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Comprehensive Study of Military and Civil Drone Applications: Assessing Key Areas of Significance and Future Prospects

This study aims to provide a comprehensive overview of unmanned aircraft systems (UAS) encompassing both civilian and military application in contemporary operations, emphasising their potential impact on future advancements. Through an in-depth analysis, we examine the current state-of-the-art UAS technologies, their applications, and evaluate their efficiency in various sectors. Furthermore, this research offers insights into the potential trajectories and challenges that may arise as drone technology continues to evolve and integrate into our daily lives.

Keywords: *Nagorno-Karabakh, Ukraine-Russia, unmanned aircraft system, loitering ammunition, dual use*

1. Introduction

Unmanned Aircraft Systems (UAS) have gained substantial popularity in both civil and military domains owing to their remarkable versatility and operational efficiency. As the demand for UAS continues to surge, it is imperative for stakeholders to remain abreast of the latest advancements and research in this burgeoning field. Notably, the scientific community has exhibited significant interest in UAS, as evidenced by a plethora of review papers and books scrutinising various facets of UAS development and research across diverse applications [1]. These applications serve as linchpins in propelling the progress of both civil and military UAS technology and represent pivotal subjects of inquiry for researchers and practitioners alike.

Given the expansive scope of UAS research and the diverse subdomains within this multifaceted discipline, coupled with substantial investments, a cadre of critical research inquiries has emerged. Central among these is the inherently interdisciplinary nature of UAS research [2], which amalgamates aerospace engineering, computer science, robotics, and remote sensing. Profoundly comprehending the synergies among these disciplines and devising effective collaborative strategies through precise categorisation and application analysis stand as paramount imperatives for the advancement of UAS technology. Addressing these challenges and cultivating solutions holds the potential to optimise the seamless integration of UAS into our professional environment. This integration presents opportunities across a numerous sector, including military operations, agriculture, environmental monitoring, disaster response, surveillance, and infrastructure inspection, to name a few [3].

Recognising the urgency of grappling with these research inquiries, particularly within the UAS research community, it is incumbent upon us to furnish a comprehensive guide that navigates the expansive terrain of UAS research. By synthesising latest findings and insights drawn from diverse applications, our aspiration is to furnish a substantive resource for scholars and practitioners engaged in this dynamic field. Through collaborative endeavours and the dissemination of knowledge, we collectively endeavour to propel UAS technology forward, unlocking its full potential across a broad spectrum of applications, thereby contributing to the advancement of both civil and military objectives in the ever-evolving landscape of unmanned aerial systems.

2. Military area of use

Experts, who study the specificities of the drone's military use, have taken different approaches to this issue. Is the emergence of drones on the battlefield is as revolutionary as the use of missiles was during World War II? Can drones decide the outcome of the war or not? It is a fact that these flying machines are having become a standard "weapon" regulated in almost all countries. Terms like "revolutionary", "pioneering", "earth-shattering'", "decisive" are often used to describe drones, but they remain slogans until their role in combat becomes *game-changer.* There are numbers of advantages, such as the strikes accuracy, the ability to keep soldiers away from "hot spots", the ability to detect what is happening on the ground. Even NGOs (non-governmental organisations) gain benefit of drones during their missions. UASs make war easier and more bearable for soldiers, and make war cheaper and more effective for the government, meanwhile provide the ability to act independently [4].

The revolutionary role of drones can also be seen in how, along with their deployment, strategic thinking is transformed, how military doctrines change along with it, and how the military of a country undergoes an organisational transformation with the acquisition and deployment of drones.

Countries who were the leaders of drone proliferation and owning requisite expertise with "infinite resources" had taken into account the following five views at the field of drone use cases, which influences *the directives of development:*

- be capable for carrying weapons;
- be able to carry out precise strikes;
- be applicable over war- and no war zones;
- be applicable not only in armed strikes, but also in military intelligence;
- be able for autonomous operation and at the same time for long-distance remote controlling outside the area of operations [5].

The core capabilities of military drones are:

- intelligence;
- surveillance;
- target acquisition;
- reconnaissance.

The list above stands for ISTAR[1] for short. Why do we need these capabilities? To collect, analyse, and share information with maximum effects in order to provide decision-makers and actors in the AO[2] with better situational awareness to operate effectively. Commanders at all levels must see first and understand the battlespace so that they could act quickly and decisively. It is used for both defensive and offensive operations [6].

Table 1.
Categorisation of drones by levels of military operations [7]

Level	**Tactical**		**Operational**	**Strategical**
Forces	Task Unit	Task Group	SOCC	Joint
UAS Category	Micro/Mini UAS	Mini UAS	Tactical UAS	MALE[3]/HALE[4] UAS
UAS Flight Time	30-60 minutes	Up to 6-9 hours	12-24 hours	24+ hours

As Table 1 shows, drones are categorised based on their suitability for various levels of military operations, ranging from tactical to strategic. Micro/Mini UASs are typically deployed at the tactical level, offering short flight times of 30-60 minutes, ideal for task unit operations. Mini UASs and Tactical UASs extend operational capabilities, with flight times of up to 6-9 hours, suitable for task group assignments. Moving into the operational level, MALE and HALE UASs provide extended flight durations ranging from 12 to over 24 hours, enabling sustained reconnaissance and surveillance missions within a theatre of operations. Finally, at the strategic level, UASs with flight times exceeding 24 hours serve the needs of Special Operations Command (SOCC) and Joint Forces, offering persistent surveillance and intelligence gathering capabilities essential for strategic planning and decision-making.

