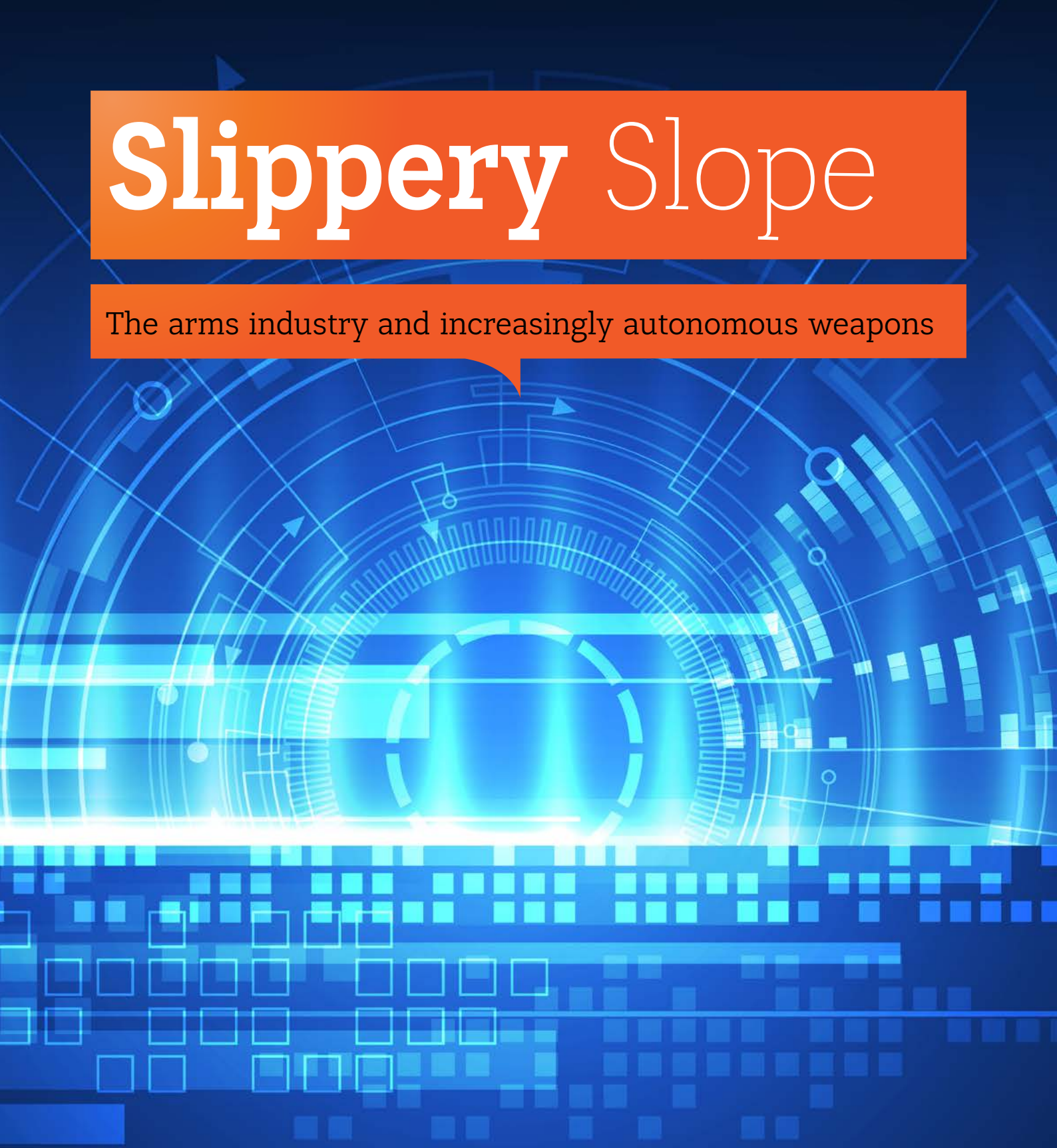
Slippery Slope

The arms industry and increasingly autonomous weapons



PAX

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Reprogramming War

This report is part of a PAX research project on the development of lethal autonomous weapons. These weapons, which would be able to kill people without any direct human involvement, are highly controversial. Many experts warn that they would violate fundamental legal and ethical principles and would be a destabilising threat to international peace and security.

In a series of four reports, PAX analyses the actors that could potentially be involved in the development of these weapons. Each report looks at a different group of actors, namely states, the tech sector, the arms industry, and universities and research institutes. The present report focuses on the arms industry. Its goal is to inform the ongoing debate with facts about current developments within the defence sector. It is the responsibility of companies to be mindful of the potential applications of certain new technologies and the possible negative effects when applied to weapon systems. They must also clearly articulate where they draw the line to ensure that humans keep control over the use of force by weapon systems.

If you have any questions regarding this project, please contact Daan Kayser (kayser@paxforpeace.nl).

Colophon

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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. PAX is a co-founder of the Campaign to Stop Killer Robots.

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Executive summary

The development of increasingly autonomous weapons has raised deep concerns and has triggered an international debate regarding the desirability of these weapons. Lethal autonomous weapons systems, popularly known as killer robots, would be able to select and attack individual targets without meaningful human control. This report analyses developments in the arms industry, pointing to areas of work that have potential for applications in lethal autonomous weapons and shows the trend of increasing autonomy in weapon systems. In the last ten years there has been a big increase in the number of countries and companies working on these technologies. There is an urgent need for governments to make new legislation to prevent lethal autonomous weapons becoming a reality. At the same time arms producers should take action to ensure they do not contribute to this development.

Lethal autonomous weapons

Artificial intelligence (AI) has the potential to make many positive contributions to society, but it is important to avoid the negative effects of the use of AI. The use of AI by militaries in itself is not necessarily problematic, for example when used for autonomous take-off and landing, navigation or refueling. However, the use of AI to allow weapon systems to autonomously select and attack targets is highly controversial. The development of these weapons would have an enormous effect on the way war is conducted. It has been called the third revolution in warfare, after gunpowder and the atomic bomb. Many experts warn that these weapons would violate fundamental legal and ethical principles and would destabilize international peace and security. In particular, delegating the decision over life and death to a machine is seen as deeply unethical.

INCREASING AUTONOMY IN THE MILITARY

As part of an imminent arms race to develop increasingly autonomous weapons, states rely on and involve arms producers to contribute to the development of such weapons. These technologies are applied by a growing number of companies in a growing number of countries. Working on an ever-expanding range of military systems, in the air, on the ground and at sea, these systems can operate in larger numbers, for longer periods and in wider areas, with less remote control by a human. This raises serious questions of how human control is guaranteed over these weapon systems.

This report underlines a number of weapons currently in use or under development that clearly show how the industry is working towards making these systems more autonomous. Loitering munitions in particular risk crossing the line into lethal autonomous weapons. Examples of such systems are:

- Turkish state-owned company STM is improving the capabilities of its KARGU loitering munitions through using AI, including facial recognition. According to the

company, the KARGU can "autonomously fire-and-forget through the entry of target coordinates". It has been suggested that these systems will be deployed on the border with Syria.

- The Mini Harpy, produced by Israel Aerospace Industries (IAI), has a range of 100km and an endurance of 120 minutes. IAI states that the system "loiters in the air waiting for the target to appear and then attacks and destroys the hostile threat within seconds".

Relatively small and cheap loitering munitions with increasingly advanced AI may enable an ever larger group of countries (and non-state actors) to possess such weapons.

High risks

Fifty arms producers were selected and asked to participate in a short survey. Selection of these companies was based on the size of their military turnover and/or as a supplier of products specifically relevant in the area of increasingly autonomous weapons. Based on this survey and our research these companies are ranked based on three criteria:

- Is the company developing technologies that are relevant in the context of lethal autonomous weapons?
- Does the company work on increasingly autonomous weapons?
- Has the company committed to not contributing to the development of lethal autonomous weapons?

To be considered as 'best practice', the company must have responded with a clearly framed position or policy for keeping the human in the loop of the weapon system. Companies are ranked as high concern if they work on increasingly autonomous weapon systems and do not appear to have a policy in place and did not respond in a meaningful way to our survey.

Based on these criteria, four companies were classified as showing 'best practice', 16 as companies of 'medium concern' and 30 as 'high concern' (see table next pages). The group of high concern companies includes three of the world's largest arms producers: Lockheed Martin, Boeing and Raytheon (all US), as well as AVIC and CASC (China), IAI, Elbit and Rafael (Israel), Rostec (Russia) and STM (Turkey). These companies are all working on technologies most relevant to lethal autonomous weapons while not having clear policies on how they ensure meaningful human control over such weapons. It is therefore more urgent than ever that states take bold steps to stop lethal autonomous weapons from becoming reality.

RECOMMENDATIONS

In the meantime, arms producers should take steps themselves to prevent their products from contributing to the development and production of lethal autonomous weapons:

- Commit publicly to not contributing to the development of lethal autonomous weapons.[1]
- Establish a clear policy stating that the company will not contribute to the development or production of lethal autonomous weapons.
- Ensure employees are well informed about what they work on and allow open discussions on any related concerns.

Table:
COMPANIES SURVEYED FOR THIS REPORT

Based on our research and survey companies have been ranked by levels of concern based on three criteria:

1. Is the company developing technology that could be relevant in the context of lethal autonomous weapons?
2. Does the company work on increasingly autonomous weapons?
3. Has the company committed to not contribute to the development of lethal autonomous weapons?

COMPANY	BEST PRACTICE	MEDIUM CONCERN	HIGH CONCERN	HQ	EXAMPLES OF AUTONOMOUS SYSTEMS	POLICY / STATEMENT
AeroVironment			■	US	Switchblade loitering munitions	-
Airbus			■	EU	Dual-mode Brimstone guided missile (MBDA); 'Many Drones Make Light Work' swarm technology	-
Almaz-Antey		■		Russia	-	-
AVIC			■	China	GJ-11 Sharp Sword UCAV; ASN-301 loitering munition	-
BAE Systems		■		UK	Taranis UCAV; dual-mode Brimstone guided missile (MBDA); RTD UGV; Maritime Autonomous Platform Exploitation (MAPLE)	Supports "customers' view that there needs to be human input over the use of force and use of autonomous systems does not mean a loss of command or the abdication of responsibility for decisions."
Boeing			■	US	Stingray UCAV; Wave Glider USV; Echo Voyager UUV	- -
CASC			■	China	CH-901 and WS-43 loitering munitions	-
Dassault			■	France	nEUROn UCAV	-
DefendTex			■	Australia	Drone 40 loitering munitions	-
DoDAAM Systems			■	S. Korea	Super aEgis II automated border control gun	
Dynetics			■	US	Swarm technology: Gremlins	Not in a position to respond.
ECA Group		■		France	Cobra, Nerva and Caméléon UGVs; autonomous underwater vehicles	-
Elbit			■	Israel	Skystriker loitering munitions; Seagull USV	-
FLIR			■	US	Black Hornet nano UAV; Ripsaw M5 RCV	-
General Atomics			■	US	Agile Condor AI enhanced MQ-9 Reaper UAV	-
General Dynamics		■		US	UUVs: Bluefin; Black Pearl	-
Hanwha			■	S. Korea	SGR-1A sentry robot; multipurpose UGV;UUV	-
Huntington Ingalls		■		US	Orca autonomous submarine	Chose to not take part in survey.
IAI			■	Israel	Harpy, Mini Harpy, Harop, Green Dragon loitering munitions; Robattle UGV;	-
Kongsberg			■	Norway	Guided missile: JSM/NSM	-
KNDS			■	France/ Germany	Main Ground Combat System, Nerva and Caméléon UGVs	

COMPANY	BEST PRACTICE	MEDIUM CONCERN	HIGH CONCERN	HQ	EXAMPLES OF AUTONOMOUS SYSTEMS	POLICY / STATEMENT
Kratos			■	US	XQ-58A Valkyrie swarm technology	-
L3Harris		■		US	UGVs; C-Target 9, MAST-9 USVs; Sonobuoy Dispenser System.	-
Leidos			■	US	Sea Hunter USV	-
Leonardo	■			Italy	nEUROn UCAV; dual-mode Brimstone guided missile (MBDA)	"The use of autonomous systems in safety-critical contexts must be subject to supervision and human control. […] Committed to respect of core principles of IHL".
LIG Nex1		■		S. Korea	Portable UGV; Sea Sword II, USV	-
Lockheed Martin			■	US	LRASM cruise missile; Have Raider manned-unmanned teaming	-
Milrem	■			Estonia	THeMIS UGV	"Human control should always be maintained over all defence systems, including weapon systems" "Our autonomy development is only for the mobility of our UGV." "We always choose partners who share and adhere to the same values and positions we do."
NCSIST			■	Taiwan	Hong Que (Cardinal) mini-UAVs; Chien Hsiang loitering munition	-
NORINCO			■	China	Cavalry, War Wolf, Sharp Claw and King Leopard UGVs	-
Northrop Grumman		■		US	X-47B UCAS; MQ-4C Triton UAV; MQ-8 Fire Scout autonomous helicopter; OFFSET swarm technology	"Not developing weapon systems that can autonomously select and attack targets without meaningful human control". No policy that specifically covers this area.
Praesidium Global		■		Australia	Mission Adaptable Platform System UGV	-
QinetiQ	■			UK	Titan and EMAV UGV; Taranis UCAV; Maritime Autonomous Platform Exploitation (MAPLE)	Policy developed by Ethics Committee. "Policy prohibits the development of any system capable of firing a weapon without human intervention."
Rafael			■	Israel	Spice guided missile; Orbiter K loitering munitions; Sentry Tech border control	-
Raytheon			■	US	JSM/NSM cruise missile; SeaRAM, SM-2 Block IIB, MIM-104 Patriot air defence; Coyote and OFFSET swarm technology	-
Rheinmetall		■		Germany	Wiesel Wingman and Mission Master UGV	-

COMPANY	BEST PRACTICE	MEDIUM CONCERN	HIGH CONCERN	HQ	EXAMPLES OF AUTONOMOUS SYSTEMS	POLICY / STATEMENT
Rostec (Kalashnikov; Ural vagonzavod)			■	Russia	KYB and Lantset loitering munitions; Uran-9 UGV; unmanned T-72 tank	-
Saab		■		Sweden	nEUROn UCAV; Autonomous underwater vehicles (AUV-62) and autonomous aerial vehicles (Skeldar V-200)	-
Safran			■	France	nEUROn UCAV; Patroller UAV; Vampir NG USV	"Complies fully with all Singapore laws and observe all UN sanctions and abide to all treaty obligations to which Singapore is a signatory".
ST Engineering		■		Singapore	DroNet UAV	
STM			■	Turkey	KARGU, ALPAGU, TOGAN loitering munitions	-
Swiftships			■	US	Anaconda USV	-
Teledyne		■		US	'Next-Generation Nonsurgical Neurotechnology' (DARPA); Autonomous underwater vehicles	-
Textron			■	US	Ripsaw M5 RCV; Common Unmanned Surface Vehicle	-
Thales		■		France	Watchkeeper UAV; Halcyon USV; SwarmDivers MCM; Maritime Autonomous Platform Exploitation (MAPLE)	Working on "AI that is Transparent, Understandable and Ethical, where humans always remain in control".
United Aircraft (Sukhoi)			■	Russia	Sukhoi Okhotnik UCAV	-
UVision		■		Israel	Hero loitering munitions	-
Volvo (Arquus)	■			Sweden	Self-driving Dagger, Scarabee armoured vehicles	Policy "has always been that a weapon should be at all times under meaningful human control, and that under no circumstance a weapon could autonomously open fire".
WB Group			■	Poland	Warmate loitering munitions	-
Yunzhou Intelligence		■		China	SE40, TC40 USVs	-

■ **HIGH CONCERN** Company working on relevant autonomous weapons technologies + did not respond to our survey in a meaningful way.

