By Alexander Glaser

Toward Verifiable Definitions of a Nuclear Weapon

Defining a nuclear weapon is difficult. At first, this observation may seem counterintuitive given the unique nature and unmatched destructive power of nuclear weapons, but previous attempts to agree on a definition have emphasized the physical processes that occur once such a weapon is used.

These phenomena and effects cannot be verified, for example, during an inspection. Unsurprisingly, nuclear arms control agreements generally have avoided defining a nuclear weapon altogether even when they sought to limit the deployed numbers of these weapons or manage their proliferation.[1] For more than 30 years, weapons and verification experts have tried to find an answer to this question.

A different path to achieve this goal is possible. First and foremost, it would be timely and important to agree on a verifiable, broadly supported definition of what is not a nuclear weapon. This is by no means a trivial task, but one in which nuclear-weapon and non-nuclear-weapon states actively could engage, even today. Verification of several possible future arms control measures can be supported by such a negative definition, including the removal of tactical nuclear weapons from entire geographical regions, verification procedures relevant for the Treaty on the Prohibition of Nuclear Weapons (TPNW), and verified limits on total stockpiles.

A Brief History of Definitions

One of the earliest legal definitions of a nuclear weapon appears in the Modified Brussels Treaty of 1954, by which the Western European Union was established and West Germany undertook "not to manufacture in its territory atomic, biological and chemical weapons." Annex II of the treaty includes definitions for these weapons, including defining an atomic weapon as "any weapon which contains, or is designed to contain or utilise, nuclear fuel or radioactive isotopes and which, by explosion or other uncontrolled nuclear transformation of the nuclear fuel, or by radioactivity of the nuclear fuel or radioactive isotopes, is capable of mass destruction, mass injury or mass poisoning."[2]

Most other attempts to define a nuclear weapon have referred similarly to the capability of explosive energy release, its ability for mass destruction, or its possible use for warlike purposes. For example, the 1967 Treaty of Tlatelolco, which establishes a nuclear-weapon-free zone in Latin America and the Caribbean, defines a nuclear weapon as "any device which is capable of releasing nuclear energy in an uncontrolled manner and which has a group of characteristics that are appropriate for use for warlike purposes."[3] Other nuclear-weapon-free-zone treaties have continued to use definitions that are, in essence, equivalent to the Treaty of Tlatelolco. Most recently, the glossary of

Alexander Glaser is co-director of the Program on Science and Global Security at Princeton University and an associate professor in the university's School of Public and International Affairs and the Department of Mechanical and Aerospace Engineering.

The plutonium cores of the Trinity Device tested in New Mexico on July 16, 1945 (shown here) and the "Fat Man" nuclear weapon that destroyed the city of Nagasaki on August 9, 1945 (opposite page) were insertable, primarily for safety reasons.
(Photo courtesy of Los Alamos National Laboratory)

key nuclear terms agreed by the working group of the five nuclear-weapon states under the nuclear Nonproliferation Treaty, first issued in 2015 and expanded in 2022, describes a nuclear weapon as a "weapon assembly that is capable of producing an explosion and massive damage and destruction by the sudden release of energy instantaneously released from self-sustaining nuclear fission and/or fusion."[4]

All these formal definitions, spanning a period of more than 60 years, have one major problem: they are de facto unverifiable because an inspector cannot confirm the very characteristics that are used to define a nuclear weapon itself. The topic reemerged, implicitly, in the early 1990s, when specialists from Russian and U.S. nuclear weapons laboratories initiated then-unprecedented discussions on the verification of warhead reductions. The talks were focused on how to confirm that a declared item was a genuine warhead, with the goal of devising methodologies that would protect sensitive design information. Unfortunately, these efforts ended before a broad consensus on concepts, definitions, and verification approaches was reached. In any event, it appears that such a conversation today would need to involve additional participants, such as China but ideally also other nuclear-weapon and non-nuclear-weapon states, to lay the basis for broader future arms control and disarmament efforts.

