Autonomous Weapon Systems, Human Dignity and International Law
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Chapter Two

Typology of Autonomous Weapon Systems

I. Introduction

As stated in the Introduction, for the purposes of this dissertation, an 'autonomous weapon system' is defined as a 'weapon system that, once activated, can select and attack targets without further intervention by a human operator.'[1] Depending on how one interprets technical specifications, arguably such weapon systems have been in use for decades. For example, the navies of many nations operate the 'Phalanx Close in Weapons System' on their ships against urgent air warfare threats such as planes and missiles. The U.S. Navy describes Phalanx as 'the only deployed close-in weapon system capable of autonomously performing its own search, detect, evaluation, track, engage and kill assessment functions.'[2] In addition, South Korea and Israel have deployed autonomous weapons systems along their borders whose sensors can detect approaching soldiers or infiltrators and respond with lethal force.[3]

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[1] This dissertation limits its scope to kinetic autonomous weapon systems as opposed to autonomous cyber weapons. Malicious software, i.e. computer code designed to damage or disable other programs, and/or to collect intelligence, is referred to as 'malware.' K Hamlen, 'Stealthy Software: Next Generation Cyber-attacks and Defenses', Proceedings of the 11th IEEE Intelligence and Security Informatics Conference (ISI), p. 109–112, June 2013, <http://www.utdallas.edu/~hamlen/hamlen13isi.pdf>. Cyber weapons are anonymous and invisible and the unique cyberspace domain makes geography and distance (in the physical sense) irrelevant between adversaries. H Harrison-Dinnis, 'Cyber Warriors, Patriotic Hackers and the Laws of War', in D Saxon (ed.), *International Humanitarian Law and the Changing Technology of War* (Leiden: Martinus Nijhoff, 2013), pp. 252 – 256. In addition to state armed forces, 'adversaries' in cyber warfare easily can be individuals, loosely-organized groups of anonymous 'hackers,' as well as other non-state actors who take advantage of weaknesses in 'our collective armour.' Michael Daniel, Special Assistant to the President and White House Coordinator for Cybersecurity, remarks at 'Cybersecurity in a World Without Borders', RSA Conference, 2014, <http://www.rsaconference.com/speakers/michael-daniel>. For comprehensive treatments of the relationship between cyber weapons and international law, see M Roscini, *Cyber Operations and the Use of Force in International Law* (Oxford University Press, 2014) and M. Schmitt (director), *Tallinn Manual on the International Law Applicable to Cyber Warfare* (Cambridge University Press, 2013).

[2] 'Phalanx Close-In Weapons System', About.Com, The United States Navy Fact File, <http://usmilitary.about.com/library/milinfo/navyfacts/blphalanx.htm>.

[3] J Cho, 'Robo-Soldier to Patrol South Korean Border', ABC News, 29 September 2006, <http://abcnews.go.com/Technology/story?id=2504508>; E Cohen, 'Robots on Every Scene', Israel Defence, 2 December 2011, <http://www.israeldefense.com/?CategoryID=411&ArticleID=688>. According to Horowitz and Scharre, at least thirty countries possess similar 'human supervised autonomous defensive systems …. designed for situations where the time of engagement may be too short for human to adequately respond,

The crucial distinction is in the amount of freedom of manoeuvre delegated to the weapon system. For example, 'Wide-Area Loitering Munitions,' such as Israel's 'Harpy,' are missiles designed to patrol large areas of terrain or ocean from the air, detect enemy radar defence installations and destroy them.[4] Thus, the last human decision is a determination to launch the missile rather than a targeting judgment. In 2013, Professor Heyns singled out Harpy as a robotic weapon system 'currently in use' with a degree of autonomy and lethality.[5] Israel Aerospace Industries, the manufacturer of Harpy and its successor, 'Harpon,' asserts that 'there is always a man-in-the-loop in all target acquisition processes' and that the loitering mode of the system does not exist in current systems.[6] Publicly-available promotional material about the Harpy system from Israel Aerospace Industries, however, indicates that such autonomous loitering and targeting technology has existed in weapon systems for several years:

> 'Harpy operates autonomously, detecting, engaging and destroying emitting enemy radar. Harpy is ground launched and navigates autonomously to and in the target area. Harpy loiters for many hours, detecting and attacking emitting targets. .... Multiple Harpies are deployed to autonomously suppress and destroy the enemy radar systems in a wide area.'[7]

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necessitating automation.' 'Meaningful Human Control in Weapon Systems: A Primer', Centre for a New American Security, March 2015, pp. 12-13.

[4] Israel Aerospace Industries describes the Harpy Loitering Weapon as 'a "Fire and Forget" autonomous weapon, launched from a ground vehicle behind the battle zone', <http://www.iai.co.il/2013/16143-16153-en/IAI.aspx>, accessed 30 June 2015; 'IAI's MBT HARPY System', Israel Aerospace Industries, <https://www.youtube.com/watch?v=AyKXUfOubH0>; 'Weapons from Israel', The Maccabean Online, March 2009, <http://www.freeman.org/MOL/pages/march2009/weapons-from-israel.php>. The United States' 'Harpoon' Anti-Ship Missile', system has similar capabilities although more recent versions permit human control over the final attack on a target. 'Harpoon', WeaponSystems.net, <http://weaponsystems.net/weapon.php?weapon=HH10+-+Harpoon>.

[5] 'Report of the Special Rapporteur on Extrajudicial, Summary or Arbitrary Executions, Christoph Heyns', A/HRC23/47, 9 April 2013, para. 45.

[6] Electronic mail messages from Noga Nadler Mozes, Corporate Communications, Israel Aerospace Industries, 29 June 2015.

[7] 'IAI's MBT HARPY System', Israel Aerospace Industries, <https://www.youtube.com/watch?v=AyKXUfOubH0>. Also see 'HARPY', Israel Aerospace Industries, <http://www.iai.co.il/2013/36694-16153-en/IAI.aspx> accessed 8 July 2015; 'Successful Flight Demonstrations for HAROP Loitering Munitions', Israel Aerospace Industries, <http://www.iai.co.il/2013/32981-46464-en/MediaRoom_News.aspx> accessed 8 July 2015.

States that field fully autonomous weapons will experience an increase in their sense of military confidence and superiority over their enemies. Conversely, new autonomous weapons technology looms as a threat to all who lack it.[8] Furthermore, after conflict, there is a tendency for those who lose to imitate the victors.'[9] These dynamics will drive a continuing race to develop autonomous weapon systems because no one wants to be left behind in the race for better military technology:

> In the end, we want to prevent our enemies from leaping ahead of us. There is a risk associated with investing a lot of money and a risk to not doing anything. You have allies and potential threats that are moving forward with robotics. We have to acknowledge conditions on the battlefield in 2025 will include robotics whether we invest in it or not.[10]

At the same time, weapons technology is outpacing law.[11] Moreover, like the fog of war, there is a 'fog of technology'[12] that also can cloud how human beings apply the law. In spite of the trend towards more autonomous unmanned weapon systems, the current legal literature contains limited discussion of the technical attributes and capacities of lethal autonomous weapon systems.[13] Without this knowledge, debates about whether autonomous weapon systems can be used in conformity with international law occur in a partial vacuum

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[8] See M McLuhan, *Understanding Media: The Extensions of Man* (Cambridge, Massachusetts: MIT Press, 1994), p. 344.

[9] J Weller, *Wellington in India* (London: Longman/Camelot Press, 1972), p. 296.

[10] Lt. Colonel Matt Dooley, Chief, Lethality Branch, Army Capabilities Integration Centre (ARCIC), in J Gould, 'U.S. Army Readying Unmanned Systems Doctrine', Defense News, 8 April 2015, <http://www.defensenews.com/story/defense/land/army/2015/04/08/us-army-readying-unmanned-systems-doctrine/25473749/>. The research and manufacture of autonomous weapon technologies is a twenty billion USD industry in forty different countries. A Kasperson, Head of International Security at the World Economic Forum, Remarks to 'Private Sector Perspectives on the Development of Lethal Autonomous Systems,' Geneva, 12 April 2016.

[11] L Antebi, 'Changing Trends in Unmanned Aerial Vehicles: New Challenges for States, Armies and Security Industries', 6 *Military and Strategic Affairs* (August 2014), 24. To put the growing demand for more unmanned military technology in perspective, today, more than seventy nations operate unmanned aerial systems, including platforms with autonomous functions. Unmanned aerial systems are manufactured on every continent with the exception of Antarctica and, as of 2012, nearly fifty countries were producing almost 900 different types of unmanned aerial systems. Israel alone has exported unmanned aerial systems to dozens of nations. Non-state actors, such as Hizbollah, operate these systems for combat as well as intelligence purposes. *Ibid*, 23 - 28.

[12] D Hollis, 'The Fog of Technology and International Law', Opinio Juris Blog, 15 April 2015.

[13] For a description of several kinds of contemporary lethal autonomous weapons, see J Beard, 'Autonomous Weapons and Human Responsibilities', 45 *Georgetown Journal of International Law*, (2014), 617, 628 – 634.

and it is impossible to ask the right questions and construct appropriate standards.[14] Thus, this chapter describes several basic concepts and elements of autonomous weapon systems as well as important technical characteristics and capacities of specific systems.

