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Article36

Nanoweapons

Discussion paper for the Convention on Certain Conventional Weapons (CCW)

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Article 36 is a UK-based not-for-profit organisation working to promote public scrutiny over the development and use of weapons.*

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Nanomaterials have the potential for significant and diverse impacts on human society.[1] Better energy storage, more rapid computations and lower power consumption are but a few innovations that can lead to considerable improvements in devices and products.[2] Nanomaterials also have potential applications in the military and security sectors. Suggested developments include garments designed to increase soldier survivability[3] and camouflage against thermal detection,[4] as well as new weapons and surveillance technologies.[5]

This bulletin provides an introduction to possible military uses of nanomaterials and suggests some areas of concern, notably:

- Novel or poorly understood mechanisms of harm and new ways of applying force (e.g. using genetic markers as a tool for targeting) may challenge existing values, norms and instruments (e.g. the principle of humanity, the prohibitions on indiscriminate attacks and superfluous injury or unnecessary suffering, or on blinding laser weapons).
- At a conceptual level, certain developments could fall between the boundaries of multilateral weapons control instruments. This is because the use of nanomaterials can challenge the distinctions and categorizations by which regulatory instruments and control regimes are articulated (e.g. between conventional weapons and weapons of mass destruction).
- At a practical level, certain developments may negatively impact disarmament and arms control. For example, nanomaterials or nanodevices (e.g. metal-less firearms, miniaturized weapons) may escape existing verification techniques. This may lead to a loss of trust in the effectiveness of multilateral weapons control regimes in securing international peace and security.

Based on this, the paper recommends that High Contracting Parties to the Convention on Certain Conventional Weapons (CCW):

- monitor developments in nanotechnologies and assess how potential military uses of nanomaterials may challenge existing restrictions or prohibitions on weapons, or impact national and human security, peace and international security, arms control and disarmament;
- examine the how certain effects from nanomaterials should be considered in relation to existing Protocols of the CCW and make national interpretations where appropriate;
- explicitly include reference to nanomaterials in ongoing work, including in relation to weapons reviews in line with Article 36 of Additional Protocol I to the Geneva Conventions, and promote a precautionary approach to risks that such materials may present;
- cooperate with the Biological Weapons Convention (BWC), the Chemical Weapons Convention (CWC) and other relevant bodies, to ensure that nanomaterials are addressed by the legal regime appropriate to their effects;
- foster open dialogue and information exchange about military uses of nanomaterials and their potential impacts.

What are nanomaterials?

The prefix ‘nano’ means one thousand millionth of a metre (1 nm = 10^{-9} m).[6] Nanoparticles occur naturally in the environment, such as in volcanic ash, and in some man-made substances, such as depleted uranium. What is new is the ability to deliberately create, manipulate or modify nanomaterials for specific ends.[7] This is of interest because at nanoscale (below 100 nm)[8] matter exhibits different reactive, optical, electrical and magnetic properties than at macroscale.

Nanomaterials also present profound challenges. Chemical, biological and physical properties merge at nanoscale, making some traditional regulatory distinctions uncertain. Furthermore, some materials are toxic at nanoscale even if their macro counterparts are not.[9] Much has been written over the last decade about the regulation of nanotechnologies in general, but comparably little attention has been paid specifically to military applications and weapons.[10]

This bulletin considers possible applications of nanomaterials for military or security purposes, including weapons and combat systems where one or more parts is manipulated artificially, or causes harmful effects, at nanoscale.

Current state of play

The total global, private and public, investment in nanotechnology research and development has grown rapidly since the early 1990s,[11] but research by the military remains mostly out of the public domain, although some states, including China, Germany, France, India, Israel, the Netherlands, Russia, Sweden, the UK and the USA are publicly investing in nanotechnologies for military purposes.[12]

The literature cites a large array of potential military applications of nanotechnologies, claiming advantages related to better detection and surveillance as well as improved stealth and camouflage, cost- and fuel-efficiency, increased accuracy of weapon delivery and scalability of weapon effects, the greater destructive force of weapons as well as materials better able to withstand force. The bullet points below provide a partial list of some of the developments utilizing properties of nanomaterials (which may be at different stages from concept to development):[13]

