Where to **draw** the **line**

İncreasing Autonomy in Weapon Systems – Technology and Trends

PAX

www.paxforpeace.nl

Colophon
November 2017. This April 2018 version has corrected a few typos.

ISBN: 978-94-92487-22-3 NUR 689
PAX serial number: PAX/2017/14

Author: Frank Slijper
Cover picture: ‘Robot Wireframe Hologram in Motion’, Vandrage Artist via Shutterstock. Any potential similarity with an existing weapon system would be accidental.
Other photos: Jastrow/Wikimedia Commons; MarkBlackUltor/Wikimedia Commons; QinetiQ Group (https://www.flickr.com/photos/qinetiq/4789729740); U.S. Navy; and U.S. Navy/John F. Williams.
Graphic Design: Het IJzeren Gordijn

In preparing this report, PAX commissioned Armament Research Services (ARES) to review its technical basis. ARES is an apolitical technical intelligence consultancy. Furthermore, the author would like to thank Daan Kayser and Miriam Struyk for their invaluable input.

About PAX
PAX works with committed citizens and partners to protect civilians against acts of war, to end armed violence and to build peace. PAX operates independently of political interests.

P.O. Box 19318
3501DH Utrecht
The Netherlands

info@paxforpeace.nl
www.paxforpeace.nl

Table of Contents

“Artificial intelligence and autonomy are advancing to the point where, in the near future, unmanned aircraft will no longer need pilots to move small drones with a stick and rudder”

- Col. Brandon Baker, US Air Force, Chief Remotely Piloted Aircraft Capabilities Division[1]

1. Introduction

As military technology moves towards greater automation, specifically in the development and acquisition of remotely-controlled systems that require reduced levels of decision-making from a human operator, artificial intelligence is advancing at an ever-faster pace. This has given rise to increasing concerns regarding the emergence of so-called 'lethal autonomous weapon systems' (LAWS), also more popularly known as killer robots. "As sensors, algorithms and munitions are increasingly interlinked, questions arise about the acceptability of autonomy in certain 'critical functions,' particularly around identification, selection and application of force to targets. These concerns span ethical, legal, operational and diplomatic considerations".[2]

Such considerations surrounding the delegation of the use of force, especially decisions over life and death, to machines strongly determine the vision of PAX that LAWS need to be banned pre-emptively. In order to contribute to the debate on LAWS, PAX believes it is of critical importance to understand the technology and its trends.[3]

Distinctions must be drawn between those weapons which are *automated* and those which are *autonomous*. A future in which robotic weapons are able to select and attack individual targets without any meaningful human control deeply worries many civil society organisations. That is, the removal of the 'man-in-the-loop' principle present in existing weapon systems. 'Automated' is therefore likely the better term for describing systems in which there is a meaningful man-in-the-loop element to a weapon's employment, and any robotic element serves to assist the weapon operator at varying stages in the kill chain.

Purpose

This briefing paper aims to show the trend towards increased automation and autonomy by identifying a number of systems which have the ability to select and attack targets with automated critical functions. For this purpose, most of the focus of this paper is on active, moving weapons, searching and engaging potential targets with varying levels of automation and autonomy. Examples of such systems include advanced unmanned combat systems (e.g. unmanned ground vehicles (UGV) or unmanned aerial vehicles (UAV); also known as unmanned ground systems (UGS) and unmanned aerial systems (UAS)) or so-called 'loitering' munitions. Some of these systems are in production, whereas others are still under development. Despite the predominance of western-made systems in this briefing, the developments of such systems produced in other nations (such as China and Russia), whilst more difficult to investigate due to more limited available open-source information, remain significant.

Secondly, as autonomy in critical functions covers a spectrum of options, with varying levels of human control, this briefing aims to illustrate the generally accepted notion that key autonomous

features are rapidly emerging and are increasingly becoming notable aspects of tomorrow's weapons.

Classification

While technology has advanced at a rapid rate, its lexicography has not kept pace. In the past, 'autonomy' and 'automation' were relatively interchangeable, however they now have different meanings. To date, no formal acceptance of the distinctions has been agreed upon. For the purpose of this briefing note, 'autonomous/autonomy' implies independence of a system whilst 'automated/automation' indicates that there remains a significant man-in-the-loop who retains meaningful control of critical functions.

PAX - cofounder of the international Campaign to Stop Killer Robots - considers killer robots, or lethal autonomous weapon systems as weapons which, once activated, using sensors and/or artificial intelligence, will be able to operate without meaningful human control over the critical functions. This definition highlights the autonomous nature of any 'autonomous' system and specifies the lack of a man-in-the-loop.

It is important to note that manufacturers have both contributed to and taken advantage of this blurred line between the terminology in use today. As such, some manufacturers have inaccurately described their products as 'autonomous', where the term 'automated' would be more precise, and vice versa.

Additionally, these manufacturers gladly highlight their full range of products, including those 'under development', in order to increase their market presence. As such, a number of systems may never see practical use, although the advances made during the development process could well be applied to successor systems or to other technical areas.

Concerns

Weapon systems with no meaningful human control over the critical functions raise various legal, ethical and security concerns. Can these weapons comply with international humanitarian law? Can they can distinguish between soldiers and civilians, and ascertain whether an attack is proportional? Would these weapons lower the threshold to use armed violence? What happens if dictators or terrorists get hold of these weapons? Who is responsible if something goes wrong? And what is the impact on human rights if police forces also use such technology?

However, the overarching objection of PAX is ethical in nature: a machine should never make life-or-death decisions. PAX believes that taking the human out of the loop, having a machine deciding about life and death, goes against the principle of human dignity and outsources morality in an unacceptable way.

Future

The current trend is towards higher levels of automation in weapon systems, with the man in the loop element becoming increasingly reduced. Although there is reluctance by some states to sanction weapons systems development that would remove the man-in-the-loop completely, this seems unlikely to halt the technological development of manufacturers, or indeed the support they receive from other states.

