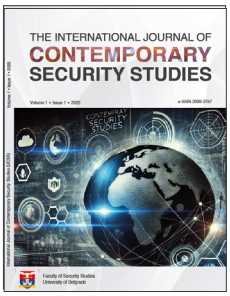
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Article

The Role of Non-Nuclear Weapon States in Nuclear Disarmament Verification

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ABSTRACT

This research explores the key role of the Non-Nuclear Weapon States (NNWS) in nuclear disarmament verification, showing their significant contributions through normative advocacy, technical innovations, and multilateral cooperation. This paper applies a multi-approach, which includes looking into major treaties such as the Nuclear Non-Proliferation Treaty (NPT), the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and the Treaty on the Prohibition of Nuclear Weapons (TPNW), to highlight the NNWS's initiative in promoting norms, advancing technical contributions, and building the regional framework. South Africa's voluntary disarmament is a case study for evaluating the current verification regime. The research highlights the NNWS's contributions and challenges. The key findings highlight the NNWS as a proactive force that shapes disarmament norms and advocates for technologies through different initiatives. The paper also identifies key challenges, including political resistance, technical limitations, and institutional barriers. Policy recommendations include strengthening verification mechanisms, leveraging emerging technologies such as zero-knowledge proofs, and increasing trust-based transparency to increase multilateral collaboration and advance global disarmament goals. The research highlights the transformative potential of achieving a nuclear-weapon-free world.

KEYWORDS

Non-Nuclear Weapon States (NNWS); Nuclear Verification; Nuclear Disarmament.

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1. Introduction

Nuclear disarmament remains one of the most significant yet challenging objectives in global security, shaped by complex interactions among geopolitical competition, international legal frameworks, and rapid technological advancement. Major international agreements, including the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and the Treaty on the Prohibition of Nuclear Weapons (TPNW), represent important milestones in advancing this goal. Nevertheless, structural weaknesses, technical limitations, and the political reluctance of Nuclear Weapon States (NWS) to make meaningful disarmament commitments often undermine their effectiveness. Within this context, the role of Non-Nuclear Weapon States (NNWS) has become increasingly important. Once regarded primarily as passive participants in

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non-proliferation regimes, NNWS have emerged as norm entrepreneurs, technical innovators, and influential advocates for a humanitarian-centered approach to nuclear disarmament. Despite these contributions, enduring obstacles, including entrenched deterrence doctrines, institutional deadlock, and persistent verification gaps, continue to hinder progress toward a world free of nuclear weapons (Cvetković, 2026; Cvetković & Martinović, 2021).

This paper argues that, despite enduring structural power asymmetries, NNWS can reshape nuclear verification governance through normative entrepreneurship, technical capacity-building, and institutional innovation. At the same time, NWS geopolitical interests and strategic priorities constrain their influence.

A three-dimensional analytical framework underpins this analysis. The normative dimension explores how NNWS redefine nuclear disarmament through legal, ethical, and humanitarian principles. The technical dimension investigates their contributions to verification technologies, safeguards, and monitoring mechanisms. The multilateral and institutional dimension focuses on their influence on treaty architecture, regional verification arrangements, and coalition-based diplomacy. Together, these dimensions provide a structured basis for evaluating NNWS's contributions and limitations across the NPT, CTBT, and TPNW regimes.

Building on this framework, the study pursues three research objectives:

1. Map the normative and technical contributions of NNWS to global nuclear verification regimes.
2. Evaluate the effectiveness of NNWS initiatives and the structural constraints they encounter under the NPT, CTBT, and TPNW.
3. Identify actionable and prioritized policy pathways for strengthening the multilateral nuclear verification architecture.

2. Methods

This study uses a qualitative research design to examine the role of Non-Nuclear Weapon States (NNWS) in nuclear disarmament verification. The study integrates treaty analysis, documentary review, and a focused case study to systematically assess NNWS contributions, structural constraints, and potential policy pathways.

The analysis covers 2000 to 2025. This timeframe captures major developments in the post-Cold War verification landscape, including the evolution of verification practices, the operationalization of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) monitoring regime, and the normative shift introduced through the negotiation and adoption of the Treaty on the Prohibition of Nuclear Weapons (TPNW).

The research corpus comprises more than 150 documents, organized into three categories. The first comprises international legal instruments, including the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the CTBT, the TPNW, and Nuclear-Weapon-Free Zone (NWFZ) treaties. The second includes institutional and technical reports published by the International Atomic Energy Agency (IAEA), the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the United Nations Office for Disarmament Affairs (UNODA), and the International Partnership for Nuclear Disarmament Verification (IPNDV). The third includes peer-reviewed journal articles, scholarly books, and policy briefs that examine verification technologies, nuclear governance, and NNWS diplomatic strategies.

A structured thematic coding approach guided the data analysis and was aligned with the study's three-dimensional analytical framework. The study first applied deductive coding using the normative, technical, and multilateral dimensions as the primary analytical categories. We then identified inductive subthemes through iterative document review to capture emerging patterns and perspectives. Iterative memoing and peer debriefing strengthened analytical rigor by improving coding consistency and interpretive reliability (Table 1).

Table 1. The Three-Dimensional Analytical Framework of NNWS Contributions

Analytical Dimension	Core Mechanism	Key Examples	Primary Constraints
1. Normative	Reframing disarmament through legal, ethical, and humanitarian imperatives.	TPNW adoption, Humanitarian Initiative, Nuclear-Weapon-Free Zones (NWFZs).	NWS resistance; entrenched deterrence doctrines limiting normative translation into binding mandates.
2. Technical	Advancing verification tools, safeguards protocols, and data management systems	Additional Protocol (AP) stress-testing, Zero-Knowledge Proofs (ZKPs), nuclear archaeology.	High costs; NWS secrecy restricting access to classified data needed to train or validate new tools.
3. Multilateral & Institutional	Shaping treaty architecture, regional frameworks, and coalition-based diplomacy.	IAEA funding/support, New Agenda Coalition (NAC), Stockholm Initiative, UN First Committee resolutions.	IAEA governance weighted toward NWS; Conference on Disarmament (CD) consensus paralysis.

South Africa serves as the primary case study because it is the only state to have independently developed and then voluntarily dismantled its nuclear weapons and to have accepted comprehensive IAEA verification of the process (von Baeckmann et al., 1995). Its experience offers a unique empirical benchmark for evaluating the feasibility and credibility of NNWS-led verification initiatives. Process tracing examined how domestic political decisions, institutional reforms, and IAEA engagement interacted to produce verifiable disarmament outcomes.

Several methodological limitations should be acknowledged. Exclusive reliance on publicly available documents may exclude classified verification procedures and confidential diplomatic negotiations, potentially limiting the analysis's completeness. The selection of documentary evidence also emphasizes documented NNWS-led initiatives, creating a potential positive selection bias toward successful cases. To address this concern, we incorporated contested initiatives and negative cases in which NNWS advocacy encountered significant structural or political barriers. Although the South African case provides an important empirical benchmark for voluntary nuclear disarmament verification, its distinctive historical and geopolitical circumstances limit how far its findings can be generalized to states with opaque security doctrines or active nuclear weapons programs.

