Creating a Verification Protocol for the Biological Weapons Convention:

A MODULAR-INCREMENTAL APPROACH

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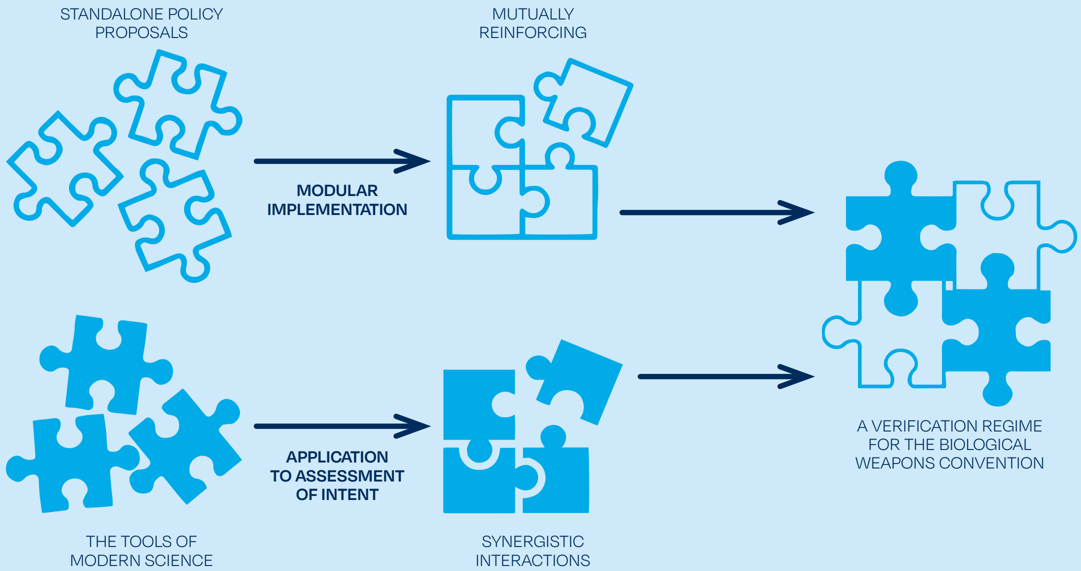
Executive Summary

The 1972 Biological and Toxin Weapons Convention (BWC) is severely weakened by a lack of a workable verification mechanism. Throughout the treaty's 50-year existence, signatory State Parties (SPs) have disagreed on numerous political and technical issues, blocking the creation of a verification regime. Meanwhile, innovations in the biosciences have radically reimagined what is possible not just in sophisticated state-funded labs, but in commercial facilities and individual homes as well, creating opportunities for advancements, but also vastly increasing means for misuse.

More effective governance is hindered by a failure to rethink "verification" in light of the ambiguities inherent in modern biotechnology. It simply is not possible to "verify" compliance with the BWC in the same way as other arms control conventions from the 20th century. The authors consulted subject matter experts as part of a review of relevant literature in an attempt to redefine what verification should mean for the BWC. Through this process, they developed a new definition centering around a novel approach to verification: an ongoing assessment of a signatory's *intent* to comply with the BWC. Implementing this definition requires that any verification mechanisms incentivize cooperation, leaving only malintent as a reason for resistance.

We propose taking a modular-incremental approach (Figure 1) to establishing a comprehensive verification regime under this new definition. This strategy proposes an array of stand-alone policy proposals that comprise the pillars of a comprehensive verification regime. Each mechanism is mutually reinforcing, supported by the tools of modern science, and designed to adapt flexibly and incrementally to changing scientific and political conditions. The concept recognizes that, ungoverned, modern biotechnologies potentially pose an existential threat to humanity, and progress toward establishing effective governance structures must be made, even if that means settling for incrementalism.

Figure 1: The Modular-Incremental Approach envisions individual policy proposals and the tools of modern science as interlocking puzzle pieces. Each piece performs a vital role individually, with each additional piece building out a more complete picture. The mutually reinforcing and synergistic interactions between and among both the various policy proposals and the tools of modern science enable the development of a functional verification regime for the Biological Weapons Convention.



