

# **VERIFICATION AT RISK: EXAMINING GROWING CHALLENGES TO VERIFY ARMS CONTROL REGIMES**

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# **Verification at Risk: Examining Growing Challenges to Verify Arms Control Regimes**

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## **Executive Summary**

The verification measures used to validate and monitor compliance of multilateral arms control agreements are under threat. Geopolitical dynamics and emerging technologies threaten to undermine the norms and values perpetuated by these institutions, while simultaneously lowering barriers to WMD production. As revisionist states continue to exploit institutional loopholes and thwart verification efforts, it remains to be seen how these agreements and their institutions will fare moving forward. The following paper assesses this situation by first clarifying the role of verification in international arms control and outlining the measures established by the Nuclear Nonproliferation Treaty, the Biological Weapons Convention, and Chemical Weapons Convention. It then explores the political and technological challenges facing verification. The paper concludes with a discussion of the path forward for arms control verification, acknowledging the shortcomings of existing measures and underscoring opportunities for improvement.

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<sup>1</sup> *The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or Lawrence Livermore National Security, LLC, and shall not be used for advertising or product endorsement purposes.*

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## Introduction

Verification measures serve as a valuable instrument for multilateral arms control agreements—detecting and deterring violations and reinforcing nonproliferation norms. They play a critical role in the nonproliferation of weapons of mass destruction (WMD) by verifying compliance with the arms control agreements they serve; however, verification measures for multilateral agreements like the Nonproliferation of Nuclear Weapons (NPT) are suffering from geopolitical tensions and emerging technologies, which make verification more challenging.

Verification is broadly described as the process a nation or institution uses to assess the compliance of another nation (or nations) to a given arms control agreement. Yet not all arms control agreements are created equal. While some provide for the establishment of an organization or agency tasked with verification implementation, others fail to address verification entirely, relying instead upon voluntary declarations from States Parties. Therefore, as geopolitical agendas and emerging technologies threaten to exploit the loopholes of verification regimes, it remains to be seen how arms control agreements and the norms they perpetuate will fare.

This paper addresses the question: how are heightened geopolitical tensions and emerging technologies affecting the verification of multilateral arms control agreements including the NPT, the Biological Weapons Convention (BWC), and the Chemical Weapons Convention (CWC)? The paper begins with a discussion of the role of verification measures in arms control agreements, followed by an outline of the verification measures and implementation mechanisms established by three modern, multilateral WMD arms control agreements. The next section introduces the political and technical threats undermining these institutions, including geopolitical dynamics, misinformation campaigns, cross-cutting technologies, and domain-specific technologies. The paper concludes with a discussion of the path forward for arms control verification, acknowledging the shortcomings of existing measures and underscoring opportunities for improvement.

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## Section I: Understanding Verification

### The Purpose of Verification

Verification serves three purposes: violation detection, violation deterrence, and norm establishment/confidence building.<sup>2</sup> Violation detection is perhaps the most obvious objective of arms control verification. Although accession to an arms control agreement is voluntary, membership alone has historically proven insufficient to guarantee compliance. This is, in large part, due to the myriad causes of noncompliance which extend beyond malicious intent to include institutional barriers, lack of political will, and insufficient funding, among others. Therefore, in an international environment prone to noncompliance, verification measures have been crafted and integrated to increase accountability among all States Parties and provide compliant states with “timely warning of any threat” posed by noncompliant states.<sup>3</sup>

Violation deterrence occurs when violation detection is effective, and states are deterred from pursuing noncompliant courses of action because the risk of being caught is raised. This, in turn, increases the cost and effort associated with clandestine violations, creating an environment in which nations must go to greater lengths to violate an agreement while successfully evading detection. It should be noted that deterrence in arms control operates in line with larger deterrence theory, which is largely dependent upon shaping an adversary’s perceptions. In essence, to some degree, deterring arms control violations is less reliant upon the actual efficacy of an agreement’s verification measures and more reliant upon the perception that violations can and will be detected.

Finally, verification is instrumental to the creation and perpetuation of arms control norms via confidence building. The provision of data indicating a state’s adherence to the provisions of an arms control agreement has a self-perpetuating effect on the agreement itself. Demonstrated compliance creates a political environment in which arms control is seen as a feasible and beneficial norm. These norms then raise the reputational costs incurred from noncompliance, thereby deterring “the manipulation of an atmosphere of trust in the pursuit of unilateral advantage.”<sup>4</sup>

### Verification Implementation

Who can be trusted to verify treaty compliance? Depending on the agreement, verification can be an independent or collaborative effort. Multilateral agreements, possessing a higher degree of complexity, are typically collaborative in nature. As such, verification of these agreements is often outsourced to other entities including international verification agencies, like the International Atomic Energy Agency (IAEA). Although these institutions are typically more robust than relying on state declarations alone, it should be noted that they are “crucially dependent upon the political,

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<sup>2</sup> U.S. Arms Control and Disarmament Agency, *Verification: The Critical Element of Arms Control*, (April 2, 1982). <https://apps.dtic.mil/sti/tr/pdf/ADA112881.pdf>. Accessed January 6, 2025.

<sup>3</sup> Ibid., p. 2.

<sup>4</sup> Ibid., p. 3.

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financial, and technical support of treaty parties.”<sup>5</sup> Furthermore, these agencies can be prone to political hurdles: empowering States Parties to engage in ‘spoiling efforts,’ evade verification, or provoke measures, like challenge inspections, in a retaliatory manner.<sup>6</sup> In essence, regarding the quality and efficacy of arms control verification measures, nations will ‘get out what they put in.’

The United Nations (UN) and non-governmental organizations (NGOs) also play critical roles in arms control verification. Although the UN contributes to arms control verification via research and treaty negotiations, its most crucial role lies in enforcement. Although punishments (typically sanctions) for noncompliance can be imposed unilaterally, they are more effective when imposed multilaterally. As such, the UN Security Council’s (UNSC’s) ability to pass a binding resolution imposing sanctions on a particular nation carries a great deal of weight—lending institutions like the IAEA to report violations to the UNSC in instances of noncompliance. It should be noted, however, that the ability of any member of UNSC’s permanent five members (P5) to cast an absolute veto and thus singlehandedly prevent the adoption of such a resolution makes treaty enforcement highly politicized and difficult.

NGOs, meanwhile, assist in arms control monitoring. Since the advent of the internet and subsequent ‘sensor revolution’ NGOs have gained access to exponentially more open-source information, some of which is derived from previously classified technology.<sup>7</sup> This information can then be compiled, analyzed, and transmitted to multilateral institutions as a supplement to their own data. Due to perceptions of NGO advocacy agendas, however, these contributions are typically limited in nature, and if considered alone, would be insufficient to draw conclusions of noncompliance.

## Verification Techniques and Measures

A wide variety of techniques and measures are available for use in the verification of arms control and nonproliferation agreements. Because agreements are designed to address specific threats and are concluded at different times (often in different geopolitical circumstances), verification techniques can vary significantly from one treaty to the next.

### Types of Verification Measures

Verification can be achieved through a wide variety of techniques and tools. Writ large, however, “verification techniques can be categorized as either passive or active, remote or on-site.”<sup>8</sup> Passive verification techniques describe circumstances in which states collect information on themselves or receive declarations from another State Party, while active verification refers to the act of one

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<sup>5</sup> United Nations Institute for Disarmament Research, *Coming to Terms with Security: A Handbook on Verification and Compliance*, (October 2003). <https://undir.org/files/publication/pdfs/coming-to-terms-with-security-a-handbook-on-verification-and-compliance-en-554.pdf>. Accessed January 3, 2025. p. 7.

<sup>6</sup> U.S. Arms Control and Disarmament Agency, *Verification: The Critical Element of Arms Control*, (April 2, 1982). <https://apps.dtic.mil/sti/tr/pdf/ADA112881.pdf>. Accessed January 6, 2025.

<sup>7</sup> United Nations Institute for Disarmament Research, *Coming to Terms with Security: A Handbook on Verification and Compliance*, (October 2003). <https://undir.org/files/publication/pdfs/coming-to-terms-with-security-a-handbook-on-verification-and-compliance-en-554.pdf>. Accessed January 3, 2025.

