

# From Deadlock to New Opportunities: The Security Dilemma and Its Resolving Path in the Construction of the BWC Verification Mechanism

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## Article

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# Abstract

Over the past 50 years, the Biological Weapons Convention has been one of the main foundations in the global field of biological arms control and has consistently contributed significantly to the administration of global biosecurity. However, there is a conflict between national interests and security in international arms control cooperation, known as the Security Dilemma. Simultaneously, the significance of the BWC's verification system in improving the BWC's compliance and verification has continued to garner attention. This article examines the Security Dilemma in international disarmament cooperation, emphasizes that striking a balance between national security and information transparency is a crucial way to resolve this dilemma, and goes on to examine the two key influencing factors for reaching this balance: an independent third-party monitoring agency and the creation of remote monitoring technology. The current CBMs and Peer Review system cannot ease the tension associated with the Security Dilemma, but the willingness of States Parties to cooperate and technological advancements have created a new opportunity for the discussion of developing the BWC's verification mechanism. Therefore, we think that the best way to resolve this situation is to develop a BWC verification mechanism based on information transparency and security balance.

## 1 Introduction

The Biological Weapons Convention (BWC) was initiated for endorsement in 1972 and became operational in 1975. In the last half-century, this treaty has garnered backing from 189 signatory parties (UNODA, 2026). In the realm of biology, the BWC performs roles that are not addressed by other international treaties, including those of the World Health Organization and the World Organization for Animal Health. Other global treaties often emphasize health-related occurrences and lack the preventive and normative roles of the BWC in delineating the limits between lawful biological practices and the outlawing of weaponization conduct (Meyer & Mariosi, 2025). Consequently, ensuring the efficient functioning of the BWC aids in addressing the regulatory deficiencies within the broader biological security framework, namely in discerning if biological threats emanate from malicious motives.

While the BWC aligns with the non-proliferation objectives of other disarmament agreements in arms control, it encounters distinct obstacles, the most significant being the absence of a verification mechanism and related organizational framework (Shearer et al., 2025). The significance of institutional backing for the execution of international disarmament agreements has been a longstanding issue of interest. The validation of international treaties' execution holds equal significance to the creation of the treaties. Should there be insufficient focus on the execution of the treaties, the extensive discussions that occurred during their creation will become trivial and will not facilitate the ultimate achievement of disarmament objectives (Flowerree, 1990). Since the BWC was opened for signature, all States parties have pledged to attain the objective of global biological disarmament. During the 1970s, the BWC treaty, created without a verification system, struggled to address the intricate international landscape resulting from technological competitiveness and the obstacles posed by technological advancement itself. Consequently, establishing an equitable and efficient verification system that aligns with the present

technological advancements is essential for addressing the deficiencies in the global biological disarmament arena, while also serving as a foundational institution that fosters a cohesive and stable outlook for the international community. The Ninth Review Conference in 2022 resulted in a unanimous agreement among all States Parties to recommence initiatives aimed at enhancing the implementation of the convention, with the aim of forming institutional verification and compliance arrangements (United Nations, 2022).

Currently, investigations into the verification mechanism of the BWC, along with wider studies in international disarmament, have insufficiently tackled the conflict between information transparency and state security during the development of the verification mechanism. The tension between acquiring data on a nation's biological weapons and the authenticity of this data in demonstrating the nation's compliance, particularly regarding transparency and the implications of information disclosure for the security of States Parties, is a critical concern that must be tackled during discussions on the verification mechanism of the BWC to mitigate the Security Dilemma in international disarmament collaboration. Consequently, this article centers on the discourse surrounding the equilibrium between informational transparency and national security, and further elucidates methods to develop a more viable verification mechanism for this balance, aiming to improve the verification and compliance to the BWC.

## **2 the Security Dilemma and the Balance between Transparency-Security for the International Disarmament matters**

### **2.1 the Security Dilemma in the International Disarmament Cooperations**

In traditional international relations theories, the discourse surrounding the "Security Dilemma" has been prevalent since the previous century. The actions implemented by a nation to bolster its own security ostensibly appear to improve the collective security of that nation and its populace; nonetheless, the security initiatives of one nation frequently diminish the security of others (Jervis, 1978). This is especially evident in the realm of weaponry: a nation's allocation of resources toward military strength, irrespective of whether its goal is to dissuade other nations or simply to bolster its own security, has indeed posed a significant threat to other states (Wainstein 1971: 155). In situations where nations have conflicting interests, a lack of comprehensive monitoring of military and armament activities may lead to secret military expansions and weapon development, ultimately undermining the objective of universal arms control (Fearon, 2018). The Security Dilemma addresses scenarios devoid of conflicting interests and elucidates the significant factors hindering States from achieving disarmament agreements and establishing requisite compliance and verification frameworks, primarily due to apprehensions regarding adversarial deceit, the clandestine advancement of weaponry by other nations to bolster their superiority and jeopardize national security, which subsequently incites armament actions (Kydd 1997, 2000).

