STATUS OF THE OPERATOR: BIOLOGICALLY INSPIRED COMPUTING AS BOTH A WEAPON AND AN EFFECTOR OF LAWS OF WAR COMPLIANCE

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ABSTRACT

Artificial intelligence and machine learning technology are developing in such a way that neural networks and systems architecture will soon mimic the structure and functions of the human brain. Consequently, autonomous weapons systems that rely on the limited analytical skills of today's artificial intelligence and machine learning capabilities may soon realize human-like judgment. This biologically inspired technology known as neuromorphic computing presents a breakthrough for weapons' capabilities, particularly in the management and analyses of battlefield environments. Future cognitive lethal autonomous weapons systems (CLAWS) could complement important roles in combat, such as accountability obligations, whereas their independent compliance to the principles of distinction, proportionality, military necessity, and humanity, could surpass that of their human and machine predecessors.

I. INTRODUCTION

[1] In July 2019, during the Telluride Neuromorphic Cognition Engineering Workshop, an event centered on neuromorphic computing, scientists and technologists gathered around a foosball table to watch a game—a game not played by humans, but rather a game controlled by neuromorphic computer chips and event-based cameras.[1] One of the workshop participants, Prof. Greg Cohen, explained, "We're trying to figure out how to make robots, systems, and computers work in a more biologically-inspired manner."[2]

[2] This "biologically inspired" focus is what sets neuromorphic computing apart from conventional artificial intelligence (AI) and machine learning technology. First introduced by Carver Mead in the 1980s, Mead believed that neuromorphic computing was a possibility, as "[t]here is nothing that is done in the nervous system that we cannot emulate with electronics if we understand the principles of neural information processing."[3] Nearly forty years later, the fundamentals of Mead's statement are apparent in the workshop's objective "to bring the organizing principles of neural cognition into machine intelligence, and to use lessons and technology from machine intelligence to understand how brains work."[4]

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[1] Samuel K. Moore, *Intel's Neuromorphic System Hits 8 Million Neurons, 100 Million Coming by 2020*, IEEE SPECTRUM (July 15, 2019), https://spectrum.ieee.org/tech-talk/artificial-intelligence/embedded-ai/intels-neuromorphic-system-hits-8-million-neurons-100-million-coming-by-2020 [https://perma.cc/4TD8-F9AL#toggle-gdpr]; Aimee Chanthadavong, *UWS uses Intel chips to create biologically-engineered foosball table*, ZD NET (Aug. 1, 2019, 7:25 PM), https://www.zdnet.com/article/uws-uses-intel-chips-to-create-biologically-engineered-foosball-table/ [https://perma.cc/WN8B-JDL8].

[2] Chanthadavong, *supra* note 1.

[3] Carver Mead, *Neuromorphic Electronic Systems*, 78 PROC. IEEE 1629, 1630 (Oct. 1990).

[4] *About the Workshop*, TELLURIDE 2019, https://sites.google.com/view/telluride2019/about-workshop?authuser=0 [https://perma.cc/K2LN-8WWX].

[3] While conventional AI and machine learning technologies also draw inspiration from biology, neuromorphic computing takes this one step further by actually mimicking biology so as to function and perform similar to a brain.[5] With this shift to biologically-accurate operations, neuromorphic systems can achieve significantly reduced power consumption and can "support dynamic learning in the context of complex and unstructured data."[6] According to Mike Davies, a leading researcher in the field of neuromorphic engineering, this is why the game of foosball is a "nice illustration" of neuromorphic technology: "It's fast, requires quick response, quick planning, and anticipation. These are what neuromorphic chips are good at."[7]

[4] Four years prior to this workshop, a report by the U.S. Department of Energy's (DOE) Office of Science noted that "the mission areas of DOE in national security, energy sciences, and fundamental science will need even more computing capabilities than what can be delivered by [existing] systems."[8] The report specifically focused on the advantages of neuromorphic computing and contrasted them with the current disadvantages of conventional AI and machine learning technology.[9]

[5] The report noted that while conventional systems have "some unique characteristics (e.g., speed, size, operation range), they are limited in other crucial aspects (e.g., energy consumption, rigid design and

[5] Samuel Greengard, *Neuromorphic Chips Take Shape*, 63 COMMC'NS ACM 9, 10 (2020).

[6] U.S. DEP'T OF ENERGY, NEUROMORPHIC COMPUTING: FROM MATERIALS TO SYSTEMS ARCHITECTURE, REPORT OF A ROUNDTABLE CONVENED TO CONSIDER NEUROMORPHIC COMPUTING BASIC RESEARCH NEEDS, 6 (2015) [hereinafter DOE ROUNDTABLE].

[7] Moore, *supra* note 1.

[8] DOE ROUNDTABLE, *supra* note 6, at 6.

[9] *See id.* at 3 (explaining how "the main differences between neuromorphic and conventional computing" were considered).

functionality, inability to tolerate faults, and limited connectivity)."[10] By comparison, "the brain is based on large collections of neurons . . . that are adaptable and fault tolerant."[11] By modeling computer systems after biology, neuromorphic technology could "exploit massive, fine-grain computation; enable the near real-time analysis of large-scale data; learn from examples; and compute with the power efficiency approaching that of the human brain."[12]

[6] The report frankly concluded that "[t]echnology that has the advantages of both biological and engineered materials, with the downsides of neither, is needed."[13] This assertion is particularly relevant to the field of national security and advanced weaponry. Where humans have traditionally served on the frontlines of battle, lethal autonomous weapons systems (LAWS) that use conventional AI and machine learning technology are now being introduced as an alternative.[14] While these state-of-the-art weapons are highly adept and excel in essential areas of task performance over their human counterparts, significant objections have been raised about their use due to specific technological limitations.[15] These limitations primarily pertain to rigidness, or an inability to subjectively analyze situations and

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[10] *Id.* at 8.

[11] *Id.*

[12] *Id.* at 4.

[13] DOE ROUNDTABLE, *supra* note 6, at 10.

[14] *See* Kenneth Anderson et al., *Adapting the Law of Armed Conflict to Autonomous Weapon Systems*, 90 INT'L L. STUD. 386, 391 (2014).

[15] *See, e.g.*, INT'L COMM. RED CROSS, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN ARMED CONFLICT: A HUMAN-CENTRED APPROACH 10 (June 2019), https://www.icrc.org/en/document/artificial-intelligence-and-machine-learning-armed-conflict-human-centred-approach [https://perma.cc/UB8P-SDEG] [hereinafter ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING] (explaining how "[d]epending on their use or misuse—and the capabilities and limitations of the technology—these decision-making applications could lead to increased risks for civilian populations.").

modify behavior to changing circumstances, and non-explainability, or lack of accessible insight into the machine's decision-making processes and potential dataset-based biases.[16]

[7] The International Committee of the Red Cross (ICRC) and Human Rights Watch both raise objections to LAWS that independently select and engage targets in armed conflict.[17] Rather than the deployment of LAWS that operate fully autonomously, they advocate for LAWS that are subject to meaningful human control so as to include a measure of flexibility for human judgement and emotion in the decision-making process, which they consider essential for the preservation of lawful and ethical practices in combat.[18]

[8] Despite a willingness among interested members of the international community to consider and discuss meaningful human control, disagreements over what it entails have slowed progress in the development of standards.[19] Nevertheless, the rationale behind this objective is clear—to prevent erroneous behavior on the battlefield by ensuring compliance with the context-specific analyses of the Laws of Armed Conflict (LOAC).[20] Indeed, the foundational principles of the LOAC each require some form of thoughtful analyses before an authorized actor can select and engage military targets, and LAWS' rigid technology, coupled with the difficulty

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[16] *Id.* at 10–11.

[17] *Id.* at 2, 5; HUMAN RIGHTS WATCH, LOSING HUMANITY: THE CASE AGAINST KILLER ROBOTS 1, 4 (2012), https://www.hrw.org/report/2012/11/19/losing-humanity/case-against-killer-robots# [https://perma.cc/DW2Z-SYE7] [hereinafter LOSING HUMANITY].

[18] LOSING HUMANITY, *supra* note 17, at 21, 34, 36–37.

[19] Chris Jenks, *False Rubicons, Moral Panic, and Conceptual Cul-De-Sacs: Critiquing & Reframing the Call to Ban Lethal Autonomous Weapons*, 44 PEPP. L. REV. 1, 14 (2016).