<sup>8</sup> Ibid., p. 18.

State Party collecting information on another. On-site verification occurs when a State Party or designated verification organization is granted access to another State Party's facilities or materials. These facilities and materials do not necessarily need to be state owned; inspections can occur at commercial locations if private companies are responsible for researching, designing, assembling, or storing controlled items. Remote verification activities, however, take place further away, "usually outside the territorial limits of the country being targeted."<sup>9</sup> **Table 1** below displays where some verification tools fall within the passive/active and remote/on-site spectrum. Position on this spectrum, however, does not indicate the accuracy or comprehensiveness of a verification technique or tool. Active on-site verification is not necessarily any better than passive remote verification. Rather, it is widely acknowledged that a comprehensive verification system requires a patchwork of techniques and tools tailored to an individual threat landscape and treaty.

*Table 1: Examples of Active/Passive, Remote/On-Site Verification*

	Active	Passive
Remote	IAEA personnel remotely access surveillance data recorded previously installed electronic seals	UN Implementation Support Unit receives BWC State Party Confidence Building Measure forms
On-site	IAEA or OPCW personnel conduct an on-site inspection at a State Party's facility	IAEA personnel receive data transmissions from surveillance cameras installed in a State Party's facility

Source: United Nations Institute for Disarmament Research

## National Technical Means

National technical means (NTM), defined as "nationally owned and operated technologies and techniques used to monitor the activities of other states," contribute to verification for all arms control agreements.<sup>10</sup> Perhaps the largest appeal of NTM is that they allow negotiators to bypass the difficult and occasionally unsuccessful political discussions associated with the establishment of more 'invasive' verification measures. As such, these measures often fall under the 'active' and 'remote' categories. Furthermore, data obtained from NTM can be considered more "reliable and readily accessible" than data provided by adversaries.<sup>11</sup> Despite these benefits, it should be noted that data gathered via NTM are often gathered by systems designed for purposes other than treaty verification. For example, satellites deployed in low-earth orbit may be capable of capturing and transmitting relevant imagery; however, their fields of view may not be trained on a precise location of concern. As such, capturing arms control data on specific locations may require temporarily maneuvering a satellite away from its intended target. Alternatively, nations can supplement their

<sup>9</sup> Ibid., p. 18.

<sup>10</sup> Ibid., p. 20.

<sup>11</sup> U.S. Arms Control and Disarmament Agency, *Verification: The Critical Element of Arms Control*, (April 2, 1982). <https://apps.dtic.mil/sti/tr/pdf/ADA112881.pdf>. Accessed January 6, 2025. p. 16.

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NTM with infrastructure designed and deployed specifically for collecting data for verification, but interest in allocating funds for this purpose dropped significantly following the cold war.<sup>12</sup>

## Information Exchanges and Declarations

When states are willing to pursue more than unilateral NTM for verification, they may engage in information exchanges and declarations to notify other member states of their activities. Information exchanges serve as the foundation for collaborative verification efforts. Also referred to as data declarations or notifications, this verification technique may involve the direct transmission of data from one nation to another or the use of an intermediary, such as a designated verification body, responsible for assessing the validity of submissions.

Although the terms noted above are often used interchangeably, they can be associated with specific contexts. Data declarations, for example, are often made to establish a baseline between two or more nations and “are often made when a treaty enters into force.” These are typically followed by data exchanges, which occur at specified intervals to ensure ongoing compliance and build confidence. Finally, some treaties require member states to notify one another prior to or within a certain period of a specific event happening. For example, the New START treaty requires the United States and Russia to notify one another of planned ballistic missile launches and the deployment status of “all strategic delivery vehicles and launchers.”<sup>13</sup>

## On-site Verification Measures

When nations are willing and able to negotiate more invasive verification measures, on-site verification becomes a possibility. According to the UN Institute for Disarmament Research (UNIDIR), on-site verification techniques can be separated into two categories: continuous on-site monitoring and on-site inspections. Continuous on-site monitoring, by nature, requires continuous surveillance which can either be carried out by personnel stationed at key sites or through the installation of remote monitoring devices like surveillance cameras, sensors, or electronic seals. On-site inspections are briefer by comparison, but they can also be more disruptive. For example, IAEA inspectors retain the right to place seals on rooms which, depending on the room’s contents, can arrest work until the seal is removed. Within the category of on-site inspections, there is additional variety. Specifically, these inspections can be routine/planned, short-notice, random, or challenging in nature.

Routine/planned inspections often pose the fewest political challenges because they offer the most time for preparation for the investigators. Short-notice and random inspections do not offer this courtesy; the sheer possibility of being subjected to one could further deter States Parties from pursuing a prohibited course of action. Finally, issued in response to an underlying implication or outright allegation of noncompliance, ‘challenge inspections’ are aptly the most challenging to mount. Not only is the burden of proof high, but in the event a challenge inspection can be

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<sup>12</sup> Interview with Amb. Ron Lehman, Counselor to the Director of Lawrence Livermore National Laboratory (December 8, 2024).

<sup>13</sup> U.S. Department of State, “New START Treaty,” (June 1, 2023), <https://www.state.gov/new-start/>. Accessed January 3, 2025.

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approved, it “is likely to be such an unusual and politically contentious event that the receiving State may not fully cooperate in making the necessary arrangements.”<sup>14</sup>

## Section II: Verification Across Domains

According to the UN General Assembly (UNGA), “determinations about the adequacy, effectiveness and acceptability of specific methods and arrangements intended to verify compliance with the provisions of an arms limitation and disarmament agreement can only be made within the context of that agreement.”<sup>15</sup> In essence, the efficacy of verification techniques can only be assessed within the context of the treaty it seeks to verify. Therefore, the objective of this section is to outline the treaty structure and verification measures of the international agreements at the forefront of nuclear, chemical, and biological weapons arms control (the NPT, CWC, and BWC) and highlight the mechanisms they have in place to reduce access to dangerous materials and technology.<sup>16</sup>

### The NPT: Structure and Implementation

The NPT has perhaps the most institutionalized and comprehensive verification measures among the three multilateral arms control agreements referenced in this report. This status is largely reflective of international concern regarding the nuclear arms race and the prospect of mutually assured destruction. Efforts to stem the development of nuclear WMDs began in earnest in 1953 with President Eisenhower’s Atoms for Peace speech to the UN in which he called for the establishment of “an international atomic energy agency.” This call was answered four years later when the IAEA was officially formed as an UN-based, autonomous organization. Finally, in 1970, decades of concerted effort resulted in the NPT, which endowed the IAEA with a legal mandate to serve as its verification body.

The implementation of IAEA safeguards begins with the conclusion of a safeguards agreement. As dictated by Article III of the NPT, non-nuclear weapon states (NNWS)<sup>17</sup> are required to conclude a comprehensive safeguards agreement (CSA) with the IAEA. With a CSA in place, the IAEA “has the right and obligation to ensure that safeguards are applied on all such nuclear material for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other

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<sup>14</sup> United Nations Institute for Disarmament Research, *Coming to Terms with Security: A Handbook on Verification and Compliance*, (October 2003). <https://unidir.org/files/publication/pdfs/coming-to-terms-with-security-a-handbook-on-verification-and-compliance-en-554.pdf>. Accessed January 3, 2025. p. 25.

<sup>15</sup> Ibid., p. 98.

<sup>16</sup> Annex I contains a table illustrating the differences in verification techniques implemented for the NPT, BWC, and CWC.

<sup>17</sup> Non-nuclear weapons states can be defined as nations who had not detonated a nuclear weapon prior to January 1, 1967, and have agreed, by becoming a State Party to the NPT, not to pursue the development of nuclear weapons. See United Nations Office for Disarmament Affairs, “Nuclear Non-Proliferation Treaty,” (n.d.). <https://www.unrcpd.org/wmd/the-nuclear-non-proliferation-treaty/#:~:text=The%20NPT%20defines%20a%20nuclear,weapon%20states%20under%20the%20Treaty>. Accessed January 16, 2025.

