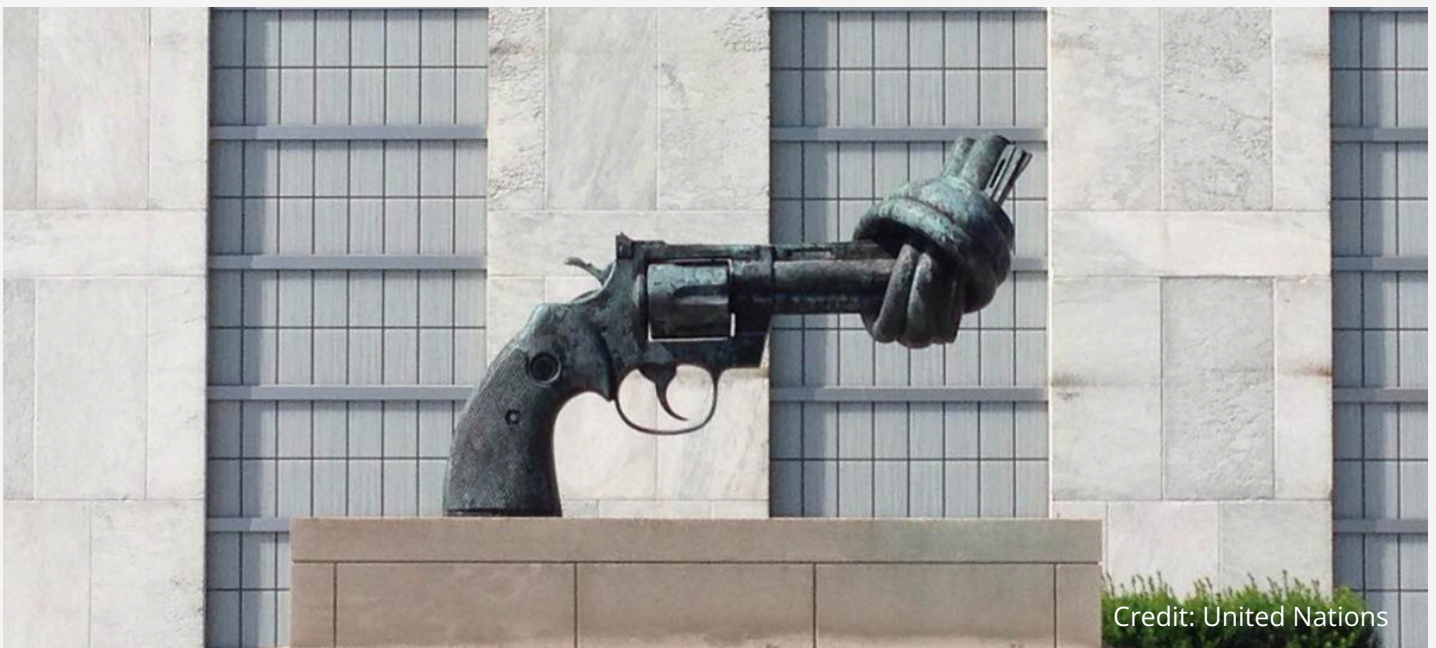


Governing the Atom Brief No. 9

Understanding the Principle of Irreversibility: A Primer for Future Negotiations

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The principle of irreversibility in nuclear disarmament has been part of international discourse at official and non-governmental levels since the early days of the nuclear era. Its operationalisation, however, is a more recent phenomenon and has its origins in nuclear arms control negotiations between the United States and the Russian Federation. When the two parties started to use the term ‘irreversibility’, they sought to ensure that reductions would not later be undone. To this end, they devised various technical, legal,

political, and normative measures that can be instructive for nuclear disarmament efforts today.

The principle of irreversibility has had applications in nuclear arms control, weapons-origin fissile material reductions, nuclear safeguards, and in the review process of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). This brief details the history of the principle of irreversibility and offers key considerations for future negotiations.