Table 2.
Categorisation of drones by US Department of Defense UAV classification system standard [8]

Category	**Size**	**Maximum Gross Take-off Weight (MGTW) (lbs/kg)**	**Normal Operating Altitude (feet/m)**	**Airspeed (knots/km/h)**
Group 1	Small	0–20/0–9.07	< 1,200 AGL/365.7 (above ground level)	< 100/185.2
Group 2	Medium	21–55/9.53–24.95	< 3,500/1068	< 250/463
Group 3	Large	< 1,320/ 598.74	< 18,000/5486 MSL (mean sea level)	< 250/463
Group 4	Larger	> 1,320/ 598.74	< 18,000/5486 MSL	Any airspeed
Group 5	Largest	> 1,320/ 598.74	> 18,000/5486 MSL	Any airspeed

Table 2 outlines the classification of drones according to the US Department of Defense UAV Classification System Standard. Drones are categorised into five groups based on their size, maximum gross take-off weight, normal operating altitude, and airspeed. Group 1 comprises small drones with MGTW ranging from 0 to 20 pounds, operating at altitudes below 1,200 feet above ground level and speeds below 100 knots. Medium-sized drones fall into Group 2, with MGTW between 21 and 55 pounds, operating at altitudes below 3,500 feet and speeds below

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[1] Intelligence, Surveillance, Target Acquisition, Reconnaissance.
[2] Area of Operation.
[3] Medium-altitude long-endurance.
[4] High-altitude long-endurance.

250 knots. Group 3 includes large drones with MGTW less than 1,320 pounds, operating at altitudes below 18,000 feet mean sea level and speeds below 250 knots. Groups 4 and 5 encompass larger and largest drones, respectively, with MGTW exceeding 1,320 pounds and capable of operating at altitudes exceeding 18,000 feet MSL, with no specified airspeed limitations.

Table 3.
NATO UAV classification [9]

CLASS	**Category**	**Normal employment**	**Normal Operating Altitude**	**Normal Mission Radius**	**Primary Supported Commander**	**Example Platform**
Class I (less than 150 kg)	SMALL > 20 kg	Tactical Unit (employs launch system)	Up to 5K feet AGL	50 km (LOS – line of sight)	Battalion, Regiment	Luna, Hermes 90
	MINI 2–20 kg	Tactical Sub-unit (manual launch)	Up to 3K feet AGL	25 km (LOS)	Company / Squadron	Scan Eagle, Skylark
	MICRO < 2 kg	Tactical Pl, Sect, Individual (single operator)	Up to 200 feet AGL	5 km (LOS)	Section	Black Widow
Class II (150 kg to 600 kg)	TACTICAL	Tactical Formation	Up to 10,000 feet AGL	200 km (LOS)	Brigade	Hermes 450, Aerostar
Class III (more than 600 kg)	Strike/ combat	Strategic / National	Up to 65,000 feet	Unlimited (BLOS – beyond line of sight)	Theatre COM	
	HALE	Strategic / National	Up to 65,000 feet	Unlimited (BLOS)	Theatre COM	Global Hawk
	MALE	Operational / Theatre	Up to 45,000 feet MSL	Unlimited (BLOS)	JTF COM	Predator, Heron, Hermes 900

Table 3 presents the NATO classification system for UAVs, categorising them into three main classes based on weight and intended use. Class I encompasses small UAVs, weighing less than 150 kilograms, subdivided into three categories: Small (> 20 kg), Mini (2–20 kg), and Micro (< 2 kg). These UAVs are primarily employed at the tactical level, with varying altitudes and mission radii depending on their size and capabilities. Class II comprises tactical UAVs weighing between 150 and 600 kilograms utilised for tactical formations with operational altitudes up to 10,000 feet AGL and mission radii of up to 200 kilometres. Class III includes strike/combat UAVs, further classified into HALE and MALE platforms, designed for strategic and operational/theatre-level missions, operating at altitudes up to 65,000 feet and BLOS operations.

2.1. Examples for micro, mini, tactical and male/hale UAV's

2.1.1. Micro-mini category

The Black Hornet, developed by Prox Dynamics, measures 16.8 cm by 2.5 cm and the rotor diameter 123 mm. It is capable of spending more than 25 minutes airborne and fly 2 km far from the operator's location. It withstands 15 knots/gust 20 knots (7.71 m/s/gust 10.28 m/s) wind and precipitation of 2.5 mm (0.1 in)/hr (Light rain). Its optics are also noteworthy. The resolution of the EO video is 640 × 480, which is not a very high quality, but may be enough to identify certain threats. Its snapshot is a different story, with a resolution of 1600 × 1200 pixel it can provide a quite sharp image on what's happening. I should also mention that the EO camera is able to capture thermal video and snapshots at 160 × 120 resolution. It can be ready and being launched in 30-120 seconds. It distinguishes four operating modes:

- auto and Manual Hover & Stare;
- route and user selectable waypoint actions;
- automatic return in case of LOL[5].

