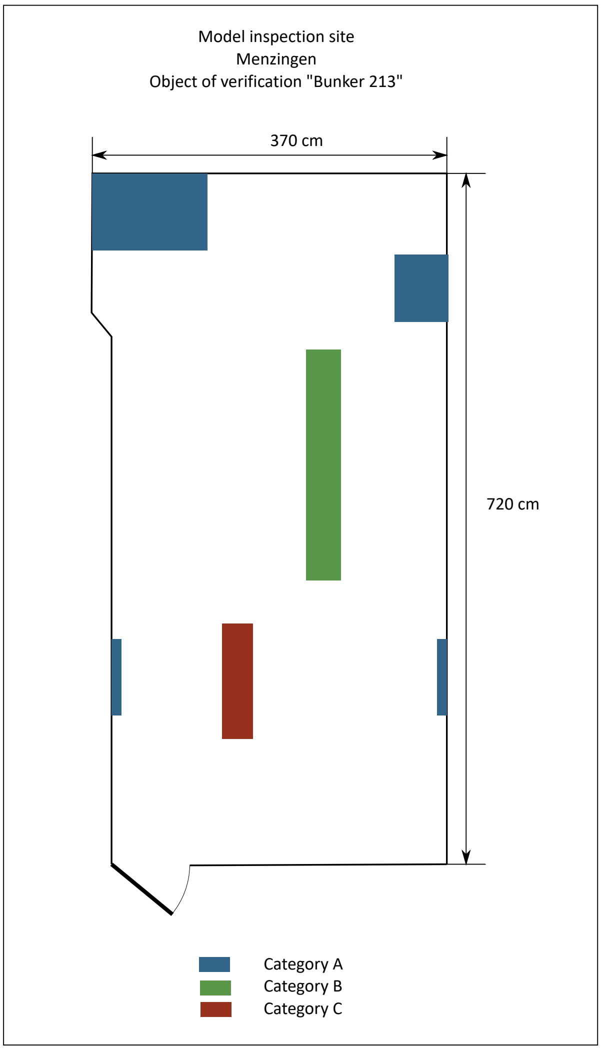
On either side of the room were two heating radiators of Category A, visually identical to those found in Bunker 212. Above the radiator on the right-hand side was a Category A generator similar to the one seen in Bunker 212. Inspectors visually examined the generator and saw that it was turned off (Figure 8, top). The inspectors also noted a hygrometer on the right-hand wall that was not reflected in the floor plan.

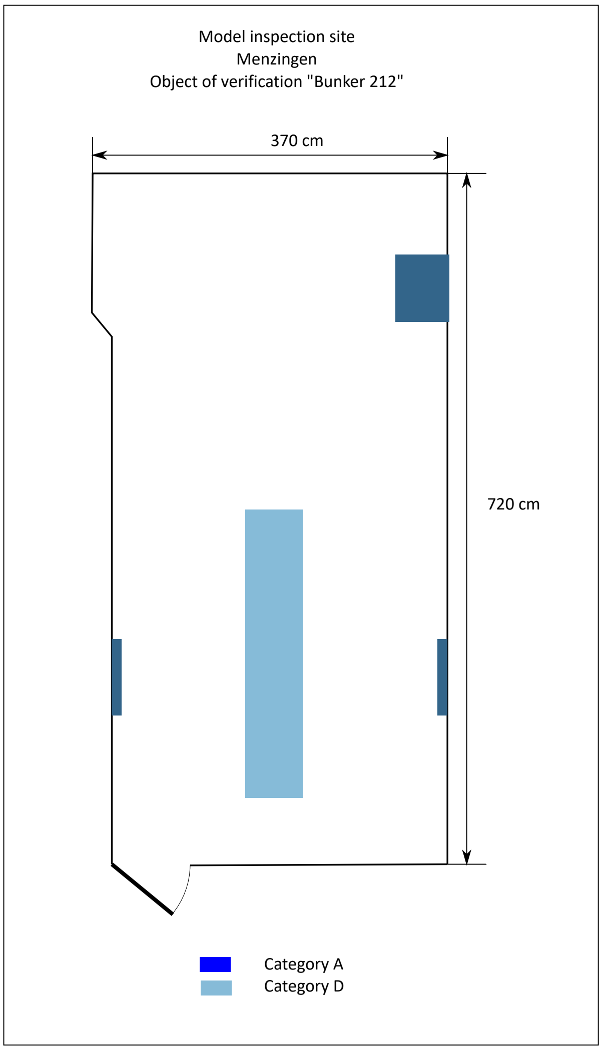
The inspectors examined the two Category A items at the far end of the bunker. These were two stacked wooden boxes. At the inspectors' request, the escort team opened the lid of the top box and lifted the top box to demonstrate that both boxes were empty.

The inspectors measured the Category B and Category C items located in the bunker to confirm that these items were properly categorized. The measurements and confirmation were included in the inspection report. Following the script developed for this experiment, the inspectors selected these two items to be inspected further by means of radiation measurements to confirm their non-nuclear nature.

Normally, after items are selected for radiation measurements (or other kinds of detailed inspection), inspectors would tag and seal the items to preserve the chain of custody. This inspection step was not included in this experiment, as it has been thoroughly explored elsewhere. It was assumed that the inspectors had tagged and sealed the selected items.

Figure 7. Bunker 213 prepared for the inspection and the floor plans of Bunkers 213 and 212. The floor plans were included in the inspection report as Attachment 5.





Additional inspection procedures

The Protocol on Inspection specified that the procedures that can be applied to Category B and Category C items were limited to the measurement of their dimensions and radiation measurements as specified. However, the participants took the opportunity to test several visual inspection procedures that can be used to confirm the non-nuclear nature of various items. For these tests, the Category B and Category C items in Bunker 213 were treated as if they were Category A items that allow for visual inspection.

A close examination of the Category B item showed that it was a plastic container with metal elements. The escort team explained it to be a mock-up missile box used for training purposes. With the approval of the escort team, one inspector was able to partially lift the pallet with the item, which suggested that it weighed less than 100 kg. This would be a strong indication that the container does not have a nuclear weapon inside. In addition, the inspectors asked a member of the escort team to tap on the container. The sound produced by tapping strongly suggested that it was an empty plastic container.

As for the Category C item, the inspectors examined the markings that showed it to be a training munition (Figure 8, bottom right, “Engin guidé antichar sol-sol BB 77 obus d’exercice 90”). Tapping on the item also strongly suggested that it was an empty metal container (Figure 8, bottom left).

These experiments demonstrated that there is a broad range of methods that can be used to confirm the non-nuclear nature of items by simple inspection. Such methods can be applied to a variety of items independent of their dimensions, provided that the parties agree to use them.

Radiation measurements

In a normal inspection sequence, the inspectors will have the right to select certain items for radiation measurements to confirm their non-nuclear nature. The inspection procedure that is applied to an item is determined by its category. The definitions of categories and the procedures would be agreed in advance and included in the Annex on Equipment and Procedures to the Protocol on Inspection (see Chapter 2).

The category definitions used in this experiment were notional and reflected the availability of items to be examined rather than a judgment about the applicability of any particular method of examination. It was assumed that Category B includes relatively small containers unable to contain a significant amount of neutron-shielding material and thus that could be examined with passive techniques.

Category C items would include larger containers that could contain some shielding and therefore would require employment of active techniques. It must be emphasized that the measurements made during this experiment tested the possibility of conducting radiation measurements in the field rather than the applicability of a particular method in specific circumstances.

Figure 8. Inspection of individual items in Bunker 213. A visual inspection of the generator (top), tapping on the metal container (bottom left), training munition label on the container (bottom right).

The radiation measurements that were performed during the experiment are described in Chapter 4 of this report. For the purposes of the inspection report, it was assumed that the Category B item in Bunker 213 was the empty container that was placed in Bunker 201. The Category C item selected for the inspection in Bunker 213 was assumed to be identical to the empty container placed in Bunker 204.

As explained in Chapter 4, the radiation measurements detected an anomaly in Bunker 201 and confirmed the absence of nuclear material in the item in Bunker 204. Accordingly, the inspection report reflected that the inspectors could not confirm the absence of special weapons in Bunker 213, where the items were located.

Inspection report and departure

After the inspection activities were completed, the inspection team drafted an inspection report. Normally, the report would be signed by both parties at the end of the inspection. If necessary, the leader of the escort team can add clarifications and explanations.

Since the radiation measurements detected an anomaly at one of the items selected for inspection, the inspectors concluded that they could not confirm the absence of nuclear weapons at the site. The report also contained a number of requests to amend the site diagram.

During the experiment, the inspection report was discussed by participants at the post-inspection workshop that took place on 9 March 2023. An edited copy of this report is included in this chapter as Box 1.

It should be noted that the inspectors were not expected to confirm the presence or absence of nuclear weapons at the site. The information collected during the inspection would be reported to the national authorities of the inspecting party, where it would be combined with other data, including those collected by national technical means, to inform judgement about compliance of the inspected party with its obligations. The report would then be submitted to the treaty implementation commission that would consider any issues raised by the inspectors.

Box 1. Inspection report

Report of an on-site inspection carried out at the Menzingen site on 8 March 2023

The inspection team departed the designated entry point at Lucerne at 8:00 CET on 8 March 2023.

The inspection team arrived at the Menzingen site, designated for the inspection, at 9:00 CET.

A safety and security briefing took place at 10:10 CET in the briefing facility. An updated site diagram submitted during the briefing is in Attachment 1 [Figure 3]. The Category A object on the updated diagram was declared to be a training model of the BL-64 missile at an open launch pad.

The coordinates of the site, 47.1584 N, 8.5860 E, verified by the escort team in accordance with the Protocol on Inspection.

The inspection to confirm the accuracy of the site diagram began at 10:17 CET. It was conducted by two sub-teams. It was agreed that the inspection will be conducted on foot. The map that shows the inspected locations is included in this report as Attachment 2 [Figure 4].

The inspectors conducted a visual inspection of the auxiliary building at Location 1, identified as a power station.

Inspection of a place marked as Location 2 showed an underground bunker that is not reflected on the site diagram. The request to access the bunker was denied. The request to document the location of the building and take photo of its exterior was granted. The photograph was taken by an instant camera and included in the report as Attachment 3 [Figure 5]. Request is made to add the structure to the site diagram.

Inspection of the object at Location 3, declared to be a Category A item, included a visual inspection of the item. The item is marked as “INERT” in several places. It appears to be a training model of the BL-64 missile installed on a launcher. The diameter of the central missile was measured to be 54.6 cm and that of the ramjet engine to be 42 cm.