■ **MEDIUM CONCERN** Company working on relevant autonomous weapons technologies + explaining in response to our survey how human control is ensured; or

Company not known working on relevant autonomous weapons technologies + did not respond to our survey.

■ **BEST PRACTICE** Company explaining in response to our survey how human control is ensured.

\- Unknown.

UAV, UCAV, UGV, USV, UUV etc. – see List of Abbreviations

NB: This table ranks companies according to the level of concern regarding lethal autonomous weapons. It does not take into account concerns regarding for example other controversial types of weapons or controversial export destinations of these companies.

1. Introduction

Turkish arms producer STM expects that its Kargu loitering munition will be deployed along the border area with Syria.[2] The Kargu can operate in a swarm of 30 small drones and has the "ability to autonomously fire-and-forget through the entry of the target coordinates".[3] It has been called one of the first systems to be deployed that can "find, track and kill people without human intervention".[4]

Weapon systems are becoming increasingly autonomous and an increasing number of companies worldwide are working on this. Without a clear new international norm there is a substantial risk of losing human control over such weapons.

AI and related technologies are progressing rapidly and have enormous potential for helping humanity in countless ways, from improving healthcare to lifting people out of poverty and helping achieve the United Nations Sustainable Development Goals—if deployed wisely.[5] In recent years, there has been increasing debate within the private sector about the impact of AI on our societies, and where to draw the line between acceptable and unacceptable uses. Concerns related to privacy, human rights and other issues have been raised. The issue of weapon systems with increasing levels of autonomy, which could lead to lethal autonomous weapons, has also led to heated debate.

In order to realise the potential for AI to make the world a better place, it is important to avoid negative effects and backlashes from the inappropriate use of AI. Most of the progress in AI has taken place in tech companies, which are developing these technologies primarily for civilian applications.[6] Militaries and arms producers have, however, been investing a lot in the use of these technologies in military applications, including with the aim of making weapon systems increasingly autonomous. The use of AI by militaries is not necessarily problematic, for example when applied to autonomous take-off and landing, navigation or refuelling. However, the development of lethal autonomous weapons, which would be able to select and attack targets without human intervention, has raised deep concerns and triggered heated controversy.

This is an important debate in which the arms industry plays a key role, as the developers of new weapon technologies and suppliers of weapon systems to the military. To ensure that this debate is fact-based and productive, weapon producers should articulate and publicise clear policies on their stance, clarifying where they draw the line to ensure that humans keep control over the use of force

by weapon systems.

Concerns about Lethal Autonomous Weapons

Lethal autonomous weapon systems are weapons that can select and attack individual targets without meaningful human control.[7] This means that the decision to use lethal force is delegated to a machine, and that an algorithm can decide to kill humans. The function of autonomously selecting and attacking targets could be applied to various autonomous platforms, for instance drones, tanks, fighter jets or ships. The development of such weapons would have an enormous effect on the way war is conducted and it has been called the third revolution in warfare, after gunpowder and the atomic bomb.[8]

Militaries are developing these weapons so that they can react more rapidly, and thus gain an advantage over the enemy. Another reason to develop unmanned and increasingly autonomous systems is to reduce the direct exposure of troops to hostilities. Furthermore, these systems can operate for long periods in contested environments where even remote control by a human would not be possible.

However many experts warn that lethal autonomous weapons would violate fundamental legal and ethical principles and would be a destabilising threat to international peace and security. Moral and ethical concerns have centred on the delegation of the kill decision to an algorithm. Legal concerns are related to whether lethal autonomous weapons could comply with International Humanitarian Law (IHL, also known as the law of war), and more specifically whether they could properly distinguish between civilians and combatants and make proportionality assessments.[9] Military and legal scholars have pointed out an accountability vacuum regarding who would be held responsible in the case of an unlawful act.[10]

Increasingly, others have voiced concerns that lethal autonomous weapons would be seriously destabilising and threaten international peace and security. For example, by enabling risk-free and untraceable attacks, they could lower the threshold to war and weaken norms regulating the use of force. Delegating decisions to algorithms could result in the pace of combat exceeding human response times, creating the danger of rapid conflict escalation. Lethal autonomous weapons might trigger a global arms race in which they become mass-produced, cheap and ubiquitous since, unlike for example nuclear weapons, they do not require any hard-to-obtain raw materials. They might therefore proliferate, spread to a large number of states and end up in the hands of criminals, terrorists and warlords. Sized and priced similar to smartphones, lethal drones with GPS and facial recognition might enable anonymous political murder, ethnic cleansing or acts that even loyal soldiers would refuse to carry out. Algorithms might target specific groups based on sensor data such as perceived age, gender, ethnicity, dress code, or even place of residence or worship. Experts also warn that "the perception of a race will prompt everyone to rush to deploy unsafe AI systems".[11]

"Because they do not require individual human supervision, autonomous weapons are potentially scalable weapons of mass destruction; an essentially unlimited number of such weapons can be launched by a small number of people. This is an inescapable logical consequence of autonomy", wrote Stuart Russell, a computer science professor at the University of California in Berkeley.[12] Therefore "pursuing the development of lethal autonomous weapons would drastically reduce international, national, local, and personal security", according to Russell.[13] Decades ago, scientists

used a similar argument to convince presidents Lyndon Johnson and Richard Nixon to renounce the US biological weapons programme and ultimately bring about the Biological Weapons Convention.

Twenty-nine states, including Austria, Brazil, China, Egypt, Mexico and Pakistan, have so far called for a ban, and most states agree that some form of human control over weapon systems and the use of force is required.[14] United Nations (UN) Secretary-General António Guterres has called lethal autonomous weapons "morally repugnant and politically unacceptable", urging states to negotiate a ban on these weapons.[15] The International Committee of the Red Cross (ICRC) has called on states to establish internationally agreed limits on autonomy in weapon systems that address legal, ethical and humanitarian concerns.[16]

The Campaign to Stop Killer Robots, a coalition of 129 civil society organisations across 60 countries, aims to stop the development and use of fully autonomous weapons through an international treaty.[17] An IPSOS poll in 26 countries showed that 61 per cent of respondents oppose lethal autonomous weapons. Two-thirds answered that such weapons would "cross a moral line because machines should not be allowed to kill".[18]

This Report

This report analyses developments in the military industry, pointing to areas of work that could potentially lead to applications in lethal autonomous weapons, specifically in facilitating the autonomous selection and attack of targets. While certain technologies may well ensure sufficient human control over a weapon's use, it is often unclear what this entails and how this is ensured. Similarly, certain technologies may be intended for uncontroversial uses that do not cause harm, but it is often unclear how companies ensure their technology will not be adapted for lethal autonomous weapons. It is the responsibility of companies to be mindful of the potential applications of certain new technologies and the possible negative effects when applied to weapon systems.

Many emerging technologies are dual-use and have clear peaceful uses. In the context of this report, the concern is with products that could be used in lethal autonomous weapons. The development of lethal autonomous weapons covers a wide spectrum, with levels of technology varying from simple automation to full autonomy, and with technology being applied in different weapon systems' functionalities. This has raised concerns of a slippery slope where the human role is gradually diminishing in the decision-making loop regarding the use of force. This has prompted suggestions that companies, through their research and production, must help guarantee meaningful human control over decisions to use force.

The research for this report is based on information available in the public domain, either from company websites or from trusted (military-oriented) media outlets. PAX also sent out a survey to 50 arms-producing companies that we deemed relevant because of the size of their military turnover and/or because they supply products that are specifically relevant in the area of increasingly autonomous weapon systems. The survey questionnaire asked companies about their involvement in the development or production of lethal autonomous weapons and whether the company has a position or policy regarding these weapons (see Annex: 'Survey Questions').

Based on this survey and our research these companies are ranked based on three criteria:

- Is the company developing technologies that are relevant in the context of lethal autonomous weapons?
- Does the company work on increasingly autonomous weapons?
- Has the company committed to not contribute to the development of lethal autonomous weapons?

This report is clearly not intended to be an exhaustive overview of such activities and technologies, nor of the sector itself. Rather, it covers a relevant range of products and companies to illustrate the sector's role in the development of increasingly autonomous weapons.

In the hope of contributing to that discussion, this report illustrates some developments in this area, with varying levels of actual or alleged autonomy or use of AI. The information in the report is based on publicly available information. However, not all technical information about companies' technologies and projects is publicly available. Therefore, the report does not draw any conclusions based on the perceived levels of autonomy and human control in the products and projects described in the report.

Also, for years terms such as 'autonomy' or 'fully autonomous' have been considered by arms producers as positive labels when marketing new weapon systems. With the emergence of the public and political debate on autonomous weapon systems, arms companies have started to change the language on their websites and in their product descriptions. Now many companies explicitly mention a 'human in the loop' or 'human control' in the description of their products. This is important to keep in mind when analysing companies' descriptions of the weapon systems they develop.

Some of the systems in this report have been in use for years without causing major legal or ethical issues. However with the trend towards increasing the level of autonomy in these weapons, they risk losing meaningful human control.

In the next chapter, we will look at the companies and their increasingly autonomous weapons: what do we know about the largest five arms producers and what do we know about a range of producers of specific weapon systems, including advanced armed drones, loitering missiles, and unmanned land and sea vehicles? Chapter 3 then provides an overview of what we know from companies with regard to their stance on autonomous weapons. The report then ends with conclusions and recommendations.

2. The Arms İndustry and İncreasingly Autonomous Weapons

Developments in the area of unmanned technologies and military applications of artificial intelligence have made significant progress in recent years. İt is an area where military establishments and arms producers often operate in tandem, the former providing policy guidance and financial support (for research), the latter undertaking research, development and production.[19] While unmanned (especially aerial) vehicles have been around for much longer, technological progress in terms of Aİ, miniaturisation, survivability, reach, agility and their weaponisation has led to huge changes hardly imaginable at the start of this century. This represents a significant transformation in military technology with the potential to revolutionise warfare as major artificial intelligence breakthroughs become fully integrated in weapon systems and in communication between weapon systems.

Thanks to the significant progress in the area of AI, unmanned systems are acquiring increasingly autonomous functions. They range from aspects such as logistics and navigation to the more controversial selection, target and attack capabilities. At the same time we see that these developments are no longer confined to the small number of states (mainly the US and Israel) that have long dominated the market. Today, up-and-coming weapon producers from China and Russia as well as Turkey and South Korea have also entered that domain, with European producers catching up as well. Altogether, there has been a dramatic increase in the number of different producers and types of unmanned weapon systems over the past ten years.[20]

In this context, it is important to note that some manufacturers have inaccurately described their products as 'autonomous' where the term 'automated' would be more accurate and vice versa, which has sometimes blurred the debate. Regardless of this, however, it is beyond question that weapon systems have become increasingly autonomous in a range of functionalities and that the human role is gradually becoming more limited in the decision-making loop.

These developments have taken place both within the large, traditional arms-producing companies and within specialist start-up companies that have developed a special range of niche products. These start-ups will often be taken over at a later stage by one of the big producers.

In this chapter, we will look at a cross-section of such companies, 50 of which we also approached with a simple two-question survey about their position on lethal autonomous weapons (see Annex: 'Survey Questions'). First we examine the largest five arms producers. Then we consider a number of producers of unmanned aerial, ground and sea vehicles.

OVERVIEW OF COMPANIES SURVEYED

To select the 50 companies for the survey, we first took those companies that are ranked among the 20 largest arms producers as listed by *both* the Stockholm International Peace Research Institute (SIPRI) and Defense News in their respective top-100 rankings.[21] Then we included companies further down the top-100 lists that have emerged as active players in the area of unmanned systems and increasingly autonomous weapons. The list was completed with a dozen smaller companies outside the top 100, working on relevant niche products.

Generally speaking, Western companies have ample information publicly available. The survey also showed a much higher response rate from European companies than from US companies, only one of which responded to our survey at all. While Chinese companies are among the largest arms producers in the world, they are particularly difficult to assess, as there is limited publicly available information. It also turns out to be very difficult, if not impossible, to contact them by email.[22] To some extent the same holds true for Russian and South Korean companies.

2.1 The Big Five

The world's five largest arms producers—Lockheed Martin, Boeing, Raytheon, Northrop Grumman and BAE Systems—account for a total of USD 159 billion in revenues from military contracts,[23] representing more than one third of the top 100 companies' total revenues. With the United States having by far the world's largest defence budget,[24] it should be no surprise that four of these five companies are American. Moreover, while BAE Systems is a UK company, much of its revenue comes from US military contracts. A brief outline follows below of what these companies research, develop and produce in the area of increasingly autonomous weapons.

LOCKHEED MARTIN

Lockheed's motto is 'The Future of Autonomy Isn't Human-less. It's Human More'.[25] But it is not really clear what that means, especially when the clarification given is: "the question isn't just about who's the best person for the job—it's about what's the best team for the mission".[26] At the very least, it suggests a focus on those using its weapon systems rather than on civilians in conflict areas where their weapons could be used.

In the area of autonomous and unmanned systems, "Lockheed Martin is investing in the development of optionally-manned and unmanned systems that serve as a capability multiplier. [...] AI-enabled autonomous systems are changing the way militaries operate and protect their forces, the way first responders fight fires, how researchers explore the far reaches of space and the ocean's depths".[27] According to Lockheed Martin, "autonomous systems also have the ability to access hazardous mission environments, react more quickly, and provide persistent capabilities without fatigue".[28] There are several examples of technologies and systems Lockheed Marin is developing that have increasing levels of autonomy.
The US Air Force partnered with Lockheed Martin's top-secret Skunk Works laboratory on an experiment called ***Have Raider***, designed to demonstrate the technologies required for an unmanned

vehicle to fly with a manned vehicle in the battlespace. "Using an experimental F-16 as a surrogate unmanned aircraft, the demonstration proved the ability to autonomously plan and execute air-to-ground strike missions", according to a programme manager at Skunk Works.[29] "We started to marry autonomous vehicle control with autonomous battle management", he said, coining the idea of "dialable autonomy", whereby the level of control can be varied by the operator, from full direct control over flight and other aspects through to a level of autonomy whereby the autonomous system will decide what to do and how to complete a mission and ask the operator if it is cleared to do so.[30]

Also relevant in this context is the ***AGM-158C LRASM*** (Long-Range Anti-Ship cruise Missile), which Lockheed Martin was calling "an autonomous, precision-guided anti-ship standoff missile" until 2014.[31] Its "'autonomous capability' enables the missile to use target cueing data to locate and destroy its target in denied environments".[32] LRASM's long-range radio-frequency receiver can passively detect moving targets and discriminate between vessels.[33] "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", according to The New York Times.[34] "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."

Lockheed Martin subsidiary Sikorsky has transformed its legacy ***Black Hawk S-70*** attack helicopter into an optionally manned version. It is incorporating more autonomy software and sensors in the aircraft, with a fully autonomous flight projected sometime in 2020, according to Igor Cherepinsky, Sikorsky's Director of Autonomy.[35] This is "to augment the pilots, not replace the pilots", Cherepinsky said. "A pilot is 100% in the loop".