[20] Rebecca Crootof, *War Torts: Accountability for Autonomous Weapons*, 164 U. PA. L. REV. 1347, 1399 (2016) ("If autonomous weapon systems are eventually better able to comply with the law of armed conflict than human soldiers, for example, it would be unfortunate to ban them at this early stage of development.").

in explaining the machine's decision-making processes, may hinder lawful compliance with these requirements.[21]

[9] Although members of the international community object to fully autonomous weapons, especially with respect to their ability to lawfully select and engage targets without human involvement, weapons that utilize neuromorphic technology, or cognitive LAWS (CLAWS), could incorporate human-like discretion. Properly employed, CLAWS could conduct complex decision-making by managing, planning, anticipating, and adapting to unstructured battlefield environments, all with amplified efficiency, reduced bias, and increased transparency. And while neuromorphic technology may not extend to replicating human emotion, military leaders may pursue non-technological avenues in combination with CLAWS to resolve ethical questions of LAWS' employment.

[10] In order to understand the capabilities unique to CLAWS, Part II will first explore the challenges and benefits of LAWS' capabilities. Next, Part III will examine the technical aspects of neuromorphic computing and how it compares to conventional technology. Part IV will analyze CLAWS' ability to comply with the LOAC. Part V will conclude.

II. Lethal Autonomous Weapons Systems (LAWS): Challenges and Benefits

[11] LAWS have been a hotly debated issue for over a decade now.[22] One of the reasons these debates continue is the dichotomous nature of LAWS' challenges and benefits. For example, the rigid nature of LAWS' decision making capabilities means they are vulnerable to making mistakes when selecting and engaging targets, thus increasing the probability of

[21] Losing Humanity, *supra* note 17, at 30–31.

[22] Eric Talbot Jensen, *Autonomy and Precautions in the Law of Armed Conflict*, 96 Int'l L. Stud. 578, 580 (2020).

LOAC non-compliance.[23] On the other hand, highly advanced sensors and processors enable more precise targeting, which can lead to fewer mistakes and, if properly employed, closer compliance with the LOAC.[24] Conflicting issues such as these make it difficult to come to a broad consensus about the use of LAWS in armed conflict. Thus, the debates persist. The following sections will address both the challenges and benefits of the use of LAWS in armed conflict.

A. Challenges

[12] In dynamic combat situations where subjective analysis and judgment are paramount to legal compliance, opponents argue that LAWS' rigid decision-making capabilities, lack of moral and ethical judgment, and issues of explainability and bias render these weapons systems too problematic for a fully autonomous operation.[25]

[13] First, limited decision-making capabilities can constrain the amount of adaptability LAWS exhibit when managing complex situations. The legal principle of distinction, codified in Article 51(1) of Additional Protocol I to the Geneva Conventions, requires actors to distinguish and avoid civilians and civilian objects in an attack.[26] Consider conditions "where adversaries and civilians are outwardly indistinguishable, [and] a combatant's targetable status must be determined by other less visible clues, like past

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[23] *See* Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I) art. 57, June 8, 1977, 1125 U.N.T.S 3 [hereinafter Additional Protocol I] (identifying distinction, proportionality, military necessity, feasible precautions in attack, accountability, and humanity as critical components of the Law of Armed Conflict).

[24] *See, e.g.*, John Pike, *MK 15 Phalanx Close-In Weapons System (CIWS)*, FED'N AM. SCIENTISTS MIL. ANALYSIS NETWORK (Jan. 9, 2003), http://www.fas.org/man/dod-101/sys/ship/weaps/mk-15.htm [https://perma.cc/9ETS-5GLR].

[25] LOSING HUMANITY, *supra* note 17, at 3–4.

[26] Additional Protocol I, *supra* note 23, at art. 51.2–4 (prohibiting attacks on "[t]he civilian population as such, as well as individual civilians" and "indiscriminate attacks").

behavior and intent."[27] In these situations, it would be difficult for LAWS to "cope with the complex tree of possibilities, [in] understanding what's going on and what to do about it."[28] LAWS' AI and machine learning technology is currently not advanced enough to amend behavior for each changing circumstance.[29] Explained further:

> A machine learning demonstration or research project starts with data purportedly representative of the real world, keeps some aside for final evaluation, and after training reports some measure of accuracy evaluated on the held out data. The measure is typically some combination of precision and recall. There are two pitfalls. The first is well-understood, that the training data may not be sufficiently representative of the real world. The second is that in the real-world, some errors are much worse than others. If these can be anticipated, then extra training data can be used to make sure these mistakes don't happen. Commercial experience suggests that it's very hard to think of all of these in advance.[30]

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[27] Annemarie Vazquez, *LAWS and Lawyers: Lethal Autonomous Weapons Bring LOAC Issues to the Design Table, and Judge Advocates Need to Be There*, 228 MIL. L. REV. 89, 104 (2020).

[28] RICHARD POTEMBER, PERSPECTIVES ON RESEARCH IN ARTIFICIAL INTELLIGENCE AND ARTIFICIAL GENERAL INTELLIGENCE RELEVANT TO DOD 54 (MITRE Corp. 2017) (illustrating how AI technology can fail in real-world environments).

[29] *Id.* at 53–54 (stating that solving issues of adaptability to unforeseen circumstances in autonomous vehicles requires additional research and engineering).

[30] *Id.* at 54.

[14] Although humans can also be susceptible to adversarial deception,[31] they can more readily adapt to and learn from surrounding information to make complex analyses.[32] As a result, opponents question whether LAWS are the best choice for battlefield environments when humans can handle complex decisions with more flexibility. [33]

[15] While opponents of LAWS contend that having a human in control serves as an essential safeguard against most analytical complications, they also recognize that meaningful human control over LAWS does not guarantee compliance.[34] Rather, it is the technological issues inherent in LAWS that must be addressed. The ICRC notes that

> [a]n overall principle of human control and judgement is an essential component, but it is not sufficient in itself to guard against potential risks of AI and machine learning in armed conflict. Other related aspects to consider will be ensuring: predictability and reliability – or safety – in the operation of the system and the consequences that result; transparency – or explainability – in how the system functions and why it reaches a particular output; and lack of bias – or fairness – in the design and use of the system. These issues will need to be addressed in order to build trust in the use of a given

[31] Michael N. Schmitt & Jeffrey S. Thurnher, *"Out of the Loop": Autonomous Weapons Systems and the Law of Armed Conflict*, 4 HARV. NAT'L SEC. J. 231, 247–48 (2013) ("[A]symmetrically disadvantaged enemies have been feigning civilian or other protected status to avoid being engaged by human-operated weapon systems for centuries. The fact that the techniques sometimes prove successful has never merited classifying those systems as indiscriminate *per se*. In fact, it would be counter-productive to take such an approach because it would incentivize the enemy's use of the tactic in order to keep weapon systems off the battlefield.").

[32] *Id.* at 248.

[33] LOSING HUMANITY, *supra* note 17, at 46–47.

[34] ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, *supra* note 15, at 7.

> system, including through rigorous testing in realistic environments before being put into operation.[35]

[16] Here, the ICRC argues that until the machines themselves can be shown to be reliable, transparent, and fair, it will be difficult to accept LAWS as trustworthy weapons of war even if humans maintain control over them. This rationale in turn begs the question: Why does a human need to retain control over the machines if they can be shown to be legally compliant, independent from human oversight? According to opponents of fully autonomous LAWS, other non-legal, but equally important considerations—such as human emotion—must also be factored in.[36]

[17] While there is no explicit legal requirement for emotion in the LOAC, Human Rights Watch explains why such concerns should factor into the argument against LAWS:

> Legal and ethical judgment gives people the means to minimize harm; it enables them to make considered decisions based on an understanding of a particular context. As machines, fully autonomous weapons would not be sentient beings capable of feeling compassion. Rather than exercising judgment, such weapons systems would base their actions on pre-programmed algorithms, which do not work well in complex and unpredictable situations.[37]

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[35] *Id.* at 12.

[36] LOSING HUMANITY, *supra* note 17, at 37–39; ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, *supra* note 15, at 9–10.

[37] HUMAN RIGHTS WATCH, HEED THE CALL: A MORAL AND LEGAL IMPERATIVE TO BAN KILLER ROBOTS 2 (2018), https://www.hrw.org/sites/default/files/report_pdf/arms0818_web.pdf [https://perma.cc/WS45-2YUP] [hereinafter IMPERATIVE TO BAN KILLER ROBOTS].