What Is Not a Nuclear Weapon

Despite the long-standing, persistent challenges of verifiably defining a nuclear weapon, even when using concepts such as templates or attributes, a work-around has proven valuable in the context of the New Strategic Arms Reduction Treaty (New START). The goal is to confirm the absence of a nuclear weapon or, in other words, define what is not a nuclear weapon. Under New START, parties declare the number of warheads deployed on a missile that is accountable under the treaty, and additional items that may be present during an on-site inspection must be shown to be "non-nuclear objects."[5]

The New START procedures to confirm the non-nuclear nature of an object rely on gross neutron counts. Such measurements work for weapons that contain kilogram quantities of plutonium, but weapons that contain uranium only would have negligible neutron emissions and cannot be detected by the procedures developed for New START. Concepts to confirm the absence of uranium-based weapons have been proposed, but they have not been fully demonstrated and require further analysis.[6]

Building on the New START model, an explicit definition of an object that is not a nuclear weapon could be as simple as this: "An object is accepted not to be a nuclear weapon if (a) it does not exceed an agreed neutron or gamma radiation level or (b) the inspector can confirm its nature as a non-treaty-accountable item, for example, through direct visual access."

There are many ways to draft such a negative definition, and there will be trade-offs between simplicity and specificity. It is not the intention here to provide a definitive formulation, but a reference to the absence of nuclear radiation appears important.

One major challenge will be agreement on criteria for an inspectable "object" and, in particular, on a minimum size of such an object. New START largely avoided this dilemma by focusing on deployed weapons, namely objects located on the front section of ballistic missiles, but an agreement that seeks to confirm the absence of nuclear weapons anywhere at an inspected site or in a geographical region could not as easily dodge this question. For example, there could be concerns that a party stores nuclear weapons partly disassembled. Indeed, the nuclear components of the first implosion-type nuclear weapons—"Gadget" and "Fat Man"—were inserted only hours before the use of those weapons, and early postwar weapon designs also had removable nuclear components.

In the 1980s, there were proposals to reintroduce such "clip-in" or "insertable" warheads into the U.S. stockpile, perhaps for lower-yield tactical nuclear weapons, a prospect considered an "arms control nightmare" by some analysts.[7] The negotiators of the Intermediate-Range Nuclear Forces Treaty ended up banning all intermediate-range missiles, nuclear and conventional, thus avoiding possible ambiguities and complications with regard to verification. Ultimately, if the absence of nuclear weapons is to be confirmed with some reasonably high confidence, it may be necessary to consider for inspection even relatively small objects. Some items used for civilian or military research purposes may not automatically pass an absence test and may only be "cleared" after a visual inspection.[8]

Absence measurements such as those proposed here have important advantages. The instruments and measurement techniques are relatively simple, sensitive information does not need to be protected, and measurements do not require any form of information barrier. Moreover, inspector access to relevant sites could be much easier overall because sensitive nuclear items should not be present. Verification approaches based on such measurements may be the most promising path forward for nuclear arms control efforts in the medium term, especially given the current mistrust among nuclear-weapon states, which could make more intrusive approaches unrealistic.

Although confirming the non-nuclear nature of an object has already proven useful as part of New START, other types of agreements could similarly rely on this concept of negative definitions. In that regard, two possible directions for nuclear arms control are presented below.

Zero Deployment or Regional Removal of Nuclear Weapons. One can imagine future agreements that require parties not to have deployed nuclear weapons in storage facilities near military bases with airfields or delivery systems. This could help prevent inadvertent escalation of a crisis and would be particularly meaningful in Europe.

The core of such a zero-deployed arrangement, as first proposed by researchers at the UN Institute for Disarmament Research, would be the transfer of nuclear warheads associated with nonstrategic delivery systems to a small number of storage facilities, either in the same host country or elsewhere.[9] Confirming the absence of nuclear weapons at those former deployment sites could become a key verification task, and it could be implemented using a negative definition as proposed above.

Negative definitions can go a long way in supporting nuclear arms control and disarmament.

This scenario would also become relevant once a country that previously hosted nuclear weapons joins the TPNW. Such a country would have 90 days for the removal of those weapons,[10] which would likely be followed by verification procedures to be agreed by the TPNW states-parties.

