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YOUTH FOR CTBT

CTBTO
PREPARATORY COMMISSION

CTBTO
RESEARCH FELLOWSHIP

A Collection of
Fellowship Research Papers

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About the CTBTO Research Fellowship

The CTBTO Research Fellowship was launched in 2021 and organized in cooperation with the Center for Energy and Security Studies (CENESS) to help promising young scholars build their professional networks by giving them access to top professionals and experts in the field of nuclear disarmament and nonproliferation. The Fellows were invited to attend a series of webinars lectured by prominent experts and diplomats, conduct research on the CTBT, nonproliferation, and disarmament issues, and engage with distinguished scholars and practitioners.

About the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization

The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) was established in 1996, with its seat in Vienna. Its main tasks are promoting the Comprehensive Nuclear-Test-Ban Treaty and building the verification regime to ensure its operational readiness when the Treaty enters into force. The Commission is headed by the Executive Secretary, Dr. Robert Floyd. The CTBTO Youth Group (CYG), launched in January 2016, is open to students and young professionals dedicated to achieving the entry into force and universalization of the CTBT. As of May 2026, the Group had grown to over 1,930 members from 137 countries. The year 2026 marks two significant milestones for the CTBT: the 30th anniversary of the Treaty's opening for signature and the 10th anniversary of the establishment of the CYG.

About the Center for Energy and Security Studies

The Center for Energy and Security Studies (CENESS) is an independent, non-governmental think tank established in 2009. Headquartered in Moscow, the Center's main goal is to promote independent, unbiased, systematic, and professional analyses on nuclear nonproliferation, arms control, and the peaceful uses of nuclear energy. The flagship project of CENESS is the Moscow Nonproliferation Conference, which includes a New Generation Experts Segment, held biennially. The Director of CENESS is Anton Khlopkov.

NOTE

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Pro et Contra: Chinese, Russian and U.S. Approaches to Commitments under the CTBT

■ Edward Kendall ■ Larisa Saveleva ■ Yue Yuan

ABSTRACT

Amid rising tensions in the world, the Comprehensive Nuclear-Test-Ban Treaty (CTBT) has become both a source of stability and a point of disagreement. This paper examines how and to what extent CTBT Non-Ratifying P5 States – China, Russia and the U.S. – continue to view the Treaty as an important barrier to renewed nuclear testing while also pursuing their own national security priorities. As their respective testing moratoria face political pressure and mutual distrust grows, one needs to analyze specific factors shaping Chinese, Russian, and U.S. approaches to the CTBT and to identify practical measures that could reduce the risk of resumed nuclear explosive testing and strengthen the broader arms control and nuclear non-proliferation regime.

NEGOTIATING THE CTBT: THE ROLE OF CHINA, RUSSIA, AND THE U.S.

The Comprehensive Nuclear-Test-Ban Treaty's (CTBT) origins are deeply intertwined with earlier disarmament frameworks, such as the 1963 Partial Test Ban Treaty and 1968 Nuclear Non-Proliferation Treaty (NPT), which called upon parties to pursue "the discontinuance of all test explosions of nuclear weapons for all time." With mounting pressure in the leadup to the 1995 NPT Review and Extension Conference, Beijing, Moscow, and Washington came to recognize that a comprehensive global prohibition on nuclear testing has become a key ingredient for the survival and consolidation of the nuclear non-proliferation regime.

As decades-long negotiations on nuclear test ban in the Conference on Disarmament (CD) were approaching their final stage in 1994, the three powers were viewing them with distinct priorities (see Table 1). China's nuclear policy narrative was still largely based on its 30-years old statement, dating back to 1964, when China conducted its first nuclear test. The statement contained a declaration that China would never be the first to use nuclear weapons under any circumstances and called for the comprehensive prohibition and complete elimination of nuclear weapons. Thus, Beijing has treated the CTBT less as a stand-alone technical instrument than as an element within a wider nuclear disarmament and arms control framework.[1]

1 The State Council of the People's Republic of China, "Gazette of the State Council of the People's Republic of China", No. 22, Serial No. 836, 1996, <https://www.gov.cn/gongbao/shuju/1996/gwyb199622.pdf/, accessed 26 April 2026>.

Building on this, in January 1994, China was the first among the nuclear-weapon states to propose a draft treaty on the mutual no-first-use of nuclear weapons.[2] It has also expressed support for a comprehensive nuclear testing ban and the pursuit of complete nuclear disarmament, and introduced a moratorium on testing in 1996.[3]

For the U.S., the principal stated concern was the credibility of the verification regime and, ultimately, the political feasibility of Senate ratification. At the same time, in light of the dramatic dissolution of the U.S.'s arch-rival, the USSR, the main strategic rationales for the CTBT were to prevent smaller nuclear-weapon states from reaching the U.S. level of technological sophistication in the field of nuclear weapons and to strengthen barriers against proliferation. Thus, in response to a combination of strategic, political, and domestic considerations, the United States introduced a moratorium on nuclear testing in 1992.

Following the Soviet Union's dissolution in 1991, the Russian Federation as the successor state continued to play an active role in shaping the CTBT's verification and entry-into-force (EIF) provisions. It also continued to observe the testing moratorium (announced by the USSR in 1990), and in 2001, Moscow even proposed additional verification measures for former test sites in order to motivate Washington to go ahead with the ratification of the Treaty.[4]

Table 1. Summary of the history of nuclear testing and its moratorium in China, Russia, and the U.S.[5,6]

	CHINA	USSR/RUSSIA	UNITED STATES
First test conducted	Xinjiang, 1964	Semipalatinsk, 1949	Alamogordo, 1945
Last test conducted	Xinjiang, 1996	Novaya Zemlya, 1990	Nevada, 1992
Total number of tests conducted	45	715	1054
Signed CTBT	24 September 1996	24 September 1996	24 September 1996
Ratification	No	Yes, 2000; Withdrew ratification, 2023	No

2 Ministry of Foreign Affairs of the People's Republic of China, "No-First-Use of Nuclear Weapons Initiative", July 2024, <https://www.mfa.gov.cn/eng/xw/wjbxw/202407/t20240723_11458632.html/, accessed 30 April 2026>; "China's Signature on Comprehensive Nuclear Test Ban Treaty", Ministry of Foreign Affairs of the People's Republic of China, May 2024, <https://www.fmprc.gov.cn/eng/zy/wjls/3604_665547/202405/t20240531_11367587.html/, accessed 30 April 2026>.

3 "Chinese Minister of Foreign Affairs Expresses Support for Comprehensive Nuclear-Test-Ban Treaty", CTBTO Preparatory Commission, September 2023, <https://www.ctbto.org/resources/for-the-media/press-releases/chinese-minister-foreign-affairs-expresses-support/, accessed 30 April 2026>.

4 "Rossiya i SShA idut neispytannymi putyami" ["Russia and the USA are following untested paths"], Kommersant, 2 October 2023, <https://www.kommersant.ru/doc/6252062/, accessed 28 April 2026>.

5 V. N. Mikhailov, Catalog of Worldwide Nuclear Testing (Sarov: RFNC-VNIIEF, 1999), p. 2.

6 "Status of Signatures and Ratification", CTBTO Preparatory Commission, 2025, <https://www.ctbto.org/our-mission/states-signatories/, accessed 30 April 2026>.

HEIGHTENED TENSIONS AND EVOLVING THREAT PERCEPTIONS

In 2016, marking the twentieth anniversary of the CTBT's opening for signature, the UN Security Council adopted Resolution 2310, which noted a 15 September (2016) joint statement by the five permanent members affirming that "a nuclear-weapon test explosion or any other nuclear explosion would defeat the object and purpose of the CTBT." In doing so, the resolution reaffirmed the shared understanding among the P5 in line with the 1969 Vienna Convention on the Law of Treaties, that all CTBT Signatories are obliged to refrain from conducting nuclear test explosions even before the Treaty formally enters into force.[7]

China

China continues to describe the CTBT as an important pillar of the international nuclear non-proliferation regime, and it has underscored this position through testing moratorium in place and practical engagement with the CTBTO verification regime. From the Chinese perspective, the primary obstacle to the Treaty's entry into force is the lack of U.S. ratification. In 2014, former Chinese Ambassador to the UN Office at Geneva Sha Zukang, who served as China's chief negotiator during Treaty negotiations, explained that the hesitation of the National People's Congress to ratify the CTBT was largely driven by U.S. actions. He noted that after urging others to conclude the CTBT, the U.S.'s refusal to ratify appeared to signal a desire to preserve its nuclear superiority—raising doubts in Beijing and beyond. Sha further expressed his belief that, should the U.S. ratify the CTBT, China would likely follow.[8]

Given that the CTBT was a key element of the bargain that enabled the indefinite extension of the NPT in 1995, its prolonged stalemate is viewed in China as undermining confidence in global disarmament commitments. In recent years, shifts in the nuclear policies of several major powers have reflected growing strategic mistrust and frustration over the stagnation of multilateral arms control. Viewed with increasing concern in Beijing, these trends have introduced new uncertainty into the environment surrounding the CTBT's entry into force.

Russia

Especially since the first public U.S. accusations in 2019 regarding alleged Russian testing activities, Moscow has grown increasingly frustrated with U.S. criticism of non-compliance in the absence of any practical steps toward U.S. Treaty ratification.[9] Amid deteriorating bilateral Russia-U.S. relations and heightened strategic instability after 2022, Russia formally withdrew its ratification of the CTBT in 2023, while maintaining adherence to its testing moratorium. Russian lawmakers framed this step as restoring "parity of obligations" with the U.S.[10] The move was presented and communicated as a political signal rather than preparation for renewed testing.

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[7] "Vienna Convention on the Law of Treaties", United Nations, May 1969, <https://legal.un.org/ilc/texts/instruments/english/conventions/1_1_1969.pdf/, accessed 30 April 2026>.

[8] Zukang Sha, "The Entry into Force of the CTBT: The Chinese Perspective", European Leadership Network, September 2014, <https://europeanleadershipnetwork.org/commentary/the-entry-into-force-of-the-ctbt-the-chinese-perspective/, accessed 25 April 2026>.

[9] "Nevidimye vzryvy: zachem SShA obvinili Rossiyu v novykh yadernykh ispytaniyakh" ["Invisible Explosions: Why the United States Accused Russia of New Nuclear Tests"], RBK, 20 June 2019, <https://www.rbc.ru/opinions/politics/20/06/2019/5d0a35c49a794741fbb5f789/, accessed 30 April 2026>.

[10] "Explanatory Note to the Draft Federal Law 'On Amendments to the Federal Law On Ratification of the Comprehensive Nuclear Test Ban Treaty'", State Duma of the Russian Federation, 2023, <https://sozd.duma.gov.ru/bill/458681-8#bh_note/, accessed 28 April 2026>.

Russia's Ministry of Foreign Affairs has linked this decision to broader tensions, including NATO's nuclear-sharing arrangements. To reflect its concerns over the interconnection between strategic arms control and global stability, Russia declined to participate in the 14th Conference on Facilitating the Entry into Force of the CTBT, arguing that the final document was inconsistent with Russia's stance and unfairly targeted partners such as the DPRK.[11]

In response to the U.S. presidential statements in October 2025 on potential nuclear test resumption by the U.S., Russia's President Vladimir Putin, during a meeting of the Russian Security Council the following month, instructed various governmental agencies and ministries to "gather more information" on U.S. testing plans while assessing "whether it is advisable to begin preparations for nuclear tests", emphasizing that Russia has always strictly adhered to its obligations under the CTBT and does not intend to deviate from them.[12] This corresponds to Russia's previously articulated position that it would resume testing should the U.S. do so. Some observers have suggested that these recent steps serve an "emotional or domestic" agenda and are "somewhat self-defeating and against Russia's international interests."[13]

United States

U.S. engagement with the CTBT has always been shaped by competing security and political priorities. Since the 1990s, the United States has maintained a moratorium on nuclear explosive testing—subject to a series of safeguards and successful establishment of a stockpile stewardship program[14]—but successive administrations have declined to pursue Senate ratification. The debate has evolved from early doubts about maintaining arsenal reliability without testing to contemporary concerns about potential cheating by other states.[15] The U.S. has long questioned the completeness of the IMS, arguing that it cannot reliably detect very low-yield or well-concealed tests by technologically advanced states.[16] These verification concerns resurfaced in May 2019, when Defense Intelligence Agency Director Lt. Gen. Robert Ashley Jr. alleged that Russia was "probably not adhering" to its testing moratorium consistent with the CTBT's "zero-yield" standard.[17]

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11 "Foreign Ministry Statement on the Reasons for Russia's Refusal to Participate in the 14th Conference on Facilitating Entry into Force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT)", Ministry of Foreign Affairs of the Russian Federation, 27 September 2025, <https://mid.ru/ru/press_service/spokesman/official_statement/2049467/?lang=en/, accessed 30 April 2026>.

12 "Meeting with Permanent Members of the Security Council", President of Russia, 5 November 2025, <http://en.kremlin.ru/events/president/news/78403/, accessed 30 April 2026>.

13 Written interview conducted by the authors with a U.S. expert, November 2025.

14 "Presidential Decision Directive/NSC-15", The White House, September 1993, <https://www.clintonlibrary.gov/sites/default/files/documents/pdd-15.pdf/, accessed 28 April 2026>; Whitney Spivey, "The Architect of Stockpile Stewardship", Los Alamos National Laboratory, December 2020, <https://www.lanl.gov/media/publications/national-security-science/1220-architect-of-stockpile-stewardship/, accessed 25 April 2026>.

15 Steven Pifer, "The Logic for US Ratification of the Comprehensive Nuclear Test Ban Treaty", Bulletin of the Atomic Scientists, March 2024, <https://thebulletin.org/premium/2024-03/the-logic-for-us-ratification-of-the-comprehensive-nuclear-test-ban-treaty/, accessed 30 April 2026>.

16 National Academies of Sciences, Engineering, and Medicine, The Comprehensive Nuclear Test Ban Treaty: Technical Issues for the United States, Washington, DC: National Academies Press, 2012, <https://doi.org/10.17226/12849/, accessed 26 April 2026>.

17 "Russia Has Restarted Low-Yield Nuclear Tests, U.S. Believes", New York Times, 29 May 2019, <https://www.nytimes.com/2019/05/29/us/politics/russia-nuclear-tests.html/, accessed 30 April 2026>.

The 2018 Nuclear Posture Review (NPR) under the first Trump administration openly stated that the U.S. would not seek CTBT ratification. Nevertheless, it would continue to support the CTBTO Preparatory Commission, the IMS, and the International Data Centre (IDC). It stated that nuclear explosive testing would resume only if "necessary to ensure the safety and effectiveness" of the U.S. arsenal and urged all nuclear-armed states to maintain their moratoria. In June 2023, the National Nuclear Security Administration proposed new transparency measures, including reciprocal observation at the Nevada National Security Site, to alleviate suspicions surrounding U.S. subcritical tests, to which neither China nor Russia responded.

Finally, under the second Trump administration, President Trump publicly suggested that the U.S. should resume nuclear testing "on an equal basis" with adversaries, an idea which he never elaborated but which nevertheless was supported by several U.S. lawmakers.[18] As of writing, it is unclear whether President Trump's pronouncements refer to testing delivery systems, non-nuclear weapons components; hydrodynamic, subcritical, or hydronuclear experiments; or full-yield nuclear test explosions.

During the United Nations General Assembly vote in September 2025 on a resolution supporting the CTBT, the U.S. voted against "because several paragraphs are inconsistent with U.S. policy or are undergoing policy review."[19] Thus, the broader U.S. policy debate remains muted: the CTBT is largely absent from contemporary national security discussions, reflecting a shift in attention toward nuclear modernization and great-power competition rather than treaty-based arms control.

This being said, as relations between the U.S. and China and Russia continue to deteriorate, mutual suspicion fuels mirror-image perceptions: the U.S. views Russian and Chinese opacity as potential cheating; China regards U.S. modernization efforts and subcritical testing as undermining the zero-yield norm; and Russia, by revoking its ratification, signaled its unwillingness to "protect" earlier achieved understanding in arms control against general worsening of relations with the U.S. and against what some scholars in Russia believe to be the process of "devaluation of Russian nuclear deterrence."[20]

CTBT SIGNIFICANCE IN THE VIEW OF CHINA, RUSSIA, AND THE U.S.

China

In China's view, an end to nuclear explosive testing helps prevent the spread of nuclear weapons and promotes progress toward nuclear disarmament, goals that are closely aligned with China's security philosophy.[21] From China's perspective, a universally accepted and

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[18] U.S. Senate, Committee on Armed Services, To Consider the Nomination of: Vice Admiral Richard A. Correll, USN, to be Admiral and Commander, United States Strategic Command, Stenographic Transcript, 119th Cong., 1st sess., 30 October 2025, p. 49, <https://www.armed-services.senate.gov/imo/media/doc/10-30-2025_transcript_nom.pdf/, accessed 30 April 2026>.

[19] "80th Session of the United Nations General Assembly", U.S. Mission to International Organizations in Geneva, 31 October 2025, <https://geneva.usmission.gov/2025/10/31/80th-session-of-the-united-nations-general-assembly/, accessed 30 April 2026>.

[20] "What Will Russia's CTBT Withdrawal Mean?", Kommersant, 6 October 2023, <https://www.kommersant.ru/doc/6265152/, accessed 28 April 2026>."

[21] "Statement by the Chinese Delegation at the 57th Session of the CTBTO PrepCom", Permanent Mission of the People's Republic of China to the UN, November 2021, <https://vienna.china-mission.gov.cn/eng/hyyfy/202111/t20211113_10447687.htm/, accessed 28 April 2026>.

observed test ban curtails qualitative improvements of nuclear arsenals, thereby helping to level the playing field among nuclear-armed states.

In practical terms, China has supported the CTBT by accelerating the construction of several IMS within its territory, many of which are now certified and transmitting data to the CTBTO. Beijing has co-hosted training workshops and regional conferences with the CTBTO, while Chinese experts actively engage in its working groups and scientific cooperation initiatives. Diplomatically, China continues to urge all remaining Annex 2 States to sign and ratify the Treaty, asserting that universal participation is essential for its entry into force. Having been among the first countries to sign the CTBT, China has submitted it to the National People's Congress for review, yet its ratification remains linked to improvements in the international security environment and corresponding actions by other key states. Overall, China views the CTBT as a convergence of its restrained nuclear posture and multilateral arms control engagement—a legally binding test ban that not only stabilizes relations among nuclear powers but also represents a vital step toward the ultimate goal of complete nuclear disarmament.[22]

Russia

While treating the CTBT as a cornerstone of the global non-proliferation regime, Russia has continuously emphasized that CTBT-related discussions should focus exclusively on the Treaty's implementation—opposing attempts to use them to advance unrelated political agendas. Accordingly, while revoking its ratification in 2023, Russia nevertheless continued to support the IMS. As stated by the Russian Ministry of Foreign Affairs in September 2025: "We emphasize that Russia remains committed to the values of the Treaty," including through "the completion on 14 December 2023 of the Russian segment (the second largest in the world) of the IMS, which is a major component of the CTBT verification mechanism."

Following recent rhetorical escalation and possible preparations for the resumption of nuclear testing on both sides, some experts now voice concerns that a U.S. decision to resume testing would serve as a green light for other states seeking to conduct tests—facing far fewer political and reputational risks as the U.S. would bear the primary international costs. They further note that pro-testing sentiment would grow not only at the political level but also within technical communities, particularly in countries that conducted fewer tests during the Cold War, which would fuel the nuclear arms race while undermining the global non-proliferation regime.[23]

Nevertheless, in May 2025 Russian Foreign Minister Sergey Lavrov held a meeting with Executive Secretary of the CTBTO Preparatory Commission Robert Floyd, emphasizing Russia's commitment to the "importance of continuing work on the universalization of the CTBT in the interests of strengthening international peace and security."[24]

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[22] "Report of China on the Implementation of NPT", Ministry of Foreign Affairs of the People's Republic of China, December 2021, <https://www.fmprc.gov.cn/web//wjb_673085/zzjg_673183/jks_674633/fywj_674643/202112/t20211228_10476386.shtml/, accessed 30 April 2026>.

[23] Written interview conducted by the authors with a Russian expert, November 2025.

[24] "Press Release on Foreign Minister Sergey Lavrov's Meeting with Robert Floyd, Executive Secretary of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO)", Ministry of Foreign Affairs of the Russian Federation, 27 May 2025, <https://mid.ru/en/foreign_policy/news/2020213/, accessed 28 April 2026>.

United States
The U.S. disposition towards the CTBT demonstrates significant pressures pulling U.S. decisionmakers between competing priorities with contradictory policy prescriptions. On the one hand, the CTBT can be seen as locking in a U.S. advantage, leaving it with access to historical nuclear test data while imposing significant barriers to latecomers that might be seeking to horizontally or vertically proliferate. On the other hand, increased competition with nuclear peers creates pressure to field new systems as foreshadowed by debates over the W76-2 and W93.[25] Further divergence from pre-moratorium design and production methodologies may eventually create pressure to renew nuclear explosive testing, as designs move away from models calibrated to historic test data, uncertainty in stockpile reliability assessments increases.

These competing pressures encapsulate the ambivalence of the U.S. position on CTBT ratification that borders on a policy of strategic neglect: the United States has thus effectively adopted a deliberate posture of neither seeking ratification nor formally repudiating the Treaty. This status quo—observing a testing moratorium without legal commitment—largely serves U.S. interests, even in the absence of the Treaty's entry into force.

While full Treaty implementation would yield additional benefits from the onsite inspection mechanism and increased strategic stability, the current status quo largely fulfills U.S. nonproliferation objectives, leaving U.S. decisionmakers loath to shoulder the additional risks inherent in seeking ratification, nor international constraints it would entail for U.S. nuclear options. See Table 2 for an overview of the states' positions on the CTBT and potential confidence-building measures (CBMs).

Table 2. Summary of key CTBT-related positions and concerns by China, Russia, and the U.S.[26]

	CHINA	RUSSIA	UNITED STATES
Key policy statements	November 2025 white paper "China's Arms Control, Disarmament, and Non-Proliferation in the New Era"	Russian MFA's September 2025 statement on IMS launch & continued CTBT compliance	2022 NPR: reaffirmed U.S. support for CTBTO verification, pledged to engage Russia & China on compliance & transparency
Key concerns regarding Treaty ratification	U.S. non-ratification	US-Russia strategic relationship crisis, U.S. non-ratification	Chinese & Russian alleged testing and concerns over parity, unwillingness to limit itself by international treaties

25 The W76-2 is a US low-yield warhead deployed on a limited number of Trident II D5 missiles meant to address a perceived low-yield deterrence gap, the W93 is a warhead being designed to replace W76 and W88 warheads that represent the at-sea leg of the US triad.

26 Based on publicly available official statements, authors' interviews with Chinese, Russian, and U.S. experts in November and December 2025, and remarks by former Heads of NNSA L. Brooks and J. Hruby during the CTBTO Research Fellowship webinar on 8 December 2025.

Measures perceived least likely to succeed	Chinese, Russian, and U.S. experts alike are skeptical of proposals to redefine "zero yield" or to permit low-yield tests, arguing that these are not only unnecessary but represent attempts by states to move away from the Treaty and create "workarounds" that would allow the testing of new weapons—precisely what the CTBT was designed to prevent	
Suggested realistic CBMs	IMS launch considered a key CBM; reluctant towards more transparency with the U.S. given current tensions	Reciprocal transparency at test sites

SUGGESTIONS FOR A PATH TOWARDS RATHER THAN AWAY FROM THE CTBT

Indirect CTBT Promotion

Although China, Russia, and the United States differ in their level of support for the CTBT—with Washington being the most skeptical—all three continue to uphold key CTBT provisions in practice, especially through their backing of the IMS. While this remains their main direct means of supporting the Treaty, they can also advance it indirectly by reinforcing broader strategic stability and nuclear riskreduction norms.

For instance, China has promoted P5 risk reduction messaging, including the leaders' Joint Statement on Preventing Nuclear War and Avoiding Arms Races, and has coordinated two editions of the P5 Glossary of Key Nuclear Terms.[27] Russia recently proposed that the U.S. and Russia mutually uphold New START numerical limits for another year. The U.S. has previously suggested reciprocal visits to test sites. These initiatives have not yet gained traction, but continued proposals are important so they can be revived when political conditions improve.

Experts also emphasize resuming technical consultations at the P5/N5 level. Now that the three countries are effectively on equal footing in terms of their respective legal commitments to the CTBT, such exchanges could be more candid and thus more productive—if not in generating solutions, then at least in ensuring that national security concerns are clearly communicated.

With the 2026 Integrated Field Exercise in Namibia approaching, it would also be valuable for all five nuclear-weapon states to participate at a high level to demonstrate practical commitment to the Treaty's purpose.

Further Incentivization Strategies

Although often cited as an essential step in promoting Treaty implementation and entry into force, it is currently difficult to envision how states—whether China, Russia and the U.S. or others Annex 2 States—can be meaningfully incentivized to ratify. The strongest signal for others would be for Washington and Moscow to manage their current impasse without resuming nuclear testing. As noted by one senior U.S expert, "there is no magic form of leverage that can force the U.S. to refrain from testing other than for many, if not all states, to deliver the message that a resumption of nuclear testing is unacceptable and would be very much against the U.S national security interests."[28]

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[27] "China's Arms Control, Disarmament, and Non-Proliferation in the New Era", Ministry of Foreign Affairs of the People's Republic of China, November 2025, <https://www.fmprc.gov.cn/eng/zy/wjzc/202511/t20251127_11761656.html/, accessed 5 February 2026>.

[28] Written interview conducted by the authors with a U.S. expert, November 2025.

For the three major powers, one earlier proposal suggested that China and the United States coordinate CTBT ratification and that Russia move to reratify.[29] Given current conditions, such ideas may need to be scaled down to more realistic forms of parallel progress—such as unilateral statements clarifying intentions or otherwise reducing ambiguity. At a minimum, all three should reconfirm their commitment to the Treaty's object and purpose.

Given President Trump's inclination to frame strategic negotiations in broad terms—such as initiating "denuclearization talks with China and Russia"[30]—one possible approach could imply "coupling" CTBT-related discussions with other strategic issues currently on the agenda, creating additional incentives to engage in a discussion while allowing some "buffer" on particularly sensitive aspects. Further, given the sensitivity of the issue to the U.S., China and Russia "should take the initiative and propose a format for discussions that avoid "trilateralizing" all nuclear conversations,"[31] which would be both politically unfeasible and strategically unattractive.

Enhancing the Role of NGOs and Epistemic Communities

Given the current political climate at the official level, a particularly useful CBM would be to expand Track 1.5 and Track 2 discussions. Government reluctance to publicly champion the CTBT can actually strengthen these unofficial channels, which could operate with fewer political constraints and greater continuity. Promoting hybrid formats—given challenges in financing non-proliferation initiatives—as well as more focused thematic sessions involving experts and former officials from all three states can help reduce adversarial rhetoric and clarify substantive differences, whether in terminology or underlying concepts and understandings.

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[29] Anastasia Malygina et al., "The Risk of Renewed Nuclear Testing", Deep Cuts Working Paper, August 2024,<https://deepcuts.org/media/pages/publications/working-papers/the-risk-of-renewed-nuclear-testing/68d0177b8c-1723033465/working-paper-the-risk-of-renewed-nuclear-testing-2.pdf/, accessed 25 April 2026>.

[30] "Trump Renews Push for Denuclearization Talks with Russia and China", Reuters, 26 August 2025, <https://www.reuters.com/world/china/trump-renews-push-denuclearization-talks-with-russia-china-2025-08-26/, accessed 30 April 2026>.

[31] Written interview conducted by the authors with a U.S. expert, November 2025.

Understanding Non-Annex 2 Ratification Pathways: Case Studies of The Gambia and Cuba, Implications and Lessons for Yemen and Saudi Arabia

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ABSTRACT

The Comprehensive Nuclear-Test-Ban Treaty (CTBT), adopted in 1996, remains a cornerstone of global nuclear disarmament. The Treaty has a unique procedure for its entry into force: it requires ratification of 44 states listed in Annex 2 of the document. While ratification by Annex 2 States is legally required for the Treaty to enter into force, from a purely legalistic point of view, it simply does not matter, whether all, some, or none of the states, whose names do not appear on Annex 2, ratify the Treaty. It will simply not enter into force until the last (44th) country listed in Annex 2 completes its ratification procedure.