This chapter demonstrates that the focus of the design and development of certain autonomous weapons (and particular semi-autonomous weapons) is not directed to the creation of opportunities for human reasoning or the protection of human dignity. Nor, as discussed further below, does fulfillment of a 'meaningful human control' or other problematic, semantic standard appear to be an important prerequisite for the use of these weapons. Instead, the focus – and quite logically from a military perspective - is on the creation of faster, more autonomous and more overwhelming weapons.[15] This trend helps to illustrate why it is unrealistic to believe that human beings will have the ability to apply international law to kinetic and cyber autonomous weapons of the future.

We have already seen that the function of law is to allow humans to adjust their rights between themselves, and between individuals and states. As the technology of autonomous weapon system advances and increases in speed, however, humans will be unable to apply the relevant law, much less adjust their rights and duties with respect to the use of these weapons. Indeed, with the introduction of 'swarm' technology, described below, we have reached a 'tipping point' with autonomous weapon technology. The use of larger and faster swarms of autonomous weapon platforms will make it impossible or nearly impossible to maintain human reasoning as part of the 'system.' The shrinking spaces for human reasoning in the

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[14] Even where definitive answers are elusive, it is still worthwhile to improve the questions. H Kelsen, 'What Is Justice?' in H Kelsen, *What Is Justice: Justice, Law and Politics in the Mirror of Science: Collected Essays*, (Berkeley, University of California, 1957), p. 1.

[15] 'In modern asymmetrical warfare, the number of [military] targets is increasing and the timeframe for engaging and killing each target is decreasing.' 'Aviation Defence Equipment Technology: Rafael Spice 250', AirRecognition.com, 14 January 2015, <http://www.airrecognition.com/index.php/focus-analysis-photo-report-aviation-defence-industry/aviation-defence-industry-technology/1424-rafaels-spice-250-precision-guided-glide-bomb-undergoing-adaptation-test-on-iafs-fighters.html>.

operation of these weapons means that at best, humans will be 'programmers of the law.' That is a poor substitute for the foundational role of law and reasoning in human life. Limitations on autonomous functions, therefore, are necessary to maintain human machine teamwork and interdependence, and thus**,** the role of human reasoning in warfare.

In order to ensure the continued role of humans, care should be taken at the design phase of autonomous weapon systems to ensure that they operate as partners of humans rather than substitutes. Weapons designers and developers, therefore, must ensure that the design of autonomous weapons be based on an interdependent, "co-active design" in order to reduce the speed of autonomous weapon systems to a velocity where humans can: i) apply reasoning and law (in particular international humanitarian law and international human rights law) during their operation, and (ii) ensure that human reasoning and judgment is available for cognitive functions better suited for human than machines.

II. Autonomous Weapon Technologies

A. Automatic v. Autonomous

Preliminarily, it is important to distinguish between 'automatic' and 'autonomous' weapon systems. '"Automatic" systems are fully preprogrammed and act repeatedly and independently of external influence or control.'[16] In a sense, even human soldiers exhibit automatic qualities because they are trained to act instinctively, without thinking, during basic combat functions such as shooting, moving and communicating.[17] Soldiers in the field who hesitate often put themselves and those around them in great danger.[18]

[16] 'Unmanned Systems Integrated Roadmap FY2011 – 2036', U.S. Department of Defence, p. 43, <http://www.acq.osd.mil/sts/docs/Unmanned%20Systems%20Integrated%20Roadmap%20FY2011-2036.pdf>.

[17] Modern militaries want soldiers to operate in combat as quickly and effectively as possible. Thus, 'you want soldiers to be automated in terms of the technical aspects of fighting.' However, when situations – such as changing conditions in the battlespace – arise that require thinking and reasoning, the soldier must apply her

By contrast, 'autonomous' weapon systems are self-directed as they choose their behaviour to achieve a human-determined goal. Autonomous weapon systems, therefore, are 'capable of a higher level of performance compared to the performance of a system operating in a predetermined manner.'[19]

B. Artificial Intelligence and Computer Software

Autonomous weapon systems contain multiple components (for guidance, communication, targeting, etc.) that are directed and coordinated by computer programs (or 'software' or 'code'). Essentially, software comprises a series of instructions, expressed in mathematical terms, that computers follow to achieve certain tasks. These mathematical statements are known as 'algorithms' and they function at 'blinding speed.'[20]

The term-of-art for sophisticated computer software that guides autonomous systems is 'artificial intelligence.'[21] Hannah Arendt perceived that 'the main characteristic of mental

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contextual knowledge of the environment in which she operates. Author interview with Allen Borelli, former U.S. Army Intelligence Specialist, The Hague, 15 July 2015.

[18] M Waxman, 'Detention As Targeting: Standards of Certainty and Detention of Suspected Terrorists', 108 *Columbia Law Review* (2008), 1365, 1409.

[19] *Ibid.* The 'Science of Autonomy' combines related fields such as biology/animal behaviour, computer science, economics, management theory, cognitive science, psychology and neuroscience. Long Range Broad Agency Announcement (BAA) for Navy and Marine Corps Science and Technology, U.S. Office of Naval Research, BAA Announcement No. ONRBAA15-001, p. 17, <http://www.onr.navy.mil/~/media/Files/Funding-Announcements/BAA/2015/15-001-LR.ashx>. Expertise in these and additional disciplines is necessary to overcome difficult challenges in autonomous weapon systems such as: 1) 'Autonomous learning, reasoning, and decision-making in unstructured, dynamic, and uncertain environments; 2) Human interaction/collaboration including understanding intent and actions of human team members, adversaries, and bystanders; and 3) Organic perception/understanding to support decision-making, reasoning, and actions in a complex, dynamic world. *Ibid*, 18.

[20] B Gates, EdX Course CS50x3 (Computer Science 50), Harvard College, Week 1 2015. Fiber optic cables can transfer internet messages at close to the speed of light. In reality, however, internet speed often is slower because many fiber optic cables are made from cheaper materials that transmit code at slower speeds. Electronic mail message from Associate Professor Kevin Hamlen, University of Texas, Dallas, 28 May 2015.

[21] For example, the commonly-used 'Google' internet search engine is a form of artificial intelligence. L Steels, 'Ten Big Ideas of Artificial Intelligence', remarks to 25th Benelux Conference on Artificial Intelligence, Delft Technical University, 8 November 2013. Although algorithm-based artificial intelligence is the most common form in use today, and will be the standard adopted by this dissertation, it is not the only design. For example, 'Statistical Machine Learning,' whereby autonomous robots learn to modify their behaviour by trial-and-error, is a significant area of research. *Ibid.* Author Interview with Gianfranco Visentin, Head, Automation and Robotics Department, European Space Agency, Noordwijk, 4 November 2013. P Margulies, 'Making Autonomous Weapons Accountable: Command Responsibility for Computer-Guided Lethal Force in Armed Conflicts.'

activities is their invisibility.'[22] So a slight paradox underlies the term 'artificial intelligence' as all intelligence – including human intelligence – has an artificial, unreal quality because the processes of thinking and reasoning are intangible and invisible. Artificial intelligence, however, in the form of computer code, can be planned and programmed, checked after events, re-designed and re-programmed.[23] In that sense, 'artificial' intelligence is more tangible than human reasoning.

Thus, in addition to the important pieces of mechanical equipment of an autonomous weapon system, the different software/artificial intelligence systems also are critical components of the weapons platform. However, because software usually is a detailed expression of mathematical statements, it does not fail in the same sense as a mechanical system.[24] Software does not 'break;' instead it fails in a conceptual sense. Moreover, besides failures caused by mistakes in the computer code, software also can function unpredictably due to design errors which lead to poor interaction between different systems.[25]

C. Autonomy Is a Dynamic State

Contemporary writers often frame debates about human supervision, if any, of autonomous weapon systems in the deceptively simply phraseology of 'semi-autonomous weapon systems' vs. 'fully autonomous weapon systems' vs. 'man-in-the-loop' systems vs. 'man-on-the-loop' systems.

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[22] *The Life of the Mind* (New York: Harcourt, 1978), p. 71.

[23] E Lubofsky, 'A Smarter Undersea Robot: Engineers Seek to Correct a Curious Deficiency', Oceanus, 16 January 2015, <http://www.whoi.edu/oceanus/feature/a-smarter-undersea-robot>.

[24] J Lyons, ARIANE 5, Flight 501 Failure, Report by the Inquiry Board, 19 July 1996, <https://www.ima.umn.edu/~arnold/disasters/ariane5rep.html>.

[25] *Ibid*. 'Spy Plane Causes Air Traffic Chaos', BBC NEWS, 6 May 2014, <http://www.bbc.com/news/technology-27292440>. Given the potential for catastrophic results should computer programmes in autonomous weapon systems be inadequate, designers and developers should assume that the software is faulty until the most rigorous testing methods prove otherwise. Lyons, Flight 501 Failure, Report by the Inquiry Board.

The United States military uses a category called "semi-autonomous' weapon systems: a 'weapon system that, once activated, is intended to only engage individual targets or specific target groups that have been selected by a human operator.'[26] Modern fighter planes, for example, often operate essentially as 'semi-autonomous' weapons systems. During aerial missions where targets have been pre-selected and their coordinates pre-programmed into avionic software, fighter pilots approaching their targets verify that their weapons contain the right coordinates and that the weapons appear to be functioning correctly, and then simply drop their bombs.[27] Similarly, cruise missiles, after launch, fly for great distances and hit targets that have been identified, selected and approved by a human chain-of-command.[28]

Progressively, the categorization of 'semi-autonomous' v. 'autonomous' is becoming a distinction without a difference as the line between the two becomes more difficult to discern.[29] The reality of combat often requires automatic, instinctive human responses.[30]

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[26] A Carter, 'Autonomy in Weapons Systems', Department of Defence Directive, United States of America, Number 3000.09, Part II, 'Definitions', 21 November 2012, pp. 13.

