

## Chapter 2

# Aviation History and Unmanned Flight

*Heavier-than-air flying machines are impossible.*

Lord Kelvin, 1895

*It is apparent to me that the possibilities of the aeroplane,  
... have been exhausted, and that we must turn elsewhere.*

Thomas Edison, 1895

*Flight by machines heavier than air is unpractical and  
insignificant, if not utterly impossible.*

Simon Newcomb, 1902

This ‘pictorial’ Chapter presents a historical perspective on unmanned flight starting from the ancient times and reaching the beginning of the 21<sup>st</sup> Century. This is not aimed to be an exhaustive account of the history of neither aviation nor UAS. It is rather a glimpse of the stages of UAS evolution, complemented by an overview of the broad range of modern UAS sizes, types and capabilities, as well as, the large number of roles they are called upon to play. This will also put into perspective the daunting task of integrating all these different types of unmanned aircraft into an already crowded airspace. We believe that the best way to achieve this goal is through an account of key events and a series of photos.

This Chapter is divided into four sections corresponding to different time periods and — to a degree — to a different concept of what an unmanned aircraft is. The first Section concerns the first flying machines of antiquity and the Renaissance. The second Section is devoted to the first designs of unmanned aircraft that led to target drones and cruise missiles; followed by a section on the developments of the Cold War era, when the focus on research and development turned to unmanned, airborne reconnaissance. Finally a number of modern day systems, including some future designs are presented in the fourth Section.

## 2.1 Precursors of Flight and Unmanned Aircraft

In modern times, manned aviation appeared in the late 1700s and it took another century for heavier than air machines to take to the skies. Unmanned aircraft followed soon after the advent of the airplane, appearing around the time of the First World War (1916). However, the idea for a ‘flying machine’ was first conceived close to 2,500 years ago, in ancient Greece and China!

Pythagoras, Archimedes and others studied the use of autonomous mechanisms for a variety of applications. The first known autonomous flying machine has been

credited to Archytas from the city of Tarantas or Tarentum in South Italy, known as Archytas the Tarantine. Archytas has been referred to as Leonardo Da Vinci of the Ancient World and was also the father of number one in number theory [9] and the solution for doubling the cube. He was also possibly the first engineer, designing and building various mechanisms. In 425 B.C. he built a mechanical bird, which he called “the pigeon”, shown in Fig. 2.1. According to Cornelius Gellius in his *Noctes Atticae*, the bird was made of wood, nicely balanced with weights and flew using air (most likely steam) enclosed in its stomach [1]. It is alleged that Archytas’ pigeon flew about 200 meters before falling to the ground, once all energy was used. The pigeon could not fly again, unless the mechanism was reset [2].



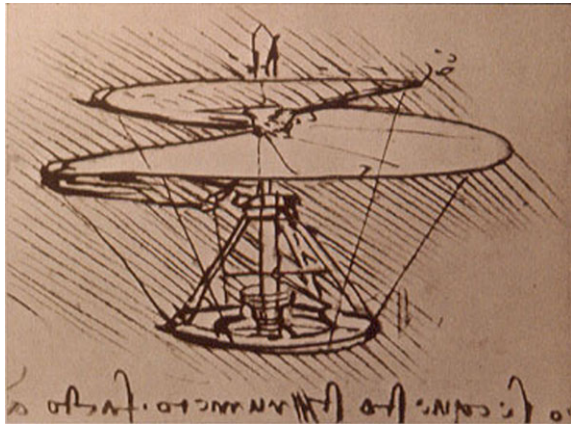
**Fig. 2.1** An artist’s depiction of the flying pigeon, the first documented UAS in history. It is reported that it flew for about 200 meters

During the same era in a different part of the Ancient World — China — at about 400 B.C., the Chinese were the first to document the idea of a vertical flight aircraft. The earliest version of the Chinese top consisted of feathers at the end of a stick. The stick was spun between the hands to generate enough lift before released into free flight.

Over the years, the Chinese experimented with other types of flying machines such as hot air balloons, rockets or kites. It is noteworthy that although some of these machines were used for entertainment, some of the applications were military

in nature. In fact there are historical records of a “wooden hawk” that was used for reconnaissance around 450 B.C., as well as a kite in the shape of a crow, which was employed during the Ming Dynasty to bomb enemy positions [11].