As part of a cross-domain experiment, Lockheed Martin deployed a Vector Hawk Unmanned Aerial Vehicle (UAV) from a Marlin Unmanned Underwater Vehicle (UUV) with an Ocean Aero Submaran Unmanned Surface Vessel (USV). "We showed that an unmanned aircraft, surface vessel, and undersea vehicle can communicate and complete a mission autonomously", according to one of its directors.[36]

BOEING

Boeing has a dedicated Autonomous Systems webpage explaining what it means for the company:

> *Autonomy has the potential to revolutionize the way humans connect, protect, explore and inspire. But autonomy is about more than just the latest unmanned product. […] For 100 years, Boeing has led manned and unmanned technology innovation and integration from sea to air to space. Autonomy will define the next 100 years—and Boeing is driving the safe innovation and integration of autonomy to maximize human potential.*[37]

Boeing's work in this area is supported through its **Phantom Works** research facilities and the dedicated **Collaborative Autonomous Systems Laboratory** "to test hardware and software that will make a new generation of autonomous air, sea and land vehicles".[38] In September 2019, Boeing signed a cooperation agreement with Australia's Defence Cooperative Research Centre on embedding machine-learning technologies on board unmanned systems to enable them to "better understand and react to threat environments" by designing and testing "cognitive AI algorithms to enable sensing under anti-access conditions and to navigate and conduct enhanced tactics in denied environments".[39]

MQ-25 demonstration, 29 January 2018

Boeing's start-up focused investment group **HorizonX Ventures** has invested in **SparkCognition**, an AI company that works on swarm technologies.[40] It has also taken over a number of companies working on autonomous systems, including **Insitu** and **Liquid Robotics** (both covered below), as well as **Aurora Flight Sciences**, "to accelerate Boeing's development of game-changing autonomy technology for innovative aerospace vehicles".[41]

Insitu produces the ***ScanEagle***, which autonomously detects "objects of interest on the sea surface. The system relies on a Visual Detection And Ranging (ViDAR) sensor that can only differentiate between water and non-water; the system can only detect non-aqueous objects and cannot discriminate between such objects".[42]

The ***MQ-25 Stingray*** is Boeing's unmanned aerial refueler aircraft, developed at its secretive Phantom Works laboratory.[43] "Billed as the successor to the aborted Unmanned Carrier-Launched Aerial Surveillance and Strike (UCLASS) programme, the MQ-25 Stingray will instead be a ship-launched aerial refuelling platform. In addition to its tanking role, the MQ-25 will be equipped for intelligence, surveillance, and reconnaissance (ISR)".[44] Given its UCLASS background as well as the fact that it is being equipped with ISR capabilities, the Stingray could still evolve into a weaponised version at a later stage.

In the maritime domain, Boeing's "long-endurance, autonomous maritime vehicles offer new ways to gather data and conduct missions in the ocean".[45] These include, for example, the ***SHARC*** (Sensor Hosting Autonomous Remote Craft), aka the ***Wave Glider***, manufactured by Liquid Robotics and dubbed "the world's most proven autonomous surface vehicle".[46] It is serving as a "communications gateway in a network of manned and unmanned assets, enabling seabed to space monitoring" and suitable for "Anti-Submarine Warfare (ASW), intelligence, surveillance, and reconnaissance (ISR), and other military applications".[47] In December 2016, Boeing acquired Liquid Robotics "to grow its seabed-to-space autonomous capabilities".[48]

Echo Voyager is "a fully autonomous extra large unmanned undersea vehicle (XLUUV)",[49] considered by Boeing to be "a game-changing platform, capable of performing as a multi-mission system and playing a pivotal role in future force structure. The vehicle's advanced autonomy allows it to operate for months at a time without physical human contact and in congested waters".[50]

RAYTHEON

"Making smart investments in autonomy is an imperative for the aerospace and defense industry", according to a Raytheon vice president in 2017.[51] A 2016 brochure of the company sums up some priority technologies for the company, including artificial intelligence, human-machine interaction and "miniaturized munitions" (e.g. bringing guidance to small-arms systems).[52]

Since October 2017, Raytheon has been the lead sponsor for the new **Center for Autonomous Systems and Technology**, a research facility at Caltech "advancing the science of bio-inspired systems and autonomous technologies like drones. The mission: Improve the working relationship between robots and the human operators that control them".[53]

The ***JSM/NSM*** (Joint Strike Missile/Naval Strike Missile), made in partnership with the Norwegian company **Kongsberg**, is a "fifth-generation cruise missile that will be integrated onto the F-35 and also available for integration on other aircraft intended for offensive anti-surface warfare applications".[54] It uses "autonomous target recognition, made possible by an imaging infrared seeker".[55] Its features include an "advanced engagement planning system" and a "two-way networking data link [...] offering target-update, retargeting and mission-abort capabilities".[56] Unlike most guided missiles, JSM/NSM "are not assigned to a specific target, they rather are assigned a target area, where they will have the task of finding targets that match a predefined target type", according to SIPRI; the precise nature of the human-systems command-and-control relationships remains unclear.[57] According to Kongsberg, there is close to zero probability of the NSM inadvertently attacking civilian ships.[58]

It is not unusual in the arms industry for the same company to develop both certain weapons and defences against those weapons. Raytheon is no exception, as it not only has a line of attack missiles, but also offers a wide range of missile defence systems. In its line of standard missiles—"the world's premier fleet-area air defense weapon, providing superior anti-air warfare and limited anti-surface warfare capability against today's advanced anti-ship missiles"—the ***SM-2 Block IIIB*** "enhances the IIIA's existing superior capabilities by adding autonomous infrared acquisition".[59]

SeaRAM is another missile defence system for warships, designed to engage a range of threats including cruise missiles, drones and helicopters.[60] It is capable of autonomously detecting, tracking and engaging enemy targets, and can engage multiple targets at once.[61]

A well-known product is its ***MIM-104 Patriot***, one of the first air defence systems to introduce autonomy.[62] Its goal it is to "detect, identify and defeat tactical ballistic missiles, cruise missiles, drones, advanced aircraft and other threats".[63] Each missile has a range of 70 kilometres and a maximum flight time of less than three and a half minutes. While its performance has much improved since its introduction on the battlefield during the 1991 Gulf War, there is scepticism about the system's effectiveness against cruise missiles and smaller targets, illustrated by the September 2019 aerial attacks on Saudi oil infrastructure, which were partly protected by Patriots.[64]

The ***Coyote*** is Raytheon's small expendable unmanned aircraft system that can be deployed from the ground, air or a ship, and can be flown individually or netted together in swarms. In demonstrations conducted on land and at sea, over two dozen Coyote systems launched in a swarm and moved in formation, demonstrating the effectiveness of autonomous networking. "The swarming capability can be applicable in multiple missions, from ISR activity to strikes against moving targets in a battlefield environment".[65]

The ***MK 48 Mod 6 AT*** (Advanced Technology) heavyweight torpedo is "designed for optimum effectiveness against all targets, in both littoral and deep-water environments. [...] Software-based guidance and control enables autonomous operation, 'fire and forget' tactics, simultaneous multiple target engagement and close-in attack".[66]

NORTHROP GRUMMAN

Northrop Grumman has a dedicated webpage for 'Autonomous Systems', one of its five core 'capabilities': "From space telescopes and unmanned aerial vehicles to hazardous-duty robots, underwater minehunting systems and defense readiness targets, Northrop Grumman is a recognized leader in autonomous systems, helping our customers meet a wide variety of missions at sea, air, land and space".[67]

While Northrop Grumman appears to label everything 'unmanned' as 'autonomous', a number of its weapon systems clearly have advanced autonomy features.
The ***X-47B*** Unmanned Combat Air System (UCAS) is a tailless, strike fighter-sized unmanned aircraft, designed for stealth and carrier-based launches.[68] It emerged from the now-defunct US Navy UCLASS programme.[69] 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.[70] By May 2015 the aircraft's primary test programme was declared complete.[71] It is unclear whether the X-47B concept may be revitalised at some point.

The ***MQ-8 Fire Scout*** is a "combat proven, autonomous helicopter system that provides real-time Intelligence, Surveillance, Reconnaissance, and Target-acquisition (ISR&T), laser designation, and battle management to tactical users without relying on manned aircraft or space-based assets".[72] The US Navy successfully tested an onboard weapons capability for the Fire Scout, but what weapon will eventually be used is unclear for now.[73] The newest MQ-8C version, an unmanned Bell 407 helicopter, "has the ability to autonomously take-off and land on any aviation-capable ship and from prepared and unprepared landing zones".[74] It can provide targeting information for over-the-horizon surface missiles, and Northrop Grumman aims to provide in-flight target updates to the weapon.[75]

The ***MQ-4C Triton*** unmanned aircraft, a derivative of the Global Hawk, provides real-time ISR over oceans and coastal regions. "Triton is a high-altitude, long-endurance unmanned system that delivers a critical autonomous capability to the Navy, expanding the service's maritime patrol mission".[76] Its "autonomous operations are supported by land-based command and control mission planners and sensor operators".[77] As SIPRI mentions, the Triton "can autonomously plan a route, but the general navigation parameters (e.g. speed, altitude and mission objective) are still set by a human operator."[78] It has been sold to the US Navy and Australia.

Northrop Grumman's Unmanned Ground Vehicles (UGVs) are "fielded across all U.S. military services and bomb squads in 36 countries"; its subsidiary **Remotec** is developing the ***Andros*** series of UGVs, including the ***Nomad***.[79]

BAE SYSTEMS

'Human +' is British company BAE Systems' vision of a responsible approach to human–machine collaboration. "We are in favour of delegating to a machine tasks that it can do more effectively, but humans must remain in control and should continue to take the big strategic decisions. The use of autonomous technology or AI does not mean loss of command, the removal of the individual or the abdication of responsibility for decisions".[80]

At the same time, BAE Systems has a dedicated 'Intelligent Autonomous Systems R&D' webpage elaborating how its "ahead-of-the-curve Autonomy R&D keeps our customers ahead of their opponents with rapid problem solving and deployment that puts inventive new capabilities in warfighters' hands while others are still making plans". It further boasts that its "unparalleled autonomous solutions deliver on land, at sea, in the air, in space, and beyond".[81] BAE Systems distinguishes the following areas of work in this context: decision-making and mission planning; situational assessment and understanding; and artificial intelligence and machine learning.

While there is almost no information about the latest developments, the ***Taranis*** Unmanned Combat Aerial Vehicle (UCAV) is designed to "create an unmanned air system which, under the control of a human operator, is capable of undertaking sustained surveillance, marking targets, gathering intelligence, deterring adversaries and carrying out strikes in hostile territory".[82] Under development by a team led by BAE Systems (with **Rolls-Royce**, **General Electric** and **QinetiQ**), Taranis would be able to reach a preselected area using a programmed flight path, and automatically identify and target the threat within that area. It would send data back to its home base, where information would be verified by a human operator, who then OKs a target for attack. The Times reported in 2016 that the company was "proceeding on the basis that an autonomous strike capability could be required in the future".[83]

According to SIPRI, the "vast majority of guided munitions use autonomy only to find, track and hit targets or target locations that have been pre-assigned by humans. In that sense, autonomy does not support the target selection process; it solely supports the execution of the attack".[84] It considers the ***Dual-Mode Brimstone***, produced by the UK arm of **MBDA** (itself a joint venture of **Airbus**, **BAE** and **Leonardo**), as one of the few guided munitions with some target selection autonomy. "In contrast to regular guided missiles, [...] they are assigned a target area, where they will have the task of finding targets that match a predefined target type". SIPRI labels the Dual-Mode Brimstone as "the only guided munition featuring target selection autonomy that is currently operational. It works like a fire-and-forget missile. Once launched, the missile operates in full autonomy; it does not include a human-in-the-loop mode".[85]

In 2016, BAE Systems partnered with QinetiQ, Thales and SeeByte to deliver Maritime Autonomous Platform Exploitation (***MAPLE***), a transportable command and control centre with the capability for integrating unmanned systems from multiple suppliers.[86]

"Autonomous and unmanned systems are widely regarded as a vital technology for the future, but there is a great deal of work to be done if we are to unlock its true potential and understand how they are best integrated into wider systems", according to BAE Systems' Head of Technology for Combat Systems.[87]

2.2 Autonomous Aerial Killing

ADDING AI TO ARMED DRONES

Ever since the first ***Predator*** drone attack in 2001, the use of armed drones has become key in US counter-terrorism policies in particular. Crucially, both the technology and its use have proliferated rapidly across the world ever since. At least 24 states are currently known to possess armed drones, and they have been used in combat in 13 countries.[88]

Meanwhile drone technology has been adapted with new functionalities, in part to take advantage of the latest digital possibilities. For example, **General Atomics Aeronautical Systems (GA-ASI)**, the manufacturer of the Predator and (its successor) Reaper drones, was recently awarded a US Air Force contract to demonstrate the use of ***Agile Condor*** artificial intelligence technology in a ***MQ-9 Reaper UAV***. "The ability to autonomously fuse and interpret sensor data to determine targets of interest is at the forefront of unmanned systems technology", according to General Atomics President David Alexander.[89] Flight demonstrations will help determine "the optimum artificial intelligence and machine learning methodologies to find, identify and track select targets".[90] Agile Condor will further enhance its "effectiveness by specifically allowing a MQ-9 to surveil a large area of operations, autonomously identify pre-defined targets of interest and transmit their locations".[91] Taiwan's National Chung Shan Institute of Science and Technology (**NCSIST**) is testing AI-enabled target-acquisition technologies on its Hong Que (Cardinal) mini-UAVs, which are designed to be capable of carrying an explosive payload. In its current test layout, it has an electro-optical/infrared payload "that is supported by indigenously developed machine learning/artificial intelligence" algorithms. "We are integrating state-of[-the]-art object detection and multi-object tracking algorithms which will take us one step further to realising a fully automatic and highly intelligent system", according to an NCSIST spokesperson.[92]

At the other end of the spectrum, two well-known examples of unmanned stealth bomber drones are **BAE Systems**' ***Taranis*** (see previous section) and the ***nEUROn***, developed by French company **Dassault**; **Leonardo** and **Saab** were the main partners in the project.[93]

In the same category of flying wing UCAVs are **Northrop Grumman**'s demonstration ***X-47B*** and ***Okhotnik,*** developed by the Russian company **Sukhoi** (a **United Aircraft** company).[94] The ***GJ-11 Sharp Sword*** (or ***Lijian*** in Chinese), developed by a Chinese consortium including **AVIC**, was on display extensively during the 2019 military parade celebrating the 70th anniversary of the socialist state.[95]

These are clear further steps towards the development of autonomous weaponised drones able to operate with limited or no human input. From identifying targets without the need for a human decision to destroying those targets is a small step that could be achieved with existing technology. It is clearly a growing field of research, as military planners eye future combat scenarios where human–machine communications might be limited and where technology could allow military systems to assess the way forward without human input.

LOITERING MUNITIONS

Similarly, the numbers of producers and types of loitering munitions—also known as kamikaze drones—have risen exponentially over the past ten years, far beyond the handful of countries (most prominently Israel) traditionally producing them. A hybrid between a drone and a guided missile, loitering munitions are equipped with high-resolution electro-optical and infrared cameras which enable the targeter to locate, survey and guide the weapon to the target. A defining characteristic

Warmate UAV, military fair, Kyiv, 2017

is the weapon's ability to 'loiter' in the air for an extended period before striking. Their operational utility lies in the fact that they are not aimed at a predefined target but rather at a target area.[96]

With the increased application of artificial intelligence technologies, here too the line between controlled operations and autonomously operating loitering munitions is becoming progressively more blurred. Relatively small and cheap loitering munitions with increasingly advanced AI may enable an ever larger group of countries (and non-state actors) to possess such weapons.