Next in line in this category is the RQ-11B Raven. It has two different antennas, each has its very own characteristic. Omni antenna transmits within a radius of 5 kilometres in LOS, the Patch antenna, on the other hand, transmits for 10 kilometres, but not in a radius, but 60 degrees forward. The antenna must be pointed towards the current direction of the UAV, otherwise the LOL function will be activated if the operator does not do so, in which case the preset protocol will be automatically executed: "land immediately", Return to Base etc. These assets (micro–mini–small) do not have a large logistical footprint and, therefore, do not produce as much and as high quality results as their counterparts. The larger the logistical footprint of a tool, the more and better quality results it can deliver at the current level of our technical development. Small asset + small camera = small resolution = poorer results. The dangers of this are that you have to sacrifice safety for results. You have to fly closer over the target area to get a result, risking the possibility of detection. The Short-range UAV (SUAV) itself is not very big, weighing around two kilograms, with a wingspan of 1.4 metres and a length of just 0.9 metres. Its battery provides 60–90 minutes of flight time. The aerial vehicle has a minimum operating altitude of 30–150 metres AGL and a maximum of approximately 4000 metres MSL. The payload is a gimballed camera called Mantis i23. It has two modes. There is a dual 5 MP EO/IR + LWIR (improved long-wave infrared) for night and a dual 18 MP EO (Electro-optical) for daylight.

It distinguishes five operating modes:

- altitude;
- manual;
- navigation;
- home;
- loiter.

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[5] Loss of Link.

The NX 70 Novadem drone is a versatile and reliable unmanned aerial vehicle designed to support a wide variety of commercial and industrial operations. The UAV measures 51 cm long, 51 cm wide, and 13 cm high. Maximum take-off weight is 1 kg. Its standard range is about 1 km, the maximum range is 5 km and the flight time is up to 45 minutes. It is equipped with a high-resolution bi-spectral ultra-high resolution electro-optical day and thermal camera, as well as an obstacle avoidance system and advanced navigation features that allow autonomous flight in any environment. Durable and lightweight construction is ideal for long-range missions, while its modular design allows easy customisation to meet specific mission requirements. Its advanced flight control system and intuitive user interface provide pilots with the tools they need to perform their tasks with precision and accuracy. The NX 70 Novadem micro quadcopter drone is an excellent choice for anyone looking for a reliable and high-performance UAV. Please, note that the micro UAV can lift and drop different devices, such as a medical kit, smoke grenade and jammers, making it the only multi-role micro-drone available for defence applications.

2.1.2. Mini UAS category

Skylark I-LEX (Mini-UAS) is a small, lightweight drone developed by Elbit Systems for tactical intelligence, surveillance and reconnaissance missions. It has a low acoustic signature and can be operated autonomously or remotely. Its small size and low weight make it ideal for missions in urban environments, where it can provide real-time intelligence on enemy movements. The drone can be equipped with various sensors, including an electro-optical payload, which provides high-resolution imagery and video. It also has a GPS navigation system and an advanced communications system for secure data transmission. The Skylark I-LEX with its 3 hours flight time and a range of a 40 km is a reliable and versatile drone used for a variety of military applications. Maximum payload of this asset is 1.2 kg, its wingspan is 3 m, the take-off weight is 7.5 kg, and the service ceiling is 4.5 km. Launch method is a bungie assisted hand-launch or the use of a portable mini launcher. The recovery method is a deep stall manoeuver on an inflatable airbag.

The Skylark 3 (see Figure 1) field deployed tactical ISTAR UAS has high resolution, gimbaled and stabilised dual EO/IR payload facilitate a wide-range of applications, including:

- over-the-hill intelligence;
- force and convoy protection;
- strategic infrastructure protection;
- border patrol;
- security operations.

The platform is fully autonomous from take-off to landing and is designed for mission-oriented operation that does not require any piloting skills. The Skylark 3 drone, developed by Elbit Systems, is a small, lightweight, and versatile tactical UAV. It has a range of 100 km and can fly for 6 hours. The Skylark 3 is equipped with a wide range of sensors and payloads, including electro-optical, infrared, laser designator and communications relay. It is designed for use in battlefield reconnaissance; surveillance, target acquisition, and communications relay missions. It can be launched from a catapult launcher, and can be operated autonomously or manually. The Skylark 3 is highly reliable and has been used by the military forces of several countries including the Hungarian Defence Forces as well [10].

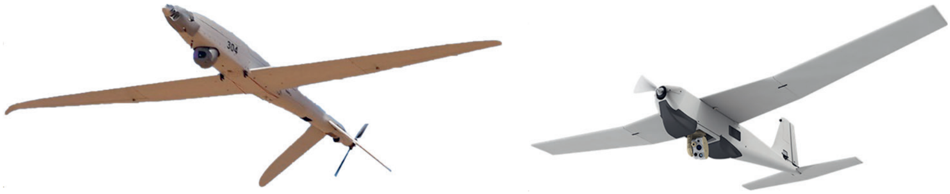

Figure 1.
Portrayed Unmanned Aircraft Systems (left: Skylark 3, right: Puma AE RQ-20B) [30], [31]

Another *Aerovironment* product at an even higher level is the Puma AE RQ-20B (see Figure 1). Can be launched manually or from a rail (catapult). Its payload is gimbaled, capable of 360-degree continuous pan, +10 to –90 degrees tilt, stabilised EO and IR camera. All in one modular illuminator payload that is much more efficient than the previous payload versions. Its operating altitude is 500 feet (152 m) AGL.

