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المركز المصري للفكر والدراسات الاستراتيجية

EGYPTIAN CENTER FOR STRATEGIC STUDIES

UAV/DRONES

HISTORY, OPERATIONS, AND FUTURE

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UAV/Drones:

History, Operations, and Future

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EGYPTIAN CENTER FOR STRATEGIC STUDIES

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Foreword

The terms Unmanned Aerial Vehicle (UAV) and drones have been used repeatedly and broadly during the last decade, especially armed drones, becoming a central issue of both global security and human rights agendas.

Drones are bound to be part of the advanced arsenals of many states for the foreseeable future and may be joined by other new technologies, such as increasingly autonomous weapons systems. They are unique in some aspects, which necessitates special care in the regulation of their use. They make the long- distance deployment of targeted lethal force across national borders much easier than before, which might lower the war threshold. These remotely controlled aircraft allow the states using them to keep their own forces safe, while gathering information and directing force with great precision against their enemies.

But these advantages will make it easier to go to war, and to stay at war. Drones seem to make it easier for states to decide to use force in situations that may not qualify as armed conflicts, for example, in places far away from established battlefields. The increased use of drones raises the specter that targeted killing could become the rule, not requiring special justification.

UAV systems represent a significant advance in technology and are generating fundamental changes in warfare and the use of military force and force projection. In addition to the surveillance and real-time intelligence capabilities they provide, UAVs make it possible to target lethal force precisely and with reduced risk of collateral damage. They are a central element in ongoing efforts to suppress and eliminate the threat like from al- Qaeda and associated forces and have been used along with other military aircraft in the attack against the Islamic State (IS) in Iraq and Syria, **fig 1.**

UAV weapons are more accurate and discriminating than conventional bombing. They can loiter for extended periods over potential targets, with flight times more than three times greater than that of traditional surveillance aircraft. They allow operators to gather large amounts of information and provide the ability to launch pinpoint strikes against specific individuals or groups. Also, they enable engage in military operations over long distances without putting boots on the ground or incurring casualties among their own forces. They permit armed strikes in remote and dangerous locations where conventional bombing, or the use of ground forces would involve significant costs. UAVs overcome the limitations of human endurance among fighter pilots. At less than the cost of an F-16, they are easier to produce and more expendable than conventional combat aircraft. They provide the option of conducting prolonged counterterrorism operations with reduced risks to the forces using them as the previous experience while conducting GWOT campaign in both Afghanistan and Pakistan [1].

1- David Glade, Unmanned Aerial Vehicles: Implications for Military Operations, Occasional Paper No. 16 Center for Strategy and Technology Air War Colle, July 2000

A Brief History of UAVs and their Characteristics

Unmanned Aerial Vehicles (UAVs), more popularly known as "drones," have become emblematic of 21st century military technologies [1]. The term "unmanned aerial vehicle" is synonymous with "unmanned aircraft" and can be defined as an aircraft that is intended to operate with no pilot on board [2].

UAV acronym, definition, and synonyms:

The term "unmanned aerial system" refers to a UAV and its associated support and logistical elements. The term "remotely piloted aircraft" refers to the subset of UAVs that are controlled by a pilot who is not on board the vehicle, in contrast to an "autonomous aircraft", which refers to unmanned aircraft that do not allow pilot intervention in the management of its flight.

It should be noted, however, that several remotely piloted aircraft can fly autonomously without pilot intervention for managing portions of their flight, although remotely piloted and autonomous aircraft may pose many similar challenges and present gigantic debate especially in international law arenas.

Another definition of drones provided by the US Department of Defense (DOD) defines UAVs as powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.

Ballistic or semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered UAV, RPV, UAS or drones. Over that time, they have been called drones, robot planes, pilotless aircraft, RPVs (remotely piloted vehicles), RPAs (remotely piloted aircraft) and other terms describing aircraft that fly under control with no person aboard. They are most often called UAVs, and when combined with ground control stations and data links, form UAS, or unmanned aerial systems. Also, UAVs- by the DOD definition are either described as a single air vehicle (with associated surveillance sensors), or a UAV system (UAS), which usually consists of three to six air vehicles, a ground control station, and support equipment.

Brief history of UAV/drones

Over the past decades, drones have been used during many military battles, in various forms depending on the technological development that prevailed during each of these eras, and this use has developed since the nineteenth century, up to our present era. This development can be seen in the upcoming historical review:

Early history, World War I, interwar period, and World War II

UAVs had already been used in the early 19th century. Balloons were used to bomb enemy cities. In 1849, the Australians launched 200 pilotless balloons with bombs against Venice [3].**Fig 1**

Balloons were also used during the US Civil war (1862). Yet the use of balloons had another objective: aerial reconnaissance, as used on the French Revolution (1889), for example. At this point, it was clear that air power had two main objectives: tactical, for supporting ground forces through reconnaissance, supply, and communications; and strategic, for winning the war through the bombing of cities.

The outbreak of World War I (1914-1918) [4] marks the beginning of the Air War, since it was the first time when aircraft were used on the battlefield. However, the first use of airspace in war wasn't for combat, but for reconnaissance, **fig 2**. First raids had the objective of taking pictures and locating enemy combatants and line of supplies and communications. But soon the possibilities of air attack were exploited when pilots started to carry bombs or guns to strike armies, cities and factories. Air combat also started in WWI, when pilots shot each other in direct combat.

Besides aircraft, aerial torpedoes[5], **fig 3**, and flying bombs were also developed in WWI. Nonetheless, they didn't have as much success due to problems in the stabilization and operation of the new technologies. In the United States, in 1911, Elmer Sperry tried to use his invention, the gyroscope, on unmanned aircraft. Until the end of the war, he, along with Carl Norden and Glenn Curtiss, tried to develop an aerial torpedo, trying to use radio technology to control it, but it failed it could never be used on the battlefield.

Another project was being developed by the British, which was a radio-controlled aircraft. Its remote-control components, which designed by Dr. Archibald Low named "Queen Bee", then in 1918 Charles Kettering, from the US, developed an unmanned flying bomb, later called "Kettering Bug", **fig 4**, but it failed too, just like similar British and German projects. However, all this effort wasn't in vain: later they would be used for cruise missiles.

Projects of UAV weren't interrupted in the Interwar Period. The development of radio technology enabled the emergence of target drones, used on training exercises by the air defense forces. In 1936, the term drone was used for the first time to refer to aerial targets. In the United States, in 1938, aerial targets were used for the first time in naval training. Through the 1920s, the Royal Air Force from the United Kingdom tried to develop a radio-controlled unmanned aircraft **fig 5** that could bomb the enemy: Fairey Bee was created on 1933 and a later version, Queen Bee **fig 6**, fought on the WWII[6].

World War II (1939-1945)

It began with some UAVs under development, as Germany lost the previous war, its air force (Luftwaffe) was quenched. However, unofficially, the Luftwaffe was already being trained. The Spanish Civil War, in 1936, was the test for Germany's air force, and Guernica was the first victim of the Luftwaffe bombing. This was also the beginning of the Blitzkrieg when Air Force and Army acted together and coordinated. A defining point of World War II was the Battle of Britain (1940-1941), between the Luftwaffe and the Royal Air Force, due to the use of strategic bombing and radars. Germany developed an unmanned flying bomb called [7]"V-1", **fig 7**, which wasn't very effective, but did cause a lot of destruction.

Meanwhile, the British reaction was Project "Aphrodite", **fig 8**, an aircraft loaded with bombs that would take off with pilots, who would eject when the aircraft was passing the English Canal, and a "mothership" that would direct the aircraft to the target, but this also wasn't very successful. The UK, on the other hand, was pioneer in the development of radars and radio communication since this was needed to defend its insular position of the Luftwaffe bombing. At the end, one of the results of these two Great Wars was the development of new technologies for air power, which would change forever the ways to do war in the skies.

The Cold War and the War on Terror

By the end of World War II and beginning of Cold War, the breakthrough in advanced technologies, UAVs projects start to show real results. The Korean War (1950-1953) brought an innovation: the first operational unmanned helicopter, "QH-50", **fig 9**, from the United States. Afterwards, the Vietnam War (1955-1975) saw the most extensive use of drones until then and it was a turning point in the UAV history, because from that moment on sensors played important roll instead of a target which was a precious asset in reconnaissance missions [8].

The main UAV used by the United States in that war was the "Lightning Bug", an evolution of "Firebee". The central improvement of this new model was that Lightning Bug could be controlled by ground, unlike Firebee, that was launched and controlled from a plane. It performed 3,425 reconnaissance missions and was used to spy Chinese territory, in the 6 October War 1973 (Yom Kippur War), Israel used Firebees [9], **fig 10**, (brought from the United States in 1971) to break the anti-aircraft missiles from Egypt and neutralize its air defense. The use of UAV fueled Israel's interest in this new technology. Later, in the 1980s, that country would develop modern drones like the "Scout", **fig 11**, and the "Pioneer", capable of live video remote streaming. In 1982, when Israel invaded Lebanon (Al-Bekaa Valley operation), the country also used UAVs to damage the Lebanese air defense system.

Lots of projects of new UAVs were developed in the decades of 1960s, 1970s [10] and 1980s. The great majority was canceled because of the lack of investment or consecutive failed tests. One of these projects was "Aquila", **fig 12**, from the United States, in 1975. The idea was of an UAV that could provide laser designation for a precision munition strikes. The tests did well, but it was cancelled before it entered in production. One of the main obstacles was the size of the components (data link and mission payload), which didn't fit the vehicle due its big size and heavy weight.

The Gulf War (1990-1991) [11], which encompassed Operation Desert Storm and Operation Desert Shield, had a great use of UAVs, mainly the Pioneer, which United States had brought from Israel in 1986. This UAV is still in service after the Gulf War because of its great success, having flown in Bosnia, Haiti and Somalia In the 1990s, the United States gained experience in the use of UAVs (such as with the Pioneer, Hunter, Pointer, Exdrone and Predator in combat situations, which proved very important in the later War on Terror. In fact, the War on Terror was another turning point for the UAV history, when it, besides being a sensor, turned into a weapon.

After the 9/11 attacks, the United States launched Operation Enduring Freedom against Afghanistan (2001) and Operation Iraqi Freedom against Iraq (2003) [12], using UAVs for surveillance, but also – and for the first time – for target killing enemies. Equipping the UAV with weapons (Hellfire) was a remarkable step in the history of this technology, and the birth of the Unmanned Combat Air Vehicles (UCAVs). The main UAVs used on this war were the "Predator" to provide the lethal payloads and the "Global Hawk", for reconnaissance and field monitoring, besides the Israeli Hunter UAV. The Global Hawk was responsible for providing near-real-time, high-resolution intelligence, surveillance and reconnaissance images The Predator, by its turn, could serve both functions: surveillance or target killing. "When it's not firing Hellfire anti-tank missiles at the enemy, the Predator uses its powerful surveillance cameras to give the theater air component commander continuous real-time surveillance of the battlefield" Some of the Predator's devices are the synthetic aperture radar (SAR) and the de-icing equipment, which allows its use on overcast weather and for flying above the clouds – decreasing the risk of being detected by anti-aircraft fire – and the Ku-band satellite link, that allows the transmission of real-time full-motion video and facilitates the communication on air.

Unmanned Aerial Systems (UAS) were lately developed due to several reasons, such as advanced navigation. Communication technologies became available just a few years ago, and increases in military communications satellite bandwidth have made the remote operation of UAS more practical.

Significance and advantages of Drones

The continuous development of unmanned aircraft systems has imposed a diversification of their missions and operational capabilities, which has added to this type of air system qualitative characteristics and advantages in terms of tactical and strategic aspects.

Unmanned aerial vehicles (UAVs) offer two major advantages over manned aircraft: they eliminate the risk to a pilot's life, and they have aeronautical capabilities, such as endurance, which are not bound by human limitations. UAVs also protect the lives of pilots by performing dangerous missions that do not require a pilot in the cockpit. UAVs may also be cheaper to procure and operate than manned aircraft. However, the lower procurement cost of UAVs can be weighed against their greater tendency to crash, while the minimized risk to onboard crew can be weighed against the complications and hazards inherent in flying unmanned vehicles in airspace shared with manned assets.

For instance, the cost of drones is less and their size is smaller than manned aircraft. However, since a drone is not operated individually, but as part of a more complex system consisting of several aircraft, sensors, ground control, and satellite linkages, the number of personnel needed to operate a Predator Combat Air Patrol is estimated to exceed 80 people, and 128 soldiers are needed to operate a Platoon of four MQ-1C Gray Eagles. Still, in overall, drones present a slight advantage over mannedAircraft, therefore, when relating their low costs with their operational uses, it is shown the advantages to use drones in military operations. Drones like the Predator are often called "hunter-killer", since they can be used to fly in search for targets and strike them. Surveillance drones can be very effective since due to its low-flying capability they are difficult to observe with a ground-based radar because of their stealth capability. As a result, airspace at low altitude is not strictly controlled, making it possible for one to fly in contested and none contested airspace without being detected.

The significance of armed UAV can be concluded in four features as follows [13]:

- Due to their remotely piloted nature, armed UAV deployments pose little to no direct risk of harm to operators.
- Armed UAVs can loiter over a target or battlefield, providing real-time and persistent surveillance.
- When armed, UAVs can reduce the time between target identification and a strike decision. Unlike other intelligence, surveillance and reconnaissance capabilities, there is no need to deploy additional capabilities to deploy lethal force, depending on the command and control processes of the operator.
- Current-generation armed UAVs are highly susceptible to air defense systems and are relatively easy to identify and destroy or disrupt. New armed UAV systems are being developed to overcome these challenges.

Figures

Figure 1

Unmanned balloons with explosives 1849

Figure 2

Aerial reconnaissance and observation

Figure 3

Aerial Torpedo

Figure 4

Kettering Bug

Figure 5

Radio controlled aircraft

Figure 6

Queen Bee

Figure 7

German V-1 UAV

Figure 8

Aphrodite Radio-controlled aircraft

Figure 9

QH-50 UAV

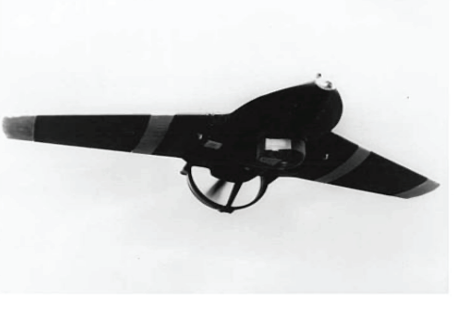
Figure 10

Firebee lunch from aircraft

Figure 11

Israeli Scout UAV

Figure 12



Aquila drone

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Classifications and Applications of the Use of UAVs [1]

UAVs have several unique characteristics that give them greater potential to be misused. These characteristics - such as, inter alia, their low cost, relatively small size and portability, as well as the perceptions of reduced risk of harm to operators, potentially lowering political risks associated with decisions to use force while simultaneously expanding the geographical scope of armed conflicts - include factors that make these systems more attractive to covert special forces, intelligence agencies and non-state actors than manned combat aircraft [2].

UAVs for civil and military use, including those used to conduct armed strikes, can be distinguished, and categorized based on physical characteristics such as maximum take-off weight, range, payload, endurance and means of command and control. Civil demand remains limited generally to small UAVs with a maximum take-off weight of less than 150 kg **fig 1**. Armed forces operate UAVs of all weight classes. Most armed UAVs are large systems with a maximum take-off weight more than 600 kg. There are examples, however, of armed medium-weight UAVs capable of carrying existing types of air-to-surface rockets. Furthermore, smaller systems can employ weapons, either by design or adaptation, and being flown beyond the visual line-of-sight of the operator.