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nuclear explosive devices.”<sup>18</sup> While nuclear weapon states (NWS)<sup>19</sup> are not required to conclude a CSA, all five have concluded voluntary offer agreements (VOAs) with the Agency in which they declare and offer up materials and sites to the Agency for verification. For NNWS, however, the term ‘comprehensive’ proved to be a misnomer, as CSAs were insufficient to “detect undeclared nuclear material and activities” in Iraq and North Korea.<sup>20</sup> Therefore, CSAs were later strengthened by the introduction of the Additional Protocol (AP) in 1997, which expanded the IAEA’s access to information and physical sites. Although negotiating and signing an AP is optional for member states, an overwhelming 141 nations (plus Euratom) have APs in force.<sup>21</sup> These clearcut, binding agreements have served as a strong legal foundation for nuclear verification activities

With a safeguards agreement in place, the IAEA is empowered to employ a patchwork of verification techniques to deter and detect the unauthorized possession and/or use of prohibited materials and technologies. Because the IAEA serves as a third-party verification organization, information shared from States Parties takes the form of data declarations, rather than data exchanges.<sup>22</sup> When states have both a CSA and AP in place, these declarations can include “nuclear material accounting reports, advance notifications of transfers of nuclear material and facility design information, and information about the State’s nuclear and nuclear-related activities.”<sup>23</sup>

Declared information is then checked against other sources including open-source information analyzed by IAEA researchers such as government reports, commercial satellite data, and operator publications. Although neither CSAs nor APs mandate the use of NTM, data collected via NTM is inevitably considered when states voluntarily provide “third party information” on one another. In addition to data declarations, the IAEA safeguards system includes robust protocols for in-person inspections of the ad hoc, routine, and special variety when member states have an AP in place. During these inspections, IAEA personnel cross reference state declarations with physical inventory in a process called nuclear material accountancy. Inspectors also engage in design information verification, environmental sampling, and monitoring via cameras and electronic seals.

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<sup>18</sup> International Atomic Energy Agency, “More on Safeguards Agreements,” <https://www.iaea.org/topics/safeguards-legal-framework/more-on-safeguards-agreements>. Accessed January 3, 2025.

<sup>19</sup> As defined by the NPT, nuclear weapon states are nations which had detonated a nuclear weapon prior to January 1, 1967. See United Nations Office for Disarmament Affairs, “Nuclear Non-Proliferation Treaty.” <https://www.unrcpd.org/wmd/the-nuclear-non-proliferation-treaty/#:~:text=The%20NPT%20defines%20a%20nuclear,weapon%20states%20under%20the%20Treaty>. Accessed January 16, 2025.

<sup>20</sup> International Atomic Energy Agency, “Additional Protocol,” <https://www.iaea.org/topics/additional-protocol>. Accessed January 3, 2025.

<sup>21</sup> Ibid.

<sup>22</sup> Although States Parties to the NPT provide information to the IAEA, rather than one another, information sharing in support of NPT obligations is not entirely one-sided. The IAEA provides information to States Parties via numerous publications including a yearly Safeguards Statement which details information on the organization’s activities, methodologies, budget, and safeguards conclusions. See IAEA, “Safeguards Statement for 2023,” (June 7, 2024). [https://www.iaea.org/sites/default/files/24/06/20240607\\_sir\\_2024\\_part\\_ab.pdf](https://www.iaea.org/sites/default/files/24/06/20240607_sir_2024_part_ab.pdf). Accessed January 16, 2025.

<sup>23</sup> International Atomic Energy Agency, “IAEA Safeguards Serving Nuclear Non-Proliferation,” (June 2015). [https://www.iaea.org/sites/default/files/safeguards\\_web\\_june\\_2015\\_1.pdf](https://www.iaea.org/sites/default/files/safeguards_web_june_2015_1.pdf). Accessed January 3, 2025.

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## The BWC: Structure and Implementation

The Biological Weapons Convention, formally known as the Convention on the Prohibition of the Development and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, entered into force in 1975. Its origins, however, lie in the Geneva Protocol which entered into force in 1928 following World War I at a time when chemical and biological weapons were often discussed in tandem.<sup>24</sup> Ultimately, the Geneva Protocol addressed first use concerns surrounding the two categories of WMDs but failed to effectively prohibit retaliatory use for countries like France, the UK, and the USSR who asserted that, should another nation violate the first-use prohibition, they would retain the right to respond in kind.<sup>25</sup> The protocol also failed to address or prohibit the development or possession of such weapons.

Efforts to pursue a more comprehensive agreement for biological weapons began in earnest in 1969 with a British proposal to the UN's Eighteen Nation Disarmament Committee (ENDC) which proposed the elimination of biological weapons alone. Separating chemical and biological threats proved contentious, with the USSR claiming the action would cause an arms race for chemical weapons. The United States, on the other hand, argued that "biological weapons presented less intractable problems, and an agreement on banning them should not be delayed until agreement on [...] chemical weapons could be reached."<sup>26</sup> Although the United States' subsequent unilateral renouncement of all biological warfare was supported by other nations, including the UK, Canada, and Sweden, traction on the issue was not gained until "the Soviet Union and its allies changed their position" in 1971. Ensuing negotiations ultimately culminated in the BWC.

Once in force, the BWC was regarded as "the first measure, reached since the Second World War, involving the destruction of existing weapons."<sup>27</sup> Despite this achievement, and greater optimism in the arms control field surrounding the successful implementation of the NPT, the BWC ultimately fell short of its goals. Although the BWC prohibits the production, stockpiling, use, and transfer of biological weapons and their component materials and technology, it fails to establish a robust verification system or assign verification responsibility to any particular entity.

The lack of infrastructure necessary to verify the BWC has not gone unnoticed. Efforts to establish such a protocol have been recurring since 1991. One such notable attempt was the establishment of the VEREX<sup>28</sup> ad hoc group in 1991 which was formed to "identify and examine potential

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<sup>24</sup> United Nations Office for Disarmament Affairs, "History of the Biological Weapons Convention," <https://disarmament.unoda.org/biological-weapons/about/history/>. Accessed January 3, 2025.

<sup>25</sup> United Nations General Assembly, *Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare*, (June 17, 1925). <https://2009-2017.state.gov/t/isn/4784.htm>. Accessed January 3, 2025.

<sup>26</sup> U.S. Department of State, "Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction," <https://2001-2009.state.gov/t/ac/trt/4718.htm#:~:text=The%20United%20States%20supported%20the,all%20methods%20of%20biological%20warfare>. Accessed January 3, 2025.

<sup>27</sup> United Nations Office for Disarmament Affairs, "History of the Biological Weapons Convention," <https://disarmament.unoda.org/biological-weapons/about/history/>. Accessed January 3, 2025.

<sup>28</sup> The name VEREX is short for 'verification experts.' See Graham S. Pearson, "The Fourth BWC Review Conference," *Arms Control Today*. <https://www.armscontrol.org/act/1997-01/features/fourth-bwc-review-conference>. Accessed January 16, 2025.

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verification measures from a scientific and technical standpoint.”<sup>29</sup> The group, which consisted of government experts, met four times from 1992 to 1993 and ultimately published a final report detailing 21 potential verification measures for the BWC. A Special Conference was held in 1994 to discuss the report and subsequently called for the establishment of another Ad Hoc group to draft a formal verification protocol for the Treaty. By 2001, the group had constructed a draft protocol, which was ultimately rejected by the United States at the group’s last scheduled meeting. Reasons for rejecting the protocol included a lack of belief that the protocol, in its then-current state, could effectively verify member states’ adherence to the BWC and a concern that “the protocol would not ‘provide sufficient protection’ for U.S. biodefense programs” or commercial proprietary information.<sup>30</sup> Despite the failure to reach consensus on the draft protocol, progress was made again in 2022 when a Working Group was established to strengthen the convention. The group’s mandate will last from 2023 to 2026. According to UNIDIR, this marks “the first time in 20 years that verification will be formally discussed within the BWC framework” since the failure to ratify the draft protocol in 2001.<sup>31</sup>

Although the BWC lacks a formal verification protocol and enforcement body, groups have pursued alternative means to strengthen the Treaty. Since the BWC’s entry into force, States Parties have utilized review conferences as opportunities to implement confidence building measures (CBMs) as a stop gap. The BWC’s Third Review Conference, held in 1991, was particularly fruitful in this regard, yielding a “a new format of confidence-building measures to improve international cooperation in the field of peaceful bacteriological (biological) activities.”<sup>32</sup> As dictated by the format, States Parties agree to increased data exchanges and declarations including information on: national biological defense programs, outbreaks of infectious diseases, regulations and legislation, past biological research (of the offensive and defensive variety), and vaccine production facilities, among other topics. Though helpful, CBMs, by nature, are voluntary and do not obviate the need for verification measures. Furthermore, it should be noted that although voluntary declarations have increased over the years, in 2024, 44% of States Parties to the BWC (83 nations) failed to report on the topics noted above.<sup>33</sup> With these observations in mind, the BWC does comparatively little in the way of verification to decrease the biological threat landscape.