[27] The burden to ensure that the pilot is bombing the correct target, in accordance with international humanitarian law and the rules of engagement, rests on the pilot's chain of command and the officer who approved the mission. Electronic mail message, General B.A. Fabio Giunchi, Commander of Air Cooperation School, Guidonia Airport, Italian Air Force, 16 February 2015. General Guinchi is a former fighter pilot and participant in the development of the F-35 Lightning II, the next-generation stealth, multirole fighter jet undergoing testing and development by the NATO powers.

[28] *Ibid*.

[29] Author interview with Colonel Denny Traas, MSc, Chief Air Force Branch, Plans Directorate, Defence Staff, Netherlands Ministry of Defence, The Hague, 20 February 2015. To create more sophisticated and complex ('semi-autonomous') weapon systems, the U.S. Government has begun a programme called 'SoSITE,' which stands for 'System of Systems Integration Technology and Experimentation.' SoSITE will link together a network of manned and numerous unmanned aerial vehicles (i.e. a 'swarm') 'to enhance mission effectiveness.' The unmanned systems would enter enemy territory with weapons, electronic warfare systems, etc., while the manned platforms would 'control' the unmanned systems using information fused by the technology. The pilot of the manned aircraft will 'command' the swarm of unmanned vehicles but he 'is relieved of control burdens through the use of advanced distributive battle management aids.' Prior to the pilot's decision to engage a target, 'only a limited amount of information' will be transmitted from the unmanned systems to the pilot.' Thus, 'the planning of the engagement, selection and programming of weapons and generation of a targeted solution again [will be] conducted with minimal pilot burden ….' 'New Concept for Air Warfare', DARPA Advancing System-of-Systems Open Architectures for Airborne Assets', AUVSI News, 31 March 2015, <http://www.auvsi.org/blogs/auvsi-news/2015/03/31/darpasos>. In reality, it is difficult to distinguish this 'semi-autonomous' weapon system from a fully autonomous system.

[30] F de Mulinen, Handbook on the Law of War for Armed Forces, International Committee of the Red Cross, Geneva, 1987, rule 278 ('Combat requirements'). For this reason, training in international humanitarian law must also form part of the basic training of soldiers. *Ibid.*

For example, at present, flying the airplane is now a secondary or tertiary task of fighter pilots.[31] The onboard digital flight computer controls steering and the plane's stability. Similarly, a digital control system adjusts the power level of the engine within set limits, based on the pilot's input. This technology reduces the pilot's workload tremendously and he/she can focus on other tasks, such as engaging with targets. Nevertheless, the pilot of contemporary jets such as the F-16 must 'fuse' (i.e. interpret) different information provided by the aircraft's sensors and electronics that indicate whether an approaching object is an enemy fighter or a 'friendly' plane. In the future, the new, more technologically advanced F-35 fighter jet will fuse the different data and then present the best information to the pilot, thereby removing this 'judgment call' from the pilot's responsibility.[32] 'Whether it's correct or not, I don't know. At least I don't have to spend time assessing information from multiple sources and worry about it.'[33] In such situations, attempts to classify the F-35 as a semi-autonomous or autonomous weapon system are artificial as the pilot's real participation in targeting decisions can vary significantly.[34]

Similarly, the phrase 'man-in-the-loop' refers to a design whereby the weapon system is supervised by human beings and has no independent decision-making ability.[35] 'Man-on-the-loop' refers to weapon systems with sufficient autonomy to operate and make decisions independently, but which also allow for humans to monitor their behaviour and either confirm or veto the machine's decisions; in other words, exercise human judgement over the

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[31] Author interview with Colonel Denny Traas.
[32] 'Much of the F-35's electronic warfare and intelligence, reconnaissance and surveillance (ISR) capabilities are made possible by a core processor that can perform more than one trillion operations per second.' Lockheed Martin, 'Multi-mission Capability for Emerging Global Threats', F-35 Lightning II, <https://www.f35.com/about/capabilities>.
[33] Author interview with Colonel Denny Traas. See for example, description of the M426S E-Scan IFF Interrogator, produced by SELEX ES, <http://www.selex-es.com/-/m426s>.
[34] Modern fighter pilots are 'automated' to rely and react to the information provided to his instruments; 'that's how he is trained.' Author interview with Allen Borelli.
[35] D Akerson, 'The Illegality of Offensive Lethal Autonomy', in D Saxon (ed.), International Humanitarian Law and the Changing Technology of War, p. 71.

behaviour of the weapons platform.[36] Although the F-35, in a technical sense, can be called a 'man-in-the-loop' weapon system, the human-machine interface, particularly at supersonic speeds when the pilot is so dependent on 'fused' information from his avionic suite, suggests a more autonomous system.

The difficulty with such labels and categories is that they reveal little about the challenges faced by persons and/or machines in understanding their environment, particularly during the stress of armed conflict and law enforcement activities.[37] In 'man-in-the-loop' systems, such as remote-controlled 'drones,' one of these challenges is simple boredom while, for example, intelligent and highly trained personnel must watch a house for many hours to see if an individual exits. The tedium of such tasks can result in complacency, leading to missed tactical opportunities and/or 'unintended engagements' that produce civilian casualties.[38] Furthermore, so-called "man-on-the-loop" systems must function in highly fluid and complex environments where the need for human judgement constantly shifts and can overwhelm the 'operator.'[39] It is important, therefore, to recognize that 'autonomy' should

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[36] *Ibid*, pp. 71 – 72. Akerson also describes a system of "variable autonomy" where autonomous weapon systems could switch from 'man-on-the-loop' mode to "man-in-the-loop" mode." *Ibid.* Markus Wagner also describes three categories of autonomy: 'remotely-controlled systems,' "automated systems" and 'autonomous weapons systems.' 'Autonomy in the Battlespace: Independently Operating Weapon Systems and the Law of Armed Conflict' in D Saxon (ed.), International Humanitarian Law and the Changing Technology of War, pp. 103 - 105.

[37] 'To understand the world is never a matter of simply recording our immediate perceptions. Understanding inescapably involves reasoning. We have to 'read' what we feel and seem to see, and ask what these perceptions indicate and how we may take them into account without being overwhelmed by them.' A Sen, *The Idea of Justice* (London: Penguin, 2010), pp. viii. Indeed, traditionally, in battle, no one knows 'much of anything' except for what occurs in his own immediate environs. Thucydides, *The History of the Peloponnesian War* (431 BC), Richard Crawley (trans.), Chapter XXII, <https://www.gutenberg.org/files/7142/7142-h/7142-h.htm>.

[38] M Cummings et. al., 'Boredom and Distraction in Multiple Unmanned Vehicle Supervisory Control,' 25 *Interacting with Computers* (2013), 34–37.

[39] Increased autonomy empowers a single operator to monitor multiple robots while performing other tasks requiring coordination and complex decision-making. However, the cognitive capacity necessary to monitor multiple weapons platforms can exceed that of a single human operator, even with higher levels of automation and autonomy. F Gao et. al., 'Teamwork in Controlling Multiple Robots,' Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction (2012), p. 81-88, <http://web.mit.edu/aeroastro/labs/halab/papers/hri167-gao.pdf>. Cf. 'Vehicle Management', in VCS-4586 Capabilities Guide, Lockheed Martin, p. 4, <http://www.lockheedmartin.com/content/dam/lockheed/data/ms2/documents/cdl-systems/VCS-4586%20CAPABILITIES%20GUIDE-August2013.pdf>.

change as conditions in the battlespace evolve. Different kinds and different amounts of human reasoning and judgement are necessary depending on the situations of the autonomous weapon systems and their human operators.[40]

Decades ago, T.B. Sheridan developed a list of at least ten different levels of machine/computer autonomy based on an interface between a single human being and a single computer.[41] Today, advances in technology permit additional and much more complex variations of autonomy. For example, a single human operator may monitor several autonomous weapon systems simultaneously.[42] A single autonomous weapon system, however, may contain multiple computer sub-systems, each with its own degree of autonomy. For example, a navigation sub-system may direct the autonomous weapon to change location due to bad weather, while the weapon sub-system simultaneously decides to launch an attack.[43]

Furthermore, models of a single autonomous weapon system actually represent a simplified version of modern warfare. Large military operations often are 'a system of systems' with the autonomous weapon platform forming only one portion of the overall system.[44] Absent from the single autonomous weapon system scenario, for example, are

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[40] At the European Space Agency, for example, robotics scientists apply a gradient containing four separate levels of autonomy. The highest level of autonomy (known as "E4") could be further sub-divided into additional degrees. Author Interview with Gianfranco Visentin.

