EVOLUTION OF THE UNMANNED AERIAL VEHICLES UNTIL PRESENT

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ABSTRACT:

The origin and development of unmanned aviation has been almost matched that of manned aviation, starting both from an almost common point. As in conventional manned aviation, military applications, have been the motor of technological development and the potential applications of these types of systems throughout much of the twentieth century and early twenty-first century. Finally it has been in relatively recent times that these systems are experiencing an impressive boom due to the discovery of the wide variety of commercial and civil operations that are able to perform very effectively. This paper attempts to summarize the historical evolution that these systems have suffered and in the end, to present a quick analysis of the major civil / commercial applications, trying to provide an overview of the main types of systems, their classification and general configuration.

Key Words: UAV, RPAS, unmanned, aircraft configuration

1. INTRODUCTION

Unmanned aviation shares its beginnings with the manned since the first steps of the pioneers of the latter had as a means to build small scale unmanned models which aimed to perfect their designs. Pioneers such as Cayley, Ninomiya, Du Temple, Langley or Cody created these first unmanned aircraft although none of them is truly considered the creator of this concept, which will have to see how it unfolds first manned aviation. It was not until World War I, at which the flight of the first unmanned aircraft actually takes place created as such, with its own mission beyond to validate aircraft design. Since that distant date of 1917 to the present, the development of these aircraft has undergone constant improvement, albeit with more or less fruitful periods, up to the present time in which they are suffering an unprecedented expansion with hundreds of platforms very different in weight, size and features as well as a myriad of civilian and military missions to be answered. Throughout this work as well and as a second part of it, possible configurations, types and applications of these aircraft will be summarized and explained.

Unmanned aircraft have received very different names throughout their history. Since the so-called Tesla’s "Teleautomaton" (the first torpedo in history), the Sperry’s "aerial torpedo", ancestors of today's cruise missiles, air targets or "drones" (nowadays widespread name to refer to the so-called RPAS, which will be defined later), recreational or sports radio-controlled models, to a whole set of names by means of acronyms such as RPV, SPA, UMA, UAV, UAS or the latest RPAS, there are many names for the same concept.

The terms UAV and RPV are no more than two between near the dozen of names that have been receiving the robotic unmanned aircraft throughout its existence, being the vast majority developed in the military world. So it seems appropriate to refer to the definitions given by relevant organizations in the field of defense for a possible definition of what a UAV is. When consulting the USA Department of Defense (DoD) [1] for the term "unmanned aircraft" the following definition is found: "an aircraft that does not carry a human operator and is capable of flight with or without human remote control", and "unmanned aircraft system", as follows: "that system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft; also called UAS".

On the other hand, the United Kingdom Ministry of Defence (MoD) [2], defines "unmanned aircraft" as "an aircraft that does not carry a human operator, is operated remotely using varying levels of automated function, is normally

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recoverable, and can carry a lethal or non-lethal payload"; in the UK, cruise and ballistic missiles are not considered to be unmanned aircraft, while defining "unmanned air system" as "a system, whose components include the unmanned aircraft and all equipment, network and personnel necessary to controlling the unmanned aircraft"; it is recognized that the terms UAS and RPAS are used interchangeably to describe unmanned and remotely piloted aircraft systems. This British definition is much more restrictive than that given by the DoD. While the US definition allows the aircraft to be totally autonomous, in the British definition it is assumed that there is always a remote pilot, but the aircraft can carry a higher or lower level of automation. It also explicitly excludes the missiles, both cruise and ballistic.

Additionally the MoD is introducing a key terminology nowadays. It is worth paying attention to the last of the acronyms used extensively nowadays, which is RPAS. In 2011 the International Civil Aviation Organization (ICAO), a specialized agency of the United Nations for the civil aviation and of which Spain is part having signed the Convention in Chicago in 1944, published its Circular 328 [3] in which for the first time recognizes the unmanned aircraft as aircraft, with all the implication that this brings. Also among all the possible types, ICAO chooses the ones which are remotely controlled to be considered as suitable for civil aviation, and no other types (such as autonomous aircraft). In this way the terms that appear below have been introduced, having nowadays validity and worldwide applications in almost all areas. These terms are the following:

- Remotely-Piloted Aircraft, RPA: aircraft in which the pilot in command is not on board;
- Remotely-Piloted Aircraft System, RPAS: a set of configurable items formed by an RPA, its remote control station associated (RPS - Remote Pilot Station), the required system-link command and control and any other item required at any point during the operation of the flight.