## The CWC: Structure and Implementation

Events in the late 1980s served as a motivating factor for reaching a consensus on a multilateral arms control agreement on chemical weapons (CW). These events included “the chemical attack

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<sup>29</sup> U.S. Department of State, “Biological Weapons Convention,” (November 12, 1996). <https://1997-2001.state.gov/global/arms/factsheets/wmd/bw/bwcover.html>. Accessed January 3, 2025.

<sup>30</sup> Rebecca Whitehair and Seth Brugger, “BWC Protocol Talks in Geneva Collapse Following U.S. Rejection,” Arms Control Association. <https://www.armscontrol.org/act/2001-09/press-releases/bwc-protocol-talks-geneva-collapse-following-us-rejection#:~:text=In%20a%20highly%20anticipated%20speech,for%20the%20Ad%20Hoc%20Group>. Accessed January 6, 2025.

<sup>31</sup> James Revill, “Verifying the BWC: A Primer,” United Nations Institute for Disarmament Research (2023). [https://unidir.org/wp-content/uploads/2023/10/UNIDIR\\_Verifying\\_BWC\\_Primer.pdf](https://unidir.org/wp-content/uploads/2023/10/UNIDIR_Verifying_BWC_Primer.pdf). Accessed January 6, 2025.

<sup>32</sup> Nuclear Threat Initiative, “Biological Weapons Convention.” <https://www.nti.org/education-center/treaties-and-regimes/convention-prohibition-development-production-and-stockpiling-bacteriological-biological-and-toxin-weapons-btbc/#:~:text=Background.and%20establish%20confidence%2Dbuilding%20measures>. Accessed January 6, 2025.

<sup>33</sup> United Nations, “BWC Confidence Building Measures.” <https://bwc-cbm.un.org/>. Accessed January 6, 2025.

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on Halabja, Iraq in 1988, publicity given to the threat of chemical warfare during the Gulf War, and the announcement of a bilateral United States–Soviet Union agreement to destroy most of their CW stockpiles and to refrain from further CW production.”<sup>34</sup> These developments, in conjunction with ongoing negotiations, eventually yielded the Chemical Weapons Convention, which entered into force in 1977 and is heralded as “the world’s first multilateral disarmament agreement to provide for the elimination of an entire category of weapons of mass destruction within a fixed time frame.”<sup>35</sup>

Despite (or perhaps due to) perceptions that addressing chemical weapons would be difficult, the CWC has been endowed with a robust verification system. Unlike the BWC, the CWC benefits from an organization tasked with verification implementation. As outlined in Article VIII, the Organization for the Prohibition of Chemical Weapons (OPCW) is responsible for verifying that States Parties do not produce, stockpile, use, or transfer chemical weapons. Much like the IAEA, the OPCW pursues this goal through various verification techniques, many of which fall into the categories of data declarations and inspections.

Prior to discussing CWC verification techniques, it should be noted that the structure of the CWC is such that verification is implemented in degrees. In essence, facilities that present a higher risk of contributing to chemical weapons production or the illicit diversion of chemicals are subject to greater scrutiny. Risk, in turn, is determined by the presence of specific chemicals. The CWC’s Annex on Chemicals separates toxic chemicals and their precursors into three ‘schedules’ based on their utility to known chemical weapons processes. Schedule 1 chemicals are said to pose a “high risk”, while Schedule 2 and 3 chemicals are labeled as a “significant risk” and “risk” respectively.<sup>36</sup> Thus, facilities which produce, consume, store, stockpile, or transfer Schedule 1 chemicals are subjected to more extensive verification techniques.

Data declarations represent a significant portion of CWC verification activities. Upon ratifying the CWC, States Parties are responsible for providing an initial declaration within 30 days, followed by annual declarations, which include information on scheduled chemicals (including quantities produced, processed, consumed, imported, and exported), chemical facilities (both state-owned and commercial), and any existing chemical weapon stockpiles. In general, because Schedule 1 chemicals consist of those used in known chemical weapons, more detailed information must be provided on an annual basis. This includes advance notifications of any transfers and detailed information on quantities produced, processed, consumed, and transferred. Schedule 2 chemicals are subject to similar reporting guidelines (without advance notices), while the possession of Schedule 3 chemicals requires reporting on production, imports, and exports. This data is then collected, assessed, and compiled by the OPCW’s Verification Division.<sup>37</sup>

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<sup>34</sup> Organisation for the Prohibition of Chemical Weapons, “History,” (n.d.). <https://www.opcw.org/about-us/history>. Accessed January 6, 2025.

<sup>35</sup> Ibid.

<sup>36</sup> “Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction,” opened for signature January 13, 1993, *Treaties and International Agreements Registered or Filed and Recorded with the Secretariat of the United Nations* 1974, no. 33757 (1997): 45-466, <https://treaties.un.org/doc/Publication/UNTS/Volume%201974/v1974.pdf>. Accessed January 16, 2025.

<sup>37</sup> Organisation for the Prohibition of Chemical Weapons, “The Verification Regime of the Chemical Weapons Convention: An Overview,” (November 28, 2008). <https://www.opcw.org/media-centre/news/2008/11/verification-regime-chemical-weapons-convention-overview>. Accessed January 6, 2025.

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In conjunction with these declarations, States Parties are responsible for negotiating and concluding individual facility agreements, which form the basis for on-site inspections. Much like data declarations, inspections are also guided by risk assessments. For example, facilities handling high risk Schedule 1 chemicals in quantities greater than 100 grams must be inspected. At these sites inspectors are not given a time limit to conclude their work and must only provide a minimum of 24 hours' notice prior to initiating an inspection. In sharp contrast, facilities handling Schedule 3 chemicals only require inspections when production is more than 200 aggregate tonnes (200,000 kilograms) annually. Inspections on these sites require an advance notice of at least 120 hours and must conclude within 24 hours unless an extension is obtained.

Once facility agreements are established, the OPCW develops a program of inspections in which sites are selected for inspection via an algorithm that prioritizes high risk facilities.<sup>38</sup> Inspections are then carried out by technical experts<sup>39</sup> from the OPCW's Inspectorate Division who employ a variety of techniques including seal installation, environmental sampling, and design verification among others. This work is supported by the work of the OPCW Laboratory and a network of 20 additional OPCW-approved labs responsible for the analysis of collected samples.

It should also be noted that, in addition to regularly scheduled inspections, the CWC provides for the execution of investigations of alleged use and challenge inspections.<sup>40</sup> While investigations of alleged use have yielded subsequent fact-finding missions in the past, challenge inspections have yet to be initiated due to concerns that the measure would be used in a retaliatory manner. Furthermore, although the OPCW has famously advertised the verifiable destruction of "100% of the chemical weapons stockpiles declared by possessor States," questions abound as to whether *all* stockpiles have been declared.<sup>41</sup> Known CW use by member states like Russia and Syria suggest otherwise. Therefore, while implementation of the measures discussed above may significantly reduce WMD threats by restricting access to sensitive materials and ensuring the absence of weapons technology, the impact of geopolitical dynamics and emerging technology on this progress remains to be seen.

## Section III: Challenges to Verification Measures

Multilateral nonproliferation agreements are under threat. As geopolitical tensions rise, these institutions have become yet another arena for proxy fights, undermining norms and verification measures. Meanwhile, emerging technologies threaten to exploit verification loopholes and lower barriers to WMD production. This section thus begins with a discussion on the ways in which geopolitical tensions have impacted the multilateral agreements noted above, followed by an

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<sup>38</sup> Organisation for the Prohibition of Chemical Weapons, "How Does the OPCW Monitor Compliance with the Chemical Weapons Convention?," (October 11, 2020).

