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The challenges of nuclear disarmament verification

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Introduction

In one of the first initiatives in favor of nuclear disarmament, the authors of the Acheson-Lilienthal report "concluded unanimously that there is no prospect of security against atomic warfare in a system of international agreements to outlaw such weapons controlled only by a system which relies on inspection and similar police-like methods." Instead, the report proposed placing all nuclear material under the control of an international organization.[1]

The failure of the Baruch plan, proposed the following year to the United Nations to eliminate the nuclear threat based on the recommendations of this report, illustrates the challenge highlighted by its authors. On the one hand, it was possible to create a system of international guarantees on the peaceful use of nuclear technologies, strongly limiting the proliferation of military nuclear programs. On the other hand, virtually no verification regime has been deemed strong or credible enough to allow for the consideration of complete disarmament. President Truman's 1946 statement that "*I am of the opinion that we [the US] should not under any circumstances throw* away *our gun until we are sure the rest of the world can't arm against us*"[2] could therefore still be used today for all nine nuclear states.

As early as in 1946, the question of verification was a key issue in discussions about nuclear weapons. However, it was only in 1987 that a first bilateral agreement between the United States and the Soviet Union contained genuine verification-related provisions other than the use of national technical means (intelligence). Indeed, verification is only one aspect of diplomatic efforts towards arms control and disarmament. Only 10 per cent of agreements today have specific provisions in this area. Verification is therefore not necessarily indispensable, and when it exists, it always serves a specific purpose, in a specific context, in response to a given binding agreement and is not an end in itself.

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* Translated from the French.

[1] The Acheson-Lilienthal Report on the International Control of Atomic Energy, Washington, D. C., 16 March 1946.

[2] Larry Gerber, "The Baruch Plan and the Origins of the Cold War," *Diplomatic History*, vol. 6, n°1, Winter 1982.

Proposals for general disarmament in the literature generally incorporate extensive verification measures,[3] building in particular on the work of Jeremy Wiesner, who in 1961 showed that the smaller the arsenals, the higher the level of confidence in inspections must be.[4] In the case of a Nuclear Weapons Convention, the concealment of a single weapon or even a few kilograms of weapons-grade fissile material could have considerable effects. It can therefore be assumed that states require a high degree of assurance of compliance with such commitments by competitors or adversaries before embarking on a disarmament process themselves. Certainly, history shows that reductions in arsenals can be made unilaterally and on the basis of good faith (reduction of half of the French arsenal after the Cold War, Presidential Nuclear Initiatives and Soviet reciprocal measures in 1991 for the elimination of tactical nuclear weapons, etc.). Nevertheless, it seems unlikely that such confidence-building initiatives would be envisaged in a perspective of disarmament to zero.

The only verified case of unilateral disarmament, De Klerk's South Africa, offers partial lessons. The country itself dismantled its nuclear weapons in 1990 and destroyed a number of sensitive documents. Nevertheless, from 1991 to 1994, the country cooperated with P5 members and the IAEA, opened its sites to inspections and handed over its fissile material production archives, enabling the agency to affirm in 1994 its confidence in the complete nature of South African disarmament.[5] However, it is conceivable that this type of procedure would be insufficient in a bilateral or multilateral disarmament framework.

The requirements necessary in this type of scenario have been under consideration for many years. Thanks to the various studies and projects carried out, the outlines of realistic and necessary criteria in terms of verification are emerging. Thus, the literature focuses on the question of the baseline declaration, a document in which states could indicate their volumes of weapons, fissile materials and certain location elements, depending on the specifics of the agreement and respecting non-proliferation and national security constraints. The next logical step would be the identification of the weapons, their controlled transport in sealed containers and their tracking to a dismantling site. The dismantling operation is then envisaged without direct access by inspectors to the process ("black box") for reasons of sensitivity, but with provisions to ensure that no objects or materials are diverted. The final steps involve the final disposition or dilution of the fissile material, verification of the consistency of the volumes returned to the civilian circuit through inspections and the destruction of other non-nuclear components.

Beyond this overall pattern, many uncertainties remain. At the general level, it is difficult to define what level of confidence (and uncertainty) could be considered

[3] See for instance George Perkovich and James Acton (eds.), *Abolishing Nuclear Weapons. A Debate*. Washington: *Carnegie* Endowment for International Peace, 2009.

[4] Jerome B. Wiesner, "Inspection for Disarmament," *in* Louis B. Henkin, *Arms Control*, Issues for the Public, Englewood Cliffs, N. J.: Prentice-Hall, 1961.

[5] Steve Fetter, "Verifying Nuclear Disarmament," *Occasional Paper No. 29,* Stimson Center, October 1996.

acceptable by states parties to a disarmament treaty. Even more broadly, the contours of the regulatory systems governing a world without nuclear weapons are extremely blurred, whether on the future of certain technologies (use of plutonium in civil reactors...) or on the essential question of the authority responsible for enforcing such a rule.

In a more detailed and specific way, for many of the proposed steps, the technologies available today have not been sufficiently tested and need further reflection to be adaptable to a real application scenario.

In this context, several states, non-governmental institutions and scientific laboratories have chosen to launch more or less sophisticated research programs to make progress in a field that some consider essential. As progress in disarmament is slow, others question the usefulness of working on a subject that necessarily remains highly theoretical. The United States and the United Kingdom have since the 1990s been very active on this issue and have launched several cooperative projects, which have also included non-nuclear weapon states such as Norway and Sweden. France, initially reluctant to explore this field at the multilateral level, has recently revised its commitment upwards, in particular by organizing an exercise in September 2019, in cooperation with Germany, to test the procedures for one stage of a fictitious disarmament scenario. President Macron also indicated in February 2020 that this work is one of France's four priorities in the area of disarmament.[6]

This paper aims to provide an overview of the various efforts that have been undertaken in the field of verification of nuclear disarmament. It discusses the conclusions that have been drawn from this work, as well as the interplay between technological, strategic and political considerations in this field. It notes the points of progress, but also the areas that still raise questions, and concludes on the prospects of nuclear disarmament verification in the short term.

1. Verification as a corollary of arms control

1.1. A consequence of bilateral arms control initiatives

1.1.1. An issue raised at the outset of strategic arms reduction efforts

As early as in the 1960s, when the first arms control agreements were being negotiated, the United States launched exercises on the verification of nuclear disarmament. For example, in 1963 the Arms Control and Disarmament Agency (ACDA) initiated the Cloud Gap program to test the technical feasibility of potential

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[6] Speech by President Emmanuel Macron on Defence and Deterrence Strategy to the trainees of the 27th class of the Ecole de Guerre, elysee.fr, 7 February 2020.

disarmament and arms control measures.[7] This program culminated in 1967 with the practical exercise FT-34, under the leadership of the Pentagon and the ACDA, which converted 60 tons of weapons-grade uranium into uranium suitable for civilian applications. This large-scale exercise consisted in the destruction of 40 real weapons and 32 fictitious weapons and the testing of different inspection models, mobilizing 80 people within the Department of Defense (DoD). The results of these exercises demonstrated the difficulty for inspectors to distinguish with certainty between real and fictitious weapons without intrusive verification measures, and the near impossibility of gaining assurance on this issue without divulging classified information. Nevertheless, it concluded that a correct diagnosis can be made in about 80 percent of cases in the most intrusive inspection scenario.[8] Without any particular protective measures, and carried out in operational facilities, this scenario included the potential disclosure of some 100 classified information.[9]

However, this initial research remained rather theoretical in so far as the agreements envisaged with the Soviet Union were based on fairly basic verification measures. Thus, for the Salt I, ABM or Salt II Treaties, the parties were invited to use their national intelligence capabilities to ensure compliance with mutual obligations. Furthermore, there were no plans at the time to monitor nuclear warheads.

1.1.2. Feasibility studies in the United States and Russia

The situation evolved around 1985. The negotiation of the INF Treaty introduced a far-reaching verification regime, requiring in particular the exchange of notifications and data, and providing for the possibility of conducting on-site inspections. The adoption of the Start Treaty went a step further in the ambition to better guarantee compliance, with the possibility of conducting on-site inspections, planned or unannounced, and that of carrying out portal perimeter monitoring on certain sites.

In the 1990s, the progress made in arms control, but also the reflections on advanced verification regimes for a Comprehensive Nuclear Test Ban Treaty, prompted American and Russian engineers and scientists to deepen their reflections on what is verifiable in the field of disarmament.

Between 1991 and 1995, American national laboratories, as well as certain groups of experts such as JASON or FAS, carried out numerous studies, most of them unclassified, on the possibility of verifying an agreement on the dismantling of nuclear

[7] Memorandum for the Record, Steering Committee Meeting for Project Cloud Gap, ACDA, 7 February 1963.

[8] Final Report – Volume :1, Field Test Ft -34, Demonstrated Destruction of Nuclear Weapons (U), United States Arms Control And Disarmament Agency, January 1969.

[9] Wyn Q. Bowen, Hassan Elbahtimy, Christopher Hobbs and Matthew Moran, *Trust in Nuclear Disarmament Verification*, London, Palgrave MacMillan, 2018.

warheads.[10] The reports submitted by these working groups, especially by the Department of Energy, put forward a number of conclusions. In particular, they referred to the risk of passing on sensitive information during the process, the difficulty of determining the number of warheads with certainty, the inadequacy of national intelligence resources to ensure dismantling, and the virtual impossibility of achieving irreversible disarmament. They viewed the asymmetry of the Russian and American arsenals as an additional difficulty. This being the case, the Department of Energy considered at the time that its facilities could be adapted to a disarmament procedure which should focus on the initial declaration and the permanent monitoring of declared inventories. The reports noted the potentially significant costs of such mechanisms.[11]

In 1997, a new study, commissioned from the Department of Energy in anticipation of the Start III negotiations, proposed a balance between confidence in the data collected by the inspectors and protection of classified data. For its authors, a correct level of confidence could be achieved without unacceptable intrusion, provided that a very strict chain of custody is put in place very early in the process.[12]

In 1998, the Los Alamos National Laboratory carried out a demonstration of the destruction of a nuclear pit. In 1999, the Laboratory published a study entitled "*International Facility Monitoring System*" presenting experiments conducted on tags and seals.[13]

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[10] These include, for example: John B. Brown, Jr., "Nuclear Dismantlement Center (NDC) Alternatives Study (U)," Executive Summary, Volume I and II, Report Classification SRD, Prepared by Pacific Northwest Laboratory for Division of Policy and Technical Analysis, Office of Arms Control, US DOE, PNL-X-1837, 1838, 1839, November 1990, p. 19, (Executive Summary), p. l72 (Vol.I), p. 316 (Vol.II).

Report to Congress, "Verification of Nuclear Warhead Dismantlement and Special Nuclear Material Controls (U)," Report Classification SRD, Department of Energy, DP-5.1-7375, July 1991, p. 90 (the 3151 Report).

"Verifying the dismantlement of nuclear warheads," Federation of American Scientists, Report Unclassified, June 1991, p. 58.

C. Olinger, W.D. Stanbro, D.A. Close, J.T. Markin, M.F. Mullen and K.E. Apt, "Potential Transparency Elements Associated with Warhead Disassembly Operations at the Pantex Plant," Report Unclassified, Los Alamos National Laboratory, LA-CP-93-355, December 1992, p. 28.

S. Drell (Chairman) *et al.*, "Verification of Dismantlement of Nuclear Warheads and Controls on Nuclear Materials," Report Unclassified, JASON/MITRE, JSR-92-331, January 1993, p. 119.

Rodney K. Wilson (ed.), "Analysis of Potential Measures for Monitoring U.S. Nuclear Warhead Dismantlement (U)," Executive Summary, Volume II and Volume III, Report Classification SRD, Sandia National Laboratories Draft Report Numbers VST-Q49 and VST-050, October 1993, pp. 6 (Executive Summary), pp. 52 (Vol.II), p. 116 (Vol.III).

Rodney K. Wilson and George T. West, "Cooperative Measures for Monitoring U.S. Nuclear Warhead Dismantlement," Report Unclassified, Sandia National Laboratories, VST-Q51, July 1994, p. 90.

[11] Transparency and Verification Options: An Initial Analysis of Approaches for Monitoring Warhead Dismantlement, The Department of Energy, Office of Arms Control and Nonproliferation, 19 May 1997.

[12] *Ibid.*

[13] Eric R. Gerdesa, Roger G. Johnston and James E. Doyle, "A Proposed Approach for Monitoring Nuclear Warhead Dismantlement," *Science & Global Security*, Volume 9, 2001.

