

A quarterly publication from the AAAS Center for Science Diplomacy

Beatrice Maneshi and Jonathan E. Forman, "The Intersection of Science and Chemical Disarmament," *Science & Diplomacy*, Vol. 4, No. 3 (September 2015).  
<http://www.sciencediplomacy.org/perspective/2015/intersection-of-science-and-chemical-disarmament>.

**This copy is for non-commercial use only.** More articles, perspectives, editorials, and letters can be found at [www.sciencediplomacy.org](http://www.sciencediplomacy.org). *Science & Diplomacy* is published by the Center for Science Diplomacy of the American Association for the Advancement of Science (AAAS), the world's largest general scientific society.

## The Intersection of Science and Chemical Disarmament

*Beatrice Maneshi and Jonathan E. Forman*

SCIENCE has always played an important role in international diplomacy, particularly in regard to weapons of mass destruction disarmament treaties. Yet science and disarmament often appear at odds. From a security perspective, scientific discoveries and technological advances bring forth concerns about "dual-use"<sup>1</sup> potential that overshadow consideration of potential societal benefits;<sup>2</sup> and trends in multidisciplinary scientific discoveries (e.g., the "convergence" of chemistry and biology<sup>3, 4</sup>) are evaluated for their potential to challenge treaty implementation policies. Further widening the divide between science and multilateral disarmament diplomacy is the reality that most of the world's scientific research is conducted outside disarmament treaty contexts. Nevertheless, disarmament needs science,<sup>5</sup> and scientific practices can actually support the norms of disarmament. To this effect, we take a look at the Chemical Weapons Convention (CWC)<sup>6</sup> with its implementing body, the Organisation for the Prohibition of Chemical Weapons (OPCW), and its Scientific Advisory Board (SAB) to illustrate the complementarity and tensions between science and disarmament.

---

*Beatrice Maneshi is currently a candidate for a master of arts degree in Nonproliferation and Terrorism Studies at the Middlebury Institute of International Studies at Monterey. She served as an intern in the Office of Strategy and Policy at the Organisation for the Prohibition of Chemical Weapons in the summer of 2015.*

*Jonathan E. Forman is the science policy advisor in the Office of Strategy and Policy at the Organisation for the Prohibition of Chemical Weapons.*

## **Origins**

The CWC is one of three widely recognized (and in-force) international treaties that regulate the disarmament and nonproliferation of weapons of mass destruction, the others being the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT)<sup>7</sup> and the 1972 Biological Weapons Convention (BWC).<sup>8</sup> The nations supporting these treaties (the “States Parties”) include most of the world’s 196 internationally recognized states, although the membership list of each treaty is not identical. All these treaties are underpinned by science and technology—with scientific principles directly informing key articles, from the definitions of classes and categories of weapons, through to the articles that govern mechanisms and verification of compliance, inspection, and assistance and protection. Science likewise played a key role in the negotiation of all three treaties, providing a technical basis on which to inform policy.

The CWC was opened for signature in 1993 and entered into force on April 29, 1997, with eighty-seven States Parties (plus another seventy-eight signatories taking steps to ratify or accede to the treaty subsequently); today there are 191 States Parties, the most recent, as of August 7, 2015, being Myanmar. The treaty was created to eliminate an entire category of weapons of mass destruction by prohibiting the development, production, acquisition, stockpiling, retention, transfer, or use of chemical weapons by States Parties. These States Parties, in turn, must take the steps necessary to enforce that prohibition within their jurisdiction. Implementation revolves around a verification regime, agreed to by the States Parties, that allows international chemical weapons inspectors to verify the destruction of military stockpiles and to inspect chemical production facilities (including commercial facilities) meeting certain criteria within the territories of the States Parties.

States joining the CWC are obligated to disarm (destroy) existing chemical weapons stockpiles and to prohibit the use of scientific and technological advancements for any chemical weapons purposes. The treaty regime looks to technical experts to define methods of disarmament and oversight, basing technical cooperative agreements and assistance measures on scientific recommendations for best practices and implementation.