Lethal autonomous weapon systems have been on the agenda of the UN Convention of Certain Conventional Weapons (CCW) since 2013. In 2014, 2015 and 2016, several informal expert meetings took place at the CCW to discuss killer robots. Numerous aspects were discussed, including international humanitarian law, accountability, technological developments, international security and ethics. Since 2013, 78 states have spoken on the issue of LAWS, of which 19 have called for an international ban.[4] In December 2016, the CCW decided to proceed to a more formal basis of discussions, a so called Group of Governmental Experts (GGE).

The International Committee of the Red Cross (ICRC) has suggested States “develop the parameters of human control in light of the specific requirements under IHL and ethical considerations (principles of humanity and the dictates of public conscience), thereby establishing specific limits on autonomy in weapon systems”.[5]

Since we see lethal autonomous weapons developing within a continuum, with levels of technology varying from simple automation towards full autonomy, and in different functionalities of weapon systems, we also witness a slippery slope where the human role is gradually diminishing in the decision making loop. Therefore PAX believes that it is imperative that states draw a clear line, guaranteeing meaningful human control over decisions of the use of force.

Hoping to contribute to that discussion, without trying to be exhaustive, the remainder of this paper highlights a number of weapon systems currently operational or under development, with varying levels of (proclaimed) automation and autonomy. Each section shows characteristics of selected weapons per category. PAX does not draw conclusions from these perceived levels of human control.

2. Weapon Systems

Loitering Munitions

No universally-established definition of a 'loitering munition' exists. Generally, they are agreed to be something of a hybrid between UAVs and guided missiles. According to one definition, "[a] loitering munition is a type of unmanned aerial vehicle designed to engage beyond line-of-sight ground targets with an explosive warhead. Loitering munitions are often portable and many are meant to provide ground units such as infantry with a guided precision munition. They are equipped with high resolution electro-optical and infrared cameras that enable the targeter to locate, surveil, and guide the vehicle to the target. A defining characteristic of loitering munitions is the ability to "loiter" in the air for an extended period of time before striking, giving the targeter time to decide when and what to strike."[6]

Harpy - Jastrow/Wikimedia Commons

HARPY

What: A ground-launched 2.1 m long loitering missile with a 15 kg explosive warhead and 9-hour flight time.[7] The latest version is called Harpy NG (New Generation).[8]
Automation: "Harpy is a 'fire and forget' autonomous weapon launched from a ground vehicle behind the battle zone. The Harpy weapon detects, attacks and destroys enemy radar emitters, hitting them with high hit accuracy" according to its producer.[9]
Made by: Israel Aerospace Industries (IAI).[10]
Sold to: China, India, Israel, South Korea and Turkey.[11] Additionally, Taiwan's National Chung-Shan Institute of Science and Technology (NCSIST) appears to have developed a close copy.[12]
Video: https://youtu.be/AyKXUfOubH0

HAROP

What: Slightly larger than the Harpy at 2.5 m, the Harop (AKA 'Harpy 2) has maximum flight time of 6 hours, 1,000 km range, and a 15 kg explosive warhead.[13] The system has recently been updated to include a version optimised for maritime attack.[14]
Automation: Harop attacks any identified target, but with 'man-in-the-loop'. Advertised as "autonomous platform operation", it has an "abort attack capability" indicating the technical possibility for a soldier to intervene to avoid unintended attacks.[15]
Made by: Israel Aerospace Industries (IAI)
Reportedly sold to: Azerbaijan, India, Israel and Turkey.
Video: https://youtu.be/ELsxY_liTvk

SWITCHBLADE

What: This miniature intelligence, surveillance, and reconnaissance (ISR) and lethal platform is "designed to provide the warfighter with a back-packable, non-line-of-sight precision strike solution with minimal collateral effects." A 0.6 m long loitering munition with a 40 mm modular payload warhead, a 10-minute flight time and a maximum range of 50 km.[16] Several models have been observed.
Automation: Switchblade "can be operated manually or autonomously."[17]
Made by: AeroVironment (USA). Orbital ATK supplies a 0.45 kg warhead.[18]
Sold to: US Army has deployed some 4,000 Switchblades in Afghanistan.[19] Models have also been observed in Syria and Iraq.[20]
Video: https://www.youtube.com/watch?v=EdKsu5ZgwIU

WARMATE

What: 4 kg lethal UAV with a range of 10 km and an endurance of 30 min. It has electro-optical and infrared (IR) sensors and two warhead options: one for use against light armoured vehicles, the other a fragmentation device.[21]
Automation: "WARMATE can be operated as an autonomous and independent system"; but "the operator has the ability to make sure the observed object is a real target to be engaged." Also: "Fully automatic flight control (hunt phase)/Aided flight control (engage phase)".[22]
Made by: WB Electronics (Poland)
Sold to: It is speculated that India is the unidentified customer of the weapon.[23]
Video: https://www.youtube.com/watch?v=eJa2iKgqKbk

XQ-06 'FI' [24]

What: Man-portable, tube-launched loitering munition. It has a 0.5 kg explosive payload, with a thermobaric warhead offered as an option, with a 10-15 minute flight time and 12 km range. "We wanted to make everything operator-friendly with very simple interfaces, few buttons and minimal data to interpret".[25]
Automation: Initial version under direct control, but "major difference between Fi and other loitering munitions is that it is intended to be largely autonomous and able to operate in swarms. […] In future engagements, the operator may simply designate the target and let the swarm do the rest."[26]
Made by: Kartal Savunma Teknolojileri (Turkey)
Sold to: Unknown. Company aims at wider export market, avoiding components under US export control.[27]
Video: https://www.youtube.com/watch?v=p1abliUhm1I

Unmanned Combat Aircraft

Armed drones have become an increasingly common feature in modern warfare capabilities. So far, these are predominantly surveillance drones equipped with missiles, such as the American Predator and Reaper, the Israeli Hermes and the Chinese Wing Loong. Over the past decade several demonstrator projects have emerged, combining higher speeds, advanced sensor systems, increased command and control, and internal weapon bays. Two examples are the Taranis and nEUROn described below, which may merge as part of the Franco-British government-supported Unmanned Combat Air System (UCAS) demonstration program, "the most advanced of its kind in Europe".[28] In March 2016 the two governments pledged to jointly invest £1.5 billion in a BAE-Dassault Aviation-led effort to build a prototype vehicle.[29]