[https://www.youtube.com/watch?v=0aQY98AACCU&t=98s&ab\\_channel=OPCW](https://www.youtube.com/watch?v=0aQY98AACCU&t=98s&ab_channel=OPCW). Accessed January 16, 2025.

<sup>39</sup> Technical experts include analytical chemists, munitions experts, chemical engineers and health and safety experts. Ibid.

<sup>40</sup> Organisation for the Prohibition of Chemical Weapons, "Responding to the Use of Chemical Weapons," (n.d.). <https://www.opcw.org/our-work/responding-use-chemical-weapons>. Accessed January 6, 2025.

<sup>41</sup> Organisation for the Prohibition of Chemical Weapons, "OPCW By the Numbers," (August 31, 2024). <https://www.opcw.org/media-centre/opcw-numbers>. Accessed January 6, 2025.

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exploration of how emerging technologies can affect the nuclear, chemical, and biological threat landscape we face today.

## Geopolitical Challenges to Verification

The geopolitical landscape is changing. As the United States acclimates to the realities of a multipolar world order, multilateral nonproliferation and arms control regimes are experiencing their own growing pains at the hands of revisionist powers like Russia, China, North Korea, and Iran. As these nations find themselves chafing under the confines of the norms these institutions promote, they are pursuing a variety of subtle, covert, and overt actions to undermine them.

The subtle agendas of revisionist states are largely relegated to the policy domain where nations strategically exercise veto rights, vote down resolutions, and thwart attempts to reach consensus. Within the OPCW, Russia is guilty of all three tactics. For example, Russia used its veto authority within the UNSC in 2017 to curtail the tenure of the investigative team responsible for attributing the use of chemical weapons in the Syrian Civil War. Russia was then aided by China, and later Iran, in its attempts to postpone further investigations and “vote down the 2019 OPCW program and budget.”<sup>42</sup> These actions, though legal, underscore the ways in which treaty structures enable a small minority to obstruct the efforts of those seeking to uphold arms control norms.

Nations have also pursued a variety of covert and overt actions to undermine international institutions. According to Dutch and UK officials, in April 2018 agents from Russia’s GRU military intelligence agency conducted a cyberattack on the OPCW and UK Defense and Science Technology Lab. The following month, GRU agents targeted OPCW personnel through the dissemination of phishing e-mails in which they impersonated Swiss authorities. The timing of these attacks suggested Russia may have been attempting to hinder the application of verification measures in the wake of the targeted assassination of former Russian military officer Sergei Skripal. In other, more overt instances, member states have refused to comply with international agreements and their respective inspection teams. North Korea attempted this strategy in the 1990s—starting with the denial of access requests for specific facilities, escalating to cutting seals and disabling IAEA surveillance systems, and ending with the withdrawal of North Korea from the NPT.<sup>43</sup>

## The Impact of Misinformation on Verification

Misinformation campaigns, though disdained in the public eye, have nevertheless evolved to serve a large role in geopolitical strategy. WMD programs and verification measures for nonproliferation regimes are no exception, and they have been the target of misinformation. For example, during the Cold War, the USSR conducted Operation Denver in which they attempted to spread the idea that the U.S. AIDS epidemic was “the result of secret experiments by the United States’ secret services

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<sup>42</sup> Alicia Sanders-Zakre, “Russia Blocks Consensus at CWC Conference,” *Arms Control Today* 42, no. 1 (January/February 2019). <https://www.armscontrol.org/act/2019-01/news/russia-blocks-consensus-cwc-conference>. Accessed January 6, 2025.

<sup>43</sup> International Atomic Energy Agency, “Fact Sheet on DPRK Nuclear Safeguards,” (n.d.). <https://www.iaea.org/newscenter/focus/dprk/fact-sheet-on-dprk-nuclear-safeguards>. Accessed January 6, 2025.

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and the Pentagon with new types of biological weapons that [...] spun out of control.”<sup>44</sup> In fact, the operation proved “remarkably effective,” ultimately convincing swaths of people across the globe, and even U.S. citizens, that HIV was the product of U.S. government bioweapon experiments gone wrong.<sup>45</sup> Government officials are also at risk of believing these false campaigns. In 2016, Pakistan’s defense minister fell prey to an article falsely claiming Israel had stated it would “destroy [Pakistan] with a nuclear attack” if they placed troops in Syria.<sup>46</sup> In response, Pakistan’s defense minister responded via Twitter reminding Israel that, “Pakistan is a nuclear state too.”<sup>47</sup>

Beyond ratcheting up tensions in an already complex and contested geopolitical environment, misinformation can have a direct effect on nonproliferation regimes and the verification measures they rely on. First, misinformation campaigns have an overall erosive effect on arms control and nonproliferation norms. As noted by the Center for the Study of WMDs, misinformation “allows the state actors controlling the information environment to feel they can act with impunity, including potentially using these dangerous and banned weapons.”<sup>48</sup> This trend has been observed in the ongoing Russia-Ukraine war, during which Russia has utilized riot control agents (RCAs) against Ukrainian troops, in direct violation of the CWC, while simultaneously making unsubstantiated claims that Ukraine has employed chemical weapons in warfare and operated a chemical weapons program prior to the invasion.<sup>49</sup>

Misinformation has also been utilized to thwart attribution. Following Syria’s adoption of the CWC in 2013, the OPCW led a fact-finding mission in 2014, which concluded that chemical weapons had been used during the Syrian Civil War. The OPCW-UN Joint Investigative Mechanism (JIM) was then established to discern which party was responsible, ultimately attributing the violations to the Syrian military in 2016. Following a Sarin attack in 2017, Russia and the Assad Regime “quickly flooded the media with disinformation and outright fabrications, claiming the opposition itself had launched the attack to falsely accuse the Assad regime.”<sup>50</sup> The use of misinformation to thus erode arms control mechanisms has caused institutions like NATO to pose the question: “How do we have verifiable arms control when everything is ‘narrative’?”<sup>51</sup>

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<sup>44</sup> Mark Kramer, “Lessons From Operation ‘Denver,’ the KGB’s Massive AIDS Disinformation Campaign,” The MIT Press Reader (May 26, 2020). <https://thereader.mitpress.mit.edu/operation-denver-kgb-aids-disinformation-campaign/>. Accessed January 6, 2025.

<sup>45</sup> Ibid.

<sup>46</sup> Emma Graham-Harrison, “Fake news story prompts Pakistan to issue nuclear warning to Israel,” The Guardian (December 25, 2016). <https://www.theguardian.com/world/2016/dec/26/fake-news-story-prompts-pakistan-to-issue-nuclear-warning-to-israel>. Accessed January 6, 2025.

<sup>47</sup> Sam Meyer, “Fake News, Real Consequences: The Dangers of WMD Disinformation,” Nuclear Threat Initiative (December 7, 2017). <https://www.nti.org/analysis/articles/fake-news-real-consequences-dangers-wmd-disinformation/>. Accessed January 6, 2025.

<sup>48</sup> Center for the Study of Weapons of Mass Destruction, “Russian Information Manipulation About Chemical Weapons,” National Defense University (n.d.). <https://wmdcenter.ndu.edu/Education/WMD-Disinformation/>. Accessed January 6, 2025.

<sup>49</sup> Ibid.

<sup>50</sup> Kenneth D. Ward, “Syria, Russia, and the Global Chemical Weapons Crisis,” *Arms Control Today* 51, no. 7 (September 2021). <https://www.armscontrol.org/act/2021-09/features/syria-russia-and-global-chemical-weapons-crisis>. Accessed January 6, 2025.

<sup>51</sup> Sarah Jacobs Gamberini and Justin Anderson, “Russian and Other (Dis)information Undermining WMD Arms Control: Considerations for NATO,” (July 12, 2022). Prepared remarks to the NATO Committee on Proliferation. <https://wmdcenter.ndu.edu/Portals/97/Documents/Publications/Presentations/RF%20and%20other%20Disinfo%20on>

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## Emerging Technologies

Emerging technologies pose a threat to arms control regimes by confounding the application of verification measures. Cross-cutting technologies like additive manufacturing, artificial intelligence, and nanotechnology lower technological, fiscal, and/or operational barriers to WMD production while, in some cases, also increasing efficiency. Meanwhile, domain-specific technologies including advancements in synthetic biology and synthetic chemistry threaten to change and/or reduce the presence of signatures current verification measures are designed to detect.

