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The Gathering Swarm: The Path to Increasingly Autonomous Weapons Systems

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THE GATHERING SWARM: THE PATH TO INCREASINGLY AUTONOMOUS WEAPONS SYSTEMS

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ABSTRACT: Unbeknownst to many, Lethal Autonomous Weapons (LAWS) have existed for decades, but they have largely been defensive and anti-material. However, as increasingly advanced defensive LAWS, such as complex swarming systems, become more prominent, states will assuredly develop ways to counter, including offensive LAWS. Certainly, the near-term developmental focus of such systems will be on operational environments in which there are relatively low risk of injury or death to civilians or untoward incidents in general, but it is a matter of when, not if, these systems will be widely used in direct combat situations. As such, LAWS are a frequent topic of debate among states and human rights organizations with many viewing LAWS as killer robots that should be banned indefinitely. But as autonomy increases in civil society, particularly through applications with life or death consequences, like driverless cars and robotic surgery, the public's perception of risk and human/machine interaction will likely change. Whether that attitude change will translate to widespread acceptance, or indifference, of LAWS is yet to be known. Ultimately, this article explores the developmental history and trajectory of defensive and offensive LAWS in all areas of the military, and seeks to explain why an outright ban is unlikely.

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> If we go on waiting upon events, how much shall we throw away of resources now available for our security and the maintenance of peace? How many friends will be alienated, how many potential allies shall we see go one by one down the grisly gulf? How many times will bluff succeed until behind bluff ever-gathering forces have accumulated reality?
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> —Winston S. Churchill[1]

In December 2016, the States Parties to the Convention on Certain Conventional Weapons (CCW)[2] agreed to continue and formalize discussions on weapons systems that are capable of selecting and engaging targets without further human intervention, otherwise known as lethal autonomous weapons (LAWS).[3] As a result, a Group of Governmental Experts (GGE) will meet in 2017 to "explore and agree on possible recommendations on options related to emerging technologies in the area of LAWS."[4] The Campaign to Stop Killer Robots, an

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1. 1 WINSTON S. CHURCHILL, THE SECOND WORLD WAR: THE GATHERING STORM 272 (1948). In *The Gathering Storm*, Churchill describes how conflict resolution attempted after World War I played a part in causing World War II. The title and theme of the Churchill book serve as inspirations for this article.

2. As of March 2, 2017, there are 123 States Parties to the CCW, *see* Fifth Review Conference of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects, *Final Document of the Fifth Review Conference*, 12, U.N. Doc. CCW/CONF.V/10 (Dec. 23, 2016) [hereinafter Fifth Review CCW], the purpose of which is "to ban or restrict the use of specific types of weapons that are considered to cause unnecessary or unjustifiable suffering to combatants or to affect civilians indiscriminately." *The Convention on Certain Conventional Weapons*, U.N. OFF. FOR DISARMAMENT AFF., https://www.un.org/disarmament/geneva/ccw/ (last visited June 16, 2017). States are parties to the CCW, and the treaty body operates by consensus, meaning that any one country may block all action. There are currently five protocols to the CCW as noted below.

I. Non-Detectable Fragments

II. Mines, Booby Traps & Other Devices

III. Incendiary Weapons

IV. Blinding Laser Weapons

V. Explosive Remnants of War

Id. Proponents of a ban on LAWS would have that as the sixth protocol.

3. *See* Fifth Review CCW, *supra* note 2, at 9. On the definition of LAWS, see Christof Heyns, *Rep. of the Special Rapporteur on Extrajudicial, Summary or Arbitrary Executions*, ¶ 38, U.N. Doc. A/HRC/23/47 (Apr. 9, 2013), a report describing the definition as "widely used" and "endorsed inter alia by both the United States Department of Defense and Human Rights Watch."

4. Michael Biontino, Chair, Informal Meeting of Experts, *Recommendations to the 2016 Review Conference*, ¶ 3, http://www.unog.ch/80256EDD006B8954/(httpAssets)/6BB8A498B0A12A03C1257FDB00382863/$file/Recommendations_LAWS_2016_AdvancedVersion+(4+paras)+.pdf (last visited June 29, 2017). Currently, a GGE session will be held in November 2017, which will be different than previous CCW LAWS meetings. *2017 Group of Governmental Experts on Lethal Autonomous Weapons Systems (LAWS)*, UNOG, http://www.unog.ch/80256EE600585943/(httpPages)/F027DAA4966EB9C7C12580CD0039D7B5?OpenDocument (last visited July 19, 2017); *see also Formal Talks Should Lead to Killer Robots Ban*, CAMPAIGN TO STOP KILLER ROBOTS (Dec. 16, 2016), https://www.stopkillerrobots.org/2016/12/formal-talks/ [hereinafter *Formal Talks*]. Previous CCW LAWS meetings were considered informal and the experts were not affiliated with a state

international coalition,[5] claims that the upcoming GGE meetings should lead to a LAWS ban,[6] and Human Rights Watch (HRW) asserts that such a prohibition is now "firmly within reach."[7] By exploring and predicting the developmental path of LAWS, this article explains why a ban is increasingly unlikely.

The CCW LAWS discussion began in 2013 when the States Parties agreed that LAWS were within the treaty's mandate.[8] Between 2014 and 2016, annual informal experts' meetings were held, but failed to generate consensus on anything other than that additional discussions were warranted. That the international community is not able to reach consensus on an issue is not particularly surprising. What is surprising is that with LAWS there is not even agreement as to scope of the discussion. This was exemplified at the 2016 experts meeting. A representative from HRW claimed that there was a "common understanding in the room," and that they were "talking about future weapons systems that . . . will be able to select and engage targets on their own."[9] A short time later, the International Committee of the Red Cross (ICRC) delivered remarks, contending that "[s]ome weapon systems in use today can select and attack targets without human intervention."[10] That prominent organizations like the ICRC and HRW do not agree on whether the LAWS discussion includes extant or only

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party. *Formal Talks*, *supra*. In contrast, the GGE will be formal and feature experts who are part of a state party delegation, though the sessions will also be open to non-state parties such as international and nongovernmental organizations. *Id.*

5. *Who We Are*, CAMPAIGN TO STOP KILLER ROBOTS, https://www.stopkillerrobots.org/coalition (last visited June 4, 2017). The Campaign "is a global coalition of 63 international, regional, and national non-governmental organizations . . . that calls for a preemptive ban on fully autonomous weapons." *Id.*

6. *Formal Talks Should Lead to Killer Robots Ban*, *supra* note 4.

7. Mary Wareham, *Banning Killer Robots in 2017*, HUM. RTS. WATCH (Jan. 15, 2017, 12:00 AM), https://www.hrw.org/news/2017/01/15/banning-killer-robots-2017.

8. *See* Meeting of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects, *Consideration and Adoption of the Final Report*, ¶ 32, U.N. Doc. CCW/MSP/2013/10 (Dec. 16, 2013).

9. Stephen Goose, Human Rights Watch, Statement at the General Exchange of Views during the Informal Meeting of Experts on Lethal Autonomous Weapons Systems, Convention on Conventional Weapons (Apr. 12, 2016), http://www.unog.ch/80256EDD006B8954/(http%20Assets)/252007F8C3EB3E1EC1257FAE002F4DE5/$file/HRW+intervention+Goose+12+April+2016.pdf.

10. Convention on Certain Conventional Weapons, *Statement of the ICRC: Autonomous Weapons; Decisions to Kill and Destroy Are a Human Responsibility*, INT'L COMM. RED CROSS, (Apr. 11, 2016), https://www.icrc.org/en/document/statement-icrc-lethal-autonomous-weapons-systems; *see also* INT'L COMM. OF THE RED CROSS, AUTONOMOUS WEAPON SYSTEMS TECHNICAL MILITARY, LEGAL, AND HUMANITARIAN ASPECTS 65–69 (2014), https://www.icrc.org/en/document/report-icrc-meeting-autonomous-weapon-systems-26-28-march-2014 (noting that the vast majority of these weapons systems are designed to target material aircraft, vessels at sea, and inbound missiles).