While it is possible to improve the cognitive judgment skills of LAWS with respect to legal analysis, emotional judgment continues to be an irreplicable trait.[38]

[18] The issues of explainability or non-transparency stem from the properties of neural networks used in today's AI and machine learning systems, which are unable to provide a rationale behind their decision-making processes.[39] The reason for this is "the sheer magnitude, millions or billions of parameters (i.e. weights/biases/etc.), which are learned as part of the training of the net . . . . [T]his untransparent mass of coefficients makes it impossible to really understand exactly how the network does what it does."[40] This means that

> [y]ou can't just look inside a deep neural network to see how it works. [The] network's reasoning is embedded in the behavior of thousands of simulated neurons, arranged into dozens or even hundreds of intricately interconnected layers. The neurons in the first layer each receive an input, like the intensity of a pixel in an image, and then perform a calculation before outputting a new signal. These outputs are fed, in a complex web, to the neurons in the next layer, and so on, until an overall output is produced.[41]

Because of this massive decision-making process, it is not possible for programmers to follow along or even teach the system how to provide an

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[38] Camilo Miguel Signorelli, *Can Computers Become Conscious and Overcome Humans?*, FRONTIERS ROBOTICS & AI 1, 2 (2018).

[39] *See* Will Knight, *The Dark Secret at the Heart of AI*, MIT TECH. REV. (Apr. 11, 2017), https://www.technologyreview.com/s/604087/the-dark-secret-at-the-heart-of-ai/ [https://perma.cc/2Y8Y-9VU6].

[40] POTEMBER, *supra* note 28, at 28.

[41] Knight, *supra* note 39.

explanation of its thinking processes.[42] Therefore, the system inherently operates within a black box.[43]

[19] The black box poses a problem for the commanders who deploy LAWS, because "lack of understandability and transparency hinders trust and accountability and undermines the commander's ability to use LAW[S] properly."[44] Because accountability is a critical component to the rule of law, military personnel must be held responsible for the actions of autonomous weapons systems under their supervision.[45] But if there is no way to confidently predict or understand the machine's decision-making processes, it is arguably unfair to hold a commander responsible for LAWS' mistakes.[46]

[20] In conjunction with explainability is the issue of bias—or deviations from a standard—which may be introduced into the system based on the parameters set by programmers during the training of algorithms.[47] Without system transparency, bias is difficult to detect and mistakes can be unpredictable.[48] The United Nations Institute for Disarmament Research (UNIDR) explains this challenge:

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[42] *Id.*

[43] *Id.*

[44] Vazquez, *supra* note 27, at n.73.

[45] *See* Crootof, *supra* note 20, at 1389.

[46] *See* LOSING HUMANITY, *supra* note 17, at 42.

[47] U.N. INST. FOR DISARMAMENT RSCH., ALGORITHMIC BIAS AND THE WEAPONIZATION OF INCREASINGLY AUTONOMOUS TECHNOLOGIES 6 (2018), https://unidir.org/sites/default/files/publication/pdfs/algorithmic-bias-and-the-weaponization-of-increasingly-autonomous-technologies-en-720.pdf [https://perma.cc/N4RQ-LSCV] [hereinafter ALGORITHMIC BIAS].

[48] *Id.* at 2.

> Algorithmic biases potentially present themselves wherever algorithms are used to analyse and filter data to extract information or reach a decision. Often, these biases are imperceptible to the layperson or go unnoticed, lending to the conceptualization that the algorithm is, in fact, an objective, impartial black box that takes unbiased data as input and necessarily outputs the correct response. [49]

In adversarial environments, where there may be "no possibility for appeal or correction" as a result of the mistakes caused by bias, this poses a grave problem.[50] The UNIDR explains that:

> [automatic weapon systems (AWS)] can behave in surprising or unanticipated ways when one or more sources of bias is present. The system might identify unexpected targets, or find surprising routes through the battlespace. . . . [T]hese possibilities raise serious challenges for the development of trust in the expected performance of an AWS. Trust is critically necessary on the battlefield, but surprising behaviour by an autonomous system can impair the development of that trust. Most seriously, some unanticipated behaviour could threaten or violate international humanitarian law in particular contexts. This type of behaviour does not simply harm a military's ability to achieve its objectives, but represents potentially serious legal violations, depending on the nature (and possibly outcome) of the weapon's behaviour. [51]

[49] *Id.* at 6.

[50] *Id.* at 7.

[51] *Id*. at 8–9.

[21] While there are some proposals to mitigate machine bias through increased regulation during the development phase,[52] and human monitoring and intervention during deployment,[53] bias and explainability remain fundamentally technical issues inherent in current AI and machine learning systems. Efforts to mitigate may prove successful for legal compliance, but as noted above, the preferred approach is to address and resolve the problems in the machines themselves.

B. Benefits

[22] Proponents see LAWS as an ideal choice for combat for a number of reasons. Namely, LAWS' judgment is not impeded by physical or mental distractions,[54] their capabilities allow for reduced mistakes and more exact targeting in response to a threat,[55] and they prevent fatalities and injuries by serving in place of humans on the battlefield.[56]

[23] Proponents contend that, absent the emotions of humans, LAWS may perform with a more deliberate focus.[57] Indeed, sometimes it is humans who are the errant decisionmakers due to their susceptibility to non-rational behaviors and their own difficulties in distinguishing a combatant's targetable status or actions.[58] Michael Schmitt and Jeffrey Thurner highlight

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[52] Vazquez, *supra* note 27, at 106.

[53] *Id.* at 104.

[54] *See* Charles P. Trumbull IV, *Autonomous Weapons: How Existing Law Can Regulate Future Weapons*, 34 EMORY INT'L L. REV. 533, 545–46 (2020).

[55] *See* Pike, *supra* note 24.

[56] *See* Schmitt & Thurnher, *supra* note 31, at 264.

[57] CONG. RSCH. SERV., U.S. GROUND FORCES ROBOTICS AND AUTONOMOUS SYSTEMS (RAS) AND ARTIFICIAL INTELLIGENCE (AI): CONSIDERATIONS FOR CONGRESS 34 (2018).

[58] *See* Trumbull, *supra* note 54, at 545–46.

how "human judgment can prove less reliable than technical indicators in the heat of battle"[59] with two examples:

> [D]uring the 1994 friendly fire shootdown of two U.S. Army Blackhawks in the no-fly zone over northern Iraq, the U.S. Air Force F-15s involved made a close visual pass of the targets before engaging them. Pilot error (and human error aboard the AWACs monitoring the situation) contributed to their misidentification as Iraqi military helicopters. Similarly, in 1988 the USS Vincennes engaged an Iranian airliner that it mistakenly believed was conducting an attack on the ship. The warship's computers accurately indicated that the aircraft was ascending. Nevertheless, human error led the crew to believe it was descending in an attack profile and, in order to defend the ship, they shot down the aircraft.[60]

In addition to human error, physical fatigue and mental burnout can also affect the reliability of human judgment.[61] Moreover, emotionally charged decisions such as revenge seeking can be problematic for combatants who are expected to make rational and lawful decisions with respect to their adversaries.[62]

[24] Unlike humans, LAWS are not impaired by personal considerations, thus they compute their doubt values differently.[63] For example, "[a]s with other unmanned systems, [LAWS] are not constrained by the notion of self-preservation. Therefore, the systems could, in some conceivable

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[59] Schmitt & Thurnher, *supra* note 31, at 248.

[60] *Id.* at 248–49.

[61] Ryan J. Vogel, *Drone Warfare and the Law of Armed Conflict*, 39 DENV. J. INT'L L. & POL'Y 101, 123–24 (2010).

[62] Trumbull, *supra* note 54, at 545–46.

[63] Schmitt & Thurnher, *supra* note 31, at 264.

circumstances, be programmed to either hold their fire until being fired upon or essentially sacrifice themselves to 'reveal the presence of a combatant.'"[64] Because LAWS take a different approach in their decision-making processes, issues stemming from doubt, fatigue, mental burnout, emotionally charged decision-making, and self-preservation are eliminated, creating a more focused and dependable decision maker.

[25] A more obvious benefit of LAWS is the increased capacity for speed and precision.[65] Because greater speed and precision can lead to more exact targeting and reduced mistakes when responding to a threat, military commanders have requested this type of technology for use in situations where timing is essential and targeting is difficult, such as when there are "highly mobile vehicles moving on the ground in an urban battlefields with many civilians."[66] This laser-like precision comports with the legal principle of proportionality found in Additional Protocol I, Article 57.2(a)(iii), which states that:

> those who plan or decide upon an attack shall: refrain from deciding to launch any attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated.[67]

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[64] *Id*.

