

Eyes in the Sky: A Review of Civilian Unmanned Aerial Vehicles (UAVs)

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ABSTRACT

This paper presents results of an exhaustive survey of commercially-applied drones or unmanned aerial vehicles (UAVs) including a review of their applications, features, characteristics, and other information through a wealth of secondary data, particularly online records and documents consulted along with key-informant interviews. A simple descriptive-quantitative method was applied to treat the data.

It was found that UAVs are now used in such areas as Agriculture, Real Estate, Film and TV, Oil and Gas, Construction, Fisheries, Wildlife Surveillance, Water Management and Security. Out of 30 sample applications documented, 23.33% are dedicated in providing support to public/civilian security. Agriculture, Photography and Wildlife Surveillance rank next with 16.67%. Three (3) or 10% were used in Real Estates; two (2) or 6.67% were for Fisheries; and one (1) or 3.33% were used each for Oil and Gas, Construction and Water Management.

Fixed-winged UAVs are used for surveying and capturing wider range of imagery while multi-rotors are used to taking close and contained objects and locations here there is need for greater maneuverability on capturing images.

The ScanEagle drone developed by Boeing is the most expensive costing \$500,000. It has a fixed-wing design, launched through a catapult, and has a range of 100 kilometers. It can fly at 69 miles per hour at an altitude of 19,500 feet for 24 hours carrying a load of up to 48.5 pounds.

General Terms

Unmanned Aerial Vehicles

Keywords

Unmanned Aerial Vehicles, UAV, Drones

1. INTRODUCTION

Unmanned aerial vehicles or drones have recently gained popularity in many areas. Use of these systems was once limited to military purposes. Recently however, these machines have found civilian and/or commercial uses ranging

from aerial surveys [1], remote sensing [2], mapping of historical uranium mines [3], monitoring & surveillance of wildlife species [4], traffic monitoring [5], law enforcement [6], oil and gas pipeline threat detection [7] and [8], and several others.

There are also studies elsewhere implying the potential contribution of this technology in the estimation of population size of Dugongs and other marine fauna [9], fish finding through surveillance by UAVs [10] and on damage assessments in the aftermath of natural disasters [11] and [12].

Early novel applications of UAVs in agriculture in general, and crop monitoring in particular have been found to be effective and promising. For instance, in a practice known as precision agriculture common among highly industrialized countries, UAVs have been used to monitor crops such as wheat [13], vineyards [14], vegetation [15] and diseases of opium poppy [16].

Here in the Philippines, the use of unmanned systems has mainly focused on remote sensing, mapping, surveillance, and games. As the applications of drones are very promising in commercial and scientific domains, a survey and inventory of various UAV systems available, along with their functionalities, specifications, features, and characteristics present an interesting prospect. Hence, a motivation of this paper is to offer vital information to researchers, users, and designers.

2. METHODS

Data obtained were primarily extracted from various resources in the internet in the form of documents and records such as brochures, websites, published papers, and similar other secondary data sources. Roughly fifty (50) online documents were consulted and fifty-seven (57) websites were visited for secondary data gathering.

Phone-calls and emails were also exchanged among manufacturers into what appears like key informant interviews. Raw data were then structured into tabular form to record frequencies and values. A simple descriptive – quantitative method was then applied to interpret the data.

Table 1. Summary of Applications of UAVs for Civilian Purposes

Civilian Use	Description	Features/ Functionalities Preferred
Agriculture	<ul style="list-style-type: none"> - Used to monitor health of crops and livestock. - Used to gather variety of image-based data about the conditions of crops field: <ul style="list-style-type: none"> • Plant height, Plant count, Plant health • Presence of nutrients • Presence of disease 	<ul style="list-style-type: none"> - Fixed wing drones are often preferred by farmers because they cover more area and spend more time in air than multirotor platforms - Fixed wing is best suited for large open-field scanning. - Fixed wing can carry more payload which means

