Strengthening compliance and verification under the Biological Weapons Convention

International Science Council

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Strengthening compliance and verification under the Biological Weapons Convention

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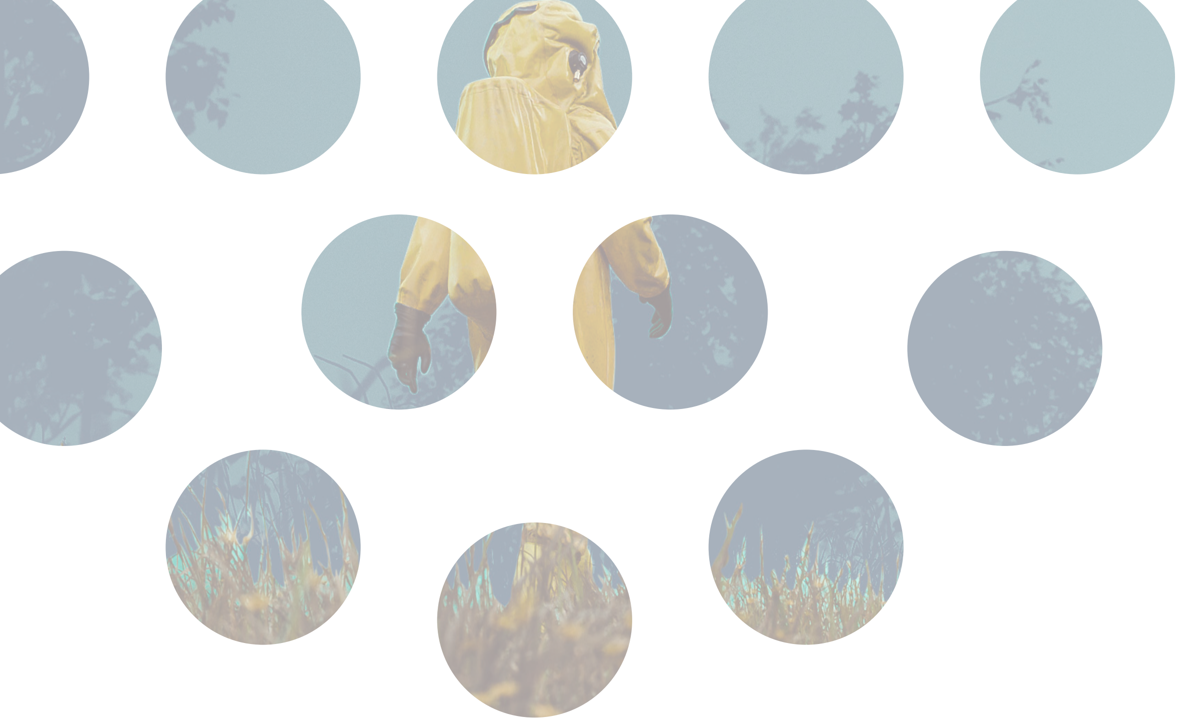

Executive Summary

The Biological Weapons Convention (BWC) faces unprecedented challenges in an era when emerging biotechnologies and artificial intelligence have fundamentally transformed the biosecurity landscape. Traditional approaches to verification and compliance, primarily focused on pathogen watchlists and facility inspections, are increasingly inadequate for addressing a complex spectrum of potential biological threats.

This paper proposes a comprehensive framework that could inform and support discussions on compliance and verification in the context of the BWC. At its core, the framework recognizes verification as a process for judging compliance rather than as a binary assessment. This nuanced approach acknowledges that the global proliferation of 'dual-use' biological research technologies (that are designed for beneficial purposes but could be misused) makes it impossible to treat verification as questions requiring a simple yes/no response.

The proposed framework introduces three fundamental objectives for verification: building confidence among States Parties about responsible state behaviour; creating mechanisms to deter potential non-compliance; and establishing mechanisms for detecting non-compliance in trigger scenarios. To achieve these objectives, the framework advocates for a data-driven approach that triangulates multiple sources, including Confidence-Building Measures, World Health Organization (WHO) International Health Regulations reporting, and implementation matrices from United Nations Security Council Resolution 1540 as a start point.

A key innovation is the framework's response to emerging biothreats. Rather than relying solely on traditional pathogen watchlists, it proposes monitoring a range of weaponization indicators across epidemiological, environmental, intelligence, and medical infrastructure domains. This approach is particularly crucial given the potential for seemingly harmless organisms to be manipulated into deadly pathogens through advanced technologies.

The framework introduces an expansive verification system, acknowledging work done by VEREX (an ad hoc committee assembled in 1991 by the Third Review Conference of the BWC), combining off-site and on-site measures, and leveraging cutting-edge technologies such as AI-enabled satellite imaging, blockchains for data integrity, and portable DNA sequencing. This technological integration is balanced against practical considerations of cost and feasibility, with measures prioritized through a deterrence–cost matrix to ensure efficient allocation of resources.

