Nanotechnology and the International Law of Weaponry: Towards International Regulation of Nano-Weapons

HITOSHI NASU AND THOMAS FAUNCE*

Abstract

The development of nanotechnology for military application is an emerging area of research and development, the pace and extent of which has not been fully anticipated by international legal regulation. Nano-weapons are referred to here as objects and devices using nanotechnology or causing effects in nano-scale that are designed or used for harming humans. Such weapons, despite their controversial human and environmental toxicity, are not comprehensively covered by specific, targeted regulation under international law. This article critically examines current international humanitarian law and arms control law regimes to determine whether significant gaps exist in the regulation of nanotechnology focused on offensive military application. It presents and evaluates the reasons why more robust regulatory mechanisms under international law for nano-weapons should, or should not, be considered. Lastly, the strengths and weaknesses of different models of international regulation for nano-weapons will be examined.

1 Introduction

The renewed Israeli military attack in Gaza in early 2009 was widely condemned as contrary to basic principles of international humanitarian law, one notable example being the indiscriminate use of lethal and maiming white phosphorus in densely populated civilian areas.[1] Equally problematic under

* Hitoshi Nasu: Lecturer, The Australian National University College of Law, Australia.

Thomas Faunce: Associate Professor, The Australian National University College of Law and Medical School, Australia. Australian Research Council Future Fellow.

1 See eg, *Human Rights in Palestine and Other Occupied Arab Territories: Report of the United Nations Fact Finding Mission on the Gaza Conflict*, 247-250, UN Doc A/HRC/12/48 (15 September 2009) ('*UN Gaza Report*'); *Rain of Fire: Israel's Unlawful Use of White Phosphorus in Gaza*, Human Rights Watch, (March 2009) <http://www.hrw.org/sites/default/files/reports/iopt0309web.pdf>; Peter Herby, *Phosphorus Weapons – The ICRC's View*, International Committee of the Red Cross, 17 January 2009, <http://www.icrc.org/web/eng/siteeng0.nsf/html/weapons-interview-170109>. For the legality of white phosphorus in general, see eg, I J MacLeod and A P V Rogers, 'The Use of White Phosphorus and the Law of War' (2007) 10 *Yearbook of International Humanitarian Law* 75.

the international law of weaponry in that conflict, albeit not so widely reported, was the alleged use of a novel weapon called Dense Inert Metal Explosive (DIME).[2] DIME involves an explosive spray of superheated micro shrapnel made from milled and powdered Heavy Metal Tungsten Alloy (HMTA), which is highly lethal within a relatively small area.[3] The HMTA powder turns to dust (involving even more minute particles) on impact. It loses inertia very quickly due to air resistance, burning and destroying through a very precise angulation everything within a four-meter range — and it is claimed to be highly carcinogenic and an environmental toxin. This new weapon was developed originally by the US Air Force and is designed to reduce collateral damage in urban warfare by limiting the range of explosive force.[4] Its capacity to cause untreatable and unnecessary suffering (particularly because no shrapnel is large enough to be readily detected or removed by medical personnel) has alarmed medical experts.[5] DIME (at least on some definitions) may well be a manifestation of a new generation of nano-scale technological impacts upon modern warfare that at present appears to be poorly regulated under international law.

Nanotechnology is a rapidly expanding industry estimated to be worth US$1 trillion worldwide within the next ten years.[6] It involves research and manipulation of matter on the atomic and molecular level, working on the nanometre scale (1nm = 10^{-9}m) generally speaking at a range less than 100nm (1 micron). A nanometer is a billionth of a metre, and engineered nanoparticles (ENPs) are highly reactive and mobile within the human body. At this level, the physical and chemical properties of many engineered nanoparticles (ENPs), as studied by techniques such as atomic force microscopy (AFM), neutron and

---

2 See, *UN Gaza Report*, above n 1, 251–253; Richard Falk, *Human Rights Situation in Palestine and Other Occupied Arab Territories: Report of the Special Rapporteur on the Situation of Human Rights in the Palestinian Territories Occupied Since 1967*, UN Doc A/HRC/10/20 (11 February 2009) [34]; Raymond Whitaker, '"Tungsten Bombs" Leave Israel's Victims with Mystery Wounds', *The Independent* (United Kingdom) January 18, 2009.

3 See, David Hambling, *Cancer Worries for New U.S. Bombs*, DefenseTech, <http://www.defensetech.org/archives/002434.html>; *Dense Inert Metal Explosive (DIME)*, Global Security, <http://www.globalsecurity.org/military/systems/munitions/dime.htm>.

4 James Brooks, *Warfare of the Future, Today? The DIME Bomb: Yet Another Genotoxic Weapons* (12 December 2006) Grass Roots Peace, 3, <http://www.grassrootspeace.org/israel_dime_bombs_121206.pdf>.

5 Alexandra C Miller, et al, 'Neoplastic Transformation of Human Osteoblast Cells to the Tumorigenic Phenotype by Heavy Metal Tungsten Alloy Particles: Induction of Genotoxic Effects' (2001) 22 *Carcinogenesis* 115.

6 Vicki Brower, 'Is Nanotechnology Ready for Primetime?' (2006) 98(1) *Journal of the National Cancer Institute* 9.

small angle X-ray scattering, differ considerably from their bulk equivalents.[7] For example, they have considerably larger surface area per unit mass (increasing their potential for both reactivity and biopersistence), are very hydrophobic and electrophilic, and have quantum effects below 10nm involving altered conductivity, catalytic properties, wavelength of emitted light, magnetisation and potential to magnetically activate cell surface receptor proteins.[8] This creates promising opportunities for diagnostic and therapeutic product development.[9] The above factors, however also are stimulating intense concern about health and environmental risks.[10] Such risks are also relevant to the rapid development of military nanotechnology.

The military use of nanotechnology is expanding rapidly, as evidenced by details of the funding poured into military research and development in nanotechnology in countries such as the US, UK, India, Sweden, and Russia. Nano-weapons, as we discuss in this article, are an under-regulated form of military technology in international law and this is likely to cause major problems for both civilians and combatants during and after armed conflict. Nano-weapons are hard to define, but encompass not only objects and devices using nanotechnology that are designed or used for harming humans, but also those causing harmful effects in nano-scale if those effects characterise the lethality of the weapon.

Governmental secrecy surrounding military research and development makes it difficult to describe the current level of military applications of nanotechnology with any degree of certainty. Nanotechnology, however, has reportedly found actual or potential military applications for lighter, stronger and more heat-resistant armour and clothing, bio/chemical sensors, lighter and more durable vehicles, miniaturisation of communication devices, conventional missiles with reduced mass and enhanced speed, small metal-less weapons made of nanofibre composites, small missiles and artillery shells with enhanced accuracy guided by inertial navigation systems, and armour-piercing

---

7 Bradley P Ladewig, et al, 'Physical and Electrochemical Characterization of Nanocomposite Membranes of Nafion and Functionalized Silicon Oxide' (2007) 19(9) *Chemistry of Materials* 2372; Mildred S Dresselhaus, Gene Dresselhaus and Phaedon Avouris (eds), *Carbon Nanotubes: Synthesis, Structure, Properties and Applications* (2001).

8 Robert J Mannix, et al, 'Nanomagnetic Actuation of Receptor-Mediated Signal Transduction' (2008) 3 *Nature Nanotech* 36.

9 Kewal K. Jain, *The Role of Nanobiotechnology in Drug Discovery*, 10(21) Drug Discovery Today 1435-1442 (2007); T Kubik, et al, 'Nanotechnology on Duty in Medical Applications' (2005) 6 *Current Pharmaceutical Biotechnology* 17.

10 Tom Faunce, et al, 'Sunscreen Safety: The Precautionary Principle, The Australian Therapeutic Goods Administration and Nanoparticles in Sunscreens' (2008) 2(3) *NanoEthics* 231.

projectiles with increased penetration capability.[11] The development and military application of nanotechnology are thus not confined to defensive capabilities, but encompass offensive 'nano-weapons' including particularly objects and devices using nanotechnology that are designed or used for harming human beings. The definition, effects and impacts of nano-weapons are yet to be comprehensively detailed under any of the existing international legal regimes on weaponry.

Technological developments with novel military applications have always posed challenges to effective international regulation, not least because of the inevitable secrecy during their research and production.[12] International arms control regimes have been set up to regulate the manufacture, deployment, use and monitoring of certain types of weapons with major focus on chemical, biological and nuclear weapons.[13] Recently, however, the application of computing and software innovations to various emerging technologies has led to major changes in the military tactics of developed nations, which may have outpaced existing arms control regimes under international law.[14]

This article, therefore, critically examines current international humanitarian law and arms control law regimes for regulating nanotechnological developments for military application. It first describes the current state of military nanotechnology and the potential harmful effects that could be posed by the deployment of nano-weapons, taking into account the considerable

---

11 See eg, Jun Wang and Peter J Dortmans, *A Review of Selected Nanotechnology Topics and Their Potential Military Applications* (2004), Defence Science and Technology Organisation, Australian Government Department of Defence, 22-30 <http://www.dsto.defence.gov.au/publications/2610/DSTO-TN-0537.pdf>.

12 Frits Kalshoven, 'The Conventional Weapons Convention: Underlying Legal Principles' (1990) 279 *International Review of the Red Cross* 510, 518.

13 See eg, *Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction*, opened for signature 13 January 1993, 1974 UNTS 45 (entered into force 29 April 1997) ('*Chemical Weapons Convention*'); *Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction*, opened for signature 10 April 1972, 1015 UNTS 163 (entered into force 26 March 1975) ('*Biological Weapons Convention*'); *Treaty on the Non-Proliferation of Nuclear Weapons*, opened for signature 1 July 1968, 729 UNTS 161 (entered into force 5 March 1970) ('*Nuclear Non-Proliferation Treaty*'). One of the notable exceptions is *Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects*, opened for signature 10 April 1981, 1342 UNTS 137 (entered into force 2 December 1983) ('*Convention on Conventional Weapons*').

14 See generally, Peter Dombrowski and Eugene Gholz, *Buying Military Transformation: Technological Innovation and the Defense Industry* (2006); Henry C Bartlett, et al, 'Force Planning, Military Revolutions and the Tyranny of Technology' (Fall 1996) 24(4) *Strategic Review* 28.

scientific uncertainty surrounding the effects and risks posed by ENP exposure. It then examines the relevant arms control regimes and international humanitarian law principles concerning weaponry, demonstrating that arms control regimes tend to be under-inclusive, whereas the international humanitarian law principles tend to be over-inclusive, in relation to the regulation of new weapons. It then presents and evaluates the reasons why more robust regulatory mechanisms under international law for nano-weapons should, or should not, be considered. Lastly, the strengths and weaknesses of different models of international regulation for nano-weapons will be examined.