3. Results

3.1. NNWS Contributions to NPT Verification

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT), in force since 1970, is a cornerstone of global non-proliferation and disarmament, with 191 States Parties (United Nations, 2023). Three main pillars underpin this treaty: non-proliferation, peaceful use of nuclear technology, and disarmament (Article VI); the NPT relies heavily on non-nuclear-weapon states (NNWS) to institutionalize verification mechanisms. Despite critiques of its asymmetrical structure, which legitimizes Nuclear Weapons States' (NWS) arsenals, NNWS uphold rigorous International Atomic Energy Agency (IAEA) safeguards, promote enhanced verification protocols, and support institutional frameworks that shape the global disarmament architecture.

3.1.1. Legal Commitment to Verification: Establishing a Baseline Norm

Under Article III of the NPT, NNWS accept IAEA safeguards Agreements (INFCIRC/153) that require regular inspections and material-accountancy audits (Elbahtimy, 2021). By the end of 2023, 181 states had comprehensive safeguards agreements (INFCIRC/153) in force (International Atomic Energy Agency, 2024), providing an empirical baseline for disarmament verification (Elbahtimy, 2021). Article III compliance required the NNWS to establish a State System of Accounting and Con-

trol (SSAC), institutionalizing verification domestically. These national regulatory bodies standardize material tracking, train technical personnel, and create bureaucratic paths that outlast political cycles, effectively integrating verification into state practice.

This compliance serves as "diplomatic capital," enabling NNWS coalitions to embed Review Conference outcomes in verification benchmarks and condition continued treaty support on measurable NWS disarmament progress. By maintaining high verification standards, NNWS such as Canada and EURATOM states demonstrate leadership and build global confidence in disarmament commitments (Elbahtimy, 2021). Historical precedents underscore this leadership. South Africa's voluntary dismantlement of its nuclear arsenal and immediate acceptance of full-scope safeguards (1991) established verification as a prerequisite for reintegration into the regime. Similarly, the Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials (ABACC) pioneered bilateral verification mechanisms that later informed IAEA regional safeguards practices. These adherence pressures push NWZS to align with these benchmarks, despite slow progress on Article VI amid NWS modernization programs (U.S. Department of Defense, 2022). Despite uneven implementation across the 50 NNWS due to legislative or resource constraints, advanced safeguards states (e.g., Japan, Sweden, Canada) lead IAEA technical cooperation and peer-reviewed networks, sustaining normative momentum through North-South and South-South capacity transfer.

3.1.2. Promoting Enhanced Verification: The Additional Protocol

NNWS elevate global verification standards by adopting and advocating for the IAEA's Additional Protocol, which grants broader access and information rights for inspections (Elbahtimy, 2021). As of 31 March 2023, 141 states and Euratom had Additional Protocols in force, predominantly NNWS, enhancing the credibility and accuracy of verification tools (International Atomic Energy Agency, n. d.). For instance, South Korea and Australia use the Additional Protocol, allowing intrusive measures like environmental sampling and access to undeclared sites (Elbahtimy, 2021).

This commitment raises the transparency bar and pressures NWS to adopt reciprocal measures. NNWS like Ireland and South Africa have pushed for universalizing the AP at NPT review conferences, reinforcing its status as the verification "gold standard" (New Agenda Coalition, 2015). Beyond current non-proliferation goals, NNWS treat the AP as a foundational template for future disarmament verification.

NNWS has also piloted next-generation safeguards technologies enabled by the AP's expanded data access. NNWS has stress-tested unattended monitoring systems, remote data transmission, environmental sampling analytics, and AI-assisted material accountancy in NNWS facilities. These innovations reduce inspector burden, increase detection probability, and create scalable models for verifying future multilateral disarmament agreements.

Despite broad adoption, AP implementation remains uneven, with over 50 NNWS still lacking protocols in force due to legislative delays, resource constraints, or political hesitation. In response, NNWS with advanced safeguards infrastructure (e.g., Sweden, Canada, Japan) have led IAEA technical cooperation programs, peer-review missions, and regional training networks to accelerate universalization. This south-south and north-south knowledge transfer sustains the AP's normative momentum while addressing structural capacity gaps.

3.1.3. Institutional Strengthening of Verification Mechanisms

NNWS bolsters the operational and political backbone of disarmament verification by funding, staffing, and diplomatically supporting agencies such as the IAEA and United Nations initiatives (Elbahtimy, 2021). Institutional resilience depends on financial and technical architecture. These investments create a decentralized expertise network that sustains verification capacity during funding shortfalls and reduces reliance on NWS-dominated research pipelines. NNWS function as

normative entrepreneurs, leveraging mini lateral coalitions to institutionalize verification priorities within fragmented global governance.

This firewall approach prevents verification from becoming a tool of coercive diplomacy, thereby maintaining regime credibility and reducing escalation risks during regional crises. At the 2015 NPT Review Conference, the NAC proposed a legally binding disarmament.

Despite these efforts, institutional strengthening operates within structural constraints. The IAEA's governance remains weighted toward NWS through Board composition and consensus norms, while voluntary funding exposes verification programs to geopolitical conditionality. Moreover, the Conference on Disarmament's procedural paralysis limits NNWS capacity to translate institutional advocacy into legally binding verification mandates for disarmament. Recognizing these limits clarifies why NNWS institutional leadership, while indispensable, remains necessary but insufficient for treaty-wide disarmament progress.

3.2. Strategic Compromises for Flexible Verification Frameworks

NNWS pragmatic compromises secured TPNW adoption by adopting a phased verification model. Article 4 deliberately leaves disarmament verification modalities open for future elaboration by NWS upon accession (Kmentt, 2021b). This flexibility was strategic, as negotiators recognized that NWS's absence from negotiations necessitated adaptability. For instance, Article 3 makes IAEA comprehensive safeguards a baseline obligation for every State Party, building on the NPT safeguards system that NNWS already implement (United Nations, 2017).

Concerns remain that the TPNW's verification provisions are not very clear; this openness reflects a dynamic design rather than a flaw. This allows NWS to co-define verification measures upon joining. The TPNW accommodates geopolitical shifts and supports long-term stability through technically complex measures, exemplifying NNWS efforts to develop actionable verification pathways (Kmentt, 2021b).

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3.2.1. Reshaping the Global Nuclear Order

The TPNW empowers NNWS to institutionalize verification mechanisms, challenge NWS dominance, and redefine disarmament as a humanitarian obligation. It establishes binding verification baselines, strategic compromises, and civil society leverage. NNWS have created a dynamic treaty that can adapt to future NWS accession. The TPNW's normative influence, rooted in IHL and amplified by initiatives like the Humanitarian Pledge, shifts verification from a NWS -controlled process to a collective responsibility. Despite NWS opposition and technological gaps posing challenges, the TPNW's flexibility and NNWS leadership ensure its potential to transform the global nuclear order by fostering an inclusive, transparent verification framework. NNWS are not only filling NPT gaps but also creating a new paradigm for disarmament governance.