### Additive Manufacturing

Additive manufacturing (AM) has the potential to significantly impact a multitude of WMD categories. Defined as “an emerging means of production in which objects are created by layering materials in precise geometric shapes according to a predetermined design,” AM offers a means to produce WMD component parts with cheap, easily acquired technology through a variety of techniques.<sup>52</sup>

Historically, many AM techniques (like 3D printing) have been restricted to employing specific starches, plasters, or plastics, thereby constructing final products with lower tensile strength and mechanical properties dependent upon print direction.<sup>53</sup> However, novel techniques such as selective laser melting (SLM) are expanding access to materials with more advantageous properties. As one industry professional stated, these techniques will allow people to “throw the entire polymer chemistry textbook at this and [...] design chemistries that can give rise to the properties you really want.”<sup>54</sup> With better materials, however, comes higher risk: allowing actors to build components with materials better suited to the unique needs of weapons systems, like maraging steel. In fact, Cannon et al. (2022) outline a staggering 33 AM techniques, nine of which were labeled as “high risk,” indicating “current [AM] applications for the nuclear fuel cycle and nuclear power reactors.”<sup>55</sup> These developments, though often analyzed through the lens of nuclear proliferation, can lower barriers to entry for all WMDs by allowing actors to easily construct component parts for delivery systems or other machinery in the weaponization process.

Regarding verification, it should be noted that the use of AM to produce WMD components is difficult to track. With AM technology, actors with malintent may be less inhibited by international controls such as those imposed by multilateral export control regimes (MECRs). Computer-aided design (CAD) files, serving as an AM device’s instruction manual for a specific design, are easily

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[%20Arms%20Control\\_remarks%20to%20NATO%20Committee%20on%20Prolif\\_12%20July%202022\\_FINAL.pdf](#).

Accessed January 6, 2025.

<sup>52</sup> Center for Arms Control and Non-Proliferation, “Fact Sheet: Additive Manufacturing,” (October 19, 2023).

<https://armscontrolcenter.org/fact-sheet-additive-manufacturing/>. Accessed January 6, 2025.

<sup>53</sup> Joseph DeSimone, “What if 3D printing was 100x faster?” (March 19, 2015). Prepared remarks to TED2015 Conference.

[https://www.youtube.com/watch?v=ihR9SX7dgRo&ab\\_channel=TED](https://www.youtube.com/watch?v=ihR9SX7dgRo&ab_channel=TED). Accessed January 6, 2025.

<sup>54</sup> Ibid.

<sup>55</sup> Natalie Cannon, Steven Biegalski, and Anna Erikson, “Additive manufacturing: A Challenge to Nuclear Nonproliferation,” *Journal of Radioanalytical and Nuclear Chemistry* 331, no. 12 (2022), p. 4999.

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transmittable via the internet, thereby allowing actors to evade export controls and licensing requirements. Furthermore, AM equipment can have a relatively small footprint, depending on the size/build volume of the components being ‘printed.’ Finally, advances in print speed may also present an issue for arms control and verification by potentially reducing the time available to detect and disable an actor’s capabilities.

## Artificial intelligence

Artificial intelligence (AI) is another cross-cutting technology posing a proliferation risk for WMDs. Concerns regarding the application of AI to weapons of mass destruction fall into three categories: the use of AI to make WMDs more efficiently, the use of AI to expand access to WMD technological knowledge, and the potential for AI to “lower the threshold of WMD use.”<sup>56</sup> In terms of efficiency, AI can make great strides in research and development, particularly in the discovery of novel toxic compounds and biological agents engineered for enhanced toxicity or transmissibility. This is especially true when AI is applied to technologies such as combinatorial chemistry, discussed below. Second, although commercial AI providers have generally restricted the ability of their technology to provide dangerous information, if these controls are overridden, users can prompt the software to provide a step-by-step how-to guide for WMDs.<sup>57</sup> Finally, AI poses a threat to WMD use when integrated with key WMD controls. Although AI has been integrated into WMD control systems, such as nuclear command, control, and communication (NC3) infrastructure, this integration comes with inherent risks. Specifically, AI can reflect the biases and preferences of its programmers and can be fed faulty data, both of which could lead to disastrous decision making by those in charge of WMDs.

AI can also compound the proliferation risk posed by other technologies. This convergence (sometimes referred to as ‘super convergence’) can “create asymmetrical threats through game changing capabilities we cannot even imagine.”<sup>58</sup> Notably, AI machine learning models (MLMs) can assist in the optimization of additive manufacturing. Argonne National Laboratory has demonstrated that AI can successfully be used to detect defects in products as they are being printed.<sup>59</sup> Optimization can also be achieved by using AI to “predict potential issues before production begins, validate designs for 3D printing suitability, and minimize waste and iteration cycles.”<sup>60</sup> Applied to WMDs, this convergence means states can potentially produce better weapons more efficiently. The same is true when applying AI to combinatorial chemistry: “a synthesis strategy that enables the simultaneous production of large numbers of related

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<sup>56</sup> Oliver Meier, “The fast and the deadly: When Artificial Intelligence meets Weapons of Mass Destruction,” European Leadership Network (June 27, 2024). <https://europeanleadershipnetwork.org/commentary/the-fast-and-the-deadly-when-artificial-intelligence-meets-weapons-of-mass-destruction/>. Accessed January 6, 2025.

<sup>57</sup> Ibid.

<sup>58</sup> Christopher Daase, Grant Christopher, Ferenc Dalnoki-Veress, Miles Pomper, and Robert Shaw, “WMD Capabilities Enabled by Additive Manufacturing,” Middlebury Institute of International Studies at Monterey (September 3, 2019). [https://nonproliferation.org/wp-content/uploads/2019/09/NDS\\_Report\\_1908\\_WMD\\_AM\\_2019.pdf](https://nonproliferation.org/wp-content/uploads/2019/09/NDS_Report_1908_WMD_AM_2019.pdf). Accessed January 6, 2025.

<sup>59</sup> Nikki Forrester, “Researchers Unveil New AI-driven Method for Improving Additive Manufacturing,” Argonne National Laboratory (March 9, 2023). <https://www.anl.gov/article/researchers-unveil-new-aidriven-method-for-improving-additive-manufacturing>. Accessed January 6, 2025.

<sup>60</sup> Anthony Massobrio, “How AI is Transforming Additive Manufacturing,” Neural Concept (n.d.). <https://www.neuralconcept.com/post/how-ai-is-transforming-additive-manufacturing>. Accessed January 6, 2025.

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compounds.”<sup>61</sup> Although AI is typically applied to combinatorial chemistry in a pharmaceutical context, identifying novel chemical compounds for medical treatments, the parameters can be reversed to maximize harm. This phenomenon has been demonstrated by scientists who merely “flip[ped] a little inequality symbol in [a] code” originally designed to discover novel, non-toxic drugs and then provided the AI program with a robust dataset from which to mix and match chemicals.<sup>62</sup> Overnight the program was able to produce a substantial library of compounds designed to inhibit acetylcholinesterase, many of which were deemed more toxic than the nerve agent VX.