Although less work has been published on the Russian side, the All-Russian Institute for Scientific Research in Experimental Physics (VNIIEF) in Arzamas and the All-Russian Institute for Automation Research in Moscow also took an interest in the issue at that time, enabling them to carry out experimental research programs and to propose procedures and instruments to their American counterparts during cooperative projects between laboratories.[14]

1.2. A bilateral exercise focusing on technical aspects

1.2.1. The development of bilateral tools and procedures

The work carried out internally found a bilateral echo from the 1990s onwards. Indeed, in the wake of the Start I Treaty, Russian and American negotiators questioned the relevance and feasibility of implementing measures including the destruction of nuclear warheads. Thus, as early as 1993, the Gore-Chernomyrdin Commission provided for the setting up of a working group to verify the reduction in the number of nuclear warheads. The following year, the two partners agreed to exchange information on the composition of nuclear warheads. In addition, the US-Russian Warhead Safety and Security Exchange Agreement promoted bilateral scientific cooperation in this field by allowing the exchange of declassified data.15

In 1995, Presidents Clinton and Yeltsin issued a joint communiqué on "*transparency and irreversibility in the process of nuclear arms reduction.*" The text gives an idea of the measures envisaged at the time and mentions, inter alia, the following:

> *"The United States of America and the Russian Federation will negotiate agreements to increase the transparency and irreversibility of nuclear arms reduction that, inter alia, establish:*
>
> - *An exchange on a regular basis of detailed information on aggregate stockpiles of nuclear warheads, on stocks of fissile materials and on their safety and security;*
> - *A cooperative arrangements for reciprocal monitoring at storage facilities of fissile materials removed from nuclear warheads and declared to be excess to national security requirements to help confirm the irreversibility of the process of reducing nuclear weapons, recognizing that progress in this area is linked to progress in implementing the joint U.S.-Russian program for the fissile material storage facility at Mayak; and*

[14] Alexei Arbatov, Vladimir Dvorkin et Sergei Oznobischchev (eds.), *Russia and the Dilemmas of Nuclear Disarmament*, NTI, IMENO/RAN, Moscow, 2012.

[15] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Verifying Baseline Declarations of Nuclear Warheads and Materials*, Cultivating Confidence Verification Series, Nuclear Threat Initiative, July 2014.

- *Other cooperative measures, as necessary to enhance confidence in the reciprocal declarations of fissile material stockpiles."*[16]

In 1996-1997, bilateral cooperation was launched within the framework of the Helsinki consultations. At the Helsinki Summit, the two leaders again embarked on this path and decide that a future Start III agreement would include: "*measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads"*.[17]

1.2.2. Extensive experimentation up to 2000

In this framework, Russia and the United States carried out several extensive experiments in transparency and verification until the end of the Clinton-Yeltsin era.

As early as in 1989, they conducted a series of seven experiments to test the usefulness of several radiation detection instruments. The scenario foresaw the detection of the nuclear warhead of a cruise missile on board a ship (*Black Sea Experiment*). The methods used and the information recovered were very revealing and seem impossible to replicate in a scheme involving non-nuclear-weapon states (NNWS). Indeed, real operational Soviet weapons were used during the exercise. American scientists were satisfied with the results, and believed that if the measurement does not last too long, detection does not require the transfer of sensitive information. The Russians did not a priori have the same diagnosis. Both teams recognized the limitations of the equipment used to detect weapons protected by armored containers and the importance of being very close to the weapon in order to detect it. Despite the progress demonstrated by this project, the two countries have not replicated any new experiments involving such transfer of information since then.[18]

In 1991, the Bush and the Gorbachev administrations decided to dismantle a large part of their tactical nuclear arsenals, without associated verification measures. Nevertheless, joint work in this area continued, in particular with the launch of the Trilateral Initiative in 1996. Russia, the United States and the International Atomic Energy Agency (IAEA) and a few additional partners worked together on this project until 2002. The aim was to study the extent to which the IAEA could safeguard fissile material derived from nuclear weapons without getting access to proliferation-sensitive data. The 98 experiments conducted under this project concerned the detection of plutonium. They used the attribute method to determine the presence or absence of plutonium in a container, the presence or absence of weapons-grade plutonium, or whether the mass of the container is bigger than a given value. The

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[16] Presidents William J. Clinton et Boris Yeltsin, Joint Statement on the Transparency and Irreversibility of the process of reducing nuclear weapons, Moscow, 10 May 1995.

[17] Presidents William J. Clinton and Boris Yeltsin, Joint Statement on Parameters on Future Reductions in Nuclear Forces, Helsinki, 21 March 1997.

[18] Thomas B. Cochran, The Black Sea Experiment, Presented at "From Reykjavik to New START: Science Diplomacy for Nuclear Security in the 21st Century," Washington, 19 January 2011.

latter information was provided by measuring the multiplicity of neutrons, in addition to high-resolution gamma spectroscopy.

Most of the experiments were conducted in US and Russian weapon laboratories and production sites, with some additional experiments conducted in the United Kingdom, Japan and Italy. One of the challenges raised by the project was the question of the equipment used: it was designed by a joint team (Russia - United States - IAEA) and manufactured under mutual supervision. Certification tests were carried out prior to their use.

The project confirmed that it is possible to verify nuclear material containing plutonium of classified composition without revealing sensitive information. At the end of the project, the creation of a dedicated permanent international center on the study of verification techniques and the opening up of the project to non-nuclear-weapon states were considered, but these proposals failed to gather consensus. In addition, the IAEA considered setting up a model verification agreement. However, the political changes of the 2000s led to the initiative coming to a halt without these plans taking shape.[19]

During the same period, the United States and Russia also experimented with the final stage of fissile material destruction, signing an agreement in 1993 allowing Washington to dilute excess HEU stocks from Russia.[20] Stocks of plutonium were transformed into MOX (for Mixed Oxide Plutonium Uranium Oxide) until 2016, thanks to amendments to the Plutonium Management and Disposition Agreement.

1.3. Strategic arms control: still the point of reference

1.3.1. New Start as a reference and a starting point

The mandates of G.W. Bush and Vladimir Putin were marked by a slowdown in cooperation programs and a deterioration of bilateral relations, linked in particular to the unilateral American withdrawal from the ABM Treaty.

However, the signing of the New Start Treaty in 2010 marked further progress not only in arms control but also in verification. Indeed, the New Start retains the main measures adopted in the Start I Treaty, but simplifies the inspection process while adding new provisions. For example, the parties undertake to place a unique tag on each missile, launcher or bomber covered by the Treaty. They must also inform their counterparts of any movement of objects controlled by the Treaty. In addition, for the first time, the Treaty provides for a maximum number of warheads allowed, not just a

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[19] Thomas Shea and Laura Rockwood, *Nuclear Disarmament: The Legacy of the Trilateral Initiative*, Deep Cuts Working Paper No. 4, March 2015.

[20] Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from Nuclear Weapons, signed on 18 February 1993.

theoretical number for each missile. The number of re-entry vehicles per delivery vehicle can be checked during inspections, bearing in mind that under the Treaty, a re-entry vehicle is treated as a warhead. The Treaty provides for the possibility of conducting two types of on-site inspections. Type 1 inspections check data and inspect re-entry vehicles at deployment sites, while type 2 inspections focus on non-deployed systems. The Treaty allows parties to cover re-entry vehicles during inspections to preserve confidential information on deployed weapons. It also allows the inspected party to use radiation measuring instruments to demonstrate the non-nuclear nature of certain items.[21] As the only treaty dealing with re-entry vehicles that can demonstrate the presence or absence of a nuclear warhead, the New Start appears to be an essential point of reference for a future treaty, even if it only partially incorporates new technologies.[22]

To date, New Start has led to more than 300 on-site inspections, which provides both parties with exceptional experience in organizing inspection visits, but also in setting up a verification procedure in general.[23] As the most successful operational bilateral system to date, New Start logically serves as a model and as a starting point for considering possible new bilateral or multilateral agreements. The New Start case study not only provides an opportunity to reflect on the concrete issues associated with inspections, but also to provide feedback on what events might occur during the lifetime of a treaty and how to deal with them.

1.3.2. An endeavor to develop relevant technologies in anticipation of a Treaty

The work carried out in the context of the Start I and II negotiations in anticipation of Start III and in the context of New Start shows that in the United States, disarmament verification thinking has historically been associated with the prospect of bilateral arms control agreements. The objective was therefore to learn about possible verification techniques and their implications in terms of reliability, but also security and confidentiality, in order to negotiate more finely the protocols to treaties aimed at reducing the volume of nuclear arsenals.

It is also with this objective in mind that the United Kingdom began to take an interest in the issue in the late 1990s. For London, the political value of working on verification was clear, but it seems to have been outweighed by a desire to train experts on these issues in view of possible future arms control agreements involving the country. This is

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[21] Annex on Inspection Activities to the Protocol to the Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, 8 April 2010.

[22] NATO Nuclear Policy in a Post-INF World, Speech by NATO Deputy Secretary General Rose Gottemoeller at the University of Oslo, 9 September 2019.

[23] New START Treaty Inspection Activities, State Department, accessed on 10 June 2020 – https://www.state.gov/new-start-treaty-inspection-activities/

in line with the country's existing work on verification protocols for nuclear testing, fissile material production and chemical weapons.[24]

Indeed, given the rapid progress in disarmament in the 1990s, London believed that it was possible that the country may be affected by stockpile reduction agreements in the future. The country therefore took a political decision in 1998 to invest in this subject and to employ engineers from the Atomic Weapons Establishment (AWE) to develop a better understanding of the issues at stake and possible solutions so that it could participate in this type of agreement while guaranteeing the security of sensitive information and the credibility of the British deterrent at all times. This state of mind was at the origin of a rapprochement with Washington with the aim of benefiting from the American experience in this field.[25]

Today, AWE officials continue to view verification as an acceptable compromise between preserving deterrence and providing guarantees on the effectiveness of disarmament, in an incremental logic. The importance of preserving strategic stability throughout the process is considered paramount.[26]

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While the issue of verification is now often seen from a political perspective, it is clear that it originates primarily in a strategic and technical context. Indeed, as parties to agreements aimed at limiting and then reducing arsenals, Russia and the United States needed to understand as early as in the 1960s what was negotiable and what was unverifiable. They wanted to know the reliability of the various technologies available and the degree of transparency that could be adopted without compromising the security and effectiveness of their deterrence. Since the beginning of the 21st century, this objective of expertise has remained central to the research carried out domestically, particularly by American laboratories. However, the slowdown trend observed in the field of disarmament has made some work more theoretical. Moreover, the inclusion of NNWS in the debate is changing the perspective of international cooperation, with a more political than operational emphasis.

2. Verification: a multilateral political exercise?

As early as in 1996, the establishment of the Canberra Commission by the Australian government showed the interest of NNWS in verification issues, which was seen as an important corollary of medium- to long-term disarmament projects. The Commission's broad mandate was to consider "a realistic program" for achieving a nuclear-weapon-

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[24] Telephone interview, London, 7 May 2019.

[25] Interview conducted in London, 22 May 2019.

[26] Interview conducted in London, 22 May 2019.

free world. However, this group confined itself to political aspects without engaging in new experiments or the introduction of new technologies.[27] It offered a global vision of the various elements to be taken into account in verifying disarmament, but also the multiple parameters to be activated, for nuclear-weapon states (NWS) and NNWS, during and after the process of eliminating nuclear arsenals (Fissile Material Cut-Off Treaty or FMCT, Extended Additional Protocol, Missile Convention, extended control of plutonium and tritium, etc.). Annex A of the Commission's report looks more specifically at decommissioning issues, showing the possibility of building confidence, but also raising the inevitable high costs and uncertainties of the process.

The Canberra Commission initiated a movement to open up the debate towards NNWS, which continues today. This broader interest was initially reflected in certain specific experiments, carried out in particular with the United Kingdom. It now culminates in two parallel initiatives: the IPNDV and the UN-led Group of Governmental Experts (GGE).

2.1. The gradual integration of new players

2.1.1. UKNI and Quad: the emergence of the United Kingdom and the integration of NNWS

As early as in 1998, the AWE began working on the issue of verification. In 2000, it launched a cooperative program with the United States to test and assess the viability of certain technologies. This program, highly technical and classified for a long time, enabled the AWE to increase its expertise and to develop know-how in a peer review logic.[28] Involving above all the Ministry of Defence and AWE engineers, it got little public mention until 2005, when the Ministry of Foreign Affairs became aware of the political opportunity of promote this work. Indeed, the British delegation referred to the research in progress as one of the country's efforts to implement its obligations under Article VI of the Non-Proliferation Treaty (NPT) at the 2005 Review Conference. Furthermore, the United Kingdom announced that "*For the future, the United Kingdom will continue to monitor and evaluate technological developments with relevance to verification but, in terms of the processes and procedures needed to underpin any verification exercise, it is felt that a more focused approach should now be adopted addressing specific areas and issues. […] In the latter context the possibility of some collaboration will be explored*".[29] The political goal of integrating new partners was

[27] Commission composed of diplomats, former military, and civil society members from both NWS and NNWS. See published report: Report of the Canberra Commission on the Elimination of Nuclear Weapons, Department of Foreign Affairs and Trade, Austria, August 1996.

[28] Telephone interview, London, 16 July 2019.