Several centuries later, Leonardo Da Vinci, in 1483, designed an aircraft capable of hovering, called aerial screw or air gyroscope, shown in Fig. 2.2. It had a 5 meter diameter and the idea was to make the shaft turn and if enough force were applied, the machine could spin and fly. This machine is considered by some experts as the ancestor of today’s helicopter [3]. Da Vinci also devised a mechanical bird in 1508 that would flap its wings by means of a double crank mechanism as it descended along a cable.

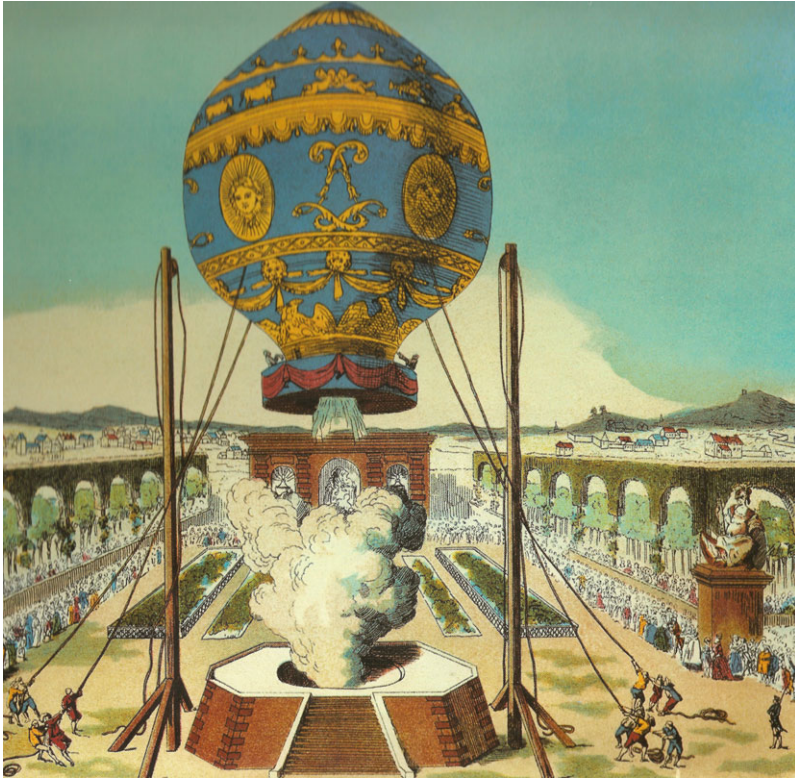


**Fig. 2.2** Leonardo Da Vinci’s air screw, a forerunner of modern helicopter designs (Public domain photo)

The first widely recognized manned flight took place in 1783 using a hot air balloon designed by the Montgolfier brothers and commemorated in Fig. 2.3. Soon after, similar attempts took place in England and for several years ballooning dominated manned flights, until the first helicopters in the 1860s and later fixed-wing aircraft.

Many flying machines were designed between 1860 and 1909, initially focusing on vertical take-off and landing aircraft because of the limitations of the steam-powered engines that were in use at the time. As the power to weight ratio of engines improved, these early machines were transformed to the helicopter and airplane designs that are in use today.

The main drive behind aircraft development has always been the fast and safe transportation of people and cargo. Nevertheless, the military soon realized the potential benefits of unmanned aircraft and efforts to adapt flying machines to operate without a pilot onboard started. Such systems were initially unmanned ordnance delivery systems, what would now be referred to as ‘missiles’ or ‘smart bombs’. Another use for such systems was to operate as ‘target drones’ that assisted in the training of anti-aircraft gun operators. Today UAS have been defined as those systems that are designed to be recovered after each mission and although they may carry weapons, the weapon is not by itself an integral component of the airframe [5].



**Fig. 2.3** The first manned flight using a hot air balloon took place in 1783 in France (Photo Credit: Bildarchiv Preussischer Kulturbesitz, Berlin)