Inspection of a place marked as Location 4 revealed a structure that is not reflected on the site diagram. The structure appears to be a semi-underground room behind a locked door. Request is made to add the structure to the site diagram.

The inspection of buildings and structures at Location 5 included a visual inspection of the exterior and limited access to the interior of the buildings. While the buildings are identified as auxiliary on the site diagram, the inspectors cannot confirm that these buildings cannot be used for storage of special armaments.

The inspectors conducted external inspection of the auxiliary building at Location 6 identified as a radio transmission building.

Several structures are not marked on the site diagram. These are the structure identified as a guard station center in Location 7 and the structure that is identified as a shelter at Location 9. Request is made to add these structures to the site diagram.

An unmarked forest road with freshly distributed soil identified at Location 10. The escort team identified it as a tree cutting area. A visual inspection of the cut piles was performed.

An unmarked building at Location 8. The building is similar to the bunkers but taller and narrower. A request for clarification of the building was made. It was explained to be an auxiliary building for transportation support functions. Access to the interior of the building was not granted. Request is made to add the building to the site diagram.

A visual inspection was conducted around the bunker structure at Location 11. The air vent and exhaust window on the east side were observed. An official challenge was made and the permission to photograph and measure the entrance of the bunker was granted. Photographs included in this report as Attachment 4 [Figure 6] were taken outside of the bunker and in the space between the doors. The width of the door measured to be 95.3 and 216.5 cm, the height was 280 cm, and the depth was 21.5 cm.

The structures marked as objects of verification in the Location 12 area were examined from outside. The objects are bunkers arranged in pairs and numbered, from West to East, as 219/218, 216/215, 213/212, and 210/209.

The inspection to confirm the accuracy of the site diagram concluded at 11:30 CET.
At 11:30 CET, the inspectors notified the escort team of the intent to inspect two bunkers marked 212 and 213 at Location 12 as objects of verification.

At 13:00 CET, the escort team submitted floor plans of the bunkers 212 and 213 selected for the inspection. The floor plans are included in this report as Attachment 5 [Figure 7].
The inspectors entered Bunker 212 at 13:00 CET. The floor and walls seem to be solid concrete structure. The internal dimensions of the room correspond to the submitted floor plan. No visual signs of hidden rooms are detected.

The items designated as Category A were visually inspected. A small item on the right wall is not shown on the floor plan. A request for clarification was made. The escort team explained that the object is a hygrometer.

The Category D item shown on the floor plan was examined. The measurements confirmed that its dimensions correspond to those of the Category D item. After examination in accordance with the Protocol on Inspection no anomaly was detected.

Inspectors requested and gained approval to measure the dimensions of the bunker door. The door’s width is 97 cm and 213 cm, the height is 260 cm, and the depth is 22 cm. The entrance to the bunker has a removable ramp.

In Bunker 213 the inspectors confirmed that the internal dimensions of the bunker correspond to the submitted floor plan. The floor and walls seem to be solid concrete structure. No visual signs of hidden rooms are detected.

A visual inspection was conducted in the bunker. The items designated as Category A were visually inspected. Two wooden containers were opened and shown to be empty. No anomaly was detected. An object identical to the hygrometer seen in Bunker 212 was not marked on the site diagram.

The position of the Category B item corresponded to that shown on the floor plan. The item is a rectangular box. The measurement showed that the dimensions of the item are 33x36x243 cm. Request was made to perform radiation measurements of this item in accordance with the Protocol on Inspection. The request was granted. [The inspectors applied a tag with serial number T201 to the selected item.]

The position of the Category C item corresponded to that shown on the floor plan. The item is a cylindrical object. The measurements showed that the diameter of the item is 33 cm, and its length is 138 cm. Request was made to perform radiation measurements of this item in accordance with the Protocol on Inspection. The request was granted. [The inspectors applied a tag with serial number T204 to the selected item.]

The inspectors performed radiation measurements on the selected Category B item following the procedure described in the Protocol on Inspection. The result of the measurement was "Anomaly detected." The worksheet of the measurements is attached [Figure 6 in Chapter 4].

The inspectors performed radiation measurements on the selected Category C item following the procedure described in the Protocol on Inspection. The result of the measurement was "Absence confirmed." The worksheet of the measurements is attached [Figure 6 in Chapter 4].

The inspectors concluded that they cannot confirm the absence of special armament at the inspected site. This report and the requests to amend the site diagram will be submitted to the treaty implementation commission for consideration.

The inspection activities on site were concluded at 17:00 CET.

Signed

Leader of the inspection team
Leader of the escort team

Menzingen, 17:00 CET, 8 March 2023

4. Radiation measurements

Eric Lepowsky, Manuel Kreutle, Christoph Wirz, and Alexander Glaser

Background

Progress in nuclear disarmament requires the development of a wide range of verification tools and methods that can support different approaches to disarmament. Possible frameworks could include reductions with verified warhead dismantlement, limits on the total stockpiles of nuclear weapons, or approaches that avoid warhead inspections altogether.[1] In many, if not all, of these scenarios, it is plausible that inspection approaches would benefit from the ability to confirm the absence of nuclear weapons at an inspected site or within specified areas on that site. These procedures were first used in the START treaty, which allowed the use of radiation detection equipment "to measure nuclear radiation levels in order to demonstrate that objects declared to be non-nuclear are non-nuclear".[2] New START developed these techniques further, including provisions to confirm that an "object located on the front section [of a ballistic missile] and declared by the in-country escort to be a non-nuclear object" is in fact non-nuclear.[3] New START does not, however, cover warheads in storage and relies on neutron measurements only, which can indicate the presence of plutonium, but cannot be used for uranium-only weapons or weapon components.

The Menzingen Verification Experiment described in this report included a radiation measurement component that provided an opportunity to test in the field the procedures that can support future treaty provisions based on the absence of nuclear weapons. This chapter describes the setup of the radiation measurements conducted during the experiment and discusses the results and lessons learned.[4]

The experimental setup

The radiation measurements were conducted in a series of bunkers in the south-eastern area of the base (Figure 1). The scenario developed for the exercise assumed that some containers had been previously flagged by inspectors for further inspection; these containers had been moved to these dedicated bunkers for radiation measurements.[5] In order to test procedures for cases where anomalies are detected, gamma and neutron sources were provided and installed by Spiez Laboratory in some of these containers.

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1 Malte Göttsche and Alexander Glaser, "Toward Nuclear Disarmament: Building up Transparency and Verification," 2021, 156; Pavel Podvig and Joseph Rodgers, *Deferred Verification: Verifiable Declarations of Fissile Material Stocks* (UNIDIR, 2017), https://unidir.org/sites/default/files/publication/pdfs/deferred-verification-verifiable-declarations-of-fissile-material-stocks-en-694.pdf.

2 "The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Reduction and Limitation of Strategic Offensive Arms (START)," U.S. Department of State, July 31, 1991, Annex 8 to the Inspection Protocol, Section VI.F.1, https://2009-2017.state.gov/t/avc/trty/146007.htm.

3 "Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms," April 8, 2010, Annex on Inspection, Part Five, Section VI.1, https://2009-2017.state.gov/newstart; "Radiation Detection Equipment: An Arms Control Verification Tool" (Defense Treaty Inspection Readiness Program, October 2011), https://www.hsdl.org/c/view?docid=715954.

4 An extended version of this chapter has been accepted for publication in *Science & Global Security*.

5 See Chapter 3 in this report.

Two bunkers (201, 202) had previously been prepared for passive neutron measurements, one of them containing a containerized californium-252 spontaneous neutron source, while the container in the second bunker was empty. The neutron bunkers were inspected using a polyethylene-moderated helium-3 neutron detector. Two additional bunkers (204, 205) had been prepared for gamma measurements, one of them containing containerized depleted-uranium projectiles,[6] while the container in the second bunker was again empty. Inspections of the gamma bunkers used a custom-developed device and inspection protocol, which are described in detail below. The order of the empty and source-containing bunkers was unknown to the inspectors, and the goal was to correctly identify 'cold' and 'hot' bunkers.

Systems and protocols

As part of the experiment, the organizers provided the host and inspector teams with a script specifying the inspection protocol. Worksheets (reproduced in Figure 6) were used to record relevant values acquired during the radiation measurements. For the two neutron bunkers, a polyethylene-moderated helium-3 proportional counter (Berthold LB 6414, Figure 2, left) was used to provide the count rate averaged over a previously agreed period of time. The neutron detector was positioned on a tripod such that the helium-3 tube was at approximately the same height as the centre of the inspected container. The measurements largely followed the New START inspection protocol consisting of a background measurement and a measurement of the inspected container. Although non-ideal, and as further discussed below, the neutron background was acquired in the open, just outside the bunker (see Figure 1, bottom) because the containers themselves could not be moved from their positions. The threshold for anomaly detection was set using the 'four-sigma' test; i.e., an anomaly was recorded when the counts observed during the inspection exceeded the background by four standard deviations.

Verification of the gamma bunkers followed the inspection protocol previously proposed for the Absence Confirmation Experimental (ACX),[7] using a revised version of the original prototype (Figure 2, right). The ACX 2.0 device is comprised of a Raspberry Pi single-board computer and a 7-inch display installed in a portable Pelican case. A rechargeable power-over-Ethernet battery contained within the case supplies power to the computer and the external detector, which connects via Ethernet to the device. The experiment used a collimated 2-inch Mirion/Canberra NaI scintillator (Model 802) connected to an Osprey Digital MCA Tube Base.[8] The device has minimal user-accessible inputs/outputs, including an Ethernet port, power button, and a USB port to connect a numeric keypad. A custom Python script controls the detector and guides the user through the protocol steps in a shell-based application. No measurement data are saved to disk.

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6 Uranium-235 only emits low-energy gamma radiation. Despite the small uranium-238 content, highly enriched uranium and weapon-grade uranium (more than 90 per cent uranium-235) are best detected using gamma radiation from uranium-238, namely, via a prominent gamma line at 1.001 MeV. With appropriate scaling of results, depleted uranium can therefore be used as
a stand-in for weapon-grade material.

7 Eric Lepowsky, Jihye Jeon, and Alexander Glaser, "Confirming the Absence of Nuclear Warheads via Passive Gamma-Ray Measurements," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 990 (February 21, 2021), https://doi.org/10.1016/j.nima.2020.164983.