In the study of the Security Dilemma, while numerous debates indicate a tendency toward endorsing competitive strategies, the variations in them analyzes concerning the costs and risks associated with

competitive versus cooperative strategies do not substantiate the assertion that the Security Dilemma inevitably culminates in competitive policies (Jervis, 2011). Charles Glaser has highlighted this aspect. While pursuing collaboration may not consistently be the optimal approach to tackle the security apprehensions of stakeholders, cooperation in global politics has not been entirely supplanted by adversarial strategies (Jervis 1978: 417). Furthermore, he underscored the need of acquiring advance knowledge to bolster confidence between nations, noting that this serves as the cornerstone for formulating arms control treaties, allowing countries to gather indications for monitoring the circumstances of others. Despite the presence of skepticism, collaboration can still be attained provided suitable responsibilities and obligations are established to guaranty that the interested parties can trust that there will be sufficient repercussions in the event of a breach or potential hazards (Jervis 1978: 418).

If we regard the attainment of international disarmament treaties as a form of collaboration among nations, specifically international cooperation aimed at achieving global disarmament objectives, initial analyzes have indicated that this cooperation is also influenced by the Security Dilemma (Jervis 1978: 168). The chaotic condition of the international community hinders nations from achieving consensus on shared interests, and the lack of authoritative executive bodies grounded in international law for developing and executing pertinent cooperation frameworks, such as the BWC, which still lacks an independent verification agency, exacerbates the challenges in attaining cooperation objectives. There are two concerns present here. The initial concern pertains to the necessary conditions for dialog, specifically that nations must exhibit a readiness to collaborate; the subsequent issue revolves around the elements that can facilitate cooperation amidst the security dilemma.

In the initial scenario, presuming that nations are or have been engaged in discussions about collaboration, if all nations demonstrate a readiness to cooperate, the advantageous objective of collaboration can be realized; however, if certain participants opt out of cooperation, the negotiation process may entirely disintegrate (Jervis 1978: 179). This presumption regarding the manifestation of cooperative intent is also evident in the historical negotiation process concerning the verification mechanism of the BWC; specifically, the failure of the protocol negotiations in 2001 was directly attributable to the withdrawal of cooperative intent by one State Party (United Nations, 2001).

Although criticism of this State Party is frequent, the reason for its refusal of the verification mechanism to reach an agreement also provides resources for us to observe the second issue, that is, what factors can promote international biological weapons disarmament cooperation under the security dilemma: for the verification of a country's biological weapons situation, it needs to be based on the requirement of information transparency for verification, without causing the country to severely damage its sense of security regarding power due to the disclosure of such information. In the realm of international disarmament collaboration, the implementation of uniform standards and processes ensures that the verification practices of all stakeholders will align. However, the more advanced the growth status of a participating entity, the more significant its apprehensions will be. The information revealed by a party in a more advantageous developmental position possesses greater worth due to its dominance over

others, resulting in an increased sense of vulnerability to this party's authority. Essentially, overseeing military installations is not challenging to accomplish. In contrast to the subjective motivations underlying actions, it appears that if a nation permits other nations to access its territory for investigative purposes, there is adequate evidence to demonstrate compliance with the disarmament treaty. However, in actuality, such comprehensive authorization is nearly unattainable. Consequently, this type of entirely authorized oversight frequently evolves into the clarity of the information that a nation can reveal regarding arms control. Due to the complexities of territorial sovereignty between nations regarding physical space, it appears more prudent to reduce the emphasis on physical invasion and concentrate primarily on information disclosure, particularly for technologically advanced countries.

A major determinant in this matter is information, which encompasses insights into a nation's intentions and capabilities. It not only demonstrates a nation's readiness to collaborate but also indicates the status of its military capabilities. Nonetheless, the challenges of disarmament discussions continue to be evident in past actual experiences. The aforementioned challenge mostly arises from the conflict between information transparency and national security. Consequently, the function of this information in pursuing arms control collaboration brings us to the subsequent topic, specifically the balance between information transparency and national security.

## **2.2 The Balance between Transparency-Security as An Important Point in the Security Dilemma under the Arms Control's Issue**

The formulation of arms control treaties and the development of corresponding verification systems necessitate a thorough examination of this dichotomy: an excessive focus on information transparency may undermine national authority due to the high level of information exposure, significantly diminishing the nation's willingness to adhere to disarmament accords; conversely, an overemphasis on safeguarding national security concerning sovereignty and sensitive military information could hinder the disarmament agreement's effectiveness in attaining global disarmament objectives, as inadequate transparency would obstruct the verification mechanism's ability to ascertain compliance with disarmament commitments (COE & VAYNMAN, 2019). Consequently, from this viewpoint, the attainment of the global disarmament objective is seen essential, namely to establish prudent institutional frameworks that ensure a balance between information transparency and national security. The examination and discourse by Andrew J. Coe and Jane Vaynman regarding the transparency-security trade-off indicate that the balance between information transparency and national security perception has influenced nearly all disarmament negotiations, particularly during the Cold War era. It is noted that previous disarmament studies overlooked this balance relationship and concentrated primarily on national motivations, thereby inadequately elucidating the challenges in achieving disarmament agreements and the restrictive conditions necessary for the effective construction and operation of verification mechanisms (COE & VAYNMAN 2019: 343).

The discourse and examination by Andrew J. Coe and Jane Vaynman identify two pivotal elements that enhance the advancement of disarmament accords and significantly influence the development of the

verification framework. The initial step is to create a verification entity that is reliable for all stakeholders in the contracting nations. Engaging an independent third-party verification entity can, in theory, mitigate the conflict between information transparency and national security, contingent upon the trust of all involved parties in the third party's capabilities, which must be independent, neutral, and equipped with verifiable methods of assessment. Moreover, the third party may acquire requisite authority from many nations and reveal solely the information needed to ascertain if the States Parties have adhered to disarmament obligations. The effective implementation of verification measures in the CWC and the NPT demonstrates the practicality of employing an independent third party as the verification entity. Consequently, particularly in the domain of biological weapons regulation, under the auspices of the current multilateral disarmament treaty, the BWC, it is more judicious to establish an independent third-party verification body based on practical experience.