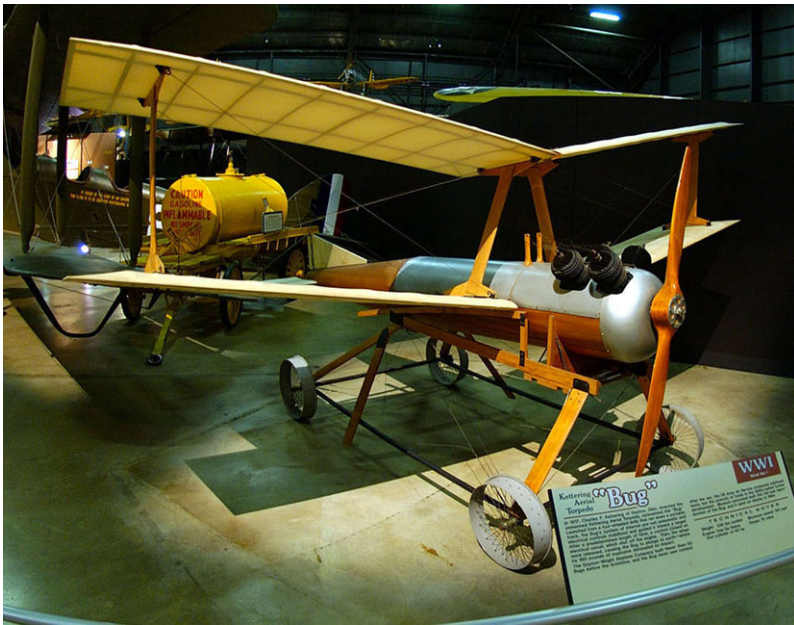
Nevertheless, in the early days of unmanned flight, these distinctions were not that important since the technological obstacles were the same and were even shared by manned aircraft as well.

## 2.2 1916–1944

In 1916, less than 15 years after the Wright brothers historical flight, the first modern unmanned aircraft was demonstrated. It was the Hewitt-Sperry Automatic Airplane, named after the two inventors that designed it. This aircraft could not have become a reality without the previous work of Sperry on gyroscopic devices that were needed to provide flight stabilization. Sperry managed to attract the interest of the US Navy resulting in the development of the Curtiss-Sperry Aerial Torpedo, while at the same time the US Army Air Force sponsored the Liberty Eagle Aerial Torpedo of Charles Kettering shown in Fig. 2.4 [12]. Due to technical problems and lack of accuracy,



interest on “automatic” planes was lost but the potential for use of remotely operated drones for target practice was soon realized.



**Fig. 2.4** The USAF Liberty Eagle Aerial Torpedo, also known as the Kettering Bug after its creator Charles Kettering (Photo Credit: National Museum of the USAF)

In Britain, experiments with unmanned aircraft took place throughout the 1920s with the RAE 1921 Target. In 1933, the Royal Navy used the Queen Bee target drone (Fig. 2.5) for the first time [5]. It was a modified version of the DeHavilland Tiger Moth biplane and was successfully employed for gunnery practice.



**Fig. 2.5** The DH.82B Queen Bee drone (Photo Credit: Adrian Pingstone)

Remote operation required the perfection of radio control, a concept proposed and demonstrated in 1895 and 1898, respectively, by Tesla [5]. Yet again private industry spurred developments, when actor Reginald Denny opened his “Reginald Denny Hobby Shops” in 1934 and started selling radio controlled airplanes. A few years later he demonstrated his work for the US Army that led to the development of a very successful target drone used extensively during WWII.

## 2.3 The Machines of the Cold War

Soon after the end of WWII, interest in reconnaissance missions increased. The descendants of Reginald Denny’s target drones became the basis of the first reconnaissance drone, the SD-1 [5]. Also known as the MQM-57 Falconer, it was developed in the mid 1950s and by the end of its career close to 1,500 had been built [4]. The SD-1 (Fig. 2.6) was remotely operated, carried a camera and after a 30 minute flight returned to base and was recovered with parachute [12].



**Fig. 2.6** The SD-1, also known as the MQM-57 Falconer, was the first reconnaissance drone of the US Army and remained in service until the 1970s (Photo Credit: National Museum of the USAF)

The loss of the U-2 spy plane over the Soviet Union in 1960 gave a new push towards unmanned reconnaissance drones and the loss of a second U-2 over Cuba two years later helped circumvent any doubts and funding problems [12]. The USAF supported the Ryan Model 147 drone that evolved into a series of models with different capabilities. Two variations of the more than two dozen available, are shown in Figs. 2.7 and 2.8. They were also based on a drone design and were used for reconnaissance missions by the US over China, Vietnam and other countries in the 1960s and 70s [5, 12]. During this time, close to 3,500 Lightning Bugs were launched and close to 84% returned [10]. It is noteworthy that these drones were credited with kills that occurred when fighters tried to shoot them down and one drone was given ace status after being responsible for the loss of five North Vietnamese MIGs [12].