In the case of Spain, the concept RPA has been also adopted (being translated into Spanish as "*Aeronaves pilotadas por control remoto*") and also have been incorporated to the national regulations by means of the Law 18/201 (Art. 50 and 51), which entered in force on the 15th of October 2014. By means of this Law, the civil RPAS with a maximum take-off weight under 150 kg are regulated in Spain. Civil RPAS with maximum take-off weight over 150 kg are regulated at European level, being the European Aviation Safety Agency the competent organization.

Regardless of the details of the above definitions, this paper aims to review the historical background of these systems, and in its final chapters summarizes what is the current state of the art in terms of the different general layouts that can adopt different types of existing platforms today. Later a second paper will analyze in detail the different types of operations that these aircraft can develop, especially in civilian missions where the number of platforms and operators are growing at a breakneck pace.

2. HISTORY OF UNMANNED AVIATION

2.1. FROM THE PIONEERS TO THE I WORLD WAR

In Europe, the aviation pioneers were the first to develop the physical principles of aeronautics and trying to apply them to viable aircraft tested and flew uninhabited models which could be considered the first UAV or RPA in history. Aviation pioneers in various countries around the world followed a common progression, evolving from gliders to powered unmanned aircraft, and then to manned flights. Nevertheless they suffered from a technological barrier because there was not an enough powerful engine available which could be applicable to their designs. American engineers were more efficient and managed to overcome the challenge, being the first to make a manned flight with one engine-powered aircraft [4].

However it is necessary to mention Nikola Tesla, which is considered the creator of the concept of cruise missiles and unmanned aviation. In 1898 he invented the "Telautomaton": a naval craft able to move, stop, go left or right and send different radio signals. In 1912 the invention briefly reemerged in prototype form of radio-controlled torpedo. However, Tesla was not alone in pursuing the idea of remotely controlled weapons. In 1888, the Irish inventor Louis Brennan proved able to fly, remotely via a cable, a torpedo by the Mead River (England). Later, in 1908, the French artillery officer René Lorin proposed a jet propelled flying bomb, similar to the future German V-1, which could be controlled by means of radio signals.

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During World War I, conventional aviation progressed rapidly, while the unmanned looked hampered by lack of technological development. The barriers relied on the problems of automatic stabilization, remote control and autonomous navigation. Elmer Ambrose Sperry was the first person to solve all these problems in a viable unmanned aircraft. Elmer Sperry conducted some successful experiences with gyroscopes for maritime applications, which led him to develop a gyrostabilizer for an aircraft in 1909, which was too heavy and had a mediocre performance. Supported by the aviation pioneer Glenn Hammond Curtiss, he improved his invention, which was again tested in 1911. The system was much smaller, and allowed to control the airplane in the three axes, coupling it to the controls of the airplane by means of servomotors. In 1914 he won a prize at an exhibition in France including a former invention, a primitive artificial horizon [5].

In 1915 Sperry was contacted by the inventor of electric lighting systems, Peter Cooper Hewitt, to take up the ideas of Tesla using as a basis the device invented by Sperry. In 1916 the first demonstration Sperry's device for guiding a conventional aircraft took place, the Hewitt-Sperry Automatic Airplane, whose pilot took off before engaging the autopilot. After the airplane was flying a scheduled route and then pitched. The pilot recovered the aircraft at that time and was returning to the airfield. In 1917 the US Navy funded the idea and delivered five seaplanes Curtiss N-9 to carry out the experience.

In parallel the Curtiss Aeroplane and Motor Company embarked on the manufacture of airframes for unmanned aerial torpedoes, delivering the first six Speed Scout in late 1917. The first flight successfully controlled of an unmanned aircraft took place finally on March 6th, 1918, 14 years after the Wright brothers. In October 1918 it was fitted with catapults. Sperry air torpedo bomber was an unmanned wood biplane, with a weight of only 270 kg, including a payload of 136 kg and was driven by a 40 hp Ford engine. The guidance method towards its goal was primitive but ingenious. Once the wind and the distance to the target were known, the required engine speed was calculated to achieve the target. The airplane was controlled with a simple gyro, and an aneroid barometer was available onboard. Once the calculated speed was reached, the wings were separated from the fuselage, dropping it on the target.