- sensors that allow for improved reconnaissance, better sensory capabilities of weapons and munitions,[14] and the detection, reduction and elimination of biological or chemical agents, or trace quantities of explosives;[15]
- pervasive, distributed nanoscale sensor nets with computational and wireless communication abilities ('smart dust'), potentially as components of an autonomous weapon system;[16]
- missiles, artillery projectiles or mortar rounds with reduced mass, greater destructive force, increased penetration capability, tailored energy release, smaller size or improved accuracy;[17]
- lighter and smaller firearms made of nanofibre composites with low or no metal content, and 'self-steering' bullets equipped with optical sensors;[18]
- means of weapon delivery with reduced drag and increased payload and range,[19] nano-enhanced miniaturized munitions, including for UAVs (drones), and nano- and micro-combat robots, enabling swarming;[20]
- improvements in solid-state and electric laser systems, making them mobile and readily deployable as a weapon;[21]
- novel chemicals and biological agents (potentially self-replicating);[22]
- Nano-implants in soldiers, brain-machine interfaces and manipulation of biological processes, for example to reduce fatigue, increase reaction time or alter perceptions, emotions or thoughts.[23]

Possible adverse effects and risks

It has been argued that nanotechnologies may offer '[w]hole new classes of accidents and abuses'.[24] Aside from wider social and ethical issues,[25] key military and security concerns regarding the use of nanomaterials include:

- Novel biochemical agents or toxic substances that can be difficult to detect and counter, and enhanced delivery mechanisms, as well further miniaturization, could make the use of biological, chemical or nuclear weapons more feasible.[26] An additional concern relates to the possibility of using genetic markers to target specific groups or individuals.[27]
- Some nano-enhanced technologies may affect strategic stability, for example by giving a distinct advantage to the offence. This may weaken belief in deterrence, raise the risk of escalation and accidental war and lead to an arms race.[28]
- Certain military applications of nanotechnologies can undermine existing control regimes and mechanisms by calling into question categories and boundaries around which regulations are articulated. The use of nanomaterials can challenge legal definitions of prohibited weapons or acts,[29] thresholds based on calibre, quantity, size or weight of an item,[30] the distinction between conventional weapons and weapons of mass destruction, and between ammunition/munitions and their means of delivery.[31] The difficulty of detecting nano-engineered materials and devices (e.g. novel chemical agents or metal-free small arms) challenges transfer and proliferation controls and verification mechanisms.
- Nanoapplications offer the potential for inexpensive, ubiquitous and pervasive surveillance and intrusive methods of data gathering, raising both human and national security concerns.[32]
- Nano-engineered surveillance devices and weapons, potentially in large quantities, would likely be within the reach of individuals or groups (whether commercial or politically organized), due to easy access to raw materials and knowledge, and because there is no need for large production facilities.[33]

Another key concern is that very little is known about the short- and long-term effects of nanomaterials and the possible negative and unintended side effects for humans and the environment.[34] Nanoparticles are able to traverse the gastrointestinal tract and lungs, and cross cell walls and the blood-brain barrier. Their unique characteristics may lead to unusual toxic effects that are different from those seen at a larger scale, and can complicate their detection and removal from human tissue, the air, water or soil.[35] Nanoparticles interacting with cells can disrupt cellular structures and/or processes essential for cell survival and induce DNA damage, which can lead to cancer or genetic abnormalities in reproductive cells.[36] Risks may be gender- or generationally differentiated.[37]

Governance and regulation

A number of existing regulatory frameworks constrain military uses of nanomaterials. These include weapon-specific treaties already in place such as the 1925 Geneva Gas Protocol, the 1972 BWC and the 1993 CWC). Together, these instruments ban nanomaterials of known toxic chemicals or biological agents, as well as nano-sized devices designed to deliver them,[38] except where intended for prophylactic, protective or other peaceful purposes.[39] A strong argument can also be made that the legal bans on biological and chemical weapons extend to nanomaterials with novel properties that affect life processes in ways analogous to known toxic chemicals and pathogens.[40] It has also been argued that using nanoparticles whose physical properties or accumulation in the human body injure at the cellular level without biochemical action, or nanorobots that are programmed to do this, may fall foul of the prohibition in international humanitarian law (IHL) on the use of poison and poisoned weapons.[41]