To address varying national capabilities, the framework proposes a graded assessment of compliance using a scale of various qualitative values rather than binary judgements. This sliding scale ranges from 'full compliance' to 'incomplete compliance', recognizing that some States Parties may have low compliance because of a lack of capacity rather than an intention not to comply. This approach is intrinsically linked to the International Cooperation and Assistance Mechanism, ensuring that states requiring support can receive targeted capacity-building assistance.

The framework also establishes clear parameters for investigating potential non-compliance, including specific trigger scenarios and a structured approach to categorizing biological incidents. This systematic approach ensures that investigations are evidence based and respectful of state sovereignty, while also maintaining the Convention's integrity.

By integrating these elements, the framework offers a practical pathway to strengthen the BWC's verification regime while acknowledging resource constraints and technological advancement. It represents a significant step towards building a more robust global biosecurity architecture capable of addressing 21st-century biological threats. ■

Key Recommendations

1. Framework development

- Establish an agreed set of biothreat indicators and scientifically feasible scenarios based on existing and emerging biotechnology trends
- Create compliance requirements focused on biosecurity measures, early-warning systems and risk assessments
- Design verification mechanisms that combine off-site surveillance with proportionate on-site measures
- Implement a Likert-scale compliance assessment system to reflect varying state capabilities

2. Institutional structure

- Create a designated BWC body for compliance assessment and data analysis
- Revise requirements of Confidence-Building Measures to align with a new compliance framework
- Establish formal partnerships with WHO, the United Nations Security Council and other organizations relevant to data sharing
- Institute an appeals process so that States Parties can contest compliance assessments

3. Resource optimization

- Utilize a deterrence–cost matrix to prioritize verification measures and conduct subsequent feasibility analysis
- Integrate existing reporting mechanisms (International Health Regulations, United Nations Security Council Resolution 1540) to reduce duplicate reporting and flesh out a substantive open-source intelligence approach
- Scale the intensity of verification processes in line with States Parties' biological research capabilities

4. Capacity building

- Link compliance assessments to targeted technical assistance through the International Cooperation and Assistance Mechanism
- Support the development of national biosecurity frameworks

5. Compliance and verification considerations

- Define clear trigger scenarios for non-compliance investigations
- Establish scientific parameters for attributing biological incidents
- Create transparent processes for presenting and evaluating evidence
- Develop graduated response protocols for different levels of non-compliance

These recommendations aim to strengthen the BWC while ensuring equitable implementation across States Parties with varying resources and capabilities. Success requires sustained political commitment, adequate funding and continuous adaptation to emerging technologies and threats. ■

In May 2024, the ISC was awarded a grant by the Geneva Science–Policy Interface to strengthen the Biological Weapons Convention (BWC) by facilitating science–policy synergies. This initiative addresses the need, highlighted during the 2022 Ninth Review Conference of the BWC, to integrate scientific developments into the Convention's operations, particularly through scientific review and possible mechanisms for verification. Over a period of six months, the ISC aimed to support the Working Group on the Strengthening of the Biological Weapons Convention by providing scientific insights into policy discussions, with targeted support to the Friends of the Chair on: science and technology; compliance and verification; and international cooperation and assistance.

Following two online discussions with the Friends of the Chair, the ISC Expert Group for the Biological Weapons Convention drafted this policy brief on compliance and verification. Further exchanges between the expert group and the Friends of the Chair took place during a side event to the fifth session of the Working Group on the Strengthening of the Biological Weapons Convention in December 2024, leading to further refinement of this brief.

1 Scope and framing of compliance and verification

While there is no universally agreed understanding of what 'verification' may encompass in the context of the BWC (Shearer et al., 2022), the expert group understands the term as the means through which a judgment on compliance is made. Thereby, verification is a process, whereas 'compliance' is the requirement that needs to be met.

Moreover, it is well acknowledged that the growth of 'dual-use' biological research technologies (that are designed for beneficial purposes but could be misused) makes it challenging to treat verification of compliance or non-compliance as a binary process. For example, focusing only on biosafety level (BSL) 4 laboratories would not provide sufficient verification – as biological weapons and threats could feasibly emerge from facilities at a lower BSL level, or a network of small laboratories equipped with access to AI-enabled biological design tools and benchtop DNA synthesizers. In addition, given the diverse fields and sectors in which biological weapons may be developed or deployed, taking an integrated 'One Health' approach encompassing human, animal, plant and environmental indicators is critical when considering compliance and verification.

Views on verification in the context of the BWC vary widely, encompassing scepticism about its feasibility, recognition of its role in promoting responsible behaviour, and calls for practical tools to support assessments of compliance (Findlay, 2006; UN Office of Disarmament Affairs, 2018; Working Group on the Strengthening of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 2024; Wunderlich et al., 2021). This paper posits three objectives of verification: 1) build confidence among States Parties about responsible state behaviour towards the promotion of safe use of biotechnologies; 2) create mechanisms to deter potential non-compliers; and 3) outline mechanisms for detecting non-compliance in trigger scenarios.