Paul Scharre and Michael Horowitz, in a 2015 working paper, listed sixteen "[s]elected [e]xamples of [h]uman-[s]upervised [a]utonomous [w]eapon [s]ystems." Paul Scharre & Michael Horowitz, An Introduction to Autonomy in Weapon Systems 21–23 app. B (Feb. 2015) (working paper), https://www.cnas.org/publications/reports/an-introduction-to-autonomy-in-weapon-systems [https://perma.cc/5W84-J4SH]. Other estimates are that "[a]s many as 40 nations are currently developing military robotics" and "[s]ome weapons already in use may be considered 'autonomous.'" Steven Groves, *The U.S. Should Oppose the U.N.'s Attempt to Ban Autonomous Weapons*, Heritage Found. (Mar. 5, 2015), http://www.heritage.org/research/reports/2015/03/the-us-should-oppose-the-uns-attempt-to-ban-autonomous-weapons [https://perma.cc/R5M9-RTER].

future, potential, weapons systems is an apt reflection of the last three years of discussion. This almost meta disagreement in and of itself augurs poorly for the 2017 GGE meetings to generate consensus upon which a ban would be negotiated.

Although the decision to develop LAWS is framed as a future and binary one, advances in computational, sensing, and communications technology are continuous.[11] Indeed, while CCW States Parties met in the fall of 2016 for a Review Conference to authorize the LAWS GGE, the navies of several of those same countries were simultaneously conducting "Unmanned Warrior," the world's largest exercise for unmanned and autonomous systems in the maritime environment.[12]

Able to perform some tasks more effectively than humans, notably collecting and evaluating sensor data in a time compressed environment, LAWS provide unique operational capabilities to military forces around the world.[13] And both the gap between man and machine performance, and resulting capabilities, are exponentially enhanced with the development of swarming technology, where hundreds or even thousands of autonomous systems collaboratively adapt to each other and the environment.[14]

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11. Bob Violino, *New "Sentient" Tools Set to Explode on the Global Market*, ZDNET (Feb. 8, 2017, 12:11 PM), http://www.zdnet.com/article/new-sentient-tools-set-to-explode-on-the-global-market/ ("Quantum leaps in technology in areas such as artificial intelligence (AI), the Internet of Things (IoT), smart cities, cloud intelligence, and robotics have set the stage for new "sentient" tools to explode onto the global market . . . .").

12. *Unmanned Warrior*, ROYAL NAVY, http://www.royalnavy.mod.uk/news-and-latest-activity/operations/uk-home-waters/unmanned-warrior (last visited Apr. 1, 2017). The purpose of Unmanned Warrior was "[t]o explore the feasibility of increasing the use of unmanned and autonomous systems in delivering maritime capability." *Id.* The United Kingdom hosted the exercise off the coast of Scotland and a total of eighteen countries "demonstrat[ed] the latest unmanned system technologies, including air, surface, and subsurface vehicles and sensors." *Id.* The exercise involved the navies of Australia, Canada, Sweden, the United Kingdom, and the United States, all of which are CCW States Parties, and other unspecified European countries. *See* Press Release, Saab, Saab's Anti-Submarine Warfare Training System Participates at Unmanned Warrior (Oct. 5, 2016), http://saabgroup.com/Media/news-press/news/2016-10/saabs-anti-submarine-warfare-training-system-participates-at-unmanned-warrior/.

13. *See generally* P.W. SINGER, WIRED FOR WAR: THE ROBOTICS REVOLUTION AND CONFLICT IN THE 21ST CENTURY (2009). This book describes the extent of the "robot revolution" in that human fighter pilots are on the verge of obsolescence and "tiny robots the size of flies [will] carry out reconnaissance work now handled by elite Special Forces troops." *The Book*, P.W. SINGER, https://wiredwar.pwsinger.com/the-book/ (last visited June 16, 2017). The argument for employing robotic systems is that they can perform at least some tasks to a much greater degree than human service members while reducing the risk of service member injury or death. *See id.*

14. Aaron Mehta, *DoD Weapons Designer: Swarming Teams of Drones Will Dominate Future Wars*, DEF. NEWS (Mar. 30, 2017), http://www.defensenews.com/articles/dod-weapons-designer-swarming-teams-of-drones-will-dominate-future-wars ("Future wars will be fought with swarms of expendable, disaggregated, intelligent systems rather than . . . big, expensive weapon platforms . . . ."). Examples of swarming technology, which are discussed *infra*, include the "Loyal Wingman" program in which unmanned aerial and ground systems are linked to manned systems; the Perdix, a series of over a hundred small aerial drones that share a distributed "brain" for decision-making; and small autonomous Navy attack boats which currently operate in groups of up to thirteen vessels. Valerie Insinna, *30 Years: Unmanned Systems—Revolutionizing Modern Warfare*, DEF. NEWS (Oct. 25, 2016), http://www.defensenews.com/articles/30-years-unmanned-systems-revolutionizing-modern-warfare.

At the same time, current LAWS, and those of the foreseeable future, are not always capable of performing tasks more effectively than humans, and, in many cases, fall short of their human counterparts. For example, understanding context and intent when dealing with an enemy who is potentially surrendering is a task much better suited for humans, at least for the time being.[15] Yet, the limitations of current LAWS and the circumstances in which their use would violate international humanitarian law has often been conflated with categorical illegality, a nonsense in both fact and law.[16]

Ultimately, militaries will continue to develop LAWS even as the CCW discussions are ongoing.[17] This article explains the developmental path LAWS will likely take, and indeed already are taking. Certainly, LAWS will be developed with an inverse relationship to the likelihood of civilian harm. Additionally, militaries will focus on maritime LAWS (operating on, under, and over the surface of the world's oceans), then aerial systems, and last on ground-based systems.

Thus far, most LAWS are defensive systems, but the increased efficacy of swarming defensive systems may prove to be the catalyst for swarming offensive systems. While these outcomes seem likely, one commentator notes: "Given that artificial intelligence has utility far beyond the military context, commercial and academic research alone will likely push the realm of the possible in autonomous systems forward."[18] Therefore the pace of LAWS development may depend, at least in part, on the as of yet unknown societal reaction to advances in autonomy in civil society, particularly involving the performance of functions with life and death consequences.[19]

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15. *See* Rob Sparrow, *Twenty Seconds to Comply: Autonomous Weapon Systems and the Recognition of Surrender*, 91 INT'L L. STUD. 699, 705–09 (2015). Surrender recognition is a challenge for robots because of what Sparrow labels the problem of perception and the significance of context. *Id.*

16. *See* Michael N. Schmitt, *Autonomous Weapon Systems and International Humanitarian Law: A Reply to the Critics*, HARV. NAT'L SEC. J. FEATURES 2 (2015), http://harvardnsj.org/2013/02/autonomous-weapon-systems-and-international-humanitarian-law-a-reply-to-the-critics/.

17. If LAWS are defined as weapons systems that are capable of selecting and engaging without further human intervention, then the following States employ LAWS: Australia, Bahrain, Belgium, Canada, Chile, China, Egypt, France, Germany, Greece, India, Israel, Japan, Kuwait, Netherlands, New Zealand, Norway, Pakistan, Poland, Portugal, Qatar, Russia, Saudi Arabia, South Korea, Spain, Taiwan, United Arab Emirates, United Kingdom, and United States. Scharre & Horowitz, *supra* note 10, at 12.