[29] Verification of nuclear disarmament: final report on studies into the verification of nuclear warheads and their components, Working paper submitted by the United Kingdom of Great Britain and Northern Ireland, NPT/CONF.2005/WP.1, 2005 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, New York, 18 April 2005.

supported outside the Ministry of Foreign Affairs and in particular by certain engineers who saw it as an opportunity to work in a declassified manner.[30]

In 2006, Norway, in search of technology cooperation programs, approached the United Kingdom. The two states met for the first time to evoke collaborative opportunities in 2007. Despite the hesitation and discomfort displayed during initial contacts, the two sides managed to set up an exercise in Norway that demonstrated the possibility of working with a NNWS.[31]

The initial work carried out by the UK-Norway Initiative (UKNI) intended to address two aspects of verification. On the one hand, it developed a prototype information barrier. On the other hand, a team worked specifically on the methodology of on-site inspections.[32]

Using a fictitious and generic scenario, the first exercise showed the possibility for a NNWS to be confident about a dismantlement procedure without gaining access to classified information. The exercise took into account the issues of managed access, tags and seals, information barriers and portal perimeter monitoring. The experiment was carried out in a cooperative spirit, without any willingness or attempt to cheat on the part of the actors, with the aim at this stage of identifying potential points of disagreement between the inspected party and the inspectors, and factors creating mutual confidence.[33]

The second exercise, finalized in 2010 on AWE′s premises, was carried out in a less cooperative manner in order to take the experiment further, but was also concluded in a climate of trust.[34]

At the same time, from 2013 to 2015, more academic experiments involved British and Norwegian students. The proposed scenario foresaw a break in the chain of control. The reactions recorded made it possible to better take into account the psychological and behavioral factors that create confidence in the specific field of verification. Indeed, the researchers noted that objective elements (documents, inspections) play a complementary role to human factors (present and past attitudes) to increase the credibility of the inspected teams.[35]

Following the UKNI, Oslo and London included Sweden and the United States in their cooperative framework to set up new projects in a format known as "Quad".

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[30] Interview conducted in London, 22 May 2019.

[31] Telephone interview, Oslo, 21 June 2019.

[32] Hassan Elbahtimy, David Cliff and Andreas Persbo, Verification of Warhead Dismantlement: Challenges, solutions and prospects, IAEA-CN-184/204, 2010.

[33] Wyn Q. Bowen, Hassan Elbahtimy, Christopher Hobbs and Matthew Moran, *Trust in Nuclear Disarmament Verification*, *op. cit.*

[34] *Ibid.*

[35] *Ibid.*

The expansion of the program in 2015 brought complications in implementation, and it took almost three years to define the upcoming exercise. Benefiting from strong political support, and combining the technical skills and budgetary input of all parties, the Quad maintained a very technical dimension.[36] In October 2017, the Quad conducted the Letterpress exercise at the British base in Honington, which tested mainly the implementing of a chain of custody and the procedures of managed access, since it involved tracking weapons from the time they are withdrawn from operational deployment to the dismantling site.[37] The exercise was characterized by greater realism and a willingness to focus on a step that would be necessary at an early stage in the implementation of a strategic arms control agreement.[38] A detailed report of the exercise is expected to be presented to the NPT Review Conference (RevCon) in 2021. The four partners are developing a five-year work plan, which should lead to a new exercise in four years′ time.

2.1.2. Objectives and conclusions of the two exercises

The UKNI and the work of the Quad do not have similar political and technical reaches. From a technical point of view, the UKNI′s contribution is not nil but remains basic. Both exercises showed the ability to set up a measuring instrument that provides a barrier to the dissemination of certain information, is inexpensive and easy to replicate. It meets the pedagogical requirement of ensuring that the inspecting team master all the technologies deployed.[39] The information barrier system presented is designed to be simple, inexpensive, and creating confidence in its reliability for the user. As a corollary to this voluntary choice, the instrument remains rather unsophisticated, not very precise and does not offer very high safety guarantees. Moreover, the choice of a very simple protocol and scenario means that the exercises did not provide much new information in technical terms, even if repeating them could possibly yield useful data on inspection procedures.[40]

Generally speaking, the UKNI′s objective was primarily to demonstrate the feasibility of cooperation between a NWS and a NNWS, and this objective was met.[41] Furthermore, it can increase the understanding of non-proliferation and security issues by a NNWS, which may initially have thought that these notions were deliberately exaggerated, but

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[36] Telephone interview, London, 16 July 2019.

[37] Statement to be delivered on behalf of the QUAD, 2018 Preparatory Committee for the 2020 Review Conference of the Treaty on Non-Proliferation of Nuclear Weapons, Permanent Mission of Sweden in Geneva, 24 April 2018.

[38] Tom Plant, "The Disarmament Laboratory: Substance and Performance in UK Nuclear Disarmament Verification Research," *FIIA Working Paper*, n°111, October 2019.

[39] Telephone interview, Oslo, 21 June 2019.

[40] Interview conducted in Paris, 22 July 2019.

[41] Telephone interview, London, 16 July 2019.

became aware during the exercise of the real issues in this area.[42] Finally, it is a basis for further research as all the work carried out is published on a dedicated website.[43]

The UKNI, on the other hand, has had a much more extensive political use. From the 2010 RevCon onwards, the United Kingdom has emphasized its role in this project to comfort his image as a progressive state in the field of disarmament. This choice initially aroused some controversy domestically, but it is now assumed, and leads to cooperative work with non-governmental actors (VERTIC, King's College London...).[44]

Concerning the Quad, and pending the report on the Letterpress exercise, the format seems to be working thanks to the mobilization of technical players, but its usefulness will undoubtedly be confirmed if it manages to repeat several exercises under realistic conditions. Thanks to its political impact in the forums linked to the NPT RevCon, the political and financial support of the four states for an extension of the project seems assured.

A major innovation in both programs is the involvement of NNWS in an issue that was previously considered exclusively by a few NWS. With the political valorization of the work carried out, this parameter is becoming increasingly important, with new initiatives considering verification no longer in a bilateral or a partnership framework, but from a multilateral perspective.

2.2. IPNDV and GGE on verification: two instruments to insert the debate into a multilateral framework

2.2.1. Origins and functioning of the IPNDV

In late 2013, State Department officials began to explore the creation of an informal partnership on substantive issues related to disarmament verification. In 2014, the Nuclear Threat Initiative (NTI) study on the subject recommended the creation of a network of experts and greater involvement of NWS and NNWS in thinking about the issue.[45] This led to the creation of a public-private partnership between the State Department and NTI, the formation of which was announced in December 2014. The first meeting took place in Washington in March 2015.

Phase I of the International Partnership for Nuclear Disarmament Verification (IPNDV) was structured around four plenary meetings and three working group meetings and

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[42] Tom Plant, "The Disarmament Laboratory: Substance and Performance in UK Nuclear Disarmament Verification Research," *op. cit.*

[43] United Kingdom – Norway Initiative, https://ukni.info

[44] Telephone interview, London, 16 July 2019.

[45] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Verifying Baseline Declarations of Nuclear Warheads and Materials*, *op. cit.*

ended in November 2017 in Buenos Aires. Approximately 25 countries participated,[46] divided into three working groups (Verification and Monitoring Objectives, On-site Inspections and Technical Challenges and Solutions). During the first phase, the working groups published around 50 papers. More broadly, the Partnership agreed on a 14-step process, described below.

In practice, the first phase consisted largely of informing participants of the initiatives carried out to date: New Start, UKNI, Trilateral Initiative, but also the lessons learned in verification by organizations such as the IAEA and the Organization for the Prohibition of Chemical Weapons (OPCW). It rapidly moved towards the central phase of dismantling a nuclear weapon. From a technical point of view, this phase seems to present maximum difficulties and challenges, while at the same time being essential for building confidence in a disarmament process. On the other hand, the nuclear-weapon states wished to limit the discussion by avoiding too concrete aspects (storage sites, transport chains, etc.) or by working on a scenario that would appears too realistic.[47]

Designed to give a multilateral echo to an issue related to disarmament, in a global perspective of openness desired by the Obama administration, the IPNDV is a pedagogical tool that allows for the sharing of certain analyses and knowledge, particularly American, with like-minded states. It also aims to convey messages on the limits of verification, and in particular on the restrictions justified by the reliability, security and safety of arsenals that are still operational. From this point of view, the participants note that, even if it does not for the time being make it possible to develop concrete, shared solutions,[48] the group is useful from an educational point of view as it explains to actors who are new to these issues why certain proposals are unrealistic or unacceptable.[49] In this sense, Phase I saw a real evolution, with marked disagreements at the outset on the scope of the initiative, which tended to fade away with the launch of Phase II in a more cooperative and refocused state of mind.

Phase II, launched in 2018, saw the creation of three new working groups, respectively dedicated to the verification of baseline declarations, the verification of reductions (inspections, monitoring of dismantlement of nuclear weapons) and related technologies. Phase II involved four working group meetings and two plenary meetings, with a final meeting in Ottawa in December 2019 concluding the phase.[50] During this phase, the group tried to develop procedures beyond the existing ones and

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[46] Argentina, Australia, Belgium, Brazil, Canada, Chile, China (observer), European Union, Finland, France, Germany, Holy See, Indonesia, Italy, Japan, Jordan, Kazakhstan, Mexico, Netherlands, Norway, Philippines, Poland, Russia (observer), South Korea, Sweden, Switzerland, Turkey, United Arab Emirates, United Kingdom, United States of America.

[47] Interview conducted in Paris, 28 June 2019.

[48] Interview conducted in Paris, 28 June 2019.

[49] Interview conducted in Paris, 22 July 2019.

[50] IPNDV, Phase II Summary Report: Moving from Paper to Practice in Nuclear Disarmament Verification, December 2019.

to reflect on new dimensions of the issue. It tended to increase its external communication and to promote its work in particular during the preparatory meetings for the RevCon initially planned for 2020. In addition, some members used the forum as an incubator to look for partners and launch new technology demonstration projects. These projects were presented to the group and illustrated the role of linking up potential partners and stimulating the launch of new, more concrete or more technical initiatives.[51]

Several national or bi-national projects have thus emerged, independently but integrated into the logic of the Partnership. One example is an exercise carried out by Belgium at the Belgian Nuclear Research Centre in Mol (SCK-CEN). From 9 to 19 September 2019, the Centre hosted some thirty participants of the IPNDV for a technological demonstration of various methods for verifying the presence or absence of special nuclear material.[52] France and Germany also proposed an exercise in 2019 open to other partners to test some of the procedures identified in the first phase of the IPNDV (see below).

Focus on the Franco-German NuDiVe exercise
Nuclear Disarmament Verification Exercise

From 23 to 27 September 2019, France and Germany jointly conducted a practical exercise on multilateral inspection procedures relating to the dismantlement of a nuclear weapon. This independent exercise is valued in the framework of the IPNDV and its results will be presented more formally at the RevCon 2021.

The genesis of this project is above all political, since from the summer of 2017, the French Foreign Ministry has showed interest in conducting a cooperative project with Germany on disarmament issues. This initiative received strong political support on both sides of the border and the project is launched.

Led by the Ministry of the Armed Forces on the French side, jointly with the Ministry of Foreign Affairs, the project was mainly financed by Germany, which also provided the necessary equipment. As France could not conduct the exercise in national facilities, it took place at Forschungszentrum Jülich (North Rhine-Westphalia) in the controlled laboratory area of the Institute of Energy and Climate Research (IEK), Section IEK-6: Nuclear Waste Management and Reactor Safety. Unsurprisingly, the exercise did not involve real nuclear weapon components, but to enable the use of the detection portals, it featured radioactive substitute materials.

The two states involved requested the expertise of the United Kingdom and the United States to prepare the exercise and the whole scenario was tested for the first time in June 2019.

In September 2019, about 20 participants from 11 countries among the IPNDV partners joined Jülich and were divided into three teams (hosts, inspectors and evaluators). The week included

[51] Telephone interview, London, 16 July 2019.

[52] "30 scientists from 10 different countries: an international exercise to move closer to verifying nuclear disarmament," *SCK-CEN*, 9 September 2019.

two days of training (presentation of the scenario, location, tools and equipment, reports to be written). The exercise itself lasted three days.

NuDiVe aimed to test step 8 of the IPNDV, but did not focus on the technological aspects since a real weapon could not be used. The objective was in fact to carry out the inspection procedure and to ensure during the exercise that the chain of custody remained unbroken through the dismantling phase of the nuclear materials initially integrated in a nuclear warhead. In order to make the scenario more relevant with regard to the nature of the Jülich installations, the scenario envisaged isolating the explosives during a fictitious preliminary stage, not considered in the exercise. The step considered by NuDiVe therefore consisted solely of the separation of the nuclear material from the other components of the weapon (neither explosives nor nuclear). The objective of the inspectors was to ensure that no diversion of nuclear material occurred during this dismantling process, by guaranteeing the monitoring of the installation (perimeter portal monitoring, CCTV, etc.).[53]

France's involvement brought a touch of realism to the exercise, particularly in the conduct of inspection procedures, designed to take into account non-proliferation and national security issues, as well as the safety and security constraints associated with the regulations of a NWS. All participants welcomed the innovative multilateral nature of the exercise (11 nationalities). The actors involved unanimously acknowledged the exercise's political rather than technical scope. Participants nevertheless noted several lessons learned from the exercise, in particular on the operational nature of the work carried out by the IPNDV, and on how to organize disarmament-related exercises with realism.

In December 2019, Canada demonstrated the use of muon tomography, a technology that uses cosmic muons to produce three-dimensional images.