MQ-8C FIRE SCOUT

What: The Fire Scout is an automated helicopter system that provides real-time intelligence, surveillance, target-acquisition and reconnaissance (ISTAR), laser designation, and battle management capabilities to its users.[30] It is 12.6 m long, has a maximum speed of 250 km/hr, a range of 2,272 km and 12 hour endurance. It has an internal payload capability of 500 lbs (227 kg).[31]
Automation: Capable of automated take-off and landing, in both prepared and unprepared landing zones. The Fire Scout can provide targeting information for over-the horizon surface missiles. A planned aim is for an in-flight target update to a net-enabled weapon.[32]
Made by: Northrop Grumman (USA)
Sold to: US Navy
Video: https://www.youtube.com/watch?v=AaG2EDPVBqc

NEURON

What: Stealthy Unmanned Combat Air System developed under a €405 million demonstrator programme, which had its first flight in 2012.[33] The 10 m long, aircraft has a 12.5 m wingspan weigh 5,000 kg empty, with max 7,000 kg weight and can fly for over 3 hours autonomously.[34]
Automation: Fully automated attack capabilities, target adjustment, and communication between systems.[35] Ranked as most autonomous weapon system currently under development/in production.[36]
Made by: Dassault Aviation (France) is prime contractor.
Sold to: under development/demonstrator phase.
Video: http://www.dassault-aviation.tv/100th-flight-of-the-neuron-1162-en.html

Taranis - QinetiQ Group (https://www.flickr.com/photos/qinetiq/4789729740)

TARANIS

What: UK's top secret £185 million advanced armed drone named after the Celtic god of thunder. 12.5 m in length, with a 10 m wingspan[37], according to a UK Defence official it is the "most technologically advanced demonstration aircraft ever built in the UK".[38]
Automation: Taranis would be able to reach a preselected area using a programmed flight path. It would automatically identify and target the threat within that area. It sends data back to its home base, where information is verified by a human operator, who OK's target for attack. Euphemistically, according to officials, it has "a degree of automated capability"[39], though the producer stresses that it is "under the control of a human operator".[40] The Times reported in 2016 that the company was "proceeding on the basis that an autonomous strike capability could be required in the future".[41]
Made by: BAE Systems (UK) leads team with Rolls-Royce, General Electric and QinetiQ.
Sold to: under development/demonstrator phase.
Video: https://www.youtube.com/watch?v=qPAOO5LoFvM

X-47B

What: The X-47B is a tailless, strike fighter-sized unmanned aircraft, designed for stealth and carrier-based launches.[42] Measuring nearly 12 m in length, with a wingspan of 19 m, the X-47B has a range of more than 3,890 km and a high subsonic top speed. Although it is currently designed for intelligence, surveillance, and reconnaissance tasks[43], it has twin internal weapon bays, with a 4,500 lb (2,041 kg) design load.[44]
Automation: Capable of autonomous launch and landing on the deck of an aircraft carrier, it is also able to fly autonomously, as well as being able to refuel mid-air.
Made by: Northrop Grumman (USA)
Sold to: US Navy
Video: https://www.youtube.com/watch?v=pCAe81aq6k0

Precision Guided Munitions

Precision guided munitions are self-propelled missiles with typically four system components: targeting/guidance, flight system, engine and warhead. They can be used for multiple purposes including surface-to-surface and air-to-surface (ballistic, cruise, anti-ship, anti-tank, etc.), surface-to-air, anti-ballistic, air-to-air, and anti-satellite.

Of note, the MIM-104 Patriot system was one of the first systems to introduce autonomy, with its Initial Operational Capability in the US Army in 1984. Over the following 30 years, continual improvements have been made, so much so that the modern version shares little more than a name and basic purpose.[45] It does, however, highlight the historical developments of a 'legacy' system through to 'futuristic' LAWS. Whilst modern technology has improved the means by which information is acquired, analysed, and acted upon, as well as doctrine and concepts of operations, the advantages of incorporating automation into weapon systems have been understood at a tactical level for decades.

AGM-158C LRASM

What: The Long Range Anti-Ship Missile (LRASM) is a stealthy cruise missile, armed with a 1,000 lb (454 kg) penetrator and blast fragmentation warhead[46], that can find its own target autonomously by using active radar homing to locate ships in an area. The LRASM is also capable of hitting land targets.

Automation: "It is intended to fly for hundreds of kilometers, manoeuvring on its own to avoid radar, and out of radio contact with human controllers. […] The Pentagon nonetheless argues that the new anti-ship missile is only semiautonomous and that humans are sufficiently represented in its targeting and killing decisions. But officials at the Pentagon's Defense Advanced Research Projects Agency (DARPA), which initially developed the missile, and Lockheed Martin declined to comment on how the weapon decides on targets, saying the information is classified."[47]
Made by: Lockheed Martin with DARPA (USA)[48]
Sold to: Developed for the US Navy and Air Force; expected to be operational in 2018.[49]
Video: https://www.youtube.com/watch?v=h449oIjg2kY

MIM-104 PATRIOT

What: Patriot is a missile defence system consisting of radars, command-and-control technology and multiple types of interceptors, all working together to detect, identify and defeat tactical ballistic missiles, cruise missiles, drones, advanced aircraft and other threats. Each missile has a range of 70 km and a maximum flight time of less than three and a half minutes.[50]
Automation: "A target engagement can be carried out in manual, semi-automatic or automatic mode. When the decision has been made to engage the target, the engagement control station selects the launch station or stations and pre-launch data is submitted to the selected missile. After launch the Patriot missile is acquired by the radar."[51]
Made by: Raytheon (USA)
Sold to: USA and twelve other nations.[52]
Video: https://www.youtube.com/watch?v=MjQqDiHfkoo

SEARAM

What: SeaRAM is an anti-ship missile defence system, designed to engage high performance, supersonic and subsonic threats, including sea-skimming anti-ship missiles, high-speed incoming vessels, rotary and fixed-wing aircraft, and other aerial and surface targets.[53] It combines the accuracy, extended range and high manoeuvrability of the RAM missile with the high-resolution search-and-track sensor and reliable, quick-response capability of the Phalanx Block 1B system.[54]
Automation: The SeaRAM is capable of autonomously detecting, tracking and engaging enemy targets, with an increased ability to engage multiple targets at once, through the use of "automated dual-mode passive radio frequency and infrared guidance".[55] It works independently of the ship's combat system, and has missile-to-missile fratricide avoidance.[56]
Made by: Raytheon (USA)
Sold to: US Navy
Video: https://www.youtube.com/watch?v=og86EPpEsVs

Unmanned Ground Vehicles

Autonomous Unmanned Ground Vehicles operate without the need for a human controller. They can be used to provide information via reconnaissance, to provide physical security on patrol, carry weapon systems, carry cargo and act as a forward observation platform.