The first systems were developed as long-range weapons (precursors of actual cruise missiles) in devices such as the 1917 US aerial torpedo just discussed, the Liberty Eagle aerial torpedo, better known as Kettering "Bug" in 1918 and the British aerial target "AT", started in 1914. The "Kettering bug" was a lighter biplane designed to carry a payload of 82 kg, and had a behavior similar to the Sperry torpedo. Furthermore, the British A.T. was an unmanned monoplane radio-controlled airplane powered by a 35 hp engine. The concept of the A.T. series served to demonstrate the feasibility of using radio signals as guidance system to fly the aircraft to their destination.

However, none of these devices were successfully developed to be used for military purposes before the end of the First World War. However, they marked the beginning of a new technology era, but guidance systems were crude and unreliable. During the 1920s the interest of Britain armed forces in unmanned systems was revived, especially by the Royal Navy. So a monoplane aircraft capable of carrying a war load of 114 kg was developed, being able to fly at a distance of 480 km, and made its first flight in 1927. It was equipped with an Armstrong-Siddeley Lynx 200 hp engine and was named LARNYX (long-range gun with Lynx engine). This aircraft had a radio-controlled system for the first moments of the flight, but then it followed a specified flight plan. Only twelve units were built, with five of them being equipped with military cargo and tested in the Iraq desert [5].

2.2. THE II WORLD WAR AND THE POSTWAR PERIOD

United Kingdom decided to abandon the development of cruise missiles and ran to the field of air targets with complete radio control despite its limited scope. With that purpose several tests were performed on a Fairey model but, between 1934 and 1943, four hundred and twenty radio-controlled models of a new target called "Queen-bee", intended for use by the Navy and the Army, were built. The Queen-bee was a version of the De Havilland DH.82 Tiger Moth aircraft. They were used primarily for the training of artillery forces of both armies during World War II. At the same time in the US, the RP4 from the Radioplane Company was developed and produced in thousands as a training system for the armed forces during the war. The use of these aircraft was a perfect benchmark to develop and improve an early remote radio-control technology.

However Germany also worked in the concept of cruise missiles during World War II with the Fieseler Fi 103 or "Vengeance Weapon 1" (commonly known as V1), which was the first cruise missile equipped with a pulsejet engine.

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The guidance system was only slightly better than previous devices. It was based on a barometric system to regulate speed and height, and an anemometer used to estimate the distance. Germany built some thirty thousand units and launched more than twenty thousand, approximately. Their launching sites were located in the Netherlands, northern France, and western Germany, in order to bombard Belgium and England mainly.

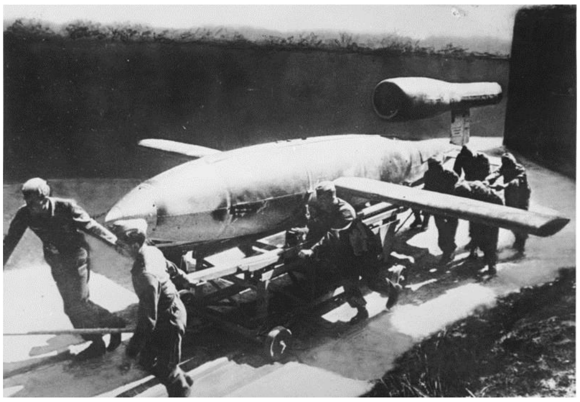

Fig. 1: Left-hand-side, the Kettering bug, and right-hand-side, the Vengeance Weapon 1 (V1).

2.3. THE COLD WAR

After the war the Radioplane Company, later Northrop, successfully developed a series of unmanned aerial targets called "Falconer" or "Shelduck" that continued in production until the 80s, in evolved versions. In general, the successful development of jet engines led to the development of faster and longer range targets, as the "Ryan Firebee" (later called Teledyne-Ryan), whose program had begun in the late 50s. These were then modified to carry ground attack weapons [4].

Subsequently Firebee, like other UAV at the time, were equipped with cameras for reconnaissance missions over enemy territory. These aircraft operated at low altitudes, where the radio control in line of sight from a ground control station was possible, or higher altitudes controlled from a manned aircraft. These spy aircraft were difficult to be detected and the fact of being unmanned was very interesting from the point of view of avoiding capturing the pilot in case of the manned spy aircraft was intercepted. The Northrop "Chukar" was also a target equipped with a turbojet type engine designed in that decade, but much smaller and lighter than Firebee. The version developed in the 70's was equipped with an advanced autopilot for operations Beyond Line-of-Sight (BLOS) [4].

