IV.4

MILITARY AND DEFENCE ISSUES OF DRONES AND ROBOTS

CHAPTER 12

ROBOTS AND DRONES ON BATTLEFIELDS: NEW CAPABILITIES AND EMERGING CHALLENGES

ZVONKO TRZUN

Abstract

Recent armed conflicts have proved the undeniable value of systems commonly called robots or drones. The astonishing success of Azerbaijan in the 2020 Nagorno-Karabakh conflict, largely attributed to the strategic use of unmanned aerial vehicles (UAVs) by the Azerbaijani military, left experts and analysts in awe. However, the worth of UAVs had already been proven years earlier with the advent of the multi-role MQ-1 Predator.

This chapter provides a concise overview of UAV development, current capabilities, and potential future directions. The text is structured so that the first part describes the development of UAVs, and the second part focuses on unmanned ground vehicles (UGVs). The third part examines the extent to which Europe has embraced these new armed systems, analysing both European armed forces and industries – both striving to catch up with the main players in the unmanned vehicles market.

The chapter also describes the general shift in the world's security landscape, the rising sense of uncertainty, the long-forgotten fear of war, and the consequential surge in spending on military equipment. The development of artificial intelligence (AI) and the increasing autonomy of drones are briefly touched upon as this is an emerging field with the first AI-controlled systems still being tested. However, it is a topic deserving of a completely separate discussion. These points ultimately underscore the technical issues accompanying the usage of UAVs and UGVs, which occasionally lead to tragic errors. Whether the likelihood of such errors will decrease

---

Zvonko Trzun (2024) 'Robots and Drones on Battlefields: New Capabilities and Emerging Challenges'. In: Katarzyna Zombory – János Ede Szilágyi (eds.) *Shielding Europe with the Common Security and Defence Policy. The EU Legal Framework for the Development of an Innovative European Defence Industry in Times of a Changing Global Security Environment,* pp. 527–579. Miskolc–Budapest, Central European Academic Publishing.

https://doi.org/10.54237/profnet.2024.zkjeszcodef_12

or increase as AI eventually replaces humans in controlling drones ("human out-of-the-loop") is likely to become evident in the very near future.

Keywords: drones, robots, unmanned aerial vehicles, unmanned ground vehicles, European military industry, artificial intelligence

1. Introduction

Analysing the increased use of robots and drones on modern battlefields, Colonel T. E. Hanson (at that time, director of U.S. Army Combat Studies Institute) said that they marked non-linear changes on the battlefields of the world.[1] Mathematically speaking, it would be correct to say that instead of linear growth, military capabilities experienced exponential growth, which physicists might call quantum leaps. Quite true, there are moments when breakthrough technologies have so strongly changed the previous balance of power that it is no exaggeration to say that nothing was the same thereafter. One such change was the discovery of gunpowder; another was the discovery of the atomic bomb; and the latest seems to be the introduction of autonomous unmanned weapons, the first technology to fundamentally affect not only the question of HOW wars will be fought in the future, but also WHO will fight in them.[2]

Going to war, or preparing for it, is not cheap. For example, the operational costs of military aircraft are staggering: In fiscal year 2018, a single B-2 Spirit bomber incurred expenses of 63 million dollars, flying a single F-22 Raptor fighter cost 22 million dollars, and flying the F-35, in one of its A/B/C versions, amounted to 13.4 million dollars. It is reasonable to assume these figures have significantly inflated due to rising costs in recent years. In stark contrast, unmanned weapons operate at a fraction of these costs.[3]

The advantages of robotic warfare are substantial. Robots respond to the increasing move to reduce human resources in the military. They accelerate operations, displaying unwavering focus and endurance without succumbing to human limitations like hunger, fear, or forgetfulness. Furthermore, robots possess capabilities that surpass those of humans: they can operate in radioactive environments, and they exhibit unparalleled precision in targeting (hitting a coin from 300 metres away, a feat beyond even the most skilled infantryman). Finally, robots will not hesitate to shoot to kill, a stark contrast to the moral dilemmas often faced by human soldiers.[4]

---

[1] Doaré et al., 2014, p. 4.

[2] Singer, 2009, p. 17.

[3] McCarthy, 2020.

[4] Tisseron, 2014, p. 5.

Experienced military leaders recognise the value of robots. General Rick Lynch, former commander of the U.S. Army's 3rd Armored Corps, commented on losing 155 men in combat. He asserts that 80% of those casualties were avoidable. There is no doubt in his mind: deploying a superior robot army could have saved 122 young lives in Iraq, which convincingly underscores the potential of unmanned weapons in mitigating human losses on the battlefield.[5]

2. Terminology Defined: Robots, Drones and Unmanned Vehicles

Although there is no shortage of definitions for the term "robot", there is no universally accepted definition. The ISO 8373:2021 standard states that a robot is a 'programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning'.[6] An additional note has been added, which states that a robot includes the control system. Autonomy is defined as the ability to perform intended tasks based on current state and sensing, without human intervention.

Another definition declares a robot to be a highly autonomous machine that '(1) senses, (2) thinks (in a deliberative, nonmechanical sense), and (3) acts'.[7]

The *Oxford English Dictionary* definition of a robot is: "a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer". In the book *Elements of Robotics*[8] the analysis delves deeper into this definition, particularly the phrase '…carrying out a complex series of actions automatically'. The phrase suggests that robots can perform tasks automatically, but it also emphasises that these tasks are inherently complex. For instance, anti-tank mines are not considered robots as they execute only a single action, even though they operate autonomously. Missiles are excluded from the category of robots for the same reason. The authors also highlight a pivotal characteristic of robots not explicitly stated in the Oxford Dictionary definition – the use of sensors. Simple machines cannot adapt their actions to their environment – but robots can, thanks to sensors.

Drawing from these elements, robots in this chapter are defined as machines equipped with sensors designed to perceive their environment; they can execute complex actions based on the perceived situation and are programmed to carry out these actions with varying degrees of autonomy. Unmanned vehicles are also types of robots, and depending on the domain, we divide them into aerial (UAVs), ground

---

[5] Magnusson, 2010.

[6] International Organization for Standardization [ISO], 2021.

[7] Lin et al., 2008, p. 4.

[8] Ben-Ari and Mondada, 2018, pp. 1–5.

(UGVs), surface (USVs), and underwater vehicles (UUVs). Some authors distinguish fixed-wing UAVs from rotary-wing UAVs, preferring the latter to be called drones. Considering that the term UAV is still more often used in professional literature, we also decided to give it priority.

3. Brief History of Unmanned Aerial Vehicles

The early application of modern military UAVs finds its roots in the development of the aerial torpedo in 1916. This groundbreaking weapon was engineered to target naval warships during World War I.[9] One of history's most renowned UAVs is the V-I flying bomb, also known as the "doodlebug", engineered in Nazi Germany. The V-I had an 848-kilogram warhead and was used during World War II. From June 1944 to March 1945, more than 9,000 V-I missiles were directed at England's territory.[10]

After World War II, research into UAVs continued, benefiting from significant advancements in automatic systems. In 1953, the Radioplane division at Northrop initiated the AQM-35 supersonic pilotless target aircraft. This aircraft had its maiden flight in 1956, achieving speeds of up to Mach 1.55. Its primary role was to assist in training the military to counter supersonic aerial threats.[11]

In the 1970s, Israel emerged as a leading manufacturer of UAVs, marking a significant era in the country's UAV development. Two standout UAV models during this period were the Mastiff and Scout. These drones played a crucial role in gathering intelligence, covering both ground and aerial surveillance of enemy forces, including precisely identifying radio locator locations and their parameters. They were also used in Israeli air strike operations. Their use extended to reconnaissance missions, to gather information on the effectiveness of these strikes, and to closely monitor the movements of enemy units.

After significant strides in UAV technology during the 1970s and 1980s, Israel ceded its leading position to the United States. The military conflicts of that era significantly shaped this transition in UAV leadership. In 1991, the United States launched Operation Desert Shield in Iraq in collaboration with its allies, attaining rapid success, which could be largely attributed to their cutting-edge technological capabilities. Subsequently, the Yugoslav War emerged as another significant conflict, where NATO and United Nations Member States jointly conducted Operation Deliberate Force in 1995. Reconnaissance assumed a central role in military planning during these conflicts, with military strategists drawing on the lessons gleaned from the Gulf War.

---

[9] Ranquist, Steiner and Argrow, 2017, p. 1.

[10] Sloggett, 2015, p. 24.

[11] Palik and Nagy, 2019, p. 158.

Since the 1990s, UAVs have undergone a remarkable transformation, evolving into indispensable assets able to amass extensive data while operating at high altitudes over territories controlled by enemy forces.[12] Well before the onset of the War on Terror, the Central Intelligence Agency (CIA) already employed unmanned drones during the Bosnian conflict in 1994, operating under the classified designation of "Lofty View".[13]

The deployment of RQ-2 Pioneers by the Marines in Bosnia (1994) and Kosovo (1999), with launch operations conducted from the Ponce De Leon, marked notable instances of drone utilisation. Concurrently, the Hunter, a UAV jointly developed by Israel Aerospace Industries and TRW, was presented to the U.S. Army to fulfil its requirement for a short-range reconnaissance UAV. A substantial order of fifty Hunter drones, totalling $200 million, was delivered in 1993. However, the envisioned multi-billion-dollar programme faced eventual cancellation despite the Army, Navy, and Air Force all deploying Hunter drones. Designated as RQ-5A, the Hunter drones played a role in Operation Allied Force during the Kosovo conflict, amassing a cumulative flight time of 30,000 hours by 2004. This history of the Hunter underscores the long-term reliability of drones and highlights that armed forces were not fully ready to integrate them comprehensively.[14]

3.1. Predator: A Defining Milestone in UAV Technology

A more recent history of unmanned aerial vehicles will be illustrated through the most prominent UAV, General Atomics' Predator, along with its successors, the MQ-9 Reaper and MQ-9B Sky Guardian. However, large armed UAVs do not encompass the full spectrum of unmanned aircraft capabilities. UAVs have been designed in various sizes to cater to various tasks. They range from micro-drones weighing less than a kilogram, serving as surveillance tools to provide soldiers with a glimpse of what lies beyond the next wall, to giants weighing several tonnes, equipped with powerful missile systems capable of obliterating even heavily fortified enemy shelters.

The U.S. Military and NATO recognise three classes of UAVs: Class III includes aircraft weighing more than 600 kg, Class II are aircraft weighing 150-600 kg, and Class I includes the smallest unmanned aircraft. Class I drones are further divided into small, mini and micro UAVs. Normal deployment varies from tactical subunit for micro aerial vehicles to strategic and national employment for the largest UAVs.[15] The largest ones garner significant media attention, but a separate chapter could be easily written also for small drones, or for medium-sized ones.

In January 1994, the U.S. Department of Defense (DOD) finalised a contract with General Atomics to procure three systems, totalling ten aircraft, all based on the

---

[12] Michel, 2013.
[13] Shoker, 2021, p. 133.
[14] Frantzman, 2021, p. 19.
[15] NATO, 2019.

GNAT 750, a UAV that had previously been developed and utilised by the CIA. The new UAV was named the "Predator".

The Predator marked a significant milestone as the first medium-altitude endurance UAV created for the U.S. Air Force (USAF). Prior endeavours involving endurance UAVs, exemplified by the Compass Cope program, had focused exclusively on high-altitude endurance vehicles. The Predator's operational range extended between 3,000 and 25,000 feet, boasting impressive endurance, capable of remaining in flight for over 20 consecutive hours.[16]

Following the establishment of the Defense Airborne Reconnaissance Office, the inaugural operational utilisation of UAVs transpired in 1995. The USAF deployed its inaugural Predator unit, formally designated as the 11th Reconnaissance Squadron, to Bosnia in July of that year. This squadron fulfilled a pivotal role by furnishing indispensable aerial reconnaissance data until the conclusion of its mission in November. During this period, two Predators were lost – one due to enemy actions and another due to an engine malfunction.

Nevertheless, the surviving Predator was a crucial asset to NATO forces. The Predators communicated with ground pilots through a UHF satellite connection. This connectivity facilitated the transmission of real-time still images to ground terminals. The intelligence gleaned from the Predator's reconnaissance flights corroborated the violation of arms-removal agreements by several conflicting parties and contributed to identifying targets for an ensuing bombing campaign. This bombing campaign, in turn, played a pivotal role in compelling the warring factions to reengage in negotiations – which ultimately culminated in the signing of the Dayton Accord in 1995.[17]

3.2. Predator Transforms into a Multi-Role UAV

The USAF officially designated the Predator as the RQ-1. The Air Force employed the letter "Q" for designating unmanned aircraft dating back to World War II when the tradition began. In this context, the "R" denoted the aircraft's primary role in reconnaissance missions. When the Air Force employed a Predator aircraft to launch a Hellfire air-to-ground missile in 2002 (marking another pivotal moment in the platform's operational history), the UAV was again re-designated MQ-1 where "M" stands for "multi-role".

In the period spanning from June 2005 to June 2006, Predator UAVs were deployed on a total of 2,073 missions, accumulating an impressive 33,000 flight hours. During this time, they tracked 18,490 targets and executed 242 targeted attacks. These operational statistics reflect the Predator's strong performance during that particular period. As the utilisation of UAVs expanded, so did the demand for their services. By 2007, approximately 180 Predator UAVs were actively deployed, with multiple military units receiving approximately 300 hours of operational data

---

[16] Blom, 2010, p. 92.

[17] Ibid., p. 93.

and surveillance information from these aircraft daily. Although substantial, the available Predator fleet could not fully meet this high demand. These UAVs were primarily operated from the United States, yet they frequently launched their missions from locations near active war zones, as exemplified by their operations at Balad Air Base in Iraq. This strategic positioning allowed for swift and effective responses to emerging situations in conflict regions.[18]

As of September 2008, the United States Air Force had a total inventory of approximately 110 Predator aircraft (the number was constantly changing due to the poor reliability and frequent crashes of these aircraft). Predators played a pivotal role in the surge operations conducted in Iraq the same year, by providing an impressive 13,000 hours of video footage to ground troops every month. During this period, the Air Force conducted 24 simultaneous combat air patrol missions, ensuring continuous coverage. This remarkable operational intensity was possible because of a novel approach known as “split remote control”. Under this framework, the take-off and landing phases were managed through line-of-sight control within the theatre of operations. Once the aircraft was airborne, control was seamlessly transferred to pilots located in the continental United States.[19] This innovative approach significantly expanded the pool of available pilots, resulting in an almost threefold increase in Predators operational at any given time. The utilisation rate increased from 30% to 85% of the overall inventory.[20]

A 2010 assessment of the drone inventory conducted by the U.S. DOD task force revealed there were 8,000 drones (large ones like MQ-1 Predators and MQ-9 Reapers, but also a great number of smaller UAVs), constituting 41% of the total military aircraft inventory. At that time, only a fraction of these drones – less than 1% – were equipped with weaponry. Their usage was still predominantly dedicated to intelligence, surveillance, and reconnaissance (ISR) missions.[21]

The inventory included 127 MQ-1 Predator, 31 MQ-9 Reaper, ten RQ-4 Global Hawk strategic reconnaissance aircraft, and various other UAVs serving diverse purposes. The Predator and Reaper UAVs could carry missiles, thus enabling new types of ground attack missions.

In addition to UAVs, the U.S. Army has deployed over 2,400 Talon unmanned ground vehicles (UGVs). These robots are equipped with cameras, motion sensors, and sound detectors and can operate day and night. They have robotic arms, flexible rotating shoulders, wrist and finger joints, and memory and learning capabilities. These attributes make them well-suited for reconnaissance within areas such as buildings, courtyards, sewers, and caves. Furthermore, they excel in the inspection of vehicles, removing roadblocks, and conducting border security patrols, among other functions.

---

[18] Frantzman, 2021, p. 38.
[19] Cuadra and Whitlock, 2014.
[20] Blom, 2010, p. 108.
[21] Frantzman, 2021, p. 23.

Modern armies were quick to recognise the growing importance and potential of unmanned military systems. For example, as early as 2009, the USAF had trained more pilots for UAVs than for traditional aircraft. By September of that year, 240 UAV pilots had graduated, outnumbering the 214 fighter pilots trained for manned aircraft. Although unmanned vehicles had yet to prove their worth in future conflicts (such as those in Nagorno-Karabakh or the Russo-Ukrainian war), this shift signalled an early indication of the approaching new era, with all the benefits and drawbacks that such a pivotal moment would bring.[22]

3.3. Poor Reliability of Predators

The MQ-1 Predator UAV is a weapon that has left a significant mark on military history, its success hard to dispute. Predators accumulated several million flight hours during their active service. Remarkably, while it took around fifteen years to accumulate the first million flight hours, the additional two million mark was reached in just two-and-a-half years, although this includes the hours accumulated by Predator's successor, the MQ-9 Reaper.[23] The Predator found its purpose and performed exceptionally well. In March 2018, USAF officially retired the MQ-1 Predator from operational service. A total of 268 Predators had been delivered to the service, of which just over 100 were still in service by the start of 2018.[24] The data on the small final number of active Predators provides one of the answers to the question – why would such a successful system be retired at all?