2 *Military Applications of Nanotechnology*

The military use of nanotechnology is already a reality, as is illustrated by the funding poured into military research and development in nanotechnology in the US, UK, India, Sweden, and Russia.[15] In 2001, for example, the US established the National Nanotechnology Institute (NNI) as an inter-agency cross-cut program that coordinates federal research and development activities in nanotechnology. The NNI allocated US$460–464 million in 2008–2009 and proposed US$379 million for 2010 as investment in nanotechnology research and development in the Department of Defense.[16] The UK initiated its military nanotechnology program in a much smaller scale, investing £1.5 million in 2001.[17] Sweden has reportedly invested €11 million over five years in nanotechnology research for military purposes.[18] More recently, India has sanctioned expenditure of Rs12.48 crore under the Armament Research Board in the fields of high energy materials, armament sensors and electronics, ballistics, aerodynamics, detonics, technology for the detection of explosives, and small and nano-materials.[19] India's Defence Research and Development

---

15 Alain de Neve, *Military Uses of Nanotechnology and Converging Technologies: Trends and Future Impacts*, Royal High Institute for Defence, Centre for Security and Defence Studies, Focus Paper 8, <www.mil.be/rdc/viewdoc.asp?LAN=nl&FILE=doc&ID=1535>; M C Roco, 'International Perspective on Government Nanotechnology Funding in 2005' (2005) 7 *Journal of Nanoparticle Research* 707; M C Roco, 'Government Nanotechnology Funding: An International Outlook' (2002) 54(9) *Journal of the Minerals, Metals and Materials Society* 22.

16 The National Nanotechnology Initiative, *Supplement to the President's 2010 Budget* (2009), 8 <http://www.nano.gov/NNI_2010_budget_supplement.pdf>.

17 Jürgen Altmann, *Military Nanotechnology* (2006) 64.

18 Nanoforum, *Military Uses of Nanotechnology and Military-Based Projects in the USA, UK, Sweden, and European Union*, (21 July 2006) AZoNanotechnology, <http://www.azonano.com/details.asp?Article ID=1659>.

19 Indian Ministry of Defence, *Annual Report 2008-2009* (2009) 103 <http://mod.nic.in/reports/welcome.html>.

Organisation has proposed to establish five centres of excellence, including a centre for nanotechnology-based sensors for WMD detection, and a centre for nano optoelectronic devices, each having been budgeted Rs50 crore over five years.[20] Although figures are not made public, Russia has also reportedly been investing in nanotechnology that will enable new offensive and defensive weapons system.[21]

Government departments are not the only actors in this area. The US government, for example, has used public funds to establish the Institute for Soldier Nanotechnologies (ISN) as a centre for research collaboration between the United States Army and the Massachusetts Institute of Technology (MIT), combining basic and applied research into military applications of nanoscience and nanotechnology in three broad areas: 'protection; injury intervention and cure; and human performance improvement.'[22] Private companies such as QinetiQ,[23] BAE Systems,[24] Industrial Nanotech Inc,[25] and Raytheon,[26] have also been heavily involved in the research and development of military nanotechnology, often in partnership with the government, especially in the areas of nano-sensors and body armour. An advanced armour-piercing projectile involving the potential use of NanoSteel™ was recently patented in the US.[27]

---

20 See Defence Research and Development Organisation website <http://www.drdo.gov.in/centerofexcellence.html>.

21 'Russia to Invest over US$1 Billion in Nanotechnology in Next Three Years', *International Herald Tribune* (online), 8 April 2007, <http://www.iht.com/articles/ap/2007/04/08/technology/EU-TEC-Russia-Nanotechnology.php>.

22 Institute for Soldier Nanotechnologies: Enhancing Soldier Survivability, <http://web.mit.edu/ISN/>.

23 Corporate Watch, *The UK Nanotech Industry*, (30 September 2009) <http://www.corporatewatch.org.uk/?lid=2066>.

24 BAE Systems, *BAE Systems to Develop Nano-Sensor Technology in Agreement with Micromem Applied Sensor Technologies*, (30 June 2008) <http://www.baesystems.com/Newsroom/NewsReleases/autoGen_10853014158.html>.

25 Nanotechwire, *Industrial Nanotech Begins Work with US Army*, (2 February 2009) <http://www.nanotechwire.com/news.asp?nid=7437>.

26 Raytheon, *Raytheon Awarded Phase Two Contract for Nano-Composite Optical Ceramics Project*, (29 October 2009) <http://investor.raytheon.com/phoenix.zhtml?c=84193&p=irol-newsArticle&ID=1348339&highlight=>; Nanotechwire, *Raytheon Awarded Contract for Nano Thermal Interface Material Development*, (25 June 2009) <http://www.nanotechwire.com/news.asp?nid=8120>.

27 US Patent 7520224, 21 April 2009.

Currently, no effective method exists for monitoring ENP exposure, and the health risks involved are potentially unique and only partially documented. Crucial chronic *in vivo* animal exposure studies (in particular of reproductive toxicity) have not been published to date. Research suggests that the health risks of nanostructures cannot be predicted *a priori* from their bulk equivalents. Yet, some ENPs have also been shown in isolated cell experiments to preferentially accumulate in mitochondria and inhibit function. Others may become unstable in biological settings and release elemental metals. Furthermore, short-term animal exposure to some (but not all) ENPs has produced dose-dependent inflammatory responses and pulmonary fibrosis.[28] Ensuring the safety of nanotechnology presents global policy challenges for public health, not only because gathering, analysing, categorising, and characterising safety data for individual nanotherapeutic products may be unusually difficult, but also because it is unclear whether there are general safety risks or whether risks are confined to uniquely engineered nanomaterials with novel surface binding properties.[29]

The relevance of nanotechnology to the military resides particularly in its enabling applications in electronics, optoelectronics, and information and communication systems for detecting, preventing and deterring bioterrorism, the latter being a national research priority in developed nations.[30] Nanotechnology thus has a recognised defensive military capability. Standard bioterrorist threats, for example, could involve aerosol attacks on individuals or crowds, 'dirty' bombs and targeted contamination of food sources, each utilising chemical or biological agents of a size, amount or distribution that nanotechnology sensors and computing will greatly assist in uncovering.[31] Bioterrorist threats such as botulinum in milk,[32] or release of pathogenic

---

28 Thomas A Faunce, 'Toxicological and Public Good Considerations for the Regulation of Nanomaterial-Containing Medical Products' (2008) 7(2) *Expert Opinion in Drug Safety* 103.

29 Thomas A Faunce, John White and Klaus I Matthaei, 'Integrated Research into the Nanoparticle-Protein Corona: A New Focus for Safe, Sustainable and Equitable Development of Nanomedicines' (2008) 3(6) *Nanomedicine* 859.

30 See eg, Australian Government, *Transnational Terrorism: The Threat to Australia* (2004), 33, 90 <http://www.dfat.gov.au/publications/terrorism/transnational_terrorism.pdf>; United Kingdom, *Pursue Prevent Protect Prepare: The United Kingdom's Strategy for Countering International Terrorism* (2009), 126-131 <http://security.homeoffice.gov.uk/news-publications/publication-search/general/HO_Contest_strategy.pdf?view=Binary>.

31 Bruce Alberts, 'Modeling Attacks on the Food Supply' (2005) 102 *Proceedings of the National Academy of Sciences* 9737.

32 Lawrence M Wein and Yifan Liu, 'Analyzing a Bioterror Attack on the Food Supply: The Case of Botulinum Toxin in Milk' (2005) 102 *Proceedings of the National Academy of Sciences* 9984.

organisms and biotoxins in the water supply may not themselves involve nanoscale agents, but their detection may require correlation of vast amounts of information beyond the capacity of non-nanotechnology sensing, information and communication systems.[33] Likewise, threat responses to unexpectedly virulent modifications such as mousepox IL-4,[34] or a highly virulent strain of influenza virus (akin to the strain which caused the Spanish influenza pandemic in the winter of 1918–1919 and killed up to 50 million people worldwide),[35] are likely to benefit greatly from defensive nanotechnology surveillance systems. Atlantic Storm, for example, was a simulated bioterrorism exercise based on the deliberate release of smallpox viruses in various European and North American cities. It revealed that many nations had inadequate vaccine stockpiles, response plans, and public health laws to effectively respond. Such exercises have illuminated the need to develop innovative defensive technologies (including nanotechnology) capable of allowing health officials to promptly detect minute amounts of viral loads in widely dispersed locations and effectively communicate the relevant details to public health authorities.[36] States negotiating under the *Biological Weapons Convention* (BWC) recently emphasised the need for broad-based codes of conduct for both scientists and public health physicians to counter future bioterrorist threats, partly by warning of the professional perils involved in deliberate or inadvertent release of information and substances.[37]

Military applications of nanotechnology will not be confined to defensive capabilities, however. Nanotechnology allows the building of conventional missiles with reduced mass and enhanced speed, small metal-less weapons made of nanofibre composites, small missiles as well as artillery shells with enhanced accuracy guided by inertial navigation systems, and armour-piercing projectiles with increased penetration capability. Although it is still highly speculative, further research could lead to the development of micro-combat

---

33 Jennifer B Nuzzo, 'The Biological Threat to US Water Supplies: Toward a National Water Security Policy' (2006) 4(2) *Biosecurity and Bioterrorism* 147.

34 Ronald J Jackson, et al, 'Expression of Mouse Interleukin-4 by a Recombinant Ectromelia Virus Suppresses Cytolytic Lymphocyte Responses and Overcomes Genetic Resistance to Mousepox' (2001) 75 *Journal of Virology* 1205.

35 Jeffery K Taubenberger, et al, 'Characterization of the 1918 Influenza Virus Polymerase Genes' (2005) 437 *Nature* 889; Terrence M Tumpey, et al, 'Characterization of the Reconstructed 1918 Spanish Influenza Pandemic Virus' (2005) 310 *Science* 77.

36 Daniel S Hamilton and Bradley T Smith, 'Atlantic Storm' (2006) 7(1) *European Molecular Biology Organization Reports* 4.

37 *Report of the Meeting of States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction*, Doc BWC/MSP/2005/3 (14 December 2005), paras 18–24, <http://www.opbw.org/new_process/msp2005/BWC_MSP_2005_3_E.pdf>.

robots, micro-fusion nuclear weapons, new chemical agents carried by nanoparticles, and new biological agents with self-replication capability.[38]

Some of the potential offensive military applications of nanotechnology could span several traditional technological compartments and blur the distinction between conventional weapons and weapons of mass destruction. The ability of nanotechnology to design and manipulate molecules with specific properties could lead to biochemicals capable of altering metabolic pathways and causing defined hostile results ranging from temporary incapacitation to death.[39] Nanotechnology could also make it possible to contain and carry a minute amount of pure-fusion fuel safely until released, detonating a micro-nuclear bomb at a microspot.[40] As will be shown below, it is likely that those new weapons would be subjected to prohibition and inspection under existing treaties, as long as currently available chemicals and biological agents are used in nano-size.[41] However, the dual-use potential of nanotechnology and the low visibility of nanoparticles in weapons make it hard to detect their development and use as weapons.