Furthermore, questions have been raised as to whether nanomaterials that are not readily detectable or removable from human tissue are compatible with the letter and spirit of 1980 CCW Protocol I, which prohibits the use of weapons that primarily injure by non-detectable fragments;[42] whether miniaturized missiles and similar explosive projectiles run counter to the prohibition on the use of exploding bullets;[43] whether nano-enhanced lasers raise issues under CCW Protocol IV on blinding laser weapons;[44] whether small armed robots undermine the effectiveness of existing strictures on landmines;[45] and whether a nanodevice that is designed to kill or injure and functions unexpectedly when a person performs an apparently safe act, such as breathing, violates the prohibition on booby traps.[46]

IHL also limits the use of nano-enhanced weapons, means and methods of warfare. Fighters are protected against weapons, means or methods of warfare of a nature to cause superfluous injury or unnecessary suffering or that render death inevitable,[47] as may be the case with nanomaterial-induced health effects. Civilians 'enjoy general protection against dangers arising from military operations',[48] which would include, for example, protection from hazardous nanoparticles released into the environment as a result of the degradation of armour or as components of surveillance networks. They are also protected against attacks employing a method or means of combat whose effects cannot be limited as required by IHL, for example, due to the release of hazardous particles.[49] Precautions must be taken against such effects, including in the choice of weapons and targets, so as to minimize the danger to civilians.[50]

Additional restrictions derive from states' duties under international human rights and environmental law. Everyone is protected, at all times, against discriminatory targeting practices[51] and acts of genocide,[52] which may be facilitated by the ability to target at the DNA level. In light of the release of potentially hazardous nanoparticles during security or military operations, states must take measures to effectively protect the rights to life, health and food.[53] In this regard, measures to prevent environmental damage, including in armed conflict, will be particularly important. Nanotechnology-enabled surveillance possibilities call for measures by states to protect the right to privacy.[54] States should also anticipate that the difficulty of detecting nanomaterials or nanodevices is likely to exacerbate existing accountability challenges, especially where applications are tested on or used among populations that have limited recourse against their effects.

Given the potential for serious negative consequences, it is widely accepted that a precautionary approach is essential. Views diverge, however, on what that implies in practice. Some argue for a strict application of the 'no data, no market' principle,[55] whereas others promote the development of regulations or meta-regulatory tools to 'help ensure the technology achieves its potential for good'.[56] The public (scientific) debate on potential risks and hazards has, however, largely ignored military uses of nanomaterials. Although states have a legal obligation under IHL to review the compatibility of new weapons, means or methods of warfare with their international legal obligations,[57] such reviews suffer from well-known limitations and lack of implementation. There are also many open questions about their effectiveness when it comes to nano-enhanced weapons, means or methods of warfare.[58]

Many consider, therefore, that prompt action is required to govern the potential risks of nano-enhanced weapons and other military uses of nanomaterials. Proposals include:

- the creation of a new treaty or an arms control regime to devise limits and verification methods;[59]
- amendments to existing instruments, notably the CWC and the BWC, or clarification of their provisions;[60]
- clearer guidance and transparency for weapon reviews;[61]
- and the development of guidelines and scientific protocols to promote self-regulation by states and scientific communities.[62]

END NOTES

1 E.g., The Royal Society and The Royal Academy of Engineering, July 2004, 'Nanoscience and Nanotechnologies: Opportunities and Uncertainties', p. 5, https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2004/9693.pdf; M. C. Roco and W. Sims Bainbridge (eds), 'Societal Implications of Nanoscience and Nanotechnology', NSET Workshop Report, National Science Foundation, 2001, p. 3, http://www.wtec.org/loyola/nano/NSET.Societal.Implications/nanosi.pdf. Nanotechnology is not a single industry or discipline, but rather 'sets of enabling technologies applicable to many traditional industries'. It is therefore more appropriate to speak of nanotechnologies (J. Schummer, 'Identifying Ethical Issues of Nanotechnologies', H. A. M. J. ten Have (ed.) *Nanotechnologies, Ethics and Politics*, 2007, p. 87, http://unesdoc.unesco.org/images/0015/001506/150616e.pdf).

2 See, e.g., The Project on Emerging Nanotechnologies, 'Inventories', http://www.nanotechproject.org/inventories.

3 'U.S. Scientists Design Smart Underpants That Could Save Lives', *Reuters*, 10 June 2010, http://uk.reuters.com/article/oukoe-uk-underpants-health/u-s-scientists-design-smart-underpants-that-could-save-lives-idUKTRE6591C920100610.