18. Mehta, *supra* note 14 (quoting Professor Michael Horowitz, University of Pennsylvania).

19. As discussed *infra*, it will be particularly interesting to see what effect advances in driverless cars and robotic medicine will have on societal attitudes towards delegation of functions with life and death consequences to machines. *See* Jonathan Cohn, *The Robot Will See You Now*, ATLANTIC (Mar. 2013), https://www.theatlantic.com/magazine/archive/2013/03/the-robot-will-see-you-now/309216/ (discussing robotic medicine) [https://perma.cc/7WB9-WJZB]. With these advances comes new potential harms, and the reaction to the inevitable deaths caused in some way by or through an autonomous system will also be important and telling. *See* Martin Bryant, *This Story of a Hacked Jeep Is Quite Frankly Terrifying*, TNW (July 22, 2015), https://thenextweb.com/dd/2015/07/21/this-story-of-a-hacked-jeep-is-quite-frankly-terrifying/#.tnw_8Dewue3o (describing the increasing potential of cars to be remotely hacked) [https://perma.cc/7PQS-LWSQ].

I. WEAPONS SYSTEMS & AUTONOMY

The ICRC defines autonomous weapons system as follows: "Any weapon system with autonomy in its critical functions. That is, a weapon system that can select (i.e. search for or detect, identify, track, select) and attack (i.e. use force against, neutralize, damage or destroy) targets without human intervention."[20] Applying this definition, at least thirty countries have employed LAWS of one type or another from as early as 1980.[21]

In terms of the capabilities LAWS provide, consider the Patriot Missile System, able to track up to 100 aerial objects up to sixty miles away, and provide intercept missile guidance data for up to nine missiles to engage up to nine different targets.[22] And while the Patriot performs those functions more effectively than humans, that's a statement of relative and not absolute performance. The Patriot is also the source of several untoward incidents resulting in the loss of human life. For example, in separate incidents during the 2003 invasion of Iraq, U.S. Patriot missile systems, operating in an autonomous mode, misidentified friendly aircraft as enemy, leading to the downing of a U.S. F-18[23] and a British Tornado,[24] killing the crews of both. Somewhat paradoxically, those incidents in which LAWS killed people generated less attention and controversy than other military robotic system incidents in which no one was harmed.

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20. Int'l Comm. of the Red Cross, *Views of the International Committee of the Red Cross (ICRC) on Autonomous Weapon System* (Apr. 11, 2016), https://www.icrc.org/en/document/views-icrc-autonomous-weapon-system.

21. Scharre & Horowitz, *supra* note 10, at 12; *see also* INT'L COMM. OF THE RED CROSS, AUTONOMOUS WEAPON SYSTEMS TECHNICAL MILITARY, LEGAL, AND HUMANITARIAN ASPECTS 59 (2014), https://www.icrc.org/en/document/report-icrc-meeting-autonomous-weapon-systems-26-28-march-2014 (noting that "estimates of the number of countries that have developed these [unmanned air] systems range from 50 to over 80."). The earliest of these systems were the 1980 Close-In Weapon System (CIWS), a ship-based system that detects, tracks, and engages targets with missile and gun systems and the 1981 Patriot, a surface-to-air missile system that detects, tracks, and launches interceptor missiles against incoming aircraft. U.S. defense companies developed both systems and they have been used by the U.S. military and, in the case of CIWS, twenty-four other States, and in the case of Patriot, by twelve other States. *See* Scharre & Horowitz, *supra* note 10, at 21 app. B.

22. *Patriot Missile Long-Range Air-Defence System, United States of America*, ARMY TECH., http://www.army-technology.com/projects/patriot/ (last visited June 4, 2017). The Patriot system identifies and distinguishes between multiple aerial objects, determining altitude, heading, speed, intercept trajectories, whether the object is manned, and even whether the object is carrying ordinance. *See* PEO MISSILES & SPACE, WEAPON SYSTEMS BOOK 89–92 (2012), https://www.msl.army.mil/Documents/peoWeaponSystems.pdf; *see also* Marshall Brain, *How Patriot Missiles Work*, SCI.: HOW STUFF WORKS (Mar. 28, 2003), http://science.howstuffworks.com/patriot-missile.htm.

23. Neil Tweedie, *US Fighter Shot Down by Patriot Missile*, TELEGRAPH (Apr. 4, 2003, 12:01 AM), http://www.telegraph.co.uk/news/worldnews/middleeast/iraq/1426631/US-fighter-shot-down-by-Patriot-missile.html (describing the incident by which a U.S. Army Patriot missile system shot down a U.S. F-18 warplane, killing the pilot, U.S. Navy Lieutenant Nathan White).

24. *RAF Tornado Downed by US Missile*, BBC NEWS (Mar. 23, 2003, 3:16 PM), http://news.bbc.co.uk/2/hi/uk_news/2877349.stm (describing the incident by which a U.S. Army Patriot missile system shot down a Royal Air Force Tornado, killing the two crew members, Flight Lieutenants Kevin Main and David Williams).

Between 2007–2008, the U.S. Army deployed to Iraq but decided not to use an armed ground robotic system.[25] The special weapons observation reconnaissance detection system (SWORDS) TALON is a small, tracked weaponized robot.[26] Significantly, a human operator remotely controls the system and its weapon(s), so it is not a LAWS. The magazine *Popular Mechanics*, which had featured the SWORDS TALON on its cover, ran a story (correctly) quoting the Army's Program Executive Officer (PEO) for Ground Forces that on one occasion the weapon on a SWORDS TALON had moved "when it was not intended to move."[27] As one source noted, the hyperbolic, and inaccurate, result was that

> [t]he Internet immediately began to bubble with countless articles like "US War Robots in Iraq 'Turned Guns' on Fleshy Comrades" and "Combat Robot Attempts Rebellion Against Human Masters in Iraq." The idea that a SWORDS malfunction had very nearly precipitated a major friendly-fire incident soon became a widely circulated story.[28]

The SWORDS TALON incident demonstrates both how the robotic use of force draws attention and how the U.S. military's concern with that attention impacts not only public opinion but ultimately weapons system development.[29] As the PEO noted, correctly if inartfully, when dealing with military robotic weapon systems, "[o]nce you've done something that's really bad, it can take 10 or 20 years to try it again."[30] Untoward incidents, and even the risk (or misperception) of one, appear to heavily factor into the developmental path of LAWS.

II. DEVELOPMENT TRAJECTORY

LAWS development has, and will continue to, focus on operational environments in which there is relatively less risk of untoward incidents in general and injury or death of civilians in particular. This approach both recognizes and operationalizes Schmitt's view that even LAWS that are devoid of any capacity to distinguish protected persons and objects from lawful military targets can be used without endangering the former.[31] Given that risk constraint, while efforts are ongoing to develop LAWS for all environments, there will be greater opportunities for the development of maritime systems, which operate in, above, and

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25. *See The Inside Story of the SWORDS Armed Robot "Pullout" in Iraq: Update*, POPULAR MECHANICS (Oct. 30, 2009), http://www.popularmechanics.com/technology/gadgets/a2804/4258963/.

26. *TALON Tracked, Military Robot, United States of America*, ARMY TECH., http://www.army-technology.com/projects/talon-tracked-military-robot/ (last visited June 21, 2017).

27. *The Inside Story of the SWORDS Armed Robot "Pullout" in Iraq: Update*, *supra* note 25.

28. Ben Crispin, *What Killed the Robot Soldier?*, STRANGE HORIZONS (Nov. 10, 2008), http://strangehorizons.com/non-fiction/articles/what-killed-the-robot-soldier/.

29. The attention given the robotic use of force is in some ways understandable. But often lost in the discussion is that one of the largest drivers of the development of LAWS is the prospect of limiting risk to both military members and civilians. *See* Mehta, *supra* note 14 (discussing the employment of "wave after wave of cheap, disposable systems that come with no risk of losing a U.S. service member").

30. *The Inside Story of the SWORDS Armed Robot "Pullout" in Iraq: Update*, *supra* note 25.