Concern has been raised about the potentially unique harmful effects of nano-weapons. At an individual level, explosives such as those using nano-energetic particles, nano-aluminum or non-metal nano-fibre composites, and nano-medicines that improve soldiers' ability to overcome sleep deprivation,[42] could cause unnecessary suffering to both combatants and non-combatants. At a larger, strategic level, the development and deployment of smaller, longer range missiles with greater precision, or new bio-chemical agents could dramatically change the balance of military power and the way in which a war is fought. Because of these concerns, there have been calls for moratoriums or bans on nanotechnology.[43] Others have proposed the creation of a preventative arms control regime based on prospective scientific, technical, and military operational analysis of nanotechnology.[44] However, no international

---

38 Altmann, above n 17, 84–103; Jürgen Altmann, 'Military Use of Nanotechnology: Perspectives and Concerns' (2004) 35 *Security Dialogue* 61, 66-70; Wang and Dortmans, above n 11, 22–30.

39 Juan Pablo Pardo-Guerra and Francisco Aguayo Ayala, 'Nanotechnology and the International Regime on Chemical and Biological Weapons' (2005) 2(1) *Nanotechnology Law and Business* 55, 58–59.

40 Altmann, above n 17, 100–101; Altmann, above n 38, 68.

41 Pardo-Guerra and Ayala, above n 39, 59.

42 Daniel Moore, 'Be All You Can Be: The Nano-Enhanced Army' (2009) (15) *Nano Magazine*, <http://www.nanoethics.org/nanomagazine_1209.pdf>.

43 Sean Howard, 'Nanotechnology and Mass Destruction: The Need for an Inner Space Treaty' (2002) 65 *Disarmament Diplomacy* <http://www.acronym.org.uk/dd/dd65/65op1.htm>.

44 Altmann, above n 17, 154–176; Altmann, above n 38, 70–73.

agreement alone would be effective or even feasible in halting or controlling the development of nanotechnology without proper regulatory mechanisms that will address the right balance between military necessity, humanitarian considerations and peaceful applications of nanotechnology.

The next section will examine the current state of international law to ascertain the extent to which nano-weapons might already be, or can be, prohibited or regulated, before turning to the issue of potential new regulatory mechanisms.

3 International Law Governing Nano-Weaponry

3.1 Arms Control Law and Nano-Weaponry

Currently there is no international treaty that has specific provisions regulating nano-weapons. Therefore, in order to determine the extent to which nano-weapons are covered by existing international law it will be necessary to examine whether general principles governing weaponry apply, or whether extant arms control treaties impose restrictions by reasonable extension.

States have agreed in a variety of international treaties to specific and express rules on arms control, which apply even in peacetime. Yet, the adoption of treaties to prohibit certain weapons tends to be reactive (rather than pre-emptive) and limited in scope, and has been largely dictated by considerations of military effectiveness.[45] Thus, states have agreed to ban the use of projectiles of a weight below 400 grams that are explosive or charged with fulminating or inflammable substances,[46] expanding bullets,[47] asphyxiating, poisonous or

---

45 In recent years, however, civil society has increased its influence on the development of arms control treaties. Cf Kenneth Anderson, 'The Ottawa Convention Banning Landmines, the Role of International Non-Governmental Organizations and the Idea of International Civil Society' (2000) 11(1) *European Journal of International Law* 91.

46 *St. Petersburg Declaration Renouncing the Use, in Time of War, of Explosive Projectiles under 400 Grammes Weight* (29 November/11 December 1868) 138 CTS 297–299, reprinted in Adam Roberts and Richard Guelff, *Documents on the Laws of War* (3rd ed, 2000) 54–55 ('*St Petersburg Declaration*'). The limit of 400 grams was more or less arbitrary, reflecting the dividing line, discernible at that time, between explosive artillery and rifle munitions, the latter not being generally rendered indispensable in enhancing military utility. Frits Kalshoven, 'Arms, Armaments and International Law' (1985-II) 191 *Recueil des Cours* 185, 207–208. Later on, light explosive or incendiary projectiles below 400 grams were developed and have been widely accepted unless they are used against human beings. See Kalshoven, ibid, 223.

47 *Hague Declaration (III) Concerning Expanding Bullets* (29 July 1899) 187 CTS 459–461 para 1, reprinted in Roberts and Guelff, above n 46, 64–65.

other gases,[48] biological weapons,[49] chemical weapons,[50] blinding laser weapons,[51] anti-personnel mines,[52] and most recently, cluster munitions.[53] Nanotechnology, if used as an enabling technology for weapons development in these areas, would be regulated at least in part by the relevant convention. For example, prototype nanotechnology lasers producing megawatts of continuous power are far more powerful than those previously known,[54] and are likely to be subject to the 1995 *Protocol on Blinding Laser Weapons* in the visible region.[55] Nanotechnology can also produce toxic chemicals with novel properties,[56] and may facilitate the development of synthetic organisms with a high degree of lethality.[57] Yet the arms control treaties in these areas were drafted without any consideration of nanotechnological developments.

The recent development and deployment of DIME, for example, illustrates the difficulty in defining whether new weapons fall within the nanotechnology category, or within existing rules of international arms control law. DIME was

---

48 *Hague Declaration (II) on the Use of Projectiles the Object of Which is the Diffusion of Asphyxiating or Deleterious Gases* (29 July 1899) 187 CTS 453–455, reprinted in Roberts and Guelff, ibid, 60–61; *Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare*, opened for signature 8 February 1928, 94 LNTS 65.

49 *Biological Weapons Convention*, opened for signature 10 April 1972, 1015 UNTS 163 (entered into force 26 March 1975).

50 *Chemical Weapons Convention*, opened for signature 13 January 1993, 1974 UNTS 45 (entered into force 29 April 1997).

51 *Protocol (IV) on Blinding Laser Weapons to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects*, opened for signature 13 October 1995, 35 ILM 1218 (entered into force 30 July 1998), reprinted in Roberts and Guelff, above n 46, 525 ('*Protocol on Blinding Laser Weapons*').

52 *Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction*, opened for signature 3 December 1997, 2056 UNTS 211 (entered into force 1 March 1999).

53 *Convention on Cluster Munitions*, opened for signature 30 May 2008 (entered into force 1 August 2010).

54 Geoffrey Duxbury, et al, 'Quantum Cascade Semiconductor Infrared and Far-Infrared Lasers: From Trace Gas Sensing to Non-Linear Optics' (2005) 34(11) *Chemical Society Reviews* 921.

55 *Protocol on Blinding Laser Weapons*, opened for signature 13 October 1995, 35 ILM 1218 (entered into force 30 July 1998).

56 Joyce S Tsuji, et al, 'Research Strategies for Safety Evaluation of Nanomaterials, Part IV: Risk Assessment of Nanoparticles' (2006) 89(1) *Toxicological Sciences* 42.

57 Peixuan Guo, 'RNA Nanotechnology: Engineering, Assembly and Applications in Detection, Gene Delivery and Therapy' (2005) 5(12) *Journal of Nanoscience and Nanotechnology* 1964.

developed at the US Air Force Research Laboratory in order to achieve low collateral damage by producing a highly powerful blast within a relatively small area. Its development originates from depleted uranium research and is the latest innovation in the US military's long-running development of Focused Lethality Munitions (FLM),[58] designed to provide the 'weapons of choice' in targeting terrorists hiding among civilians.[59] Upon detonation, the carbon fibre warhead case disintegrates into minute, non-lethal fibres with little or no metallic fragments, then sprays a superheated micro-shrapnel of powdered (potentially nano-scale) tungsten particles with sufficient penetration mass for disabling the target within a small lethal footprint.

Due to the undetectable nature of tungsten micro-particles in human tissue, the question arises whether this weapon falls within the scope of the 1980 *Protocol (I) on Non-Detectable Fragments to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons* ('1980 *Protocol (I)'*).[60] It appears that the design intent of this weapon meets the threshold for the prohibition, as the primary effect of metal dust sprayed with DIME is to kill, injure, or damage by blast without leaving much trace of fragments.[61] When the 1980 *Protocol (I)* was adopted unanimously, states did not have such weapons in their inventory, nor did they foresee any conceivable use of them in the future.[62] It could well be argued, according to a textual interpretation, that DIME is not prohibited under the 1980 *Protocol (I)*, as micro-shrapnel could still be detectable by X-ray, no matter how difficult it might be in practice. Yet, both a contextual and purposive interpretation of the *Protocol* support the case that DIME is prohibited given the potential seriousness of injuries caused by DIME attacks and the difficulty of treatment due to the size of the fragments.[63]

---

58 See notes 2–4 above and accompanying text.

59 Greg Jaffe, 'Air Force Seeks a Bomb with Less Bang' *Wall Street Journal/Pittsburgh Post-Gazette* (online), 4 November 2006, <http://www.post-gazette.com/pg/06096/679996-84.stm>.

60 *Protocol (I) on Non-Detectable Fragments to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects*, opened for signature 10 October 1980, 1342 UNTS 137 (entered into force 2 December 2 1983) ('1980 *Protocol (I)'*).

61 For an analysis of the scope of the prohibition, see William H Boothby, *Weapons and the Law of Armed Conflict* (2009) 196–198.

62 W J Fenrick, 'The Conventional Weapons Convention: A Modest But Useful Treaty' (1990) 279 *International Review of the Red Cross* 498, 503; Howard S Levie, 'Prohibitions and Restrictions on the Use of Conventional Weapons' (1994) 68 *St John's Law Review* 643, 654.

63 Boothby observes that the *Protocol* can catch types of weapons which were not in the contemplation of the drafters because the prohibited weapons are defined by reference to the effects that they may have. See Boothby, above n 61, 198.

DIME bombs were reportedly employed by Israel during the 2006 conflicts in Gaza and Southern Lebanon, and more recently during the Gaza conflict in January 2009.[64] As Israel is a party to the 1980 *Protocol (I)*,[65] it is arguable that it breached those treaty obligations by employing DIME bombs. Few authoritative allegations, however, have been made against the use of DIME by Israeli forces on such grounds.[66] If DIME is to be considered at least in some respects a nano-weapon chiefly due to the potential nano-scale of powders produced upon impact, this would complicate the assessment of its legality under the existing treaty obligations.