[65] *See Counter-Rocket Artillery Mortar (C-RAM) Intercept Land-Based Phalanx Weapon System (LPWS)*, U.S. ARMY, https://asc.army.mil/web/portfolio-item/ms-c-ram_lpws/ [https://perma.cc/54A5-798M] (explaining how the C-RAM weapons system is able to target incoming rounds based on their parabolic arc—an equation that could never be done in time by humans).

[66] Anderson et al., *supra* note 14, at 390–91.

[67] Additional Protocol I, *supra* note 23, at art. 57.2(a)(iii).

By reducing the number of mistakes and harm to civilians and civilian objects through more exact targeting, LAWS can produce less destructive outcomes for combatants and civilians while providing militaries with increased compliance with the principle of proportionality.

[26] In addition to tactical and legal advantages, LAWS may also reduce the amount of harm sustained by military personnel.[68] The emotional and physical toll of combat weighs heavily on those serving on the front lines, and the trauma and memories can and usually do last a lifetime.[69]

[27] While opponents of LAWS argue that emotions are a necessary component of combat, there are circumstances where reducing or avoiding emotional trauma is beneficial. Once again, conflicting issues such as these make it difficult to come to a broad consensus about the use of LAWS in armed conflict. But at least now there is a choice. In weighing the challenges and benefits of LAWS, it is important to consider whether using humans is ethical or moral given the available alternative, and whether human combat, at least in certain circumstances, be rendered obsolete.[70]

[28] Ultimately, there are clear benefits and challenges to using fully autonomous LAWS in combat. While emotion-based judgment would need to be resolved through non-technological avenues, many of LAWS'

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[68] *See* Masahiro Kurosaki, *Toward the Special Computer Law of Targeting: 'Fully Autonomous' Weapons Systems and the Proportionality Test*, *in* NECESSITY AND PROPORTIONALITY IN INTERNATIONAL PEACE AND SECURITY LAW 1, 18–19 (Claus Kreß & Robert Lawless eds., Oxford Univ. Press 2020).

[69] *See* Christina M. Marini et al., *Psychological Adjustment of Aging Vietnam Veterans: The Role of Social Network Ties in Reengaging with Wartime Memories*, 66 GERONTOLOGY 138, 139–40 (2020); Kim Korinek et al., *Physical and Mental Health Consequences of War-related Stressors Among Older Adults: An Analysis of Posttraumatic Stress Disorder and Arthritis in Northern Vietnamese War Survivors*, 72 GERONTOLOGY 1090, 1091 (2017).

[70] LOSING HUMANITY, *supra* note 17, at 37–39; ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, *supra* note 15, at 9–10.

technological challenges can be addressed through advancements in neuromorphic computing.

III. NEUROMORPHIC COMPUTING

[29] In the field of neuromorphic computing, scientists and technologists are continuously seeking "to create chips that function less like traditional computers and more like the human brain."[71] Several key advantages are realized by using technology that mimics the neural networks of the human brain.[72] Examples of these advantages include energy efficiency and scalability, learning systems that adapt to dynamic environments and process complex data, and systems with more transparent decision-making processes—all in addition to the previously-discussed advantages and benefits provided by conventional AI and machine learning systems.[73]

[30] Neuromorphic neural networks are descendants of first-generation AI, or artificial neural networks (ANNs), which are largely "rules-based and emulate[] classical logic to draw reasoned conclusions within a specific, narrowly defined problem domain."[74] The second-generation of ANNs, known as deep neural networks (DNNs), have achieved superior performance in problem solving based on a more advanced sensory- and perception-based learning process, but their neuron model is still not

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[71] *Intel Scales Neuromorphic Research Systems to 100 Million Neurons*, INTEL NEWSROOM (Mar. 18, 2020), https://newsroom.intel.com/news/intel-scales-neuromorphic-research-system-100-million-neurons/#gs.mddnrd [https://perma.cc/3RVS-GHC2] [hereinafter *Intel*].

[72] DOE ROUNDTABLE, *supra* note 6, at 25.

[73] *Id.*

[74] *Beyond Today's AI New Algorithmic Approaches Emulate the Human Brain's Interactions with the World,* INTEL LABS, https://www.intel.com/content/www/us/en/research/neuromorphic-computing.html [https://perma.cc/A2DB-TNQB] [hereinafter *Beyond Today's AI*].

biologically realistic to its prototype: the brain.[75] Therefore, DNN systems functionally inhibit the cognitive capabilities that a brain is able to achieve, such as interpretation and autonomous adaptation.[76] Spiking neural networks (SNNs) used in neuromorphic computing are the third generation of AI, and are the first to achieve a biologically realistic neuron model.[77]

[31] What sets SNNs apart is the way in which they communicate: through spikes of encoded information.[78] This allows for decisions to be made at points in time and in reaction to circumstances. In other words, the information received and reaction to it are dynamic, where the system can "learn" and adjust to its stimuli. ANNs and DNNs operate in a continuous manner, pursuant to the receipt of input from all of the neurons in one layer, before signaling every neuron in the subsequent layer and so on, eventually

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[75] *Id.*; *see also* DOE ROUNDTABLE, *supra* note 6, at 9 (DNNs have been trained to classify images, detect objects, identify people from faces, generate text from speech, translate natural languages, and many other tasks. For many of these tasks, DNNs have achieved performance that exceeds what humans typically do).

[76] DOE ROUNDTABLE, *supra* note 6, at 13.

[77] *See* Zhixiong Yue, *ANNs, DNNs and SNNs What's the Difference?*, MEDIUM (Nov. 22, 2019), https://medium.com/@yuezhixiong915/anns-dnns-and-snns-6f6fdbd4bb59 [https://perma.cc/3JHW-XPKE].

[78] *See e.g.*, Signorelli, *supra* note 38, at 8. ("Drums can respond with different and complex vibration states when they are stimulated, and they can be also understood on computational terms: input (hits), rules (physical laws, physical constraints such as material, tension, etc.), and outputs (vibration, sounds, normal modes). [T]he brain has many more similarities with [the] dynamical system [of] a drum than with digital computers, which are based on discrete states. Drums, as well as brains, are dynamical systems with emergent and sub-emergent properties, drums have different modes of vibration, superposition, physical memory, [and] sparse "storage" of this memory, among other features."); *see also* Amirhossein Tavanaei et al., *Deep Learning in Spiking Neural Networks*, 111 NEURAL NETWORKS 47 (2019) ("[N]eurons in area V1 detect primary visual features, such as oriented edges…Each V1 neuron is selective to a particular orientation, meaning that when a stimulus with this orientation is presented, only selective neurons to this orientation respond maximally. Representation learning methods, which use neural networks such as autoencoders and sparse coding schemes, learn to discover visual features similar to the receptive field properties found in V1.").

resulting in the computation of the final output.[79] This operation creates a bottleneck problem because:

> [t]raditional computational architectures and their parallel derivatives are based on a core concept known as the von Neumann architecture []. The system is divided into several major, physically separated, rigid functional units such as memory (MU), control processing (CPU), arithmetic/logic (ALU), and data paths. This separation produces a temporal and energetic bottleneck because information has to be shuttled repeatedly between different parts of the system. This "von Neumann" bottleneck limits the future development of revolutionary computational systems. Traditional parallel computers introduce thousands or millions of conventional processors each connected to others. Aggregate computing performance is increased, but the basic computing element is fundamentally the same as that in a serial computer and is similarly limited by this bottleneck.[80]

On the other hand, SNNs operate through event-driven processes that take place at points in time, avoiding the bottleneck issue.[81] Michael Pfeiffer and Thomas Pfeil explain:

> [T]he asynchronous data-driven mode of computing leads to fast propagation of salient information through multiple layers of the network . . . In combination with an event-based sensor, this results in pseudo-simultaneous information

[79] *Id.*

[80] *Id.* at 7.

[81] *See* Devin Soni, *Spiking Neural Networks, the Next Generation of Machine Learning*, TOWARDS DATA SCI. (Jan. 10, 2018), https://towardsdatascience.com/spiking-neural-networks-the-next-generation-of-machine-learning-84e167f4eb2b [https://perma.cc/SU4G-Z86Z].