2.1.3. Tactical UAS

Watchkeeper (see Figure 2), which has been in service since 2014 and still operates, is a British-made UAV, although Thales and Israel's Elbit developed it. The device sought to fuse all of the useful UAV capabilities found in the current and future technology platforms, so it received an advanced sensor package that transmitted the reconnaissance data directly to the combat command; both the weapon system and the ground mobile station customers received it. From the beginning of the development, the Watchkeeper was beset by difficulties, the first test flights were carried out between 2008 and 2010, but unfortunately, by then most of its advantageous characteristics were not considered technological innovations, because it did not exceed the capabilities of the Hermes 450, so hiring it was a better solution. While the Hermes 450 had electro-optical and infrared detection capabilities, the Watchkeeper was equipped with a modular multisensory system and synthetic aperture radar, and since its autonomous systems were more advanced than the Israeli type, it could be operated not only by pilots but also by soldiers trained for the task. Among its advantages are that it is mobile, easy to install, relatively easy to transport as it is stored in containers that meet international standards, and the British Army plans to keep it in service for 30 years.

Figure 2
Portrayed Unmanned Aircraft Systems (left: Watchkeeper, right: Scan Eagle) [32], [33]

The ScanEagle (see Figure 2) developed by Insitu, boasts a compact design and long endurance, making it ideal for intelligence, surveillance, and reconnaissance missions. With a wingspan of 3.11 metres and a maximum take-off weight of 22 kilograms, it can stay airborne for up to 24 hours, transmitting real-time video and imagery. Launched via a pneumatic catapult and recovered using a skyhook system, it eliminates the need for a runway, enhancing its versatility for various environments, including maritime operations. Equipped with advanced cameras and sensors, the ScanEagle serves military, scientific, and commercial purposes effectively.

The RQ-7B Shadow (see Figure 3) is primarily utilised for reconnaissance and surveillance missions. Developed by AAI Corporation, it features a wingspan of 4.27 metres and a maximum take-off weight of approximately 204 kilograms. With a payload capacity of 27 kilograms, it can carry various sensors and cameras for gathering intelligence. The Shadow operates at altitudes up to 8,000 feet and has an endurance of up to nine hours. Deployed by military forces worldwide, it provides real-time situational awareness, enhancing battlefield effectiveness. Its reliability, endurance, and versatility make it a valuable asset for military operation.

Figure 3.
Portrayed Unmanned Aircraft Systems (left: RQ-7 Shadow, right: Anka S) [34], [35]

The Anka (see Figure 3) is developed by Turkish Aerospace Industries (TAI). Featuring a wingspan of 17.3 metres and a maximum take-off weight of 1,600 kilograms, it operates at altitudes up to 30,000 feet. Powered by a heavy-fuel engine, it achieves speeds of up to 140 knots. Equipped with advanced sensors and communication systems, the Anka provides real-time surveillance and reconnaissance capabilities. With a range exceeding 200 kilometres and an endurance of up to 24 hours, it serves various military and civilian applications with efficiency and reliability.

2.1.4. MALE/HALE UAS

The payload of the UAV encompasses a state-of-the-art electro-optical/infrared (EO/IR) camera, adept at capturing high-resolution imagery and video across diverse weather conditions, including day and night. Additionally, the MALE/HALE UAV is usually equipped with an identification system for distinguishing between friendly and hostile entities (IFF),[6] further augmented by a laser designator and range finder for precise target acquisition and engagement.

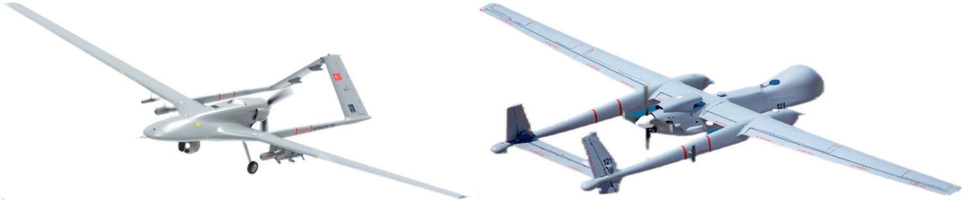

Figure 4.
Portrayed Unmanned Aircraft Systems (left: Bayraktar, right: Heron) [36], [37]

The Bayraktar TB2 (see Figure 4) is designed and manufactured by Turkey's Baykar. It features a wingspan of 12 metres and a maximum take-off weight of 650 kilograms. Equipped with a Rotax 912 engine, it can fly at speeds up to 130 knots and reach altitudes of 24,000 feet. The drone is capable of carrying various payloads, including electro-optical and infrared cameras, as well as guided munitions. With a range of over 150 kilometres and an endurance of up to 27 hours, the Bayraktar TB2 provides long-range reconnaissance and surveillance capabilities for military and security operations.

The Heron (see Figure 4) is developed by Israel Aerospace Industries (IAI). With a wingspan of 16.6 metres and a maximum take-off weight of 1,270 kilograms, it can operate at altitudes of up to 35,000 feet. Equipped with a Rotax 914 engine, it can reach speeds of 207 kilometres per hour. The Heron is capable of carrying payloads such as electro-optical and infrared sensors, synthetic aperture radar, and signals intelligence systems. With a range of over 2,500 kilometres and an endurance of up to 45 hours, it provides versatile surveillance and reconnaissance capabilities for military and civilian applications.

Figure 5.
Portrayed Unmanned Aircraft Systems (left: MQ-1 Predator, right: MQ-9 Reaper) [38], [39]

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[6] Identification Friend or Foe.