	<ul style="list-style-type: none"> • Presence of weed • Relative biomass estimates • 3D/ volumetric data (piles, patches, holes, and hills) <p>- Livestock operations:</p> <ul style="list-style-type: none"> • Monitor locations, status and movement of animals 	<p>more sensors</p> <ul style="list-style-type: none"> - Multi rotors are best suited to precision sensing of small and contained areas and 3D scanning of field objects due to maneuverability - Multi rotor commonly takes ½ more time compared to fixed wing - Multi rotors are cheaper in cost
Real Estates	<ul style="list-style-type: none"> - Used in differentiating property listings through high quality photography and videos - Used to produce dramatic, sweeping, shots of landscape, ocean and mountain vistas and seamless fly-arounds of gorgeous home exteriors - Property appraisal - Home inspection - Documenting hurricane and fire damage monitoring land erosions - Documenting property lines - Visioning and master planning 	<ul style="list-style-type: none"> - Commonly used type of UAVs are multi-rotor for maneuverability - UAVs for real estates are commonly equipped with 4K Camera, 3-axis gimbal, flying platform, live video, advanced flight control software and a flight controller.
Film and TV	Used in taking aerial shots and even crane shots	<ul style="list-style-type: none"> - Filming and TV take advantage of UAVs in taking up commonly expensive shots. These shots required UAVs with the capability taking stable imagery through 3-axis stabilization and a good quality shot with the aid of 4k cameras. - Commonly, multi-rotor UAVs are being used.
Oil and Gas	<ul style="list-style-type: none"> - Used to obtain real-time data pertaining to the location of an assets as well as the state it is in enabling them to cut down inventory, downtime, logistics and storage costs. - Monitoring of pipelines - Automation of workflow for safety operations to be carried out - 3D mapping of dangerous sites - Advanced seismography 	<ul style="list-style-type: none"> - Oil and gas companies prefer self-piloted fixed-wing drones which require zero maintenance
Construction	<ul style="list-style-type: none"> - Aerial photography - Site Evaluation by taking several photos and building-up comprehensive view of potential site - Logistics planning by capturing traffic flows surrounding project sites and optimally schedule pick-up and deliveries - Detailed updates by sending updates on the project day-by-day and using the data to conduct root-cause assessment and track progress. 	<ul style="list-style-type: none"> - Construction companies prefer drones with forward mounted high resolution cameras that can move 180 degrees up and down, has long battery life and remote operations that don't require on-site pilots. - Most UAV's for construction used highly maneuverable multi-rotor drones
Fisheries	<ul style="list-style-type: none"> - Fishing photography - Overhead view and territory covering ability which is perfect for scouting fishes, scrutinizing topography and observing fish behaviors. 	<ul style="list-style-type: none"> - 4k video, pre-programmed basic shots, thermal imaging camera, Helicopter-typed drones, GPS-equipped - Fixed-wing drones for transect-typed flight plans, wide area coverage and longer flight durations - Copter-typed drones for greater maneuverability
Wildlife Surveillance	<ul style="list-style-type: none"> - Use UAV as a tool in studies of wildlife to collect more and better data on wildlife behavior and populations - Tracking down individual research animal - Capturing animals in order to affix GPS collars - Counting herds or flocks. 	<ul style="list-style-type: none"> - Prefer quiet, small UAV rather than fixed-wing aircraft or helicopters which can be flown lower and slower providing improved quality of data - Employed techniques such as infrared and photography to detect highly elusive animals that human eyes might miss

Water Management	<ul style="list-style-type: none"> - Monitoring soil erosion, water balance, recharge, flood, draught, water leaks, water quality, crop water, soil moisture, wetlands, reservoir content, etc. - Used for providing highly precise crop mapping with readings of vegetation or water stress indices. 	<ul style="list-style-type: none"> - Studies suggest fixed-wing UAV with high payload capability enabling it to carry more sensors including multispectral, infrared and hyperspectral camera
Security	<ul style="list-style-type: none"> - Used to provide decisive advantage in protecting the public from threats such as terrorist attacks and successfully identifying crimes by providing appropriate air support. - Provides comprehensive recordings on scenes such as traffic incidence, operations against looter, coastal monitoring, surveillance against illegal activities, operations against poachers, etc. 	<ul style="list-style-type: none"> - Preferred micro-sized drones equipped with required/needed payload (e.g. laser camera) for quicker, more comprehensive reporting and aerial support.

3. RESULTS

Table 1 above provides a summary of common civilian uses of drones. As shown in the table, UAVs are now used in such areas as Agriculture, Real Estate, Film and TV, Oil and Gas, Construction, Fisheries, Wildlife Surveillance, Water Management and Security.

Two main types of drones compete in application: Fixed-wing drones are more advantageous than rotor drones when range is an issue. That is, if the area to be covered is large, fixed-wing drones are more appropriate due to its longer range. On the other hand, if more details and precision are needed, rotor drones are better because they can hover in one spot to get a closer look at the object of interest and are also more maneuverable.