Furthermore, technological advancements have expanded the avenues for acquiring information, allowing oversight and validation to diverge from the overdependence on physical inspections. Andrew J. Coe and Jane Vaynman's study highlighted a significant hypothesis that, in the latter half of the 20th century, advancements in communication technologies and other innovations contributed to the rise in arms control agreements established during that time (COE & VAYNMAN 2019: 352). Based on their deduction model and the negotiations between the United States and the Soviet Union concerning nuclear weapons oversight during the Cold War, a significant conclusion is that the advent of remote sensing technology enabled remote supervision methods, eliminating the necessity for intrusive on-site verification at all times and locations. This advancement allows for the identification of prohibited facilities thru remote monitoring, thereby achieving a degree of information transparency essential for verification while mitigating national security risks compared to traditional on-site verification methods. Ultimately, both nations consented to implement a remote monitoring oversight model, alleviating the conflict between information transparency and security (COE & VAYNMAN 2019: 353). This has resulted in the inference that the domain of biological weapons regulation may also gain from this theoretical aspect. The United States emphasized in its address at the 80th United Nations General Assembly in September 2025 its dedication to improving the verification and adherence to the BWC via advancements in artificial intelligence technology (Field, 2025). This resembles its discussions with the Soviet Union concerning nuclear armaments during the Cold War. As a facet of computer technology, artificial intelligence is adept at managing online information with minimal disruption to physical domains, namely sovereign territories. This facilitates remote oversight and validation, so transmitting a comparable message to past experiences: depending increasingly on distant data and information-driven monitoring techniques is a more viable option for the United States. This has significant relevance in the formulation and discussion of the BWC verification system, as the resistance from the United States was the primary factor leading to the unsuccessful discussions of the BWC protocol.

### **3 Challenges and Necessities of construction of the verification mechanism of BWC**

### **3.1 Challenges of the verification mechanism of BWC**

During the Fifth Review Conference in November 2001, the United States sought to dissolve the Ad Hoc Group by revoking its mandate. Despite the unsuccessful endeavor, the Ad Hoc Group was preserved. Nevertheless, subsequent to that, the contracting entities failed to achieve a consensus on reinstating the discussions of the Ad Hoc Group (Feakes & Littlewood, 2002). Consequently, the collapse of the Ad Hoc Group discussions at the close of 2001 signified a significant setback in the negotiations about the verification mechanism of the BWC. Following the exit of the Bush administration and the inauguration of the Obama administration, the United States' stance on the verification system remained unchanged, contrary to the expectations of the international community. During the 2010 Meeting of States Parties, the United States explicitly indicated that it did not deem it an opportune moment to recommence discussions on the protocol, and the advantages of the BWC's verification mechanism remained largely unchanged (U.S. MISSION GENEVA, 2010). The disposition of the United States government, akin to that of 2001, was largely at odds with the desires of the majority of contracting parties. This unfavorable position endured for an extended period.

Excluding the United States, other nations often exhibited a positive outlook toward the establishment of the verification mechanism. The European Union endorsed the development and implementation of concrete, actionable, and pragmatic strategies to ensure adherence to the BWC (the Member States of the European Union, 2024). In the lack of a definitive verification protocol, the European Union urged all nations to engage in Confidence-Building Measures (CBMs), positing that CBMs serve as a viable substitute for the BWC verification mechanism to some degree (the Member States of the European Union, 2024). Russia delivered a document outlining practical approaches for the verification mechanism to the Working Group on Strengthening the Convention, advancing discussions on the development of the BWC's verification mechanism (the Russian Federation. 2024), and issued several joint statements with China, highlighting the imperative to bolster the BWC and attain an agreement that includes a robust verification mechanism and a legally binding protocol (UNODA, 2021).

Concerning the historical conflicts and difficulties associated with the verification mechanism of the BWC, this addresses the initial inquiry posed in the latter section of this article about the Security Dilemma within the realm of international disarmament collaboration, emphasizing that nations must cultivate a readiness to collaborate prior to engaging in detailed subsequent discussions. Simultaneously, given that the ultimate failure of the negotiations regarding the protocol discussion stemmed from the United States' opposition, it also addresses another crucial element highlighted in the latter section of this article, namely, that to mitigate this Security Dilemma and ultimately attain cooperative objectives, we must adjust the institutional framework to prioritize the security concerns of technologically advanced nations.

### **3.2 Necessities of the verification mechanism constructing of BWC**

### **3.2.1 Inadequate Binding Force of Internal-BWC Existing Measures**

The lack of a verification mechanism hinders the acquisition of information regarding biological activity in States Parties, complicating the evaluation of their compliance. Consequently, Confidence-Building Measures (CBMs) designed to improve transparency inside the BWC framework were developed. CBMs were initially suggested at the Second Review Conference in 1986 and have undergone ongoing revisions, ultimately establishing a voluntary information-sharing framework based on six categories (the Implementation Support Unit, 2022). In accordance with applicable regulations, States Parties must provide the Implementation Support Unit (ISU) with information on CBMs by April 15 annually, and they have the option to either disclose the information publicly or limit access just to other contracting states (United Nations, 2026a). Nonetheless, the inherent voluntary aspect of CBMs from the outset is a crucial constraint.