The RQ-1 was designed for surveillance and reconnaissance missions. The designation was changed to MQ-1 (see Figure 4) in 2002. The “M” is the Department of Defense (DoD) designation for multi-role, and “Q” means remotely piloted aircraft system. The “Q” series has been introduced to designate reusable unmanned aerial vehicles [11].

The “9” indicates that it is the ninth in the series of remotely piloted aircraft systems. As it was mentioned earlier, intelligence, surveillance, targeting, and reconnaissance are their main purposes. However, their capabilities expanded during the years of experience. They are also used for close air support, combat search and rescue, precision strike, buddy-lase, convoy/raid overwatch, route clearance, target development, and terminal air guidance. In summary, it can provide a unique capability to perform Strike, Coordination and Reconnaissance (SCAR) against high-value, fleeting, and time-sensitive targets.

3. Significant armed conflicts from the past years

3.1. Afghanistan

“Since 2001, the drone has shifted from instrument of training and surveillance to a tool for conducting offensive strikes against enemy targets” [12]. War in Afghanistan provided the ideal territory for asymmetric warfare and resulted coalitional focus on Counter Insurgency (COIN) operations for 20 years. Unmanned Combat Aerial Vehicles (UCAVs) played a significant role in that conflict supporting US and coalition forces alike. This technology have quietly become weapon of choice against terrorism, or any adversary targets. Relatively speaking, the drone-based warfare is low budget and does not risk soldiers’ life in eliminating the enemy at a great rate of success, assuming that the enemy is not in possession any form of air defence. If it does, that might be a game-changing factor. In fact, Afghanistan has been the country with the highest number of drone strikes in history since that time, and along with the United States both the British and German forces have been testing the most effective ways to deploy and use drones during this period. Each device that the mentioned nations used were equipped with a GPS, radio, and Bluetooth, transponder to help navigate and communicate. In addition, imaging sensors, cameras for daytime and infrared operation, and synthetic aperture radars for 3D imaging. Signal Intelligence (SIGINT) and Communication Intelligence (COMINT) devices, spectral sensors for sophisticated sound detection, electronic jamming and interception devices, and they were capable of dropping lethal weapons such as missiles and bombs, and non-lethal weapons such as marker paints or nets. The RQ-1/MQ-1 (Predator) is capable of carrying two Hellfire missiles, while the Reaper can carry six different missiles and bombs. That time troops flied mostly the fixed-wing drones, which in most cases required some kind of infrastructure but several ones had manually deployable versions. United States’ drone strikes required extensive infrastructure for overseas operations where the distance between the remote station and the drone was more than 10,000 km. The relaying station was installed at Ramstein Air Base, which connected to the transatlantic control station with seabed cables and connected to the remote drone base by wireless contact. Drone strikes over Afghanistan, Pakistan and Yemen, known as target killing missions, have sometimes claimed civilian victims [13].

In the battlefields of ongoing wars, drone operations are not characterised by targeted strikes and gathering of wide-spectrum reconnaissance information, but rather by a show of force and destruction of ground infrastructure. The following statements could summarise what motivates the development of drones most suited to current conflicts:

- the risen significance of the combat micro-environment;
- the importance of visual imaging and data transmission has been appreciated as war is transmitted directly into our living room;
- the battles fought over continental distances became territorial;
- the significance of the payload determines the characteristics of the drone carrier;
- the cheaper devices, the more mobile infrastructure and the more variable network options should utilise.

3.2. Second Nagorno-Karabakh War

The war between Armenia and Azerbaijan over the Nagorno-Karabakh began in late September 2020 and ended on 10th of November with a Moscow-brokered ceasefire that resulted in the deployment of 2,000 Russian peacekeepers and significant Armenian territorial losses. Clashes were characterised by intense artillery fire, rocket and drone attacks, with Azerbaijan being the eventual winner of the war. Eado Hecht, PhD, a leading researcher and professor at the Begin-Sadat Center for Strategic Studies (BESA), Bal Ilan University, Israel, has asked whether drones are just a new tool for fighting the war or whether their significance is revolutionary and epoch changing [14]. Many accounts of the war have described it as a one-sided interaction of Azeri drones versus Armenian ground forces; with Azeri ground forces figuratively "riding on the backs of drones" to victory with minimal fighting. This was the first modern war primarily decided by unmanned weapons. It was arguably the first postmodern conflict in which unmanned aircraft defeated conventional ground forces, rendering them inert and immobile, opening the way for the Azeri ground forces to move in and seize a strategic point. "Azerbaijani sensors, mostly mounted on UAVs, gave the Azerbaijani military a clear, 24-hour, unblinking view of the battlespace" [15].

Figure 6.
Portrayed Unmanned Aircraft Systems (HAROP) [40]

Studying of Armenia's air defences, however, shows that its forces were not "formidable", certainly not in terms of drones. The exact quantities of the various missile systems are not available, but they had Strela-10 (SA-13), Osa (SA-8), Kub (SA-6), Krug (SA-4), S-300 and Tor air defences in combination. With the exception of the Tor, all of them were older, less effective. The Tor was the only device that posed threat to the Turkish Bayraktar TB-2 and the Israeli HAROP kamikaze drones. The effective range of Strella-10s and Osa's against targets with size of TB-2 drones was shorter than the range of missiles they carried. The longer-range Kubs, Krugs, and S-300s were optimised against targets that are larger and faster than drones, so the drones were invisible to them. Armenian positions that were camouflaged in the traditional way were still identified by electro-optical and thermal cameras. Intelligence Surveillance and Reconnaissance (ISR) platforms were merged with strike capability in the forms of the TB2 and HAROP. High-definition, full-motion-real-time videos from these platforms provided ISR, destroyed systems and personnel, and provided accurate BDA. Here are the specifics of the Bayraktar TB2 UCAV (see Figure 4) and the Loitering ammunition called HAROP (see Figure 6) [16].