Table 2. Distribution of Drone Usage in Civilian Application

Total Number of UAVs Reviewed = 30		
Application Area	No. of UAVs Found	Percentage
Agriculture	5	16.67 %
Real Estate	3	10 %
Photography and Films	5	16.67 %
Oil and Gas	1	3.33 %
Construction	1	3.33 %
Fishery	2	6.67 %
Wildlife Surveillance	5	16.67 %
Water Management	1	3.33 %
Security	7	23.33 %

In Agriculture, Oil & Gas, and Water Management, fixed-wing drones are more preferred while in Real Estates, Film & TV, Construction, Wildlife Surveillance, and Security preference is on rotor drones. In Fisheries, some situations require use of either fixed-wing or rotor drones.

Table 2 (shown left) is the distribution of drone usage using a sample of 30 UAVs. Most drones are used in Security, with twenty-three percent (23.33%) being utilized in this area. Agriculture, Photography and Wildlife Surveillance rank next with 16.67%. Of the 30 UAVs sampled, 3 or 10% of 30 UAVs were used in Real Estates; 2 or 6.67% were for Fisheries; and 1 or 3.33% for Oil and Gas, Construction and Water Management.

Table 3.a shown next is a comprehensive listing of UAVs according to their general specifications, in terms of Manufacturer, Estimated Cost in US Dollars, Wing-Type, Launch/Landing, and Fuel Type. Detailed specifications of these UAVs are presented in Table 3.b according to performance: Range, Endurance, Speed, Maximum Altitude, and Maximum Weight. These tables are arranged by application area.

It is observed that the wing-type of the UAV is dependent to the overall purpose of the flight. Fixed wings are used for surveying and capturing wider range of imagery while multi-rotors are used to taking close and contained objects and locations where there is need for greater maneuverability on capturing images (e.g. Photography and Film).

When it comes to the UAV's endurance, fixed-wing drones last longer than the models with multi-rotors. Fuel/source of UAV's power are commonly in rechargeable batteries and only few used alternatives such as gasoline, embedded solar panels and Fuel-cells.

Table 3-a. Summary of Reviewed UAVs for Civilian Use (General Specification)

Agriculture	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
SenseFly eBee Ag	SenseFly	25,000.00	Fixed Wing	Battery	Linear Landing
Precision Hawk Lancaster	Precision Hawk	25,000.00	Fixed Wing	Battery	Hand Launched
Trimble UX 5	Trimble	50,999.00	Fixed Wing	Battery	Catapult/ Belly landing
Trimble ZX 5	Trimble	50,000.00	Multi-rotor	Battery	Lift-off
AgEagle RX60	AgEagle	17,500.00	Fixed Wing		Catapult
Real Estate	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
Typhoon H	Yuneec	1,300.00	Multi-rotor	Battery	Lift-off
Phantom 4	DJI	1,400.00	Multi-rotor	Battery	Lift-off
DJI Inspire I v2.0	DJI	2,000.00	Multi-rotor	Battery	Lift-off
Photography and Film	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
350 QX3 combo drone	Horizon Hobby	400.00	Multi-rotor	Battery	Lift-off
DJI Evo S800	DJI	2,080.00	Multi-rotor	Battery	Lift-off
DJI Phantom 2	DJI	1,400.00	Multi-rotor	Battery	Lift-off
Walkera GPS QR X820	Walkera	1,900.00	Multi-rotor	Battery	Lift-off
Spreading Wings s900	DJI	1,200.00	Multi-rotor	Battery	Lift-off
Water Management	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
Q-pod	Quest-UAV	5,000.00	Fixed-wing	Battery	Safe launch
Oil and Gas	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
Boomerang	BlueBird Aero System	--	Fixed-wing	Fuel-cell	Catapult
Wildlife Surveillance	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
3DR Solo	3D Robotics	800.00	Multi-rotor	Battery	Lift-off
Super bat da-50	Martin UAV	--	Fixed Wing	Gasoline	Catapult/ Autonomous
Zeta FX-61 Phantom	Zeta	99.00	Fixed Wing	Battery	
RQ11 Raven	AeroVironment	35,000.00	Fixed Wing		Hand launched
HexaKopter	MikroKopter	8,000.00	Multi-rotor	Battery	Lift-off
Fishery	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
ScanEagle	Boeing	500,000.00	Fixed Wing		Catapult
DJI Phantom 3	DJI	1000.00	Multi-rotor	Battery	Lift-off
Construction	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
Parrot Bebop	Parrot	400.00	Multi-rotor	Battery	Lift-off
Security	Manufacturer	Estimated Cost (USD)	Wing type	Fuel Type	Launch/Landing
SpyHawk H301S	Hubsan	234.00	Fixed Wing	Battery	Hand Launched
Microdrone md4-1000	Microdrones	2,000.00	Multi-rotor	Battery	Lift-off
Air Shepherd ZT-TIC	Air Shepherd	--	Multi-rotor	Battery	
Silent Falcon UAS	Silent Falcon	12,000.00	Fixed Wing	Electric/ Solar	Catapult/ Parachute
100 km Skywalker	Skywalker	4,200.00	Fixed Wing	Battery	Hand Launched
UASUSA Tempest	UASUSA	28,000.00	Fixed Wing	Battery	Catapult
SenseFly eBee Plus	SenseFly	25,000.00	Fixed Wing		Catapult