[41] 1. The computer offers no assistance to its human superviser(s); 2. The computer offers a complete set of alternatives to its human superviser(s); 3. The computer narrows the selection to a restricted set of options and sends the reduced list to the human superviser(s); 4. The computer sends a single option for action to its human superviser(s); and 5. The computer executes that option if the human superviser(s) approves; or 6. The computer allows the human superviser(s) to veto the action before automatic execution; or 7. The computer informs the human superviser(s) after execution; or 8. The computer informs the human superviser(s) after execution if he/she asks; or 9. The computer informs the human superviser(s) after execution if it decides to; or 10. The computer decides everything without communication to the human superviser(s). T B Sheridan, et al. 'Adapting Automation to Man, Culture and Society', 19 *Automatica*, 6 (1983), 605, 611.

[42] *Joint Doctrine Note 2/11*, para. 506.

[43] Author Interview with Gianfranco Visentin.

[44] *Joint Doctrine Note 2/11*, paras. 104 and 513. Moreover, systems and the institutions that create and operate them 'interact to form more embracing systems.' T Hughes, 'Convergent Themes in the History of Science, Medicine and Technology, 22 *Technology and Culture* (July 1981), 550, 555.

manned weapon systems,[45] satellites that are crucial for maintaining communications,[46] sensors, radars and additional forms of technology such as (autonomous) cyber weapons. Moreover the armed forces from different states, may also integrate their systems so as to carry out joint operations.[47] Other factors will affect the use of autonomous weapons at different moments, such as the intent, orders and influences expressed by commanders at different levels.[48]

These scenarios will only become more complex with the ongoing development of 'swarm' technologies that permit large numbers of robotic weapon systems to operate cooperatively and communicate rapidly amongst themselves.[49] Swarm technologies developed from the combined efforts of engineers and social scientists to create a relatively simple algorithm that mimics the behavior of animals in nature, such as flocks of birds or schools of fish.[50] Over time, and importantly for later work on swarms of autonomous

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45 Modern manned weapons platforms also represent 'systems of systems.' For example, the last generation U.S. Navy fighter-bomber, the F-18, contains eleven different weapon systems to control different kinds of rockets, missiles, bombs and guns. Aircraft Weapon Systems, pp. 15-19 – 15-20, <http://www.globalsecurity.org/military/library/policy/navy/nrtc/14313_ch15.pdf>.

46 For example, an autonomous weapon system may detect and report about its own position and condition, as well as moving objects such as unknown vehicles, non-combatants, allied and/or cooperating autonomous weapons systems, identifiable targets and threats. It might also detect and report about stationary objects such as targets and topographic obstacles. R Bamberger Jr. et. al, 'Flight Demonstrations of Unmanned Aerial Vehicle Swarming Concepts', 27 *Johns Hopkins APL Technical Digest*, 1 (2006), 41, 49, <http://www.jhuapl.edu/techdigest/TD/td2701/Bamberger.pdf>.

47 General J Shapland, lecture to Conference on *Air Defence in the Modern Era*, Institute for National Security Studies, 18 March 2014, <http://www.inss.org.il/index.aspx?id=4479&categoryid=59>.

48 For example, in a Tactical Directive issued in 2010 for members of the International Security and Assistance Forces ('ISAF') in Afghanistan, General David Petraeus reminded his subordinates that '[s]trategic and operational commanders cannot anticipate every engagement. We have no desire to undermine the judgment of tactical commanders. However, that judgment should always be guided by my intent.' 'General Petraeus Issues Updated Tactical Directive: Emphasizes 'Disciplined Use of Force'', ISAF News List, 2010-08-CA-004, 4 August 2010 (emphasis in original), <http://www.isaf.nato.int/article/isaf-releases/general-petraeus-issues-updated-tactical-directive-emphasizes-disciplined-use-of-force.html>.

49 D Werner, 'Drone Swarm: Networks of Small UAVs Offer Big Capabilities', Defence News, 12 June 2013, <http://www.defensenews.com/article/20130612/C4ISR/306120029/>. Israel's HARPY System can operate as a swarm of loitering autonomous missiles. 'IAI's MBT HARPY System', Israel Aerospace Industries, <https://www.youtube.com/watch?v=AyKXUfOubH0> accessed 30 June 2015.

50 J Kennedy & R. Eberhardt, 'Particle Swarm Optimization', Neural Networks, Proceedings, IEEE International Conference, 1995, 1942-1948, <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.248.4138&rep=rep1&type=pdf>.

weapons, the developers modified and adjusted their algorithm to model this kind of social behavior, 'which is multidimensional and collision-free.'[51]

The ability to cooperate in the midst of uncertainty will be crucial to the success of any swarm.[52] Consequently, the design of contemporary, multi-algorithm swarm systems requires consideration of many factors such as ease of use, workload of the human operator, information flow between individual robots (including random communication interruptions), and between individual robots and the operator, speed of individual robots as well as speed of the swarm, whether individual robots will perform single tasks or multiple tasks (and how these tasks will be updated), and software and hardware maintenance.[53] Furthermore, when deciding whether to perform a current task, the artificial intelligence of individual vehicles in a swarm must consider 'what future tasks are possible in order to maximize the expected performance of the entire team.'[54] Swarm technology can be adapted for all weapons platforms in all battlespace domains[55] and logically, larger and faster swarms of robots are more difficult for humans to monitor and control.[56] To add to the complexity, in armed conflict scenarios, much of this autonomous behavior must occur in the face of opposition from enemy forces.

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[51] *Ibid*, 1945. There are five basic principles of swarm intelligence: 1) proximity: the population should be able to carry out simple space and time computations; 2) quality: the population should be able to respond to quality factors in the environment; 3) diverse response: the population should not commit its activities along excessively narrow channels; 4) stability: the population should not change its mode of behaviour every time the environment changes; 5) adaptability: nevertheless, the population must be able to change its behaviour when necessary. *Ibid*, 1946 – 1947.

[52] *Ibid*, 262.

[53] J McLurkin, 'Speaking Swarmish: Human-Robot Interface Design for Large Swarms of Autonomous Mobile Robots', Association for the Advancement of Artificial Intelligence (2006); E. Raboin, et. al, 'Model-Predictive Asset Guarding by Team of Autonomous Surface Vehicles in Environment with Civilian Boats', 38 *Autonomous Robot* (2015), pp. 261-263. Most of these factors also are relevant to the design and function of single autonomous weapon systems.

[54] *Ibid*, 262.

[55] In the future, operations of the Israeli Defence Forces will include swarms of autonomous land, air and sea weapon systems, including networks of miniature and nano-technology platforms. Lt. General B Gantz, 'The IDF in 2025', Address to The Begin-Sadat Centre for Strategic Studies, 9 October 2013, <http://besacenter.org/new-at-the-besa-center/idf-chief-staff-benny-gantz-speaks-besa-center/>.

[56] A Kolling, 'Towards Human Control of Robot Swarms', *Human-Robot Interaction* (2012), 89, 95 – 96.

One might argue that similar military scenarios, albeit involving human commanders and units of human soldiers, existed throughout history. For example, during the Second World War, commanders in the United Kingdom, the U.S.A., the Soviet Union, Germany and Japan monitored and supervised military units spread over several continents and oceans (including submarines and air craft).[57] A distinguishing characteristic of current and future autonomous weapon systems, however, in addition to their independence, is the speed with which these machines communicate information and execute decisions.[58] This quality will generate opportunities for significant military advantages. It will also, however, further limit capacities for human command and control, i.e. the exercise of human reasoning and judgment.[59]

Schmitt and Thurnher argue that 'humans are never really 'out of the loop' because 'humans will decide when and where to deploy the [autonomous weapon] system and what parameters to embed within it.'[60] However, when autonomous weapons react to events and use force (as they already do in certain cases) at speeds that effectively prohibit human influence or intervention, soldiers, operators and commanders are, effectively, 'out of the loop.'[61]

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[57] B H Liddell Hart, *History of the Second World War* (New York: G.P. Putnam's Sons, 1970), pp. 99, 229, 235, 257, 259, 264, 269, 276, 329, 349, 438 and 684.

[58] D Werner, *Drone Swarm*; M Zenne, 'Death from a Swarm of Tiny Drones', Daily Mail, 20 February 2013, <http://www.dailymail.co.uk/news/article-2281403/U-S-Air-Force-developing-terrifying-swarms-tiny-unmanned-drones-hover-crawl-kill-targets.html>; P Fiddian 'UAV Swarm Technology Trial Success', Armed Forces International News, 7 August 2012, <http://www.armedforces-int.com/news/uav-swarm-technology-trial-success.html>.

[59] U.K. Doctrine on unmanned aircraft systems notes that 'practical methods to control swarming systems have yet to be fully developed and demonstrated' and refers to commentary 'that suggests that the increasing speed, confusion and information overload of modern war may make human response inadequate….' Joint Doctrine Note 2/11, paras. 316 and 520.

[60] M Schmitt and J Thurnher, 'Autonomous Weapon Systems and LOAC,' 4 *Harvard National Security Journal* (2013), 231, 280.

[61] Colonel Shane Riza, a U.S. Air Force fighter pilot, explains that presently military "communication occurs at the speed of light" and recognizes that autonomous weapons systems permit 'the speed of future decision cycles outpacing the human mind.' M Shane Riza, *Killing Without Heart: Limits on Robotic Warfare in an Age of Persistent Conflict* (Washington, D.C.: Potomac Books, 2013), p. 41.