31. Schmitt, *supra* note 16, at 11.

under the ocean. From there development will next expand in aerial LAWS, and finally, land based systems.

A. Maritime

The Unmanned Warrior exercise discussed in the introduction has been called the "world's biggest robot war game."[32] The development of autonomous unmanned undersea vehicles (UUVs) in particular is referred to as "a major priority for the U.S. Navy and navies around the world. . . . [with systems that] could eventually be capable of remaining submerged for months at a time, [and] will serve in a variety of roles, including anti-submarine warfare and mine-hunting."[33] Over the next few years, the U.S. Navy's use of UUVs is expected to exponentially increase as the result of increased funding on development and research.[34]

In 2015, the U.S. Navy's budget to research and procure UUVs was $146.2 million.[35] The next year, 2016, saw an $86.7 million increase to $232.9 million.[36] And the Department of Defense (DoD) budget for Fiscal Year 2017 provides over $350 million for UUVs.[37] By way of comparison, the United States is devoting over four times the amount of money to UUVs as to unmanned ground vehicles.[38] Additionally, DoD allocated over $944 million for 2017 towards an autonomous maritime intelligence, surveillance, and reconnaissance aircraft system.[39]

The relative expanse of the ocean provides challenges to navies, but also allows for the less risky employment of LAWS, particularly subsurface.[40] Ac-

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32. David Hambling, *The 10 Coolest Drones at the World's Biggest Robot War Games*, POPULAR MECHANICS (Oct. 19, 2016), http://www.popularmechanics.com/military/research/g2820/the-10-drones-unmanned-warrior/.

33. Dan Gettinger, *Underwater Drones (Updated)*, CTR. FOR STUDY DRONE (Oct. 28, 2016), http://dronecenter.bard.edu/underwater-drones-updated/.

34. *See* Kris Osborn, *Chinese Seizure of Underwater U.S. Drone Underscores UUV Importance*, DEF. SYS. (Dec. 17, 2016), https://defensesystems.com/articles/2016/12/17/uuv.aspx (comparing UUV development to how the U.S. military "operated merely a handful of drones at the beginning of [Operation Iraqi Freedom in 2003] before growing the fleet exponentially to thousands of [aerial drones] in following years").

35. Dan Gettinger, *What You Need to Know About Underwater Drones*, CTR. FOR STUDY DRONE (Nov. 16, 2015), http://dronecenter.bard.edu/underwater-drones/.

36. *Id.*

37. Dan Gettinger, *Drone Spending in the F17 Defense Budget*, CTR. FOR STUDY DRONE, (Feb. 15, 2016), http://dronecenter.bard.edu/drone-spending-in-the-fy17-defense-budget/. It's important to recognize that the FY2017 DoD budget of $4.6 billion for unmanned systems is not an upward spike, it's actually a decrease. The FY2016 budget for unmanned systems was $5.8 billion. *Id.*

38. *Id.*

39. *Id.*

40. As the Defense Advanced Research Projects Agency has noted, "Nearly 50 percent of the world's oceans are deeper than 4 km, which provides vast areas for concealment and storage." *DARPA Ocean Drone Would Lift 'Upward Falling Payloads,'* GPS WORLD (Apr. 10, 2015), http://gpsworld.com/darpa-ocean-drone-would-lift-upward-falling-payloads/ [hereinafter *Upward Falling*].

cordingly the U.S. Navy is developing systems like "Hydra," a submerged, undersea network of "unmanned payloads and platforms,"[41] and "Upward Falling Payloads," a weaponized "drone that can hibernate on the ocean floor for years at a time before being launched to the surface and into the air."[42]

B. Air

In contrast, developments in aerial LAWS seem more straightforward. While there is some debate as to whether the F-35 Joint Strike Fighter will be the last manned fighter aircraft the U.S. develops,[43] in the near term the U.S. Air Force plans to turn older, manned jets into unmanned autonomous combat aircraft as so called "Loyal Wingm[e]n."[44] The current challenges appear to be how to evaluate the testing program for the autonomous combat aircraft and how human pilots would develop trust in their "robotic wingmen."[45] Researchers have developed a system to operate the autonomous aircraft that "every 6.5 milliseconds [] can take in the entirety of sensor data, organize the data and create a complete mapping of the scenario, analyze its current [course of action] and make changes, or create an entirely new [course of action]."[46] But the only way to test the system appears to be through another system.[47] In terms of why or how human pilots would trust the autonomous system, the head of the Air Force's research lab suggests that "[t]he cornerstone of trust is not integrity and truth. The cornerstone of trust is competence. The system has to do what you expect it to do in a way that supports the mission every time. When it does, you start to trust it."[48]

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41. Allen McDuffee, *DARPA's Plan to Flood the Sea with Drones, Carrying More Drones*, WIRED (Sept. 13, 2013, 6:30 AM), https://www.wired.com/2013/09/hydra-darpa/. Hydra has been described as an unmanned submersible "mothership" that could deploy both unmanned underwater and unmanned aerial systems. Tim McFarland, *Factors Shaping the Legal Implications of Increasingly Autonomous Military Systems*, 97 INT'L REV. RED CROSS 1313, 1331–32 (2015).

42. *Upward Falling*, *supra* note 40. In being activated and "recalled" to the surface, the system would "fall upward." *Id.*

43. *See* Richard Whittle, *Air Force Begs to Differ with Mabus: F-35 Not Last Manned Fighter*, BREAKING DEF. (Apr. 29, 2015, 1:05 PM), http://breakingdefense.com/2015/04/air-force-begs-to-differ-with-mabus-f-35-not-last-manned-fighter/.

44. Clay Dillow, *The Pentagon Wants Autonomous Fighter Jets to Join the F-35 in Combat*, FORTUNE (Mar. 30, 2016), http://fortune.com/2016/03/30/autonomous-fighter-jets-join-the-f-35/.

45. Patrick Tucker, *The Air Force Doesn't Know How to Test Its Future Robotic Wingmen*, DEF. ONE (Oct. 20, 2016), http://www.defenseone.com/technology/2016/10/military-unsure-how-test-future-autonomous-drones/132525/.

46. *Id.* (quoting Nicholas Ernest et al., *Genetic Fuzzy Based Artificial Intelligence for Unmanned Combat Aerial Vehicle Control in Simulated Air Combat Mission*, 6 J. DEF. MGMT., no. 1, 2016, at 1, 6–7).

47. *See id.* That's in part because the system "is so fast that it could consider and coordinate the best tactical plan and precise responses, within a dynamic environment, over 250 times faster than . . . human opponents could blink." *Id.*

48. *Id.*

C. Ground

Comparatively speaking, the area in which there will be the least near term development will be ground-based systems primarily designed to target personnel.[49] This is because of the challenges in "sens[ing] or interpret[ing] the difference between soldiers and civilians, especially in contemporary combat environments."[50]

The import of these challenges is not that ground-based LAWS are illegal, but that their employment will likely be limited to areas that mitigate the risks the challenges pose. For example, the Republic of South Korea employs a robotic sentry system on the demilitarized zone (DMZ) dividing North and South Korea.[51] The DMZ is roughly 4 kilometers wide, with guard towers and barbed wire fences on both sides of one of the world's largest minefields. Thus while the sentry robot may not be able to distinguish between an attacking North Korean soldier and an errant North Korean farmer, the operational context severely limits the chances of the later even being in the DMZ.[52]

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49. As the predicate "[c]omparatively speaking" reflects, the limits on developing ground-based LAWS are relative to that in maritime and high altitude. There is considerable ongoing development and increases in autonomy in ground-based systems, just much of it does not fall under LAWS. The U.S. Army for example is testing driverless trucks to perform resupply missions and the use of "robotic wingmen" combat vehicles. Jen Judson, *US Army to Demo Robotic Wingman Vehicles in 2017*, DEF. NEWS (Dec. 28, 2016), http://www.defensenews.com/articles/army-to-demo-robotic-wingman-vehicles-in-2017; *see* Kelsey D. Atherton, *Army Tests Self-Driving Supply Trucks*, POPULAR SCI. (Oct. 24, 2016), http://www.popsci.com/army-tests-self-driving-supply-trucks.