Primarily, the inadequate involvement of States Parties constitutes a significant barrier hindering CBMs from improving the enforcement of the BWC. The data indicates that while the submission rate of CBMs has notably risen (surpassing 100 documents for the first time in 2023 and achieving 122 documents in 2025) (United Nations, 2026b), there is significant potential for enhancement when juxtaposed with the total of 186 States Parties. Regardless of their involvement, the absence of obligatory enforcement results in varying levels of participation among each State Party. This scenario of partial engagement and fluctuating participation diminishes the equity of CBMs and has a restricted impact on enhancing the overall compliance rate. The current submitting status of States Parties demonstrates that CBMs have not succeeded in establishing effective factual coercive authority.

Secondly, the barriers to information gathering and the limitations on quality have curtailed the reinforcing impact of CBMs on the BWC. Regarding the procurement of information, merely a few of nations deliberately opt to provide information openly in practice. The percentage of publicly available reports has consistently remained under 35% from 2021 to 2025 (United Nations, 2026b). This means that the CBMs system that relies on voluntary participation cannot ensure the quality of information through third-party supervision in the absence of an enforcement agency capable of conducting information verification. Regarding the caliber of information disclosure, the structure of the CBMs forms is somewhat generic, lacking explicit criteria for information precision, which permits nations to independently decide the extent of disclosure. Furthermore, due to the functional positioning issues of the ISU, it only assumes a rudimentary information collection role. It is not an oversight entity, as it neither analyzes CBM information nor verifies the authenticity of submitted data, and this lack of verification regarding information authenticity hampers the ability of CBMs to support systematic compliance conclusions.

### **3.2.2 The Limitations of the Adaptability of External-BWC Measures**

Owing to the inadequate efficacy of the previously described CBMs as evaluative tools inside the BWC framework for implementation, many States Parties have sought other mechanisms beyond the BWC, including Peer Review. This mechanism is characterized by the Organization for Economic Cooperation and Development as a framework wherein nations do systematic evaluations to gage the efficacy of other nations, aimed at enhancing decision-making and practices (Revill, 2013). This notion was presented by France during BWC deliberations in 2011, advocating for the creation of a mutual assessment framework among States Parties concerning their implementation circumstances (France, 2011). Subsequently, France initiated the inaugural effort in 2013 (France, 2013), while Belgium, Luxembourg, and the Netherlands executed assessment exercises in 2015 (Belgium, Luxembourg & the Netherlands, 2015).

The previously mentioned process of Peer Review exhibits numerous essential traits. Initially, it significantly depends on the voluntary engagement of States Parties, with the decision to partake in Peer Review and its extent being chosen by the states themselves (Revill 2013: 12). Secondly, the Peer Review content has been segmented, enabling States Parties to select review areas independently in addition to the obligatory modules (Revill 2013: 13). Third, it underscores a collaborative approach, given that current Peer Review methodologies also serve the purposes of policy discourse and technical interchange (France, 2013). Fourth, it is exceptionally specialized, as this methodical evaluation depends significantly on specialists in particular domains to guaranty the review's quality (Revill 2013: 75–76). Nonetheless, its fundamental constraint resides in these factors, as its significant dependence on voluntariness implies that this mechanism can solely encompass States Parties with a genuine intention to adhere, yet it cannot deter prospective defaulters, and the modular structure of the content may be manipulated to selectively convey a misleading semblance of compliance instead of revealing the actual implementation status. Consequently, this optional and incomplete external metric cannot achieve the fundamental purpose of the verification mechanism.

In summary, both the current CBMs within the BWC framework and the external initiatives like Peer Review, alongside the technologies and methodologies employed, as well as the incremental successes of the involved States Parties, suggest that advancements in technology, particularly in remote data monitoring, can bolster the engagement of States Parties. Nonetheless, both possess inherent constraints stemming from their significant dependence on voluntariness and the inadequate thoroughness and veracity of the information revealed. Simultaneously, both entities are devoid of a crucial independent third-party verification body that could reconcile information transparency with national security, so failing to alleviate this tension fundamentally. Consequently, developing a formal verification system for the BWC that can reconcile the need for information transparency with security remains a crucial approach to addressing the practical challenges in biological arms control.

## **4 the Accessibility of Construction of the Verification Mechanism of the BWC**

## 4.1 Consensus of the Construction of the Verification Mechanism

The document presented by the European Union to the BWC underscores that the establishment of the verification mechanism must rely on consensus among the States Parties (the Member States of the European Union, 2024). In recent years, the development of the BWC agenda and the position documents of the States Parties have validated that a consensus has been established.