Examples of loitering munitions include the following products:

In Turkey, the state-owned company Savunma Teknolojileri Mühendislik ve Ticaret (**STM)** produces the ***KARGU*** (autonomous tactical multi-rotor attack), ***ALPAGU*** (fixed-wing autonomous tactical attack) and ***TOGAN*** (autonomous multi-rotor reconnaissance) loitering systems.[97]
STM has been working on improving the capabilities of the KARGU system through the use of AI, including facial recognition, as well as increasing the diversity of the explosives the system can use, currently thought to include fragmentation and thermobaric options.[98] According to a video produced by the company, KARGU has the "ability to autonomously Fire-and-Forget through the entry of the target coordinates".[99] The New Scientist concludes that "Turkey is to become the first nation to use drones able to find, track and kill people without human intervention".[100]

Weighing less than 7 kilograms each, KARGU has a range of 15 kilometres and can stay in the air for 30 minutes. It is possible to operate up to 30 KARGUs together in a swarm that could destroy a military unit or warship, according to Murat İkinci, general manager of STM.[101] STM has delivered around 150 KARGUs to the Turkish armed forces.[102] İkinci has suggested that KARGUs will be deployed in the east of the country and at the border with Syria.[103]

The ***Harpy*** and ***Harop*** are both produced by **Israel Aerospace Industries (IAI)**. The Harpy is a ground-launched "'fire-and-forget' autonomous weapon" that detects, attacks and destroys enemy radars.[104] It has a 15 kilogram warhead and maximum flight time of nine hours. It has been sold to the

armed forces of China, India, Israel, South Korea and Turkey. Harop has a flight time of six hours and a 1,000 kilometre maximum range. It attacks any identified target, but with a 'man in the loop'. Advertised as having "autonomous platform operation", it has an "abort attack capability" indicating the technical possibility for a soldier to intervene to avoid unintended attacks.[105]

Combining the capabilities of the Harop and the Harpy, IAI unveiled the ***Mini Harpy***, designed to provide operators with control up to the last moment, including "cessation of attack at any stage", according to a company statement.[106] At the same time it is labelled as "closing the attack circle at low cost. […] In an age of asymmetrical warfare and fast moving targets that 'blink' for a few seconds at a time, the use of loitering munitions provides strong capabilities for closing the fire loop. Rather than relying on precise reference points, the system we developed loiters in the air waiting for the target to appear and then attacks and destroys the hostile threat within seconds", according to IAI.[107] The Mini Harpy can be launched from land, sea and air platforms, and has a range of 100 kilometres and an endurance of 120 minutes.

Two other IAI loitering missiles are the ***Rotem*** family of quadcopter assault vertical take-off and landing loitering munitions and the ***Green Dragon***, a small, electrically powered loitering weapon that launches from canisters packed on vehicles or boats.[108] When airborne, "the operator can designate and attack targets as they appear on the tablet screen, or abort the attack any time before impact, through a built-in 'abort and circle' capability, designed to prevent collateral damage or mistaken targeting".[109]

Another three Israeli companies in this area are Elbit, Rafael and UVision.
Elbit Systems' ***SkyStriker*** is a ground-launched UAV equipped with a small electro-optic payload and a relatively large warhead, "big enough to defeat a tank".[110] SkyStriker is meant to improve the "lethality, situational awareness, and survivability" of ground forces on the battlefield.[111] It is a "fully autonomous UAS that can locate, acquire and strike operator-designated targets" and can be armed with a 5kg or 10kg warhead.[112] "The weapon employs an autonomous navigation system during the cruising and loitering phases and can be locked onto a target by the operator using an electro-optical sensor".[113] As a Jane's journalist further notes: "The advantages of these types of weapon over surface-to-surface missiles is that they can acquire their own targets, so can be launched without prior intelligence, and then be recovered if no targets are found".[114]

Rafael bought drone and loitering munitions company **Aeronautics** in 2019. Its ***Orbiter 1K*** is designed to target and attack both people and "soft-skinned" vehicles with a blast fragmentation warhead with tungsten pellets.[115] According to SIPRI, it can find, track and attack targets in complete autonomy once launched, but has a human-in-the-loop modus as well.[116] It made the headlines when in 2017 when Israel's defence ministry blocked an attempt by Aeronautics to sell the Orbiter 1K to Azerbaijan, following reports that the system had been demonstrated in Azerbaijan against Armenian targets, something the company has denied.[117]

UVision, founded in 2011, is developing a family of ***Hero*** loitering munitions with different sizes and configurations, with different capabilities and warhead options. In an interview, CEO Avi Mizrachi calls loitering munitions "the most efficient solution in terms of reaction time for closing the sensor-to-shooter loop, and [they] enable tactical forces to react independently, and in real-time, if or when mission parameters change".[118] UVision says the Hero has an abort capability that can be activated up to the last seconds of impact.[119] According to UVision US CEO Jim Truxel, Hero offers a "lightweight precision-strike munition alongside the ability to reduce collateral damage, as there

is a man in the loop at all times".[120] In 2016, UVision signed an agreement with Raytheon to adapt the Hero-30 for US military requirements. A similar agreement is in place with Thales in the UK to facilitate opportunities in Europe, and in Canada with **Twenty20 Insight**.[121] In 2019 it opened a subsidiary in the US.[122] However, it looks as if UVision has not received any concrete orders so far.

Taiwan's **NCSIST** has showcased the ***Chien Hsiang*** anti-radiation loitering munition, which resembles the Harpy, although the company told the military media company Jane's that any physical similarities are purely "coincidental".[123] It is designed to follow a pre-programmed flight profile and will home in on actively radiating radar systems. If a target's radar is switched off, Chien Hsiang will abort its approach and continue its search flight.
Taiwan will spend around USD 2.5 billion over five years to develop and manufacture 104 Chien Hsiangs.[124]

Less coincidental similarities can be found in the Chinese Harpy lookalike, the ***ASN-301*** anti-radiation loitering munition system, produced by Aviation Industry Corporation of China (**AVIC**) and displayed for the first time in Abu Dhabi in 2017.[125] China bought the Harpy from Israel in the 1990s, much to the anger of the US.[126]

The ***CH-901*** is a Chinese loitering munition, produced by China Aerospace Long-March (**ALIT**), a subsidiary of China Aerospace Science and Technology Corporation (**CASC**). It is in use by the People's Liberation Army (PLA).[127] It was first publicly displayed at the DSA 2016 arms fair in Malaysia and again in Jordan in 2018.[128] Another CASC product is the ***WS-43***. According to Jane's, "the system can deliver payloads of up to 20 kg, at distances of up to 60 km, and loiter for up to 30 minutes before hitting its target. […] The weapon can track, and engage both moving and static targets".[129]

Switchblade is the US company **AeroVironment**'s miniature "combat proven" loitering munition. It has been used extensively by US troops in Afghanistan and has been observed in Iraq and Syria as well.[130] It measures 60 centimetres and has a maximum 15-minute flight time and 10-kilometre radius. It is advertised as a "back-packable, rapid-deployable, loitering precision strike missile for use against beyond-line-of-sight [BLOS] targets" and with "very low collateral damage".[131] According to the producer, it "can be operated manually or autonomously".[132] Northrop Grumman produces its 450-gram high-explosive fragmentation warhead.[133]

The Polish company **WB Group** produces the ***Warmate*** family of loitering munitions. The original concept, unveiled in 2014, is rather ambiguously described as a "fully autonomous solution allowing real-time operation of airborne warfare […]. The operator has full control and bears full responsibility for switching to the ARMED [sic] to execute a combat task".[134]
Warmate 2 is a bigger, catapult-launched version "with an anti-personal, anti-tank or thermobaric warhead. The addition of a daylight and thermal camera (uncooled IR), integrated in the fuselage allows for automated targeting and the assessment of a target before finalizing a strike".[135]
Once the target is indicated, Warmate becomes fully autonomous and man-in-the-loop control is no longer required, although the system features a mission abort capability, according to WB Group Vice President Adam Bartosiewicz.[136]

"Designed to detect, locate and destroy the target", the multi-rotor ***Warmate V*** "provides an ideal solution to carry out a military mission in a dense urban environment, where the use of fast unmanned aircrafts is impossible", according to WB Group.[137] An "integrated, automatic videotracker allows for target tracking and attack with minimum operator intervention".[138]

Its ***SWARM*** reconnaissance-strike system is designed to enable small units to detect, identify and track a variety of targets up to a distance of 50 kilometres with multiple WB Group Fly Eye UAVs operated from a reconnaissance and command vehicle. These targets are then attacked from strike vehicles which can carry up to 20 Warmates.[139]

In 2017, WB Group secured a Ukrainian deal to deliver an undisclosed number of Warmates.[140] The Polish Ministry of Defence bought 1,000 missiles for an estimated USD 28 million; another unnamed NATO country and two unidentified Middle Eastern countries are also customers.[141] In 2019, the Warmate was presented as part of the German company **Rheinmetall**'s new ***Mission Master*** UGV.[142]

In Russia, **ZALA Aero**, a subsidiary of the **Kalashnikov Group**, which in turn is part of **Rostec**, showed its ***Lantset (Lance)*** loitering munition for the first time in June 2019. It comes in two configurations: the heavier Lantset-3 carries a 3-kilogram warhead and has a 40-minute mission endurance, while the lighter Lantset-1 has a 1-kilogram warhead and 30-minute mission endurance.[143] Another kamikaze drone is its ***KYB***, presented at the IDEX arms fair in Abu Dhabi earlier in 2019. ZALA Aero has developed artificial intelligence visual identification (AIVI), which can perform "real-time recognition and classification of detected objects". According to a spokesperson, "AIVI results in a 60-fold increase of an area covered during a single flight".[144]

Australia's **DefendTex** offers the ***Drone 40***, a quadcopter 40mm grenade launcher. "When carrying a 110 gram payload, it can fly for about 12 minutes. The person commanding the Drone 40 can remotely disarm the munition, letting the drone land inert for later recovery".[145] Using GPS, the drone can follow a waypoint-plotted course to a target, or it can use its own synthetic aperture radar to identify and track a target. According to its CEO, Travis Reddy, it can distinguish the radar profile of a T-72 tank, for example, and then follow it autonomously.

Drone 40 is designed to fly with minimal human involvement. "Most of the flying, identifying and tracking of targets is done autonomously; however, human control remains an essential part of the machine's operation". According to Reddy, that is because the Australian defence ministry "has very strict rules around any use of autonomy in the battlefield [...]. We always have to have either man in the loop or man on the loop. The weapon system will never be autonomous, fully acquire and prosecute target without authorization and confirmation from the human".[146] To reduce production costs, DefendTex makes extensive use of commercially available technology with a goal of getting the unit costs down to around USD 500.

GREMLINS AND SKYBORGS: SWARMING DRONES, BOMBS AND MISSILES

As a number of examples in the previous section showed, there is a clear tendency towards operating multiple drones or loitering munitions at the same time. The question then emerges how this affects the degree of human control over the actions of these weapons, especially when the weapons operate in self-coordinated swarms that can adapt to changing circumstances. The emergence of more sophisticated counter-drone systems will likely further boost swarming technology in an effort to overwhelm such defences.[147] While much of this technology is still in its infancy, it is developing rapidly. A few examples are given below of some recent developments.[148]

US experiments with swarming drones have included the ***Perdix***[149] and ***OFFSET*** (OFFensive Swarm-Enabled Tactics) programmes, the latter with the aim of "using swarms comprising upwards of 250 unmanned aircraft systems (UASs) and/or unmanned ground systems (UGSs) to accomplish diverse

missions in complex urban environments".[150] This is a "science fiction-sounding goal", as a military reporter notes. Phase 1 of this DARPA project was led by **Raytheon** and **Northrop Grumman**. In the project, teams work on five areas: swarm tactics, swarm autonomy, human–swarm teaming, virtual environment and physical testbeds.[151]

China, meanwhile, is experimenting with similar techniques. In 2017, **China Electronics Technology (CETC)**, a state-owned company, demonstrated the launch of 119 drones with a slingshot-like device. They then gathered in a formation and flew in patterns around nearby mountains.[152]

Gremlins is another DARPA programme, which aims to demonstrate that multiple small UAVs can be launched from a carrier aircraft, recovered in flight, returned to base and readied for a new mission.[153] The rationale is that being able to send larger numbers of UASs "with coordinated, distributed capabilities", for example to attack enemy air defences, could provide the US with better operational flexibility at a much lower cost.[154] **Dynetics** was awarded the Gremlins Phase III contract in May 2018.[155]

Under the so-called ***Gray Wolf*** demonstration programme of the US Air Force Research Laboratory (AFRL), **Lockheed Martin** and **Northrop Grumman** (see also section 2.1) received contracts worth USD 110 million to develop a prototype low-cost autonomous cruise missile.[156] Gray Wolf was meant to augment the US Air Force's current higher-cost stand-off weapons "with a new affordable, high volume swarming missile solution" designed to overwhelm adversarial air defence systems.[157] In the summer of 2019, the project was abandoned in favour of ***Golden Horde***, an effort to get existing munitions, such as Boeing's Small Diameter Bomb (SDB), to cooperate in combat. Golden Horde would enable bombs and missiles to 'plan' their next steps together once fired.[158]

Building on the previously mentioned Have Raider programme (see section 2.1, 'Lockheed Martin'), and in an effort to gain more experience with increasingly complex autonomy and AI capabilities, the AFRL is investing significantly in so-called 'loyal wingman' concepts, where unmanned aircraft assist and augment the capabilities of manned aircraft.[159]

One such project is the ominously named ***Skyborg***, initiated in 2018 to develop a "fighter-like aircraft that can be used to quickly update and field iteratively more complex autonomy", or an unmanned combat air vehicle with an "AI brain" that could be operational within five years.[160] In Skyborg, autonomy is defined as "the ability to independently compose and select among different courses of action to accomplish goals".[161] "We know that when you couple autonomy and AI with systems such as low-cost attritable [UCAVs], that can increase capability pretty quickly and be a force multiplier", according to an AFRL manager.[162] "Once the system is in place, you could introduce more and more complex levels of AI to accomplish certain tasks or subtasks in a mission", said a colleague.[163]

The US company **Kratos** has for some years been developing inexpensive UCAV technology, with the latest effort being its ***XQ-58 Valkyrie***, developed under another AFRL programme.[164] The XQ-58 can carry weapons internally.
Another loyal wingman programme is led by **Boeing**'s ***Airpower Teaming System (ATS),*** developed with Australian government support to counter China.[165]

2.3 Rise of the Ground Robots

For years, most unmanned military developments have been for deployment in the air. Navigation is highly challenging for land vehicles, much more so than at sea. But a lot has changed over the past decade, for example with significant progress in the area of self-driving cars. While still controlled by a human operator, robotic vehicles are becoming increasingly autonomous. US General Mark Milley believes that "robotics technologies are likely to change ground combat fundamentally in the next 10-15 years".[166] Clear signals of such changes were seen at the DSEI arms fair in London in September 2019, where a defence journalist noted that "the comfort level with armed ground robots is apparent by the sheer number of systems on the showroom floor compared to recent years in the international trade show circuit".[167]

Most attention has focused on one robot vehicle in particular: ***THeMIS***, which the Estonian company **Milrem** has been manufacturing since 2014. According to the above-mentioned defence journalist, THeMIS "was all over DSEI with other defense contractors systems' integrated onto the platform".[168] Indeed it appears to have become the industry standard for tracked UGVs.[169] In the space of a few years, it has attracted some of the world's largest arms producers, which have integrated and tested their weapons on the THeMIS. They include **Lockheed Martin, Raytheon and MBDA**.

Currently, THeMIS is far from being a lethal autonomous weapon (and its makers want it to stay that way—see Chapter 3). Two soldiers are needed to operate the vehicle, and its operational range is limited: remote control is only possible within the line of sight and at a maximum distance of 100 metres; the hybrid vehicle can run on electricity for some one-and-half hours.[170] But Milrem is keen to further develop its platform and to increase its (navigational) autonomy, one of its key focus areas.[171] With an eye to the future, more and more militaries seem keen to develop an armed unmanned ground force. And that is where established weapon producers see an interest in THeMIS: as an established test platform to further develop armed UGVs.