One of the reasons for the replacement was the appearance of the MQ-9 Reaper, a larger and more powerful UAV. Another reason pertains to the Predator's notorious unreliability. One report from 2014[25] revealed that from 2001, more than 400 large U.S. military drones had been involved in major accidents worldwide. Among these incidents, 194 drone crashes were categorised as Class A accidents,[26] indicating complete destruction of the aircraft or damages amounting to more than $2 million.[27] Military UAVs have occasionally landed on houses, farms, roads, or crowded areas. Sometimes, Predators and other UAVs behaved so unpredictably that pilots had to deliberately ram the drone into a mountain to avoid it falling into populated areas. In one notable incident, a UAV collided mid-air with a C-130 Hercules transport plane. One military UAV weighing approximately 150 kg fell near an elementary school playground in Pennsylvania, just minutes after students had left for home. Fortunately, no fatalities have occurred, but disasters have been only narrowly averted, often by a few feet. The list of incidents is extensive and several military drones have even vanished without a trace. Control over one armed Reaper was lost and it flew

---

[22] Wu, 2022, p. 168.
[23] Martin, 2013.
[24] Donald, 2018.
[25] Whitlock, 2014.
[26] Gibb and Olson, 2008, p. 4.
[27] Light et al., 2020, p. 2.

unguided across Afghanistan. Eventually, USAF fighters located and shot it down as it neared neighbouring Tajikistan.

Some accidents have occurred due to human error. For instance, in 2010, a Predator carrying a Hellfire missile crashed near Kandahar because the pilot failed to realise it was flying upside down. Certain human errors are caused by a lack of situational awareness of the ground control station (GCS). Unusual vibrations, noises, smells, and other sensory cues that a manned aircraft pilot would rely on are absent for a pilot situated thousands of miles away from a UAV.[28] To address this issue, General Atomics designed an enhanced GCS featuring high-resolution display that offers a 120° view, thereby improving the limited field of view (FOV) of a single-camera system.[29] Despite these enhancements, a UAV pilot cannot attain the same level of situational awareness as his counterpart in a manned aircraft.

Limited situation or operational awareness partially absolves the manufacturer of responsibility and should not impact the assessment of the aircraft's reliability. However, there are also numerous errors caused by technical problems. By 2014, almost half of all Predators had been involved in at least one incident – which explains why only around 100 Predators (out of the 268 purchased) "survived" their operational life.

Air Force officials acknowledged that Predators crash more frequently than regular military aircraft, but also claimed that the safety record of drones has improved considerably after the initial period of adjusting to the specific conditions of operating drones, which previously resulted in an extraordinarily high crash rate. For every 100,000 hours of Predators flown, there were 13.7 Class A accidents. Since 2009, this rate has dropped to 4.79 Class A accidents per 100,000 flight hours. However, this remained a very high accident rate, and therefore, most operators welcomed the new Reaper UAV that appeared in 2007.

Chris Cole from Drone Wars UK[30] (a site that follows the development of UAVs, but also the problems associated with their development) gives a somewhat discouraging diagnosis: 'Remotely controlled drones are inherently less safe than aircraft with a pilot onboard, and that is why we see so many crashes'. He sees more problems in the possibility that UAVs could be included in civil air traffic: 'While the military drone crashes that have happened so far tend to be in remote locations, if regulators give in to the increasing pressure to open up British and European airspace to these large drones, the impact is likely to be far greater'.[31] DOD officials have consistently defended the reliability of their UAVs – and yet, they have also admitted that this reliability can never match that of conventional aircraft with a pilot in the cockpit.

[28] Gundlach, 2012, p. 674.
[29] Jha, 2017, p. 65.
[30] Cole, 2015.
[31] BBC News, 2016.

3.4. MQ-9 Reapers: Bigger, Stronger, Even More Powerful UAVs

The success of the Predator fuelled a desire to develop an even more powerful UAV, equipped with a larger arsenal of weapons and capable of spending longer periods in the air, tirelessly hunting down the next potential target. The new UAV was based on the Predator, but with an increase in all dimensions: the wingspan was increased to 20 metres (14.8 m for the Predator), the length of the aircraft was increased to 11 m (8 m for the Predator) and it was equipped with a 950-shaft- horsepower/712 kW turboprop engine (a significant upgrade compared to the Predator's 115 hp/86 kW piston engine). The operational range has been increased to 1900 km, with an absolute ceiling of 50,000 ft. (15,420 m). Endurance is a staggering 27 hours or even 32 hours with additional external fuel tanks capable of holding 1,300 lbs of fuel. A particularly impressive leap forward has been achieved in terms of firepower. While later versions of the Predator could carry two AGM-114 Hellfire missiles, the Reaper can carry either eight AGM-114 Hellfire missiles or four Hellfire and two 500 lb (230 kg) GBU-12 Paveway II laser-guided bombs. The 500 lb (230 kg) of GBU-38 joint direct attack munition can also be carried.[32] However, this increased capacity comes at a price: the Reaper costs $32 million – eight times more than the Predator.

A Reaper system consists of three aircraft, a GCS, line-of-sight and a beyond-line-of-sight satellite and terrestrial data links, support equipment, personnel, and deployed crews, enabling 24-hour operations. Due to its impressive properties, it is on the wish list of many of the worlds' armed forces. In Europe, Belgium, Italy, France, Greece, Netherlands, Spain, and the United Kingdom have begun or already completed the procurement process.[33] Germany considered procuring Reapers, but eventually decided to lease the Israeli Heron UAV, while Finland and Poland recently announced their intention to purchase Reapers.[34]

The Reaper has been perfected based on lessons learned from extensive deployment of the Predator.[35] Additional valuable insights came from missions conducted using the Reaper, with the UAV being significantly enhanced from version to version. For example, the U.S. Navy asked for more range – quite understandable given its operations conducted across vast expanses of ocean. General Atomics responded by adding the additional external fuel tanks, a four-bladed propeller, engine alcohol and water injection, and elongated wings and tail surfaces as key upgrades. The new Reaper was 11.7 m long, and the wingspan was increased to 24 m. All these modifications have increased its endurance from 27 to 33–35 hours. The production designation of the new aircraft is Predator B/extended-range, although the name MQ-9B Reaper or simply Reaper ER appears more often in the media.

---

[32] U.S. Air Force, 2021.

[33] Gosselin-Malo, 2023; Kokkinidis, 2022; Stevenson, 2015.

[34] Defense Industry Daily, 2023; Adamowski, 2022.

[35] Gundlach, 2012, p. 18.

With its extended wingspan and increased range, the Reaper ER now meets the standards for civil aviation regulations. General Atomics CEO, Linden Blue, declared, '…the wing was designed to conform to STANAG 4671, and includes lightning and bird strike protection, non-destructive testing, and advanced composite and adhesive materials for extreme environments'.[36] Consequently, Reaper ER became the first medium-altitude long-endurance remotely piloted aircraft system (MALE RPAS) certified for operation within civilian airspace, complying with European flight regulations. No longer confined to military operations in conflict zones, Reaper transformed into an aircraft capable of long-term surveillance of civilian skies, able to undertake activities like border surveillance, search and rescue missions, anti-trafficking operations, and similar tasks. However, the MQ-9B SkyGuardian features weapons capability, harnessing the proven precision strike capacity of the MQ-9A Reaper. This Reaper variant is typically armed with 500-pound GBU-12 Paveway II laser-guided bombs and/or AGM-114 Hellfire missiles.[37]

Table 1. Comparison of MQ-1 Predator, MQ-9 Reaper and MQ-9B SkyGuardian (Reaper ER) characteristics.

	MQ-1 Predator	**MQ-9 Reaper**	**MQ-9B Reaper (ER)**
Introduced – Retired	1995-2018	2007	2016
Maximum Operational Altitude (ft)	25,000	50,000	45,000
Maximum Endurance (h)	24	27	> 40
Range (km)	1250	1900	2500
Maximum Take-off Weight (kg)	1020	4760	5670
Armaments	2xHellfire Missile	Combination of AGM-114 Hellfire missiles, GBU-12 Paveway II, GBU-38 Joint Direct Attack Munitions	Combination of AGM-114 Hellfire missiles, GBU-12 Paveway II, GBU-38 Joint Direct Attack Munitions
Price ($M)	4.5	30	32

---

[36] General Atomics, 2016.

[37] Attariwala, 2017, pp. 20–23.

The Reaper ER conducted its first operational flight in August 2015. Given that it will fly over civilian space, this certifiable Reaper was given the more appropriate name SkyGuardian or SeaGuardian, based on mission and payload. In 2016, the British Ministry of Defence (MoD) revealed that the extended-range version of the Reaper, the MQ-9B SkyGuardian, was selected for acquisition from 2018 to 2030.[38] In Britain, the aircraft will be called Protector. The new drone will be in service with the RAF from around mid-2024. An initial aircraft was handed over to the RAF in October 2022 but will remain in the U.S. for testing and training purposes. The USAF operated more than 300 MQ-9 Reapers as of May 2021, and it is still unclear how many UAVs the United Kingdom intends to order.[39]

The long-range capability of the SeaGuardian/MQ-9B Reaper is particularly attractive to countries with extensive maritime borders. For example, this issue is particularly important for the Indian Navy, because of the threat of Pakistani submarines. In 2023, India announced that it would begin the procurement of 31 MQ-9B Reapers in a contract worth 3.07 billion dollars. Indian officials and military leaders expect the procurement to significantly strengthen the Indian Navy's air anti-submarine warfare (ASW) capabilities. In keeping with the size of the oceans it oversees, the Indian Navy will receive 15 of the 31 new drones. Once India deploys the new MQ-9B Reapers, its Navy will become the second in the world (but certainly not the last) to conduct ASW operations using large UAVs.[40]

3.5. Reliability of the Reaper: Better than the Predator, Worse than Manned Aircrafts

But even as large UAVs become more powerful, they still have the problems of all new, under-tested systems that have been rushed to market. The new UAV MQ-9 Reaper is significantly more reliable than its predecessors, with 3.17 Class A accidents per 100,000 flying hours. However, this rate remains noticeably worse than manned aircraft; for instance, the F-16 fighter had a Class A accidents rate of only 1.96, while the F-15 had an even better rate of 1.47 accidents per 100,000 flying hours.

A good starting point for interested scholars is the Drone Wars UK site.[41] Their drone crash database is the result of methodical and persistent monitoring of USAF Accident Investigation Board reports, Wikileaks war logs, *The Washington Post* drone crash database, and general and military press reports. The site reports on crashes of large (Class II and III) military drones since early 2007.

For example, Drone Wars UK revealed that more than 400 large U.S. military drones were involved in major accidents worldwide from 2001–2014 (from a

---

[38] Stevenson, 2015.

[39] Insinna, 2021.

[40] Haider, 2023.

[41] Drone Wars UK, 2022.

comprehensive analysis conducted by *The Washington Post*).[42] Alongside the list of incidents, the main causes, referred to as 'fundamental safety hurdles' are outlined in the report as follows:

- Limited ability to detect and avoid trouble: Cameras and high-tech sensors on drones cannot fully substitute for a pilot's eyes and ears in the cockpit, leading to challenges in identifying and avoiding potential issues.
- Pilot error: Flying a drone is more complex than it appears, making human error a significant factor in accidents.
- Persistent mechanical defects: Some commonly deployed UAV models were designed without backup safety features and were rushed into service without extensive testing, leading to ongoing mechanical issues.
- Unreliable communications links: Drones rely on wireless transmissions for relaying commands and navigational information, but these connections can be fragile. In over a quarter of the worst crashes, communication links had been disrupted or lost, highlighting the vulnerability of drone communication systems.

Incidents involving large unmanned aircraft are particularly intriguing to the public and concealment of the details of such incidents is challenging. For instance, information about an MQ-9 Reaper that crashed into Lake Ontario during a training mission on November 12, 2013, was leaked to the public.[43] Although the Reaper was equipped with more safety mechanisms than its predecessors, these measures proved insufficient to save the malfunctioning UAV. According to the report, the drone's ground-based aircrew attempted to guide the Reaper back to base when it lost connectivity by switching to autopilot and charting a course back to base that avoided populated areas and potential obstacles. Another air crew attempted to connect with the drone, but a further global positioning system (GPS) and inertial guidance system error occurred. Within seconds, the drone initiated an automated right turn, causing it to invert and eventually enter into an unrecoverable spin.

Certain technical challenges are nearly insurmountable without a fundamental shift in design philosophy. The lightweight construction of the Reaper offers advantages, but it also makes the drone susceptible to strong winds, meaning that it must be grounded in adverse weather conditions. This poses a significant problem given that many missions occur over turbulent mountainous regions.[44] Additionally, there are other technical issues to consider. Older Reapers could not detect other aircraft, rendering them vulnerable to mid-air collisions. While the risk is relatively low when drones are flown over remote areas like Afghanistan, it significantly escalates if the Reaper operates over regions with heavy air traffic, such as Europe or the United States. It was not until 2019 that the introduction of a military Ground-Based Detect and Avoid Radar system at Syracuse International Airport allowed the Reaper to land and take off safely at this location. Before this

---

[42] Whitlock, 2014.

[43] Aegerter, 2013.

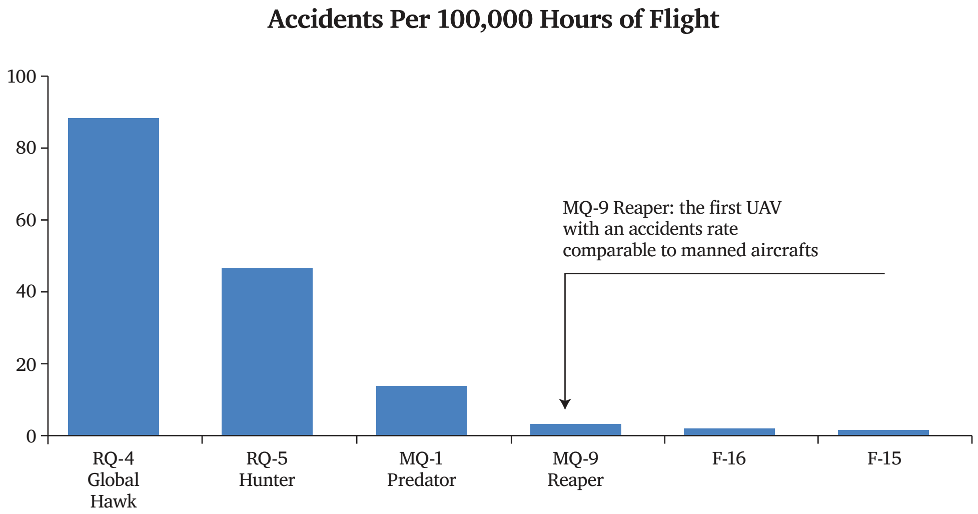
[44] DoD Inspector General, 2020.

development, the MQ-9 had to be escorted by a manned civil air patrol aeroplane when ascending to and descending from altitudes of up to 18,000 feet.[45]

By early 2016, it was clear that the Reaper had persistent electrical problems. Problems with a faulty starter-generator caused the crashes or Class A accidents of 20 Reapers, half of which were in 2015 alone. Another early issue with the Block 5 aircraft, the newer generation of the Reaper, was that the avionics and other internal systems could not handle hot weather conditions. As a result, 2015 marked the worst year for drone crashes the USAF has ever had.[46] The problems were eventually solved by replacing critical components, after which the Reapers finally became more reliable.

Despite multiple problems, the latest General Atomics' unmanned aircraft demonstrate an above-average level of reliability, compared with earlier models. A 2005 U.S. DOD report[47] showed that in the late 1990s and early 2000s, UAVs were involved an unusually large number of Class A accidents, with a mishap rate (i.e., Class A accidents per 100,000 hours of flight) of 47 for the RQ-5 Hunter, 191 for the AAI RQ-7 Shadow and 281 for the AAI RQ-2 Pioneer. Even the largest UAV, weighing 14.6 tonnes and worth 130 million dollars, the Northrop Grumman's RQ-4 Global Hawk registered a mishap rate of 88, which is ten times higher than that of General Atomics' Predators and Reapers.