50. BONNIE DOCHERTY, HUMAN RIGHTS WATCH, LOSING HUMANITY: THE CASE AGAINST KILLER ROBOTS 30 (2012), http://www.hrw.org/sites/default/files/reports/arms1112ForUpload_0_0.pdf.

51. *Id.* at 14. It is unclear whether the sentry system, the Samsung SGR-1, is autonomous. *Id.* at 14–15. Initial reports, as well as statements by the South Korean government, indicated that the SGR-1 had a mode in which the system would employ force, meaning fire its machine gun or grenade launcher, without a human directing the action. *Id.* at 15 n.46. South Korea has since modified its position and removed statements on the SGR-1's modes of firing from government websites. *Id.*; *see* PATRICK LIN ET AL., AUTONOMOUS MILITARY ROBOTICS: RISK, ETHICS, AND DESIGN 19 (2008). Lin's report describes the SGR-1 as

> stationary, designed to replace a manned sentry location. It is equipped with sophisticated color vision sensors that can identify a person entering the DMZ, even at night under only starlight illumination. Since any person entering the DMZ is automatically presumed to be an enemy, it is not necessary to separate friend from foe. The system is equipped with a machine gun, and the sensor-gun assembly is capable of rotating in two degrees of freedom as it tracks a target. The firing of the gun can be done manually by a soldier or by the robot in fully-automatic (autonomous) mode.

Id. As autonomous weapons receive more and more public and media attention, actions like Hanwha Techwin's, which developed the SGR-1, and South Korea's, which employs it, will become more common. The actions are not to stop developing or using LAWS, but rather to either stop advertising that you are doing so or to claim that the system is not autonomous but automated or automatic, or both.

52. Under most circumstances South Korea would likely use the sentry remote in a remote-controlled mode in which a human operator would decide whether to fire. But if North Korea were to attempt (another) incursion into South Korea, the autonomous mode would presumably provide a quicker engagement/fire rate than with a human operator making individualized targeting decisions.

III. SWARMING

A. Background

Swarming technology will change the type of LAWS that are developed. The concept of swarming originates in nature and has been used as a military tactic for millennia. What is relatively new is that advances in autonomy are facilitating machines applying behavior models from nature. This section briefly describes swarming and then discusses how such massed, collaborative weapons systems may impact LAWS development.

In the context of biological systems, the term swarming describes "decentralized self-organizing behavior in populations of (usually simple) animals. Examples include path formation, nest sorting, food source selection, thermoregulation, task allocation, flocking, nest construction, and hunting behaviors in many species."[53]

In the military context, it has been stated that swarming

> describe[s] a battlefield tactic that involves decentralized, pulsed attacks. The link between these two uses of the word is not coincidental. Insect self-organization is robust, adaptive, and persistent, as anyone can attest who has tried to keep ants out of the kitchen, and military commanders understand the advantage of being able to inflict the confusion, frustration, discomfort, and demoralization that a swarm of bees can visit on their victims.[54]

Additionally, it has been shown that examples of swarming as a military tactic

> can be found throughout history, from the Scythian horse archers who fought Alexander in ancient times . . . . Swarming [has been] employed at the tactical and operational levels, on land, sea, and air, both defensively and offensively, by conventional and unconventional forces, and by men and manned machines.[55]

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53. John A. Sauter et al., *Performance of Digital Pheromones for Swarming Vehicle Control*, *in* PROCEEDINGS OF THE FOURTH INTERNATIONAL JOINT CONFERENCE ON AUTONOMOUS, AGENTS AND MULTIAGENT SYSTEMS 903, 903 (2005). Another way of thinking of swarming is that in nature, creatures

> come together in inconceivable numbers—sometimes in millions, billions, and even trillions. Included are bats and bees, locust and ants, monarch butterflies in Mexico, 17-year cicada hatches, grunion in the Sea of Cortez and carp in the Mississippi River, sardine runs off the coast of South Africa, super flocks of parakeets in the Australian Outback, mayflies on the 4th of July, and even penguins and wildebeest. Some gather to breed or to migrate, some for protection, some simply to keep warm in the cold. But in the process, a kind of super-organism is created in which individual intelligence is superseded by a collective consciousness that shares information and moves with a single purpose for the benefit of all.

About the Gathering Swarms, PBS: NATURE (May 21, 2014), http://www.pbs.org/wnet/nature/the-gathering-swarms-about/8970/.

54. Sauter et al., *supra* note 53.

55. SEAN J.A. EDWARDS, SWARMING AND THE FUTURE OF WARFARE 77 (2005), http://www.rand.org/content/dam/rand/pubs/rgs_dissertations/2005/RAND_RGSD189.pdf (detailing swarming as a military tactic as long as some 2,300 years ago); *see also* JOHN ARQUILLA & DAVID RONFELDT, SWARMING AND THE FUTURE OF CONFLICT (2000) (discussing examples of swarming in nature and history).

Furthermore, the idea of "swarm intelligence" exists, and may be defined as "the collective behavior of decentralized, self-organized systems, natural or artificial."[56] One of the first glimpses, and sounds, of swarming as applied to artificial or manmade systems came from the General Robotics, Automation, Sensing & Perception Laboratory (GRASP) lab at the University of Pennsylvania. In 2011, the lab released videos of a relatively small number of unmanned aerial system (UAS) quadcopters "navigating obstacle courses, formation flying, building structures, and literally flying through hoops."[57] No one from the GRASP lab was piloting or controlling the quadcopters, rather the systems plotted their own course through designation of time way points. Next, in 2014, Harvard's Wyss Institute demonstrated the autonomous swarming of over 1000 small devices that arrange themselves in different shapes.[58]

While the anticipated future civilian applications for autonomous swarms range from agriculture to search and rescue to mining, militaries are already incorporating the technology. In the summer of 2014, the U.S. Navy demonstrated the use of swarming autonomous patrol boats on the James River in Virginia.[59] The patrol boats simulated an escort mission, protecting a manned vessel.[60] There were no sailors on the boats, nor were the boats remote controlled. Instead, the boats were controlled by a system originally used by NASA in its Mars rover program.[61] The system, Control Architecture for Robotic Agent Command and Sensing (CARACaS), steers the boats and also coordinates each boat's actions with other vessels.[62] As Jeremy Hsu explains: "Each robot boat transmits its radar views to the others so the group shares the same situational awareness. They're also continually computing their own paths to navigate around obstacles and act in a cooperatively manner."[63]

The impetus behind the swarming patrol boats was the suicide boat attack against the USS Cole while it was refueling in a harbor in Yemen in 2000.[64] And

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56. Manish Mahant et al., *A Profound Survey on Swarm Intelligence*, 2 INT'L J. ADVANCED COMPUTER RES. 31, 31 (2012).

57. Jeff Blagdon, *Flying Robot Swarm Plays James Bond Theme on Real Instruments*, VERGE (Feb. 29, 2012, 9:59 PM), http://www.theverge.com/2012/2/29/2834622/quadrocopter-drone-orchestra-james-bond. In 2012, the GRASP UAS performed the James Bond movie theme. *Id.* This technology has led to Intel's LED equipped UAS swarms flying to music, which in turn may become "flying billboards." Matt McFarland, *Intel's Drones Could be the First Step Toward Flying Billboards*, CNN:TECH (Nov. 7, 2016, 11:47 AM), http://money.cnn.com/2016/11/07/technology/intel-drone-fireworks/.