Classification and functions

Governments and international organizations make use of various systems for classifying and categorizing UAVs. These classifications are generally based on several basic characteristics, particularly weight, endurance, and operating range. Various categories of UAVs also correlate generally with other characteristics, such as normal/maximum operating altitude, command and control capability, wing-type and typical uses or functions. The great diversity in the types and capabilities of all types of UAVs works against the establishment of all-encompassing classification systems.

Civilian and military authorities tend to structure their classification of drones based on maximum gross take-off weight and typical/maximum cruising altitude. While many national classification systems employ similar terms and basic approaches, definitions and the delineations between categories can vary.

UAVs Categories:

UAVs can be categorized, as mentioned above, in terms of wing design (rotary wings or fixed wings), range, altitude and weight [3].

1. **Small UAVs** are typically defined as systems with a maximum take-off weight of up to 150 kg. They are normally flown within the visual line-of-sight of the operator up to a maximum altitude of 500 feet above the ground. The development of UAVs of this weight class are experiencing the fastest commercial growth because of their low cost, ease of use and less complicated integration into national airspace. There is already an active market for civil/small UAVs for visual line-of-sight operations, although there is growing demand and interest in more advanced small UAVs capable of operating beyond visual line-of-sight, including for the purpose of routine commercial cargo and delivery flights. Although cut-off weights vary between national classification systems, small UAVs can be subcategorized as follows:

- **Miniature UAVs** are smaller than 10 kg and generally can be launched manually by a human. Some classification systems consider "mini" to extend up to 20 kg, a size at which catapults or some other form of assistance, such as rockets, a launch tube or use of a runway, become necessary for the launch of fixed-wing systems. Most UAVs used by militaries in target acquisition roles are small systems that fall within this subcategory and can be hand-launched.
- **Miniature systems,** which, in military roles, can be sophisticated enough to require a crew of two or more individuals to operate, are often further distinguished from "micro" UAVs, which are generally smaller than 2 kg and can be hand-launched and operated by a

single person. There are fewer examples of UAVs in this smallest tier, although it includes models designed for military use in intelligence, surveillance and reconnaissance (ISR) roles as well as for civil, commercial and recreational use.

2. **Medium UAVs** are typically defined as systems with a maximum take-off weight between 150 kg and 600 kg. Most systems in this weight class are operated only by militaries, mainly for use in ISR roles. They are typically operated below 18,000 feet above sea level, have a range of less than 800 km and an endurance of only a few hours. Payloads for these systems are generally below 100 kg, although larger systems in this tier, such as the Hermes 450 (Elbit Systems), can carry a payload in excess of 200 kg and thus can be adapted to employ existing types of air-to-surface rockets or other arms. These systems generally operate beyond the visual line-of-sight of the operator, who controls the system from a ground station. It should be noted, however, that most examples of systems in this tier are limited to radio line-of-sight operations.

3. **Large UAVs** are typically defined as systems with a maximum take-off weight above 600 kg. Existing systems in this weight class are currently in operation only by armed forces, where they are generally used in highly specialized missions, including long-term ISR and targeted strikes. This category includes the most complex systems, requiring a large logistical footprint similar to manned aircraft and a runway for take-off and landing. In comparison to other tiers, many large UAVs can operate at long ranges, beyond radio line-of-sight, via the use of satellites and/or other forms of data links, such as ground-, sea- or air-based relays and mobile telephone networks.

Ways to distinguish between classes of large drones:

- **Altitude and endurance** are commonly used to differentiate between categories of large systems. Although already obsolete in some classification systems, the category of medium altitude long endurance (MALE) UAVs is still frequently used, referring to systems that normally fly up to 45,000 feet above sea level and have an endurance of more than several hours. Most known armed UAVs currently in operation and under development fall into this subcategory and include systems such as the ASN-209 (Xian Aisheng), the MQ-1 Predator (General Atomics), the MQ-5 Hunter (Northrup Grumman), the MQ-9 Reaper (General Atomics) and the Hermes 900 (Elbit Systems).

- **High altitude long endurance (HALE) UAVs** refer to systems that can fly up to 65,000 feet. Systems of this class currently in operation are used for ISR missions, carry large and sophisticated sensor payloads, and include systems such as the RQ-4 Global Hawk (Northrup Grumman) and the BZK-009 (Guizhou Aviation). These are among the largest UAVs currently in operation and are designed to fly at altitudes above those of typical commercial aircraft.
- **Existing MALE UAVs** are used for tactical and battlefield support operations. Due to their unique characteristics, they perform missions that might not normally be assigned to manned aircraft. In comparison to manned aircraft, these systems are slower, often loiter for hours above potential targets and lack the means to counter sophisticated air defenses or to operate in contested airspace.
- **Several countries** are, however, planning or developing long-range strike UAVs that could incorporate stealth technology and fly at supersonic speeds, thereby enabling them to fulfil roles currently performed by manned combat aircraft and strategic bombers, including the employment of nuclear weapons. Current planned and experimental systems of this type include the X-47B (Northrop Grumman), the Neuron (Dassault) and the proposed Long-Range Strike Bomber.

Characteristics of and technological trends in civilian and military UAV [4]

As described above, definitions and guidelines used are of increasingly limited use in distinguishing between UAVs intended for civil use and UAVs capable of employing weapons.

A- Physical characteristics [5]

Certain physical characteristics, such as weight and payload. **Fig 2**

Weight continues to be a useful but non-exclusive means of distinguishing between military and civil UAVs. While examples of military UAVs can be found in all weight classes, the vast majority of civilian UAVs available on the market or under development are small systems with a maximum gross take-off weight of less than 150 kg. A number of manufacturers are developing much larger systems for civil use, which may, however, make weight a less definitive criterion in the future. For example, on 20 July 2015, the Spanish company Singular Aircraft conducted its maiden test flight of the amphibious Flyox I, which has a listed maximum take-off weight of 3,800 kg, including a maximum payload of 2,050 kg.

Most civil/small UAVs are not capable of carrying surface-to-air rockets and small diameter bombs designed specifically for use by UAVs. Most of these weapon systems, such as the China Aerospace Science and Technology Corporation AR-1 and the Lockheed Martin AGM-114 Hellfire, have a total weight of approximately 45 kg. It should be noted, however, that smaller missile systems have been developed for multirole UAVs, including those available for export, such as the 16-kg Tian Lei-2, which reportedly carries a 4-kg warhead.

Although weight and payload can be used to categorize UAVs, but due to a number of factors, they are not distinctive in distinguishing between weapons-capable UAVs and other types unarmed military UAVs despite the relevance of these characteristics for some arms control purposes. First, some of the largest and most capable military UAVs, such as the RQ-4 Global Hawk (Northrup Grumman) and the Hermes 900 (Elbit Systems), are designed and used primarily for ISR missions and not in attack roles. Second, UAVs commonly used for armed strikes are marketed as multirole systems, such as the MQ-9 Reaper (General Atomics) and the ASN-209 (Xian Aisheng), and are frequently exported in non-armed variants, largely for ISR missions. Third, currently, small UAVs are increasingly capable of carrying a lethal payload at long ranges beyond visual line-of-sight.

B- Command and control

1. Due to technological innovations, the ability to operate UAVs beyond line-of-sight is not useful as a distinguishing characteristic for differentiating between civil, unarmed military UAVs and armed military UAVs, especially as sophisticated command and control capabilities are not necessary for this purpose. Small UAVs for civil use are increasingly capable of being operated beyond radio line-of-sight via mobile telephone data networks. While the availability of such networks may not be relevant for state armed forces, this technological trend could have significant implications for the ability of non-state actors and relatively unsophisticated armed groups to adapt commercially available UAVs for use as long-range, remotely piloted munitions. Furthermore, there are a growing number of armed UAVs available for export that can operate via direct radio line-of-sight data links.

2. It is notable, however, that some of the most advanced military UAVs continue to be distinguished by their reliance on sophisticated means of command and control, including direct radio line-of-sight communication for launch, recovery and battlefield operations, as well as satellite and other relays for the cruise portions of flight. The operation of such systems entails a large logistical footprint with the possible widespread deployment of land-, sea- and air-based supporting infrastructure, including on the territory of third-party states. Depending on the type of support provided by third parties to UAV operations, this may raise issues of liability, transparency and accountability for those third-party states.

D- Loitering munitions

As a final observation, it is notable that certain remotely piloted vehicles have been designed to function as loitering munitions, hence there is a blurring line between UAVs and cruise missiles: Cruise missiles, these systems are essentially flying bombs and carry weapons or warheads that are integrated into the airframe. Notably they are generally much lighter than UAVs designed to carry air-to-surface rockets or bombs. Such systems in operation include the Harpy and Harop, both manufactured by Israel Aerospace Industries. Remotely piloted munitions, however, can be distinguished from cruise missiles, which are pre-programmed, fly along a pre-determined flight path and strike pre-determined targets [6].

3. The adoption of remotely piloted loitering munitions raises the specter that virtually no weight-based threshold could capture all UAVs capable of functioning as a weapon system. Some small UAVs under development, such as the Cutlass (L3) and the Futura (Alcor Technologies), are marketed as being capable of functioning as expendable munitions. The former features a payload of approximately 1.4 kg, comparable to the amount of high explosives contained within a heavy mortar shell or the Tian Lei-2 air-to-surface missile, and the latter has a payload of 10 kg, comparable to the size of the warhead carried by the AGM-114 Hellfire and AR-1 missiles. Small and expendable systems such as these may pose the greatest challenge for arms control, especially if they prove to be an attractive option for non-state armed groups.

UAV system components

UAV systems usually comprise modules that should be found entirely or partially in any system. A complex one composed of six main sub modules that work coordinately to obtain a highly valuable observation platform. **Fig 3** depicts a schematic view of each sub module.

1. **The UAV airframe:** A simple, lightweight, aerodynamically efficient and stable platform with limited space for avionics.

2. **The flight computer (autopilot):** The heart of the UAV. A computer system designed to collect aerodynamic information through a set of sensors (accelerometers, gyros, magnetometers, pressure sensors, GPS, etc.), in order to automatically direct the flight of an airplane along its flight-plan via several control surfaces present in the airframe.

3. **The payload:** A set of sensors composed of TV cameras (EO-electro optical sensors), infrared sensors, thermal sensors, etc.to gather information that can be partially processed on-board or transmitted to a base station for further analysis, or it can be Rockets or bombs in case of the armed drones.

4. **The mission/payload controller:** A computer system onboard the UAV that has to control the operation of the sensors included in the payload. This operation should be performed according to the development of the flight-plan as well as the actual mission assigned to the UAV.

5. **The base station:** A computer system on the ground designed to monitor the mission development and eventually operate the UAV and its payload.

6. **The communication infrastructure:** A mixture of communication mechanisms (radio modems, satcomm, microwave links, etc.) that should guarantee the continuous link between the UAV and the base station [7].

It is worthy to mention that current UAV technology offers feasible technical solutions for airframes, flight control, communications, and base stations that can be used for commercial and civil drones.

UAV military and civilian applications [8] fig 4

Unmanned aerial systems already started to alter not only contemporary force structures but also great part of civilian community activities as a result of this technology diffusion, In this regard, the US has increased its reliance on drones. Moreover, various studies in the military literature have started to focus on potential future effects of unmanned platforms and advanced payload they carry on conduct of warfare and military deployments around the world.

Moreover, the invention of and reliance on unmanned platforms may alter geo-strategic considerations as well. Operation of drones require infrastructure such as airfields around the world. Countries such as the US and the UK may consider utilization of drones when planning resource allocations. Besides, future aircraft carriers may carry significant numbers of unmanned aerial vehicles on board. As far as the current trends are concerned, political and financial limitations may encourage the polities to rely on unmanned aerial systems while conducting limited military campaigns.

Invention and use of unmanned aerial systems is a part of evolution of airpower. Since the first uses of airpower in the context of conduct of warfare, how to utilize it for desired strategic effects and to increase overall strategic performance will remains as a valid question, The vast majority of drone used, almost 90 percent, in main military applications utilize UAVs in ISR intelligence, surveillance, reconnaissance missions and battle field monitoring, hence the rest utilizing UAVs in combat mission or as known as targeting killing mission , also close combat support for ground troops in fighting areas and boarder monitoring in addition to counterinsurgency operations which the US and - recently - other nations relay heavily in this kind of missions on drones as was apparently in both Afghanistan and Pakistan.

Drones civilian applications and market [9]

Although it has yet to materialize, the market for UAVs in civil and commercial applications can be segmented several different ways. However, a consensus about how best to divide up this segmentation is beginning to emerge. It is expected that these markets will not emerge simultaneously, but experience will permeate between different sectors as UAVs are increasingly used. Government users are expected to be the first adopters within the civil market, based on knowledge of past and ongoing activities. Also of significance is military procurement, since it is expected that in the short-term, UAVs supposedly purchased for military activities will additionally be utilized in civil applications, such as maritime patrol or security for major events. It is also true that military experience of UAVs can infiltrate into wider government and commercial application markets. The main advantages of using UAVs for civilian purposes are broadly similar to those applicable in the military context. These include, perseverance, cost-effectiveness and the ability to function in an environment hazardous to human operator per se. Although all these mentioned advantages should result in a prosperous UAV civilian market, still legislative and regulatory factors are making the emergence of the market significantly delayed.

As stated earlier, the raise and high demand on procuring drones has

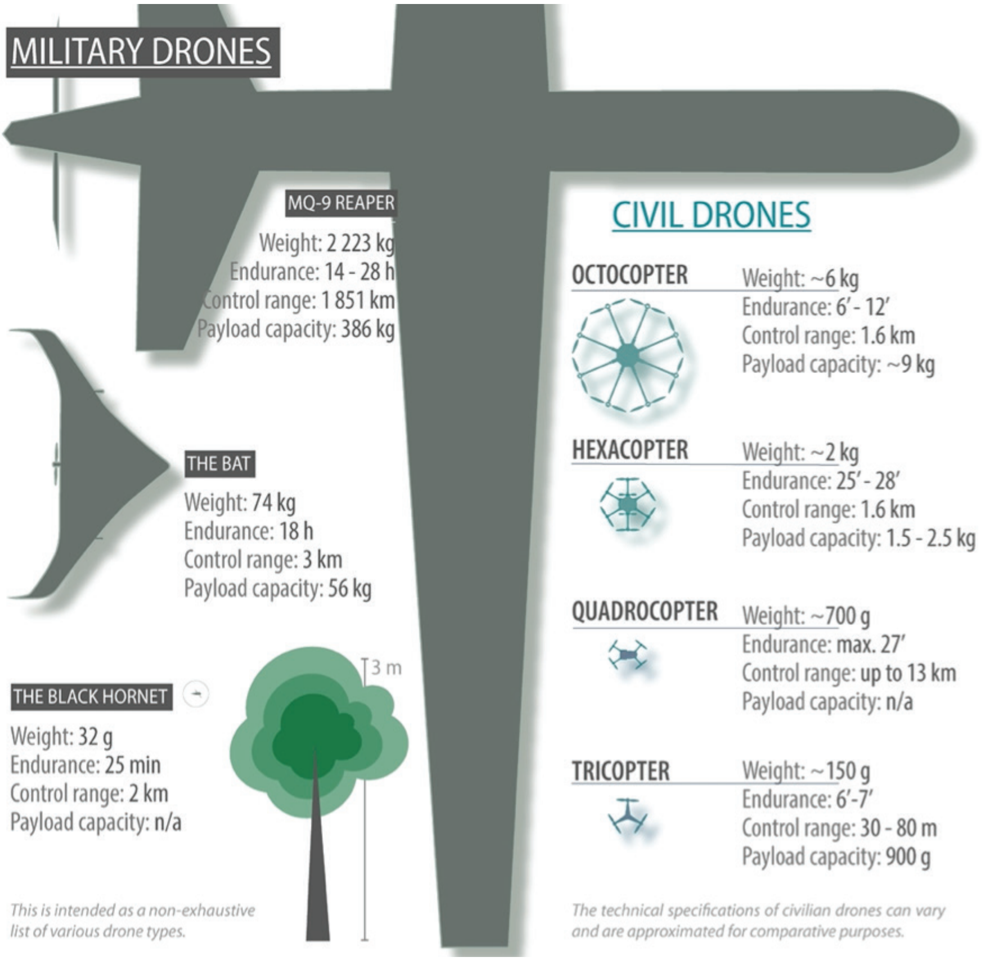
increased vastly throughout the last decade especially in the civilian market due their various usage such in many fields like:

aerial photography, search and rescue missions, inspection of power lines and pipelines, counting wildlife, delivering medical supplies to otherwise inaccessible regions and detection of illegal hunting, reconnaissance operations, cooperative environment monitoring, border patrol missions, convoy protection, forest fire detection and monitoring, surveillance, coordinating humanitarian aid, plume tracking, land surveying, fire and large-accident investigation, landslide measurement, illegal landfill detection, the construction industry, smuggling, and crowd monitoring, borders patrolling, scout property and locate fugitives. One of the first authorized for domestic use was the Shadow Hawk in Montgomery County, Texas SWAT and emergency management offices. Citizens and media organizations use UAVs for surveillance, recreation, news-gathering, or personal land assessment – a UAV was used to successfully locate a man with dementia who had gone missing for three days – archeology, cargo transport, healthcare, filmmaking, hobby and recreational use, law enforcement, scientific research, pollution monitoring, agriculture and pandemic response (China).