8 "802 Scintillation Detectors, Datasheet" (Mirion Technologies, 2017), https://mirion.s3.amazonaws.com/cms4_mirion/files/pdf/spec-sheets/csp0232_802_super_spec_2.pdf; "Osprey: Universal Digital MCA Tube Base for Scintillation Spectrometry, Datasheet" (Mirion Technologies, 2017), https://mirion.s3.amazonaws.com/cms4_mirion/files/pdf/spec-sheets/c48365_osprey_spec_sheet_update_2.pdf.

Figure 1. Location of the radiation measurement area at the Menzingen site (top left) and a close-up of the area (bottom) with a view of the four bunkers used for measurements (top right). Locations for neutron background measurements are indicated (B); after completion of the experiment, and after the removal of the sources from the bunkers, an additional background measurement was conducted in Bunker 201, where neutron radiation levels were about 10 times lower.

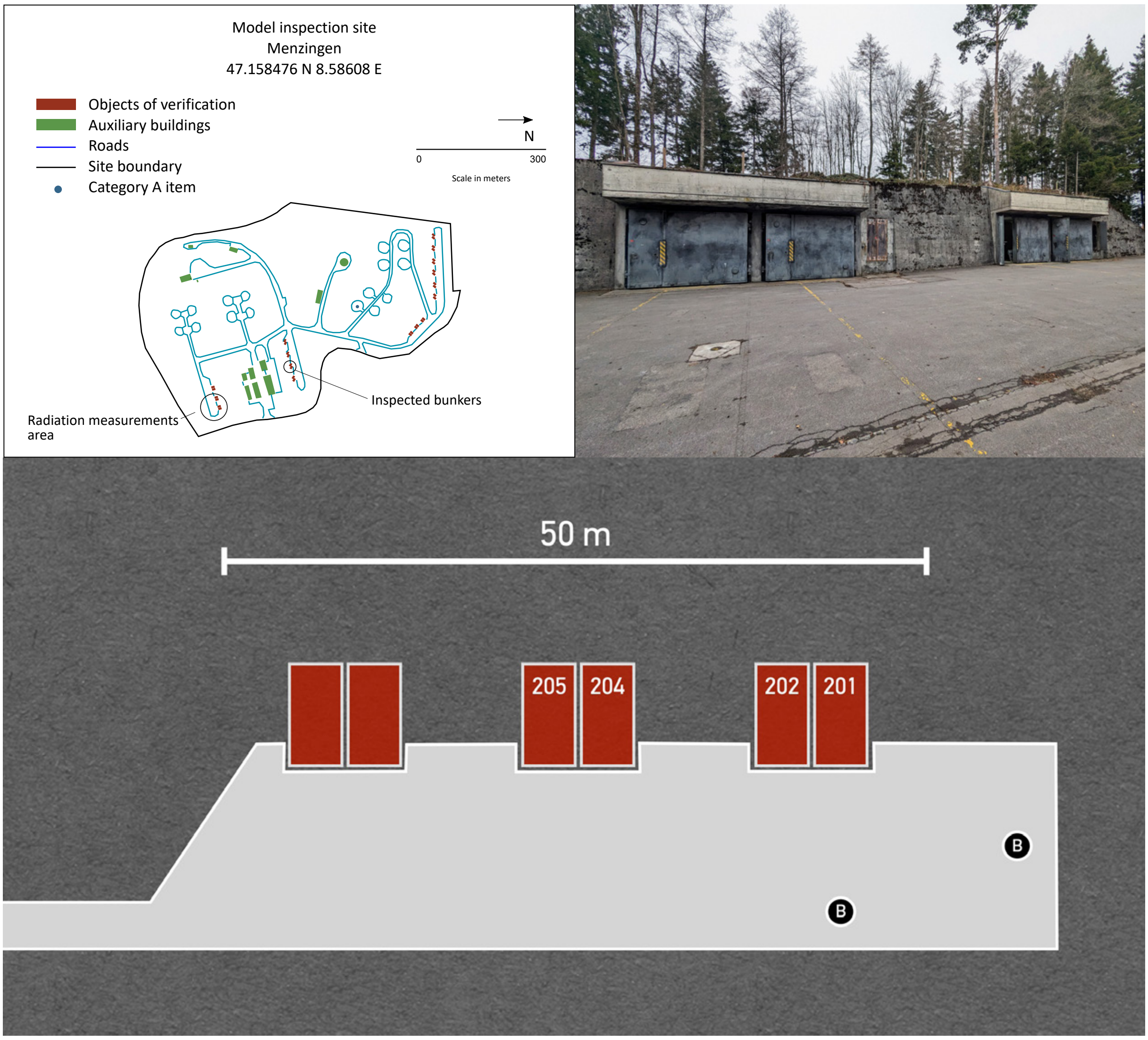

Figure 2. The detector used for the neutron measurements, Berthold LB 6414, uses a polyethylene-moderated helium-3 tube and is optimized for plutonium search applications (left). The ACX 2.0 device during the measurements.

The protocol begins with background acquisition and detector calibration. A strong (cesium-137) reference source is then placed at a suitable distance in direct view of the detector such that the inspected container can later be placed between the detector and this source. By comparing the signal with and without the container, the reference source is used to estimate the shielding introduced by the inspected container. In the final step of the inspection, the reference source is removed so that emissions from the inspected container itself can be measured. Overall, seven measurement values are collected in different regions of interest (see inspection worksheet for gamma measurements in Figure 6). These values are used to estimate the effective shielding thickness introduced by the inspected container and to determine the ultimate inspection result: absence of plutonium and uranium confirmed, or anomaly detected. The inspection result can also be inconclusive if too much shielding was present or the measurement time was too short to yield a conclusive outcome.

Inspection results

The most straightforward inspection results were obtained for those bunkers where sources were present. In both cases, the threshold values were clearly exceeded. In the case of the neutron measurements, which used a californium-252 source emitting on the order of 90,000–95,000 n/s, the total counts acquired during the inspection exceeded the threshold value by more than two orders of magnitude (4,485 counts vs. 28 counts; see Figure 6, Location 202). Similarly, in the case of the gamma measurements, which used depleted-uranium projectiles summing to about 800 grams of uranium-238 (equivalent to 11–12 kg of weapon-grade uranium with 7 per cent U-238), 1,744 counts were observed during the inspection of the container with depleted uranium, while only 52 counts were sufficient to trigger an anomaly for uranium. For both the neutron and gamma measurements, the containers introdusced only negligible amounts of shielding and no other shielding was present.

The results acquired for the empty bunkers are more complex—and therefore perhaps also more interesting.

Neutron measurements—empty container

During the inspection of the empty container, the total counts exceeded the previously established threshold value by a small, but statistically significant, amount (45 vs. 28 counts; see Figure 6, Location 201). The inspection report, therefore, noted an anomaly. Once the experiment had concluded and all sources been removed from the bunkers, the inspectors were able to perform additional measurements in an effort to explain the data. Indeed, only 1.5 counts were observed in Bunker 201 compared to 45 counts during the inspection. This strongly suggests that neutrons had been leaking from the neighbouring Bunker 202, where a source was located, thus interfering with the measurements in Bunker 201 during the inspection. It is worth noting that this would have been irrelevant had the inspectors been able to conduct the background measurement inside the bunker itself (with the inspected container absent); it is also worth noting that the neutron background in the bunker was almost 10 times lower than the background measured outside.

Figure 3. Participants of the Menzingen Inspection Experiment. Left: Host (yellow vests) and inspector (orange vests) teams discussing the operation of the Absence Confirmation Experimental (ACX 2.0) device. Right: Participants set up the NaI detector for passive gamma ray and transmission measurements of the inspected container.

Gamma measurements—empty container

The measurement in Bunker 204 correctly confirmed the absence of uranium (and plutonium) sources in the inspected container. When reviewing the values of the container-only measurements (Lines 6a–6c in the respective worksheet, Figure 6), the value for the region of interest for plutonium stands out: here, 130 counts were recorded above the background measurement of 1,971 counts. While this increase is statistically not impossible, the most plausible explanation is due to the way the background measurement was conducted. As the container could not be removed from the bunker, the inspectors rotated the shielded detector by 90 degrees, orienting it towards the bunker wall. During the inspection, however, the detector was oriented towards the bunker doors. It is likely, but cannot be confirmed with certainty after the fact, that the background levels were measurably different for these two orientations; in fact, the difference corresponds to an increase of only about 7 per cent (from 1,971 counts to 2,101 counts, or from 4.38 cps to 4.67 cps, for a measurement time of 450 seconds). It is worth noting that even such a slight increase in background is potentially problematic. In this particular case, the system would have indicated an anomaly had the counts in the region of interest for plutonium exceeded a value of 146 counts (Line 7b in the worksheet, Figure 6). In other words, the experiment came close to a false-positive inspection outcome.

Finally, it should be noted that detector drift could have added some additional measurement error. Indeed, the experiment used a non-temperature-stabilized detector. The equipment was moved from room temperature to an ambient temperature of about 5 °C (40 °F), and the measurement process took more than two hours. There is, however, no clear evidence that detector drift affected the results.

Lessons learned

Thanks to extensive preparations, which included the development of inspection approaches and laboratory testing of the equipment, the experiment provided important new insights about the feasibility of using radiation measurements as part of an on-site inspection to verify the absence of nuclear weapons. At the same time, the experiment provided a number of new and important lessons.

First, and perhaps quite self-evidently, possible field conditions must be carefully considered when designing the hardware and software. Ideally, the equipment ought to be tested in environments that effectively reproduce the conditions that could be encountered in the field. At Menzingen, the equipment had to be moved between outdoor and indoor settings multiple times throughout the day and, ultimately, be operated at temperatures far below room temperature. While the temperatures were within the equipment's allowed operating range, detector calibration and drift can pose significant challenges, in particular for the gamma measurements, which extended over several hours and used a non-temperature-stabilized detector. Even though the equipment ultimately worked as expected, printing calibration parameters, displaying other non-sensitive information to confirm equipment functionality, and allocating additional time for recalibration would have reassured both the inspector and host teams.

With regard to the usefulness of simple radiation measurements to confirm the absence of nuclear weapons, it was confirmed that the ACX (2.0) device equipped with a NaI detector is best suited for uranium detection, less so for plutonium detection.

The lower region of interest (300–500 keV), centred around some prominent gammas emitted by plutonium, is triggered when other radiation sources are present, often due to the elevated Compton continuum. While this does not compromise the functionality of the device, it does make it more prone to false-positive results. One way to address this challenge would be to work with a high-resolution detector and identify isotope-specific gamma lines; this would, however, increase the complexity of other aspects of the measurement, both on the software and hardware side. Ultimately, one may conclude that neutron measurements are sufficient for plutonium detection while gamma measurements are most useful for uranium detection, such that coverage is provided by a combination of both.