The increasingly complex and globalized risks from emerging biothreats warrants a need to be open and transparent, and to ensure that compliance and verification measures can be applied consistently across all States Parties.

1.1. Compliance and verification tethered to an appropriate framing of bioweapons

For compliance and verification to work effectively, it is necessary to understand the emergence of biothreats facilitated by new technologies – while at the same time being aware of existing threats and what might be considered low-technology tools. New scientific breakthroughs and technology inflection points may create novel avenues for bioweaponization, which warrants an on-going assessment of the threat landscape, in collaboration with a Science and Technology Advisory Mechanism.

This approach also warrants a deeper understanding of what constitutes a bioweapon or a biothreat nowadays. The BWC is 50 years old, and the concept of bioweapons has shifted significantly in this timeframe. For instance, the North Atlantic Treaty Organization (NATO) has cited the pursuit of neuromodulation devices that can both 'read' and 'write' brain activity as presenting huge potential for cognitive warfare (Cao et al., 2021). s this a bioweapon with regard to the remit of the BWC? Similarly, many scientific experts have recently cited the potential for 'mirror life' creation as catastrophic (Adamala et al., 2024), despite the technology not previously being on anyone's radar as posing a risk of this magnitude.

These developments illustrate the importance of characterizing the biothreat landscape alongside the use of concrete measures of verification to assess whether any aspect of research, development and/or acquisition is non-compliant. This characterization should include both the known threat landscape and the classical signatures that have come to be associated with the development of bioweapons programmes – such as the construction of purpose-built facilities or unusual outbreaks of concerning variants of existing viruses. An example characterization framework is provided in Section 3 of this paper. ■

2 Main steps for establishing compliance and verification

We propose taking the following steps to initiate the development of a comprehensive framework that could inform and support discussions on compliance and verification in the context of the BWC.

- Define and agree on a set of biothreat indicators/parameters and scientifically feasible scenarios, based on existing and emerging biotechnology trends, in order to outline how and where bioweapons may emerge. Such scenarios might include using AI to create a virus with increased pathogenicity, developing mirror bacteria, or accessing synthetic nucleic acids without screening. This set of parameters and scenarios should be updated regularly – to ensure a shared understanding of what is meant by biothreats and bioweapons with regards to the remit of the BWC, while taking into account technological advancements and novel mechanisms through which bioweapons may be generated.

- Propose a set of compliance requirements, based on how States Parties can strengthen biosecurity measures; gear up for early-warning systems that detect non-compliance (e.g. global toxin/pathogen surveillance); conduct risk assessments (e.g. of emerging biological design tools); and establish national and international deterrence mechanisms (e.g. international synthesis screening), and response and resilience measures against bioweapons and biothreats. These types of compliance requirements would undoubtedly be of value for States Parties in strengthening their own security and sovereignty.

- Based on agreed compliance requirements, carry out an evidence-led assessment of the extent to which these compliance requirements are being met by using on-site and off-site mechanisms for verification (see Table 1).

- Use a Likert-scale assessment to provide a compliance status for States Parties – from ‘in compliance’ to ‘in process of building compliance’ to ‘purposeful non-compliance’, etc. (see Section 6). This would reflect the reality in which compliance which can be hampered by a lack of capacity or infrastructure (see Section 5).

Given the above, it would be beneficial to think of verification as an ongoing assurance/reassurance process where we are assessing not only non-compliance but also varying levels of compliance and ability – with a view to building trust and transparency and facilitating provision of support where warranted. Verification should therefore focus on the presence, absence or development of compliance with requirements for bioweapons prevention, detection and deterrence, as agreed by States Parties. Moreover, annual reports on Confidence-Building Measures (CBMs) should align to this framework of compliance requirements, and be used as one of the many mechanisms for verification, thus creating a meaningful exchange of information (see Figure 1).

This proposal encourages States Parties to establish compliance criteria/requirements alongside verification processes and CBM reports that detect the extent to which compliance has occurred. This is crucial for building credibility and trust in the BWC and to enable more effective use of existing data from States Parties.