The political reality is, of course, far more multifaceted and nuanced. Non-Annex 2 States constitute more than a qualified majority in the world; a number of these states occupy important positions of influence in their respective regions and beyond, some possess enough "soft power" to lead significant groups of other countries (including those listed in Annex 2).

Non-Annex 2 States contribute significantly to the Treaty's normative universalization. This report examines the ratification pathways of The Gambia and Cuba, two Non-Annex 2 States that recently ratified the CTBT. The Gambia signed it in 2003 and ratified – in 2022, while Cuba signed and ratified the Treaty in 2021. Their experiences highlight how political transitions, normative alignment, and diplomatic signaling of commitment to nuclear disarmament can drive ratification. Comparative insights are extended to the Republic of Yemen and The Kingdom of Saudi Arabia, both of which remain outside the Treaty. The report concludes that while lessons can be drawn from the experience of The Gambia and Cuba, engagement strategies must be tailored to each country's domestic and geopolitical context.

CASE STUDY: THE GAMBIA

The Gambia signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 2003 but ratified it only in 2022. The delay reflected institutional constraints, limited technical expertise, and the prioritization of socio-economic challenges over nuclear issues.[1] Previous administrations adopted a cautious approach to external oversight, which contributed to limited engagement with multilateral treaties.[2]

[1] "The Gambia ratifies the CTBT", CTBTO, 24 March 2022, <https://www.ctbto.org/news-and-events/news/gambia-ratifies-comprehensive-nuclear-test-ban-treaty/, accessed 8 April 2026>.

[2] "The Gambia ratifies the Comprehensive Nuclear-Test-Ban Treaty", Ban Monitor, 24 March 2022, <https://banmonitor.org/, accessed 8 April 2026>.

Ratification occurred after the democratic transition in 2017, when the new government emphasized reintegration into international institutions. The decision aligned with The Gambia's commitments under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Treaty on the Prohibition of Nuclear Weapons (TPNW), and the Pelindaba Treaty,[3] reinforcing policy coherence across disarmament frameworks. Regional peer pressure also played a role, as most African states had already ratified the CTBT. Ratification enhanced The Gambia's visibility in multilateral fora, signaling renewed commitment to international norms.

Participation in NPT Review Conferences and International Atomic Energy Agency (IAEA) General Conferences increased after 2017, supporting the argument that ratification was part of a broader re-engagement strategy. Financial considerations remain relevant: the Government of The Gambia is required to fulfill its financial obligations to the IAEA, comprising contributions to the Working Capital Fund (WCF), the Technical Cooperation Fund (TCF), and the Regular Budget. As of 2025, the WCF advance remained at 152 EUR, while the Regular Budget contributions[4] assessed for the Gambia amount to 3,578 EUR and 570 USD for 2025. Voting rights remain intact. Additional obligations related to the TCF, National Participation Costs (NPCs), and Assessed Programme Costs (APCs) may apply and are detailed separately in the IAEA's TCF Target Share letter, which amounts to 980 EUR.

CASE STUDY: CUBA

Cuba signed and ratified the CTBT on 4 February 2021, becoming the 169th signatory. Although Cuba had long been committed to nuclear disarmament[5] and was active in the UN disarmament machinery, it didn't ratify the Treaty until 25 years after its opening for signature in 1996. As a Non-Annex 2 State, this did not affect the Treaty's entry into force, but its eventual ratification marked an important step toward universalizing the norm against nuclear explosive testing.

One of the main reasons for Cuba's recent ratification was concern about the scope of the CTBT. During its negotiations in 1996, Cuba, alongside several other States in the Conference on Disarmament, argued that the treaty should ban all nuclear tests.[6] The CTBT's focus on explosive testing, while valuable, was seen as insufficient because it allowed nuclear-weapon states to continue modernizing arsenals through subcritical testing, computer simulations and other sophisticated methods. This position was consistent with Cuba's broader critique of discriminatory regimes which purposely delay the goal of the total elimination of nuclear weapons as reflected in its accession to the NPT in 2002, which Havana ratified while maintaining strong reservations about its limitations.[7]

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3 "Treaty of Pelindaba (African Nuclear-Weapon-Free Zone): Status of Treaty – The Gambia", African Union, 1996, <https://www.peaceau.org/uploads/treaty-en-african-nuclear-weapon-free-zone.pdf/, accessed 8 April 2026>.

4 "Regular Budget Contributions: Member States assessed contributions", IAEA, 2023, <https://www.iaea.org/sites/default/files/gc/gcspl.3-5.pdf/, accessed 8 April 2026>.

5 "Cuba joins Comprehensive Nuclear Test Ban Treaty", Cuba News, 5 February 2021 <http://www.cubanews.acn.cu/cuba/12409-cuba-joins-comprehensive-nuclear-test-ban-treaty/, accessed 5 April 2026>.

6 "Report of the Ad Hoc Committee on a Nuclear Test Ban to the Conference on Disarmament", UN Doc. CD/1425, August 16, 1996, UN Digital Library, <https://digitallibrary.un.org/record/221694/, accessed 10 April 2026>.

7 "Letter dated 7 November 2002 from the Permanent Representative of Cuba to the United Nations addressed to the Secretary General", A/57/597, 2002, <https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://docs.un.org/en/A/57/597&ved=2ahUKEwjcxpSC4diQAxXQElkFHe1KBpgQFnoECCcQAQ&usg=AOvVaw3EX8d3kZddkwArCMXxCu8J/, accessed 20 April 2026>.

Financial obligations also contributed to the recent ratification. The CTBT requires contributions from signatory States to support Treaty, that may be deemed significant by developing States. Cuba's annual CTBTO contribution in 2024 was estimated at over 127,000 USD,[8] far higher than the few thousand dollars required for other disarmament conventions such as the Biological Weapons Convention (BWC), the Convention on Certain Conventional Weapons or the Convention on Cluster Munitions.[9] For a developing country,[10] these costs were a substantial factor in evaluating the timing of ratification.

Despite these concerns, Cuba's eventual ratification reflected its sustained commitment to nuclear disarmament and to further integration in its international legal architecture.[11] Already a party to the NPT, TPNW, the Treaty of Tlatelolco, and Chemical and Biological Weapons conventions, Cuba's CTBT ratification reinforced its normative consistency. The adoption of the TPNW in 2017, which bans nuclear testing under any circumstance, complemented the CTBT and helped address Cuba's concerns about scope. Cuba's swift ratification of the TPNW also demonstrated its institutional capacity to review and adopt treaties efficiently.

Regionally, Cuba's decision aligned with Latin America's strong disarmament tradition. The region was the first to establish a nuclear-weapon-free zone in a densely populated area under the Treaty of Tlatelolco and later declared itself a "Zone of Peace" in 2014, an initiative led by Cuba. Through the Agency for the Prohibition of Nuclear Weapons in Latin America and the Caribbean, or OPANAL, Latin American states have maintained active engagement with nuclear-weapon states and international organizations. Ratifying the CTBT allowed Cuba to further harmonize with regional norms and strengthen collective commitments to disarmament.

Cuba was also motivated by the scientific and civilian benefits of ratifying the CTBT. Access to IMS data and cooperation with the International Data Centre (IDC) provides valuable information for disaster preparedness, particularly in a hurricane-prone region.[12] Since 2021, Cuba has established a National Data Centre, integrated CTBTO data into its early warning

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8 The precise annual assessed contributions per country to the CTBTO are not public record. The estimate provided here (127,035 US dollars) considers the financial rules of the CTBTO (CTBT/RR/13 «Financial Regulations and Rules of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty, Organization», Article 6 entitled «Provision of Funds» Regulation 6.1), whereby the contribution is calculated considering the UN scale of assessment, applied to the CTBTO budget. For 2024, Cuba's UN regular budget scale of assessment was 0.095% (A/RES/76/238 «Scale of Assessments for the apportionment of the expenses of the United Nations»). The 2024 CTBTO budget was 133 722 000 US dollars (CTBTO «2024 Annual Report Vigilance in a Changing World», page 59). Applying Cuba's 2022–2024 UN rate of 0.095% directly to the CTBTO 2024 budget gives the indicative amount.

9 See UNODA Financial Dashboard.

10 Statement at the CD during consideration of the draft treaty text: "Nor must we overlook the fact that the limitations of the draft take on added relevance against the background of the sizeable financial demands which it is planned to make on States by virtue of the treaty, including the poorest of the third world States which will have to ratify the Treaty before it can enter into force". CD/1436, 1996.

11 "Two States Ratify the CTBT", Arms Control Now Blog, 2021 <https://www.armscontrol.org/blog/2021-04-05/two-states-ratify-ctbt/, accessed 1 April 2026>.

12 "Cuba se adhiere al Tratado de Prohibición Completa de los Ensayos Nucleares (TPCE)", CTBTO, 2021, <https://www.ctbto.org/resources/for-the-media/press-releases/cuba-se-adherie-al-tratado-de-prohibicion-completa-de-los/, accessed 5 April 2026>. The Cuban ambassador in Vienna stated: The possibility of benefitting from the technology, data and capacity building programmes of the CTBTO contributed to Cuba´s decision to join the CTBT. Access to these resources will allow Cuban experts to widen and reinforce their work in a number of scientific and civilian fields, in particular, the modelling and preparedness for natural disasters for both Cuba, and the region.

systems, participated in training programs, and concluded a Tsunami Warning Agreement with the CTBTO in September 2025, after the visit of CTBTO Executive Secretary Robert Floyd to the country in March, earlier that year.[13] These tangible benefits reinforced the value of ratification beyond normative commitments.

Finally, sustained CTBTO outreach played a role. Since 2015, Cuba had participated regularly in the Preparatory Commission as an observer. Former CTBTO Executive Secretary Lassina Zerbo visited Cuba multiple times (2016, 2018 and 2019), engaging with high-level officials, not only in the Foreign Affairs Ministry but also within scientific institutions, and maintaining continuous dialogue. By 2019, Cuban authorities confirmed that internal consultations were underway, leading to ratification two years later. This consistent engagement demonstrated how diplomatic outreach can encourage states to overcome reservations.[14]

COMPARATIVE ANALYSIS: THE GAMBIA AND CUBA

The Gambia and Cuba illustrate distinct pathways to CTBT ratification. The Gambia's delay was shaped by institutional weakness and political prioritization, while Cuba's delay reflected a concern with the CTBT's practical impact on nuclear disarmament and financial concerns. Both ultimately ratified as part of broader strategies of integration and further alignment with international norms. The Gambia's and Cuba's financial contributions vary on account of The Gambia's status as a Least Developed Country, a factor which is considered in the UN scale of assessments. However, as developing countries, and comparatively to other disarmament regimes, the CTBTO still entails considerable financial contributions, which may be perceived as onerous by developing States and which in turn can delay their ratification. These financial considerations also highlight the importance of tailoring CTBTO outreach and support strategies for smaller states like The Gambia, to whom capacity-building and technical assistance are key, highlighting the substantial support and cooperation that the CTBTO offers upon ratification. Ultimately, the financial dimension is not uniform across Non-Annex 2 States. It must be understood as a critical variable shaping ratification pathways, reinforcing the need for differentiated engagement strategies that reflect each country's economic realities and institutional priorities.

Table 1. Analytical comparison between the Gambia and Cuba

DIMENSION	THE GAMBIA	CUBA	ANALYTICAL INSIGHT
Signature	2003	2021	Different timelines reflect different considerations regarding the Treaty, either domestic, geopolitical or legal ones.

[13] "Cuba signs Tsunami Warning Agreement with CTBTO", September 2025, <https://www.ctbto.org/news-and-events/news/cuba-signs-tsunami-warning-agreement-ctbto/, accessed 5 April 2026>.

[14] "Executive Secretary inaugurates science diplomacy events in Cuba and in the Dominican Republic", October 2019, <https://www.ctbto.org/news-and-events/news/executive-secretary-inaugurates-science-diplomacy-events-cuba-and-dominican/, accessed 5 April 2026>.

Ratification	2022	2021	Both recent, signaling renewed engagement with nuclear disarmament and multilateralism.
Delay Factors	Institutional weakness, policy prioritization	Scope concerns, financial costs	Domestic critiques vs concerns on the Treaty and its practical implications.
Motivation for Ratification	Democratic transition, regional alignment	Further engagement in nuclear disarmament, regional homogenization, access to scientific benefits	Ratification used as diplomatic signaling of renewed commitment, further integration to and regional alignment.
Regional Context	Pelindaba Treaty	Tlatelolco Treaty	Regional norms reinforced ratification.
Verification	No IMS stations yet	Active IMS cooperation	Cuba leveraged scientific benefits.
CTBT Estimated Annual Contribution	1,337.21 USD	127,035 USD	In comparison with other regimes, the financial obligations under the CTBT are particularly challenging for developing nations.

LESSONS LEARNED AND IMPLICATIONS FOR THE REPUBLIC OF YEMEN AND THE KINGDOM OF SAUDI ARABIA

The Republic of Yemen signed the CTBT in 1996 but has not ratified it yet.[15] The delay reflects political instability, civil wars, weak institutions, and economic constraints. Despite this, Yemen has demonstrated normative alignment by ratifying the NPT, BWC, and the Chemical Weapons Convention (CWC).[16] Ratification remains a matter of timing and stabilization rather than opposition to the Treaty's objectives.

The Kingdom of Saudi Arabia has not signed the CTBT yet. Its delay reflects strategic ambiguity and regional security considerations, particularly balancing relations with current and latent nuclear powers. The Kingdom is nevertheless party to the core non-proliferation and disarmament treaties, including the NPT, BWC, and CWC. Unlike Yemen, Saudi Arabia possesses strong institutional capacity, but strategic calculations have outweighed normative commitments.[17] However, both countries are active members of the IAEA and in United Nations General Assembly dialogues on establishing a Middle East Nuclear Weapon Free Zone (MENWFZ).

15 "Yemen Embassy in Vienna", CTBTO, last modified 29 August 2018, <https://www.yemenembassy.at/ctbto/, accessed 10 April 2026>.

16 "Yemen", Nuclear Weapons Ban Monitor, <https://banmonitor.org/profiles/yemen/, accessed 10 April 2026>.

17 Amina Abdelkhayer et al., "The CTBT and the Middle East: A Long Road to a Nuclear Test-Free Region", CTBTO Research Fellowship Collection of Papers, April 2022, <https://youthgroup.ctbto.org/node/2649/, accessed 10 April 2026>.

Table 2. Analytical comparison between the Kingdom of Saudi Arabia and the Republic of Yemen

DIMENSION	YEMEN	SAUDI ARABIA	ANALYTICAL INSIGHT
Signature	1996	Not signed	Different stages of engagement.
Ratification	Non-ratified	Non-ratified	Different priorities and instability vs strategic concerns.
Delay Factors	War, weak institutions, economic crisis[18]	Strategic ambiguity, regional security concerns	Domestic instability vs. strategic reservations.
Motivation for Ratification	Stability and unified government	Regional leadership, credibility in multilateral forums	Both could strengthen CTBT universalization.
Regional Context	Endorses MENWFZ	Endorses MENWFZ	Clear stands for domestic and regional stability.
Institutional Capacity	Severely weakened	Strong, but cautious	Institutional strength does not guarantee signing/ratification.
Symbolic Significance	Would signal stabilization	Would signal leadership	Both cases carry symbolic weight.
CTBT's International Monitoring System (IMS) Presence	No IMS verification stations	Two planned verification seismic stations	Yemen, through the National Centers for Monitoring and Study of Seismology and Volcanoes, have access to the International Data Centre (IDC), while Saudi Arabia will access it through IMC stations.

Yemen's CTBT ratification depends primarily on restoring a unified government and political stability. Since the 1990s, repeated internal conflicts have pushed ratification to the back burner. The Iran-backed Houthis' takeover of the capital Sana'a in 2014 plunged the country into chaos and further sidelined the CTBT. This fragmentation has entrenched political instability, making any national effort to ratify the Treaty highly unlikely in the near term. Furthermore, even after the country reaches a stable state, economic recovery will require significant time, keeping ratification and its associated financial commitments a low priority.

Saudi Arabia, by contrast, can deepen engagement with the CTBT framework without formal accession by expanding cooperation with the CTBTO. This can include formalizing IMS Facility Agreements for the two planned seismic stations in the Kingdom. Such steps would signal further commitment to verification norms and enhance transparency while preserving regional and strategic leverage. This approach aligns with Saudi Arabia's expanding

[18] "Republic of Yemen: Selected Issues", International Monetary Fund Staff Country Reports, vol. 2001, issue 061, 20 April 2001, <https://www.elibrary.imf.org/view/journals/002/2001/061/002.2001.issue-061-en.xml/, accessed 10 April 2026>.

global political and economic role. Embracing the CTBT would signal regional leadership, enhance credibility in multilateral disarmament forums, and strengthen the relationship with the international monitoring and verification regime as Saudi Arabia develops its civilian nuclear program. Under current conditions, both Yemen and Saudi Arabia will continue to demonstrate strong normative support for the CTBT.

The experiences of The Gambia and Cuba demonstrate that Non-Annex 2 signing and ratification is shaped by individual and country-specific circumstances and thus, lessons cannot be universally applied. Yemen's civil war and Saudi Arabia's strategic calculations differ fundamentally from the contexts of The Gambia and Cuba. CTBTO engagement must therefore be tailored to each country's domestic and geopolitical realities rather than assuming uniform pathways.

CONCLUSION

Ratification by Non-Annex 2 States strengthens the CTBT's normative legitimacy. The Gambia and Cuba show that political transition, normative alignment, regional integration, scientific cooperation and diplomatic signaling are decisive factors. For the Republic of Yemen and the Kingdom of Saudi Arabia, engagement strategies must be context-specific, balancing institutional realities with regional security considerations. The CTBT's universalization depends not only on Annex 2 States but also on the commitments of Non-Annex 2 States.

Earthquake or Nuclear Test? The CTBT's Capacity in Confidence-Building

■ Jafar Yaghoubi ■ Abdulla Alkaabi

ABSTRACT

The October 2024 seismic events that struck near Semnan, Iran, rapidly became the subject of public and media speculation, with some commentators alleging that the tremors were the result of a clandestine subterranean nuclear test. This paper examines the Semnan case as a technically and politically salient example of how ambiguous seismic events can generate misinformation and escalation risks in the international system characterized by strategic mistrust and accelerated social-media news cycles within the context of a tense geopolitical environment. Drawing on data analysis conducted by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Organization (CTBTO/PC), the study demonstrates how information from more than 25 stations of the International Monitoring System conclusively identified the events as natural earthquakes consistent with the region's historical seismicity. Beyond the empirical findings, the paper situates the Semnan event within a functionalist theoretical framework, arguing that repeated technical cooperation within specialized institutions fosters epistemic consensus and institutional trust, thereby enhancing political confidence among states. It describes the CTBT multi-stage verification methodology, spanning detection, scientific analysis, consultation, and clarification, and explains how the integration of seismic, infrasound, hydroacoustic, and radionuclide technologies enables reliable discrimination between nuclear tests and natural or industrial events. Particular attention is given to the role of media framing and the propagation of unverified claims, highlighting the growing tension between rapid information dissemination and the slower, evidence-based processes of international verification.

The paper concludes that the CTBTO/PC functions not only as a technical watchdog of the nuclear test-ban norm but also as a stabilizing actor in international security by countering misinformation with impartial science. While acknowledging structural limitations stemming from the Treaty's non-entry into force and remaining gaps in the monitoring network, the study proposes policy options to strengthen transparency, data integration, and public visibility. In doing so, it highlights the enduring relevance of the CTBTO/PC also as a confidence-building institution whose scientific authority is increasingly vital in an era of geopolitical tension and pervasive digital misinformation.

RESEARCH OUTLINE

The earthquakes that struck Semnan, Iran, on 5 October 2024, sparked widespread speculation regarding their nature. Against the backdrop of tense geopolitical developments, some observers and news outlets[1] even suggested the possibility of a subterranean explosive test, a rumor that quickly gained traction in certain circles. The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Organization (CTBTO/PC) soon entered the scene, analyzed the relevant data gathered from more than 25 International Monitoring System (IMS) stations and concluded that the two events were consistent with previous earthquakes in this area in Iran.[2] The event is as technically important as it is politically relevant, as – amid geopolitical tensions and a broiling regional conflict – it threw the confidence-building role of the CTBTO in a distinguished relief.

The significance of the Semnan earthquakes—and a host of similar events that have transpired throughout the history of the CTBTO/PC—transcends national boundaries and offers enduring lessons for the broader non-proliferation and verification regime. In a world where mutual suspicion and strategic opacity shape the behavior of states, the ability to distinguish between natural seismic occurrences and anthropogenic, possibly nuclear, events is not merely a technical matter but a profoundly political one. Each such incident tests the credibility and resilience of the IMS and, by extension, the confidence that the international community places in multilateral verification mechanisms.

The CTBTO/PC's scientific response to these ambiguities, which is rooted in data transparency, cross-validation among its 300-plus monitoring stations, and the timely dissemination of findings, serves as a stabilizing force in international relations. When speculation and rumor arise in the wake of tremors, the Organization's capacity to provide authoritative, empirically grounded analysis becomes indispensable in preventing escalation and mistrust. Such episodes remind policymakers that verification is neither a one-time assurance, nor a one-way street, but an ongoing process of mutual confidence building between the Organization and its member state(s); one that bridges scientific objectivity with diplomatic prudence.

Furthermore, the lessons from Semnan reaffirm the CTBTO/PC's dual role: as both a guardian of the test ban norm and a facilitator of cooperative security. Through its demonstration of impartial science and open communication, it reinforces the notion that even within the current transitional international order, trust can be institutionally cultivated.

MEDIA ROLE DURING THE COVERAGE OF THE EVENT

The media plays a crucial role in covering various events based on the information gathered and disseminated through print, audio, and visual media. This is where discussions and rumors begin, circulating and being analyzed in studios, on broadcasting channels, and on social media platforms.

The recent earthquake caused a significant stir on various social media platforms, with many claiming it was an Iranian nuclear test, given the sensitivity of the current situation surrounding the Iranian nuclear program and the events surrounding it. These claims are

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1 "Nuclear Test or Earthquake in Semnan: What Is a Rumor and What Is the Truth", Euronews (Persian), 7 October 2024, <https://parsi.euronews.com/2024/10/07/nuclear-test-or-earthquake-in-semnan-what-is-a-rumor-and-what-is-the-truth/, accessed 9 April 2026>.

2 "CTBTO Detects Two Earthquakes in Northern Iran on 5 October", CTBTO, 2024, <https://www.ctbto.org/news-and-events/news/ctbto-detects-two-earthquakes-northern-iran-5-october/, accessed 9 April 2026>.

made without clear or conclusive scientific evidence to substantiate the claim. Instead, these platforms disseminate inaccurate and misleading technical information unrelated to the event, such as regarding the Semnan earthquake,[3] to conveniently support the narrative of an Iranian nuclear test and conspiracy theories.

Table. Media Framing of the 5 October 2024 Iran Seismic Event

Date	5 October 2024[4]
Location	Near Semnan, Iran
Event type	Natural earthquake (tectonic seismic event), not a nuclear test
Magnitude	Small to moderate, consistent with ordinary regional seismicity
Main rumor	Social and some news claims that it was a secret underground nuclear test
Scientific Finding	Seismic signatures matched an earthquake, not an underground explosion
Media issue	Some international outlets amplified the nuclear-test narrative from social media without sufficient verification

These events are covered by various countries around the world to understand the details and how they are being addressed at the international security level. This underscores the importance of information verification and critical media literacy, particularly in contexts where misinformation, bias, and conspiracy-based narratives may shape public understanding. It also highlights the need to consider international organizations that possess the necessary tools to investigate such events related to nuclear testing, as is the case with the CTBTO/PC.

THEORETICAL AND PRACTICAL BASIS

The main hypothesis of this research is that in the current international environment, repeated technical cooperation within functionally specialized institutions (such as the CTBTO) fosters epistemic consensus and institutional trust, which in turn enhances political confidence and mitigates the risks of escalation arising from ambiguous events. To that end, the authors have drawn upon functionalist theories of international relations according to which enduring peace and cooperation among states are more likely to emerge from practical, technical collaboration than from grand political agreements. To apply such thinking, however, is not as straight a path to rigorous conclusions as it might seem, mainly because some critics assert that even scientist and technicians are never free of their political and ideological prejudices. On a plain where the CTBTO/PC and other similar entities operate, power relations are impossible to be ignored, as they directly bear upon the agendas of these organizations. Despite CTBTO/PC's highly technical work, which relies on standardized monitoring methodologies and scientific data, the interpretation of seismic

[3] Irontortoise, "How Misinformation About October 5, 2024 Iranian Quake Traveled Almost as Fast as its Seismic Waves", Daily Kos, 2025, <https://www.dailykos.com/stories/2025/2/5/2301555/-How-Misinformation-About-October-5-2024-Iranian-Quake-Traveled-Almost-as-Fast-as-its-Seismic-Waves/, accessed 9 April 2026>.

[4] USGS, "Iran Earthquake Catalogue and Regional Seismicity", USGS, 2024, <https://earthquake.usgs.gov/earthquakes/eventpage/us6000nwr9/region-info/, accessed 9 April 2026>.

evidence still involves analytical and institutional judgment. Decisions regarding what constitutes sufficient evidence, which detection thresholds are applied, and how data from different monitoring stations are weighted are influenced by methodological assumptions, expert assessments, and operational protocols rather than being entirely value-neutral or purely automatic.

Critiques aside, the CTBTO/PC epitomizes a functionalist institution which operates through a global scientific structure (the IMS) comprising seismological, hydroacoustic, infrasound and radionuclide networks; a technocratic, apolitical knowledge-based community of scientists, analysts and data experts whose work transcends political boundaries, yet directly bear upon international politics; and a transparent data-sharing framework allowing all member states equal access to raw and processed information.

What makes the CTBTO's work rigorous and relevant, and to some extent free of power relations, is the purely systematic analysis of the tremor waves and a scientifically sound way of telling a tremor from a test through a combination of physical principles, sensor data, and cross-validation across the IMS network.

CTBTO/PC INTERNAL PROCESS FOR A SUSPICIOUS EVENT OCCURS

The CTBTO/PC plays a pivotal role in monitoring and verifying events involving earthquakes or explosions that occur from time to time, whether originating from a nuclear test, a powerful non-nuclear explosion, or a natural earthquake. This is achieved through its IMS. Through verification and monitoring, the Organization works to build trust among its member states and supports security and stability efforts by disseminating accurate information to member states in an era rife with misinformation and easily spread.

The CTBT implies a multi-stage scientific verification methodology to assess suspicious events that may indicate a nuclear test. This methodology is to be implemented on the ground once the CTBT enters into force and includes:

- The Detection Phase: This phase involves detecting the tremors through the global monitoring system. In total, the Treaty provides for 337 facilities, including 321 monitoring stations worldwide, which are to transmit data to the International Data Center (IDC) in Vienna, where analysts receive and process the information and notifications. Of these, 307 facilities are already operational.[5]
- Scientific Verification Phase: The IDC verifies information and notifications by examining data and comparing it to a natural earthquake using data from various monitoring stations.[6] Nuclear tests often exhibit a distinctive pattern that can be detected by multiple stations.[7] If a pattern is detected only by one seismic station, the event is continuously monitored for days or weeks.

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[5] CTBTO, "International Monitoring System Map", CTBTO, 2026, <https://www.ctbto.org/our-work/ims-map/, accessed 10 April 2026>.

[6] Lassina Zerbo, "The CTBTO and the Verification of Nuclear Test Bans", CTBTO, 2016, <https://www.ctbto.org/the-organization/history-of-the-ctbt/verification-of-the-test-ban/, accessed 20 April 2026>.

[7] "Seismo Blog Of Nuclear Bombs and Earthquakes", Berkeley Seismology Lab, 2009, <https://seismo.berkeley.edu/blog/2009/05/25/of-nuclear-bombs-and-earthquakes.html#:~:text=There%20are%2C%20however%2C%20major%20differences%20between%20the,nuclear%20test%20lack%20most%20of%20these%20waves/, accessed 9 April 2026>.

- Event Bulletin Creation Phase: In this phase, the organization creates comprehensive information for the public about the event and its verification, whether it was a natural earthquake or a nuclear test. This information is reviewed by member states to determine the next steps in responding to the event. If the organization has any doubts, it contacts national data centers of member states to obtain further data.
- Consultation and Clarification Phase for Member States if Doubts Remain: In accordance with Article IV,[8] States Parties exchange data, request on-site inspection (OSI) – again, possible only once the Treaty enters into force – and the organization provides information to support its assessment. This phase aims to refute misinformation.
- Final Decision Phase: In this phase, the organization provides confirmation regarding a nuclear test, the veracity of the information, or a natural seismic event.