4 B. Kim et al, 'Patternable PEDOT Nanofilms With Grid Electrodes for Transparent Electrochromic Devices Targeting Thermal Camouflage', 2(1) *Nano Convergence* (October 2015), https://doi.org/10.1186/s40580-015-0051-9.

5 In particular, J. Altmann, *Military Nanotechnology: Potential Applications and Preventive Arms Control*, 2006, Chapter 4.

6 Nanowerk, 'Nanotechnology Frequently Asked Questions', http://www.nanowerk.com/nanotechnology_frequently_asked_questions.php.

7 B. Bhushan, 'Nanotechnology', B. Bhushan (ed.), *Encyclopedia of Nanotechnology*, 2012; K. Leins, 'Regulation of the Use of Nanotechnology in Armed Conflict', IEEE Technology and Society Magazine, n.d.

8 International Organization for Standardization, 'ISO TC 229: Nanotechnologies', https://www.iso.org/committee/381983.html. 'An upper limit of 100 nm is commonly used by general consensus, but there is no scientific evidence to support the appropriateness of this value' (European Commission, Recommendation of 18 October 2011 on the definition of nanomaterial, 2011/696/EU, §8)

9 According to Schummer, 'Identifying Ethical Issues of Nanotechnologies', p. 85, 'national regulations for chemicals, consumer products and work safety disregard the size- and shape-dependence of properties and focus solely on chemical composition. This means that a substance could, for instance, pass the required toxicity tests for new chemicals if the tests are performed on large particles, even if small particles of the same substance are toxic'.

10 There is no agreed definition of a 'nano-(enhanced) weapon'. The term sometimes refers to 'objects and devices using nanotechnology … that are designed or used for harming humans'. It can also designate devices that cause harmful effects in nanoscale, though some scholars limit the category to those whose 'effects characterise the lethality of the weapon' (H. Nasu and T. Faunce, 'Nanotechnology and the International Law of Weaponry: Towards International Regulation of Nano-Weapons', 20 *Journal of Law, Information & Science* (2009–2010) 21, 23.

11 Several indicators can be used to assess research and development in nanotechnologies, for example, the number of patent filings, the development of sub-areas or the number of citations. See, e.g., M. C. Roco et al (eds), *Nanotechnology Research Directions for Societal Needs in 2020: Retrospective and Outlook*, 2010, pp. xlii–xlvi, http://www.wtec.org/nano2/Nanotechnology_Research_Directions_to_2020/Nano_Resarch_Directions_to_2020.pdf. For data, see OECD, 'Tapping Nanotechnology's Potential to Shape the Next Production Revolution', OECD, *The Next Production Revolution: Implications for Governments and Business*, 2017.

12 For a recent overview, see J. Altmann, 'Preventing Hostile and Malevolent Use of Nanotechnology: Military Nanotechnology After 15 Years of the US National Nanotechnology Initiative', M. Martellini and A. Malizia, *Cyber and Chemical, Biological, Radiological, Nuclear, Explosives Challenges: Threats and Counter Efforts*, 2017), pp. 52–56. See also A. de Neve, 'Military Uses of Nanotechnology and Converging Technologies: Trends and Future Impacts', Center for Security and Defence Studies, Royal High Institute for Defense, Focus Paper 8, n.d., https://www.yumpu.com/en/document/view/23516906/military-uses-of-nanotechnology-and-converging-technologies-; M. Berger, 'Military Nanotechnology – How Worried Should We Be?', Nanowerk, 13 November 2006, https://www.nanowerk.com/spotlight/spotid=1015.php.

13 According to, Rain Liivoja, Kobi Leins and Tim McCormack, 'no nanotechnology-derived weapons appear to be in production as yet' (R. Liivoja et al, 'Emerging Technologies of Warfare', R. Liivoja and T. McCormack (eds), *Routledge Handbook of the Law of Armed Conflict*, 2016, p. 618). For recent estimates of the time of potential introduction of selected military applications, see Altmann, 'Preventing Hostile and Malevolent Use of Nanotechnology', p. 58.

14 H. Paschen et al, *Nanotechnology: Summary*, Working Report no 92, Office of Technology Assessment at the German Bundestag July 2003, p. 7, https://www.tab-beim-bundestag.de/en/pdf/publications/summarys/TAB-Arbeitsbericht-ab092_Z.pdf.