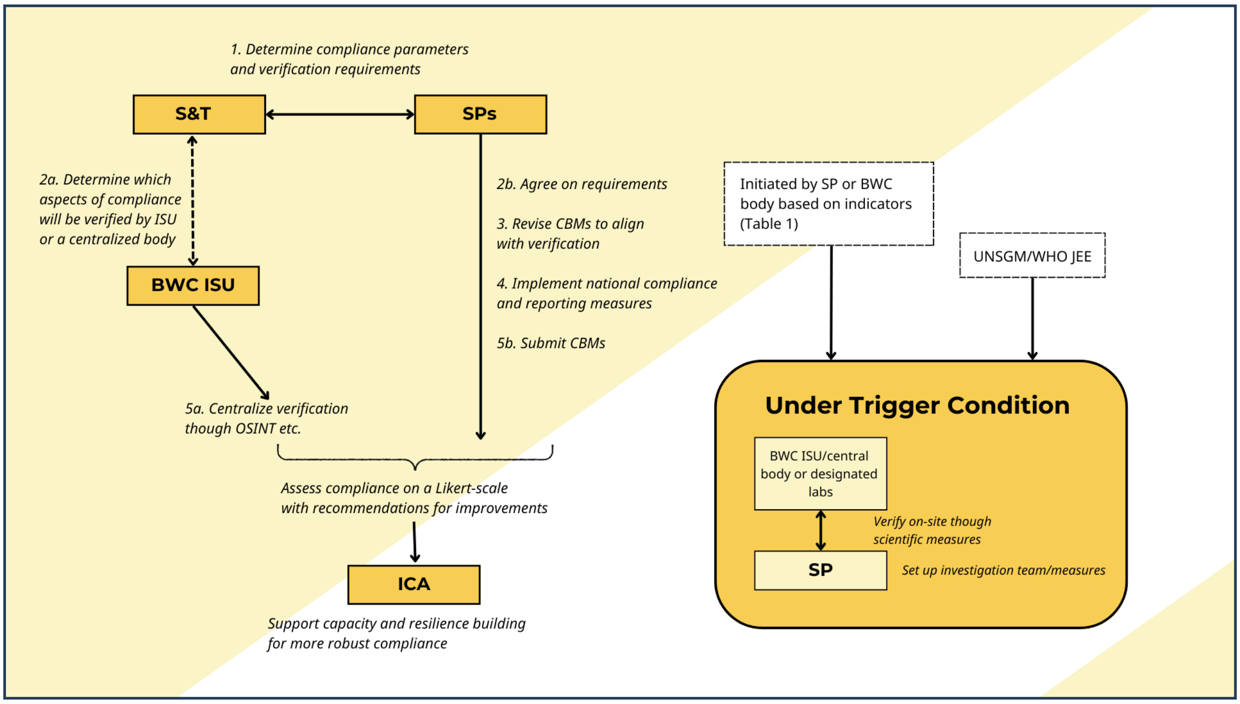

Figure 1. Visualization of compliance processes of the Biological Weapons Convention

2.1. A verification process based on data

A designated BWC organization (either the Implementation Support Unit of the United Nations Office for Disarmament Affairs or another independent body) could lead the capturing of data for verification purposes – using open-source intelligence (OSINT) data sources, in conjunction with revised CBM submissions, and with further triangulation of other existing data collection efforts such as reporting in accordance with the World Health Organization International Health Regulations (WHO IHR) and the United Nations Security Council Resolution (UNSCR) 1540. In fact, a review of WHO IHR and Joint External Evaluation, and UNSCR 1540 implementation matrices, reveals a fundamental alignment (Sture et al., 2013) on biosecurity, which sits at the nexus of public health, dual-use research of concern, and biothreats/weapons.

We therefore recommend an assessment exercise to align reporting requirements across the UNSCR 1540, WHO IHR, and CBMs of the BWC, and to leverage existing datasets to provide assurance for both biosecurity and global health security, which are inextricably linked. These triangulated datasets would not only reduce the burden for States Parties reporting on BWC compliance, but could also more robustly inform a status on compliance, thus enhancing the credibility of BWC assessments. ■

3 Characterization of biology that can be weaponized

Technologies in the life sciences and adjacent fields of research are maturing to allow humans an unprecedented understanding of biology based on large data sets. They allow us the power to use biological knowledge to the benefit of humanity as well as to create novel threats that could be weaponized. These new threats are not limited to traditional pathogens and toxins but include entirely novel compounds that could wreak global havoc in the hands of a malicious actor.

This expanding scope of threats to biosecurity has made the traditional approach of maintaining watchlists for pathogens and toxins ineffective. Today, seemingly harmless organisms can be manipulated to develop deadly pathogens, rendering such lists inadequate. Indeed, relying solely on watchlists may create a false sense of security among States Parties, which may ultimately prove counterproductive. Therefore, it is crucial to explore compliance strategies beyond watchlists.

It is impossible to verify all biological research given its inherent dual-use nature. It is, however, feasible to strategically assess what kind of activities could be considered risky and which, if not contained or used with clear safeguards in place, could easily violate the provisions of Article I of the BWC. Such an assessment could provide a framework for understanding and outlining the early signs and metrics that are associated with the presence or development of bioweapons, or the potential for weaponization based on a lack of safeguards. While this approach may not be exhaustive, it would nevertheless represent a step change, by tethering verification to actual indicators of what might constitute a threat or a weapon (see Table 1).