Figure. CTBTO Internal Process for a Suspicious Event Occurs

Note: At the current moment, when the CTBT has not yet been ratified by all Annex 2 States and, hence, is not yet in force, any verification activity in the full meaning of this term, is not possible. On-site inspections can only be activated after the entry into force of the CTBT.

TEST OR TREMOR

In distinguishing a nuclear test from a natural tremor, seismic waves tell a definitive story. The globe-spanning IMS,[9] covering 89 countries through its over 300 stations and 16 laboratories, function as the future CTBTO's eyes and ears across the globe detecting tiny vibrations, sounds or traces of radioactive particles. The IMS employs four types of sensors: seismic stations; infrasound stations; hydroacoustic station; and radionuclide stations. These sensors can pick up tremors of the ground, low-frequency sounds in the air, underwater sounds, and radioactive gases or particles. The surveillance is continuous and streams a steady flow of real-time data to the CTBTO/PC for analysis. The system has already proved its

[8] "Comprehensive Nuclear Test-Ban Treaty (CTBT)", U.S. Department of State, 2017, <https://2009-2017.state.gov/t/avc/trty/16522.htm/, accessed 7 April 2026>.
[9] "International Monitoring System (IMS) Map", CTBTO.

effectiveness, detecting all six DPRK's nuclear tests between 2006 and 2017.[10] In addition to this, it continuously picks up a wide range of phenomena, including earthquakes, volcanic eruptions and meteor strikes, as well as non-nuclear explosions such as the blast that devastated Beirut in 2020.[11]

In simple terms, both tests and tremors shake the ground, but in different ways. The cause, wave pattern, depth and shape of wave signal differ from a tremor to a test. In a tremor, tectonic stress and rock fracture along fault lines cause the tremor which wreaks sideways motion several kilometers deep in the ground with very complicated long-lasting signals. In the event of a test, on the other hand, a detonation causes the quake which leads to outward wave patters at a very shallow depth emitting a very sharp sudden pulse. Triangulated analysis of the data allows scientist to pinpoint the exact location and depth of the event. However, this cannot be deemed as definitive proof. What constitutes definitive proof is radioactive evidence. In the case of a nuclear detonation, radionuclide stations can detect gases or radioactive particles leakage from the test site, a clear signature of a nuclear reactions, thus confirming a suspected explosion as a nuclear test.

Simply put, CTBTO/PC scientists do not merely rely on a single source. A combination of all the data, i.e., wave patterns, location and depth, sound or radionuclide detection and the geographical context contributes to the determination of the nature of a tremor.

A HISTORY OF TREMORS

The seismic events in Semnan, Iran, on 5 October 2024 were not isolated incidents but part of a broader pattern of natural seismic activity in the region.[12] The CTBTO/PC analyzed data from over 25 monitoring stations within its IMS and concluded that the recorded waveforms were consistent with previous earthquakes in the area, thereby refuting any speculation otherwise.

Notably, the Semnan region, situated along active fault lines, has a historical consistency of moderate earthquakes, including similar events on 15 January 2018 and 25 August 2015, with magnitudes of 4.1 and 4.2, respectively. These magnitudes are significant in the context of verification; for instance, a magnitude 3.5 event in hard rock corresponds to approximately 100 tons (0.1 kilotons) of yield, meaning the events in Semnan were well above the detection threshold for the region, which is estimated to be approximately magnitude 3.25.

The CTBTO/PC's ability to distinguish these tremors from nuclear explosions relies on epistemic consensus, that is, the use of objective physical principles and archives of previous tectonic signals to identify natural discriminants. Specific technical factors related to the Semnan include:

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[10] "September 2017 DPRK Nuclear Test", CTBTO, 2017, <https://www.ctbto.org/our-work/detecting-nuclear-tests/2017-dprk-nuclear-test/, accessed 8 April 2026>.

[11] "International Monitoring System (IMS) Map", CTBTO.

[12] Saeid Naserieh, Ali Moradi, Noorbakhsh Mirzaei et al., "Identifying and Removing Quarry and Mine Blasts from the Iranian Seismological Center's (IRSC) Earthquake Catalog (2006–2024)", Journal of Seismology, vol. 29, pp. 713-730, 2025, <https://www.researchgate.net/publication/392329528_Identifying_and_removing_quarry_and_mine_blasts_from_the_iranian_seismological_center's_IRSC_earthquake_catalog_2006-2024/, accessed 7 April 2026>.

- Waveform Consistency: Unlike the sharp, impulsive signals produced by nuclear tests (such as the DPRK tests recorded by the IMS), the Semnan waveforms matched the complex, extended signatures of tectonic regional waves.
- Depth Estimation: Seismological research allows for the determination of event depth; events determined to be deeper than 10 km are confidently identified as earthquakes, as nuclear tests are conducted much closer to the surface.
- Multi-Technology Verification: Beyond the 50-station primary seismic network, the CTBTO/PC can leverage infrasound and hydroacoustic sensors to ensure no atmospheric or underwater signals were present, further confirming the underground tectonic origin.

By placing the October 2024 tremors within this well-documented seismic history and subjecting them through the rigorous verification process described above, the CTBTO/PC effectively transformed scientific data into a tool for international confidence-building and potentially prevented geopolitical escalation based on misinformation.

STRENGTHS AND LIMITATIONS OF THE INTERNATIONAL ORGANIZATIONS

The scientific credibility of the CTBT is anchored in its multi-technology IMS, which integrates seismic, hydroacoustic, infrasound, and radionuclide sensors to provide a continuous, high-fidelity global picture.[13] This technical framework facilitates an epistemic consensus, that is a shared scientific understanding that would allow the CTBTO to act as a stabilizing force by providing authoritative, empirical data to all member states.[14] Through a transparent data-sharing framework, member states receive both raw and analyzed information, ensuring that evidence is based on physical principles rather than political prejudice, thereby refuting misinformation that could lead to rapid geopolitical escalation. Furthermore, the Treaty carries immense normative value, having established a near-universal global norm against testing that makes any violation diplomatically and politically costly even before the Treaty's formal activation.

Despite these strengths, the Treaty is not yet in force – due to a significant Article XIV requirement, which mandates ratification by all 44 Annex 2 States—those possessing nuclear research or power reactors as of 1996. This legal requirement means that the on-site inspection mechanism, which is the only way to obtain definitive proof of a violation through the collection of physical radioactive samples or drilling at a suspect site, cannot be legally implemented. The system's effectiveness is further challenged by the potential for public misunderstanding regarding "anthropogenic events"; for instance, "ripple-fired" industrial mining blasts can generate seismic signals that mimic small explosions, potentially creating false alarms or ambiguity in the absence of a fully operational inspection regime.

[13] Robert Floyd, "Twenty-five Years of CTBTO", Nuclear Risks and Arms Control - Problems and Progresses in the Time of Pandemics and War, Chapter 2, Springer, 2023, https://link.springer.com/chapter/10.1007/978-3-031-37731-3_2/, accessed 9 April 2026>.

[14] Ola Dahlman, Svein Mykkeltveit, and Hein Haak, "Nuclear Test Ban: Converting Political Visions to Reality, Springer Publications", Springer, 2009, <https://link.springer.com/book/10.1007/978-1-4020-6885-5/, accessed 9 April 2026>.

CONCLUSION

The CTBTO/PC serves as a stabilizing force by providing authoritative, empirically grounded analysis that prevents rapid escalation and systemic mistrust during periods of geopolitical tension. A primary example of this capability was the 2024 seismic event near Semnan, Iran; IMS used data from over 25 stations to confirm the tremors were natural earthquakes, thereby refuting rumors of clandestine nuclear testing. This process fosters an "epistemic consensus," where definitions of evidence are grounded in physical principles and cross-validated data rather than political prejudice. By countering misinformation with impartial science, the CTBTO/PC reinforces the global non-proliferation norm.

Several policy options to further bolster the verification regime are listed below. However, it must be kept in mind that any further increase in the efficiency of an information collection system may result in the registration and processing of data considered sensitive for reasons unrelated to the nuclear test ban. Moreover, the fact that the Treaty is not yet in force makes it more difficult to insist on further upgrades to the system.

- Continuous Reporting: Enabling continuous data streams from 120 auxiliary seismic stations (currently used only on request) would lower detection thresholds by 0.25 to 0.5 magnitude units in critical regions. This reporting should also reach lay audiences, making it more accessible through social media outlets and thereby enhancing the overall visibility of the Organization's work.
- Scientific Data Integration: Formalizing the use of data from thousands of non-IMS sensors operated for earthquake hazard monitoring would significantly increase the difficulty of clandestine testing.
- Mining Transparency: Providing technical advice to mine operators on "ripple firing" methods helps distinguish industrial blasts from the sharp pulses of nuclear explosions.
- Voluntary Notifications: Strengthening the practice of notifying the Technical Secretariat of large chemical explosions (over 300 tonnes) reduces industrial "noise" that can lead to suspicious events.
- Evolving Technology: Sustained investment in noble gas detection (xenon isotopes) and infrasound background research is essential to stay ahead of potential evasion scenarios.

In summary, the CTBTO/PC does not merely monitor for tests; it cultivates a global culture of verification. By pursuing these technical enhancements, the Organization ensures its scientific capabilities grow faster than geopolitical challenges, securing its role as a guardian of the nuclear test-ban norm. Furthermore, in an era characterized by explosive social media news cycles and the rapid spread of misinformation, the need for greater visibility of the CTBTO/PC's work has become more pressing than ever. Public discourse on security and nuclear issues is increasingly shaped by short, emotionally charged narratives that often lack technical accuracy or historical context. In such an environment, the CTBTO/PC's quiet but essential mission risks being overlooked or misunderstood.

Opportunities and Obstacles in Hosting IMS Stations

■ Artur H. Frantz ■ Abdul Moiz Khan ■ Ashika S. Prasad

ABSTRACT

The International Monitoring System (IMS) is a central functional element of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). It has been largely built, made operational and remains effective despite the Treaty's stalled entry into force. While nearly 90 percent of IMS stations are functional, further progress is hindered by political, legal, and strategic concerns shared by some of the host states. This paper argues that hosting IMS stations is a low-cost, high-yield investment in national security and scientific capacity, and that the remaining obstacles are manageable. The paper advances three recommendations: reaffirming a shared commitment the global norm on nuclear testing; improving transparency on subcritical tests; encouraging the conclusion of flexible facility agreements; and accelerating efforts to complete and assign the remaining IMS stations.

INTRODUCTION

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is often presented and praised as a successful component of the nuclear arms control and non-proliferation regime.[1] The International Monitoring System (IMS) is one of the major reasons for this success, as it is central to CTBT's verification system. Although the Treaty has not yet entered into force, hindering the full potential of the compliance monitoring, the IMS is already operational and nearly fully deployed. However, the system is not free from challenges. States are not always willing to host monitoring stations as the Preparatory Commission for the CTBT Organization (CTBTO) attempts to roll them out. This paper highlights the benefits of hosting IMS stations and argues that while states raise strategic, political, technical, and financial questions, there are instruments in place to mitigate such concerns and advance IMS implementation with direct benefits to hosting states.

Article IV of the CTBT outlines the structure of its verification regime that shall be comprised of (a) an International Monitoring System; (b) Consultation and clarification; (c) On-site inspections; and (d) Confidence-building measures. The IMS is active even before entry into force, and, when completed, will comprise 321 monitoring stations, including seismic, hydroacoustic, infrasound, and radionuclide ones, as well as 16 laboratories; around 90% of

[1] Eleonora Neri, "The CTBT: A success story and keystone for reinforcing the NPT regime ahead of the next 2026 NPT Review Conference", <https://europeanleadershipnetwork.org/commentary/the-ctbt-a-success-story-and-keystone-for-reinforcing-the-npt-regime-ahead-of-the-next-2026-npt-review-conference/, accessed 15 April 2026>; NTI, "The Comprehensive Nuclear-Test-Ban Treaty: A Success Story Ready for Completion", <https://www.nti.org/risky-business/the-comprehensive-nuclear-test-ban-treaty-a-success-story-ready-for-completion/, accessed 15 April 2026>.

these facilities are already operational.[2] The IMS collects high-quality data that are provided to States signatories so they can detect and evaluate potential nuclear explosions (i.e. violations of the Treaty) if and when they occur.

However, as CTBTO/PC Executive Secretary Robert Floyd has argued, the Treaty and its organisation are not only scientific institutions but primarily confidence-building instruments.[3] The core aspect of such confidence refers to national security. By providing credible information about events that may or may not be nuclear explosions through data gathered by the IMS, the CTBT helps strengthen the norm against nuclear explosive testing.[4] In the past, many states have expressed an understanding that such a norm, and its upkeep by the CTBT, is in line with their security interests. For instance, in 2020, Japan made clear its commitment to promoting the Treaty's entry into force, motivated by the IMS's successful identification of tests by the Democratic People's Republic of Korea (DPRK).[5] In 2013, the United States, despite not having ratified the Treaty, stated that "the Treaty will benefit U.S. national security," adding that "the United States will be much better off with the CTBT in force than without it".[6]

Besides verification, IMS data serve a variety of scientific, economic and life-saving purposes, such as earthquake prediction, tsunami warnings, and others. Its benefits may also stretch far beyond data collection. Given the current deadlocks in international negotiations, technical cooperation is often seen as an alternative route for confidence-building measures. As the CTBT faces its own political challenges regarding holdout states and delayed entry into force, the IMS is well-suited to play a role in the efforts to build rapport and establish trust between states. To do so effectively, however, the concerns of hosting states must be addressed. According to the CTBTO/PC, 21 stations have not yet been installed.[7] Of those, 17 have already been assigned to specific states, including Treaty ratifying States such as Brazil and the United Kingdom, and States signatories such as Egypt and the United States.[8] Additionally, four stations are listed as "TBD," meaning they have not yet been assigned to a host country. This highlights that, while already impressive in its current form, the IMS still has room to grow.

This paper proposes three key recommendations: (i) nuclear-weapon states should improve transparency on subcritical testing by sharing basic information on major experiments and supporting joint technical studies; (ii) states hosting IMS facilities should be encouraged

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2 "The International Monitoring System", CTBTO, <https://www.ctbto.org/our-work/international-monitoring-system/, accessed 15 April 2026>.

3 Stephanie Liechtenstein, "Russia and the US threatened to resume nuclear testing after several decades. Here is why it matters" <https://apnews.com/article/nuclear-test-ban-monitoring-network-treaty-ab9a80d523bfb6cc3591b0decfb7527d/, accessed 20 April 2026>.

4 Ibid.

5 Permanent Mission of Japan to the International Organizations in Vienna, "Nuclear Disarmament and Nuclear Test Ban", 7 May 2020, <https://www.vie-mission.emb-japan.go.jp/itpr_en/ctbto_en.html/, accessed 20 April 2026>.

6 U.S. Department of State, "National Security Benefits of the CTBT", 2013, <https://2009-2017.state.gov/t/avc/rls/212164.htm/, accessed 20 April 2026>.

7 "Station Profiles", CTBTO, <https://www.ctbto.org/our-work/station-profiles/, accessed 20 April 2026>.

8 Planned IMS stations by country (2024): Brazil: 2 (RN12, RL4); Central African Republic: 2 (PS11, IS12); China (People's Republic): 1 (RL6); Egypt: 2 (PS16, AS29); Ethiopia: 1 (RN25); Iran (Islamic Republic of): 2 (RN36, IS29); Libya: 1 (RN41); Nepal: 1 (AS68); Pakistan: 2 (PS29, IS38); South Africa: 1 (RN62); United Kingdom of Great Britain and Northern Ireland: 1 (RN69); United States of America: 1 IS54; TBD: 4 (PS20, AS39, RN35, IS28).

to conclude facility agreements to address political, legal, and operational concerns; and (iii) CTBTO/PC and States signatories should build momentum for completing the remaining IMS stations, including assigning host countries for the four unallocated sites in currently underserved regions.

BENEFITS OF HOSTING IMS STATIONS

The decision of a sovereign state to host an IMS station is often regarded as a contribution to international peace and security. Moreover, beyond the normative appeal of non-proliferation, hosting presents the host states with significant security, political, and technical advantages. For both signatories and non-signatories, hosting IMS stations is a low-cost, high-yield investment that builds scientific capacity, projects international influence, and enhances national security. This section analyses these benefits, illustrating examples from various host nations.

Primary Applications: National and Regional Security Advantages

The genuine benefit of this arrangement lies in the credible, independent verification capability it provides. States hosting IMS stations gain the assurance that any nuclear test within their region will be rapidly detected and recorded by multiple independent monitoring technologies. This is particularly valuable for states in regions prone to geopolitical tensions, as it removes ambiguity about potential nuclear testing and provides objective, internationally-recognised evidence that can inform diplomatic responses and confidence-building measures.

The increase in global IMS detection capability correlates directly with the declining feasibility of conducting undetected nuclear tests. Currently, with around 90 percent of the 321 stations and 16 laboratories already operational, even relatively low-yield tests are increasingly difficult to conceal.[9] Technical assessments for the CTBT have concluded that, once the IMS reaches full completion and uses regional seismic data, the effective detection threshold for typical underground nuclear explosions can be at or below about 1 kiloton, with many regions detectable well below that level, making covert testing extremely difficult.[10] This transparency serves a deterrent effect, which is a primary security benefit that transcends bilateral or regional relationships and underpins global nuclear restraint. At the same time, a key question arises: how the presumed detectability threshold of 500 tonnes should be addressed in the future, and whether additional studies are needed to determine the feasibility of such tests, their detectability, and their consequences for the Treaty regime.

Secondary Applications: Technical and Scientific Benefits

Access to high-quality, real-time data: IMS data are transmitted to the International Data Centre (IDC), which is shared with all States signatories both in raw and analysed form. Beyond the primary purpose of nuclear test detection, IMS data can be utilised for wider

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[9] Pierrick Mialle and Martin B. Kalinowski, “Nuclear Explosion Monitoring and Verification: Science and Technology to Tackle Global Challenges: An Introduction”, Pure Appl. Geophys, 2024, <https://doi.org/10.1007/s00024-025-03890-0/, accessed 25 April 2026>.

[10] Chirobe Courage Tatenda, “25 years of CTBTO: progress with verification technologies and looking towards the future 25 years and beyond”, CTBTO Science and Technology Conference, 2021, <https://conferences.ctbto.org/event/7/contributions/1282/, accessed 25 April 2026>.

civil and scientific use. Some of the most significant applications include tsunami warnings. Data from seismic stations monitor earthquakes and tsunamis, leading to improved early warning systems and better seismic hazard evaluation for urban planning and construction, for example. The CTBTO/PC is currently providing data for tsunami warning purposes from its seismic and hydroacoustic stations to nine countries, mainly bordering the Pacific or Indian Oceans.[11] Japan provides an important case study in this regard. After the devastating 2011 Tohoku earthquake and tsunami, authorities reported that CTBTO seismic data helped them issue timely tsunami alerts so that many people could escape the tsunami.[12]

Similarly, data from radionuclide stations help in identifying and responding to nuclear accidents, not related to nuclear tests. IMS initiated the detection of radioactive particles and noble gases emitted from reactors following the meltdowns at the Fukushima plant in 2011.[13] The data from infrasound and hydroacoustic stations enable real-time detection of volcanic eruptions, which in turn can inform safety considerations for civil aviation. Infrasound stations also help in identifying plane crashes,[14] and hydroacoustic stations have helped in detecting the last known position of a missing Argentinian submarine, ARA San Juan.[15] Data from hydroacoustic stations have also been used to enable improved weather predictions, scientific studies like the migration pattern and population density of marine mammals, etc.[16]

Capacity Building and Training

IMS stations are state-of-the-art facilities that provide the host nations access to the global scientific network. By hosting a radionuclide, seismic, or other IMS stations, a nation gains infrastructure and all supporting equipment, such as radionuclide samplers, seismic sensors, data links, for example, along with technical assistance, whose operational costs are borne by the CTBTO Preparatory Commission. The verification system is advanced, utilising highly sophisticated technologies in data gathering, transmission, and processing. It thereby ensures that host states have access to cutting-edge technologies and scientific methodologies. It provides technical and financial support to host nations to help them with the establishment, upgradation, operation, and maintenance of equipment, thereby deepening the host nation's scientific expertise.[17] More importantly, local scientists and students get to learn to operate and use these systems. A compelling example is how

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11 "Disaster risk reduction: The CTBTO's Contribution", CTBTO, <https://www.ctbto.org/news-and-events/news/disaster-risk-reduction-ctbtos-contribution/, accessed 25 April 2026>.

12 "Station Profiles: RN38, Takasaki, Japan", CTBTO, <https://www.ctbto.org/our-work/station-profiles/rn38-takasaki-japan#:~:text=The%20Fukushima%20Power%20Plant%20Accident/, accessed 25 April 2026>.

13 "Civil and Scientific Applications", CTBTO, <https://www.ctbto.org/our-work/civil-and-scientific-applications#:~:text=IMS%20stations%20can%20contribute%20to,emitted%20by%20the%20damaged%20reactors/, accessed 25 April 2026>.

14 Incidents such as the collision in 2003 of two F16 aircraft during a military exercise in Belgium, and the 2009 crash of a FedEx cargo plane at Narita International Airport, Japan, were detected by IMS infrasound stations up to hundreds of kilometres away. See CTBTO, "Civil and Scientific Applications".

15 "CTBTO hydroacoustic data used to aid search for missing submarine ARA San Juan", CTBTO, <https://www.ctbto.org/news-and-events/news/ctbto-hydroacoustic-data-used-aid-search-missing-submarine-ara-san-juan/, accessed 30 April 2026>.

16 "The International Monitoring System", CTBTO, <https://www.ctbto.org/our-work/international-monitoring-system/, accessed 30 April 2026>.

17 "Membership benefits", CTBTO, <https://www.ctbto.org/resources/for-member-states/membership-benefits/, accessed 30 April 2026>.

students in Tanzania gain practical laboratory experience at RN64, a station operated by the University of Dar es Salaam (UDSM).[18] CTBTO/PC provides training courses and workshops for IMS station operators, equipping them with the necessary skills for the implementation of the Treaty at the national level. Experts receive hands-on training on how to effectively make use of the monitoring data.

A critical dimension of the human resource development argument is that knowledge persists independent of infrastructure. Even if an IMS station is eventually decommissioned or relocated, the technical competence developed by local scientists, engineers, and technicians remains embedded in their expertise and professional networks. This creates a permanent capacity-building benefit: the trained personnel can apply their expertise to other nuclear-related verification activities, expand to related fields (seismology, meteorology, radiological protection), or serve as mentors for the next generation of scientists.

STATE COMMITMENTS TO THE CTBT AND IMS PARTICIPATION

Table. Country profile

COUNTRY	CTBT SIGNATURE STATUS	RATIFICATION STATUS	IMS HOSTING STATUS
China	Signed	Not ratified	11 certified, 1 under construction
DPRK	Not signed	Not applicable	None
Egypt	Signed	Not ratified	2 planned IMS stations
India	Not signed	Not applicable	None
Iran	Signed	Not ratified	2 planned, 2 installed, 1 certified
Israel	Signed	Not ratified	3 certified
Pakistan	Not signed	Not applicable	2 planned IMS stations
Russian Federation	Signed	Revoked its ratification on 8 November 2023	32 certified
United States	Signed	Not ratified	37 certified, 1 planned

Source: CTBTO Country Profile

The CTBTO/PC presents an interesting diplomatic puzzle, particularly concerning which countries host its IMS stations without having formalised their commitment to the Treaty. China is an important example of this, as it has signed, but not ratified the CTBT. Yet, it is

[18] "CTBTO Chief Dr. Floyd commends UDSM for hosting the Global Nuclear Test Monitoring facility", CTBTO, <https://udsm.ac.tz/index.php/news/ctbto-chief-dr-floyd-commends-udsm-hosting-global-nuclear-test-monitoring-facility/, accessed 30 April 2026>.

deeply integrated into the verification framework by hosting a substantial number of IMS stations. The DPRK, India, and Pakistan have not signed the Treaty; India and the DPRK have not initiated hosting of IMS stations. While Iran and Israel are hosting nations, Egypt is planning to host IMS stations. The US has not ratified the Treaty, yet it hosts the largest number of IMS facilities, with 38 stations spread across its territories. The Russian Federation ratified the CTBT in 2000 but formally revoked its ratification in 2023.[19] Despite this, the Russian Federation continues to cooperate with the CTBTO, maintaining IMS sites under formal agreements.

Under the current arrangements, a non-signatory state can gain accredited observer status if it is specifically designated by the Treaty to host IMS facilities. This legal pathway enables critical operational data flow and participation in verification discussions without requiring the host country to commit fully to the Treaty's legal obligations.[20] Non-signatory States designated to host IMS stations face distinctive legal and political hurdles. They lack the CTBT's treaty framework, so they must independently grant the CTBTO legal personality plus specific privileges and immunities. These include, for example, exemption from taxes and customs duties, freedom to import equipment, and protection for CTBTO staff, to allow smooth installation, operation, and servicing of stations.[21] Without such arrangements, even routine maintenance, repair, and replacement of IMS equipment can become administratively burdensome and legally uncertain, undermining long-term station sustainability.[22] Because the CTBTO is not automatically recognised in domestic law, non-signatory hosts usually rely on a Facility Agreement with the Preparatory Commission, further explained below. Model facility agreements are designed to fill this gap by defining the CTBTO's status, allocating responsibilities for upkeep, and embedding limited, function-related immunities, and they can be concluded even with states that have not signed the CTBT, if national law permits.[23] According to CTBT annexes and regional analyses, only Pakistan and Saudi Arabia are presently designated IMS hosts that have not at least signed the Treaty, illustrating how rare and politically delicate such arrangements are.[24]

CHALLENGES FACED BY IMS STATIONS

Although almost 90% of IMS stations have been completed, it is important for states to sign facility agreements with the CTBTO/PC, progress on which is rather slow. A facility agreement is a legal arrangement between the CTBTO and each State signatory that hosts an IMS facility. These agreements are important, as they help address the entire bandwidth

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[19] Arms Control Association, "Russia Withdraws Ratification of Nuclear Test Ban Treaty" <https://www.armscontrol.org/blog/2023-11/nuclear-disarmament-monitor/, accessed 30 April 2026>.

[20] "Facility Agreements," CTBTO, <https://www.ctbto.org/resources/for-member-states/facility-agreements/, accessed 30 April 2026>.

[21] CTBTO, CTBT/PTS/INF.1204 ("National Implementation Measures – Privileges and Immunities"), <https://www.ctbto.org/sites/default/files/Documents/CTBT-PTS-INF1204.pdf/, accessed 30 April 2026>.

[22] "Legal Resources," CTBTO, <https://www.ctbto.org/resources/for-member-states/legal-resources/, accessed 30 April 2026>.

[23] "Join the Comprehensive Test Ban Treaty's International Monitoring System", Stimson Center, <https://www.stimson.org/2017/join-comprehensive-test-ban-treatys-international-monitoring-system/, accessed 30 April 2026>.

[24] VERTIC, "The CTBT: Lack of Progress in the Middle East and South Asia", TV121, <https://www.vertic.org/media/assets/TV121.pdf/, accessed 30 April 2026>.

of issues regarding IMS facilities between CTBTO and hosting countries.[25] According to the CTBTO, facility agreements need to be concluded with 89 countries hosting IMS stations. As of 2025, facility agreements with 42 States signatories (jointly hosting around 50% of all IMS facilities) have entered into force, while 8 more (another 8% of IMS facilities) have already been signed. Forty state signatories (representing 44% of all IMS facilities) have yet to sign a facility agreement.[26]

Facility agreements are important as they tackle political, legal, technological, and operational issues between the CTBTO and host states. Politically, signing the agreement represents a formal commitment on the host state's part to cooperate with the CTBTO in establishing, testing, operating, upgrading, and maintaining IMS stations even before the Treaty goes into force. Legally, these agreements address issues such as ownership transfer, conclusion of subsidiary arrangements with local operators, and granting immunities and privileges to the CTBTO and its officials. Technologically, under the agreement, the host state has to take measures to operate and maintain the facility as well as transmit data to the IDC in accordance with requirements and procedures. Operationally, they help ensure coordination between the CTBTO and host countries regarding visits of officials, access to stations, and physical security of stations.