Finally, the DASH (Anti-Submarine Helicopter Drone) was the first rotary-wing UAV, which also first introduced the attack mission from a boat. It was a dedicated design, and not the adaptation of a target system. Its design goal was to be able to fly from the US Navy frigates and transport torpedoes or nuclear warheads to attack enemy submarines that were far from the range of the other weapons available in the frigate [4].

2.4. FROM THE SEVENTIES TO THE PRESENT

The 70s and part of the 80 will witness the development of various UAS designed for reconnaissance and surveillance operations both for short-range and long-range, and high altitude missions. Under the effects of the Cold War, these systems became more sophisticated both in mission and safety communications requirements. It is important to note that it was believed that the next world war would be nuclear and this led to the conclusion that the reconnaissance missions, following a nuclear exchange would be suicidal for the crews due to the residual radiation. This fact announced in this way the importance for the development of UAS, in those years, as reconnaissance aircraft.

In such way the U.S. Air Force began exploring the HALE (High Altitude Long Endurance) UAS for reconnaissance in the late 60s. LTV Electrosystems was contracted in 1968 to build two prototypes, manned or unmanned, known as L-450F, based on the glider Schweizer 2-32. The first flew in 1970 and the second evolved into the UAV XQM-93.

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Afterwards another model of LTV was tested under the Compass Dwell program. It was Martin Marietta 845A aircraft, which flew in 1972. The program was abandoned, but before, the Martin obtained a record of 27 hours of endurance.

Subsequently the Boeing YQM-94 Gull, or Cope-B was the winner in 1971, of the Compass Cope USAF competition for the development of a HALE recognition system. The program's goal was to reach 16770 m altitude, and 20 hours endurance carrying a payload of 680 kg. This payload included equipment for photographic reconnaissance, communications relay and signals intelligence (SIGINT) in a range of 300 km, day and night and in all weather conditions. The first prototype crashed and while preparing the second, its direct competitor the Teledyne Ryan YQM-98 (Cope-R) flew with great success. It achieved an endurance record of 28 hours and 11 minutes. The Cope-R 275 design owed much to its predecessor (the same manufacturer) Compass Arrow (AQM-91 Firefly) which was a reconnaissance UAV, and announced many external features that would be used in its new design, Global Hawk, 29 years after [5].

On the other hand, in the field of MALE (Medium Altitude Long Endurance) UAS it is necessary to go back to the DARPA's (Defense Advanced Research Projects Agency) Amber project. Amber was a joint DARPA/U.S. Navy project aimed at building a low cost MALE UAV capable of being used as a weapon or as recognition system. The Amber project evolved into a low-cost version for export called Gnat-750, which is the direct ancestor of the famous family Predator, built by General Atomics. The first Predator, version A, flew for the first time in operations in Albania in 2001. To date, there are completed versions A, B and C, with notable differences in their performances, power plant and payload.

Finally, to conclude this historical overview of the evolution of UAS, is should be mentioned that during the 80s several armed forces worldwide sought at that time the necessity of extending ISTAR (information, surveillance, target acquisition, and reconnaissance) operations in real time with UAS at longer ranges (the order of 100 km). This required improving the accuracy and reliability of flight control systems. For this purpose several models of short and medium range UAS were built, of which the IAI Scout can be considered the first one in adopting the well-known configuration used today with the double tail cone and pusher propeller. This system, along with similar model Tadiran Mastif, led the IAI (Mazlat) Pioneer, which has been in service in both Israel and the US until the mid-2000s.

Fig. 2: Left-hand-side, the Predator A, and right-hand-side, the IAI Scout.

3. ACTUAL UAV GENERAL CONFIGURATIONS

3.1. MISSIONS

It is possible to separate the missions that UAVs can conduct in civil or commercial missions, and military or defence missions. Nowadays, most of these missions are related to military purposes, and the major investments are found in this field and its future applications. UAVs support the required aspects by the armies and the security forces to reinforce the operational security in missions that involve deployment and high mobility and transportability.

On one hand, military missions can be separated in three different categories: naval missions, ground missions and aerial missions. Each of these categories has several kinds of possible tasks. In naval operations detection and tracking of ships, radar confusion, port protection, anti-submarine warfare, electronic intelligence, radio relay or maritime

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surveillance are the most significant. Reconnaissance and surveillance, target designation, electronic intelligence, support to different systems in the battlefield or landmine detection and destruction are some applications referred to ground missions. Finally, in aerial missions it is possible to find electronic intelligence, early warning against other enemy aircraft, anti-aircraft systems counter and interception, or pre-strike radar [4].