Figure 1: The accidents rate for the most used UAVs, compared with manned aircrafts



---

45 Olney, 2019.
46 Smith, 2016.
47 U.S. Department of Defense, 2005.

We have mentioned a large number of difficulties and incidents in this chapter – but maybe the picture is not so grim after all. Maybe UAVs were simply going through the development and testing stages that every other new product has to go through. The rapid decline in the number of accidents after 2015 suggests that the early 2000s represented what the 1900s were for manned aviation: a time of trial and error, constant learning, and countless lessons that this time (in the case of unmanned aviation) were not paid for in blood but only dollars.

In addition, it is crucial to recognise that not all UAV accidents are caused by technical failures; a significant portion can be attributed to the crews operating these systems. The role of an unmanned aircraft pilot is incredibly demanding, stressful, and often underappreciated. It is not surprising that they develop typical symptoms of post-traumatic stress disorder (PTSD), just like pilots who fly manned aircraft.[48] Confined, uncomfortable spaces and intensely concentrating on screens for hours, these pilots respond to constant inquiries from various agencies, analysts, troops, and, of course, commanders. The pilots receive fragmented information without context yet are expected to provide comprehensive real-time updates in return. One analysis succinctly captures the issue: ‘Prior to drones, commanders relied on information flowing up the chain of command. Now they hunt for this information themselves, undermining the value of their own subordinates’.[49] Caught amidst conflicting directives from commanders at different levels of the chain of command, pilots strive to accommodate everyone, leading to stress, diminished concentration, and, ultimately, errors that can result in the destruction of the UAV.

3.6. What Is Next: The End of the Road, Or a Brand New Start for Reapers?

The U.S.AF announced their intention to upgrade the entire fleet, including 144 Block 1 and 136 Block 5 aircraft, to extended-range standards. These alterations are likely to be the final ones, as General Atomics is already developing the Reaper’s successor, anticipated to be even more powerful, with an expected introduction in 2031. The end of service life of the MQ-9 fleet is scheduled for 2035.[50] But there is still no definitive decision, and the future of the Reaper appears uncertain at this juncture. The U.S.AF has been seeking approval to reduce its Reaper fleet from 351 to 276 aircraft by the end of fiscal 2023. Additionally, they propose halting the production of new Reapers entirely.

That strategic shift is likely influenced by information about new weapons developed by rival nations. The U.S.AF is concerned that Reapers could become vulnerable targets for Chinese air defences in a potential conflict. Given the substantial cost of each large UAV, such a scenario could be financially disastrous. Consequently, the Air Force is inclined towards developing smaller unmanned vehicles capable of

---

[48] Werner et al., 2020, pp. 27–28.

[49] McClure, 2015.

[50] Insinna, 2021.

launching swarm attacks, thereby overwhelming enemy air defences at a reduced overall expense. Smaller unmanned aircraft can be very useful on the battlefield, using their small dimensions for easier survivability while performing reconnaissance missions, gathering information or directing artillery fire.[51] In light of this new strategy, there is diminishing room for Reapers, which cost tens of millions of dollars. Therefore, the Air Force hopes to retire more than half of the existing MQ-9 fleet by fiscal year 2027.

Advocates for continuing Reaper utilisation argue that the MQ-9 shares comparable survivability with other fourth-generation aircraft, indicating its potential to operate in threat environments akin to F-15s or F-16s.[52] The eventual outcome of this debate – whether supporters or staunch opponents of large, unmanned aircraft will prevail – remains uncertain. Some Reapers are scheduled to remain in service until 2035, although the exact number is unknown.[53]

UAVs must transition from being used to engage with poorly organised extremist organisations to operating in contested airspace. The initial upgrade will introduce a self-protection anti-jam antenna system, followed by the integration of new weaponry, an enhanced power system, and upgraded electro-optical and infrared systems.[54] Reapers must adapt to more formidable wartime conditions, or they risk vanishing from the skies permanently.

It is also possible that the Reaper will no longer be used as an independent hunter-killer, but instead, become a carrier of smaller UAVs. In recent years, the concept of a large unmanned aircraft acting as a mothership (central hub), bringing smaller UAVs closer to the target, has been explored. Discussion since 2020 suggest that the MQ-9 Reaper, or its upgraded version, the MQ-9B Sky Guardian, could potentially carry up to four smaller Sparrowhawks. The initiative, dubbed the Adaptive Airborne Enterprise (A2E), envisions an expanded role for MQ-9s. Under A2E, these aircraft would transcend their conventional functions and transform into mobile control hubs for a network of small drones and other systems. This network aims to establish an extensive sensing grid, facilitating target detection or establishing communication pathways for special operations forces operating deep within enemy territory.[55]

At present, this entire concept remains in the theoretical stage, much like the Sparrowhawk itself, which is still undergoing development. This compact unmanned aircraft system is designed as an “airborne launch and recovery demonstrator aircraft”, meant to be carried and retrieved by a mothership, which could be either another larger drone or a different type of aircraft.[56] The benefit of employing compact, affordable, and disposable combat drones is clear: their capabilities, especially when

---

[51] Bartulović et al., 2023, pp. 77–78.
[52] Cohen, 2022.
[53] Insinna, 2021.
[54] Tirpak, 2021.
[55] Roza, 2023.
[56] Larson, 2020.

deployed in a coordinated swarm, could accomplish the desired mission objectives. All of this comes at a fraction of the cost of larger aircraft, and would not endanger the lives of pilots when used with a manned mothership.

3.7. More UAVs From Predator/Reaper Family

Several novel UAVs have been designed based on the architecture of the Predator and Reaper. While not all of them have been integrated into the Air Force or other military branches, they illustrate potential directions for UAV development in the near future:

- MQ-20 Avenger (formerly Predator C). Unlike the MQ-1 Predator and MQ-9 Reaper, the Avenger is powered by a turbofan engine. First launched in 2009, its design includes stealth features such as internal weapons storage and an S-shaped exhaust for reduced infrared and radar signatures. The Avenger is equipped with the same armament as the MQ-9. The jet engine allows it to fly at high subsonic speed (720 km/h), significantly faster than other UAVs from the same family: The maximum speed of the Reaper is 400 km/h, and the Predator flies at a mere 216 km/h. After testing, the U.S.AF decided that this platform still did not offer significant advantages over the MQ-9 Reaper, which they already had in service. The fact that the focus of operations at that time was Afghanistan, where the advantages of the Avenger did not come to the fore, probably contributed to the decision. However, in future, at least some UAVs will certainly follow the path of the Avenger: a jet engine will be necessary to achieve supersonic speeds and the possibility of fighting with manned fighters, while stealth characteristics will be a great advantage when the opponent uses the Anti-Access /Area Denial (A2/AD) strategy.
- Altair: this UAV is equipped with extra-long wings (wingspan is 26 m). It is powered by the same engine as the Reaper. The maximum altitude is an impressive 52,000 feet (16 km), and endurance is 36 hours. Today, these aircraft are used by NASA's Earth Science Enterprise, but it is conceivable that a similar design could be adopted by spy aircraft intended to collect data deep inside enemy territory.
- Mojave: this is a UAV with short take-off and landing (STOL) capabilities. Initially, the aim was to create a drone capable of vertical take-off and landing. However, this proved impractical as it required significant compromises in payload or endurance. Consequently, the focus shifted to a STOL design, ensuring optimal performance while requiring less runway space. Its configuration closely resembles that of the MQ-9 Reaper. Mojave successfully completed its inaugural test flight in the summer of 2021. In 2023, the UK announced its plans to acquire a Mojave system for trials aboard its Queen Elizabeth-class aircraft carriers. This UAV architecture is likely to be used in the future on aircraft carriers and elsewhere where take-off and landing space is limited.

4. When a 'Perfect' Machine Makes a Mistake: Civilian Casualties

As pointed out in Chapter 13, the use of UAVs is generally not controversial from a legal standpoint; however, a controversy arises in relation to the ways in which UAVs are employed. While it may be philosophically acceptable to excuse errors in armed systems by asserting nothing is perfect, such justifications lose credibility when faced with the most severe mistakes – those that lead to the loss of innocent human lives. UAVs have not been exempt from such errors, and it appears that, in numerous cases, the cause of fatal errors was the human factor.

In September 2023, *The New York Times* revealed that the final U.S. drone strike before the withdrawal of American troops from Afghanistan resulted in a tragic error, causing the deaths of 10 civilians, including seven children. Initially, the Pentagon denied this, but eventually, under mounting evidence, it had to acknowledge the accuracy of the newspapers' claims. The extensive investigation conducted by *New York Times* reporters showed that the U.S.AF had launched a Hellfire missile from an unmanned aircraft at an ordinary civilian vehicle. U.S. military officials attempted to defend their actions, claiming that the ground commander had compelling evidence to support the decision he had made. General Kenneth F. McKenzie Jr. (U.S.MC), Commander, U.S. Central Command, stated: 'At the time of the strike, based upon all the intelligence and reports we had, I was confident that the strike had prevented an imminent threat to our forces at the airport. Given that assessment, I and other leaders in the department consistently affirmed the validity of this strike'.[57]

U.S. military officials further attempted to bolster the legitimacy of their actions by pointing to a subsequent, larger blast that occurred in a nearby courtyard. However, upon inspecting the strike site, no evidence of a second, more substantial explosion was found. Despite their efforts to justify the incident, military officials were forced to abandon this last argument, subsequently suggesting that the second explosion might have been caused by a flare-up from a propane tank in the courtyard or perhaps the gas tank of a second vehicle in the area.[58]

The steadfast determination displayed by military officials in justifying their missile strike on an innocent man only raises more scepticism about the credibility of their claims. Their arguments, which bordered on the surreal, included labelling the driver as a terrorist merely for visiting a suspected Islamic State safe house (a claim later disproven), driving a white Toyota Corolla, and at one point loading something into the vehicle – an action that was carelessly and recklessly misconstrued as carrying explosives.

The MQ-9 Reaper, the UAV used for the attack, is equipped with the impressive Multi-Spectral Targeting System (MTS-B), featuring visual sensors for precise

---

[57] U.S. Department of Defense, 2021.

[58] Schmitt and Cooper, 2021, Section A, p. 1.

targeting. This system has an infrared sensor, colour and monochrome daylight TV cameras, shortwave infrared camera, laser designator, and laser illuminator. Full-motion video from each imaging sensor can be viewed as separate video streams or fused together.[59] However, even with this advanced technology, incidents can occur if the UAV is misused – or if commanders see only what they want to see.

Andrew Milburn, a retired Marine Corps colonel and former commanding officer of the Marine Raider Regiment and Combined Special Operations Task Force in Iraq, raises valid questions and provides answers in his insightful analysis: 'Anyone who has spent time in Afghanistan, indeed the Middle East, must be driven to question how "reasonable certainty" could be ascribed to a target description that loosely matched one in five vehicles on Afghan roads'. Mckenzie's statement reveals an opinion based more on wishful thinking than sound intelligence. When combined with high rank and a dominant personality, confirmation bias compounds initial errors, and causes other more junior but important participants in the process to be reluctant to challenge the views of a commander. The result is often what followed in this case – misidentification and tragic error.[60]

The incident on August 29, 2021 is a classic case of confirmation bias. This date marked the second-to-last day of the American forces' withdrawal from Afghanistan, a moment captured vividly in recent images: desperate individuals clinging to the wings and wheels of the final U.S.AF planes departing Kabul, now once again under Taliban control. General McKenzie reported more than 60 clear "threat vectors" indicating an imminent attack on Kabul airport. And only three days before, ISIS orchestrated a bombing that claimed 170 lives, including 13 American service members. The prevailing atmosphere was one of pervasive fear and uncertainty, with a pressing need to safeguard the lives of Afghan civilians and American soldiers.

But despite this tense environment, the unprovoked drone killing of an Afghan craftsman highlights the peril of wielding the lethal power of drones indiscriminately. This incident also raises a question – would the outcome have been the same if the decision had been in the hands of a pilot operating a manned aircraft? As Milburn perceptively observes, there is a prevailing, albeit implicit, notion that distancing human beings from such acts could somehow mitigate the moral weight of the act. At the same time, the U.S. President fostered the misconception that drones are more precise and less harmful to non-combatants. This notion is completely misguided, rooted in an overreliance on technology coupled with wishful thinking. The stark truth remains: drones are thirty times more likely to cause civilian casualties compared to manned aircraft.

For more than two decades, the problem of civilian casualties resulting from drone strikes has arisen persistently in conflicts in regions like Afghanistan and Iraq. In December 2013, a tragic incident occurred when the USAF targeted a convoy of 11 cars and pickup trucks in rural Yemen with four Hellfire missiles. Initially,

---

[59] U.S. Air Force Website, 2021.

[60] Milburn, 2021.

both the Yemeni authorities and the U.S. government labelled the victims as terrorists, claiming the operation had targeted a high-ranking member of Al-Qaeda in the Arabian Peninsula. However, it was later revealed by witnesses and relatives that the victims were actually part of a wedding procession.[61]

This incident is just one among many misdirected strikes. Independent estimates from non-government organisations, New America and the Bureau of Investigative Journalism, indicate that civilians accounted for 7.27% to 15.47% of deaths in the U.S. drone strikes in Pakistan, Yemen, and Somalia from 2009 to 2019.[62] The same organization reported hundreds of civilians killed.[63] Unfortunately, this issue is unlikely to be resolved soon as the Washington administration maintains its focus towards what officials refer to as "over the horizon" operations in Afghanistan – strikes conducted against terrorist targets in countries at a considerable distance from ground control.[64]

The initial step in preventing future mistakes involves acknowledging responsibility and thoroughly analysing the reasons behind the error. However, there is little optimism that the U.S. Military will exercise more caution in approving new strikes on alleged terrorists. A mere two months after the Kabul incident came to light, Pentagon inspectors concluded their investigation, stating that the U.S. UAV strike that claimed the lives of 10 Afghan civilians was an error, albeit not a violation of any laws. USAF Inspector Lieutenant General Sami Said informed reporters, 'It was an honest mistake',[65] leaving them to speculate on the exact implications of such phrasing and why those responsible for an "honest mistake" are not held accountable.

What is unequivocal, however, is that the MQ-9 Reaper and Hellfire missile it deployed functioned flawlessly. Yet, given that the use of these exceptional weapons can swiftly lead to catastrophic consequences, it is evident that unmanned weapons, or at least their distant pilots, are not yet prepared to operate over civilian populations or to be used for tasks such as border surveillance and similar law enforcement activities.

4.1. Reaper's Potential Flaws: Technology in Focus

We have established that the equipment installed in the Reaper UAV represents the top available technology, including the MTS-B EO/IR (Multi-Spectral Targeting System) that combines electro-optical/infrared, laser designation, and laser illumination capabilities in a single sensor package. This system for Reapers is supplied by Raytheon. According to General Atomics, the Reapers are equipped so that they

---

[61] Human Rights Watch, 2014.
[62] Grossman, 2019.
[63] Gittins, 2020.
[64] Milburn, 2021.
[65] Schmitt, 2021, Section A, p. 1.

deliver the best image to the pilots, and there is even a ground/dismount moving target indicator to help pilots with the automatic identification and tracking of the target:

> GA-ASI's Lynx Multi-Mode Radar is a high-performance system that provides high-resolution, photographic-quality imagery that can be captured through clouds, rain, dust, smoke and fog… Integrated into USAF MQ-9 Reaper RPA, the DMTI mode allows pilots to detect slow-moving, operationally significant personnel or vehicles. In addition, pilot can select a GMTI/DMTI target and automatically cross-cue to the EO/IR sensor in narrow FOV for visual identification of the target.[66]

In other words, the Reaper ensures clear images without interference from clouds or smoke when transmitting to the GCS. The system automatically tracks the targets, revealing their location and where they hide. But can this be entirely trusted?

4.2. Poor Image Quality

In a New York Times article (written by the same journalist who revealed the story to the U.S. public, and then to the whole world), scenes filmed during the disastrous Reaper attack on civilians on August 29, 2021, are described as "murky"; later journalists write about "blurry images" or "blurry footage". Actually, the word "blurry" is mentioned six times.[67] If Reaper's pilots and their commanders really had to decide whether to launch an attack based on such poor-quality footage, could they even have made a better decision? The MQ-9 Reaper does have the higher-resolution colour camera, but it seems that it was used too little or too late on this occasion.

The second article[68] highlights numerous errors made by USAF unmanned aircraft pilots, including the July 2016 incident when what were thought to be three ISIS staging areas on the outskirts of Tokhar, northern Syria were targeted. The Pentagon reported 85 enemy fighters killed. However, the reality was very different: U.S. missiles struck houses far from the front line, where farmers, their families, and other local residents sought refuge from nightly bombings and gunfire. Tragically, over 120 villagers lost their lives in the attack. The article mentions the promises made by U.S. military officials regarding the enhanced "over the horizon" long-range surveillance capabilities of UAVs. In stark contrast, multiple official reports highlight shortcomings in both the quality and quantity of video footage, which ideally should form the basis for targeted attacks with minimal collateral damage.