The borders between automation and autonomy, however, need not be static. To improve the effectiveness of human-machine interactions, new engineering designs such as 'adjustable autonomy' and 'adaptive automation' permit the roles of humans and computers to change within dynamic environments.[62] For example, the algorithms in 'Automated Planners' make adjustments – without human intervention – to the tasks of autonomous vehicles at the tactical level while human operators periodically update algorithms that guide the autonomous vehicles at the strategic level.[63] Due to the speed of communications between individual vehicles, the tactical adjustments occur at a faster rate than updates from the human operator.[64] This design could assist operators of swarms of autonomous weaopon to moderate their workload and thereby avoid mistakes.[65]

D. Examples of Ground-Based Autonomous Weapon Systems

In addition to the Korean and Israeli ground-based lethal autonomous weapons mentioned above, the Russian military is developing an autonomous version of the Taifun-M, a robot capable of guarding strategic missile sites and detecting and destroying stationary or moving targets.[66] Furthermore, the U.S. Department of Defence, in collaboration with Carnegie Mellon University, has developed an autonomous ground-based vehicle called 'The Crusher.' The vehicle weighs more than 6,000 kilograms and can navigate independently from point to point for specific missions, including the use of force.[67] Currently, however,

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[62] A Clare, et. al. 'Assessing Operator Strategies for Real-time Replanning of Multiple Unmanned Vehicles', 6 *Intelligent Decision Technologies* (2012), 221, 222.
[63] *Ibid*, 222 – 223.
[64] *Ibid*, 222.
[65] *Ibid*, 230.
[66] Defence and Security News – Russia, 23 April 2014, <http://www.armyrecognition.com/april_2014_global_defense_security_news_uk/russian_army_to_use_unmanned_ground_robot_taifun-m_to_protect_yars_and_topol-m_missile_sites_2304143.html>.
[67] 'Robotic Warriors: The Crusher', 22 August 2013, <http://www.military.com/video/logistics-and-supplies/military-equipment/robotic-warriors-the-crusher/2623237187001/>.

consistent with Department of Defence Policy Directive 3000.09, the U.S. is not developing robots with autonomous capability to engage humans.[68]

The Israeli Defence Forces deploy the Guardium Unmanned Ground Vehicle. Designed for reconnaissance and leading troop movements, this weapon system possesses remote-controlled weapons as well as the capability for 'autonomous decision making.'[69] Israel has also developed 'Iron Fist,' a defensive autonomous weapon system mounted on tanks, armoured personnel carriers, etc. to protect them from rocket, grenade or missile attacks. The Iron Fist's sensors detect an approaching munition and launches a counter-shell that destroys it in mid-air.[70]

E. Examples of Air-Based Autonomous Weapon Systems

The United States Navy has developed LOCUST, a system of swarming autonomous aerial vehicles that can overwhelm an enemy. The relatively inexpensive individual weapons share information and work collaboratively in order to find and attack targets. Moreover, they will force adversaries to concentrate on responding to the swarm.[71] U.S. Naval officials state that 'there will always be a human monitoring the mission, able to step in and take control as desired.'[72]

The 'Switchblade' is a portable flying weapon system currently used in combat by the U.S. Army in Afghanistan. A soldier can carry in the system in her backpack and launch the miniature missile against enemy targets up to ten kilometres away. The missile can 'loiter'

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[68] D Vergun, 'Lethality Expert, TRADOC to Publish Helpful Robotics Doctrine', WWW.ARMY.MIL, 9 April 2015, <http://www.army.mil/article/146129/Lethality_expert__TRADOC_to_publish_helpful_robotics_doctrine/>.
[69] 'Guardium Mark2 UGV: Field Proven UGV with Enhanced Combat Capabilities', GNIUS Unmanned Ground Systems, <http://g-nius.co.il/pdf/brochures/GuardiumLS.pdf>.
[70] 'Future Weapons Israel: Iron Fist APS', Discovery, <https://www.youtube.com/watch?v=fI_cbAdCZCw>.
[71] The LOCUST swarm can be launched from ground-based vehicles, ships and planes. D Smalley, 'LOCUST: Autonomous Swarming UAVs Fly into the Future', America's Navy, 4 April 2015, <http://www.navy.mil/submit/display.asp?story_id=86558://>.
[72] *Ibid.*

for up to ten minutes before engaging a stationary or moving target and can operate autonomously or via remote control.[73] In addition to the "Harpy' loitering missile discussed above, Israel also operates the "Spyder" ground-to-air missile system which seeks out, identifies and destroys enemy aircraft and munitions.[74] A human operator may launch the Spyder, or, the missile may launch autonomously in response to a perceived threat.[75]

'Brimstone' is a missile developed for the Royal Airforce of the United Kingdom with 'human-in-the-loop capability to meet restrictive rules of engagement.'[76] Released from a fighter jet, the missile seeks enemy targets at long range. It uses radar and lasers to 'distinguish between valid and invalid targets' before destroying them.[77] Brimstone missiles (currently in use in missions over Iraq and Syria) provide the ability to engage multiple targets simultaneously, including fast moving and maneuvering vehicles, tanks and armoured vehicles and 'swarming' naval vessels.[78]

Israel also produces the 'Spice Bomb,' a 'stand-off autonomous weapon system' that can be launched from modern jet fighters such as the F-15, F-16 and the F-35. The weapon can search for up to 100 optional, stationary and mobile targets.'[79] Rather than flying to pre-programmed Global Position System coordinates, each autonomous 'Spice Bomb' compares

[73] 'Switchblade', Overview, <https://www.avinc.com/downloads/Switchblade_Datasheet_032712.pdf>; 'Switchblade', AeroVironment, <https://www.avinc.com/uas/adc/switchblade/>; B Carey, 'AeroVironment Seeks to Grow "Switchblade" Missile Business', AINonline, 8 May 2015, <http://www.ainonline.com/aviation-news/defense/2015-05-08/aerovironment-seeks-grow-switchblade-missile-business>.

[74] 'Future Weapons Israel Special Part V, Spyder ADS', Discovery, <https://www.youtube.com/watch?v=YW8G-8uyqdA>. 'SPYDER-SR ADS Short Range Air Defence System', Rafael Advanced Defence Systems Ltd., <http://www.rafael.co.il/Marketing/186-704-en/Marketing.aspx>.

[75] 'Future Weapons Israel Special Part V, Spyder ADS'; India's armed forces also operate the Spyder system. 'India Buys Israeli "SPYDER" Mobile Air Defence System', Defence Industry Daily, 19 August 2009, <http://www.defenseindustrydaily.com/india-to-buy-israeli-spyder-mobile-air-defense-system-02702/>.

[76] 'Brimstone Precision Attack Weapon', MBDA Missile Systems, http://www.mbda-systems.com/air-dominance/brimstone/.

[77] 'Brimstone', Royal Air Force Website, http://www.raf.mod.uk/equipment/brimstone.cfm.

[78] 'Brimstone Precision Attack Weapon'.

[79] A Egozi, 'Israeli F-35s to Use Spice Bomb Kits', F-16.Net, 13 March 2013, <http://www.f-16.net/forum/viewtopic.php?t=23226>.

‘real time’ images to ‘reference images’ that have been stored in the weapon’s computer.[80] After it performs ‘the scene-matching process,’ Spice ‘acquires the target automatically.’[81] Israeli air, sea and ground platforms also launch ‘Delilah,’ another ‘standoff’ missile which autonomously seeks out and identifies pre-designated targets. Once the target is identified, the launching pilot, for example, from an F-16 or a ship, can confirm that it is correct, or change it, and direct the missile into the target.[82]

The U.S. Air Force launches the ‘small diameter bomb (‘SDB’)’ from aircraft to engage fixed, relocatable and/or moving targets at any time of day or night and in adverse weather conditions.[83] The SDB has ‘autonomous stand-off attack capability.’[84] Also launched from an aircraft, the ‘Sensor Fused Munitions,’ in use since operation Iraqi Freedom, are large, aerial-launched ‘pods,’ which contain ten smaller sub-munitions. Each of the sub-munitions release four sensor-based warheads that loiter in the air and identify and engage stationary and moving targets. Thus, these forty warheads function akin to the swarm technologies discussed above.[85]

Similarly, the United States military has developed the Close-In Covert Autonomous Disposable Aircraft (‘CICADA’). CICADAs are autonomous weapon systems that fit in the

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[80] ‘Spice: Precision Guided Weapon Kit’, Rafael Advanced Weapon Systems, <http://www.rafael.co.il/Marketing/332-891-en/Marketing.aspx>.
[81] ‘Spice: Smart, Precise-Impact and Cost-Effective Guidance Kits’, Rafael: Smart and To the Point, <http://www.rafael.co.il/marketing/SIP_STORAGE/FILES/4/924.pdf>.
[82] ‘Future Weapons Israel Special Part VI Delilah Missile’, Discovery, <https://www.youtube.com/watch?v=zvMH-Z5IFjI>. ‘DELILAH SL – Ship Launched’, Israeli Military Industries, Ltd., <http://www.imi-israel.com/vault/documents/delilah_SL.pdf> and <http://www.imi-israel.com/home/doc.aspx?mCatID=65740>. This semi-autonomous system requires that the human reasoning process continue until the destruction of the target or the abortion of the mission.
[83] Chairman of U.S. Joint Chiefs of Staff, Joint Publication 3-09, Joint Fire Support, 12 December 2014, p. III-8.
[84] *Ibid*.
[85] ‘CBU-Sensor Fuzed Weapon/BLU-108 Submunition’, Textron Systems, <http://www.textronsystems.com/sites/default/files/pdfs/product-info/TS%20WSS%20Sensor%20Fused%20Weapons%20SFW.pdf>. ‘Sensor Fused Weapon (SFW) CBU-105 With BLU-108 Submunitions’, Textron Systems, <https://www.youtube.com/watch?v=9HkauuIyDsM>.