On the other hand, civil and commercial missions allow for a big amount of applications. Some of them are focused on agriculture (crop monitoring, crop sowing and spraying), photography and cinematography, SAR (search and rescue), power lines and pipelines monitoring, fire-fighting, environment information, providing internet access, communications or meteorological services, helping traffic or authority agencies, fighting against poaching, managing emergencies and natural disasters, transporting organs for transplants, scientific applications, and many others.

It is advisable to pay attention to some features of the UAVs at the moment of the selection of the aircraft. The mission involves all the requirements to accomplish it, the performances (take-off, landing, endurance and range), available speeds, manoeuvres or the maximum payload that the aerial vehicle can transport on board. The possibility to improve the existing model of the platform to readapt it in the future with the objective of conducting new missions is also important. Previous experience to ensure the correct decisions in the development of the project, economic aspects and operation safety and security are other aspects to be taken into account.

3.2. SYSTEMS

An unmanned aerial vehicle is a system that contains many systems inside at the same time, and also it is a part of a major complex system composed of several elements such as other aerial and ground platforms, satellites and the communications between the UAV and the other mentioned components.

As a first approximation, it is possible to distinguish two sections in the UAS: one aerial and another on ground. The aerial section is formed by three different systems: the aerial platform, the required payload to accomplish the mission, and a part of the communication system. The ground section also includes some systems: the control system of the aircraft and its payload, the communication equipment, and the GCS (Ground Control Station). The GCS allows to show the information of all sensors to the corresponding users in one of two different ways, one directly and another through networks. Finally, the union element between these two sections is the launch and recovery system.

Now, the different systems just cited are going to be described in detail. The aircraft (aerial platform) has many diverse parts, also called systems or subsystems of the platform. The used term depends on the treatment chosen for the aerial vehicle. There is a wide variety of aerial platforms, varying in size (from micro UAVs to aircraft with 40m of wingspan like Global Hawk), the geometry, the way of generating lift (fixed-wing, rotary-wing…) or the propulsion system (turbojet, internal combustion engines, electric powertrains…). The platform also has the positioning, navigation, communication and data link systems on board. All these components are needed to achieve the flight control, as well as the mission control and the download of the relevant information of the sensors.

The payload is defined by the required means and equipment for the specific mission, as EO (electro-optical) and IR (Infrared) sensors, IR target designators, electronic warfare equipment, SAR and radar systems, weapons, etc. The GCS is part of the ground section. It contains the systems and equipment dedicated to the mission planning and control (control of the flight, the payload…) and to the distribution of the information to external users, ATC communications, etc. Also, the GCS has the communication system and the data link LOS (Line-of-Sight) or BLOS (Beyond Line-of-Sight) necessary to access the platform or the external systems.

The launch and recovery system (LRS) is often considered as a part of the Ground Control Station. The purpose of this system is the control of the platform during taxying, take-off, the first intervals of the flight, and during the approach and landing (all concerning about its launch and recovery). These LRS vary according to the weight and the size of the UAS. So, the vehicles can take-off and land making use of the landing gear (guided or automatic-ATOL), can be launched from the ramp with pneumatic actuators or auxiliary rockets, can be launched by hand, etc. and also can be recovered with parachutes, nets, or other devices.

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Finally, the required communication systems are grouped into another subsystem, divided into the aerial platform and the Ground Control Station. This subsystem includes: the terminals of data links (on board and on ground), the satellite terminal to communications BLOS, the communication equipment to its actuation as communication relay, etc.

3.3. CLASSIFICATION

From all the previous systems, it is usual to pay special attention to the aerial platform itself in order to establish a classification. One possible classification is based on the range, altitude, endurance and Maximum Take-Off Weight (MTOW) of the platforms. Table 1 presents the classification of aerial vehicles according with these parameters.