The Ryan Model 147, which became known as the Lightning Bug was probably the first unmanned aircraft that can withstand today's definition of a UA. In fact, modernized versions of this drone are still being built and used to carry out missions to this day.

**Fig. 2.7** The AQM-34Q, one of several variations of the Ryan Model 147 unmanned reconnaissance drone, used in the 1960's and 1970's (Photo Credit: National Museum of the USAF)



**Fig. 2.8** The BGM-34C was another member of the Ryan Model 147 family. It was a multi-role drone capable of performing reconnaissance, electronic counter-measure and strike missions (Photo Credit: US Air Force)

Meanwhile, the US Navy acquired a helicopter drone from the Gyrodine Company called the QH-50 DASH (Fig. 2.9) [12]. This design was preferred because it could be launched from smaller vessels. Its main mission was to launch antisubmarine torpedoes, nevertheless, it was also used for surveillance, cargo transport and other applications. This was despite reliability issues with its electrical system that led to large number of peacetime losses [12].

**Fig. 2.9** A QH-50 DASH-drone armed with torpedoes over the flight deck of the USS Hazelwood (Photo Credit: US Navy)



In the late 1960s, the CIA was involved in its own hypersonic, long-range reconnaissance drone, designed to be launched from another “mother” aircraft. The D-21 Tagboard (Fig. 2.10) program was mired with technical problems, accidents and failed missions that led to its ultimate cancellation in the early 1970s [12].



**Fig. 2.10** The Lockheed D-21B Tagboard (Photo Credit: National Museum of the USAF)



In parallel with US efforts, the Soviet Air Force developed its own reconnaissance drones. The first system was the TBR-1 based on a popular target drone and it was soon followed by the DBR-1 (Fig. 2.11) that allowed for higher range and capabilities [12]. The DBR-1 was not designed to be fully recovered, instead when it reached the recovery area it dumped fuel, ejected the nose containing the sensor package and the rest of the airframe crashed. As a result, the DBR-1 involved high operational costs which led to its replacement in the mid 1970s by the Tu-141/143 (Fig. 2.12), a mid- and short-range, respectively, reconnaissance drone that were fitted with parachutes for recovery.



**Fig. 2.11** The DBR-1 also known as the Tupolev Tu-123 Yastreb (Photo Credit: Tupolev)



**Fig. 2.12** The Tupolev Tu-143 Reys reconnaissance drone with SPU-143 launcher at the Ukrainian Air Force Museum (Photo Credit: George Chernilevsky)

In Europe the unmanned system of choice of the time was funded by Canada and the UK and was developed by Canadair [12]. This resulted in the CL-89 Midge (Fig. 2.13) that was also acquired by the French and German armies. It was designed to follow a pre-programmed course, take photographs (day or night) and return to be recovered by parachute [12]. A more sophisticated version, the CL-289, that also featured better range was developed in the late 1970s with major funding coming now from Germany [12].



**Fig. 2.13** German reconnaissance drone CL-289 (Photo Credit: Karsten Franke)

Another major player in the area of unmanned aircraft was the Israeli Air Force, that acquired and operated a squadron of American drones for reconnaissance purposes during the Yom Kippur War [12]. Later the Israeli Aircraft Industries and Tadiran developed their own aircraft, the Scout (Fig. 2.14) and Mastiff, respectively [12]. The Mastiff was the basis of the very popular Pioneer system and the Israeli designs have also influenced the construction of the Predator and Shadow UAS [5].



**Fig. 2.14** The Israeli Aircraft Industries Scout drone. The similarity with the Pioneer UAS that was later bought by the US Armed Forces are evident (Photo Credit: Wikimedia Commons User Bukvoed)

## 2.4 Modern Systems

This Section is devoted to modern systems. Rather than following a chronological order, the systems are presented in groups of similar design or functionality. Furthermore, this Section only presents a small percentage of the vast number of operational UAS that are currently available.

The first group concerns the direct descendants of the reconnaissance drones. It includes the very popular Pioneer (Fig. 2.15) of the 1980s, which had over 1,500 flight hours in the Desert Storm operation [12]. Another very successful system is the Predator (Fig. 2.16), the improved version of the Gnat-750.



