Review on UAVs used for Aerial Surveillance

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Abstract - Unmanned aerial vehicles (UAVs) known variously as drones or remotely piloted vehicles (RPVs) are small aircraft that can fly without an onboard human operator. They are either autonomous or semi-autonomous and can carry cameras, sensors, communication equipment or other payloads. Their uses have been seen as the most effective for aerial surveillance. In this paper, we review the various trends in their development vis-à-vis their application in aerial surveillance. The results gathered from our review shows that UAVs are very effective for aerial surveillance.

Keywords — Unmanned Aerial Vehicle, Drone, Aerial Surveillance, aircraft.

I. INTRODUCTION

Drones, or unmanned aerial vehicles (UAVs), are aircraft that can fly without an onboard human operator [1][4]. The entire system includes the flight controller, digital network and personnel on the ground. Drones can fly either by remote control or on a predetermined flight path; can be as small as an insect and as large as a traditional jet [2]. They can be produced more cheaply than traditional aircraft and can keep operators out of harm's way [1].

According to [2], they use aerodynamic forces to provide air vehicle lift, and they are designed to carry nonlethal payloads for missions such as reconnaissance, surveillance, command and control, and deception. Although, in recent times, they are being programmed to carry lethal weapons. They are mostly directed or coordinated by a ground or airborne controller or are preprogrammed [2].

In the past years, UAVs are mostly used in military applications. But presently, their use is expanding in commercial, scientific, recreational and other applications, such as policing and surveillance, aerial photography and agriculture [2][3][4]. Civilian drones now vastly out number military drones, with estimates of over a million sold by 2015 [3]. In addition to these, drones are being considered for use in domestic surveillance operations to protect valuable assets, assist in crime fighting, disaster relief, immigration control, and environmental monitoring.

In most developed country like the USA, drones have been employed domestically by federal, state, and local governments in a range of circumstances. They are being use to police their borders to deter unlawful border crossings by unauthorized aliens, criminals, and terrorists, and to detect and interdict the smuggling of weapons, drugs, and other contraband into the country [3]. They may also be employed for a wide range of transportation operations and planning applications: incident response, monitor freeway conditions, coordination among a network of traffic signals, traveler information, emergency vehicle guidance, track vehicle movements in an intersection, measurement of typical roadway usage, monitor parking lot utilization, estimate Origin-Destination (OD) flows.

Drones gained notoriety during their use in the post-9/11 armed conflicts in the Middle East. The United States government use drones to conduct detailed surveillance on countries such as Afghanistan, Iraq, and Iran, as well as to drop targeted missiles. In early 2007, more than 700 drones were being utilized in Iraq alone [7].

The major advantage of UAVs that make them useful for aerial surveillance is that, they can move at higher speeds than ground vehicles as they are not restricted to traveling on the road network. They can potentially fly in conditions that are too dangerous for a manned aircraft, such as evacuation conditions, or very bad weather conditions. UAVs are programmed off-line and controlled in real-time to navigate and to collect transportation surveillance data. UAVs can view a whole set of network of roads at a time and inform the base station of emergency or accidental sites. It also permits timely view of disaster area to access severity of damage. Figure 1 and 2 shows an example of a typical aerial surveillance UAV. Most UAVs are able to be flown for up to 45 minutes on a single battery charge and can travel up to 2 miles from the controller, reaching effective surveillance altitudes of approximately 1,000 feet [15].

Fig. 1. Home surveillance UAV

a. (source: (http://tinyurl.com/jb4ecb4))

Fig. 2. Commercial Drone for surveillance

b. (source: (http://tinyurl.com/znyxu6t))

As discussed in [15], surveillance UAVs can be program to launch at regular intervals throughout the day, survey specific areas or features on the map, record video and transmit it all back in real-time, or record it to a DVR for logging and review later. They can also be programmed to deploy when event-driven triggers, such as seismic sensors, motion detectors and invisible infrared geo-fences are activated by an unidentified presence.

The rest of the paper is organized as follow: section II discusses the various classifications of existing UAVs, section III highlighted some of the UAVs used for aerial surveillance, section IV discuss the issues of Privacy as it relates to surveillance UAVs while section V concludes the paper.