Category of UAS	Range (km)	Altitude (m)	Endurance (h)	MTOW (kg)
Stratospheric	>2000	20000-30000	48	<3000
High altitude and long endurance (HALE)	>2000	20000	48	15000
Medium altitude and long endurance (MALE)	>500	14000	24-48	1500
Low altitude and long endurance (LALE)	>500	3000	Around 24	Around 30
Low altitude and depth penetration	>250	50-9000	0.25-1	350
Medium range	70 to >500	8000	6-18	1250
Short range	10-70	3000	3-6	200
Mini	<10	<300	<2	<30
Micro	<10	<250	<0.5	<1

Table 1: First UAS classification according to its range, altitude, endurance and MTOW. [6]

Once the previous table has been shown, it is time to separate the UAVs into two different groups: fixed-wing UAVs and rotary-wing UAVs.

3.3.1. Fixed-wing UAVs

This kind of vehicles always has horizontal take-off. Attending to the geometry of the wing it is possible to find different layouts: conventional, canard, flying wing, delta, joined wing, box-wing, blended-wing-body (BWB), rectangular or trapezoidal, with or without swept, high wing, medium wing, or low wing. It is also possible to establish another classification in terms of the geometry of the tail: low horizontal tail plane, V tail, and double tail or H form.

As a final point of this classification it is possible to present another taxonomy based on the engines. There are two possibilities at the time of selecting the propulsion plant: turbojet for high subsonic speed, and turbo-propeller or piston engines with propeller, for low subsonic speed. The engine position can change from one platform to other: in the front part of the aircraft (tractor propeller), at the rear-end of the aircraft (normally pusher propeller and turbojets) or under the wing (turbojet, pusher or tractor propeller with an even number of engines). Below there are several photographs of different UAVs to show some of the cited features.

The Shadow 200 (RQ-7B) is a representative aircraft of conventional wing. This UAV is shown in Figure 3 (left-hand-side). In Figure 3 (right-hand-side) a canard configuration is represented with the UAV Rustom-1. An example of flying wing can be the X-47B, in Figure 4 (left-hand-side). The X-47A has a delta wing and is shown in Figure 4 (right-hand-side).

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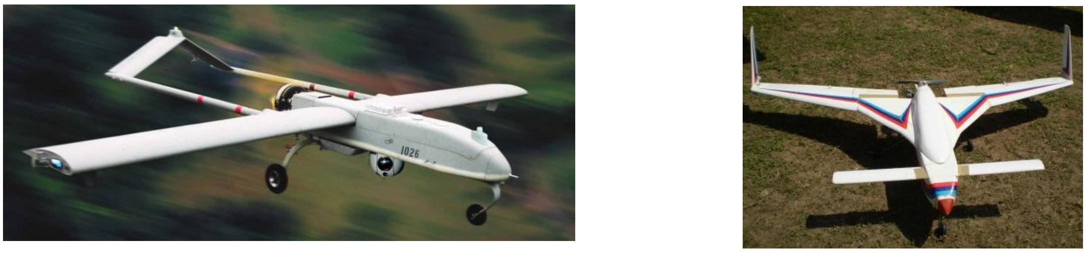

Fig. 3: Left-hand-side, the Shadow 200 (RQ-7B), and right-hand-side, the Rustom-1

Fig. 4: Left-hand-side, the X-47B, and right-hand-side, the X-47A.

If the classification is made referred to the tail possibilities, is usual to find conventional tail as the Elbit Skylark I in Figure 5 (left-hand-side), V tail as Predator in Figure 2, or H tail as IAI-Heron in Figure 5 (right-hand-side).

Fig. 5: Left-hand-side, the Elbit Skylark 1, and right-hand-side, the IAI Heron.

Finally, paying attention to the power plant the Global Hawk, X-47B and X-47-A, for example, they have a turbojet and are represented in Figure 6 (left-hand-side), Figure 4 (left-hand-side) and Figure 4 (right-hand-side), respectively. With pusher propeller and the power plant situated at the rear-end of the fuselage there are the Shadow 200 (RQ-7B) or the Rustom-1, in Figure 3 from the previous examples. The Elbit Skylark I has tractor propeller at the front part of the aerial vehicle and is represented in Figure 5 (left-hand-side). As it has been shown, there are a wide variety on the forms and geometries that UAVs can adopt. The last image is reserved for the Proteus in Figure 6 (right-hand-side), which has a very unusual configuration.