## **Scientific Advisory Board**

Science, technology, and world events can change rapidly, requiring new insights and understandings on activities related to treaty implementation and necessitating that CWC treaty adherents have access to scientific advice. The need to “review scientific and technological developments that could affect the operation of this Convention” is explicitly stated in CWC Article VIII.<sup>9</sup> To this end, the OPCW has as one of its subsidiary bodies the SAB. The SAB, an independent body that renders specialized advice to the OPCW director-general, has a membership of

twenty-five scientific experts nominated by States Parties and appointed by the director-general. The members serve up to two consecutive three-year terms in their individual capacity, not as a representative of a State Party. The board meets once to twice a year and has held twenty-two meetings since 1998, with the most recent in June 2015.<sup>10</sup>

Every five years, the CWC States Parties hold a review conference on the implementation of the CWC. The SAB prepares a comprehensive report for submission to these conferences assessing developments in science and technology that are relevant to treaty implementation, with a focus on both benefits and challenges.<sup>11</sup> The work of the SAB provides the OPCW with a connection to the greater scientific community—a critical need for sound assessments of new science and technology.

In the interim five-year periods between Review Conferences, the SAB is called upon to provide guidance on a wide range of issues—for example, riot control agents;<sup>12</sup> medical treatments for blister and nerve agents;<sup>13</sup> and, most recently, new science and technology with potential verification dimensions.<sup>14</sup> Reports are made publicly available through the OPCW website,<sup>15</sup> and SAB recommendations are considered by the director-general for further action, with any implementation undertaken by the OPCW Technical Secretariat.<sup>16, 17</sup> Some recommendations move forward through initiatives within the OPCW. For example, suggestions on monitoring scientific developments have led to broader engagement of the OPCW with scientific communities<sup>18</sup> and an informal science and technology newsletter;<sup>19</sup> and recommendations on enhancing science-themed engagement with policy makers prompted the launch of a series of “Science for Diplomats” briefings.<sup>20</sup>

When SAB recommendations have a potential impact on treaty implementation policies, the States Parties themselves become involved, moving a technical recommendation into the realm of multilateral diplomacy. Two examples discussed here are the formation of chemical warfare agents as unavoidable by-products of chemical-production processes and the meaning of “produced by synthesis.”

Regarding unavoidable by-products, in 2012 the SAB reported that it is technically feasible for sulphur and nitrogen mustards to form in low concentrations (as impurities) in certain industrial chemical-production processes.<sup>21</sup> However, sulphur and nitrogen mustards are both classified as Schedule 1 chemicals,<sup>22</sup> or chemicals that can be used directly as or in the manufacturing of chemical weapons. While the low concentrations that form would be impractical to isolate,<sup>23</sup> the production of any Schedule 1 chemical, irrespective of its concentration, is subject to the restrictions, declarations, and inspections set forth in the CWC; therefore, such impurities could have regulatory consequences.<sup>24</sup> The SAB recommended establishing a low-concentration limit for Schedule 1 chemicals. After consultations with States Parties, a procedure for handling unavoidable Schedule 1 by-products was developed.<sup>25</sup>

Another area where SAB recommendations had potential treaty implications is in the meaning of the term “production by synthesis.” States Parties are obligated to submit declarations on industrial chemical facilities within their territories at which discrete organic chemicals (DOCs)<sup>26</sup> are “produced by synthesis.”<sup>27</sup> Because bulk and fine chemicals are increasingly produced with biologically mediated processes (e.g., microbial fermentation or enzymatic processes), the boundaries between classic chemistry and classic biology have become blurred.<sup>28</sup> There are also inconsistencies in how States Parties declare facilities producing DOCs via bio-mediated production methods: some States Parties do not consider biologically based processes as being “production by synthesis” Because these declarations are inconsistent, the selection of facilities for inspection may also be inconsistent among States Parties.<sup>29</sup> In this regard, the SAB endorses the view that any process designed for the formation of a chemical substance should be covered by the term “produced by synthesis.”<sup>30</sup> The issue has been considered in temporary working groups of the SAB on the convergence of chemistry and biology<sup>31</sup> and verification.<sup>32</sup> These groups advised that the degree of relevance to the object and purpose of the CWC for bio-based facilities requires further assessment by the OPCW Technical Secretariat, the SAB, and the policy-making organs. At present, technical recommendations have been proposed and follow-up actions are being considered.<sup>33</sup>

## **Scientific Collaboration and Capacity Building**

Expertise in analytical science is critical for treaty implementation activities. The OPCW maintains a network of laboratories across currently seventeen of its States Parties to provide support for inspections and investigations.<sup>34, 35</sup> Scientists from these laboratories work both independently and collaboratively, as demonstrated in a recent topical issue of a scientific journal related to their work in chemical disarmament.<sup>36</sup>

The SAB and the designated laboratory system represent examples of international scientific collaboration intended to support and strengthen disarmament. These collaborations are valuable for maintaining an effective treaty regime, yet scientific collaboration itself, outside a purely disarmament focus, also plays a role in treaty implementation.