Regarding verification, the introduction of AI has pros and cons. It should be noted that although AI can optimize processes related to WMDs and democratize access to related information, it does not provide people with access to information they could not otherwise have. The ability of AI to ‘connect the dots’ between critical pieces of open-source information, however, may be significant in altering the ‘intent’ component of WMD threats: making specific weapons more attractive by lowering barriers to their creation and use. Furthermore, while AI can contribute to a state’s ability to acquire technological knowledge necessary to develop WMDs and may be easily transmitted via the internet, like CAD files. While these developments do not necessarily affect verification by altering known signatures, their potential to create an increased demand for verification regimes should not be understated, particularly regarding the need to discern state violations from those committed by non-state actors. However, it should be noted that AI can optimize and improve verification measures via its “ability to process immense amounts of data and detect unusual patterns” and “improve situational awareness.”<sup>63</sup>

## Nanotechnology

Nanotechnology is the third and final category of crosscutting technology. Defined as “engineering processes and tools that allow the manipulation of individual atoms and molecules,” nanotechnology is poised to make a big impact in biology and chemistry.<sup>64</sup> Specifically, the application of nanotechnology can improve both the production and transportation of chemical/biological (CB) agents. Furthermore, nanotechnology requires a smaller volume of these agents, thereby reducing the footprint required for weaponization and making the detection of covert operations more difficult. Employed in conjunction with advances biology and chemistry, nanotechnology can enable the creation of novel agents: complicating the identification of agents and the attribution of their use. In fact, when paired with synthetic biology tools like gene editing (discussed below) it may be possible “to create entirely new organisms, or to build new chemicals

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<sup>61</sup> Ken Appell, John J. Baldwin, and William J. Egan, “Combinatorial Chemistry and High-Throughput Screening in Drug Discovery and Development,” *Separation Science and Technology* 3, (2001).

<sup>62</sup> Jamie Durrani, “Drug discovery AI that developed new nerve agents raises difficult questions,” *Royal Society of Chemistry* (March 31, 2022). <https://www.chemistryworld.com/news/drug-discovery-ai-that-developed-new-nerve-agents-raises-difficult-questions/4015462.article>. Accessed January 6, 2025.

<sup>63</sup> Oliver Meier, “The fast and the deadly: When Artificial Intelligence meets Weapons of Mass Destruction,” *European Leadership Network* (June 27, 2024). <https://europeanleadershipnetwork.org/commentary/the-fast-and-the-deadly-when-artificial-intelligence-meets-weapons-of-mass-destruction/>. Accessed January 6, 2025.

<sup>64</sup> Nicholas Winstead, “The Applications and Implications of Nanotechnology,” *American University* (April 15, 2020). <https://www.american.edu/sis/centers/security-technology/the-applications-and-implications-of-nanotechnology.cfm>. Accessed January 9, 2025.

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from the ground up.”<sup>65</sup> This poses a threat to the BWC, which lacks a formal verification system, and the CWC whose OPCW database may lack the priming to detect the unknown.

## Synthetic Biology and Genetic Engineering

Improvements in synthetic biology and genetic engineering threaten to lower barriers to the creation of biological weapons through the recreation of known pathogens and spread of easily accessible gene editing technology. Synthetic biology is a broad field, referring to “a set of concepts, approaches, and tools within biotechnology that enable the modification or creation of biological organisms.”<sup>66</sup> The field itself has advanced via the application of tools from disciplines including chemistry, engineering, and more, yielding critical scientific achievements like DNA and protein synthesis. Although this knowledge has been applied to developing vaccines and drugs, it can also be applied to the recreation of dangerous viral and bacterial strains whose genomes have already been codified. This concern was made salient in 2011 after an international team of researchers successfully codified the genome of the *Yersinia pestis* bacterium, famously known for causing the Black Plague.<sup>67</sup>

Chief among the concerning applications enabled by synthetic biology is genetic engineering: the manipulation of an organism’s genome.<sup>68</sup> CRISPR-Cas9 is perhaps the most well-known genetic engineering tool available, offering actors an “easier, cheaper, and more precise” means of altering an organism’s genome while it is still alive.<sup>69</sup> Although this technology creates opportunities to ‘knock-out’ or repair a disadvantageous gene from an organism’s DNA (such as a predisposition to develop cancer) it can also be used to easily fortify known pathogens by enhancing transmissibility or resistance to antibiotics. Some experts assess the risk of CRISPR technology in the hands of the average person as “relatively low;” however, when it comes to state actors, locating personnel with technological know-how may not be significant hurdle.<sup>70</sup> These advancements are particularly concerning considering the BWC’s nonexistent verification system and lackluster participation in confidence building measures.

## Synthetic Chemistry

The application of emerging technologies to known synthetic chemistry methods poses a risk to current verification measures by reducing the footprint required to produce toxic chemicals, altering chemical signatures, and eliminating the need for specialized parts. Modern synthetic chemistry can create new pathways for toxic chemicals to form, thereby making chemical

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<sup>65</sup> Ibid.

<sup>66</sup> National Academies of Sciences, Engineering, and Medicine, *Biodefense in the Age of Synthetic Biology* (Washington, DC: The National Academies Press, 2018), p. 15.

<sup>67</sup> Nicholas Wade, “Scientists Solve Puzzle of Black Death’s DNA,” *The New York Times* (October 12, 2011). <https://www.nytimes.com/2011/10/13/science/13plague.html>. Accessed January 16, 2025.

<sup>68</sup> National Academies of Sciences, Engineering, and Medicine, *Biodefense in the Age of Synthetic Biology* (Washington, DC: The National Academies Press, 2018), p. 117.

<sup>69</sup> Dominik Juling, “Future Bioterror and Biowarfare Threats for NATO’s Armed Forces until 2030,” *Journal of Advanced Military Studies* 14, no. 1 (2023), p. 127.

<sup>70</sup> Annie Sneed, “Mail-Order CRISPR Kits Allow Absolutely Anyone to Hack DNA,” *Scientific American* (November 2, 2017). <https://www.scientificamerican.com/article/mail-order-crispr-kits-allow-absolutely-anyone-to-hack-dna/>. Accessed January 16, 2025.

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signatures “less direct” and potentially less likely to be detected when compared to the OPCW’s database if sampled during an on-site inspection.<sup>71</sup>

The use of photochemical and electrochemical methods may have a similar effect, reducing the need for traditional heat sources by using light or electricity to catalyze chemical reactions. Although neither photochemistry nor electrochemistry are emerging technologies, advancements in continuous flow platforms have enabled chemists to overcome issues of scale and efficiency. Flow chemistry, by nature, allows for the continuous production of compounds by steadily introducing streams of reactants to a chamber at predetermined flow rates.<sup>72</sup> This process, in contrast to traditional batch processing, requires a significantly smaller footprint and could allow states to more easily conceal operations. When used in conjunction with photochemical processes, the continuous flow method could also obviate the need for corrosion-resistant components required for more corrosive methods.<sup>73</sup> This, in turn, eliminates the need for states to procure specialized, closely tracked, and recognizable equipment to manufacture chemical weapons. In short, emerging technology could lower barriers to creating chemical weapons while also undermining the efficacy of verification measures established by the CWC.

## Section IV: The Path Forward and Opportunities for Improvement

### The Path Forward

The growing capacity of state actors and emerging technologies alike to undermine multilateral nonproliferation regimes and their verification measures has prompted many to question the utility of their existence going forward. After all, verification and implementation come at a hefty price. In 2023 alone, the IAEA and OPCW budgets were approximately \$457.9 million and \$82.2 million respectively.<sup>74</sup> The BWC, void of a verification mechanism and implementing body, had annual expenditures totaling roughly \$3.1 million.<sup>75</sup>

Assessing these budgets in an environment of repeated violations, the question then arises: are nations paying too much to preserve an imperfect system? The answer: it depends. If the overall aim of arms control and verification is to completely prevent the development and use of specified weapons systems, then perhaps the answer is yes. North Korea developed a nuclear weapons program despite its membership in the NPT, while Syria and Russia have both engaged in chemical weapons use after joining the CWC. If, however, the objective is to raise the perceived or actual costs of noncompliance as high as possible to promote compliance among as many state actors

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<sup>71</sup> Tuan H. Nguyen, “Countering the future chemical weapons threat: Shift focus from disarmament to preventing reemergence,” *Science* 376, no. 6591 (2022), p. 356.

<sup>72</sup> Mettler Toledo, “Flow Chemistry: Improve Safety, Reduce Cycle Time, Increase Quality and Yield,” (n.d.). [https://www.mt.com/us/en/home/applications/L1\\_AutoChem\\_Applications/continuous.html#:~:text=Flow%20chemistry%20continuous%20processing%20or,is%20collected%20at%20the%20outlet](https://www.mt.com/us/en/home/applications/L1_AutoChem_Applications/continuous.html#:~:text=Flow%20chemistry%20continuous%20processing%20or,is%20collected%20at%20the%20outlet). Accessed January 9, 2025.