**Fig. 2.15** An RQ-2 Pioneer ready for launch during operation Desert Shield (Photo Credit: US Marine Corps)



**Fig. 2.16** An armed MQ-1 Predator flying a training mission. The MQ-1 is used for armed reconnaissance, airborne surveillance and target acquisition, can carry two laser-guided missiles and employs a crew of two [6] (Photo Credit: US Air Force)

Other systems include the RQ-4 Global Hawk (Fig. 2.17) a large, high altitude, long endurance system, the MQ-9 Reaper (Fig. 2.18), which besides reconnaissance can also be used as a hunter-killer, the Neptune (Fig. 2.19) that is used for water operations and finally the RQ-7 Shadow (Fig. 2.20), the Scan Eagle (Fig. 2.21) and Silver Fox (Fig. 2.22) systems.



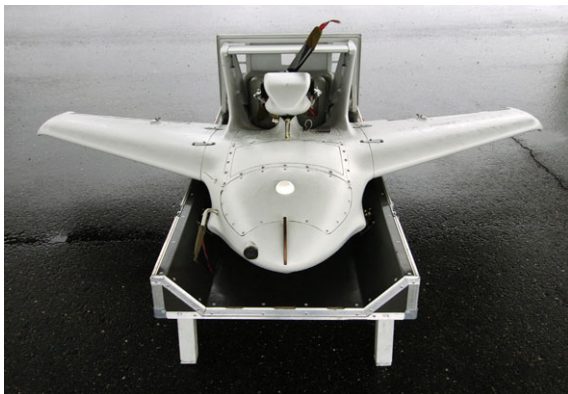
**Fig. 2.17** The RQ-4 Global Hawk is a high altitude, long endurance UAS . It was the first UAS to do a trans-pacific crossing [5] (Photo Credit: US Air Force, Master Sgt. Jason Tudor)

**Fig. 2.18** The MQ-9 Reaper is an updated version of the Predator UAS. It is primarily used as a persistent hunter-killer UAS for critical time-sensitive targets and secondarily for intelligence gathering [8] (Photo Credit: US Air Force, Staff Sgt. Brian Ferguson)





**Fig. 2.19** The Neptune, a reconnaissance UAS capable of water landings (Photo Credit: US Navy)



**Fig. 2.20** The RQ-7 Shadow is developed by AAI for the US Army and has been deployed in Iraq (Photo Credit: US Army)



**Fig. 2.21** Scan Eagle is a low-cost, long endurance UAS used by the US Marine Corps [7] (Photo Credit: US Air Force)







**Fig. 2.22** Silver Fox is a reconnaissance UAS used by the US Marine Corps. (Photo Credit: US Navy, Mate 2nd Class Daniel J. McLain)

Of course besides the US, other countries have developed their own similar systems. Specifically, more than 50 countries are currently involved in the development of over 1,000 different UAS. Israel has been updating its own fleet with systems such as the IAI Heron (Fig. 2.23). In Britain the BAE Phoenix (Fig. 2.24) has been used for combat surveillance while the french-built SPERWER (Fig. 2.25) has been acquired by a number of other European armed forces.



**Fig. 2.23** The IAI Heron is medium altitude long endurance UAS. Specifically it can fly for close to two full days. (Photo Credit: US Air Force)

**Fig. 2.24** The BAE Systems Phoenix was a British surveillance drone used in Kosovo and Iraq until its retirement (Photo Credit: Wikimedia Commons User BilborneOne)



**Fig. 2.25** The french SPERWER. It is used by the military forces of several European nations (Photo Credit: David Monniaux)

In the Russian Federation there are several companies involved with UAS development. Yakovlev has fielded several systems, an example of which is the Pchela (Fig. 2.26). Similarly, the Irkut Corporation is developing a range of UAS systems, including the Irkut 2M, 3, 10, 200 (Fig. 2.27) and 850 systems. The Dozor-600 (Fig. 2.28) is another recent, Russian UAS. Argentina, Australia, Belgium, Brazil, Canada, Chile, Greece, Italy, Iran, South Africa, Spain, Sweden Switzerland and Turkey are only some of the other countries around the world developing their own systems, sometimes in collaboration.

**Fig. 2.26** The Yakovlev Pchela surveillance and observation UAS (Public domain photo)



**Fig. 2.27** The Irkut-200 Aerial Remote Sensing System with up to 12 hours of flight endurance (Photo Credit: Wikimedia Commons User Allocator)



**Fig. 2.28** The Dozor-600 is a long endurance surveillance platform similar to MQ-1 Predator or the Hermes 450 (Public domain photo)



Although some of the aforementioned UAS like the MQ-9 Reaper can be armed, there is an entire class of systems being developed that their primary mission is combat operations. Although many of these systems known as Unmanned Combat Aircraft Systems (UCAS) are still in experimental stages, there are several that are operational. Examples of UCAS include the Neuron (Fig. 2.29), the Barracuda, the Italian Sky-X (Fig. 2.30), the MiG Skat, the General Atomics Avenger, the BAE Mantis (Fig. 2.31) and the Northrop Grumman X-47 system (Fig. 2.32).