palm of a human hand. Planes will drop hundreds of CICADAs from high altitudes to simultaneously attack and overwhelm enemy positions[86]

F. Examples of Sea-Based Autonomous Weapon Systems

The United States Navy recently conducted a successful test of a swarm of thirteen autonomous boats that can defend friendly vessels and deter and attack enemy ships at sea. Each individual boat is directed by artificial intelligence software – originally developed for the Mars Rover - called Control Architecture for Robotic Agent Command and Sensing ('CARACAS'), which allows it to function autonomously as part of a swarm, and react to a changing environment.[87] Israel has developed a similar system, called 'Protector.'[88]

In addition, autonomous underwater vehicles currently have the capacity to travel hundreds of miles beneath the ocean surface without human supervision.[89] Designed as anti-mine systems, these platforms can operate thousands of metres below the surface and can also engage submarines and shipping. Eventually, multiple autonomous underwater vehicles will be deployed from a 'mothership' to operate collaboratively rather than as single units.[90] Furthermore, the Stonefish class of sea mines uses acoustic, magnetic and pressure sensors to assess the characteristics of passing ships. When the mine determines that: 1) the target is

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[86] D Basulto, 'CICADAs, Locusts and the New Innovation of Military Infestations', The Washington Post, 20 May 2015, <http://www.washingtonpost.com/blogs/innovations/wp/2015/05/20/cicadas-locusts-and-the-new-innovation-of-military-infestations/?wpisrc=nl_innov&wpmm=1>.

[87] P Tucker, 'Inside the Navy's Secret Swarm Robot Experiment', Defence One, 5 October 2014, <http://www.defenseone.com/technology/2014/10/inside-navys-secret-swarm-robot-experiment/95813/>; 'Autonomous Swarm', U.S. Navy Research, 4 October 2014, <https://www.youtube.com/watch?v=ITTvgkO2Xw4&feature=youtu.be>.

[88] 'Protector: Unmanned Naval Patrol Vehicle', Rafael Advanced Defence Systems, <http://www.rafael.co.il/Marketing/288-1037-en/Marketing.aspx?searchText=autonomous>.

[89] D Parry, 'Navy Mine-Hunter AUV Sets Mission Endurance Record', Naval Research Laboratory News, 20 November 2013, <http://www.nrl.navy.mil/media/news-releases/2013/navy-mine-hunter-auv-sets-mission-endurance-record>.

[90] G Turnbull, 'A New Era for Underwater Drones', Naval Technology.com, 15 August 2013, <http://www.naval-technology.com/features/feature-new-era-underwater-drones-unmanned-systems/>.

genuine, 2) it represents an enemy target and 3) the target is within the destructive blast radius of the mine, it will detonate.[91]

G. Standards and Semantics

Recent legal, philosophical and policy debates addressing lethal autonomous weapon systems suggest that agreement on semantic standards about the design and use of these weapons will resolve concerns about their lawfulness and morality.[92] Commentators and state officials usually express these standards as 'appropriate levels of human judgment'[93] or 'meaningful human control'[94] over the use of force by autonomous weapons.[95]

However, further analysis reveals that phrases such as 'appropriate levels of human judgment' and 'meaningful human control' over autonomous weapon systems solve little and actually reduce clarity in the discussion.[96] As noted in the Introduction, these constructions

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[91] See 'Stonefish (mine)', Digplanet, <http://www.digplanet.com/wiki/Stonefish_(mine)>.

[92] See the comments of states, international institutions, non-governmental organisations and individual experts at the 2015 Meeting of Experts on *Lethal Autonomous Weapons* at the Convention on Certain Conventional Weapons, April 2015, <http://www.unog.ch/80256EE600585943/(httpPages)/6CE049BE22EC75A2C1257C8D00513E26?OpenDocument>.

[93] Carter, 'Autonomy in Weapons Systems', part 4 (a).

[94] Statement of the Netherlands to the 2015 Meeting of Experts on *Lethal Autonomous Weapons* at the Convention on Certain Conventional Weapons, April 2015, <http://www.unog.ch/80256EDD006B8954/(httpAssets)/4AD55D74C760290FC1257E2D002C7D0F/$file/2015_LAWS_MX_Netherlands_W.A.pdf>; Statement of Professor Christoph Heyns to the 2015 Meeting of Experts on *Lethal Autonomous Weapons* at the Convention on Certain Conventional Weapons, April 2015, <http://www.unog.ch/80256EDD006B8954/(httpAssets)/1869331AFF45728BC1257E2D0050EFE0/$file/2015_LAWS_MX_Heyns_Transcript.pdf>.

[95] In addition, Professor Beard refers to the 'effective exercise of human judgment' over autonomous weapon systems. J Beard, 'Autonomous Weapons and Human Responsibilities', 45 *Georgetown Journal of International Law* (2014), 617, 681.

[96] Horowitz and Scharre observe that without clear definitions of these terms, they become empty platitudes, devoid of common meaning. M Horowitz and P Scharre, 'Meaningful Human Control in Weapon Systems: A Primer', Centre for a New American Security, Project on Ethical Autonomy Working Paper, March 2015, 6, <http://www.cnas.org/sites/default/files/publications-pdf/Ethical_Autonomy_Working_Paper_031315.pdf>. For a critique of the United States' 'appropriate level of human judgment over the use of force' standard, see D. Saxon, 'A Human Touch: Autonomous Weapons, DOD Directive 3000.09 and the Interpretation of 'Appropriate Levels of Human Judgment Over the Use of Force', in Nehal Bhuta et. al. (eds.), *Autonomous Weapons Systems – Law, Ethics, Policy* (Cambridge University Press, 2015), pp. 185 - 208.

are open to multiple interpretations[97] and disagreements about their 'meaning' are easy to surmise.[98]

For example, with respect to the phrase 'meaningful human control,' the word 'meaningful' can refer to the human who exerts the control, and the moral reasoning underlying her decisions, as well as the degree of operational and tactical control exercised by that human over the weapon.[99] Should the act of programming the computers that direct an autonomous weapon system constitute 'meaningful human control'? Or does the phrase only refer to human observations and/or interventions that occur during and after an attack? In addition, 'meaningful' could speak to the retention of criminal and/or moral responsibility by the human over the machine vis a vis violations of international law.[100] Or, 'meaningful' can refer to the *result* of the actions of an autonomous weapon system or systems during a particular attack, operation, or military campaign.[101] Depending on the answer to the last question, the term 'meaningful' could also subsume considerations of military necessity and/or military advantage. A single definition for 'meaningful human control' (if possible)

[97] R Moyes, Director of Article 36, Remarks on 'Towards a Working Definition of Lethal Autonomous Weapon Systems,' Informal Expert Meeting on LAWs, Convention on Conventional Weapons, Geneva, 12 April 2016, http://www.unog.ch/80256EE600585943/(httpPages)/37D51189AC4FB6E1C1257F4D004CAFB2?OpenDocument.

[98] 'One can of course agree,' observes Jan Paulsson, 'that words should be taken to mean anything at all.' *Denial of Justice in International Law* (Cambridge University Press, 2005), pp. 57.

[99] Ethicist Jeroen van den Hoven argues that meaningful human control means that 'everything that transpires' with respect to the operation of autonomous weapon systems must satisfy demands of moral reasons and the process of moral reasoning so that, ultimately, a human is responsible for the effects of the weapon system. 'Why the Future Needs Us Today: Moral Responsibility and Engineering Autonomous Weapon Systems', Presentation to 2015 Meeting of Experts on *Lethal Autonomous Weapon Systems* at the Convention on Certain Conventional Weapons, April 2015, p. 3-4, <http://www.unog.ch/80256EE600585943/(httpPages)/6CE049BE22EC75A2C1257C8D00513E26?OpenDocument>.

[100] Horowitz and Scharre, 'Meaningful Human Control in Weapon Systems: A Primer', 8.