3.3. East-Ukraine vs. Russia war

This conflict between these countries is one of the best examples of hybrid warfare. "In conceptual terms, we can say that hybrid warfare is a combination of conventional regular (linear, conventional) and irregular (non-linear, non-conventional) warfare in soft, medium and hard methods and procedures, with the aim of destroying the enemy's state, armed forces and impose its will, in particular by strategic objective of ensuring that the level of violence during the conflict does not exceed the level of war" [17]. The outbreak of the war was the result of a series of bad political decisions traced back to the collapse of the Soviet Union and its aftermath. The acquisition of the strategically important Crimean Peninsula – where predominantly Russian population is resident, and at the same time it is the base of Russian naval corps – led to invasion. Under the Treaty of Friendship, Cooperation and Partnership, Russia was allowed to retain the Sevastopol naval base and its lease was extended in 2010 until 2042, although a number of diplomatic conflicts made the agreement insecure. In the 2014 parliamentary elections, the pro-Russian government was overthrown in Ukraine, after which protests by pro-Russian and anti-government groups began in the Donetsk and Luhansk regions. The protests continued in an armed conflict because of the activities of the Euromaidan (Independence) movement. The first eight years of the conflict was featured by naval incidents, cyber warfare and political tensions. The war has degenerated into a static conflict with repeated failed attempts to engage a ceasefire. In 2015, Russia and Ukraine signed the Minsk II Agreement, but a number of disputes prevented its full implementation. The war in eastern Ukraine began with the Russian invasion on February 24, 2022, *using World War I-style mortars* and Soviet-made artillery. Since then, the situation has taken on a more *modern dimension,* with *soldiers monitoring the battlefield* on a small satellite monitor while their palm-sized drone hovers out of sight [18]. With *hundreds of reconnaissance and attack drones* flying over Ukraine every day, the 18th century struggle for land has become a competition for technological supremacy in the digital age. *In previous conflicts, drones were typically used by one side* to reconnaissance, like the U.S. operations in Afghanistan, the Middle East, or the Armenian–Azerbaijani war, *right now a multi-front drone war is brewing* [19].

3.3.1. Drones and loitering ammunitions used by Russia

Shahed-136 (GERAN-2)

The main role of this drone is to attack stationary ground targets by Pre-set coordinates. This drone is not efficient against moving targets. There are both advantages and disadvantages for the Shahed-136 (see Figure 7). The benefits of this drone is that the radar systems either do not detect or have difficulty detecting them. In an operational environment, it has proven to be resistant to anti-drone rifles and electronic warfare systems. The drone is launched from a rack, which holds 5 of these drones. The rack can be installed on a truck allowing for mobile „hit-and-run” operations. In traveling, it looks like a standard logistical truck with a canvas cover. The Shahed 136 is launched nearly horizontally and uses a rocket-assisted take-off. Last but not least, shooting down a surface-to-air missile costs much more than the price of this drone. On the other hand, the main role of this drone is to attack stationary ground targets, which coordinates are known. (pre-set coordinates) This drone is not efficient against moving targets. It is slow and very noisy. Its piston engine makes a characteristic lawnmower or moped sound. That is why the Ukrainians nicknamed them “flying mopeds” [20].

Figure 7.
Portrayed Unmanned Aircraft Systems (left: Shahed-136, right: Orlan-10) [41], [42]

Orlan-10 medium range, multi-purpose unmanned aerial vehicle (Special Technology Center)

A few more interesting things that make it more efficient than its peers. The Orlan-10 (see Figure 7) has electronic warfare capability and can distinguish between friendly and hostile means of transmitting information. It can be equipped with a jamming transmitter payload and is capable of creating zones for jamming the mobile phone network. An internal combustion engine, operating a two-blade propeller mounted in the nose, powers it. Developed by Russian state-owned *Roselectronika,* the GCS is able to control up to four UAVs at the same time [21]. It can be launched from a rack that is able to hold five of them. Its mobility makes it for a perfect candidate of conducting “hit and run” operations and can be covered with a canvas so it can be disguised as a common truck.

Kvazimachta, originally non-lethal “hardware lifting system” drone is designed to hover in place, unable to move outside the length of the electrical cable connected to the ground station that powers the drone. The tether is limited around 70 metres, but allows it to stay aloft for some time like from hours to days before it must be landed for maintenance checks. Even though it is only stationary, it has its advantages like providing persistent ISR, tactical communications and border surveillance. The Kvazimachta equipped with camera and telecommunications hardware allows it to serve as a "hovering mast" transferring signals to its specified destination as a relay station [22].