Emerging threats are taking shape across environmental, agricultural and cyber sectors, and beyond. To address these challenges, we propose a compliance and verification framework that is intrinsically linked to a future Science and Technology Advisory Mechanism led by the BWC. We envisage that this integration would enable dynamic, technology-led, science-informed oversight to effectively monitor and respond to the evolving global landscape of biothreats. ■

Table 1. An example compliance and verification framework to inform reporting at the national level and Confidence-Building Measures between States

Bioweaponization avenues and scenarios	Potential indicators of weaponization	Requirements for compliance by States Parties	Mechanisms for verification by the Biological Weapons Convention
• Use of AI and synthetic biology tools • Synthesis of nucleic acids • Commercialization of libraries containing data on human genomes	• **Epidemiological indicators:** unusual outbreak patterns; resistance; unusual morbidity and mortality rates • **Environmental and biological surveillance indicators:** unusual outbreak patterns; resistance; unusual morbidity and mortality rates in animals or food supply chains • **Intelligence and security indicators:** unusual procurement activity of laboratories and technologies; cyber hacking or infiltration incidents relating to biological data, research or facilities • **Medical infrastructure indicators:** a sudden burden on hospitals; establishment of new medical countermeasures; scaling up of measures • **Geopolitical indicators:** sudden import/export controls on data and research infrastructure; diplomatic or military activity; global supply chain breakdown; global surveillance data discrepancies; drastic legislative measures introduced	• Development frameworks/ processes identifying dual-use research of concern, that extend to industry and academia • Safeguarding biobanks; genomic data repositories; pathogen databases with cybersecurity measures • Standardized BSL-3/4 standard operating procedures for handling samples, and dealing with accidental leaks and exposures • Guidelines/policies for synthesis screening (Gronval, n.d.) • Know-your-customer approaches for companies which sell synthesizers or provide nucleic acids • Surveillance guidelines/practice/ development across the One Health sector (i.e., animals, humans, plants, environment)	**Verification through off-site measures** • Presence/absence/development of governance and oversight mechanisms and frameworks and risk mitigation policies (e.g. standard operating procedures, dual-use research of concern frameworks, synthesis screening) • Screening of open-source intelligence data including global surveillance databases • Returns on Confidence-Building Measures aligned to compliance requirements • AI satellite imaging and aerial surveillance drones • Predictive analytics based on supply chain monitoring/trends **Verification through on-site measures** • Blockchain technology for assessing data integrity of laboratory records • Epidemiological modelling; environmental sensing/ biosurveillance • Portable DNA sequencing

4 Good practice and utilization of technology for verification

As discussed above, verification should be an ongoing endeavour under routine and non-routine conditions, and should focus on both assessing and supporting compliance requirements, as listed illustratively in Table 1. Requirements should link to where bioweapons threats may emerge, and hence will be of direct relevance for States Parties themselves, helping them to monitor and prepare for threats through anticipatory and future-focused assessments.

Verification of compliance and non-compliance can take place through multiple channels and mechanisms and through two main modalities: off-site and on-site verification. We recognize that not all States Parties will have all proposed compliance requirements in place, due to capacity restraints or simply because they are not investing in biological research. Therefore, evidence collected for verification of compliance and non-compliance should be assessed in a manner proportionate to the biological research conducted in a given State Party. We also recognize the role of the private and academic sectors in meeting compliance requirements. Both these sectors can help with technology integration for effective assessment of compliance, and a robust national scientific network can lead to the informal peer review of ongoing activities.

Although VEREX (Ad Hoc Group of Governmental Experts to Identify and Examine Potential Verification Measures from a Scientific and Technical Standpoint, n.d.) proposed 21 measures for verification, many of the these now appear redundant when mapped against each other (e.g. interviewing lab personnel, monitoring personnel, examining personnel) and could be deemed intrusive when taken together. Moreover, many of these measures do not account for technological advancements, or are not tethered to compliance requirements or indicators of bioweapons, as proposed in Table 1.

We may therefore need to deploy a triaged set of verification measures ranging from off-site investigations to more intrusive on-site measures, depending on the state of evidence captured through off-site datasets and whether there have been claims by States Parties that would trigger a deeper investigation. Some examples of potential measures to update VEREX's proposals are listed below, categorized as on-site and off-site and by level of intrusiveness.