While the CWC came into existence to disarm and prevent proliferation of chemical weapons, it also promotes peaceful uses of chemistry to enable international cooperation for economic and technological development.<sup>37</sup> To begin with, international scientific collaboration can build trust between States Parties, an important aspect of maintaining an effective treaty regime. Additionally, promoting scientific collaboration provides a platform through which inequality between scientific haves and have-nots can be reduced. Both the NPT (Article IV) and BWC (Article X) expressly promote scientific collaboration.

Under Article XI of the CWC, States Parties will “undertake to facilitate, and have the right to participate in, the fullest possible exchange of chemicals, equipment and scientific and technical information relating to the development and application of chemistry for purposes not prohibited under this Convention.”<sup>38</sup> The OPCW supports Article XI through a series of capacity-building programs focused on developing countries and countries with transitional economies. These programs include analytical skills development courses; conference participation support; scientific equipment exchange; laboratory assistance; fellowships for scientists and engineers; chemical safety and security management courses; and small grants for research project support.<sup>39</sup> From 2010 to 2014, 147 projects were directly funded or co-funded, with the International Foundation for Science, across countries in Africa, Asia, Latin America, and the Caribbean, demonstrating the programs’ reach.<sup>40</sup> As of June 2015, these projects had resulted in fifty-seven publications in areas including green chemistry, chemical analysis, drug discovery, health, environment, food chemistry, and renewables. As these research projects generate publications and conference participation—which can also be supported through Article XI programs—the scientists gain exposure for their work; in turn, awareness of the OPCW and its disarmament mission is raised within scientific networks. Many States Parties can support the spirit of Article XI through other initiatives using mechanisms outside their disarmament-focused government agencies.

The international cooperation and capacity-building aspects of treaty implementation would appear to benefit science and promote science diplomacy, thus begging the question: how well does it work? In practice, achieving disarmament and nonproliferation while promoting scientific and technological progress requires a carefully calibrated balance between rights and obligations.

## **Moving Toward a World Free of Chemical Weapons**

In our twenty-first-century world, scientific and technological developments occur at an ever increasing pace, so fast in effect that laws, regulations, and treaties lag behind.<sup>41</sup> This occurs across sectors and on a global scale, aided by the diffusion of technologies through globalized economies and an ever more “connected” world. The speed of scientific development and discovery is self-reinforcing, such that states with developed and advanced science and technology infrastructure continue to technologically evolve more quickly than the ability of less technologically developed countries to catch up. In the disarmament and nonproliferation regime context, the difference is pronounced in terms of priorities between capacity building and nonproliferation. States with no weapons of mass destruction (“Non-Possessor States”) that find incentives for participation in these treaty regimes through the development and cooperation mechanism view capacity building as a higher priority than do the states possessing, or having the

technological capability to acquire, weapons of mass destruction; the latter states are likely to be the more advanced science and technology nations of the world.

These different sentiments are reflected in issues raised by States Parties during the meetings and conferences through which treaty implementation is reviewed and managed. The Non-Aligned Movement, which represents the largest bloc of States Parties in the United Nations as a loose political group, has called on the States Parties and implementing bodies to uphold their obligations to share science and technology, and submitted an action plan on the full implementation of CWC Article XI at the 2013 Third Review Conference. The plan called for a “steady increase, on an annual basis, of funding for the OPCW’s international cooperation and assistance programme through the regular budget.”<sup>42</sup> Other States Parties responded by highlighting their financial contributions to capacity-building programs and their support for the provisions of Article XI.<sup>43</sup>

As with so many aspects of diplomacy, the States Parties’ views on CWC Article XI remind us that despite agreement on intent and purpose—promoting international cooperation in support of CWC norms—there will always be debates on the particulars of States Parties’ obligations to a treaty, and how those obligations should be undertaken.