Methodology

The definition of "verification" in the arms control context relies on three operational components: gathering information related to the fulfillment of an obligation; analysis, interpretation, and evaluation of that information; and assessing compliance with the obligation (Drobysz, 2020; Zilinskas, 1998). This approach naturally lends itself to an "accounting"-driven framework that meticulously documents facilities, tools, and raw materials relevant to state treaty obligations which is both technologically and practically infeasible in the context of the BWC (Trapp, 2019; Lentzos, 2019). Unlike developing nuclear or chemical weapons, creating a biological weapon (BW) presents fundamentally different verification challenges as required materials are relatively cheap, increasingly accessible, and critically important to peaceful applications of modern bioscience (NASEM, 2018).

To redefine verification in the context of a 21st century biological arms control treaty, the authors engaged subject matter experts (Edwards, 2022; Hobson, 2022; Lancaster, 2022; Warmbrod, 2022; Sandbrink, 2022) and conducted a literature review to identify shared themes. This examination revealed that there is virtually no agreement among stakeholders on what "verification" should mean (Shearer, Potter, Vahey et al., 2022). However, there was some agreement that the objective of any verification regime for the BWC should focus less on reaching a binary determination of compliance. Instead, verification should be an ongoing process of data monitoring, assessment, and evaluation aimed at appraising a SP's intent to comply with the BWC while also accounting for ambiguities inherent in the dual-use nature of biotechnology (Revill, 2017). By 'ambiguities' the authors refer to the fact that advances in modern biotechnology have the potential to be used for offensive as well as peaceful purposes and that discerning between them is not straightforward.

In addition to the significant definitional issues, the authors explored other challenges to establishing a verification regime, including the dual-use nature of biology as a technology, pre-existing political fractures among SPs, and lack of effective and financially sustainable governance mechanisms.

Findings

Any discussion of verification challenges must begin with funding. Unlike other treaties, the BWC lacks a sustained source of funding (Mackby, 2019). Without consistent institutional support, many SPs struggle with national implementation (Implementation Support Unit, 2016; Lentzos, 2015). Additional funding, perhaps sourced from an agreement on expanding the system of mandatory dues or from a permanent budget provided by the U.N. General Assembly, is critical for supporting national implementation and developing a workable verification regime.

Further, scientific breakthroughs have complicated the technical challenges the BWC faces. Ever-wider access to, and more effective iterations of, cutting-edge biotechnologies have made differentiating between peaceful and offensive applications of modern bioscience substantially more difficult. Simultaneous efforts to democratize cutting-edge biotechnologies have opened the door to potential misuse by corporations, sub-state organizations, and even individuals. These new ambiguities and distributed security risks have led some experts to argue that attribution, much less compliance verification, is currently impossible (Shearer, Potter, and Vahey, 2022). This paper offers solutions to some of the political and technical challenges that have led to this conclusion.

Despite the lack of a verification protocol, much progress has been made to create the tenuous status quo. While not universal, 183 ratifying states suggests that most countries would condemn the development or use of BWs. The norm against BWs has also been indirectly strengthened by complementary instruments such as the United Nations Security Council Resolution (UNSCR) 1540. However, in the face of the increasing accessibility and sophistication of biotechnology, the persistent inability to reach an agreed-upon verification mechanism for the BWC risks eroding that norm (Kahn, 2011). Although they broadly agree on the security risk posed by BWs, SPs have historically struggled to reach consensus on any politically realistic mechanism for resolving disputes among member states (Walker, 2020).

The prescribed methods for dispute resolution under the terms of the BWC are twofold. The first, Article V[4], directs SPs to "cooperate in solving any problems which may arise". The second, Article VI[5], creates a mechanism for elevating serious allegations to the UN Security Council (UNSC) for investigation. Though Article V has been successfully invoked in the past (Tucker, 2011), the highly politicized nature of the UNSC means that the outcome of triggering Article VI is unclear and unlikely to produce satisfactory results. Instead, it is assumed that the BWC would rely on the United Nations Secretary-General's Mechanism for Investigating Alleged Use of Chemical and Biological Weapons (UNSGM) if an international investigation ever became necessary. Dependency on the UNSGM as an investigatory tool has weakened the BWC by discouraging cooperative fact-finding and limiting the scope of investigations to outright violations.

