AUTOMATED DEFENSE TECHNOLOGY

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Automated defense technology (ADT) refers to weaponry designed to fend off incoming threats that is typically employed in international combat and utilizes automation in some part of its operation. Because of this automation, ADT removes some human error from warfare, and more recent automation technology allows machines to make certain decisions about engagement without any human input. The goal of this piece is to provide a rudimentary introduction to the concept of, and implications for, automation in defense technology. This paper first explores a brief history of automated weaponry, then it supplies operational definitions for modern ADT, and finally it considers some ethical implications for the future of ADT use and development.

I. THE HISTORY OF AUTOMATED WEAPONRY

As early as the 15th century, Leonardo da Vinci contemplated non-human soldiers. Sketches from his notebooks show designs for a humanless knight capable of human-like movement, designed to be controlled by a system of pulleys.[1] However, autonomous weapons were not invented until after the industrial revolution, when functioning blueprints came to exist alongside the development of effective and sustainable power sources.[2]

The First World War saw enormous growth in automated weapon technology. For example, machine guns, which utilized energy from initial combustion in order to supply the energy to load the next bullet into the

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1 Ty McCormick, *Lethal Autonomy: A Short History*, FOREIGN POL'Y (Jan. 24, 2014, 10:41 PM), https://foreignpolicy.com/2014/01/24/lethal-autonomy-a-short-history/ [https://perma.cc/S3QQ-9W6L].

2 *See generally* Jimmy Stamp, *Unmanned Drones Have Been Around Since World War I*, SMITHSONIAN.COM (Feb. 12, 2013), https://www.smithsonianmag.com/arts-culture/unmanned-drones-have-been-around-since-world-war-i-16055939/ [https://perma.cc/9H8Z-R4JJ].

chamber, eliminated the need for soldiers to load and lock each individual bullet, cutting down on wasted time tremendously.[3] Also during this period, engineers in the United States began designing the first unmanned aircraft, a type of technology better known today as drones. In 1918, Charles F. Kettering and Orville Wright developed a quarter-ton unmanned aircraft that could drop a bomb at a pre-calculated point in its flight path.[4] Kettering and Wright calculated how many engine revolutions would occur before the aircraft was over the target location, at which point a camshaft would prompt the expulsion of the bomb.[5] This Kettering "Bug," however, was never deployed in combat.[6] Furthermore, despite how innovative this type of automation was for its time, automated weaponry remained only mechanical—not digital or software-based. Humans still predetermined any 'decisions' that had to be made by the weapons; the technology was simply an extension of a human act.

World War II saw the introduction of much more intelligent and lethal weaponry. Notably, the United States and Britain began utilizing radar in weaponry during WWII.[7] For example, proximity fuses utilized radar to trigger an explosion when the weapon was still twenty to fifty feet in the air.[8] Shrapnel would erupt into the space above the ground, causing much more damage than a typical shell.[9] This was an effective weapon for aircraft flying over the battlefield.[10] Arguably, these weapons were among the first truly automated weapon systems used in warfare because the system inside the shell itself was making the operational decision. The internal radar system triggered the 'decision' to explode, rather than a human operator.[11]

The latter half of the twentieth century saw a dramatic expansion in the development of guided missiles. Most modern automated defense technology utilizes features first implemented by guided missile

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[3] ENCYCLOPAEDIA BRITANNICA, MACHINE GUN (2019) https://www.britannica.com/technology/machine-gun [https://perma.cc/A5XN-C6WU].
[4] Stamp, *supra* note 2.
[5] *Id.*
[6] *Kettering Aerial Torpedo "Bug"*, NAT'L MUSEUM OF THE U.S. AIR FORCE (Apr. 7, 2015), https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/198095/kettering-aerial-torpedo-bug/ [https://perma.cc/L9XT-3RSN].
[7] ENCYCLOPAEDIA BRITANNICA, HISTORY OF RADAR (2018) https://www.britannica.com/technology/radar/History-of-radar [https://perma.cc/4KBS-EPML].
[8] ENCYCLOPAEDIA BRITANNICA, PROXIMITY FUZE (2018) https://www.britannica.com/technology/proximity-fuze [https://perma.cc/EU2P-ZY5B].
[9] *Id.*
[10] *Id.*
[11] The next section will discuss more about what constitutes automation in weapons.