15 N. Pala and A. N. Abbas, 'Terahertz Technology for Nano Applications', B. Bhushan (ed.) *Encyclopedia of Nanotechnology*, 2016, 4070; M. Sadeghi et al, 'Decontamination of Chemical Warfare Sulfur Mustard Agent Simulant by ZnO Nanoparticles', 6(3) *International Nano Letters* (1 September 2016), https://link.springer.com/content/pdf/10.1007%2Fs40089-016-0183-x.pdf.

16 A. Ananthaswamy, 'March of the Motes', *New Scientist*, 23 August 2003; TheNanoAge.com, 'Military Uses of Nanotechnology', http://www.thenanoage.com/military.htm.

17 E.g., J. Altmann and M. Gubrud, 'Anticipating Military Nanotechnology', *IEEE Technology and Society Magazine*, Winter 2004; Paschen et al, Nanotechnology: Summary; 'US Air Force Invests in Western New York Technology; Grants NanoDynamics™ Contract for Nanostructured Tantalum', Nano Tsunami, 29 August 2005, http://www.voyle.net/Nano%20Defence%202005/Defence%202005-0012.htm.

18 Altmann, *Military Nanotechnology*, 85; T. Lewis, 'US Military's Self-Steering Bullets Can Hit Moving Targets', *Live Science*, 28 April 2015, https://www.livescience.com/50648-darpa-self-steering-bullets.html.

19 E.g., A. Lang et al, 'Shark Skin Drag Reduction', B. Bhushan (ed.), *Encyclopedia of Nanotechnology*, 2016), 3639.

20 Altmann, Military *Nanotechnology*, pp. 93–95; Altmann and Gubrud, 'Anticipating Military Nanotechnology', p. 36. On nanorobotics, generally, see S. Tsuda, 'Nanorobotics', B. Bhushan (ed.), *Encyclopedia of Nanotechnology*, 2016.

21 H. Nasu, 'The Future of Nanotechnology in Warfare', *The Global Journal*, 4 July 2013, http://www.theglobaljournal.net/article/view/1132/.

22 M. E. Kosal, 'Anticipating the Biological Proliferation Threat of Nanotechnology: Challenges for International Arms Control Regimes', H. Nasu and R. McLaughlin (eds), *New Technologies and the Law of Armed Conflict,* 2014, p. 163.

23 J. Thorpe et al, 'Maintaining Military Dominance in the Future Operating Environment: A Case for Emerging Human Enhancement Technologies That Contribute to Soldier Resilience', Small Wars Journal, 13 July 2017, http://smallwarsjournal.com/jrnl/art/maintaining-military-dominance-in-the-future-operating-environment-a-case-for-emerging-huma; K. Leins, 'Shining a Regulatory Spotlight on New Lasers: Regulation of the Use of Nanolaser Technologies in Armed Conflict', 56 *Jurimetrics* (Spring 2016) 266–68; P. Tucker, 'A Breakthrough in the Checkered History of Brain Hacking', *Defense One*, 1 July 2014, http://www.defenseone.com/technology/2014/07/breakthrough-checkered-history-military-brain-hacking/87709/.

24 The Royal Society and The Royal Academy of Engineering, 'Nanoscience and Nanotechnologies', §28.

25 There is concern that advances in nanotechnologies will exacerbate existing biases and inequalities and 'precipitate a redefinition of the concepts of normalcy, disability, health, and disease, and may challenge the very concept of human dignity' (International Bioethics Committee (IBC), Report of the IBC on the Principle of Non-Discrimination and Non-Stigmatization, 3 June 2014, p. 25, http://unesdoc.unesco.org/images/0022/002211/221196e.pdf).

26 Altmann, *Military Nanotechnology*, pp. 101–103; 'Nanotechnology Paves Way for New Weapons', Jane's Chem-Bio Web, 27 July 2005, http://www.hartford-hwp.com/archives/27a/317.html; Kosal, 'Anticipating the Biological Proliferation Threat of Nanotechnology; A. Gsponer, 'From the Lab to the Battlefield? Nanotechnology and Fourth-Generation Nuclear Weapons', 67 *Disarmament Diplomacy*, (October–November 2002), http://www.acronym.org.uk/old/archive/dd/dd67/67op1.htm.

27 Altmann and Gubrud, 'Anticipating Military Nanotechnology', p. 36; Leins, 'Regulation of the Use of Nanotechnology in Armed Conflict', 47; Mark Wheelis, 'Will the New Biology Lead to New Weapons?', *Arms Control Today,* July 2004, https://www.armscontrol.org/act/2004_07-08/Wheelis.