58. Ed Yong, *A Swarm of a Thousand Cooperative, Self-Organizing Robots*, NAT'L GEOGRAPHIC PHENOMENA: NOT EXACTLY ROCKET SCI. (Aug. 24, 2014, 4:01 GMT), http://phenomena.nationalgeographic.com/2014/08/14/a-swarm-of-a-thousand-cooperative-self-organising-robots/.

59. Jeremy Hsu, *U.S. Navy Tests Robot Boat Swarm to Overwhelm Enemies*, IEEE SPECTRUM (Oct. 5, 2014), http://spectrum.ieee.org/automaton/robotics/military-robots/us-navy-robot-boat-swarm.

60. *Id.*

61. *Id.*

62. *Id.*

63. *Id.*

64. *See* Kelsey D. Atherton, *Navy Demonstrates Swarm of Armed Robot Boats*, POPULAR SCI. (Oct. 6, 2014), http://www.popsci.com/article/technology/navy-demonstrates-swarm-armed-robot-boats.

while a U.S. Navy spokesperson (and Rear Admiral) told the media at the 2014 demonstration that the swarming patrol boats "would have prevented" the Cole bombing,[65] how exactly the swarming patrol boats would protect a manned vessel is less clear. Perhaps they could block an approaching boat's path, and ram that boat, but also employ lethal force. As noted commentator Peter Singer contends, "Future versions of these systems will be armed with non-lethal weapons that could shut down the engines of the targeted boat, and even lethal weapons that could be remotely operated by humans from afar."[66]

In this initial demonstration a human had to designate the vessel the patrol boats were to swarm around. But in 2016, the Navy conducted another iteration only now the swarming patrol boats, through enhancements to CARACaS, had the ability to classify vessels as friendly or hostile.[67] This improved capability was the result of "automated target recognition" and CARACaS ability to "evaluate potential threats based on their behaviors; for example, taking note of how close a suspect vessel is getting to a port, ship, or other asset. This capability, which was not demonstrated in the [2014] tests, allows new images and behaviors to be entered into the boats' threat library."[68]

At the same time the U.S. Navy began demonstrating swarming patrol boats, the U.S. Air Force began testing the Perdix system. Perdix systems are defined as "autonomous micro-drones capable of low altitude [i]ntelligence, [s]urveillance, and [r]econnaissance (ISR) and other missions. They can be air, sea-, or ground-launched and operate in both small and large swarms to perform their missions."[69]

According to DoD,

> Perdix are not preprogrammed, synchronized individuals. They share a distributed brain for decision-making and adapt to each other, and the environment, much like swarms in nature. Because every Perdix communicates and collaborates with every other Perdix, the swarm has no leader and can gracefully adapt to changes in drone numbers. This allows this team of small inexpensive drones to perform missions once done by large expensive ones.[70]

Following tests in 2014 and 2015 involving swarms of up to twenty systems, DoD deployed over 100 Perdix systems over China Lake, California in October 2016.[71] DoD's Strategic Capabilities Office noted that the demonstration

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65. *Id.*

66. Eric Adams, *The Navy's New Robot Boats Swarm the Enemy on Their Own*, WIRED (Jan. 8, 2017, 7:00 AM), https://www.wired.com/2017/01/navys-new-robot-boats-swarm-enemy/ (quoting Peter Warren Singer, American political scientist).

67. Patrick Tucker, *The U.S. Navy's Autonomous Swarm Boats Can Now Decide What to Attack*, DEF. ONE (Dec. 14, 2016), http://www.defenseone.com/technology/2016/12/navys-autonomous-swarm-boats-can-now-decide-what-attack/133896/.

68. *Id.*

69. Strategic Capabilities Office, *Perdix Fact Sheet*, https://www.defense.gov/Portals/1/Documents/pubs/Perdix%20Fact%20Sheet.pdf (last visited May 28, 2017) [hereinafter *Perdix Fact Sheet*].

70. *Id.*

71. The TV news program 60 Minutes was at the test and initially found Perdix flew "too fast—upwards of 40–50 miles per hour—and too unpredictably for a conventional news camera to

> [s]howed off Perdix's collective decision-making, adaptive formation flying, and self-healing abilities. The drones collectively decide that a mission has been accomplished, fly on to the next mission, and carry out that one. The benefit of the swarm is that if one drone drops out—and a few appear[ed] to crash—the group can rearrange itself to maintain coverage.[72]

The Perdix systems are 6½ inches long, with a wingspan of approximately a foot.[73] Perdix is powered by a propeller, and can fly at least seventy miles per hour and for at least twenty minutes.[74] It is equipped with foldable wings and is packed in a canister that is launched by an aircraft; once launched, a small parachute deploys.[75] As the head of the DoD's Strategic Capabilities Office explains, at that point, Perdix has to

> wake up and boot as they fall, and then they have to find each other and then they go fly whatever mission that we've programmed them for . . . . [l]et's say if we're telling these guys to go out and survey a field, then as a group they know that mission and what they will do is then allocate and optimize the best way to do it.[76]

The Perdix swarm acts in concert and thus whoever is overseeing their employment communicates with the group, not each individual Perdix system.[77] Significantly, Perdix was built using 3D printed parts and is not currently designed to be recoverable.[78]

While the Perdix systems are relatively small, swarming technology is being created in matter as small as dust. Microelectricalmechanical Systems (MEMS) are comprised of components that are micrometers in size and can contain sensors.[79] Referred to as "smart dust," MEMS might be used to track movement, provide biometric information, and take microscopic pictures.[80]

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follow." *Capturing the Swarm*, CBS NEWS: 60 MINUTES (Jan. 8, 2017), http://www.cbsnews.com/news/60-minutes-capturing-the-perdix-drone-swarm/.

72. Kyle Mizokami, *The Pentagon's Autonomous Swarming Drones Are the Most Unsettling Thing You'll See Today*, POPULAR MECHANICS (Jan. 9, 2017), http://www.popularmechanics.com/military/aviation/a24675/pentagon-autonomous-swarming-drones/.

73. *Perdix Fact Sheet*, *supra* note 69.

74. *Id.*; Jon Harper, *Secretive Pentagon Office Developing Next-Generation Swarming Drones*, NAT'L DEF. MAG. (Sept. 8, 2016), http://www.nationaldefensemagazine.org/articles/2016/9/8/secretive-pentagon-office-developing-next-generation-swarming-drones (quoting William Roper, Head of DoD Strategic Capabilities Office, who described Perdix's speed and endurance as the "numbers that [DoD] protect[s]").

75. Harper, *supra* note 74.

76. *Id.* (quoting William Roper's discussion during a media roundtable at the Defense Advanced Research Projects Agency headquarters).

77. *Id.*

78. *Id.* ("They don't come back, so we have to keep them relatively low cost or else it's not a great idea. . . ." (quoting William Roper)).

79. *See* Anil Ananthaswamy, *The March of the Motes*, NEW SCIENTIST, Aug. 23, 2003, at 26, 26–27 (2003). A micrometer is one millionth of a meter; *Introduction to Microelectricalmechanical Systems (MEMS)*, BYU COMPLIANT MECHANISMS RES., https://compliantmechanisms.byu.edu/content/introduction-microelectromechanical-systems-mems (last visited June 12, 2017).

80. Jason Dorrier, *Smart Dust Is Coming: New Camera Is the Size of a Grain of Salt*, SINGULARITY HUB (June 28, 2016), https://singularityhub.com/2016/06/28/smart-dust-is-coming-new-camera-is-the-size-of-a-grain-of-salt/ [https://perma.cc/RQ8E-FQ7B].