[101] For example one objective of the 'System of Systems Technology and Experimentation Programme' ('SoSITE') under development by the U.S. Defence Advanced Research Projects Agency ('DARPA') is the application of 'warfighter-managed autonomy to coordinate *distributed effects*.' J Shaw, 'System of Systems Technology and Experimentation Programme (SoSITE)', DARPA, <http://www.darpa.mil/program/system-of-systems-integration-technology-and-experimentation>.

would be simpler. However, a perspective that is appropriate for ground combat – or one aspect of ground combat – may be unworkable in the air, sea and space domains.[102]

In recent years, experts on the topic of lethal autonomous weapon systems have proposed definitions of 'meaningful human control' ranging from the unrealistic to the vague. Professor Sharkey offers a draft definition with five aspirational components:

> A commander or operator will
>
> '1. have full contextual and situational awareness of the target area at the time of initiating a specific attack;
>
> 2. be able to perceive and react to any change or unanticipated situations that may have arisen since planning the attack, such as changes in the legitimacy of the targets;
>
> 3. have active cognitive participation in the attack;
>
> 4. have sufficient time for deliberation on the nature of targets, their significance in terms of the necessity and appropriateness of an attack, and the likely incidental and possible accidental effects of the attack; and
>
> 5. have a means for the rapid suspension or abortion of the attack.'[103]

Each of these criteria is problematic because they create duties that do not exist in the laws of war and/or impose impossible burdens on commanders. For example, with respect to the first requirement, no rule of international humanitarian law requires commanders to have 'full contextual and situational awareness of a target area when initiating an attack.'[104] Indeed, in most combat situations, this appears to be an impossible standard to meet. For example, does 'contextual awareness' include the historical and political contexts or simply

[102] Horowitz and Scharre, 'Meaningful Human Control in Weapon Systems: A Primer', 11 and 12.
[103] N Sharkey, 'Staying in the Loop: Human Supervisory Control of Weapons', in Bhuta et. al. (eds.), Autonomous Weapons Systems: Law, Ethics, Policy, p. 28.
[104] Instead, international law imposes a duty on soldiers to take all feasible precautions when planning and executing attacks to spare the civilian population, civilians and civilian objects, see Art. 57, 1977 Geneva Protocol I Additional to the Geneva Conventions of 12 August 1949 and Relating to the Protection of Victims of International Armed Conflicts ('API').

the military circumstances existing at the time? How will a commander know she her 'situational awareness' is complete or whether certain details may be missing?

Similarly, criteria two would instantly outlaw the use of artillery, rockets and missiles that are not reprogrammable in flight. As Mark Roorda explans: '[t]here is a moment that [sic] a person will perform an act – or not perform an act – after which it is irreversible that violent action will – or could – occur. In most cases this is the decision to fire or launch a weapon.'[105]

Criteria three would prohibit modern automated naval anti-ship missile defence systems such as 'Phalanx,' in use for decades by navies around the world, which operate so quickly that it is difficult to argue that humans have 'active cognitive participation" when the system fires on a target.[106] Although international humanitarian law requires combatants to consider the possible incidental effects of attacks on civilians, criteria four's additional requirement concerning 'possible accidental effects' has no legal basis. Criteria five has similar problems as criteria two. Thus, while admirable, these aspirational benchmarks are not practical and lie outside the law.

Horowitz and Scharre argue that 'meaningful human control' over autonomous weapon systems has three components:

1. Human operators are making informed, conscious decisions about the use of weapons.

2. Human operators have sufficient information to ensure the lawfulness of the action they are taking, given what they know about the target, the weapon, and the context for action.

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[105] M Roorda, 'NATO's Targeting Process: Ensuring Human Control Over and Lawful Use of "Autonomous" Weapons', *Amsterdam Law School Legal Studies Research Paper No. 2015-13* (Amsterdam Centre for International Law, June 2015), 10.

[106] See 'Phalanx Close-In Weapons System', The United States Navy Fact File, <http://usmilitary.about.com/library/milinfo/navyfacts/blphalanx.htm>.

3. The weapon is designed and tested, and human operators are properly trained, to ensure effective control over the use of the weapon.[107]

These criteria raise more questions than they answer. With respect to the first standard, it is unclear what amount of knowledge and experience with autonomous weapons systems (particularly for commanders who lack a background in science or engineering) is necessary to make an 'informed' decision, in particular when the circumstances of a weapon's use can vary dramatically.[108] Moreover, the nature of a 'conscious' decision is a matter of debate, particularly when combatants must react to threats and/or information from their instruments in micro-seconds. Similarly, criteria two is oddly vague and redundant as 'sufficient information' is open to multiple interpretations and seems to depend on the similar phrase 'given what they know.' The phrase 'effective control' in criteria three refers to the human operator's understanding of the capacities and limitations of the autonomous weapon system so that it can be used 'appropriately.'[109] The term 'appropriately' however, is another vague term that opens up moral, legal and ethical discussions about the 'appropriate' use of lethal autonomous weapon systems. Furthermore, and confusingly, the term 'effective control' is the same standard used to define a superior-subordinate relationship between commanders and their (human) subordinates in international criminal law.[110]

In addition, phrases such as 'appropriate levels of human judgment' and 'meaningful human control' are not legal standards and, indeed, have no basis in international law. A

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[107] Horowitz and Scharre, 'Meaningful Human Control in Weapon Systems: A Primer', 14 – 15.

[108] Unfortunately, Horowitz and Scharre provide a very circular description of the amount of information that is 'adequate' to make an informed decision: '[i]t should be enough information about the target, the weapon, and the context for engagement for the person to make an informed decision about the lawfulness of their action.' *Ibid*, 13. This 'informed decision' standard appears to lower the bar below the 'feasible precautions' standard for planning and executing attacks enunciated in Art. 57 of API. In at least some circumstances, a broad range of options exist to reduce uncertainty and increase the 'informed' character of decisions. Roorda, 'NATO's Targeting Process: Ensuring Human Control Over and Lawful Use of "Autonomous" Weapons', 12 and 16.

[109] *Ibid*, 13.

[110] *Judgment*, Prosecutor v. Delalić, No. IT-96-21-A, 20 February 2001, paras. 196 – 198.

focus on these terminologies creates a confusing distraction from the more fundamental questions concerning the legalities of autonomous weapons.[111]

Furthermore, an emphasis on semantics ignores several important dynamics that affect the use and/or abuse of autonomous weapon systems and which are not examined carefully in the legal and philosophical literature. For example, the technical aspects and capacities of these weapon systems (as described above) naturally affect their relationship with human beings and with international law. Will the perception of 'meaningful human control' change if the technology varies? Do cruder forms of autonomous technologies always require more control to be 'meaningful'? Or, if a highly sophisticated autonomous weapon system is available, will minimal or no human control suffice, as long as the overall result is 'meaningful'?[112]

Arguably, this dissertation's emphasis on the importance of the concept of human dignity vis a vis autonomous weapon systems presents similar problems to the use of standards such as 'meaningful human control.' As I acknowledge, respected commentators offer more than one definition of human dignity and this notion is not amenable to scientific precision. Thus, it is not unreasonable to suggest that, by basing objections to the development and employment of autonomous weapons on human dignity, this thesis creates comparable issues of interpretation and semantics. Nevertheless, as I elaborate in the next chapter, human dignity has served as a foundational value of international law for generations.

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[111] W Boothby, 'Possible Challenges to International Humanitarian Law', Presentation to Expert Meeting on *Lethal Autonomous Weapons*, Convention on Certain Conventional Weapons, April 2015, p. 3–4, <http://www.unog.ch/80256EDD006B8954/(httpAssets)/616D2401231649FDC1257E290047354D/$file/2015_LAWS_MX_BoothbyS+Corr.pdf>; The U.K. Government has stated that 'international humanitarian law provides the appropriate paradigm for discussion.' Statement to Informal Meeting of Experts on *Lethal Autonomous Weapons*, Convention on Certain Conventional Weapons, April 2015, p. 2, <http://www.unog.ch/80256EDD006B8954/(httpAssets)/1CBF996AF7AD10E2C1257E260060318A/$file/2015_LAWS_MX_United+Kingdom.pdf>.

[112] Mark Roorda suggests the opposite, i.e. the more sophisticated the weapon system, the more a commander may restrict its use due to a lack of understanding of the system's capacities, reactions and effects. "NATO's Targeting Process: Ensuring Human Control Over and Lawful Use of "Autonomous" Weapons', 16.

As reflected in treaty and customary law, human dignity grounds our understanding of, inter alia, international humanitarian law, international human rights law, international criminal law and the law of state responsibility. In spite of its contestable definition, the value of human dignity clearly informs our understanding and interpretation of the rules of international law. In that respect, human dignity is starkly different from language such as 'meaningful human control' and 'appropriate levels of human judgment.'

Professor Heyns contends that lethal autonomous weapon systems 'must be tools in the sense that humans use them to pursue their own objectives. Posing the requirement of meaningful human control is just another way of saying that autonomous weapon systems are acceptable only insofar as they are tools in the hands of humans.'[113] The crucial question then, is what kind of decisions require human control over these tools. I argue that, with respect to autonomous weapon systems, humans must make decisions that involve complex and/or conflicting values.[114] Consequently, autonomous weapon designs must ensure structural and cognitive interdependence between human operators, commanders and the machine.[115] I discuss the importance of this 'co-active' design in the next section.

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[113] C Heyns, Comments to Informal Meeting of Experts on Lethal Autonomous Weapons, Convention on Conventional Weapons, 16 April 2015, p. 7, <http://www.unog.ch/80256EDD006B8954/(httpAssets)/1869331AFF45728BC1257E2D0050EFE0/$file/2015_LAWS_MX_Heyns_Transcript.pdf>.

[114] The use of automated or autonomous defensive weapon systems, such as the Phalanx anti-missile/anti-plane system for use at sea and Israel's Iron Dome system used to intercept and destroy Hamas rockets in the air are less likely to implicate complex values than offensive systems designed to target human adversaries or manned military targets. Regarding the Iron Dome system, see 'How Israel's Iron Dome Missile System Works', CBC News, 20 November 2012, <http://www.cbc.ca/news/technology/how-israel-s-iron-dome-missile-defence-system-works-1.1219839>.