The lack of a legally enforceable mechanism for collecting evidence for or against any allegation, owing to the voluntary nature of the Confidence-Building Measure (CBM) system, contributes to the BWC's reliance on outside investigatory mechanisms. The CBMs were proposed to facilitate information sharing regarding biological activities and build trust among state parties, but fewer than half of SPs submit them regularly (Implementation Support Unit, 2016; Revill and Maceda, 2022). National implementation and compliance monitoring is a costly and difficult endeavor, as access to certain information may be distributed across a federal system or may not be collected at all (Implementation Support Unit, 2016; Lentzos, 2015). Moreover, some states do not submit CBMs as they do not necessarily see the benefit either from providing the information or receiving it from other states (Koblentz and Chevrier, 2011).

4 Under Article V of the BWC, state parties agree on "Undertaking to consult bilaterally and multilaterally and cooperate in solving any problems which may arise in relation to the objective, or in the application, of the BWC."

5 Under Article VI of the BWC, state parties agree on the "Right to request the United Nations Security Council to investigate alleged breaches of the BWC and undertaking to cooperate in carrying out any investigation initiated by the Security Council."

The 2021 Global Health Security (GHS) Index provides evidence for why states are largely unprepared to deal with these risks (Bell and Nuzzo, 2021), and this is clearly exemplified by the death toll from the COVID-19 pandemic. Global cooperation, which is essential for responding to any major disease outbreak, is particularly important in the event of a BW attack. Measured across six metrics, the GHS Index indicated that the average country is not fully compliant with international health norms (Bell and Nuzzo, 2021). Specifically, the GHS Index found that general whole-of-government biosecurity systems lack oversight over potentially dangerous biological activities. Only 10.3 percent of states have updated national records of especially dangerous pathogen or toxin inventories and only 5.64 percent of states regulate dual use research (Bell and Nuzzo, 2021). Only 1.03 percent of states *require* synthesized DNA to be screened against lists of known pathogens prior to sale (Bell and Nuzzo, 2021), although about 80 percent of commercially synthesized DNA is *voluntarily* screened by the producer (Carter and Friedman, 2015). Indicators from the 2021 GHS Index point to a global inability to regulate potentially harmful biological activity or respond to emerging biothreats, highlighting the growing urgency of long-needed reforms to the BWC. Governance failures create opportunities for actors with malignant intent, undermining the "deterrence by denial" strategy often advanced by biosecurity analysts (Beaver, Lim, and Parr et al., 2021; Lebeda 1997; Owens 2009; Parthemore and Weber, 2021).

Policy Proposals

A MODULAR-INCREMENTAL APPROACH TO IMPLEMENTING A COMPREHENSIVE VERIFICATION REGIME

Previous efforts to build a verification regime for the BWC have been frustrated by political and technical challenges to meeting past verification objectives (Lentzos, 2019; Liang, Menghui and Xiaoli, 2021; Revill and Maceda, 2022). A different approach is imperative to avoid repeating past mistakes.

We propose that verification in the context of the BWC should be defined as "the collective evaluation of intent to adhere to both the positive ("to do") and negative ("not to do") obligations of the BWC." Actualizing this new definition will entail reducing the barriers to and incentivizing the submission of Confidence Building Measures (CBMs) by strengthening Article X[6], expanding institutional support to the member states, and instituting a formal mechanism under Article V to collaboratively review evidence of noncompliance.