3.3. NNWS Contributions to Disarmament Norms and Verification

Non-Nuclear Weapons States (NNWS) play a key role in advancing nuclear disarmament by acting as norm entrepreneurs, setting verification standards, innovating legal frameworks, and filling institutional gaps left by Nuclear Weapon States (NWS). Through coalitions, treaties, and civil society partnerships, NNWS reshape the global nuclear order, highlighting the humanitarian imperative and multilateral accountability. This paper explores how NNWS strengthen normative and verification architectures by leveraging initiatives such as the Treaty on the Prohibition of Nuclear Weapons (TPNW), Nuclear-Weapon-Free Zones (NWFZs), and inclusive forums to advance disarmament.

3.3.1. Setting Verification Standards

NNWS have been instrumental in establishing robust verification standards for the IAEA safeguards system, driving technical innovation, institutional reform, and diplomatic momentum to strengthen global nuclear non-proliferation and disarmament verification. NNWS have set benchmarks that not only increase the IAEA's ability to detect undeclared nuclear activities but also pressure NWS to align with these standards. The authors argue that NNWS leadership has been critical in shaping a credible, adaptable verification regime, using evidence from historical and contemporary efforts to underscore its impact.

NNWS have set a foundational standard for verification by near-universally adopting Comprehensive Safeguards Agreements (CSAs) under INFCIRC/153, ensuring rigorous oversight of nuclear materials. As of the end of 2023, 181 states had CSAs in force, with only four NPT states yet to bring one into force, enabling the IAEA to verify that nuclear materials are not diverted to weapons programs and establishing a baseline for global non-proliferation (International Atomic Energy Agency, 2024). The IAEA's INFCIRC/153, approved in 1971, requires NNWS to submit all nuclear material to safeguards, creating a material-accounting framework that helps prevent diversion (International Atomic Energy Agency, 1998). For instance, Japan's early acceptance of safeguards on transferred nuclear technology in the 1950s set a precedent for NNWS compliance and fostered international confidence in peaceful nuclear use (International Atomic Energy Agency, 1998). The NNWS cooperation, such as South Africa's transparency during its denuclearization, allowed the IAEA to verify highly enriched uranium (HEU) inventories through "nuclear archeology," setting a standard for verifying initial declarations in states with complex nuclear histories (Office of Technology Assessment, 1995). This compliance has been critical in maintaining the IAEA's credibility as a verification body.

Beyond compliance, NNWS have driven technical innovation in verification, setting standards that increase the IAEA's ability to detect declared and undeclared nuclear activities. The Additional Protocol (AP), in force with 141 states (including the five NWS) and Euratom by March 31st, 2023, grants the IAEA expanded access to sites and information, enabling comprehensive state evaluations to detect clandestine activities. (International Atomic Energy Agency, n. d.)The NNWS, such as Australia, Canada, and Japan, volunteered for field trials under Program 93+2, testing environmental sampling and unannounced inspections that shaped the AP's development (Office of Technology Assessment, 1995). For instance, Canada's support for the IAEA's Safeguards Analytical Laboratory in Seibersdorf has advanced environmental sampling, detecting trace nuclear materials to identify covert facilities (International Atomic Energy Agency, 1998). Japan's collaboration with the U. S. on the Containment and Surveillance Data Authenticated Communication System, tested at Sandia National Laboratories, exemplifies NNWS contributions to remote monitoring technologies, reducing inspection costs while maintaining high standards (Office of Technology Assessment, 1995). These advancements help the IAEA adapt to emerging challenges, such as small modular reactors (Government Accountability Office, 2024).

NNWS has also set verification standards through regional and institutional cooperation, creating models that enhance efficiency and global applicability. The quadripartite agreement between Argentina, Brazil, the Argentine-Brazilian Agency for Accounting & Control of Nuclear Materials (ABACC), and the IAEA demonstrates how NNWS integrate national systems of accounting and control (SSACs) with IAEA oversight, setting a cost-effective standard for regional safeguards (International Atomic Energy Agency, 1998). Argentina's commitment to export controls under this agreement aligns with Nuclear Suppliers Group (NSG) guidelines, strengthening global verification by regulating dual-use items (Office of Technology Assessment, 1995). Similarly, regional treaties such as the Tlatelolco Treaty (Nuclear Threat Initiative, n.d.), led by Mexico, and the Rarotonga Treaty (Nuclear Threat Initiative, n.d.), pushed by Australia, cover entire regions under safeguards, setting a precedent for comprehensive verification. These efforts demonstrate how NNWS leadership fosters scalable verification frameworks that reduce proliferation risks and encourage global adoption.

NNWS have set standards that indirectly pressure NWS to engage in disarmament verification by modeling transparency. NNWS's rigorous adherence to CSAs and APs encouraged NWS to adopt voluntary offer agreements (VOAs), with the U.S. and U.K. placing civilian nuclear activities under

safeguards to support NNWS NPT adherence (International Atomic Energy Agency, 1998). South Korea's voluntary participation in environmental sampling set a transparency benchmark that NWS could emulate in its military facilities (Office of Technology Assessment, 1995). For example, Norway and the Netherlands' participation in the International Partnership for Nuclear Disarmament Verification (IPNDV) alongside NWS has helped develop warhead-dismantlement protocols, showing that NNWS can lead in creating verification standards applicable to disarmament (International Partnership for Nuclear Disarmament Verification, 2017). This transparency, coupled with diplomatic advocacy at IAEA General Conferences, pushed NWS like France to sign APs by 1998 and fostered joint verification exercises (International Atomic Energy Agency, 1998).

In the absence of NWS action, NNWS leadership has been pivotal in sustaining verification standards and ensuring the IAEA's adaptability and credibility. The NNWS's role in post-Gulf War reforms, such as Program 93+2, which introduced universal reporting of nuclear material exports and imports, enhanced the IAEA's ability to detect undeclared facilities (Office of Technology Assessment, 1995). Japan's funding of the LASCAR study, which developed safeguards for plutonium reprocessing plants, exemplifies NNWS's financial commitment to verification innovation (Office of Technology Assessment, 1995). South Africa's cooperation in verifying its denuclearization set a global standard for dismantling nuclear weapon programs, influencing states like Argentina and Brazil (International Atomic Energy Agency, 1998). Moreover, by proposing verification-focused resolutions, NNWS maintain momentum despite NNWS reluctance, ensuring the safeguards system evolves to address modern proliferation risks.