There are several reasons behind the reluctance of states to sign facility agreements with the CTBTO.[27] These include, but are not limited to, sovereignty and security concerns, lack of trust in data confidentiality, political and strategic reservations regarding the CTBT, technical and financial burdens, uncertainty about the CTBT's future, and delays in negotiation and certification due to domestic political issues. One of the concerns for states when signing a facility agreement is that the monitoring systems and their sensors can reveal their military movements, and the data can be exploited for intelligence purposes.[28] As transmitting data to the IDC is a necessary part of the facility agreement, this is a major hurdle for certain states to sign the agreement. In the case of some states, like India, that have not signed the CTBT, their reluctance stems from their reservations regarding the Treaty altogether.[29] Moreover, as the United States has not ratified the Treaty, they are reluctant to sign a facility agreement before the Treaty can go into force.[30]

Technical and financial reservations of states are another reason for their reluctance to sign facility agreements. Developing countries do not always have the necessary technical expertise to keep and operate these systems. As it is the responsibility of host states to maintain the stations, some states see it as an unnecessary financial burden, while others face a shortage of skilled experts.

There are several consequences for not signing the facility agreement for both the host state and the Preparatory Commission for the CTBTO. For the host state, it could prevent

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25 "Facility Agreements", CTBTO.

26 Ibid.

27 Insights obtained from a CTBTO official.

28 Ibid.

29 Ruhee Neog, "CTBTO at 20: Why India Won't Sign the Treaty", South Asian Voices, 2016, <https://southasianvoices.org/ctbt-at-20-why-india-wont-sign-the-treaty/, accessed 28 April 2026>.

30 Stephen Herzog, "The Nuclear Test Ban: Technical Opportunities for the New Administration", Arms Control Today, 2017, <https://www.armscontrol.org/act/2017-01/features/nuclear-test-ban-technical-opportunities-new-administration?, accessed 28 April 2026>.

the transfer of ownership of equipment, delay the establishment of tax and customs exemptions, and hinder the smooth operation and maintenance of the IMS stations. For the CTBTO, it can result in delays in shipping equipment for repair or replacement, impacting data availability and overall program implementation. Furthermore, the absence of a signed facility agreement may increase operational costs, as taxes and customs duties, which are a liability on the Organization's limited resources, and at odds with the spirit of the CTBT and the Resolution establishing the Preparatory Commission, could be triggered.

However, there are also many incentives for states to sign a facility agreement with the CTBTO and to host IMS stations. There are political and technical benefits that can come with building IMS stations on one's territory and cooperation with the CTBTO. One of the benefits of hosting IMS stations is having more technical and political clout within the working of organisation. Moreover, there are dual-use benefits of hosting IMS stations, as they can also help in earthquake detection, tsunami warning, and other research activities.[31] States benefit from CTBTO data, technical workshops, and expertise-building, among others.

RECOMMENDATIONS

Sharing Information on Sub-Critical Testing

Nuclear states could introduce voluntary notifications for major subcritical experiments, sharing the date, location, and purpose via CTBTO channels, paired with annual briefings on program safeguards. This builds trust without intrusive inspections, directly benefiting host states by framing IMS data as neutral evidence against secret activities. Piloting joint IMS-national data studies could further validate detection thresholds below 1 kiloton, turning stations into proactive deterrence tools.

Encouraging States to Sign Facility Agreements

States can be encouraged to sign FAs through targeted outreach and emphasising the advantages, such as compliance with CTBT obligations, a reputational boost, and increased operational efficiency. Additionally, FA signing decreases the burden on all states' assessed contributions by avoiding additional taxes and customs duties. Impediments include the political considerations of the host states, as the conclusion of the FA requires that the action be politically opportune. Additionally, national legislative processes may be slow or complicated, further delaying the signing. Flexible approaches, such as different forms of agreements (e.g., exchange of letters or memoranda of understanding), may be used to facilitate this process.

Push for Missing Stations

CTBTO should hold focused talks at the next PrepCom session or Article XIV Conference to assign homes for the 4 open TBD stations (PS20 primary seismic, AS39 auxiliary seismic, RN35 radionuclide, IS28 infrasound), targeting coverage gaps in high-risk zones like South Asia, the Middle East, or Africa. Start with low-pressure outreach: free site surveys, dual-use demos (e.g., tsunami warnings or quake alerts), and tailored briefings on host perks, inviting prospects like India, building on Pakistan's two planned stations (PS29, IS38), without demanding CTBT signature upfront. Regional groupings (SAARC, AU) could nominate sites, framing hosting as a shared security win.

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[31] Sylvia Mishra Bidgood Sarah, "Join the Comprehensive Test Ban Treaty's International Monitoring System," South Asian Voices, 31 May 2019, <https://southasianvoices.org/join-the-ctbt-international-monitoring-system/, accessed 28 April 2026>.

CONCLUSION

The analysis shows that hosting IMS stations is not simply a symbolic contribution to the CTBT, but a concrete way for states to enhance their own security, scientific capability, and international standing. IMS data give governments credible, independent insight into potential nuclear tests while also supporting vital civil uses such as tsunami and earthquake early warning, nuclear safety monitoring, and environmental and atmospheric research. These dual-use benefits, combined with sustained training and technology transfer, mean that the skills and institutions built around IMS facilities continue to serve host societies long after individual projects or stations change.

At the same time, the paper highlights why some states remain cautious: unresolved questions about low-yield and subcritical testing, concerns over sovereignty and data use, incomplete legal frameworks, and the political sensitivity of hosting verification assets. Addressing these concerns requires more than technical reassurance; it calls for clear political commitments, tailored legal instruments, and practical support for host countries. The three recommendations outlined here, improving transparency on subcritical testing, encouraging the conclusion of facility agreements, and pushing to complete and assign the remaining IMS stations, offer a realistic pathway to do so. Taken together, they show how a more complete and politically supported IMS can both strengthen the global norm against nuclear explosive testing and deliver tangible benefits to the states that choose to host it.

CTBTO Integrated Field Exercise: Lessons from Kazakhstan and Jordan and the Road Ahead

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ABSTRACT

One of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) verification capacity-building instruments is the Integrated Field Exercises (IFEs), which are large-scale, realistic drills that help assess the Treaty's On-Site Inspection (OSI) structures and techniques in the run-up-to the entry-into-force. In essence, IFEs test the CTBTO's future ability to verify whether a nuclear test has occurred. IFE represents more than an exercise; it can serve as an additional tool of information on the workings of OSI, which will require more creativity and cooperation. Since the Treaty's opening for signature, two IFEs have taken place, one in Kazakhstan in 2008 (IFE08) and another one Jordan in 2014 (IFE14). A third IFE exercise is scheduled to take place in Namibia in 2026 (IFE26). This paper examines the past two missions by reviewing the exercises, comparing them and deriving lessons learned. Furthermore, it utilizes such lessons to improve the upcoming Namibian exercise. In parallel, this paper will also propose new ideas for IFE26, such as intensifying media and public outreach, inviting youth experts to the exercise and involving local universities, all of which are aimed at building a stronger public narrative.

INTRODUCTION

International Monitoring System

It is important to think of the International Monitoring System (IMS) as a worldwide alarm network that monitors the globe for potential nuclear tests. The IMS uses four kinds of monitoring systems: seismic stations (which measure wave form movements in the earth's crust), infrasound stations (which listen for ultra-low-frequency sound waves that cannot be heard by human ears), hydroacoustic stations (which monitor for sound waves in seawater and oceans), and radionuclide stations (which detect radioactive particles and gases created by the fission of nuclear materials) which is expected to be placed across 89 countries.[1] If a nuclear explosion happens anywhere (underground, underwater, or in the atmosphere), the IMS is designed to notice specific signals and send out an alert. Thus, the IMS capabilities make highly likely that a nuclear test would be detected, which in itself deters countries from attempting testing.

[1] The Protocol (Part I) to the Treaty establishes the requirement for a global monitoring network and refers to the facilities specified in Annex I to the Protocol as the system of stations that must be established and operated. It provides 337 facilities: 321 monitoring stations and 16 laboratories. "The International Monitoring System", Comprehensive Nuclear Test Ban Treaty Organization (CTBTO). <https://www.ctbto.org/our-work/international-monitoring-system/, accessed 24 April 2026>.

On-Site Inspection

The sole purpose of an On-Site Inspection (OSI) – which can only be activated once the Treaty enters into force – is to clarify whether a nuclear weapon test explosion or any other nuclear explosion has been carried out in violation of Article I of the Treaty and, to the extent possible, to gather facts, which might assist in identifying a possible violator.[2] The request for an OSI must be based on information from the IMS, national technical means or a combination thereof. An OSI begins after the Executive Council (EC) approves an inspection request by a State Party.[3] Inspectors receive a mandate specifying inspection objectives, geographic area, and authorized techniques. Prior to deployment, the inspection team conducts planning, logistical preparation, and coordination with the Inspected State Party (ISP), including safety and access arrangements. Upon arrival, the team initiates entry formalities, site orientation, and preliminary surveys to verify inspection conditions before full deployment of equipment and sampling procedures. While working in the inspection area, inspectors use techniques outlined in the Treaty such as environmental sampling, passive seismological monitoring, visual observations of physical cues (fresh craters, unusual gases) and still photography. OSI aims to clarify the information gathered by the IMS through inspecting what has happened on the ground. As such, the IMS works in complementarity with OSI. It should be noted that most of the CTBT provisions relating to OSI have been developed based on the assumption that the "suspected area" to be investigated is located in the territory of a State Party to the Treaty. Yet, the Treaty text does reflect another possibility, namely that a suspicious event could have taken place in an area beyond the jurisdiction or control of any state (paragraphs 105–108 of Part II of the Protocol to the CTBT), although the Treaty provisions are much less detailed when an inspection is to be conducted in such an area.

Integrated Field Exercises

Integrated[4] Field Exercises (IFEs) are large, realistic drills that are designed to evaluate the implementation of nearly all OSI techniques, systems, procedures, and operational mechanisms within a scientifically credible and technically realistic scenario. In this way, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) can test the effectiveness of its ultimate verification tool before the Treaty's entry-into-force.[5] Teams deploy to a host country, set up equipment, manage logistics and work through political and practical hurdles under time pressure and limited information.[6] A typical mission consists of a team of inspectors that arrive at the ISP, carrying tons of equipment that cover the Treaty's inspection techniques. A predetermined scenario is created prior to the IFE that is designed to test the inspection team's ability to either prove or disprove the existence of nuclear explosion traces.[7]

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2 Article IV, Paragraph 35 of the Comprehensive Nuclear-Test-Ban Treaty.

3 Article IV, lett d., Comprehensive Nuclear-Test-Ban Treaty; "The final verification measure: on-site inspection", CTBTO, <https://www.ctbto.org/our-work/on-site-inspection/, accessed on 24 April 2026>.

4 "Integrated" refers to the comprehensive, combined testing of nearly all elements of an On-Site Inspection (OSI) in a realistic scenario, bringing together multiple verification techniques, operational procedures, logistics, and inspection phases into a single exercise rather than testing methods separately.

5 "Sri Lanka to host next on-site inspection integrated field exercise in 2025", CTBTO, 24 July 2023, <https://www.ctbto.org/news-and-events/news/sri-lanka-host-next-site-inspection-integrated-field-exercise-2025/, accessed on 24 April 2026>.

6 On-site Inspection IFE14 Jordan: Frequently asked questions", CTBTO, <https://www.ctbto.org/sites/default/files/Documents/IFE14_media_Questions_and_Answers.pdf/, accessed 24 April 2026>.

7 "Integrated field exercise 2014 (IFE14)", CTBTO, <https://www.ctbto.org/our-work/on-site-inspection/on-site-inspection-exercises/ife14/, accessed 24 April 2026>.

IFE08 VS IFE14 DESIGN – STEP BY STEP SOPHISTICATION

To date, the Preparatory Commission for the CTBTO conducted two major IFEs to test and refine its OSI capabilities under the CTBT: IFE08 in Kazakhstan and IFE14 in Jordan. Although both shared the overarching goal of validating inspection procedures in realistic settings, they differed significantly in scenario design, scale, location and strategic purpose, illustrating the CTBTO's progressive enhancement of its inspection capabilities. Firstly, IFE14 was larger than IFE08 in terms of the time taken to prepare and conduct the exercise. While this increased the cost of IFE14, it allowed the Organization to conduct a more complex inspection and test seven other inspection techniques, additional to the eight ones tested in IFE08. Secondly, the use of different scenarios and site selection in the two IFEs ensured that inspectors were prepared for a wide range of possible outcomes. Although only two IFEs were conducted, these exercises contributed to promoting the CTBT in different regions. Finally, the CTBTO has engaged with media representatives and other invitees starting from IFE08, mindful of the power that public opinion has; as representation of media members can aid in publicizing the important work of the organization, further encouraging States to host IFEs.[8] A step further was taken in IFE14 with an introduction of a VIP tour, consisting of high-level officials and scholars, designed to enhance their understanding of the Treaty. However, the VIP tour featured no young experts, hence limiting the opportunity for disseminating non-proliferation regimes among the youth.[9]

Table. CTBTO IFE Comparison: Kazakhstan 2008 vs Jordan 2014

PARAMETERS	IFE08 (KAZAKHSTAN)	IFE14 (JORDAN)
Preparation	7 weeks[10]	28 weeks[11]
Duration[12]	3 weeks (from 1 to 25 September, 2008)[13]	5 weeks (from 3 November to 9 December, 2014)[14]
Total cost	About USD 6mln[15]	USD 10.3mln[16]

8 After the Treaty's entry-into force, media is not expected to be allowed in OSIs due to the nature of sensitive information disclosed.

9 This information was shared by one of the IFE14 VIP tour participants during an interview conducted in the course of preparation of the present paper.

10 "On-site Inspection IFE14 Jordan: Frequently asked questions", CTBTO, <https://www.ctbto.org/sites/default/files/Documents/IFE14_media_Questions_and_Answers.pdf/, accessed 27 April 2026>.

11 Ibid.

12 An OSI can last for a maximum of 130 days, with an initial period lasting up to 25 days from EC approval, a continuation period lasting up to 60 days from EC approval and an extension period lasting up to 130 days from EC approval. An IFE usually lasts for a shorter period as it is designed to serve only as an exercise that tests OSI capabilities.

13 "Media Advisory: CTBTO to Conduct First Integrated On-Site Inspection Exercise in September in Kazakhstan", CTBTO, <https://www.ctbto.org/resources/for-the-media/press-releases/media-advisory-ctbto-conduct-first-integrated-site/, accessed 27 April 2026>.

14 "Integrated field exercise 2014 (IFE14)", CTBTO, <https://www.ctbto.org/our-work/on-site-inspection/on-site-inspection-exercises/ife14/, accessed 11 October>.

15 Oliver Meier, "SPECIAL REPORT: Major Exercise Tests CTBT On-Site Inspections", Arms Control Association, <https://www.armscontrol.org/act/2008-11/special-report-major-exercise-tests-ctbt-site-inspections/, accessed 28 April 2026>.

16 Daryl G. Kimball, "CTBTO Conducts Major Field Exercise", Arms Control Association, <https://www.armscontrol.org/act/2014-12/news/ctbto-conducts-major-field-exercise/, accessed 28 April 2026>.

Location	Former Soviet nuclear test site at Semipalatinsk featuring real test artifacts and residual radiation from past explosions[17]	Geological diversity, significant seismic activity located in the Great Rift Valley[18]
Territory[19]	1,000 square kilometres[20]	1,000 square kilometres[21]
Scenario	"Compliance" scenario meaning that no nuclear explosion had occurred[22]	"Non-compliance" scenario, with evidence pointing to the occurrence of a nuclear explosion[23]
Participants	49 members of the inspection team[24] Nearly 200 participants from more than 40 countries[25]	40 members of the inspection team 200 experts and scientists from 44 countries[26]
Inspection activities and techniques	8 out of 17 techniques:[27] 1. Position finding 2. Visual observation 3. Still photography 4. Gamma radiation monitoring and energy resolution analysis 5. Environmental sampling and analysis 6. Passive seismology 7. Magnetic field mapping 8. Ground penetrating radar	15 out of 17 techniques:[28] 1. Position finding 2. Visual observation 3. Video 4. Still photography 5. Multi-spectral imaging 6. Gamma radiation monitoring and energy resolution analysis 7. Measurements of Argon-37 8. Measurements of RadioXenon 9. Environmental sampling and analysis 10. Passive seismology 11. Active seismic surveys 12. Magnetic field mapping 13. Gravitational field mapping 14. Ground penetrating radar 15. Electrical conductivity measurements
Invitees	One day was dedicated to journalists[29]	One day was dedicated to journalists A VIP tour for high-level officials and scholars[30]

[17] Edward Ifft, "On-Site Inspections Under the Comprehensive Nuclear-Test-Ban Treaty", AIP Publishing, 15 November 2017, <https://doi.org/10.1063/1.5009217/, accessed 28 April 2026>.

[18] Ibid.

[19] According to the Treaty, the area of an on-site inspection shall be continuous and its size shall not exceed 1,000 square kilometres.

[20] "Integrated field exercise 2008 (IFE08)", CTBTO, <https://www.ctbto.org/our-work/on-site-inspection/on-site-inspection-exercises/ife08/, accessed 28 April 2026>.

[21] "IFE14 Kicks Off", CTBTO, <https://www.ctbto.org/news-and-events/news/ife14-kicks/, accessed 28 April 2026>.

[22] Edward Ifft, "On-Site Inspections Under the Comprehensive Nuclear-Test-Ban Treaty", AIP Publishing, 15 November 2017.

[23] Ibid.

[24] Only 40 inspectors were on the site simultaneously, which falls under the scope of the Treaty.

[25] "Head of CTBTO Visits Kazakhstan", CTBTO, <https://www.ctbto.org/news-and-events/news/head-ctbto-visits-kazakhstan/, accessed 28 April 2026>.

[26] Mackby, "SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion?".

[27] "On-Site Inspection Integrated Field Exercise in 2026 (IFE26)", Conferences CTBTO, <https://conferences.ctbto.org/event/30/contributions/6081/attachments/2820/5397/P4.5-546_SUMMERS.pdf/, accessed 28 April 2026>

[28] Ibid.

[29] "Media Advisory: CTBTO to Conduct First Integrated On-Site Inspection Exercise in September in Kazakhstan", CTBTO.

[30] "On-site Inspection IFE14 Jordan: Frequently asked questions", CTBTO.

INSPECTION ACTIVITIES AND TECHNIQUES

The inspection sites in Kazakhstan (2008) and Jordan (2014) provided compelling evidence of the reliability of OSI. The unique feature of IFE08's location — being the former Soviet nuclear test site in Semipalatinsk — allowed CTBTO to test its contamination protection protocols.[31] Due to radiological safety considerations, inspectors worked in the field for a maximum of six hours per day and were required to undergo decontamination procedures after activities ended in the field.[32] This aspect of IFE08 demonstrated CTBTO's ability to implement effective protection measures against radiological exposures. Subsequently, IFE14 in Jordan explored OSI's ability to adapt its inspection mechanisms to challenging locations, as IFE14's inspection area had a wide variety of geological features, including sinkholes reaching depths of up to 420 meters below sea level and mountains reaching 1,854 meters above sea level.[33] Although logistical challenges were noted in IFE08 — partially due to the location's highly remote area — logistical issues were resolved in IFE14. This is due to CTBTO's introduction of the Intermodal Rapid Deployment System, which allowed equipment to be used straight from the containers.[34] Overall, the blend of challenge and realism offered by IFE08 and IFE14's location underscored OSI's functionality and adaptability.

While both IFE08 and IFE14 were effective in their objective and purpose, the latter was regarded as being much more sophisticated than the former. That is quite logical, since the scenario for the IFE14 was developed, taking into account many useful lessons from IFE08. IFE14's exercise was characterized by a wider range of activities and increased technical complexity than IFE08.[35] In terms of inspection activities, both IFE08 and IFE14 utilized the same technical logic of beginning the exercise with the least intrusive methods during the initial period and gradually using more intrusive methods in the continuation period. This principle of maximizing efficacy while minimizing intrusiveness is vital in OSI, which aims to investigate the evidence of nuclear testing while safeguarding the national security interests of the ISP.[36] In the initial phase of both IFE08 and IFE14, the inspecting team utilized techniques such as visual observation, initial overflight, radiation monitoring, passive seismic monitoring, and environmental sampling and analysis. In this phase, inspectors focus on identifying visual changes, such as craters, that could indicate an explosion. In the continuation phase, inspectors use more intrusive techniques such as magnetic field mapping and electrical conductivity measurements.[37] In IFE14, only drilling

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31 "On-Site Inspection: Integrated Field Exercise 2008 Movie", CTBTO, <https://www.youtube.com/watch?v=8HCMtglqHLo/, accessed 27 April 2026>.

32 Ibid.

33 Jenifer Mackby, "SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion? On-Site Inspection and the CTBT", Arms Control Association, January 2015, <https://www.armscontrol.org/act/2015-01/features/special-report-did-maridia-conduct-nuclear-test-explosion-site-inspection-and/, accessed 28 April 2026>.

34 On-site Inspection IFE14 Jordan: Frequently asked questions", CTBTO, <https://www.ctbto.org/sites/default/files/Documents/IFE14_media_Questions_and_Answers.pdf/, accessed 27 April 2026>.

35 "Integrated field exercise 2014 (IFE14)", CTBTO.

36 Article IV, paragraph 57(b) of the Comprehensive Nuclear-Test-Ban Treaty: "In accordance with the provisions of this Treaty and the Protocol, the inspected State Party shall have: (b) The right to take measures it deems necessary to protect national security interests and to prevent disclosure of confidential information not related to the purpose of the inspection".
Malcolm Coxhead, "On-site inspections for the CTBT: long-running discussions achieve progress", The Verification Research, Training and Information Centre (VERTIC), July 2008, <https://www.vertic.org/media/assets/VERTIC%20brief%207_Coxhead.pdf/, accessed 29 April 2026>.

37 On-site Inspection IFE14 Jordan: Frequently asked questions", CTBTO.

and resonance seismometry, which measures underground seismic tremors to identify cavities underground, were not tested.[38] Due to heavy financial constraints, drilling was not tested in either IFE08 or IFE14.[39] This is not considered to be a drawback, since in a real OSI, drilling is considered to be a last-resort technique due to its high level of intrusiveness on the ISP's land. The testing of nearly all techniques during IFE14 further legitimates CTBTO's technical capabilities in OSI.

Given the unique nature of OSIs, which features international inspection teams investigating State Parties for nuclear testing, it is expected that tensions could arise between the inspection team and ISP. Fortunately, according to the scenario (script), both exercises experienced tensions offering opportunities and examining ways of conflict resolution. In IFE08, a disagreement arose after the ISP representative called to limit the access of the inspector team beyond the restricted-access site (RAS) — a measure which is not covered by the Treaty.[40] When the inspector team leader noted this point — raising the concern that the proposition is in violation of Treaty stipulations — the ISP team leader responded with "take it or leave it". The issue was later resolved through negotiations and compromise, which included the CTBTO director-general, the inspection team, and the ISP.[41] Similarly, a smaller disagreement occurred in IFE14 when, during the exercise's scenario, an inspector took a sample before asking permission from the ISP, causing tensions that could have resulted in the inspector being asked to leave.[42] While these incidents represent operational complications, they reflect real-life dynamics that test the challenging act of conducting OSI and provide realistic solutions that reinforce the credibility of OSI.

LESSONS LEARNED

While both IFE08 and IFE14 were successful in testing OSI capabilities, valuable lessons were noted which could be used to improve future exercises. For instance, the large inspection area of 1,000 square kilometers in both IFE scenarios presented challenges to inspectors. In IFE14, experts observing the exercise noted that inspectors underestimated the time needed to deploy to locations within the inspection area, causing delays in the activities of the inspection.[43] This highlights the importance of studying the area's terrain before deployment to gain a clear understanding of potential challenges and to plan inspection activities accordingly. IFE14 was also met by cultural circumstances as the inspecting team required permission from landowners and local populations to install equipment.[44] This incident not only caused delays in inspection activities but also posed a security risk with such equipment being left unattended. This underlines the unique challenges that inspectors may face in different countries and indicates the importance of hosting IFEs in different geographical locations. In IFE08, the absence of constructed roads made travel more difficult for the inspection team. This — alongside the constraint of working for only

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38 Ibid.

39 Edward Ifft, "On-Site Inspections Under the Comprehensive Nuclear-Test-Ban Treaty", AIP Publishing, 15 November 2017, <https://doi.org/10.1063/1.5009217/, accessed 29 April 2026>.

40 Article IV, paragraph 94 of the Comprehensive Nuclear Test Ban Treaty: "The inspection team shall have the right to place equipment and take other steps necessary to conduct its inspection up to the boundary of a restricted-access site."

41 Meier, "SPECIAL REPORT: Major Exercise Tests CTBT On-Site Inspections".

42 Mackby, "SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion?".

43 "Integrated field exercise 2014 (IFE14)", CTBTO.

44 Mackby, "SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion?".

a maximum of six hours per day in a given area — created further delays in inspection activities.[45] Furthermore, difficult weather conditions in Kazakhstan affected the normal progression of inspection activities in the field. The initial overflight — which is usually conducted on the first day of inspection — had to be delayed by a few days due to unsafe weather conditions.[46] Malfunctions in equipment were also noted in both IFE exercises, highlighting the importance of operating and testing equipment before deployment in the field. Issues in base camp operations were also noted in IFE08 due to problems with diesel fuel that affected equipment functionality and led to a halt in electricity supply.[47] This highlights the importance of ensuring smooth operational capacity of both the equipment and base camp operations. Both exercises also encountered issues related to field data collection and management. In IFE14, data losses were noted due to the presence of rodents that damaged cables.[48] Concurrently, data processing during IFE14 was argued to be difficult to keep up with by the ISP team lead during the exercise, who called for more streamlining to help teams keep track of the information.[49] The control team lead in IFE14 also noted that inspectors in IFE14 could have benefited from additional preparations through build-up exercises.[50] This is backed up by comments made from experts invited in the exercise who observed that the inspecting team might have been able to determine certain locations, or polygons, as being an unlikely location for a nuclear test through more extensive reviews of the data.[51] Similarly, they suggested that additional sampling in the field could have potentially enabled inspectors to find the iodine-131 sample[52] at an earlier stage.[53] These incidents shed light on potential recommendations and insights for improving the upcoming IFE26, scheduled to take place in Namibia.

THE ROAD AHEAD: NAMIBIA AND BEYOND

In 2026, the CTBTO/PC will carry out its third major full-scale IFE26 for the OSI verification regime under the CTBT, hosted by Namibia, precisely in Swakopmund,[54] for over six weeks in October and November 2026.[55] IFE26 will welcome approximately 250 participants (between the CTBTO staff and national experts)[56], who will work in an inspection area of

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45 Meier, "SPECIAL REPORT: Major Exercise Tests CTBT On-Site Inspections".

46 "Integrated field exercise 2008 (IFE08)", CTBTO, <https://www.ctbto.org/our-work/on-site-inspection/on-site-inspection-exercises/ife08/, accessed 25 April 2026>.

47 Meier, "SPECIAL REPORT: Major Exercise Tests CTBT On-Site Inspections".

48 Mackby, "SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion?".

49 "IFE14, The Movie", CTBTO, <https://www.youtube.com/watch?v=XfCjslo_nUc/, accessed 25 April 2026>

50 Ibid.

51 Mackby, "SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion?".

52 Iodine-131 is a radioactive isotope which is produced during a nuclear fission and its presence can indicate a recent nuclear explosion. Iodine-131 has a half-life of approximately eight days, signifying the time pressure on inspectors to detect the isotope earlier in the exercise.

53 Ibid.

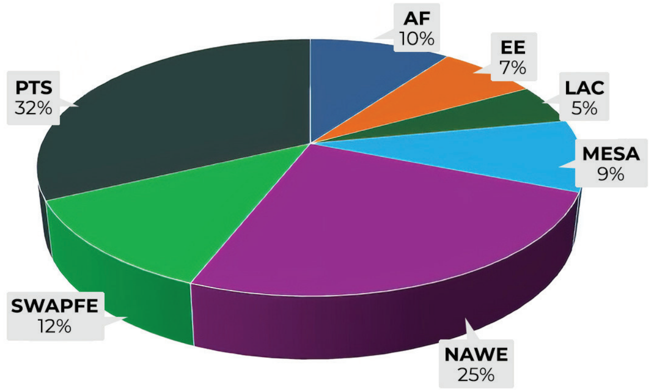
54 A coastal city on Namibia's Atlantic coast at the edge of the Namib Desert, featuring a mild, hyper-arid desert climate with very little rainfall and frequent coastal fog driven by the cold Benguela Current that can reach far inland and influence visibility and atmospheric conditions. The surrounding terrain is dominated by sandy soils, with saline and gypsum-rich deposits typical of the Namib, and sparse vegetation, which affects surface conditions for instrumentation and mobility. Source: Richard F. Logan, "Namib", Encyclopedia Britannica, <https://www.britannica.com/place/Namib/, accessed 23 April 2026>.