Arms control regimes also face an inherent problem with application to non-contracting parties. Whilst resorting to an examination of customary law status of a particular prohibition remains an option for long-existing weapons, this is generally not the case for new weapons because of the inevitable absence of state practice. In fact, the customary law status of the prohibition on non-detectable fragments has been subject to considerable disagreement among commentators for this reason.[67]

3.2 International Humanitarian Law Principles and Nano-Weaponry

The international arms control treaties noted above usually concentrate on regulating or prohibiting the specified weapon's construction aims and characteristics. General principles of international humanitarian law, on the other hand, tend to regulate the conduct of warfare by reference to the harmful effects produced by the use of means or methods of warfare.[68] The general principle, for example, that 'the right of belligerents to adopt means of warfare is not unlimited' may have had its roots in compassion and rejection of unnecessary suffering textually manifesting in Ancient Greece and India.[69] No

---

64 See, eg, Whitaker, above n 2.

65 See, ICRC, *International Humanitarian Law – Treaties & Documents*, <http://www.icrc.org/ihl.nsf/WebSign?ReadForm&id=505&ps=P>. There are 107 state parties to the 1980 Protocol I as of July 13, 2009.

66 See the references in note 2 above.

67 Compare, eg, Jean-Marie Henckaerts and Louise Doswald-Beck, *Customary International Humanitarian Law* (vol 1, 2005) 275–277; with David Turns, 'Weapons in the ICRC Study on Customary International Humanitarian Law' (2006) *11 Journal of Conflict and Security Law* 226, 226–227; Boothby, above n 61, 198–199.

68 Christopher Greenwood, 'The Law of Weaponry at the Start of the New Millennium' in Michael N Schmitt and Leslie C Green (eds), *The Law of Armed Conflict: Into the New Millennium* (US Naval War College Studies, vol 71, 1999) 185, 192.

69 *Hague Convention (IV) Respecting the Laws and Customs of War on Land and its Annex: Regulations Concerning the Laws and Customs of War on Land*, opened for signature 18 October 1907, 205 CTS 277–298, art 22 (entered into force 26 January 1910), reprinted in Roberts and Guelff, above n 46, 73–82 ('*1907 Hague Regulations*');

matter how nascent this was as a legal principle before the emergence of modern international law of armed conflict, it has received widespread support amongst the leaders of nations over many years. There is now little doubt about whether this broad statement about the regulation of weaponry is a reflection of 'elementary considerations of humanity'.[70] More specifically, there are two basic principles of international humanitarian law highly relevant to nano-weaponry: one prohibiting the employment of arms, projectiles, or material 'of a nature to cause superfluous injury' (or 'calculated to cause unnecessary suffering');[71] and the other prohibiting the use of weapons that indiscriminately affect both combatants and non-combatants.[72]

The principle of prohibiting superfluous injury or unnecessary suffering is central to the consideration of legality under the international law of conventional weapons, as opposed to weapons of mass destruction.[73] It was first enunciated in the preamble to the 1868 *St Petersburg Declaration*,[74] but was a rhetorical expression of the drafters' inspiration, rather than their intention to impose legal obligations.[75] It was formally adopted as a binding rule in the subsequent treaties,[76] and since then has attained the status of customary

---

Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts, opened for signature 8 June 1977, 1125 UNTS 3, art 35(1) (entered into force 7 December 1978) ('*Additional Protocol I*'). Judge Weeramantry elaborated on the multicultural traditions underpinning limitations to the conduct of warfare in his dissenting opinion in the *Legality of Nuclear Weapons* case. See, *Legality of the Threat or Use of Nuclear Weapons (Advisory Opinion)* [1996] ICJ Rep 226 (hereinafter '*Legality of Nuclear Weapons Opinion*') 478–482.

70 This terminology appears in the ICJ judgment in the *Corfu Channel Case (United Kingdom v Albania)* [1949] ICJ 4, 22.

71 *Hague Convention (II) Respecting the Laws and Customs of War on Land*, opened for signature 29 July 1899, art 23(e) (entered into force 4 September 1900); *1907 Hague Regulations*, art 23(e). Although the authentic French text remained the same (*maux superflus*), the identical phrase in the two instruments was translated differently. See, English translation of the treaty texts provided in James Brown Scott (ed), *The Hague Conventions and Declarations of 1899 and 1907* (1915) 116. Article 35(2) of the *Additional Protocol I* placed those two expressions side by side.

72 *Additional Protocol I*, art 51(4).

73 The prohibition on indiscriminate attacks regulates the way in which a particular conventional weapon is employed, but does not necessarily render any use of the weapon illegal.

74 It reads, 'the employment of arms which uselessly aggravate the sufferings of disabled men, or render their death inevitable; … would, therefore, be contrary to the laws of humanity'.

75 Kalshoven, above n 12, 511.

76 See references in above n 71.

international law.[77] This is so irrespective of the distinction between civilian and military targets.[78] The prohibition is now incorporated into the 1998 *Rome Statute* of the International Criminal Court as one of the criminal offences.[79] This principle appears to be principally relevant to the international regulation of nano-weapons insofar as those weapons could pose novel, unnecessarily severe and long-term health and environmental impacts.

The specific rules of arms control law, as they potentially apply to nano-weapons, are thus a subset of the general principles of international humanitarian law on weaponry.[80] Assuming that it may not be clear whether a nano-weapon is prohibited, general humanitarian law principles then may serve as a general legal or moral basis for questioning its legality and starting negotiations which may result in its prohibition.[81] Such a debate will have to take account of the 'Martens Clause',[82] although 'principles of humanity' and 'dictates of public conscience' alone provide no firm legal basis to prohibit the use of particular weapons.[83]

In practice, it is likely to prove difficult to rely on general humanitarian law principles by themselves as laying down a firm legal basis for restricting the

77 See, eg, Henckaerts and Doswald-Beck, above n 67, 237–244.

78 See, *Legality of Nuclear Weapons Opinion*, [1996] ICJ Rep 226, 257 para 78.

79 See, *Rome Statute of the International Criminal Court*, opened for signature 17 July 1998, 2187 UNTS 3, arts 8(2)(b)(xix) and (xx), (entered into force 1 July 2002).

80 Roger S Clark, 'Methods of Warfare that Cause Unnecessary Suffering or Are Inherently Indiscriminate: A Memorial Tribute to Howard Berman' (1998) 28 *California Western International Law Journal* 379, 385.

81 See, Guido den Dekker, 'The Law of Arms Control and Depleted Uranium Weapons' in Avril McDonald, Jann K Kleffner and Brigit Toebes (eds), *Depleted Uranium Weapons and International Law* (2008) 75, 81; Detlev F Vagts, 'The Hague Conventions and Arms Control' (2000) 94 *American Journal of International Law* 31, 36.

82 Preamble to the 1868 *St Petersburg Declaration* and *Additional Protocol I*, art 1(2). Article 1(2) reads: 'In cases not covered by this Protocol or by other international agreements, civilians and combatants remain under the protection and authority of the principles of international law derived from established custom, from the principles of humanity and from dictates of public conscience'.

83 See, eg, Christopher Greenwood, 'Historical Development and Legal Basis' in D Fleck (ed), *Handbook of International Humanitarian Law* (2nd ed, 2008) 101; Antonio Cassese, 'The Martens Clause: Half a Loaf or Simply Pie in the Sky?' (2000) 11 *European Journal of International Law* 187; Theodor Meron, 'The Martens Clause, Principles of Humanity, and Dictates of Public Conscience' (2000) 94 *American Journal of International Law* 78; Cf *Legality of Nuclear Weapons Opinion*, [1996] ICJ Rep 226, 408 (Judge Shahabuddeen dissenting opinion).

usage of nano-weapons outside a specific arms control treaty.[84] In the *Legality of Nuclear Weapons Opinion*, for instance, the International Court of Justice was unwilling to declare the threat or use of nuclear weapons illegal in all circumstances, even though it explicitly acknowledged the applicability of the general humanitarian law principles.[85]

Another illustrative debate with implications for nano-weapons, concerns the legality of depleted uranium (DU) munitions.[86] Concerns about the effects of the use of DU munitions were first publicly raised in relation to speculation that 'Gulf War Syndrome' was linked to exposure to DU, although no causal relationship was established.[87] However, a recent scientific study shows that toxic chemicals that are released upon impact (arguably in the form of nano-particles) are suspected of weakening the immune system, causing acute respiratory conditions and severe kidney problems, and increasing the chances of genetic birth defects and cancer.[88] Although scientific analysis is still

---

84 Yves Sandoz, Christophe Swinarski and Bruno Zimmerman (eds), *Commentary on the Additional Protocols of 8 June 1977 to the Geneva Conventions of 12 August 1949* (1987) 402, para 1415.

85 *Legality of Nuclear Weapons Opinion*, [1996] ICJ Rep 226, 266, para 105.

86 Depleted uranium is a waste product of the uranium enrichment process in which radioactive isotopes U-234 and U-235 are removed. DU is almost entirely U-238 and is 40-60% radioactive as natural uranium. It is chemically toxic like lead, nickel and other heavy metals. For more detailed description of depleted uranium, see, Dan Fahey, 'Depleted Uranium and its Use in Weapons' in Avril McDonald, Jann K Kleffner and Brigit Toebes (eds), *Depleted Uranium Weapons and International Law* (2008) 3, 4; D E McClaim, A C Miller and J F Kalinich, *Status of Health Concerns about Military Use of Depleted Uranium and Surrogate Metals in Armor-Penetrating Munitions* (2005) 2–8, <http://www.afrri.usuhs.mil/www/outreach/pdf/mcclain_NATO_2005.pdf>; United Nations Environment Programme (UNEP), *Depleted Uranium in Bosnia and Herzegovina: Post-Conflict Environmental Assessment*, (May 2003) 15, available at <http://postconflict.unep.ch/publications/BiH_DU_report.pdf>; Michael H Repacholi, *Background Material on Depleted Uranium (DU)* (8 January 2001) <http://www.nato.int/du/docu/d010108e.htm>.

87 See, eg, Melissa A McDiarmid, et al, 'Health Effects of Depleted Uranium on Exposed Gulf War Veterans: A 10-Year Follow-Up' (2004) 67(4) *Journal of Toxicology and Environmental Health* 277.

88 See generally, Antonietta Gatti and Stefano Montanari, *Nanopathology: The Health Impact of Nanoparticles* (2007) 54–55; Dan Fahey, 'Environmental and Health Consequences of the Use of Depleted Uranium Weapons' in Avril McDonald, Jann K Kleffner and Brigit Toebes (eds), *Depleted Uranium Weapons and International Law: A Precautionary Approach* (2008) 29; The Royal Society Working Group on the Health Hazards of Depleted Uranium Munitions, 'The Health Effect of Depleted Uranium Munitions: A Summary' (2002) 22(2) *Journal of Radiological Protection* 131, 132-134 (2002).

inconclusive, evidence against DU continues to mount,[89] indicating an intrinsic illegality of DU weapons under the general principles prohibiting superfluous injury or unnecessary suffering.[90]

Three relevant issues potentially arise regarding the actual meaning and scope of this international humanitarian law principle against superfluous or unnecessary suffering in relation to nano-weapons.