Finally, and most importantly, the verification experiment highlighted the critical importance of adequate background measurements. As part of New START, such measurements were manageable because the treaty deals with deployed weapons in known configurations, and radiation measurements are generally conducted outdoors. Future agreements may, however, envision fundamentally different inspection environments including, in particular, indoor and 'in situ' measurements. These could include measurements on warheads or warhead components in storage or, as in the case of the Menzingen Verification Experiment, confirming the absence of treaty-accountable items in various areas and buildings of an inspected site. During the experiment, the inspectors were not able to move containers that were selected for inspection; for this reason, background measurements had to be taken nearby (i.e., just outside the bunker) or with a modified setup (i.e., with a re-oriented detector). This led to complications for both types of measurements conducted: one measurement indicated an anomaly due to neutron leakage from an adjacent bunker even though the true neutron background in the bunker was 10 times lower than the background acquired outside; another measurement produced some confusing results for one region of interest and was close to indicating an anomaly. These complications can be avoided entirely if items selected for inspection can be moved as needed—these aspects ought to be carefully considered when verification protocols are negotiated.

In passing, we note that there are possible non-compliance scenarios that are particularly relevant for absence measurements, where the host could, for example, introduce a concealed radiation source during the background measurement so that an inspected item containing plutonium or uranium would later pass the inspection, i.e., produce a false-negative. Given that the host controls the inspection environment, additional safeguards may have to be considered to preclude such interference.

Overall, there is continued room for improvement and much consideration necessary for such absence-confirmation measurement protocols and equipment, but the experiment demonstrated promise for how it may fit into the larger verification landscape.

Figure 6. Worksheets from the Menzingen Verification Experiment.

Inspection Worksheet for Neutron Measurements (with LB 6414)

Revision 0.6
Menzingen Experiment
March 2023

Date	March 8, 2023
Local time	14:02
Location	201
Inspected item ID	Category B

Measurement time proposed by host (60–150 seconds)	01	150	seconds
Measurement time chosen by inspector	02	150	seconds
Line 02 must be ≥ Line 01 but ≤ 150 seconds			
Average background count rate	03a	0.085	cps
Total background counts (B = Line 03a x Line 02)	03b	13	counts
Rounded up to next integer			
Reference number (R) with R = B + 4 x √B	04	28	counts
Rounded up to next integer			
Distance from detector to center of item	05	60	cm
Line 05 must be ≤ 70 cm			
Average count rate during inspection	06a	0.300	cps
Total counts acquired during inspection (Line 06a x Line 02)	06b	45	counts
Rounded down to previous integer			

Check box if Line 06b ≤ Line 04		Non-nuclear object confirmed
Check box if Line 06b > Line 04	X	Anomaly detected

Notes

Inspection Worksheet
for Neutron Measurements (with LB 6414)

Revision 0.6
Menzingen Experiment
March 2023

Date	March 8, 2023
Local time	13:32
Location	202
Inspected item ID	Category B

Measurement time proposed by host (60–150 seconds)	01	150	seconds
Measurement time chosen by inspector	02	150	seconds
Line 02 must be ≥ Line 01 but ≤ 150 seconds			
Average background count rate	03a	0.085	cps
Total background counts (B = Line 03a x Line 02)	03b	13	counts
Rounded up to next integer			
Reference number (R) with R = B + 4 x √B	04	28	counts
Rounded up to next integer			
Distance from detector to center of item	05	60	cm
Line 05 must be ≤ 70 cm			
Average count rate during inspection	06a	29.9	cps
Total counts acquired during inspection (Line 06a x Line 02)	06b	4485	counts
Rounded down to previous integer			

Check box if Line 06b ≤ Line 04		Non-nuclear object confirmed
Check box if Line 06b > Line 04	X	Anomaly detected

Notes

Inspection Worksheet
for Gamma Measurements (with ACX 2)

Revision 0.6
Menzingen Experiment
March 2023

Date		March 8, 2023	
Local time		14:30	
Location		204	
Inspected item ID		Category C	
Measurement time proposed by host	01	450	seconds
Measurement time chosen by inspector (and used)	02	450	seconds
Line 02 must be ≥ Line 01			
Background, Region of Interest for plutonium	03a	1971	counts
Background, Region of Interest for uranium	03b	318	counts
Distance from detector to center of item	04	48	cm
Line 04 must be ≤ 70 cm			
Reference source (without container)	05a	316370	counts
Reference source (with container)	05b	288337	counts
Container only (ROI for reference source)	06a	0	counts
Container only (ROI for plutonium)	06b	130	counts
Container only (ROI for uranium)	06c	0	counts
Critical limit (ROI for plutonium)	07a	146	counts
Critical limit (ROI for uranium)	07b	58	counts
Estimated thickness of shielding, lead-equivalent	08	1	mm
Maximum shielding thickness (ROI for plutonium)	09a	27	mm
Maximum shielding thickness (ROI for uranium)	09b	24	mm

INSPECTION RESULT

- [x] Absence confirmed
- [ ] Inconclusive
- [ ] Anomaly detected

Notes

Inspection Worksheet
for Gamma Measurements (with ACX 2)

Revision 0.6
Menzingen Experiment
March 2023

Date	March 8, 2023
Local time	16:30
Location	205
Inspected item ID	Category C

Measurement time proposed by host	01	300	seconds
Measurement time chosen by inspector (and used)	02	300	seconds
Line 02 must be ≥ Line 01			
Background, Region of Interest for plutonium	03a	1767	counts
Background, Region of Interest for uranium	03b	255	counts
Distance from detector to center of item	04	40	cm
Line 04 must be ≤ 70 cm			
Reference source (without container)	05a	226735	counts
Reference source (with container)	05b	177113	counts
Container only (ROI for reference source)	06a	2275	counts
Container only (ROI for plutonium)	06b	10603	counts
Container only (ROI for uranium)	06c	1744	counts
Critical limit (ROI for plutonium)	07a	138	counts
Critical limit (ROI for uranium)	07b	52	counts
Estimated thickness of shielding, lead-equivalent	08	1	mm
Maximum shielding thickness (ROI for plutonium)	09a	26	mm
Maximum shielding thickness (ROI for uranium)	09b	19	mm

INSPECTION RESULT

- [ ] Absence confirmed
- [ ] Inconclusive
- [x] Anomaly detected

Notes

5. Satellite imagery

Jaewoo Shin, Veronika Bedenko, Pavel Podvig

Use of satellite imagery in verification

The idea of using remote sensing for regime verification is not new. Exploration of the use of intelligence satellites for arms control verification started at least as early as the late 1960s to the early 1970s.[1] Such means of treaty verification became an important part of that is referred to as 'national technical means' (NTM). Satellites were used, for example, in the Strategic Arms Limitation Talks Interim Agreement (SALT I) and the Anti-Ballistic Missile (ABM) Treaty.[2] Prior to developing the on-site inspection arrangement, NTMs were almost the sole means of monitoring compliance with arms control treaties.[3] The 1987 Intermediate-Range Nuclear Forces (INF) Treaty created the first precedent in the arms control field for developing a comprehensive verification regime that combined NTM for monitoring and on-site inspections.[4]

NTM, including military intelligence satellites, are capabilities that are only available to State actors. However, in the past several decades, the world has witnessed a rapid development of commercially available means of remote observation that can be applied for purposes of non-proliferation and disarmament verification.[5] Satellite imagery providers, such as Airbus, Maxar, and Planet Labs, offer their tasking and archive purchases to NGOs, academic institutions, and the private sector, thus eliminating the State-exclusive privilege for high-resolution remote-sensing observation. Though such commercial solutions have not yet been used as a formal part of a verification regime of an arms control treaty, they are used for monitoring and verification by individual government entities, as well as a number of international organizations and their related bodies, such as the IAEA, OPCW and United Nations Panels of Experts.

While States are likely to continue to rely on NTM as the primary verification tool, the availability of commercial imagery can play an important role in this process. In particular, it can usefully augment NTM and increase the amount of information available for verification purposes. With the introduction of imagery with sub-1 m resolution and further democratization of the satellite imagery field through platforms like Google Earth, States that do not have their own sufficiently developed NTM will be able

1 Dwayne A. Day, "Arms Control and Satellites: Early Issues Concerning National Technical Means," *The Space Review*, October 10, 2022, https://www.thespacereview.com/article/4463/1.

2 Dwayne A. Day.

3 Aaron Bateman, "Trust but Verify: Satellite Reconnaissance, Secrecy and Arms Control during the Cold War," *Journal of Strategic Studies*, January 8, 2023, 1–25, https://doi.org/10.1080/01402390.2022.2161522.

4 Bateman.

5 Tamara Patton et al., "Emerging Satellites for Non-Proliferation and Disarmament Verification" (Vienna Center for Disarmament and Non-Proliferation, January 2016), https://vcdnp.org/wp-content/uploads/2016/06/160614_copernicus_project_report.pdf.

to participate in verification processes. This democratization process has also allowed non-State actors to contribute to verifying allegations regarding clandestine nuclear and missile-related facilities and activities.[6] Finally, commercially available images can be freely used in the dispute resolution process as they are not subject to restrictions regarding intelligence sources and methods.

However, more research is needed to test the applicability of commercially available satellite imagery to real verification activity scenarios in support of an arms control agreement. This chapter describes the use of satellite imagery in the Menzingen Verification Experiment. The question that the experiment sought to explore in this area was the potential of remote sensing tools to support on-site inspections. Commercial satellite imagery was used in two roles—as a proxy for NTM, to assess the utility of remote sensing in general, and as a complement to NTM, to assess the value that commercial imagery can add to the verification process.

The experiment

The Menzingen Verification Experiment modelled an on-site inspection of a nuclear weapons storage facility, which was represented by a former air defence site managed by the Swiss Armed Forces (see Chapter 2). It was assumed that the inspection was conducted within the framework of an agreement that requires its parties to remove all nuclear weapons from specified weapon storage sites. Accordingly, the purpose of the inspection was to confirm the absence of nuclear weapons at a selected facility. The inspection activities were governed by a Protocol on Inspection that was developed specifically for the experiment, based on the inspection arrangements of the Conventional Forces in Europe (CFE) and New START treaties.[7]

As specified in the Protocol on Inspection, an on-site inspection includes several components. It begins from the moment the inspecting party submits a formal notification of the intent to inspect. Once the inspection team arrives at the point of entry, they designate the specific site they wish to inspect. From that moment on, the site selected for inspection must be placed in lockdown until the time inspectors arrive at the site. At the site, the inspectors receive an updated site diagram. After checking the accuracy of the diagram, the inspectors select several buildings (objects of verification) for a detailed inspection and verify that these buildings do not contain any nuclear objects. The results of the inspection are recorded in the inspection report.