55 "Namibia to host CTBTO's Integrated Field Exercise 2026", CTBTO, <https://www.ctbto.org/resources/for-the-media/press-releases/namibia-host-ctbtos-integrated-field-exercise-2026/, accessed 24 April 2026>.

56 Oleg Rozhkov, Director of the OSI Division (CTBTO), Ibid.

1000 square kilometers in the coastal Erongo Region. The exercise will require the transportation of around 150 tons of equipment to Namibia.[57]

Figure. Participants' regional distribution of the upcoming IFE26



This graph shows the regional distribution of participants for IFE26;

PTS – Provisional Technical Secretariat of the CTBTO;

AF – Africa;

EE – Eastern Europe;

LAC – Latin America and the Caribbean;

MESA – Middle East and South Asia;

NAWE – North America and Western Europe;

SWAPFE – South West Asia and Pacific Far East[58]

Drawing on lessons from previous exercises, which have already been analyzed in this paper, a series of actionable recommendations ought to guide the planning and conduct of the Namibia 2026 exercise.

1. Strengthen logistics and support under challenging field conditions: IFE08 suffered delays and difficulties under extreme weather and remote-terrain conditions.[59] For Namibia, the CTBTO/PC should ensure robust contingency planning for logistics: transport of heavy equipment, base camp set-up, field mobility (including aerial support), and supply of critical consumables (fuel, food, communication). Pre-deployment reconnaissance and simulation of worst-case weather/terrain scenarios would mitigate risk.

2. Maximize integration of techniques and data flows: Both previous exercises highlighted that the integration of disparate inspection methods and the seamless flow of information between field teams and the Operations Support Centre is crucial.[60] In IFE08, subsurface geophysics teams needed to coordinate more tightly with visual, seismic, and radionuclide sampling teams.[61] In IFE14, the usage of more advanced sensors (e.g., airborne multispectral/infrared) improved coverage, but further work remains in real-time data fusion[62] and decision-making.[63] Namibia should emphasize fully integrated command-and-control,

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[57] Ibid.

[58] Simon Summers and Andrew Bramnik, "On-Site Inspection Integrated Field Exercise in 2026 (IFE26)", CTBTO. E-poster for the Science and Technology Conference 2025, <https://conferences.ctbto.org/event/30/contributions/6081/attachments/2820/5397/P4.5-546_SUMMERS.pdf/, accessed 18 April 2025>.

[59] "High-level group observes IFE14's field activities", CTBTO, <https://www.ctbto.org/news-and-events/news/high-level-group-observes-ife14s-field-activities/, accessed 24 April 2026>.

[60] "CTBTO Tests its on-site inspection regime in Kazakhstan", CTBTO, <https://www.ctbto.org/sites/default/files/2022-08/ife08.pdf/, accessed 25 April 2026>.

[61] "Integrated on-site inspection exercise in Kazakhstan reaches a successful conclusion", CTBTO, <https://www.ctbto.org/resources/for-the-media/press-releases/integrated-site-inspection-exercise-kazakhstan-reaches/, accessed 25 April 2026>.

[62] Real-time data fusion is the integration of heterogeneous data streams (e.g. airborne imagery, seismic data, ground measurements, and environmental observations) into a single, continuously updated operational picture). During IFE14, real-time data fusion remained limited since data were often analyzed post-collection rather than dynamically during operations. Source: "Integrated field exercise 2008 (IFE08)", CTBTO.

[63] Ibid.

ensure interoperable communication systems, and simulate realistic time-pressure decision thresholds for inspection teams.

3. Enhance capacity-building and regional engagement: Hosting the IFE in Jordan underscored the value of geographic inclusiveness and regional engagement in the Middle East. With Namibia as host, the CTBTO/PC has a valuable opportunity to deepen Africa-region capacity-building by involving local universities, mapping agencies, and host-nation logistics; run workshops before and after the field work; and create a legacy of human-resource capability in the region.

4. Intensify media coverage and public outreach: Past exercises have received limited media and public visibility despite their importance in demonstrating global commitment to nuclear test verification, risking weaker international understanding of the CTBT's verification regime. To increase transparency and public engagement, the CTBTO should develop a comprehensive communication strategy, including an online platform with regular updates, expert interviews, and short educational insights on verification technologies and procedures during IFE26. Social media should be leveraged strategically through curated posts, short video clips, interactive Q&A sessions, and behind-the-scenes features to reach a broader global audience in real time. As the first IFE to take place fully in the digital era, IFE26 offers a unique opportunity to showcase the CTBTO's verification capabilities and international cooperation through dynamic, inclusive, and multilingual communication. A coordinated media and social media strategy would enhance public understanding, reinforce transparency and trust, and transform IFE26 from a primarily technical exercise into a visible demonstration of collective commitment to a world free of nuclear testing.

One important aspect should be clarified at this point. During a real OSI, participants should be rather restrained when disseminating information about the progress of a given inspection, communicating with the media, and involving various research centers, because such "openness" may result in the leaking of confidential information, promote unsubstantiated accusations, complicate the progress of an inspection, and prevent the achievement of OSI objectives. By contrast, during an exercise such openness would be welcome, as it would help spread knowledge about the CTBT, the CTBTO, and their verification capabilities.

5. Include the new generation of young experts in the exercise: IFE26 presents a valuable opportunity for emerging professionals in the field of nuclear non-proliferation and disarmament to observe the CTBTO in action. This new generation of experts should encompass individuals from both scientific and policy-oriented backgrounds, ensuring a comprehensive understanding of the field. CTBTO could also consider involving four to six members of the CTBTO Youth Group (CYG) in the event in Namibia. Participation could be determined through an open and competitive selection process. The selected participants should reflect both disciplinary diversity and balanced geographical representation. In order to guarantee full coverage of their travel expenses, the CYG could collaborate with universities in order to get enough funds for this purpose. In addition, CYG members could play an active role in supporting the social media and outreach strategy of IFE26, helping to amplify its visibility and engage wider audiences globally.

6. Extend the invitation to IFE26 to those countries that have not signed the Treaty yet: This would allow such states to observe first-hand the technical capabilities and the utility of the verification regime. By including them in this exercise, the Organization could foster greater understanding, build broader confidence in the Treaty's objectives and mechanisms, and encourage further dialogue towards its entry into force. Invitation of experts from those

countries could, in turn, secure universal participation in upcoming exercises. Moreover, experts from such states could enrich the exercise with their knowledge, providing technical complexity. This invitation illustrates the importance of international cooperation in building up IFE's technical capabilities and supporting OSI's mission.

NOT JUST IMPROVEMENT, BUT REGULARITY

It can be argued that both the sophistication of IFEs and their regularity are important. The last exercise was held over 10 years ago; Sri Lanka, chosen as the host country for IFE26, withdrew from hosting the exercise, citing the new government's priority for domestic challenges, including on the economic front.[64] This underlines the limited capability of participating states in hosting an IFE, which does not contribute to a strengthened regime, but rather makes it increasingly fragile given the recent countries' statements on exploring the possibility of conducting a nuclear test. It is therefore important to organize build-up exercises on a regular basis, without extended interruptions, in order to preserve the expertise accumulated — including by inspectors — and to ensure that the format does not fall into disuse. In this regard, another important direction is to maintain the practice of conducting smaller exercises — the so-called tabletop and directed exercises — that the CTBTO organizes to progressively test, validate and demonstrate enhanced OSI capabilities.

Enhanced media coverage and public outreach could play a crucial role in promoting the CTBTO. Assuming the role of a host represents a complex undertaking that requires considerable governmental investment and commitment. Nevertheless, organizing such an event with increased media participation would provide a state with an opportunity to demonstrate its dedication to the objectives of non-proliferation and to strengthen its reputation in the international arena. Furthermore, increased interest in hosting an IFE would contribute to a more competitive selection process, thereby enabling future exercises to be conducted under a broader range of conditions — for instance, by simulating a scenario in which a nuclear explosion has taken place underwater somewhere in the world ocean, outside the jurisdiction and control of any state.

Another interesting option could envisage a double IFE at the test sites of the two leading nuclear powers — Russia and the United States (in Novaya Zemlya and Nevada, respectively). This would not only increase the attention of the media, the scientific community, and the public at large, but, with some luck, would also allow for the discussion "on site" and in a non-confrontational manner of certain additional CBMs with regard to super-low-yield explosions. Such a discussion, if successful, could lead to the earlier entry into force of the CTBT.

[64] "Sri Lanka withdraws from Nuclear Test Ban Treaty field event", EconomyNext, February 2025, <https://economynext.com/sri-lanka-withdraws-from-nuclear-test-ban-treaty-field-event/-/206209/, accessed 23 April 2026>.

Emerging Technologies and Nuclear Test Ban Verification: Opportunities, Risks, and Governance Preconditions

Hree Putri Samudra ■ Andrei Kupriianov ■ Adjoa Amponfi

ABSTRACT

This paper examines whether emerging technologies; machine learning algorithms, commercial satellite imagery, open-source intelligence (OSINT), and cloud-based analytics can supplement the Comprehensive Nuclear-Test-Ban Treaty Organization's (CTBTO) Preparatory Commission verification architecture. And also, without undermining its political legitimacy, legal integrity, or equitable access. Drawing on the capabilities and documented limitations of the International Monitoring System (IMS) and International Data Centre (IDC), the paper assesses the governance challenges that each technology category introduces: explainability deficits in neural network classifiers, private ownership and shutter control risks in satellite constellations, validation gaps in open-source analysis, and data sovereignty conflicts in cloud infrastructure. The analysis identifies three conditional pathways for integration; structured procurement agreements for equitable satellite access, sustained NDC-anchored regional technical hubs, and validated competency standards for algorithmic and OSINT contributors. It is also argued that, phased pilot programmes governed by transparent accountability structures must precede any broader deployment. The conclusion rests on the fact that technologies which cannot be governed to strengthen rather than complicate verification should remain external to formal processes. And that, maintaining this distinction is as political as much as it is a technical precondition for preserving state confidence in multilateral nuclear test ban verification.

INTRODUCTION

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) prohibits all nuclear explosions globally. Although the Treaty is not yet in force, the Vienna-based Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has spent three decades building a verification and compliance architecture: the International Monitoring System (IMS), with 90% of its planned 337 facilities across six continents now operational,[1] the International Data Centre (IDC) processing roughly 30 gigabytes daily, and On-Site Inspection (OSI) provisions unimplemented except through training exercises. The Commission faces persistent operational pressures: discriminating against nuclear test signals from natural seismic events and industrial activity, managing continuous data streams, reducing dissemination latency, and modernizing aging infrastructure in a rapidly evolving digital environment.

[1] CTBTO, "International Monitoring System Map", CTBTO, 2026, <https://www.ctbto.org/our-work/international-monitoring-system/, accessed 10 April 2026>.

Yet these operational challenges mask deeper verification questions that emerging technologies expose. Beyond efficiency gains, technological integration intersects with three fundamental governance issues. First, verification equity: will states without advanced national technical means be able to access and independently understand verification products, or will technological asymmetries leave them dependent on a small number of technologically advanced states to interpret monitoring data on their behalf? Second, institutional legitimacy: will the Preparatory Commission (and, later, the CTBTO) retain authority as external actors publish independent analyses that diverge from the Preparatory Commission's official monitoring products and event bulletins? Third, regime resilience: can verification adapt to rapid technological change without fragmenting into competing parallel systems reaching incompatible compliance conclusions? These questions admit no purely technical solutions.

Commercial satellite operators now provide metre-resolution optical and synthetic aperture radar imagery unimaginable when the Treaty was negotiated. Civil society organizations monitor Punggye-ri, Nevada, Novaya Zemlya, and Lop Nur, tracking tunnel excavation, equipment movements, and post-test subsidence. The Preparatory Commission itself has piloted False Event Identification and Bayesian multi-sensor fusion frameworks, reporting detection sensitivity improvements of up to 40% for lower-magnitude seismic events. Machine learning has challenged traditional human-centric workflows.

Yet integrating open-source intelligence (OSINT), machine learning algorithms, and cloud-based analytics raises a question beyond operational efficiency: can these technologies strengthen verification without undermining political legitimacy, legal integrity, and equitable access? Article IV, paragraph 11 invites states to examine "the verification potential of additional monitoring technologies," but this language is exploratory rather than prescriptive. Integration would require consensus on validation standards, governance mechanisms, and accountability structures (and protocols) that do not currently exist.

Each new technology introduces distinct risks. Machine learning operates as black boxes that diplomats and non-specialist states struggle to audit. Open-source intelligence depends on private corporations subject to selective access and politicization. Cloud computing raises unresolved data sovereignty questions: where would infrastructure be hosted, under whose jurisdiction, and who controls encryption keys?

This paper examines whether new/emerging technologies could supplement the Preparatory Commission's architecture while addressing three challenges: maintaining institutional authority and state confidence, reducing verification dependency for states lacking advanced technical means, and preventing new technological asymmetries. The analysis proceeds in three parts: current capabilities and documented limitations, a risk-benefit assessment of machine learning, satellite imagery, and cloud infrastructure, and exploratory pathways for phased integration subject to rigorous governance frameworks.

CURRENT VERIFICATION CAPABILITIES AND OPERATIONAL CONSTRAINTS

The Preparatory Commission's IDC receives approximately 30 gigabytes of information daily from 306 certified monitoring facilities scattered across six continents and both polar regions.[2] Automatic processing systems scan this incoming stream for coherent signals that might indicate seismic, hydroacoustic, infrasound, or radionuclide activity consistent with a nuclear test explosion.[3] Analysts then review flagged events manually, distinguishing genuine detections from background noise, natural phenomena, and system artifacts. This two-stage workflow has functioned continuously since 2000, but persistent technical challenges limit its speed, sensitivity, and certainty.

Signal discrimination remains difficult. Seismic records capture thousands of earthquakes annually alongside mining blasts, quarry operations, and tectonic activity that can mimic explosion signatures.[4] Regional propagation effects, station calibration variations, and complex source mechanisms produce ambiguous waveforms that defy automated classification. Infrasound stations detect not only atmospheric explosions but also bolide entries, volcanic eruptions, industrial activity, and wind noise that must be filtered out.[5] Radionuclide detection presents perhaps the steepest analytical obstacles. Atmospheric transport models depend on meteorological data with inherent uncertainties; sparse station coverage leaves large geographic gaps; and isotopic signatures from civilian nuclear facilities, medical isotope production, and legacy contamination complicate source attribution.[6]

Processing latency compounds these difficulties. Manual review delays can stretch to hours during high-activity periods, reducing the timeliness that states expect from a continuous monitoring system. The Preparatory Commission has acknowledged these constraints in official progress reports and is exploring algorithmic assistance, infrastructure upgrades, and expanded training for National Data Centres to address them.[7] Whether emerging technologies can resolve or exacerbate these limitations remains an open question requiring rigorous evaluation against both technical performance metrics and the political realities of multilateral verification.

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[2] M. Villagran Herrera, G. Graham, and Z. Mindaoudou Souley, “The CTBTO International Data Centre (IDC)”, Proceedings of the Institute of Nuclear Materials Management (INMM), April 2023, <https://resources.inmm.org/sites/default/files/2023-07/finalpaper_490_0428101733.pdf/, accessed 17 April 2026>.States that the IDC creates approximately 30 GB of information per day from IMS data processing; as of 2023, 306 IMS facilities were certified and transmitting data.

[3] Ibid., pp. 7-8. Describes the automatic processing systems (APS) pipeline including signal detection, event location, magnitude estimation, and initial classification across seismic, hydroacoustic, infrasound, and radionuclide technologies.

[4] T. Kvarnaerna and F. Ringdal, “Monitoring Nuclear Test Explosions”, Science for Security: The CTBTO’s Global Monitoring System, ed. CTBTO Preparatory Commission, CTBTO, Vienna, 2009, pp. 34-36, <https://www.ctbto.org/sites/default/files/2022-08/science_for_security.pdf/, accessed 8 April 2026>. Notes that discrimination capability degrades as magnitude decreases; regional high-frequency data essential for small-event classification but often ambiguous.

[5] Patrick Hupe et al., “International Monitoring System Infrasound Data Products for Atmospheric Studies and Civilian Applications”, Earth System Science Data 14, no. 9, 2022: 4201-4230, <https://essd.copernicus.org/articles/14/4201/2022/, accessed 13 April 2026>. Documents how wind noise, unwanted coherent signals, and environmental factors reduce detection capability and increase false alarm rates at IMS infrasound stations.

[6] Yuhan Xu et al., “Efficient Bayesian Source Reconstruction and Uncertainty Quantification for Radioactive Release with Sparse Monitoring Network”, Journal of Hazardous Materials 482, 2025: 136018, <https://www.sciencedirect.com/science/article/abs/pii/S0304389425010866/, accessed 10 April 2026>. States that sparse spatiotemporal coverage of radioactive monitoring networks produces multimodal a posteriori distributions and unrealistic source parameters in Bayesian reconstruction.

[7] “Annual Report 2024”, CTBTO, pp. 12-15, <https://www.ctbto.org/sites/default/files/2025-08/AR2024_OV.pdf/, accessed 13 April 2026>. Describes ongoing IDC progressive commissioning Phase 5b experiments, machine learning pilot projects (FEI, VISA), and capacity-building initiatives for National Data Centres.

EMERGING TECHNOLOGIES: CAN THEY STRENGTHEN OR COMPLICATE VERIFICATION?

Machine Learning Algorithms and the Explainability Crisis

The International Data Centre has experimented with machine learning since 2011, when the False Events Identification (FEI) project entered operational testing to assist analysts in separating genuine seismic detections from system artifacts.[8] The project emerged from operational necessity: automatic processing algorithms flagged thousands of events daily, many of them spurious signals generated by electronic noise, calibration pulses, or propagation anomalies rather than real seismic activity.[9] More recently, the Vertically Integrated Seismic Association (VISA) suite applies Bayesian methods to fuse data from multiple sensor networks, with pilot evaluations suggesting detection threshold improvements of up to 40% for low-magnitude events compared to legacy association algorithms.[10] Outside Vienna, academic seismologists have trained convolutional neural networks (CNNs) and support vector machines (SVMs) on waveform features, achieving discrimination accuracies above 98% when separating explosions from earthquakes under controlled laboratory conditions using curated test datasets.[11]

These results raise the question of whether algorithmic screening could relieve analysts of routine classification burdens, accelerate processing timelines, and extend detection sensitivity into lower yield ranges where manual interpretation struggles. Yet they also expose fundamental governance dilemmas. Deep neural networks function as black boxes: they produce classifications without exposing the decision logic that generated them.[12] Nuclear regulators typically demand transparent, auditable methodologies before certifying safety-critical systems, but explainable AI (XAI) techniques remain unreliable and can generate conflicting explanations for identical predictions. Diplomatic contexts compound the problem. If an algorithm flags an ambiguous seismic event as a possible nuclear test, which state representative can defend that assessment to a skeptical counterpart when the classification rests on 10 million learned weights distributed across hidden network layers that no human can meaningfully interpret?

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[8] G. Letivan and Z. Kasima, "Machine Learning at the CTBTO: Testing and Evaluation of the False Events Identification (FEI) and Vertically Integrated Seismic Association (VISA) Projects", presented at the CTBT Science and Technology Conference (SnT2024), Vienna, Austria, P5.1-027, June 2024, <https://conferences.ctbto.org/event/30/contributions/6103/, accessed 19 April 2026>. Slide 6: FEI project launched 2011 to assist IDC analysts in distinguishing real seismic events from processing artifacts and electronic noise.

[9] Ibid., slides 7-9. Describes operational context: automatic processing generates thousands of daily event detections, many spurious; FEI designed to reduce manual review burden by pre-screening low-confidence detections.

[10] Ibid., slide 18. Reports that VISA Bayesian multi-sensor association algorithms achieved 40% improvement in detection capability for low-magnitude events (mb 3.5-4.0 range) compared to traditional single-technology event association methods in pilot evaluations on historical IMS data.

[11] Louisa Barama et al., "Global and Regional Explosion Discrimination: Improving Classification with Machine Learning," CTBT Science and Technology Conference (SnT2025), <https://conferences.ctbto.org/event/30/contributions/5611/attachments/2973/5748/SnT2025_Barama.pdf/, accessed 15 April 2026>. Tables 2-3: convolutional neural networks (CNNs) and support vector machines (SVMs) trained on regional seismic datasets achieved discrimination accuracies exceeding 98% under controlled test conditions using curated waveform databases with verified ground truth.

[12] IBM Research, "What is Explainable AI (XAI)?", IBM Technology Topics, <https://www.ibm.com/think/topics/explainable-ai/, accessed 30 April 2026>. Explains that deep neural networks typically function as black boxes: internal decision processes involve millions of learned parameters across hidden layers, making it difficult to trace why specific input features produced specific output classifications.

Training data access presents another barrier. High-performing models require thousands of labeled examples spanning the full range of source types, propagation paths, and noise conditions, yet institutional and technical restrictions limit the availability of historical waveform archives for independent algorithm development and benchmarking.[13] This creates asymmetries: states with advanced research programs and access to proprietary datasets can develop and validate discriminators, while others cannot independently audit the systems they are asked to trust. Adversarial vulnerabilities add further risk. Carefully crafted inputs can fool neural classifiers, and supply chain compromise could introduce backdoors into training pipelines or deployment environments.[14] These concerns are not speculative. A 2025 study found that minor perturbations to seismic waveforms, imperceptible to human analysts, caused state-of-the-art CNN discriminators to misclassify explosions as earthquakes with high confidence in 73% of adversarial test cases.[15]

The core question is whether states will accept verification classifications generated by systems they cannot independently audit, and whether machine learning can strengthen verification without undermining the political legitimacy that multilateral monitoring requires. Many National Data Centres lack the technical capacity to validate algorithmic outputs, creating dependencies on a small number of advanced states with specialized expertise. Without consensus on transparency standards, validation protocols, and human oversight structures capable of sustained technical judgment, algorithm-assisted verification risks reproducing rather than resolving the technological inequities that Article IV, paragraph 11 was intended to address. Such oversight cannot rest on under-resourced staff performing pro forma reviews; it demands genuine expertise and institutional commitment. Absent safeguards against data manipulation, algorithm bias, and unauthorized modification, integration becomes untenable.

Satellite Imagery, Open-Source Intelligence, and the Validation Problem

Commercial satellite constellations have produced a global imagery market. Optical sensors now deliver sub-meter resolution imagery of any terrestrial location, weather permitting, within hours of tasking.[16] Synthetic aperture radar (SAR) operates through clouds and at

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[13] CTBTO Preparatory Commission, "Scientific Advances in CTBT Monitoring and Verification", CTBTO, Vienna, 2013, ch. 3, pp. 45-48, <https://www.ctbto.org/sites/default/files/2022-08/ctbto_st11_web_complete.pdf/, accessed 30 April 2026>. Notes that access to historical IMS waveform archives is constrained by technical factors (data volume, format compatibility) and institutional factors (data-sharing agreements, proprietary restrictions), limiting ability of independent researchers and National Data Centres to train and validate algorithms across a full range of operating conditions.

[14] Ian Goodfellow et al., "Explaining and Harnessing Adversarial Examples", 2014; discussed in OECD Nuclear Energy Agency Task Force on Artificial Intelligence and Machine Learning for Scientific Computing in Nuclear Engineering, "AI/ML in Nuclear Safety and Safeguards", Technical Report NEA/NSC/R(2023)10, November 2023, <https://www.oecd-nea.org/jcms/pl_77779/, accessed 20 April 2026>. Demonstrates that small, carefully crafted perturbations (often imperceptible to humans) can cause neural networks to misclassify inputs with high confidence; discusses implications for adversarial attacks on safety-critical ML systems.

[15] Ibid. Notes that the adversarial vulnerability documented in the literature extends to seismic waveform classifiers, with perturbation-based attacks capable of producing high-confidence misclassifications in controlled experimental conditions.

[16] Maxar Technologies, "WorldView Constellation Technical Specifications", <https://www.maxar.com/products/worldview-3/, accessed 4 April 2026>. Describes sub-meter optical imaging; Planet Labs, "PlanetScope Imagery: 3-Metre Resolution Global Daily Coverage", <https://www.planet.com/products/planetscope/, accessed 13 April 2026>.

night, while interferometric techniques detect millimeter-scale surface deformation from tunnel collapses or subsidence craters. Civil society organizations have applied these tools to monitor declared nuclear test sites, documenting construction activity, equipment movements, and post-event landscape changes.

The Treaty prohibits nuclear test explosions, not nuclear weapons development more broadly.[17] Relevant monitoring targets are tunnel excavation and portal construction, heavy equipment deployment, post-event surface subsidence and cratering, and radionuclide venting or seepage points.[18] Relevant sites include Punggye-ri in the DPRK, the Nevada National Security Site in the U.S., Novaya Zemlya in Russia, and Lop Nur in China. Notable exclusions, such as missile deployments, warhead storage facilities, and enrichment or reprocessing plants, fall outside the CTBT scope and risk mission creep if included.[19] If the Preparatory Commission were to integrate commercial satellite monitoring, clarity about what constitutes Treaty-relevant information would be essential to maintain states' confidence that verification remains bounded by the Treaty text.

Open-access platforms like Copernicus provide 10-meter multispectral imagery with five-day revisit cycles at no cost, lowering barriers for states that lack classified reconnaissance assets.[20] Yet open-source intelligence presents a paradox for multilateral verification. The promise of transparency (publicly accessible data, independent analysis, reduced dependency on classified national technical means) comes with more risks than benefits when institutional validation mechanisms do not exist. Most high-resolution satellites belong to private firms subject to national licensing regimes that can restrict image sales during crises, a practice known as shutter control.[21] If the Preparatory Commission relies on imagery from vendors headquartered in nuclear-armed states, how can non-nuclear-weapon states trust that their access will not be selectively curtailed when political tensions escalate?

Second, validation mechanisms do not exist for open-source analysis. Who verifies OSINT when OSINT itself requires verification? States accept verification because obligations are reciprocal and institutionally mediated. Open-source outputs lack institutional standing. Adversaries can fabricate imagery, manipulate metadata, or exploit constellation gaps to conduct activities unobserved. Without authentication procedures and evidentiary standards, OSINT outputs risk politicization: contested analyses fuel disputes, and states

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[17] "Comprehensive Nuclear-Test-Ban Treaty", Article I. Treaty prohibits "any nuclear weapon test explosion or any other nuclear explosion."

[18] VERTIC, "Strengthening Nuclear Test Ban Monitoring and Verification: The Role of Commercial Satellite Imagery", 16 July 2024, pp. 15-20, <https://www.vertic.org/wp-content/uploads/2024/07/VM32-Strengthening-Nuclear-Test-Ban-Monitoring-The-Role-of-Satellite-Imagery.pdf/, accessed 5 April 2026>.

[19] Ibid., p. 12. Distinguishes treaty-relevant from treaty-irrelevant satellite observations.

[20] European Commission, "Copernicus Satellite Data Access", 22 September 2024, <https://www.copernicus.eu/en/accessing-data-where-and-how/copernicus-services-catalogue/, accessed 8 April 2026>. Sentinel-2 constellation: 10m resolution, 5-day revisit cycle, worldwide open access.

[21] James A. Vedda, "Updating National Policy on Commercial Remote Sensing", Center for Space Policy and Strategy, The Aerospace Corporation, July 2017, p. 4, <https://csps.aerospace.org/sites/default/files/2021-07/CommercialRemoteSensing_0.pdf/, accessed 11 April 2026>.

may weaponize claims to advance strategic narratives rather than clarify adherence.[22] Third, attribution remains ambiguous. Satellite signatures rarely distinguish nuclear test preparations from routine military engineering or mining operations. Analysts require subject matter expertise, historical site baselines, and fusion with seismic or radionuclide data to draw defensible conclusions.[23] Absent agreed analytical standards, divergent OSINT assessments can create perceived discrepancies with official Preparatory Commission products, weakening institutional authority. The question is not whether satellite imagery has technical utility. The question is whether commercially controlled, institutionally unvalidated information can be integrated into multilateral verification in ways that enhance rather than complicate trust.