In some instances, the issue was not just the quantity of the video but also its quality. Analysts at the military's Combined Air Operations Center in Qatar encountered this challenge when they examined 17 minutes of unclear footage preceding

---

[66] General Atomics, 2020.

[67] Savage et al., 2022, Section A, p. 1.

[68] Khan, 2023.

a strike on an ISIS “defensive fighting position” in Ramadi on November 13, 2015. Upon further review, they determined that what was initially identified as an ‘unknown heavy object’ being moved into a building was, in fact, ‘a person of small stature’, resembling ‘how a child would appear standing next to an adult’.[69]

Accurately identifying the enemy is a fundamental aspect of the targeting process. However, there have been several cases where ordinary citizens were mistakenly identified as combatants. While we are on the subject, the Pentagon presents disproportionately low figures regarding misidentification. Their official records indicate that misidentification occurred in just 4% of cases. However, during visits to incident sites conducted by The New York Times, misidentification played a significant role in 17% of cases, contributing to almost a third of civilian deaths and injuries. Why is this happening? After all, the prerequisites for precision strikes seem to have already been achieved. The weaponry carried by the MQ-9 Reaper has already been rigorously tested. The systems have been constantly upgraded over the years, and they proved their worth in the 1991 Persian Gulf War, in NATO’s 1999 campaign in the Balkans, in Yemen and Somalia. This applies both to the Reaper Multi-Spectral Targeting System and also to the laser guidance of Hellfire missiles. So when the weapon is already so perfected, it should be utilised appropriately: after the Trump administration came to power, the pace of using powerful UAVs was significantly accelerated. American forces have executed more than 50,000 airstrikes in Iraq, Syria, and Afghanistan. Trump also gave the CIA the authority to conduct drone strikes; that decision is discussed in Chapter 13, where CIA operations are aptly characterised as having a “clandestine nature”. All of this obviously suggests a rising trust in unmanned weapons, a trust that is largely justified, but occasionally still excessive.

4.3. Laser Guidance, Known Issues

Excessive confidence arises because the subpar quality of the video is not the only critical aspect of the technology in use. The MQ-9 Reaper employs two types of ammunition: the AGM-114 Hellfire guided missile and GBU-12 Paveway II bombs (where “GBU” stands for “Guided Bomb Unit”). Both weapon systems are laser-guided. The sensor operator, stationed alongside the pilot in the GCS, utilises a laser targeting marker to “paint” the target, a task that can also be performed by ground troops in conventional combat zones. The challenge with this type of guidance lies in its susceptibility to being compromised by clouds, smoke, fog, or dust. This is precisely why many militaries resort to GPS-guided weapons. The GPS guidance may be less precise, but it will not be affected by unfavourable environmental conditions.

However, even if we presume the weapon operates optimally – with flawless video quality enabling target display, seamless functioning of the Ground/Dismount Moving Target Indicator allowing automatic target identification and tracking, and

---

[69] Ibid.

impeccable performance of Reaper's missiles and bombs that accurately follow the designated laser beam – the reality is that the operation of large UAVs is still far from the promised 'putting warheads on foreheads'.[70] This phrase should signify the UAV's ability to hit its target with surgical precision, minimising, and perhaps even eliminating collateral casualties.

Undoubtedly, the Hellfire missile has achieved remarkable accuracy and precision. In external ballistics, "accuracy" denotes the alignment of the mean impact point with the target position, whereas "precision" refers to the dispersion of impact points.[71] Low accuracy typically results from systematic deterministic errors, while low precision arises from non-deterministic errors, such as deviations in the thrust force direction from the missile's longitudinal axis of symmetry, errors occurring during missile production, and unpredictable sudden changes in wind, among others.[72] The accuracy of the Hellfire is satisfactory, and its Circular Error Probable (CEP) is among the smallest in its class of laser-guided missiles. According to the DOD Dictionary of Military and Associated Terms, CEP is "an indicator of the delivery accuracy of a weapon system, used as a factor in determining probable damage to a target. It is the radius of a circle within which half of a missile's projectiles are expected to fall".[73]

4.4. A Misalignment of Purpose: The Anti-Tank Weapon in the Wrong Role

Therefore, accuracy should not be the primary concern, even in (moderately) unfavourable conditions. The real issue lies in the Hellfire's lethality. Originally designed as an anti-armour missile, its "kill zone" extends up to 15 metres and has an "injury radius" of 20 metres. This means that any inadequately shielded target within 20 metres of the Hellfire's impact site will sustain severe injuries, and a significant number of enemies (but also innocent bystanders) may be fatally wounded.[74] Such a projectile can hardly be deemed as having a "selective effect"; expecting the target to be isolated and at least 20 metres away from everybody else is highly unrealistic, especially in conditions of urban warfare.

The pursuit of "winning hearts and minds" seems to ignore this inherent logical flaw. To satisfy global public opinion, public relations services tend to promote what former USAF officer Peter Goodrich, in his yet unpublished but extensively cited discussion, dubs 'the surgical precision myth'.[75] This myth concerns the illusion that only "bad guys" will be struck by smart ammunition, sparing civilians. In fact, the prolonged use of cutting-edge weapon systems – updated UAVs, skilled crews, and state-of-the-art laser-guided missiles – demonstrates that even this combination

---

[70] Mulrine, 2008, p. 45.
[71] Wall, 2013.
[72] Trzun et al., 2021, pp. 18–19.
[73] U.S. Department of Defense, 2011.
[74] Chamayou, 2015, p. 199.
[75] Goodrich, 2003.

cannot guarantee that only individuals positively identified as terrorists or enemies will be targeted.

Some authors assert that smart munitions are not designed to safeguard civilian lives but merely to advance the political and economic interests of the entities deploying such missiles. They concede, however, that abandoning the practice of “carpet bombing” (employed until the advent of smart ammunition, even in wars of the 1980s) significantly reduced civilian casualties. The use of smart ammunition also has additional advantages, including cost reduction due to fewer sorties required, a reduction in hostilities from nations where air operations are conducted, and increased protection for one’s own pilots and troops involved in combat.[76]

From an engineering perspective, the combination of the MQ-9 Reaper UAV and smart ammunition like the AGM-114 Hellfire represents perhaps the most viable solution at present, especially in regions where air superiority has been established (the UAV’s ability to counter modern manned aircraft will be discussed later). Unfortunately, it remains imperfect at present. This is to be expected given that it carries a warhead weighing 8-9 kg, whose impact cannot be confined to just one individual.

The new ammunition set to replace the Hellfire, the AGM-179 Joint Air-to-Ground Missile, incorporates a tri-mode seeker featuring a low cost imaging sensor, Semi-Active Laser sensor, and Millimeter Wave (MMW) sensor. While this developmental direction will undoubtedly enhance target tracking, the missile’s substantial warhead mass suggests that the issue of collateral victims will remain unresolved.

4.5. Human Error

The risk of human error has been constantly reduced. However, it seems that despite the many improvements made in the last three decades, there is still room for improvement in the quality of the technology of large UAVs and their weaponry, and the existence of these technological limitations do not completely remove the burden of guilt from the personnel involved. Today, operating UAVs is accompanied by high levels of responsibility, and the process of approving an individual attack is rigorous and complies with the law of armed conflict (the legal basis is explained in Chapter 13, with a particular distinction between “old” and “new” weapons). To deploy the selected missile, clearance from both the mission commander and military lawyer must be obtained before the sensor operator guides it to the target and the pilot fires the missile. In accordance with these refined procedures and all technological advancements, one can expect the future will bring the most precise and transparent air campaign ever. However, investigations by journalists and non-government organisations seem to present a different reality, particularly in cases where mistakes lead to unintended civilian casualties.

After the August 2021 incident in Kabul, Cpt, Bill Urban, spokesman for the U.S. Central Command, said that ‘even with the best technology in the world, mistakes

---

[76] Herold, 2008, pp. 96–99.

do happen, whether based on incomplete information or misinterpretation of the information available. And we try to learn from those mistakes'. He also admitted that confirmation bias is a genuine concern and emphasised the need for further efforts to address this issue. Indeed, he specified that the fight against errors (caused by technological or human flaws) is still far from over.

Large UAVs are extremely complex weapon systems, involving the UAV's video and targeting sensors, missiles equipped with precise laser designation, and the proficiency and judgement of the pilot and commander. However, it appears that there are instances where at least one component of this system fails, resulting in tragic consequences. Unfortunately, at this point, a single error within only one component of these highly complex systems is all it takes to create the conditions for tragedy, especially given the absence of an adequate backup in technology and procedures.

Some authors argue that even modern UAVs like the MQ-1 Predator or the MQ-9 Reaper are not autonomous or robotic platforms since they are operated by human controllers in real time.[77] They are classified as robots due to their ability to perform autonomous actions, such as patrolling above designated areas or returning to base when communication with the GCS is lost. Although they require pilot confirmation to launch a missile, this necessity primarily arises from safety and legal concerns rather than the UAVs' inability to conduct strikes autonomously. Unfortunately, it is now clear that keeping "the human in the loop" (the concept is further explained in Chapter 13) does not completely eliminate the possibility of tragic errors.

4.6. Issues Caused by Enemy Electronic Warfare

The use of unmanned vehicles introduces a certain risk because there is no pilot/operator to correct and halt unforeseen movements, and unforeseen incidents are quite possible in the event of a communication breakdown with the remote pilot.

Best lessons related to deployment of unmanned vehicles come from the conflict in Ukraine. Initially, the Ukrainian Army managed to partially compensate for a manpower shortage and less advanced equipment by employing robots and drones. Unmanned aircraft, in particular, posed problems for the Russians, with UAVs constantly flying across the sky, collecting data, directing artillery fire, and even attacking Russian vehicles and infantry. However, it appears that, after the initial shock, the Russian Army managed to regroup. A comprehensive summary from November 2023 encapsulates it all most effectively:

> Ukrainian and Russian forces continue to grapple with the challenges electronic warfare (EW) systems pose on the front. The Economist reported that superior Russian EW systems are impeding Ukrainian reconnaissance, communication, and strike capabilities. The Economist, citing Western experts, stated that Russia has placed a "huge focus" on producing and developing superior EW capabilities and that

---

[77] Jha, 2017, p. 224.

> Ukraine is struggling to produce equivalent EW systems and EW-resistant weapons domestically.[78]

According to General Valery Zaluzhny, the commander-in-chief of the Ukrainian Army, their forces initially faced weak electronic warfare (EW) capabilities from the Russians. This allowed them to utilise unmanned weapons, primarily aerial and occasionally floating drones, to a significant extent. However, the Russians quickly bolstered their EW systems, deploying them extensively along the entire frontline. These are no longer outdated Soviet-era systems but modern setups capable of disrupting drone communication with control stations, often determining the location of Ukrainian remote pilots and redirecting artillery fire accordingly. Even modern Western missiles like Excalibur or High Mobility Artillery Rocket System (HIMARS) started experiencing accuracy issues due to Russian jamming.

Where do Russia's unexpectedly advanced EW capabilities originate? After facing setbacks in electronic warfare during the 2008 Russo-Georgian War, Russia shifted its focus to enhance capabilities in the electromagnetic spectrum. The shortcomings became apparent as Russia's EW proved inadequate in suppressing Georgian air defences, providing cover for advancing forces, and establishing effective jamming zones. These failures acted as a wake-up call for Russia, prompting an acknowledgement of deficiencies within its forces and their deployment.[79]

Moscow embarked on an ambitious programme to reform and modernise its military forces. A commitment was made to achieve a target of 70% new or modernised military inventory. Thereafter, many observers and defence officials asserted that Russia's prowess in EW surpasses that of Western countries. Russia places a significant focus on EW due to its cost-effectiveness in diminishing the capabilities of adversaries. While NATO countries boast modern military systems that Russia may find unaffordable or technologically inaccessible, EW allows Russia to effectively counter nearly all that NATO currently possesses.[80]

EW is assuming a growing and essential role, rightfully earning its status as a force multiplier. This is evident in Russia's daily demonstrations on the battlefields in Ukraine. The present-day Russian military exhibits substantial strength compared to the Soviet military in the 1990s. It is plausible that the effectiveness of the Russian military against weapons sent by the West to aid Ukraine is, in part, attributed to its formidable EW capabilities.

Systems like RB-341V Leer-3, R-330Zh Zhitel, 1RL257 Krasukha-4, and others perform their designated tasks with notable success, including jamming communication signals, transmitting false GPS signals, and employing various methods to execute the three primary operational functions of electronic warfare:

---

[78] Evans et al., 2023.
[79] Smith, 2020, p. 2.
[80] Ibid., p. 5.

- Electronic Attack, which encompasses jamming. In this context, a transmitter overwhelms or disrupts the waveform of a hostile radar or radio.
- Electronic Support, involving surveillance and warning information derived from intercepted electromagnetic emissions.
- Electronic Protection, offering protection to the host platform against electronically controlled threats.[81]

Ukraine is countering Russian EW measures with quantity, having trained approximately 10,000 drone pilots who constantly strive to identify vulnerabilities in the heavily fortified Russian EW defence. The Ukrainians rely on quantity, modifying inexpensive commercial drones to exploit weaknesses in Russian defences. However, these budget-friendly drones have a significant drawback – susceptibility to jamming. It is estimated that as a result, Ukraine loses up to 2,000 drones per week. Their communication with control stations is disrupted, leading them to aimlessly roam the sky until their batteries deplete, after which they fall to the ground. Although autonomous systems governed by AI might overcome such countermeasures, this option is currently not feasible, at least not for mini-drones that Ukrainians use.[82]

A particular issue is the ability of Russian EW forces to swiftly and accurately locate the source of electromagnetic (EM) radiation emanating from Ukrainian forces. On Ukraine's battlefields, the simple act of powering up a cell phone can attract enemy artillery fire. The same holds true for Ukrainian artillery radars and remote-control stations for UAVs.[83] Consequently, sending drones has become a perilous activity carried out only from well-established cover. Ukrainian pilots sadly remark that they once could operate their aircraft from considerable distances, but now they must approach almost to the front lines of the Russian forces. UAVs have a very limited time to reach an enemy target and launch an attack before they are disabled by EW measures.

The U.S. DOD is actively seeking ways to minimise civilian casualties resulting from U.S. military operations. In 2022, they introduced the Civilian Harm Mitigation and Response Action Plan (CHMR), aiming to identify and implement necessary measures. Some of these measures can be swiftly put into action, for instance: 'Combatant commands [will] identify and incorporate CHMR lessons learned and recommendations into current joint targeting processes to reduce the risk of civilian harm in future operations.'.[84] Further, it is essential to enhance situational awareness, and understand the local population behaviours. Based on past negative experiences, the focus now is on implementing practices to gain information about civilians and civilian objects across the joint targeting process. This includes details about civilian

---

[81] McDermott, 2017, pp. 15–28.

[82] The Economist, 2023.

[83] Stashevskyi and Bajak, 2022.

[84] U.S. Department of Defense, 2022, p. 12.

patterns of life, population density, and infrastructure, which is vital for civilian health and safety.

The Under Secretary of Defense for Acquisition and Sustainment, in collaboration with the Under Secretary of Defense for Research and Engineering, is tasked with updating the DOD Standard Practice System Safety. This update includes 'incorporating features into system safety reviews for future weapon systems that support civilian harm mitigation objectives, such as render safe, pre-planned post-launch abort, and scalable yields'.[85]

As mentioned earlier, it appears that the new AGM-179 (JAGM) program does not currently focus on reducing the likelihood of collateral casualties. While there is a heightened emphasis on enhancing weapon efficiency, it is possible that the new guidelines might bring significant changes in this regard as well.

4.7. UAVs Engaged in Direct Combat Against Manned Fighters

Today, UAVs are achieving remarkable success and ever increasing reliability in their operations, as illustrated in Figure 1. Although their primary functions have historically centred on reconnaissance and surveillance, a significant shift is underway. These UAVs are progressively moving into domains traditionally exclusive to manned aircraft. For instance, the MQ-9 Reaper has assumed the role of a hunter-killer, the MQ-20 Avenger has emerged as one of the pioneering jet UAVs, and the Boeing MQ-25 Stingray stands as the premier aerial refuelling drone. This trend signals a transformative era where UAVs are expanding their operational scope beyond previous limitations.

The next inevitable step is confrontations between UAVs and manned military aircraft. In this imminent clash, UAVs may be guided by remote pilots or operate autonomously, driven by embedded AI.