II. UAV CLASSIFICATION

UAVs can be broadly classified into five functional categories:

1) Target and decoy UAVs: they provide ground and aerial gunnery; a target that simulates an enemy aircraft or missile.

2) Reconnaissance (Surveillance) UAVs: they provide battlefield intelligence.

3) Combat UAVs: they provide attack capability for high-risk missions.

4) Logistics UAVs: they are used for delivering cargos.

5) Civil and commercial UAVs – they are used for agriculture, aerial photography and data collection.

Another classification is in terms of their range/altitude:

a) Hand-held: 2,000 ft (600 m) altitude, about 2 km range.

b) Close range: 5,000 ft (1,500 m) altitude, up to 10 km range.

c) NATO type: 10,000 ft (3,000 m) altitude, up to 50 km range.

d) Tactical: 18,000 ft (5,500 m) altitude, about 160 km range.

e) MALE (medium altitude, long endurance): up to 30,000 ft (9,000 m) and range over 200 km.

f) High-Altitude Long Endurance (high altitude, long endurance – HALE): over 30,000 ft (9,100 m) and indefinite range.

g) Hypersonic high-speed, supersonic (Mach 1–5) or hypersonic (Mach 5+): 50,000 ft (15,200 m) or suborbital altitude, range over 200 km.

h) Orbital low earth orbit (Mach 25+).

i) CIS Lunar Earth-Moon transfer.

Basically, classifying UAVs as given above does not follow any laydown rule. It is to be noted that, with a growing number of UAVs being developed and deploy in recent years, there is the problem of classifying these new UAVs. As UAVs are used in a variety of applications, it is difficult to develop one classification system that encompasses all UAVs. It has been decided that the UAVs will be classified into the two main aspects of a UAV, their performance specifications and their mission aspects. Their specifications include; weight, payload, endurance and range, speed, wing loading, cost, engine type and power [6]. But according to the U.S. Department of Defense, UAVs are classified into five categories, as contain in Table 1.

TABLE I. UAVs Classification according to the US Department of Defense (DoD)

Category	Size	Maximum Gross Takeoff Weight (MGTW) (lbs)	Normal Operating Altitude (ft)	Airspeed (knots)
Group 1	Small	0 – 20	<1200 AGL	<100
Group 2	Medium	21 – 55	<3500	<250
Group 3	Large	<1320	<18000 MSL	<250
Group 4	Larger	>1320	<18000 MSL	any
Group 5	Largest	>1320	>18000	Any
AGL = Above Ground Level MSL = Mean Sea Level				

III. AERIAL SURVEILLANCE UAVs

According to [8], surveillance is the close observation of a person, group of people, behaviours, activities, infrastructure, building etc, for the purpose of managing, influencing, directing, or protecting. There are several different methods of surveillance, including GPS tracking, camera observation, stake-outs, data mining and profiling, and biometric surveillance among others.

As noted in [7] and [8], traditional observational surveillance methods are typically limited by the stationary nature of the camera, which is usually handled manually or fixed upon a tripod or other structure. Aerial surveillance can be performed using a helicopter; whilst this achieves the desired result, it is also very costly. Unmanned aircraft systems (UAVs) provide the ideal solution to the problems and limitations faced by other surveillance methods. They present an easier, faster, and cheaper method of data collection, and a number of other key advantages. Surveillance UAVs can enter narrow and confined spaces, produce minimal noise, and can be equipped with night vision cameras and thermal sensors, allowing them to provide imagery that the human eye is unable to detect.

Surveillance drones are equipped with sophisticated imaging technology that provides the ability to obtain detailed photographs of terrain, people, homes, and even small objects. Giga-pixel cameras used to outfit drones are among the highest definition cameras available, and can "provide real-time video streams at a rate of 10 frames a second". They can also carry infrared cameras, heat sensors, GPS, sensors that detect movement, and automated license plate readers [7].