<sup>73</sup> Tuan H. Nguyen, “Countering the future chemical weapons threat: Shift focus from disarmament to preventing reemergence,” *Science* 376, no. 6591 (2022), pp. 356-357.

<sup>74</sup> These values were converted to USD using the average exchange rate of 1.0821 USD for 2023. The 2023 IAEA and OPCW budgets were originally documented as €422.5M and €76M, respectively.

<sup>75</sup> This value was converted to USD using the average exchange rate of 1.0821. USD for 2023. The 2023 BWC budget was originally documented as €2.9M.

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as possible, then the answer is no. Given that total arms control for any weapon is highly unlikely due to the potential for undeterrable states, the NPT, BWC, and CWC should be considered largely successful. Therefore, while the gravity of nations pursuing WMD programs should not be understated, it should be compared to the potential for unchecked proliferation if these agreements and their verification mechanisms are dissolved.

## Opportunities for Improvement

### Strengthening Verification through Emerging Technologies

Although emerging technologies threaten to lower production barriers for WMDs, many of the emerging technologies discussed above are dual use in nature and, as such, cannot feasibly be banned. Furthermore, in some cases they can be used to strengthen verification measures. For example, while AI can be used to create libraries of toxic chemicals from which state actors can choose, the same library can be created and utilized by a verification organization, like the OPCW, for detection purposes. Likewise, nanotechnology has “enabled advances in detection technologies, including biosensors.”<sup>76</sup> In fact, the OPCW noted that nanotechnology, if used in conjunction with other technologies like Surface Enhanced Raman Spectroscopy (SERS), could be used to detect biological or nerve agents in an on-site inspection. Verification methods benefit from their own set of emerging technologies, irrespective of those altering the threat landscape. Advances in gamma radiation detection and attempts to detect chemical bonds unique to uranium processing represent some such developments.<sup>77</sup>

The application of emerging technologies to verification measures is, in large part, made possible through the creation of teams devoted to this goal. The IAEA pursues this mission through its Division of Technical and Scientific Services (DTSS) housed within the Department of Safeguards. In 2020, DTSS was responsible for launching a campaign to acquire proposals for a new and improved passive seals. This campaign eventually led to the creation and use of the field verifiable passive seal (FVPS) in 2022, thus replacing the traditional metal cap seals in use since the 1960s.

The CWC, understanding the critical link between science and verification methods, established a similar group at its inception. The Scientific Advisory Board (SAB), operating under the auspices of the OPCW, is responsible for regularly reporting to the Director General on advancements in science in technology which could pose a risk to chemical weapons proliferation and/or enhance verification measures. More recently, the group has turned its focus to applications of AI and the use of chemical forensics for attribution.

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<sup>76</sup> Organisation for the Prohibition of Chemical Weapons, *Report of the Scientific Advisory Board on Developments in Science and Technology for the Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention*, RC-4/DG.1 (November 21-30, 2018).

[https://www.opcw.org/sites/default/files/documents/CSP/RC-4/en/rc4dgg01\\_e\\_.pdf](https://www.opcw.org/sites/default/files/documents/CSP/RC-4/en/rc4dgg01_e_.pdf). Accessed January 9, 2025.

<sup>77</sup> Meg Murphy, “Explained: Detecting the Threat of Nuclear Weapons,” MIT News (June 8, 2018).

<https://news.mit.edu/2018/explained-detecting-threat-nuclear-weapons-scott-kemp-0608#:~:text=Detecting%20plutonium%20production%2C%20Kemp%20says,of%20heat%2C%E2%80%9D%20he%20says>. Accessed January 16, 2025.

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In contrast to the NPT and CWC, the BWC has thus far been unsuccessful in establishing a similar, permanent body of its own. In 1991, States Parties established the VEREX ad hoc group to “identify and examine potential verification measures from a scientific and technical standpoint.”<sup>78</sup> Having accomplished its goal, compiling a list of 21 potentially suitable verification measures, the group dissolved in 1993, but subsequent efforts to codify their recommendations and establish a formal verification mechanism failed in 2001. The BWC’s Ninth Review Conference, held in 2022, was somewhat fruitful: establishing a Working Group on the Strengthening of the Convention to address “scientific and technological developments relevant to the Convention, and compliance and verification,” among other objectives.<sup>79</sup> Most recently, the Working Group held its Fifth Session in December 2024. If successful, this meeting could yield a Special Conference in 2025 dedicated to codifying mechanisms for “international cooperation and assistance [and] scientific and technological review.”<sup>80</sup> However, as of January 2, 2025, the results of this session have not yet been released to the public.

### Strengthening Verification by Capturing Intent

In addition to applying technological advancements to verification measures, institutions could benefit from approaching proliferation threats from a holistic perspective. As previously noted, threats are comprised of three factors: access to dangerous materials, access to technology/procedural knowledge, and intent. Of these factors, material and technological access are often given precedent. After all, possession of prohibited materials or equipment is considerably easier to verify than an actor’s intent to do harm or make and use a WMD. If assessed correctly, however, intent can play a critical role in arms control and the allocation of verification resources.

The IAEA demonstrated this concept through the adoption of the Additional Protocol and implementation of the State-level concept. In short, the Additional Protocol expanded information available to the IAEA, enabling the agency to move beyond the traditional facility-to-facility approach. This, in turn, allowed the IAEA to develop and implement individualized safeguards plans. A similar approach, tailored to fit the needs of the BWC and CWC could be likewise beneficial. However, barriers to this approach are high. The NPT was able to achieve widespread adoption of the Additional Protocol thanks to several nations making its ratification a prerequisite for ‘peaceful nuclear cooperation.’<sup>81</sup> Even if a similar quid pro quo arrangement could be devised for the BWC and CWC, in an era of increasing geopolitical tensions states may be incentivized to provide skewed or falsified reports on one another to provoke more intensive verification

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<sup>78</sup> VEREX, “Fourth Session Summary Report,” (September 24, 1993). <http://www.bwc2011.info/BB2011-by-doc/2/VEREX-8.pdf>. Accessed January 17, 2025.

<sup>79</sup> International Science Council, “Call for nominations of experts: Providing scientific advice within the Biological Weapons Convention,” (June 20, 2024). <https://council.science/news/call-experts-bwc/#:~:text=As%20the%20BWC%20approaches%20significant,Convention%2C%20and%20compliance%20and%20verification>. Accessed January 9, 2025.

<sup>80</sup> Gabrielle Essix, “BWC at 50: Taking bold Steps to Secure the Future,” Nuclear Threat Initiative (November 25, 2024). <https://www.nti.org/risky-business/bwc-at-50-taking-bold-steps-to-secure-the-future/>. Accessed January 16, 2025.

<sup>81</sup> The Center for Arms Control and Non-Proliferation, “Factsheet: The Additional Protocol.” <https://armscontrolcenter.org/wp-content/uploads/2015/06/Additional-Protocol-Factsheet.pdf>. Accessed January 16, 2025.

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measures. Therefore, while a more holistic review of a State Party's activities could provide better insight on intent, copying the Additional Protocol will be insufficient.

## Conclusion

The verification systems supporting multilateral arms control agreements face a myriad of threats, both political and technological. Increasing geopolitical tensions continue to spill over into the arms control space, undermining norms and interfering with the implementation of verification measures. Meanwhile, emerging technologies threaten to lower barriers to WMD materials, technology, and procedural knowledge, while in some cases also altering the signatures verification measures are designed to detect. As geopolitical tensions show no signs of diminishing and revisionist states continue to pursue the erosion of arms control through misinformation campaigns and the exploitation of institutional loopholes, the survival of existing verification systems becomes increasingly contingent upon their ability to incorporate and adapt to emerging technologies. As such, the establishment and continuity of working committees dedicated to this mission is essential. Furthermore, as the expansion of dual use technologies continues to blur the line between arms control compliance and non-compliance, intent becomes difficult to accurately assess. Therefore, verification regimes may benefit from a more holistic review of state activities made possible through the adoption of an additional protocol. However, given the circumstances under which the IAEA's Additional Protocol achieved widespread adoption, multilateral arms control agreements like the BWC and CWC should first examine whether opportunities exist to establish a similarly effective quid pro quo.