However, current UAV technology is not fully prepared for this face-off. UAVs manufactured by General Atomics are engineered to be lightweight, with highly efficient engines, and wings designed to generate adequate lift even at low speeds. The challenge in wing construction lies in achieving the optimal drag/lift ratio under anticipated operational conditions. Unlike modern manned fighters equipped with delta wings that offer relatively low resistance at supersonic speeds while ensuring sufficient lift, UAVs have wings swept at very low angles. These long, slender wings give UAVs a resemblance to gliders rather than traditional manned fighters – but such construction grants them extended endurance and ample lift at low speeds.[86]

Resolving conflicting criteria within a single design is a challenge. Consequently, current UAVs remain tailored for prolonged, slow flight, prioritising endurance over high speeds or abrupt manoeuvres. Even advanced jet-powered models like the

---

[85] Ibid., p. 13.

[86] Gundlach, 2012, p. 374.

MQ-20 Avenger were rejected by the USAF due to their unsuitability for surveillance and counter-terrorism missions.

In March 2023, a significant event highlighted the limitations of lightweight UAVs designed for prolonged flight. This incident confirmed what was already anticipated: in a direct confrontation, UAVs stood little chance against manned aircraft. A declassified video released by the U.S. European Command captured the moment when two Russian fighter jets aggressively approached a U.S. drone flying over the Black Sea, clearly intending to expel it from the area. If the UAV did not alter its course immediately, the Russian jets openly threatened to attack it and bring it down.[87] While the UAV was flying at about 25,000 feet, two Russian Su-27 fighter jets made 19 high-speed passes near the Reaper.

The attack, executed by a Russian Su-27 fighter, lasted approximately 30 to 40 minutes. The MQ-9 Reaper UAV's rear-facing camera recorded the tense encounter, revealing the Russian Sukhoi fighter approaching and, just before the UAV passed over, releasing fuel onto the U.S. Reaper. Despite the unexpected impact, the UAV maintained stability and continued its flight. In a subsequent pass, the Russian jet repeated the manoeuvre, dumping fuel as it neared the UAV. The video feed from the UAV was then disrupted as the Russian fighter collided with the MQ-9 Reaper, causing damage to the propeller and compelling the U.S. forces to bring down the drone in the Black Sea.[88]

The Kremlin denied any collision, while the Pentagon acknowledged the physical contact, diplomatically suggesting it might have been an unintended mistake by the Russian pilot. This incident underscored the vulnerability of lightweight UAVs in direct encounters with manned military aircraft. The incident was not the first of its kind, and it certainly will not be the last. In July 2023, a Russian fighter jet flew "dangerously close" to a U.S. drone over Syria. During the last pass, the Russian manned aircraft deployed a flare that severely damaged the Reaper's propeller and forced it to return to its home base.[89] It seems that the Russians have found an efficient way to eliminate unwanted surveillance UAVs from their area of interest without resorting to an overt attack that could provoke a strong reaction from the other side.

'The Russian fighter's blatant disregard for flight safety detracts from our mission to ensure the enduring defeat of ISIS', said the Air Force Central Command[90] – but as far as their reaction is concerned, everything is left to verbal condemnation. Currently, their UAVs cannot compete with enemy fighters in any way. Lacking robust self-defence mechanisms and possessing highly restricted manoeuvrability, UAVs are akin to "sitting ducks", relying solely on the hope that they will not draw the attention of vastly superior manned aircraft.

---

[87] Olson and Chappell, 2023.

[88] Schmitt and Cooper, 2023, Section A, p. 7.

[89] Breen, 2023.

[90] Liebermann, 2023.

Engineers from General Atomics attempted to give their UAVs a chance to fight back. Shortly before the start of Operation Iraqi Freedom, several MQ-1 Predators were armed with AIM-92 Stinger air-to-air missiles to deter Iraqi jet fighters from shooting down UAVs on their reconnaissance missions. On December 23, 2002, remote pilots of one of the Stinger-armed Predators observed an Iraqi MiG-25 turning in to attack. The Predator fired the Stinger at the MiG-25 just moments after the Iraqi aircraft launched its missile. Recorded footage showed the two missiles passing each other in the air. The Predator's missile missed, but the Iraqi missile did not.

Reportedly, this episode convinced the Iraqi Air Force that it was better for their aircraft to avoid approaching American UAVs. However, it also demonstrated to the USAF senior leadership that engaging in conflicts with vastly more agile and capable manned jet fighters did not make much sense. The experiment with Stingers was not repeated, and today it is only mentioned as an interesting footnote in the rich history of large unmanned aircraft.[91]

In discussing the interaction between UAVs and manned aircraft, we could also mention research aimed at fostering cooperation between these two types of aircraft against adversarial targets, whether manned or unmanned.[92] This brings into focus the concept of manned-unmanned teaming (MUM-T). General Dynamics has been working on this approach with its F-16 X-62 Vista, while in Europe, AIRBUS is engaged in the Future Combat Air System (FCAS) project.

5. Ground drones – battling complex environments

As demonstrated in the previous chapters, UAVs have come a long way and have reached a high level of applicability. After years of refinement, they are now widely used in various forms and sizes. On one end of the spectrum, there are UAVs such as the Black Hornet Nano, an ultra-light micro drone (only 18 g including the battery) that is small enough to fit in one hand, used by reconnaissance platoons to achieve full local situational awareness. On the other end of the spectrum are the largest Class III drones, such as the previously mentioned MQ-1 Predator, MQ-9 Reaper or the largest among them RQ-4 Global Hawk, a high-altitude long-endurance (HALE) unmanned aircraft with a gross weight of 14,600 kg. The Global Hawk is a strategic reconnaissance UAV capable of being used in missions requiring exceptional endurance (34+ hours) and an outstanding service ceiling of 18,000 m.

Aerial unmanned systems operate freely over vast empty skies, especially in conditions of uncontested airspace, as was the case in Afghanistan. However, ground-based unmanned systems struggled to navigate through terrains filled with numerous

[91] Boyne, 2009, pp. 42–45.

[92] Maier and Schulte, 2022, pp. 4–5.

static and dynamic obstacles, resulting in their application being significantly more limited and development being challenging and considerably slower.

Announcements of armed and intelligent autonomous unmanned ground vehicles have long been a subject of debate among sociologists and war theorists who fear the emergence of so-called “killer robots”. However, from an engineering perspective, these fears are currently unfounded, and killer robots still belong to the realm of science fiction. The battlefield missions, environments, and systems pose profound complexity to robot development – so profound that today’s unmanned ground vehicles (UGVs) are still confined to completing predetermined tasks (such as path following) and, if possible, only in the simplest of environments (for example, a flat surface of a modern constructed road).[93]

Achieving autonomous navigation for UGVs in challenging terrain, while avoiding obstacles, has proved to be an exceptionally complex task. The Defense Advanced Research Projects Agency (DARPA) conducted a series of competitions, known as the DARPA Urban Challenge, at the beginning of the 21st century. The first two “Grand Challenges” were intended to demonstrate that autonomous ground vehicles could cover significant distances in off-road terrain, while the 2007 competition was designed to foster innovation in autonomous vehicle operation in busy urban environments. The competitions clearly highlighted the challenges that await autonomous UGVs, and despite the allure of prestige and substantial cash prizes only six teams reached the goal. Competition was fierce, with teams from almost all top U.S. tech universities participating.

Winner of the competition, Carnegie Mellon University, emphasised the complexity of modelling the moving robot environment and the challenges of avoiding both static and dynamic obstacles. The motion planning subsystem consisted of two planners, each capable of avoiding static and dynamic obstacles while approaching a desired goal.[94] Interestingly, even in the final round, collisions occurred when multiple vehicles found themselves on the same streets of the simulated town – and this happened despite vehicles being equipped with an array of sensors (2D lidar, 3D lidar, camera, GPS positioning, Doppler radar, a stationary beam LIDAR sensor, laser scanner, etc.).

Regarding autonomy (which remains a challenging aspect for ground robots), there are three degrees of machine autonomy:

1. **Pre-programmed Autonomy**: This refers to the machine’s ability to carry out a specific set of actions by following instructions pre-programmed by an operator. In the context of weaponry, an example could be the Phalanx automated gun-based close-in weapon system. Once activated, it can autonomously select and engage targets within the narrow parameters of its programming.
2. **Supervised Autonomy**: This means that a robot is capable of autonomously performing most of its functions without relying exclusively on

---

[93] Monckton, 2018, p. 30.
[94] Urmson et al., 2009, p. 3.

pre-programmed behaviours. However, in more complex or sensitive functions such as weapons release, it is still controlled by a human pilot.

3. **Complete Autonomy**: This indicates that a robot can perform all actions completely autonomously without the need for any human input. Such robots must possess a certain level of AI, allowing them to learn independently and modify their behaviour accordingly.[95]

Interestingly, more than two decades ago, several authors realistically estimated that robots were not yet intelligent enough. However, they believed that AI could reach a sufficient level to take over autonomous robot control by 2030.[96] Now, in the year when the development of AI has astonished the world, it seems that the early-century estimate was entirely realistic. But it is still unknown when AI will reach a sufficiently high level to create a turning point in the development of autonomous ground robots and UGVs.

5.1. Advantages of Robots

It seems certain that robots will take over more and more tasks from human soldiers. Increased autonomy, especially, will lead to such an outcome. The development of such systems is facilitated by the decreasing costs of technology (due to mass production and miniaturisation), greater speed in sensing, measuring, and analysing large sets of data, the resilience of robots and their ability to function under extreme weather conditions where human beings could not, and their greater resistance to wear and tear during conflicts that cause physical fatigue in humans. Furthermore, there are numerous cultural and moral advantages to robots that have no problems eliminating an opponent, do not develop PTSD, and avoid the currently dominant respect for human life as the highest value.[97]

In the realm of politics and decision-makers who determine engagement in armed conflicts, robots offer the advantage of being an easier sacrifice than a human soldier, consequently alleviating the pressure placed on leaders by the public and voters. Compared to people, machines are more resilient and stronger: they do not get tired, but can handle monotonous processes. In other words, robots cope better with the so-called ‘dull, dirty, and dangerous jobs’,[98] which include extended reconnaissance missions that stretch the limits of human endurance to its breaking point, environmental sampling after a nuclear or biochemical attack, and finally neutralising improvised explosive devices (IEDs).

---

[95] Krishnan, 2009, pp. 43–45.

[96] Ichbiah, 2005, p. 507.

[97] Szegedi et al., 2017, p. 222.

[98] U.S. Department of Defense, 2005, pp. 1–2.

5.2. Counter-IED Efforts: Where Robots are Indispensable

Unfortunately, for the last couple of decades, the headlines have been dominated by victims of IED and the dreadful casualties they cause. ReliefWeb, a humanitarian information service run by the United Nations Office for the Coordination of Humanitarian Affairs, states on its website:

> Over the last decade – between October 2010 and the end of September 2020, there have been 28,729 incidents of explosive violence, resulting in 357,619 casualties (263,487 civilians) recorded in English language media worldwide. Of these, 171,732 people were recorded as being from IEDs – a number that includes both civilians and armed actors. 48% of all people killed or injured by explosive weapons globally, then, were harmed by IEDs.[99]

Other sources state that IEDs have caused approximately half of U.S. and UK troop casualties in Iraq since 2003. Media more open to sharing information than official sources report that by 2007, the U.S. had deployed over 5,000 robots in Iraq and Afghanistan, which neutralised 10,000 IEDs – and the number of both robots and IEDs kept growing in the following years.

These robots have saved numerous lives, both of soldiers and civilians. They are remotely operated and equipped with cameras and communication devices, with their manipulator or arm being particularly suitable for inspecting potential bombs and placing explosives on them for neutralisation. Among the most iconic are the PackBot series, military robots developed and produced by Endeavor Robotics, an international robotics company founded in 2016 with roots and extensive experience dating back to iRobot (which had been producing military robots since 1990). The current base model is PackBot 510, controlled using a videogame-style hand controller. There are various versions of the 510 family, some featuring an explosive ordnance disposal (EOD) kit, a fast tactical manoeuvring kit designed for infantry troops, or a HazMat Detection Kit that collects air samples to detect chemical and radiological agents, among others.

Thanks to extensive testing and subsequent use on real battlefields, the PackBot has proven its reliability and wide applicability. Attempts have been ongoing for years to assign new roles to it. Four such projects were presented in the *Proceedings* journal: CHARS, a chemical and radiation sensor payload deployed on PackBots to search for chemical and nuclear weapons in Iraq; Griffon, a man-portable hybrid UGV/UAV based on the PackBot with a gasoline engine and a parafoil wing; Valkyrie, a man-portable battlefield casualty extraction robot based on the PackBot, and finally, Wayfarer, a project aimed at developing autonomous urban navigation capabilities for PackBots and other UGVs.[100]

---

[99] Overton, 2020.

[100] Yamauchi, 2004, pp. 230–232.

Of particular interest is the last project, which aims to enable the PackBot to perform urban reconnaissance tasks autonomously. If successful, the robot could be assigned tasks such as reconnaissance along a specified route or street, or surveillance of a specific perimeter. To achieve this, it is equipped to detect and avoid obstacles in an environment with a complex 3D structure, where the UGV may be tilted to any orientation and not only parallel to the ground plane. The Wayfarer project is just one of the many projects aiming to achieve completely autonomous robots for urban or field conditions. A lot of them are underway even today, but for now, everything still remains at the prototype level.

5.3. Large U.S. Army Robots

We will illustrate the development of UGVs using the example of the U.S. Army, which uses two major types of autonomous and semi-autonomous unmanned ground vehicles:

1. Large vehicles, such as tanks, trucks and HUMVEEs;
2. Small vehicles, which may be carried by a soldier in a backpack, such as the PackBot described earlier.

DARPA has developed, in cooperation with Carnegie Mellon University, a 6-tonne unmanned vehicle known as the Crusher, capable of carrying 1000 kg at about 50 km/h and capable of withstanding a mine explosion; it can be equipped with one or more guns. There are no intentions to deploy the Crusher vehicle in active service – instead, it will serve as the base for the development of future unmanned vehicle designs.[101]

Recent reports indicate that engineers at the U.S. Army Combat Capabilities Development Command Aviation & Missile Center are testing the Autonomous Multi-Domain Launcher (AML). This resilient autonomous UGV is based on the HIMARS but has been enhanced with both hardware and software modifications to enable remote control or autonomous operation. Weighing 17 tonnes and featuring six wheels, this vehicle is designed to navigate through open country, traversing terrains without paved roads but featuring cliffs, holes, and hidden obstacles. AML offers a wingman concept to soldiers already on the battlefield. Serving as a supplementary missile launcher, it amplifies the capabilities of the HIMARS system, which requires reloading once all six rounds are fired. However, with an AML alongside, equipped with an additional 12 missiles, the firepower and ability to support frontline troops are significantly multiplied.[102] In 2021, the Army shared a video depicting C-130s landing on an island, where they unloaded a manned HIMARS and an unmanned AML. The two operated collaboratively as a manned-unmanned team, engaging enemy threats and subsequently returning to the C-130s, which swiftly departed.

---

[101] Lin et al., 2008, p. 13.

[102] Davis Skelley, 2022.

The video showed the launcher firing Precision Strike Missiles (PrSM), highlighting one of the Army's new long-range firepower capabilities.[103]

Still, as remarkable as large vehicles may be, it is currently the small vehicles that are having their moment of glory. These small robots are the ones that approach suspicious packages left at airports, assisted in search and rescue efforts at Ground Zero after 9/11, and played a crucial role in clean-up operations following the Fukushima meltdown. They have also disarmed countless IEDs in Iraq and Afghanistan – and earned a place in the popular culture of today.

5.4. Armed Robots and Their Use in Combat

Russian sources reported[104] (and Western sources echoed[105]) that the first use of robots in combat occurred at the end of December 2015 in Latakia, a province of Syria. Six Platform-M robotic systems and four Argo systems participated in the operation, with robot attacks supported by self-propelled artillery Akatsiya systems and Syrian soldiers. Reconnaissance was conducted using UAVs. Gathering intelligence, robot control, and target designation for self-propelled cannons were coordinated from the 5 km distant command vehicle of the latest automated troop management system, Andromeda-D, which replaced Polet-K. During the alleged attack, robots were the first to engage: they approached within 100 metres of Syrian rebels and opened fire. The rebels responded, thus revealing their firing positions. Subsequently, they were targeted by self-propelled cannons coordinated by Andromeda-D. After a brief 20-minute battle, the rebels fled, leaving their dead and wounded behind. According to Russian sources, 70 rebels were killed on that occasion, while only four soldiers were reportedly injured. While the accuracy of this account remains somewhat uncertain, it certainly suggests a possible direction for future research and the goals that military planners may hope to achieve.