This chapter focuses on the elements of the verification process that directly benefit from the capabilities provided by satellite imagery. One of the key elements of an inspection is the confirmation of the accuracy of the site diagram. As described in this chapter, satellite imagery is an important tool that can complement on-site activities and help inspectors to conclude with high confidence that the diagram accurately reflects the status of the site.

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6 Frank Pabian, "Commercial Satellite Imagery as an Evolving Open-Source Verification Technology – Emerging Trends and Their Impact for Nuclear Nonproliferation Analysis" (Joint Research Centre, Institute for Transuranium Elements, January 21, 2016), https://doi.org/10.2789/933810.

7 See Chapter 2 in this report.

This experiment also explored the potential role of satellite imagery in monitoring site lockdown. Since the objective of an inspection is to verify the absence of nuclear weapons at a declared site, the inspecting party must be confident that no items have been removed from the site prior to the arrival of inspectors. This chapter outlines the key benefits and challenges of using satellite imagery for this purpose.

It should be noted that the activities involving the use of satellite imagery are not directly regulated by the inspection protocol. Each party may use whatever means it has at its disposal and is under no obligation to inform the other parties of these capabilities. The information obtained by satellites (and other national technical means) will be combined with the information obtained during on-site inspections and other cooperative verification activities in order to reach a conclusion about compliance with the obligations accepted by the parties in the underlying agreement. As will be shown below, a degree of uncertainty about the specific capabilities available to the parties plays a role in strengthening the verification mechanism.

Accuracy of the site diagram

In the scenario developed for this experiment, on-site inspections were to be conducted to verify the absence of nuclear weapons at declared sites. This would require the parties to submit lists of facilities that are covered by the obligation to remove nuclear weapons. For each declared site, the parties submit a site diagram that shows its coordinates, the site boundaries, entrances, and roads and buildings located on the site.

In the initial design of the experiment, each building on the diagram was marked according to its category. Dedicated nuclear weapons storage facilities, such as bunkers, were supposed to be marked as objects of verification. These structures would be subject to inspection during the on-site inspection. All other structures would be marked as auxiliary buildings. It is assumed that these are not suitable for nuclear weapon storage and therefore do not need to be inspected.

Once the initial declarations are submitted, the parties will use optical satellite imagery to perform the initial verification of the site diagrams. Nuclear weapon storage facilities are located in areas that are constantly monitored by a variety of national technical means. This means that normally there will be a large number of satellite images of each facility going back at least several years.

For example, the easily accessible database of satellite images provided by Google Earth contains 16 images of the Menzingen site at 50 cm resolution. The earliest high-resolution image of the site accessible through Google Earth was taken in July 2009. The database also contains a low-resolution Landsat image obtained in 1985. In another example, the Google Earth database contains almost 30 images of the Kolosovka storage site in Kaliningrad, Russian Federation, with the earliest one taken in September 2002. In most cases, additional archive images can be acquired from commercial service providers. For example, Maxar's archive of Menzingen contains 109 images and goes back to 2001. In addition, it is certain that the set of images obtained by national technical means contains more images than the publicly or commercially available set. It is also likely to include higher resolution images.

Figure 1. 3 m Planet Scope image with an overlay of the site layout on the left (red: objects of verification; green: auxiliary buildings).

The availability of historical satellite imagery is a very important factor in verifying the accuracy of the initial declaration. In particular, it makes it virtually impossible to conceal major construction activities at storage sites that took place in the past, before the parties agreed to open their sites to inspection.[8]

In addition to providing information about the history of the inspected site, satellite images also provide a baseline for a specific inspection. When the inspectors select a site for an inspection, the inspected party must submit an updated diagram of the site and explain the nature of the modifications. It should be expected that in preparation for the inspection the inspecting party will acquire a series of baseline images to ensure that the updated diagram correctly reflects the status of the site.

This experiment demonstrated that the acquisition of the optical baseline image could be complicated by the weather conditions at the site. During the days preceding the inspection date, the site was covered by clouds, preventing the acquisition of a high-resolution image. As a result, the baseline assessment was based on two sets of images. First was an archived medium-resolution Planet Scope image from the most recent day without cloud coverage, 24 February 2023. As shown in Figure 1, the 3 m resolution of the image was sufficient for assessing that no significant infrastructural discrepancies were present between the existing site layout and the current status of the site. In addition, the accuracy of the baseline was accessed with the help of the publicly available Google Earth images of the site. The most recent of these images was taken on 4 April 2021.

8 See, for example, Hans M. Kristensen, “Russia Upgrades Nuclear Weapons Storage Site In Kaliningrad,” *Federation Of American Scientists* (blog), June 18, 2018, https://fas.org/blogs/security/2018/06/kaliningrad.

Figure 2. 0.5 m Planet SkySat image.

The experiment also showed that in a more realistic scenario, when the inspecting party can choose the inspection date, the acquisition of a baseline image is unlikely to be a significant challenge. In the case of the experiment, the weather conditions improved on the day after the inspection—the 0.5 m resolution Planet SkySat image acquired on 9 March 2023 is shown in Figure 2. In the experiment we were constrained by the availability of the site, but if the inspecting party had been able to choose the date of the inspection, this image could have served as a baseline.

An analysis of historical and recent satellite images identified several structures at the site that were not reflected on the site diagram submitted during the model initial data exchange prepared for the experiment. Accordingly, the inspectors were prepared to examine the structures closely during the inspection.

Overall, optical satellite imagery proved to be a valuable tool in preparation for on-site inspection. It helps the inspecting party to assess the accuracy of site diagrams and identify the areas and structures that must be closely inspected during the on-site visit. Importantly, the availability of historical satellite imagery significantly increases confidence in the absence of hidden structures at the site, as the inspected party can never be certain that the past work has not been detected by national technical means.

Lockdown

Another application of satellite imagery that was tested in this experiment was the monitoring of the lockdown of the site. Since the purpose of the inspection is to verify the absence of nuclear weapons permanently stored on site, the inspecting party must ensure that no items have been removed from the site prior to the arrival of inspectors.

According to the model Protocol on Inspection developed for this exercise, the sequence of events preceding the arrival of inspectors on site is as follows.[9] First, the inspecting party submits a notification of intent to inspect (Protocol, Section IV). This notification must be submitted no less than 24 hours in advance of the estimated time of arrival of inspectors to the point of entry designated in the notification. After arriving at the point of entry, the inspectors designate the site to be inspected (Protocol, Section VII). Once the designation is announced, the inspected party has the right to prepare the site for inspection and must organize transport to the designated site. The timelines selected for this experiment were notional. In practice they would depend on the selection of the points of entry, accessibility of declared sites, and other factors. For example, the CFE Treaty required that travel time not exceed nine hours (up to 15 hours for sites to which access is difficult). In this experiment, the time between the formal designation of the site and the arrival of inspectors was about 90 minutes.

Once the inspecting party designates the inspection site, the inspected party must institute a lockdown at that site (Protocol, Section VII.3). Specific lockdown restrictions would have to be negotiated, but the purpose of the lockdown is to prohibit the movement of vehicles and equipment from or on the site.

While the inspected party does not know which specific site will be selected for an inspection until it is formally designated, in practice it will start preparations immediately after receiving the notification of intent to inspect. The preparations will begin at all sites that can be reached from the point of entry identified in the notification. This means that the inspected party would have at least 24 hours, and possibly up to 48 hours, to remove items from the sites that can be inspected. Accordingly, the inspecting party must ensure that it can detect any such removal.

Lockdown is arguably the most challenging stage of the verification process. Since satellites cannot provide continuous monitoring of a site, the inspected party can, in principle, move items during the time when no satellite is in a position to detect the movement. However, if the inspecting party can achieve a reasonable probability of detecting the movement this can deter attempts to circumvent restrictions of the zero-deployed weapons arrangement.

There are several factors that help the inspecting party to achieve the deterrence effect. A significant violation of the agreement would suggest that a site is being used to house nuclear weapons. An attempt to conceal that fact would require the removal of all weapons prior to an inspection. This operation would likely involve a significant number of personnel, vehicles, and equipment. It would also require security measures that increase the footprint of the operation.

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9 See Appendix A in this report.

Another factor that favours the inspecting party is its ability to create uncertainty regarding when the site will be monitored. While the parties would normally know the time when dedicated (and highly capable) military reconnaissance satellites are in a position to observe their sites, they would not know whether the inspecting party had tasked a commercial satellite to acquire imagery of a site. As the number of commercial service providers increases, it will become increasingly difficult to find a suitable window for the removal of weapons from a site.

Weather conditions can certainly complicate observation, as cloud cover would make optical observations impossible. However, the inspected party cannot be certain that the weather will cooperate in concealing the movement of weapons. In addition, the inspectors can acquire data from synthetic aperture radar (SAR), which does not require cloudless conditions.

The goal of this experiment was to test the potential utility of satellite data for monitoring a lockdown. In order to do so, Open Nuclear Network engaged six different commercial providers for tasked high-resolution optical imagery and SAR data. The time window of interest identified in the request spanned from the time the inspectors submitted the notification of intent to inspect, 6 March 2023, 12:00 UTC, to the time inspectors were expected to arrive at the site, 8 March 2023, 08:00 UTC.

In the end, two providers were able to provide adequate tasking windows within the specified period. The images acquired for the experiment are listed in Table 1.

Table 1. Satellite images acquired for the experiment.

TIME	PROVIDER/SENSOR	IMAGE TYPE	RESOLUTION
24 February, 09:18 UTC	Planet Super Dove	Optical	3 m
5 March, 09:21 UTC	Planet SkySat	Optical	0.5 m
6 March, 07:06 UTC	Planet SkySat	Optical	0.5 m
7 March, 13:12 UTC	ICEYE	SAR	0.5x0.25 m (Slant), 1x1 m (Ground)
7 March, 13:29 UTC	Planet SkySat	Optical	0.5 m
7 March, 13:42 UTC	Planet SkySat	Optical	0.5 m
7 March, 19:56 UTC	ICEYE	SAR	0.5x0.25 m (Slant), 1x1 m (Ground)
8 March, 09:45 UTC	Planet SkySat	Optical	0.5 m
9 March, 10:22 UTC	Planet SkySat	Optical	0.5 m

Figure 3. Illustration of a moving object identified based on ICEYE SAR data; overlaid on Planet SkySat image.