Some of the UAVs that are specially designed for aerial surveillance or reconnaissance are discussed below:

A. *General Atomics MQ-9 Reaper*

General Atomics MQ-9 Reaper (formerly named Predator B) is an unmanned aerial vehicle (UAV) capable of remote controlled or autonomous flight operations, developed by General Atomics Aeronautical Systems (GA-ASI) primarily for the United States Air Force (USAF). It is often refers to as a Remotely Piloted Vehicles/Aircraft (RPV/RPA) by the USAF to indicate their human ground controllers [9][10]. Figure 3 shows a typical Reaper UAV. MQ-9 Reaper UAV is being used by US Air force, NASA and US Homeland Security. Other users outside US include; Australia, Dominican Republic, France, Germany, Italy, Netherlands, Spain and UK.

Fig. 3. MQ-9 Reaper

c. (source: (http://tinyurl.com/hsy9hdg))

As noted in [11], MQ-9 Reaper is the first hunter-killer UAV designed for long-endurance, high-altitude surveillance. It has a 950-shaft-horsepower (712 kW) turboprop engine. Its greater power allows it to carry 15 times more ordnance payload and cruise at about three times the speed of the MQ-1 and it can be monitored and controlled by aircrew in the Ground Control Station (GCS).

As contained in [12], MQ-9 system consists of multiple aircraft, ground control station, communications equipment, maintenance spares, and personnel. The aircraft is powered by a 950 horsepower (710 kW) turboprop, with a maximum speed of about 260 knots (480 km/h; 300 mph) and a cruising speed of 150–170 knots (170–200 mph; 280–310 km/h). With a 66 ft (20 m) wingspan, and a maximum payload of 3,800 lb (1,700 kg), the MQ-9 can be armed with a variety of weaponry, including Hellfire missiles and 500-lb laser-guided bomb units [13]. The Reaper has a range of 1,000 nmi (1,150 mi; 1,850 km) and an operational altitude of 50,000 ft (15,000 m), which makes it especially useful for long-term loitering operations, both for surveillance and support of ground troops [14].

B. *Arcturus T-20*

According to [16], Arcturus T-20 is a runway independent tactical surveillance UAV developed by Arcturus-UAV, LLC and is primarily used by the United States Navy since 2009. It is of medium range, fully composite capable of internal and external payloads. Figure 4 shows an Arcturus T-20 in operation. The T-20 system includes three aircraft, ground control station, portable launcher, and support trailer for equipment and personnel. The airframe is entirely composite with complex wet wings tested to stresses of 10 G's [16].

Fig. 4. Arcturus T-20

d. (source: (http://arcturus-uav.com))

T-20 carries a retractable gimbal-mounted, digitally stabilized, electro-optical/infrared (EO/IR) camera that relays video in real time via a C-band LOS data link to the ground control station (GCS). It is powered by a 4-stroke, fuel injected gasoline engine, the aircraft burns 2 lbs of fuel per hour at cruise. It does not require an airfield to operate and lands on dirt, grass, desert, or gravel roads. The internal payload bay (11"x11"x36") allows for sensor arrays to be pre-assembled on 'payload pallets' that attach from the bottom of the aircraft [16].

T-20 general specifications and performances are; Length: 9.4 ft in (2.8 m), Wingspan: 17.2 ft in (5.2 m), Height: 3.0 ft in (1 m), Empty weight: 110 lb (50 kg), Gross weight: 175 lb (79 kg), Powerplant: 1×1 Aviation Gasoline Avgas 110 LL 4 stroke internal combustion, 10 hp (7.5 kW) each. Maximum speed: 104 mph (167 km/h), Range: 55 LOS miles

(89 km), Endurance: 16 hours, Service ceiling: 23,500 ft (7,162 m) [16].

C. *DRS RQ-15 Neptune*

As noted in [17], DRS RQ-15 is a surveillance UAV developed by DRS in the United States in 2010. DRS RQ-15 Neptune is the latest in the DRS family of mobile, low-footprint tactical Unmanned Aircraft Systems (UAS). The RQ-15 Neptune can be operated from land or sea. It can be disassembled into three parts and carried in its launcher/transport case. One of its unique features is a pair of built-in receiver tubes, which allows it to slide onto its launch rails for compact storage inside the transport container. It can be pneumatically auto launched in a matter of minutes. The launcher/transport container provides a Tactical UAS in a Mini-UAS footprint [18].