Platform-M is a robotic system based on a self-propelled armoured tracked chassis. It is remotely operated, equipped with a machine gun, grenade launcher, and anti-tank missile launcher, along with various sensors – a radar, thermal camera, rangefinder, video camera, and CBRN analyser. It weighs 800 kg and has a payload capacity of 300 kg. Its speed is not particularly impressive (12 km/h), but it boasts decent autonomy (10 hours). The pilot can control it visually at a distance of up to 1500 m, and the range significantly increases if video cameras or communication through a companion UAV are used.

The Argo robot on a wheeled chassis is even more impressive. It weighs a tonne, and is armed with a machine gun and four grenade launchers. Its maximum land speed is 20 km/h, and in water, it can reach 4.6 km/h. Its autonomy is an impressive

---

[103] Eversden, 2022.

[104] Tuchkov, 2016.

[105] Urcosta, 2018.

20 hours. As for the U.S.-originated armed robot vehicles, the following two could be mentioned:

(1) the Talon SWORDS (Special Weapons Observation Reconnaissance Detection System) made by Foster-Miller, which can be equipped with machine guns, grenade launchers, or anti-tank rocket launchers as well as cameras and other sensors; and

(2) the MAARS (Modular Advanced Armed Robotic System). While vehicles like SWORDS and the newer MAARS can autonomously navigate towards specific targets using their GPS, complex tasks such as firing onboard weapons are conducted by a soldier located at a safe distance. Foster-Miller provides a universal control module for the war fighter to use with any of their robots. The MAARS features a more powerful machine gun than the original SWORDS. While the original SWORDS weighed about 70 kg, MAARS weighs around 160 kg. It is equipped with a new manipulator capable of lifting 45 kg, allowing it to replace its weapon platform with an IED identification and neutralisation unit.[106]

Talon robots have demonstrated their value as a counter-IED tool. In 2000, during the U.S. military intervention in Bosnia, the first Talon robots were deployed to assist in the removal of enemy explosives. Subsequently, hundreds of Talon EOD robots have been deployed in Iraq and Afghanistan. They are used in military missions as armed robots capable of maintaining a designated perimeter or deterring enemy attacks, but there have been some contradictory reports on their effectiveness,[107] and it seems that they have been grounded before seeing any real action. The first armed ground robots deployed onto a battlefield are positioned behind sandbags instead of being sent on patrol along Iraqi streets, as envisioned by their inventors. Senior Army leadership was not comfortable sending them out for combat missions due to safety reasons. The reasons should certainly be sought for the technical issues the robots faced during the testing phase. As much as these problems might have been caused by extremely unfavourable conditions of use, there was still a fear that unexpected robot behaviour could occur; therefore, they are now placed in fixed positions.[108]

The capabilities of a robot are crucial when assessing its utility in the field, but along with capabilities, reliability is equally important, especially for an armed robot. Before the Talon SWORDS robot was deployed in Iraq, there were three concerning incidents of uncommanded movements. Allegedly, all three occurred before the 2006 safety certification. A spokesperson from Foster-Miller explains how they occurred: ‘One case involved a loose wire. So, now there is redundant wiring on every circuit. One involved a solder, a connection that broke. Everything now is double-soldered’. The third case was a test where the robot was placed on a 45-degree hill and left to run for two and a half hours. ‘When the motor started to overheat, the robot shut the motor off, causing the robot to slide back down the incline’.[109] But

---

[106] Lin et al., 2008, p. 12.
[107] Army Technology, 2020.
[108] Weinberger, 2008.
[109] Ibid.

however convincing these explanations may be, they were evidently insufficient to reassure the Army's leadership (after all, we are talking about armed robots!), and therefore, these robots were put on hold.

There is a good probability that the great success of robots claimed by the Russians has also been exaggerated for propaganda purposes. This is evident from the fact that very little has been written for years about armed robots or UGVs, while UAVs have flourished and become one of the most important weapons on the modern battlefield. They have even been called the decisive factor for Azerbaijan's success in Nagorno-Karabakh[110] or 'the saviour and future of warfare' in the early months of the war in Ukraine.[111] During the same period, armed UGVs received almost no attention, a silence that speaks for itself.

5.5. What Comes Next For UGVs?

It appears that, for various reasons, armed UGVs, especially those with fully autonomous systems, will not be deployed on battlefields for some time. As previously mentioned, the use of autonomous armed robots evoked scepticism from military leaders, even when they were confronted with a technologically inferior adversary during asymmetric warfare in Iraq and Afghanistan. Consequently, the swift deployment of these robots to the battlefield seems improbable, especially considering the technological parity or superiority of potential opponents.

Nevertheless, this does not negate the current use of UGVs nor the potential plans for their future deployment. If the future development direction of UGVs cannot be determined with certainty, some of the main trends can already be anticipated. A notable example is the Ratel S (Honey Badger) UGV, proudly unveiled by the Ukrainians at the end of 2023.[112] This small, unmanned vehicle is capable of carrying grenades or even anti-tank mines. Due to its compact dimensions, it can be manoeuvred under enemy armoured vehicles and its explosive payload detonated there, targeting the most vulnerable parts of armoured vehicles and tanks where the armour is significantly thinner than on the front.

Equally important is the enhanced antenna and communication system reported for Ratel S, indicating improved counter-electronic warfare (C-EW) capabilities. This could be a crucial feature for the overall usability of the small UGV, especially when considering the formidable Russian EW systems. Russian Krakushas and Leers boast a high success rate in halting enemy guided projectiles and unmanned vehicles, both ground and aerial.

Even at first glance, the Ratel S exemplifies the desirable traits of future UGVs – compact size and low cost of production. In contrast, large drones have proven impractical and often unsuccessful against Russian EW systems (for example, the

---

[110] Sapmaz, 2021, pp. 11–17.

[111] Shoaib, 2023.

[112] Struck and Brown, 2023.

Bayraktar UAV[113]), prompting a shift towards deploying a multitude of inexpensive UAVs or UGVs, some of which have the chance to break through and strike the target. Therefore, whether the solution lies in small, expendable robots relying on numbers or in large systems with powerful counter-EW measures will be revealed in the future.

Another future development idea is marsupial robots, which are UAVs carrying smaller UAVs or UGVs within them.[114] The concept of marsupial robots offers significant possibilities, merging the mobility of UAVs with the stealthy approach capability of UGVs and effectively combining the strengths of both unmanned vehicle families. The potential applications are diverse; for instance, fast fixed-wing UAVs could serve as a mother ship, releasing a swarm of smaller rotary-wing UAVs close to the target and allowing them to infiltrate enemy bunkers and facilities.

A third idea involves reversing the scenario by establishing a connection between tele-operated UGVs and tethered UAVs. Tele-operated UGVs suffer from insufficient situational awareness due to onboard sensing limitations, but this could be rectified by a tethered UAV providing a better view of the terrain.[115] This flying visual assistant could be tele-operated, requiring an additional human operator and a coordinated crew.[116] On the other hand, possibilities expand if the UAV operates autonomously, navigating through the area where the UGV is passing.

While these concepts are presently confined to the future, it does not appear that their realisation is too far off (akin to the thought of armed robots). However, today's robots are yet to reach that level and are mainly employed for transporting cargo and offering logistical assistance to soldiers.

6. European Armies and U.S. Industries in the ERA of UAVs

An assessment of European armies reveals a notable lag in the development of UAVs over the past decades, particularly in recent years. This holds true for European manufacturers as well. According to a 2019 study,[117] competitiveness is satisfactory only in the small UAVs category but worsens for larger UAVs categories.

Utilisation of tactical UAVs is poor, and an even worse situation is in the MALE category. Virtually no HALE (High-Altitude Long Endurance) UAV exists in European armies. The study only highlights the "future procurement of Triton by Germany and the United Kingdom", referring to the potential acquisition of several

[113] Clark, 2022.
[114] De Petris et al., 2022, pp. 1–7.
[115] Monckton, 2018, pp. 40–41.
[116] Xiao et al., 2021, pp. 15–29.
[117] Kunertova, 2019, pp. 10–13.

U.S. Navy MQ-4C Triton Global Hawk UAVs after abandoning the customised EuroHawk version. In the MALE and HALE category, a strong monopoly of American platforms is evident.

The same study notes that armed UAVs are virtually unused by any European military. The UK is the only European country operating the armed version of the Reaper. Other European armies, in the face of public pressure, remain reluctant to arm their UAVs, utilising them exclusively for ISR purposes. Incidentally, a similar lack of unity is evident in the legislative sphere, where for years there has been a futile attempt to adopt a uniform legal practice that would be accepted by all EU member states, as explained in Chapter 13. However, experiences from the Russo-Ukrainian War suggest that such a mindset may be out dated.

6.1. The War in Ukraine as a Wake-Up Call

The poor equipment and lack of readiness in defence sectors are a consequence of a false sense of security that has prevailed in Europe since the dissolution of the Soviet Union in the early 1990s. Since then, European armies have been continuously reduced, along with investments in the defence system, and research and development have been especially minimized. The consequences of such policies are evident today, as European states struggle to even initiate production of simple products such as 155 mm shells in long-abandoned defence industry facilities. However, the Russo-Ukrainian War has been a harsh wake-up call. Suddenly, all the problems that had been suppressed and swept under the rug for years came to the surface. One article states:

> European nations have adopted a piecemeal approach to defence – European armies have 17 types of main battle tanks and 20 different fighter aircraft, while the U.S. has one tank and six types of fighters. Europe depends on the U.S. for command and control, intelligence and surveillance, air transport, and aerial refuelling.[118]

But following Russia's brutal aggression towards Ukraine, the situation started to change: Europe's military spending has increased from USD $420.7 billion in 2021 to $480.3 billion in 2022. This represents a significant increase of 14.2%, and the growth continues in 2023. However, two urgent questions arise:

1. Should more investments be allocated to compensate for thirty years of neglecting defence systems?
2. Should independent investment in development and equipment continue, or would it be more beneficial to undertake joint projects?

---

[118] Duncan, 2023.

6.2. Joint European UAV Programmes: Underfunded, Suboptimally Specified, Finally Abandoned

For years neglected, the development of European UAVs now needs to be accelerated to at least reduce the gap with leading players. In a recent interview,[119] Lt. Gen. Ingo Gerhartz, Chief of the German Air Force, stated that faster progress in the fielding of new military drones is needed. He specifically refers to the trinational program FCAS, involving Germany, France, and Spain. The programme promises amazing new capabilities and encompasses the development of remote carrier vehicles (swarming drones) as well as a new sixth generation jet fighter. However, the timeline has been set extremely unambitiously, and the system is only predicted to be fully operational in 2040 at the earliest. This is just one example of European projects whose development spans years and even decades, and when the first prototype finally sees the light of day, it turns out to be already outdated.

There is a long line of European programmes that have been halted due to funding issues or poor results of the initial versions.[120] For example, there was a project known as Advanced UAV or Talarion, launched in 2006 by the French, German, and Spanish governments. The Talarion UAV was built by the European Aeronautic Defence and Space Company (EADS), formed through the merger of the French Aérospatiale and the German DASA. EADS initially planned to produce 15 systems under a European programme worth around €3 billion ($3.9 billion). However, after even France, Germany, and Spain did not commit to buying the Talarion and thus provide financial backing, EADS halted future development of the UAV. In a last attempt to save the project, EADS offered the Talarion to the UK Royal Air Force, rebranding it as the "X-UAS", but the UK instead backed the Telemos UAV, a programme started in a French-British partnership.

Telemos was jointly developed by BAE Systems and Dassault. There was even an exclusive agreement between BAE Systems and Dassault not to cooperate with other partners on the development of similar UAVs, thereby reducing the risk of competition. However, even this did not results in orders being placed for Telemos by the armed forces of the two partner nations, leading to the programme being eventually discontinued in July 2012. These repeated failures ultimately encouraged European countries to acquire foreign MALE drones – and as could be expected, Europe chose the American Predator and Reaper, with the exception of Germany, which leased the Israeli Heron.

Despite recent increases, only 18% of equipment procurement within the EU was conducted jointly in 2021, a figure that falls significantly short of the 35% objective agreed upon by member states. Joint procurement is expected to enable member states to achieve economies of scale, curtail the inflation of equipment prices, and prevent smaller states from being disadvantaged or receiving services last. In order

---

[119] Sprenger, 2023.

[120] Buzzoni et al., 2022.

to avert fragmentation, price inflation, potential supply shortages, and to offer the EDTIB (European Defence Technological and Industrial Base) the necessary attention for growth, the European Commission has introduced two incentives: EDIRPA (short term) and EDIP (long term). These initiatives are designed to consolidate European demand through the encouragement of joint acquisitions and strengthen the competitiveness of the EDTIB by augmenting the production capacity of the European defence industry.[121]

Some analysts even suggest that European joint programmes are almost certainly doomed to failure.[122] Given that participating nations have different (and sometimes mutually exclusive) operational needs, defining the system features takes a long time, and the overall project ultimately ends up being suboptimally specified. Delays in the payment of national contributions also occurs quite frequently, leading to delays in production. This, in turn, compels the involved parties, as well as other potential European buyers, to acquire systems that have already been developed by a nation more efficient in the production process – most likely the United States.

6.3. Choosing to abandon R&D and buy off the shelf

Because of numerous failed joint European projects, an analyst at *The Telegraph* suggests that ‘time is too short for Britain to start building its own weapons’,[123] and then emphasises:

> …all across Europe and the UK, arms companies are salivating at the idea that their governments will sink huge sums into developing, from scratch, various weapons technologies that only America has… But we need this equipment quickly, and we need it to actually work and be affordable. We must stop using our defence budgets as job creation schemes and instead buy working kit off the shelf.

The author also praises Poland for opting for ready-made solutions from South Korea, Turkey, and the United States. Faced with a war on its eastern border, Poland has signed a contract with South Korean manufacturers expressing readiness to purchase weapons worth $22 billion. As part of the procurement, Poland will acquire 1000 K2 tanks, 672 self-propelled K9 howitzers (including versions produced in Poland), 288 units of the rocket artillery system MLR K239, and 48 FA-50 light combat aircraft. Poland also ordered four Bayraktar TB2 UAVs – the first in the EU to do so – and concluded a lease agreement with General Atomics to lease MQ-9A Reapers in preparation for eventual purchase.

The lessons learned from the Russo-Ukrainian War indeed underscore that when a country is on the brink of war, time emerges as a pivotal factor in safeguarding

---

[121] Schnitzler, 2023, pp. 3–5.
[122] Tilenni, 2023.
[123] Page, 2023.

national security. Buying already proven solutions turns out to be more justifiable than investing in the long and uncertain R&D process for new weaponry. However, to maintain at least some of the domestic industrial capabilities could be of utmost importance later in the course of war, when new weapons (for example, small or micro UAVs) could be developed based on the existing platforms.

This is evident in Ukraine, where, faced with an ever-escalating demand, the Ukrainians modified inexpensive Chinese drones, while the Russians tailored cost-effective Iranian loitering munitions. Both sides have devised ingenious solutions to bypass EW measures installed by the other side. Mobilising their domestic industrial potential allows both sides to swiftly replenish the thousands of UAVs destroyed month after month. Such an achievement would not be feasible if this industry and corresponding know-how had been neglected and lost in the years preceding the war.

6.4. Eurodrone: Is it a MALE UAV That Nobody Needs?

Eurodrone stands as one of the most ambitious joint European projects in recent decades, aiming to provide Europe with its own MALE UAV while circumventing the strict limitations of the United States regulatory regime International Traffic in Arms Regulations.[124] Four European countries have previous experience with MALE systems: Italy uses the General Atomics MQ-9 Reaper and the MQ-1 Predator, deployed in the Middle East; France also had Reapers, while Spain have recently ordered them, and Germany has experience with the leased Israel Aerospace Industries Heron TP for reconnaissance missions in Afghanistan.[125]

However, the programme started exceptionally slowly, requiring two years to study required capabilities and an additional two years for contractor selection. The prime contractor was the German Airbus Defence and Space GmbH, with major subcontractors Airbus Defence and Space S.A.U, Leonardo, and Dassault Aviation. The construction contract was signed only in 2022, and it was agreed that 20 systems would be produced (seven for Germany, five for Italy, and four each for France and Spain). Each system comprises three flight units and two ground control stations.

Despite a prototype expected by early 2023, delays have already occurred (and are projected to continue by at least two years) due to fundamental differences in expectations among the four countries. Germany, in particular, complicated the project by insisting on Eurodrone having two engines to safely traverse its national territory. The new UAV is anticipated to weigh up to 11 tonnes, significantly more than the 4.5-tonne MQ-9 Reaper.[126]

---

[124] This regime mandates that buyers of U.S. Predators and Reapers seek U.S. Congress permission for practically any significant use.

[125] Tilenni, 2023.