Another question to explore is how scientific practices from outside the realm of disarmament intersect with treaty implementation. Scientific and technological innovation is more prominent across the globe than ever before in history, and barriers to communication are quickly dropping. We are seeing changes in the types and availability of technologies as well as changes in the regions of the world that bring forth innovation.<sup>44</sup>

Investment in science and technology development, independent of region, provides opportunities for international scientific collaboration. As an example, China is third behind the collective twenty-eight European Union countries and the United States in total output of scientific and engineering publications;<sup>45</sup> and a closer look at the Chinese publications, using data from 2010, shows that more than 20 percent of these publications are co-authored with international collaborators—with about 40 percent of these co-authored papers involving institutions in the United States.<sup>46</sup> A study on patent applications noted frequent collaborative (internationally co-invented) patent filings associated with American companies opening facilities overseas—and especially in less-developed countries with weaker intellectual property protections.<sup>47</sup> Likewise, such collaborative practices are found across scientific communities of all nations. What makes these trends and observations relevant in the disarmament context is that scientists, both academic and industrial, in their collaborative efforts across sectors and countries are indirectly promoting one of the norms of disarmament treaties—international scientific collaboration.

As the journey continues toward a world free of chemical weapons—some 90 percent of declared military stockpiles have now been verified as destroyed, with

the remaining portion expected to be complete by 2023—the OPCW will focus increasingly on preventing the re-emergence of chemical weapons.<sup>48</sup> To this end, further promotion of scientific and technological capacity building is critical. Scientists, for their part, are sure to continue increasing the pace and output of innovation through international collaborations—collaborations that support disarmament. This complementarity between science and disarmament, although strained at times, leaves us with continuing opportunities to discuss the varied nature of science and technology that generates security concerns. In effect, the OPCW as the overseer of CWC implementation could provide a platform for enhanced interaction among scientists and policy makers, thereby helping further extend the reach of science diplomacy. Science and disarmament may sometimes appear to be strange bedfellows, but the two can be mutually reinforcing in unexpected ways. **SD**

#### Endnotes

1. Dual-use is a term used to describe science and technology developed or used for civilian purposes that has the potential to contribute to the proliferation of weapons of mass destruction or to have military applications.
2. Michael Crowley and Malcolm Dando, *Down the Slippery Slope? A Study of Contemporary Dual-Use Chemical and Life Science Research Potentially Applicable to Incapacitating Chemical Agent Weapons*, Biochemical Security 2030 Policy Paper Series no. 8 (October 2014), <https://biochemsec2030dotorg.files.wordpress.com/2013/08/down-the-slippery-slope-final-web.pdf>.
3. Ralf Trapp, *Convergence at the Intersection of Chemistry and Biology—Implications for the Regimes Prohibiting Chemical and Biological Weapons*, Biochemical Security 2030 Policy Paper Series, no. 6 (July 2014), <https://biochemsec2030dotorg.files.wordpress.com/2013/08/trapp-paper-6-online-version.pdf>.
4. *Convergence of Chemistry and Biology: Report of the Scientific Advisory Board's Temporary Working Group* (The Hague, The Netherlands: Organisation for the Prohibition of Chemical Weapons, June 2014), [https://www.opcw.org/fileadmin/OPCW/SAB/en/TWG\\_Scientific\\_Advisory\\_Group\\_Final\\_Report.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/TWG_Scientific_Advisory_Group_Final_Report.pdf).
5. *5OPCW Today: Science and Technology Issue 3*, no. 1 (August 2014), [http://www.opcw.org/fileadmin/OPCW/OPCW\\_Today/OPCW\\_Today\\_-\\_Vol\\_3\\_No\\_1.pdf](http://www.opcw.org/fileadmin/OPCW/OPCW_Today/OPCW_Today_-_Vol_3_No_1.pdf).
6. "Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction," Organisation for the Prohibition of Chemical Weapons, <https://www.opcw.org/chemical-weapons-convention>.
7. "Treaty on the Non-Proliferation of Nuclear Weapons," United Nations Office for Disarmament Affairs, <http://www.un.org/disarmament/WMD/Nuclear/NPT.shtml>.
8. "The Biological Weapons Convention: Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction," United Nations Office for Disarmament Affairs, <http://www.un.org/disarmament/WMD/Bio>.
9. Chemical Weapons Convention, Article VIII, Part B, Paragraph 21(h), [www.opcw.org/chemical-weapons-convention/articles/article-viii-the-organization](http://www.opcw.org/chemical-weapons-convention/articles/article-viii-the-organization).
10. *Report of the Twenty-Second Session of the Scientific Advisory Board* (Organisation for the Prohibition of Chemical Weapons, July 21, 2015), [https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-22-01\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-22-01_e_.pdf).
11. *Report of the Scientific Advisory Board on Developments in Science and Technology for the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons* (Organisation for the Prohibition of Chemical Weapons, October 29, 2010), [https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg01\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg01_e_.pdf).
12. *Declaration of Riot-Control Agents: Advice from the Scientific Advisory Board* (Organisation for the Prohibition of Chemical Weapons, May 1, 2014), [https://www.opcw.org/fileadmin/OPCW/S\\_series/2014/en/s-1177-2014\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/S_series/2014/en/s-1177-2014_e_.pdf).
13. *Response to the Director-General's Request to the Scientific Advisory Board to Provide Further Advice on Assistance and Protection* (Organisation for the Prohibition of Chemical Weapons, April 29, 2014), [https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-21-wp07\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-21-wp07_e_.pdf) [https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-22-wp02\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-22-wp02_e_.pdf).