The goal of fostering the capabilities of UAVs can most easily be accomplished by removing many of the technical and regulatory barriers to civil UAV flight. This means that concerned organizations (NASA, ICAO...) must endeavor to develop technologies from the low technology readiness levels to ones that can be readily developed in the commercial sense. In addition, policies must be fostered to facilitate UAV flight in the National Air Space. As a result of these efforts, cost will become a lesser impact to market development. When these become reality, innovation and entrepreneurship will drive down the cost of UAV flights and enhance the safety, reliability, and operability of UAVs. As the costs go down and access to the airspace becomes routine, the market for UAV is expected to expand rapidly based on various market forecasts. This cost shift will drive the explosive market growth in the civil sector that is forecasted in several studies. This assessment will facilitate the market growth by identifying critical user-defined technology and capability requirements that currently do not have funding plans in place [10].

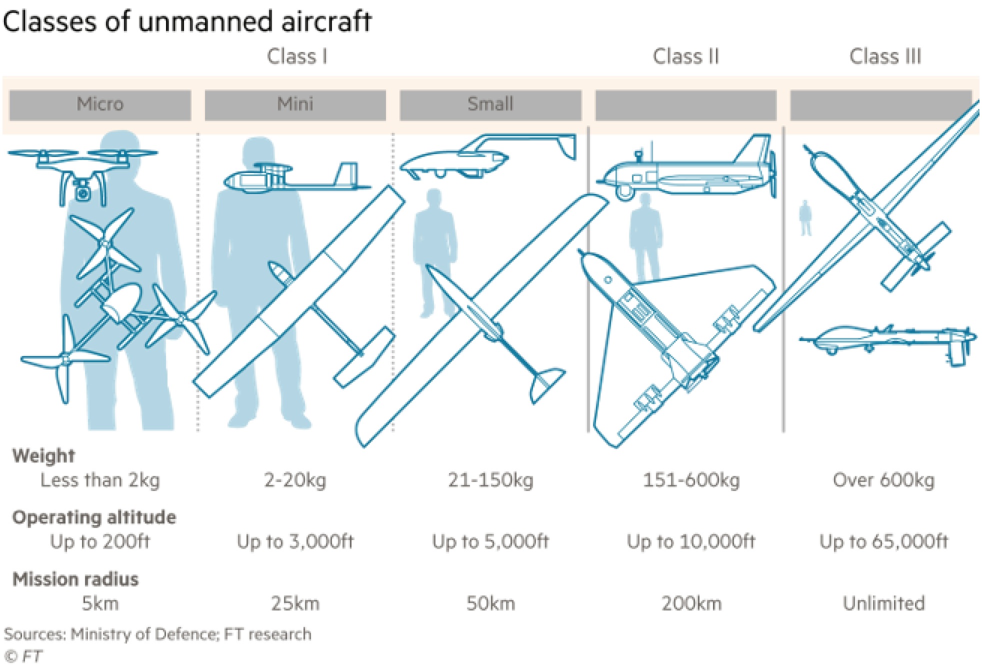
Figures

Figure 1



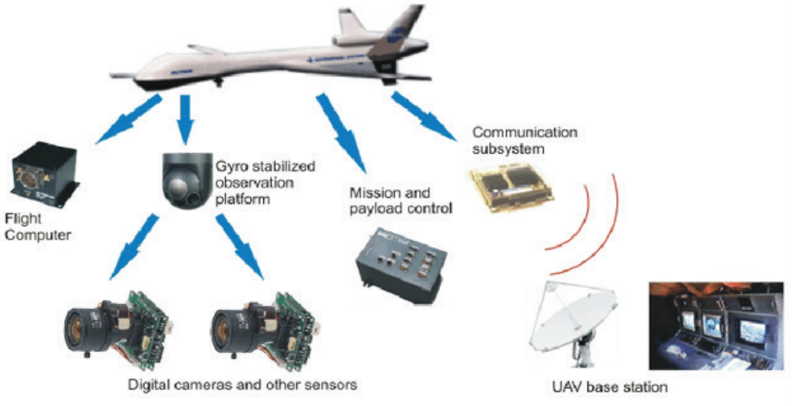
Military and civil drones

Figure 2



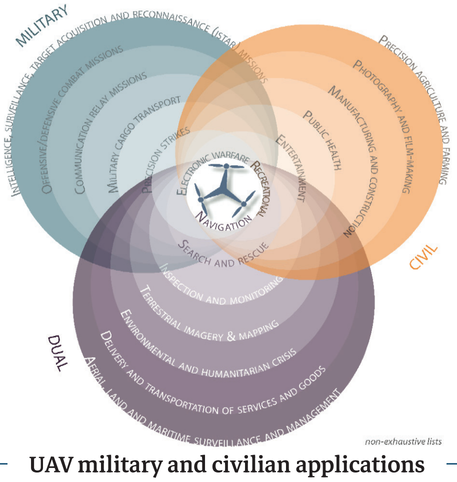
UAV classes

Figure 3



UAV surveillance systems

Figure 4



UAV military and civilian applications

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World Leading Countries in UAV Technology

Since there is no certain criteria to clearly classify countries in descending or ascending order other than information available from open source and media, the below order, essentially, will be based on the volume of procured systems and the declared systems in the country's inventory as a reference.

Yet, there are many UAV systems today, with different objectives and diverse characteristics. Nonetheless, UAVs are not restricted to the United States and Israel only. In fact, in the past decade showed UAVs have proliferated around the globe. The United States is still the country that most invests in UAVs procurement, R&D but this investment has shown to be stable. In the rest of the world, the interest on UAVs is growing. At least 95 countries now maintain active military drone programs **fig 1** recording a 58 percent increase over a decade ago, and that there are likely at least 21,000 military drones in operation around the globe[1]. Of these, 50 have projects to develop UAVs, but most are just proposals. 23 countries are developing armed UAVs (China, France, Germany, Greece, India, Iran, Israel, Italy, Lebanon, North Korea, Pakistan, Russia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Tunisia, Turkey, United Arab Emirates, United States and United Kingdom) **fig 2**. Israel and the United States are the largest exporters of UAVs, but China and Iran can also compete in this market (Davis, McNerney, et al. 2014).

The growing production of drones worldwide has been significant in recent years. As mentioned previously, the US and Israel, have really pioneered the adoption of UAVs for military applications, with European States beginning to make use of the technology on military operations from the mid-1990s.

Early experiences in Bosnia and Kosovo at times proved to be problematic and to have little major influence on situational awareness in theater, where deception, immature technology, weather conditions and most importantly a lack of understanding in how to best utilize UAVs combined to make an inauspicious beginning to the market in Europe, at least when compared to the growth since 2003. Research conducted by Frost & Sullivan has indicated that between 2004 and 2008, the number of UAVs deployed globally on operations has increased from around 1,000 to 5,000 systems. The great majority of this growth is driven by the United States, whose budget and current need is larger than any other country or region in the world[2]. **Fig 3**

European and United States forecast future investment in UAV This segmentation has emerged remarkably quickly and enabled UAVs to replace manned aircraft (such as Global Hawk gradually taking over from the U2, or the Predator taking over from the Canberra PR9), and offering new 'organic' surveillance capability to Land Forces. The emergence of hand-launched UAVs, in particular, has contributed to wider use and experience of UAVs in smaller countries in Europe, which may not otherwise have been able to afford larger systems. It is apparent that European military organizations have been gradually building up a critical mass in the experience and utilization of UAVs to the point where countries across the European Union are all either using UAVs or planning on procuring UAVs in the future. Whilst the US is set to remain the larger market, particularly in the military field, Europe is growing at a considerably faster rate, particularly in the short-term. In both the US and in Europe, the markets rapid growth has been consolidated around clear definable segments outlined in this chart **Fig 4.**

In this section we will overview key countries in the UAV industry in terms of technology, UAV procurement and of course the inventory:

United States of America

The United States will continue to lead the pack, with R&D spending increasing from an estimated $2.2 billion in 2020 to $2.7 billion in 2029, and procurement ramping up from $1.649 billion in 2014 to about $3.777 billion by the end of the decade, **fig 5**. Billions of additional dollars are expected to be invested when classified programs are taken into account. However, the US military will be the unrivaled leader in developing medium-altitude long endurance (MALE) armed drone technology; it is projected to account for 62 percent of all drone research and development and 55 percent of all procurement over the next decade. With a projected $80 billion in global spending over the next ten years, drones constitute a potential growth industry for the aerospace and defense sectors[3].

Military:

The US inventory has many types of drones and classes, depending on the branch of service or even the corps in each branch. for instance, army corps has different UAS which varied from micro/small UAV like Raven and Puma, medium like shadow and pioneer and heavy like gray eagle; I-gant or hunter, due the broad usage of these systems and its integration into NCW(as previously explained) to sustain the vast intelligence as much as possible in the operation area or battel field.

The US is the most open about its drone stocks. The IISS data shows that is has at least 678 drones in service, of 18 different types. Some 14 of them are identified as 'heavy', and includes UAVs such as the MQ-1B Predator, of which it has over 100 [4].

Currently the US has many UAS systems, such as [5]:

MQ-1 Predator, RQ-2 Pioneer, MQ-5 Hunter, RQ-14 Dragon Eye, RQ-16 T-Hawk, FQM-151 Pointer, CQ-24A K-MAX; Desert Hawk; MQ-1C Gray Eagle; RQ-4 Global Hawk; MQ-4C Triton; RQ-7 Shadow; MQ-8B Fire Scout/MQ-8C Fire Scout; MQ-9 Reaper; CQ-10 Snow goose; RQ-11 Raven; RQ-12 Wasp; MQ-19 Aerosonde; RQ-20 Puma; RQ-21 Blackjack; RQ-170 Sentinel; RQ-180; Black Hornet Nano; Coyote; Snipe NAV; Switchblade; ScanEagle; Northrop Grumman Bat, and more [6], **fig 6.**

Civilian UAVs:

Since 2006, DoD has had very specific and stringent guidance on the domestic use of DoD UAS. On occasion, DoD operates UAS domestically in support of a request from Federal or State civilian authorities. DoD only conducts these operations with the approval of the Secretary of Defense, who in 2018, delegated the approval of the use of smaller UAS to the Secretaries of the Military Departments, or the Geographic Combatant Commander where smaller UAS use supports Force Protection and Defense Support of Civil Authorities [7] **fig 7**.

Russia

Russian armed forces currently do not have armed drones, although the Ministry of Defense signed contracts with domestic aerospace firms to build a prototype by 2014, with the goal of the drones entering service by 2020. Russia claims to have developed the Lutch, an armed drone capable of holding 350 pounds of munitions and remaining aloft for 18 hours, although there are no known sales [8] .

Most of the UAV units in the Russian Ground Forces appear to be company-sized formations equipped with various Class I tactical systems. They are generally attached as organic support elements to Motor Rifle Brigades, each UAV Company is organized into platoons that each operate different UAVs [9]. Other Russian Ground Forces formations also appear to contain UAV elements of varying sizes. Several formations, such as the 16th Special Purpose Brigade in the Eastern Military District, incorporate UAV units that are probably smaller than a full UAV Company. The Russian Navy has activated one UAV regiment with the Northern Fleet and one UAV squadron with the Black Sea Fleet [10] Russian UAV inventory: **Fig 8**

Orion is a Class III fixed-wing UAV developed by the Kronshtadt Group. Possibility for a high-altitude long-endurance variant of the Orion is called the Orion-2[11].The Altair is a twin-engine Class III fixed-wing UAV. The Simonov Design Bureau (SDB) a high-altitude drone for arctic surveillance missions. The Okhotnik is a Class III fixed-wing UAV developed by Sukhoi, designed to serve as a combat drone capable of reaching a top speed of 1,000 kilometers per hour.67 The Forpost-M is a variant of Searcher Mk II developed by the Ural Civil Aviation Plant (UZGA). The Corsair is a Class II fixed-wing UAV developed by OKB Luch. This is a twin-boom aircraft with a push-propeller design. The Katran is a Class II rotary-wing UAV developed by Russian Helicopter Group. It is expected to replace the Schiebel Camcopter S-100. The Carnivora is a Class I fixed-wing UAV developed by NPP Mikran. It is designed for both strike and counter-UAV missions and is advertised as capable of operating in denied environments [12].

China [13]

China invests in drone programs, with at least 25 prototypes in development, including armed variants potentially for export. The Chinese aerospace spokesperson said that "the United States doesn't export many attack drones, so we're taking advantage of that hole in the market."[14] However, Chinese displays at air shows have been limited to models and computer graphics. Little is known about the Chinese program. According to a recent Pentagon report, "Data on the actual extent of [drone] production is nearly non-existent, and there is little available information on China's overall procurement objectives."[15] However, the available programs that belong to China can be concluded in the following types: **Fig 9**

The Wing Loong is a class III fixed-wing system developed by the Aviation Industry Corporation of China (AVIC). A scale model of the Wing Loong III's design, which is based on the Wing Loong I, was unveiled at the 2016 Zhuhai airshow[16].

The Divine Eagle is a class III fixed-wing system developed by Shenyang Aircraft Corporation with a 45-meter wingspan. The Divine Eagle is among the largest drones in the world. It has conducted test flights at Shenyang Beiling air base.

The cloud shadow is a class III fixed-wing drone developed by AVIC. It was unveiled at China's Zhuhai airshow in 2016 and features a wp-11c turbojet engine, sleek fuselage to carry out high-altitude surveillance and strike missions[17]. The AV500W is a class II rotary-wing UAV developed by AVIC. It was unveiled at the 2016 Zhuhai airshow. It is notable for being China's first strike-capable unmanned rotary-wing aircraft[18].