Using our new definition of verification, we propose a modular-incremental approach to establishing a pragmatic verification regime for the BWC. The approach centers around maximizing initial political viability and long-term flexibility by offering a "menu" of stand-alone, minimalist improvements to BWC verification designed to adapt to future scientific advancements. Each of the *modular* proposals are designed to operate independently and reinforce each other as they are adopted. Although our individual proposals seem modest individually and narrow in scope initially, they are designed to achieve gradual progress despite difficult political and scientific realities. As SPs become confident in a modest version of each adopted proposal, they can then incrementally grow the scope and authority of each.

Incrementalism is not without challenges. It is possible that small successes may reduce the urgency to negotiate and develop stronger verification measures. However, achieving minor victories might also build rapport among SPs and generate political capital for making progress on more controversial issues. Without the benefit of omniscience, the pragmatic course of action is to accept that progress toward a functional verification regime is a preferable alternative to waiting for the perfect opportunity to enact a more sweeping, and potentially rigid, set of verification protocols.

The following policy proposals are enabled by tools of modern science that increase the value of available information and overcome barriers to past verification negotiations. Each proposal is paired with a specific example of a modern science and technology tool to exemplify how science can make policy more effective. These examples, however, should not be understood to be the only, or even the best, applications of modern scientific tools to this complex issue. By drawing on these tools, our approach emphasizes feasibility, flexibility, and progress.

Expansion of Permanent Institutional Support

Currently, institutional support for the BWC consists entirely of three non-permanent staff members with an overwhelming set of responsibilities (Jenkins, 2017; U.N. Office for Disarmament Affairs, n.d.). Properly supporting a comprehensive verification mechanism for the BWC will require additional institutional support for, among other things, reviewing CBM submissions, resolving technical disputes between SPs, and providing scientific guidance on emerging technologies (Chevrier and Hunger, 2000). We propose establishing a permanent and independent group of experts whose size, responsibilities, and authorities can be tailored to support an array of verification mechanisms. Experts may range from experienced thought leaders specializing in other disarmament treaties to industry specialists in emerging biotechnologies.

The first priority for the permanent expert group should be to conduct an ongoing review of CBM submissions to identify potential noncompliance and assess intent.

6 Under Article X of the BWC, state parties agree on "Undertaking to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and information for peaceful purposes."

Although there is currently little institutional data review that exists, Open Source Intelligence (OSINT) could enable an expanded Implementation Support Unit (ISU) to verify the accuracy of CBM submissions.

OSINT refers to intelligence derived from publicly available information, as well as other unclassified information that has limited public distribution or access. It has been successfully used to monitor compliance with nuclear (Hobbs and Moran, 2014; Panda and Dalton, 2021) and chemical (Hobbs and Moran, 2014) weapons disarmament treaties. Although the dual-use nature of biological activities complicates the types of signals that can be derived from open-source data, the application of OSINT techniques to monitor BWC compliance is not novel, as it is being used to identify discrepant CBM claims (Isla, 2006). Jeremias and Himmel (2016) also highlighted the ways in which state-level and commercial biotech activities can be subject to public monitoring. The ever-growing digitalization of commercial and academic research activities may prove to generate a greater volume of more relevant data that can be analyzed to provide signals for BWC compliance.

In addition to confirming the accuracy of CBM submissions, OSINT can help an expanded ISU provide additional facts to SPs during future allegations or negotiations, create previously overlooked links between seemingly unrelated sources, and generate a more complete picture of any data collected to support verification activities. As the verification mechanism is strengthened by the adoption of other proposals, SPs can seek the input of these independent experts to assist with updating CBMs to align with scientific advancements, establishing shared understandings of data or evidence, or conducting investigatory site visits.

Universalizing Confidence Building Measure Submissions

The current system of CBMs gathers information instrumental to determining a SP's intent to comply with their BWC obligations. However, the submission rate for CBMs is abysmal – 2021 was the first year since the CBM system came into effect that more than half of SPs submitted CBMs (Biological Weapons Convention Implementation Support Unit, 2022). SPs often cited technical and political challenges to making submissions (Biological Weapons Convention Implementation Support Unit, 2016; Biological Weapons Convention Implementation Support Unit, 2022; Lentzos, 2015). Overcoming this obstacle requires refocusing on collecting information most relevant to assessing intent while simultaneously incentivizing and lowering the technical barriers to CBM submission.