GLADIATOR

What: 6-wheeled 'Gladiator' Tactical Unmanned Ground Vehicle (TUGV), including mounts for M249 and M240G machine guns and multi-purpose assault weapon.[57] Use of non-lethal ammunition is also an option.[58]
Automation: While developed with an operator control unit, it has been called the "world's first multipurpose combat robot" with the potential "to be upgraded to semiautonomous and then fully autonomous modes".[59] Automated features were also extensively tested, e.g. the Crusher and Black Knight unmanned vehicle systems, also developed by Carnegie Mellon/NREC.[60]
Made by: Carnegie Mellon University's National Robotics Engineering Center (NREC) with United Defense (now BAE Systems). Programme appears discontinued.
Sold to: USA
Video: https://www.youtube.com/watch?v=0p5HdJuTTVk

ROBATTLE

What: First shown at the Eurosatory arms fair in France in June 2016, this 6-wheeled UGV can be equipped with different types of machine guns and is designed to "support a wide range of missions including intelligence, surveillance and armed reconnaissance; convoy protection, decoy, and ambush and attack."[61]
Automation: "The system can be operated autonomously in several levels", though its weapon systems are currently remotely controlled.[62]
Made by: IAI (Israel)
Sold to: Unknown
Video: https://www.youtube.com/watch?v=InO8I-HHB3E

THEMIS ADDER

What: The Tracked Hybrid Modular Infantry System is an unmanned ground vehicle, equipped with (Singapore Technology) ST Kinetics Adder remote weapon system, which can accommodate different types of machine guns. "The onboard video tracking system allows engagement of both stationary and moving targets. The ADDER also features day and night imaging cameras, a laser rangefinder and an optional 40mm air-bursting munition system."[63]
Automation: "In remote control mode, a command and control station allows the operator to receive real-time sensor data from the THeMIS unmanned vehicle and to transmit command data to the vehicle through a tactical data link. An autonomous controlled system installed in the UGV provides autonomous real-time control and obstacle avoidance capabilities. It automatically directs the vehicle to reach a target along the desired path."[64]
Made by: MILREM (Estonia)
Sold to: under development with support of the government of Estonia
Video: https://www.youtube.com/watch?v=DfqGuFYKSoE

Unmanned Marine Vehicles

Unmanned marine vehicles can operate on the surface of the water (unmanned or autonomous surface vehicles) as well as underwater (unmanned or autonomous underwater vehicles). They can be used for a wide range of military and commercial applications. Military roles include Mine Counter Measures (MCM), Intelligence Surveillance and Reconnaissance (ISR), Anti-Submarine Warfare (ASW) and attack craft.

AN-2 ANACONDA

What: Special operations riverine unmanned surface vessel that can carry up to five weapon systems. The all-aluminium Anaconda is a Swift Autonomous Vessel which offers "enhanced surveillance and reconnaissance, identification and interception capabilities".[65]
Automation: It should become a "completely autonomous watercraft equipped with artificial intelligence [AI] capabilities" and to "perform tactical manoeuvres and loiter in an area for long periods of time, all without human intervention".[66]
Made by: Swiftships, with the University of Louisiana at Lafayette (USA)[67]
Sold to: Under development with the US Navy
Video: https://www.youtube.com/watch?v=BN32phtF13U

Sea Hunter - U.S. Navy/John F. Williams

SEA HUNTER

What: This self-driving warship, designed to hunt for enemy submarines, was hailed by the Pentagon as a major advance in robotic warfare.[68] Launched in April 2016 the 40 m-long unarmed prototype should cruise on the ocean's surface for two or three months at a time – without a crew or anyone controlling it remotely.
Automation: "This is an inflection point," [then] deputy US defence secretary Robert Work said at the launch. "This is the first time we've ever had a totally robotic, trans-oceanic-capable ship." […] "I would like to see unmanned flotillas operating in the western Pacific and the Persian Gulf within five years," he said, comparing the prototype ship with early drone aircraft and raising the possibility of positioning weapons on the Sea Hunter. He stressed that even if the US would decide to arm robotic naval systems such as Sea Hunter, any decision to use offensive lethal force would be made by humans. "There's no reason to be afraid of a ship like this," Work said.[69]
Made by: Developed by the Pentagon's Defense Advanced Research Projects Agency (DARPA)[70]
Sold to: Under development
Video: https://www.youtube.com/watch?v=o6jG49iFTwk

SEAGULL

What: A prototype of what is claimed to be the world's first unmanned system for anti-submarine warfare (ASW) and mine countermeasures (MCM) missions, with "underwater robotic vehicles to identify and neutralize mines".[71] It can perform deep-water missions for four days at a time at line-of-sight ranges of up to 100 km.
Automation: "By transforming small, remotely operated surface platforms into advanced, highly autonomous networked systems, we're bringing asymmetry to the advantage of our customers".[72]
Made by: Elbit Systems (Israel)[73]
Sold to: under development
Video: https://www.youtube.com/watch?v=s4NtAGfKLrM

Border Control

With border control technology a major niche in the military and paramilitary market, robotics become a key feature of border control equipment.