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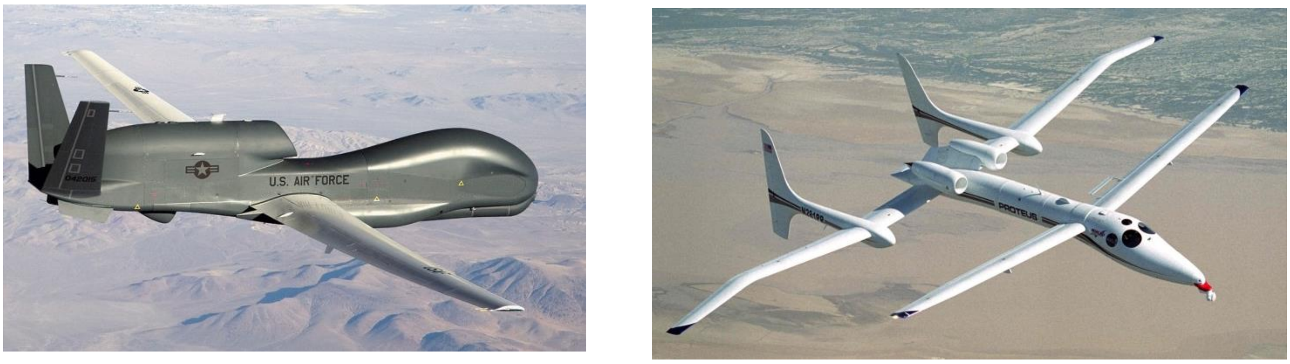

Fig. 6: Left-hand-side, the Global Hawk, and right-hand-side, the Proteus.

3.3.1. Rotary-wing UAVs

Rotary-wing UAVs fly by harnessing the lift generated by rotary-wings or rotor blades. These rotor blades are usually mounted on a single mast and revolve around it, forming the mechanical system known as rotor. There are also different types of rotary-wing UAVs, which can be classified as: helicopter UAVs, cyclogyro UAVs, autogyro UAVs or gyrodyne UAVs, depending on their rotor(s) configuration.

Helicopter UAVs can take off vertically, hover, fly forwards, backwards and laterally, as well as land vertically, using one or more powered engines throughout the flight. Helicopters with a single main lift rotor require some sort of anti-torque system in order to compensate for yaw, with tail rotor being the most common system among UAVs. One of the smallest UAVs ever designed is the tiny Black Hornet Nano, a 10 x 2.5 cm helicopter UAV, shown in Fig. 7.

Fig. 7: Left-hand-side, the Black Hornet Nano, and right-hand-side, the Parrot AR Drone quadrotor helicopter.

In cyclogyro UAVs, blades rotate about the horizontal axis while being parallel to it, offering advances in terms of efficiency, speed, noise and vibration. Cyclogyros should not be mistaken for flettner airplanes, which use cylindrical wings to generate lift, harnessing the Magnus effect. Although a number of cyclogyros were built in the 1930s, successful designs date only from 2011 on, currently being an active field of research.

Autogyro UAVs, inspired on the aircraft design of Spanish engineer Juan de la Cierva, utilizes an unpowered rotor driven by autorotation to generate lift, while thrust is provided by an engine-powered propeller, similar to that of a fixed-wing aircraft, offering a greater flight envelope at the cost of smaller speeds.

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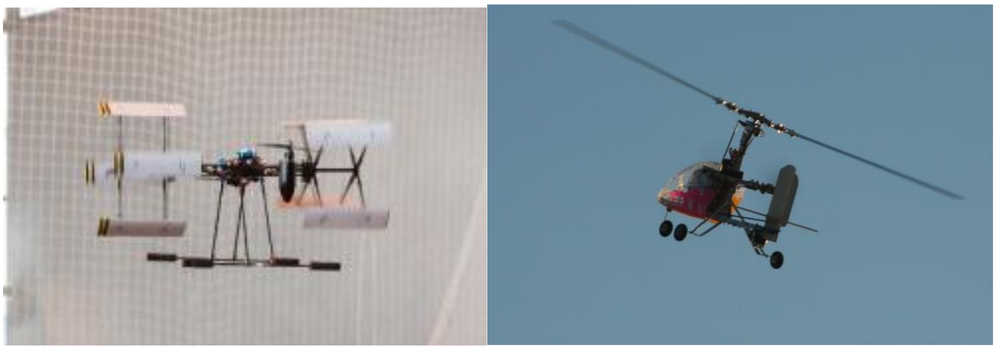

Fig. 8: Left-hand-side, a cyclocopter UAV prototype developed at Northwestern Polytechnical University en China, and right-hand-side, a UAV model of autogyro developed by FUVEX.