The first point concerns whether the legality of a nano-weapon should be assessed in the light of the primary intention behind its development, or by reference to the objective nature or likely outcome of its use. This debate traces its origin back to the different English texts used to translate the principle enunciated in the 1899 and 1907 *Hague Regulations*.[91] The phrase 'of a nature to cause' in the 1899 text indicates the objectiveness of this criterion, whereas the term 'calculated to cause' in the 1907 text is more restrictively interpreted to refer to a more subjective intention by the force employing it.

Although the actual text of this principle was settled with 'of a nature to cause' in the 1977 *Additional Protocol I*, there remains a disagreement about the test to be applied. Some commentators look at the primary purpose for which the new weapon is designed in order to determine whether it causes injury or suffering disproportionate to its military effectiveness.[92] Others, reading it in conjunction with Article 36 of *Additional Protocol I*, focus on the effects of normal or expected use of the new weapon.[93] Depending on which approach is taken, military applications of nanotechnology with the primary purpose of reducing civilian casualties, for example, may well be deemed illegal due to the potentially unnecessary health and environmental effects.

---

89 For example, some scientists assert combined health effects of chemical toxicity and irradiation causing damage to DNA. See, Duncan Graham-Rowe, 'Depleted Uranium Casts Shadow over Peace in Iraq' (19 April 2003) 178(2391) *New Scientist* 4.

90 See, Jason A Beckett, 'Interim Legality: A Mistaken Assumption? – An Analysis of Depleted Uranium Munitions under Contemporary International Humanitarian Law' (2004) 3 *Chinese Journal of International Law* 43; Owen Thomas Gibbons, 'Uses and Effects of Depleted Uranium Munitions: Towards a Moratorium on Use' (2004) 7 *Yearbook of International Humanitarian Law* 191, 206–224; Michael Byers, *War Law* (2005) 124.

91 See above n 71.

92 This was the view generally held by states during the UN Conference on Certain Conventional Weapons in 1979-1980. See, eg, W Hays Parks, 'Conventional Weapons and Weapons Reviews' (2005) 8 *Yearbook of International Humanitarian Law* 55, 76–82; Fenrick, above n 62, 500.

93 See, eg, James D Fry, 'Contextualized Legal Reviews for the Methods and Means of Warfare: Cave Combat and International Humanitarian Law' (2006) 44 *Columbia Journal of Transnational Law* 453, 470–471.

This debate has been particularly pertinent to DU munitions, as they are primarily intended to be anti-*matériel* weapons, highly efficient in penetrating advanced tank armour, rather than to be anti-personnel weapons. The principle prohibiting the use of arms of a nature that causes superfluous injury or unnecessary suffering has primarily been applied in relation to anti-personnel weapons. It has not traditionally been used to question the legality of anti-*matériel* weapons that incidentally cause more severe injuries to personnel in the vicinity of the target than necessary to render them *hors de combat*.[94] Given the changing nature of modern warfare where disabling military personnel has become less and less important, the notion of superfluous injury or unnecessary suffering incidental to the destruction of military *matériel* may well need to be reconsidered.[95] Accordingly, a wider interpretation of this principle could invoke both immediate and consequential effects in assessing what is necessary to destroy the military *matériel* when it is sought to be applied to nano-weapons.

Second, regulation of nano-weapons under international humanitarian law may be caught between different interpretations of 'superfluous' and 'unnecessary' suffering. The dominant view is that this issue involves balancing between the degree of injury or suffering inflicted on the one hand, and the degree of military necessity underlying the choice of particular weapon on the other (balancing approach).[96] The practical difficulty with this approach to regulation of nano-weapons lies in the ambiguous definitions of military necessity involving comparison to the degree of injury, which cannot be clarified without an insight into the actual situation in which the choice of weapons is to be made.[97] Neither side of the equation is easy to objectively quantify.[98] Particularly troubling is the concept of 'military necessity' or

---

94 See, Michael Bothe, Karl Josef Partsch and Waldemar A Solf, *New Rules for Victims of Armed Conflicts: Commentary on the Two 1977 Protocols Additional to the Geneva Conventions of 1949* (1982) 196–197. Cf Avril McDonald, 'Averting Foreseeable and Unexpected Damage: The Case for a Precautionary Approach vis-á-vis Depleted Uranium Weapons' in Avril McDonald, Jann K Kleffner and Brigit Toebes (eds), *Depleted Uranium Weapons and International Law* (2008) 281, 285–287.

95 Marten Zwanenburg, 'The Use of Depleted Uranium and the Prohibition of Weapons of a Nature to Cause Superfluous Injury or Unnecessary Suffering' in Avril McDonald, Jann K Kleffner and Brigit Toebes (eds), *Depleted Uranium Weapons and International Law* (2008) 111, 117, 120.

96 Government experts attending at the Conference on the Use of Certain Conventional Weapons in Lucerne in 1974 were in general agreement on this point. See, International Committee of the Red Cross, *Report on the Conference of Government Experts on the Use of Certain Conventional Weapons* (Lucerne, 24 September 1974) 8–9, paras 23–24; Sandoz, Swinarski and Zimmerman, above n 84, 408, para 1428.

97 Greenwood, above n 68, 195–199; Kalshoven, above n 46, 234–235.

98 See, Zwanenburg, above n 95, 119–120.

'effectiveness' which easily slips into a justification for derogating from the rule.[99] For example, it is arguable that the application of the general principle to prohibit superfluous injury and unnecessary suffering would be enough to effectively ban the use of DIME even without relying on the 1980 *Protocol (I)*. However, there is still room for the balancing approach to play a legitimising role here,[100] emphasising the intent to reduce collateral damage to innocent civilians in targeting terrorists in a densely populated area.

Other conceptions of 'superfluous injury' or 'unnecessary suffering' under international humanitarian law would place greater emphasis on excessive harm inflicted by a nano-weapon on the victim in relation to the damage necessary to place a soldier *hors de combat* for the duration of the combat (effects approach).[101] Advocates of this view are likely to criticise the first approach for leaving too much of the determination of superfluous injury to military commanders and officers of each state.[102] Yet, the decision as to what is necessary to disable enemy combatants requires decision-makers to rely on their professional judgement. In fact, the British objections to the banning of the then new technology of dum-dum (or expanding, hollow-tip) bullets in 1899 were based on their assessment that a single rifle bullet did not have enough stopping power against tribal natives.[103] Had the use of 'dum-dum bullets' not been banned in the 1899 Hague Declaration, the British military could have continued to use the bullets on the basis that they were necessary to disable tribal natives. It is interesting to see what arguments will be made along similar lines in relation to nano-weapons.

---

99 See, Henri Meyrowitz, 'The Principle of Superfluous Injury or Unnecessary Suffering: From the Declaration of St. Petersburg of 1868 to Additional Protocol I of 1977' (1994) 299 *International Review of the Red Cross* 98, 106–109.

100 The legality of fragmentation weapons in light of the general principles was in fact a point of disagreement in the 1974 Conference of Government Experts on the Use of Certain Conventional Weapons in Lucerne. See, Kalshoven, above n 46, 239.

101 Eric David, *Principes de droit des conflits armés* (2nd ed, 1999) 280–281. See also, Jack H McCall, Jr, 'Blinded by the Light: International Law and the Legality of Anti-Optic Laser Weapons' (1997) 30 *Cornell International Law Journal* 1, 25–26.

102 See, eg, Rosario Domínguez-Matés, 'New Weaponry Technologies and International Humanitarian Law: Their Consequences on the Human Being and the Environment' in Pablo Antonio Fernández-Sánchez (ed), *The New Challenges of Humanitarian Law in Armed Conflicts* (2005) 91, 115.

103 See, Remarks by General Sir John Ardagh, in James Brown Scott, *The Proceedings of the Hague Peace Conferences: The Conference of 1899 Part II*, (1920) 276–278; Frits Kalshoven, 'The Soldier and His Golf Clubs' in Christophe Swinarski (ed), *Etudes et essays sur le droit international humanitaire et sur les principes de la Croix-Rouge, en l'honneur de Jean Pictet* (1984) 369, 374–376.

The 'SIrUS project',[104] supported by the International Committee of the Red Cross in the late 1990s, attempted to overcome the subjectivity of this standard in relation to new weapons such as nano-weapons. The project draws on medical assessments to establish a series of baselines relating to injury and suffering resulting from the effects of conventional weapons, and regards any other foreseeable effects of weapons as constituting superfluous injury or unnecessary suffering.[105] The project, however, met strong opposition by governments and experts for various doctrinal and practical reasons.[106] This episode demonstrates that any attempts to establish objective criteria for determining what amounts to superfluous injury or unnecessary suffering in relation to nano-weapons are likely to be compromised if they do not take into account strategic and military operational factors important for governments and militaries.

The third major issue concerning the applicability of international humanitarian law principles to nano-weapons concerns the definition of injury and suffering caused by them. There is a subtle difference under this international humanitarian law principle between 'injury' and 'suffering'. The former indicates immediate, physical damage, whereas the latter may entail incidence of permanent damage or disfigurement.[107] This distinction, and emphasis on permanent damage or disfigurement, is of increased significance, given that, as will be shown below, technological advancement has been making it more difficult to appreciate the full range of damaging effects of a new weapon for the human body by looking only at the weapon's construction.[108] Moreover, the meaning of suffering could even be extended to harmful effects that ensue after hostilities have ended, when the principle is read in conjunction with Article 55(1) of *Additional Protocol I*, which prohibits

---

104 This term is an acronym of 'Superfluous Injury or Unnecessary Suffering'.

105 See, Robin M Coupland, 'The SIrUS Project: Towards a Determination of Which Weapons Cause "Superfluous Injury or Unnecessary Suffering"' in Helen Durham and Timothy L H McCormack (eds), *The Changing Face of Conflict and the Efficacy of International Humanitarian Law* (1999) 99; Robin M Coupland and Peter Herby, 'Review of the Legality of Weapons: A New Approach, the SIrUS Project' (1999) 835 *International Review of the Red Cross* 583; Robin M Coupland, 'Abhorrent Weapons and "Superfluous Injury or Unnecessary Suffering": From Field Surgery to Law' (1997) 315 *British Medical Journal* 1450. The project was not well received by states. See, 'ICRC Expert Meeting on the Legal Reviews of Weapons and the SIrUS Project' (2001) 842 *International Review of the Red Cross* 539, 541.

106 For a comprehensive critique, see, eg, Donna Marie Verchio, 'Just Say No! The SIrUS Project: Well-Intentioned, But Unnecessary and Superfluous' (2001) 51 *Air Force Law Review* 183.