3.3.2. Legal and Institutional Innovation in Nuclear Disarmament by NNWS

The TPNW, adopted on July 7th, 2017, at the UN, is a groundbreaking achievement led by NNWS that addresses legal gaps in nuclear disarmament under the NPT. Article VI of the NPT mandates "effective measures" toward disarmament, but NWS resistance in forums like the CD has stymied progress (United Nations, 1970). The TPNW prohibits the development, testing, production, stockpiling, use, or threat of use of nuclear weapons, with verification mechanisms under Articles 3 and 4 requiring states to declare and dismantle nuclear programs under IAEA oversight (United Nations, 2017). Article 1(a) specifically bans developing, testing, producing, manufacturing, acquiring, possessing, or stockpiling nuclear weapons, establishing a critical legal prohibition norm that supports irreversibility (Hajnoczi, 2023). The treaty also mandates victim assistance, acknowledging disproportionate impacts on women, girls, and indigenous peoples (Pytlak, 2018).

NNWS leadership avoids traditional deadlocks through inclusive platforms; Norway, Mexico, and Austria hosted the conferences on the humanitarian impact of nuclear weapons in Oslo (2013), Nayarit (2014), and Vienna (2014), and the 2016 UN open-ended working group, which operated outside the CD's consensus constraints, recommended negotiating a legally binding prohibition, galvanizing TPNW support. (International Campaign to Abolish Nuclear Weapons, n. d.) The Humanitarian Initiative, backed by 127 states (through the Humanitarian Pledge) and civil society, including WILPF through the International Campaign to Abolish Nuclear Weapons (ICAN), reframed the debate around humanitarian impacts, leading to the TPNW's adoption (Pytlak, 2018).

TPNW's verification framework requires baseline declarations of nuclear programs, a critical step for compliance and irreversibility. (Nuclear Weapons Ban Monitor, n. d.) Secure cryptographic declarations protect sensitive data while building trust, allowing states to reveal information gradually. Irreversibility, as a continuum rather than an absolute state, aims to make rearmament costly and difficult (Cliff et al., 2011). TPNW's Article 5 mandates national implementation through legal, administrative, and penal measures. Article 4 offers NWS two pathways: join and dismantle, or dismantle and then join, as South Africa's unilateral disarmament shows, eliminating its nuclear arsenal with ex-post verification (Evans, 2021).

NWFZs institutionalize non-proliferation and disarmament norms across 116 states. Treaties such as Tlatelolco (1967) and Pelindaba (1996; Fuhrmann & Li, 2009) exemplify NNWS leadership in creating legally binding frameworks prohibiting nuclear weapons, with IAEA safeguards ensuring

compliance (OPANAL, 1967; African Union, 1996). These zones contribute to irreversibility by establishing regional legal norms that deter rearmament. However, NWS non-endorsement of NWFZ protocols limits the scope of verification (Hamel-Green, 2009). NNWS continue to expand these frameworks, with the Bangkok and Central Asian NWFZs reinforcing regional norms.

NWFZs rely on IAEA safeguards (International Atomic Energy Agency, n. d.) But non-intrusive methods such as satellite imagery and environmental sampling could enhance verification by detecting undeclared activities. These methods reduce reliance on on-site inspections, increase acceptance among states wary of intrusive regimes, and support irreversibility by making covert rearmament easier to detect and more costly (International Atomic Energy Agency, 2002).

Tlatelolco covers 33 Latin American and Caribbean states, all of which comply with IAEA safeguards (Nuclear Threat Initiative, n.d.). Pelindaba's adaptable verification mechanisms face challenges because of the NWS's reluctance. South Africa's disarmament, which preceded the Pelindaba Treaty (opened for signature in 1996), shows how verified unilateral actions can achieve irreversible outcomes (von Baeckmann et al., 1995).

The CD's consensus rule has stalled disarmament because of the NWS objections. NNWS countered by proposing alternative forums, such as the OEWG and humanitarian conferences, that operate without veto constraints (Kmentt, 2021a). These platforms enabled proposals for verification models, disarmament timelines, and irreversibility measures, with civil society support. Absence verification, which confirms the absence of undeclared warheads, is a practical approach for early disarmament phases and requires minimal sensitive measures. This supports irreversibility by raising the cost of reversal, as seen in international exercises such as the IPNDV (Hajnoczi, 2023). The TPNW's Article 17 withdrawal clause, which requires 12 months' notice and delays withdrawal while the withdrawing state is party to an armed conflict, strengthens irreversibility compared to the NPT's 3-month period. However, challenges remain due to potential violations. (United Nations Office for Disarmament Affairs, n. d.)

The CD's paralysis prioritizes NWS interests. NNWS initiatives, supported by Civil society, highlight inclusivity and humanitarian principles, making them responsive to global demands. Gendered discourse frames disarmament as "weak," highlighting humanitarian security benefits (Pytlak, 2018).

TPNW is the first nuclear treaty to address gendered impacts, recognizing women's and girls' disproportionate harm from radiation and advocating for women's participation in disarmament (United Nations, 2017). Women face unique health risks, including reproductive issues and social stigmatization in affected communities (Pytlak, 2018). The 2017 Women's March, led by figures like Kozue Akibayashi, highlighted women's leadership and aligned with gendered security paradigms (International Campaign to Abolish Nuclear Weapons, 2017). These challenging masculinized narrative frames nuclear weapons as stronger and disarmament as weakness.

Monitoring fissile materials stocks is important for irreversible disarmament, as the nuclear-armed states hold the world's military stocks of highly enriched uranium and plutonium, sufficient for thousands of weapons (Podvig, 2019b). Current IAEA safeguards are insufficient for NWS, necessitating "nuclear archaeology" to reconstruct the production histories. Non-intrusive methods like perimeter monitoring and standoff detection could verify production halts, reduce the need for on-site inspections, and support irreversibility by increasing reversal costs. For instance, South Africa's disarmament verification focused on fissile-material records, a model for larger programs, and achieved irreversibility through the destruction of its nuclear infrastructure (von Baeckmann et al., 1995). International exercises like the IPNDV test absence verification, giving scalable solutions (Grant, 2019).

Irreversibility faces challenges from the treaty withdrawal clause and potential violations. The TPNW's Article 17 requires 12 months' notice and delays withdrawal while the withdrawing state is party to an armed conflict, a stronger barrier than the NPT's 3-month notice (Hajnoczi, 2023). However, as seen in the DPRK's NPT withdrawal, enforcement relies on international sanctions to make violations costly. Chile proposed a non-withdrawal clause during TPNW negotiations, but it was rejected, highlighting political barriers to absolute irreversibility (Hajnoczi, 2023).