technology during the 1950s.[12] Guidance systems found in these missiles perform three crucial functions: navigation, guidance, and control. Navigation technology allows a missile to track its location in space, while guidance and control capabilities allow the missile to continue its course toward the final location and make directional adjustments accordingly.[13] In the mid-1950s, the United States began using the Talos system; this system was a ship-mounted weapons system, deploying missiles capable of course-correcting mid-flight using a homing device.[14] The missiles were directed towards a target by a human actor, but once launched, the missiles themselves corrected for height and distance automatically.[15] Although more sophisticated versions of these missiles are still in use today, the decision-making functions aboard such weapons are not designed to select targets.[16]

The advent of software, the ability of computers to account for microscopic variations in atmosphere, and the discovery of machine learning led to the development of modern automated defense technology. These advances allow weaponry that previously utilized automation in parts of its deployment to become fully automated. Three types of automated weapons, discussed below, are used primarily for defending vehicles, aircraft, buildings (or camps), and ships during wartime: semi-autonomous weapons, human-supervised autonomous weapons, and fully autonomous weapons.

II. OPERATIONAL TAXONOMY FOR MODERN AUTOMATED DEFENSE TECHNOLOGY

"Autonomy" can involve several different machine functions, and the terms *autonomous* and *automated* are not particularly helpful in categorizing modern weapons, of which many perform at least *some* functions automatically. Leading national security scholars suggest that there are multiple dimensions to the concept of "autonomy" insofar as it relates to defense technology.[17] In order to more clearly delineate the

[12] *Guidance and Control*, FED'N OF AM. SCIENTISTS, https://fas.org/man/dod-101/navy/docs/fun/part15.htm [https://perma.cc/CU8L-JJ4L].
[13] Ashish Tiwari, *How Do Guided Missiles Work?*, SCIENCEABC (2016), https://www.scienceabc.com/innovation/how-guided-missiles-work-guidance-control-system-line-of-sight-pursuit-navigation.html [https://perma.cc/2XV8-T7SC].
[14] Elmer D. Robinson, *The Talos Ship System*, 3 JOHNS HOPKINS APL TECHNICAL DIG. 161, 166 (1982).
[15] *Id.*
[16] This distinction will become important in the next section.
[17] Paul Scharre & Michael C. Horowitz, *An Introduction to Autonomy in Weapons Systems* 5–6 (Feb. 13, 2015) (Working Paper), https://s3.amazonaws.com/files.cnas.org/documents/Ethical-Autonomy-Working-

categories of these weapons, this paper adopts definitions set forth by Paul Scharre and Michael C. Horowitz.[18] Scharre and Horowitz describe three theoretical categories of weapons designed to select and engage targets based on the level of human input at different stages of their deployment:[19]

- *Autonomous weapon systems* are those that "once activated, [are] intended to select and engage targets where a human has not decided those specific targets are to be engaged."[20]
- *Human-supervised autonomous weapon systems* are those that share the characteristics of autonomous weapons, but a human is able to monitor their operations and intervene if necessary.[21]
- *Semi-autonomous weapon systems* "incorporate[] autonomy into one or more targeting functions and, once activated, [are] intended to only engage individual targets or specific group[s] of targets that a human has decided are to be engaged."[22]

Scharre and Horowitz's definitions are critical because they clearly delineate levels of human input and culpability. For many, these systems' significance comes from their capacity to cause injury and destruction to human life and real property to a magnitude not anticipated by the party deploying them.[23] Specifically, a machine that falsely identifies a target, and subsequently makes the decision to eliminate that target, could cause millions of dollars of property damage and inflict needless casualties. When a human plays a decision-making or auditing role in a weapon's operation, a liable actor can be readily identified in the event of a misfire. Grouping these machines according to their level of decision-making capability is particularly useful for anyone examining the legal and ethical implications of their deployment. For regulators, these categorizations are important tools that focus on who may be held responsible for outcomes, instead of a highly technical categorization system focused only on the functions of the weaponry.