China fervently supports the establishment of the verification mechanism. In 2022, China presented a working document at the Ninth Review Conference, underscoring the urgency of implementing an efficient verification mechanism promptly and reinforcing the Convention, which is a collective obligation of the States Parties and should be prioritized during the Review Conference (China, 2022). Following the Ninth Review Conference, the United States engaged proactively in discussions inside the BWC framework and presented materials. Despite not addressing the request for legally binding measures, the documents it presented to the Working Group on Strengthening the Convention encompassed the verification mechanism and introduced the notion of the Verification Toolbox (United States of America, 2024). Additionally, during the 80th United Nations General Assembly in 2025, President Trump suggested the implementation of an AI system to improve the verification and compliance to the BWC (Field, 2025). This shown a commendable readiness for collaboration, particularly as the nation that wielded the most significant impact on the prior discussions over the procedure. France championed the verification system during the Working Group meeting in 2024 (France, 2024). The 27 member states of the European Union unequivocally endorsed the development of precise and attainable measures for verification and compliance in the collaborative agreement (the Member States of the European Union, 2024). Russia evaluated potential on-site verification methods considering the advancements in biotechnology and emphasized the necessity of expert evaluation of possible verification techniques prior to deliberations on establishing the verification mechanism (the Russian Federation, 2024). Cuba sought the reinstatement of discussions regarding a legally binding protocol at the Ninth Review Conference (Cuba, 2022). Thailand endorsed the facilitation of dialogs concerning verification and compliance matters (The Kingdom of Thailand, 2024).

This multi-tiered engagement of the global community corroborates the international consensus formed of the verification mechanism. Primarily, the acknowledgment of global regulations by independent nations establishes the foundation for their adherence. The prevailing agreement suggests that States Parties have, to some degree, shown a readiness to participate in international disarmament collaboration, thereby satisfying the condition for addressing the alleviation of the Security Dilemma in global cooperation and further reconciling the conflict between information transparency and national security; Furthermore, the international consensus itself represents a manifestation of shared human interests, which not only underscores the importance of establishing a verification mechanism but also illustrates the collective intent of the States Parties to advance it.

## 4.2 The Practical Foundation of the Verification Mechanism for International Disarmament

The current extensive treaties governing weapons of mass destruction among the international community have predominantly instituted a verification process. The disparities in their models primarily arise from historical context, weapon attributes, and regulatory stipulations. Based on the legislative framework, they can be categorized into three types: core type focused on data disclosure, core type centered on technological monitoring, and a combined type of data and on-site inspection.

The NPT exemplifies the data disclosure fundamental category of regulatory strategy. This accord, in partnership with the IAEA, has instituted a multilateral verification system. Upon its inception in 1957, the IAEA's primary obligation was to furnish security assurances (Carlson, 2020). In 1965, the IAEA began to undertake the verification duties outlined in the treaty (Carlson 2020: 6). Subsequent to 1970, its duties expanded, progressively establishing a verification framework focused on material accounting, augmented by closed and monitoring protocols (Carlson 2020: 21). The operational features are primarily exhibited as follows: firstly, the principal procedure involves the closed-loop oversight of nuclear material transactions (IAEA, 1997); secondly, it performs more than 3,000 on-site verifications annually (IAEA, 2025); thirdly, the IAEA fulfills dual roles in both verification and the advancement of nuclear energy use. The significant influence of this mechanism model primarily arises from the particularity of nuclear proliferation, together with its robust association with materials and infrastructure, fostering an efficient synergy between data and on-site verification. It is important to acknowledge that the IAEA, functioning as a multilateral third-party independent institution, concurrently holds significant supervisory responsibilities and authorities.

The CWC exemplifies a regulatory strategy that integrates both data and on-site methodologies. This verification method is more methodical and exhibits enhanced functionality, emphasizing the importance of on-site verification. It mandates that States Parties diligently submit facility information, after which the convention organization performs initial verification and ongoing assessments (UNODA, 2020a). This verification mode notably establishes an inquiry-based inspection system, allowing any States Parties to request obligatory verification at any site without prior consultation (UNODA, 2020b). The notice timeframe for this inquiry is brief and cannot be declined, leading to its significant intrusion. All verifications are required to generate reports, with routine reports provided via a confidentiality protocol and the inquiry verification reports forwarded to the Director-General for assessment and dissemination (UNODA, 2020b). The attributes of this approach include: being governed by an independent third-party entity; prioritizing thorough on-site validation; and establishing a comprehensive dispute resolution framework. These design elements primarily cater to the attributes of chemical weapons manufacture, which depends on extensive chemical manufacturing facilities and is readily recognizable and traceable.

Historically, both the NPT and the CWC have illustrated the efficacy of employing an independent third-party institution as the verification entity, which has enabled the successful implementation of the

verification system.

## 4.3 Supports from Emerging Technologies

Technological advancement facilitates the functioning of the verification system. The VEREX expert group previously indicated that the BWC is subject to verification (United Nations, 1992). More than three decades of scientific advancement have enhanced the verification toolkit.

Artificial intelligence (AI) can assume two distinct functions in the detection of biological threats. One approach involves extracting potential biological weapon threats from open-source data, with AI capable of scrutinizing scientific literature, patents, or research initiatives to detect dual-use hazards (Chile, 2025); another method entails uncovering concealed biological weapon risks within information released by nations, where AI can evaluate diverse disclosures (such as CBMs data) to ascertain any non-compliance by the States Parties (Revill, 2025).

Blockchain technology can be utilized for the mitigation and tracking of biological hazards. Blockchain technology can secure the documentation of sensitive biological technology operations reported by different nations for verification agencies or States Parties to access, and in the event of a biological threat, the verification agencies, can trace the origin of the danger thru the records produced by the blockchain, aiding in subsequent responses (Chile, 2025).