IPNDV participants are unanimous on the desirability of launching a Phase III of the partnership, although they occasionally diverge on the issues that it should address. Many actors wish to give the work a much more concrete character by trying to work around an application scenario. Some countries, including France, want to avoid giving the impression that the framework should be taken as an example for future negotiations. Others fear that there will be no real progress if new dimensions are not addressed, including in significantly different fields (North Korea's disarmament, for example). The compromise will probably be to propose one or more scenarios that are sufficiently fictitious and vague, so as not to give the impression of creating a single implementation model, to avoid going into details deemed sensitive and to reflect the diversity of cases that may be encountered.[54]

The IPNDV plays a key role in opening the discussion to new actors. However, it is inevitably imperfect. On the one hand, the United States' choice to initially invite about 20 countries for practical reasons mechanically excludes many other potentially interested countries.[55] Secondly, participation in the work requires a level of

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[53] Interview conducted in Paris, 7 June 2019.

[54] Interview conducted in Utrecht, 17 June 2019.

[55] Interview conducted in Utrecht, 17 June 2019.

investment since countries need to send delegates to several meetings annually. Many countries do not have the financial or human resources to be active in the partnership, which contributes to making the group less representative by favoring the richer and more industrialized states. Finally, since 2018, Russia no longer participates in the work, and neither China. These withdrawals, officially motivated by the fear that the initiative might facilitate proliferation, mainly reflect political considerations. The absence of India and the Pakistani withdrawal contribute to make the IPNDV Western-centric, which tends to tarnish its legitimacy among a number of actors.

2.2.2. An issue included to the agenda of the United Nations

To help address this criticism in particular, Norway and Brazil proposed in 2017 to establish a governmental group of experts within the United Nations. The First Committee and then the UN General Assembly adopted the proposal on 14 December 2016, with only 6 abstentions, including Russia and China.[56]

The group planned three five-day working sessions between 2018 and 2019, with the publication of a report to be presented at the RevCon in 2021. The group, composed of 25 participants,[57] had the advantage of being geographically and politically diverse and of including almost all nuclear states.[58] It reintegrated Russia into the discussion, a key player on this subject but very cautious about opening the discussion to NNWS. The GGE bore witness to the importance of the subject, which is considered by the vast majority of states to be a relevant topic in disarmament discussions. It also made it possible to have archived discussions and to publish the state of the debate, and in particular the compromises acceptable in the current environment on the principles of verification of nuclear disarmament.[59]

During the GGE's meetings, the example of the group of scientific experts that reflected on the verification system of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) was regularly mentioned. At the last meeting of the group, Brazil proposed the creation of a counterpart group attached to the Conference on Disarmament. The proposal was received with some skepticism, especially from the nuclear states, for which it seems premature. In particular, some considered that it could be redundant with the IPNDV and other existing forums, while others, led by Russia, were concerned about the potentially proliferating nature of such an initiative.[60]

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[56] Resolution adopted by the General Assembly on 5 December 2016 [on the report of the First Committee (A/71/450)] 71/67.Nuclear disarmament verification, 14 December 2016.

[57] Algeria, Argentina, Brazil, Chile, China, Finland, France, Germany, Hungary, India, Indonesia, Japan, Kazakhstan, Mexico, Morocco, Netherlands, Nigeria, Norway, Pakistan, Poland, Russia, South Africa, Switzerland, United Kingdom, United States.

[58] Telephone interview, London, 16 July 2019.

[59] Final Report of the Group of Governmental Experts on Matters of Verification of Nuclear Disarmament, A74/90, 15 May 2019.

[60] Interview conducted in Paris, 7 June 2019.

2.3. An issue of growing political importance in the NPT framework

2.3.1. Incremental efforts to communicate on the advances achieved

In the course of their national and bilateral work, the Russians and the Americans chose to publish certain reports and data. Some documents were primarily scientific works published for their contribution to research in nuclear physics and other disciplines. Other publications are seen as a gesture of transparency, either to the domestic population, to an adversary or to the international community, in this case to build confidence and make a step towards disarmament.

Thus, the United States produced a declaration in 1994 listing the volumes of plutonium produced since 1944, in a de-classification initiative justified by the need for greater transparency and made possible by the end of the Cold War. The United States indicated at the time that it hoped that the report would "*encourage other nations to declassify and release similar data*", available for "*formulating policies with respect to disposition of excess nuclear materials.*"[61] The report was updated in 2012[62] and complemented by a similar document on HEU inventories.[63] The United States saw the publication of these reports as an opportunity to disseminate official information on the amount of material held, and thus to promote DoE discussions on the storage of materials, their safety and security and the disposal of excess nuclear material. The UK followed with the publication of the plutonium accounting in 1998[64] and the highly enriched uranium accounting in 2006.[65] In the interest of transparency and as a confidence-building measure *vis-à-vis* the international community, the IAEA encourages all countries concerned to publish such data. In the framework of their Safeguards Agreements, France, for example, publishes certain information on its possession of civilian highly enriched uranium (HEU) (INFCIRC 549). In the course of the past Nuclear Security Summits, France encouraged the adoption of standardized forms for the publication of this information.[66]

Efforts to achieve transparency are therefore also linked to the implementation of IAEA safeguards systems and are pursued by these countries with the objective of being exemplary in terms of fissile materials safety and security. These efforts are

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[61] Plutonium: the First 50 Years. United States Plutonium production, acquisition and utilization from 1944 through 1994, DOE/DP-0137, U.S. Department of Energy, February 1996.

[62] The United States Plutonium Balance, 1944-2009 (An update of Plutonium: The First 50 Years, DOE/DP-0137, February 1996), U.S. Department of Energy, June 2012.

[63] Highly Enriched Uranium Inventory: Amounts of Highly Enriched Uranium in the United States, U.S. Department of Energy, 2006.

[64] Plutonium and Aldermaston: An Historical Account, Ministry of Defence, 2000.

[65] Historical Accounting for UK Defence Highly Enriched Uranium. A report by the Ministry of Defence on the role of historical accounting for Highly Enriched Uranium for the United Kingdom's Defence Nuclear programmes. March 2006.

[66] Civilian HEU: France, *NTI, updated* 8 October 2019, https://www.nti.org/analysis/articles/civilian-heu-france/

therefore promoted in forums dedicated to these topics within the IEAE. Thus, the Trilateral Initiative was the subject of detailed presentations within the Agency. From 2000 onward, the issue has also been regularly addressed within the framework of the NPT.

2.3.2. A rising political profile

For example, the United Kingdom released a first working paper on the issue of nuclear disarmament verification at the 2000 Review Conference, setting out its work program and making it a cornerstone of the implementation of its obligations under Article VI of the Treaty.[67] From 2000 to 2019, the United Kingdom published seven working papers on this subject, including a report on the UKNI experiments. Several events were also organized by the United Kingdom in the margins of Conferences or Preparatory Committees on this subject.

From 2012 onwards, other actors published papers on nuclear disarmament verification, including papers from the Non-Aligned Movement (NAM)[68] and the European Union.[69] The United States dedicated their first side-events to the topic in 2014: one presented American-British cooperation, the second dealt with the innovations approach framed in collaboration with NTI. The following year, the State Department presented the IPNDV, and again in 2018, when the Quad Letterpress exercise was also the subject of a presentation. Other states used NPT Preparatory Committees and RevCon to publicize their work, or those of NGOs, such as New Zealand in 2017 (UNIDIR report), Norway (GGE in 2018), Sweden (Quad), or France and Germany in 2019 (NuDiVe exercise), including the organization of side-events. Several other papers or events are planned for the 2021 Review Conference.

The purpose of these presentations is clearly to promote the work done under the disarmament pillar. This effort is seen as all the more important for the NWS, given the meager tangible progress in terms of disarmament, and the fact that they are regularly accused of failing to implement their Article VI obligations. It is also highly valued by some NNWS, including NATO allies, which are strongly committed to the implementation of NPT disarmament obligations and are accountable to demanding public opinion in this regard.

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[67] Working paper submitted by the United Kingdom of Great Britain and Northern Ireland, NPT/CONF.20VO/MC.IIWP.6, 2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 4 May 2000.

[68] "Multilateral nuclear disarmament verification: applying the principles of irreversibility, verifiability and transparency," Working paper submitted by South Africa on behalf of Brazil, Egypt, Ireland, Mexico, New Zealand and Sweden as members of the New Agenda Coalition, Preparatory Committee for the 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2015/ PC.I/WP.30, 26 April 2012.

[69] "Nuclear disarmament verification, Working paper submitted by the European Union," Preparatory Committee for the 2020 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF.2020/PC.II/WP.6, 8 March 2018.

Many feel that communication could be further intensified and that working documents could be better circulated.[70] Indeed, the often technical nature of the work explains the difficulties in reaching a wide audience on this subject. However, the emphasis placed on the issue in recent years is undeniable, leading some NNWS to denounce a certain "political display" rather than a sincere effort to make progress on disarmament.[71]

It is difficult to assess the extent to which this political valorization is beneficial to states that make it a major element of their disarmament diplomacy. The case of the United Kingdom is interesting in this regard. At the national and political level, funding for research in the field of verification is one of the measures that have placed the United Kingdom at the forefront of efforts to promote multilateral disarmament. In particular, this position was seen as essential by the Labour Government (1997-2010) to counterbalance the decision to reinvest in the naval component of its deterrent. This choice was contested within the government and in Parliament, and it seemed fundamental for several political leaders at the time to favor a policy perceived as balanced between deterrence and disarmament.[72]

Since then, London's leading role in verification, and in particular the UKNI program, has been systematically highlighted in the presentation of British nuclear policy, particularly to Parliament.[73] Many parliamentarians support this investment during debates on the subject[74] and it is regularly quoted as a trademark of the British commitment to disarmament, for example in strategic documents.[75] This work is therefore seen by many elected representatives, particularly from the Labour, as a sign of the British Government's good faith in implementing its disarmament obligations. Among unofficial experts, this specificity contributes to making the United Kingdom appear to be a good citizen in the field of disarmament (along with the major reductions to its arsenal and the elimination of the air component).[76] The literature frequently designates London as the most advanced and progressive of the P5 countries in terms of disarmament.[77] In general, this preliminary work is considered

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[70] Interview conducted in Utrecht, 17 June 2019.

[71] Interview conducted in Livingstone, 10 July 2019.

[72] Tom Plant, "The Disarmament Laboratory: Substance and Performance in UK Nuclear Disarmament Verification Research," *op. cit.*

[73] "The UK's nuclear deterrent: what you need to know," *Policy Paper*, Defence Nuclear Organisation, Ministry of Defence, updated on 19 February 2018.

[74] Debate, House of Lords, Nuclear Weapons (International Relations Committee Report), Volume 799, 16 July 2019.

[75] *National Security Strategy and Strategic Defence and Security Review 2015, A Secure and Prosperous United Kingdom*, Cm 9161, November 2015.

[76] Shatabhisha Shetty, "The UK and the NPT Review Conference: Beyond the Status Quo?," *Commentary*, European Leadership Network, 23 April 2019.

[77] Lawrence Freedman, "British Perspectives on Nuclear Weapons and Nuclear Disarmament," *in* Barry Blechman et Alexander Bollfrass, *National Perspectives on Nuclear Disarmament*, Stimson Center, mars 2010.

rather useful in substance, not just as a symbol, by British experts, and is therefore supported.[78]

Nevertheless, this analysis must be qualified. First of all, at the national level, movements challenging deterrence, which are nowadays found within the SNP or on the left wing of the Labour, tend to have little interest in the issue and to judge that London is not succeeding in implementing its disarmament promises.[79]

At the international level, the political benefits are less clear-cut. Indeed, the British investment is appreciated by disarmament-sensitive Allied states, particularly its Nordic partners, as it reflects a serious commitment, not just a "communications stunt".[80] It goes more unnoticed by the states that are most critical of the way in which Article VI of the NPT is being implemented today. These states do not insist on the policies and specificities of the nuclear-weapon states, and the delegitimization of nuclear weapons promoted by the Humanitarian Initiative tends to increase this phenomenon. Indeed, its proponents state that the possession of nuclear weapons cannot be justified and that there can be no doctrine of responsible or safe deterrence. In this context, a long-term policy, such as that aimed at addressing verification, does not appear to be up to the task. Moreover, London's willingness to play a positive role in the P5 on disarmament issues may look inconsequential in the face of the deterioration of inter-power relations and the collapse of the arms control system. The fact that the publication of reports, for example on UKNI and the Quad, coincides with the renewal of Trident prevents London from fully benefiting from its efforts. Finally, the last RevCon split over the treatment of the Humanitarian Initiative and the question of a zone free of weapons of mass destruction, two points on which the British positions are not reconcilable with those of a large majority of NNWS. If the United Kingdom's aim was to use its expertise in disarmament verification for the sole purpose of improving its image within the NPT, then it would be impossible to qualify such a maneuver as a success.

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The difficulties encountered in the field of arms control and disarmament over the past decade or so are changing the approach to many verification-related discussions. The link between bilateral agreements and verification is becoming blurred. Tensions between Moscow and Washington make it unlikely that there will be a renewal of extensive experimentation, for example on real nuclear weapons. The integration of

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[78] Tom Plant, "The Disarmament Laboratory: Substance and Performance in UK Nuclear Disarmament Verification Research," *op. cit.* ; Cristina Varriale, "Considering UK Disarmament Efforts", *The UK Project on Nuclear Issues Blog,* RUSI, 26 April 2019.

[79] Stephen Gethins, "The UK, Scotland, and the call for nuclear disarmament," *Commentary*, European Leadership Network, 1 December 2016 ; Tim Street, "The UK's Nuclear Future: Options between Rearmament and Disarmament," *Oxford Research Group*, 31 March 2016.