Paper_021015_v02.pdf.
[18] *Id.* at 16.
[19] These definitions very closely resemble categorical definitions set out by the United States Department of Defense in a 2012 Directive. *Id.* at 19.
[20] *Id.*
[21] *Id.*
[22] *Id.*
[23] For more information on the operational risks of autonomous weapons generally, see Paul Scharre, Autonomous Weapons and Operational Risk (Feb. 2016) (Working Paper), https://s3.amazonaws.com/files.cnas.org/documents/CNAS_Autonomous-weapons-operational-risk.pdf [https://perma.cc/RL6T-54FA].

A. Semi-Autonomous Weapon Systems[24]

In the deployment of a semi-autonomous weapon, a human actor selects the target or group of targets. This human decision is the defining feature of this system. The classic example of a semi-autonomous weapons system is guided munition.[25] These weapons were introduced during World War II and include "projectiles, bombs, torpedoes, and other weapons" that can correct for human error after a human has deployed the technology to locate a specific target or location."[26] In pre-modern munitions, errors involved in the target acquisition could not be corrected until after the projectile left the control of the human actor.[27] In modern semi-autonomous weapons, the significant autonomous features of the weapon allow for corrections in flight path after the weapon has left direct human control. In this way, guided munitions are more accurate and generally more cost-efficient than previous projectile weapons.[28]

In modern warfare, most semi-autonomous weapons include missiles, although their tracking and guidance systems vary greatly between manufacturer and model.[29] These missiles are classified by the type of termination point they are designed to hit: go-onto-target (GOT) weapons or go-onto-location-in-space (GOLIS) weapons.[30]

1. Go-Onto-Target Missiles

Go-Onto-Target missiles are fired at a specific target, such as an enemy plane or ship. In this class of missiles, guidance technology varies greatly. Many of these weapons use a radar detection system, housed onboard the weapon, to correct for movement of the target after deployment.[31] Radar detection functions by sending out radio waves and processing the signals that return after bouncing off of objects in the space around the weapon.[32] GOT weapons may also use heat-seeking or noise detection technology, which employ sophisticated sensors to measure the

[24] Some drones, or UAVs, may fall under this category. For the purposes of this paper, I will not be covering the autonomous features of drones.
[25] Scharre & Horowitz, *supra* note 17, at 8.
[26] *Id.*
[27] R.J. HEASTON & C.W. SMOOTS, INTRODUCTION TO PRECISION GUIDED MUNITIONS 5 (Tactical Weapon Guidance & Control Info. Analysis Ctr., 1983), http://www.dtic.mil/dtic/tr/fulltext/u2/a135619.pdf [https://perma.cc/7KYK-HVB5].
[28] *Id.* at 6.
[29] *See* Scharre & Horowitz, *supra* note 17, at 21–23.
[30] *Id.* at 9.
[31] *Id.*
[32] Marshall Brain, *How Radar Works*, HOWSTUFFWORKS (Apr. 1, 2000), https://science.howstuffworks.com/radar.htm [https://perma.cc/VTF6-WW8Y].

types of disturbances in the atmosphere.[33] Generally, these weapons are aimed in the direction of the target by the human decision-maker and, after deployment, the weapon utilizes the onboard technology to correct for location. This guidance may happen throughout flight or begin as the missile approaches the target.[34] This type of weapon may be used to attack both moving and stationary targets, but GOLIS missiles are often alternatively preferred for their accuracy in targeting stationary objects.

2. *Go-Onto-Location-in-Space Missiles*

For targeting stationary objects, a GOLIS missile is a more accurate weapon because it fixes in on a geographical location. These weapons use a guidance device outside of the missile itself in order to ensure that the designated target is precisely hit.[35] Many GOLIS systems communicate with satellite-based global positioning systems during flight in order to arrive at a pre-programmed point on the Earth.[36] This technology functions by continuously communicating information to the satellite about wind speed, direction, and height—receiving real time corrections. One significant limitation of these weapons is their dependence on location communications with separate technology. If a satellite were to lose a communication signal for even a fraction of a second, the warhead could diverge from the flight path.