Furthermore, the advancement of the verification system has demonstrated a profound positive relationship with technological innovations: throughout the Cold War, remote sensing technology led to a comprehensive verification framework, whereas modern advanced technologies are forging novel avenues for the verification of biological armaments, such as high-precision remote sensing facilitating real-time environmental surveillance, artificial intelligence aiding in the amalgamation of diverse data sources and the detection of anomalous activities, and the global public health network establishing biological monitoring points; cloud computing markedly improves the efficacy of genomic and environmental data analysis (Berke, 2025). These technical advancements not only improve the practicality of verification but also offer a substantial basis for developing the verification mechanism of the BWC. The techniques selected by the verification system that arose with technology advancements, along with the established model practices in international disarmament, all reflect a minimally invasive strategy centered on remote information and data surveillance. Consequently, in the realm of biological weapons regulation, it is imperative to thoroughly use the successful methodologies and developmental insights of this nature.

To more accurately illustrate the impact of the Security Dilemma and its alleviation strategies on the BWC verification process, along with the connection to the mechanism design in the subsequent section, we have created Fig. 1 for clarification.

## 5 the Pathway to Constructing the Verification Mechanism of BWC

## 5.1. The Newly Established Executing Agency shall be the Main Body of Verification Implementation

According to the current methodologies of international arms control agreements, there are two primary approaches for executing the verification mechanism. The initial approach entails States Parties acting as the verification body, but the subsequent mode incorporates a newly formed or authorized independent organization as the verification entity. The initial mode is exemplified by the New START Treaty, in which the States Parties function as the verification body. This verification mechanism works by depending on discussions among States Parties to establish verification protocols and criteria, followed by the execution of verifications. In a similar vein, conflicts identified throughout the verification process are predominantly addressed by the bilateral consultation committees that have been established (The United Nations and the Russian Federation, 1993). The limitation of this model is also found in this facet. While this approach allows for comprehensive verification according to the specific conditions of the States Parties, the fact that the States Parties serve as the verification bodies means that one nation's information will be immediately revealed to its counterpart. This feeling of uncertainty is coupled with the rigor of the validation process and is challenging to mitigate. The second method is characterized by the CWC, wherein a designated or sanctioned executive body is tasked with carrying out verification duties, including the gathering and processing of information, as well as doing on-site verifications. This paradigm emerges from the necessity for multi-party agreements to foster confidence among State Parties. Nevertheless, the extensive number of States Parties renders mutual verification among all of them unfeasible (OPCW, 2026). Opting to delegate the verification to an entity sanctioned by all States Parties is a more pragmatic decision. Despite being limited by elements like the extensive number of member states and independent functioning, the verification conducted by these executive entities may exhibit reduced detail and challenge severity relative to the initial bilateral model (OPCW, 2026). Nonetheless, the limitation regarding intensity presents a chance for enhanced information transparency and the strain on national security. The verification technique of relatively low intensity can restrict the revelation of certain facts about a nation, so diminishing the threat to its sovereignty.

Leveraging prior experience, this study posits that a model featuring an independent executive agency as the implementing body is more appropriate for the arms control requirements of the BWC. Initially, there is an absence of an appropriate authorized entity inside the current international biological arms control domain. The accredited organizations represented by the IAEA, possessing attributes like robust professionalism, significant recognition, and extensive universality among member nations, fail to satisfy the criteria. Nonetheless, the diverse entities within the global biological weapons control domain frequently exhibit a lack of universality, and the endorsement of these organizations may influence member states' impartiality regarding the verification method. This framework corresponds with the primary critical element and remedy for mitigating the conflict between information transparency and national security, which involves establishing an independent third-party entity, jointly sanctioned by the States Parties, to serve as the verification authority. In this approach, an independent executive body created beyond the States Parties of the BWC can more effectively promote compliance among States

Parties and facilitate the seamless functioning of the verification mechanism. Initially, the assessment performed by the executive body established under the BWC can substantially improve the compliance readiness of the involved parties. The independence of the executive agency diminishes the intrusion of the States Parties in the information and verification outcomes. In contrast to the concept where States Parties serve as the verification bodies, ensuring information transparency helps mitigate nations' concerns about their sovereignty security, improve the equity of the verification system, and subsequently promote adherence. Simultaneously, the verification outcomes of the executive agency are acknowledged via the formal protocols established by the BWC, and this process inherently fosters the internal readiness of the States Parties to embrace the verification. Secondly, the recently formed executive agency can effectively address the multi-faceted dynamics of the BWC with its 189 contracting partners. Its cohesive management of data gathering, validation execution, and intelligence assessment can more efficiently facilitate the identification and prevention of infractions, as well as foster mutual confidence among contracting entities, representing a viable approach to guaranty the seamless functioning of extensive multilateral verifications.