The TB-001 is a class III fixed-wing drone developed by Tengoen technology, the Chinese package delivery firm, has conducted field tests of a tb-001 modified for cargo operations[19] . The Caihong-7 (CH-7) is a class III jet-powered flying-wing system developed by the 11th research institute of the China Aerospace Science and Technology Corporation (CASC). It was unveiled in 2018 at the Zhuhai airshow. The Tian Ying is a class III fixed-wing drone developed by China Aerospace Science Industry Corporation (CASIC). Like the CH-7, the Tian Ying has a tailless flying wing design, though it is only half the size of the CH-7, with an estimated 10-meter wingspan. The JY-300 is a class III fixed-wing that will serve as an early warning aircraft, with miniature phased-array radar strips lining its fuselage. The Fei Long-1 is a class III fixed-wing UAV developed by Zhong Tian. The Yaoying-2 is a class III fixed-wing known as the "air sniper," and is a strike-capable system with a 16-hour endurance and 200 kilometer operational radius. The Qi Mingxing is a class III fixed-wing solar-powered UAV. The Feihong-98 is a class III fixed-wing system based on the Antonov AN-2, a manned Soviet-era biplane. The SD-40 sea cavalry is a class I fixed-wing vertical take-off and landing UAV.

Iran

Due to the international embargo and lack of technology transfer availability, Iran relies on local development programs. Hence, most of its drones are extremely crude and primarily used for anti-aircraft target practice. Several of Iran's more capable spy drones, like the Ababil III, were easily tracked down over Iraq by US fighter jets[20]. Iran also claims to have fielded an armed drone called the Ambassador of Death, which would effectively function as an imprecise one-time-only cruise missile. In the absence of an indigenous armed drone capacity, interested states are looking to buy UAVs form Iran.

The Iranian inventory **Fig 10** has at least 17 different UAVs (plus variants) in use or in development by Iran with six of these being UCAVs, the Ababil-T, Nazir, Ra'ad. The Sarir H-110 is based on the Israel Aerospace Industries Hunter and the Shahed-129 on the Elbit Systems Hermes-450. The Shahed-129 is reportedly capable of a missile payload for a non-stop 24-hour flight over 2,000 km. This is twice the range of the Karrar, a first generation Iranian UCAV. Such technological improvements are believed to have been made possible in part through reverse engineering of intercepted enemy hardware (such as Lockheed Martin RQ-170 Sentinel that Iran downed in December 2011)[21].

Israel

Israel has a rich history in UAV manufacturing and utilization due to the political situation and the security imperative which dictates the high alert of its forces. Israel is one of the world's leading exporters of drones in terms of volume, variety and number of countries exported to. Israeli companies were responsible for 41 percent of all UAV exports worldwide between 2001 and 2011[22] . Israeli UAV sales have amounted to $4.6 billion over the past eight years, making up nearly 10 percent of Israel's total defense exports[23] . This is projected to grow by 5-10 percent per year. At least 52 different UAVs (plus variants) are in use or in development by Israel, four of these being UCAVs, though there are likely more being developed in this latter category. Israeli UAV companies export to customers across Asia, Africa and Latin America. Searcher-II, Heron and Harpy UAVs have been sold to India and Azerbaijan has purchased $1.6 billion worth of Israeli military hardware, including Searchers, Herons and Hermes. The Harop and Harpy UCAVs are in service with India and Turkey, and China currently uses the Harop.

Israel's combat doctrine has, over time, shifted from conventional warfare characterized by classic battlefield force concentration to one typified by close-quarter and often low-intensity urban warfare in highly built-up civilian centers which requires precise strikes and heavily depending on intelligence gathering.

Of course, Israel's inventory, **Fig 11**, has many types of drones and classes, depending on the branch of service and level, such as army artillery Corps[24] use Skylark, skylark-3 and Hermes 450[25]. Meanwhile, the Naval Reconnaissance division uses Heron-1.

Drones (both surveillance and armed) will therefore continue to play a crucial role in Israel's existing theatres and conflicts. In the short to medium term, an increasing number of expendable drones (such as the Harop) are likely to be used in SEAD missions and possibly decapitation strikes at enemy leaderships. Israel is one of only three countries (together with the United States and Britain) known to have successfully used UCAVs for lethal strikes. The IDF will continue to be at the forefront of developing new tactical and operational doctrines using the latest drone technologies.

The Israeli inventory has many UAVs, such as: Army, Harpy IAI Israel I Loitering munition, Phantom1, Mavic2, Matrice3 Skylark Elbit, Skylark 3, Hermes 450 IAI, Air Force Hermes 9004 Elbit, Heron 15 IAI, Heron TP6 IAI

Turkey [26]

Turkey's UAV program started in the 2000s[27] and it was depending on Israeli-made drones to assist in its conflicts and dispute areas, especially in its asymmetric warfare with Kurdish rebels. Later on it came up with the first indigenous UAV Anka. Now Turkey considers itself as one of the top developers in the world in the field of UAV technology. It possesses more than 250 drones[28] . The army was using the Falcon 600/Firebee, the Canadair CL-289 and about two dozen of their own indigenous Bayraktar tactical UAVs. Their air force selected to use the Gnat 750/I-GNAT ER and the Heron. Their fleet has expanded greatly since then. Open Briefing has identified at least 24 different UAVs (plus variants) in use or in development by Turkey, with four of these being UCAVs. Turkey operates a special variant of the Israeli Heron. It uses Turkish-designed sub-systems and a more powerful engine for enhanced performance.

Turkey's inventory, **Fig 12**: Black Hornet. Serçe-1, Bayraktar Mini, Bayraktar TB2. Harpy, Kargu, Heron 1, Anka, and Karayel-SU.

France [29]

France is one of the most experienced users of military UAVs in Europe, with significant expertise centered in the 61st Artillery Regiment, which uses CL-289[30] and Sperwer UAVs. France was procuring significant numbers of the DRAC UAV in a contract ongoing to 2012. Also of significance is the likely procurement of replacement TUAVs and significant purchases of MALE UAVs. A number of different French companies are building partnerships to bring in Israeli or US developed platforms with French technology to meet this emerging requirement. It is also worth noting that France is likely to seek to procure jointly with other countries, with industry making joint offers to France and Spain in particular, France is expected to utilize UAVs across a wide range of civil applications, particularly for Law Enforcement.

Germany

Germany has a strong track record in the use of UAVs and is looking to acquire a full spectrum of UAV[31] capabilities, more so than any other European country. Headline procurement is the Eurohawk HALE UAV which will be utilized in a SIGINT role. Germany has also speeded up its plans to procure MALE UAV to meet ongoing operational requirements, and is expected to make a purchase decision in the near future. Germany's current extensive inventory of UAVs will also likely be replaced with new systems during the next 10 years. In particular, Germany is interested in the potential for micro-UAV and for VTOL UAVs. Germany is rated as having a high likelihood of utilizing UAVs in civilian applications, with particular focus on Law Enforcement, Energy Sector, Border Security and Agriculture.

Italy [32]

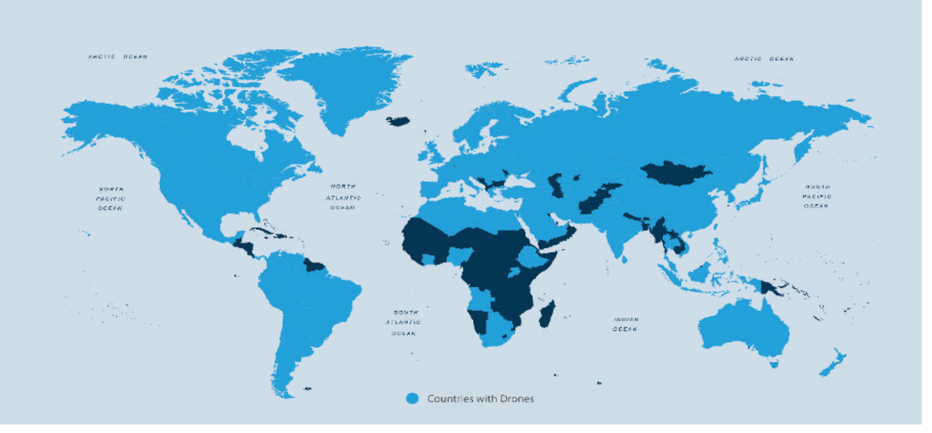
Italy has gained considerable experience in the use of military UAVs in Iraq and is expected to make considerable purchases in the future across all segments, with the exception of HALE UAVs. Italy is rated as a strong opportunity for using UAVs in civilian applications, particularly for maritime border security, Fire Fighting, Earth Observation and Remote Sensing missions. Finmeccanica's Sky-Y UAS and UAV Falco is targeted specifically at the civilian market.

United Kingdom

The United Kingdom has proven to be one of the largest markets for UAVs in Europe, with procurement of a significant number of UAVs **Fig 13**, largely in sync with major deployments on operations. As such, the UK has usually required on urgent operational requirements to provide a UAV capability, and has used this procurement route for its Desert Hawk Mini-UAV, its Hermes 450 TUAV and its protector MALE systems. The UK has also recently procured a small ducted-fan VTOL UAV for use on operations, known as the MAV. In the past the UK has used a number of different systems [33], including the Phoenix TUAV [34], as well as testing the Scan Eagle Mini-UAV from naval vessels. The UK is expected to continue its use of UAVs, which is further driven by the emergence of a parliamentary report encouraging greater and wider adoption of Unmanned Systems by the Ministry of Defense. The main program of interest is the Army's Watchkeeper program, under which around 58 air platforms will be procured, along with ground vehicles, stations and other elements. In the short-term, the UK will procure Predator systems to replace airframes lost on operations, and for this purpose has raised a potential sale of 10 systems with the US Defense and Security Co-operation Agency should more replacements be needed due to attrition. It is unlikely that the UK will invest in a HALE UAV, but both the Army and the Navy are expected to procure VTOL aircraft in the future. The UK is pioneering the use of UAVs in civilian applications, but due to restrictions imposed by regulators on the use of UAVs in non-restricted airspace, it is instead seeing industry taking a role of educating potential end users in the utility of UAVs through a number of different Partnerships, such as the South Coast Partnership, through which BAE Systems provides the use of a UAV system, but there is no procurement. However, a number of nonmilitary organizations have been actively looking at the potential provided by UAVs; Surrey Police conducted a study in their use, Merseyside Police procured some remotely piloted systems and West Mercia Police have utilized lighter-than-air systems for surveillance. Furthermore, the ASTRAEA program has allowed the UK to tackle the use of UAVs in civilian airspace in a practical manner. The UK is rated as having a high likelihood of using civilian UAVs in a wide range of applications.

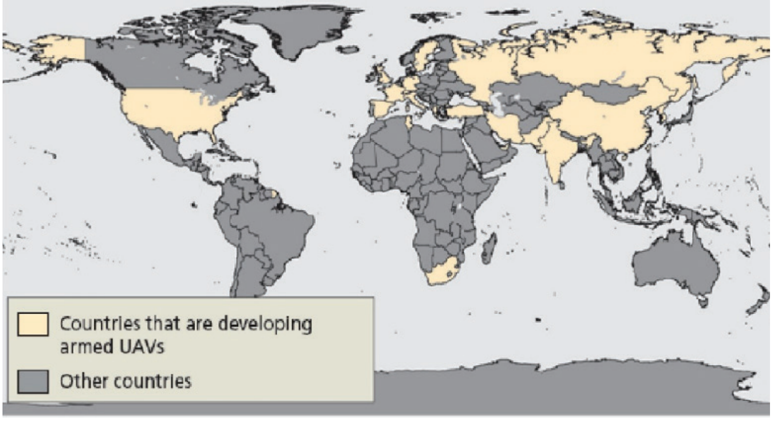
Figures

Figure 1



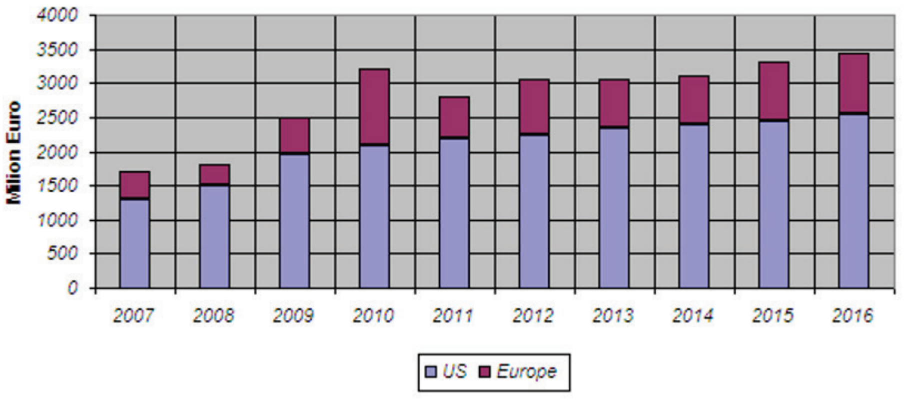
Drones programs around the world

Figure 2



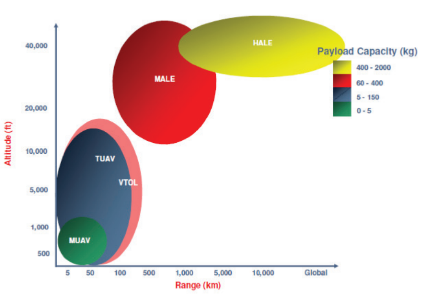
countries developing armed UAVs

Figure 3



The growth of UAVs budget around the world

Figure 4

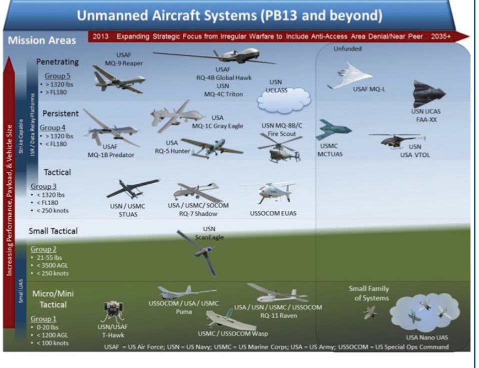


The classifications of UAVs according to altitude and range

Figure 5

U.S spending on UAVs systems

Figure 6



US Military UAV classification

Figure 7

DoD UAS Operations/Exercises	Requesting Agency	UAS Platform	Duration
Defense Support of Civil Authorities Southern Border Support	2-13th Aviation Regiment (TRADOC)	MQ-1C Gray Eagle 4	On Call Throughout 2018
DoD Installation Support Within DoD Airspace	Naval Station Kitsap-Bangor Submarine Base Kings Bay	RQ-11B Raven	2018
DoD Installation Support Within DoD Airspace	Marine Corps Base Camp Pendleton	DJI Phantom	2018
Defense Support of Civil Authorities Incident and Awareness Assessment California Sonoma/Napa Fires	Governor of California Cal Fire	MQ-9 Reaper	Oct 10 – Dec 31 2017
Defense Support of Civil Authorities Incident and Awareness Assessment California Thomas Fire	Governor of California Cal Fire	MQ-9 Reaper	Dec 5 – 31, 2017
efense Support to Civilian Law Enforcement Support to Counterdrug Operations	U.S. Customs and Border Patrol	RQ-21 Blackjack	Nov 2017 – March 201
Training and Exercises Operations Incident and Awareness Assessment Exercise Vigilant Guard	Governor of New York	MQ-9 Reaper	May 7 – 10, 2018
ublic Affairs Support Within DoD Airspace Air Show Support	Marine Corps Air Station Cherry Point	DJI Phantom	May 2018
Defense Support of Civil Authorities Incident Awareness and Assessment California Rim Fire	Governor of California Cal Fire	MQ-9 Reaper	Jul 1 – Dec 31 2018
Defense Support of Civil Authorities Incident Awareness and Assessment California Rim Fire	Governor of Oregon	MQ-9 Reaper	Jul 1 – Dec 31, 2018
Defense Support of Civil Authorities Incident Awareness and Assessment Hurricane Florence Flood Response	South Carolina National Guard Joint Force Headquarters	RQ-11B Raven	Sept 7 – 29, 2018

Some cases of the military UAV usage in civilian tasks

Figure 8

Russian Drones inventory

Figure 9

Major Chinese drones

Figure 10

Major Iranian drones

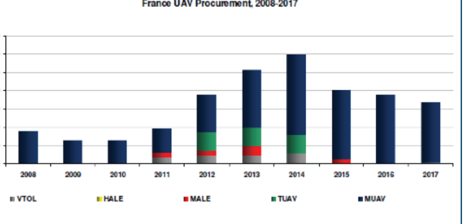
Figure 11

Israeli Drones

Figure 12

Major Turkish drones

Figure 13



UK UAV procurement

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The Implications of Using UAV Technology by Nonstate Actors

Among the most notable development that can be observed in recent years is the spread of unmanned systems among various regular armies as well as many terrorist and rebel groups, which has posed remarkable and important challenges to governments and armies around the world.