[126] Pons, 2022.

The main concern, however, lies in the overall cost-effectiveness of the Eurodrone. While American Predators and Reapers performed well in missions in the uncontested airspace of Afghanistan and Iraq, experiences in the Syrian war and the downing of a Reaper by Russian fighters over the Black Sea demonstrated the vulnerability of large UAVs to enemy air defences. Recent events in the war in Ukraine also indicate that large UAVs are susceptible to electronic jamming. With the delivery postponed to 2029, there is a possibility that the ambitious €7.1 billion project may become outdated by the time it is ready for use. However, tactical UAVs are becoming more cost-effective and powerful, offering the best current combination of cost and capabilities.[127]

6.5. Tactical UAVs: The Most Promising UAV Class of Today

The conflict in Ukraine has showcased the extensive capabilities of small and medium-range tactical UAVs. These aircraft, which come at a relatively low cost, effectively carry out intelligence gathering, surveillance, target acquisition, and reconnaissance (ISTAR). While they may be less autonomous to MALE drones, tactical UAVs prove equally valuable at the operational level. Under favourable conditions, they have even been deployed for attack missions targeting enemy personnel, equipment, vehicles, and structures. Moreover, they offer significant propaganda potential by leveraging footage captured through onboard cameras. Current experiments explore the integration of EW equipment onto these platforms.

Recognising their value, all EU countries with advanced armed forces understand the potential of incorporating tactical UAVs in their strategic plans. But despite shared operational requirements, most nations have opted for independent solutions, driven by political and industrial considerations to support their respective national defence industries. The consequence is the foreseeable proliferation of individual programmes.

This lack of collaboration leads to duplicated efforts and increased costs, especially given that nearly all countries stipulate similar requirements for their tactical UAVs. Notable examples include French Safran’s development of the Patroller UAV, Spain’s joint project with Colombia on the Sistema Remotamente Tripulado de Altas Prestaciones (SIRTAP) tactical UAV, and Italy’s initiative with the Leonardo FALCO EVO. Each of these tactical UAVs boasts an endurance of over 20 hours, a range of approximately 200 km, a payload of around 200 kg, a ceiling of 6000 m, and a maximum speed of around 200 km/h. The associated costs are considerable – around EUR 500 million per country.[128] Many other European countries have developed tactical UAVs, independently, such as Germany (Rheinmetall LUNA NG), Greece (HAI Pegasus), Hungary (ProTAR), and others.

---

[127] Kunertova, 2022, pp. 3–4.
[128] Tilenni, 2023.

Given their favourable cost-effectiveness, tactical UAVs are likely to become more prevalent in the armed forces of Europe and beyond. Rather than emphasising competition or exclusivity between tactical and MALE UAVs, it would make more sense to view one class as complementing the other. As suggested in a 2022 analysis, European countries should ‘adopt a holistic approach on drones and anti-drone defences.’[129] This approach involves drawing pertinent lessons from the conflict in Ukraine, and, accordingly, fostering UAV diversity. Different UAV classes serve distinct military roles and offer varying effects. Therefore, European countries should align their drone acquisition strategies to encompass a comprehensive spectrum of UAVs – if resources allow it. If funding constraints arise, opting for a larger number of smaller UAVs appears more viable than investing in one or two large MALE UAVs. The anticipated progress in AI could further elevate weaponry capabilities, especially for smaller UAVs, bringing them to an entirely new level.

7. Conclusion

The robots and drones of today represent a true breakthrough in military technology and the way wars are fought. Enhanced with each new version, they offer astonishing capabilities in practically all aspects of military operations. However, in the rapidly changing world of modern technology, it is challenging to predict which of these systems will succeed and establish themselves as indispensable solutions and which may disappear from the battlefield or undergo a fundamental transformation.

One category with an uncertain future is large MALE and HALE UAVs. It is possible that they will become more agile and similar to today’s manned aircraft in the future, or they might evolve into mere carriers of smaller UAVs that will then perform the majority of tasks.

Based on experiences from Ukraine, tactical UAVs are increasingly emerging as highly desirable and versatile solutions. Their agility and adaptability make them exceptionally useful, suggesting that they could play a significant role in future conflicts. If this happens, existing military strategies will need to be revised, and technological development may shift towards the creation of small or micro UAVs that operate in swarms to overcome enemy EW systems.

While UAVs dominate the airspace, ground robots/drones (UGVs) still struggle to find their place on the battlefield. Unlike UAVs, which are already integrated into military operations, UGVs are still in the early stages of development. Their final future depends on the development of artificial intelligence (AI) which will

---

[129] Kunertova, 2022, p. 2.

enable them to efficiently navigate around obstacles and find optimal routes to their targets.

As things stand now, the future of warfare is likely to involve a diverse fleet of both large and small UAVs. Managed by AI systems, they will collaborate with UGVs to achieve the goals of complex military operations. Existing technologies, as well as those currently in development, will collectively shape future military strategies and contribute to a paradigm shift in the way wars are conducted.

References

Adamowski, J. (2022) ‘Poland leases MQ-9A Reapers ahead of drone buy’, *Defense News*, 21 October 2022. [Online]. Available at: https://www.defensenews.com/global/europe/2022/10/21/poland-leases-mq-9a-reapers-ahead-of-drone-buy/ (Accessed: 5 January 2024).

Aegerter, G. (2013) ‘Drone worth millions crashes into Lake Ontario, military says’, *NBC News*, 12 November 2013. [Online]. Available at: https://www.nbcnews.com/news/world/drone-worth-millions-crashes-lake-ontario-military-says-flna2d11582458 (Accessed: 5 January 2024).

Attariwala, J. (2017) ‘MQ-9B SkyGuardian’, *Canadian Defence Review*, 23(5), pp. 19–23.

Bartulović, V., Trzun, Z., Hoić, M. (2023) ‘Use of Unmanned Aerial Vehicles in Support of Artillery Operations’, *Strategos*, 7(1), pp. 71–92.

Ben-Ari, M., Mondada, F. (2018) ‘Robots and Their Applications’ in Ben-Ari, M., Mondada, F. (eds.) *Elements of Robotics*. New York, NY: Springer International Publishing, pp. 1–20, https://doi.org/10.1007/978-3-319-62533-1_1.

Bird, S.M., Fairweather, C.B. (2007) ‘Military fatality rates (by cause) in Afghanistan and Iraq: a measure of hostilities’, *International Journal of Epidemiology*, 36(4), pp. 841–846.

Blom, J. (2010) *Unmanned Aerial Systems: A Historical Perspective*. Leavenworth, WA: Combat Studies Institute Press and US Army Combined Arms Center Fort Leavenworth.

Boyne, W.J. (2009) ‘How the Predator Grew Teeth’, *Air And Space Forces Magazine*, 1 July 2009. [Online]. Available at: https://www.airandspaceforces.com/article/0709predator/ (Accessed: 5 January 2024).

Breen, K. (2023) ‘Russian fighter jet damages U.S. drone flying over Syria, U.S. military says’, *CBS News*, 25 July 2023. [Online]. Available at: https://www.cbsnews.com/news/russian-fighter-jet-damages-us-drone-flying-over-syria-video-shows-military/ (Accessed: 5 January 2024).

Buzzoni, L., Brillaud, L., Schmidt, N. (2022) ‘The Eurodrone: An industrial project fuelled by politics’, *Investigate Europe*, 31 March 2022. [Online]. Available at: https://www.investigate-europe.eu/posts/eurodrone (Accessed: 5 January 2024).

Chamayou, G. (2015) *A Theory of the Drone*. New York, NY: The New Press.

Clark, B. (2022) ‘The Fall and Rise of Russian Electronic Warfare’, *IEEE Spectrum*, 30 July 2022. [Online]. Available at: https://spectrum.ieee.org/the-fall-and-rise-of-russian-electronic-warfare (Accessed: 5 January 2024).

Cohen, R.S. (2022) ‘Air Force’s first Pacific MQ-9 squadron comes at crossroads for drone’, *Air Force Times*, 25 October 2022. [Online]. Available at: https://www.airforcetimes.com/news/your-air-force/2022/10/25/air-forces-first-pacific-mq-9-squadron-comes-at-crossroads-for-drone/ (Accessed: 5 January 2024).

Cole, C. (2015) ‘What 200 military drone crashes tells us about the drone wars’, *Drone Wars UK*, 27 February 2015. [Online]. Available at: https://dronewars.net/2015/02/27/what-200-military-drone-crashes-tells-us-about-the-drone-wars/ (Accessed: 5 January 2024).

Cuadra, A., Whitlock, C. (2014) ‘How drones are controlled’, *The Washington Post*, 20 June 2014. [Online]. Available at: https://www.washingtonpost.com/wp-srv/special/national/drone-crashes/how-drones-work/ (Accessed: 5 January 2024).

Davis-Skelley, K. (2022) ‘Testing of the Army’s first autonomous vehicle speeds ahead’, *DEVCOM Aviation & Missile Center Public Affairs*, 11 August 2022. [Online]. Available at: https://www.army.mil/article/259244/testing_of_the_armys_first_autonomous_vehicle_speeds_ahead (Accessed: 5 January 2024).

De Petris, P., Khattak, S., Dharmadhikari, M., Waibel, G., Nguyen, H., Montenegro, M., Khedekar, N., Alexis, K., Hutter, M. (2022) 'Marsupial Walking-and-Flying Robotic Deployment for Collaborative Exploration of Unknown Environments', *2022 IEEE International Symposium on Safety, Security, and Rescue Robotics*, pp. 188–194.

Department of Defense, Inspector General (2020) *Evaluation of Weather Support Capabilities for the MQ-9 Reaper*. Washington, DC: US Department of Defense.

Doaré, R., Danet, D., Hanon, J.-P., de Boisboissel, G. (2014) *Robots on the battlefield – Contemporary issues and implications for the future*. Leavenworth, WA: Combat Studies Institute Press US Army Combined Arms Center Fort Leavenworth.

Donald, D. (2018) 'U.S. Air Force Ends Predator Operations', *AIN Media Group*, 13 March 2018. [Online]. Available at: https://www.ainonline.com/aviation-news/defense/2018-03-13/us-air-force-ends-predator-operations (Accessed: 5 January 2024).

Duncan, M. (2023) 'Europe's defence goals', *Graphic News*, 2 May 2023. [Online]. Available at: https://www.graphicnews.com/en/pages/44231/military-europes-defence-goals (Accessed: 5 January 2024).

Evans, A., Harward, C., Grace, M., Stepanenko, K.K.F.W. (2023) 'Russian Offensive Campaign Assessment, November 25, 2023', *The Institute for the Study of War*. [Online]. Available at: https://www.understandingwar.org/backgrounder/russian-offensive-campaign-assessment-november-25-2023 (Accessed: 5 January 2024).

Eversden, A. (2022) 'Army's autonomous HIMARS moving forward, will be at Project Convergence', *Breaking Defense*, 17 June 2022. [Online]. Available at: https://breakingdefense.com/2022/06/armys-autonomous-himars-moving-forward-will-be-at-project-convergence (Accessed: 5 January 2024).

Frantzman, S.J. (2021) *The Drone Wars: Pioneers, Killing Machines, Artificial Intelligence, and the Battle for the Future*. New York, NY: Bombardier Books.

Gibb, R.W., Olson, W. (2008) 'Classification of Air Force Aviation Accidents: Mishap Trends and Prevention', *The International Journal of Aviation Psychology*, 18(4), pp. 305–325; https://doi.org/10.1080/10508410802346913.

Gittins, P. (ed.) (2020) *A Global Security System: An Alternative to War*. World Beyond War.

Goodrich, P.S. (2003) *The Surgical Precision Myth: After the Bomb Explodes – (CCDP) Cumulative Collateral Damage Probability*. Providence, RI: Providence College (unpublished manuscript).

Gosselin-Malo, E. (2023) 'Reveal of French-made combat drone stirs up industry', *C4ISR.Net*, 19 June 2023. [Online]. Available at: https://www.c4isrnet.com/global/europe/2023/06/19/reveal-of-french-made-combat-drone-stirs-up-industry/ (Accessed: 5 January 2024).

Grossman, N. (2019) 'Trump Cancels Drone Strike Casualty Report: Does It Matter?', *War On The Rocks*, 2 April 2019. [Online]. Available at: https://warontherocks.com/2019/04/trump-cancels-drone-strike-civilian-casualty-report-does-it-matter/ (Accessed: 5 January 2024).

Gundlach, J. (2012) *Designing Unmanned Aircraft Systems: A Comprehensive Approach*. Schetz, J.A. (ed.) Published online: American Institute of Aeronautics and Astronautics, Inc.

Haider, U. (2023) 'Indian Navy's Mq-9b Sea Guardian Purchase Puts Pakistan's Subs on Notice', *Geopolitical Monitor*, 26 September 2023. [Online]. Available at: https://www.geopoliticalmonitor.com/indian-navys-mq-9b-sea-guardian-purchase-puts-pakistans-subs-on-notice/ (Accessed: 5 January 2024).

Herold, M. (2008) 'Illusion: Our modern military warfare only kills the "bad guys."' in P. Buchheit, P. (ed.) *American Wars: Illusions and Realities*. Atlanta, GA: Clarity Press, pp. 97–99.

Human Rights Watch (2014) 'A Wedding That Became a Funeral: US Drone Attack on Marriage Procession in Yemen', 19 February. [Online]. Available at: https://www.hrw.org/report/2014/02/19/wedding-became-funeral/us-drone-attack-marriage-procession-yemen (Accessed: 5 January 2024).

Ichbiah, D. (2005) *Robots: From Science Fiction to Technological Revolution*. New York, NY: Harry N. Abrams publishing.

Insinna, V. (2021) 'Get ready for another fight over the future of the MQ-9 Reaper', *Defense News*, 26 May 2021. [Online]. Available at: https://www.defensenews.com/air/2021/05/26/get-ready-for-another-fight-over-the-future-of-the-mq-9-reaper/ (Accessed: 5 January 2024).

International Organization for Standardization [ISO] (2021) *ISO 8373:2021(en) Robotics – Vocabulary*. International Organization for Standardization [ISO].

Jha, A. (2017) *Theory, Design, And Applications Of Unmanned Aerial Vehicles*. Boca Raton, FL: CRC Press; https://doi.org/10.1201/9781315371191.

Khan, A. (2021) 'Hidden Pentagon Records Reveal Patterns Of Failure In Deadly Airstrikes', *New York Times*, 18 December 2021. [Online]. Available at: https://www.nytimes.com/interactive/2021/12/18/us/airstrikes-pentagon-records-civilian-deaths.html (Accessed: 5 January 2024).

Kokkinidis, T. (2022) 'US Deploys Eight MQ-9 Reaper Drones to Greece', *GreekReporter*, 26 November 2022. [Online]. Available at: https://greekreporter.com/2022/11/26/us-deploys-eight-mq-9-reaper-drones-greece/ (Accessed: 5 January 2024).

Krishnan, A. (2009) *Killer Robots: Legality and Ethicality of Autonomous Weapons*. Farnham, UK: Ashgate Publishing Limited.

Kunertova, D. (2019) *Military Drones in Europe: The European Defense Market and the Spread of Military UAV Technology*. Syddansk Universitet, Danemark: Center for War Studies.

Kunertova, D. (2022) 'The Ukraine Drone Effect on European Militaries', *Policy Perspectives*, 10(15); https://doi.org/10.3929/ethz-b-000584078.

Larson, C. (2020) 'Sparrowhawk: This Drone Can Be Launched from the Air and Recovered by a Mothership', *The National Interest*, 30 September 2020. [Online]. Available at: https://nationalinterest.org/blog/buzz/sparrowhawk-drone-can-be-launched-air-and-recovered-mothership-169856 (Accessed: 5 January 2024).

Liebermann, O. (2023) 'Russian fighter jet damages US military drone over Syria', *CNN*, 25 July 2023. [Online]. Available at: https://edition.cnn.com/2023/07/25/politics/russia-us-drone-damaged-syria/index.html (Accessed: 5 January 2024).

Light, T., Hamilton, T., Pfeifer, S. (2020) *Trends in U.S. Air Force Aircraft Mishap Rates (1950-2018)*. RAND Corporation; https://doi.org/10.7249/RRA257-1.

Lin, P., Bekey, G., Abney, K. (2008) *Autonomous Military Robotics: Risk, Ethics, and Design*. San Luis Obispo, CA: California Polytechnic State University.

Magnuson, S. (2010) 'Robot Manufacturers Lament Absence of Strong Army Advocate. National Defense', *National DEFENSE*, 19 March 2010. [Online]. Available at: https://www.nationaldefensemagazine.org/articles/2010/3/19/robot-manufacturers-lament-absence-of-strong-army-advocate (Accessed: 5 January 2024).