Gyrodyne UAVs have great historical importance, since at it was already mentioned, the gyrodyne DASH, shown in Fig. 9 (left-hand-side) was the first manufactured rotary-wing UAV. They use their main engine for take-off and landing and also include one or more engines to provide forward thrust during cruising flight. Gyrodyne UAVs are more efficient than autogyros, since no autorotation is needed and they also minimize the adverse effects of retreating blade stall of helicopters, all of it at the cost of a higher complexity.

Rotary-wing UAVs may also be classified attending to the number of rotors, which usually varies between three (tricopters), and eight (octocopters), with four rotors (quadrotors) being the most common UAV configuration by far. The most typical configurations are shown in Fig. 9 (right-hand-side). Usually a larger number of motors simply implies more lift as there are more motors producing thrust. Single rotor prototypes have been developed as well, like the spherical UAV presented in 2011 by the Japanese Ministry of Defense, which uses control surfaces to compensate the yaw rotation. There are as well recent examples of UAVs with a large number of rotors. For instance, NASA latterly developed a 10-rotor UAV, claimed to be four times more aerodynamically efficient in cruise than a standard helicopter.

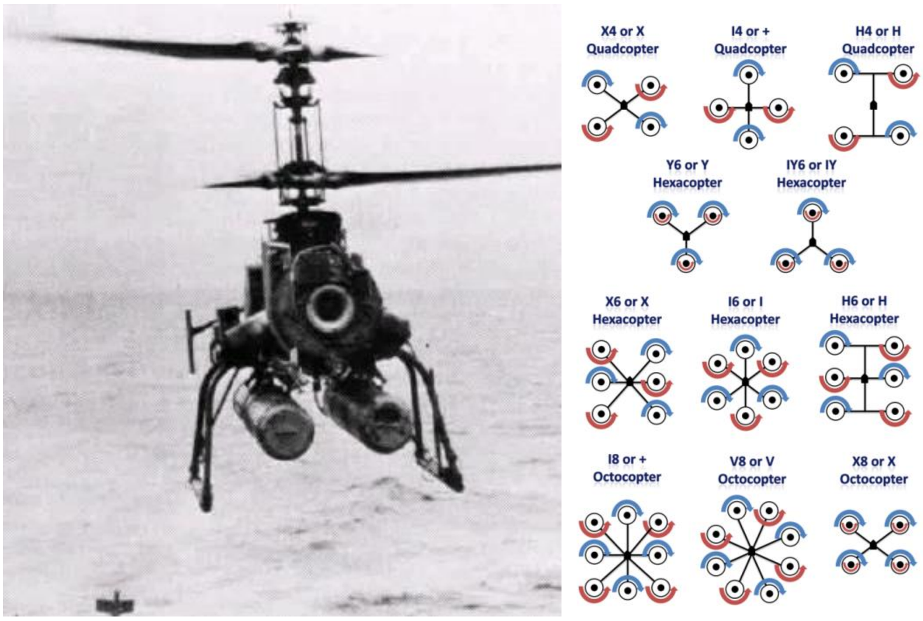

Fig. 9: Left-hand-side, Gyrodyne QH 50 DASH, and right-hand-side, most common rotor configurations in multirotor helicopter UAVs.

A last kind of UAV is the so-called flapping wings UAV, where the rotary movements of the motors are transformed into a flapping movement of some kind of flexible wings. This type of UAV are mainly designed for micro UAV called

FWMAV and they have big bio-inspiration component in their design, being currently focus of modeling research [9] as well as in actuators and wing deign [10]

4.- CONCLUSSIONS

Unmanned aviation is as older as manned, but in recent times the UAS/RPAS market is developing very fast mainly due to the increasing number of interesting and promising civil/commercial missions. In such way there are also a large number of platforms with very different configurations and performances. Nevertheless for a seamless integration of civil and commercial operations of these aircraft, several problems will have to be solved.

The challenges to address in the near future will come from the hand of the proper development and implementation of the following aspects:

- New technologies, new materials, bio-mimetic configurations and performance, completely autonomous operation, ability to "see and avoid", etc.
- New "roles": evolution similar to those of manned aircraft into completely new missions, which have never been undertaken by any other type of aircraft, as the automatic air cargo and passenger transport.
- New challenges: to further develop unmanned aviation, and unmanned aircraft specifically, greater reliability, an appropriate regulatory framework and stable portfolio of orders is required.

FOR DEEPER KNOWLEDGE

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