In 2016, **Singapore Technologies**' ADDER was the first remote weapon station to be integrated into THeMIS.[172] Milrem has also teamed with Belgian arms manufacturer **FN Herstal**, with its DeFNder remote weapon station. The combination of THeMIS fitted with the French company **Nexter**'s (now **KNDS**) ARX-20 remote-control weapon station is called ***OPTIO – X20***. This product was first displayed at the Eurosatory arms fair in 2018.[173]

The IMPACT anti-tank system of missile producer **MBDA** (a joint venture of **Airbus, BAE Systems** and **Leonardo)**, which includes two ready-to-fire missiles and a 7.62mm machine gun, was integrated into THeMIS.[174] In 2019, MBDA unveiled a plan to equip THeMIS with a cassette of six Brimstone missiles, the UK's primary ground attack missiles, which are normally fired from Eurofighters jets and Apache attack helicopters.[175]
In September 2019, a team from **Raytheon** and **Lockheed Martin** test-fired Javelin anti-tank missiles from a modified THeMIS using a **Kongsberg** remote weapons station, the Protector.[176] The modified UGV was developed together with **Qinetiq North America** and was renamed ***Titan***. Titan features enhanced sensing and hardware capabilities for autonomous navigation; its robotic operating system enables "a range of software packages to be installed to increase its autonomy capability".[177]

Rheinmetall's ***Mission Master*** UGV falls in a larger category. In addition to cargo and surveillance versions, it also offers a range of weapon options, including one with two **Thales**-made rocket

Uran-9 UGV, Army 2016

launchers that fit eight 70mm rockets each. The vehicle can also accommodate loitering munitions in a six-tube launcher.[178] The Mission Master can run autonomously for eight hours and has a maximum speed of 30 kilometres per hour. Rheinmetall Canada is reportedly seeking to evolve the Mission Master by "increasing its autonomous capability and the capacity to operate in swarms of UGVs conducting the same mission".[179] The Netherlands intends to buy a couple of units in order to develop operation concepts, according to the company. The company also has a contract with one undisclosed customer.[180]

Hyundai Rotem and **Hanwha** are currently competing for a South Korean UGV contract. Hanwha's multipurpose UGV can attain a maximum speed of 20 km/h, and can be equipped with a machine gun and an electro-optical/infrared system.[181]

Norinco, one of China's largest arms producers, is developing the ***Cavalry*** lightweight tracked UGV. It is equipped with a remote weapon station, armed with a machine gun and a pair of rocket launchers. It is understood to have high levels of autonomy but with a human operator in charge. According to a Norinco spokesperson, "some of the major difficulties in putting autonomous unmanned ground vehicles in the field have been the limitations on machine vision and intelligent behaviour. […] Sensing in the highly cluttered ground environment requires high fidelity to ensure the safety of the vehicle" and thus "necessitates high computing power to achieve such levels of fidelity".[182]

Meanwhile in Russia, the ***Marker*** UGV is making an impression. An official statement from research agency **ARF**—Russia's DARPA—says the Marker is designed to work as "a pair with a fighter, receiving target designation from the sight of his weapon", or be controlled remotely.[183] ARF sees the Marker

as a learning tool, saying "the evolution of combat robots is on the path of increasing the ability to perform tasks in autonomous mode with a gradual reduction in the role of the operator".[184]

The ***Uran*** UGVs are produced by **Kalashnikov**, which is part of the **Rostec** weapons conglomerate. They include the Uran-6 mine clearing vehicle and the Uran-9 combat tank. The latter was used by Russia in the war in Syria.[185]

The US Army is planning to field a mixed fleet of Robotic Combat Vehicles (RCV), to validate manned/unmanned teaming by exploring the current state of the technology, as well as increasing formation effectiveness".[186] Contenders include: **Textron Systems**, **Howe & Howe Technologies** and **FLIR Systems**, together pitching the ***Ripsaw M5***; **Rheinmetall** with its ***Wiesel Wingman*** concept; **QinetiQ** and **Pratt & Miller** with the ***Expeditionary Modular Autonomous Vehicle (EMAV***) and **BAE Systems** with the ***Robotic Technology Demonstrator (RTD)***.[187]

2.4 Testing the Waters

Unmanned marine vehicles can operate on the surface of the water (USVs) as well as underwater (UUVs). They can be used for a wide range of military and commercial applications. Military roles include Mine Counter Measures (MCM), ISR, ASW and attack craft.

The sea is considered to be a useful testing ground for autonomous weapon systems.[188] As it is a relatively uncluttered environment, where it is generally easier to operate than on land, there has been a spike in testing exercises by companies and the military in recent years.

For example, in September 2019 NATO held a large exercise in Portugal with a range of unmanned systems, including at sea. NATO stated that maritime unmanned systems technologies can be a "game-changer in countering multiple threats in the maritime domain. Using Maritime Unmanned Vehicles can help effectively counter new submarines armed with more powerful weapons. They can also prevent military personnel from moving into risky situations in countering threats like sea mines".[189]

Sea mines, often placed a long time ago in order to deter an imminent naval attack, stay around for decades after a conflict. The seas around Europe are still littered with tens of thousands of mines from World Wars I and II, which are an enduring risk. In that context, it is of course an appealing idea to see whether there are robots that could safely do the job. The fearsomely labelled Hell Bay was one series of such exercises, part of the 'five-eyes' military science and technology forum established by Australia, Canada, New Zealand, the UK and the US.[190] From 2013 to 2016, it aimed at testing unmanned systems in MCM with growing levels of autonomy and interoperability.

In 2018, **Thales** and the US company **Aquabotix** started cooperating on the research and design of micro-sized autonomous robot minesweepers called ***SwarmDivers***, formally described as a "rapidly deployable Mine Counter Measures (MCM), Rapid Environment Assessment (REA) and Military Hydrographic autonomous system mission solution".[191] Released by a 'mothership', the robots scout, identify and ultimately neutralise mines in littoral waters. "Autonomy is key here, as communicating underwater is difficult and communicating with above-water assets from underwater especially tricky".[192]

USV demonstration, 2014.

Developed by the US company **Leidos**, the 40-metre trimaran-hull ***Sea Hunter*** was originally designed to hunt for enemy submarines and it was hailed by the Pentagon as a major advance in robotic warfare.[193] It is now a more generic science and technology testbed. Last year, Sea Hunter became the first vessel to successfully navigate autonomously from San Diego to Pearl Harbour, Hawaii.[194] But in the future it may develop like then Deputy Secretary of Defense Bob Work envisioned Sea Hunters at war back in 2016: "You can imagine anti-submarine warfare wolf packs, you can imagine mine warfare flotillas, you can imaging distributed anti-surface warfare action groups … and you might be able to put a six-pack or a four-pack of missiles on it. Now imagine 50 of these warships … operating together under the hands of a flotilla commander. This is really something".[195]

Made by **Elbit Systems**, the ***Seagull*** is claimed to be the world's first unmanned system for ASW and MCM missions, with "underwater robotic vehicles to identify and neutralize mines".[196] It can perform deep-water missions for four days at a time at ranges of up to 100 kilometres. "By transforming small, remotely operated surface platforms into advanced, highly autonomous networked systems, we're bringing asymmetry to the advantage of our customers", according to the company.[197]
The ***AN-2 ANACONDA*** is a riverine special operations USV made by the US company **Swiftships** in collaboration with the University of Louisiana Lafayette. "AN-2 will offer a unique design and completely autonomous vessel. The basic concept is to create a "Sensor Bot on Water" that is able to navigate without using pre-programmed way points, but instead using GPS/sensory data autonomous to any human interaction", according to the company.[198] The idea is that it will become a "completely autonomous watercraft equipped with artificial intelligence [AI] capabilities" and be able to "perform tactical manoeuvres and loiter in an area for long periods of time, all without human intervention".[199] The Anaconda can carry up to five weapon systems.

Many other major arms-producing companies are involved in the development of a range of naval unmanned systems. In Sweden, **Saab** is working with local partners looking at both commercial and military applications.[200] In the UK, **BAE Systems** and **QinetiQ** have participated in several test programmes.[201] Norway's **Kongsberg** has long been developing its family of ***REMUS*** UUVs for reconnaissance and explosive ordnance disposal.[202] The US company **General Dynamics** has designed a range of underwater vehicles as well, including the ***Knifefish*** and ***Black Pearl.***[203]

China Shipbuilding and Offshore International Company is developing a USV called ***JARI***, which is about 12 times smaller than the Chinese navy's manned Type -55 destroyer, but has all the same mission areas: anti-submarine, anti-surface and anti-air warfare.[204]

South Korea's LIG Nex1 and Hanwha showed prototype unmanned naval vessels at an arms show in the country in October 2019. LIG Nex1's Hae Gum II (Sea Sword II) USV can conduct a range of mission types, including surveillance and reconnaissance. It was shown with a machine gun-armed remote weapon station and an eight-cell guided-rocket launcher. It is further equipped with multiple electro-optic/infrared sensors, including laser range detection for navigation and weapon guidance.[205] Hanwha showed a model UUV dedicated to ASW operations.[206]

3. Time to Commit

There is a wide variety of labels that companies put on their products to describe their levels of autonomy and the degree of control that a human operator has over the functioning of a weapon system, from navigation and surveillance to the detection, selection and attack of targets. Some companies appear to see high levels of autonomy as advertising added value over less autonomous versions, whereas other companies seem more aware of the public debate and the discussion that has taken place in diplomatic circles, where the necessity of meaningful human control over the selection and attack of targets has been widely shared. These latter companies generally emphasise autonomy and the added value of AI, but stress that there is always a human in control. Clearly such diverging views and understandings of what autonomy and AI in weapon systems may entail makes it difficult to compare companies with regard to their policies and practices on lethal autonomous weapons.[207]

Nevertheless, there have been a number of occasions where companies have publicly mentioned their position and concerns regarding lethal autonomous weapons. Additionally, of 11 out of 50 companies that responded to our short survey (see Appendix), eight took the effort to answer our questions.

Very clearly, and rather uniquely for such a broad representative body, the German industry association **BDI (Bundesverband der Deutschen Industrie**) released a position paper on artificial intelligence in early 2019, in which it states that "the final decision on the use of a weapon against humans must not be left to a machine", and it "therefore calls on the Federal Government to advocate a binding ban on such systems".[208]

Despite being at the centre of most recent developments in the area of armed unmanned ground vehicles, **Milrem** is rather clear in its position on lethal autonomous weapons: "Our clear position is that human control should always be maintained over all defense systems, including weapon systems. Milrem Robotics' R&D adheres to this position".[209] Asked about how that relates to their UGVs, a spokesperson replies, "Our autonomy development is only for the mobility of our unmanned ground vehicle (UGV). The autonomous functions being developed only allow the vehicle to move by itself between waypoints and detect and avoid obstacles to reach the predetermined waypoint. So in short—it's simply not possible to autonomously target".[210] Asked about the companies Milrem teams with, he further says, "We always choose partners who share and adhere to the same values and positions we do. This ensures any final product delivered to customers also adheres to our values." UK's **QinetiQ** is also rather unambiguous with a clear policy on the matter, as a spokesperson answers, "QinetiQ has a group-wide policy on unmanned systems, developed by the company's Ethics Committee and approved at Main Board level. [...] The policy prohibits the development of any system capable of firing a weapon without human intervention. [...] Where an unmanned ground system is used as a platform for a weapon—such as the Titan Strike robot—decisions regarding target acquisition and firing can only be taken by highly trained and qualified military personnel".[211]

The CEO of French arms company **Thales** has been very clear regarding lethal autonomous weapons. "It has been discussed for too long, to be honest. It's not that difficult to say no to

killer robots", Patrice Caine told a group of journalists in Montreal in January 2019.[212] However, in response to our survey, the company more generally repeated its newly released AI initiative: "Thales is working on TrUE AI, an AI that is Transparent, Understandable and Ethical, where humans always remain in control. Thales is also currently preparing a Charter about Ethics and Digital Transformation that will detail how these TrUE AI principles are fully integrated in our daily activities".[213] As a journalist notes, "The final part of TrUE AI is the ethical dimension. This may prove to be the most challenging element of delivering trustable AIs".[214] There is talk of creating an internal council to monitor decisions on AI deployment, and Thales will train developers on ethics. It remains to be seen whether all this is sufficient to ensure human control over autonomous weapons.

The Israeli companies Elbit and IAI were less willing to engage publicly on this issue. **Elbit** replied that it could not "respond beyond what is stated in our publicly released information",[215] while **IAI** wrote that "at this point we will not take part" in the survey".[216]

In response to our survey, the Italian company **Leonardo** answered that it is "not currently researching, developing or producing Lethal Autonomous Weapon Systems (LAWS), or key components thereof [...] Leonardo's position on LAWS is in line with recognized standards of Human-On-The-Loop (HOTL) and Human-In-The-Loop (HITL), according to which the use of autonomous systems in safety-critical contexts must be subject to supervision and human control. In the application of Artificial and Intelligent Systems (A/IS) for security and defense, Leonardo is committed to respect the core principles of International Humanitarian Law (IHL), including:

- distinction between civilian and military targets, limiting as much as possible any collateral damage;
- proportionality to the security or military necessity.

We recognize the scenario on this topic is evolving, surrounded by risks and opportunities to be managed responsibly".[217]

Northrop Grumman replied: "No, we are not developing weapon systems that can autonomously select and attack targets without meaningful human control. [...] We currently do not have a policy that specifically covers this area", but the company referred to its human rights policy and its corporate responsibility in general.[218]

BAE Systems Chairman Roger Carr has described autonomous weapons as "very dangerous" and "fundamentally wrong", and has made clear that BAE only envisions developing weapons that keep a connection to a human who could authorise and remain responsible for lethal decision making.[219] Responding to our survey, BAE indeed confirmed they were not developing or making lethal autonomous weapons or key components thereof. With regard to the company's policy, it said that it "support[s] our customers' view that there needs to be human input over the use of force".[220] It is important to note that 'input' suggests a more distant and limited role than 'control'.
BAE further emphasises what it sees as the positive role of autonomous systems: "We believe that the use of autonomous systems does not mean a loss of command or the abdication of responsibility for decisions. Our position is that there are obvious benefits to autonomous and semi-autonomous systems which augment and improve human capabilities. We are developing a range of autonomous systems and future concepts to enable naval, land and air forces to carry out a number of different roles including air surveillance, anti-submarine warfare and better situational awareness to provide greater protection for the armed forces".[221]

In earlier correspondence with German civil society organisation Facing Finance in 2018, BAE Systems made a stronger statement: "While there are obvious benefits to unmanned systems, our view is that there should always be a 'human in the loop' when it comes to key decisions, including the use of lethal force. We firmly believe that humans must always be in charge when there is a decision such as the use of lethal force".[222]

ST Engineering replied that it was not researching, developing or producing lethal autonomous weapons or key components thereof. "ST Engineering is a responsible defence technology manufacturer that complies fully with all Singapore laws and regulations on manufacturing of military products. Beyond Singapore, we also observe all UN sanctions and abide to all treaty obligations to which Singapore is a signatory."[223] Apparently the company does not have a specific position with regard to developments in increasingly autonomous weapons.

Finally, the French **Volvo** subsidiary **Arquus** (which develops autonomous driving armoured vehicles) is also one of the companies with a policy on the issue. It replies that "Arquus' constant policy, as well as our understanding of the French Army's and the French authorities' policy, has always been that a weapon should be at all times under meaningful human control, and that under no circumstance a weapon could autonomously open fire".[224]

Clearly these include some positive and encouraging responses from industry players. We invite other companies that have been silent so far to make their positions and policies regarding lethal autonomous weapons public. As more companies speak out on this issue, this strengthens the norm that meaningful human control should always be exercised over the selection and attacking of targets.

More importantly, states should lead developments towards a pre-emptive ban on lethal autonomous weapons. If not, arms race dynamics will likely push less responsible companies to cross the threshold and eliminate the human from the decision-making loop in their emerging weapon technologies.

4. Conclusions & Recommendations

This report has provided an overview of developments in the arms industry that are relevant in the context of lethal autonomous weapons that can select and attack targets without meaningful human control. The emergence of such weapons would have an enormous effect on the way war is conducted. İt has been called the third revolution in warfare, after gunpowder and the atomic bomb.

As part of an imminent arms race to develop increasingly autonomous weapons, states rely on and involve arms producing companies in those efforts. While digital technology, especially artificial intelligence, can be beneficial in many ways, countless AI and robotics experts have warned that the technology must not be used to develop lethal autonomous weapons.

The research however shows the clear proliferation of increasingly autonomous weapon systems. Not only is there a growing number of companies in a growing number of countries developing such weapons, these technologies are also applied to an ever-expanding range of military systems, in the air, on the ground and at sea.