**Fig. 2.29** The Neuron is an experimental UCAS being developed by a consortium of European companies (Photo Credit: Wikimedia Commons User Tangopaso)



**Fig. 2.30** The Sky-X is an Italian UCAS built by the Finmeccanica group. It first flew in 2005 (Photo Credit: Wikimedia Commons User Duch.seb)



**Fig. 2.31** The BAE Mantis is a demonstrator platform for an advanced UCAS that first took flight towards the end of 2009 (Public domain photo)



**Fig. 2.32** The X-47 started from the DARPA sponsored J-UCAS and is now part of a US Navy program to develop a carrier-based UCAS (Photo Credit: DARPA)

Almost all of the aforementioned systems are of the fixed-wing design. However, there is a number of helicopter UAS available, several of which are currently operational in military and civil applications. Some examples of helicopter UAS include the A-160 Hummingbird (Fig. 2.33), the APID55 (Fig. 2.34), the Schiebel S-100 (Fig. 2.35) and the MQ-8 Firescout (Fig. 2.36).



**Fig. 2.33** The A-160 Hummingbird built by Boeing/Frontier. It is a demonstrator for improvements in range endurance and controllability [7] (Photo Credit: US DoD)



**Fig. 2.34** The APID55 is a multi-purpose, fully autonomous helicopter platform with an endurance of over three hours and payload capacity of over 50 kg. It is built by Cybaero (Photo Credit: Cybaero)



**Fig. 2.35** The Schiebel S-100 is a helicopter UAS used by a number of nations particularly for navy operations (Photo Credit: Matthias Kabel)



**Fig. 2.36** The MQ-8 Fire Scout is being developed by Northrop Grumman Corporation to support US Army and Navy requirements (Public domain photo)



In recent years there is an increasing interest for long endurance UAS, systems that can fly for several days. Besides the RQ-4 Global Hawk previously presented, which was the first UAS to do a trans-pacific crossing, the Aerosonde Laima (Fig. 2.37) was the first to do the trans-atlantic crossing. A large number of long endurance systems are used for civilian applications. For example NASA employs the Helios, Altair and Ikhana UAS (Figs. 2.38 to 2.40) primarily for earth science missions. Finally the Zephyr (Fig. 2.41) managed to remain for almost four days airborne, taking into advantage its lightweight design and solar power.



**Fig. 2.37** The Aerosonde Laima was the first UAS to make a trans-atlantic crossing [5] (Public domain photo)



**Fig. 2.38** The Helios UAS developed by NASA and AeroVironment. During its second high-altitude flight, it reached 96,863 ft, shattering the existing world altitude record for sustained level flight for both propeller and jet-powered aircraft (Photo Credit: NASA)



**Fig. 2.39** The Altair is a Predator variant developed for NASA for high altitude, earth science missions (Photo Credit: NASA)



**Fig. 2.40** The Ikhana is a Predator B UAS acquired by NASA and retrofitted for earth science missions (Photo Credit: NASA)

**Fig. 2.41** The Zephyr is a solar-powered, high endurance UAS developed by Qinetiq. In July of 2008 it performed an 82 hour long flight (Photo Credit: Qinetiq)



When the size of a UAS is reduced, its payload capacity will need to be reduced as well. Nevertheless, there is a number of small and miniature UAS in operation or active development. This is because they are versatile, portable, and easy to maintain; they can be employed for the same applications as larger UAS on a smaller scale and at a lower cost. In fact several of these systems are considered expendable and no recovery is attempted especially if there is any risk perceived.



**Fig. 2.42** The Skylark is a hand-launched system for tactical surveillance and reconnaissance developed by Elbit (Photo Credit: MORH)

Examples of small UAS include the Skylark (Fig. 2.42), the Evolution (Fig. 2.43) the Puma (Fig. 2.44) and the Aerocon Inspector (Fig. 2.45). In the miniature category, there exist systems that weigh less than 1–3 kg and are easily back-packable (some are even foldable). Such systems include the Cyberbug, Raven, WASP, BAT-CAM, Nighthawk and the Dragon Eye (Figs. 2.46 to 2.51).