28 Altmann and Gubrud, 'Anticipating Military Nanotechnology', p. 38; M. E. Kosal, 'Military Applications of Nanotechnology: Implications for Strategic Security I', PASCC Final Report, p. 65, https://www.hsdl.org/?view&did=767053.

29 Nanomaterials can be used to induce changes in the human body that challenge the bans on blinding laser weapons, biological and chemical weapons. See, e.g., Leins, 'Shining a Regulatory Spotlight on New Lasers'.

30 Consider, e.g., the definitions of conventional armaments and equipment in the 1990 Conventional Forces in Europe (CFE) Treaty, the weight-based definition of prohibited explosive projectiles in the 1868 St Petersburg Declaration or weight restrictions on the production of scheduled chemicals in the CWC. See Altmann and Gubrud, 'Anticipating Military Nanotechnology', p. 36.

31 See, e.g., M. Bolton and W. Zwijnenburg, *Futureproofing Is Never Complete: Ensuring the Arms Trade Treaty Keeps Pace with New Weapons Technology*, International Committee for Robot Arms Control (ICRAC) working paper, October 2013, p. 4.

32 J. van den Hoven and P. E. Vermaas, 'Nano-Technology and Privacy: On Continuous Surveillance Outside the Panopticon', 32(3) *Journal of Medicine and Philosophy* (2007).