14. *Verification Report of the Scientific Advisory Board's Temporary Working Group* (Organisation for the Prohibition of Chemical Weapons, June 11, 2015), [https://www.opcw.org/fileadmin/OPCW/SAB/en/Final\\_Report\\_of\\_SAB\\_TWG\\_on\\_Verification\\_-\\_as\\_presented\\_to\\_SAB.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/Final_Report_of_SAB_TWG_on_Verification_-_as_presented_to_SAB.pdf).
15. See the documents section on the OPCW's "Scientific Advisory Board" webpage: <https://www.opcw.org/about-opcw/subsidiary-bodies/scientific-advisory-board/documents/>.
16. *Director-General's Response to the Report of the Scientific Advisory Board on Developments in Science and Technology for the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention* (Organisation for the Prohibition of Chemical Weapons, January 31, 2013), [https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg02\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg02_e_.pdf).
17. *Status of the Follow-Up to the Recommendations on Science and Technology Made to the Third Review Conference* (Organisation for the Prohibition of Chemical Weapons, September 5, 2014), [https://www.opcw.org/fileadmin/OPCW/SAB/en/ec77dg11\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/ec77dg11_e_.pdf).
18. These activities have been described most recently in section 6 of the OPCW's 2013 and 2014 annual reports, respectively. OPCW annual reports are available at <http://www.opcw.org/documents-reports/annual-reports/>.
19. Past issues of this newsletter, the *Science & Technology Monitor*, can be downloaded from the Organisation for the Prohibition of Chemical Weapons' website: <https://www.opcw.org/special-sections/science-technology/science-technology-monitor/>.
20. "Science for Diplomats," Organisation for the Prohibition of Chemical Weapons, <https://www.opcw.org/special-sections/science-technology/science-for-diplomats/>.
21. *Report of the Nineteenth Session of the Scientific Advisory Board* (Organisation for the Prohibition of Chemical Weapons, September 12, 2012), Section 10, [https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-19-01\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-19-01_e_.pdf).
22. Schedule 1 chemicals are listed in the CWC Annex on Chemicals and include chemical warfare agents such as sulphur and nitrogen mustards. More information can be found on the Organisation for the Prohibition of Chemical Weapons' website: <https://www.opcw.org/chemical-weapons-convention/annexes/annex-on-chemicals>.
23. *Ibid.*, paragraph 10.5(c).
24. *Director-General's Response to the Report of the Scientific Advisory Board on Developments in Science and Technology for the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention*, January 31, 2013, paragraph 21. [https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg01\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg01_e_.pdf)
25. Organisation for the Prohibition of Chemical Weapons, "Technical Secretariat's Procedure for Handling Cases of Schedule 1 Chemicals as Unavoidable By-products," note, May 1, 2015.
26. A discrete organic chemical is any chemical belonging to the class of chemical compounds consisting of all compounds of carbon, except for its oxides, sulfides, and metal carbonates.
27. See subparagraph 1(a) of Part IX of the CWC's Annex on Implementation and Verification: <https://www.opcw.org/chemical-weapons-convention/annexes/verification-annex/part-ix>.
28. *Verification Report of the Scientific Advisory Board's Temporary Working Group*.
29. *Ibid.*
30. *Report of the Scientific Advisory Board on Developments in Science and Technology for the Third Special Session, of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention*, October 29, 2010, paragraph 10.
31. *Verification Report of the Scientific Advisory Board's Temporary Working Group*.
32. *Ibid.*
33. *Ibid.*
34. *Status of Laboratories Designated for the Analysis of Authentic Samples* (Organisation for the Prohibition of Chemical Weapons, April 15, 2015).
35. Stefan Mogl, Peter Siegenthaler, and Beat Schmidt, "Chemical Weapons in the Syrian Conflict," Annual Report 2013 (Spiez, Switzerland: Spiez Laboratory, 2014), 26–33, [http://www.labor-spiez.ch/en/dok/ge/pdf/88\\_003\\_e\\_laborspiez\\_jahresbericht\\_2013\\_web.pdf](http://www.labor-spiez.ch/en/dok/ge/pdf/88_003_e_laborspiez_jahresbericht_2013_web.pdf).
36. *Analysis of Chemicals Relevant to the Chemical Weapons Convention, special issue of Analytical & Bioanalytical Chemistry* 406, no. 21 (2014), <http://link.springer.com/journal/216/406/21/page/1>.
37. Chemical Weapons Convention, Article XI, <https://www.opcw.org/chemical-weapons-convention/articles/article-xi-economic-and-technological-development>.
38. *Ibid.*, paragraph 2(b).
39. "OPCW Capacity Building Programmes," <https://www.opcw.org/our-work/international-cooperation/capacity-building-programmes/>. These activities are also described in section 2 of the Organisation for the Prohibition of Chemical Weapons' annual reports, which are available at <http://www.opcw.org/documents-reports/annual-reports/>.
40. Further details on the Research Support Programme from 2010 to 2014 are available in the June 2015 issue of the *OPCW Science and Technology Monitor*, [https://www.opcw.org/fileadmin/OPCW/Science\\_Technology/Monitor/OPCW\\_S\\_T\\_2-7.pdf](https://www.opcw.org/fileadmin/OPCW/Science_Technology/Monitor/OPCW_S_T_2-7.pdf).