Confirming Numerical Limits on Total Stockpiles. It is often assumed that arms control agreements eventually could place limits on all nuclear weapons in the stockpiles, including those in storage and perhaps those slated for dismantlement, so that the gap between existing weapons and those captured by arms control regimes gradually can be closed.[11] Such agreements could be bilateral or multilateral and have separate ceilings for different parties or even envision nonbinding declarations to discourage major nuclear buildups over short periods of time.[12] The most basic approach to confirming numerical limits as part of such an “all-warhead agreement” is to rely solely on baseline declarations followed by regular data exchanges. In this case, during an on-site inspection, the host would get credit for the number of items declared for that site and identify those items as such. These declared items could be accepted as treaty-accountable items and never accessed or inspected.[13] The inspectors would then be allowed to confirm that other items available at the site are in fact not treaty accountable using the concepts discussed above. If an object does not pass the absence test, it simply could be considered a treaty-accountable item. Taken together, the required verification activities and technologies could be relatively simple and nonintrusive even though such an all-warhead agreement would represent a major milestone in nuclear arms control.

Depending on the scope of future arms control agreements, key nuclear components such as those used in the bomb that destroyed Nagasaki (shown here) and in the Trinity Device (opposite page) could be considered “treaty accountable” or “prohibited” even when they are separate from the main body of the weapon.
(Photo courtesy of Los Alamos National Laboratory)

Looking Further Ahead

Negative definitions can go a long way in supporting nuclear arms control and disarmament. If they can be agreed, it is unlikely that more specific definitions will be needed in the foreseeable future, even under the most optimistic circumstances. Ultimately, however, positive definitions may be considered preferable to support specific reduction efforts. For example, nuclear-weapon states tend to deploy only a few types of weapons at any given time.[14] It is possible that negotiators may find it useful to constrain arsenals by warhead type, that is, to gradually phase out and eliminate specific types of weapons while allowing others to remain in the stockpiles. In this case and following a more traditional verification approach, warheads that are subject to reductions or removals could be inspected prior to dismantlement to confirm their identity.

Indeed, research since the 1990s has focused on unique characteristics or attributes of nuclear weapons that can be confirmed with radiation measurements. This led to the introduction of a series of concepts that are still being researched today and include, in particular, templates, attributes, and information barriers.[15] Unfortunately, these concepts and approaches have introduced new challenges: The data acquired in these measurements are highly sensitive, and information barriers to protect these data have proven difficult to certify and authenticate. Significant progress has been made over the years in overcoming some of these technical challenges,[16] and efforts have included several international collaborations and original research at governmental laboratories and universities.[17] A sustained research and development effort should be able to demonstrate the concepts and technologies needed, even for such verification approaches involving warhead inspections.

It is also possible, however, that radiation measurements for warhead inspections in an arms control setting will always remain elusive, most likely for political reasons. As argued previously, radiation measurements on sensitive nuclear items are not needed for some verification approaches relevant for the removal of nuclear weapons from specific regions and for verified stockpile limits.[18] Indeed, if warhead inspections remain a persistent source of controversy among parties, it may be possible to avoid them altogether, even in scenarios in which there are deep cuts in the nuclear arsenals.

Despite the current crisis of nuclear arms control, it may be beneficial to address some of these questions soon. In fact, jointly exploring verifiable warhead definitions and relevant inspection approaches, while acknowledging concerns with regard to access and intrusiveness, may be more amenable than directly discussing even more complicated topics at this time, such as the scope of possible treaties.

ENDNOTES

1. Most famously, the nuclear Nonproliferation Treaty does not define a nuclear weapon even though the term is used throughout the treaty text. The issue of defining a nuclear weapon rose to the top of the agenda as recently as 2020, when the United States and Russia last discussed the possibility of a warhead freeze. Michael Gordon and Ann M. Simmons, "U.S., Russia Near Deal to Extend Nuclear Treaty and Freeze Warheads for a Year," *The Wall Street Journal*, October 20, 2020.