To maximize the value of CBMs, submissions should incrementally be made mandatory while offsetting the burden on states lacking technical expertise by creating a benefit sharing system. Form E, which asks SPs to declare legislation, regulations, and other progress toward national BWC implementation, is an ideal starting point for mandating CBM submissions because it provides insight on intent by revealing how much effort highly capable SPs are putting into national implementation (Chevrier and Hunger, 2000). Form E also would be useful for targeting needed support for national implementation, optimizing the distribution of aid under any benefit-sharing system.

Although current efforts to strengthen national implementation of CBMs through training workshops are laudable, they are usually subject to the availability of funding by individual SPs (U.N. Office for Disarmament Affairs, 2021a; U.N. Office for Disarmament Affairs, 2021b). Our proposed benefit sharing system would enhance Article X by obligating the sharing of financial and technical resources by SPs with an established track record of CBM submissions with new or under-resourced SPs to support national implementation. This system is similar to existing benefit sharing systems such as the Pandemic Influenza Preparedness Framework (World Health Organization, 2019). Pairing mandatory CBM submissions with a benefit sharing system would ease the burden of mandating CBM submissions and incentivize voluntary submissions (Revill and Maceda, 2022).

Although a benefit-sharing system for SPs encourages CBM submissions, we have identified two major barriers, other than malign intent, to universal CBM submissions: difficulty obtaining the necessary data and a perception of low informational value for the time investment. CBMs may be perceived as burdensome because of the sheer volume of textual data required and the lack of a consistent reporting standard, complicating both data collection and analysis.

Recent advances in artificial intelligence, including Natural Language Processing (NLP), have allowed for the integration of heterogeneous data structures in a process known as data harmonization (DH) (Kumar et al., 2021). DH is able to overcome the heterogeneity arising from structured, semi-structured, and unstructured (SSU) textual data to produce relevant insights. This has been successfully applied to analyze trends and aid auditing of multisource data in fields ranging from banking (Li, Chai, and Chen, 2015) to healthcare (Chondrogiannis Andronikou, and Karanastasis et al., 2019).

Text mining (TM) and DH can strengthen the perceived significance of CBMs in two ways. First, these methods can dramatically reduce the effort required to analyze CBM submissions and accelerate their contribution to investigative mechanisms. Second, TM can be augmented by automation to enable continuous, passive CBM monitoring. This can help uncover suspicious inconsistencies or activities in CBM submissions that might otherwise be overlooked by manual analysis. Simplifying analytical methods with DH and TM would facilitate reporting generalized data not targeted at any specific state party, which can lead to greater transparency in biological activities globally and increase the informational value of CBMs to SPs.

Collaborative Investigative Mechanism

Currently, Article VI provides for a legally binding mechanism to investigate allegations of noncompliance with the BWC. SPs have never triggered Article VI, partly because there is an assumption that politics within the UNSC would block any attempt to initiate an Article VI investigation. Instead, SPs are likely to turn to the UNSGM (Kimball, 2022), but it is not an ideal investigatory mechanism. The UNSGM is only as transparent as the UN Secretary-General decides it should be, potentially compromising universal acceptance of any findings. More importantly, it is designed only to *respond after* the initial deployment of a biological or chemical weapon (U.N. Office for Disarmament Affairs, 2022; U.N. Office of the Secretary General, 1987). It is critical for the scope of investigative mechanisms to include allegations of other types of noncompliance, including the development, production, and stockpiling of weapons.

An alternative investigative mechanism is needed to cooperatively review evidence and investigate potential noncompliance. Article V should be strengthened by expanding the mechanism whereby SPs can work together to establish an objective, scientific basis for dismissing, escalating, or continuing discussions of a wide range of issues at consultative meetings. This model was successfully tested in 1997 when the Republic of Cuba requested a formal consultative meeting to accuse the U.S. of violating the BWC (Tucker, 2011). The advantages of a collaborative investigatory mechanism under Article V, as opposed to utilizing the UNSGM or Article VI, are many. For example, it would increase transparency by allowing the accused and the accuser to openly state their positions and share their evidence. Critically, the accused's cooperation with a voluntary investigation, or the lack thereof, provides further evidence for other SPs to assess intent.