Origins of the Irreversibility Principle in the NPT

In 2000, irreversibility of nuclear disarmament became an integral part of the NPT review process, starting with the 13 “practical steps for the systematic and progressive efforts to implement Article VI” of the NPT on nuclear disarmament.¹ Per step five of these measures, the principle of irreversibility should “apply to nuclear disarmament, nuclear and other related arms control and reduction measures.”²

The 2010 NPT Review Conference agreed on a 64-point action plan, action two of which committed States Parties “to apply the principles of irreversibility, verifiability and transparency in relation to the implementation of their treaty obligations.”³ Additionally, action 17 encouraged States Parties to “support the development of appropriate legally binding verification arrangements, within the context of the IAEA, to ensure the irreversible removal of fissile materials designated by each nuclear-weapon State as no longer required for military purposes.”⁴

While the Review Conferences in 2005, 2015, and 2022 were unable to reach consensus on a final outcome document, discussions on irreversibility were held at each of them.

Irreversibility, Verifiability, and Transparency

There have been significant efforts to achieve a common definition or a shared understanding of what irreversibility could mean in nuclear disarmament. The contours of that understanding have remained rather general.

Similarly, the relationship between the principles of irreversibility, verifiability, and transparency, which many have characterised as three pillars of nuclear disarmament, has been widely acknowledged. However, efforts made to reach a unified understanding of this interrelation have been challenged by the significant amount of overlap between the three concepts and the fact that implementation of any potential future disarmament steps will likely need to be tailored to the requirements and views of the parties involved.

Generally, the depth of verification and extent of transparency depends on the desired degree of irreversibility, but views on specific requirements differ. Transparency is a condition for any cooperative arrangements among States, but arrangements can vary depending on the decision of the States that enter such arrangements. Historically, the extent of transparency has also varied with the political climate. It can be deep or shallow and can be implemented through an informal regime or be codified in a binding agreement.

¹ Final Report of the 2000 Review Conference (NPT/CONF.2000/28 (Parts I and II)), pg. 14. Available at: <https://disarmament.unoda.org/wmd/nuclear/npt-review-conferences/>.

² Ibid.

³ Final Document of the 2010 Review Conference (NPT/CONF.2010/50 (Vol. I)), pg. 20. Available at: <https://www.reachingcriticalwill.org/images/documents/Disarmament-fora/npt/revcon2010/FinalDocument.pdf>.

⁴ Ibid.



IAEA headquarters at the Vienna International Centre. Credit: IAEA.

Similarly, the frequency, intensity, intrusiveness, and even the desirability of verification measures may vary. Parties might even decide that verification is not necessary to provide assurance that a given step towards disarmament is not being reversed. Consensus, however, has been that verification is needed, but how much and which measures should be part of it remains under discussion.

Discussions in various international forums and expert studies have played a valuable role in clarifying key concepts, their relationships, and practical options. Yet, experience of past measures related to disarmament has demonstrated that, in the end, decisions on practical implementation are made in the course of negotiations on specific agreements by parties participating in these negotiations.

Considerations from Past Practice

Lessons from nuclear safeguards, arms control, and weapons-usable fissile material disposition efforts may be instructive when considering the irreversibility principle in future negotiations.

Nuclear Safeguards

The IAEA applies safeguards to provide credible assurance that fissile material is not being diverted from peaceful uses to nuclear weapons.⁵

Through a safeguards lens, one can think of irreversibility in fissile material disposition as “practically irrecoverable for nuclear use”,⁶ which is directly relevant to the irreversible disposition of fissile material, regardless of the context. This concept was developed before

⁵ Safeguards are implemented based on legal agreements, including those based on INFCIRC/153, which informs the structure and content of safeguards agreements required under the NPT, also known as comprehensive safeguards agreements (CSAs).