Cloud Computing and Big Data Analytics

Cloud infrastructures now offer elastic, on-demand computing and storage that can scale with workload, supported by distributed processing frameworks such as Apache Spark and containerized deployments orchestrated with tools like Kubernetes.[24] For an operation like the IDC, which ingests several gigabytes of IMS data per day from more than 300 monitoring facilities and distributes processed products worldwide, these architectures are directly relevant.[25] Other nuclear and regulatory bodies, including the IAEA and EU institutions, have begun piloting secure cloud environments for sensitive analytical workflows, indicating that cloud platforms can host high-stakes applications when coupled with appropriate controls.[26] Moving selected IDC functions to secure cloud or hybrid environments would allow CTBT PC to absorb data surges during crises, expand archive capacity beyond current multi-petabyte scales and sustain higher processing throughputs without the same capital intensity as continual on-premises upgrades.

Regional processing nodes and limited edge computing near key IMS stations could reduce transmission latency and compress multi-hour notification timelines toward near-real-time alerts, materially strengthening the perceived responsiveness of the verification regime.[27] Cloud-based predictive-maintenance pipelines and built-in disaster-recovery features would improve network resilience, while shared dashboards and standardized analytics

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[22] Sara Al-Sayed and Toby Dalton, "Revisiting Societal Verification for Nuclear Non-Proliferation and Disarmament", Journal for Peace and Nuclear Disarmament 5, supp. 2, 2022: 410, <https://www.tandfonline.com/doi/full/10.1080/25751654.2022.2133336/, accessed 15 April 2026>.

[23] Frank Pabian, "Commercial Satellite Imagery: Another Spin Around the Cycle", IAEA Safeguards Symposium, Vienna, October 2014, cited in UNIDIR, "Arms Control Verification: Practices and Challenges," Disarmament Forum no. 4, 2023, pp. 34-36, <https://unidir.org/wp-content/uploads/2023/09/arms-control-verification-en-320.pdf/, accessed 19 April 2026>.

[24] CTBTO Preparatory Commission, "Advances in Computing, Processing and Visualization for Verification Applications", Scientific Advances in CTBT Monitoring and Verification, CTBTO, Vienna, 2013, pp. 82-90, <https://www.ctbto.org/sites/default/files/2022-08/4._advances_in_computing_processing_and_visualization_for_verification_applications.pdf/, accessed 30 April 2026>.

[25] "International Data Centre", CTBTO, 31 August 2022, <https://www.ctbto.org/our-work/international-data-centre/, accessed 29 April 2026>.

[26] Council of the European Union, "Council Decision (CFSP) 2020/901 of 29 June 2020 in support of activities of the Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)", Service for Foreign Policy Instruments, 2020, <https://fpi.ec.europa.eu/document/download/74efd28b-2b86-475f-8ae9-6abe41b56083_en/, accessed 17 April 2026>.

[27] "M. Villagran Herrera, G. Graham, and Z. Mindaoudou Souley, "The CTBTO International Data Centre (IDC)". Outlines IDC architecture, IMS data intake and processing requirements, and the challenges of maintaining timely analysis across hundreds of stations.

environments could enable National Data Centres and other authorized users to access authenticated products simultaneously, narrowing information gaps between states with and without advanced technical infrastructures.[28] Advanced cloud computing integration for verification data raises predictable questions about data sovereignty, legal compliance and security. Many states restrict cross-border storage of sensitive information, and alignment with national cybersecurity laws and regimes such as the GDPR will likely require regionally distributed deployments and carefully designed data-residency controls.[29] At the same time, shifting core processing to shared infrastructure expands the attack surface and can generate significant bandwidth and egress costs if large-scale post-processing is not kept largely in-cloud, making clear service-level agreements, multi-layered security architectures, and vendor-neutral cloud designs essential.[30] Without such safeguards, cloud-based analytics risk reinforcing perceptions that advanced processing capacity remains concentrated in a few technologically dominant states at the expense of a more inclusive and geographically balanced CTBT data-sharing and analysis system.

PATHWAYS FORWARD: CONDITIONAL, CAUTIOUS, AND CONTINGENT

The analysis above suggests that emerging technologies present verification dilemmas as much as they offer verification opportunities. Machine learning cannot be integrated if states cannot audit them. Commercial satellite imagery cannot supplement verification if ownership concentrates in private hands. Cloud infrastructure cannot enhance accessibility if jurisdictional conflicts exist. Open-source intelligence cannot strengthen institutional authority without validation mechanisms. The question is not whether to deploy, but whether they can be governed to address asymmetries.

Three directions emerge. First, the Preparatory Commission could negotiate structured procurement agreements with commercial satellite providers to ensure National Data Centres in non-nuclear-weapon and Global South states receive equitable access to declared test site imagery.[31] This shifts satellite monitoring from external pressure toward institutionally mediated resources. Copernicus and UNOSAT offer precedent.[32] The challenge is preventing such arrangements from replicating dependencies on providers in technologically dominant states, where shutter control could curtail access during crises.

Second, capacity-building must move beyond episodic training toward sustained regional technical hubs. NDCs4All has delivered support to least developed and small island developing states.[33] Yet these remain one-off interventions. Designating NDC-anchored

[28] "Annual Report 2024", CTBTO.

[29] Council of the European Union, "Council Decision (CFSP) 2020/901".

[30] CTBTO Preparatory Commission, "Advances in Computing, Processing and Visualization for Verification Applications", pp. 82-90.

[31] CTBTO Preparatory Commission, Annual Report 2024 (Vienna: CTBTO, 2024), pp. 45-48.

[32] European Space Agency, "Copernicus: Europe's Eyes on Earth", ESA Earth Observation Portal, <https://www.esa.int/Applications/Observing_the_Earth/Copernicus/, accessed 18 April 2026>; UN Operational Satellite Applications Programme (UNOSAT), "About UNOSAT," <https://unosat.org/about/, accessed 5 April 2026>. Documents procurement and access arrangements with commercial satellite providers for humanitarian response and peacekeeping missions.

[33] "Strengthening National Data Centre Capacity: The NDCs4All Initiative", CTBTO, <https://www.ctbto.org/NDCs4All/, accessed 13 April 2026>.

regional hubs in Lima, Ulaanbaatar, Tunis, and Djibouti, co-located with or formally linked to national universities and research institutions, and connecting them to IDC workflows for algorithm validation and satellite interpretation, would build enduring capacity. Such hubs receive training data and satellite products, conduct independent assessments using local expertise, and feed results back into verification products in ways that enhance rather than fragment institutional authority.

Third, clear competency standards and validation procedures must precede integration of open-source intelligence and machine learning outputs. The On-Site Inspection provisions offer structural precedent: defined qualifications, agreed protocols, institutional oversight balancing investigative thoroughness with state sovereignty.[34] A comparable framework for OSINT and algorithmic contributors would specify training requirements (demonstrated expertise in satellite interpretation, seismic discrimination, atmospheric transport modeling), validation procedures (independent peer review, cross-comparison with classified national technical means, methodological transparency), and accountability structures (institutional affiliation, conflict-of-interest disclosures, remedies for inaccuracy). Civil society and academic outputs remain unverified verification without such structures: useful context, but inadmissible as formal evidence.

Operationally, these directions must be phased through tightly scoped pilots rather than wholesale adoption. A machine learning pilot would evaluate FEI and VISA algorithms against manually reviewed IDC products, with independent audits and transparency about training datasets and performance metrics across regions and magnitude ranges. A parallel satellite imagery demonstration would task commercial providers to deliver regular coverage of one or two agreed test sites, with National Data Centres conducting independent interpretations and comparing findings with official assessments.[35] Both pilots operate under governance rules established upfront: data-handling protocols, security requirements, and communication standards specifying when pilot findings may be referenced in official products.

Budget pressures create incentives to pursue quick wins through early AI adoption, but verification integrity cannot be sacrificed to cost-effectiveness imperatives. Premature integration undermines the institutional credibility that decades of careful technical work have built. Lessons from pilots would inform whether broader deployment is advisable. Safeguards must address data manipulation, algorithm bias, supplier lock-in, unauthorized access, and politicization.[36] These are not just technical details, but also political preconditions for maintaining state confidence in multilateral verification.

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[34] Comprehensive Nuclear-Test-Ban Treaty, Article IV, paragraphs 60-73. Establishes On-Site Inspection procedures including inspector designation, qualifications, training protocols, and institutional oversight mechanisms balancing verification objectives with state sovereignty protections.

[35] G. Letivan and Z. Kasima, "Machine Learning at the CTBTO: Testing and Evaluation of the False Events Identification (FEI) and Vertically Integrated Seismic Association (VISA) Projects". Slide 6: FEI project launched 2011 to assist IDC analysts in distinguishing real seismic events from processing artifacts and electronic noise.

[36] Ian Goodfellow et al., "Explaining and Harnessing Adversarial Examples"; OECD Nuclear Energy Agency Task Force on Artificial Intelligence and Machine Learning for Scientific Computing in Nuclear Engineering, "AI/ML in Nuclear Safety and Safeguards", Technical Report NEA/NSC/R(2023)10, November 2023, <https://www.oecd-nea.org/jcms/pl_77779/, accessed 24 April 2026>.

External actors will develop and deploy these technologies regardless of Preparatory Commission decisions. Civil society will publish satellite analyses. Academic researchers will train algorithms. The question is whether the Preparatory Commission shapes how these technologies intersect with verification, or cedes that role to actors outside the Treaty structures and institutional accountability. Article IV, paragraph 11 provides legal space to explore integration pathways, but exploration is not endorsement. Technologies that cannot be governed to strengthen rather than complicate verification should remain external to formal processes, useful as context but inadmissible as authoritative evidence. The Treaty's integrity depends on maintaining that distinction.

Final observation: in order to fully understand the potential impact, additional opportunities and obvious and hidden risks associated with new technologies in a complex verification process, researchers, analysts and politicians should not limit their work to a single area of verification – in this case, verification of the nuclear test ban. It would be useful to be aware of – and to understand – relevant problems arising in other fields of arms control and disarmament. Some of these problems would differ, but there will likely be a degree of commonality in concerns and approaches. For example, U.S. President Trump's September 2025 statement to the United Nations General Assembly contained the following remarkable paragraph: "I'm announcing today that my administration will lead an international effort to enforce biological weapons convention, which is going to be meeting with the top leaders of the world by pioneering an AI verification system that everyone can trust. Hopefully the UN can play a constructive role and it will also go, be one of the early projects under AI. Let's see how good it is because a lot of people saying it could be one of the great things ever, but it also can be dangerous, but it could be put to tremendous use and tremendous good, and this would be an example of that…"[37] President Trump specifically stated that the proposed AI verification system (for the Biological Weapons Convention) should be one that "everyone can trust." Clearly, this requirement applies no less to an AI-based CTBT verification system, should such a system be developed.

[37] "US President Donald Trump address to the United Nations General Assembly", 23 September 2025, <https://www.astrid-online.it/static/upload/trum/0001/trump-un-23-9-25.pdf/, accessed 30 April 2026>.

Expectations, Prospects and Challenges for the 2026 NPT Review Conference: Can Discussion on the CTBT Make a Positive Difference?[1]

■ Vhaire Gudgeon ■ Nigel Li ■ Oladokun Ojewole ■ Wenhui Shi

ABSTRACT

Madness is often defined as doing the same thing again and again, each time expecting a different result. Neither of the past two Review Conferences of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) saw the adoption of a final document, due to rising geopolitical rifts, precluding consensus in 2015 and 2020. A sanguine outlook for the 2026 Review Conference (RevCon) appears increasingly elusive. Against this background, the authors decided to pose the question of whether, in the time remaining before the NPT Review Conference, one can expect positive results in at least some of the key relevant areas on the RevCon agenda, so as to use these results as building blocks for the success of the Conference. The fate of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) is, beyond any doubt, a highly relevant issue for the NPT. The CTBT was opened for signature in 1996, and even without its formal entry into force (so far) is viewed as a relative success: the number of explosive nuclear tests worldwide having been dramatically reduced. The CTBT therefore presents a powerful normative commitment against nuclear testing, rendering the subject largely taboo. The article further examines what can be done in order to turn the issue of nuclear testing into one of the success factors for the RevCon.

THE CTBT-NPT NEXUS

The creation of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) has historically been intertwined with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), although efforts to achieve the former had been launched almost a decade earlier. It was the NPT, however, that reiterated the determination to seek “the discontinuance of all test explosions of nuclear weapons for all time.”[2] The CTBT can also be viewed as a direct outcome of NPT Article VI, according to which all parties undertake to “pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament...”[3] For many non-nuclear-weapon states (NNWS), the CTBT represents a vital step toward fulfilling this commitment, serving as an effective measure for disarmament and for preventing the qualitative sophistication of nuclear arsenals.

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[1] The paper was finalized by its co-authors in February 2026, prior to the 2026 NPT Review Conference.

[2] IAEA, “Treaty on the Non-Proliferation of Nuclear Weapons”, INFCIRC/140 - Treaty on the Non-Proliferation of Nuclear Weapons, 22 April 1970, <https://www.iaea.org/sites/default/files/publications/documents/infcircs/1970/infcirc140.pdf/, accessed 10 January 2026>.

[3] Ibid.

The CTBT-NPT nexus was further reinforced in 1995, when the indefinite extension of the NPT was linked to and based upon the expectation that CTBT negotiations would soon be completed.[4]

Functionally, while the NPT provides the goals and framework, the CTBT serves as a key operational measure to achieve them, offering robust support for the NPT's two main pillars: namely, nuclear non-proliferation and nuclear disarmament. With regard to nuclear disarmament, the CTBT largely freezes the qualitative technological race in nuclear weapon design among nuclear-weapon states (NWS), effectively locking in their nuclear arsenals at their existing level. In turn, this creates a more predictable and stable technical foundation for future arms control negotiations. As for nuclear non-proliferation, the ban on explosive nuclear testing significantly raises the threshold for NNWS seeking to develop nuclear weapons, robustly curbing their proliferation. Furthermore, a strengthened non-proliferation regime enhances international confidence in the peaceful nuclear applications, representing the CTBT's indirect support for the third pillar of the NPT – peaceful uses of nuclear energy.

WHAT NEEDS TO BE DONE AT THE 2026 NPT REVCON?

The alarming combination of current geopolitical crises and rising nuclear risks places an immense burden on the upcoming 2026 NPT RevCon. The world faces real and increasing dilemmas that have characterized the international nuclear landscape: inherent divergences in strategic interests among nuclear-armed states, lagging efficacy of existing coordination mechanisms, persistent erosion of trust in the nuclear domain, and a resurgent emphasis on nuclear deterrence and modernization, all of which breeds confrontation and makes differences harder to resolve. Whilst the deliberations at RevCon 2026 will inevitably address these issues, any draft document that suggests a favouring of one position, applies unilateral pressure, or disregards the balance of core interests among NWS and NNWS is likely to be doomed to failure long before a final vote. Proceedings of the third PrepCom of the current NPT review cycle in April - May 2025 failed to agree on which recommendations to present at RevCon 2026, a telling sign of what to expect. Concerned voices argue that a third failure of the NPT RevCon process to produce a consensus final document "could further erode the NPT and nonproliferation efforts in general".[5] However, it may be vital not to over-conflate the potential failure of states with polarised and diverse strategic interests to reach consensus with the death of the NPT and vital non-proliferation architecture more broadly. Rather than getting lost in intractable strategic problems, practical opportunities can be found in focusing on areas of existing and potential consensus between NWS and NNWs.

In the current turbulent global landscape, a comprehensive test ban is an objective that all States Parties - NWS and NNWS - can fundamentally agree on in principle. Although the CTBT has not formally entered into force due to a lack of ratification by specific 'Annex

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[4] Daryl G. Kimball and Randy Rydell, "The NPT in 1995: The Terms for Indefinite Extension", Arms Control Association, May 2020, <https://www.armscontrol.org/act/2020-05/features/npt-1995-terms-indefinite-extension/, accessed 10 February 2026>.

[5] William Potter and Sarah Bidgood, "Waiting for Godot at the 2026 NPT Review Conference", Arms Control Association, September 2025, <https://www.armscontrol.org/act/2025-09/features/waiting-godot-2026-npt-review-conference/, accessed 10 February 2026>.

2 States', it has largely been credited with the global absence of nuclear testing in the 21st century, with the exception of a single state. Furthermore, the robust verifications regime under the CTBT is of benefit to NNWSs and NWSs alike, fostering, even today, confidence in future compliance with the CTBT. The International Monitoring System (IMS) is a major technical achievement itself: although not yet fully complete, it is operational, with 90% of its planned 337 facilities already running.[6] For NNWS, the CTBT reduces the risk of the diffusion of nuclear threats, and a strengthened international nuclear governance framework helps remove obstacles to the peaceful uses of nuclear energy by states, in line with their development needs. As for NWS, the CTBT reinforces strategic stability by preventing qualitative upgrades of nuclear weapons and new breakout nuclear states from upsetting the strategic balance. This aligns with the strategic interests of NWS - avoiding the costly dynamics of arms racing while sustaining strategic stability through predictability and risk reduction measures. Furthermore, with a growing number of states interested in pursuing nuclear energy production, greater emphasis should be placed on the importance of international apolitical monitoring and verification structures, including the IAEA's distinct role in safeguarding nuclear materials and ensuring compliance with relevant provisions of the NPT.

At a time when the NPT finds itself at the crossroads, the 'quasi-in-force' CTBT can serve, at least temporarily, as an important instrument for advancing the nuclear disarmament process, reinforcing non-proliferation practices, and reducing nuclear risks. The broader endeavour to achieve a world free of nuclear weapons can be seen as an uphill battle: the NPT provides the roadmap - progress has been made, yet the path ahead remains long - while the CTBT marks a possible renewed starting point for this journey, with a world without nuclear weapons as the shared summit. Discussions centred around the CTBT, which holds potential for broad support, could create a theoretical 'safe space' for maintaining and rebuilding trust among nations, and serve as a reminder that success in reducing nuclear risks is possible. Crucially, the CTBT also offers the international community a practical focus for advancing the NPT agenda, urging all countries to take concrete actions with established support and momentum to uphold international nuclear disarmament and non-proliferation architectures and maintain global strategic balance and stability.

MANAGING EXPECTATIONS AND CHALLENGES AHEAD

As important pillars of nuclear security architecture are (for one or another reason) expiring, including the termination of the Joint Comprehensive Plan of Action (JCPOA) in October 2025 and the expiration of New START in February 2026, nuclear risks are increasing globally. A sense of profound pessimism towards the upcoming NPT RevCon is brewing, bolstered by fears that specific states may decide to defect from the NPT altogether, by skyrocketing investments into nuclear modernization programs and prospects of rapid vertical proliferation, including new types of nuclear warheads, and most significantly, renewed danger of nuclear testing. In this global landscape that has been referred to as

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[6] CTBTO, "International Monitoring System Map," CTBTO, 2026, <https://www.ctbto.org/our-work/ims-map/, accessed 10 February 2026>.

'the end of arms control',[7] the strength and breadth of support that most states currently afford the CTBT is nothing short of an oasis in the desert. At the 2015 NPT RevCon, despite its absence of a consensus outcome document, support for the CTBT was voiced over 100 times from a wide and highly diverse range of States Parties.[8]

We should be honest and realistic: success on a single issue alone, regardless of its importance, will not be sufficient to redress the gloomy situation or to save the next NPT Review Conference from failure. Nevertheless, it may help to make a difference and to arrive at a shorter, sober, yet still positive and consensual concluding document. Such an outcome would not come about on its own; it would require concrete action by participating states. To this end we have developed the following policy recommendations.

POLICY RECOMMENDATIONS:

1. Call for P5 to sign a joint declaration against explosive nuclear testing during RevCon 2026
A joint declaration between the P5 states reaffirming the harms of nuclear weapons testing would be a positive outcome, as it would set the tone for cooperation and prove a confidence building measure for wavering NPT state parties. Such a joint declaration would be an opportunity for the P5 to clarify their current policy positions towards explosive nuclear testing whilst reducing geopolitical tensions. Such an outcome would reinforce the goals of the CTBT, advancing not only its symbolic but practical role in the international non-proliferation regime. The shared benefits of an absence of nuclear weapons testing should be re-emphasised, from humanitarian, environmental or even hard security perspectives that render the CTBT overwhelmingly within the interests of NPT states.

2. Set Pragmatic Objectives
The primary focus of subsequent efforts should acknowledge current political realities that may preclude the imminent entry into force of the CTBT. It is important not to hold the CTBT's imminent entry into force as the key metric of success, but focus on further entrenching the Treaty's established normative effect, its broad support, and the robustness of its well-developed international verification regime. Specifically, the Final Document of the Review Conference could employ strong language to explicitly reaffirm the prohibition of all types of nuclear explosive testing and condemn any potential nuclear tests as inconsistent with the legal obligations of all states that have signed or ratified the CTBT.

3. Adopt Flexible Diplomatic Approaches
A flexible and constructive diplomatic path should be pursued. On the one hand, all states, particularly Annex 2 States, should be actively encouraged to reaffirm or commit to a 'voluntary moratorium on nuclear testing', whether through political declarations or even legally binding forms.

7 European Leadership Network, "Tried and tested: why the CTBT must be preserved", December 2025, <https://europeanleadershipnetwork.org/policy-brief/tried-and-tested-why-the-ctbt-must-be-preserved/, accessed 10 February 2026>.

8 "NPT Review Conference: Support for the CTBT voiced over 100 times", CTBTO, 6 May 2015, <https://www.ctbto.org/news-and-events/news/npt-review-conference-support-ctbt-voiced-over-100-times/, accessed 10 February 2026>.

CONCLUSION

Without yet being in force, the CTBT has been credited with the near eradication of explosive nuclear testing in the 21st century, and fostering a taboo on nuclear tests. The CTBT therefore offers a rare opportunity for a moment of consensus at the 2026 NPT RevCon, but it cannot independently mend deep political divisions between NPT States Parties that have precluded a successful outcome document at the 2015 and 2020 RevCons. The CTBT could offer a constructive focal point for the NPT RevCon, prompting focus on areas of consensus towards reducing nuclear risks rather than on points of conflict, highlighting how states with diverse perspectives and priorities have together fostered a longstanding norm against nuclear testing, and reminding States Parties to the NPT of past successes of global cooperative security architectures, the tangible benefits of that success, towards renewed motivation for the future.

The CTBT in Focus: Enhancing Visibility in a Time of Geopolitical Turbulence

■ Masaki Ito ■ Vanda Proskova ■ Facundo Saponara

ABSTRACT

Since its inception in 1996, the Comprehensive Nuclear-Test Ban Treaty (CTBT) has remained a crucial instrument for curbing nuclear testing worldwide. Yet, regardless of its critical role within the international security architecture, public awareness and interest in nuclear testing and the CTBT remain limited and sporadic when compared to other global platforms and challenges (the NPT, the SDGs, or other frameworks). Given the detected gap between the technical relevance of the Treaty and its public outreach, this paper analyzes potential approaches to enhance the visibility of the CTBT, focusing primarily on communication channels and educational policies. Disseminating the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization's role and achievements through storytelling, through content that is social media-friendly, shall be a quintessential aspect of the proposed communicational strategy. Similarly, expanding the CTBTO's educational content and strengthening fellowship programs are viable approaches to increase the Treaty's exposure. Lastly, highlighting the interconnectivity between the CTBT and other international frameworks, such as the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) Review Conference, is also a significant pillar of the strategy hereby presented.

INTRODUCTION

The Comprehensive Nuclear-Test Ban Treaty (CTBT) is an essential component of the international security architecture and has proven instrumental in tapering vertical and horizontal proliferation efforts. Yet, the Treaty's rich technical nature has limited the public's access to its goals of backing international counter-proliferation measures by monitoring, detecting, and identifying nuclear tests through its integrative International Monitoring System (IMS).

The erosion of the international security environment has placed nuclear arsenals, once again, as the centerpiece of the strategic calculus of nuclear and non-nuclear weapon states (NWS and NNWS, respectively), further reducing the margin for the CTBTO to enable international monitoring and nuclear testing detection. Whether it be by advocating or actively taking steps to facilitate the qualitative and quantitative upscaling of preexisting nuclear arsenals or the materialization of dual-use programs of current threshold states, the looming threat of nuclear testing resumption is becoming ever more prevalent. In this context, it is imperative to enhance communication strategies to meet the challenge, foster an international conscience, and generate an upstream demand focusing on systematic-level assurances to prevent further nuclear testing.

To achieve such a goal, this paper will analyze the communicational challenge faced by the CTBT by addressing its current visibility deficit and technical communication gap. Specifically, this analysis will proceed in four parts: first, examining the current communication landscape of the CTBT and the limitations of its traditional outreach; second, proposing a strategic communications shift to make the Treaty more visible through accessible narratives of success stories of the IMS; third, outlining an approach for educational innovation to cultivate a new generation of CTBT advocates, and; finally, outlying a clear roadmap to address visibility and viability challenges of fostering international communication efforts against nuclear testing and build enduring public and political support.

THE CTBT IN THE CURRENT COMMUNICATION LANDSCAPE

Within the landscape of strategic communication, over the past two decades, nuclear testing has occupied a rather quiet corner of NWS strategic signaling, with only sporadic increased media coverage as a result of specific events, such as: 1) A new State joining the "Nuclear Club" (resulting from six DPRK tests that were conducted from 2006 to 2017); 2) Changes to State or Signatory Parties status within the CTBT (such as the Russian revocation of its ratification in November 2023), and most recently; 3) Official announcements concerning the possible resumption of nuclear testing from NWS (the most recent one being the *US President social media posting* on the matter in late October 2025)[1] – all underscoring why visibility and public discourse around this topic are crucial.

Despite the centrality of this matter to key security discussions, nuclear testing remains secluded from public discourse, seemingly overshadowed by other – though related – topics, such as climate change, artificial intelligence, the development and employment of nuclear-capable delivery systems, and the deployment and redeployment of NWS strategic assets. When projected over nuclear-weapon states and countries under the umbrella of extended deterrence policies, this dynamic represents a communicational paradox: where public support for non-proliferation efforts is granted, yet the assignment of diplomatic or political resources to thoroughly address the status of the CTBT, to which they are a signatory, is not (resulting in non-ratification).[2,3] Thus, directly contributing to preventing the Entry into Force of the Treaty.

The CTBTO has played a consistent and central role in drawing international attention to nuclear testing through international fora, despite the Treaty not yet entering into force. The Conference on Facilitating Entry into Force of the CTBT, more commonly known as "Article XIV Conference (AFC)", has been held every other year since 1999.[4] There, Signatory Parties have issued a joint statement that calls for the signature and ratification of the Annex 2 States that have not yet done so.[4] Another key occasion is the CTBT Ministerial Meeting by the "Friends of the CTBT" group held in the years between the AFCs.[5] This initiative was launched by Japan, Australia, and the Netherlands in 2002, and the group has now expanded to Canada, Germany, and Finland.[5] The CTBT Ministerial Meeting has also

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1 Trevor Hunnicutt et el. Trump tells Pentagon to resume testing US nuclear weapons, October 2025, Reuters, <https://www.reuters.com/world/china/trump-asks-pentagon-immediately-start-testing-us-nuclear-weapons-2025-10-30/, accessed 4 April 2026>.

2 Nuclear Non-Proliferation Treaty, U.S. Department of State, <https://www.state.gov/nuclear-non-proliferation-treaty/, accessed 1 April 2026>.

3 "Status of signatures and ratifications", Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), <https://www.ctbto.org/our-mission/states-signatories/, accessed 1 April 2026>.

4 "Article XIV Conferences", CTBTO, <https://www.ctbto.org/our-mission/article-xiv-conferences/, accessed 2 April 2026>.

formalized a joint statement that enhances the awareness of the urgent need for the Entry Into Force of the Treaty.[5]

Looking at the public discourse sphere, UN Member States, and the CTBTO at large, have failed to exploit international fora to attract further levels of attention to nuclear testing beyond the perspective of a mere security concern, disregarding its environmental, humanitarian, or sustainability aspects.

A major milestone that should be considered and configured into the communication effort of the CTBTO is the Review Conferences to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The CTBTO should seek to exploit the traction of attention that the 2026 Review Conference has with the public at large, highlight the interconnectivity of both treaties, while simultaneously participating in the discussions taking place at the forum to enhance the reach of the CTBTO's mission by linking it with those of other more prominent fora.