Especially significant are the developments related to loitering munitions, which are able to operate for longer amounts of time and over larger areas in order to select and attack targets. Major efforts related to swarm technologies multiply the potential of such weapons. These developments raise serious questions of how human control is guaranteed over these weapon systems.

On the more positive side, in response to the survey for this report, four companies - Leonardo (Italy), Milrem (Estonia), QinetiQ (UK) and Volvo/Arquus (France) - have clearly set out how they ensure their technologies will not be used for the development or production of lethal autonomous weapons. While some of these companies may still develop or produce weapons with certain levels of autonomy, they have elaborated positions on these issues. Others, such as BAE Systems (UK), Northrop Grumman (US), Singapore Technologies and Thales (France), had a less clear position, but confirmed that they are not currently researching, developing or producing lethal autonomous weapons or key components thereof.

These efforts can be seen as positive developments, but there is an urgent need for *all* arms companies to speak out on this issue as well as develop clear policies and concrete measures to ensure meaningful human control over the weapon systems they develop, produce and sell.

Unfortunately, most companies have not committed themselves to public policies ensuring that their technology will not be used in future lethal autonomous weapons, while at the same time

these companies are developing weapon systems with increasing levels of autonomy. In this report, loitering munitions and other aerial weapons have been highlighted in particular because of the imminent concern that these weapons are just one step away from operating without meaningful human control.

Thus we have identified 30 of the 50 companies surveyed as 'high concern'. These include three of the world's largest arms producers: Lockheed Martin, Boeing and Raytheon (all US), as well as AVIC and CASC (China), IAI, Elbit and Rafael (Israel), Rostec (Russia) and STM (Turkey). These companies are all working on technologies most relevant to lethal autonomous weapons while not having clear policies on how they ensure meaningful human control over such weapons.

Recommendations

There are concrete steps companies should take to avoid contributing to the development and production of lethal autonomous weapons:

- Commit publicly to not contributing to the development of lethal autonomous weapons.[225]
- Establish a clear policy stating that the company will not contribute to the development or production of lethal autonomous weapons. This policy should include implementation measures such as:
  - Ensuring each new project is assessed by an ethics committee;
  - Ensuring the principle of meaningful human control is an integral part of the design and development of weapon systems.
  - Adding a clause in contracts, especially in collaborations with ministries of defence and other arms producers, stating that the technology developed may not be used in lethal autonomous weapon systems.
- Ensure employees are well informed about what they work on and allow open discussions on any related concerns.

List of Abbreviations

AFRL	US Air Force Research Laboratory
AI	Artificial Intelligence
ASW	Anti-Submarine Warfare
DARPA	US Defense Advanced Research Projects Agency
IHL	International Humanitarian Law
ISR	Intelligence, Surveillance and Reconnaissance
LAWS	Lethal Autonomous Weapon Systems
MCM	Mine Counter Measures
NATO	North Atlantic Treaty Organisation
PLA	People's Liberation Army (China's armed forces)
RCV	Robotic Combat Vehicles
SIPRI	Stockholm International Peace Research Institute
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UCAS/V	Unmanned Combat Aerial System/Vehicle
UCLASS	Unmanned Carrier-Launched Aerial Surveillance and Strike
UGV	Unmanned Ground Vehicle
USV	Unmanned Surface Vehicle/Vessel
UUV	Unmanned Underwater Vehicle
UN	United Nations

Annex: Survey Questions

All companies surveyed and included in the table in the Executive Summary were asked two questions.

Survey questions

When we mention 'lethal autonomous weapons' below, we define them as 'weapon systems that can autonomously select and attack targets without meaningful human control'.

1. Is your company currently researching, developing or producing lethal autonomous weapons or key components thereof? (Yes/No/Prefer not to answer).

2. Does your company have a position or policy to ensure your work does not contribute to the development of lethal autonomous weapons? If so, can you share this position or policy? If not, why not?

Notes

1 See for example: Ariel Conn, 'AI Companies, Researchers, Engineers, Scientists, Entrepreneurs, and Others Sign Pledge Promising Not to Develop Lethal Autonomous Weapons', Future of Life Institute, 18 July 2018, https://futureoflife.org/2018/07/18/ai-companies-researchers-engineers-scientists-entrepreneurs-and-others-sign-pledge-promising-not-to-develop-lethal-autonomous-weapons/.

2 Emre Eser, 'İlk drone gücü 2020'de', Hürriyet, 12 September 2019, http://www.hurriyet.com.tr/ekonomi/ilk-drone-gucu-2020de-41328505 [with Google translate] and James Bingham, 'Loitering munition received by Turkish special forces', Jane's Defence Weekly, 20 December 2017.

3 https://www.youtube.com/watch?time_continue=1&v=Oqv9yaPLhEk

4 David Hambling, 'Autonomous killer drones set to be used by Turkey in Syria', New Scientist, 20 September 2019, https://www.newscientist.com/article/2217171-autonomous-killer-drones-set-to-be-used-by-turkey-in-syria/.

5 R. Vinuesa et al., 'The role of artificial intelligence in achieving the Sustainable Development Goals', 2019, https://arxiv.org/ftp/arxiv/papers/1905/1905.00501.pdf.

6 PAX's previous report 'Don't be Evil?' looks at the role of the tech sector in this debate. See www.reprogrammingwar.org.

7 Within the UN and elsewhere, lethal autonomous weapon systems are often referred to as LAWS or as fully autonomous weapon systems, and more popularly as killer robots. In this report we will use the terms 'lethal autonomous weapons' and 'autonomous weapons' interchangeably. For more information on the UN process, see: https://www.unog.ch/80256EE600585943/(httpPages)/8FA3C2562A60FF81C1257CE600393DF6?OpenDocument. For a brief general introduction to this topic, see: https://www.paxforpeace.nl/media/files/pax-booklet-killer-robots-what-are-they-and-what-are-the-concerns.pdf.

8 Future of Life Institute, 'Autonomous Weapons: An Open Letter From AI & Robotics Researchers', 28 July 2015, https://futureoflife.org/open-letter-autonomous-weapons/.

9 See for example: Peter Asaro, 'On banning autonomous weapon systems: human rights, automation, and the dehumanization of lethal decision-making', International Review of the Red Cross, No. 886, 2012; Human Rights Watch, 'Heed the Call: A Moral and Legal Imperative to Ban Killer Robots', August 2018; Heather Roff, 'Killing in War: Responsibility, Liability and Lethal Autonomous Robots', 2014; Robert Sparrow, 'Killer robots', Journal of Applied Philosophy, 24(1), 2007.

10 Bonnie Docherty, 'Mind the Gap: the Lack of Accountability for Killer Robots', Human Rights Watch, 9 April 2015, https://www.hrw.org/report/2015/04/09/mind-gap/lack-accountability-killer-robots; Thomas Chengeta, 'Accountability Gap, Autonomous Weapon Systems and Modes of Responsibility in International Law', SSRN, 30 September 2015, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2755211.

11 Paul Scharre, 'Killer Apps: The Real Dangers of an AI Arms Race', Foreign Affairs, May/June 2019, https://www.foreignaffairs.com/articles/2019-04-16/killer-apps

12 Stuart Russell, 'The new weapons of mass destruction?', The Security Times, February 2018, https://www.securityconference.de/fileadmin/MSC_/2018/Dokumente/Security_Times_Feb2018.pdf.

13 Ian Sample, 'Ban on killer robots urgently needed, say scientists', The Guardian, 13 November 2017, https://www.theguardian.com/science/2017/nov/13/ban-on-killer-robots-urgently-needed-say-scientists.

14 Campaign to Stop Killer Robots, 'Actions and Achievements', August 2019, https://www.stopkillerrobots.org/about/; China states that its call is to ban the use of fully autonomous weapons, but not their development or production.

15 UN News, 'Autonomous weapons that kill must be banned, insists UN chief', UN News, 25 March 2019, https://news.un.org/en/story/2019/03/1035381.

16 See for instance: ICRC, 'Autonomous weapons: States must agree on what human control means in practice', 20 November 2018, https://www.icrc.org/en/document/autonomous-weapons-states-must-agree-what-human-control-means-practice.

17 Numbers as of late October 2019; see: https://www.stopkillerrobots.org/about/.

18 'Killer Robots – What are they and what are the concerns?', PAX, March 2019, https://www.paxforpeace.nl/media/files/pax-booklet-killer-robots-what-are-they-and-what-are-the-concerns.pdf.

19 See for example: 'State of AI – Artificial intelligence, the military and increasingly autonomous weapons', PAX, May 2019, https://www.paxforpeace.nl/media/files/state-of-artificial-intelligence--pax-report.pdf.

20 See for example: 'Unmanned Ambitions – Security implications of growing proliferation in emerging military drone markets', PAX, July 2018, https://www.paxforpeace.nl/media/files/paxrapportunmannedambitionsv10lowres.pdf.

21 See: https://www.sipri.org/publications/2018/sipri-fact-sheets/sipri-top-100-arms-producing-and-military-services-companies-2017 and https://people.defensenews.com/top-100/. This concerns Lockheed Martin, Boeing, Northrop Grumman, Raytheon (including UTC, now taken over), BAE Systems, General Dynamics,

Airbus, Thales, Leonardo, Almaz-Antey, L3 Harris (now merged) and Huntington Ingalls Industries.

22 The only available public contact email addresses of four of the largest Chinese arms producers—CASIC, CASC, CSIC and NORINCO—all bounced. All except for CASIC had no contact web form on their sites either. Only two relevant companies—AVIC, the largest aerospace company, and underwater robotics company Yunzhou—had working email addresses, but neither company replied.

23 https://people.defensenews.com/top-100/.

24 USD 649 billion in 2018. "The USA remained by far the largest spender in the world, and spent almost as much on its military in 2018 as the next eight largest-spending countries combined." See:
'World military expenditure grows to $1.8 trillion in 2018', SIPRI press release, 29 April 2019, https://www.sipri.org/media/press-release/2019/world-military-expenditure-grows-18-trillion-2018.

25 https://www.lockheedmartin.com/en-us/capabilities/autonomous-unmanned-systems.html.

26 Ibid.

27 Ibid.

28 https://www.lockheedmartin.com/en-us/capabilities/autonomous-unmanned-systems/unmanned-military-case-study-have-raider-demo.html.

29 https://www.lockheedmartin.com/en-us/capabilities/autonomous-unmanned-systems/unmanned-military-case-study-have-raider-demo.html; also see: https://news.lockheedmartin.com/2017-04-10-U-S-Air-Force-Lockheed-Martin-Demonstrate-Manned-Unmanned-Teaming.

30 Richard Scott and Huw Williams, 'Bargain hunt: Air forces move to embrace low-cost UCAVs', Jane's International Defence Review, July 2017.

31 See for example: 'Lockheed Martin Successfully Launches First LRASM Boosted Test Vehicle From MK 41 Vertical Launch System', Boeing press release, 17 September 2013, archived at https://web.archive.org/web/20170118104602/http://www.lockheedmartin.com/us/news/press-releases/2013/september/mfc-091713-lm-successfully-launches-first-lrasm-boosted.html.

32 Robin Hughes, 'USAF boosts LRASM stocks', Jane's International Defence Review, January 2019.

33 Steve Trimble, 'Sea Strike Rebirth', Aviation Week & Space Technology, 11-24 February 2019. Also see: Geoff Fein and Richard Scott, 'BAE Systems commences production of LRASM sensor', Jane's International Defence Review, January 2018.

34 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.

35 Oriana Pawlyk, 'The First Pilotless Black Hawk Will Soon Take Flight', Military.com, 10 October 2019, https://www.military.com/daily-news/2019/10/10/first-pilotless-black-hawk-will-soon-take-flight.html.

36 Marina Malenic, 'Lockheed Martin conducts UAV launch from UUV', Jane's International Defence Review, November 2016; Graham Warwick, 'Manufacturers Showcase Cross-Domain Potential Of Unmanned Aircraft', Aviation Week & Space Technology, 29 September 2016, http://aviationweek.com/electronic-warfare/manufacturers-showcase-cross-domain-potential-unmanned-aircraft.

37 http://www.boeing.com/defense/autonomous-systems/index.page

38 'Boeing Opens Collaborative Autonomous Systems Laboratory in Missouri', Boeing press release, 30 June 2016, https://boeing.mediaroom.com/2016-06-30-Boeing-Opens-Collaborative-Autonomous-Systems-Laboratory-in-Missouri.

39 'Boeing Australia collaborates on AI research for unmanned systems', Boeing news release, 25 September 2019, https://www.boeing.com.au/news/releases/2019/september/boeing-australia-collaborates-on-ai-research-for-unmanned-systems.page. See also: https://tasdcrc.com.au/about-us/.

40 Zachary Fryer-Biggs, 'Boeing makes investment in AI company', Jane's Defence Weekly, 5 July 2017. Also see: 'Don't be Evil? A survey of the tech sector's stance on lethal autonomous weapons', PAX, 19 August 2019, https://www.paxforpeace.nl/publications/all-publications/dont-be-evil.

41 http://boeing.mediaroom.com/2017-10-05-Boeing-to-Acquire-Aurora-Flight-Sciences-to-Advance-Autonomous-Technology-Capabilities

42 Vincent Boulanin and Maaike Verbruggen, 'Mapping the development of autonomy in weapon systems', SIPRI, November 2017, p.28. Also see: Beth Stevenson, 'Boeing to test high levels of unmanned autonomy', FlightGlobal, 24 October 2016, https://www.flightglobal.com/news/articles/boeing-to-test-high-levels-of-unmanned-autonomy-430661/.

43 David Larter 'The US Navy's new autonomous refueling drone takes historic first flight', Defense News, 19 September 2019, https://www.defensenews.com/naval/2019/09/19/the-us-navys-new-autonomous-refueling-drone-takes-historic-first-flight/; Michael Fabey, 'US Navy awards Boeing contract for MQ-25A Stingray', Jane's Defence Weekly, 5 September 2018; 'Boeing Shares Sneak Peek of Aerial Refueler for MQ-25 Competition', Boeing news release, 19 December 2017, https://boeing.mediaroom.com/2017-12-19-Boeing-Shares-Sneak-Peek-of-Aerial-Refueler-for-MQ-25-Competition.

44 Gareth Jennings, 'General Atomics partners with Boeing on MQ-25 Stingray for the US Navy', Jane's International Defence Review, April 2018.

45 https://www.boeing.com/defense/autonomous-systems/index.page

46 http://www.boeing.com/defense/autonomous-systems/wave-glider-sharc/index.page

47 Ibid.

48 https://www.liquid-robotics.com/press-releases/boeing-to-acquire-liquid-robotics-to-enhance-autonomous-seabed-to-space-information-services/

49 http://www.boeing.com/defense/autonomous-systems/echo-voyager/index.page; also see http://boeing.mediaroom.com/2016-03-10-Boeing-Unmanned-Undersea-Vehicle-Can-Operate-Autonomously-for-Months

50 http://www.boeing.com/resources/boeingdotcom/defense/autonomous-systems/echo-voyager/echo_voyager_product_sheet.pdf

51 https://www.raytheon.com/news/feature/future_of_autonomy.html

52 'Securing Tomorrow – Future Warfare – Cultivating Emerging Technologies', Raytheon brochure, 2016, http://www.raytheon.com/news/rtnwcm/groups/corporate/documents/content/rtn_303213.pdf

53 https://www.raytheon.com/news/feature/future_of_autonomy.html

54 https://www.raytheon.com/capabilities/products/jsm

55 Ibid.

56 Ibid.

57 Vincent Boulanin and Maaike Verbruggen, 'Mapping the development of autonomy in weapon systems', SIPRI, November 2017, p.49.

58 Idem, p.50.

59 https://www.raytheon.com/capabilities/products/sm-2/

60 'SeaRAM anti-ship missile defense system', Raytheon, http://www.raytheon.com/capabilities/products/searam/. Also see: https://www.youtube.com/watch?v=og86EPpEsVs.