⁶ IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/153), paras 11 and 35, 1972. Available at: <https://www.iaea.org/sites/default/files/publications/documents/infcircs/1972/infcirc153.pdf>.

the NPT as a prerequisite for the termination of safeguards on nuclear material and was carried forward into the current safeguards system. The term 'practically irrecoverable' was left without a formal definition, which was likely intentional. Attempts to define specific, technical criteria for the termination of safeguards have been unsuccessful, owing to the variety of physical forms, quantities, concentrations, and compositions of nuclear material, particularly waste.

Nuclear Arms Control

Historically, nuclear arms control treaties have focused on delivery vehicles rather than nuclear warheads or fissile material because of the relative ease of devising corresponding counting rules. The concept of irreversibility, however, applied to them as well because it was necessary to prevent rapid or clandestine restoration of reduced capability. Two treaties in particular had strong elements of irreversibility: the 1987 Intermediate-Range Nuclear Forces (INF) Treaty and the

1990 Strategic Arms Reduction Treaty (START I).

Irreversibility of reductions was achieved through a combination of elimination or conversion procedures (applying both to delivery vehicles and associated facilities) and verification, which was supposed to confirm continued compliance. Specific rules and procedures, however, were custom-made for each treaty reflecting compromises driven by practicalities of implementation and the dynamic of negotiations.

For example, the INF Treaty provided for the complete elimination of missiles whereas START I foresaw a mix of procedures depending on the type of delivery vehicle, varying from physical elimination to relatively modest conversion.

The verification regimes of both treaties included intrusive measures, including on-site inspections and national technical means, and were supported by transparency measures,



Soviet General Secretary Mikhail Gorbachev and US President Ronald Reagan signing the INF Treaty in 1987. Credit: US Government.

such as regular data exchange. These measures were chosen, in part, based on the degree of irreversibility deemed sufficient by the parties.

However, the INF Treaty's verification regime was in force for only 13 years, after which the Treaty was implemented without verification. Furthermore, the parties failed to use the Special Verification Commission intended to resolve conflicts, resulting in the collapse of the INF treaty in 2019. This experience highlights that it may be risky to abandon or weaken the verification regime – an important lesson for negotiation on and implementation of nuclear disarmament. START I's verification regime went further than the INF Treaty in terms of intrusiveness but also turned out to be cumbersome and expensive to implement. Based on that experience, in the context of the 2010 New START Treaty, the parties negotiated a more cost-effective and streamlined verification system.

More generally, US-Soviet/Russian experience with arms control demonstrated the trade-offs between irreversibility and the level of verification and transparency on the one hand, and expediency, negotiability, and costs on the other.

Weapons-Origin Fissile Material Disposition

In the 1990s, the United States and the Russian Federation initiated a number of initiatives aimed at reducing stockpiles of weapons-usable fissile material previously designated for weapons programmes.

The 1993 HEU Purchase Agreement provided for downblending of 500 tonnes of Russian weapons-grade highly enriched uranium (HEU) into low-enriched uranium (LEU) to be sold to the United States for use in civilian power generation. Monitoring and verification protocols agreed by the two sides provided confidence that the downblending was occurring per the agreement. For the purposes of this programme, the disposition of the HEU was irreversible once the resulting downblended LEU was used in power reactors in the United States.

In 2000, the United States and Russia signed the Plutonium Management and Disposition Agreement (PMDA), which provided for the elimination of 34 metric tonnes of plutonium declared excess for national security needs by each side.⁷ The agreement explicitly provided for an irreversible method of disposition. Unlike the HEU Purchase Agreement, there was debate between the parties as to whether the disposition methods were truly irreversible.⁸ This debate continued as the political relationship between the two sides worsened and the PMDA was suspended in 2016 without resolving that matter.

⁷ Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation, as amended by the 2010 Protocol, 2000. Available at: <http://fissilematerials.org/library/PMDA2010.pdf>.