Chinese drone manufacturer DJI primarily designs its drones for filmmakers and photographers, but both sides in the Ukrainian conflict use DJI helicopters for reconnaissance, such as BDA[7] artillery correction, and small-infantry grenade launches. Cheap commercial drones like the Matrice 300 have dramatically increased combat visibility. Many were donated to Ukrainian troops. The latest Mavic is equipped with a low-quality telephoto lens that allows you to observe targets beyond hearing range. The quadcopter is powerful enough to carry and drop a single trigger-operated grenade (VOG 17-30 mm). Mavics are most commonly used as a form of psychological warfare. In Kharkiv, the volunteer Khartia battalion is dropping small, cylindrical projectiles on the Russian bases. Explosives cannot cause serious damage in a tank, but they can have a significant psychological effect on the enemy, who is afraid that a bigger attack could come at any moment.

3.3.2. Drones and loitering ammunitions used by Ukraine

The Switchblade 300 (see Figure 8) is a cross between a grenade launcher and a loitering projectile. There is a need for a drone aloft to communicate with the launched operating loitering ammunition of course. Why is this good? You do not need to have a CAS (Close Air Support) capable aerial vehicle in the air near you. It is enough to have a Micro-mini class drone nearby to mark the target and provide the necessary telemetry data and other recordings, such as target characteristics, coordinates and so on. Then the crew decides the necessity of the launch of the loitering ammunition from different platforms like ground asset, waterborne or under water surface.

Figure 8.
Portrayed Switchblade Loiter Ammunition (left: Switchblade 300, right: Aerorozvidka R18) [43], [44]

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[7] Battlefield Assessment.

Volunteers and IT professionals in response to the events of 2014 founded Aerorozvidka. Their aim was to help the Ukrainian armed forces, who were in dire need of reconnaissance capabilities. Such a drone costs about $20,000, and ammunition from abandoned or unused depots is free (e.g. RKG-3). R18 (see Figure 8) drones are reusable, have a small logistical footprint and are difficult to detect and shoot down by SAF (Small Arms Fire). Aerorozvidka claims that its products are more effective than the Bayraktar TB2 [23].

4. Civilian area of use

The main objective of the European Union was to accelerate the Drone Strategy that is why last November they published their initiatives in order to strengthen the drone service, drone market and other potential uses of drones in the European airspace. There are numerous policy objectives that should be taken into consideration like the green transmission, urban air mobility, industrial renewal and those cutting-edge technologies that may support R&D, and at the same time the dual, military-civilian use of drones. These ideas can be applied to all areas of drone use and have getting into focus due to the growing military expenditure with the war in Ukraine. The clear message of the European Union with the creation of *Drone strategy 2.0* is to support the market with the emergence of drone defence technologies and to exploit the synergies that arise in the use of military drones. The funding of this research and development program is supported by Horizon Europe and the European Defence Fund. The dual use of drones involves not only the SUAV, but also, mainly, MALE RPAS, which are of strategic importance and allow the protection of European airspace [24].

4.1. Emergency response and disaster management

Trends in number of reported disasters like drought, earthquake, extreme temperature, famine, flood, insect infestation, volcanic eruption, wave and surge, wild fire and windstorm have been rising due to the growing of human population, which means increased food and energy demands [25]. Drones, as excellent carrier platforms equipped with appropriate sensors, are also useful for disaster prevention, rescue and recovery. In this environment, the reduction of available resources can be a problem. Dwindling resources lead to a shortage of information, human and mechanical resources for search and rescue, making it difficult to assess the damage, detect victims and deliver aid.

4.2. Urban planning and transport

Drones play a major role in geospatial and land surveying for development. Crowded cities' administrations or companies can use it for traffic and crowd management. Fast take-offs and flights over cities or rural areas to collect data using automated flights reduce costs and fieldwork time. Creating 3D models with accurate, geo-referenced data that can be readily fitted into the BIM models[8] helps in visualising designs.

The sustainable air mobility is a key issue of urban transport all over the world. Roads are crowded, public transport networks are no longer expanding, but mobility is inevitable for transportation of goods, equipment and people themselves. Drone's flight altitude can affect the level of manned aviation, and at the same time, they must actively avoid obstacles on the ground to finally be safe enough for human transport. This area of drone use involves the most complex capabilities with equipment requirements that meet the principles of maximum robustness [26].

4.3. Conservation of endangered species

Drones are used to monitor wildlife and tagging animals or collecting samples. Drones help to get rid of poachers, replant forests destroyed by fires, and monitor populations of threatened wildlife.

4.4. Healthcare

Drones enable quick deliveries and access to drugs, blood and medical technologies in remote areas. Drones are now being used to deliver vital medical supplies to hard-to-reach areas. They also make live video feeds of high-risk birth procedures.

4.5. Agriculture

Drones help farmers to gather data and automate redundant processes to maximise efficiency. Agricultural drones allow farmers to monitor crop and livestock conditions from the air to keep watch for potential problems and help optimise field management. There are several functions of agricultural drones that farmers and other agri-business owners can use, including land imaging [27].

4.6. Weather forecasting

Weather drones aid in weather forecasting by physically following weather patterns. These drones can collect data on temperature, humidity, air pressure, wind speed and direction in different ways. One way is via temperature, humidity or air pressure sensors attached directly

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[8] Building Information Modeling (BIM) is an intelligent 3D model-based process that enables architecture, engineering, and construction (AEC) professionals to plan, design, construct, and manage buildings and infrastructure with greater efficiency, while providing a vastly improved workflow.

to the drone. Another possibility for data collection is offered by so-called dropsondes.[9] The precise weather forecast is a huge potential in many areas of business. Findings of drone-supported atmospheric measurement over a restricted area could engage cost-safe actions for business. There are many weather critical activities like road cleaning, precise agriculture, highway structure, etc. where the commonly spread procedures are expensive and at same time harmful for the environment [28].