61 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.

62 See for example: John Hawley, 'Patriot Wars', CNAS, January 2017.

63 'Global Patriot Solutions', Raytheon, http://www.raytheon.com/capabilities/products/patriot/.

64 See for example: Seth Frantzman, 'Are air defense systems ready to confront drone swarms?', Defense News, 26 September 2019, https://www.defensenews.com/global/mideast-africa/2019/09/26/are-air-defense-systems-ready-to-confront-drone-swarms/ and Jeremy Binnie, 'Analysis: Saudi air defences ill prepared for low-level attacks', Jane's Defence Weekly, 25 September 2019.

65 https://www.raytheon.com/capabilities/products/coyote/

66 https://www.raytheon.com/capabilities/products/mk48/

67 http://www.northropgrumman.com/Capabilities/AutonomousSystems/Pages/default.aspx; also see: https://news.northropgrumman.com/multimedia/photo/autonomous-systems and https://news.northropgrumman.com/news/features/australias-autonomous-evolution.

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

69 'X-47B UCAS', Northrop Grumman Data Sheet, 2015, http://www.northropgrumman.com/Capabilities/X47BUCAS/Documents/UCAS-D_Data_Sheet.pdf. Also see: https://en.wikipedia.org/wiki/Unmanned_Carrier-Launched_Airborne_Surveillance_and_Strike.

70 http://www.northropgrumman.com/Capabilities/X47BUCAS/Pages/default.aspx

71 Sam LaGrone, 'Forbes Calls on SECNAV Mabus to Extend X-47B Testing', USNI News, 1 May 2015, https://news.usni.org/2015/05/01/forbes-calls-on-secnav-mabus-to-extend-x-47b-testing.

72 'Fire Scout', Northrop Grumman, http://www.northropgrumman.com/Capabilities/FireScout/Pages/default.aspx.

73 Valerie Insinna, 'Weaponization of unmanned Fire Scout helicopter 'on hiatus' until 2023', Defense News, 9 April 2018, https://www.defensenews.com/digital-show-dailies/navy-league/2018/04/09/weaponization-of-unmanned-fire-scout-helicopter-on-hiatus-until-2023/.

74 'Fire Scout', Northrop Grumman, http://www.northropgrumman.com/Capabilities/FireScout/Pages/default.aspx.

75 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. Also see: James Drew, 'Fire Scout keeps evolving', Aviation Week & Space Technology, 29 January-11 February 2018.

76 https://news.northropgrumman.com/news/releases/northrop-grumman-delivers-first-operational-mq-4c-triton-to-us-navy

77 http://www.northropgrumman.com/Capabilities/Triton/Pages/default.aspx

78 Vincent Boulanin and Maaike Verbruggen, 'Mapping the development of autonomy in weapon systems', SIPRI, November 2017, p.22; also see p.27.

79 'Northrop Grumman Remotec Introduces Next-generation Multifunction, Multimission Robot', Northrop Grumman news release, 25 September 2017, https://news.northropgrumman.com/news/releases/northrop-grumman-remotec-introduces-next-generation-multifunction-multimission-robot.

80 Andy Wright, 'Human+: A responsible vision for human-machine collaboration', BAE Systems Blog, 13 October 2016, https://www.baesystems.com/en/blog/human-plus.

81 https://www.baesystems.com/en/product/autonomy-r-d

82 'Taranis', BAE Systems, http://www.baesystems.com/en/product/taranis. Also see: Beth Stevenson, 'ANALYSIS: Taranis developers reveal test flight specifics', Flight International, 16 May 2016, https://www.flightglobal.com/news/articles/analysis-taranis-developers-reveal-test-flight-spec-425347/;
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.

83 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/.

84 Vincent Boulanin and Maaike Verbruggen, 'Mapping the development of autonomy in weapon systems', SIPRI, November 2017, p.49.

85 Idem, p.50. Also see Paul Scharre, 'Army of none', Norton, 2018, pp.105-08.

86 'BAE Systems at the heart of Unmanned Warrior', BAE Systems, 6 May 2016, https://www.baesystems.com/en/article/bae-systems-at-the-heart-of-unmanned-warrior. Also see: 'We demonstrate our autonomous naval technologies in the solent', BAE Systems news release, 18 July 2016, https://www.baesystems.com/en/article/we-demonstrate-our-autonomous-naval-technologies-in-the-solent.

87 'Grant awarded to launch UK's first maritime autonomous systems testing service', BAE Systems news release, 16 July 2017, https://www.baesystems.com/en/article/bae-systems-awarded--457-000-to-launch-uk-s-first-maritime-autonomous-systems-testing-service.

88 'Unmanned Ambitions – Security implications of growing proliferation in emerging military drone markets', PAX, July 2018, https://www.paxforpeace.nl/media/files/paxrapportunmannedambitionsv10lowres.pdf.

89 Greg Waldron, 'GA-ASI to conduct AI, machine learning work with MQ-9', FlightGlobal.com, 18 September 2019, https://www.flightglobal.com/news/articles/ga-asi-to-conduct-ai-machine-learning-work-with-mq-460919/ and 'GA-ASI To Demonstrate Agile Condor Capability for USAF', General Atomics, 16 September 2019, http://www.ga-asi.com/ga-asi-to-demonstrate-agile-condor-capability-for-usaf.

90 'GA-ASI To Demonstrate Agile Condor Capability for USAF', General Atomics, 16 September 2019, http://www.ga-asi.com/ga-asi-to-demonstrate-agile-condor-capability-for-usaf.

91 Ibid.

92 Kelvin Wong, 'NCSIST unveils Fire Cardinal mini-UAV', Jane's International Defence Review, October 2019.

93 '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/. See also: 'Where to draw the line. Increasing Autonomy in Weapon systems – Technology and Trends', PAX, November 2017, https://www.paxforpeace.nl/media/files/pax-report-where-to-draw-the-line.pdf.

94 'Russian drone Okhotnik makes maiden flight', DW, 7 August 2019, https://www.dw.com/en/russian-drone-okhotnik-makes-maiden-flight/a-49935124; 'Russia's Okhotnik UCAV breaks cover', Air Forces Monthly, 23 January 2019, https://airforcesmonthly.keypublishing.com/2019/01/23/russias-okhotnik-ucav-breaks-cover/.

95 Ankit Panda, 'A Modern, Advanced People's Liberation Army: First Takeaways From the 70th Anniversary Parade', The Diplomat, 2 October 2019, https://thediplomat.com/2019/10/a-modern-advanced-peoples-liberation-army-first-takeaways-from-the-70th-anniversary-parade/; Stefano D'Urso, 'China Exhibits New Sharp Sword UCAV During Military Parade for PRC's 70th Anniversary', The Aviationist, 1 October 2019, https://theaviationist.com/2019/10/01/china-exhibits-new-sharp-sword-ucav-during-military-parade-for-prcs-70th-anniversary/; Joseph Trevithick, 'China Showcases Stealthier Sharp Sword Unmanned Combat Air Vehicle Configuration', The Drive, 1 October 2019, https://www.thedrive.com/the-war-zone/30111/china-showcases-stealthier-sharp-sword-unmanned-combat-air-vehicle-configuration.

96 Vincent Boulanin and Maaike Verbruggen, 'Mapping the development of autonomy in weapon systems', SIPRI, November 2017, p.50.

97 https://www.stm.com.tr/en/business-areas/technology/competencies/autonomous-drone-systems

98 Emre Eser, 'İlk drone gücü 2020'de', Hürriyet, 12 September 2019, http://www.hurriyet.com.tr/ekonomi/ilk-drone-gucu-2020de-41328505 [with Google Translate] and James Bingham, 'Loitering munition received by Turkish special forces', Jane's Defence Weekly, 20 December 2017.

99 https://www.youtube.com/watch?time_continue=1&v=Oqv9yaPLhEk

100 David Hambling, 'Autonomous killer drones set to be used by Turkey in Syria', New Scientist, 20 September 2019, https://www.newscientist.com/article/2217171-autonomous-killer-drones-set-to-be-used-by-turkey-in-syria/.

101 Emre Eser, 'İlk drone gücü 2020'de', Hürriyet, 12 September 2019, http://www.hurriyet.com.tr/ekonomi/ilk-drone-gucu-2020de-41328505 [with Google Translate].

102 Lale Sariibrahimoglu, 'Turkey's STM delivering Kargu loitering munitions to TSK', Jane's Defence Weekly (online), 21 May 2019, https://www.janes.com/article/88686/turkey-s-stm-delivering-kargu-loitering-munitions-to-tsk.

103 Emre Eser, 'İlk drone gücü 2020'de', Hürriyet, 12 September 2019, http://www.hurriyet.com.tr/ekonomi/ilk-drone-gucu-2020de-41328505 [with Google Translate].

104 Harpy brochure, IAI, 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.

105 '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.

106 Yaakov Lappin, 'IAI announces Mini Harpy tactical loitering munition', Jane's Defence Weekly, 27 February 2019; 'IAI Unveils New Loitering Munition - Mini Harpy', IAI news release, 19 February 2019, https://www.iai.co.il/iai-unveils-new-loitering-munition-mini-harpy.

107 'IAI Unveils New Loitering Munition - Mini Harpy', IAI news release, 19 February 2019, https://www.iai.co.il/iai-unveils-new-loitering-munition-mini-harpy.

108 See for example: Anna Ahronheim, 'IAI tests new capabilities of latest Rotem "suicide drone"', Jerusalem Post, 26 June 2018, https://www.jpost.com/Israel-News/IAI-tests-new-capabilities-of-latest-Rotem-suicide-drone-560877; 'IAI's New Loitering Munitions', IAI North America, 27 May 2016, https://iainorthamerica.com/iais-new-loitering-munitions/.

109 Tamir Eshel, 'Drones Turned Into Weapons', Aviation Week & Space Technology, 16 July 2018, http://aviationweek.com/defense/drones-turned-weapons.

110 Ibid.

111 Yaakov Lappin, 'Elbit announces new SkyStriker loitering munition', Jane's Defence Weekly, 14 September 2016.

112 Elbit Systems, 'Skystriker', https://elbitsystems.com/product/skystriker/.

113 Yaakov Lappin, 'Elbit announces new SkyStriker loitering munition', Jane's Defence Weekly, 14 September 2016.

114 Ibid.

115 Robin Hughes, 'Aeronautics debuts first loitering munition', Jane's International Defence Review, August 2015.

116 Vincent Boulanin and Maaike Verbruggen, 'Mapping the development of autonomy in weapon systems', SIPRI, November 2017, pp.53-4.

117 Arie Egozi, 'Rafael Not Giving Up UAS Ambitions', Aerospace Daily & Defense Report, 17 August 2018, https://aviationweek.com/defense/rafael-not-giving-uas-ambitions.

118 Robin Hughes, 'Interview Major General (res) Avi Mizrachi Chief Executive Officer, UVision', Jane's Defence Weekly, 4 September 2019.

119 Seth Frantzman, 'Israeli firm UVision opens US subsidiary, with eye toward kamikaze drones market', Defense News, 21 February 2019, https://www.defensenews.com/unmanned/2019/02/21/israeli-firm-uvision-opens-us-subsidiary-with-eye-toward-kamikaze-drones-market/.

120 Ibid.

121 'Heros for mission success [CS19D1]', Jane's, 29 May 2019, https://www.janes.com/article/88846/heros-for-mission-success-cs19d1.

122 Seth Frantzman, 'Israeli firm UVision opens US subsidiary, with eye toward kamikaze drones market', Defense News, 21 February 2019, https://www.defensenews.com/unmanned/2019/02/21/israeli-firm-uvision-opens-us-subsidiary-with-eye-toward-kamikaze-drones-market/.

123 Kelvin Wong, 'Taiwan's NCSIST rolls out indigenous anti-radiation loitering munition',
Jane's International Defence Review, October 2019.

124 Ibid.

125 Ami Rojkes Dombe, 'China Unveils a Harpy-Type Loitering Munition', IsraelDefense, 1 March 2017, https://www.israeldefense.co.il/en/node/28716.

126 'USA and Israel in crisis over China Harpy deal', Flight International, 4 January 2005, https://www.flightglobal.com/news/articles/usa-and-israel-in-crisis-over-china-harpy-deal-191940/.

127 Jeffrey Lin and P.W. Singer, 'Come see China's new hexacopters and self-detonating drones', Popular Science, 31 July 2017, https://www.popsci.com/china-new-drones-army-hexacopters/#page-2.

128 'China defense industry presents CH-901 suicide drone at SOFEX 2018', Army Recognition, 9 May 2018, https://armyrecognition.com/sofex_2018_official_online_show_daily_news/china_defense_industry_presents_ch-901_suicide_drone_at_sofex_2018.html; Richard Fisher Jr, 'DSA 2016: China details CH-901 UAV and loitering munition', Jane's Defence Weekly, 19 April 2016.

129 http://www.alitcn.com/content/details_108_2276.html; Ridzwan Rahmat, 'Indonesian Army attend demonstration of WS-43 loitering glide bomb in China', Jane's Defence Weekly, 12 October 2016, via https://web.archive.org/web/20170228075132/http://www.janes.com/article/64551/indonesian-army-attend-demonstration-of-ws-43-loitering-glide-bomb-in-china.

130 Switchblade Datasheet, AeroVironment, 2019 https://www.avinc.com/images/uploads/product_docs/Switchblade_Datasheet_v1.pdf.

131 Ibid.

132 Ibid.

133 Robin Hughes, 'AeroVironment debuts multi-pack launcher for Switchblade', Jane's International Defence Review, December 2016.

134 https://www.wbgroup.pl/en/produkt/warmate-loitering-munnitions/ and https://youtu.be/zzzOH5fBAqw.

135 https://www.wbgroup.pl/en/produkt/warmate-2-loitering-munitions/ and https://www.wbgroup.pl/en/produkt/warmate-2-loitering-munitions-2/.

136 Robin Hughes, 'WB Electronics discloses next-generation Warmate development', Jane's International Defence Review, September 2018.

137 https://www.wbgroup.pl/en/produkt/warmate-v-loitering-munitions-system/.

138 Ibid.

139 Remigiusz Wilk, 'WB Group to launch SWARM system', Jane's International Defence Review, October 2017.

140 Remigiusz Wilk, 'Polish WB Group secures deal to deliver Warmate loitering munition to Ukraine', Jane's Defence Weekly, 13 September 2017.

141 Remigiusz Wilk, 'Poland purchases 1,000 Warmate loitering munitions', Jane's Defence Weekly, 29 November 2017.

142 Nicholas Fiorenza, 'Rheinmetall presents Mission Master UGV armed with Warmate loitering munition', Jane's Defence Weekly, 11 September 2019.

143 Miko Vranic, 'Kalashnikov 'kamikaze' UAS shown for first time', Jane's Defence Weekly, 3 July 2019.

144 Dmitry Fediushko, 'ZALA Aero pursues AI-driven detection system, containerised UAV assembly facility', Jane's International Defence Review, October 2019.

145 Kelsey Atherton, 'A drone with a can-doom attitude', C4ISRNET, 5 June 2019, https://www.c4isrnet.com/unmanned/2019/06/05/a-drone-with-a-can-doom-attitude/.

146 Ibid.

147 Kelsey Atherton, 'As Counter-UAS Gains Ground, Swarm Threat Looms', Aviation Week & Space Technology, 26 March–8 April 2018.

148 See also: Richard Scott, 'Fighting chance: UAV concept seeks to alter the air power equation', Jane's International Defence Review, June 2019; Thomas McMullan, 'How swarming drones will change warfare', BBC News, 16 March 2019, https://www.bbc.com/news/technology-47555588.

149 See for example: Andrew Tarantola, 'DoD shows off its first successful micro-drone swarm launch', Engadget, 10 January 2017, https://www.engadget.com/2017/01/10/dod-shows-off-its-first-successful-micro-drone-swarm-launch/ and Shawn Snow, 'Pentagon successfully tests world's largest micro-drone swarm', Defense News, 9 January 2017, http://www.militarytimes.com/articles/pentagon-successfully-tests-worlds-largest-micro-drone-swarm.