RQ-15 Neptune specifically addresses tactical operations over land or water where formal runway systems are unavailable. The six-foot launcher allows the aircraft to be deployed from utility vehicles or small surface vessels supporting operations day or night, on land or at sea [18]. Figure 5 depict a typical DRS RQ-15 Neptune UAV.

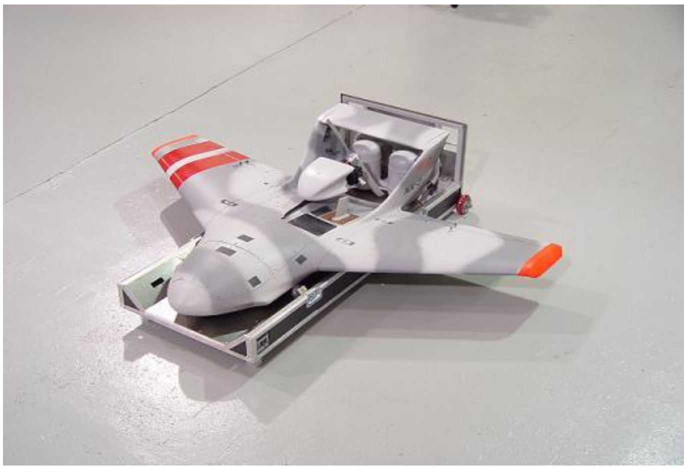

Fig. 5. DRS RQ-15 Neptune

e. (source: [17])

Its general characteristics and performance are: Crew: None, Capacity: 20 lb payload, Length: 6 ft 0 in, Wingspan: 7 ft 0 in, Gross weight: 80 lb, Powerplant: 1 × piston engine, 15 hp, Maximum speed: 100 mph, Endurance: 4 hours, Service ceiling: 8,000 ft [17].

D. *Schiebel Camcopter S-100*

Schiebel Camcopter S-100 is an Austrian unmanned aerial vehicle (UAV) using a rotorcraft design. It was produced by the Austrian company Schiebel around 2005. It operates day and night, under adverse weather conditions, with a range out to 200 km, both on land and at sea. It navigates automatically via pre-programmed GPS waypoints or can be operated directly with a pilot control unit. Missions are planned and controlled via a simple point-and-click graphical user interface. High-definition payload imagery is transmitted to the control station in real time [19]. A sample Schiebel Camcopter S-100 is as show in Figure 6.

Fig. 6. Schiebel Camcopter S-100

f. (source: [19])

As explain in [19], it has a maximum take-off weight (MTOW) of 200 kilograms (440 lb) and its endurance is 6 hours. It has a maximum speed of 220 kilometres per hour (140 mph) and a ceiling of 5,500 metres (18,000 ft). It is powered by a 55 horsepower (41 kW) Diamond engine and can carry various payloads, such as electro-optics and infrared sensors.

It has electro-optical (EO) and infrared sensors, as well as thermal surveillance equipment. The EO sensor converts light rays into electronic signals for capturing images, real-time data and videos. The Thermal surveillance equipment is used to capture high-resolution images during the night by penetrating through clouds, rain, smoke, fog and smog.

Its general characteristics and performance are: Crew: None, Capacity: 50 kg (110 lb), Length: 3.11 m (10 ft 2 in), Width: 1.24 m (4 ft 1 in), Height: 1.12 m (3 ft 8 in), Empty weight: 110 kg (243 lb), Max takeoff weight: 200 kg (441 lb), Fuel capacity: 57 L (15.5 gal) AVGas 100 LL, Powerplant: 1 × Austro Engine AE50R Wankel engine, 41 kW (55 hp) (basic), Powerplant: 1 × Schiebel heavy fuel engine (optional), Main rotor diameter: 3.4 m (11 ft 2 in), Maximum speed: 222 km/h; 138 mph (120 kn), Cruise speed: 185 km/h; 115 mph (100 kn), Never exceed speed: 241 km/h; 150 mph (130 kn), Range: 180 km (112 mi; 97 nmi), Endurance: 6 hours, Service ceiling: 5,486 m (18,000 ft), g limits: +3.5 g to -1 g, Hardpoints: 2 [19].