2. Modified Brussels Treaty, October 23, 1954.

3. Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean, February 14, 1967, 634 U.N.T.S. 9068.

4. P5 Working Group on the Glossary of Key Nuclear Terms, *P5 Glossary of Key Nuclear Terms* (Beijing: China Atomic Energy Press, 2015); P5 Working Group on the Glossary of Key Nuclear Terms, "P5 Glossary of Key Nuclear Terms, 2015 Edition," n.d., https://2009-2017.state.gov/documents/organization/243293.pdf.

5. 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, https://www.acq.osd.mil/asda/ssipm/sdc/tc/nst/annexes/inspection-activities/index.html (annex on inspection activities).

6. Eric Lepowsky, Jihye Jeon, and Alexander Glaser, "Confirming the Absence of Nuclear Warheads via Passive Gamma-Ray Measurements," *Nuclear Instruments & Methods in Physics Research*, Vol. 990 (February 21, 2021).

7. Fred Hiatt, "Insertable Nuclear Warheads Could Convert Arms," *The Washington Post*, June 15, 1986.

8. One example is the so-called BeRP Ball, which contains 4.5 kilograms of weapons-grade plutonium. The solid sphere was machined in 1980 and has been used for thousands of radiation measurement experiments.

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

10. First Meeting of States Parties to the Treaty on the Prohibition of Nuclear Weapons, "Report of the First Meeting of States Parties to the Treaty on the Prohibition of Nuclear Weapons," TPNW/MSP/2022/6, July 21, 2022. See Moritz Kütt and Zia Mian, "Setting the Deadline for Nuclear Weapon Removal From Host States Under the Treaty on the Prohibition of Nuclear Weapons," *Journal for Peace and Nuclear Disarmament*, Vol. 5, No. 1 (2022): 148-161.

11. James Fuller, "Verification on the Road to Zero: Issues for Nuclear Warhead Dismantlement," *Arms Control Today*, December 2010; Committee on International Security and Arms Control, National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities* (Washington: National Academies Press, 2005).

12. Amy Nelson and Michael O'Hanlon, "Putin's Treaty Withdrawal Doesn't Spell Doom for Arms Control," *The Hill*, March 7, 2023.

13. Similarly, the International Partnership for Nuclear Disarmament Verification has introduced the concept of "items declared as weapons." International Partnership for Nuclear Disarmament Verification (IPNDV), "Working Group 4 Deliverable," June 2019, pt. II, http://www.ipndv.org/wp-content/uploads/2020/04/WG4_Deliverable_FINAL.pdf ("Potential Options for Declarations on Nuclear Weapons").

14. The United States currently has seven types of warheads and bombs in its arsenal, which is many fewer than during the height of the Cold War. Similarly, France is believed to deploy three warhead designs today, and the United Kingdom only has one. It is likely that Russia retains a more diverse arsenal of nuclear weapons, but a trend to consolidate that stockpile could exist, especially in the absence of explosive nuclear testing since the 1990s.

15. Office of Nonproliferation Research and Engineering, U.S. Department of Energy, "Technology R&D for Arms Control," Spring 2001, https://www.ipfmlibrary.org/doe01b.pdf.

16. For more information, see IPNDV, "Related Resources," n.d., https://www.ipndv.org/relatedresources/ (accessed June 22, 2023).

17. The U.S. Department of Energy has recently expanded its research in this area via the new Arms Control Advancement Initiative. Jill Hruby, Remarks at the 16th Annual Strategic Weapons in the 21st Century Symposium, May 26, 2022, https://www.energy.gov/nnsa/articles/nnsa-administrator-hrubys-remarks-16th-annual-strategic-weapons-21st-century.

18. Alexander Glaser, "Monitoring Regimes for All-Warhead Agreements," in *Toward Nuclear Disarmament: Building Up Transparency and Verification*, ed. Malte Göttsche and Alexander Glaser (Berlin: German Federal Foreign Office, May 2021).

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AUKUS as a Nonproliferation Standard?

By Toby Dalton and Ariel Levite

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