Given that UAVs have lowered the threshold for using lethal force, and the fact that the US has created its own criteria for what constitutes legitimate targets, states and nonstate actors are increasingly likely to adopt the use of drone strikes. We will explore this on two levels, those of state actors and non-state actors.

State Actors

It is estimated that the number of states that have acquired a complete drone system has grown from 41 countries in 2005 to 76 countries in 2012. Over that same period of time, the number of total drone programs within those states increased from 195 to 900 programs. As is the case in the US, the vast majority of all drones developed by other countries will be used exclusively for government or civilian intelligence, surveillance, and reconnaissance (ISR) missions. Some advanced industrial economies like Russia, Taiwan, and South Korea have developed increasingly sophisticated and largely indigenous drone capabilities, but they have also missed deadlines for when they would field armed drones, according to their own defense ministries. There is no international association for drone manufacturers and operators similar to those that exist for civilian nuclear facilities or commercial space launches that provides reliable information. In this essay, we will talk about the top 10 UAV countries in Europe, Asia, CONUS, and the MENA region who have unmanned aerial vehicle (UAV) programs.

Nonstate Actors

A few nonstate actors have developed armed UAVs. For instance, the Palestinian agents belonging to the Fatah movement who in December 2002 carried out IED model airplane attacks on Jewish sections in Jerusalem. These agents intended to broaden the scope and use hundreds of such model airplanes in similar attacks, but this plan never got beyond the flight test stage[1].

Three incidents subsequently took place where UAVs were to be used to launch attacks, reconnaissance, and for protest purposes. The first was in 2003 and was a joint effort by a Hezbollah cell that was supporting the Al-Aqsa Martyrs Brigade, an arm of Fatah. The intent was to launch an IED UAV attack on Jewish settlers in Gaza; however, the plot was interdicted by Israeli security forces[2].

Then, on 7 November 2004, a Hezbollah[3] drone was launched from southern Lebanon and engaged in a 20-minute reconnaissance operation over Nahariya in northern Israel. The Mirsad-1 drone was provided by Iran and was of military grade quality. There are conflicting reports of the drone either crashing in the sea off the Lebanese coast or returning to its Hezbollah base after the reconnaissance flight. The final incident took place on 11 April 2005 and involved another Mirsad-1 drone operated by Hezbollah from southern Lebanon. In this incident, the drone flew over the northern Israeli city of Acre as a form of protest of Israeli airspace violations in Lebanon, according to Hezbollah. The drone completed its mission successfully and return back to its Hezbollah base.

On 2 August 2019, the spokesperson of the Yemeni Houthi [4] movement (Ansar Allah) announced that the group had launched over 50 UAV attacks into Saudi Arabia between May and August of that year. The latest, titled Operation First Deterrence Balance, occurred on 17 August and saw Ansar Allah successfully target an Aramco gas facility deep into Saudi Arabia using 10 UAVs[5]. Ansar Allah does not have an air force. Its first recorded use of UAVs came in December 2015, when it flew a DJI Phantom series quadcopter – a commercially available hobbyist system – that it had been allegedly stolen from a local television station.

In January 2016, stories emerged of Ansar Allah deploying a UAV[6] in an ISR capacity in the province of Ma'rib.

The same model of UAV seen in December was shot down while reportedly carrying out further ISR operations by forces loyal to the coalition-backed president, Abd Rabbo Mansour. The seizure of a done by the United Arab Emirates Presidential Guard in a truck containing several unassembled Qasef-1 **Fig 1** UAVs in November 2016 cast further doubt on the technological capabilities of Ansar Allah. In January 2018, the United Nations Panel of Experts (PoE) on Yemen reported that this system is "virtually identical in design" to that of an Iranian Ababil-T UAV. However, Iran denied the whole story. The Houthi deployment of UAVs serves two key functions – punishment and propaganda. Despite the fact that the tactical advantage of UAVs is limited, the symbolic value of their use against the coalition and their territories is significant.

Nonstate actors could easily carry out similar terrorist attacks with explosives-laden drones that would inflict little damage. At the same time, it must be acknowledged that UAVs have unique characteristics that make them particularly susceptible to misuse in comparison to other technologies. These include their low costs, which can aid their rapid proliferation; their small size and precision, which can tempt covert armed forces and nonstate actors to use them secretly and without transparency, control, or accountability; and the minimal risk to their operators, which can lower political thresholds for the use of force which in turn would destabilize peace and security for the international community and international relations.

In what may or may not be considered a major escalation of nonstate drone capabilities, on 13 August 2006−during the Second Lebanon War-three Ababil (military grade) Iranian drones supplied to Hezbollah were launched against Israel from southern Lebanon **Fig 2**. Each drone was said to be carrying a 40-50-kilogram warhead and was intended for use against a "strategic target," according to Hezbollah. The threat was taken seriously enough that F-16 Israeli fighters shot down these UAVs near Tyre, Lebanon and near Haifa and Western Galilee in Israel. Upon inspecting the wreckage of some of these craft, Israel claimed that they were carrying warheads[7].

Four more escalatory incidents by Hezbollah and Hamas using UAVs took place between the latter part of 2012 and mid-2014. On 6 October 2012, Hezbollah sent an Iranian Ayoub drone over Dimona, Israel−a restricted area which contains that nation's nuclear weapons facilities–for reconnaissance purposes. The timing of the drone incident coincided with Israeli military exercise preparations. Given the sensitivity of this area, the drone was shot down by an Israeli F-16, although not until after it had been aloft for some hours.[8]Another Hezbollah drone of an unspecified type was shot down by an F-16 10 kilometers out to sea west of Haifa on 22 April 2013. The mission of this UAV is unknown.

A Hamas agent at a local university intended to send a UAV carrying explosives into Israel in October 2013, but was interdicted by the Palestinian Authority in Hebron. In the last of these incidents, on 14 July 2014, a homemade Hamas drone was shot down over Ashdod, Israel, by a patriot missile. This 5-foot-long drone was outfitted with small air-to-ground rockets and was on its way to engage an undisclosed Israeli target.

Terrorist and Insurgent Use of UAVs [9]

The use, and attempted use, of UAVs by terrorists and insurgents can at least be dated back to the 1994 attempts by the Japanese apocalyptic cult Aum Shinrikyo to conduct dry runs to release the nerve agent sarin by means of remote-controlled helicopters with aerial spray systems. The attempts failed as the mini-helicopters crashed during testing, with the terrorist group going on to utilize different dispersal methods when they launched their sarin attacks on a Matsumoto courthouse and later on the Tokyo subway system. The latter attack resulted in about a dozen deaths and 5,500 injuries.

The next incident was a July 2001 plot by Al-Qaeda to use an improvised explosive device (IED) to attack G8 Summit leaders in Genoa, Italy. This plot may have only entered the what-if stage, with Osama bin Laden musing about its potentials, but it is not clear whether the plot was ever put into motion. Two more Al-Qaeda plots followed: one in February 2002 out of Pakistan, and the other in June 2002 from an unspecified location. The first plot, which was tied to Moazzam Begg, sought to launch a drone filled with anthrax against the English House of Commons. [10] Begg was sent to Guantanamo Bay Prison for his involvement, but was later released in January 2005 after the original charges became questionable. The second plot involved IED-carrying remote-controlled planes being used against passenger airlines-though the plot is said to have never gotten beyond the concept stage.

Then, in August 2002, a Colombian army unit seized nine remote controlled planes from a camp deep in the jungle belonging to the Fuerzas Armadas Revolutionaries de Colombia (FARC) guerrilla group. The intended use of these planes is unknown, but some speculation existed that they may have been intended to carry IEDs[11].

Two Pakistani terrorist group-linked incidents then took place on 13-14 September 2005. In the first, the Pakistani army raided an Al-Qaeda hideout in North Waziristan. In the raid, they seized a Chinese made remote-controlled model airplane that was said to be used for the surveillance of Pakistani security forces prior to attacking them. The IED weaponization potentials of this model aircraft were also mentioned.

Ala Asad Chandia (Abu Qatada) was arrested in Fairfax County, VA, for obtaining an MP 1OOOSYS electronic automatic pilot system for model aircraft. This Lashkar-e-Taiba trained individual was federally indicted and subsequently convicted for attempting to send this technology to the terrorist group for its drone use in Pakistan.

Between 2006 and May 2012, two Al-Qaeda incidents and one Taliban UAV incident took place. In Columbus, OH, in 2006 or 2007 (exact dates are unknown), the Al-Qaeda-trained Christopher Paul was conducting drone research, utilizing a 5-foot-long model helicopter for terrorism purposes. He was arrested by the FBI in August 2007 and was subsequently convicted in June 2008 (he took a plea deal that resulted in a shorter sentence).

In the next incident, which took place on 28 September 2008, Rezwan Ferdaus−an Al-Qaeda affiliate−was arrested by the FBI in Ashland, MA. He was caught in a terrorist sting operation related to his plot to pilot F-86 Sabre and F-14 Phantom scale models (with GPS capability) loaded with C-4 explosives into the Pentagon and Capitol buildings. He was convicted for this plot in 2012 and also took a plea deal for a shorter sentence. Finally, on 19 May 2012, an allied raid on a Taliban base in Helmand Province, Afghanistan, turned up a small drone-possibly a NATO Desert Hawk-along with some IEDs and small arms. The intended Taliban use of the drone was unknown, quite possibly for reconnaissance purposes, though it appeared slightly damaged in a photo of the arms cache and no control unit was found with it.

The Islamic State (IS) [12]joined the nonstate threat drone proliferation club with three successful UAV operations in August and September 2014. The first incident was on 23 August 2014 near Raqqa province in northern Syria. It involved the use of a commercial system–a DJI Phantom FC40 quadcopter **Fig 3** –to recon Syrian Army Base 93 prior to an IS ground assault on the base. The quadcopter video imagery was subsequently used in IS propaganda videos. On 30 August 2014, an unspecified IS drone was used over Fallujah, Iraq, to provide imagery of attacks on the city for online propaganda purposes. In the last IS operation on 12 September 2014 in Kobani, northern Syria, another unspecified drone was used to capture video imagery of suicide bomber and ground attacks on that city for propaganda purposes.

On 21 September 2014, Hezbollah engaged in a successful drone strike operation against Al-Nusra Front–an Al-Qaeda-linked group–near Arsal in northeastern Lebanon. Twenty-three Al-Nusra terrorists were said to have been killed in the attack, which was followed up by a group assault–an incident that ushered in terrorist-on-terrorist drone warfare. Whether the drone utilized in the attack carried a warhead or air-to-ground projectiles is unknown. A final incident involving terrorist and insurgent use of UAVs occurred on 16 March 2015, near the city of Fallujah, Iraq. In that incident, an IS militant flew a small model aircraft for about 20 minutes. After the drone landed, the IS operative placed the drone in the trunk of a car and proceeded to drive off, at which point US coalition military forces launched an airstrike destroying the insurgent, the drone, and the vehicle[13].

Figures

Figure 1

Qasef UCAV

Figure 2

Hezbollah drones

Figure 3

Phantom DJI4 drone

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The military use of UAVs

The emergence of UAV technology gives states the ability to conduct more efficient military operations by lifting the fog of the war and giving a precise picture of the arena, which has helped for quicker decision-making on different levels.

In this section, we will discuss historical cases where UAVs were used and explain their benefits in these operations:

- The Iran-Iraq War (1980-1988).
- The First Gulf War (1991) and the Second Gulf War (2003-2011).
- The Azerbaijani-Armenian War in Nagorno-Karabakh (September 2020).
- The latest clash between the Israeli army and Hamas in the Gaza Strip (May 2021).

Iran-Iraq War (1980-1988):

This was a prolonged military conflict between Iran and Iraq. Open warfare began on 22 September 1980, when the Iraqi armed forces invaded western Iran along the two countries' joint border, though Iraq claimed that the war had begun earlier that month, on September 4, when Iran shelled a number of border posts. Fighting was ended by a ceasefire in 1988, although the resumption of normal diplomatic relations and the withdrawal of troops did not take place until the signing of a formal peace agreement on 16 August 1990.

Background of UAV use

This war can be considered the real starting point of using UAVs in the region. During battles, the Iranian army, with a lack of spare parts for its US-made fighter jets, began to examine the possibility of locally producing UAVs for reconnaissance to avoid the risks of using fighter jets. So, several universities and military factories related to Islamic Revolutionary Guard Corps (IRGC) started in 1983 to develop a UAV for this purpose. Quds Air Industries and the Iran Aircraft Manufacturing Company (HESA) were among the most important centers that worked on designing and manufacturing UAVs for surveillance and reconnaissance missions **Fig 1**. In 1985, Quds Air Industries, following the culmination of the Iraq-Iran war, began to produce a small model UAV equipped with low resolution cameras. These models managed to take useful photos of Iraqi positions from a distance of three kilometers. On the heels of this success, the company began in the same year to produce Mohajer-1 , which can be categorized as a single-engine tactical UAV.

Mohajer-1[1] Fig 2

Features

This UAV had a narrow cylindrical fuselage, twin tail booms, and straight wings mounted high and to the rear of the body. It had a single engine in a pusher configuration, and was guided by ailerons on the wings, an elevator on the horizontal stabilizer ,[2]and rudders on the tail booms. This type of UAV also had three fixed landing gears for launch and recovery. It could also be recovered by parachute. The Mohajer-1 was about 8 feet long and had a wingspan of about 10 feet.

The Mohajer-1 UAV carried a single still camera, fitted with film that was developed after the drone landed. It was controlled by a hobby-class radio, which was easily jammed. Iran attempted to turn this type in to an unmanned combat air vehicle (UCAV) by arming it with six RPG-7 rockets, three under each wing, though this was not very successful. The Mohajer-1's range is not definitively known, but it was severely limited by the hobbyist radio link and lack of an autopilot system, which meant that the aircraft could only survey Iraqi positions when operated from the Iranian front lines. There are no details on the Mohajer-1's airspeed, endurance, or ceiling.

Mission Imperatives

Providing reconnaissance, surveillance, and target acquisition (RSTA) and performing indirect gunfire correction/support.

Examples of UAV achievements

The Mohajer-1 was operated by the IRGC's Raad Brigade and was used to correct artillery fire and photograph

Iraqi positions. The Mohajer-1's first known use was in Operation Dawn-8 in 1986 [3], and it was also used in Karbala 5 in 1987. The UAV photographed Iraqi lines and completed 619 sorties by the war's end, taking 53,772 photographs in total, covering a 18,570 square-kilometer area between 1986 and 1988.

Gulf Wars

Background

After Iraqi president Saddam Hussein ordered the invasion and occupation of neighboring Kuwait in early August 1990, the UN Security Council demanded Iraq's withdrawal from Kuwait, but to no avail. By mid-January 1991, the Gulf War began with a massive US-led air offensive known as Operation Desert Storm. After 42 days of relentless attacks by the allied coalition in the air and on the ground, US President George H.W. Bush declared a ceasefire on 28 February.[4]After almost 13 years, on 20 March 2003, a coalition of countries, principally the US and the UK, invaded Iraq, contending that the Iraqi government, still headed by Saddam, had developed or was in the process of developing chemical weapons and weapons of mass destruction. The Second Gulf War lasted just three weeks and ended with Saddam Hussein's overthrow[5].