107 Bothe, Partsch and Solf, above n 94, 196.

108 For a similar view in the context of fragmentation of bullets, see, Robin Coupland, 'Clinical and Legal Significance of Fragmentation of Bullets in relation to Size of Wounds: Retrospective Analysis' (1999) 319 *British Medical Journal* 403.

the use of methods or means of warfare that are intended or may be expected to cause widespread, long-term, and severe damage to the natural environment and 'thereby to prejudice the *health* or survival of the population' (emphasis added).[109]

The application of the precautionary principle, as founded in the field of international environmental law, to international humanitarian law governing the use of nano-weapons would be an intriguing and necessary consideration.[110] Unfortunately, there is little evidence, for example, to support the application of the precautionary principle to the legal assessment of DU munitions in state practice. The potential health and environmental risks associated with the use of DU munitions appear to have been acknowledged, and yet regarded as insignificant, in the 1970s.[111] The use of DU ammunition became widespread in the 1990s when the precautionary principle had already emerged as the norm of international law.[112] DU ammunition was employed to attack armoured targets in response to the Soviet introduction of large numbers of sophisticated, heavily armoured vehicles (for example T-72 tanks).[113] Since then, a variety of DU munitions including anti-tank munitions, missiles and projectiles have reportedly been used in the 1991 Gulf War, Bosnia conflict, Kosovo air campaign, 2001 allied incursion into Afghanistan, and 2003 invasion of Iraq.[114] After the 2001–2002 bombing in Afghanistan, scientists from the Uranium Medical Research Centre found that urine of Afghans living near US bombing sites contained 4 to 20 times the normal level of non-depleted uranium.[115] This allegedly indicates that even more toxic, slightly enriched uranium has recently been used.[116]

---

109 See, Meyrowitz, above n 99, 111–112.

110 Compare McDonald, above n 94, 299–305; with Beckett, above n 90, 82–83.

111 See, Fahey, above n 86, 6–7.

112 See generally, eg, Arie Trouwborst, *Evolution and Status of the Precautionary Principle in International Law* (2002); Nicolas de Sadeleer, *Environmental Principles: From Political Slogans to Legal Rules* (2002) ch 3; James Cameron, 'The Precautionary Principle: Core Meaning, Constitutional Framework and Procedures for Implementation' in Ronnie Harding and Elizabeth Fisher (eds), *Perspectives on the Precautionary Principle* (1999) 29; Harald Hohmann, *Precautionary Legal Duties and Principles of Modern International Environmental Law* (1994).

113 Fahey, above n 86, 6–7.

114 For details, see, Fahey, above n 86, 12–23.

115 Asaf Durakovic, 'The Quantitative Analysis of Uranium Isotopes in the Urine of the Civilian Population of Eastern Afghanistan after Operation Enduring Freedom' (2005) 170(4) *Military Medicine* 277.

116 Robert Fisk, 'Mystery of Israel's Secret Uranium Bomb', *The Independent* (online), 28 October 2006, <http://news.independent.co.uk/world/fisk/article1935945.ece>.

On the other hand, it is noteworthy that despite scientific uncertainty as to the adverse health and environmental effects of DU munitions in nano-scale, some states have already moved to refrain from the use of DU munitions.[117] The European Parliament went even further, adopting a resolution on 22 May 2008 calling for a global treaty to ban (depleted) uranium weapons.[118] In any event, tungsten alloy ammunition and tank guns have recently been developed and are replacing DU, leading to the reduction of its use in munitions.[119]

It is unclear to what extent humanitarian law concerns have led to the reduction or prohibition of the use of DU munitions and might therefore extend by implication to similar nano-weapons. Like specific engineered nanoparticles, it has been reported that tungsten alloy ammunition also represents health and environmental risks that may cause DNA and genomic damage, as well as tumour formation around implanted pellets.[120] Some even suggest that tungsten alloy may pass on its genetic damage to the next generation.[121] The decision to replace DU munitions with tungsten alloy ammunition certainly provides a response to media hysteria surrounding the use of DU munitions, but the extent to which it addresses the fundamental issue of health and environmental effects of weapons would require more careful and thorough consideration.

---

117 See, International Coalition to Ban Uranium Weapons, (21 April 2010) <http://www.bandepleteduranium.org/en/i/71.html>; Lesley Wexler, 'Limiting the Precautionary Principle: Weapons Regulation in the Face of Scientific Uncertainty' (2006) 39 *University California Davis Law Review* 459, 493–495.

118 European Parliament, *European Parliament Resolution of 22 May 2008 on (Depleted) Uranium Weapons and Their Effect on Human Health and the Environment – Towards a Global Ban on the Use of Such Weapons*, (22 May 2008) <http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2008-0233+0+DOC+XML+V0//EN>. Civil society has been calling for adopting a treaty to ban DU weapons for some years. See, M Mohr and A Samuel, *Draft Convention on the Prohibition of Development, Production, Stockpiling, Transfer and Use of Uranium Weapons and on Their Destruction* (27 September 2006) International Coalition to Ban Uranium Weapons, <http://www.bandepleteduranium.org/en/docs/101.pdf>.

119 See, Fahey, above n 86, 11–12; Gibbons, above n 90, 214–215.

120 See, eg, Miller, et al, above n 5; McClaim, Miller and Kalinich, above n 86, 8–14; Alexandra C Miller, et al, 'Effect of the Military-Relevant Heavy Metals, Depleted Uranium and Heavy-Metal Tungsten Alloy on Gene Expression in Human Liver Carcinoma Cells (HepG2)' (2004) 255 *Molecular and Cellular Biochemistry* 247; Nikolay Strigul, et al, 'Effects of Tungsten on Environmental Systems' (2005) 61(2) *Chemosphere* 248.

121 Alexandra C Miller, et al, *Preconceptional Paternal Exposure to Radiation or Heavy Metals Like Cadmium Can Induce Cancer in Unexposed Offspring*, (2006), Proceedings of the Annual Meeting of the American Society of Cancer Research, 47 <http://www.aacrmeetingabstracts.org/cgi/content/abstract/2006/1/448-b>.

Thus, while the principle prohibiting superfluous injury or unnecessary suffering remains a 'significant source of inspiration',[122] its over-inclusiveness and indeterminacy preclude an objective assessment of the legality of nano-weapons.

4 Should Nano-Weapons be Specifically Regulated under International Law?

4.1 Problematic Current Regulation of Nano-Weapons

The interaction between technological development and armed forces is a constant feature throughout the history of human warfare. It is arguable that it is about to enter a new phase with the emergence of nanotechnology. Technological development can be stimulated by, and dedicated directly to, addressing military requirements, as has been the case with DU and DIME weapons. On other occasions, technological development outside the military sphere affects or informs the conduct of warfare and military expectations. It is expected that nanotechnological developments have already entered a new phase, moving from basic research to military applications.

As we have shown, regulation of nano-weapons is likely to be significantly hampered by the indeterminacy of basic principles of international humanitarian law.[123] Illegality of nano-weapons is difficult to prove in the absence of a specific treaty.[124] The development of international law on arms control, on the other hand, has been in a 'perpetual state of reaction',[125] the law attempting to catch up with technological developments rather than pre-empting them. The conspicuous illegality of DIME weapons in violation of the 1980 *Protocol (I) on Non-Detectable Fragments* forms an exception in this respect. Cynics might claim with some justification that arms control is nothing more than the outcome of a process of military evaluation, which is zealously and tightly controlled by the military.

States party to the 1977 *Additional Protocol I* have an obligation under Article 36 to assess the legality of weapons at each stage of their development and

---

122 Antonio Cassese, 'Weapons Causing Unnecessary Suffering: Are They Prohibited?' in Antonio Cassese, *The Human Dimension of International Law: Selected Papers* (2008) 192, 214.

123 See, Greenwood, above n 68, 220.

124 See above Part 3.2.

125 Timothy L H McCormack, 'A Non Liquet on Nuclear Weapons – The ICJ Avoids the Application of General Principles of International Humanitarian Law' (1997) 316 *International Review of the Red Cross* 76, 90.

acquisition.[126] Yet, that provision does not provide much practical guidance as to how a nano-weapon, for example, should be assessed. The state practice of weapons review is patchy and, even in countries where a formal review procedure is in place, only a handful of experts within defence ministries are involved, with little publicity of the results.[127] Concerns about the development of new weapons have recently moved beyond strategic fears of destructive impacts that could threaten the balance of power in international relations, to humanitarian concerns about unnecessarily devastating impacts on civilians during and after the conflict, and even to health and environmental concerns. Against this background, it has become more forcefully arguable that the current mechanism that applies to assessment of the legality of nano-weapons has serious deficiencies not the least because a few experts and scientists on military payrolls monopolise the informational inputs and control the research on destructive instruments.[128]

4.2 Rationales Against the Specific Regulation of Nano-Weapons

Let us first examine whether, and to what extent, the traditional rationales for technological advancement of weaponry justify the lack of transparent regulatory oversight in relation to offensive uses of military nanotechnology. The first rationale is that, as weapons become more technologically advanced, warfare naturally becomes more humane. Traditionally, this self-serving rationale justified secrecy in weapons development on the basis that as the technological gap between states increases, the war will end more quickly, easily and humanely.[129] Yet, more recently, considerations of humaneness have

---

126 *Additional Protocol I*, art 36. It reads: 'In the study, development, acquisition or adoption of a new weapon, means or methods of warfare, a High Contracting Party is under an obligation to determine whether its employment would, in some or all circumstances, be prohibited by this Protocol or by any other rule of international law applicable to the High Contracting Party'.

127 See generally, Fry, above n 93, 466–480; Marie Jacobsson, 'Modern Weaponry and Warfare: The Application of Article 36 of Additional Protocol I by Governments' in Anthony M Helm (ed), *The Law of War in the 21st Century: Weaponry and the Use of Force* (2006) 183, 185–189 (in relation to the Swedish practice); Parks, above n 92, 105–135; Justin McClelland, 'The Review of Weapons in accordance with Article 36 of Additional Protocol I' (2003) 850 *International Review of the Red Cross* 397; Isabelle Daoust, et al, 'New Wars, New Weapons? The Obligation of States to Assess the Legality of Means and Methods of Warfare' (2002) 846 *International Review of the Red Cross* 345.

128 See, Raymond G Decker and Mary Cynthia Dunlap, 'War, Genetics and the Law' (1971) 1 *Ecology Law Quarterly* 795, 817–818.

129 In truth, technological advancement has often led to the exponential growth in the sheer destructiveness of war. See, Charles J Dunlap, Jr, 'Technology: Recomplicating Moral Life for the Nation's Defenders' (1999) 29(3) *Parameters* 24, 24–25.

shifted the focus to reducing civilian collateral damage during military operations, as represented by the on-going development of the Focused Lethality Munitions (FLM) program. Technological development from time to time undoubtedly has promoted more humane conduct of warfare. Yet it is illogical to use that as a reason to refuse to subject nano-weapons development to more robust, greater public scrutiny in terms of their direct and indirect adverse health and environmental effects.