> processing, which means that a first approximate output of the final layer is available immediately after recording the first input spikes. This is true even for multi-layer networks, because spikes begin to propagate immediately to higher layers as soon as the lower layer provides sufficient activity [].[82]

By avoiding the bottleneck issue, computational efficiency increases and power consumption decreases, resulting in greater overall energy efficiency.[83]

[32] Energy efficiency, in turn, facilitates scalability. More available power can lead to increases in neural capacity, which subsequently increases a computer's ability to accomplish more advanced tasks.[84] Intel Corporation describes the advantage of scalability with regard to its neuromorphic chip and systems:

> In the natural world even some of the smallest living organisms can solve remarkably hard computational problems. Many insects, for example, can visually track objects and navigate and avoid obstacles in real time, despite having brains with well under 1 million neurons. Similarly, Intel's smallest neuromorphic system, Kapoho Bay, comprises two Loihi chips with 262,000 neurons and supports a variety of real-time edge workloads. Intel and INRC researchers have demonstrated the ability for Loihi to recognize gestures in real time, read braille using novel

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[82] Michael Pfeiffer & Thomas Pfeil, *Deep Learning With Spiking Neurons: Opportunities and Challenges*, 12 FRONTIERS NEUROSCI., Oct. 25, 2018, at 1, 3.

[83] *See* Jim Salter, *Brains scale better than CPUs. So Intel is building brains*, ARSTECHNICA (Jul. 16, 2019), https://arstechnica.com/science/2019/07/brains-scale-better-than-cpus-so-intel-is-building-brains/ [https://perma.cc/3PZ8-DG28].

[84] *See Intel*, *supra* note 71.

> artificial skin, orient direction using learned visual landmarks and learn new odor patterns—all while consuming tens of milliwatts of power. These small-scale examples have so far shown excellent scalability, with larger problems running faster and more efficiently on Loihi compared with conventional solutions. This mirrors the scalability of brains found in nature, from insects to human brains.[85]

By mimicking the activity of the brain, SNNs can operate with decreased power consumption, creating space for expansive processing power and facilitating "larger and more sophisticated neuromorphic workloads."[86]

[33] Another advantage of SNNs, when used with neuromorphic hardware, is accelerated, on-chip learning that has the capacity to continuously evolve and solve complex tasks.[87] Because SNNs are analogous to human functions, they can be trained to mimic traits such as interpretation and autonomous adaptation.[88] Recent findings show that tests done on a network using spike-timing-based mechanisms "excel[led] at rapid, online learning with the capacity to generalize beyond experience in novel environments with unpredictable sources of variance."[89] There were, however, conditions where the spike-timing-based system could not outperform traditional systems.[90]

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[85] *Id.*

[86] *Id.*

[87] Pfeiffer & Pfeil, *supra* note 82.

[88] *Beyond Today's AI*, *supra* note 74.

[89] *See* Nabil Imam & Tomas A. Cleland, *Rapid Online Learning and Robust Recall in a Neuromorphic Olfactory Circuit*, 2 NAT. MACH. INTEL. 181–91 (2020).

[90] *See id.*; Salter, *supra* note 83 (explaining why SNNs on the other hand, which operate through event-driven processes that take place at points in time, can avoid the bottleneck issue).

[34] Spike-timing-based systems have also been observed to resist catastrophic forgetting (where all learned information is completely forgotten once new information is learned, making continual learning difficult), a limitation of conventional systems. [91] Taking these factors into account, spike-timing-based systems are "likely to be favored in embedded systems intended for deployment in the wild, where rapid training, energy-efficiency, robustness to unpredictable variance, and the ability to update training with new exemplars are at a premium."[92]

[35] Another well-known limitation of conventional systems is the lack of explainability for their decision-making process, a byproduct of deterministic outputs.[93] By contrast, neuromorphic systems that express their outputs as probabilities can achieve a measure of explainability.[94] The significant benefits of this are that:

> [i]n addition to enabling intuition and prediction in AI, probabilistic methods can also be used to impart a degree of transparency to existing AI recognition systems that tend to operate as a black box. For example, today's Deep Learning engines output a result without a measure of uncertainty. Probabilistic methods can augment such engines to output a principled uncertainty estimate along with the result making it possible for an application to decide the reliability of the prediction. Making uncertainty visible helps to establish trust in the AI system's confidence in decision making.[95]

[91] Imam & Cleland, *supra* note 89.

[92] *Id*.

[93] *Beyond Today's AI*, *supra* note 74.

[94] *Id.*

[95] *Intel Neuromorphic Research Community*, SCI. OF COMPUTING (Oct. 16, 2020), http://www.socomputing.com/sochd/CPU/8.html [https://perma.cc/BX2T-B9DG].

[36] This type of visibility lets programmers and users review the internal workings/decisions made by the system to understand the decision-making rationale.[96] As noted in the above quote, in addition to a more transparent decision-making processes, this algorithmic approach (probabilistic outputs) is also fundamental in dealing with "the uncertainty, ambiguity, and contradiction in the natural world."[97]

[37] Despite all the advantages of neuromorphic computing, practical use is in its infancy. Currently, there are few useful algorithms in existence due to limited effective training methods for SNNs.[98] Similarly, there is not enough specialized neuromorphic hardware that can facilitate SNNs and eliminate the need for conventional training.[99] However, there have been recent advances in both of these areas.[100] Compared to traditional deep learning models, SNNs currently do not perform as accurately in some settings, but this may not be the case for long as the accuracy gap is actively closing. [101]

[38] While neuromorphic computing faces multiple barriers before the technology can move out of the research phase and into production, much time and effort is being channeled into making that happen—from lively

[96] *Beyond Today's AI*, *supra* note 74.

[97] *Id.*

[98] Imam & Cleland, *supra* note 89.

[99] *Beyond Today's AI*, *supra* note 74.

[100] Imam & Cleland, *supra* note 89; *see also* Michael Mayberry, *Intel Creates Neuromorphic Research Community to Advance 'Loihi' Test Chip*, INTEL. NEWSROOM (Mar. 1, 2018), https://newsroom.intel.com/editorials/intel-creates-neuromorphic-research-community/#gs.hfges7 [https://perma.cc/39HC-BATR] (explaining that Intel has created a neuromorphic chip named Loihi and has invited member of the public to collaborate on advancing this area of research).

[101] Amirhossein Tavanaei et al., *Deep Learning in Spiking Neural Networks*, 111 NEURAL NETWORKS 47 (2018).

foosball games to expansive research initiatives.[102] These ongoing innovations will also pave the way for expanded use options, such as in managing combat and effecting legal compliance as a weapon of armed conflict.

IV. CLAWS AND THE LOAC

[39] In order for states to determine the legality of a proposed weapon in armed conflict, the weapon must meet certain criteria established by international and customary law. First, the weapon cannot be one of the weapons expressly prohibited by the LOAC,[103] nor can its intended use be in violation of the principles of the LOAC, such as distinction or proportionality.[104] Second, to ensure compliance with these prohibitions, the weapon is subjected to a weapons review process.[105] Weapons such as CLAWS, which would operate fully autonomously, must further demonstrate a capability to independently comply with the requirements of the LOAC. These legal requirements include the principles of distinction, proportionality, military necessity, and humanity.[106] Each will be evaluated

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102 *Beyond Today's AI*, *supra* note 74.

103 *See, e.g.*, Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction, art. I, *opened for signature* Jan. 13, 1993, 112 U.S.T. 2681, 1974 U.N.T.S. 45 (stating that chemical weapons are explicitly banned).

104 Additional Protocol I, *supra* note 23, at art. 35(2) ("It is prohibited to employ weapons, projectiles and material and methods of warfare of a nature to cause superfluous injury or unnecessary suffering."); Schmitt & Thurnher, *supra* note 31, at 244–45 (stating "[Article 35(2)] irrefutably reflects customary international law and, therefore, the norm binds even States that are not Party to the Protocol, such as the United States").

105 *See* Additional Protocol I, *supra* note 23, at art. 36.

106 *See id.* at art. 48, 51(5)(b); DOE ROUNDTABLE, *supra* note 6, at 7, 14; U.S. DEP'T OF DEF., DEPARTMENT OF DEFENSE LAW OF WAR MANUAL § 2.3 (2016) [hereinafter DOD MANUAL].

with regard to CLAWS; however, the weapons review process and accountability concerns will be addressed first.

A. Weapons Review

[40] Article 36 of Additional Protocol I states:

> [i]n the study, development, acquisition or adoption of a new weapon, means or method 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.[107]

This weapons review requirement is largely accepted as a straightforward mechanism to ensure legally compliant weapons,[108] and similar weapons review obligations have been adopted by states, including the United States, who are not party to the protocol.[109]

[41] In the scope of a weapons review, legality is predicated on three rules.[110] First, the weapon, or the "use for which it was designed or intended," cannot be indiscriminate by nature.[111] Second, the weapon

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[107] *See* Additional Protocol I, *supra* note 23, at art. 36.

[108] Schmitt & Thurnher, *supra* note 31, at 271 ("While some commentators suggest that a disagreement exists as to whether Article 36 restates customary international law, the obligation to conduct legal reviews of new means of warfare before their use is generally considered, and correctly so, reflective of customary international law. Consensus is lacking as to whether an analogous requirement exists to perform legal reviews of new *methods* of warfare.").