The provider selection process revealed that there are several factors affecting the availability of imagery. One of these factors is the contractual relationship with a provider. In order to have the ability to task a satellite to acquire imagery during a specific time window, the customer must typically have a subscription to the provider's services. In addition, commercial providers normally prioritize various tasks from different customers that may not be compatible with each other. This prioritization process usually takes place within the week preceding a tasking date. Depending on the provider, customers can pay a premium for a higher chance that the task will be executed within a particular period. Even then, providers do not usually provide an absolute guarantee that image acquisition at a particular time will take place.

This suggests that the acquisition of images during a specific time window may require considerable resources. While this is unlikely to constrain well-resourced governments, it might prevent non-governmental or international organizations from serving as an independent verification agent. At the same time, it is important to note that the inspected party would not know which specific satellites have been tasked with acquiring images of the site or whether the inspecting party has the resources to do so. In effect, the inspected party would have to assume that all satellites that are in a position to acquire an image will do so.

The uncertainty in the image acquisition time means that the inspected party cannot be certain that activity at the site will remain undetected. An analysis of the images acquired in this experiment showed that it could indeed detect certain movements. The application of a SAR processing technique that allows for the detection of moving targets showed that a possible vehicle may have been driving on an exit ramp on the site within the 10-second acquisition duration of the 7 March 2023, 19:56 UTC task. The location of the moving object and the direction of travel are shown in Figure 3. Due to the synthetic aperture configuration of SAR acquisition geometry, moving targets in azimuth direction can be identified and visualized as such.[10]

While the inspectors might not be able to use this information during the inspection, the potential violation of lockdown would contribute to the overall assessment of the inspected party's compliance with the terms of the agreement. For example, in this experiment, movement was detected near the building that was marked as auxiliary on the site diagram. That designation was challenged during the on-site inspection.

Implications and conclusion

Several lessons can be drawn from the satellite imagery component of the experiment. Overall, it is clear that the use of commercial satellite imagery can play an important supporting role in helping to verify the terms of arms control agreements. In particular, it can assist inspectors in the preparatory phase of an inspection and also verify that there are no discrepancies between known or declared features and tasked images that show the current state of the site in question. Furthermore, tasking commercial satellites for image acquisition during a lockdown period can help in ascertaining whether the inspected party may have attempted to conceal or remove any verification-relevant objects. Satellite imagery alone, whether from NTM or commercial sources, cannot provide complete assurance that no activity in violation of a lockdown period has occurred. However, a certain level of confidence can be reached with a higher temporal resolution, which can be achieved with a sufficient budget, and as the technological offerings of commercial providers continue to improve. A party may also be sufficiently deterred from non-compliance knowing that remote observation is actively taking place.

The experiment showed that the utility of optical imagery acquisition is highly weather dependent and cannot be relied upon by itself. On the other hand, the utility of SAR acquisition is highly dependent on good knowledge of the site and its current state and/or having a current optical image for reference purposes. A combined approach is advisable. Furthermore, applying a moving target detection technique can be useful to assess whether any vehicular movement occurred during the acquisition process itself. While, for this particular experiment, getting any SAR acquisitions within the lockdown period was prioritized over getting acquisitions with a similar imaging geometry, future experiments can more closely explore application of SAR for the detection of movements and changes.

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10 Hélène Oriot, "Moving Target Detection on SAR Images," *NATO STO Review*, 2014, https://www.sto.nato.int/publications/STO%20Educational%20Notes/STO-EN-SET-191-2014/EN-SET-191-2014-07.pdf.

Lessons learned

Pavel Podvig

The Menzingen Verification Experiment successfully demonstrated the potential setup of an on-site inspection that could be an element of an agreement that removes nuclear weapons from their deployment sites. The experiment provided an opportunity to test in practice the approach to disarmament verification based on the confirmation of the absence of nuclear weapons. It also made it possible to assess the effectiveness of specific verification procedures and the applicability of various verification tools, such as radiation measurements or satellite imagery. Overall, the experiment showed the correctness of most decisions regarding the setup of an on-site inspection. At the same time, it provided a number of valuable lessons that can be used to improve the procedures and methods of nuclear disarmament verification.

The most important lesson that can be applied to all elements of the experiment is the importance of establishing the baseline for all verification activities. This applies to the satellite images of the site, information about its layout, and knowledge of the local radiation background. All these aspects require careful attention and are essential for the success of the verification.

The results of this experiment suggest that the procedure of declaring and inspecting buildings and structures must be modified in one important way. The distinction between objects of verification, defined as dedicated nuclear weapons storage structures, and auxiliary buildings proved to be less useful than expected. The experiment showed that the inspectors should have the right to inspect all buildings within the perimeter rather than rely on designations provided by the inspected party. This modification, however, would not affect the overall design of an inspection protocol. The inspectors would still walk the site to confirm the accuracy of the site diagram. The goal of this stage of the inspection would be to ensure that the diagram shows all structures present at the site. The inspectors would also have the opportunity to see if some of these structures are indeed auxiliary buildings that are not suitable for nuclear weapons storage. The inspectors would not have to share their conclusions with the inspected party, but they could decide to exclude these buildings from consideration when they select the objects of verification to inspect. The procedures for requesting clarification regarding the function of buildings would remain largely unchanged, so the inspectors could document the challenge and analyse the photographs and the results of measurements at a later time.

The elimination of the distinction between objects of verification and auxiliary buildings would also address another issue that was discovered during the experiment. Several times in the course of the inspection the escort team, following the script, refused access to the interior of auxiliary buildings. The script assumed that these buildings contained sensitive equipment and could not be used for nuclear weapons storage. In accordance with the model Protocol on Inspection, the inspectors issued a challenge. Under a modified procedure, the inspected party would have to provide access to these buildings. The equipment inside would be covered and made available for inspection like all other sensitive items.

The experiment showed that the approach to confirming the non-nuclear nature of selected items developed for this inspection worked in principle. The main area for further research is the development of verification techniques that can be applied to items that are difficult to inspect, such as large containers or fixed equipment cabinets. More work needs to be done to define item categories in a way that would streamline the verification procedures.

Visual inspection proved to be a surprisingly effective verification technique that can be applied to a broad range of items. Other simple techniques, such as checking the weight of an item or partially removing the cover, can also be quite effective, although some of them depend on the cooperation of the inspected party.

In those cases where the confirmation of the non-nuclear nature of an item requires radiation measurements, the measurement process must be designed very carefully. Although the experiment demonstrated the feasibility of performing measurements involving active radiation sources, the use of such sources complicates the experimental setup and requires the implementation of potentially cumbersome safety precautions.

More importantly, the organization of measurements must consider environmental conditions at the site, such as temperature and background radiation. Some methods may require that the item is moved for examination to a specially arranged area of the site rather than inspected in the building where it is found. In general, designing radiation measurement procedures that can work reliably in the field remains an important area of research.

The experiment showed that satellite imagery is extremely useful in several ways. The history of monitoring various military sites by satellite, combined with information from other sources, can provide high confidence in the correctness and completeness of the initial declaration of nuclear-weapon storage facilities. Since the sites that are suitable for nuclear weapon storage have distinct signatures, their locations and functions are well known. This should make it easier for the parties to exchange data about storage facilities and provide information about their layout. Historical satellite images can also be used to ensure that the site has not undergone modifications that would not be shown on the site diagram.

For the purposes of on-site inspection, satellite images can provide an update on the state of the site and serve as a reference point for confirming the accuracy of the site diagram. Indeed, an examination of publicly available satellite images of the Menzingen site, which was part of this experiment, identified several structures that raised questions during the inspection.

The evolution of Earth observation technologies opens new possibilities for using satellite data to support on-site inspections. In the experiment, data obtained by a synthetic aperture radar (SAR) satellite provided essential backup to optical observations. The capability of SAR satellites to detect movement and changes at the site also proved to be an important capability. One potential application of this technology that deserves further study is the potential ability of SAR satellites to detect changes that would be produced by the movement of personnel and equipment that would accompany a removal of weapons from a site.

The experiment also demonstrated that the increasing availability of commercial satellite data does not automatically translate into easier access to that information. Obtaining high-quality images in a timely manner still requires substantial resources. At the same time, the data supplied by commercial providers can significantly increase the overall effectiveness of the verification process.

To conclude, the Menzingen Verification Experiment fully achieved all of its goals. It explored new verification procedures and techniques, provided valuable insights into the challenges that can be encountered during an on-site inspection to verify the absence of nuclear weapons, and identified promising new approaches to verification and areas for further research.

Appendix A.
Model Protocol on Inspection

Protocol on Inspection

The States Parties hereby agree on procedures and other provisions governing the conduct of inspections as provided for in Article [NNN] of the Treaty on [XXX] of [May 13, 2022], hereinafter referred to as the Treaty.[1]

SECTION I. DEFINITIONS

1. For the purposes of the Treaty:

(A) The term “inspected State Party” means a State Party on whose territory an inspection is carried out in compliance with Article [NNN] of the Treaty:

a) in the case of inspection sites stationed on this territory by another State Party, such a stationing State Party shall exercise, in compliance with the provisions of this Protocol, the rights and obligations of the inspected State Party as set forth in this Protocol for the duration of the inspection within that inspection site.

(B) The term “stationing State Party” means a State Party stationing special armament storage sites outside its own territory and within the area of application.

(C) The term “host State Party” means a State Party on whose territory within the area of application special armament storage sites of another State Party are stationed by that State Party.

(D) The term “inspecting State Party” means a State Party which requests and is therefore responsible for carrying out an inspection.

(E) The term “inspector” means an individual designated by one of the States Parties to carry out an inspection and who is included on that State Party’s accepted list of inspectors in accordance with the provisions of SECTION III of this Protocol.

(F) The term “inspection team” means a group of inspectors designated by an inspecting State Party to conduct a particular inspection.

(G) The term “escort team” means a group of individuals assigned by the inspected State Party to accompany and to assist inspectors conducting a particular inspection, as well as to assume other responsibilities as set forth in this Protocol. In the case of inspection of a stationing State Party’s special armament storage site, an escort team shall include individuals assigned by both the host and stationing States Parties, unless otherwise agreed between them.

(H) The term “in-country escort” means a member or members of the escort team.

(I) The term “inspection site” means a declared site where an inspection is carried out.