This Article V mechanism need not preclude or undermine the option of seeking an Article VI or UNSGM investigation. Rather, the goal is to establish a system for transparently, collaboratively, and scientifically assessing accusations while maintaining the threat of a "forceful" approach through the UNSGM. The tools of modern science can help parse potentially conflicting information during Article V deliberations. For example, genetic engineering attribution, enabled by advancements in DNA sequencing and computational analysis techniques, could be used to confirm or refute allegations of noncompliance if a novel pathogen is suspected to have been engineered and, if so, attribute its likely source.

Engineered organisms often present unique characteristics that arise from the different design decisions, style, intent, and tools chosen by the engineer. These signatures are now becoming easier to identify. Advances in high-throughput sequencing (Shendure, Balasubramanian, Church et al., 2017) and omic-scale phenotyping (Ritchie et al., 2015) can generate information that could ultimately attribute the source of an engineered organism to a specific lab (Warmbrod et al., 2020). Deep learning, a class of machine learning techniques that use multiple layers to progressively extract higher-level features from data, can facilitate the analysis of DNA sequences for attribution purposes. Alley et al. (2020) developed an algorithm *deteRNNt* that achieved more than 70 percent lab-of-origin attribution accuracy by using Recurrent Neural Networks on DNA motifs and simple phenotype information, complemented with attribution to the nation-of-origin and the ancestor lab. With genetic engineering attribution capabilities, having access to ancestor lab data and the nation of origin can help determine the lab that developed a genetically engineered DNA sequence. Because these signals will be absent from naturally occurring pathogens, it is possible to differentiate between organisms with natural origins and those with laboratory origins (Dembek et al., 2007; Grunow and Finke, 2022). At the current state of technology, the effective deployment of genetic engineering attribution to identify an origin lab may be limited by the lack of readily available lab data, especially for non-state actors. There is scope for international cooperation under Article V to develop and contribute to a shared data repository on genetic engineering signatures. Nonetheless, novel approaches to genetic engineering attribution can potentially overcome barriers posed by limited means to conduct a thorough investigation into the activities of a recalcitrant SP by providing an objective measure with which to assess evidence while simultaneously deterring potential BW developers with the threat of exposure (Lewis et al., 2020).

Figure 2: The Modular-Incremental Approach: A flowchart of the thought process beginning with the basic foundational paradigm shifts that will enable verification through the application of modern scientific tools to modular policy proposals and their growth into a comprehensive verification regime for the Biological Weapons Convention.