The second rationale against specific regulation of nano-weapons may well be based on national security grounds. Secrecy in nano-weapons development is understandable, because disclosing the performance characteristics of nano-weapons used, and the specific conditions under which they can be used might provide the enemy with a distinct advantage.[130] Given that each state has an inherent right of national self-defence,[131] this conventional wisdom might be compelling to the extent that technological advancement aims to reduce threats to national security that could otherwise cause states to relinquish their sovereign authority to states possessing more technologically advanced weapons. However, secrecy in the context of weapons development and acquisition has also been from time to time a recipe for arms races, underpinning the role of communication during the Cold War to reduce this 'perceptual dilemma' for nuclear disarmament efforts.[132]

Furthermore, rapid advancement of military nanotechnology in recent years, especially in the US and its allies, may well exacerbate the shift in the nature of military combat from equal belligerency to asymmetric warfare, fundamentally undercutting traditional foundations of international humanitarian law.[133] Nanotechnology-enabled forces may have less incentive to comply strictly with the rules of international humanitarian law, as their battlefield dominance will obviate the need to expect reciprocal application of humanitarian rules.[134] The

---

130 Fry, above n 93, 469.

131 *Charter of the United Nations*, art 51 ('UN Charter').

132 See, eg, S Plous, 'The Nuclear Arms Race: Prisoner's Dilemma or Perceptual Dilemma?' (1993) 30(2) *Journal of Peace Research* 163; Brian Betz, 'Response to Strategy and Communication in an Arms Race-Disarmament Dilemma' (1991) 35(4) *Journal of Conflict Resolution* 678.

133 See generally, Michael N Schmitt, 'Asymmetrical Warfare and International Humanitarian Law' (2008) 62(1) *Air Force Law Review* 1; Toni Pfanner, 'Asymmetrical Warfare from the Perspective of Humanitarian Law and Humanitarian Action' (2005) 857 *International Review of the Red Cross* 149.

134 The examples include the treatment of Iraqi detainees by US troops and NATO's aerial bombing in Kosovo. The other side of the argument is that advanced militaries are to be held to a higher standard as a matter of law because they have greater ability to exercise feasible precautions in attack. See, eg, Stuart Walters Belt, 'Missiles over Kosovo: Emergence, Lex Lata, of a Customary Norm Requiring the Use of Precision Munitions in Urban Areas' (2000) 47 *Naval Law Review* 115.

weaker, low-tech side, on the other hand, is likely to seek to compensate for this dramatic disparity of capabilities by resorting to unlawful tactics by, for example, targeting civilians and using civilian shields. This asymmetry in nanotechnology-enabled warfare challenges standard normative and doctrinal paradigms underpinning the international law on armed conflict.[135] As a result, the deterrent effect of the law of armed conflict will be increasingly weakened,[136] effectively posing greater threats to the national security of technologically under-developed states.

The third rationale concerns funding, support, and freedom of nano-weapons research and development to enable scientists to make discoveries, which would not be possible should the field be subject to public oversight. Yet, even if scientific research resulted in an accidental development of harmful property with potential use for military purposes, there is inevitably a deliberative step which must be taken in order to make it deployable as a weapon. It is a form of 'intellectual trickery' to rely upon the difficulty in drawing this line,[137] in arguing that scientific research and development for military purposes should be prioritised and protected from, for example, independent technical inspection or assessment as well as disclosure to such authorities

4.3 Rationales for Specific Regulation of Nano-Weapons

It is thus observed that the rationales for secrecy in weapons development are not strong enough (or at least not as strong as they used to be) in order to justify secrecy for all aspects of technological research and development for military application. It is understandable that some information about a new weapon's capabilities and shortcomings should not be disclosed for national security reasons. Yet, this does not necessarily preclude an independent technical inspection or the disclosure of health and environmental assessments that would provide the basis for greater public scrutiny. Let us now turn to the reasons for specific regulation of nano-weapons.

The first reason relates to the inherent limitations of the traditional rules of international law relating to the legality of military applications of nanotechnology, as examined above. The general humanitarian law principle, for example, prohibiting superfluous injury or unnecessary suffering appears too broad to play a meaningful role in proscribing any particular nano-weapon. The specific arms control treaties, on the other hand, seem too narrow in focus to comprehensively extend to nano-weapons. Such over- and under-inclusiveness is characteristic of treaties regulating specialist activities in a

135 Schmitt, above n 133, 14–38; Dunlap, above n 129, 27–30.

136 Michael N Schmitt, 'War, Technology and the Law of Armed Conflict' in Anthony M Helm (ed), *The Law of War in the 21st Century: Weaponry and the Use of Force*, (US Naval War College International Law Studies vol 82, 2006) 137, 151–154.

137 Decker and Dunlap, above n 128, 825–826.

highly complex and interconnected modern global society.[138] The indeterminacy of rules resulting from those inherent limitations has in fact been central to the proliferation of international regulatory regimes that emerged in late twentieth century.[139] The law of weaponry could benefit from adopting some models of regulatory mechanisms as a strategy to ameliorate the indeterminacy of the existing rules.

The second reason, which is related to the first, is that within the current law of weaponry there is considerable potential for diverse interpretations of a rule. DU, DIME or other more manifest nano-weapons could all well be intrinsically illegal in the light of the general principle against superfluous injury or unnecessary suffering, as well as under more specific rules such as the prohibition of non-detectable fragments. Yet, when it comes to the actual assessment of the legality of a particular weapon, there is always room for military considerations to play a legitimising role. This is particularly so in relation to the development of nano-weapons aimed to enhance military effectiveness and reduce collateral damage to innocent civilians in modern urban warfare.

Third, the application of a new technology inevitably entails scientific uncertainty and there is a need for greater public and policy focus on the 'shadow' effects of weapons. Technological advancement all too often entails adverse effects on the environment or human health that may not immediately be so obvious after its full import into battlefields is experienced.[140] Greater awareness of such 'shadow' effects of nano-weapons, particularly with the application of the precautionary principle to the wartime context,[141] could countenance the balancing process of determining the legality of weapons in the light of the principle prohibiting superfluous injury or unnecessary suffering. It is thus possible to argue that the longer the environmental or health effects last, they are more difficult to justify by military necessity.[142]

---

138 See, Julia Black, *Rules and Regulators* (1997) 6–25; Gunther Teubner, 'Autopoiesis in Law and Society' (1984) 18 *Law and Society Review* 291.

139 See generally, John Braithwaite, 'The New Regulatory State and the Transformation of Criminology' (2000) 40 *British Journal of Criminology* 222, 223–227; Giandomenico Majone, 'The Rise of the Regulatory State in Western Europe' (1994) 17 *West European Politics* 77.

140 See, Laurent R Hourcle, 'Environmental Law of War' (2001) 25 *Vermont Law Review* 653, 689–690.

141 See, eg, Andy Rich, 'The Environment: Adequacy of Protection in Times of War' (2004) 12 *Pennsylvania State Environmental Law Review* 445, 456; Rymn James Parsons, 'The Fight to Save the Planet: U.S. Armed Forces, "Greenkeeping", and Enforcement of the Law Pertaining to Environmental Protection during Armed Conflict' (1998) 10 *Georgetown International Environmental Law Review* 441, 488–489.

142 Zwanenburg, above n 95, 119.

Calling for a greater focus on the 'shadow' effects of nano-weapons and the application of the precautionary principle to their use during armed conflicts would provide necessary leverage against military planners and strategists who are likely to prioritise military concerns. Moreover, once considerable investment is made by government, business, and other institutions in the research and development of weapons, it creates a strong incentive for the initial use of a new nano-weapon and the defence of its legality. Therefore, considerations ought to be given to the 'shadow' effects of nano-weapons in accordance with the precautionary principle at an early stage when nanotechnology is developed or introduced for potential military application.[143]

It could be argued that the precautionary principle could simply be incorporated into the weapons review process as required by Article 36 of the *Additional Protocol I*, without opening up to greater regulatory oversight. However, the precautionary principle necessarily delegates accountability to an independent, external regulatory body, as it shifts the burden of proof regarding harm away from those likely to suffer harm (potential victims of armed conflict) to those desiring to change the status quo (the military introducing a new weapon).[144] Moreover, given the ambiguity and multiplicity of the precautionary principle, states may well justify the use of a nano-weapon, even if it is assessed to potentially pose an irreversibly harmful effect upon the environment or health, on the grounds that there is no more cost-effective or cost equivalent substitute, applying a weak version of the principle.[145] A robust, independent regulatory body would be better equipped to make a balanced decision, weighing tangible military necessity against both short-term and long-term effects of such weapons.

5 New Models for Regulating Nano-Weapons under International Law

5.1 General Considerations

The indeterminacy and diverse interpretations of rules, as well as the obstacles to taking into account the 'shadow' effects of weapons, all account for the 'regulatory failure' in respect of nano-weapons. A specific treaty regulating the research, development, production and use of nano-weapons does not emerge

---

143 See, Paul C Szasz, 'The Existing Legal Framework, Protecting the Environment During International Armed Conflict' in Richard Grunawalt, et al (eds), *Protection of the Environment During Armed Conflict* (US Naval War College International Law Studies vol 69, 1996) 278, 282.

144 See, eg, Malgosia A Fitzmaurice, 'International Protection of the Environment' (2001) 293 *Recueil des Cours* 9, 265–266.

145 For details, see, Wexler, above n 117, 496–504.

without a period of uncertainty during which the intrinsic illegality of a weapon is argued, which may or may not lead to the formation of a specific rule prohibiting its development or use.[146] As a result, international legal developments are unlikely to keep pace with the rapid evolution of military nanotechnology. Yet, alternative regulatory approaches might be taken to nano-weapons development in international or transnational settings.

There are, in fact, a variety of novel models of international regulation that might find useful application to nano-weapons. These range from the traditional 'top-down' command and control regulation to a more horizontal form of self-regulation.[147] The arms control regimes for weapons of mass destruction are generally supported by strong supervisory mechanisms with the aim of deterring, detecting and correcting non-compliance with the law.[148] On the other hand, arms control regimes for conventional weapons carry relatively few institutional obligations, simply encouraging the regular exchange of information, transparency and confidence-building.[149] The obligation to assess the legality of weapons under Article 36 of the *Additional Protocol I* can be seen as a form of self-regulation imposed upon the state parties. Yet, this self-regulatory system has been ineffective in regulating weapons development largely due to the dominant control by a small group of military experts.