In these two wars, separated by nearly a decade, the utilization of UAVs on the battlefield was part of the employment of so-called network-centric warfare (NCW) , which is defined as an information-superiority enabled plan of operations that generates accumulated combat power. NCW aims to achieve shared awareness by synchronic forces, speed of command, faster tempo of operations, larger lethality, more survivability, and a degree of self-synchronization by networking sensors, decision makers, and shooters. Having a better, near-real-time picture of what is happening in the battlespace reduces the level of uncertainty-the gap between what a commander needs to know and what he does know-in a meaningful way. The networking of surveyors that can perform numerous missions such as intelligence, surveillance, and reconnaissance in near real time provides the basis for developing and leveraging information superiority and battlespace awareness. For instance, the time from target acquisition to release of weapons (the sensor-to-shooter gap) was reduced from days or hours in the First Gulf War to hours or minutes in 2003.

The use of drones as surveyors has great potential to transform the battlespace by ensuring tactical responsiveness and extending the sight and reach of military power. A Predator UAV ground control station is equipped with an electro-optical-infrared surveillance system, an ultra-high frequency, and a voice relay package.

The use of UAVs during the wars

The main role that UAVs performed in these wars was ISR missions. This role has since become a major choice for field commanders. The main goal of ISR missions is to obtain real-time intelligence, which improves force capabilities. The biggest enhancement seen in UAV use throughout this period was in command and control, data processing, communications technology, image exploitation and processing, enhancing on-board sensors (precision, and weight), new platform design, the invention of powerful propulsion systems, and extended UAV endurance[6].

UAV types used in this war

Four main UAV systems (RQ-2B Pioneer, RQ-5Hunter, MQ-1B Predator and RQ-Global Hawk) were used in combat situations.

RQ-2B Pioneer[7] Fig 3

Features

The Pioneer is both a shipborne and land-based tactical, close-range UAV that can perform a wide variety of missions such as reconnaissance, surveillance, target acquisition and battle-damage assessment and provide commanders with real-time imagery of the battlespace. It has a great degree of cover as a result of its low radar cross section, reduced silhouette, low infrared signature, and remote-control versatility.

Background

The RQ-2B Pioneer has been in the service of the Navy, Marine Corps, and Army since 1986. It performs ISR missions for amphibious forces. Launched by a rocket-assisted, pneumatic launcher, or from a runway, it lands on a runway with arresting gear after flying up to five hours with a 75-pound payload .

The UAV uses a C-band, line-of-sight (LOS) data link to relay analog video in real time. The Pioneer has performed ISR missions since the Gulf War in 1991 and supported Marine forces in Operation Iraqi Freedom (OIF).

RQ-5A/MQ-5B Hunter [9]

Fig 4

Features

The Hunter is a joint-tactical UAV that is capable of performing ISR, battle-damage-assessment, target-acquisition, and battlefield observation missions. The primary payload on the RQ-5A is the multipurpose optical stabilized payload (MOSP), which includes a camera and forward-looking infrared (FLIR) to provide day and night surveillance[10].

Also, some Hunters are equipped with new sensors such as a third-generation FLIR and a spotter for the daytime TV camera. The other advanced mission payloads that the Hunter can carry include a laser designator, electronics-countermeasure payloads (i.e. a communications warning receiver, communications jammer, and radar jammer), and a communications-relay payload that extends VHF/UHF communications beyond line of sight.

Background

The RQ-5A Hunter was originally a joint Army-Navy-Marine Corps short-range UAV that the Army intended for division- and corps-level requirements. The program was initiated in 1989 and the first Hunter entered the service in 1996. It was deployed to Iraq in 2002. The MQ-5B Hunter dropped a laser-guided bomb on a target in Iraq in September 2007.

FQM-151 Pointer[11]

Features

This hand-launched system is a low-cost reconnaissance UAV designed to support battalion commanders or other users needing a short range "eye in the sky." This aircraft is powered by a 300-watt electric motor. The flight control system consists of an uplink which only allows a range of about 5-7 kilometers from the ground control unit. It is made of composite materials and is easily assembled from six parts which are interchangeable with other air vehicles. It currently carries a payload of either a color TV camera, or a black and white low-light-level TV camera, which provide real-time, high resolution video imagery[12].

Background

The Pointer was designed by AeroVironment Incorporated, with company funds, with the US Army and Marine Corps obtaining a total of about 50 beginning in 1990. The radio-controlled

Pointer was built mostly of high-impact Kevlar. Its first flight was in 1988, and it was mainly designed to provide over-hill surveillance.

MQ 1B Predator[13] Fig 5

Features

The MQ-1B Predator is a medium-altitude, long-endurance (MALE) UAV which is employed as a theater asset for ISR and target acquisition, even though it is a hunter-killer for critical, time-sensitive targets. A fully operational Predator system consists of four aircraft, a ground-control station, a primary satellite link, and approximately 55 personnel for round-the-clock operations. The aircraft can be dismantled, and the ground-control system can be transported in a C-130 transport aircraft.

The basic crew for the Predator is one pilot and two sensor operators who fly the aircraft via a line-of-sight data link, or a satellite data link for beyond line-of-sight flight. The aircraft is equipped with a color nose camera, a variable-aperture daytime TV camera, a variable-aperture infrared camera for low light and nighttime missions, and a synthetic-aperture radar (SAR) to look through smoke, clouds and haze. The cameras produce motion video while the SAR produces still-frame radar images.

The MQ-1 Predator can employ two laser-guided AGM-114 Hellfire anti-tank missiles with the multispectral targeting system (MTS).

Background

The Air Force MQ-1 Predator was one of the initial advanced technologies in 1994 and transitioned to an Air Force program in 1997. It has flown ISR missions in conflicts since 1995. It was re-designated from RQ-1 to MQ-1 after gaining the ability to employ Hellfire antitank missiles in 2001. The Air Force employs 12 Predator systems stationed in three squadrons.

RQ-4 Global Hawk [14] Fig 6

Features

The RQ-4 Global Hawk is a high altitude, long-endurance (HALE) UAV capable of precise targeting of weapons and protection of forces through superior surveillance. Cruising at very high altitudes, the Global Hawk can provide battlefield commanders and decision makers with near real-time, high-resolution ISR imagery. Global Hawks carry both an EO/IR sensor and a SAR with MTI capability, allowing day-and-night, all-weather reconnaissance. Sensor data is relayed over beyond-line-of-sight (BLOS) data links to its mission-control element, which distributes imagery to up to seven theater exploitation systems.

Once mission parameters are programmed into the Global Hawk, the UAV can autonomously taxi, take off, fly, and remain on station-capturing imagery before returning and landing [15]. The navigation and sensor plans can be changed during flight by the operator in GCS. The Global Hawk completed its first flight in February 1998, and entered the service for OEF in Afghanistan after the terrorist attacks on 11 September 2001, and served in OIF in Iraq.

UAV efficacy in both Gulf wars and role evaluation

The effectiveness of UAVs in both wars was obvious, which grabbed the attention of leaders on different levels for their future in military operations. During these wars, the UAVs showed their strengths and weaknesses, which gave a chance to learn from these lessons and make improvements.

First Gulf War [16]

The first incorporation of UAVs in this war was as a critical source of intelligence at the tactical level, conducting aerial patrols along the Saudi-Kuwait border. At least one UAV was airborne at all times during Desert Storm[17].

Mission imperatives

The mission was to constantly provide highly valued, near-real-time reconnaissance, surveillance, and target acquisition (RSTA) and battle-damage assessment (BDA). The UAVs also performed direct and indirect gunfire correction/support.

Operations proved that UAVs have the potential to fill the gap between manned platforms and satellite-reconnaissance platforms[18].

UAV mission achievements

The US Navy utilized UAVs to monitor the Kuwaiti coastline and Iraqi naval facilities and search for mines. The Pioneer’s ability to spot gunfire from US battleships in real time increased the accuracy of the big guns. The attack on the Iraqi-held Kuwaiti airport was another example of the utility of Pioneer UAVs. During this encounter, a real-time Pioneer UAV image indicated a battalion of tanks poised on the north end of the airfield for a counterattack. The Iraqi force was broken up by airborne and naval gunfire attacks before it could strike the advancing Marines[19]. In another instance, Iraqi soldiers surrendered to a Marine Pioneer during battle in Kuwait.

The UAVs also detected numerous Iraqi patrol boats, conducted a successful strike on two high-speed boats, and determined the location of two Silkworm anti-ship missile sites, 320 ships, and antiaircraft artillery positions, as well as conducted pre- and post-assault reconnaissance of Faylaka Island. As the war progressed, Navy Pioneers sent back images of surrendering Iraqi troops and the retreat of major armored units. They also enabled the Army to eliminate threats from enemy artillery to support friendly forces in the field.

The Army's Pioneers flew 155 hours and 46 sorties, providing a quick-fire link that allowed the targets they identified to be quickly engaged by other systems. Army Pioneers also helped tactical commanders to conduct situation development, targeting and BDA. Marine UAVs flew 318 hours and 138 missions during Operation Desert Shield and 185 missions and 662 hours during Operation Desert Storm[20].

The Pioneer system appears to have validated the operational employment of UAVs in combat. US forces deployed 43 Pioneers to the combat theater, flying 330 sorties and completing over a thousand flight hours. During the conflict, the US Navy flew the Pioneer for 213 hours and 64 sorties from the USS battleships Missouri and Wisconsin, conducting target selection and naval-gunfire support.

Second Gulf War

Due to the complex and dynamic environment in the operation theater, there was need for better and faster intelligence gathering. The advancements achieved in communications enabled the ideal usage of UAVs in this war.

Mission imperatives [21]

The UAVs' main role was collecting intelligence and providing time-critical targeting information via streaming video to other weapon systems.

The Global Hawk was a showcase for new concepts in time-sensitive targeting. As a result, even though Global Hawks flew only 5 percent of the OIF high-altitude missions, they accounted for 55 percent of the time-sensitive targeting against enemy air-defense equipment[22].

On 8 March 2003, the AV-3 arrived on the theater and was tasked with three missions that technically fell under Operation Southern Watch, the enforcement of the no-fly zone over southern Iraq. These missions became part of the prewar air campaign that helped strip away Iraq's air defenses. The UAV helped locate surface-to-air missile set-ups and potential Scud sites.

The Global Hawk played a pivotal role in coalition strikes on targets such as the Republican Guard. Strike planners could dispatch aircraft such as the F-15E to conduct strike coordination and reconnaissance (SCAR) for designated target areas, known as "kill boxes." Three hours in advance of an attack, it collected images for fielded ground forces and Republican Guard units.[23]Typical AV radar image showed military vehicles dug into a field between a highway, buildings, and a belt of trees. The Global Hawk snapped photos and beamed images back to the operation center analysts in Nevada and to the in-theater operation center. The analysts scrutinized the images and shared data through a special, secure online chat room. At the same time, they forwarded actual imagery over the military's Secret Internet Protocol Router Network (SIPRNET). Then, fighters in Iraq received the target information by voice from either an E-3 AWACS command and control aircraft or directly via an onboard data link.

The UAV also linked up with the B-1B and B-2 bombers, providing a "last-look" assessment on whether a bomber's designated mean points of impact (DMPIs) still contained Iraqi tanks and artillery. If not, the bomber could hold its bombs for use against unplanned targets.

Similar tactics worked with F-16CJ fighters. The fighters, flying missions to suppress the last remnants of Iraqi air defenses in the north, would carry mixed loads of weapons-Joint Direct Attack Munitions, Joint Standoff Weapons, Wind-Corrected Munitions Dispensers, and High-speed Anti-Radiation Missiles. The Global Hawk was sent through earlier to spot likely targets-a process that made the air war more efficient. Transferring from other platforms, the UAV would locate and capture images of suspected air defense sites and then pass the information back through Nevada to the combined air operation center (CAOC), then contacted the F-16CJs on VHF radio to notify them of the targets.

Global Hawk mission achievements

The RQ-4 aircraft snapped 3,655 images using all sensors (radar, infrared, and electro-optical). In 16 missions, it is indicated that Global Hawks located 13 surface-to-air (SAM) missile batteries, 50 SAM launchers, over 70 SAM transport vehicles and over 300 tanks and other key targets in mission area[24]. They also supported in the hunt for Scuds and helped keep track of Iraqi forces and over 300 SAM canisters.

UAV limitations [25]

Pioneer UAV

The RQ-2A/Pioneer achieved less-than-desired reliability metrics. According to the analyses, this could be due to several factors, including that it was an Israeli platform purchased as a non-developmental system in an accelerated procurement. In operation, the users quickly identified several deficiencies that compromised reliability.

They do not have an automatic takeoff, landing, or mission-execution capability, which has led to a high accident rate; shipboard electromagnetic interference caused several crashes. Also, the engines were thought to be too small for the platform and easily overstressed. In addition to a more reliable engine, Marine Corps users found that the system needed a smaller logistical footprint and longer endurance.

Hunter UAV

The high mishap rate of the early Hunter is comparable to that of early Pioneers, and this can be largely attributed to poor Israeli practices in UAV production in the 1980s.

The Predator UCAV

Weather conditions are the primary limitation and concern in Predator operations. The Predator is not certified by the US Air Force to operate in instrument conditions (IMC) under instrument flight rules (IFR). In addition to IMC constraints, there are limitations in terms of launch and recovery under visual flight rules. For example, the Predator UAV cannot be launched in adverse weather with visible moisture such as rain, snow, ice, frost, or fog and the crosswind limitations for takeoff and landing are 17 knots.

The Predator is vulnerable to threats because of its operating envelope. The MAE UAV's concept of operations includes operating at altitudes no greater than 25,000 feet mean sea level (MSL), at airspeeds of 60-110 knots; 15,000 feet and 85 knots are the nominal altitude and airspeed. Additionally, the EO and IR sensors provide enhanced resolution at lower altitudes (5,000 feet versus 15,000 feet MSL). The threat to the Predator in this environment is broad: radiofrequency and infrared-guided surface to-air missiles; antiaircraft artillery; and second-, third-, and fourth generation combat aircraft equipped with air-to-air missiles, guns, and rockets.

Operating at an altitude of 5,000 feet could find it in the threat envelope of the less-sophisticated, visually acquired AAA and man-portable SAM systems. Although the Predator was not specifically designed to meet low signature requirements, its relatively small size, composite materials, and shape enhance its slow signature. It does not contain an onboard EA system. Depending on its operating altitude for a given mission, it will be necessary to operate either in a standoff role or overfly target territory outside known engagement envelopes to defeat hostile SAM and aircraft systems[26].

Azerbaijani-Armenian war in Nagorno-Karabakh

Background

The Nagorno-Karabakh conflict is an ethnic and territorial conflict between Armenia and Azerbaijan over the disputed region of Nagorno-Karabakh and seven surrounding districts. In 1988, the regional legislature in Nagorno-Karabakh voted in favor of joining the Armenian Soviet Socialist Republic, a move that found little support in Moscow. Following the 1991 dissolution of the Soviet Union, Armenian separatists backed by Armenia took over control of large parts of Nagorno-Karabakh, home to a significant Azerbaijani minority, as well as seven adjacent Azerbaijani districts. This area saw many battles between the two countries, and the latest was between July and September 2020, when Azerbaijan stormed Nagorno-Karabakh.

In this conflict, UAVs played a major and undeniable role, destroying large numbers of Armenian ground-based assets and degrading the Armenian force's ability to continue to fight. The Azerbaijani army used high numbers of UAVs of different types during the 11-day battle[27].