[80] Tom Plant, "The Disarmament Laboratory: Substance and Performance in UK Nuclear Disarmament Verification Research," *op. cit.*

NNWS is provoking a renewed interest in the subject, but makes discussions more theoretical, because of the need to limit the dissemination of sensitive information. In this context, verification takes on a mainly political character: it allows countries invested in this subject to demonstrate their good faith in implementing their disarmament obligation. It is also a means, particularly for the United States, which has initiated the IPNDV, to counter what it sees as simplistic disarmament rhetoric and to point out the complexity of possible mechanisms and obstacles to an early resolution of the issue. In this context, the contours of a process are beginning to emerge and seem to be acceptable to a majority of states interested in the topic. However, some aspects remain very problematic, while other states or groups of experts offer radically different visions of a verified complete disarmament.

3. State of the debate: progress on the procedure, persisting technical challenges

3.1. The contours of a verified process

3.1.1. The 14 steps of the IPNDV: a relatively consensual general outline

The accumulation of work done by centers of expertise such as VERTIC or NTI, independent experts or groups of states has led to the emergence of shared visions of what a disarmament agreement should include in terms of verification.

As for the method, one of the most frequently detailed topics concerns baseline declarations. For the vast majority of the teams working on the subject, any multilateral disarmament process would begin with the elaboration of declarations by nuclear states that could be progressively verified throughout the disarmament process. These declarations could include information on the amount of weapons, but also their location, type, status and even serial numbers, depending on the framework of the negotiated agreement. Amounts of fissile material held could also be provided, as well as information on production sites and plants. Information on weapon materials could be disclosed progressively, either in general or in aggregate form. These declarations could not be of absolute accuracy: nuclear material accounting has not been done with the same rigor in all nuclear states since 1945,[81] so a margin of error would have to be accepted. At the end of the process, nuclear archaeology techniques, in addition to intelligence estimates, are envisaged to confirm the consistency of the baseline declarations.[82]

[81] In particular, the publication of HEU inventories by the United States and the United Kingdom led to the realization that the volumes actually inventoried did not correspond to the historical accounting work, as a few kilograms were missing from stockpiles.

[82] Steve Fetter, "Verifying Nuclear Disarmament," *op. cit.*

Most of the published reports suggest setting up, following the establishment of the baseline declaration, a chain of control on the declared objects. The aim is to be able to authenticate and track a declared object and thus avoid any attempt at diversion or concealment. This chain of custody is implemented by means of remote monitoring and on-site inspections. In order to ensure that the controlled objects are always identical, they must be identified by means of a unique, non-forgeable tag sealed on the system or its container. Tagging is also necessary to implement sampling techniques during inspections. In parallel, all sites concerned must be under surveillance, which does not require penetrating the facilities, but setting up portal perimeter monitoring that can prevent the clandestine transfer of declared materials.

Like most existing verification regimes, a nuclear weapons dismantlement program would require on-site monitoring inspections, which could, inter alia, remove doubts about declarations, ensure the chain of custody and verify that the dismantled items correspond to what has been declared. Such inspections would have to be relatively intrusive, given the stakes involved. They should, however, provide for a certain right of oversight by the state concerned, in particular for security reasons. They could be organized on a managed access basis, indicating which sites can be inspected and which facilities are off-limits.

In addition to these arrangements, most of the proposals recommend relying on national technical means, which are already widely used in the verification of other arms control agreements, and on societal verification as an ultimate guarantee (see below).

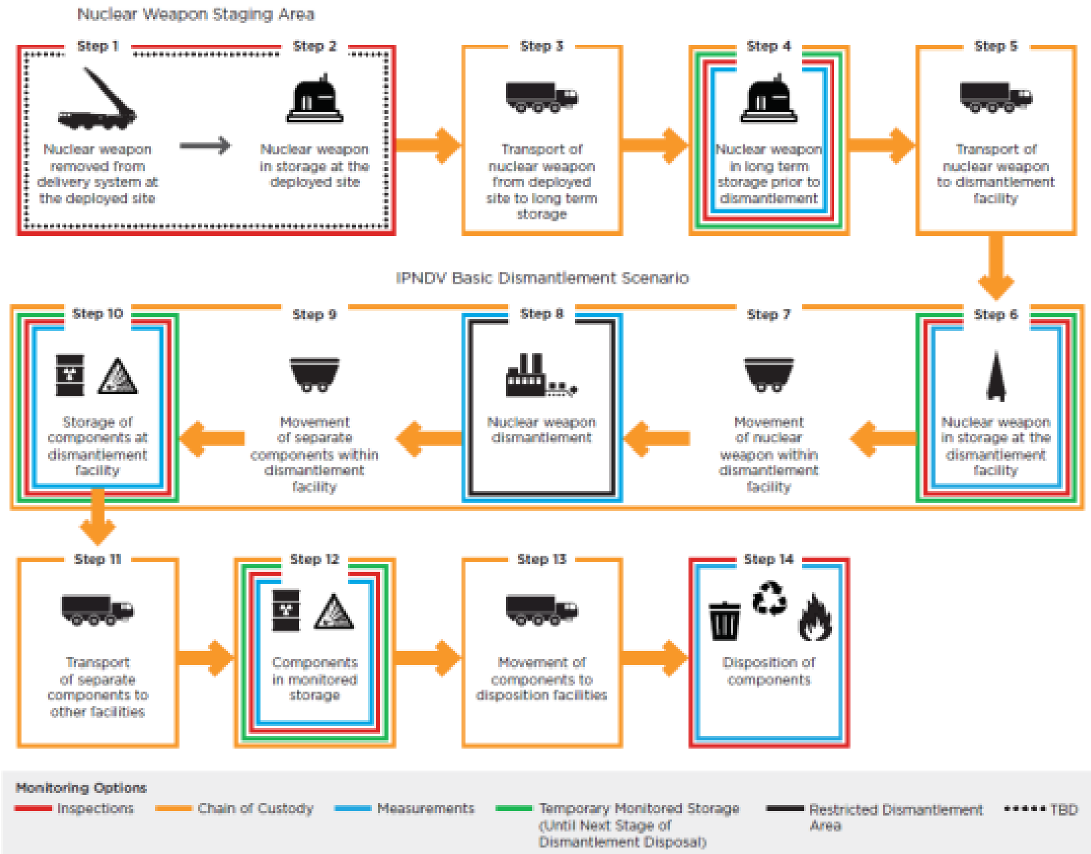
The final stages concern the destruction of non-nuclear and nuclear materials that make up nuclear weapons, with several options for making the dismantlement irreversible.

One of the virtues of the IPNDV is to put all of these methods into perspective and to break down a theoretical dismantling process into stages. To the states participating in the Partnership, as well as to a large number of researchers and academics, these 14 steps appear to be the most logical and comprehensive theoretical path to undertake verified disarmament.

The first step is to remove nuclear weapons from their delivery vehicle at the deployment site, allowing them to be stored at the deployment site (1 and 2). The weapons are then transported (3) to a long-term storage site, awaiting dismantling (4). The next step is to transport the weapons to the dismantling facility (6), where the weapons are moved (7) to their dismantling site (8). The individual components from the weapons are then sorted according to their nature (9) and stored (10). They are then transported (11) to specific facilities (12) before being transferred to processing centers (13) where they can be disposed of or reconverted to civilian use (14).

Throughout this process, various verification methods are employed, with an unbroken chain of custody from the deployment site to the disposal of the material. Six steps can be subject to on-site inspections, five of which include the possibility of carrying out measurements on nuclear objects (see diagram below).

MONITORING AND VERIFICATION ACTIVITIES, AS IDENTIFIED BY THE IPNDV, FOR KEY STEPS IN THE PROCESS OF DISMANTLING NUCLEAR WEAPONS



*We make the assumption that there will be declarations at each step in the process.

The IPNDV working groups focus on what is considered to be the core of the process, i.e. the stages centered around decommissioning, with some partners reluctant to raise certain subjects for security reasons (transport of weapons, concrete organization of facilities) or because it is difficult to imagine at this stage what decisions would be made in the distant prospect of a disarmament agreement (better way to proceed with the elimination of nuclear materials...).

The objective is to make the most of the confidence generated by the chain of custody, avoiding as far as possible intrusive, complex and costly methods such as taking measurements. The partners agree on the need to find an acceptable, realistic system that strikes a balance between effectiveness and cost. To do this, they favor a systemic approach, and building confidence throughout the process through the addition of multiple levels of control but also taking into account psychological and human factors.

The IPNDV has therefore led to the identification of a relatively consensual procedure that could be used to build a model of verified disarmament. The Partnership has also made it possible to take stock of already known technologies that could be applied to take measures or implement the chain of custody.

3.1.2. Technologies identified for a number of steps

Certain techniques now seem to be indispensable for verifying the process, although not all of them have been demonstrated to be reliable under operational conditions. They are therefore at the heart of some scientific research programs and experiments.

At the beginning of the process, it is necessary to have a system of tags and seals that cannot be tampered with or opened without detection. In 1999, the American Los Alamos national laboratory began experiments in this area.[83] At that time, American engineers noted that the seals available and in use did not meet the minimum necessary security and robustness criteria. Several necessary conditions are described for the use of seals. They must satisfy both the inspectors and the inspected party that they are not tampered with or used for intelligence gathering. The use of high technology could be counterproductive in this regard by facilitating electronic or cyber tampering, as opposed to more traditional and passive systems. Seals used for disarmament purposes must also be compatible with devices meeting nuclear security needs. A high degree of transparency should therefore be considered, in addition to other criteria generally associated with safeguards seals.[84]

Since then, some additional work has been produced on this issue, highlighting the need for reliable tags and seals, but also the lack of equipment available today to perform this function under acceptable conditions of security and reliability.[85] The IAEA has significant experience in this area, using in particular, in addition to its historic metal seals, COBRA seals, whose unique optical signature is ensured by micro-photography, or electronic seals, which can be remotely examined.[86] In 2012, Sandia National Laboratories produced a new ceramic seal to replace metal seals used since the 1960s and difficult to handle (hard to install and impossible to check for tampering at the inspection site). Research on the prototypes produced is still ongoing.[87]

Subsequently, several technologies are identified to maintain a chain of custody throughout the dismantling stage. Traditionally, IAEA inspectors, or arms control inspectors, tend to favor site monitoring, in particular through the implementation of portal perimeter monitoring. In the area of disarmament, this includes the positioning

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[83] Eric R. Gerdesa, Roger G. Johnston and James E. Doyle, "A Proposed Approach for Monitoring Nuclear Warhead Dismantlement," *Science & Global Security*, Volume 9, 2001.

[84] Roger G. Johnston, "Tamper-Indicating Seals for Nuclear Disarmament and Hazardous Waste Management," *Science & Gobal Security*, vol. 9, 2001.

[85] Frances Keel, Chris Pickett and Keith Tolk, "Preliminary Results from the 2010 INMM International Containment and Surveillance Workshop," Institute of Nuclear Materials Management, 2010.

[86] Vincent Fournier, "Surveying Safeguarded Material 24/7," IAEA Office of Public Information and Communication, 12 September 2016.

[87] Heidi Smartt *et al.*, "First Prototype of Intrinsically Tamper Indicating Ceramic Seal (ITICS)," Sandia National Laboratories, 2012.

of portal monitors designed to be reliable but not to reveal sensitive information; and external monitoring.[88]

Furthermore, it is recognized that monitoring limited to sites may not be sufficient to ensure the absence of diversion of controlled items. US laboratories are therefore working on projects to ensure better monitoring of the objects themselves. To do so, they use sophisticated radio-frequency identification tags, combined with extensive radio surveillance systems, cameras, monitoring portals and motion detectors.[89]

As the process progresses, inspections are planned to confirm the presence of a nuclear warhead through radioactivity measurements. For obvious practical reasons, sampling techniques could be used, which have already been implemented by the IAEA.[90] Several proposals have been made for a measurement protocol to ensure the presence or absence of weapons. Among the proposals and projects carried out, various indicators have been considered:

- Presence of plutonium-239 (using gamma spectroscopy);
- Minimum ratio of plutonium-239/plutonium-240 (high-resolution gamma-ray spectroscopy);
- Mass of plutonium-239 (high-resolution gamma spectroscopy and passive neutron multiplicity counting);
- Age of plutonium;
- Absence of oxide;
- Measurement of symmetry attribution of plutonium;
- Presence of uranium-235 (gamma spectroscopy);
- Uranium-235 mass (neutron multiplicity);
- Uranium enrichment beyond a certain level (neutron multiplicity);
- Presence of explosives (detection of nitrogen, carbon, nitrogen, oxygen).

Some measures are more difficult to achieve. For example, scientists consider that it could be difficult to detect the presence of uranium-235 using passive techniques, depending on the conditioning of the object being inspected, and that an active interrogation technique could be more effective, although it is intrusive and raises questions about the safety of the nuclear weapon. On the other hand, the use of neutron multiplicity has not been shown to be effective in the measurement of uranium-235. Some proposals therefore suggest simpler measurements, such as the

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[88] Danielle K. Hauck, “The Role of Portal Monitors in Arms Control and Development Needs,” Los Alamos National Laboratory, 2012.