SENTRY-TECH

What: is a modified fortified structure ('pillbox'), equipped with Rafael's Samson Mini stabilised remote weapon station, protected by folding shields.[74] A series of these are remotely networked and combined with various sensors, relaying information to a single operator who will act after following identification and verification by the commander.
Automation: "The system's highly accurate target engagement and auto-tracking capabilities, combined with accurate stabilisation mechanism, enable superior performance under the most adverse conditions".[75] "Once IDF sensors locate a potential target, the operator can cue Sentry Tech to verify or engage the target through its own electro-optic (EO) day/night sensor package. The sensor-acquired information is transferred to the electro-optic package of the weapon station, which slews to the target, enabling the operator to locate and track the target".[76] "Sources at Rafael say that the company is now developing an autonomous "see-shoot" system which will not require human intervention".[77]
Made by: Rafael (Israel)
Sold to: Israel
Video: https://www.youtube.com/watch?v=aJ6X--XYrdA

SUPER AEGIS II

What: An automated gun turret that can be mounted with a 12.7 mm (.50 in) machine gun, automatic 40 mm grenade launcher, or portable surface-to-air missile. With a detection range of 2.2 km in total darkness, utilising IR thermal sensors, colour camera with 30x magnification, laser illuminator and laser range finder.[78]
Automation: Automated detection, tracking, targeting and manual or automated firing. Although not initially designed to include manual functions, there is a requirement for manual input that permits the turret to shoot.[79] Currently the weapon has no way to distinguish between friend or foe.
Made by: DoDAAM Systems (South Korea)
Sold to: Unknown
Video: https://www.youtube.com/watch?v=3ygFeywrvjc

SGR-A1 - MarkBlackUltor/Wikimedia Commons

SGR-A1 SENTRY ROBOT

What: These armed robots operate along the border between North and South Korea (known as the demilitarised zone). The SGR-A1 has a 5.56 mm machine gun and a 40 mm grenade launcher and detects human beings via infra-red sensors. The fixed robot uses pattern recognition software to spot humans.[80]
Automation: The robot has both a supervised and unsupervised mode available. “In the unsupervised mode, the SGR-A1 identifies and tracks intruders in the demilitarised zone, eventually firing at them without any further intervention by human operators”.[81]
Made by: Hanwha Techwin (previously Samsung Techwin - South Korea)
Sold to: South Korea
Video: http://video.dailymail.co.uk/video/1418450360/2014/09/1418450360_3787197809001_robot.mp4

Counter Terrorism and Law Enforcement

Whilst very similar in technological capabilities to the previous LAWS, the use of these systems in a non-operational environment presents different and potentially more complex scenarios. Elements such as the choice of weapon system, less-than-lethal options, judicial ramifications, evidence chain, right to privacy, warrants, probable cause, and interaction with the public, combine to pose new concerns.

ANBOT[82]

What: A security robot deployed in locations such as airports that can work around-the-clock, deter suspects with sound and light, and use tools like “an electric riot fork”. The intelligent guard is 1.5 m tall and weighs approximately 75 kg.
Automation: With four digital cameras, the security robot is capable of autonomous patrols, intelligent monitoring and auto recharging.
Made by: Shenzhen Public Security Bureau, the National University of Defense Technology and a domestic technology company (China).
Sold to: China
Video: https://www.youtube.com/watch?v=0Om7CWWVUP0

PRISON GUARD

What: A 1.5 m prototype prison guard robot designed by a university in South Korea. Equipped with 3D cameras it observes prisoners' behaviour and when it detects any abnormality it can report and transmit the situation in real time to the control centre.[83]
Automation: Analysis of behaviour, as well as automated patrolling, with an option for manual control.[84]
Made by: Kyonggi University (South Korea)
Sold to: South Korea
Video: https://www.youtube.com/watch?v=-TsgEKdGCdU

Anti-Animal

A different but related development is currently taking place in the area of eliminating animals considered invasive or diseases-carrying. While such systems appear to provide clear benefits, they also demonstrate how easily technology proliferates and the borders between civil and military use may be increasingly difficult to draw. The dual-use character of these technologies, including inherent proliferation challenges, show the need to adapt policies required to control automated targeting technologies where they could become military tools.

MOSQUITO KILLER ROBOT

What: This Chinese insect killing robot recognises a mosquito and 'instantly' lasers it. The company claims the laser is capable of killing "30 to 40 mosquitoes in one second".[85] Available in both static and movable versions.
Automation: An object recognition and tracking algorithm forms the basis of the system.
Made by: LeiShen Intelligent System (China)[86]
Sold to: Unknown. Military users are at least one target, as it was shown at the Kielce arms fair (Poland) in September 2016.
Video: https://www.youtube.com/watch?v=ugy_KRHUnqQ

COTSBOT

What: A robot designed to patrol the Great Barrier Reef, targeting the crown-of-thorns starfish (COTS) population, a species responsible for the decline in coral cover. It can search for up to eight hours and deliver over 200 lethal shots. Equipped with stereoscopic cameras to give it depth perception, five thrusters to maintain stability, GPS and pitch-and-roll sensors, and a unique pneumatic injection arm to deliver a fatal dose of bile salts. It's designed to operate within a metre of the seafloor, one of the most dynamic and challenging environments for any robot.
Automation: The system is backed by "serious computational power" and can think and learn for itself in the water: "If the robot is unsure that something is actually a COTS, it takes a photo of the object to be later verified by a human, and that human feedback is incorporated into the robot's memory bank. The robot has been trained using thousands of images of COTS collected on the reef."[87] "Over the next five months we plan to progressively increase the level of autonomy the robot is allowed, leading to autonomous detection and injection of the starfish", according to the University's research team.[88]
Made by: Queensland University of Technology's Institute for Future Environments (Australia)[89]
Video: https://youtu.be/pbPyCydCBLs

Notes

1 Valerie Insinna, 'Air Force Seeking Out 'Ender's Game' Technology to Enable Drone Swarms', Defense News, 1 November 2016, http://www.defensenews.com/articles/air-force-diux-seeking-out-enders-game-technology-to-enable-drone-swarms.