Maier, S., Schulte, A. (2022) 'A Cloud-based approach for synchronous multi-pilot multi-UAV mission plan generation in a MUM-T environment', *AIAA SCITECH 2022 Forum*; https://doi.org/10.2514/6.2022-2345.

Martin, J. (2013) 'RPA reservists help reach 2 million-hour milestone', *Air Force Reserve Command*, 1 November 2013. [Online]. Available at: https://www.afrc.af.mil/News/Article/561434/rpa-reservists-help-reach-2-million-hour-milestone/ (Accessed: 5 January 2024).

McCarthy, N. (2020) 'The Mammoth Cost Of Operating America's Combat Aircraft', *Statista*, 26 November 2020. [Online]. Available at: https://www.statista.com/chart/23618/operating-cost-per-aircraft/ (Accessed: 5 January 2024).

McClure, M. (2015) '5 big problems with the drone programs', *Foreign Policy*, 10 December 2015. [Online]. Available at: https://foreignpolicy.com/2015/12/10/5-big-problems-with-the-drone-programs/ (Accessed: 5 January 2024).

McDermott, R. (2017) *Russia's Electronic Warfare Capabilities to 2025: Challenging NATO in the Electromagnetic Spectrum*. Tallinn: International Centre for Defence and Security.

Michel, A.H. (2013) 'Drones in Bosnia', *Drone Center,* 7 June 2013. [Online]. Available at: https://dronecenter.bard.edu/drones-in-bosnia/ (Accessed: 5 January 2024).

Milburn, A. (2021) 'Drone Strikes Gone Wrong: Fixing a Strategic Problem', *Small Wars Journal*, 10 August 2021. [Online]. Available at: https://smallwarsjournal.com/jrnl/art/drone-strikes-gone-wrong-fixing-strategic-problem (Accessed: 5 January 2024).

Monckton, S. (2018) 'Current And Emerging Technology In Military Robotics.' in Braun, W.G., von Hlatky, S., Nossal, K.R. (eds.) *Robotics And Military Operations*. Carlisle, PA: The Strategic Studies Institute and U.S. Army War College Press.

Mulrine, A. (2008) 'Warheads on Foreheads', *Air Force Magazine*, October 2008, pp. 44–47.

NATO Publication (2019) *ATP 3.3.8.1-Minimum Training Requirements for Unmanned Aircraft Systems (UAS) Operators And Pilots* (p. 58). Washington, DC: United States Department of Defense.

Olney, B. (2019) 'New system allows NY ANG MQ-9s to fly without chase planes', *Air National Guard*, 11 September 2019. [Online]. Available at: https://www.ang.af.mil/Media/Article-Display/Article/1957391/new-system-allows-ny-ang-mq-9s-to-fly-without-chase-planes/ (Accessed: 5 January 2024).

Olson, E., Chappell, B. (2023) 'The U.S. military releases footage of Black Sea drone crash with Russian jet', *NPR*, 16 March 2023. [Online]. Available at: https://www.npr.org/2023/03/16/1163845903/video-drone-crash-russia-black-sea (Accessed: 5 January 2024).

Overton, I. (2020) 'A decade of global IED harm reviewed', *ReliefWeb and Action on Armed Violence*, 15 October 2020. [Online]. Available at: https://reliefweb.int/report/world/decade-global-ied-harm-reviewed (Accessed: 5 January 2024).

Page, L. (2023) 'Time is too short for Britain to start building its own weapons', *The Telegraph*, 9 December 2023. [Online]. Available at: https://www.telegraph.co.uk/business/2023/12/09/putin-russia-war-economy-an-existential-threat-to-europe/ (Accessed: 5 January 2024).

Palik, M., Nagy, M. (2019) 'Brief History of UAV Development', *Repüléstudományi Közlemények*, 31(1), pp. 155–166; https://doi.org/10.32560/rk.2019.1.13.

Pons, J. (2022) 'Spain partners with Germany, France and Italy to build Europe's largest military drone', *Atalayar: Between Two Shores*, 30 January 2022. [Online]. Available at: https://www.atalayar.com/en/articulo/new-technologies-innovation/spain-partners-germany-france-and-italy-build-europes-largest-military-drone/20220129110021154853.html (Accessed: 5 January 2024).

Ranquist, E., Steiner, M., Argrow, B. (2017) *Exploring the range of weather impacts on UAS operations*. 18th Conference on Aviation, Range and Aerospace Meteorology. 22–26 January 2017. Seattle, WA: American Meteorological Society (AMS).

Roza, D. (2023) 'AFSOC Wants MQ-9 Reapers to Act As 'Capital Ships' For Smaller Drones', *Air And Space Forces Magazine*, 19 September 2023. [Online]. Available at: https://www.airandspaceforces.com/mq-9-reapers-afsoc-smaller-drones/ (Accessed: 5 January 2024).

Sapmaz, A. (2021) *The Role Of Unmanned Aerial Vehicle, Armed Unmanned Aerial Vehicle And Drones In The Second Karabakh War.* 3. International Baku Scientific Research Congress. Baku, October 15-16, 2021: Baku Eurasia University.

Savage, C., Schmitt, E., Khan, A., Hill, E., Koettl, C. (2022) 'New Footage Shows the Risk Of Drone War', *New York Times*, 20 January 2022. [Online]. Available at: https://www.nytimes.com/2022/01/19/us/politics/afghanistan-drone-strike-video.html (Accessed: 5 January 2024).

Schmitt, E. (2021) 'No Penalty Over U.S. Strike That Killed Civilians', *New York Times*, 14 December 2021. [Online]. Available at: https://www.nytimes.com/2022/01/19/us/politics/afghanistan-drone-strike-video.html (Accessed: 5 January 2024).

Schmitt, E., Cooper, H. (2021) 'Drone Attack Was a Mistake, Pentagon Says', *New York Times*, 18 September 2021. [Online]. Available at: https://www.nytimes.com/2021/09/17/us/politics/pentagon-drone-strike-afghanistan.html (Accessed: 5 January 2024).

Schmitt, E., Cooper, H. (2023) 'Attack on U.S. Drone by Russian Jets Is Seen in 42-Second Pentagon Video', *New York Times*, 17 March 2023. [Online]. Available at: https://www.nytimes.com/2023/03/16/us/politics/russia-drone-black-sea.html (Accessed: 5 January 2024).

Schnitzler, G. (2023) *EDIRPA/EDIP: Risks And Opportunities Of Future Joint Procurement Incentives For The European Defence Market*. Paris: The French Institute for International and Strategic Affairs (IRIS).

Shoaib, A. (2023) 'Bayraktar TB2 drones were hailed as Ukraine's savior and the future of warfare. A year later, they've practically disappeared', *Business Insider*, 28 May 2023. [Online]. Available at: https://www.businessinsider.com/turkeys-bayraktar-tb2-drones-ineffective-ukraine-war-2023-5 (Accessed: 5 January 2024).

Shoker, S. (2021) *Military-Age Males in Counterinsurgency and Drone Warfare*. New York, NY: Palgrave Macmillan Cham; https://doi.org/10.1007/978-3-030-52474-6.

Singer, P. (2009) *Wired for War: the Robotics Revolution And Conflict in the Twenty-first Century*. London: The Penguin Press.

Sloggett, D. (2015) *Drone Warfare: The Development of Unmanned Aerial Conflict*. New York, NY: Skyhorse.

Smith, M. (2016) '2015 Marked the Worst Year for Drone Crashes the Air Force Has Ever Had', *Industry Tap*, 26 January 2016. [Online]. Available at: https://www.industrytap.com/2015-marked-worst-year-drone-crashes-air-force-ever/34095 (Accessed: 5 January 2024).

Smith, P. (2020) *Russian Electronic Warfare: A Growing Threat to U.S. Battlefield Supremacy*. American Security Project.

Sprenger, S. (2023) 'German air chief urges haste in fielding strike, utility drones', *Defense News*, 3 November 2023. [Online]. Available at: https://www.defensenews.com/global/europe/2023/11/03/german-air-chief-urges-haste-in-fielding-strike-utility-drones/ (Accessed: 5 January 2024).

Stashevskyi, O., Bajak, F. (2022) ‘Deadly secret: Electronic warfare shapes Russia-Ukraine war’, *Associated Press*, 4 June 2022. [Online]. Available at: https://apnews.com/article/russia-ukraine-kyiv-technology-90d760f01105b9aaf1886427dbfba917 (Accessed: 5 January 2024).

Stevenson, B. (2015) ‘MoD reveals Reaper derivative will be chosen for Protector’, *Flight Global*, 7 October 2015. [Online]. Available at: https://www.flightglobal.com/civil-uavs/mod-reveals-reaper-derivative-will-be-chosen-for-protector/118450.article (Accessed: 5 January 2024).

Struck, J., Brown, S. (2023) ‘Ukraine Has a New Ground ‘Drone’ – the Ratel S (Honey Badger) UGV’, *Kyiv Post*, 24 October 2023. [Online]. Available at: https://www.kyivpost.com/post/23189 (Accessed: 5 January 2024).

Szegedi, P., Koronvary, P., Békési, B. (2017) ‘The Use Of Robots In Military Operations’, *Scientific Research And Education In The Air Force*, 2017/19, pp. 221–230; https://doi.org/10.19062/2247-3173.2017.19.1.25.

Tilenni, G. (2023) ‘UAV Programmes: a Focus on the EU’, *European Security & Defence*, 3 August 2023. [Online]. Available at: https://euro-sd.com/2023/08/articles/32890/uav-programmes-a-focus-on-the-eu/ (Accessed: 5 January 2024).

Tirpak, J.A. (2021) ‘Air Force to Upgrade MQ-9’s Mission and Capabilities for Near-Peer Fight’, *Air And Space Forces Magazine*, 21 April 2021. [Online]. Available at: https://www.airandspaceforces.com/air-force-to-upgrade-mq-9s-mission-and-capabilities-for-near-peer-fight/ (Accessed: 5 January 2024).

Tisseron, A. (2014) ‘Robotic and Future Wars: When Land Forces Face Technological Developments’ in Doaré, R., Danet, D., Hanon, J., de Boisboissel, G. (eds.) *Robots on the Battlefield: Contemporary Issues and Implications for the Future*. Leavenworth, WA: US Army Combined Arms Center, Combat Studies Institute.

Trzun, Z., Vrdoljak, M. (2020) ‘Monte Carlo Simulation of Missile Trajectories Dispersion due to Imperfectly Manufactured Warhead’ in Katalinic, B. (ed.) *Proceedings of the 31st DAAAM International Symposium (pp. 0574-0583). Mostar, BiH, 21-24th October 2020*. Vienna: DAAAM International.

Trzun, Z., Vrdoljak, M., Cajner, H. (2021) ‘The Effect of Manufacturing Quality on Rocket Precision’, *Aerospace*, 8(6); https://doi.org/10.3390/aerospace8060160.

Tuchkov, V. (2016) ‘VDV: “Andromeda-D” Will Support Strike Robots’, *SvobodnayaPressa*, 27 January 2016. [Online]. Available at: https://svpressa.ru/war21/article/141023/ (Accessed: 5 January 2024).

U.S. Department of Defense (2022) *Civilian Harm Mitigation And Response Action Plan*. Washington, DC: Department of Defense.

Urcosta, R. (2018) ‘Syria: Russia’s Military Proving Ground’, *US Naval Institute*, Proceedings, March 2018. [Online]. Available at: https://www.usni.org/magazines/proceedings/2018/march/syria-russias-military-proving-ground (Accessed: 30 October 2024).

Urmson, C., Anhalt, J., Bagnell, D., Baker, C. et al. (2009) ‘Autonomous Driving in Urban Environments: Boss and the Urban Challenge’ in Buehler, M., Iagnemma, K., Singh, S. (eds.) *The DARPA Urban Challenge: Autonomous Vehicles in City Traffic*. Heidelberg: Springer-Verlag, pp. 1-59; https://doi.org/10.1007/978-3-642-03991-1_1.

US Air Force (2021) ‘MQ-9 Reaper’, *Official US Air Force Website*. [Online]. Available at: https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104470/mq-9-reaper/ (Accessed: 5 January 2024).

US Department of Defense (2005) *Unmanned Aircraft Systems Roadmap 2005-2030*. Washington, DC: Office of the Secretary of Defense.

US Department of Defense (2011) *Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms*. Washington, DC: US Department of Defense.

US Department of Defense (2021) ‘Transcript: General Kenneth F. McKenzie Jr. Commander of U.S. Central Command and Pentagon Press Secretary John F. Kirby Hold a Press Briefing’, 17 September 2021. [Online]. Available at: https://www.defense.gov/News/Transcripts/Transcript/Article/2780738/general-kenneth-f-mckenzie-jr-commander-of-us-central-command-and-pentagon-pres/ (Accessed: 5 January 2024).

Wall, P. (2013) ‘Theory of the drone 12: ‘Killing well’?’, *Geographical Imaginations,* 8 December 2013. [Online]. Available at: https://geographicalimaginations.com/tag/hellfire-missile/ (Accessed: 5 January 2024).

Weinberger, S. (2008) ‘Armed Robots Still in Iraq, But Grounded (Updated)’, *Wired,* 15 April 2008. [Online]. Available at: https://www.wired.com/2008/04/armed-robots-st/ (Accessed: 5 January 2024).

Werner, A., Kreutzmann, U., Glowka, S., Schinkel, C. (2020) ‘The New Quality of Aviation Unmanned Aerial Vehicles (UAV) Prevent Psychological Stress of Military Drone Operators’, *Clinical Medicine Research*, 9(1), pp. 25–30; https://doi.org/10.11648/j.cmr.20200901.15.

Whitlock, C. (2014) ‘When Drones Fall from The Sky’, *The Washington Post,* 20 June 2014. [Online]. Available at: https://www.washingtonpost.com/sf/investigative/2014/06/20/when-drones-fall-from-the-sky/ (Accessed: 5 January 2024).

Wu, M. (2022) *Intelligent Warfare: Prospects of Military Development in the Age of AI*. New York, NY: Routledge, Taylor and Francis Group; https://doi.org/10.4324/b22974.

Xiao, X., Dufek, J., Murphy, R.R. (2021) ‘Autonomous Visual Assistance For Robot Operations Using A Tethered UAV’ in Ishigami, G., Yoshida, K. (eds.) *Field and Service Robotics: Results of the 12th International Conference*. Singapore: Springer Singapore, pp. 15–29; https://doi.org/10.1007/978-981-15-9460-1_2.

Yamauchi, B. (2004) ‘PackBot: A versatile platform for military robotics’ in *Defense And Security, SPIE Proceedings, (Vol. 5422). Orlando, FL, US, 12-16 April 2004*. Bellingham, WA: SPIE, pp. 228–237; https://doi.org/10.1117/12.538328.

A-10 And MQ-9 In ICT Operation | Finland Closer To Buying David’s Sling | Denmark Gets New Howitzers (2023) *Defense Industry Daily.* [Online]. Available at: https://www.defenseindustrydaily.com/a-10-and-mq-9-in-ict-operation-finland-closer-to-buying-davids-sling-denmark-gets-new-howitzers-048238/ (Accessed: 5 January 2024).

Drone Crash Database (2022) *Drone Wars UK*. [Online]. Available at: https://dronewars.net/drone-crash-database/ (Accessed: 5 January 2024).

Lynx Multi-Mode Radar: Surveillance, Tracking, Targeting for Manned and Unmanned Missions (no date) *General Atomics Aeronautical*. [Online]. Available at: https://www.ga-asi.com/radars/lynx-multi-mode-radar (Accessed: 5 January 2024).

MQ-9 Reaper (no date) *Air and Space Forces Magazine*, no date. [Online]. Available at: https://www.airandspaceforces.com/weapons-platforms/mq-9/ (Accessed: 5 January 2024).

Predator B Extended Range Conducts First Flight With Long Wings (2016) *General Atomics Aeronautical*, 25 February 2016. [Online]. Available at: https://www.ga-asi.com/predator-b-extended-range-conducts-first-flight-with-long-wings (Accessed: 5 January 2024).

Record number of US drone crashes (2016) *BBC News* 21 January 2016. [Online]. Available at: https://www.bbc.com/news/technology-35370262 (Accessed: 5 January 2024).

Russia is starting to make its superiority in electronic warfare count (2023) *The Economist*, 23 November 2023. [Online]. Available at: https://www.economist.com/europe/2023/11/23/russia-is-starting-to-make-its-superiority-in-electronic-warfare-count (Accessed: 5 January 2024).

TALON Tracked Military Robot (2020) *Army Technology*, 21 February 2020. [Online]. Available at: https://www.army-technology.com/projects/talon-tracked-military-robot/?cf-view (Accessed: 5 January 2024).