[109] *See* U.S. DEP'T OF DEF., DOD DIR. 5000.01, THE DEFENSE ACQUISITION SYSTEM 9 (2020).

[110] Anderson et al., *supra* note 14, at 399.

[111] *Id.* at 399, n.30.

cannot be "of a nature" to cause "unnecessary suffering or superfluous injury."[112] Third, "a weapon system can be deemed illegal per se if the harmful effects of the weapon are not capable of being 'controlled.'"[113] With regard to the effect of these rules on autonomous weapon systems, Kenneth Anderson, Daniel Reisner, and Matthew Waxman note that

> [n]one of these rules renders a weapon system illegal per se solely on account of it being autonomous. If a fully autonomous weapon system were supplied with sufficiently reliable parameters and it were able to act on them so as to be able to strike specific targets on the same legal terms of discrimination that would apply to a human soldier, that the weapon system was "autonomous" would not violate the "indiscriminate by nature" rule. Although some might view an autonomous weapon system as "uncontrollable," its *effects* are not uncontrollable within the meaning of the legal provision. [114]

On this point, Schmitt and Thurnher note that "[t]he sole context in a determination of whether the weapon is lawful per se is its intended, not possible, use."[115] They explain further:

[112] *Id.* at 400 (quoting Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I) art. 35(2), June 8, 1977, 1125 U.N.T.S 3.).

[113] *Id.* at 400, n.36 ("Because the rule concerns 'effects,' the claim that some might make is that autonomous weapon systems are 'uncontrollable' because for a weapon system equipped with sophisticated probabilistic programming not every decision taken by the machine would be predictable in advance, thus would be by definition uncontrolled. But apart from other aspects of control of the machine, uses and operations, the rule is about effects that cannot be uncontrolled, not an uncontrolled weapon.").

[114] *Id.* at 400–01.

[115] Schmitt & Thurnher, *supra* note 31, at 273.

> The primary intent of the legal review is to determine whether a weapon itself is unlawful under international law. Given the technological advances likely to be embedded in autonomous weapons, this straightforward task may be challenging. Lawyers conducting the reviews will need to work closely with computer scientists and engineers to obtain a better appreciation for the measures of reliability and the testing and validation methods used on the weapons. While significant, these challenges are substantively similar to those facing reviewers of other complicated, modern weapon systems, which are routinely being conducted without fanfare or criticism.[116]

Therefore, CLAWS would be evaluated on intended use, with investigators flagging any challenges that would prevent lawful implementation.[117]

[42] Two challenges that could make a weapons review difficult are the issues of explainability and bias. Major Annemarie Vazquez reports that:

> LAW[S] are characterized by their software, which receives no scrutiny under the current weapons review process. Even if it did, the gates for weapons reviews occur so late in the acquisition process that any LOAC issues arising during design would long have been set and obscured within a [lethal autonomous weapon's] algorithmic black box . . . The greatest obstacles to fielding LAW[S] is the inability to test and evaluate them because combat presents near-infinite possibilities for LAW[S]' decision-making. The black box problem means we cannot know how a learner's model makes decisions, what biases may be trained into the model,

[116] *Id.*

[117] *Id.*

> how it set about achieving its goals, how the built-in parameters affected its decision-making, and so on.[118]

While the level of scrutiny a systems' software receives during a review is not always ascertainable, as states are "not obliged to make their reviews available to others,"[119] the black box problem could be resolvable with neuromorphic computing. Specifically, CLAWS' decision-making uncertainty would be visible because of its principled uncertainty estimate.[120] Reviewers would then have access to the system's rationale and decision-making processes, which could be assessed for any problems that may affect a system's reliability.[121] This estimate could also provide helpful information for catching and addressing bias.

[43] The act of reviewing weapons for legal compliance highlights the importance of trust-building among states and demonstrates a mutual willingness to ensure that prohibited weapons are not used in armed conflict. By having access to CLAWS' decision-making process, increased transparency would provide a greater level of prediction and assurance in knowing that they are operating lawfully and for their intended purpose.

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[118] Vazquez, *supra* note 27, at 110–11.

[119] *Article 36 Reviews and Addressing Lethal Autonomous Weapons Systems: Briefing Paper for Delegates at the Convention on Certain Conventional Weapons (CCW) Meeting of Experts on Lethal Autonomous Weapons Systems (LAWS)*, ARTICLE 36 1, 2 (Apr. 2016), https://article36.org/wp-content/uploads/2016/04/LAWS-and-A36.pdf [https://perma.cc/63XL-J8M5].

[120] *Beyond Today's AI*, *supra* note 74.

[121] *See id.*

B. Accountability

[44] Article 57.2(a) of Additional Protocol I to the Geneva Conventions states that responsibility lies with "those who plan or decide upon an attack."[122] On this point, Eric Talbot Jensen notes that

> [t]he responsibility falls not only to those who execute the attacks (including an autonomous weapons system), but also to those in "higher commands" such as the local, operational, and strategic military commanders who will employ those weapons systems on the battlefield, and those in the research, production, review, and approval processes.[123]

Therefore, individuals planning or deciding upon an attack includes "those at all levels of command and decisionmaking" and, in the case of autonomous weapons, would particularly include "those who order autonomous weapons systems into battle." [124]

[45] Because higher commands would assume liability for any violations of the LOAC brought about by CLAWS, it is critical that they understand and have confidence in the system's decision-making process. The United States' delegation of governmental experts on LAWS has stated that:

> [c]ommanders must authorize the use of lethal force against an authorized targeted military objective. That authorization is made within the bounds established by the rules of engagement (ROE) and international humanitarian law (IHL) based on the commander's understanding of the tactical situation informed by his or her training and experience, the weapon system's performance informed by

[122] Additional Protocol I, *supra* note 23, at art. 57.2(a).

[123] Jensen, *supra* note 22, at 592–93.

[124] *Id.*

> extensive weapons testing, as well as operational experience and employment of tactics, techniques, and procedures for that weapon. In all cases, the commander is accountable and has the responsibility for authorizing weapon release in accordance with IHL. Humans do and must play a role in authorizing the use of lethal force.[125]

While this view holds commanders responsible for an attack, the decision-making process ultimately includes input from the autonomous weapons systems as well. Because CLAWS could be capable of providing the rationale behind their decisions, commanders and other decision makers can be kept in the "decision-making loop" and have an increased confidence in the competence and predictability of their weapons systems.[126] Transparency will serve a vital role for accountability requirements and will

[125] John Cherry & Christopher Korpela, *Enhanced Distinction: The Need for a More Focused Autonomous Weapons Targeting Discussion at the LAWS GGE*, HUMANITARIAN L. & POL'Y BLOG (Mar. 28, 2019), https://blogs.icrc.org/law-and-policy/2019/03/28/enhanced-distinction-need-focused-autonomous-weapons-targeting/ [https://perma.cc/BXU7-GR3J].

[126] Christof Heyns, *A Human Rights Perspective on Autonomous Weapons in Armed Conflict: The Rights to Life and Dignity*, *in* LETHAL AUTONOMOUS WEAPONS SYS. 1, 154 (Robin Geiß ed., 2017) https://www.auswaertiges-amt.de/blob/610608/5f26c2e0826db0d000072441fdeaa8ba/abruestung-laws-data.pdf [https://perma.cc/V7LG-48GU]; *see also* Judith Lamont, *Cognitive Computing: Is Neuromorphic AI the Next Big Thing?*, KNOWLEDGE MGMT. WORLD (May 1, 2018), https://www.kmworld.com/Articles/Editorial/Features/COGNITIVE-COMPUTING-Is-neuromorphic-AI-the-next-big-thing--124571.aspx [https://perma.cc/D35Q-5YWB] ("Another distinction from traditional neural networks is that the path to the conclusion is transparent. 'It is possible to see each node that is activated and each one that is inhibited, so the developer can provide the user with the "why" behind an answer,' [Jana] Eggers, explains. 'Unlike the black boxes of most deep learning systems, our synaptic network provides a rationale about the logic driving each possible answer. . . . The program produces the results and the developer chooses how to display the information.").

subsequently provide a greater assurance of fairness when adjudicating alleged violations.[127]

C. Context-Specific Judgments

[46] The foundational targeting principles of the LOAC require actors to make context-specific judgments based on a variety of factors meant to protect civilians and civilian objects, and in certain circumstances, combatants as well. These principles include distinction, proportionality, military necessity, and humanity.[128] Each will be analyzed with respect to CLAWS.