3.3.3. Filling Multilateral Gaps

NNWS like Austria, New Zealand, and Finland contribute significantly to transparency and verification in nuclear disarmament by leveraging advanced tools such as blockchain and AI, bypassing deadlocks in NWS-dominated forums like the CD and fulfilling their NPT Article VI obligations. Blockchain's immutability, encryption, and distributed consensus, combined with the IA's predictive analytics and automated data validation, enable secure, decentralized platforms for tracking fissile materials and verification data, fostering trust among NPT stakeholders without relying on centralized authorities. For instance, Finland's SLAFKA prototype, developed in 2020 by the Finnish Radiation and Nuclear Safety Authority (STUK) with the Stimson Center and the University of New South Wales, uses a permissioned blockchain to record nuclear material transactions on a distributed ledger, demonstrating improved transparency and efficiency in safeguards (Vestergaard et al., 2020). These technologies address the multilateral gap created by NWS dominance slowing progress: blockchain eliminates the need for a central authority, and AI reduces human error, enabling NNWS to propose platforms that encode verification protocols and use zero-knowledge proofs to protect sensitive data (Burford, 2020). Despite challenges like metadata security and governance, pilot projects like SLAFKA and diplomatic efforts by New Zealand in NPT forums stress how NNWS can build technical capacity and cooperation, aligning with initiatives like the International Partnership for Nuclear Disarmament Verification (IPNDV) to drive innovative, transparent disarmament processes (Burford, 2020; Vestergaard et al., 2020). By promoting blockchain- and AI-based systems, NNWS can transform multilateral disarmament by ensuring data integrity and fostering trust, as these technologies' unique attributes align with verification needs (Burford, 2020).

South-South cooperation empowers NNWS from the Global South, such as Indonesia and Nigeria, to challenge nuclear colonialism by forming coalitions that advocate disarmament frameworks prioritizing economic, environmental, and humanitarian justice, thereby reducing reliance on NWS-dominated agendas. Southern States' historical agency is evident in Indonesia's leadership at the 1955 Bandung Conference, which called for universal disarmament, and in Nigeria's participation in the Eighteen Nation Committee on Disarmament, whose deliberations preceded the 1963 Partial Test Ban Treaty (Plesch, 2016). This activism is a response to nuclear colonialism, exemplified by France's nuclear tests in Algeria and uranium mining in Niger, which caused environmental and social harm without economic benefits (Hennaoui, 2023). The Global South's contestation of the NPT's legitimacy, driven by its failure to advance disarmament under Article VI and its restrictions on peaceful nuclear energy access under Article IV, is seen as perpetuating colonial inequities (Herrera et al., 2023). For instance, the Non-Aligned Movement's (NAM) advocacy for the CTBT and the 2017 TPNW, adopted with the votes of 122 states, most of them from the Global South, redefines nuclear weapons as symbols of inequality (Hennaoui, 2023).25 UN disarmament treaties since 1945, many influenced by Southern activism, have given a foundation for these efforts. The Treaty of Tlatelolco and the NWFZ in Latin America show how regional coalitions address local vulnerabilities (Plesch, 2016). South-South cooperation counters the NPT's two-tier system, which increases disparities and prioritizes NWS interests. By fostering alternative pathways, such as NWFZs and TPNW, Global South countries increase representation, align disarmament with development, and challenge colonial legacies in global nuclear governance.

NNWS such as Switzerland play a key role in addressing multilateral gaps in nuclear disarmament by developing modular verification protocols that are flexible, incremental, and sensitive to NWS security concerns, fostering trust and cooperation. The IPNDV, involving more than 25 countries, demonstrates this through its 14-step generic process for warhead dismantlement, which focuses on specific tasks such as fissile-material monitoring while using managed access to protect sensitive information. (International Partnership for Nuclear Disarmament Verification (IPNDV), 2024)Similarly, the IAEA's integrated safeguards, applied in 69 states by 2022, reduced person-days of inspection (PDI) by 176 days per state, improving verification efficiency by extending timeliness goals, such as shifting spent-fuel inspections from quarterly to annual (Gastelum, 2024). For instance, Switzerland's contributions to the IPNDV's 2017 Geneva Tabletop Exercise and the UN Group of Governmental Experts (Resolution 71/67) tested modular protocols and promoted inclusive frameworks, encouraging NWS participation (Cliff et al., 2013). This integrated safeguards ap-

proach significantly reduces NWS reluctance, builds multilateral trust, and advances disarmament by building on existing IAEA frameworks (Gastelum, 2024).

3.4. NNWS Technical Contribution to Nuclear Disarmament Verification

Zero-Knowledge Proofs (ZKPs): ZKPs verify a warhead's physical characteristics without revealing classified design information. They cannot verify the complete dismantlement process or the origin of fissile materials. They require pre-agreed cryptographic templates and inputs of physical radiation data.

Blockchain: Blockchain verifies the chain of custody and the immutability of nuclear-material transaction records. It cannot verify the material's physical presence or isotopic composition. It requires digitized, sensor-generated data inputs to prevent falsified data entry.

Artificial Intelligence (AI): AI verifies compliance patterns by analyzing large datasets from environmental sampling and remote monitoring. It cannot independently confirm the absence of undeclared activities without physical sensor data. It requires vast, high-quality historical baseline data to train accurate predictive models.

NNWS are pivotal in advancing nuclear disarmament verification through technical expertise, operational support, and innovative technologies. So, by participating in initiatives like IPNDV, hosting IAEA safeguards, and developing tools such as zero-knowledge proofs (ZKPs) and nuclear archaeology, NNWS increase the credibility, inclusivity, and robustness of the global verification regime.

NNWS significantly increases nuclear disarmament verification by contributing cutting-edge scientific expertise to develop innovative technologies that authenticate nuclear warheads and fissile materials while protecting sensitive information. Research groups, working mainly in NWS and increasingly in partnership with NNWS institutions, have developed methods such as zero-knowledge protocols (Glaser et al., 2014) and physical cryptographic verification (Kemp et al., 2016) that authenticate warhead properties without revealing sensitive design details. These technologies are vital for the proposed International Nuclear Disarmament Agency (INDA) Center for Nuclear Disarmament Verification Research and Development, which relies on international collaboration to refine verification systems (Shea, 2018). NNWS scientists ensure robust, adaptable verification methods that foster trust among nuclear-armed states. However, integrating these technologies into a standardized global framework needs coordination to ensure consistency and accessibility, particularly for states with limited technical resources.

NNWS contribute to nuclear disarmament by developing and sharing low-tech, cost-effective technologies that make monitoring accessible to states with limited resources. The 2007 United Nations report on verification stresses the utility of low-tech methods, such as aerial surveillance and cooperative monitoring, which NNWS can deploy to support verification efforts (United Nations, 2007). This contribution ensures verification is feasible across diverse economic contexts and strengthens global disarmament frameworks. Challenges include meeting rigorous verification standards while remaining cost-effective.

NNWS increases nuclear disarmament verification by providing environmental sampling and analysis capabilities, essential for detecting undeclared nuclear activities and verifying compliance with disarmament agreements. Environmental sampling is a key tool for monitoring undeclared facilities and requires an advanced understanding of source-term mechanisms, environmental fate, and transport modeling (National Academies of Sciences, 2021). Through participation in IAEA safeguards and CTBTO monitoring, NNWS contributes by collecting and analyzing samples for radionuclides and proliferation indicators. For instance, Germany hosts a CTBTO radionuclide laboratory. It participates in the IAEA's Network of Analytical Laboratories (NWAL), analyzing environmental swipe samples to detect nuclear materials, as seen in verification in Iran. (International Atomic Energy Agency, n. d.)These capabilities improve global detection of clandestine activities, helping uphold disarmament agreements. However, maintaining high-precision laboratories and coordinating international efforts need sustained funding and technical training.