[89] C.A. Pickett, *et al.*, “Technologies for Real-Time Monitoring and Surveillance of High-Valued Assets,” Oak Ridge National Laboratory, 2007; and Rustem Samigulin, Dennis Nelson *et al.*, “Development of Next Generation Advanced Remote Monitoring System,” VNIIEF and Sandia National Laboratories, 2007.

[90] William H. Geist, "Title: IAEA Sampling Plan," LA-UR-17-28351, Los Alamos Laboratory, 2017.

absence or presence of fissile material.[91] Repetition of the measurement could help to increase its reliability.[92] In the light of the current proposals, the principle of taking measurements seems to be accepted, but the acceptable compromise between the degree of confidence and the complexity of the device is discussed. Moreover, the central problem surrounding any measuring remains the non-disclosure of sensitive information to the inspectors. It is therefore a question of designing instruments that answer the question posed in a binary way (yes or no), and do not give additional indications about the composition or geometry of a material or object.

These criteria are fulfilled by different information barrier systems. Two types of instruments are nowadays considered to be able to fulfill this role. The first is based on the template method, a method developed by the Brookhaven National Laboratory from 1988 onwards. It has been tested in the United States for some twenty years and since 1998 has shown that it can be used without revealing classified information. The objective of this method is to be able to compare the radiological signature of an object to a referenced template corresponding to a catalogued warhead, without having access to this information.

Most of the models developed so far focus on passive detection and target plutonium. The first prototype, called CIVET (*Controlled Intrusiveness Verification Technology*), was tested several times on objects that could be covered by a disarmament treaty in the 1990s.[93] Between 1999 and 2001, Sandia National Laboratories developed the TRIS, a model which, according to the Department of Energy, proved its reliability during demonstration exercises at the Pantex plant.[94] A more elaborate version is presented in 2007 (TRIS New Generation), whose objective is to increase the security of the system and to facilitate its authentication.[95] A model of active detection seems to have shown its effectiveness for uranium-235 during a demonstration at Oak Ridge in 1984.[96]

The disadvantage of the template method remains the difficulty of certifying the results. Its advantages are its speed (about ten minutes) and its ability to be applied on

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[91] Danielle K. Hauck and Duncan W. MacArthur, "Benefits of a 'Presence of Fissile Material' Attribute for Warhead Confirmation in Treaty Verification," LA-UR-13-25330, 54th Annual Meeting of the Institute of Nuclear Material Management, 15 July 2013.

[92] Moritz Kütt *et al.*, "Authenticating Nuclear Warheads with High Confidence," Annual Meeting if the Institute of Nuclear Material Management, 1 July 2014.

[93] Cesar Sastre, Jonathan Sanborn and Joseph Indusi, "CIVET - A Controlled Intrusiveness Verification Technology," *Verification Technologies,* March/April 1991.

[94] Kevin Seager *et al.*, "Trusted Radiation Identification System," Sandia National Laboratories, Proceedings of the 42nd INMM Annual Meeting, July 2001.

[95] Peter B. Merkle *et al.*, "Next Generation Trusted Radiation Identification System", Proceedings of the Institute of Nuclear Materials Management Annual Meeting, 2010.

[96] Yan Jie and Alexander Glaser, "The Challenge of Nuclear Warhead Verification for Arms Control and Disarmament: A Review of Attribute and Template Systems," 14th PIIC, Beijing Seminar on International Security, 2014.

large volumes. In this context, it is considered useful to re-establish a chain of custody after a voluntary or accidental break.

The template method is complementary to the attribute-type measurement. This second option consists in certifying the presence or absence of an isotope, its mass or ratio to ensure that the object is a warhead. The attribute method is all the more effective as several characteristics can be taken into account. It necessarily takes longer (between 20 minutes and one hour), especially when a more accurate measurement is being taken. It is useful for making the initial templates. Several devices, presented in the table below, have been designed and tested, using several characteristics among the indicators mentioned above.

Tableau n° 1 : SUMMARY OF ATTRIBUTE MEASURING DEVICES TESTED TO DATE

Attributes	Attribute Systems						
	TRADS (US)	AVNG (Russia)	AMS/IB (US)	NG-AMS (US)	3G-AMS (US)	UKNI* (UK-Norway)	INPC (China)
presence of plutonium	(✓)	✓	✓	(✓)	✓	✓	✓
plutonium Isotopics	✓	✓	✓	✓	✓	✓	✓
plutonium mass	✓	✓	✓	✓	✓		✓
plutonium age			✓	✓			✓
absence of oxide			✓				✓
symmetry			✓				✓
presence of U-235					✓		
uranium enrichment					✓		
U-235 mass					✓		
presence of high explosive					✓		

* As described in the text, only gamma ray sources were used in the research phase to date.

VNIEEF developed the AVNG in cooperation with Los Alamos and Lawrence Livermore National Laboratories in the context of the Trilateral Initiative. Using gamma spectroscopy and neuronic multiplicity, the AVNG seeks to identify the presence of plutonium, a plutonium mass greater than 2 kg and a Pu-240/Pu-239 isotope ratio less than 0.1. The experiment did not demonstrate that the device was fully reliable. The Russians and the Americans therefore conducted a new demonstration in June 2009 in Sarov, Russia. In 2000, engineers from Los Alamos presented a Russian team with another system including three additional features, as well as a simple yes/no display symbolizing the inclusion of an information barrier in the device. Between 2005 and 2008, the United States designed a device using commercially available hardware and software to increase user confidence in its non-falsification. At the same time, the NNSA also funded the development of the first third generation measurement system that takes into account the presence of uranium and explosives. As mentioned above, the UKNI enabled the use of a simple system based on the detection of plutonium, while China tested in 2011 a device also based on six characteristics related to plutonium (the work was carried out by the Institute of Nuclear Physics and Chemistry at the Chinese Academy of Physical Engineering).[97]

The attribute method is often considered more effective for a small number of objects, or for checking objects that do not have the same characteristics. The advantage of the attribute method is that it does not store classified data.

3.1.3. National or scientific research programs

In view of the relative consensus that exists on this verification procedure and methods, government and independent research programs are seeking to improve these technologies and to resolve certain difficulties.

At the governmental level, American laboratories continue to publish the results of their work on a regular basis, in particular on tags and seals, surveillance, or information barrier systems. Thus, Brookhaven, Pacific Northwest and Lawrence Livermore are particularly well known for their research on radiation detection. The British AWE is also involved in this field,[98] along with the United States and its Quad partners.

The US-British partnership officially began in 2000.[99] Its main projects include demonstrations of various measuring instruments and processes developed by the two partners, inspection exercises with managed access and discussions on the tools used to maintain the chain of custody and to provide an information barrier. The two states are pursuing their work around two priorities. On the one hand, the campaign to measure a series of nuclear weapons and specific components data is to be continued, with a view to archiving the findings. On the other, the two countries are working on the establishment and testing of a radiation-detecting portal that can be used safely in sites hosting nuclear weapons.[100]

Regarding NNWS, Sweden is pursuing several projects within the Swedish Defence Research Agency (FOI). Norway's verification work is conducted by the Norwegian Radiation Protection Authority (NRPA), NORSAR, the Norwegian Defence Research Institute (FFI), and the Institute of Energy Technology (IFE).[101]

Non-state research centers are also at work, thanks to public or foundation funding. VERTIC is one of the most active organizations in this field, with numerous publications and analyses related in particular to the application of safeguards systems to a nuclear-

[97] Yan Jie and Alexander Glaser, *op. cit.*

[98] Tom Plant, Arms Control Verification Research at AWE Capability Lead, September 2016.

[99] Tom Plant, « The Disarmament Laboratory: Substance and Performance in UK Nuclear Disarmament Verification Research », *op. cit.*

[100] Joint US-UK Report on Technical Cooperation for Arms Control, NNSA, NPAC, AWE, Ministry of Defence, 2017.

[101] Telephone interview, Oslo, 21 June 2019.

free world. Recently, the Center has made proposals on the creation of a group of experts related to disarmament[102] and on ways to better support research in this sector.[103] Projects had been carried out in previous years on the role of IAEA in the implementation of disarmament.

In terms of procedure, the most comprehensive approach is undoubtedly that of NTI, which set up working groups in 2012 to work on many aspects of disarmament. Three publications were drawn from these reflections. The reports make proposals on the main unresolved issues.[104]

UNIDIR, for its part, regularly works on proposals for disarmament verification, building on its work on FMCT. UNIDIR also supports the GGE on disarmament verification. This work is funded, *inter alia*, by the Scandinavian countries and New Zealand.

Other institutions focus more on scientific and technical aspects. For example, the Nuclear Futures Laboratory, a multidisciplinary project at Princeton University (Department of Mechanical and Aerospace Engineering and the Woodrow Wilson School of Public and International Affairs) and Princeton's Program on Science and Global Security have been cooperating for the past decade on projects to make the elimination of nuclear weapons credible. While the university, and in particular one of its flagship researchers Alex Glaser, are known for their work on fissile materials, their control and the improvement of safeguards systems, in 2011 they launched the "*Zero Knowledge Verification*" program, which is based on the template method of measurement but abandons the idea of building an information barrier. Indeed, the instrument envisaged is set up so as not to take or store sensitive measures. With several neutron detectors set up differently, the team believes that inspectors could obtain only the information they need (confirmation or denial of the presence of a nuclear warhead) by obtaining a signal whose characteristics are not confidential.[105]

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[102] John Carlson and Andreas Presbo, "Defining a Group of Scientific Experts for Disarmament Verification," *Brief No. 27*, VERTIC, May 2017.

[103] "Means to Reinforce Research on Nuclear Disarmament Verification: Report on a Series of Regional Conversations," Matters n°13, November 2017.

[104] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Verifying Baseline Declarations of Nuclear Warheads and Materials*, *op. cit.*

[105] Nuclear Futures Lab, Princeton University, 2011, https://nuclearfutures.princeton.edu/

Figure n° 1 : PROJECTS CARRIED OUT BY NUCLEAR FUTURES LABORATORY, PRINCETON

Zero Knowledge Project

- Use of a differential neutron radiography tool for maintaining the similarity of two objects without analyzing them

Virtual Reality

- Using virtual reality to design building architecture and verification protocols for future treaties

Next Generation and Vintage Information Barrier

- Development of a simple and low-cost prototypes with state of the art or on the other hand very old technologies

Safeguarding Centrifuge Enrichment

- Creation of simulation models to detect clandestine production of HEU, proposals to improve existing safeguards and better detect clandestine production sites

Mapping Nuclear Verification

- Creation of a pedagogical tool mapping all the sites involved in a possible verification protocol

Buddy Tags for Warhead Counting

- Development of tags separated from treaty accountable items, which enables non-intrusive verification of limits on the number of nuclear weapons or delivery systems

Open Isotopics Project

- Modeling fissile material production cycles using modern data

Nuclear Archeology

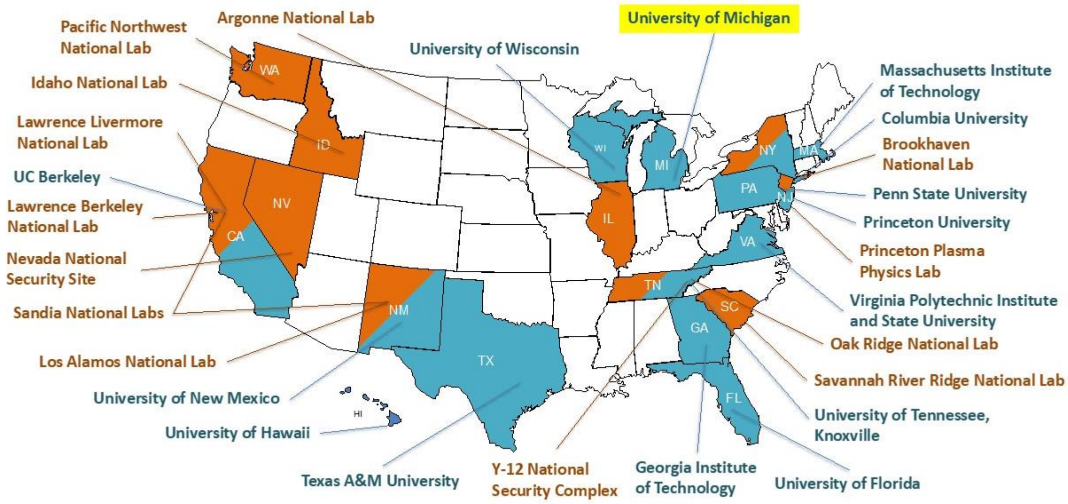
- Development of tools for reconstructing the production history of fissile material

Virtual Proof of Reality

- New protocol to check that an object is not modified without having access to it

Other American universities are interested in these issues and are cooperating in consortia. The Consortium for Verification Technology was launched and funded in 2014 by the NNSA, followed by the Consortium for Monitoring, Technology, and Verification (MTV) in 2019. The consortium for MTV comprises 14 university laboratories and the 9 national laboratories and is led by the University of Michigan.