## **5.2 A Comprehensive Verification Mechanism Utilizing Data**

The verification methodologies of current international weapons control treaties typically employ a strategy that integrates data gathering with on-site inspections. Nonetheless, there are minor distinctions in the focus of the two particular verification techniques. The initial approach, shown by the NPT, emphasizes data acquisition and predominantly depends on analytical findings to ascertain compliance status. This methodology exhibits reduced invasiveness and predominantly utilizes non-site methods like satellite surveillance and declaration documents to gather information. On-site verification serves merely as a supplementary action or is activated when anomalous data points suggest a danger of non-compliance. Consequently, the range of verification is very limited. The criteria for establishing this verification model stipulate that external technologies must proficiently detect long-term and markedly unique aberrant indicators (Tucker, 1998). Diminishing the intrusiveness of verification to a moderate extent can facilitate greater acceptance among States Parties. The second model, characterized by the CWC, relies more heavily on the outcomes of on-site verification and exhibits a more rigorous and intrusive verification process (UNODA, 2020c). This strategy incorporates a data collecting step; nevertheless, its ultimate findings predominantly stem from on-site examinations. The standard verification and the difficult verification under the CWC framework are both classified as on-site investigative techniques. The former serves to authenticate reported information, while the latter is employed to validate concerns of infractions (UNODA, 2020b). This model's practical profundity surpasses the data-centric validation. The conditions for its applicability primarily depend on the existence of certain anomalous events that persist for an extended period yet have a restricted range, necessitating identification by on-site verification (Tucker 1998: 88–91). Concurrently, pertinent facilities possess a scale attribute, enabling the execution of on-site verification domestically.

In order to more effectively honor national sovereignty and subsequently improve the acceptance of States Parties regarding the verification mechanism, while taking into account the nature of biotechnology and current practices, the BWC's verification mechanism ought to implement a hierarchical model primarily focused on data collection and analysis, with on-site inspections serving as a supplementary measure. Monitoring is often conducted via data analysis, with on-site inspections commencing only when evidence suggests a significant danger that cannot be dismissed using non-invasive techniques. The advancement of developing technologies allows remote data monitoring to partially assume the verification role. This corresponds with the second crucial element and remedy for mitigating the conflict between information transparency and national security, which advocates for the avoidance of predominantly intrusive on-site verification techniques, favoring instead monitoring approaches that utilize less demanding information technologies relative to the physical environment, thereby reducing the strain of the Security Dilemma. Initially, while the verification system is not yet in place, the creation of a new one necessitates priority the endorsement of States Parties. Selecting a methodology that prioritizes data gathering and analysis rather than physical inspections presents less obstacles to a nation's sovereignty. Data-driven validation employs national assertions and external oversight (Preparatory Commission, 2026), featuring manageable distribution techniques and reduced interference; conversely, on-site evaluations necessitate entering the nation to examine sensitive installations, so considerably heightening the difficulty. By moderating the rigor of verification and honoring the sovereignty of States Parties, this methodology not only embodies the essence of the United Nations Charter but also fosters greater acceptance among contracting parties. Secondly, the attributes of biotechnology need an emphasis on data gathering and examination. In contrast to the chemical sector, biotechnology's dual-use potential is more pronounced, the barriers to weapon manufacturing are diminished, and atypical indicators alongside natural occurrences like epidemic outbreaks are more readily misinterpreted (Tucker 1998: 81–83). A variety of elements have contributed to a notable rise in the burden of on-site verification for biological weapons, yielding minimal outcomes. Prolonged observation grounded in data evaluation is more practical.

Moreover, the validation of biological armaments encounters distinct obstacles. A composite verification system must be established that incorporates technical oversight alongside the fundamental data monitoring. Initially, the significant dual-use characteristics of biotechnology result in fluctuating alterations in high-risk raw materials. For instance, low-risk substances can be converted into armaments, but high-risk substances may also serve benign functions. Secondly, environmental indicators capable of detecting biological weapons are present, including the brief lifespan of aerosol particles, which generally lasts from a few hours to many weeks, and they can be readily mistaken for natural occurrences (Tucker 1998: 94). This resolution necessitates the BWC to transcend a singular model and develop a composite verification framework focused on technical oversight and incorporating the synergy of many technologies. The particular foundation for this is outlined as follows: Initially, the necessity for technical flexibility necessitates creative amalgamation. Artificial intelligence can detect possible external threats in open-source information, microbial forensic science can aid in the traceability of anomalous signals, and nucleic acid sequencing can oversee commercial gene production

(Berke, 2025). The continual enhancement of technological tools not only improves monitoring precision but also bolsters the trust of States Parties in the efficacy of the verification system. Secondly, the tenet of technical objectivity and impartiality mitigates the potential for politicization. A solitary verification mechanism not only inadequately guarantees the successful execution of the convention but could also transform into an instrument of global discord. Despite the intrinsic impartiality of technical monitoring, its implementation and the interpretation of outcomes may nonetheless be influenced by political factors. To guaranty the authenticity of verification, it is essential to maintain institutional seclusion to diminish political meddling and avert the transformation of the verification process into an instrument of geopolitical conflict.

## 6 Conclusion

In the realm of international politics, a nation's security protocols established for its own benefit may inadvertently jeopardize the security interests of other nations. The regulation of biological weapons, a crucial aspect of global disarmament efforts, is similarly affected by this predicament. The BWC, recognized as the paramount international convention for biological weapons regulation, has had its verification method extensively highlighted and debated about its role in attaining global disarmament objectives. The theory of information transparency and the equilibrium of national security offer solutions for mitigating the challenges of constructing this system. We utilize established analytical frameworks and have identified two significant factors that mitigate the "Security Dilemma": the first involves employing an independent third-party institution for verification, and the second pertains to remote monitoring facilitated by advancements in technology. A more in-depth analysis of the multiple approaches being pursued in the BWC has shown that neither CBMs nor Peer Review can address the Security Dilemma because there is no independent third-party entity to ensure information transparency and authenticity. Therefore, it is essential to develop a validation mechanism that satisfies these two criteria.