B. Impact

Current swarming military systems may be defensive in nature, but as noted above, the systems are capable of employing force. As Dan Gettinger states: "The importance of the swarm is not the individual components; rather, by synchronizing the behavior of the collective, [a] complex mission that would be impossible for a single [system] or human become[s] achievable."[81]

Will there come a point where the capabilities of swarming defensive systems are such that the only effective counter is swarming offensive systems? Perhaps this proposition reflects little more than the manner by which weapons systems and countering systems have always been developed. Where there is advancement in the armor of a tank, what tends to follow is a comparable advancement in antitank missiles.[82]

As discussed earlier in this article, the developmental path of LAWS seems inversely related to the potential for civilian harm. Swarming technology may just accelerate LAWS development. Swarming LAWS would mostly likely be antimaterial, targeting incoming missiles and rockets, but they could also target boats, aircraft, and vehicles, so systems that may have human occupants. And while LAWS have already killed humans, perhaps there have been so few of those instances that societally we are able to maintain a comforting fiction. This is the fiction of the relative effectiveness of human action compared to that of and by machine.

IV. AUTONOMY IN CIVIL SOCIETY AND RISK PERCEPTION

But it is of course not just in the military that machines are performing more and more functions. Advances in autonomy are yielding any number of societal benefits in civil society such as improvements in data collection and, more recently, mobile broadband and cloud computing technology across a range of products and services. However, the magnitude of these improvements may have been largely lost as to the average consumer because they did not seem to enable new, previously unknown, technologies so much as render extant devices

81. Dan Gettinger, *What You Need to Know About Drone Swarms*, CTR. FOR STUDY DRONE (Nov. 3, 2014), http://dronecenter.bard.edu/what-you-need-to-know-about-drone-swarms/ [https://perma.cc/JTU7-JVV3].

82. *See* Jon Fingas, *Smart Bullets Will Help Warships Fend Off Drone Swarms*, ENGADGET, (Jan. 16, 2017), https://www.engadget.com/2017/01/16/smart-bullets-help-warships-fight-drone-swarms/ [https://perma.cc/JBK2-UBYM]; *see also* MarEx, *DARPA Develops "Smart Bullet" for Deck Guns*, MARITIME EXECUTIVE (Jan. 18, 2017; 7:26 PM), http://www.maritime-executive.com/article/darpa-develops-smart-bullet-for-deck-guns [https://perma.cc/SPU4-6PHP]. *The Maritime Executive* describes the development of a munition that would "combine the guidance, precision, and accuracy of missiles with the speed, rapid-fire capability, and large ammunition capacity of bullets" to defend Naval vessels against swarming attack boats. *Id.* The system will potentially be able to fire two hundred rounds a minute and simultaneously engage dozens of targets. *Id.*

smaller, faster, and more capable.[83] While some of these are matters of convenience or entertainment, others involve machines performing functions better than humans, and saving human lives in the process. This raises the question of whether advances in autonomous technology in the context of civil society will alter how humans think of human/machine task apportionment. And if it does, will that affect attitudes towards increased autonomy in weapons systems?

New devices may provide overt evidence of these improvements, as well seemingly limitless modalities. To randomly note three, consider, "Connie," Hilton hotel's new robot concierge;[84] the giant sand art producing "beachbot,"[85] and the "cotsbot," an underwater robotic system that autonomously searches for and kills a form of starfish threatening the Great Barrier Reef.[86] However, driverless cars and robotic surgery may provide the most insight into relevant societal attitudes towards LAWS. Like LAWS, autonomous vehicles are thought of as future and binary, while the reality is that partial evolutions in these various component technologies are contemporary and ongoing. Both autonomous vehicles and robotic surgery involve the delegation of functions to machines—the performance of which holds life and death significance. Initial and limited studies indicate that such delegation may yield better outcomes, at least in certain circumstances.

In February 2017, the California Department of Motor Vehicles released reports from eleven different companies on the performance of increasingly autonomous vehicles.[87] As one source noted:

> The report[s] [came from] 11 companies that have been testing more than one hundred self-driving vehicles on public roads. . . . Data includes safety-related

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83. Consider advances in just phones, televisions, and computers, which on the one hand have existed for over 165 years, 90 years, and 70 years respectively. Yet current versions bear resemblance in name only to their namesakes from just 20–30 years ago. And while those devices were previously distinct they are often now merged into one. In terms of quantifying the improvements in just one area, computing power, consider that Skylake, a processor microarchitecture Intel released in 2015, delivers 400,000 times the computing power as Intel's first commercial microprocessor, released in 1971. Irving Wladawsky-Berger, *Computing Beyond Moore's Law*, WALL ST. J. (Apr. 8, 2016, 12:40 PM), http://blogs.wsj.com/cio/2016/04/08/computing-beyond-moores-law/ [https://perma.cc/X8AL-LWU9].

Intel replaced Skylake in 2016 with Kaby Lake, and, in anticipation of the processing requirements of virtual reality gaming, is set to release the faster and more capable Cannonlake in 2017. Agam Shah, *Intel: Cannonlake CPUs Will be More Than 15 Percent Faster than Kaby Lake*, PCWORLD (Feb. 9, 2017, 11:25 AM), http://www.pcworld.com/article/3167942/components-processors/intel-cannonlake-will-be-more-than-15-percent-faster-than-kaby-lake.html.

84. Nancy Trejos, *Introducing Connie, Hilton's New Robot Concierge*, USA TODAY (Mar. 14, 2016, 12:22 PM), http://www.usatoday.com/story/travel/roadwarriorvoices/2016/03/09/introducing-connie-hiltons-new-robot-concierge/81525924/.

85. Alexandra Klausner, *The Robot That Turns Any Beach into an Etch-A-Sketch: Machine Transforms Anything Its User Can Sketch into Huge Sand Drawing*, DAILY MAIL.COM (Jan. 12, 2015, 4:02 EDT), http://www.dailymail.co.uk/news/article-2904778/Disney-introduces-BeachBot-turtle-shaped-robot-draw-pictures-sand.html.

86. Ian Frisch, *The Great Barrier Reef's Best Hope is a Killer Robot*, WIRED: SCI. (Apr. 14, 2016, 10:00 AM), https://www.wired.com/2016/04/starfish-killer-robot/.

87. *Autonomous Vehicle Disengagement Reports 2016*, ST. CAL. DEP'T MOTOR VEHICLES, https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/disengagement_report_2016 (last visited (Apr. 20, 2017).

> incidents and tracked disengagement events. Disengagement refers to how many times a human has to take back control of the vehicle while it's on the road for safety reasons.[88]

The autonomous vehicles had significantly fewer incidents/events per 10,000 miles driven than the year before.[89]

While autonomous vehicles appear to be improving, the same, sadly, is not the case with human drivers. The National Highway Traffic and Safety Administration (NHTSA) reported a 7.2% increase in traffic crash fatalities in 2015 as compared to 2014.[90] The NHTSA also estimates that driver error of one type or another accounts for roughly 94% of crashes.[91] As one NHTSA administrator noted, "The data tell us that people die when they drive drunk, distracted, or drowsy, or if they are speeding or unbuckled."[92] Interestingly, the NHTSA representative went on to say that "we need to find new solutions to end traffic fatalities."[93]

While data on autonomous driving is robust, data on autonomous robotic surgery is certainly limited. But in at least one study, the Smart Tissue Autonomous Robot (STAR) yielded better outcomes than either human surgeons alone or human surgeons with robotic assistance in performing the same operation, intestine resection of anesthetized pigs.[94] There is more data available on robotic pharmacists, which shows them capable of dispensing medicine more accurately than humans. For example, the University of California San Francisco reported in 2016 that robotic pharmacists, which dispensed medication, and the autonomous bots that delivered them, had "worked for five years with 100% accuracy."[95] In contrast, a recent Houston medical center study reported that "in one

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88. *Autonomous Cars Are Safer When Humans Don't Help*, FUTURISM (Feb. 8, 2017), https://futurism.com/new-study-shows-autonomous-cars-are-becoming-safer/.