Off-site measures

- Surveillance and intelligence gathering
  - Satellite imaging with AI to detect facility modifications and unusual activities
  - Drones for aerial surveillance: AI-equipped drones for real-time monitoring of facilities
  - OSINT data triangulation: AI scans of social media, scientific papers, patents, IHR reports, Interpol published data, CBM reports
- Pattern recognition and cyber audits
  - AI predictive analytics: using trade data, financial flows and scientific research trends to flag potential violations
  - Cyber surveillance and AI-driven digital audits: tracking digital research collaborations and financial transactions
  - Analytics of outbreak patterns based on surveillance data for global diseases
  - Blockchains for data integrity: ensures tamper-proof records of facility activities and scientific research

On-site measures

- Advanced inspection and sampling
  - Portable DNA sequencing using hand-held sequencing devices for rapid pathogen analysis during inspections
  - Automated environmental biosensors to detect airborne or water-based pathogens in and around suspected sites
- Autonomous and robotics-based inspections
  - Inspections performed by autonomous robots in hazardous or sensitive areas
  - Continuous remote monitoring (Internet of Things-enabled): smart sensors within facilities provide real-time environmental data to assess compliance
- Medical and epidemiological monitoring
  - Wearable biosensors for scientists handling dangerous pathogens to track exposure risks
  - On site epidemiological surveillance/audit with AI-powered analytics to detect unnatural disease patterns and identify possible covert use of bioweapons

In the case of a specific event, or under trigger conditions, a multitude of other scientific approaches could be utilized for microbial forensics – to determine whether a given incident involving a compound is naturally occurring or engineered, and by whom. These techniques include nanopore sequencing and fingerprinting, pathogenicity arrays, phylogenetic analysis, isotope analysis and convolutional neural network-based image analysis. Epidemiological modelling and transmission analysis powered by AI can also help us understand where a biological compound has come from, and whether it has evolved naturally or been engineered. All these suggestions need to be further developed and considered in a proportionate manner.

It is worth noting that verification should not be burdensome for States Parties, especially those with developing infrastructure and limited research and innovational capital. If States Parties are found to be lacking in the requisite compliance due to a lack of capacity, BWC mechanisms such as a Science and Technology Advisory Mechanism and an International Cooperation and Assistance Mechanism could be leveraged for capacity building, training and resilience building – to detect and prevent bioweapons development (see Figure 2).

Adopting the proposed suite of compliance measures and mechanisms for verification will limit the need for intrusive checks and be respectful of sovereignty. Moreover, the need for any investigation triggers to be evidence-based also ensures that state sovereignty is respected.

This approach relies on national implementation and reporting of biosecurity measures by States Parties. However, it is important to be mindful that some biosecurity measures may be expensive, and that not all states have adequate resources for their implementation. The next section therefore provides a framework for assessing biosecurity measures and determining which should be prioritized as the most impactful. ■

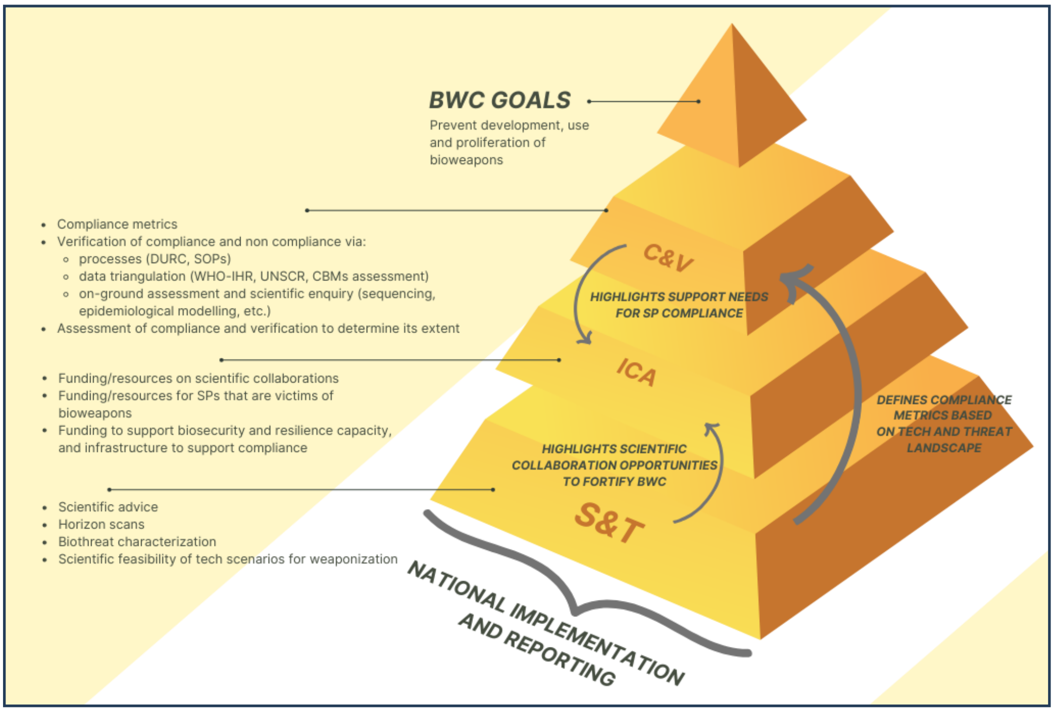

Figure 2. Operationalization of a framework to support discussions on compliance and verification in the context of the Biological Weapons Convention and interaction with a Science and Technology Advisory Mechanism and an International Cooperation and Assistance Mechanism

5 Prioritization of measures for reducing the burden on States Parties

In addition to utilizing data triangulation through parallel and existing mechanisms such as the IHR, UNSCR 1540 and CBMs, compliance and verification can rely on other low-burden data collection exercises through centralized support mechanisms such as the ISU (pending a commitment for substantive funding). To determine which measures should be used for compliance and verification from the long list in Table 1, measures could be categorized on their deterrence ability versus their cost/feasibility. This could form the basis for prioritizing compliance and verification metrics (see Table 2).