E. *Honeywell RQ-16 T-Hawk*

Honeywell RQ-16 developed in the United States by Honeywell is a ducted fan VTOL micro UAV. It is suitable for backpack deployment and single-person operation [20]. Figure 7 shows a typical Honeywell RQ-16 Hawk in operation.

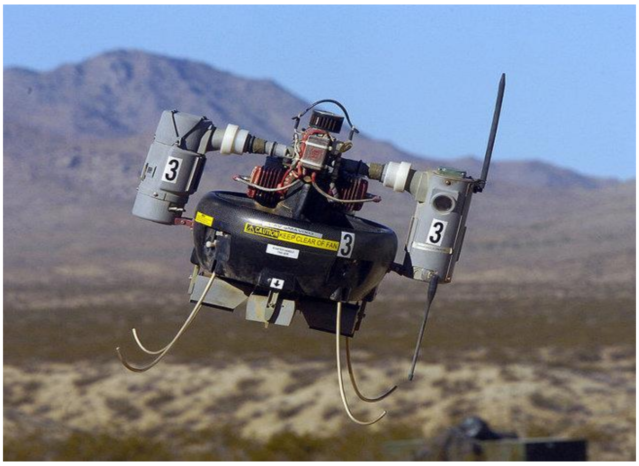

Fig. 7. Honeywell RQ-16 T-Hawk

g. (source: [20])

It originated from the DARPA "Organic Air Vehicle" (OAV) program in the early 2000s, which evaluated - among others - ducted-fan VTOL micro-UAV designs of various sizes. The prototype of the design that eventually evolved into the RQ-16 made its first tethered flight in January 2005, and the first free flight occurred in June that year. This was followed by an extensive evaluation by the U.S. Army infantry. The air vehicle was also known as G-MAV (the "G" denoting a gasoline engine), and has since been named *T-Hawk* (short for "Tarantula Hawk", a wasp species) by Honeywell [20][21].

It is to be used for short-range surveillance, reconnaissance, target acquisition and battle management. The initial military evaluation focused on the detection of IEDs (Improvised Explosive Devices). The current design features two pods on the outside of the duct, which house flight control electronics, video camera, GPS receiver and radio [20].

The T-Hawk can be operated from within the vehicle and by a single person. The navigation is supported by SAASM GPS, IMU pressure altimeter and magnetometer. It uses DDL radio for communications and supports up to 97 selectable channels. The range of communication is about five to ten kilometres. The ground control station consists of portable computer which commands the vehicle through GPS satellite coordinates. The speed and position of the MAV are monitored through an internal measurement unit. The ground control station provides video documentation of the situations in real time and can store up to 240 minutes of sensor imagery [22].

Its general characteristics and performance are: Crew: None, Gross weight: 20 lb (8.4 kg), Powerplant: 1 × 3W-56 56cc Boxer Twin piston engine, 4 hp (3 kW) each, Maximum speed: 81 mph (130 km/h), Endurance: ca. 0 hours 40 min, Service ceiling: 10,500 ft (3,200 m) [21].

F. AeroVironment RQ-20 Puma

AeroVironment RQ-20 Puma is a small, battery powered, American hand-launched unmanned aircraft system produced by AeroVironment based in California, US in 2008. It primary mission is surveillance and intelligence gathering using an electro-optical and infrared camera [24].

As explain in [23], its full mission scope is recognized as "ISRT" ("Intelligence, Surveillance, Reconnaissance and Targeting"). The payload is modular in nature and can therefore be suited to customer requirements. The Puma design is entirely waterproof which protects vital systems such as the battery compartment, allowing the Puma to operate equally-effectively over water. Standard equipment includes a stabilized electro-optical (EO) and an infrared (IR) camera with infrared illuminator while the payload is gimbaled to provide 360-degree continuous panning. Power is served through a conventional engine spinning a two-bladed propeller unit mounted to the front of the fuselage. Its noise level is rather quiet, allowing it to remain unnoticed to targets on the ground. Wings include a high-mounted main assembly with noticeable outboard dihedral and a traditional single-fin tail unit. The Puma is small enough to be managed by a single operator in the field with a second operator managing the Ground Control Station (GCS) [24]. Figure 8 illustrate a typical AeroVironment RQ-20 Puma in operation.