89. *Id.*

90. Specifically, NHTSA reported 35,092 people died in 2015 as the result of traffic crashes. Press Release, Nat'l Highway Traffic Safety Admin., Traffic Fatalities Up Sharply in 2015 (Aug. 29, 2016), https://www.nhtsa.gov/press-releases/traffic-fatalities-sharply-2015 [hereinafter NHTSA 2016]. This increase reversed a 50-year "trend of declining fatalities." *Id.*

91. Santokh Singh, DOT HS 812 115, *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey*, TRAFFIC SAFETY FACTS: CRASH STATS (Nat'l Highway Traffic Safety Admin., D.C.), Feb. 2015, at 1, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115; *see also What Lives Should Autonomous Cars Value?*, FUTURISM (Feb. 6, 2017), https://futurism.com/2-the-moral-dilemma-of-autonomous-cars-which-lives-should-you-save/.

92. NHTSA 2016, *supra* note 90.

93. *Id.*

94. *See* Eliza Strickland, *Autonomous Robot Surgeon Bests Humans in World First*, IEEE SPECTRUM (May 4, 2016, 6:17 PM), http://spectrum.ieee.org/the-human-os/robotics/medical-robots/autonomous-robot-surgeon-bests-human-surgeons-in-world-first. The Strickland article goes onto describe some disagreement in the medical community on the study's import, with views ranging from "robotic surgery breakthrough" to questions of the study's "clinical significance." *Id.*

95. Mallory Pickett, *Robots Are Now Handling Pills. Will Pharmacists Be Liberated or Out of Work?*, KQED SCI. (Apr. 28, 2016), https://ww2.kqed.org/futureofyou/2016/04/28/when-a-robot-counts-out-your-pills-what-will-your-pharmacist-do/.

year their pharmacists made an average of almost five medication errors for every 100,000 prescriptions."[96]

But does increased performance by machine correlate to a positive public perception of risks? One definition of risk perception is that it is the processing of "physical signals and/or information about potential hazards and risks associated with a technology and the formation of a judgment about seriousness, likelihood, and acceptability of this technology."[97] But how the public perceives risk can vary with the source of the risk.[98] Moreover, researchers note that "[h]umans perceive and act on risk in two fundamental ways. Risk as feelings refers to individuals' instinctive and intuitive reactions to danger. Risk as analysis brings logic, reason, and scientific deliberation to bear on risk management."[99] Will society consider autonomous cars and robotic surgery from a risk as feelings or as analysis perspective? Whatever the societal attitudes are towards those systems, will it mean anything on attitudes towards assigning increasingly more weapon system functions to machines? That broader question is better broken down into (at least) two subordinate inquiries.

First, assuming that these systems lead to less traffic fatalities and improved surgical outcomes, will this prompt societal recognition of machines being "better" at certain functions than humans?[100] Will the average person, using a driverless car at some point in the future, think they are doing so because (1) the car drives better than the person or (2) the driverless car is more convenient? The latter seems the more likely outcome, with an odd majority of people claiming or at least thinking they are above average drivers.[101] Given historical cognitive biases on human perception of human performance this answer should come as no surprise.[102]

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96. *Id.*

97. Ortwin Renn & Christina Benighaus, *Perception of Technological Risk: Insights from Research and Lessons for Risk Communication and Management*, 16 J. RISK RES. 293, 295 (2013).

98. *See, e.g.*, Joshua A. Boys et al., *Public Perceptions on Robotic Surgery, Hospitals with Robots, and Surgeons that Use Them*, 30 SURGICAL ENDOSCOPY 1310–16 (2016) (discussing survey results on attitudes towards autonomous surgery); Reece A. Clothier et al., *Risk Perception and the Public Acceptance of Drones*, 35 RISK ANALYSIS 1167, 1180 (2015) (contrasting how the public perceives risk of piloted commercial aircraft with unmanned aerial drones).

99. Paul Slovic & Ellen Peters, *Risk Perception and Affect*, 15 CURRENT DIRECTIONS PSYCHOL. SCI. 322, 322 (2006) (emphasis omitted).

100. One rationalization this group will use to explain why if they drive better than the driverless car they are not still driving, is that car insurance will incentivize increasingly autonomous cars through lower rates the less a human is operating the car. *See* Alex Glenn, *If You Hate Auto Insurance, You'll Love Driverless Cars*, USA TODAY (Aug. 27, 2016, 8:02 AM), http://www.usatoday.com/story/money/personalfinance/2016/08/27/auto-insurance-driverless-cars/89429700/.

101. *When It Comes To Driving, Most People Think Their Skills Are Above Average*, ASS'N FOR PSYCHOL. SCI. (Aug. 28, 2014), https://www.psychologicalscience.org/news/motr/when-it-comes-to-driving-most-people-think-their-skills-are-above-average.html#.WWe8tlTyuUk.

102. David D. Woods & Richard I. Cook, *Perspectives on Human Error: Hindsight Biases and Local Rationality*, *in* HANDBOOK OF APPLIED COGNITION 165–66 (Francis T. Durso et al. eds., 1999).

Second, what will the reaction be when the use of increasingly autonomous system results in human injury or death? In 2015, a robot at a Volkswagen production plant crushed a human to death in Germany.[103] And in 2016, a Tesla car in "autopilot" mode was speeding in the United States and failed to detect and react to a semi-tractor trailer, leading to a collision that killed the human "driver" of the Tesla.[104] Both these incidents received worldwide news coverage, but the attention was short-lived. Ultimately, the answers to these questions may indicate not so much the developmental path of LAWS, but its pace.

To be sure, advances in autonomous technology, in either the military or civilian context, will not always yield beneficial results. Developments will solve some problems while creating others.[105] Ten years ago, proponents of a LAWS ban struggled to raise interest because the issues surrounding autonomy seemed too distant. Now, those issues are more immediate, but the autonomy advances in the interim may render a ban impossible. Militaries are certainly increasingly reliant on LAWS. What remains to be seen is what effect, if any, increased civil society reliance on these advances will have.

Attempting to regulate a technology, while efforts to develop at least a measure of that technology not only continue, but increase, poses a significant challenge to those desiring a ban. The CCW LAWS discussions may focus on the future, but the more time that passes the more the future becomes present and the more challenging demarcating acceptable from unacceptable systems will be.

103. Rick Noack, *A Robot Killed a Factory Worker in Germany. So Who Should Go on Trial?*, WASH. POST (July 2, 2015), https://www.washingtonpost.com/news/worldviews/wp/2015/07/02/a-robot-killed-a-factory-worker-in-germany-so-who-should-go-on-trial/?utm_term=.9fbfd1302834. Of note, the Noack article quotes a report by *The Economist* referring to some 77 "robot-related accidents" in the United Kingdom in 2005. "Over the years people have been crushed, hit on the head, welded and even had molten aluminum poured over them by robots. . . ." *Id.* (quoting *Trust Me, I'm a Robot*, ECONOMIST (June 10, 2006), http://www.economist.com/node/7001829).

104. Charles Fleming, *Tesla Car Mangled in Fatal Crash Was on Autopilot and Speeding, NTSB Says*, L.A. TIMES (July 26, 2016), http://www.latimes.com/business/autos/la-fi-hy-autopilot-photo-20160726-snap-story.html.

105. The same technology that will make driverless cars safer for humans in terms of driving risks may also expose cars to the previously not possible: being hacked. *See* Andy Greenberg, *The Jeep Hackers are Back to Prove Car Hacking Can Get Much Worse*, WIRED (Aug. 1, 2016), https://www.wired.com/2016/08/jeep-hackers-return-high-speed-steering-acceleration-hacks/. And there is already driverless car insurance that factors in that risk. *See Driverless Car Insurance*, ADRIAN FLUX, https://www.adrianflux.co.uk/driverless-car-insurance/ (last visited Apr. 17, 2017) [https://perma.cc/7SBM-RPK9].