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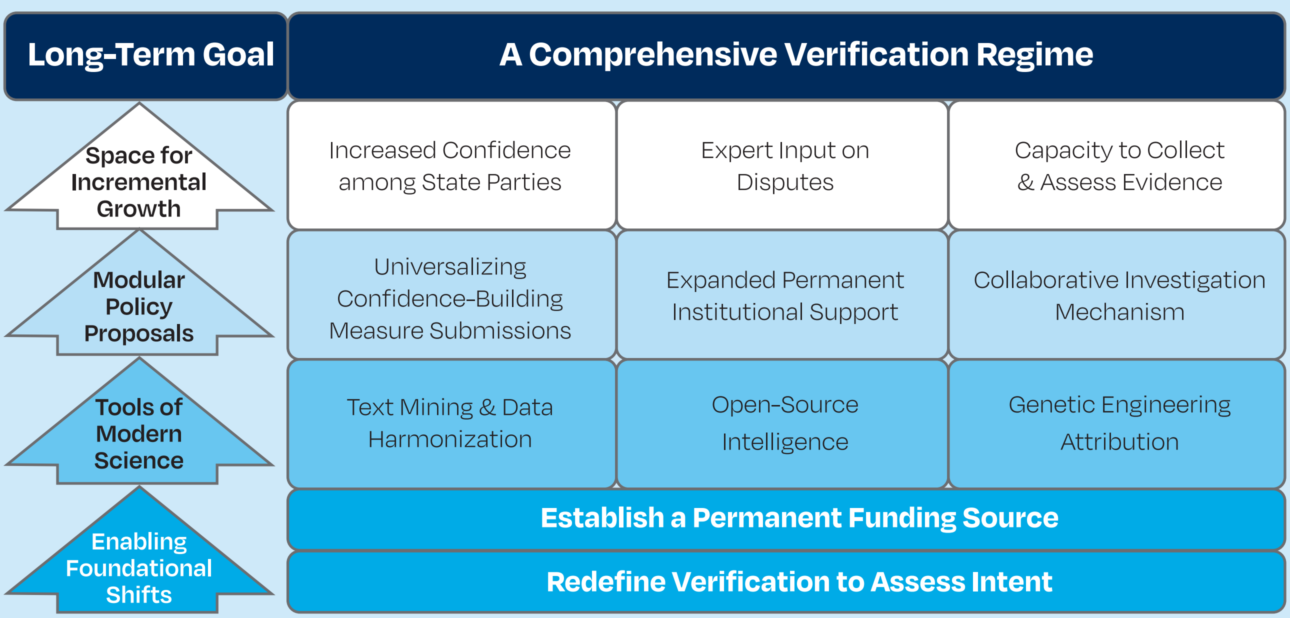

Conclusion

The challenges to establishing a verification mechanism for the BWC are politically and technically complex and cannot be solved by any single tool or implementation scheme. The authors believe that a flexible strategy that allows SPs to establish the pillars of a scientifically robust verification regime according to their priorities is politically feasible. When an impasse is reached, SPs can pivot to implementing a new mechanism, incrementally enhancing existing mechanisms, or applying novel tools of modern science. Every minor success generates political capital to spend on overcoming other barriers, and previously stalled ideas can be revisited with new technologies and personalities in the future.

Central to our approach is reimagining what "verification" means for the BWC. Verification used for chemical and nuclear weapons disarmament treaties is unlikely to succeed for the BWC because any regime must acknowledge the ambiguities created by 21st century biotechnologies. Our proposal grapples with the fundamental challenge of evaluating intent by creating mechanisms enabled by modern scientific tools to eliminate opportunities for would-be violators to hide behind ambiguity.

DH and robust benefit sharing systems lower the barrier to CBM submissions, leaving little reason for failure other than purposeful circumvention. OSINT and institutional data reviews can raise red flags. Enhancing Article V creates a forum for collaboratively reviewing evidence, like that obtained from genetic engineering attribution, OSINT, and relevant CBMs, to better assess responsible applications of biology and what the user's motivations might be.

After 50 years, the BWC remains weak due to the lack of a verification mechanism. Bioscience, meanwhile, has seen revolutionary advancements that have radically redefined what is possible, for better and for worse. The BWC has been long surpassed and the risk of failing to govern this space is potentially catastrophic. Incrementalism has the potential to break the political logjam and help the world keep pace with the rapid flood of biosciences innovation. The pace of incrementalism is not ideal, but continued inaction is unacceptable.

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Appendix

ABBREVIATION	MEANING
BW	biological weapon
BWC	The 1972 Biological and Toxin Weapons Convention
CBM	Confidence Building Measure
DH	data harmonization
DNA	deoxyribonucleic acid
GHS Index	Global Health Security Index
ISU	Implementation Support Unit
NLP	natural language processing
OSINT	open-source intelligence
SP	State Parties to the 1974 Biological and Toxin Weapons Convention
SSU	structured, semi-structured, and unstructured
TM	text mining
UN	United Nations
UNSC	United Nations Security Council
UNSGM	United Nations Secretary-General's Mechanism for Investigation of Alleged Use of Chemical and Biological Weapons