[115] Social goals, to be meaningful, must be conceived in structural as well as intellectual terms, 'not simply as something that happens to people when their social ordering is rightly directed. L Fuller, 'Means and Ends' in K Winston (ed.), *The Principles of Social Order: Selected Essays of Lon L. Fuller* (Durham: Duke University Press, 1981), pp. 57.

H. Design: Autonomy v. Interdependence

The common denominator of the new autonomous weapon systems described above, is a desire to achieve and/or maintain military superiority As a matter of strategy and common sense, armed forces prefer not to go into battle at a disadvantage, or on an equal footing with their enemy.[116] These more autonomous weapon systems extend the offensive and defensive reach of armed forces.[117]

From a purely technical perspective, the objective of designing manned and unmanned systems should be to devise the most efficient means of conducting activities, 'with human intelligence operating in the most effective location.'[118] However, efficiency is not the only salient factor in the design of complex systems because new technology, including weapons technology, must preserve the fundamental role of reason and thinking in human affairs.[119]

Furthermore, even assuming for the sake of argument that efficiency *is* the first priority for the design of autonomous weapon systems, some computer and robotics scientists contend that the 'coactive design' model for autonomous systems (described in the Introduction) provides a more effective concept for human interaction with autonomous

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[116] J Wilson, 'Interview with Brig. General Gary L. Thomas, U.S. Marine Corps Assistant Deputy Commandant for Aviation', DefenceMediaNetwork, 23 March 2012, <http://www.defensemedianetwork.com/stories/interview-with-brig-gen-gary-l-thomas-u-s-marine-corps-assistant-deputy-commandant-for-aviation/3/>.

[117] 'CARACAS (Control Architecture for Robotic Agent Command and Sensing)', Naval Drones, U.S. Office of Naval Research, Science and Technology, <http://www.navaldrones.com/CARACAS.html>. Conversely, as the control of human operators over these platforms increases, 'the less autonomous those systems can be, which defeats the purpose.' J Borrie, 'On Safety Aspects of Meaningful Human Control: Catastrophic Accidents in Complex Systems', Conference in Weapons, Technology and Human Control, United Nations Institute for Disarmament Research, New York, 16 October 2014.

[118] C Townes, 'Report of the Task Force on Space', 8 January 1969, in J Logsdon (ed.) *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program* (Washington D.C.: 1995), Vol. I: Organizing for Exploration, pP. 505, < http://history.nasa.gov/SP-4407/vol1/intro.pdf>.

[119] John Finnis describes one of the 'basic goods' of human life as 'practical reasonableness,' i.e. the ability 'to bring one's own intelligence to bear effectively (in practical reasoning that issues in action) on the problems of choosing one's actions and lifestyle and shaping one's own character.' *Natural Law and Natural Rights*, (Oxford: Clarendon Press, 2002), pp. 88-89.

weapon systems than a focus on semantic standards.[120] The coactive design model suggests that as autonomous technologies improve, the interdependence between humans and machines will *increase*.[121] More advanced coactive weapon systems with autonomous functions will create opportunities to accomplish more complex tasks.[122] Determinations as to which kinds of cognitive activities are most appropriate for computers and artificial intelligence and which are better left to humans will form a crucial aspect of weapons design and warfare itself.[123]

When weapons developers submit options to the military for new weapon systems, however, the key question for the individuals making procurement decisions is: '[w]ill it enhance my ability to carry out my strategic, military objective?'[124] Military interests require timely decision-making[125] and even with the best training of human operators, the challenge of maintaining meaningful or appropriate levels of human judgment and/or human-machine collaboration and teamwork will become increasingly difficult as decision-making cycles of autonomous weapon systems shrink to micro-seconds. Indeed, it is not difficult to envision

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[120] M Johnson et. al., 'Beyond Cooperative Robotics: The Central Role of Interdependence in Coactive Design', *Human – Centred Computing*, May - June 2011, 83, <http://www.ihmc.us/users/mjohnson/papers/Johnson_2011_HCC_BeyondCooperativeRobotics.pdf>

[121] *Ibid*. Indeed, research has shown that the 'more interactions that humans and robots have, they begin to develop their own language.' L Steels, 'Ten Big Ideas of Artificial Intelligence', Remarks to 25th Benelux Conference on Artificial Intelligence, Delft Technical University, 8 November 2013. Paul Scharre argues that 'the real future of combat – in the air and elsewhere – is human-machine teaming: physical teaming between "manned" and "unmanned" vehicles, and cognitive teaming that blends automation and human decision-making.' 'Yes, Unmanned Combat Aircraft Are the Future,' *Centre for a New American Security*, 11 August 2015, <http://www.cnas.org/opinion/yes-unmanned-combat-aircraft-are-the-future#.VhJzG03smdJ>.

[122] As several leading proponents of the coactive design model argue: 'the property of autonomy is not a mere function of the machine, but rather a relationship between the machine and a task in a given situation.' M Johnson et. al. 'Beyond Cooperative Robotics: The Central Role of Interdependence in Coactive Design', 84.

[123] Failure to carefully adhere to such allocations of function and responsibility can have catastrophic results. For example, one of the causes of the shoot-down of a civilian Iranian airliner in 1988 by the U.S. Navy vessel Vincennes was the crew's misreading of information, accurately provided by the ship's AEGIS Combat System, that the approaching airplane was ascending rather than descending. 'Investigation Report', Formal Investigation into the Circumstances Surrounding the Downing of Iran Air Flight 655 on 3 July 1988, U.S. Department of Defence, 19 August 1988, p. 61.

[124] G Corn, remarks at Autonomous Weapon Systems – Law, Ethics and Policy Conference at European University Institute, Academy of European Law, 24 April 2014.

[125] W Boothby, *The Law of Targeting* (Oxford University Press, 2012), pp. 122. Lockheed Martin, 'F-35 Experience,' Video in F-35's Capabilities: Multi-Mission Capability for Emerging Global Threats, <https://www.f35.com/about/capabilities>. 'Every wasted minute of a senior leader …. has real impacts on the battlefield.' C Fussell, forme Aide-de-Camp to General Stanley McChrystal, The Tim Ferriss Show, <http://fourhourworkweek.com/2015/07/05/stanley-mcchrystal/>.

future generations of autonomous weapon systems that will communicate between each other much more quickly than with humans.

Common sense suggests that in situations where lives depend on the fastest possible actions and reactions, the likelihood that human supervisors and operators will intervene with autonomous weapons systems will be reduced.[126] Decisions about the design and development of new automated and autonomous technologies are really 'about speed of service. The better the automated system, the faster we can accomplish the mission. That is not the only consideration, but it is the main one.'[127] A danger exists, therefore, that opportunities to impose standards such as "appropriate levels of human judgment over the use of force" or 'meaningful human control' or 'coactive design' eventually will be reduced to very little or nothing.[128] When we reach that moment, the capacity of humans to guide the conduct of autonomous weapon systems will be in question.

Decisions made today in terms of research and development affect military capability decades in the future.[129] Accordingly, to preserve the relevance of human reasoning and the function of law, validation and verification of the system's human – machine interdependence

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[126] One computer scientist observes that, as machines can function so must faster than humans, '"man-in-the-loop" means you lose.' A Fursman, Remarks to 'Private Sector Perspectives on the Development of Lethal Autonomous Systems,' Geneva, 12 April 2016. So many decisions on the battlefield are time-sensitive; to engage with the enemy and destroy them.' Corn, *supra* note ….. NATO doctrine provides that, as part of the 'battle rhythm' of NATO operations, coalition forces 'should maintain a rate of activity greater than that of the opponent.' AJP-3 (B), *Allied Joint Doctrine for The Conduct of Operations*, North Atlantic Treaty Organization, March 2011, para. 0424, available online at http://www.cicde.defense.gouv.fr/IMG/pdf/20110316_np_otan_ajp-3b.pdf.

[127] Col. John L. Haithcock, Jr. TSM FATDS, Fort Sill, OK, Letter to the Editor, Field Artillery, January – February 2006, available online at http://sill-www.army.mil/firesbulletin/archives/2006/JAN_FEB_2006/JAN_FEB_2006_FULL_EDITION.pdf.

[128] Neither abstract concepts nor the law are effective substitutes for armed conflict. H. Lauterpacht, *The Function of Law in the International Community* (Oxford: Clarendon Press, 1933), p. 437.

[129] B Burridge, Air Chief Marshall (ret.) U.K. Army, 'Military Capability is Founded on a Body of Knowledge to Which Industry Is a Major Contributor', 2010, copy in Author's possession.

as well as the capability to use it in compliance with international law must occur at the design phase of the weapon.[130]

III. Conclusions

This chapter demonstrates that states are developing weapon systems with faster and more autonomous functions, including the capacity to identify targets and destroy them with lethal force. Efforts to fit these systems into fixed categories such as 'in-the-loop,' 'on-the-loop,' 'semi-autonomous,' 'fully autonomous,' etc., fail to encompass the complexities of the systems and the fluid realities of modern armed conflict. Furthermore, as the speed of autonomous weapon systems increases, particularly with the advent and use of swarm technology, semantic standards such as 'meaningful human control' become unrealistic and irrelevant. States that develop autonomous weapon systems should prioritize a design that ensures human-machine interdependence and teamwork so that human reasoning and judgment is not discarded at critical phases of warfighting and law enforcement activities, including decisions to use lethal force.

[130] Corn, remarks at Autonomous Weapon Systems – Law, Ethics and Policy Conference at European University Institute.