B. Human-Supervised Autonomous Weapon Systems

Human-supervised autonomous weapons are those which select and seek out targets without human command, usually with a human monitoring very closely and able to intervene if necessary.[37] This category of weapons makes up what is colloquially called “autonomous weapons” because the weapon makes the ultimate decision about what to target and when to fire, within a set of programmed parameters. These human-supervised autonomous weapons are currently used by the United States and several other military powers.[38] All of these systems currently in use are employed to defend a moving object (such as a vehicle or ship) or a non-moving base and are manned by an on-site human monitor.[39] Below

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[33] Scharre and Horowitz, *supra* note 17, at 8–10.
[34] *Id.*
[35] *Id.*
[36] *Id.*
[37] *Id.* at 12–13.
[38] *Id.* at 12.
[39] *Id.* at 12–13.

are some examples of human-supervised autonomous weapons currently in use.

US Patriot System

The Patriot system is a vehicle-mounted missile defense system currently employed by the US Army.[40] The defense system contains an onboard radar system that continually monitors the space around the vehicle, up to 100 kilometers, for potential threats.[41] Once the Patriot system detects a threat, it deploys a missile automatically. The missile is equipped with a target acquisition system that collects real-time data about the target and communicates with the control center for corrections based on the data before collision.[42]

Goalkeeper System

The Goalkeeper is a Close-In Weapons System (CIWS) that is mounted aboard ships to destroy incoming projectiles or aircraft. The Goalkeeper detects threats at the surface level by employing advanced radar technology to collect information about the surrounding area, filtering out noise and other impediments, and searching the data continuously.[43] Once the radar detects a threat based on a set of characteristics found in the data, it employs a machine gun able to fire more than 4,000 rounds per minute.[44] The Goalkeeper is also monitored by a human decision-maker, but because the programmed response to a perceived threat is artillery, errors can be costly.

Iron Curtain

The Iron Curtain is a CIWS currently in production by Artis LLC, an American developer.[45] While the Iron Curtain's specific functionality is not yet well-known to the public, it is designed to be portable, attaching to

[40] *Id.* at 21.
[41] *Patriot Missile Long-Range Air Defense System,* ARMY TECH. (2018), https://www.army-technology.com/projects/patriot/#0 [https://perma.cc/GWY5-L2FR].
[42] *Id.*
[43] *Goalkeeper 30MM Close-In Ship Defense System*, GEN. DYNAMICS (2003), https://www.gd-ots.com/wp-content/uploads/2017/11/Goalkeeper.pdf [https://perma.cc/AL8R-V5TR].
[44] *Id.*
[45] *Iron Curtain Active Protection System,* ARTIS (2016), http://artisllc.com/iron_curtain_active_protection_system/ [https://perma.cc/MXC6-WQQQ].

most vehicles or buildings. The Iron Curtain system continuously monitors its surrounding area for threats and can engage them at extremely high speeds.[46] One of the system's array of countermeasures utilizes radar and on-site calculations to intercept an incoming threat, causing it to quickly burn up instead of detonating completely and disabling the threat with minimal collateral damage.[47]

C. Autonomous Weapon Systems

Autonomous weapon systems select and engage targets without any direct human oversight. Fully autonomous weapons systems in use or being publicly developed today are scarce. Presumably due to uncertainty about non-human error, many countries are hesitant to add fully autonomous weapons to their arsenals.[48] One example of an autonomous weapon system is the loitering munition. Loitering munitions, which hover over a human-designated area and strike at targets that match specific parameters, are currently only employed in Israel.[49] The *Harpy NG*, the most commonly used and advanced model manufactured by Israel Aerospace Industries, is designed to attack enemy radar systems.[50] These loitering munitions resemble drones, or UAVs, and can stay in the air for up to nine hours.[51] Because loitering munitions are set up with specific limits to their range, they may offer a model for future development of autonomous weapons that afford an element of control without the need for human monitoring.