33 The Royal Society and The Royal Academy of Engineering, 'Nanoscience and Nanotechnologies', §28.

34 M. Schillmeier, 'What ELSA/I Makes Big and Small in Nanotechnology Research',

B. Rappert and B. Balmer (eds), *Absence in Science, Security and Policy*, n.d., p. 63.
35 IBC, Report of the IBC on the Principle of Non-Discrimination and Non-Stigmatization, 25.
36 N.A. Lewinski, 'Nanoparticle Cytotoxicity', B. Bhushan (ed.) *Encyclopedia of Nanotechnology*, 2016; F. Nesslany and L. Benameur, 'Genotoxicity of Nanoparticles', B. Bhushan (ed.), *Encyclopedia of Nanotechnology*, 2016.
37 There is emerging evidence on selective placental transfer of nanoparticles, raising concerns over maternal and fetal health (A. K. Vidanapathirana, 'Use of Nanotechnology in Pregnancy', B. Bhushan (ed.), *Encyclopedia of Nanotechnology*, 2016), and it has been argued that '[c]hildren are more vulnerable because their bodies and organs are not fully developed and their body mass is smaller, allowing for greater absorption of toxic substances and lifelong damaging effects' (Women in Europe for a Common Future (WECF), *Nano – The Great Unknown*, Position Paper, February 2012, p. 2, http://www.wecf.eu/download/2012/April/WECF_NanoPositionPaper.pdf.
38 E. J. Wallach, 'A Tiny Problem with Huge Implications – Nanotech Agents as Enablers or Substitutes for Banned Chemical Weapons: Is a New Treaty Needed?', 33(3) *Fordham International Law Journal* (2009) 860–861.
39 R. D. Pinson, 'Is Nanotechnology Prohibited by the Biological and Chemical Weapons Conventions?', 22(2) *Berkeley Journal of International Law* (2004) 304, argues that nanotechnology uses that closely resemble chemical weapons may fall under these exceptions.
40 For a detailed discussion, see Wallach, 'A Tiny Problem with Huge Implications', who also raises the question of whether the CWC and the BWC prohibit the development and use of engineered viruses or nanorobots.
41 International Committee of the Red Cross (ICRC), Customary IHL study, Rules 72, 73 and 74. The dominant interpretation is that the prohibition on poisonous weapons applies only if poisoning is an 'intended' (as opposed to an incidental or accidental) injury mechanism of the weapon. See, Liivoja et al, 'Emerging Technologies of Warfare', p. 619.
42 1980 CCW Protocol I. A recent Danish military manual (Militærmanual om folkeret for danske vaebnede styrker i internationale militaere operationer, 2016, section 3.10) mentions nanotechnology in relation to that prohibition. For a discussion, see Nasu and Faunce, 'Nanotechnology and the International Law of Weaponry', 22. Note, however, that some states consider that the prohibited weapons are only those whose 'primary effect' is to injure by non-detectable fragments. It is also questionable whether nanoparticles can be likened to 'fragments'. In the view of the ICRC, weapons that contain plastic, for example, as part of their design, are not illegal if the plastic is not part of the primary injuring mechanism (ICRC, Customary IHL study, Rule 79).
43 1868 St Petersburg Declaration; ICRC, Customary IHL study, Rule 78.
44 1995 CCW Protocol IV; ICRC, Customary IHL study, Rule 86.
45 1996 Revised CCW Protocol II, 1997 Anti-Personnel Mine Ban Convention; See Altmann, 'Preventing Hostile and Malevolent Use of Nanotechnology', p. 64.
46 1996 Revised CCW Protocol II; ICRC, Customary IHL study, Rule 80. See Wallach, 'A Tiny Problem with Huge Implications', 934.
47 ICRC, Customary IHL study, Rules 70 and 72. Some states consider that a balance must be struck between military necessity and the expected injury or suffering inflicted on a person, and that only excessive injury or suffering violates the prohibition of weapons that are 'of a nature to cause superfluous injury or unnecessary suffering'.
48 Art 51(1), Additional Protocol I to the Geneva Conventions (API); See also ICRC, Customary IHL study, Rule 15.
49 Art 51(4), API; ICRC, Customary IHL study, Rules 1, 17, 71.
50 Art 57(2)(a)(ii) and (3), API; ICRC, Customary IHL study, Rules 15, 17, 18, 19 and 21.
51 Art 26, International Covenant on Civil and Political Rights (ICCPR); Art 2, Convention on the Elimination of All Forms of Discrimination Against Women; Art 2, Convention on the Elimination of Racial Discrimination; Art 6, Universal Declaration on the Human Genome and Human Rights; Art 11, Council of Europe Convention on Human Rights and Biomedicine.
52 Art 1, 1949 Convention on the Prevention and Punishment of the Crime of Genocide.
53 Art 6, ICCPR; Arts 11 and 12, International Covenant on Economic, Social and Cultural Rights.
54 Art 17, ICCPR.
55 WECF, *Nano – The Great Unknown*, p. 3.
56 Responsible Nanotechnologies Code Working Group, *Information on the Responsible Nano Code Initiative*, May 2008. See also Swiss Federal Office of Public Health, Precautionary Matrix for Synthetic Nanomaterials, version 3.0, 2013; European Commission, Commission recommendation on a code of conduct for responsible nanosciences and nanotechnologies research & Council conclusions on responsible nanosciences and nanotechnologies research, 2009, https://ec.europa.eu/research/science-society/document_library/pdf_06/nanocode-apr09_en.pdf;
57 Art 36, API.
58 E.g., how are potential risks and hazards to be assessed, and judgements made about their acceptability, given that the harm mechanisms of nanomaterials are poorly understood, there are no internationally harmonized measurement methods, there is high uncertainty about how to test biocompatibility and appropriately model environmental impacts, and there is significant controversy about whether existing hazard and risk-assessment tools adequately account for the specific properties of nanomaterials? See, e.g., T. Seager et al., 'Why Life Cycle Assessment Does Not Work for Synthetic Biology', 51(11) *Environmental Science & Technology*, 15 May 2017, https://doi.org/10.1021/acs.est.7b01604.
59 E.g., Altmann makes detailed recommendations for preventive arms control (J. Altmann, *Nanotechnology and Preventive Arms Control*, Deutsche Stiftung Friedensforschung, 2005, https://www.ssoar.info/ssoar/bitstream/handle/document/26027/ssoar-2005-altmann-nanotechnology_and_preventive_arms_control.pdf?sequence=1); Wheelis invites consideration of 'a new convention that would prohibit the nonconsensual manipulation of human physiology' (Wheelis, 'Will the New Biology Lead to New Weapons?'); Howard sketches out an 'Inner Space Treaty' (S. Howard, 'Nanotechnology and Mass Destruction: The Need for an Inner Space Treaty', 65 *Disarmament Diplomacy* (August 2002), http://www.acronym.org.uk/old/archive/dd/dd65/65op1.htm.); See also Pinson, 'Is Nanotechnology Prohibited by the Biological and Chemical Weapons Conventions?'
60 E.g., Wallach, 'A Tiny Problem with Huge Implications', 861, 954.
61 E.g., Nasu and Faunce, 'Nanotechnology and the International Law of Weaponry', 54.
62 E.g., ibid.

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