2 Heather Roff and Richard Moyes, "Meaningful Human Control, Artificial Intelligence and Autonomous Weapons', Briefing paper prepared for the Informal Meeting of Experts on Lethal Autonomous Weapons Systems, UN Convention on Certain Conventional Weapons, April 2016, http://www.article36.org/wp-content/uploads/2016/04/MHC-AI-and-AWS-FINAL.pdf.

3 Merel Ekelhof and Miriam Struyk, 'Deadly Decisions – 8 objections to killer robots', PAX, February 2014, https://www.paxforpeace.nl/media/files/deadlydecisionsweb.pdf.

4 'Country Views on Killer Robots', Campaign to Stop Killer Robots', 13 December 2016, http://www.stopkillerrobots.org/wp-content/uploads/2013/03/KRC_CountryViews_13Dec2016.pdf.

5 'Views of the ICRC on autonomous weapon systems', 11 April 2016, https://www.icrc.org/en/document/views-icrc-autonomous-weapon-system.

6 Dan Gettinger and Arthur Holland Michel, 'Loitering Munitions', Center for the Study of the Drone, 2017, http://dronecenter.bard.edu/files/2017/02/CSD-Loitering-Munitions.pdf.

7 Yoav Zitun, 'The missile that looks like a UAV', Ynetnews, 17 February 2016, http://www.ynetnews.com/articles/0,7340,L-4767278,00.html.

8 'IAI unveils the newest members in its loitering munitions family at Singapore Air Show', IAI, 15 February 2016, http://www.iai.co.il/2013/32981-46753-EN/MediaRoom.aspx.

9 IAI Harpy brochure, 2015, http://www.iai.co.il/Sip_Storage//FILES/5/41655.pdf via http://www.iai.co.il/2013/36694-16153-en/Business_Areas_Land.aspx

10 'Loitering Attack Systems', IAI, http://www.iai.co.il/2013/36694-en/Business_Areas_Land.aspx

11 SIPRI Arms Transfers Database, http://armstrade.sipri.org/armstrade/page/trade_register.php.

12 Dylan Malyasov, 'Taiwan develops new compact loitering guided weapon', Defence Blog, 18 August 2017, http://defence-blog.com/news/taiwan-develops-new-compact-loitering-guided-weapon.html.

13 'Successful flight demonstrations for Harop loitering munitions', IAI, 7 June 2015, http://www.iai.co.il/2013/32981-46464-en/MediaRoom_News.aspx; Harop brochure, IAI, 2016, http://www.iai.co.il/Sip_Storage//FILES/6/41656.pdf.

14 Tamir Eshel, 'IAI Introduces a Loitering Weapon Optimized for Maritime Attack', Defense-Update, 11 September 2017, http://defense-update.com/20170911_maritime_harop.html.

15 'Harop', IAI, http://www.iai.co.il/2013/36694-46079-en/Business_Areas_Land.aspx and Harop brochure, IAI, 2016, http://www.iai.co.il/Sip_Storage//FILES/6/41656.pdf.

16 'Switchblade', AeroVironment, https://www.avinc.com/uas/view/switchblade.

17 Switchblade Datasheet, AeroVironment, https://www.avinc.com/images/uploads/product_docs/SB_Datasheet_2017_Web_rv1.1.pdf.

18 Richard Tomkins, 'AeroVironment upgrades Switchblade missile system', UPI, 28 April 2016, http://www.upi.com/Business_News/Security-Industry/2016/04/28/AeroVironment-upgrades-Switchblade-tactical-missile-system/4971461865933/.

19 David Hambling, 'Loitering Munition Availability Expanding Internationally', Aviation Week & Space Technology, 14 April 2016, http://aviationweek.com/defense/loitering-munition-availability-expanding-internationally.

20 ARES CONMAT Database.

21 'Warmate', WB Electronics, http://wb.com.pl/warmate-en/?lang=en.

22 Ibid.

23 David Hambling, 'Loitering Munition Availability Expanding Internationally', Aviation Week & Space Technology, 14 April 2016, http://aviationweek.com/defense/loitering-munition-availability-expanding-internationally.

24 'XQ-06 Fi Loitering Munition', Kartal Savunma Teknolojileri, http://www.kartalst.com.tr/en/solutions/xq-06-fi/.

25 David Hambling, 'Loitering Munition Availability Expanding Internationally', Aviation Week & Space Technology, 14 April 2016, http://aviationweek.com/defense/loitering-munition-availability-expanding-internationally.

26 Ibid.

27 Ibid.

28 ‘Defence Secretary Secures Progress on Brimstone Sales As Unmanned Aircraft Project Moves Forward’, UK Ministry of Defence, 3 March 2016, https://www.gov.uk/government/news/defence-secretary-secures-progress-on-brimstone-sales-as-unmanned-aircraft-project-moves-forward.

29 Andrew Chuter, ‘UK Considers Further Unmanned Combat Air Vehicle Tests’, Defense News, 9 June 2016, http://www.defensenews.com/story/defense/policy-budget/industry/2016/06/09/taranis-uk-unmanned-combat-uav-drone/85653354/.

30 ‘Fire Scout’, Northgrop Grumman, http://www.northropgrumman.com/Capabilities/FireScout/Pages/default.aspx.

31 ‘Fire Scout Datasheet’, Northrop Grumman, 19 February 2015, http://www.northropgrumman.com/Capabilities/FireScout/Documents/pageDocuments/MQ-8C_Fire_Scout_Data_Sheet.pdf.

32 Sam LaGrone, ‘Northrop Grumman Pitching MQ-8C Fire Scout to Extend Lethal Range of Littoral Combat Ship’, USNI News, 18 April 2017, https://news.usni.org/2017/04/18/northrop-grumman-pitching-mq-8c-fire-scout-to-extend-lethal-range-of-littoral-combat-ship.

33 Amy Svitak, ‘Neuron Demonstrator Completes Flight Trials in France’, Aerospace Daily & Defense Report, 9 March 2015, http://aviationweek.com/defense/europes-neuron-demonstrator-completes-flight-trials-france.

34 ‘Another world first for the nEUROn’, Dassault Aviation, 4 June 2016, http://www.dassault-aviation.com/en/dassault-aviation/press/press-kits/another-world-first-neuron/.