UAVs used in conflict

The Azerbaijani army has 11 different types of unmanned air systems, some of them (Heron TP, Hermes 450, Hermes 900 and Aerostar) are ISR specific models, while others (Harop, Sky Striker, Orbiter-1K, Orbiter-3) are explosive-carrying loitering munitions. Additionally, reports indicate that the Azerbaijani military has converted a number of obsolete AN-2 biplanes into UAVs. In September 2020, the Azerbaijani army depended on four main types of unmanned air systems[28]:

1. Bayraktar-TB2: UCAV, which was the main type used by Azerbaijani army battles.
2. Orbiter-1K: Loitering munitions.
3. Harop: Loitering munitions.
4. Antonov An-2: Modified single engine biplane into a decoy.

Bayraktar TB2 Fig 7

Background

The Bayraktar TB2 is a UCAV developed and manufactured by Turkish-company Baykar. It can conduct ISR[29]and armed attack missions, as well as assault missions using its laser-guided missiles. It is fitted with imaging and targeting sensor systems, or Multi Mode AESA Radar, and has an onboard avionic suite with a triple redundant avionic system enabling a fully autonomous taxiing, take-off, landing, and cruise.

Features [30]

Communication Range: 150 to 300 km - Take-off and Landing: (Automatic (- Maximum Speed: 70 - 120 knots - Max Takeoff Weight: 700 kg - Maximum Altitude: 18,000 feet to 27,000 feet - Endurance: Up to 27 hours - Payload Capacity: 150 km - Wingspan: 12m - Height: 2.2m - Length: 6.5m - Range: 150 km - Fuel Capacity: 300 liters/gasoline - Thrust: 100 hp internal combustion injection engine.

Armaments

It has four hard points for laser-guided smart munitions, with provisions to carry combinations of L-UMTAS long range anti-tank missile system; MAM-C and MAM-L precision-guided munition; Cirit 70 mm missile system; and TOGAN air-to-surface launched 81 mm mortar munitions[31].

Mission Imperative

During the Nagorno-Karabakh battles, in addition to the targeting missions, the UCAV Bayraktar was used in several missions, including correcting artillery fire and providing ISR in real-time. Besides the Bayraktar, the TB2 loitered near the most important air defenses sites, especially S-300 systems, in order to assess the damages made by the loitering munitions . The most important role of these UCAVs was purely offensive, as they used MAM-L laser-guided anti-armor missiles against Armenian air defenses, especially the Russian-made self-propelled systems Osa and Strela 10, and targeted Armenian armored divisions, especially T-72 tanks and APCs[33].

Bayraktar accomplishments

The Azerbaijani Bayraktar UCAVs disabled a huge number of Armenian tanks, fighting vehicles, artillery units, and air defenses. Their penetration of Nagorno-Karabakh's deep rear also weakened Armenian supply lines and logistics, facilitating later Azerbaijani success in battle[34]. Bayraktar UCAVs alone destroyed 89 T-72 tanks, 29 armored vehicles, 131 artillery pieces, 61 rocket launchers, 143 trucks, nine radar systems and 15 SAM systems at the loss of just two Bayraktar UCAVs.

Azerbaijan has also used the TB2's high-definition cameras to produce propaganda videos. Videos showcasing attacks on Armenian fighters and equipment were posted online and broadcast on digital billboards[35].

What is interesting in the use of this type of UCAV is that it worked as part of a larger plan, where three other UAVs were used, in order to determine the locations of the Armenian air defense outposts and suppress them with precision. Two of these three UAV types were loitering munitions.

Orbiter 1K **Fig 8**

The first one was the Israeli-made loitering munitions Orbiter-1K[36], which targeted hostile artillery and tanks, and one of these munitions appeared in surveillance footage taken by a Bayraktar UCAV. Between 2016 and 2019, the Azerbaijani army received 100 loitering munitions of this type, and later manufactured it locally under the name Zerba. Each of this type carries between 1 and 2 kilograms of explosives and were used to target munitions transport trucks and shells attached to field artillery positions.

Harop **Fig 9**

The Azerbaijani army also used the Israeli-made loitering munitions Harop, the first batch of which was received in 2015 and 2016. This type was used by the Azerbaijani army in Nagorno-Karabakh during the April 2016 battles [37]. This type is distinguished from other Israeli-made loitering munitions with its large load of explosives, estimated at 23kg, and a greater flight range of up to 1,000 km. This type also has the ability to fly continuously for nine hours and to perform attacks at any angle, with high speeds of up to 417 km/h. It was used to destroy buses of Armenian soldiers being transported to the frontline during the battles, as well as Armenian command posts[38].

The deadliest thing about Harop is its very small radar cross-section (RCS)[39]. Harop's RCS is a mere 0.5 m2, which is considered very small, so it was very difficult for Armenia's air defenses to detect it, as these defenses consisted of obsolete Soviet-era systems like the 2K11 Krug, 9K33 Osa, 2K12 Kub, and 9K35 Strela-10.

AN 2 biplanes Fig 10

The last UAVs used by Azerbaijan in this war was the the old Soviet-era AN-2 biplanes, which were converted to UAVs[40]. The AN-2, which has been in the service of a multitude of nations since 1946, is a light aircraft intended to serve in many roles. But militarily is used for light transport and paratroopers. In 2020, it appears a new self-destructive role has been found for the dozens of AN-2s still with the Azerbaijan Air Force [41].

During the battles, the Azerbaijani air force used nearly 11 planes of this type as unmanned bait to reveal the locations of Armenia's air defense systems, and then target it them with UCAVs. This tactic required a pilot to take off with the plane, then evacuate by parachute after directing the vehicle towards Armenian lines. This type of aircraft also had the ability to act as a UCAV, but did not play that role during this war [42] .

Israeli Military Operations in Gaza

Background

For 11 days in May 2021, an asymmetric clash raged between the Israeli Defense Force (IDF) and Hamas, the Palestinian militant group that governs the Gaza Strip. Both sides used UAVs during this clash. For the IDF, the main tactical purpose for using UAVs was to destroy Hamas' mobile rocket launchers, mortars, and anti-tank missile teams. These are fleeting targets of opportunity detected by surveillance assets, either while setting up to fire or more often, due to the effective use of overhead cover, after revealing their positions by firing.

UAVs used by Israel

The IDF used two main types of UAVs during this battle, the Hermes 450 tactical UAS and the Hermes 900 MALE UAS[43].

Hermes 450 Fig 11

Background

The Hermes 450 is a multi-role high-performance tactical UAS [44]. As the primary platform of the IDF in counter-terror operations, it incorporates cutting edge payloads with selected dual-payload configurations. Choice of payloads includes EO/IR/Laser, SAR/GMTI and MPR, COMINT/COMMJAM, ELINT, hyper-spectral systems, large area scanning systems and other payloads.

Features: Take-off weight: 550 kg - Max payload: 180 kg - Service ceiling: 18,000 ft. - Maximum speed: 176 km/h - Cruise speed: 130 km/h - Stall speed: 78 km/h - Range: 300 km - Endurance: 17 hours - Rate of climb: 4.6 m/s - Max mission radius: 200 km - Length: 6.1 m - Wingspan: 10.5 m - Fuel capacity: 105 kg.

Hermes 900 Fig 16

Background:

The Hermes 900 is a medium-size, multi-payload,medium-altitude long-endurance UAV [45] designed for tactical missions.

Payload options include standard and long-range EO/IR/laser, SAR / GMTI & MPR, COMINT/DF, COMINT GSM, COMMJAM, ELINT, EW, hyperspectral systems, large area scanning systems, wide area persistent surveillance and other payloads. It can also be utilized for ground support and maritime patrol missions, as well as for integrated multi-platform, multi-sensor operations. The Hermes 900 can perform two concurrent missions from the same GCS using two ground data terminals (GDT).

Features

Capacity: 350 kg - Length: 8.3 m - Wingspan: 15 m - Gross weight: 1,100 kg - Maximum speed: 220 km/h -

Cruise speed: 112 km/h - Endurance: 36 hours - Service ceiling: 9,100 m – Take-off Weight: 1,180 kg.

Other Drones:

The IDF used flocks of small UAVs over Gaza to spot rocket launches and attack those sites. This was part of a bigger effort to develop new methods of locating launch pads. For the first time, the IDF's artificial intelligence capabilities were brought to bear on the issue, helping human analysts interpret a vast amount of satellite and aerial surveillance imagery to locate the launch pads, some of which were built to be used multiple times. In one use of artificial intelligence, the Israeli military deployed small flocks of quad copter drones over the southern Gaza Strip, with each device monitoring a specific patch of land [46], and when a rocket or mortar launch was detected, other armed aircraft or ground-based units attacked the source of the fire.

Mission Imperative for the Israeli side

Spotting rocket launcher and launching pads used by Hamas.

UAV used by Hamas

Zwari UAV - Fig 12

As for Hamas, it also used two types of UAVs during battles, one of which was a surveillance UAV, while the other one was loitering munitions. The Qassam Bridges – the military wing of Hamas – used a small UAV called Zwari to reconnaissance the sites surrounding Gaza and monitor the movements of the Israeli army's armored vehicles. This gave rocket and mortar crews, as well as drone operators, up-to-date coordinates of current threats.

Shehab Fig 13

This type of loitering munitions appeared for the first time during this battle. It was very similar to the Iranian-made loitering munitions Ababeel and its Yemeni version Qasef. The Qassam Brigades used this type to attack the sites of Israeli military units in the settlements of Sdot Nahif, Sha'ar Haneef and Eshkol around Gaza. Besides that, it performed a successful attack on a chemical factory in the settlement of Nir Oz[47].

Figures

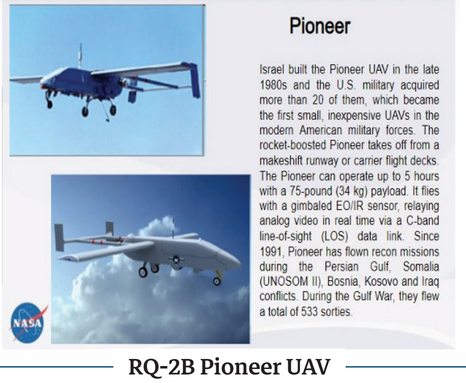
Figure 1

Iranian Drone

Figure 2

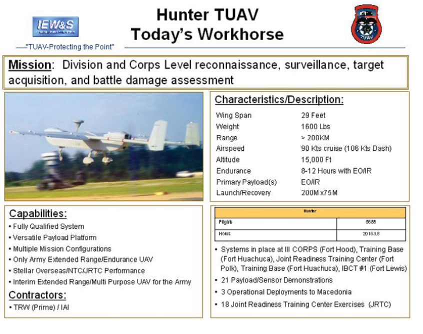
Mohajer-1 UAV

Figure 3



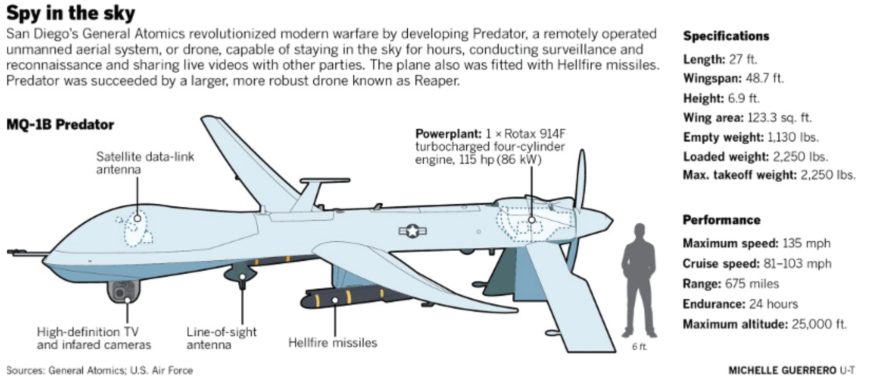
RQ-2B Pioneer UAV

Figure 4



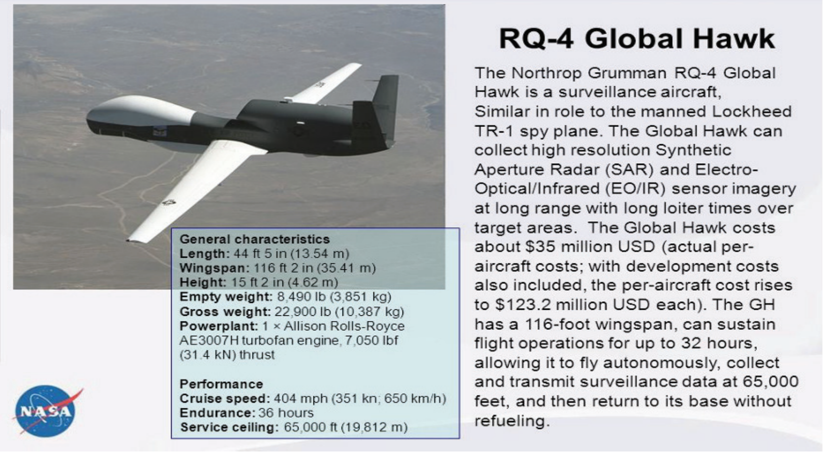
RQ-5A/MQ-5B Hunter UAV

Figure 5



MQ 1B Predator UAV

Figure 6



RQ-4 Global Hawk UAV

Figure 7

Bayraktar TB2 UAV

Figure 8

Orbiter 1K

Figure 9

Harop

Figure 10

AN 2 biplanes

Figure 11

Hermes 450

Figure 12

Zawari UAV

Figure 13

Shehab UAV

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The future development of unmanned aircraft systems

Unmanned air systems have been developed rapidly over the past two decades, which makes it necessary to explore the expected paths of this development in the upcoming future.

Military UAV technology (air superiority, autonomy, teaming and swarms)

The military use of drones has become the primary way this technology is utilized in today's world. Whether they are used as target decoys, for combat missions, research and development, or surveillance, drones have become part and parcel of military forces worldwide. According to data from Globe Newswire, the size of the global military drone market is projected to reach $23.78 billion by 2027. A single US Predator drone costs approximately $4 million.

Unmanned aerial vehicles (UAVs) will continue to be used in various military operations due to their high convenience in reducing losses and enabling the execution of high-profile and time-sensitive missions. There are various ways to develop UAVs to serve important functions:

Air superiority

Current military drones play no role in securing air superiority, as they would need significant upgrades like radar and a wider field of view for pilots to allow for dogfighting, complex air maneuvers, and air-to-air targeting. The latter can be attained due to easier target discrimination in the air compared to ground targets.

Autonomy

The use of fully autonomous or semi-autonomous UAV for lethal mission is a possible future trend in UAV innovation, although it is unlikely to happen in the near future due to many issues, mainly ethical considerations. UAVs are pre-programmed to carry out specific tasks, though these tasks are still supervised by human operators who provide subjective decision-making in some operational situations.

Teaming and swarms

Funding for research into drone-related autonomy, human-machine teaming, and swarms was roughly $865.9 million in the US FY 2019 request, up from $833.8 million in the FY 2018 request, and $549 million in the FY 2017 appropriated budget. (This category only covers stand-alone projects in this field and does not include funding for autonomy research embedded in other unmanned systems projects.) A US Army program to field advanced manned-unmanned teaming technologies increased from $6.4 million to $18.9 million in FY 2019. While the Army been working on teaming for several years, the reason for this increase is that manned-unmanned teaming is a requirement for the Army's Future Vertical Lift program, a manned tilt-rotor project. Also, the Office of the Secretary Defense (OSD) has increased funding for Project Maven from $60 million in 2018 to approximately $109 million in FY 2019. Maven uses commercial artificial intelligence technology to identify and track objects in drone video, reducing the burden on human analysts, applies machine learning algorithms to vehicle sensors to reduce operator workload.