Figure n° 2 : CARTE DES MEMBRES DU *CONSORTIUM FOR MONITORING, TECHNOLOGY, AND VERIFICATION* (MTV)[106]



The Verification Technologies Consortium, which ended in 2019, focused on six areas of research, including disarmament verification, and funded the training of students in this field, with specifically dedicated courses (such as Unmaking the Bomb at Princeton or a course on the political and technical aspects of nuclear weapons dismantlement at the University of Michigan). The consortium offered internships, fellowships, and employment opportunities for trained students, doctoral and post-doctoral fellows.[107] The new consortium operates on the same principle with a strong focus on non-proliferation and nuclear explosion detection and attribution. Since their creation, the two consortia have had annual budgets of around $5 million.

Among the universities participating in this project is MIT, Cambridge, where the Laboratory for Nuclear Security and Policy is particularly interested in a way of carrying out measurements without disclosing sensitive information, by declassifying data collected through a physical process that does not rely on software or electronic systems.[108] The project was presented in the journal *Nature* in 2018.[109] The University of Michigan is working, among other things, on active interrogation techniques and detection portals, while seeking to improve the functioning of existing gamma spectrometers. The University of Chicago is conducting innovative projects on the use of big data in the creation of radiation detector networks.

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[106] Consortium for Monitoring, Technology, and Verification (MTV), https://mtv.engin.umich.edu/about/

[107] Sara A. Pozzi, “The Consortium for Verification Technology Model for University and National Laboratory Collaboration,” 2017.

[108] “LNSP receives $3.2M for nuclear warhead verification,” *Nuclear Sciences & Engineering at MIT*, 2014.

[109] Jake J. Hecla and Areg Danagoulian, "Nuclear disarmament verification via resonant phenomena," *Nature,* n°1259, May 2018.

Elsewhere than in the United States, a few laboratories work on the subject. For example, at the University of Hamburg, the Carl Friedrich von Weizsäcker-Center for Science and Peace Research is particularly interested in the data that NNWS inspectors would need to authenticate the presence of a nuclear weapon. In cooperation with the ISFH in Hamburg (Prof. Götz Neuneck), the teams are investigating the use of new technologies in the field of arms control. For its part, the RWTH in Aachen is working, among other things, on nuclear archaeology technologies, which would eventually make it possible to verify the declared quantities of nuclear materials produced.

In the United Kingdom, researchers at King's College are working on the psychological aspects of verification. At the University of Oslo, a training program has been set up, seeking to confront NNWS students with the practical issues of verification, as advocated in the UKNI final report.

3.2. Technological and political challenges

3.2.1. The difficulty of moving forward in a purely theoretical framework

The scientific dynamism surrounding the issue of nuclear disarmament illustrates the willingness to demonstrate the feasibility of an agreed dismantlement process. It also reveals the many grey areas that remain on this subject. Indeed, despite progress, verification of nuclear disarmament continues to pose challenges, both technological and political.

In terms of thinking about the process itself, the main difficulty is undoubtedly the very theoretical nature of the approach. In a context where progress in multilateral disarmament and arms control is very slow, if not non-existent, the prospect of complete disarmament is at best very distant. It is therefore impossible to have a precise vision of the context in which it would emerge. Moreover, the states concerned clearly refuse to think about an implementation model that is too precise, so as not to commit now to a protocol or scenario that could take place several decades from now.

The fact that the issue is so far addressed essentially at a theoretical level means that several essential aspects are for the moment completely absent from the discussions. This is the case, for example, with institutional considerations (Who would be responsible for verification? Which agency would carry out the inspections? Could the IAEA's mandate be extended?). This question is linked to the issue of the funding of the operations, which could potentially be highly controversial.[110] Moreover, the questions of the implementation of a disarmament treaty, of the management of possible violations, of security in a world without nuclear weapons, and of the acceptability of a latent nuclear capability are the subjects of academic reflection but

[110] Corey Hinderstein (ed.), *Cultivating Confidence: Verification, Monitoring, and Enforcement for a World Free of Nuclear Weapons*, Hoover Institution Press Publication, 2010.

are not addressed at the diplomatic level.[111] There is today more controversy than shared visions on how to maintain stability in a world without nuclear weapons.[112] Where should verification operations take place is also still very unclear: some experts believe that specific dismantlement sites should be built for reasons of practicality, but such considerations are considered by NWS to be very premature at this stage.[113]

Within the theoretical framework of the current discussions, there is also very little discussion among states concerned of the measures needed to ensure the irreversibility of disarmament. For example, the IPNDV or the GGE do not address fissile material control. However, several studies have shown that important decisions would have to be taken on whether to change the safeguards systems on the nuclear fuel cycle, particularly on plutonium, highly enriched uranium and materials such as tritium or deuterium.[114] The fate of the materials recovered from weapons would also pose difficult challenges, particularly for plutonium where a choice would likely have to be made between long-term burial or recycling into MOX for civilian use.[115] Similarly, the current debate leaves out some issues related to the verification of baseline declarations of the volumes of nuclear material held (e.g. through nuclear archaeology), and some states refuse to link verification to parallel negotiations such as those on the FMCT.

Due to the nature of the projects carried out and the scattering of research laboratories, scientific research tends to remain in a prototype logic. The work of the IPNDV aims to give a more systemic dimension to this research, but the Partnership's Group 6 deliverables, dedicated to technologies, tend to list available technologies and recent development and do not necessarily succeed in linking technologies and operations in an operational perspective.[116] Several observers consider that it is therefore necessary to invest less in inoperative prototypes and more in global concepts that would allow a broad reflection on how a chain of custody could be set up across an entire arsenal, or on the concrete way in which measurements would be organized, or on the frequency of on-site inspections.[117]

A third phase of the IPNDV could overcome these difficulties by focusing on dismantlement scenarios. Nevertheless, the reservations of NWS on this subject clearly show the difficulty of going beyond a theoretical framework and, therefore, the

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[111] See for instance, George Perkovich and James Acton, (eds.), *Abolishing Nuclear Weapons. A Debate*, *op. cit.*

[112] Sverre Lodgaard (ed.), *Stable Nuclear Zero: The Vision and its Implications for Disarmament Policy*, Routledge, 2016.

[113] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Verifying Baseline Declarations of Nuclear Warheads and Materials*, *op. cit.*

[114] Thomas Shea, *Verifying Nuclear Disarmament*, Modern Security Studies, Routledge, 2019.

[115] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Verifying Baseline Declarations of Nuclear Warheads and Materials*, *op cit.*

[116] Interview conducted in Utrecht, 17 June 2019.

[117] Interview conducted in London, 22 May 2019.

inherent limits of the exercise as long as the contours of a disarmament agreement are not known.

3.2.2. Unproved technologies

Moreover, after decades of research, the effectiveness of certain technologies and their ability to meet the political requirements of verifying nuclear disarmament continue to be questioned. Many of the above-mentioned technologies work in theory, but have not been tested in an operational context.

In other cases, some physical problems may be intractable and would require a complete reconsideration of basic assumptions.[118]

The detection and quantification of HEU by passive interrogation methods under dismantlement conditions (in containers) is one of the unsolved challenges identified by the IPNDV at the end of Phase I. The detection of high explosives under the same conditions is also still underdeveloped. For seals, the chain of custody and information barriers, the concepts seem to be able to work but it is today very difficult if not impossible to have perfect confidence in the non-falsification of instruments: it is hard to authenticate that the electronic equipment has not been tampered with clandestinely by inspector or inspected teams. Therefore, it is the problem of confidence in the equipment that is the weakest link in today's thinking on verification, all the more so as new technologies, which are useful from the point of view of the accuracy of measurements and their transmission, can increase the risks of cyber-tampering.[119]

In a comprehensive approach, no satisfactory solution is currently available to guarantee the absence of nuclear weapons at major sites, including military facilities with significant managed access. Furthermore, with regard to the detection of isotopes in environmental samples, in addition to the issue of the ability to detect, one problem is the dating of the sample taken and thus the inability to determine whether components have been or are still present at a site.

3.2.3. The challenge of maintaining momentum over time

The participation of states in the IPNDV requires a significant human and financial investment. Indeed, for a state to participate fully, it needs to be able to dispatch three officials or experts for each meeting, whether in working groups or plenary meetings. This amounts to approximately three to four one-week meetings per year, with obvious costs and impacts on the ability of some states to remain active in the process over time. Proposals for funding are being made to encourage the participation of countries for which the financial barrier is significant, but this issue may remain an

118 Telephone interview, London, 16 July 2019.

119 Telephone interview, London, 16 July 2019.

obstacle to further participation in the long term, especially with regard to active participation that ideally requires in-house research capacity on these issues.

But even for others, there is a risk that mobilization may weaken over time. This risk is amplified by several phenomena. On the one hand, discussions within the group may give the impression of redundancy and lack of progress, for the reasons mentioned above. As such, the Partnership tries to strike a balance between a requirement to remain focused on its own issues and not to duplicate the work of similar forums (for example, on IAEA safeguards, or on the launch of negotiations on an FMCT) and the consideration of new issues. The content of Phase III, the regularity of meetings, further integration between political and technical issues, and the duration of an initiative that is likely to reach its limits in the near future if no progress on disarmament is observed are all discussed.[120] The willingness of many states to work around a concrete scenario in the coming phase reflects this desire to see the Partnership move forward and deliver on its promises around a “product” that can be easily promoted to political authorities.[121]

On the other hand, the creation of the GGE, and the discussions on the advisability of appointing a group of scientific experts, raise fears of a duplication of discussions that could compete with existing initiatives and undermine the motivation and resources devoted to current projects.[122]

3.3. Alternative visions

3.3.1. The skepticism of some actors

Despite the official political support displayed by some 20 states, and the mention of the positive role of the IPNDV by nearly 35 states during the last Preparatory Committee for RevCon 2021 (Prepcom 2019),[123] some actors continue to view the issue of verification of nuclear disarmament with skepticism and even hostility.

For Russia, the next stage of disarmament can only be bilateral, or possibly envisaged in a P5 format, but openness to NNWS remains unnecessary and undesirable. Russia has not participated in the process or made significant contributions since 2011. Its diplomats highlight the risks of such an initiative in terms of proliferation, suggesting that the control of certain technologies and information should remain the prerogative of the NWS.[124]

[120] Interview conducted in Utrecht, 17 June 2019.

[121] Interview conducted in Utrecht, 17 June 2019.

[122] Interview conducted in Utrecht, 17 June 2019.

[123] "2019 NPT PrepCom Statements Highlight IPNDV's Substantial Contribution and Progress," IPNDV, 24 May 2019.

[124] Interview conducted in London, 22 May 2019.

China followed Russia in withdrawing from the IPNDV, despite what could be perceived as greater openness and interest in building its expertise on the subject. The United Kingdom has begun to collaborate in 2014 on verification with Beijing, but the work done by Chinese teams is not public.[125]

The lack of Russian and Chinese involvement creates additional doubts about the usefulness of the projects underway since it is difficult to work on a realistic scenario without taking into account the points of view of such important actors.[126] Some note that bilateral Russian-American cooperation was more important and relevant than the establishment of a multilateral partnership.

These specific lines of criticism join that of those who believe that it is fundamentally impossible to verify a disarmament treaty, and that the negotiated elimination of nuclear weapons is therefore impossible. Indeed, these observers note that any verification regime would have loopholes, which would be unacceptable to other states. The risk of violation would be too great to be taken, and there could be no deterrent mechanism to ensure the compliance with such a treaty. Recent violations of the CWC have reinforced these arguments about the limitations of verification regimes.

France has long been among the most cautious countries in this area, which makes recent progress all the more notable and interesting. France has traditionally expressed doubts about the realism of a multilateral nuclear disarmament verification operation, pointing to the fact that precedents in terms of disarmament and arms control have always been either unilateral and unverified (without question) or bilateral. In all likelihood, arms reduction and disarmament agreements would still, in the first instance, involve the United States and Russia. Some experts were wary of a process that is perceived as unrealistic and potentially contrary to the country's international obligations, in particular in terms of proliferation.[127] Finally, some of the French stakeholders fear that the discussions and work carried out could one day be considered a binding process, a kind of model systematically imposed in a disarmament process. They therefore point out that it is difficult to go very far before the negotiation of an actual treaty and that many elements would depend on the political choices and objectives of the actors involved in such a treaty.[128]

The French authorities have for several years perceived a political interest in increasing their role in the subject and have lifted some of their reservations, as evidenced by the investment in the IPNDV and the organisation of NuDiVe and the commitment taken at the highest level by President Macron to keep working on this issue.[129] Nevertheless,

[125] Interview conducted in London, 22 May 2019.

[126] Interview conducted in Paris, 7 June 2019.

[127] Interview conducted in Paris, 28 June 2019.

[128] Interview conducted in Paris, 7 June 2019.

[129] Speech by President Emmanuel Macron on Defence and Deterrence Strategy to the trainees of the 27th class of the Ecole de Guerre, *op. cit.*

there is still a feeling among some actors that this work has more of a political interest (especially within the NPT) than an intrinsic value in the perspective of a disarmament treaty.