1. Distinction

[47] Article 48 of Additional Protocol I states that "[i]n order to ensure respect for and protection of the civilian population and civilian objects, the Parties to the conflict shall at all times distinguish between the civilian population and combatants and between civilian objects and military objectives and accordingly shall direct their operations only against military objectives."[129] In practice, this legal principle obligates combatants to distinguish military objectives from civilian objectives even in places such as "urban battlefield environments in which civilians and combatants are commingled."[130] Whether the decision to act is made by a human or an autonomous weapons system, both must have the capability to adapt to any number of changing variables and continuously reassess and distinguish lawful from unlawful objectives.

[127] *See* Hannah Bloch-Wehba, *Transparency's AI Problem*, KNIGHT FIRST AMEND. INST. (June 17, 2021), https://knightcolumbia.org/content/transparencys-ai-problem [https://perma.cc/EJR8-JEVG].

[128] *See* Additional Protocol I, supra note 23, at art. 48, 51(5)(b); DOE ROUNDTABLE, *supra* note 6, at 7, 14; DOD MANUAL, *supra* note 106, at § 2.3.

[129] Additional Protocol I, supra note 23, at art. 48.

[130] Anderson et al., *supra* note 14, at 402.

[48] Major Vazquez explains that, "[f]or LAW[S], interpreting body language and context pose significant hurdles, though not insurmountable. Yet, to be used lawfully, a commander must reasonably believe that a LAW can distinguish between correct and incorrect targets and behave predictably even when circumstances change after the LAW's mission commences."[131]

[49] LAWS can also be tricked into errantly engaging unlawful objectives through adversarial attacks (manipulated images designed to trick computer vision into making mistakes), which can pose additional challenges for a correct application of distinction requirements.[132] The ICRC notes that

> [t]he use of AI and machine learning in armed conflict will likely be even more difficult to trust in situations where it can be assumed adversaries will apply countermeasures such as trying to trick or spoof each other's systems. Machine-learning systems are particularly vulnerable to adversarial conditions, whether modifications to the environment designed to fool the system or the use of another machine-learning system to produce adversarial images or conditions (a generative adversarial network, or GAN).[133]

In sum, not only is there concern that autonomous weapons systems would have difficulty in distinguishing between civilians and combatants, particularly where the facts are not overtly apparent, there is also concern that countermeasures could cause computer vision to make mistakes in distinguishing between lawful and unlawful objectives.[134]

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[131] Vazquez, *supra* note 27, at 104–05.

[132] *See* Gamaleldin F. Elsayed et al., *Adversarial Examples That Fool Both Computer Vision and Time-Limited Humans*, ADVANCES NEURAL INFO. PROCESSING SYS. 1, 9–10 (2018), https://arxiv.org/abs/1802.08195 [https://perma.cc/RKT7-5DV2].

[133] ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, *supra* note 15, at 11.

[134] *Id.*

[50] Because neuromorphic systems include accelerated on-chip learning, they can interpret the features extracted from images, perceive and analyze multi-faceted situations during an attack, and adapt behavior based on the information gathered.[135] This capability is especially practical in today's unique battlefield environments, where situations are constantly changing, and new information must be continuously reassessed when distinguishing between combatants and civilians.[136]

[51] Furthermore, researchers have discovered that upgraded neuromorphic chips may be resistant to adversarial attacks.[137] While it is unlikely that CLAWS would be fully immune to adversarial attacks, humans are not fully immune to them either.[138] Despite no guarantee of total precision or perfection, CLAWS could still meet the threshold of compliance with the LOAC.[139] Indeed, the LOAC does not require a standard of perfection, rather, the rules are based on a standard of reasonableness.[140] Therefore, CLAWS' analytical capabilities, when combined with the benefits of decision-making transparency, could provide greater assurance to commanders that these weapons systems not only

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[135] *See* DOE ROUNDTABLE, *supra* note 6, at 14.

[136] *See The Future Battlefield Is Digital*, BOOZ ALLEN HAMILTON, https://www.boozallen.com/d/insight/thought-leadership/the-future-battlefield-is-digital.html [https://perma.cc/6GHP-W6UH].

[137] Evan Ackerman, *Hacking the Brain with Adversarial Images*, IEEE SPECTRUM (Feb. 28, 2018), https://spectrum.ieee.org/the-human-os/artificial-intelligence/machine-learning/hacking-the-brain-with-adversarial-images [https://perma.cc/A7W4-ULXV].

[138] *Id.*

[139] Schmitt & Thurnher, *supra* note 31, at 257.

[140] *Id.* ("While autonomous weapon systems would likely not be able to account for all imaginable scenarios and variables that might present themselves during hostilities, the same is true of a human confronted with unexpected or confusing events who must nonetheless make a time sensitive decision in combat. Neither the human nor the machine is held to a standard of perfection; in the law of armed conflict the standard is always one of reasonableness.").

understand the legal parameters of distinction, but that they can also effect these requirements as well.

2. Proportionality

[52] Articles 51(5)(b) and 57(2)(a)(iii) of Additional Protocol I prohibit "[any] attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated."[141] Again, compliance with the principle of proportionality is based on a reasonableness calculation, which in this case requires a reasonable evaluation of both expected collateral damage and anticipated military advantage.[142]

[53] One of the key distinctions between CLAWS and LAWS is the capacity for CLAWS to adapt to changing circumstances.[143] This is possible because of CLAWS' neuromorphic architecture, which allows circuits to "learn"[144] and then selects and improves upon the most efficient and reliable computations.[145] In other words, the decision-making capabilities that set CLAWS apart from LAWS are similar to the manner in which a biological

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[141] Additional Protocol I, *supra* note 23, art. 51(5)(b), 57(2)(a)(iii).

[142] Schmitt & Thurnher, *supra* note 31, at 254.

[143] DOE ROUNDTABLE, *supra* note 6, at 7.

[144] *Id.* at 14 ("A conventional device has a unique response to a particular stimulus or input. In contrast, the typical neuromorphic architecture relies on changing the properties of an element or device depending on the past history. Plasticity is a key property that allows the complex neuromorphic circuits to be modified ('learn') as they are exposed to different signals.").

[145] *Id.* ("Biological brains generally start with multiple connections out of which, through a selection or learning process, some are chosen and others abandoned. This process may be important for improving the fault tolerance of individual devices as well as for selecting the most efficient computational path. In contrast, in conventional computing the system architecture is rigid and fixed from the beginning.").

brain processes information.[146] These skills are particularly relevant for subjective determinations of expected collateral damage and anticipated military advantage in battlefield environments.[147]

[54] This complex decision-making capability is critical for CLAWS to meet not only distinction and proportionality requirements, but also "feasible precautions" requirements. Article 57 of Additional Protocol I obligates states to "take all feasible precautions in the choice of means and methods of attack with a view to avoiding, and in any event to minimizing, incidental loss of civilian life, injury to civilians and damage to civilian objects."[148] This requirement also demands context-specific judgments, based on available information, in order to protect civilians and civilian objects. Opponents of LAWS argue that judgments such as these must be made by human operators due to the unique and complex conditions of battlefield environments.[149] However, Jensen points out that human operators are not the essential component for compliance with the LOAC principles, rather the "rules prescribe a particular analysis that must be completed. That analysis is one, which, in the future, may be done just as effectively (if not more effectively) by weapons systems using autonomous functions."[150]

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[146] *Id.*

[147] *See generally* Moore, *supra* note 1 (highlighting CLAWS could collect and analyze data in a fraction of the time that a human could while still applying human-like judgment to that data when making proportionality decisions.).

[148] Additional Protocol I, *supra* note 23, at art. 57.2(a)(ii).

[149] *See The Threat of Fully Autonomous Weapons*, CAMPAIGN TO STOP KILLER ROBOTS, https://www.stopkillerrobots.org/learn/ [https://perma.cc/6EZ5-SAYH] ("Fully autonomous weapons would lack the human judgment necessary to evaluate the proportionality of an attack, distinguish civilian from combatant, and abide by other core principles of the laws of war.").

[150] Jensen, *supra* note 22, at 578.

[55] While opponents of LAWS have argued that the requisite analytical skills for determining proportionality and precautionary measures is beyond the capabilities of autonomous weapon systems,[151] these capabilities could be realized by CLAWS. Because CLAWS could assess information and modify behavior based on new and changing situations, these weapons systems would have the necessary judgment skills to comply with the principle of proportionality and the obligation to take feasible precautions.[152] Therefore, CLAWS could be eligible to independently conduct proportional and precautionary analyses and take reasonable measures based on those analyses.