As more and more countries have realized the game-changing potential of drone swarm[1]technology, i.e., increasing the survivability of more expensive equipment and increasing the overall efficiency of operations, militaries around the world have started a race by heavily investing in the development of drone swarms . Attaining enough UAVs would enable the creation of swarms, where a group of RPAs fly cooperatively via advanced algorithm software, targeting air defense dispersing enemy defense capabilities. This can be achieved by employing inexpensive RPAs as kamikaze. They can be very useful in lethal missions or can act as decoys to absorb surface-to-air missiles[2].

UK SME Blue Bear and Callen Lenz have demonstrated electronic warfare jamming technology that uses remotely controlled swarms of BriteCloud-equipped drones, which aim to confuse and overwhelm simulated ground-based enemy air defense radars by building strategic redundancy[3].

The semi-autonomous "loyal wingman drones" are a part of the Lightweight Affordable Novel Combat Aircraft (LANCA) program[4]. The LANCA is planned to be deployed alongside conventional aircraft like the F-35 Typhoon to "increase capability, protection, [and] survivability" of manned aircrafts and could potentially "even provide an uncrewed combat air 'fleet' in the future"[5].

Not only is the US seeking to possess this drone technology, but China has also been pursuing drone swarm capabilities for offensive missions. In October 2020, the state-owned company China Electronics Technology Group (CETC) released a video showing a test-launch of a "barrage swarm" of "48 kamikaze drones carrying high explosive warheads, potentially powerful enough to destroy tanks and other armor"[6].

Other developments include integrating UAVs in the national airspace by developing detect and avoid systems, increasing the ability of UAVs to operate in the same airspace as manned aircrafts. This will eliminate a lot of UAV command and control errors, avoiding mid-air collisions and increasing UAV usage in coast guard, border guard, and local law enforcement operations.

Commercial UAV technology

Commercial use of drones is gaining steady momentum and has become the talk of the hour, as multiple industries are using drones as part of their regular business functions. The market size of drone services is expected to grow from $4.4 billion in 2018 to $63.6 billion by 2025, and Insider Intelligence predicts consumer drone shipments will hit 29 million by the end of 2021[7]. The commercial drone industry[8] is still young, but it has begun to see some consolidation and major investments from industrial corporations, chip companies, IT consulting firms, and major defense contractors, especially in the US, EU, and Asia.

Personal drone technology economy

As sales of the civilian drones rise, the safety concerns surrounding them among regulators and law enforcement agencies also tend to go up. Drone sales are expected to exceed $12 billion in 2021, much of which will come from the sale of personal drones for filmmaking, recording, still photography and gaming. Consumers are expected to spend $17 billion on drones over the next few years. Drones come in all shapes and sizes, from small and inexpensive single-rotor devices to large, $1,000+ quadcopters with GPS, multiple camera arrays, and first-person control. These are primarily aimed at hobbyists.

Future generations of commercial drone technology

Drone technology is constantly evolving. For example, an Amazon Services affiliate advertising program operates with several generations of drones, most of them in the fifth and sixth generations[9]. Here is the breakdown of the technology generations:

- **Generation 1:** Basic remote-control aircraft.
- **Generation 2:** Static design, fixed camera mount for video recording and still photos, manual piloting.
- **Generation 3**: Static design, two-axis gimbals, HD video, basic safety models, assisted piloting.
- **Generation4:** Transformative designs,three-axis gimbals, 1080P HD video or higher-value instrumentation, improved safety modes, autopilot.
- **Generation5:** Transformative designs, 360° gimbals, 4K video or higher-value instrumentation, intelligent piloting modes.
- **Generation 6:** Commercial suitability, safety and regulatory standard-based design, platform and payload adaptability, automated safety modes, intelligent piloting models and full autonomy, airspace awareness.
- **Generation 7:** Complete commercial suitability, fully compliant safety and regulatory standard-based design, platform and payload interchangeability, automated safety modes, enhanced intelligent piloting models and full autonomy, full airspace awareness, auto action (takeoff, landing, and mission execution).

The next generation of drones, Generation 7, is already underway, as 3DRobotics has announced the world's first all-in-one smart drone called Solo. Smart drones with built-in safeguards and compliance tech, smart accurate sensors, and self-monitoring are the next big revolution in drone technology that would provide new opportunities in transport, military, logistics, and the commercial sector[10]. As these technologies continue to evolve and grow, drones will become safer and more dependable.

Figures

Figure 1

Walmart using drones as means of delivery

Figure 2

Drone "Solo"

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Conclusion

There is no doubt that recent technological advancement has increased the military value of UAVs. Drones have proven their capability in intelligence gathering and providing high-resolution data. UAVs can be employed in an unpredictable manner, can focus on a target area, and, depending on the system, can fly over an area of interest or target for extended periods. They have shortened the process of searching, locating, identifying, and destroying target. Another key reason for UAVs' mission success is that their elevated flight altitudes and slow speed make them difficult for common enemy sensors to detect or recognize. UAVs offer advantages over manned aircraft in that they are more cost-effective, have numerous applications, and do not put the lives of personnel at risk. Drone technology has also proven useful for civilian purposes in various fields like archaeology, wildlife observation, and firefighting and rescue missions. In short, the usefulness of UAVs to modern, sophisticated militaries as well as to civilian entities cannot be ignored.

LIST OF ABBREVIATIONS

A/A	Air to air
AAA	Antiaircraft artillery
ACDT	Advanced-concept technology demonstrations
ACN	Airborne-communication node
AEW	Airborne early warning
AIM	Air-intercept missile
AJCN	Adaptive, joint, C4ISR node
AOR	Area of responsibility
ARM	Anti-radiation missile
ATARS	Advanced, tactical, airborne-reconnaissance system
ATC	Air-traffic control; automatic target cueing
ATOLS	Automatic takeoff and landing system
ATR	Automatic target recognition
AWACS	Airborne warning-and-control system
BAMS	Broad-area maritime surveillance
BDA	Battle-damage assessment
BLOS	Beyond line of sight
C2	Command and control
C3I	Command, control, communications and intelligence
C4I	Command, control, communications, computer, and intelligence

CAOC	Combined aerospace operations center
CCD	Charge-coupled device; camouflage, concealment, and denial; coherent-change detection
CDL	Common data link
CFACC	Combined forces, air-component commander
CMD	Cruise-missile defense
CN	Counter-narcotics
CNC	Computer numerical control
COMINT	Communications intelligence
CONOPS	Concept of operations
CONUS	Continental United States
COTS	Commercial, off-the-shelf
CR	Close range
CSAR	Combat search and rescue
CW/BW	Chemical warfare, biological warfare
CWMD	Counter- weapons of mass destruction
DARPA	Defense Advanced Research Projects Agency
DE	Directed energy
DEAD	Destruction of enemy air defense
DoD	Department of Defense
DTED	Digital terrain-elevation data
EA	Electronic attack
ECCM	Electronic counter-countermeasures

ELINT	Electronic intelligence
EMD	Engineering and manufacturing development
EMP	Electromagnetic pulse
EO	Electro-optical
ESA	Electronically scanned array
ESM	Electronic support measures
EW	Electronic warfare
F2T2EA	Find, fix, track, target, engage, and assess
FLIR	Forward-looking infrared
FOPEN	Foliage penetrating
GCC	Global command-and-control system
GCS	Ground-control station
GDT	Ground data terminal
GMTI	Ground moving-target indication
GPS	Global-positioning system
GSE	Ground-support equipment
GWOT	Global war on terrorism
HAE	High-altitude endurance
HAZMAT	Hazardous material
HFE	Heavy-fuel engines
HPM	High-power microwave
I3	Integrated intelligence and imagery
IADS	Integrated air-defense systems

IAI	Israeli Aircraft Industries
ICBM	Intercontinental ballistic missile
IFR	Instrument flight rules
IMC	Instrument meteorological conditions
IMINT	Imagery intelligence
IR	Infrared
IRST	Infrared search and track
ISAR	Inverse synthetic-aperture radar
ISR	Intelligence, surveillance, reconnaissance
ISS	Integrated sensor suite
IUP	Israeli UAV Partnership
JDAM	Joint direct-attack munition
JITC	Joint Interoperability Test Command
JOTBS	Joint operational test-bed system
JSTARS	Joint surveillance and target-attack radar system
JTF	Joint task force
J-UCAS	Joint unmanned combat air systems
LADAR	Laser detection and ranging
LD	Laser designation
LIDAR	Light detection and ranging
LOS	Line of sight
LRE	Launch-and-recovery element
LRF	Laser rangefinder

MAE	Medium-altitude endurance
MAGTF	Marine air–ground task force
MALE	Medium altitude, long endurance
MASINT	Measurement and signature intelligence
MCE	Mission-control element
METOC	Meteorology and oceanography
MIAG	Modular Integrated Avionics Group
MMH/FH	Maintenance man-hours per flight hour
MOSP	Multipurpose optical, stabilized payload
MPEG	Motion Picture Experts Group
MPR	Maritime-patrol radar
MP-RTIP	Multi-platform, radar-technology insertion program
MR	Mishap rate
MSL	Mean Sea level
MTBF	Mean time between failure
MTI	Moving target indicator
MTS	Multi-spectral targeting system
MWIR	Mid-wave infrared
NATO	North Atlantic Treaty Organization
NBC	Nuclear, biological, chemical
NCA	National Command Authority
NCW	Network-centric warfare
NIIRS	National imagery-interpretability rating scale

NRT	Near-real time
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OOTW	Operations other than war
OSD	Office of the secretary of defense
OTH	Over the horizon
O&S	Operations and support
PAT	Pointing, acquisition, and tracking
RF	Radio frequency
ROE	Rules of engagement
RPV	Remotely piloted vehicle
RSTA	Reconnaissance surveillance and target acquisition
RT	Real time
RTB	Return to base
RVT	Remote video terminal
SA	Situational awareness; surface to air
SAB	Scientific advisory board
SAM	Surface- to-air missile
SAR	Synthetic aperture radar
SATCOM	Satellite communication
SEAD	Suppression of enemy air defenses
SFC	Specific fuel consumption
SIGINT	Signal intelligence

SIPRNET	Secret Internet Protocol Router Network
SYERS	Senior Year Electro-optical Reconnaissance System
TAF	Turkish armed forces
TAI	Turkish Aerospace Industries
TAMD	Theater air-missile defense
TARPS	Tactical air-reconnaissance pod system
TEI	Tusas Engine Industries
TEL	Transporter erector launcher
TESAR	Tactical, endurance, synthetic-aperture radar
TIES	Transportable image-exploitation system
TMD	Theater missile defense
TST	Time-sensitive target
TUAF	Turkish air force
UA	Unmanned aircraft
UAS	Unmanned-aircraft systems
UAV	Unmanned, aerial vehicle
UCAV	Unmanned, combat, aerial vehicle
UCN	UAV communications node
UGS	Unattended ground sensor
UHF	Ultra-high frequency
U.S.	United States
WAS	Wide-area search
WMD	Weapons of mass destruction

ECSS

المركز المصري للفكر والدراسات الاستراتيجية

EGYPTIAN CENTER FOR STRATEGIC STUDIES

The Egyptian Center for Strategic Studies (ECSS), established in 2018 as an independent think tank, seeks to introduce different perspectives and alternatives regarding strategic shifts taking place on the national, regional and international levels. The ECSS is particularly focused on incidents important to national security and Egyptian interests.

The ECSS targets decision-makers, by providing choices and alternatives when dealing with domestic, regional and international challenges, as well as researchers and experts specialized in the political, economic, social, and security fields, in Egypt and abroad. Through its wide array of services, the ECSS aspires to contribute to enlightening and guiding debates and public opinion in Egypt and the Middle East, as well as to enrich the principles of thinking and scientific research.

The ECSS does a variety tasks, activities and provides services such as assessments, political analysis, workshops, forums, and conferences, in addition to monthly publications in Arabic and English. The ECSS website publishes analyses of the different developments taking place on the Egyptian, regional, and international fronts, as well as the production of different research programs.

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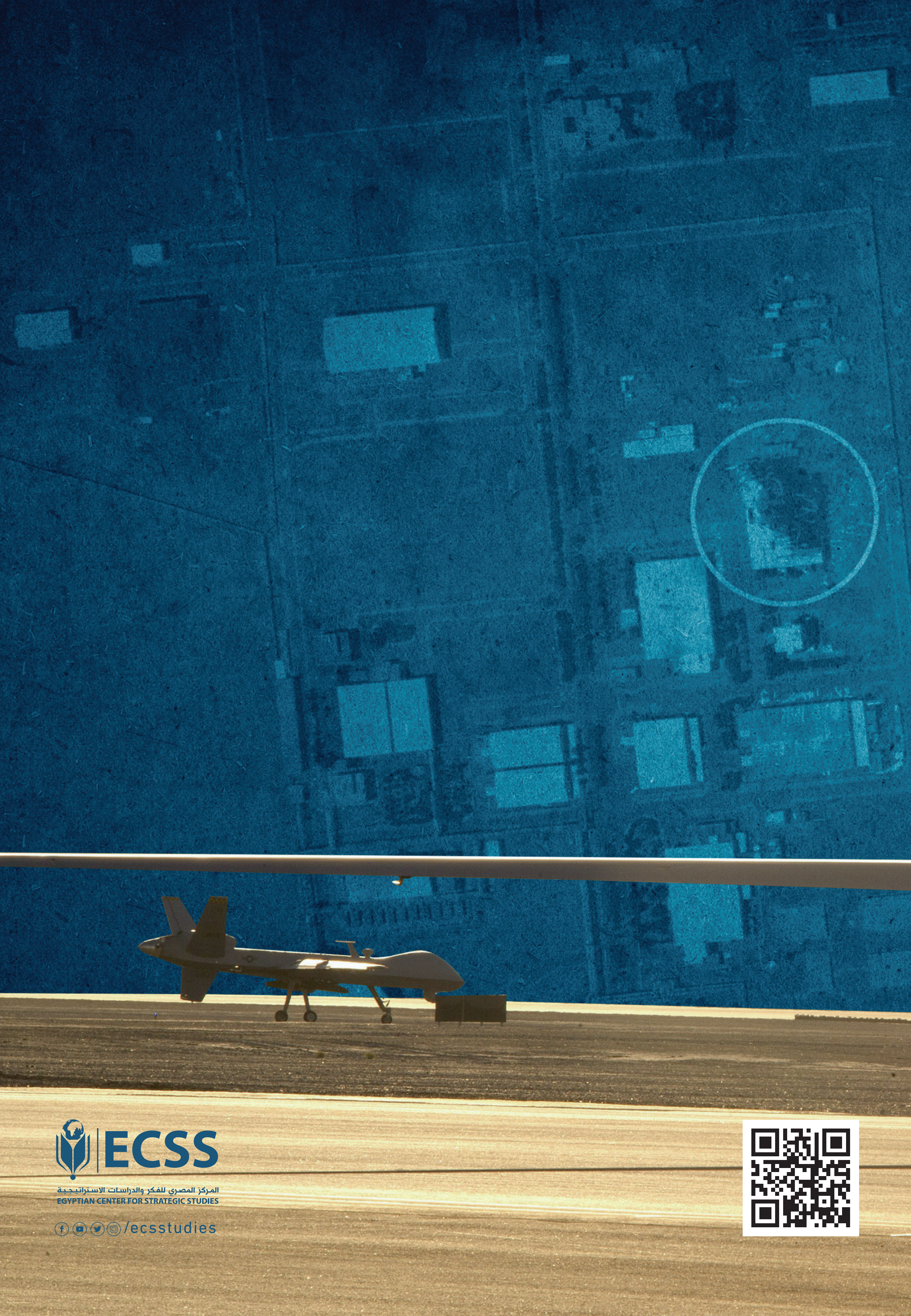
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