150 'OFFensive Swarm-Enabled Tactics (OFFSET)', DARPA, https://www.darpa.mil/work-with-us/offensive-swarm-enabled-tactics; also see: 'Teams Test Swarm Autonomy in Second Major OFFSET Field Experiment', DARPA, 7 August 2019, https://www.darpa.mil/news-events/2019-08-07.

151 Todd South, 'Drone swarm tactics get tryout for infantry to use in urban battlespace', Army Times, 8 January 2018, https://www.armytimes.com/news/your-army/2018/01/08/drone-swarm-tactics-get-tryout-for-infantry-to-use-in-urban-battlespace/.

152 Ibid. Also see: Andrew Tate, 'CETC claims new record for number of UAVs in a swarm', Jane's Defence Weekly, 28 June 2017.

153 Graham Warwick, 'Swarm Enabler', Aviation Week & Space Technology, 3-16 April 2017.

154 DARPA, 'Gremlins', (https://www.darpa.mil/program/gremlins).

155 Stephanie Lizotte, 'DARPA awards Gremlins Phase III contract to Dynetics', CBRNE Central, 13 May 2018, https://cbrnecentral.com/darpa-awards-gremlins-phase-iii-contract-to-dynetics/11180/.

156 Robin Hughes, 'Lockheed Martin, Northrop Grumman awarded low-cost 'Gray Wolf' cruise missile development contracts', Jane's International Defence Review, February 2018; Joseph Trevithick, 'USAF Wants Swarms of Cheap "Gray Wolf" Cruise Missiles That Can Overwhelm Enemy Defenses', The Drive, 29 December 2017, https://www.thedrive.com/the-war-zone/17257/usaf-wants-swarms-of-cheap-gray-wolf-cruise-missiles-that-can-overwhelm-enemy-defenses.

157 Robin Hughes, 'Lockheed Martin, Northrop Grumman awarded low-cost 'Gray Wolf' cruise missile development contracts', Jane's International Defence Review, February 2018.

158 Rachel Cohen, 'AFRL's New Goal: Make Munitions Plan Attacks', Air Force Magazine, 21 June 2019, http://www.airforcemag.com/Features/Pages/2019/June%202019/AFRLs-New-Goal-Make-Munitions-Plan-Attacks.aspx.

159 See also: Richard Scott, 'Fighting chance: UAV concept seeks to alter the air power equation', Jane's International Defence Review, June 2019.

160 Graham Warwick, 'AFRL's Skyborg Program To Develop Unmanned Wingman With "AI Brain"', Aviation Week & Space Technology, 8-21 April 2019. Also see: Valerie Insinna, 'Under Skyborg program, F-35 and F-15EX jets could control drone sidekicks', Defense News, 22 May 2019, https://www.defensenews.com/air/2019/05/22/under-skyborg-program-f-35-and-f-15ex-jets-could-control-drone-sidekicks/ and Bryan Ripple, 'Skyborg program seeks industry input for artificial intelligence initiative', USAF 88th Air Base Wing Public Affairs, 27 March 2019, https://www.af.mil/News/Article-Display/Article/1796930/skyborg-program-seeks-industry-input-for-artificial-intelligence-initiative/.

161 Graham Warwick, 'AFRL's Skyborg Program To Develop Unmanned Wingman With "AI Brain"', Aviation Week & Space Technology, 8-21 April 2019.

162 Ibid.

163 Ibid.

164 Steve Trimble, 'Kratos Steals Boeing's Thunder With XQ-58A First Flight', Aviation Week & Space Technology, 11–24 March 2019; Richard Scott and Huw Williams, 'Bargain hunt: Air forces move to embrace low-cost UCAVs', Jane's International Defence Review, July 2017.

165 Bradley Perrett and Graham Warwick, 'Team Player', Aviation Week & Space Technology, 11–24 March 2019.

166 Daniel Wasserbly, 'US Army chief eyes 'leap-ahead' technologies', Jane's Defence Weekly, 24 January 2018.

167 Jen Judson, 'Getting serious about armed ground robots', Defense News, 13 September 2019, https://www.defensenews.com/digital-show-dailies/dsei/2019/09/13/getting-serious-about-armed-ground-robots/.

168 Ibid.

169 Melanie Rovery, 'THeMIS uncovered: detailing Estonia's mid-sized unmanned export', Jane's International Defence Review, October 2018.

170 Arno de Boer, 'Robot op het slagveld kan nog niet veel', Trouw, 25 September 2019.

171 Huw Williams, 'Milrem demos THeMIS autonomy, outlines roadmap', Jane's International Defence Review, February 2018.

172 https://milremrobotics.com/themis/

173 Melanie Rovery, 'THeMIS uncovered: detailing Estonia's mid-sized unmanned export', Jane's International Defence Review, October 2018.

174 Oscar Widlund, 'Milrem Robotics unveils missile-armed THeMIS UGV', Jane's International Defence Review, April 2019; Melanie Rovery, 'MBDA teams with Milrem Robotics to develop an anti-tank UGV', Jane's International Defence Review, August 2018 and https://www.mbda-systems.com/about-us/.

175 Robin Hughes, 'MBDA unveils surface-launched Brimstone platform concepts', Jane's International Defence Review, October 2019.

176 Melanie Rovery, 'Kongsberg exhibits ATGM capability with Titan UGV', Jane's International Defence Review, October 2019; Jen Judson, 'Getting serious about armed ground robots', Defense News, 13 September 2019, https://www.defensenews.com/digital-show-dailies/dsei/2019/09/13/getting-serious-about-armed-ground-robots/; Huw Williams, 'MILREM up-guns THeMIS with Protector weapon station', Jane's International Defence Review, May 2017.

177 Melanie Rovery, 'THeMIS uncovered: detailing Estonia's mid-sized unmanned export', Jane's International Defence Review, October 2018.

178 Jen Judson, 'Getting serious about armed ground robots', Defense News, 13 September 2019, https://www.defensenews.com/digital-show-dailies/dsei/2019/09/13/getting-serious-about-armed-ground-robots/.

179 'Out of Control: Irresponsible weapons transfers and future weapon systems. Dirty Profits 7', Facing Finance, May 2019, http://www.facing-finance.org/files/2019/05/ff_dp7_ONLINE_v02.pdf, p.36.

180 Jen Judson, 'Getting serious about armed ground robots', Defense News, 13 September 2019, https://www.defensenews.com/digital-show-dailies/dsei/2019/09/13/getting-serious-about-armed-ground-robots/.

181 Sunil Nair, 'ADEX 2019: Hanwha Defense, Hyundai Rotem display prototype UGVs', Jane's Defence Weekly, 21 October 2019, https://www.janes.com/article/92052/adex-2019-hanwha-defense-hyundai-rotem-display-prototype-ugvs.

182 Kelvin Wong, 'Robot wars: Asia Pacific pursues future ground combat vehicles', Jane's International Defence Review, April 2019.

183 Kelsey Atherton, 'Russian system uses infantry to spot for robots', C4ISRNET, 3 March 2019, https://www.c4isrnet.com/unmanned/2019/03/04/russias-new-robot-is-a-combat-platform-with-drone-scouts/.

184 Ibid. Also see: Kelsey D. Atherton, 'Why robots in cities will capture attention', C4ISRNET, 21 October 2019, https://www.c4isrnet.com/unmanned/2019/10/21/russias-robotic-scout-is-a-testbed-for-autonomy/.

185 Dmitry Fediushko, 'Russian MoD to receive 12 Uran-6 UGVs in 2019', Jane's International Defence Review, 6 February 2019, https://www.janes.com/article/86187/russian-mod-to-receive-12-uran-6-ugvs-in-2019; Sebastien Roblin, 'Russia's Uran-9 Robot Tank Went to War in Syria (It Didn't Go Very Well)', The National Interest, 6 January 2019, https://nationalinterest.org/blog/buzz/russias-uran-9-robot-tank-went-war-syria-it-didnt-go-very-well-40677.

186 Ashley Roque, 'AUSA 2019: Industry unveils Robotic Combat Vehicle prototypes', Jane's International Defence Review, 14 October 2019, https://www.janes.com/article/91887/ausa-2019-industry-unveils-robotic-combat-vehicle-prototypes; Sydney Freedberg Jr., 'Textron Rolls Out Ripsaw Robot For RCV-Light … And RCV-Medium', Breaking Defense, 14 October 2019, https://breakingdefense.com/2019/10/textron-rolls-out-ripsaw-robot-for-rcv-light-and-rcv-medium/.

187 Jen Judson, 'The field narrows in US Army's light robotic combat vehicle competition', Defense News, 21 October 2019, https://www.defensenews.com/digital-show-dailies/ausa/2019/10/21/the-field-narrows-in-light-robotic-combat-vehicle-competition/.

188 See examples in: Zachary Fryer-Biggs, 'Coming Soon to a Battlefield: Robots That Can Kill', The Atlantic, 3 September 2019, https://www.theatlantic.com/technology/archive/2019/09/killer-robots-and-new-era-machine-driven-warfare/597130/.

189 'Portugal hosts maritime exercise in support of NATO's Maritime Unmanned Systems Initiative', NATO news release, 25 September 2019, https://www.nato.int/cps/en/natohq/news_168925.htm.

190 Richard Scott, 'To Hell Bay and back: UW16 pushes the boundaries for autonomous MCM', Jane's International Defence Review, June 2017.

191 'New SwarmDiver debuts [IDEX19D2]', janes.com, 18 February 2019, https://www.janes.com/article/86505/new-swarmdiver-debuts-idex19d2; Kelsey Atherton, 'Are robot swarms the future of destroying sea mines?', C4ISRNET, 27 December 2018, https://www.c4isrnet.com/unmanned/robotics/2018/12/27/are-robot-swarms-the-future-of-destroying-sea-mines/.

192 Kelsey Atherton, 'Are robot swarms the future of destroying sea mines?', C4ISRNET, 27 December 2018, https://www.c4isrnet.com/unmanned/robotics/2018/12/27/are-robot-swarms-the-future-of-destroying-sea-mines/.

193 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-smilitary-christens-self-driving-sea-hunter-warship-idUSKCN0X42I4.

194 'Sea Hunter powers ahead [DSEI19D3]', Janes.com, 12 September 2019, https://www.janes.com/article/91139/sea-hunter-powers-ahead-dsei19d3.

195 Cheryl Pellerin, 'Sea Hunter, DARPA's Game-Changing Robot Warship', DoD News, 11 April 2016, https://science.dodlive.mil/2016/04/11/sea-hunter-darpas-game-changing-robot-warship/. Also see: David Larter, 'US Navy moves toward unleashing killer robot ships on the world's oceans', Defense News, 15 January 2019, https://www.defensenews.com/naval/2019/01/15/the-us-navy-moves-toward-unleashing-killer-robot-ships-on-the-worlds-oceans/.

196 'Seagull Successfully Completes Torpedo Launch Trials', Elbit Systems, 28 June 2016, http://elbitsystems.com/pr-new/elbit-systems-seagullsuccessfully-completes-torpedo-launch-trials/ and 'Seagull Multi-Mission USV', Elbit Systems, http://elbitsystems.com/uas-seagul-multi-mission-usv-system/.

197 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/.

198 https://swiftships.com/vessels/special-operation-craft-riverine-socr/. Also see: 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.

199 Andrew White, 'Anaconda USV development progresses', Jane's International Defence Review, September 2016.

200 Lee Willett, 'SMaRC thinking: Sweden's research centre builds underwater robotics capability', Jane's International Defence Review, September 2019; Lee Willett, 'Combined course: Mapping a route to sustained underwater presence', Jane's International Defence Review, July 2019.

201 Richard Scott, 'To Hell Bay and back: UW16 pushes the boundaries for autonomous MCM', Jane's International Defence Review, June 2017.

202 Michael Fabey, Geoff Fein and Pat Host, 'Coming ashore: unmanned systems lead the way in amphibious operations', Jane's International Defence Review, July 2018.

203 Richard Scott, 'NRL looks to modify Black Pearl experimental AUVs', Jane's International Defence Review, March 2019; Daniel Wasserbly, 'US Navy's Knifefish UUV swims through new test round', Jane's Defence Weekly, 29 March 2017.

204 David Larter, 'China is working on killer robot ships of its own', Defense News, 18 February 2019, https://www.defensenews.com/digital-show-dailies/idex/2019/02/18/china-is-working-on-killer-robot-ships-of-its-own/.

205 Manash Pratim Boruah, 'MADEX 2019: LIG Nex1 unveils Sea Sword II USV', Jane's International Defence Review, 22 October 2019, https://www.janes.com/article/92093/madex-2019-lig-nex1-unveils-sea-sword-ii-usv.

206 Gabriel Dominguez, 'Hanwha Systems shows model of UUV for ASW operations', Jane's Defence Weekly, 30 October 2019.

207 Similar diverging understandings of autonomy have troubled diplomatic discussions on lethal autonomous weapons at the UN and elsewhere. This can be illustrated by the example given by Paul Scharre of the UK's definition, and how that relates to e.g. the Taranis UCAV as developed by a BAE-led team (Paul Scharre, 'Army of none', Norton, 2018, pp.108-11).

208 'Künstliche Intelligenz in Sicherheit und Verteidigung', BDI Position, January 2019, https://e.issuu.com/embed.html#2902526/66182763 [translation by author]. See also: Donata Riedel, 'Wie intelligent dürfen Waffen sein? BDI-Chef fordert KI-Strategie für Rüstungsgüter', Handelsblatt, 15 February 2019, https://www.handelsblatt.com/politik/international/muenchner-sicherheitskonferenz-wie-intelligent-duerfen-waffen-sein-bdi-chef-fordert-ki-strategie-fuer-ruestungsgueter/23986910.html.

209 Milrem email, received 25 September 2019.

210 Milrem email, received 27 September 2019.

211 QinetiQ email, received 30 September 2019

212 James McLeod, 'Killer robots aren't just science fiction anymore', Financial Post, 25 January 2019, https://business.financialpost.com/technology/wisdom-race-as-defence-firms-face-the-artificial-intelligence-future-killer-robot-question-looms-large.

213 Thales email, received 3 October 2019, which also refers to information on this issue on its website: https://www.thalesgroup.com/en/group/journalist/press-release/ai-humanity-french-industry-engages-artificial-intelligence and https://www.thalesgroup.com/en/group/journalist/press_release/thales-true-ai-approach-artificial-intelligence-be-unveiled-paris.

214 Angus Batey, 'New Thales Concept Aims to Build Trust in Artificial Intelligence', Aviation Week & Space Technology, 16 June 2019, https://aviationweek.com/paris-airshow-2019/new-thales-concept-aims-build-trust-artificial-intelligence.

215 Elbit email, received 24 September 2019.

216 IAI email, received 25 September 2019.

217 Leonardo email, received 1 October 2019.

218 Northrop Grumman email, received 13 September 2019.

219 Paul Scharre, 'Army of none', Norton, 2018, p.109.

220 BAE Systems email, received 14 October 2019.

221 Ibid.

222 'Out of Control: Irresponsible weapons transfers and future weapon systems. Dirty Profits 7', Facing Finance, May 2019, http://www.facing-finance.org/files/2019/05/ff_dp7_ONLINE_v02.pdf, p.24.

223 ST Engineering email, received 7 October 2019.

224 Arquus email, received 1 October 2019.

225 See for example: Ariel Conn, 'AI Companies, Researchers, Engineers, Scientists, Entrepreneurs, and Others Sign Pledge Promising Not to Develop Lethal Autonomous Weapons', Future of Life Institute, 18 July 2018, https://futureoflife.org/2018/07/18/ai-companies-researchers-engineers-scientists-entrepreneurs-and-others-sign-pledge-promising-not-to-develop-lethal-autonomous-weapons/.

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