**Fig. 2.43** The L-3 BAI Aerospace Evolution XTS is a portable UAS with EO/IR payload. It was employed in the rescue efforts after hurricane Katrina (Photo Credit: NIST)



**Fig. 2.44** The Puma is another evolution from the Pointer UAS. There are two versions available, the Aqua Puma and the Terra Puma for marine and land environments respectively (Photo Credit: US DoD)



**Fig. 2.45** The Aerocon Inspector weighs just 7 kg and has an operational range of 25 km (Photo Credit: Wikimedia Commons User Allocer)



**Fig. 2.46** The Cyberbug is a light-weight UAS for urban surveillance applications (Photo Credit: NIST)



**Fig. 2.47** The Raven is a back-packable UAS for “over the hill” and route reconnaissance that evolved from the Pointer UAS. In the photo paratroopers are training with an RQ-11 Raven (Photo Credit: US Army, Sgt. Amanda Jackson)



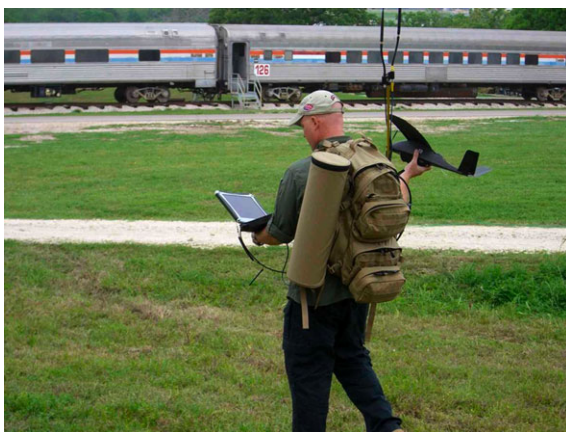
**Fig. 2.48** The WASP is a MAV that can carry an EO payload and has an endurance of over one hour (Photo Credit: NIST)



**Fig. 2.49** The Battlefield Air Targeting Camera Micro Air Vehicle (BATCAM) is a miniature, short-range UAS (Photo Credit: National Museum of the USAF)



**Fig. 2.50** The Nighthawk is the evolution of the BATCAM foldable UAS (Photo Credit: NIST)



**Fig. 2.51** The Dragon Eye is a small UAS used by the US Marine Corps for short-range Surveillance and Reconnaissance (Photo Credit: US DoD)



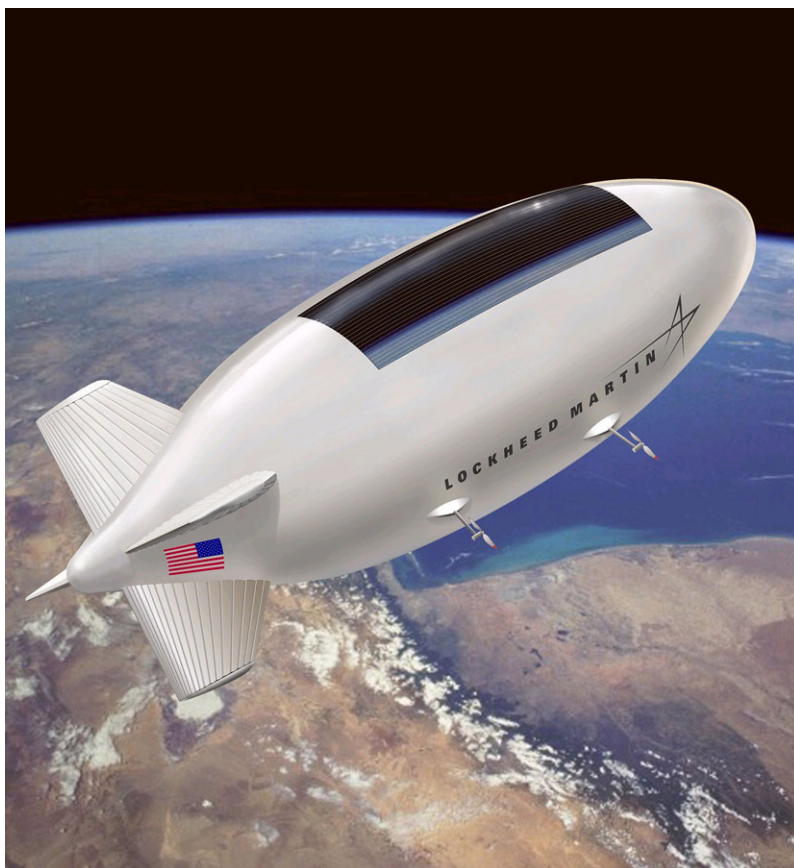
Another UAS design concerns the lighter-than-air systems or airships, a distinct UAS category with significantly higher endurance than other systems that makes them ideal for a variety of operations. The main advantage of such systems is that they provide an airborne sensor platform that can be used for persistent area surveillance. Such systems include the Joint Land Attack Elevated Netted Sensor (Fig. 2.52), the Persistent Threat Detection System (Fig. 2.53) and the Rapid Aero-stat Initial Deployment system (Fig. 2.54). The High Altitude Airship (Fig. 2.55) is an untethered platform concept that will be able of providing satellite-like services to ground forces.