(J) The term “object of verification” means any building or structure within a declared site that is declared by the inspected State Party as capable of containing special armaments.

(K) The term “auxiliary structure” means any building or structure within a declared site that is declared by the inspected State Party as not capable of containing special armaments.

(L) The term “declared site” means a precisely delineated geographic area which contains one or more objects of verification.

(M) The term “sensitive item” means any equipment or structure which has been designated to be sensitive by the inspected State Party or the State Party exercising the rights and obligations of the inspected State Party through the escort team.

(N) The term “point of entry/exit” means a point designated by a State Party on whose territory an inspection is to be carried out, through which inspection teams and transport crews arrive on the territory of that State Party and through which they depart from the territory of that State Party.

(O) The term “in-country period” means the total time spent continuously on the territory of the State Party where an inspection is carried out by an inspection team for inspections pursuant to SECTION VII and SECTION VIII of this Protocol from arrival of the inspection team at the point of entry/exit until the return of the inspection team to a point of entry/exit after completion of that inspection team’s last inspection.

SECTION II. GENERAL OBLIGATIONS

1. For the purpose of ensuring verification of compliance with the provisions of the Treaty, each State Party shall facilitate inspections pursuant to this Protocol.

2. In the case of special armament storage sites of a State Party stationed in the area of application outside national territory, the host State Party and the stationing State Party shall, in fulfillment of their respective responsibilities, cooperatively ensure compliance with the relevant provisions of this Protocol. The stationing State Party shall be fully responsible for compliance with the Treaty obligations in respect of its special armament storage sites stationed on the territory of the host State Party.

3. The escort team shall be placed under the responsibility of the inspected State Party. Inspection teams and sub-teams shall be under the control and responsibility of the inspecting State Party.

4. Inspection teams and sub-teams shall be under the control and responsibility of the inspecting State Party.

5. […]

6. Each State Party shall be obliged to accept simultaneously no more than one inspection team.

7 An inspection team conducting an inspection shall spend no more than 12 hours at a declared site.

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1 Square brackets denote either notional values used in this experiment or values that would depend on the specific circumstances of an actual agreement. Ellipses denote sections of the protocol that were not tested in the experiment.

SECTION III. PRE-INSPECTION REQUIREMENTS

1. […]

SECTION IV. NOTIFICATION OF INTENT TO INSPECT

1. The inspecting State Party shall notify the inspected State Party of its intention to carry out an inspection provided for in Article [NNN] of the Treaty. In the case of inspection of a stationed special armament storage site, the inspecting State Party shall simultaneously notify the host and stationing States Parties.

2. The notifications shall be made in accordance with Article [NNN] of the Treaty no less than 24 hours in advance of the estimated time of arrival of the inspection team at the point of entry/exit on the territory of the State Party where an inspection is to be carried out and shall include:

   (A) the point of entry/exit to be used,

   (B) the estimated time of arrival at the point of entry/exit,

   (C) the means of arrival at the point of entry/exit,

   (D) the time interval between the arrival at the point of entry/exit and the designation of the inspection site,

   (E) the language to be used by the inspection team,

   (F) the language to be used for the inspection report prepared in accordance with SECTION IX of this Protocol,

   (G) the full names of inspectors and transport crew members, their gender, date of birth, place of birth and passport number.

3. […]

SECTION V. PROCEDURES UPON ARRIVAL AT POINT OF ENTRY/EXIT

1. The escort team shall meet the inspection team and transport crew members at the point of entry/exit upon their arrival.

2. A State Party which utilizes structures or premises by agreement with the inspected State Party will designate a liaison officer to the escort team who will be available as needed at the point of entry/exit to accompany the inspection team at any time as agreed with the escort team.

3. Times of arrival at and return to a point of entry/exit shall be agreed and recorded by both the inspection team and the escort team.

4. Equipment and supplies that the inspecting State Party brings into the territory of the State Party where an inspection is to be carried out shall be subject to examination each time they are brought into that territory. This examination shall be completed prior to the departure of the inspection team from the point of entry/exit to the inspection site. Such equipment and supplies shall be examined by the escort team in the presence of the inspection team members.

5. […]

SECTION VI. GENERAL RULES FOR CONDUCTING INSPECTIONS

1. An inspection team may include inspectors from States Parties other than the inspecting State Party.

2. An inspection team shall consist of up to nine inspectors. The inspection team may divide itself at the inspection site into up to three sub-teams.

3. Inspectors and escort team members shall wear some clear identification of their respective roles.

4. The inspected State Party shall be responsible for ensuring the safety of the inspection team and transport crew members from the time they arrive at the point of entry/exit until the time they leave the point of entry/exit to depart the territory of that State Party.

5. No information obtained during inspections shall be publicly disclosed without the express consent of the inspected State Party and the inspecting State Party.

6. Throughout their presence on the territory of the State Party where an inspection is to be carried out, inspectors shall have the right to communicate with the embassy or consulate of the inspecting State Party located on that territory, using appropriate telecommunications means provided by the inspected State Party. The inspected State Party shall also provide means of communication between the sub-teams of an inspection team.

7. The inspected State Party shall provide for use by the inspection team at the inspection site an administrative area for storage of equipment and supplies, report writing, rest breaks and meals.

8. The inspection team shall be permitted to use inspection equipment in accordance with the Annex on Equipment and Procedures.

9. In discharging their functions, inspectors shall not interfere directly with ongoing activities at the inspection site and shall avoid unnecessarily hampering or delaying operations at the inspection site or taking actions affecting safe operation.

10. Except as provided for in paragraphs 11 to 14 of this Section, during an inspection inspectors shall be permitted access, entry, and unobstructed inspection to all areas within the declared site designated as roads on the site diagram.

11. During an inspection of a declared site, inspectors shall have the right to request a close visual examination of [two] structures or buildings designated as auxiliary structures. Inspectors shall not have the right to enter the auxiliary structure or building unless access is explicitly approved by the escort team.

12. During an inspection of an object of verification selected for an inspection, inspectors shall be permitted access, entry, and unobstructed inspection to the entire interior of the object of verification to confirm the accuracy of the floor plan submitted by the escort team.

13. The inspected State Party shall have the right to shroud individual sensitive items of equipment. Each sensitive item shall be assigned a category that corresponds to an agreed procedure in accordance with the Annex on Equipment and Procedures.

14. Whenever a sensitive item is present within the inspected site or within the inspected object of verification, it should be clearly marked on the site diagram or the floor plan of the object of verification along with the category assigned to this item by the inspected Party. The inspection team shall have the right to select [up to three] sensitive items for an inspection in accordance with the procedures that corresponds to the category assigned to this item by the inspected State Party.

15. Inspectors shall have the right to take photographs in accordance with the Annex on Equipment and Procedures.

16. Inspectors shall have the right to take linear measurements to resolve ambiguities that might arise during inspections in accordance with the Annex on Equipment and Procedures. Such measurements recorded during inspections shall be confirmed by a member of the inspection team and a member of the escort team immediately after they are taken. Such confirmed data shall be included in the inspection report.

17. States Parties shall, whenever possible, resolve during an inspection any ambiguities that arise regarding factual information. Whenever inspectors request the escort team to clarify such an ambiguity, the escort team shall promptly provide the inspection team with clarifications. If inspectors decide to document an unresolved ambiguity with photographs, the escort team shall cooperate with the inspection team's taking of photographs in accordance with the Annex on Equipment and Procedures. If an ambiguity cannot be resolved during the inspection, then the question, relevant clarifications and any pertinent photographs shall be included in the inspection report in accordance with SECTION IX of this Protocol.

18. The inspection shall be deemed to have been completed once the inspection report has been signed and countersigned.

19. After completion of an inspection at a declared site the inspection team shall be transported to the appropriate point of entry/exit as soon as possible and shall depart the territory of the State Party where the inspection was carried out within 24 hours.

SECTION VII. INSPECTION OF A DECLARED SITE

1. No less than [one hour] and no more than [16 hours] after arrival at the point of entry/exit, the inspection team shall designate the declared site to be inspected.

2. Inspection of a declared site pursuant to this Protocol shall not be refused. Such inspections may be delayed only in cases of force majeure or in accordance with SECTION IV of this Protocol.

3. No later than one hour after the time for the designation of the inspection site, the inspected Party shall implement the following pre-inspection restrictions at the designated inspection site, which shall remain in effect until the arrival of inspectors at the site:

   (A) The inspected party shall not remove from the inspection site or move on the inspection site any containers and vehicles large enough to contain a special armament and covered objects large enough to be a special armament.

4. The inspected State Party shall ensure that the inspection team travels to the declared site by the most expeditious means available and arrives as soon as possible but no later than [nine hours] after the designation of the site to be inspected, unless otherwise agreed between the inspection team and the escort team, or unless the inspection site is located in mountainous terrain or terrain to which access is difficult. In such case, the inspection team shall be transported to the inspection site no later than [15 hours] after designation of that inspection site. Travel time in excess of nine hours shall not count against that inspection team's in-country period.

5. Immediately upon arrival at the declared site, the inspection team shall be escorted to a briefing facility where it shall be provided with a diagram of the declared site, unless such a diagram has been provided in a previous exchange of site diagrams. The diagram of the declared site, provided upon arrival at the declared site, shall contain an accurate depiction of the:

    (A) geographic coordinates of a point within the inspection site, to the nearest 10 seconds, with indication of that point and of true north,
    (B) scale used in the site diagram,
    (C) perimeter of the declared site,
    (D) each object of verification,
    (E) auxiliary buildings and roads on the declared site,
    (F) entrances to the declared site, and
    (G) location of an administrative area for the inspection team.

6. The inspection team shall then be given a pre-inspection briefing which shall last no more than one-half hour and shall include the following elements:

    (A) safety and administrative procedures at the inspection site,
    (B) modalities of transportation and communication for inspectors at the inspection site.

7. The pre-inspection briefing shall include an explanation of any differences between the diagram of the declared site and the diagram that has been provided in a previous exchange of site diagrams.

8. The inspection team shall have the right to inspect the territory of the declared site to verify the accuracy of the site diagram. During such inspections, the provisions of SECTION VI of this Protocol shall apply.

9. The inspection team has the right to select [two] objects of verification for an inspection.

10. The inspected State Party shall have the right to utilize up to [two hours] after designation of an object of verification to prepare it for an inspection. The escort team shall provide the inspectors with access to the exterior of the selected object of verification sufficient to confirm that no items are removed from the object of verification during that period.