35 Heather Rofff and Richard Moyes, ‘Dataset: Survey of Autonomous Weapons Systems’, Global Security Initiative, Arizona State University, https://globalsecurity.asu.edu/sites/default/files/files/aggregated_weapons_systems.xlsx via https://globalsecurity.asu.edu/robotics-autonomy.

36 Ibid.; see also: Zachary Fryer-Biggs, ‘Public directory of weapons system autonomy released’, IHS Jane’s Defence Industry, 27 September 2016, https://web.archive.org/web/20160930080201/http://www.janes.com/article/64132/public-directory-of-weapons-system-autonomy-released.

37 ‘Taranis – Looking to the future’, BAE Systems, http://www.baesystems.com/en/download-en/20151124120336/1434555376407.pdf.

38 Ben Farmer, ‘Taranis stealth drone may see final test flights later this year’, The Telegraph, 13 September 2015, http://www.telegraph.co.uk/news/uknews/defence/11859967/Taranis-stealth-drone-may-see-final-test-flights-later-this-year.html.

39 Ibid.

40 ‘Taranis’, BAE Systems, http://www.baesystems.com/en/product/taranis.

41 As quoted in: Chris Cole, ‘BAE Systems pushing ahead with autonomous drone targeting’, Drone Wars UK, 11 June 2016, https://dronewars.net/2016/06/11/bae-systems-pushing-ahead-with-autonomous-drone-targeting/.

42 ‘X-47B UCAS Makes Aviation History…Again!’, Northrop Grumman, http://www.northropgrumman.com/Capabilities/X47BUCAS/Pages/default.aspx.

43 ‘X-47B Unmanned Combat Air System (UCAS), United States of America’, naval-technology.com, http://www.naval-technology.com/projects/x-47b-unmanned-combat-air-system-carrier-ucas/.

44 ‘X-47B UCAS’, Northrop Grumman Data Sheet, 2015, http://www.northropgrumman.com/Capabilities/X47BUCAS/Documents/UCAS-D_Data_Sheet.pdf.

45 ‘Global Patriot Solutions’, Raytheon, http://www.raytheon.com/capabilities/products/patriot/.

46 ‘Lockheed Martin Completes Captive Carry Tests with LRASM, Future U.S. Air Force and Navy Missile’, Navy Recognition, 12 July 2013, http://www.navyrecognition.com/index.php?option=com_content&view=article&id=1141.

47 John Markoff, ‘Fearing Bombs That Can Pick Whom to Kill’, New York Times, 11 November 2014, http://www.nytimes.com/2014/11/12/science/weapons-directed-by-robots-not-humans-raise-ethical-questions.html.

48 ‘Long Range Anti-Ship Missile (LRASM) (Archived)’, DARPA, http://www.darpa.mil/program/long-range-anti-ship-missile.

49 ‘LRASM: Overview’, Lockheed Martin, http://www.lockheedmartin.com/us/products/LRASM/overview.html.

50 ‘Global Patriot Solutions’, Raytheon, http://www.raytheon.com/capabilities/products/patriot/.

51 ‘Patriot Missile Long-Range Air-Defence System, United States of America’, army-technology.com, http://www.army-technology.com/projects/patriot/.

52 ‘Global Patriot Solutions’, Raytheon, http://www.raytheon.com/capabilities/products/patriot/.

53 ‘SeaRAM Anti-Ship Missile Defence System, United States of America, naval-technology.com, http://www.naval-technology.com/projects/searam-anti-ship-missile-defence-system/.

54 ‘SeaRAM anti-ship missile defense system’, Raytheon, http://www.raytheon.com/capabilities/products/searam/.

55 Kris Osborn, ‘The U.S. Navy’s Supersonic SeaRAM Missile System Could be a Game Changer’, The National Interest, 26 October 2016, http://nationalinterest.org/blog/the-buzz/the-us-navys-supersonic-searam-missile-system-could-be-game-18199.

56 https://www.youtube.com/watch?v=og86EPpEsVs

57 TUGV flyer, NREC, no longer available on its website.

58 https://www.youtube.com/watch?v=0p5HdJuTTVk

59 P. W. Singer, ‘Wired for war: the robotics revolution and conflict in the twenty-first century’, New York, Penguin Books, 2009.

60 Discontinued NREC webpages via https://web.archive.org/web/20170606163355/http://www.nrec.ri.cmu.edu/projects/crusher/ and https://web.archive.org/web/20170606004519/http://www.nrec.ri.cmu.edu/projects/black_knight/, as well as ‘Crusher Unmanned Ground Combat Vehicle Unveiled’, DARPA News

Release, 28 April 2006. See also: Anne Watzman and Byron Spice, 'Carnegie Mellon's National Robotics Engineering Center Unveils Futuristic Unmanned Ground Combat Vehicle', 1 June 2006, http://cmtoday.cmu.edu/issues/june-2006-issue/news-flash/carnegie-mellons-national-robotics-engineering-center-unveils-futuristic-unmanned-ground-combat-vehicle/.

61 'IAI introduces RoBattle – a combat maneuvring & support ground robot', IAI, 8 June 2016, http://www.iai.co.il/2013/32981-47061-en/MediaRoom.aspx; also see: Huw Williams, 'IAI to offer broad UGV portfolio', IHS Jane's International Defence Review, August 2016.

62 'IAI introduces RoBattle – a combat maneuvring & support ground robot', IAI, 8 June 2016, http://www.iai.co.il/2013/32981-47061-en/MediaRoom.aspx.

63 Huw Williams, 'MILREM extends THeMIS mission set', IHS Jane's International Defence Review, August 2016; 'THeMIS Hybrid Unmanned Ground Vehicle, Estonia', army-technology.com, http://www.army-technology.com/projects/themis-hybrid-unmanned-ground-vehicle/.

64 'THeMIS Hybrid Unmanned Ground Vehicle, Estonia', army-technology.com, http://www.army-technology.com/projects/themis-hybrid-unmanned-ground-vehicle/.