5.2 Policy and Technical Issues

In considering fresh international schemes for regulating nano-weapons development, two primary difficulties must be acknowledged. First, given the sensitivity of military information and strategic planning, it is highly unlikely that any suggestions for an international, independent scrutinising mechanism for nano-weapons would be embraced by states.[150] However, within the overall trend of the 'securitisation' of health and environmental issues,[151] more

146 See, Meyrowitz, above n 99, 118.

147 See generally, Robert Baldwin, 'Regulation: After "Command and Control"' in Keith Hawkins (ed), *The Human Face of Law* (1997) 65–84.

148 See generally, Guido den Dekker, *The Law of Armed Control: International Supervision and Enforcement* (2001); Charles F Parker, *Controlling Weapons of Mass Destruction: An Evaluation of International Security Regime Significance* (2001).

149 For a detailed analysis, see, den Dekker, above n 148, 167, 181–182, 206, 210.

150 Indeed, the proposal to establish a permanent international weaponry review committee was voted down in the Diplomatic Conference preceding the adoption of *Additional Protocol I*. See, Sandoz, Swinarski and Zimmerman, above n 84, 421, paras 1463–1465.

151 See, eg, Simon Dalby, *Security and Environmental Change* (2009); David P Fidler, 'From International Sanitary Conventions to Global Health Security: The New International Health Regulations' (2005) 4 *Chinese Journal of International Law* 325.

pressure could be applied upon governments to preventing, and responding to, the development, production, and use of weapons which potentially cast a long 'shadow' with respect to public health and environmental concerns.[152] Once their use becomes publicised, a growing public pressure could prompt governments to agree upon some concessions to an alternative regulatory scheme for nano-weapons.

Second, there is a technical difficulty with supervisory measures to restrict military capabilities based on dual-use technologies, which are difficult to define, restrict, and verify as to whether they are used for peaceful purposes or not.[153] The military application of nanotechnology may well simply be 'incidental' or a 'by-product' of scientific discovery, when it is by no means designed for military purposes. The extent to which states are willing to establish and comply with a supervisory mechanism to regulate dual-use nanotechnology depends on the strength of its security dimension, as opposed to its economic dimension. In other words, the stronger the economic incentive to develop and employ dual-use nanotechnology, the more difficult it would be for states to agree on a strong scheme of regulation and for any supervisory institution to enforce the regulation.[154] In preventing the proliferation threat posed by new technology, as den Dekker suggests, a better answer might be to slow down its spread by informal regimes.[155]

Given that this question involves a delicate balancing process taking into account military necessity and humanitarian considerations, calls may be made for greater community inclusion in the regulation of nano-weapons, for example, in the form of legislative oversight in the course of research and development.[156] However, the public, including NGOs, tend to focus on salient

---

152 See, David P Fidler, 'Governing Catastrophes: Security, Health and Humanitarian Assistance' (2007) 866 *International Review of the Red Cross* 247, 253–254 (in relation to threats from nuclear, biological, and chemical weapons).

153 Erwin Dahinden, 'The Future of Arms Control Law: Towards a New Regulatory Approach and New Regulatory Techniques' (2005) 10 *Journal of Conflict & Security Law* 263, 268.

154 This is one of the reasons why a verification regime is difficult to achieve for the *Biological Weapons Convention*. See, Jack M Beard, 'The Shortcomings of Indeterminacy in Arms Control Regimes: The Case of the Biological Weapons Convention' (2007) 101 *American Journal of International Law* 271, 309–313; Kristen Paris, 'The Expansion of the Biological Weapons Convention: The History and Problems of a Verification Regime' (2002) 24 *Houston Journal of International Law* 509, 541–542.

155 Guido den Dekker, 'The Effectiveness of International Supervision in Arms Control Law' (2004) 9 *Journal of Conflict & Security Law* 315, 328.

156 Decker and Dunlap, above n 128, 818.

and visible risks rather than potential yet more serious ones.[157] Civil society is likely to react only after the actual use of nano-weapons and also to ignore other weapons posing similar risks.[158]

5.3 New Regulatory Models for Nano-Weapons

A variety of novel regulatory approaches can be taken for international or transnational regulation of military application of nanotechnology. First, a more pre-emptive, informal scheme can be implemented, which strengthens the obligation under Article 36 of *Additional Protocol I* by providing clearer guidance and transparency for compliance reviews. A uniform reporting system will allow independent observers such as NGOs to monitor nano-weapons properties and make technical information more accessible to the public for wider debate, which could influence decision-making about appropriate weapons choice, rather than impose a general ban upon their use.[159] Recently, the International Committee of the Red Cross (ICRC) provided guidelines for the substantive and procedural aspects of weapons review and has also facilitated the voluntary exchange of experience on review procedures among states in order to disseminate knowledge and information about how Article 36 is implemented.[160] Such activity could be seen as a step towards the creation of 'interpretive community', without a formal institution of international supervision, which helps clarify norms and principles in a specific context.[161] The success of such a scheme in relation to nano-weapons will be dependent upon whether sufficient political will can be garnered through the growth of state practice following the guidelines for compliance reviews.

Second, an alternative scheme could aim to enhance technocratic accountability with the establishment of a new transnational institution as a regulatory oversight body that could help coordinate policies with respect to military nanotechnology research and development, train reviewers, and propose

157 See, Timur Kuran and Cass R Sunstein, 'Availability Cascades and Risk Regulation' 51 *Stanford Law Review* 683, 685–688.

158 See, Wexler, above n 117, 504–515.

159 Ibid, 515–517.

160 See, Kathleen Lawand, 'Reviewing the Legality of New Weapons, Means and Methods of Warfare' (2006) 864 *International Review of the Red Cross* 925; ICRC, 'A Guide to the Legal Review of New Weapons, Means and Methods of Warfare: Measures to Implement Article 36 of Additional Protocol I of 1977' (2006) 864 *International Review of the Red Cross* 931.

161 See, den Dekker, above n 155, 320.

measures for harmonisation of reviews.[162] Such a transnational institution, with a structured institutional decision-making process involving not only government representatives but also various interest groups and scientists, would enhance public participation by providing a 'voice' for all affected interest groups.[163] For instance, among the initiatives that the ICRC has been taking to date is its appeal in September 2002 to scientists aiming to create a culture of responsibility that is consistent with current developments in scientific ethics and existing law.[164] This scheme of technocratic regulation does not require all states to subscribe or agree to, because some states simply do not have a capacity to conduct research or develop nanotechnology and therefore the balance of capabilities does not play a crucial role for the regulation of nano-weapons development in technologically under-developed countries.[165] A group of willing states or scientific communities in the areas of nanotechnology could self-regulate their activities by adopting a guideline for appropriate methodologies and scientific protocols in conducting research and development.

Third, an independent technical secretariat comprising professional scientific organisations from different countries could be set up to make self-regulation of nano-weapons development enforceable with penalties or sanctions for the failure to follow the guidelines in good faith as well as rewards for producing requested information and test data.[166] However, unlike the regulation of biotechnology for military applications, there is no binding treaty that outlaws the development, production, stockpiling or use of offensive nano-weapons. This might leave scientists and policy-makers without a legal opportunity to encourage the first steps for self-regulation (to avoid the later regulatory 'big stick').[167] Another problem, likely to be significant with nanotechnology, is the difficulty in distinguishing benign applications from potentially malign ones. To avoid such difficulties, the novel adoption of a non-binding declaration on the ethics of military application of nanotechnology by states, similar to the

---

162 Fry, above n 93, 490; Mark Wheelis and Malcolm Dando, 'Neurobiology: A Case Study of the Imminent Militarization of Biology' (2005) 859 *International Review of the Red Cross* 553, 567–568.

163 For a more detailed account of the rationale of transnational institutions, see, Eyal Benvenisti, 'Exit and Voice in the Age of Globalization' (1999) 98 *Michigan Law Review* 168, 202–211.

164 See, Robin Coupland and Kobi-Renée Leins, 'Science and Prohibited Weapons' (2005) 308(5730) *Science* 1841.

165 See, Dahinden, above n 153, 275–276.

166 See, Cary Coglianese, Richard Zeckhauser and Edward Parson, 'Seeking Truth for Power: Information Strategy and Regulatory Policymaking' (2004) 89 *Minnesota Law Review* 277, 305–314.

167 Cf Wheelis and Dando, above n 162, 567.

Universal Declaration on Bioethics and Human Rights,[168] may assist intergovernmental expert panels or peak non-governmental bodies with the development of, and compliance with, guidelines and standards of measurement.

6 Conclusion

The lack of a specific treaty rule of international law governing the acquisition, development or use of nano-weapons, we argue, creates a hiatus where such weapons can be used experimentally and without adequate scrutiny. Although we still have to wait for a full scientific study, there are already warnings regarding the health and environmental impacts of engineered nano-particles used in military contexts.

Because of this uncertain, yet potential risk to human health and the environment, there is an urgent need for regulating nano-weapons under the international law of weaponry. However, to extend the existing international arms regulation to new nano-weapons poses a real challenge for academics, the military, policy-makers and international civil society.

From our analysis two points are clear in this regard. First, despite the normative significance of the international humanitarian law principles concerning weaponry, their practical value in regulating nano-weapons is significantly hampered by indeterminacy, diverse interpretations, and scientific uncertainty that become obvious when the principles are applied to a specific new weapon. Second, the only way to overcome those problems has traditionally been the adoption of a treaty banning specific weapons. However, those treaties are very much the outcome of a process of military evaluation, over which the consideration of strategic military consideration preponderates. Given the military sensitivity of new weapons development and scientific uncertainty that largely remains surrounding the health and environmental effects of nano-particles, it will be extremely difficult to garner political will sufficient to move states towards the adoption of a specific legally binding treaty to ban nano-weapons.

This 'regulatory failure' in respect of the development, production or use of nano-weapons suggests the value of investigating novel regulatory approaches, including those based on the precautionary principle. Yet, the key question as to which new regulatory model would effectively prevent people

---

168 The full text of the *Declaration* is available online at <http://unesdoc.unesco.org/images/0014/001461/146180E.pdf>. See also, Thomas Alured Faunce and Hitoshi Nasu, 'Normative Foundations of Technology Transfer and Transnational Benefit Principles in the UNESCO Universal Declaration on Bioethics and Human Rights' (2009) 34 *Journal of Medicine and Philosophy* 296.

from being exposed to potential health and environmental effects unnecessarily produced by offensive nano-weapons, while facilitating peaceful program of nanotechnology, remains to be answered. One state-centred proposal to achieve this goal is to strengthen the obligation upon states under Article 36 of *Additional Protocol I* by providing clearer guidance and transparency for compliance reviews. Another is to enhance technocratic accountability or self-regulation among scientists involved in the research and development of nanotechnology, guided by a non-binding international declaration on nano-ethics and security. Prompt action by governments is required, as the military use of nanotechnology is rapidly growing.