NNWS contribute to nuclear disarmament verification by developing and implementing safeguards and inspection protocols critical to ensuring compliance with agreements like the NPT. The evolution of monitoring, detection, and verification (MDV) for the nuclear fuel cycle highlights the need to enhance safeguards tools and inspection capabilities (National Academies of Sciences, 2021). As IAEA members, NNWS refine protocols under the AP to enable intrusive inspections that verify the absence of undeclared activities. Japan, with its advanced nuclear energy program, has led the development of IAEA safeguards approaches, including remote monitoring and unattended surveillance systems applicable to disarmament verification (Office of Technology Assessment, 1995). These contributions offer practical insights into effective inspection methods adaptable to warhead dismantlement and fissile material disposition. Challenges remain in standardizing protocols across diverse nuclear facilities and ensuring they remain adaptable to the disarmament context.

NNWS play a vital role in nuclear disarmament verification by supporting the technical process for disposing of fissile materials such as highly enriched uranium (HEU) and plutonium, removed from nuclear weapons. The IAEA's safeguards systems, supported by NNWS, verify disposition methods like down-blending HEU into low-enriched uranium for reactor fuel or immobilizing plutonium using the "can -in- canister" method (Shea, 2018). Japan, with expertise in managing plutonium for civilian nuclear energy, provides technical support to ensure no material is diverted back to weapon use (Shea, 2018). These efforts are critical to ensure irreversibility, remove fissile materials from military applications, and maintain disarmament integrity. However, challenges remain in securing funds for disposition programs and mitigating proliferation risks during the process, requiring high expertise and coordination with international bodies like the IAEA.

4. Discussion

4.1. Challenges Faced by NNWS in Verifying Nuclear Weapon States' Disarmament

Despite NNWS's advances in verification technologies, their limited nuclear programs compared to NWS may limit their ability to independently perform complex tasks such as warhead dismantlement and fissile-material verification.

NNWS contribute to verification through innovations like zero-knowledge proofs (ZKPs) and nuclear archaeology (Glaser et al., 2014; Göttsche, 2024). However, verifying highly enriched uranium (HEU) and Plutonium requires advanced nuclear forensics, which many NNWS lack due to limited nuclear infrastructure (Street, 2021). The TPNW's join-and-disarm option requires verifying weapon elimination without proliferation-sensitive information, a task complicated by NNWS's limited access to nuclear-weapons expertise (Podvig, 2021). In South Africa's disarmament, the IAEA verified the completeness of the initial declaration with cooperation from South African authorities, using techniques such as nuclear archaeology that most NNWS do not possess (von Baeckmann et al., 1995). For instance, Germany's nuclear archaeology research traces fissile-material histories, but scaling these technologies requires significant investment (Göttsche, 2024). Similarly, the IPNDV's work on verification tools, involving NNWS like Norway, stresses their contributions but underscores the need for NWS expertise to ensure credibility (Podvig, 2021).

NNWS's technological innovations, such as zero-knowledge and physical cryptographic techniques (Glaser et al., 2014; Kemp et al., 2016), enhance verification, but their reliance on NWS expertise or IAEA support limits their independence. This reliance reduces NNWS confidence in verifying NWS disarmament, particularly under TPNW's joint-and-disarm framework, where credibility hinges on expertise NNWS often lack (Podvig, 2021).

NWS secrecy around nuclear facilities limits NNWS verification capabilities, despite their efforts to develop non-intrusive monitoring technologies. NWS voluntary offer agreements and the CTBT's managed-access provisions protect proprietary and military secrets, restricting inspector access (Asculai, 2002). For example, the UK's Trident system operates under strict confidentiality, potentially limiting the scope of verification (Street, 2021). In South Africa's case, the IAEA had to verify the

completeness of the declaration while protecting sensitive weapon-design information (von Baeckmann et al., 1995).

NNWS such as Mexico, as members of the New Agenda Coalition, call for greater NWS transparency about their arsenals, but restricted access hinders their verification efforts (New Agenda Coalition, 2015). Limited access to NWS sites constrains NNWS contributions, such as Germany's environmental sampling for the CTBTO (Shea, 2018). Despite NNWS's advancement in monitoring archologies, restricted access fosters perceptions of an NWS-controlled process, undermining trust and limiting NNWS participation (Street, 2021).

Verifying fissile material and dual-use facilities is complex because of their classified nature and dual-use potential, challenging NNWS despite innovative verification tools. The TPNW's reliance on IAEA safeguards struggles to verify HEU and plutonium, as seen in the difficulty of confirming the completeness of South Africa's initial declaration (von Baeckmann et al., 1995). Negative verification, proving the absence of undeclared materials, has high error rates, and wide-area environmental sampling (WAES) has limited demonstrated reliability for detecting uranium enrichment (Asculai, 2002). Iraq's case exposed IAEA limitations in the absence of full transparency (Asculai, 2002). Researchers in NNWS such as Germany advance ZKPs and nuclear archaeology (Glaser et al., 2014; Göttsche, 2024), but these require intrusive access, which NWS resist. Germany's CTBTO laboratory increases environmental sampling, yet it can't fully address challenges posed by dual-use facilities (National Academies of Sciences, 2021). NNWS contributions improve verification, but the complexity of fissile material and dual-use facilities, combined with NWS resistance, undermines confidence and discourages participation because of the risk of undetected violations.

The NPT's discriminatory structure and NWS influence foster distrust, undermining NWS confidence in verification despite their diplomatic efforts. The strategic realignment of non-nuclear states through defense alliances often triggers reciprocal militarization in sensitive regions, thereby complicating the operational environment for multilateral verification efforts (Lamminparras, 2025). The NPT's division into NWS and NNWS creates perceptions of bias, with Non-Aligned Movement (NAM) states criticizing NWS for prioritizing non-proliferation (Street, 2021). The TPNW's join-and-disarm framework requires NWS cooperation, which is often lacking (Podvig, 2021). NNWS demanded concessions to adopt INFCIRC/540, reflecting skepticism about equitable treatment (Asculai, 2002).

Uneven safeguards, with NWS facing partial scrutiny in EURATOM compared to NNWS, fuel distrust (Asculai, 2002). Japan's leadership in IAEA safeguards contrasts with the limited influence of developing NNWS, highlighting structural inequalities (Shea, 2018). Despite NNWS diplomatic contributions, such as Indonesia's CTBT advocacy (Comprehensive Nuclear-Test-Ban Treaty Organization, 2012), political distrust and perceived biases reduce their engagement, as they question the fairness of the NWS-dominated process.