3. Military Necessity

[56] The principle of military necessity requires that an attack and any harm caused to civilians or civilian property be weighed against any justification of "measures needed to defeat the enemy as quickly and efficiently as possible[,]" as long as those measures are not prohibited by the law of war.[153] Not only does this principle entail context-specific judgments similar to the requirements of distinction and proportionality, but it also entails "value-based" judgments when determining the value of an attack.[154]

[57] Critics of LAWS have contended that "[f]ully autonomous weapons are unlikely to be any better at establishing military necessity than they are proportionality."[155] However, CLAWS could make myriad difficult and

[151] *See* LOSING HUMANITY, *supra* note 16, at 33.

[152] *See* DOE ROUNDTABLE, *supra* note 6, at 7, 14; Jensen, *supra* note 22, at 578.

[153] DOD MANUAL, *supra* note 106, at § 2.2.

[154] *See* LOSING HUMANITY, *supra* note 16, at 33.

[155] *Id.* at 35.

context-specific judgments with regard to weighing consequences.[156] Critics further contend that the value-based considerations unique to military necessity demand human judgment.[157] As noted earlier, compliance with the LOAC is not based on human judgment, but on analytical requirements.[158] Because CLAWS can make reasonable determinations as to whether the objective of an attack is worth the expected level of damage, CLAWS could be capable of analyzing military necessity.

4. Humanity

[58] The principle of humanity is a foundational principle of the LOAC that "forbids the infliction of suffering, injury, or destruction unnecessary to accomplish a legitimate military purpose."[159] The ICRC has stated that LAWS, as "inanimate objects and tools for use by humans . . . 'will never be able to bring a genuine humanity to their interactions, no matter how good they get at faking it.'"[160] On this point (and noted earlier), Human Rights Watch states:

> [d]ue to their lack of emotion and legal and ethical judgment, fully autonomous weapons would face significant obstacles in complying with the principles of humanity. Those principles require the humane treatment of others and respect for human life and human dignity. Humans are motivated to treat each other humanely because they feel compassion and empathy for their fellow humans. Legal and ethical judgment gives people the means to minimize harm; it enables them to make considered decisions based on an

156 ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, *supra* note 15, at 12.

157 *Id.*

158 Jensen, *supra* note 22, at 578.

159 DOD MANUAL, *supra* note 106, at § 2.3.

160 ICRC, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, *supra* note 14, at 10.

> understanding of a particular context. As machines, fully autonomous weapons would not be sentient beings capable of feeling compassion. Rather than exercising judgment, such weapons systems would base their actions on pre-programmed algorithms, which do not work well in complex and unpredictable situations.[161]

As CLAWS could be capable of making context-specific decisions regarding unnecessary suffering, injury, or destruction, any decision made by CLAWS regarding the principle of humanity would be evaluated for efficacy based on a standard of reasonableness.[162] Nevertheless, neuromorphic processes are not purported to replicate human emotion.[163] While human emotion is not a legal requirement for armed conflict, it is a driver of it, and is therefore a salient point of discussion.

[59] If the ICRC, Human Rights Watch, and other opponents of LAWS are trying to prevent armed conflict from being "dominated"[164] by unfeeling machines to preserve a measure of humanity in combat, their focus on the right type of weapon should be balanced with a focus on the humans deploying these autonomous machines. Paul Scharre writes, "[e]ven the most thoughtful regulations or prohibitions will not be able to foresee all of the ways that autonomous weapons could evolve over time. An alternative approach would be to focus on the unchanging element in war: the human."[165] He continues:

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[161] IMPERATIVE TO BAN KILLER ROBOTS, *supra* note 37, at 2.

[162] *See* Schmitt & Thurnher, *supra* note 31, at 257.

[163] Signorelli, *supra* note 38, at 6.

[164] *See* LOSING HUMANITY, *supra* note 16, at 35.

[165] Paul Scare, *Human Judgement and Lethal Decision-Making in War*, HUMANITARIAN L. & POL'Y BLOG (Apr. 11, 2018), https://blogs.icrc.org/law-and-policy/2018/04/11/human-judgment-lethal-decision-making-war/ [https://perma.cc/VC3M-KC9A].

> [t]here has been growing interest in recent years in focusing on the role of the human in war. This concept is expressed in different ways, with various parties using terms like 'meaningful human control', 'appropriate human judgment,' or 'appropriate human involvement'. While these terms are not yet defined, they suggest broad agreement that there is some irreducible role for humans in lethal force decisions on the battlefield.[166]

While emotions such as compassion are indicative of ideal human behavior, the overarching problem with arguing for meaningful human control in combat is the assumption that the military personnel charged with deploying autonomous weapons systems, or those who serve on the battlefield themselves, have the personality traits necessary to exercise such behavior. Humanness is not a guarantee for humane behavior.

[60] Currently, it is unclear whether militaries intentionally recruit service members based on their emotional capacities such as those that the ICRC and Human Rights Watch envision being relevant to armed conflict.[167] Although not required, militaries' good-faith efforts to vet and promote candidates who can intelligently apply appropriate emotion at the appropriate times could significantly enhance trust among members of the

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[166] *Id.*

[167] *See, e.g.*, Ram Charan, *Six Personality Traits of a Leader*, MILITARY.COM NETWORK, https://www.military.com/veteran-jobs/career-advice/on-the-job/6-traits-for-improved-leadership-skills.html [https://perma.cc/GZ84-7YVX] (discussing unofficial preferred personality traits of an ideal recruit, including ambition, self-confidence, integrity, and intellect); Thomas Oppong, *10 Leadership Traits Learned in the Military That Apply in the Business World*, ALLTOPSTARTUPS (Apr. 21, 2017), https://alltopstartups.com/2017/04/21/10-leadership-traits-learned-in-the-military-that-apply-in-the-business-world/ [https://perma.cc/9NJ5-UP9M]; Edie Rogers, *6 Traits of Top Military Officers (and Why the Army Comes to UNG to Find Them)*, UNIV. N. GA. (Mar. 30, 2015), https://ung.edu/news/articles/2014/03/6-traits-of-top-military-officers-.php [https://perma.cc/D7TN-TTNL].

international community by alleviating concerns over the moral and ethical decision-making role that humans will play in the future.[168]

[61] While CLAWS may "never be capable of embodying human conscience or ethical values,"[169] CLAWS would likely not be prohibited from armed conflict based on a lack of these traits. The principle of humanity does not explicitly require human emotion, but rather reasonable considerations that seek to prevent suffering, injury, or destruction unnecessary to the accomplishment of legitimate military needs. In sum, the targeting principles of the LOAC and international law all play an important role in protecting civilians and civilian objects during armed conflict, and CLAWS may demonstrate compliance with the demands of each.

V. CONCLUSION

[62] Armed conflict is on the brink of reformation. With the coming advancements in neuromorphic computing, the combined power of biologically-inspired cognitive processes and qualified technology will make possible a whole new world of rational, subjective thought and exacting performance on the battlefield. Weapons systems that use neuromorphic technology, such as CLAWS, could soon be capable of selecting and engaging targets using human-like discretion. Consequently, this enhanced capacity could resolve concerns among members of the international community who have objected to LAWS and their potential

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[168] *See* Heather A. Harrison Dinniss & Jann K. Kleffner, *Soldier 2.0: Military Human Enhancement and International Law*, 92 INT'L L. STUD. 432, 445, 482 (2016) ("The obvious difficulty would be ensuring that soldiers are trained to identify compliance with the law as the morally correct course of action, in contrast to increasing the sense of empathy. . . which may result in soldiers unfit for combat. . . The law of armed conflict allows soldiers to kill an enemy at one moment and obliges them to offer compassion and humane treatment in the next when that same enemy is not killed but is wounded or captured.")

[169] *Autonomous Weapons: States Must Agree on What Human Control Means in Practice*, INT'L. COMM. RED CROSS (Nov. 20 2018), https://www.icrc.org/en/document/autonomous-weapons-states-must-agree-what-human-control-means-practice [https://perma.cc/377U-DPJ4].

inability to lawfully select and engage targets without human involvement. This wave of change can also serve as a catalyst for revolutionizing military procedure by bringing attention to hiring practices and the reexamination of desired traits among military recruits, which could also alleviate concerns about the preservation of ethical and moral judgment in combat. Ultimately, by effecting human-like judgment and providing highly technical accuracy, CLAWS' capabilities will likely surpass both its human and machine predecessors in combat, resulting in a heretofore unseen faithfulness to the LOAC.