This is the right time for the CTBTO to not only continue its work through the usual multilateral forums but also ensure the topic of nuclear testing enters new intersectional spaces as well. Its link to these is undeniable: nuclear testing devastates ecosystems, displaces communities, undermines global trust, and affects the health and well-being of groups – all fundamental components of sustainable development.

STRATEGIC COMMUNICATION: FROM TECHNICAL GATEKEEPING TO GLOBAL STORYTELLING

The CTBT, along with its backbone, the IMS, constitutes a feat of engineering and international cooperation. Through the permanent deployment of a constellation of sensors, the CTBTO has achieved a series of critical successes, including the early detection of all of the nuclear tests conducted by the DPRK by means of its seismic and radionuclide monitoring technologies.[6,7] At times, informing Member States with preliminary information before official DPRK announcements had been made.[8] Another, more current, example that serves to demonstrate the relevance of the CTBTO in limiting the "black box effect", within the context of potential nuclear tests, was the part played by the Organization in October 2024, leading the effort to cease online speculations on an apparent Iranian nuclear test, confirming that the data collected through the IMS had been consistent with regular seismic activity.[9]

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[5] "CTBT ministerial meetings", CTBTO, <https://www.ctbto.org/our-mission/ministerial-meetings/, accessed 2 April 2026>.

[6] "Monitoring the Earth for nuclear explosions: The CTBT verification regime", November 2022, CTBTO, <https://www.ctbto.org/sites/default/files/2022-11/CTBT%20Brochure%20Verification_mod%20NOV22_PcM.pdf.com/, accessed 3 April 2026>.

[7] "Detecting Nuclear Weapon Test Explosions", CTBTO, <https://www.ctbto.org/our-work/detecting-nuclear-tests/, accessed 6 April 2026>.

[8] Monitoring the Earth for nuclear explosions: The CTBT verification regime", CTBTO.

[9] "Experts dismiss speculation over Iran nuclear testing", Arms Control Today, November 2024, <https://www.armscontrol.org/act/2024-11/news-briefs/experts-dismiss-speculation-over-iran-nuclear-testing/, accessed 1 April 2026>.

Yet, despite constituting a clear representation of cross-functional international cooperation and being a cornerstone within the international security architecture, the thorough technical rigor and intricacy of both the Treaty and the IMS have constrained the capacity of the CTBTO to connect with a broader, non-nuclear, public. The "technical gatekeeping" represented by the highly specialized language used in the CTBTO's foundational document and messaging can erect barriers between experts and non-specialist audiences, in contrast with other structural documents of this field, like the NPT.

To move from gatekeeping to enhancing engagement through strategic communication, this paper considers it essential to pursue a shift towards human-centered narratives by employing the "Awareness - Understanding - Engagement & Participation" framework, inspired by the "From deficit to dialogue in science communication" publication, in addition to employing similar communication strategies of other UN bodies, such as UNICEF, UNESCO, or UNODA.[10]

Awareness should be promoted through coherent visual branding, using opportunities such as recognized international days or infographics portraying key data. *Understanding* can be boosted through translating technical processes into powerful storytelling (e.g., illustrating how IMS data can save lives or improve disaster-response capacities). Finally, *engagement* should seek to enable diverse stakeholders (including youth) to enter the conversation with the Organization and other interested parties, contributing to its mission. While *participation* should allow for intersectionality and out-of-the-box partnerships.

A human-centered narrative would then help the CTBTO to translate scientific findings (which to non-technical audiences can often sound abstract) into tangible goals. Embarking on an outreach strategy that purely incentivizes engagement through cold technical facts, whilst not accounting for, or greatly reducing, the importance of the human-centric benefits of the Treaty, represents a liability to the visibility of the Organization. Such a human-focused approach would not portray the CTBT as a text containing complex calculations and high-end technology, but rather as a safeguard for individuals, the international community, the planet, and our shared future by aiding the effort in ensuring no nuclear tests are conducted ever again.

Simultaneously, the Organization should consider using the above-mentioned strategy to expand its Public Information activities on online platforms, effectively reaching its potential audiences where they congregate the most. While the activities highlighted in the *latest annual report* are commendable, it is necessary to highlight that as of 27 October 2025, the CTBTO has only 21,000 followers on *LinkedIn*, 929 on *Instagram*, and 17,000 on *Facebook*.[11] In comparison to other non-secretariat UN agencies or related organizations, these numbers are below average: to the same date, the IAEA has 137,000 followers on Instagram and 259,000 on LinkedIn; UNIDO's followers reached 45,000 on Instagram and 217,000 on LinkedIn; OPCW is followed by 45,000 individuals on LinkedIn.

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[10] Cathelijne Reincke, "From deficit to dialogue in science communication", Frontiers in Communication, 2020, <https://pmc.ncbi.nlm.nih.gov/articles/PMC7506985/, accessed 9 April 2026>.

[11] "Annual Report 2024", CTBTO, August 2025, <https://www.ctbto.org/sites/default/files/2025-08/AR2024_OV.pdf, accessed 2 April 2026>.

In line with the proposed success-oriented approach, the story of how the CTBTO's hydracoustic data aided the search for the missing submarine ARA San Juan serves as a useful case study. In addition to the web story originally posted by the CTBTO, the Organization could develop social media posts (or a limited series), where, for example, those involved provide their personal experience, and the relevance of the IMS can be highlighted regarding other, non-nuclear, topics (revert to Annex B for visual representation).

As such, augmenting the social media presence, especially on TikTok, Instagram, and YouTube Shorts, in addition to expanding into the world of podcasts, would prove beneficial to reach new audiences in a modern, consumer-friendly format. Seeking to implement collaborations with youth or established organizations, and social media personalities with a higher following, should boost the Organization's online presence and allow it to communicate its mission to a larger public. Through placing human-centric storytelling at the heart of the CTBTO's outreach, the Treaty can become a familiar part of global civic discourse at a time when nuclear testing has regained a space within the sphere of strategic signaling from NWS.

EDUCATIONAL INNOVATION: BUILDING THE NEXT GENERATION OF CTBT ADVOCATES

As strategic communication presents the Organization with the opportunity to tell the story of the CTBT, the implementation of expansion of educational programs will ensure that targeted audiences will be capable of spreading the message to future generations. Such a challenge could be summarized as twofold: 1) Expand learning opportunities beyond the closed doors of the Vienna International Center, and 2) Strengthen partnerships that bridge the Treaty's technical expertise with diverse stakeholders, including civil society, academia, and youth.

The *Knowledge and Training Portal (KTP)*, operated by the CTBTO, constitutes a valuable resource to obtain a better understanding of the principles, origins, and technical nature of the CTBT and the IMS. Yet, additional measures should be employed to democratize the content of the KTP. Updating it into a multilingual platform offering free online modules (categorized by difficulty and topics), in addition to resources for educators with lesson plans and classroom materials, is a clear example of such an approach.

Consequently, the Portal could utilize proven methodologies as a successful starting point. The *Disarmament Education Dashboard* – managed by the UN Office for Disarmament Affairs (UNODA) – constitutes a solid framework to be utilized, having reached 50 thousand users globally in 2025. Another example to be implemented by the CTBTO could be the *Recommendation on Open Educational Resources* by UNESCO, which suggests reusable modules with flexible, localized content for educators.[12] In the context of the CTBTO, such modules could include simulations, physics practical exercises, or model conferences. The aforementioned cases demonstrate how preexisting data and training modules at the present disposal of the CTBTO could be restructured and presented to a larger public. Above all, such interactive education methodologies would represent catalyzers for (youth) empowerment.

[12] "The 2019 UNESCO Recommendation on Open Educational Resources (OER): Supporting universal access to information through quality open learning materials", UNESCO, 2019, <https://unesdoc.unesco.org/ark:/48223/pf0000383205/, accessed 9 April 2026>.

The CTBTO Youth Group (CYG), successfully reenergized in 2025, is another decisive component of the Organization's outreach strategy, consisting of 1636 members (hailing from 131 countries) as of December 2024.[13,14] The relevance of this flagship youth program and the current existence of the necessary architecture to support the program's operations could facilitate the CTBTO in pursuing a controlled expansion of the CYG.

To embark on this challenge, the Organization could establish new programs and/or expand the CTBTO's Research Fellowship (bolstering the framework presently utilized). A potential pathway to be considered should be the implementation of mechanisms utilized by collateral fellowship programs, focusing on those similar in structure, such as the Scholarship for Peace and Security by the Organization for Security and Cooperation Europe (OSCE)[15] or Youth Champions for Disarmament by UNODA.[16] In the future, a CTBTO Youth Fellowship could expand upon the online learning phase (which the Organization is experienced in managing) to include in-person study visits. Thus, providing strategic benefits, to include: capacity building, visibility and outreach, institutional continuity, and cross-sector collaboration. Aside from its educational component, such a program would embed the CTBT's mission within the ranks of future practitioners and academics.

CONCLUSION & RECOMMENDATIONS

As the international community heads into the second half of the 2020s amid a heavily convoluted geopolitical context, State and Signatory Parties to the CTBT, and the CTBTO alike, are presented with a unique opportunity to bolster their strategic communication efforts through innovative approaches that seek to expand the exposure of the general public to the nature of the mission of the CTBTO, foster an international cross-functional network of young leaders that can attest to the relevance of the CTBT within the international security architecture, create a global conscience regarding the importance of furthering the Treaty's goals, and generate upstream demands that incentivizes national governments to take further action in regards to the ratification of the CTBT by all Annex 2 States.

The CTBTO and its IMS are not just an example of scientific precision but also one of human connection, where a global array of sensors monitors the ground, sea, and atmosphere for the sake of peace. From detecting and identifying DPRK's nuclear tests to dispelling fears of alleged Iranian tests in 2024, the CTBTO has proven its power to transform data into data-driven inputs for global security. Yet, one of the greatest challenges it faces has not to do with the technical task at hand, but rather with the capacity to turn its achievements into stories, translating the complex language of seismic waves and radionuclide readings into narratives that deeply resonate with people. Utilizing accessible stories, visual branding, and employing digital platforms to further its reach, the CTBTO can portray how its mission is not just about complex data gathering, but rather a reflection of humanity's collective effort to seek a safer world.

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[13] "Annual Report 2024", CTBTO.

[14] CTBTO Youth Group, 19 August 2025, <https://www.instagram.com/p/DNiiQE-tq5T/, accessed 9 April, 2026>.

[15] "Scholarship for Peace and Security in the OSCE area", Organization for Security and Co-operation in Europe, <https://www.osce.org/scholarship-peace-security/, accessed 7 April 2026>.

[16] Youth Champions for Disarmament, United Nations Office for Disarmament Affairs, <https://youth4disarmament.org/youth-champions-disarmament/, accessed 6 April 2026>.

Whilst storytelling is intended to make the achievements and mission of the CTBT more accessible to the general public, education ensures there will be a next generation of professionals capable of sharing said story and passing on said task to future leaders. The challenge at hand is then twofold: to create opportunities for learning beyond Vienna's walls and build bridges between the Treaty's scientific core and policy-oriented profiles.

The CTBTO's Knowledge and Training Portal already serves as a foundation for understanding the Treaty's rich content, yet it has not been capable of reaching its full potential due to the lack of multilingual tools and outdated information. An interactive learning hub that takes on the lessons learned from the success of UNODA's Disarmament Education Dashboard or UNESCO's Open Educational Resources is essential to bolster the reach of the KTP.

At the heart of this two-pronged effort is the youth, the future of the Treaty, embodied by the CTBTO's Research Fellowship. By evolving this initiative into a structured Youth Fellowship that blends online learning with in-person experiences, like those of the OSCE and the UNODA, the Organization could ensure future generations learn about disarmament – while acquiring and living its values through hands-on experiences – and promote its message to a broader audience.

Through storytelling, shared experiences, and empowerment, education becomes the bridge between science and humanity, expanding the reach of the CTBT's core message, finding new storytellers for its mission of seeking a safer world.

A key focus of the CTBTO's future communication strategy must also lie in exploiting relevant upcoming, popular milestones for the international community so as to link their agendas to the goals of the CTBT. The Review Conferences to the NPT and the closing deadline for the 2030 SDGs are two prime examples that the Organization should use to draw permanent attention to nuclear testing.

Regarding the NPT, such an approach would entail continuing to highlight the intricate interconnectivity of both Treaties as they seek to detect the early (fissile material diversion, and the transfer of dual-use technology and/or nuclear weapons) and latter stages (detection of tests intended to validate and/or advance weapon designs) of nuclear proliferation from two complementary angles. Where the NPT, through the IAEA, might face some technical and political constraints to assess unequivocally whether a State has acquired nuclear weapons (specifically due to the nature of on-site inspections and how volatile political dynamics might prevent them altogether), the IMS could unilaterally provide the necessary technical data to confirm if a nuclear test has taken place.

Coupling the CTBT and its ultimate goal of timely detecting, and thus deterring further nuclear testing, with other international agendas will increase the awareness of the general public to the importance of the CTBT itself, enabling individuals, movements, and organizations to generate an upstream demand towards National Governments to address the issue and coerce vertical or horizontal nuclear proliferation - with the ultimate goal of facilitating the political debate around the signature and/or ratification of the Treaty in light of its importance to the security, environmental, and humanitarian goals of the international community.

ANNEXES

A. Overview of recommendations

Strategic Communication and Storytelling

1. Reframe CTBT communication from a predominantly technical narrative to a human-centric storytelling approach that highlights humanitarian, environmental, and societal impacts.
2. Adopt a structured Awareness – Understanding – Engagement & Participation communication framework to guide outreach strategies.
3. Expand CTBTO public information activities across modern digital platforms, including TikTok, Instagram, YouTube Shorts, and podcasts.
4. Utilize concrete case studies (e.g. DPRK test detection, clarification of alleged Iranian test, ARA San Juan search*) to illustrate the real-world relevance of the IMS.
5. Strengthen visual branding and messaging through infographics and the strategic use of international observances to improve recall and public resonance.

Leveraging Multilateral and Political Fora

6. Continue and enhance the use of existing multilateral mechanisms, including the Article XIV Conferences and CTBT Ministerial Meetings, to maintain political momentum for entry into force.
7. Exploit high-visibility international milestones, for example, the upcoming NPT Review Conference, to amplify CTBT messaging and public awareness.
8. Expand CTBT narratives beyond a narrow security framing to include environmental, humanitarian, and sustainability dimensions.

Educational Innovation and Learning Tools

9. Upgrade the CTBTO Knowledge and Training Portal into a multilingual, open-access learning hub with tiered modules by topic and difficulty.
10. Develop tailored educational resources for educators, including lesson plans, classroom materials, simulations, and model conferences.
11. Incorporate best practices from existing UN frameworks, notably UNODA's Disarmament Education Dashboard and UNESCO's Open Educational Resources model.

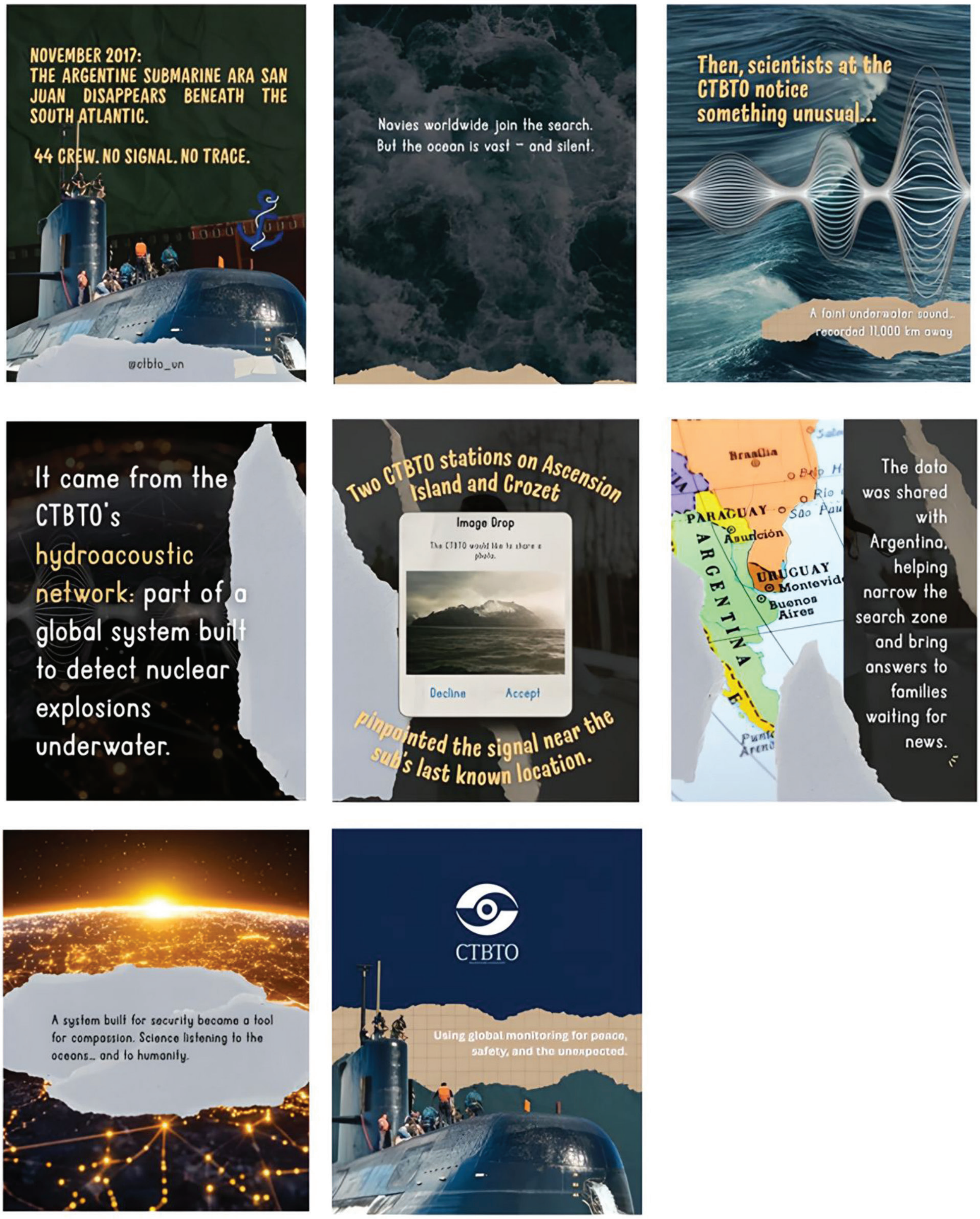
Youth Engagement and Partnerships

12. Expand and institutionalize the CTBTO Youth Group as a core pillar of outreach and education.
13. Establish a CTBTO Youth Fellowship Programme, modeled on comparable initiatives by the OSCE and UNODA.
14. Design fellowship structures combining online learning with in-person study visits or practical engagement.
15. Strengthen partnerships with universities, civil society organizations, and other UN entities to embed CTBT education across sectors.

Long-Term Impact and Political Sustainability

16. Use communication and education efforts to generate upstream public demand for no nuclear tests and CTBT ratification and universalization.
17. Position the CTBT as a test case for the credibility of multilateralism and international norms in an era of renewed nuclear risk.

B. Illustration of a potential social media post utilizing the storytelling method



CTBTO YOUTH GROUP'S 10 YEARS: A LOOK BACK AND AHEAD TO THE NEW CHAPTER

Minh Thuy Bui ■ Mehmet Haşim Çevik ■ Anton Ivashenko

ABSTRACT

Established in 2016 to bridge the generational gap in nuclear disarmament, the CTBTO Youth Group (CYG) has grown to over 1,800 members, yet the Group's potential has only been partially discovered. This paper provides a brief retrospective and forward-looking analysis of the CYG's first decade. It identifies structural challenges, influencing Group's performance: global political headwinds, uneven geographical representation, the need for additional technical diversity as well as pending sustainable financial framework. To ensure the Group's continued relevance, the study proposes strategic recommendations: clarifying the CYG's institutional relationship with the CTBTO, diversifying funding through multi-stakeholder partnerships, and further revitalizing communication strategies. Ultimately, the paper advocates for a shift from quantitative growth to qualitative impact, empowering the next generation to effectively advocate for a world free of nuclear testing.

INTRODUCTION

The Comprehensive Nuclear-Test-Ban Treaty (CTBT), although not yet in force, has gained near-universal support from 178[1] countries and established an unequivocal basis for prohibiting nuclear testing by banning all nuclear explosions.[2] As the international community approaches the 30th anniversary of the Treaty's opening for signature in 2026, marking three decades since its adoption, there is a renewed emphasis on the critical importance of achieving its long-delayed entry into force. Unlike many other international agreements, the CTBT stipulates its own dedicated organization – the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) – which is designated to advance the Treaty's goals and ensure the effectiveness of its verification regime through both technical and diplomatic efforts.[3]

The CTBTO Youth Group (CYG) was established in 2016 as a platform to engage young people from around the world in promoting the objectives of the CTBT.[4] The CYG seeks to bridge the generational gap in the disarmament and non-proliferation fields. Through

[1] "Status of Signatures and Ratification", CTBTO,<https://www.ctbto.org/our-mission/states-signatories/, accessed 20 April 2026>.

[2] "Comprehensive Test Ban Treaty at a Glance", Arms Control Association, July 2024, <https://www.armscontrol.org/factsheets/comprehensive-test-ban-treaty-glance/, accessed 19 April 2026>.

[3] "The Organization", CTBTO, <https://www.ctbto.org/our-mission/the-organization/, accessed 19 April 2026>.

[4] "CTBTO Youth Group [CYG]", CTBTO, <https://www.ctbto.org/resources/for-civil-society/ctbto-youth-group/, accessed 19 April 2026>.

conferences, mentorship programmes, and social media initiatives, the CYG empowers young professionals and students to raise awareness about the dangers of nuclear testing and to advocate for the CTBT's universalization and entry into force.

Reaching its tenth anniversary marks a significant milestone for the CYG – not only as a moment of reflection on its growth and achievements, but also as an opportunity to reassess its evolving role within the broader CTBT community. A decade provides a sufficient timeframe to evaluate patterns of engagement, regional representation, and institutional integration. This paper is therefore both retrospective and forward-looking: it seeks to identify the key factors that have shaped the CYG's development over the recent years and to propose directions for its renewed relevance and impact in the decade ahead. It first assesses the Group's current state and the main challenges faced by the CYG during the 2016-2025 period. Following the identification of these factors, practical recommendations are then formulated to increase the CYG's effectiveness.

CURRENT SITUATION

Founded in 2016, the CYG has grown to become an important tool for promoting the CTBT among younger generations. In 2025, the Group comprised over 1,816 students and young professionals from all regions of the world who are interested in working in the fields of non-proliferation and disarmament. It has organized numerous international events and participated in major global forums, such as the United Nations General Assembly, disarmament conferences, and Nuclear Non-Proliferation Treaty (NPT) review meetings, where the Group represented the youth, passionate about the CTBTO's case.

The COVID-19 pandemic hindered the CYG's activity and shifted many of its activities to online format. However, the Group's performance must not be underpriced: among the CYG's current flagship projects are the CTBTO Research Fellowship, carried out in collaboration with the Center for Energy and Security Studies (CENESS) and the mentoring programme for early career women in science, technology, engineering and mathematics (STEM).

In 2025, concerted efforts were launched to expand CYG's activities and to diversify and enhance the effectiveness of its forms and formats of engagement. One major manifestation of these efforts occurred at the CTBTO's Science and Technology Conference 2025 (SnT2025). During the Conference, the CYG hosted several events including a networking evening for youth members and senior professionals, a roundtable on youth disarmament engagement featuring representatives from UNODA Vienna, CTBT Young Professionals Network,[5] International Student/Young Pugwash (ISYP) and Open Nuclear Network (ONN), the "Be the Voice of SnT2025" contest on content creation. At the Closing Session CYG presented its "Roadmap to the Future" to CTBTO Executive Secretary Robert Floyd. Overall, about 80 CYG members attended SnT2025, almost half of them participated in the event's segment on the youth engagement.

Beyond the SnT2025, in 2025, the CYG participated in a virtual networking event on arms control organized by the Vienna Center for Disarmament and Non-Proliferation and ISYP,

[5] The CTBT Young Professionals Network (YPN) is a community of young scientists and technical professionals working on monitoring and verification of the CTBT. See more: https://ypn.ctbto.org/.

sent a representative to the Youth4Disarmament Forum at UN Headquarters in New York, partook in the 10th anniversary of the UN Security Council resolution 2250 on Youth, Peace and Security, and ran a social media campaign (#OurVoiceOurFuture) during Disarmament Week. The Group's growing activities portfolio stimulated further growth of the CYG community: its membership has considerably increased from 1,156 in 2021 to 1,816 in 2025.

The Youth Group had created quite impressive media outreach with its website and social media accounts as the centrepiece. They include broad overviews of the CTBTO and CYG activities, the Newsroom with posts on past events and CYG's involvement, references to various field-related educational resources, the CYG Handbook on Meeting Facilitation, let alone diverse visual and video content. However, the Group's WhatsApp channel and social media accounts, despite still maintaining a considerable number of subscribers and followers, looked dormant until 2025. The launch of the Instagram account in August 2025, and the revitalization of the X and LinkedIn accounts, marked a comeback to the digital world and helped demonstrate the activities of the group to a broader audience. Still, the Group's official webpage has not yet been refreshed, with the most recent news updates dating back to 2021-2022.

Furthermore, while some core CYG members have successfully sustained their involvement and attendance at international events, newer members frequently encounter impediments to meaningful participation and advancement. These challenges are often associated with external factors such as visa requirements and travel resources, alongside internal constraints on opportunities for upward mobility within the group. In order to tackle the aforementioned issues, in early 2026, the Group decided to establish the CYG Steering Committee, tasked with setting strategic direction, overseeing implementation of activities, facilitating inter-group communication and engagement with CTBTO and other external partners. While the impact of this new platform is yet to come, its potential for the Group's fine-tuning should not be underestimated.

As underlined above, the CYG has noticeably grown in its salience during 2025. Nevertheless, certain remaining challenges, compound and difficult as they are, continue complicating Group's persistent efforts towards greater role within the arms control, disarmament and non-proliferation community.

CHALLENGES

Global Political Context and the Delayed CTBT Ratification

The CYG operates within a complex global political context. Over the past decade, the CTBT has faced persistent obstacles to its entry into force, largely because eight Annex 2 States, including China, the DPRK, Egypt, India, Iran, Israel, Pakistan, the United States, have yet to ratify the Treaty. Russia's withdrawal of the CTBT ratification in 2023, while not effectively hindering fulfilment of CTBTO's main functions, echoed in the common perception of the Organization.[6,7] For a youth network that seeks to promote nuclear non-testing norms, this environment presents a structural limitation. Political stagnation and stalled disarmament

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6 "All Members", CYG Official Website, <https://youthgroup.ctbto.org/all-members/, accessed 19 April 2026>.

7 "Russia Withdraws Ratification of Nuclear Test Ban Treaty", Arms Control Association, <https://www.armscontrol.org/blog/2023-11/nuclear-disarmament-monitor/, accessed 19 April 2026>.

negotiations stifle momentum, reducing the CYG's visibility and discouraging young experts from engaging with the CYG's cause.

Departure from the CTBTO and Pending Restructurization

The CYG was established under the CTBTO's institutional umbrella, which provides legitimacy and access to expert networks. However, this affiliation also introduces certain boundaries shaped by the CTBTO's diplomatic mandate. While the connection ensures alignment with CTBTO objectives, it may limit the Group's flexibility to engage independently with diverse stakeholders. Achieving a balanced relationship that preserves institutional credibility while fostering operational autonomy will be crucial for the CYG's future development.