Table 2. Example matrix of deterrence in reducing biothreats versus cost – to prioritize compliance and verification measures

		Deterrence ability of a given measure			
		Very low	Low	High	Very high
Cost of the measure	Very low				Licensing of gene synthesis companies
	Low		Social media screening	Horizon scanning	
	High			Know-your-customer screening	Disease surveillance/ wastewater surveillance
	Very high				On-site inspections

Based on this kind of categorization, States Parties could agree to a minimum set of parameters for reporting on compliance. The Science and Technology Advisory Mechanism being discussed within the BWC could be tasked with compiling these parameters. Datasets collected from States Parties via updated CBMs, triangulated with OSINT data and other complementary data sources, could then be aggregated and expressed on a sliding scale to enable assessment of responsible state behaviour and the current state of compliance (see Section 6). ■

6 Options for Likert-scale assessment of compliance

Two options for a Likert-scale assessment of compliance with the requirements of the Biological Weapons Convention are shown in Table 3 and Table 4.

Table 3. An example of what a sliding scale assessment could contribute to discussions via a Science and Technology Advisory Mechanism and an International Cooperation and Assistance Mechanism of the Biological Weapons Convention

Status	Parameters	Outcomes
Fully compliant	Adheres to all compliance requirements prescribed by the BWC	A fully compliant State Party does not mean that accidents or bioterror incidents on that party's soil cannot happen. This only indicates that the State Party is showing responsible behaviour in curbing the potential development and use of bioweapons.
Substantial compliance	Reports, but has some inadequate measures	The State Party reports on some compliance requirements via Confidence-Building Measures, but few measures are adequately addressed.
Satisfactory compliance	Reports, has inadequate measures across all categories, but shows progress year on year	The State Party is making progress on various measures and builds confidence for providing it with further resources for development.
Unsatisfactory compliance	Reports, but inadequate measures across all categories	The State Party reports on Confidence-Building Measures, but many are not adequately incorporated, and there is no progress on their incorporation in year-on-year assessments. This status can be used to understand why States Parties are not making progress; and how help can be provided to move them to a satisfactory compliance status. If a State Party stays on unsatisfactory compliance for over five years despite help being provided, a more in-depth review and ground visits may be conducted before further resources are allocated.
Incomplete compliance	No self-reporting to the BWC	Incomplete compliance does not indicate non-compliance. This status can be followed up to understand why States Parties may not be reporting and an International Cooperation and Assistance Mechanism implemented if there is a need. Incomplete compliance over multiple years may be followed up by placing restrictions on State Party funding through international cooperation and assistance or other means.

The sliding scale shown in Table 3 requires a political judgement on compliance with the BWC and would have to be determined by formal procedures, based on data provided by the designated BWC body performing the assessments. If this option is to be used, additional provisions may be required, to allow States Parties to either contest their status, or to raise concerns about the status of other States Parties on the grounds of available and demonstratable data.

Table 4. Biological Weapons Convention (BWC) Resilience Readiness Levels, which represent a State Party's ability to respond to emerging biosecurity threats, including detection of non-compliance

Status	Parameters	Outcomes
Agile resilience	Adheres to all measures prescribed by the BWC	This status indicates an integrated approach that also has facets for tackling emerging, novel threats that have not been considered or seen before.
Integrated resilience	Reports, and has few inadequate measures	This status indicates a comprehensive resilience-building programme that integrates coordination between various domains of bioweapons proliferation across human, agriculture and animal targets.
Defined resilience	Reports, has inadequate measures across all categories, but shows progress year on year	This status indicates that in certain domains of bioweapons proliferation, there is a structured programme to enable resilience and its implementation is in progress.
Fragmented resilience	Reports, but has inadequate measures across all categories	This indicates that the State Party may have some measures in place for tackling some aspects of bioweapons proliferation, but these are siloed and not working in coordination.
Undisclosed	No self-reporting	Undisclosed resilience levels do not necessarily indicate non-compliance or lack of resilience, but simply convey a lack of data for making an assessment. This status can be followed up to understand why States Parties may not be reporting, and an International Cooperation and Assistance Mechanism implemented if there is a need. Incomplete compliance over multiple years may be followed up by conditioning State Party funding through international cooperation and assistance or other means.