3.3.2. An unnecessarily complex procedure?

With the publicity surrounding the IPNDV, the concept of the 14 steps and the preferred technological options appear to be the commonly accepted pattern. This choice is in fact historical, since it is based on the work done by the United States, the USSR and the United Kingdom in this field, in particular the postulate of weapon-by-weapon disarmament. While many specialists see this choice as logical, it is based on assumptions that are not necessarily the only ones possible.[130]

For example, UNIDIR has published a study, edited by Pavel Podvig, which questions the choice of verifying the dismantling of each warhead, one by one.[131] The approach taken by the IPNDV is to start from the stored warheads, dismantle them to obtain fissile material on the one hand and explosives on the other, with traceability throughout the process. One reason for this approach is that the report is intended to explore verification measures for a future FMCT. Nevertheless, UNIDIR experts believe that their approach might also be more appropriate for a convention on the elimination of nuclear weapons. They base their approach on the concept of “deferred verification” for the nuclear warheads currently in the arsenals of the nuclear powers. The aim is to bypass the particularly sensitive process of identifying and authenticating warheads, thereby avoiding the use of information protection systems or the use of classified data.

This process may not answer all the questions and provide absolutely accurate data, but combined with a comprehensive analysis of government transparency, it would be, according to Pavel Podvig’s team, most likely to lead to realistic and progressive disarmament verification. This alternative view seeks to avoid in particular the use of information barriers whose reliability can only be questionable. This approach has been presented to the IPNDV but does not seem to have replaced the traditional vision, which benefits from decades of reflection and therefore seems to be favored because of its more global and comprehensive nature and a certain inertia.[132] The greatest obstacle to “deferred verification” remains the hostility of some actors to disclosing sensitive information on fissile material production. However, such transparency would be very gradual, over several decades, and would be achieved in parallel with significant progress in disarmament, which could make it more plausible.

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[130] Telephone interview, London, 16 July 2019.

[131] Pavel Podvig and Joseph Rodgers, Deferred Verification Verifiable Declarations of Fissile Material Stocks, *UNIDIR Resources*, 2017.

[132] Telephone interview, Geneva, 28 June 2019.

3.3.3. More ambitious visions

On the other hand, other researchers or experts working on the subject criticize the IPNDV and its work for not going far enough. For example, some note that the published reports are not technical enough, which, in their view, indicates a lack of involvement of the US national laboratories in the process. In this context, some states could use the Initiative to refuse to go into more details and to think more holistically about the organization of a world without nuclear weapons.[133] Others believe that the IPNDV is primarily a means of conveying the message that verification is tremendously complex and thus of justifying inertia on disarmament. NNWS would be included to bear witness of the obstacles that stand in the way of nuclear disarmament, not to consider concrete and realistic solutions.[134] Some states, not involved in the process, are quietly expressing these doubts, and insist that the work on verification should not obscure the immediate goal of achieving progress on disarmament.[135] Others are in an intermediate position. For example, many believe that the non-proliferation argument used to restrain information shared with NNWS is exaggerated,[136] and support the view that classification rules should be reviewed. They promote greater transparency, interpreting the NPT in light of what is already in the public sphere.[137] Others fear that the IPNDV is primarily a display item and that the participating NWS are disingenuous about its true correlation to the cause of disarmament. Some note their preference for a multilateral framework, but also indicate that given the paucity of currently functioning disarmament initiatives, the IPNDV has at least the merit of existing.[138]

Many of the governmental and non-governmental experts interested in the topic envisage a much broader working format than is currently being discussed within the IPNDV. Recommendations published by NTI as a result of their research program include the following:

- Collecting national archives now in a format that can be adapted to a verification process and recording institutional memory on the production of fissile material and nuclear weapons with a view to consolidating verifiable data in this area, as well as the preserving disused facilities for verification purposes;
- The funding of nuclear archaeology projects for the subsequent verification of material production data;
- The establishment of a verification regime for naval HEU;

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[133] Interview conducted in London, 16 July 2019.

[134] Telephone interview, Geneva, 28 June.

[135] Interview conducted in Livingstone, 11 July 2019.

[136] Interview conducted in Utrecht, 17 June 2019.

[137] Corey Hinderstein (ed.), *op. cit.*

[138] Interview conducted in Utrecht, 17 June 2019.

- The transfer as soon as possible of excess military nuclear material to the IAEA for conversion to civilian use;
- The exchange of information on nuclear-weapons-related transport and infrastructure to consider the implementation of a chain of custody as early as possible in the process.[139]

In addition to NTI, the International Panel on Fissile Materials (IPFM) has also proposed a fairly comprehensive verification model, including a step-by-step program for the publication of baseline declarations. The group insists that states publish promptly, as part of their efforts under the NPT, as much information as possible on their fissile material inventories, starting with stocks of plutonium and HEU for civilian use, in excess of weapons and destroyed. They believe that all non-sensitive materials should be placed under IAEA safeguards as soon as possible. They suggest the launch of collaborative nuclear archaeology projects.[140]

In the reflections surrounding the irreversibility of the disarmament process, many of the recommendations concern setting up a much stricter control of the nuclear cycle in a world without nuclear weapons. Thus, many point to the need to work also on an FMCT that would eventually allow production histories to be taken into account. The introduction of control measures for all nuclear materials is also regularly considered indispensable (global ban on several types of material not essential for civilian use, internationalization of nuclear fuel production). Moreover, some experts believe that thinking on verification requires anticipating the broader issue of compliance, which often leads to wide-ranging proposals including, for example, reform of the UN Security Council, conventional arms control measures or new regulations on long-range missiles.[141]

Among the numerous works on verification of nuclear disarmament, very few publications have so far directly linked the issue with the Treaty on the Prohibition of Nuclear Weapons (TPNW). One article has been published on the issue of the “competent authority” for verification as referred to by the TPNW.[142] Only one book so far has attempted to propose a comprehensive legal and institutional regime that could be included as a “protocol” to the Treaty adopted in July 2017.[143] This proposal, by a former IAEA expert, provides for the elimination of existing arsenals and facilities, but also for measures to prevent states from rearming. Thomas Shea’s book is notable

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[139] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Verifying Baseline Declarations of Nuclear Warheads and Materials*, *op. cit.*

[140] H.A. Feiveson, A. Glaser, Z. Mian and F.N. von Hippel, “Unmaking the bomb: A fissile material approach to nuclear disarmament and nonproliferation,” IPFM, janvier 2014.

[141] Steve Fetter, "Verifying Nuclear Disarmament," *Occasional Paper No. 29*, Stimson Center, October 1996.

[142] Tamara Patton, Sébastien Philippe and Zia Mian, “Fit for Purpose: An Evolutionary Strategy for the Implementation and Verification of the Treaty on the Prohibition of Nuclear Weapons,” *Journal for Peace and Nuclear Disarmament*, 2019.

[143] Thomas Shea, *Verifying Nuclear Disarmament*, *op. cit.*

for its proposal to create a new international body responsible for organizing and verifying disarmament. It also includes extensive recommendations on the organization of a nuclear-free world, including the control of fissile material from civilian arsenals and efforts to move towards the total exclusion of plutonium and HEU; and strict IAEA safeguards over all material that could be used in a military nuclear program.

What material should be included in future IAEA safeguards is a recurrent question in the literature, with, for example, proposals for systematic prohibition or strict control of isotopes that could be used in nuclear weapons (deuterium, lithium, tritium) or easily converted into fissile material (U-238, thorium, neptunium) unless their civilian use is demonstrated.[144]

Experiments carried out in an official framework tend to focus mainly on nuclear material. However, some believe that other aspects should also be taken into account, in particular the issue of explosives and the militarization of nuclear technologies. In particular, some proposals are aimed at drawing inspiration from the JCPOA and banning certain experiments or R&D work. The export control regimes (NSG and MTCR) also list certain non-nuclear elements that could play a role in a military nuclear programme. The means of verification would then be mainly intelligence-related, but the IAEA could also see the scope of its safeguards extended.[145]

In the reflections surrounding the irreversibility of the disarmament process and the verification of a world without nuclear weapons, much work recalls the inescapable role of intelligence as a complementary means of guaranteeing compliance with a convention, but also of societal verification. The concept was coined by Joseph Rotblat in 1992 as "*a system for monitoring compliance with treaties, and detecting attempts to violate them, by means other than technological verification ... based on the involvement of the whole community, or broads groups of it*."[146] It assumes that, at a certain level, an attempted violation by a state cannot escape the vigilance of certain observers, concerned citizens, scrupulous government officials or research NGOs. This surveillance is encouraged by the multiplication of images, their dissemination through social networks and their exploitation by big data science. The integration of societal verification, regularly mentioned as the ultimate guarantee to supplement intelligence to ensure that no state is trying to cheat, may require national or international legislative adjustments. These could include provisions protecting whistleblowers or promoting transparency in various areas. Such proposals are occasionally put forward

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[144] Jonathan B. Tucker, "Verifying a Multilateral Ban on Nuclear Weapons: Lessons from the CWC," *The Nonproliferation Review*, Winter 1998.

[145] Tamara Patton, "An international monitoring system for verification to support both the treaty on the prohibition of nuclear weapons and the nonproliferation treaty," *Global Change, Peace & Security*, vol. 30, n°2, 2018.

[146] Joseph Rotblat, "Towards a Nuclear Weapon- Free World: Societal Verification," Pugwash Conferences on Science and World Affairs, London, published in *Security Dialogue,* vol. 23, n°4, 1992.

as possible pre-disarmament treaty proposals to complement provisions on arms dismantling.[147]

Although these considerations are essential to the development of a comprehensive discussion on the establishment of a verification regime for a disarmament treaty, NWS are virtually enable to address them until a concrete political project for disarmament is in place. For the time being, therefore, they remain primarily dealt with in an academic manner. The entry into force of the TPNW could give relevance to this work and encourage some of the signatory states to consider the establishment of a verification protocol to the Treaty, but this has not been mentioned so far and does not seem to be a priority.[148]

Conclusion

For some 50 years now, experts have been questioning the feasibility of a verified nuclear disarmament agreement. The first projects have been carried out with the aim of finding technical solutions for bilateral arms control agreements (United States – USSR). With the progress in reducing arsenals made possible by the end of the Cold War, prototypes and experiments multiplied. Both countries considered at the time that it was useful to reflect on practical considerations before having the precise outlines of a negotiated treaty.

With the re-emergence of international tensions, arms control agreements have marked a pause after the adoption of the New Start Treaty, which provides a comprehensive verification framework but does not consider the crucial step of dismantling a nuclear warhead. Nevertheless, work on the verification of nuclear disarmament is continuing, with the involvement of new partners who are interested in the subject for a variety of reasons: a willingness to better understand the concepts of verification in order to be able to make proposals and better ensure one′s own security, a desire for scientific improvement, and an aspiration to work on any topic useful to the ultimate cause of disarmament.

Today, at a time when the prospects for disarmament are particularly bleak and the vision of a world without nuclear weapons is distant, several exercises, partnerships and working groups are active on this issue.

Progress in the technical field, but also the political exploitation of this work within the framework of the NPT, are factors that should lead states and other actors involved to continue their investments in the years to come. However, two warnings are undoubtedly worth noting. On the one hand, the most skeptical in this field, who

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[147] *Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks, Redefining Societal Verification*, *op. cit.*

[148] Interview conducted in Livingstone, 11 July 2019.

advise against wasting time and resources on developing technological “gadgets” and procedures that are too rigid and circumstantial and which would necessarily be obsolete and unsuitable if the time came to use them. On the other hand, the most progressive NNWS on disarmament are concerned that technical discussions on verification may be used as a stopgap measure to mask the lack of real progress on disarmament and the growing difficulties in achieving a common vision among the nuclear-weapon states of a world without nuclear weapons...

Annexe 1 GLOSSARY OF TECHNICAL TERMS

Managed access: Establishing standards for access to a site that preserve certain sensitive data for the host country while maintaining the confidence of inspection teams in their ability to verify the disarmament process.

Information barrier: Systems that provide accurate and reproducible information on nuclear weapons or sensitive components while not disclosing classified information and information that could pose a security and non-proliferation risk.

Chain of custody/chain of control: All the measures taken to monitor a given object and to ensure its status and its non-falsification or concealment.

Baseline Declarations: Documents in which states participating in the disarmament process indicate all objects and materials to be controlled, their status, location and all data relevant to the verification of the disarmament process.

Tags and seals: Operations aimed at providing each declared and controlled object, such as each nuclear warhead, with a unique label to identify it and a seal to ensure its non-tampering throughout the disarmament process.

High explosive: Explosives used to trigger the nuclear reaction.

On-site Inspection: The search, on a given location, in a planned or unannounced manner, by a given team, for clues to confirm or deny the presence of given objects, and to restore the chain of custody if necessary.

Attribute Measurement Method: A method of authenticating the presence or absence of a nuclear weapon by looking for certain characteristics in its radioactive signature, such as the quantity of certain isotopes.

Template Measurement Method: A method of authenticating the presence or absence of a nuclear weapon by comparing its radioactive signature with a given template.

Portal Perimeter Monitoring: Control of a building or site to identify any entry or exit of an object, in particular through the installation of a continuous video surveillance system and motion detectors.

National technical means: Surveillance techniques, such as satellite imagery, telemetry, electro-optical and radar sensors, space-based sensors, seismic or acoustic sensors, used to verify compliance to international treaties. The term appeared for the first time, without being detailed, in the SALT Treaty between the United States and the USSR.

Societal verification: Inclusion of non-traditional actors (NGOs, citizens) in verification and transparency regimes to increase the likelihood that violations of international commitments will be detected.