11. After completing the preparations, the escort team shall provide the inspection team with a floor plan of the selected object of verification and shall permit the inspection team access, entry, and unobstructed inspection to the interior of the object of verification. During such inspections, the provisions of SECTION VI of this Protocol shall apply.

SECTION VIII. CANCELLATION OF INSPECTIONS

1. […]

SECTION IX. INSPECTION REPORT

1. In order to complete an inspection and before leaving the inspection site:

    (A) the inspection team shall provide the escort team with a written report, and

    (B) the escort team shall have the right to include its written comments in the inspection report and shall countersign the report within one hour after having received the report from the inspection team, unless an extension has been agreed between the inspection team and the escort team.

2. The report shall be signed by the inspection team leader and receipt acknowledged in writing by the leader of the escort team.

3. The report shall be factual and standardized.

4. Reports of inspections shall include:

    (A) the inspection site,
    (B) the date and time of arrival of the inspection team at the inspection site,
    (C) the date and time of departure of the inspection team from the inspection site, and
    (D) the description of activities performed by the inspection team.

5. The inspecting State Party and the inspected State Party shall each retain one copy of the report. At the discretion of either State Party, the inspection report may be forwarded to other States Parties and, as a rule, made available to the Joint Implementation Commission.

SECTION X. PRIVILEGES AND IMMUNITIES OF INSPECTORS AND TRANSPORT CREW MEMBERS

1. […]

Annex on Equipment and Procedures

SECTION I. GENERAL PROVISIONS

1. During inspections, inspection teams shall have the right to use inspection equipment listed in SECTION II and SECTION VI of this Annex. Such equipment shall include instruments and devices for making linear measurements, determining geographic coordinates, taking photographs, and conducting other inspection activities. Such equipment shall be used in accordance with the procedures specified in this Annex.

2. Inspection equipment shall be used to confirm that items identified by the inspected Party in accordance with SECTION VI.14 of the Protocol on Inspections are not special armaments and do not contain special armaments inside. For these purposes, inspection equipment shall be used in accordance with the procedures developed for the category of the item, as specified in SECTION VI and SECTION VII of this Annex. The Joint Implementation Commission can amend these procedures as necessary.

3. Equipment that the inspecting Party brings into the country shall be subject to examination each time it is brought into the country. Such equipment shall be examined by the escort team, in the presence of inspectors. The purpose of such examination shall be to ascertain to the satisfaction of each Party that the equipment cannot perform functions unconnected with the requirements of inspection activities. The examination of the equipment shall be completed prior to the departure of the inspection team from the point of entry to the inspection activity site.

4. During their stay on the territory of the inspected Party, inspectors shall have the right to use personal electronic equipment upon agreement with the inspected Party, subject to the condition that such personal electronic equipment may not be used at the inspection site.

5. Equipment for photography and printing of photographs shall be provided by the inspected Party at the request of the inspecting Party during inspection activities at any facility subject to inspection activities. The inspected Party shall ensure the operability of all sets of such equipment.

SECTION II. EQUIPMENT USED DURING THE INSPECTION

1. List of equipment for making linear measurements and additional equipment to be provided by the inspecting Party:

   (A) Measuring tapes,
   (B) Rolls of adhesive tape,
   (C) Inspection suitcase,
   (D) Flashlights,
   (E) Stopwatches,
   (F) Measuring stick.

2. List of equipment to be provided by the inspected Party for photography and printing of photographs:

   (A) Digital camera with charger and lens (minimum 10-megapixel resolution and of a commercially available make and type),
   (B) Photographic flash, either integrated with the camera or separate,
   (C) Memory card,
   (D) Portable color printer with charger (of a commercially available make and type),
   (E) Tripod.

3. The inspected Party shall provide two sets of satellite system receivers for determining geographic coordinates.

    (A) [Smartphones operated by Swiss Army representatives.]

SECTION III. METHODS AND PROCEDURES FOR USE OF EQUIPMENT FOR MAKING LINEAR MEASUREMENTS

1. During inspection activities, the inspected Party shall, at the request of the inspecting Party, use linear measurement devices.

2. Linear measurement devices shall be used to determine length, width, and height of objects and items of inspection by measuring the straight-line distance between the extreme points of these objects or, if required, between tangents drawn perpendicular to the direction of measurement from the outside points of curved surfaces.

3. The diameter of any cylindrical object shall be determined by measuring the circumference, by directly measuring the diameter, or by measuring the distance between parallel lines that are vertical tangents to the cylindrical surface of the object and that lie in a plane perpendicular to the axis of the object.

4. In determining the dimensions of an object, each dimension shall be measured at least two times. The results of these measurements shall be averaged to determine the dimension of the object.

SECTION IV. METHODS AND PROCEDURES FOR USE OF EQUIPMENT FOR PHOTOGRAPHY AND PRINTING OF PHOTOGRAPHS

1. During inspection activities, the inspected Party shall, at the request of the inspecting Party, use a digital camera on a tripod to photograph an object or building about which a question or ambiguity has arisen, using the following procedures:

    (A) The inspectors and in-country escort shall agree on perspective, view, and angle on the object or building to be photographed, using the viewfinder or digital camera screen.

    (B) The in-country escort shall place a measuring stick perpendicular to the ground and directly against the object or building to be photographed. Inspectors shall have the right to record the scale or length of such a measuring stick in the inspection activity report.

    (C) The in-country escort shall take the photograph.

    (D) Digital photographs shall be printed using a color printer.

    (E) Inspectors shall have the right to confirm that the photographed object or building, as depicted on the color print, is in focus and of sufficient resolution.

    (F) Having received such a confirmation from the inspectors, the in-country escort shall print two additional photographs for inclusion in the inspection activity report. If the photographs cannot be printed at the location where they were taken, the inspectors and the in-country escort shall agree on a time and location for the printing of such photographs.

    (G) Each photograph included in the inspection activity report shall be annotated with a description of the object or building photographed and shall be signed by the inspection team leader and a member of the in-country escort.

SECTION V. METHODS AND PROCEDURES FOR USE OF EQUIPMENT FOR DETERMINING GEOGRAPHIC COORDINATES

1. […]

SECTION VI. CATEGORIES OF INSPECTED ITEMS AND EQUIPMENT USED TO INSPECT THESE ITEMS

1. Inspection equipment used to inspect items designated as belonging to Category A:

   (A) The inspected Party shall have the right to designate any item as a Category A item.
   (B) Set of Category A inspection equipment consists of the following:

      a) Inspection equipment specified in SECTION II of this Annex,
      b) A ladder or other means of access provided by the inspected Party at the request of the inspecting Party.

2. Inspection equipment used to inspect items designated as belonging to Category B:

   (A) The inspected Party shall have the right to designate any item as a Category B item, subject to the following conditions:
      a) The minimum of the three dimensions of the item does not exceed [35] centimeters.

   (B) Set of Category B inspection equipment consists of the following:
      a) Inspection equipment specified in SECTION II of this Annex,
      b) Neutron Survey Meter LB 6414, with instruction manual,
      c) Neutron source for calibration,
      d) Stands for equipment,
      e) Equipment bags and cases,
      f) Plastic bags for weather protection.

3. Inspection equipment used to inspect items designated as belonging to Category C:

   (A) The inspected Party shall have the right to designate any item as a Category C item, subject to the following conditions:
      a) The minimum of the three dimensions of the item does not exceed [50] centimeters.

   (B) Set of Category C inspection equipment consists of the following:
      a) Inspection equipment specified in SECTION II of this Annex,
      b) Mirion/Canberra NaI scintillation detector with Osprey Digital MCA Tube Base,
      c) Electronic counter, ACX Device custom-built by Princeton University, with Raspberry Pi 2 computer, battery, and cables,
      d) Software on a Micro SD card,
      e) Detector shield and collimator,
      f) Caesium-137 gamma source for reference, with activity of approximately 0.24 mCi,
      g) Sodium-22 and Europium-155 sources for calibration, with activity of approximately 1 μCi,
      h) Lead container for reference source,
      i) Connecting cables,
      j) Stands for equipment,
      k) Equipment bags and cases,
      l) Plastic bags for weather protection.

(C) Requirements for technical characteristics of Category C inspection equipment:
  a) The equipment does not have cellular, Wi-Fi, Bluetooth, or any other communication capability,
  b) The Micro SD card with software is not returned to the inspecting Party after the measurement is completed,
  c) […]

4. Inspection equipment used to inspect items designated as belonging to Category D:

(A) The inspected Party shall have the right to designate one item in an object of verification as a Category D item, subject to the following conditions:
  a) The dimensions of the item shall not exceed [450x220x200] centimeters.

SECTION VII. CATEGORIES OF INSPECTED ITEMS AND METHODS AND PROCEDURES FOR USE OF INSPECTION EQUIPMENT

1. During inspections, the inspected Party shall have the right to use inspection equipment in order to demonstrate to inspectors that an item that was selected by inspectors for inspection is not a special armament and that it does not contain a special armament. For these purposes, the inspected Party shall have the right to use inspection equipment corresponding to the category of the selected item as specified in SECTION VI.14 of the Protocol on Inspections.

2. […]

3. At the inspection site, during an inspection of a Category A item, the inspecting Party shall have the right to use inspection equipment specified in SECTION VI.1(B) of this Annex. The inspecting Party shall conduct the inspection in accordance with the following procedures:

(A) The inspecting Party shall have the right to request the inspected Party to demonstrate the features of the inspected item that distinguish it from an item that is a special armament or that contains a special armament.

(B) In the absence of distinguishing features, the inspecting party shall have the right to request visual access to the interior of the inspected item.

(C) If the minimum of the three dimensions of the item does not exceed [35] centimeters, the inspection of the item is limited to confirming its linear dimensions.

4. At the inspection site, during an inspection of a Category B item, the inspecting Party shall have the right to use inspection equipment specified in SECTION VI.2(B) of this Annex to demonstrate that the item is not a special armament and that it does not contain a special armament. The inspecting Party shall conduct the inspection in accordance with the following procedures:
(A) [See Chapter 4 for details.]

5. At the inspection site, during an inspection of a Category C item, the inspecting Party shall have the right to use inspection equipment specified in SECTION VI.3(B) of this Annex. The inspecting Party shall conduct the inspection in accordance with the following procedures:
(A) [See Chapter 4 for details.]

6. At the inspection site, during an inspection of a Category D item, the inspecting Party shall conduct the inspection in accordance with the following procedures:
(A) The inspecting Party shall have the right to request the inspected Party to demonstrate that the inspected item has no concealed volumes that can contain a special armament.

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