Table 3-b. Summary of Reviewed UAVs for Civilian Use (Performance Specification)

Agriculture	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
SenseFly eBee	1000 ha	45 mins	40 – 90 kph	1000 m	.15 kg
Precision Hawk Lancaster	300 acres	45 mins	79 kph	8200 ft	7.8 lbs
Trimble UX 5	60 km	50 mins	80 kph	5000 m	
Trimble ZX 5		20 mins		3000 m	5 kg
AgEagle RX60	300 acres	60 mins			
Real Estate	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
Typhoon H		35 mins		400 ft	1.9 kg
Phantom 4		28 mins		6000 m ASL	1.3 kg
DJI Inspire I v2.0		18 mins	49 mph		6.74 lbs
Photography and Film	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
350 QX3 combo drone		15 mins			
DJI Evo S800		20 mins			3.7 kg
DJI Phantom 2		25 mins	15 meters per sec		1 kg
Walkera GPS QR X820		30 mins			
Spreading Wings		18 mins			8.2 kg
Water Management	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
Q-pod	100 km	1.5 hrs	40 mph	10000 ft	5 kg
Oil and Gas	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
Boomerang	50 km	>9 hrs		15000 ft ASL	9.5 kg
Wildlife Surveillance	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
3DR Solo	805m	20 mins	55 mph	400 ft	3.9 lbs
Super bat da-50	450 miles	10 hrs + reserve	45 to 80 mph	15,000 ft	
Zeta FX-61 Phantom		35 km	60 mins		1.5 kg
RQ11 Raven	10 km	80 mins	81 kph	500 ft AGL	1.9 kg
HexaKopter		36 mins			1.2 kg
Fishery	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
ScanEagle	100 km	24 hrs	69 mph	19500 ft	48.5 lbs
DJI Phantom 3	DJI	23 mins		6000 m ASL	1.2 kg
Construction	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
Parrot Bebop	820 ft	22 mins	29.2 mph		14.8 oz
Security	Range	Endurance	Speed	Max Altitude	Maximum Lift-off Weight
Spyhawk H301S		30 mins			355 g
Microdrone md4-1000	500 m	88 mins	12 meter per sec	2000 m ASL	6 kg
Air Shepherd ZT-TIC	50 km	5 hrs		4000 ft	
Silent Falcon UAS	15-100 km	7 hrs	45-90 kph	2000 ft	
100 km Skywalker	100 km	3 hrs		300 m	200 g
UASUSA	7 – 50 miles	1.5 hrs	42-50 mph	400 ft	
SenseFly eBee Plus		60 mins	28 mph		

4. CONCLUSION

This review focused mainly in the applications, features and characteristics of UAVs used for civilian purposes.

UAVs are generally categorized according to its wing type – Fixed-wing and Multi-rotor. These wing affect their suitability to different applications. Understanding the key characteristics of each type of UAV is therefore imperative when one intends to deal with these technologies.

Fixed wing aircrafts are known to be more efficient in terms of aerodynamics, length of flight durations and speed. These make fixed wing UAVs ideal for applications like aerial surveys which require the capture of geo-referenced imagery over large areas.

In contrast, multi-rotor UAVs involves greater mechanical complexity which translates to lower speeds and shorter flight ranges. The advantage, however, is that if more details and

precision are needed, rotor-typed drones are better because of its capacity to hover and its responsive maneuvering.

UAVs are now used in Agriculture, Real Estate, Film and TV, Oil and Gas, Construction, Fisheries, Wildlife Surveillance, Water Management and Security. 23.33% are dedicated in providing support to public/civilian security. Agriculture, Photography and Wildlife Surveillance rank next with 16.67%. Three (3) or 10% were used in Real Estates; two (2) or 6.67% were for Fisheries; and one (1) or 3.33% were used each for Oil and Gas, Construction and Water Management.

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