⁸ The PMDA foresaw disposition through the production and irradiation of MOX (mixed-oxide) fuel for nuclear power generation or immobilisation with highly radioactive waste. Later, the United States expressed a preference for the 'dilute and dispose' method, by which plutonium would be blended with a classified inhibitor material and disposed of in a geological repository.



Yellowcake uranium packed into steel drums. Credit: Dean Calma/IAEA.

The Trilateral Initiative (1996-2002) between the United States and Russia intended to identify legal, technical, and financial means through which the IAEA could verify that fissile material taken from nuclear weapons, including in classified forms, remained removed from US and Russian nuclear weapons programmes.⁹ The Trilateral Initiative ended in 2002 due to a lack of interest from new administrations in the United States and Russia. While a workable approach for verification of plutonium and procedures for placing it under IAEA monitoring were devised, the question of irreversibility – a central goal of the Initiative – remained outstanding.

These experiences demonstrated the importance of political will in sustaining such initiatives. Questions about irreversibility were technical in nature and, provided continued political support, may have been solved under the PMDA and the Trilateral Initiative. While these initiatives were more limited to certain

aspects of disarmament, the lessons drawn from them – both technical and political – will be important to consider in a broadly disarming world.

Recurring and Remaining Challenges

The principle of irreversibility in nuclear disarmament has seen extensive development since the 1990s and has since featured prominently in the NPT review process. This principle has been central in the negotiation of arms control agreements, fissile material disposition initiatives, and in the development of key concepts in nuclear safeguards.

The expert community has contributed extensively to the development of the irreversibility principle, including the interrelation between irreversibility, verifiability, and transparency. Ultimately, the practical meaning of these principles as well as

⁹ Thomas E. Shea and Laura Rockwood, “IAEA Verification of Fissile Material in Support of Nuclear Disarmament”, Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard University, May 2015. Available at: <https://www.belfercenter.org/sites/default/files/files/publication/iaeaverification.pdf>.

of their interrelationship will likely be decided at the negotiating table. The parties to such negotiations will likely be the ones to implement verification measures. States that remain outside will have only limited influence over these issues.

In addition to the challenges described above, the international community will have to consider other issues in the future. One of the largest outstanding questions is who the parties to an agreement on irreversible nuclear disarmament might be, e.g., only nuclear-weapon States under the NPT, other nuclear-armed States as well, or if non-nuclear-weapon States would also be involved. A related question is which body would

implement the verification of that agreement: the IAEA, a new organisation, or would verification take place between the disarming States themselves?

Another challenge is the cost of irreversible nuclear disarmament. In 1999, the IAEA Secretariat prepared a menu of options for its Member States to consider for financing the Agency's activities in verification of nuclear arms control and fissile material reductions.¹⁰ Such a menu could be instructive, but since the landscape of international nuclear governance has changed since that time, solving the issue of costs of disarmament verification is likely to remain a moving target.



The 2000 NPT Review Conference at the UN General Assembly hall. Credit: UN Photo/Eskinder Debebe.

⁹ IAEA, "Financing Agency Verification of Nuclear Arms Control and Reduction Measures" (GOV/INF/1999/9), 21 May 1999.

A further challenge will be managing the 'echoes' of a nuclear weapons programme during and after disarmament. The extensive work conducted after the collapse of the Soviet Union and after South Africa's unilateral nuclear disarmament to redirect the industrial infrastructure and human capital associated with nuclear weapons are instructive in this respect. However, this challenge is likely to be much greater in a broadly disarming world because of the extent of large nuclear weapons programmes today.

These challenges are not insurmountable. As past practice has shown, parties to an agreement can find solutions that strike an acceptable balance between irreversibility, verifiability, and transparency at a sustainable cost when political will is present. In this respect, it is important to emphasise that irreversibility is not a single end state in nuclear disarmament, but rather a spectrum of potential end states that parties to an agreement can consider during negotiations.

As the irreversibility principle is developed further, dialogue between States could contribute to a better understanding of the principles, the practicalities, and the tools to advance disarmament once an opportunity arises.



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