The IAEA and CTBTO's limited authority restrict NNWS's ability to enforce NWS compliance, despite their active engagement in these bodies. INFCIRC/153 limits the IAEA's ability to challenge state declarations, as seen in Iraq and North Korea, and does not apply to NWS, whose voluntary offer agreements cover only the facilities they choose to offer (Asculai, 2002). The CTBT's failure to enter into force limits on-site inspections, as shown by North Korea's 2017 test (Comprehensive Nuclear-Test-Ban Treaty Organization, 2017). TPNW's Article 9(3) makes the states to which nuclear weapons are attributable responsible for the costs of safeguards and elimination, so verification funding depends on their cooperation (United Nations, 2017).

NNWS like Germany and Japan support the IAEA's Network of Analytical Laboratories and CTBTO monitoring (International Atomic Energy Agency, n.d.). However, NWS dominance in the UN Security Council can block enforcement, lowering effectiveness (Street, 2021). NNWS's contributions to international verification are significant, but limited institutional authority undermines their ability to ensure compliance and discourages participation in NWS-dominated frameworks. The power imbalance, particularly in TPNW's join-and-disarm framework, discourages NNWS participation, as they feel powerless in NWS-dominated systems (Podvig, 2021).

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High verification costs and training requirements limit NNWS participation, particularly in developing states, despite their cost-effective solutions. Verification needs investments in satellite monitoring and training, which many NNWS can't afford (Asculai, 2002). The IAEA's Action Team in Iraq faced resource shortages, and high costs limit adoption (Asculai, 2002). Low-tech monitoring approaches show NNWS potential, but scaling requires funding (United Nations, 2007). Building a global cadre of verification experts requires sustained investment. Wealthier NNWS like Japan provide significant aid to IAEA safeguards, while developing states are marginalized by financial constraints (Street, 2021). The TPNW's verification process, requiring fissile material accounting, adds a financial burden for NNWS (Podvig, 2021). NNWS's cost-effective technologies increase accessibility, but financial barriers exclude developing states, reducing inclusivity. The TPNW's resource-intensive verification requirements further limit NNWS participation, reinforcing disparities (Shea, 2018).

Verifying irreversibility is challenging due to persistent nuclear knowledge and dual-use technologies, creating a security dilemma that deters NNWS participation. South Africa's verification required assurances against rebuilding capabilities, but retained knowledge posed risks (Street, 2021). Intrusive inspections, like those for NATO-Russia, can escalate tensions (Street, 2021). The TPNW's join-and -disarm option risks breakout capabilities, as weapons may remain intact until the process ends (Podvig, 2021). NNWS contributions to fissile-material disposition carry proliferation risks (Shea, 2018).

Japan's expertise in plutonium management supports disposition, but ensuring permanence is difficult because monitoring retained knowledge is challenging (Shea, 2018). The "contain and dispose" approach reduces risks by isolating materials, but NNWS can't independently verify irreversibility.

NNWS efforts in the disposition process are significant, but concerns over irreversibility and security dilemmas discourage participation. The TPNW's verification challenges amplify these risks, as NNWS lack the capacity to monitor breakout potential, limiting engagement (Podvig, 2021).

Institutional deadlocks in forums like the Conference on Disarmament (CD) hinder verification and limit the impact of NNWS's alternative diplomatic efforts. Contemporary nuclear policy architectures increasingly struggle to address modern proliferation dynamics, highlighting the need for adaptive verification frameworks that integrate advanced intelligence capabilities and account for evolving strategic deterrence postures (Porel, 2025). The CD's consensus-based approach stalls verification advancements, pushing NNWS to TPNW meetings, which lack NWS participation (United Nations, 2018). The P5 process's lack of transparency further hampers progress (Browne, 2014). Indonesia's CTBT advocacy highlights NNWS initiative but faces NWS resistance (Comprehensive Nuclear-Test-Ban Treaty Organization, 2012).

NNWS contributions through IPNDV and IAEA are significant, but alternative forums struggle to influence NWS-dominated processes (Street, 2021). The TPNW's verification authority requires NWS cooperation, which is often absent (Podvig, 2021). NNWS's diplomatic efforts are innovative but limited by institutional deadlocks and NWS non-engagement. The TPNW's reliance on a competent authority with limited NWS support reduces NNWS motivation to participate, as progress remains contingent on cooperation (Podvig, 2021).

4.2. Policy Recommendations for NNWS in Verifying NWS Disarmament

As discussed earlier, NNWS face technical, political, and structural challenges in verifying Nuclear Weapon States (NWS) disarmament, including asymmetries in expertise, restricted access, fissile material complexities, political distrust, and resource constraints. So, this paper proposes actionable policy recommendations to increase NNWS participation. These strategies leverage existing frameworks like the Treaty on the Prohibition of Nuclear Weapons (TPNW), New START, and the proposed International Nuclear Disarmament Agency (INDA), addressing barriers while fostering trust and equity in global disarmament efforts.

Absence Verification Frameworks: NNWS should advocate for verification frameworks focused on confirming the absence of nuclear weapons in specific scenarios, such as non-strategic weapons in Europe or denuclearization of the Korean Peninsula, using adapted New START protocols.

Verifying absence avoids the complexities of warhead dismantlement and fissile material verification, which require advanced expertise and access to classified NWS facilities (Street, 2021). This approach is less intrusive, leveraging tools like radiation detection that NNWS can employ without sensitive knowledge (Podvig et al., 2018). It reduces technical asymmetries and builds confidence, addressing distrust and security dilemmas (Shea, 2018).

New START's radiation detection procedures confirm non-nuclear status without revealing warhead designs, suitable for NNWS inspectors (Podvig et al., 2018). The U. S. withdrawal of nuclear weapons from South Korea under the Presidential Nuclear Initiatives (PNIs) shows absence verification's trust-building potential (Podvig et al., 2018). The Russia-Ukraine Sevastopol inspection protocol used visual checks to verify non-nuclear aircraft, offering a model for NNWS -led efforts (Podvig et al., 2018).

NNWS should propose pilot projects at TPNW Meetings of States Parties, collaborating with NATO or ASEAN to verify the absence in regions like Europe or Southeast Asia (Podvig et al., 2018). INDA's Nuclear Disarmament Institute could develop protocols (Shea, 2018) with South Korea leading efforts on the Korean Peninsula.

Technical Capacity-Building and Training: NNWS should create an IAEA- or INDA-led training program to build expertise in verification techniques, including nuclear archaeology, zero-knowledge proofs (ZKPs), and radiation detection, prioritizing the development of NNWS. Technical asymmetries limit NNWS participation, as seen in NNWS's limited access to weapons expertise (Shea, 2018). Training empowers NNWS to conduct independent inspections, lowering dependency and increasing credibility (Street, 2021). INDA's proposed training hubs align with this goal, focusing on non-intrusive methods like absence verification (Shea, 2018).

Germany's nuclear archaeology research shows NNWS potential with investment (Göttsche, 2024). New START's neutron detection techniques are straightforward, enabling NNWS to verify absence with minimal expertise (Podvig et al., 2018). The Trilateral Initiative trained inspectors in attribute verification, a model for NNWS capacity-building (Shea, 2018).