41. Jim Whitman, "The Challenge to Deliberative Systems of Technological Systems Convergence," *Innovation: The European Journal of Social Science Research* 20, no. 4 (December 2007): 329–42.
42. NAM CWC States Parties and China, "Proposal for a Plan of Action on the Full Implementation of Article XI of the Chemical Weapons Convention," statement, April 8, 2013, [https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/national-statements/NAM\\_China\\_rc3.pdf](https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/national-statements/NAM_China_rc3.pdf).
43. For example, "United States of America: Statement by Rose E. Gottemoeller, Acting Under Secretary for Arms Control and International Security, at the Third Review Conference," statement, April 9, 2013, [https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/national-statements/rc3nat45\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/CSP/RC-3/national-statements/rc3nat45_e_.pdf).
44. Martin Grueber, Tim Studt et al., *2014 Global R&D Funding Forecast* (Battelle, December 2013), [http://www.battelle.org/docs/tpp/2014\\_global\\_rd\\_funding\\_forecast.pdf](http://www.battelle.org/docs/tpp/2014_global_rd_funding_forecast.pdf).
45. Jessica Morrison, "China Becomes World's Third-Largest Producer of Research Articles," *Nature*, February 7, 2014, <http://www.nature.com/news/china-becomes-world-s-third-largest-producer-of-research-articles-1.14684>.
46. Xianwen Wang et al., "International Scientific Collaboration of China: Collaborating Countries, Institutions and Individuals," *Scientometrics* 95, no. 3 (2014): 885–94, <http://link.springer.com/article/10.1007%2Fs11192-012-0877-4>.
47. Sari Pekkala Kerr and William R. Kerr, "Global Collaborative Patents," (working paper, September 2014), <http://www.hbs.edu/faculty/Pages/item.aspx?num=48146>.
48. *The OPCW in 2025: Ensuring a World Free of Chemical Weapons* (Organisation for the Prohibition of Chemical Weapons, March 6, 2015), [https://www.opcw.org/fileadmin/OPCW/S\\_series/2015/en/s-1252-2015\\_e\\_.pdf](https://www.opcw.org/fileadmin/OPCW/S_series/2015/en/s-1252-2015_e_.pdf).