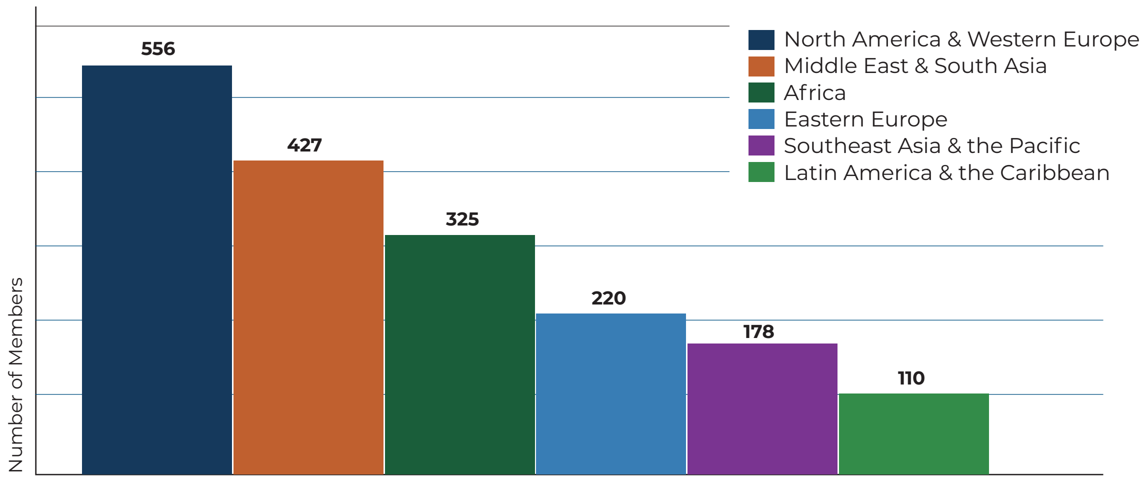
Sustaining Financial and Organizational Capacity

Ensuring financial sustainability remains an ongoing priority for the CYG. While the Group benefits from logistical and institutional support provided by the CTBTO Preparatory Commission, it currently operates without a dedicated financial framework. According to official reports, most youth engagement initiatives are funded through voluntary contributions and project-based grants.[8] This model has enabled flexibility and responsiveness but has also highlighted the need for more predictable, multi-year funding to support continuity of activities.

Regional Representation and Diversity Gaps

Despite CYG's impressive expansion to over 1,800 members worldwide[9] participation remains uneven across regions. The data below shows that North America and Western Europe account for 556 members (30.6%), and the Middle East and South Asia for 427 (23.5%), while Africa (325), Eastern Europe (220), Southeast Asia and the Pacific (178), and Latin America and the Caribbean (110) remain underrepresented (Graph 1).

Graph 1. Members Distribution by Region



In addition, most members come from policy or communication fields. This is supported by the distribution of academic backgrounds, with Social Sciences accounting for the largest share of members (509), followed by Sciences (170) and Applied Sciences (157), reinforcing

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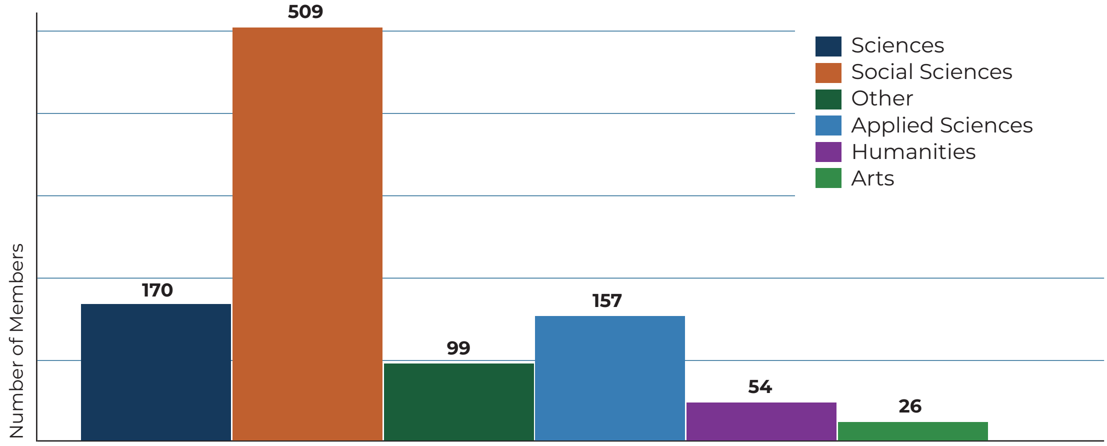
8 "Annual Report 2022", CTBTO, <https://www.ctbto.org/sites/default/files/2023-09/EN_CTBTO_AR_2022_0.pdf/, accessed 19 April 2026>.

9 "All Members", CYG Official Website, <https://youthgroup.ctbto.org/all-members/, accessed 10 January 2026>.

the observation of fewer participants from technical disciplines relevant to CTBT verification (Graph 2).[10] This imbalance limits the group's interdisciplinary potential and its capacity to bridge science and diplomacy effectively. At the same time, however, an increasing number of CYG members might partially dilute the potency of the Group as an adaptable and active young expert community.

Graph 2. CYG Members Distribution Across Academic Disciplines



Limited Post-Pandemic Engagement and Decline in Active Participation

Even after the lifting of travel restrictions introduced during the COVID-19 pandemic, many events continued to be held online, while participation in hybrid activities remained inconsistent.[11] This shift has led to a decline in active involvement, with a growing gap between highly engaged members, often those based in or near Vienna and peripheral participants who join only sporadically. Even though online-format is extremely beneficial for greater national diversity among participants and easier event arrangement, the limited return to physical gatherings has also weakened mentorship links between cohorts and reduced visibility of the CYG within the broader CTBTO community. As a result, sustaining motivation and cohesion in the post-pandemic phase has become a major challenge for the network's long-term vitality. SnT2025, with the broad in-person participation of CYG members, marked a promising step toward a renewed wave of face-to-face engagement and signaled efforts to re-establish regular in-person interaction as an important practice within the network.

Bridging Science and Policy amid "Nuclear Fatigue"

The CTBT relies on complex verification technologies that require expertise in seismology, radionuclide detection, and data analysis. However, a significant proportion of CYG members come from non-technical backgrounds, which limits their ability to translate scientific findings into accessible policy narratives. At the same time, public attention to nuclear disarmament has declined – a phenomenon known as "nuclear fatigue". This term reflects the waning public and political interest in nuclear issues after decades of policy stagnation. As newer global challenges such as climate change and digital security dominate

[10] "CYG Members Distribution Across Academic Disciplines", CYG Annual Report 2021, CYG Official Website, <https://youthgroup.ctbto.org/system/files/2022-02/Report-5%20YEARS.pdf/, accessed 19 April 2026>.

[11] See for example: "CTBTO Annual Report 2022", CTBTO Official website, <https://www.ctbto.org/sites/default/files/2023-09/EN_CTBTO_AR_2022_0.pdf/, accessed 19 April 2026>.

the international agenda, the nuclear debate often receives less visibility. Disarmament education struggles to remain relevant in an era of shifting global priorities. For the CYG, this creates a dual challenge: maintaining scientific credibility while ensuring that CTBT advocacy resonates with broader global narratives about sustainability, peace, and security.

RECOMMENDATIONS AND CONCLUSION

Clear and Discreet CYG-CTBTO Relations

The CYG should plainly define how the Group and the CTBTO correlate. Moving the CYG farther from the Organization would endow it with more multifaceted funding opportunities and greater independence from the pressure of the member-states as they will not consider the Group's activities as a direct prolongation of those of the CTBTO.

Establishing Funding Base

Through calling for sponsorship and obtaining additional financial resources the CYG would be able to sustain more long-term projects. However, it is necessary to keep funding sources either diverse or sufficiently distant from any one-sided political affiliation. Such diversified partnerships with entities could include UNODA, regional organizations, and academic institutions engaged in disarmament education. Establishing a transparent and multi-source funding mechanism would enhance the Group's resilience and autonomy while ensuring that its initiatives remain aligned with the broader objectives of the CTBT. Attracting greater funding, in turn, depends on the Group's performance in other spheres, such as media campaigning, academic research or presence at international events.

Making Membership Work for the Group's Purposes

Even though increasing the volume of members of the CYG does improve its global outreach, the numbers should not be the ultimate end on its own. Putting Group's format adaptivity and high standard of expertise in the scope would suit its goals better than pure aggrandizement. The same goes for geographical diversity: it should foster the CYG's ability to cooperate with regional organizations and expert communities rather than just extend the list of participants' origins.

Making the Group More Visible in the Professional Field

Among possible steps that the CYG could make in order to restore its salience within the arms control and disarmament community and beyond is creating its own regular events, dedicated to the Youth's contribution to the above-mentioned domains, pursuing representation at the major events that take place not only in Vienna but at least in other capitals of international diplomacy also (Geneva and New York), establishing regular contacts and joint research or public projects with other active think tanks and movements (Arms Control Association on one side and Pugwash Conferences on Science and World Affairs or International Campaign to Abolish Nuclear Weapons are just some examples).

Launching Creative and Relevant Education Initiatives

In order to boost its level of expertise and add new dimensions to the CTBT-related research, the CYG might spearhead various multifaceted advanced training and skills development programs. Such might be envisioned as a platform for convergence of students with humanitarian and technical backgrounds via performing joint exercises, co-authoring research papers, etc. Another option is creating basic training courses on open-source intelligence and strategic analysis, for example, in partnership with the Open Nuclear Network.

Social Media Communication Strategy

The CYG should continue strengthening its media outreach efforts by building on what has already been set in motion. The relaunch of Instagram and the revitalization of X and LinkedIn accounts in 2025 marked a genuine comeback to digital space, and this momentum should now be channeled into a more deliberate strategy. LinkedIn, in particular, warrants sustained attention: the focus should shift toward consistent follower growth among relevant stakeholders, with cross-platform content management. The Newsroom Project should be revived in parallel and kept regularly updated. All social media efforts should remain thematically connected to the Group's broader campaigns, such as #OurVoiceOurFuture and its presence at major events, so that digital outreach reinforces rather than stands apart from CYG's wider advocacy work. Introducing "Ask an Expert" sessions with CTBTO staff can keep engagement consistent and meaningful, while arranging "tie/hat-off" informal interviews with the Organization's senior officials might put career options and personal experiences into the spotlight.

The CYG stands at a pivotal juncture: a decade of experience has laid the groundwork, and the renewed momentum of 2025 has demonstrated that the Group is capable to scale up its activities and evolve in new directions. Sustaining this trajectory will require structural clarity, strategic communication, and a genuine commitment to delivering holistic impact to the field. Ultimately, the CYG's greatest contribution lies not only in the size of its membership, but in the depth of its engagement and the lasting impact of the next generation it empowers.

PROSPECT FOR DPRK'S ENGAGEMENT WITH THE CTBTO: WHY THERE SHOULD BE ROOM FOR OPTIMISM

■ Sohee Ha ■ Kylie Jones ■ Riccardo Villa

ABSTRACT

Engaging the Democratic People's Republic of Korea (DPRK) through the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO/PC) might offer a science-based and depoliticized framework for confidence-building on the Korean Peninsula. Such a framework may enable an incremental, verifiable (or otherwise transparent), and politically manageable process towards reinitiating international dialogue without imposing high-stakes political commitments at the outset and further down the road. This paper proposes an engagement ladder composed of modular and reversible activities, emphasizing how such an approach can institutionalize procedural interaction and progressively establish technical channels of communication between the DPRK and the CTBTO/PC. Potential complications and risks associated with previously imposed sanctions, issues of dual-use technologies, information sensitivity, and institutional mandates could be addressed through tiered access mechanisms, advance legal vetting, and transparency safeguards. Taken together, the CTBTO/PC's science-based engagement may function as both a technical enabler and a diplomatic catalyst, providing a credible, low-risk, and non-political foundation for gradual confidence-building.

STAKES AND CONTEXTS

The DPRK so far remains the only country to have conducted nuclear tests and to have joined "the nuclear club" in the 21st century, challenging the international norm against nuclear explosive testing and complicating efforts to prevent further proliferation. Traditional state-to-state negotiations and diplomacy with the DPRK have repeatedly stalled, limited by political mistrust, verification difficulties, and competing national interests. These persistent obstacles have highlighted the need for alternative approaches that do not rely solely on high-stakes diplomatic bargaining.

In this context, the CTBTO/PC might offer a uniquely promising avenue. As an international norm against nuclear testing, the CTBT establishes a verification regime resting on three pillars. The International Monitoring System (IMS) is a global network employing seismic, hydroacoustic, infrasound, and radionuclide technologies. The International Data Center (IDC) collects, processes, and distributes IMS data and derived products to States Signatories. On-Site Inspection (OSI) will become available upon the Treaty's entry into force. Together, these three pillars are designed to detect and deter nuclear explosions.[1]

[1] "Verification Regime", CTBTO, <https://www.ctbto.org/our-work/verification-regime/, accessed 30 April 2026>.

This verification mandate, as defined by States Signatories and embedded in the Treaty text, constitutes both one of the pillars and the outer limit of any CTBTO/PC activity: all engagement, including that proposed in this paper, must operate within this remit and safeguard the institutional credibility on which the verification regime depends. Within the IDC's analytical toolkit, Atmospheric Transport Modelling (ATM) is used to interpret radionuclide observations.[2] The virtual Data Exploitation Center (vDEC), a research platform separately operated by the CTBTO/PC rather than established by the Treaty itself, grants vetted researchers access to archived IMS data under a zero-cost contractual framework with strict conditions.[3] Beyond their verification purpose, these capabilities also generate data and expertise valuable for a range of Civil and Scientific Applications (CSA), including tsunami warning, earthquake hazard assessment, volcanic ash tracking, and radionuclide dispersion monitoring.[4] What is also important is that, while the CTBT is an international legal instrument establishing the global non-testing norm, it does not contain direct provisions or requirements demanding nuclear disarmament, denuclearization, reductions in nuclear arsenals, or regulating nuclear doctrines.

While the DPRK has not yet signed the Treaty, the abovementioned tools at the disposal of the CTBTO/PC may be directly relevant to the domestic priorities Pyongyang has consistently emphasized, such as disaster resilience, environmental monitoring, and public safety. Under appropriately structured cooperation, this alignment could be translated into concrete civil benefits in the form of improved hazard interpretation, more consistent inter-ministerial response procedures, and stronger institutional capacity for managing radiological and environmental information. This alignment suggests a path for cooperation that is scientifically credible, politically neutral, and directly beneficial to Pyongyang's civil institutions.

Engagement through the CTBTO/PC need not imply major political concessions by the DPRK or compromise its national security. Instead, it can serve as a low-risk, apolitical platform for stepwise interaction, allowing the DPRK to build procedural literacy and strengthen institutional routines for civil and scientific applications, such as disaster preparedness, environmental monitoring, and public-health response, rather than any operational verification or detection-evasion capability, while the international community reinforces the global norm against nuclear testing. By framing cooperation around scientific expertise and human-security objectives, the CTBTO/PC provides a realistic foundation for confidence-building and incremental trust, creating a basis for optimism about the DPRK's future engagement.

WHY OPTIMISM MAY BE WARRANTED

Although the DPRK has shown reluctance toward a range of international arms control and non-proliferation frameworks, several factors suggest grounds for cautious optimism

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2 "Atmospheric Transport Modelling", CTBTO, <https://www.ctbto.org/our-work/atmospheric-transport-modelling/, accessed 8 April 2026>.

3 "Procedures for Access to IMS Data and IDC Products by Contractors", CTBT/PC-14/1/Annex II, Appendix IV, CTBTO, 2000, <https://www.ctbto.org/sites/default/files/2022-07/CTBT-PC-14-1-Annex_II_1__0.pdf/, accessed 8 April 2026>.

4 "Civil and Scientific Applications", CTBTO, <https://www.ctbto.org/our-work/civil-and-scientific-applications/, accessed 8 April 2026>.

regarding potential engagement under the CTBTO/PC's aegis. These factors are rooted not in assumptions about political transformation, but in practical incentives and structural opportunities that may make a science-based, apolitical pathway somewhat attractive to Pyongyang.

First, the technical utility of further nuclear testing for the DPRK may be diminishing. Following six tests conducted between 2006 and 2017, culminating in a high-yield device widely assessed as thermonuclear or boosted-fission,[5] expert analyses suggest that Pyongyang has already accumulated sufficient empirical data to validate its core weapons designs and may have achieved a level of miniaturization adequate for delivery by a range of missile systems.[6] Additional explosive tests may offer limited new gains when compared with the advances achievable through non-explosive research and the associated investments in research infrastructure and technical expertise. In contrast, engagement with the CTBTO/PC's scientific and technical infrastructure, particularly the IMS and its four complementary technologies (seismic, hydroacoustic, infrasound, and radionuclide monitoring), together with IDC analytical capabilities such as ATM, provides immediate domestic benefits. These tools directly support disaster preparedness, hazard mitigation, and environmental monitoring, addressing priorities the DPRK has emphasized, such as public safety, climate resilience, and environmental stewardship. Participation in these activities can therefore deliver tangible gains while remaining fully compatible with Pyongyang's security posture.

Second, the CTBTO/PC should be in a position to provide a structured, apolitical path for incremental confidence-building. Carefully designed, modular cooperation—through training exercises, partner-led projects, and procedural familiarization—can establish habits, routines, and technical compatibility that lay the foundation for future engagement. Over time, these activities can help build technical and institutional capacity relevant to the operation of IMS-type monitoring systems, lay the groundwork for a future National Data Center (NDC), and support the modernization of policymaking across disaster management, agriculture, public health, and infrastructure planning.

Taken together, these factors suggest that engagement with the CTBTO/PC is not only technically feasible, but mutually advantageous. Given the Treaty's neutral and scientific character, and through stepwise capacity-building approaches, the international community can create conditions under which Pyongyang might participate meaningfully in the implementation of the international norm against nuclear testing. Precedents for such graduated engagement already exist: the CTBTO/PC has established institutional mechanisms for cooperation with non-signatory states, including the accredited observer status available to non-signatories that host IMS facilities, and has maintained constructive dialogue with non-signatory states such as Pakistan (a nuclear-armed state).[7] Such engagement provides a low-risk, apolitical foundation for confidence-building and lays the groundwork for a more constructive and sustainable relationship.

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5 "Backgrounder: Previous DPRK Nuclear Tests", Open Nuclear Network, 2022, <https://opennuclear.org/en/open-nuclear-network/publication/backgrounder-previous-dprk-nuclear-tests/, accessed 22 April 2026>.

6 "Revisiting North Korea's Nuclear Tests", 38 North, 2026, <https://www.38north.org/2026/02/revisiting-north-koreas-nuclear-tests/, accessed 22 April 2026>.

7 "CTBTO Visit to Pakistan", CTBTO, 2018, <https://www.ctbto.org/news-and-events/news/ctbto-visit-pakistan/, accessed 19 April 2026>; "CTBTO Preparatory Commission", Nuclear Threat Initiative, <https://www.nti.org/learn/treaties-and-regimes/ctbto-preparatory-commission/, accessed 22 April 2026>.

THE FRAMEWORK AND PROTOCOLS OF ENGAGEMENT

This paper proposes a set of engagement modules matched with the CTBTO/PC's comparative advantages and filtered through a non-misuse tri-gate: (i) zero transfer (no data, code, accounts, software, hardware, or funds handover), (ii) zero algorithmic specificity (no parameterizations, site-specific tuning, or reproducible methods disclosed), and (iii) zero temporal operability (no live feeds, nowcasting, or real-time decision advantage).

ATM Wildfire and Legacy Fallout

Seasonal dust events and episodic wildfires can re-suspend legacy radionuclides and industrial pollutants, creating challenges for public health and agricultural risk communication. To address this, the CTBTO/PC could provide an offline reference almanac developed outside the DPRK using publicly available meteorological reanalysis datasets and standard atmospheric dispersion concepts at a descriptive level.[8] The resulting materials would consist exclusively of historical, de-identified outputs, including typical seasonal movement patterns through easy-to-read maps and panels, plus simple illustrations of how material can thin out, settle, and decline over time. By standardizing how ministries interpret atmospheric transport graphics, this engagement reproduces the procedural routines that a future atmospheric analysis unit would require, while relying solely on public inputs. To avoid dual-use concerns, the materials deliberately exclude real-time forecasting, event-specific tools, source-finding methods, technical parameter settings, or local tuning. Over time, such an almanac could evolve into shared seasonal outlook notes and limited joint sensitivity discussions based entirely on public numerical weather-prediction products.

Closed-Door Technical Roundtables on Data Interpretation

Given non-signatory status and sanctions, DPRK agencies likely have limited routine exposure to the operational norms of CTBT verification fora (e.g., product lineages, citation practices, licensing/access rules), though public events like the Science and Technology (SnT) Conference provide some indirect exposure. Closed-door training sessions anchored to the CTBTO/PC's SnT community address that procedural gap without conferring status or credentials. The trainings could take place in coordination with pre-vetted and approved partner institutions presenting strictly civil IMS use cases or fit-for-purpose sessions that hinge on data shared with the DPRK. The CTBTO/PC moderates roundtables modeling question formation against publicly releasable IMS/IDC products, the correct use of provenance fields (product name, release time, version lineage), and the boundary between public summaries and restricted holdings. The contribution is procedural adaptation for a future CTBT signature by rehearsing the interaction rules an eventual NDC and liaison unit must follow. This normalizes a low-visibility technical channel with the CTBTO/PC around public inputs, reduces sanction-sensitive asks, and familiarizes protocol officers with observer-style etiquette. Public returns would be cleaner and more consistent internal briefs and narrower public lines, limiting contradictory statements. If conditions permit, the same pathway can extend to licensed vDEC accounts, visible participation at SnT conferences, and co-authored methods notes within established compliance frameworks.

[8] "Data Fusion and Atmospheric Transport Modelling (ATM)", CTBTO, <https://www.ctbto.org/our-work/international-data-centre/data-fusion-and-atmospheric-transport-modelling/, accessed 18 April 2026>.

NDC Training

National Data Centers (NDCs) are the institutional focal points designated by States Signatories to access and analyze IMS data and IDC products for the dual purposes of CTBT verification and civil and scientific applications.[9] The CTBTO/PC already supports NDC capacity through its NDCs4All Initiative (launched 2022), which provides training and technical support enabling States Signatories to use IMS data and IDC products meaningfully, both for Treaty-mandated verification and for civil applications such as disaster preparedness, environmental monitoring, and public health.[10]

Rather than designing a stand-alone training, we propose a graduated pathway in which DPRK personnel could first observe relevant CTBTO/PC training sessions under arrangements that respect data confidentiality. These would be sessions where IMS data are not directly showcased and where the focus is on procedural literacy, methodological frameworks, and the interpretation of publicly available outputs. This observer-style engagement mirrors the practice already adopted by non-signatory states and aligns naturally with the non-misuse tri-gate. Complemented by paper-based exercises using standardized briefing templates, provenance fields, and handover checklists, this approach builds shared vocabulary and procedural discipline while keeping visibility low. The result is a lawful technical channel based on public inputs that allows the DPRK to understand the value of NDC routines and the dual-purpose nature of CTBTO/PC training without compromising data confidentiality or institutional integrity, laying the groundwork for a future NDC should conditions permit.

ENGAGEMENT LADDER

The CTBT is a multilateral treaty, and engagement activities of any kind cannot modify or dilute its provisions. The ladder proposed here is therefore best understood as a structured pathway for limited familiarization with the existing CTBT verification regime, rather than as a substitute for, or modification of, the formal obligations of signature and ratification.

Within this framing, the engagement ladder is conceived as a non-temporal, modular, and reversible sequence of engagement offers whose purpose is to lower audience costs, establish a lawful technical channel around public inputs, and build familiarity with the routines and procedures associated with NDC operation under the existing verification regime, thereby creating the procedural conditions under which CTBT signature might subsequently become feasible without presuming policy changes. Entry can occur at any point since the modules are selectable rather than scheduled. All activities are conducted behind closed doors and under a tri-gate constraint that precludes transfer of data, code, accounts, equipment, or funds, avoids algorithmic specificity, and disallows temporal operability. In practice, early contacts use deniable, knowledge-focused engagements (e.g., the quake–tsunami briefing pack, radionuclide figures familiarity, or a legacy-resuspension almanac) to build a shared reading vocabulary and provenance discipline. Progression is considered when counterparts demonstrate continuity of interlocutors and bounded, provenance-aware question-framing. Subsequent practice modules (e.g., a synthetic radiological-accident tabletop and, if necessary or relevant, a seasonal resuspension

[9] "International Data Centre", CTBTO, <https://www.ctbto.org/our-work/international-data-centre/, accessed 22 April 2026>; "For Researchers and Experts", CTBTO, <https://www.ctbto.org/resources/for-researchers-experts/, accessed 22 April 2026>.

[10] "National Data Centers-for-All Initiative", CTBTO, <https://www.ctbto.org/NDCs4All/, accessed 15 April 2026>.

refresh) rehearse inter-ministerial choreography with static, historical materials that clarify what figures do and do not support. Here advancement hinges on evidence-bounded queries from core technical roles and the maintenance of clean behavior under the tri-gate constraint framework.

Institutional exposure is introduced through vDEC/SnT roundtables that familiarize participants with licensing discipline and observer etiquette, with a strictly optional, rules-bound listen-in at a later technical setting subject to Secretariat approval. Monitoring is minimal by design, with aggregated, anonymized logs used to note interlocutor continuity, delegation adequacy, and the presence of evidence-bounded queries. Risk controls and off-ramps are multiple and carefully followed, and no entitlements accrue from participation. In other words, any request for tools, data, access, or credentials, attempts to record materials without approval, site-specific or operational tasking, or churn that breaks continuity triggers an immediate pause and default reversion to foundational literacy, or suspension of the engagement altogether. The result is a flexible familiarization pathway that maximizes deniability, demonstrates bureaucratic utility, and normalizes repeat contact, laying the administrative groundwork that could make – if and when it comes to that – signature, and later ratification of the CTBT in its existing form, feasible.

RISKS & MITIGATION

As established at the outset of this paper, all engagement must operate within the CTBTO/PC's existing remit and safeguard the Organization's institutional credibility. Within that framing, while all of the above ideas are technically neutral and politically balanced, there are a number of issues that need to be carefully navigated. A first issue relates to sanctions and dual-use concerns. It is conceivable that even purely civilian technical exchanges could be perceived by some as violating UN Security Council sanctions or providing indirect support for military modernization. To minimize this risk, all cooperative activities should be conducted under a strict tiered access model that allows for the sharing of read-only data, open datasets, or synthetic training material at most. All initiatives should also be legally vetted in advance in light of applicable UN resolutions. Furthermore, a separate partner track for environmental monitoring and humanitarian uses, such as for disaster-risk reduction, atmospheric monitoring, and water-safety projects, would help to underscore the non-political and civilian nature of engagement.[11]

A second risk involves reputational and political considerations. Should the DPRK conduct a high-visibility strategic demonstration—such as a nuclear test—during the engagement process, it could complicate political support for CTBTO/PC outreach among member states and the public, prompting criticism and increased scrutiny of the outreach initiative. This can be addressed by including in the design of the process a pause and resume option that would allow a temporary suspension of such cooperation should it be abused, without losing the infrastructure for the long-term continuation of such a process. This, along with full transparency with stakeholders and the media, and use of neutral venues and possible inclusion of external observers, could go a long way toward insulating such a process from losing institutional credibility, even in the event of acute political crisis.

[11] "Civil and Scientific Applications", CTBTO.

The third issue is one of sensitivity and information. In theory, the large volumes of high-resolution seismic and radionuclide data from the IMS and IDC could be used for evasion learning.[12] To ensure sensitive information is not misused, data sharing should be subject to a sensitivity protocol with public, controlled, and restricted tiers. DPRK participation could be limited to educational and analytical aspects such as the visualization of processed bulletins through virtual means, with no exposure to raw data or the network itself.

CONCLUSION

This paper offers a science-based and depoliticized framework, which could be employed by the CTBTO/PC, or even under the Organization's auspices, as an alternative track to conventional government-to-government diplomacy, enabling step-by-step engagement with the DPRK with the overall goal of supporting confidence-building on the Korean Peninsula. It highlights the specific ways in which trust can be gradually built through science-based collaboration consistent with the CTBT and within the CTBTO/PC's existing institutional practice for engaging non-signatory states. By creating a new channel for diplomacy rooted in scientific dialogue and technical transparency, the CTBTO/PC can act as an impartial and credible facilitator, even in the absence of formal political negotiations. The impasse that has set in around the Korean Peninsula makes it clear that incremental steps of manageable political scope are needed to build confidence without imposing high-stakes political commitments at the outset. There may be reason for optimism, as the CTBTO/PC is equipped with an existing, technical, and legitimate international framework that can be used to restart engagement in a low-risk and reversible way. The proposals discussed in this paper provide tangible means for depoliticized cooperation. Building on the engagement ladder and the risk-mitigation framework detailed above, this paper argues that the CTBTO/PC can serve as both a technical enabler and a diplomatic catalyst for future dialogue. Within the analytical and institutional framework set out in this paper, this approach offers a feasible pathway through which the DPRK could gradually engage with the international norm against nuclear testing, while protecting its own national sovereignty. The realization of such engagement will inevitably depend on broader political conditions, but some relevant technical and institutional groundwork can be prepared in advance.

[12] "International Data Center", CTBTO.