III. ETHICAL IMPLICATIONS

On July 3, 1988, a semi-autonomous weapons system mounted to the *U.S.S. Vincennes*, a United States guided missile cruiser in the Persian Gulf, misidentified an Iranian commercial flight for a fighter jet. The system, which was overseen by a human operator, fired two missiles at the airplane, killing 290 people. At the time, the ship was engaged in a

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[46] *Id.*
[47] *Id.*
[48] *See* Adam Satariano, *Will There Be a Ban on Killer Robots?*, N.Y. TIMES (Oct. 19, 2018), https://www.nytimes.com/2018/10/19/technology/artificial-intelligence-weapons.html [https://perma.cc/D6N6-UEB7].
[49] Scharre & Horowitz, *supra* note 17, at 13.
[50] *Id.*
[51] Yoav Zitun, *The Missile That Looks Like a UAV*, YNETNEWS.COM (Feb. 17, 2016, 9:43 AM), https://www.ynetnews.com/articles/0,7340,L-4767278,00.html [https://perma.cc/B3D4-K8T5].

skirmish with an Iranian ship.[52] The misidentification of a large commercial airliner as a small military jet might be attributable to the state of the technology nearly three decades ago, but it raises concerns about how much capability should be given to autonomous weapons systems, even if humans are supervising them.

Many lawmakers' concerns about automated defense technology can be attributed to unease about a machine making the decision to end a life. In April 2018, military experts traveled to Geneva in order to discuss the future of "killer robots," in part because many non-governmental organizations (NGOs) fear regulations are not keeping up with the rapid pace of "killer robots'" developments.[53] One such NGO, the Campaign to Stop Killer Robots, is lobbying to codify an international statute banning autonomy in target selection and applying violent force among defense technology.[54] Technologically advanced countries like Russia and the United States are reluctant to support the organization.[55]

The Pentagon has dismissed concerns of this type by claiming that any artificial-intelligence-employing weapons system will always have a "man in the loop."[56] However, thousands of AI and computer scientists including Elon Musk and the late Stephen Hawking anticipate these developments as military resources are being diverted to the study of machine learning.[57] In 2015, those scientists signed an open letter, calling for a "ban on offensive autonomous weapons beyond meaningful human control."[58] On the other hand, many scholars argue that flat bans are dangerous.[59] Critics assert that autonomy in weapons allows for much less

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[52] Max Fisher, *The Forgotten Story of Iran Air Flight 655*, WASH. POST (Oct. 16, 2013), https://www.washingtonpost.com/news/worldviews/wp/2013/10/16/the-forgotten-story-of-iran-air-flight-655/ [https://perma.cc/7JQF-3LLW].

[53] Billy Perrigo, *A Global Arms Race for Killer Robots Is Transforming the Battlefield*, TIME (Apr. 9, 2018, 2:12 PM), http://time.com/5230567/killer-robots/ [https://perma.cc/79WR-MS9L].

[54] *Id.*

[55] *Id.*

[56] Matthew Rosenberg & John Markoff, *The Pentagon's 'Terminator Conundrum:' Robots That Could Kill on Their Own*, N.Y. TIMES (Oct. 25, 2016), https://www.nytimes.com/2016/10/26/us/pentagon-artificial-intelligence-terminator.html [https://perma.cc/L37H-QEFR].

[57] *Autonomous Weapons: An Open Letter from AI & Robotics Researchers*, FUTURE OF LIFE INST., https://futureoflife.org/open-letter-autonomous-weapons/ [https://perma.cc/S9AW-T3KS].

[58] *Id.*

[59] KENNETH ANDERSON & MATTHEW WAXMAN, HOOVER INST., LAW AND ETHICS FOR AUTONOMOUS WEAPONS SYSTEMS: WHY A BAN WON'T WORK AND HOW THE LAWS OF WAR CAN (2013).

human error and collateral damage—which could actually save lives—and a ban would stifle the development of such machines.[60]

IV. CONCLUSION

Few of the world's autonomous weapons systems make command decisions, but the potential does pose a question for the future of the intersection of autonomous weapons and artificial intelligence systems. Any fully integrated autonomous weapons technology will need a legal framework for liability and culpability when error inevitably occurs. Logistical safeguards need to be implemented, and humans must always be kept in the loop. The international community has made strides towards a consensus about the acceptability of fully automated weapons in interstate conflict. For now, nations and corporations continue to develop and deploy autonomous weapons across the globe, further delegating decision-making power to these systems.

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[60] *Id.*