Consequently, to explore a more viable approach for developing the BWC verification mechanism, we have examined ways to mitigate the conflict between information openness and national security equilibrium, and have endeavored to suggest a series of remedies. Initially, we analyze the experiences of existing successful international disarmament accords that have implemented verification mechanisms, and emphasize the necessity of creating an independent third-party organization within the BWC framework to function as the verification body. Secondly, based on the advancements in technology, particularly artificial intelligence and remote data monitoring systems, a more flexible verification framework ought to be established, emphasizing data oversight and reserving on-site intrusive verification for exceptional situations. Simultaneously, given the inherently dual-use characteristics of biotechnology, a comprehensive verification system reliant on technical oversight ought to be instituted.

## Declarations

## Author Contributions

Y.H. and Y.X. developed the argument presented in this article. Conceptualization, Y.H., and Y.X.; Methodology, Y.H., literature review, Y.H., and Y.X.; writing—original draft preparation, Y.H., and Y.X.; writing—review and editing, Y.H. and Y.X.; supervision, Y.X.; project administration, Y.X.

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## Declaration of Interest

The authors declare no conflicts of interest.

## Data Availability

Data sharing is not applicable to this research as no data were generated or analysed.

## Ethical Approval.

This article does not contain any studies with human participants performed by any of the authors.

## Informed Consent

This article does not contain any studies with human participants performed by any of the authors.

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## Figures

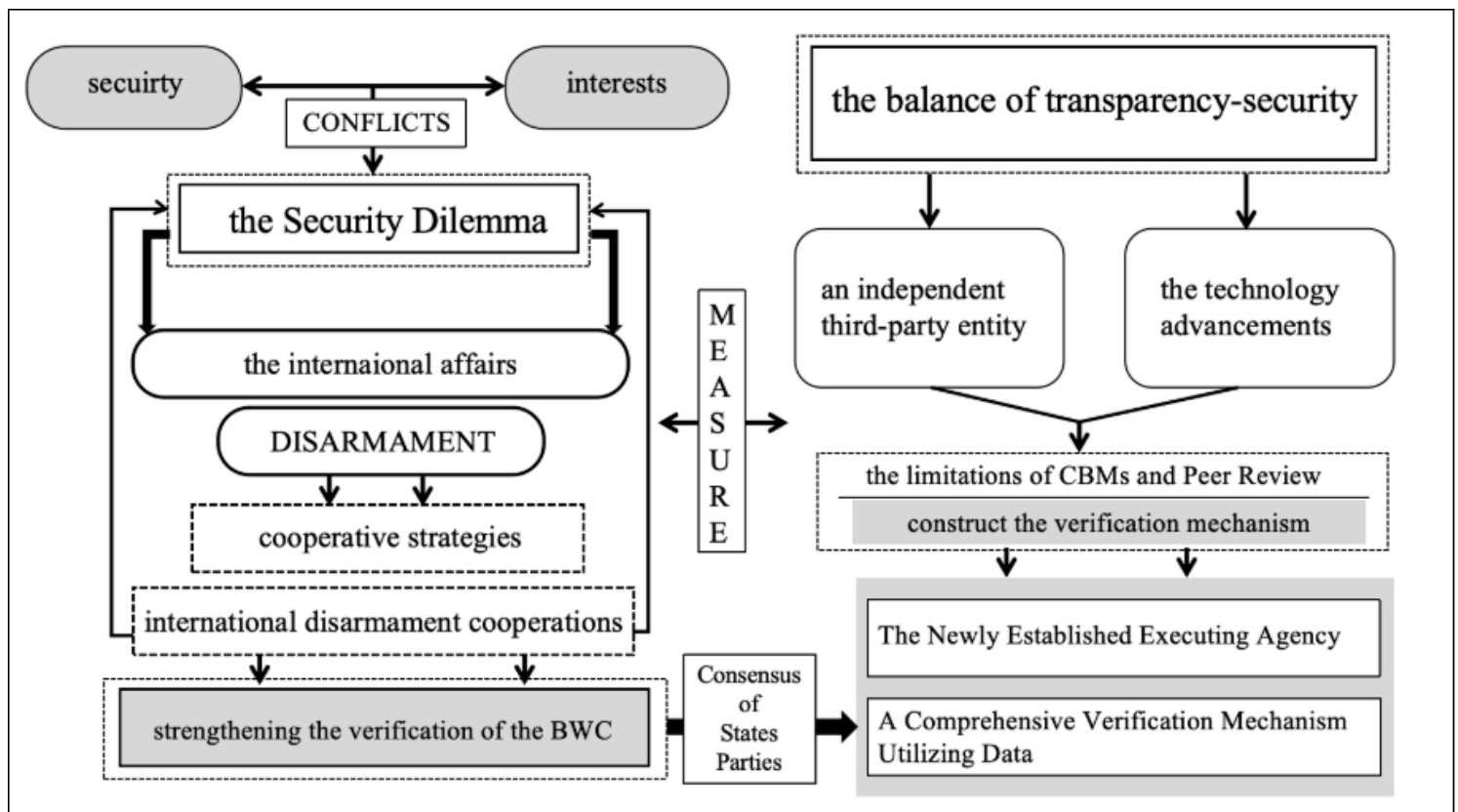


Figure 1

the relationship of the Security Dilemma and the construction of the verification mechanism of the BWC