4.7. Waste management

Drones help city administrators in the management of illegal dumping, identification of open dump areas, selection of landfill sites, landfill monitoring, calculating airspace of landfill, and collecting waste from coastlines. The University of Vigo in Spain has developed garbage-collecting drones to clean litter from beaches. Drones can monitor water quality using specialised cameras to help companies track this waste. A power company in China uses flamethrower-equipped drones to clean electric lines. Some areas use drones to watch locations of frequent littering to catch people in the act.

In most areas, laws are still regulating the use of drones in the field of industrial waste disposal, and some governments use drones to enforce these regulations. One of the most critical parts of waste management is ensuring the safety of protected environmental areas. Methane is odourless and colourless, so thermal camera-equipped drones allow companies to see it from a safe distance. To build a landfill safely, companies need to be sure they plan it well so it does not harm the surrounding environment. Laws require landfills to keep waste below a specific level of elevation, so sometimes they have to overfill cells. Drones can help landfill owners determine which cells to fill without causing a collapse. Landfills often fill individual cells as much as possible to make the most of their space. With the help of drones, they can better calculate compaction rates to determine how much to fill each cell [29].

Drones are used in mining to capture a lot of high-accuracy data fast across a mine site for constant measurement and assessment of the physical materials.

4.8. Telecommunications

Drones aid in quick assessment of problems, making servicing easier, danger-free and less time-consuming to conduct tower inspections and/or “tower based” equipment inspections. Besides that, drones are also used in telecommunications relaying, when the tower-based telecommunications are ineffective and do not provide coverage over the given area.

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[9] A dropsonde is a weather device that is designed to be dropped out of an aircraft at specified altitudes and due to the force of gravity, drop to the earth. During the descent, the GPS dropsonde collects data of the surrounding atmosphere that is remotely sent back to the aircraft by radio transmission.

5. Conclusion

This in-depth exploration of military and civilian drone applications aims to offer profound insights into the present dynamics and future trajectories of UAS. As it was highlighted in the introduction, this interdisciplinary field integrates aerospace engineering, computer science, robotics, and remote sensing, underscoring the necessity for collaborative efforts to propel UAS technology forward. Serving as a comprehensive guide, our study stands as a valuable resource for researchers and practitioners navigating the ever-evolving landscape of UAS research.

The transformative role of drones extends beyond their physical deployment on the battlefield, reshaping strategic thinking, military doctrines, and organisational structures. Nations leading in drone proliferation strategically prioritise key elements such as weapon-carrying capability, precision in strikes, adaptability to various zones, utility in military intelligence, and the capacity for autonomous operation. These considerations significantly shape the developmental trajectories of military drones. Nevertheless, military drones, encapsulated by the ISTAR acronym, play a crucial role in elevating situational awareness for decision-makers. Their capabilities, ranging from intelligence gathering to targeted strikes, underscore the evolving dynamics in modern warfare. The examples across micro, mini, tactical, and MALE/HALE UAVs showcase the diversity of purposes served, emphasising the versatility and technological advancements in this domain.

Examining armed conflicts around the globe highlights the evolving role of drones in warfare. Beyond targeted strikes, drones contribute to a display of force and the dismantling of ground infrastructure. The development of drones is increasingly influenced by the challenges posed in the combat micro-environment, the importance of visual imaging, the territorialisation of battles, and payload characteristics.

In the civilian domain, our study reveals the multifaceted roles of drones in emergency response, urban planning, conservation efforts, healthcare, agriculture, weather forecasting, waste management, mining, and telecommunications. From assessing damages during emergencies to optimising agricultural practices and contributing to efficient urban planning, drones have become indispensable tools, showcasing their potential to revolutionise various industries.

In conclusion, it must be noted that the implications of drone technology extend far beyond military applications, promising revolutionary advancements in industries, disaster response, healthcare accessibility, and sustainable environmental practices. As we navigate the complex landscape of unmanned aerial systems, collaborative research efforts, interdisciplinary approaches, and a nuanced understanding of ethical and societal implications will be paramount in unlocking the full potential of drone technology for both military and civilian objectives.

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Átfogó tanulmány a katonai és polgári drónalkalmazásokról: a legfontosabb területek és a jövőbeli kilátások felmérése

A tanulmány célja, hogy átfogó áttekintést nyújtson a pilóta nélküli repülőgép-rendszerekről (UAS), beleértve mind a polgári, mind a katonai alkalmazást a kortárs műveletekben, hangsúlyozva a jövőbeli fejlesztésekre gyakorolt potenciális hatásukat. Alapos elemzésen keresztül megvizsgáljuk a jelenlegi legmodernebb UAS-technológiákat, azok alkalmazásait, és értékeljük hatékonyságukat a különböző ágazatokban. Továbbá ez a kutatás betekintést nyújt a lehetséges pályákba és kihívásokba, amelyek a dróntechnológia további fejlődésével és mindennapi életünkbe való integrációjával kapcsolatban merülhetnek fel.

Kulcsszavak: *Nagorno-Karabah, Ukrajna–Oroszország, pilóta nélküli repülőgép-rendszer, engedély nélküli lőszerek, kettős felhasználás*

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