NNWS led by Sweden or Japan should propose a training academy at NPT Review Conference or TPNW meetings, funded through a reformed TPNW financing model. INDA's Center for Nuclear Disarmament Verification R& D should oversee curriculum development, partnering with IPNDV (Shea, 2018).

Managed Access and Information Barrier Protocols: NNWS should negotiate managed access protocols, inspired by New START, to gain limited access to NWS storage facilities and delivery systems, using ZKPs and information barriers to protect sensitive data. NWS secrecy restricts access, fostering distrust (Street, 2021). Managed access balances transparency with security, allowing NNWS inspectors to verify absence while mitigating NWS concerns (Shea, 2018). Institutionalized consultation mechanisms and structured joint planning can significantly enhance verification credibility and crisis stability, though they must be carefully calibrated to prevent exacerbating regional security dilemmas among neighboring states (Mulyanyuma, 2026). This reduces security dilemmas and encourages NNWS participation (Shea, 2018).

New START's managed access procedures use soft covers to protect sensitive data during inspections, adaptable for NNWS (Podvig et al., 2018). The Sevastopol protocol allowed Ukraine to verify Russian aircraft with minimal intrusion (Podvig et al., 2018).

NNWS such as Mexico or Indonesia should propose protocols such as TPNW or bilateral talks, targeting U. S. or Russian facilities in Europe or Asia. INDA's nuclear disarmament council should enforce compliance, piloting ZKP-based inspections (Shea, 2018).

Regional Task Forces within Nuclear-Weapon-Free Zones: NNWS should initiate regional task forces within nuclear -weapon-free zones (e. g., Tlatelolco, Pelindaba) to develop absence verifica-

tion protocols and build trust. Political distrust and NPT inequalities undermine NNWS confidence (Street, 2021). Regional initiatives leverage local expertise, reducing reliance on NWS-dominated institutions and fostering cooperation (Asculai, 2002). They align with gradual confidence-building measures (Podvig et al., 2018).

For instance, the Bangkok Treaty could enable Southeast Asian NNWS to verify the absence of nuclear weapons, enhancing regional trust. Kazakhstan, which gave up the nuclear weapons it inherited from the Soviet Union, shows NNWS leadership in regional efforts (Kassenova, 2022). The Panmunjom Declaration highlights South Korea's role in Korean Peninsula denuclearization. NNWS should form task forces at the TPNW meeting, collaborating with IAEA or INDA to share resources; Latin American and African NNWS could pilot protocols under Tlatelolco or Pelindaba.

Equitable Financing for Verification Mechanisms: NNWS need to advocate for a TPNW financing model with shared contributions, a nuclear warhead tax, and a philanthropic endowment to fund verification, prioritizing developing NNWS. So, high verification costs exclude developing NNWS, as seen in Iraq's under-resourced IAEA efforts (Asculai, 2002). Replacing Article 9.3's NWS-funded model with equitable contributions addresses financial inequities and NWS influence (Shea, 2018). A warhead tax incentivizes disarmament, while endowments support capacity-building (Street, 2021). For instance, a 1,000,000 per warhead tax could fund NNWS training and technologies (Shea, 2018). Japan's IAEA contributions contrast with developing NNWS's limitations, underscoring funding disparities (Street, 2021).

IAEA's funding model shows shared contributions can support verification (Asculai, 2002). NNWS led by Brazil or Indonesia should propose this reform at the UN General Assembly or TPNW meetings, with INDA's Budget and Finance Committee overseeing implementation. A pilot fund could support training academies.

NNWS-Led Verification Institution: NNWS may create an NNWS-led verification institution under the TPNW, complementing the IAEA and INDA, with a governing board, technical unit inspection teams, and an advisory panel including non-state actors.

NWS influence over the IAEA and institutional deadlocks in the Conference on Disarmament (CD) limit NNWS roles. An NNWS-led institution ensures accountability and bypasses NWS resistance, aligning with INDA's governance model (Shea, 2018). South Africa's transparency visits show NNWS-led initiatives can build trust (von Baeckmann et al., 1995). Kazakhstan's disarmament leadership supports alternative forums (Kassenova, 2022). Non-governmental organizations such as VERTIC also contribute to NNWS verification capacity through research and training (Cliff et al., 2013). NNWS should propose the institution at TPNW Conferences, securing UN General Assembly support through NAC coalitions. The institution could pilot ZKP-based inspections, coordinated with INDA (Shea, 2018).

Fissile Material Verification Framework: NNWS need to support an INDA-led fissile material verification framework using nuclear archaeology, AI -based detectors, and mandatory NWS declaration to address dual-use facility complexities.

Fissile material verification is challenging due to classified characteristics and dual-use risk (Shea, 2018). INDA's fissile material controls and nuclear archaeology can verify the declaration, reducing negative verification difficulties (Shea, 2018).

Germany's nuclear archaeology research shows NNWS potential (Göttsche, 2024).

Strengthening IAEA and INDA Authority through Diplomatic Forums: NNWS can use the diplomatic forums to strengthen INDA and IAEA authority, advocating for mandatory NWS compliance with inspections and expanded IAEA safeguards under TPNW Article 4. IAEA's limited authority, as viewed in Iraq and North Korea, hinders NNWS efforts (Asculai, 2002). INDA's enforcement powers and IAEA's disarmament-verification role can ensure compliance, boosting NNWS confidence; for instance, INDA's model agreements provide a legal basis for enforcement (Shea, 2018). Indonesia's CTBT advocacy shows NNWS diplomatic leverage (Comprehensive Nuclear-Test-Ban Treaty Organization, 2012). CTBT's non-entry into force underscores the need for binding commit-

ments (Comprehensive Nuclear-Test-Ban Treaty Organization, 2017). NNWS should propose resolutions at the UN General ASSEMBLY, endorsing INDA's status and expanded IAEA safeguards

Confidence-Building Measures and Irreversibility: The INDA-led confidence -building measures proposed by NNWS, including transparency visits, temporary warhead monitoring, and human-centric verification with cultural sensitivity training to ensure irreversibility and reduce tensions. Irreversibility concerns and security dilemmas undermine trust (Street, 2021). Transparency visits and monitoring, as used in South Africa, build confidence, while human-centric approaches manage interactions effectively (von Baeckmann et al., 1995).

5. Conclusions

Non-Nuclear Weapon States (NNWS) have significantly reshaped nuclear disarmament verification by serving as norm entrepreneurs, technical innovators, and key contributors to multilateral institutions. Although their influence remains constrained by geopolitical realities and structural power asymmetries, their efforts through the Treaty on the Prohibition of Nuclear Weapons (TPNW), International Atomic Energy Agency (IAEA) safeguards, and advances in verification technologies have created practical pathways toward a world free of nuclear weapons. Greater implementation of targeted, multilateral policy measures would further strengthen the capacity of NNWS to promote a more inclusive, transparent, and effective global nuclear verification architecture.

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