Fig. 8. AeroVironment RQ-20 Puma

h. (source: [23])

Also unlike other larger UAV systems, Puma is hand-launched with recovery accomplished through simple deep-stall landing. Being waterproof, the Puma can also land in water and be recovered as needed. The entire Puma system includes three aircraft and GCS units and no additional equipment is required [23].

It features an overall length of 4 feet, 7 inches with a wingspan of 9 feet, 2 inches. Maximum take-off weight (MTOW) is listed at just 13 lbs. With its onboard propulsion system, the Puma can make 52 miles per hour out to a range of 9 miles. Flight time endurance is two hours. Despite these seemingly pedestrian specifications when compared to her larger brethren, the Puma is a budget-conscious alternative to the full-sized Predator and Reaper types. Beyond the United States military, it is been deploy in Denmark and Sweden [23].

G. *Denel Dynamics Bateleur*

Bateleur is an unmanned aerial vehicle (UAV) designed and built by Denel Dynamics (formerly Kentron). It has been designed as a MALE (medium-altitude - long endurance) UAV, with its primary role being surveillance, with a secondary signals intelligence capability [25]. A typical Denel Dynamics Bateleur is shown in Figure 9.

Fig. 9. Denel Dynamics Bateleur

i. (source: [25])

The entire aircraft is constructed using a modular construction system, making future adaptations of the airframe for increased range or larger payloads simpler than would be possible with a rigid airframe. It also makes it possible for the aircraft, once disassembled, to fit inside a 6 m ISO shipping container [25].

It is able to carry a variety of payloads, with a maximum payload mass of 200 kg (440 lb). Initially, proposed payloads include the Denel Optronics Argos-410 electro-optical (E/O) and infrared (IR) system (with optional laser rangefinder), the Denel Optronics Goshawk-350 E/O and IR system (also with optional laser rangefinder), a laser designator, an Avitronics Emitter Locating System, electronic intelligence equipment, and/or a synthetic aperture radar. Though at present it has a maximum "action radius" of only 750 km (470 mi). The Bateleur takes off and lands conventionally, on a runway, and has retractable undercarriage. It is also completely autonomous, allowing it to take off, conduct its mission, and land all without human control being required [25].

IV. SURVEILLANCE UAVs AND PRIVACY ISSUES

As noted in [7][8], drones present a unique threat to privacy. Drones are designed to undertake constant, persistent surveillance to a degree that former methods of video surveillance were unable to achieve. "By virtue of their design, their size, and how high they can fly, [drones] can operate undetected in urban and rural environments."

The increased use of drones poses an ongoing threat to people and their properties. Drone surveillance also implicates public safety issues as the drones operate in airspace that may also be used by commercial and private aircraft. For this reason, federal agencies should regulate and control the proliferation of drone surveillance.

As discussed in [8], the US Supreme Court has held that individuals do not generally have Fourth Amendment rights with respect to aerial surveillance because of the ability that anyone might have to observe what could be viewed from the air. Of course, individuals do not operate drone vehicles with the capabilities of the US government. Also, some state courts have reached different conclusions about the privacy issues associated with aerial surveillance.

According to [27], privacy advocates have argued that law enforcement officers and individuals using UAVs for surveillance, should secure a warrant before using it. Some of the criteria addressed are:

1) Property Rights: As mentioned above, landowners should be allowed to deny aircraft access to a column of airspace extending from their property for up to 350ft.

2) Duration-Based Surveillance: Law enforcement officials should only be able to survey an individual using a drone for a specific amount of time.

3) Data Retention: Data collected from a drone on a surveillance flight should only be accessible to law enforcement officials for a period of time. The data would eventually be deleted when there is no longer a level of suspicion associated with the monitored individual.

4) Transparency: Government agencies should be required to regularly publish information about the use of aerial surveillance equipment.

V. CONCLUSION

The benefits of UAVs for aerial surveillance are enormous as discussed in our review. The study has avails us the opportunity to gather facts about the development of UAVs used for aerial surveillance. It was discovered that there are over hundreds of surveillance UAVs being used by the military while commercial drones take the chunk of the market. The next research for further study is the development of surveillance UAVs that will be autonomous and cost effective.

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