**Fig. 2.52** Joint Land Attack Elevated Netted Sensor (JLENS) by Raytheon/TCOM capable of providing over-the-horizon surveillance (Photo Credit: US Army)



**Fig. 2.53** The Persistent Threat Detection System (PTDS) is equipped with a high resolution EO/IR payload used for surveillance (Photo Credit: US Army)

**Fig. 2.54** The Rapid Aerostat Initial Deployment (RAID) is a smaller version of the JLENS, used in missions of area surveillance and force protection against small arms, mortar and rocket attacks. (Photo Credit: US Army)



**Fig. 2.55** High Altitude Airship (HAA) developed by Lockheed Martin. It is a solar powered, untethered, long endurance, high altitude demonstrator (Photo Credit: US Missile Defense Agency)



In addition to the popular fixed-wing and helicopter systems, other designs are also used for UAS. Figures 2.56 to 2.58 show the iStar MAV, the Sikorsky Cypher and the SELEX Galileo Spyball, all employing duct-fan designs. The IT-180 (Fig. 2.59) and the KOAX X-240 (Fig. 2.60) use two counter-rotating rotors, thus eliminating the need for a tail-rotor. The Eagle Eye (Fig. 2.61) and X-50 (Fig. 2.62) are systems that combine some of the advantages of fixed-wing and helicopter designs. The CyberQuad (Fig. 2.63) and the AirRobot AR 100-B (Fig. 2.64) are both examples of the quad-rotor design that is especially popular in academic environments.

**Fig. 2.56** The iSTAR MAV duct-fan aircraft built by Allied Aerospace (Photo Credit: US Navy)



**Fig. 2.57** The Sikorsky Cypher uses a shrouded twin-rotor design (Photo Credit: US Navy)





**Fig. 2.58** The SELEX Galileo Spyball is an ultra-light UAS that can fit inside a rucksack (Photo Credit: Wikimedia Commons User Causa83)



**Fig. 2.59** The IT-180 is a French-built light-weight UAS that uses a twin, counter-rotating rotor system (Photo Credit: Infotron)

**Fig. 2.60** The KOAX X-240 is a Swiss coaxial unmanned helicopter with 90min endurance (Photo Credit: Wikimedia Commons User ILA-boy)



**Fig. 2.61** The Eagle Eye is a tilt-rotor UAS developed by Bell Helicopter. It was selected by the US Coast Guard for its Deepwater program but was put on hold in 2007 (Photo Credit: US Coast Guard)

**Fig. 2.62** The X-50 aircraft built by Boeing Corp. It is a technology demonstrator for the Canard Rotor Wing (CRW) configuration which combines hovering capabilities with high cruise speeds [7] (Photo Credit: US DoD)



**Fig. 2.63** The CyberQuad uses a shrouded quad-rotor design that offers simple dynamics, stability and agility (Photo Credit: CyberTech)



**Fig. 2.64** The AirRobot AR 100-B features autonomous landing when it is out-of-range or when the battery is low (Public domain photo)



## 2.5 Remarks

Although this Chapter was not meant to be a comprehensive presentation of all UAS in development or service, it does indicate the range of designs and operational characteristics available. It is noteworthy that unique applications of UAS in environments traditionally inaccessible to aircraft, as in the case of low altitude urban operations, have led to the development of equally unique solutions.

A comprehensive listing of UAS developed and/or in operation around the globe is provided in App. C.

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On Integrating Unmanned Aircraft Systems into the  
National Airspace System

Issues, Challenges, Operational Restrictions,  
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