65 Susan Buchanan, 'Robotic Marine Vehicles: Meet the Anaconda-2', Marine Technology Reporter, April 2014, http://magazines.marinelink.com/Magazines/MarineTechnology/201404/content/robotic-vehicles-anaconda2-467540.

66 Andrew White, 'Anaconda USV development progresses', IHS Jane's International Defence Review, September 2016; also see: 'AN-2 Anaconda', Naval Drones, http://www.navaldrones.com/AN-2_ANACONDA.html.

67 'Special Operation Craft Riverine (SOCR)', Swiftships, http://swiftships.com/vessels/special-operation-craft-riverine-socr/.

68 Phil Stewart, 'U.S. military christens self-driving 'Sea Hunter' warship', Reuters, 7 April 2016, https://www.reuters.com/article/us-usa-military-robot-ship/u-s-military-christens-self-driving-sea-hunter-warship-idUSKCN0X42I4.

69 all quotes from: Phil Stewart, 'U.S. military christens self-driving 'Sea Hunter' warship', Reuters, 7 April 2016, https://www.reuters.com/article/us-usa-military-robot-ship/u-s-military-christens-self-driving-sea-hunter-warship-idUSKCN0X42I4.

70 Scott Littlefield, 'Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)', DARPA, https://www.darpa.mil/program/anti-submarine-warfare-continuous-trail-unmanned-vessel

71 'Elbit Systems' Seagull Successfully Completes Torpedo Launch Trials', Elbit Systems, 28 June 2016, http://elbitsystems.com/pr-new/elbit-systems-seagull-successfully-completes-torpedo-launch-trials/.

72 Barbara Opall-Rome, 'Israel's Elbit Unveils USV for Anti-Sub, Anti-Mine Missions', Defense News, 8 February 2016, http://www.defensenews.com/story/defense/naval/2016/02/08/israels-elbit-unveils-usv-anti-sub-anti-mine-missions/80001006/.

73 'Seagull Multi-Mission USV', Elbit Systems, http://elbitsystems.com/uas-seagul-multi-mission-usv-system/.

74 'Lethal Presence: Remotely Controlled Sentries Assume Guard Roles', Defense Update, 2008, http://defense-update.com/products/s/271108_sentrytech.html.

75 'Samson Mini RWS', Rafael, http://www.rafael.co.il/Module/ImageDownload.aspx?fl=598&cs=EA636747B4F0AD71DB9D518A28937F8A8F79A455.

76 Noah Shachtman, 'Robo-Snipers, "Auto Kill Zones" to Protect Israeli Borders', Wired, 4 June 2007, https://www.wired.com/2007/06/for_years_and_y/.

77 'Autonomous see-shoot systems drawing interest', Homeland Security Newswire, 15 June 2007, http://www.homelandsecuritynewswire.com/autonomous-see-shoot-systems-drawing-interest.

78 'Super aEgis II', DoDAAM Systems, http://www.dodaam.com/eng/sub2/menu2_1_4.php.

79 Simon Parkin, 'Killer robots: The soldiers that never sleep', BBC Future, 16 July 2015, http://www.bbc.com/future/story/20150715-killer-robots-the-soldiers-that-never-sleep.

80 Mark Prigg, 'Who goes there? Samsung unveils robot sentry that can kill from two miles away', Daily Mail, 15 September 2014, http://www.dailymail.co.uk/sciencetech/article-2756847/Who-goes-Samsung-reveals-robot-sentry-set-eye-North-Korea.html.

81 Guiglielmo Tamburrini in: 'Autonomous Weapons Systems: Law, Ethics, Policy', eds: Nehal Bhuta,Susanne Beck, Robin Geiß, Hin-Yan Liu, Claus Kreß, p.126; see also: Sharon Weinberger, 'Next generation military robots have minds of their own', BBC Future, 18 November 2014, http://www.bbc.com/future/story/20120928-battle-bots-think-for-themselves and Jean Kumagai, 'A Robotic Sentry For Korea's Demilitarised Zone', IEEE Spectrum, 1 March 2007, http://spectrum.ieee.org/robotics/military-robots/a-robotic-sentry-for-koreas-demilitarized-zone.

82 All quotes from: 'First security robot in service at Shenzhen airport', Xinhua, 22 September 2016, http://www.china.org.cn/china/2016-09/22 content_39347636.htm.

83 'Robotic prison warden to patrol South Korean prison', BBC News, 25 November 2011, http://www.bbc.co.uk/news/technology-15893772.

84 'Robot guards to patrol local prisons', Yonhap, 24 November 2011, http://english.yonhapnews.co.kr/news/2011/11/24/0200000000AEN20111124003600315.HTML.

85 Tony Skinner, 'Presenting, the Mosquito Killer Robot (!!)', Quill or Capture, 14 September 2016, https://quillorcapture.com/2016/09/14/presenting-the-mosquito-killer-robot/.

86 'Laser Mosquito Killer', LeiShen, http://en.leishen-lidar.com/product/miewenpao/60772b28-88f6-4fcb-8984-ccee435b513d.html.

87 Ines Nastali, 'Killer robot programmed to terminate starfish', The Marine Professional, 11 January 2016, http://www.imarest.org/themarineprofessional/item/2075-killer-robot-programmed-to-terminate-starfish; see also: Carla Herreria, 'Scientists Design Killer Robot To Protect Celebrated Reef', HuffPost, 9 September 2015, http://www.huffingtonpost.com/entry/cotsbot-great-barrier-reef-crown-of-thorns-starfish-coral-kill_55ef9a29e4b002d5c07737f4.

88 Tom Espiner, ‘Starfish-killing robot close to trials on Great Barrier Reef’, BBC News, 2 September 2015, http://www.bbc.com/news/technology-34129490.

89 ‘COTSBot’, Queensland University of Technology, Marine Robotics,https://wiki.qut.edu.au/display/cyphy/COTSBot.

Sint Jacobsstraat 12
3511 BS Utrecht
The Netherlands

www.paxforpeace.nl
info@paxforpeace.nl
+31 (0)30 233 33 46

P.O. Box 19318
3501 DH Utrecht
The Netherlands