The proposal shown in Table 4 is adapted from The GRC Pundit Blog (Rasmussen, 2022) . The resilience status does not need to be a political judgment, since it is not an assessment of compliance with the BWC. Rather, this matrix reflects the readiness of States Parties to detect and deter potential BWC violations, and may be considered a reassurance index, in case an assessment of compliance is deemed too difficult to achieve.

The kind of measures and disclosures needed under the options shown in Table 3 and Table 4 will differ, based on the objective of the exercise. In addition, an assessment of non-compliance cannot be made based on the mechanisms outlined. Non-compliance can only be demonstrated following an investigation of an outbreak of a biological agent. Section 7 examines trigger scenarios for investigating such non-compliance. ■

7 Non-compliance status and scenarios triggering investigation

The concept of non-compliance within the BWC can indicate a violation of the Convention, but this designation only applies after a thorough investigation. This process involves examining the origin of a biological incident or agent to determine whether it is a result of deliberate or accidental release. In some cases, a biological agent that is not naturally occurring (i.e. synthetic or modified) could raise suspicions that it originated from scenarios that raise concerns. Examples of these scenarios, outlined in Table 5, include different types of releases: accidental or intentional, domestic or international, and conducted by either state or non-state actors.

The aim of listing these scenarios is to provide a structured approach for identifying and categorizing incidents that may require further scrutiny under the BWC. The approach could help delineate whether an incident might justify investigation as a potential violation of the Convention, based on a set of scientifically grounded parameters. Each scenario guides the investigation by categorizing the context of the release, such as the likelihood of accidental release from a state-controlled laboratory versus a deliberate act by a non-state actor.

This framework could serve as the basis for a practical guide for BWC States Parties to initiate an investigation when certain triggers (like unusual outbreak patterns or unexpected pathogen characteristics) indicate a possible violation. It also supports transparency by defining what might qualify as a non-compliance trigger, and clarifies the evidence and assessment required for an official non-compliance designation.

Upon investigation, the perpetrating State Party can be assigned one of four non-compliance statuses (see Table 6). ■

Table 5. Likely scenarios under which an outbreak from a non-natural agent may originate

	Perpetrating actor	Accidental release	Malicious release
Domestic	State	Release from government laboratories or other supply chain processes under governmental control	State's use against its own people
Domestic	Non-state	Release from supply chain or other private facilities	A non-state actor acting without state support
Foreign	State	Release from foreign state facilities in a host country (unlikely scenario)	A State Party acting against another State Party
Foreign	Non-state	Release from foreign-owned private facilities in host country	Non-state actor acting against another State Party

Table 6. Matrix for assigning compliance

	Status	Parameters
Domestic	Accidental neglect	Non-deliberate violation of containment laws as evidenced by maintenance of protocols and appropriate documentation
Domestic	Wilful neglect	Non-deliberate use of a biological agent that was catalysed because proper protocols were not in place or not followed
Foreign	Malicious intent	A deliberate use of a bioweapon by a state or non-state actor
Foreign	Unknown intent	A clear judgement on intent cannot be made

8 Next steps and conclusion

Compliance and verification have been a contentious issue at the BWC, but there is a growing consensus about the need for better global preparedness against emerging biothreats. It is thus necessary to implement measures that can build global assurance of responsible state behaviour and compliance to the provisions of the BWC. To achieve such assurance, we recommend the following next steps:

- Characterize emerging biothreats and the probability of bioweapon development and use
- Outline trackable indicators for both emerging and existing biothreats that can inform on responsible state behaviour
- Update requirements for Confidence-Building Measures in alignment with indicators
- Partner with other organizations that can share relevant data on biosecurity
- Set up a designated BWC body for assessing data obtained through Confidence-Building Measures, partner organizations and OSINT sources
- Maintain an iterative process to stay up to date on evolving technologies

Measuring compliance to the BWC will evolve as technologies progress over the coming years. However, robust detection and deterrence mechanisms, led by global state cooperation, will remain important deterrents against the malicious use of these important and otherwise beneficial technologies. It is therefore necessary to ensure that such mechanisms are in place now and evolve alongside technological change.

States Parties must deliberate on several key questions to operationalize this compliance and verification framework under the Biological Weapons Convention. For instance:

- In cases of alleged non-compliance, where should evidence be presented, and which BWC body should receive it?
- What criteria must be met for attribution to be established with regards to weaponization?
- What avenues are available for States Parties to present counterarguments?
- What mechanisms should be established to determine violations and enforce sanctions or penalties?

Strengthening compliance and verification under the BWC is vital to countering the evolving threats posed by biological weapons. By adopting nuanced approaches such as the deterrence–cost matrix, Likert-scale assessments, and OSINT integration, States Parties can enhance transparency and trust while respecting resource constraints. Collaboration with an International Cooperation and Assistance Mechanism and a Science and Technology Advisory Mechanism will ensure a cohesive, equitable, and forward-looking strategy. Consideration of these measures could also reinforce the architecture of global biosecurity, enabling the BWC to meet the challenges of modern biological threats and technologies. ■

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