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A Review on Unmanned Aerial Vehicles/Drones used in Various Applications

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Abstract - *Drones, also known as Aerial motorized vehicle un-accompanied by humans on board, come forth as the eyes and ears of technologists in urban planning, defense, agriculture, waste management, disaster management, mining, telecommunication etc. Due to the presence of these types of inevitable application in everyday life, use of drones have stepped up. It is also forecasted that the revenue from drone technology will reach $12 billion by 2021. Even though there are many papers which gives a detailed idea regarding the technologies used in drone, a comprehensive discussion of the different types of drones are not yet coined. The main aim of this paper is to present a review of various types of drones based on their day to day application.*

Key Words: Drone, Unmanned Aerial Vehicles (UAV), thrust, drag, autonomous.

1. INTRODUCTION

Drones or Unmanned Aerial Vehicle (UAV) or Unmanned Aerial Systems (UAS) are aircrafts that can fly without a pilot on board. Typically, it can be seen that these are flying robots that can be remotely controlled or fly autonomously through software-controlled flight plans based on embedded systems. It can be affixed with a variety of adjunct accessories including, cameras, GPS guided missiles, Global Positioning Systems (GPS), navigation systems, sensors, and so on. Bernoulli's principle and Newton's third law of motion are the two main principle used in the working of drones in which the propellers convert rotational motion into thrust [1].

The earliest unmanned aerial vehicle in the history of drones was seen in 1839, when Austrian soldiers attacked the city of Venice with unmanned balloons filled with explosives. From then onwards, researchers had come up with a wide variety of drones that underwent stupendous changes in size, shape, weight, flight time etc. With the growth of this type of airship technology a new era in the aviation industry, known as the "Pioneer era" aroused. Around 1900's Wright Brothers gave their next contribution to the field of aviation and named the very first drone as Flyer I. Flyer I used conventional materials and technologies for manufacturing. The frame was covered with a finely-woven cotton cloth and was then sealed with "canvas paint". The metal fittings were made from mild steel and the aircraft was rigged with 15-gauge bicycle spoke wire. A sprocket chain drive, borrowed from bicycle technology, powered the twin propellers, which were also made by hand. Hard aluminium alloy - 92% aluminium and 8% copper constituents the engine block and remaining portions were made up of steel or cast iron. Yet another feature of Flyer I was that, it was the first aircraft with three axis control. But Flyer I was entirely different from the typical drone concept because it was designed as a machine having an onboard pilot which made it less efficient in terms of application point of view and unfortunately it got damaged by wind after the fourth flight. They returned it to Dayton; Orville restored it in 1916 and sent it to the Kensington Science Museum in London, England in 1928. Later it was known as the first piloted powered UAV.

By the end of 18th Century, Air Ministry of UK demanded a drone that would meet their requirements such as reasonable cost, dispensable and tele-operatable. The main requisites were to develop a typical unmanned vehicle that should be purely radio controlled which the Army wanted to use for their gunnery exercise. This was the time when the evolution of pilotless drone took place and this proposal steers invention of very first pilotless aircraft – Queen Bee. Even though it is meant for pilotless operation, Queen Bee was incorporated to have a cockpit and a set of physically controllable panel with radio controls and flying controls. Collateral radio controls where used for ignition and throttle, control panels were quite small and it employs a rotary dial which were used by the controller to "dial in" the transmitted command. Flying control was totally guided by commands from dial such as turn right, left, pitch up etc. Moving onto its technical specifications, it could fly at a height of 17,000 feet, with a maximum distance of 300 miles over 100mph. At that time Queen Bee technology was remarkable and indeed pioneer technology. This pilotless airship revolutionized drone technology and there after technologists came up with tremendous varieties of drones with reduced size, shape, and with application specific features. Application such as usefulness in the hostile environment increased their prominence in the market.

The paper is organized as follows – Section 2 briefly explains an overview about drones, section 3 comes up with an elaborated classification of drones in terms of their

application, section 4 gives the comparison of the reviewed drones and finally conclusion is noted in section 5.

2. DRONES AN OVERVIEW

It is well known fact that drones are autonomous flying machines with a ground controller. They range from Nano scale to Mega scale in sizes with extensive varieties like hybrid, multirotor, fixed wing etc. Technically 4 powers acts on a drone for its forward motion given by Thrust (A), Drag (B), Lift (C) and Weight (D) is as illustrated in Fig. 1.

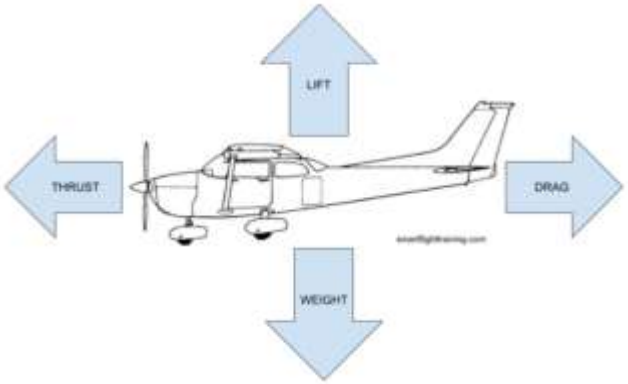

Fig -1: Four Forces acting on an aircraft/Drone's

Source: Adapted from Andrew Hartley. (2016). Beginner's Series: Four Forces of Flight, Smart Flight Training.

Thrust is the forward force produced by the drone's engine which caters drone's ability to neglect the frictional force (Drag – Backward force) acting on it. On the other hand, lift deals with the upward force achieved by the airflow over the wings that opposes weight (Downward force).

Drone System is made up of a series of dedicated components: Frame, Motor, Speed controller, Propeller, Flight Controller, Radio Receiver, Radio Transmitter, Battery Telemetry Module, Camera, Video Transmitter, Video Receiver.

3. CLASSIFICATION OF AERIAL DRONES

In the 21'st century people demanded things that will make their life easier, healthier and less time consuming. This can be comfortably achieved with the help of technologies used in electronic devices, machines, automobiles and so on. Without any suspicion it is proven that drones are one among the premier examples that aids the mankind to live an uncomplicated, unchallenging and trouble-free life. Because of these reasons they have been used in many dominant sectors of economy like agriculture sector, film sector, commercial sector etc. This paper broadly discusses some of the prominent drones that are used in aforementioned sectors.

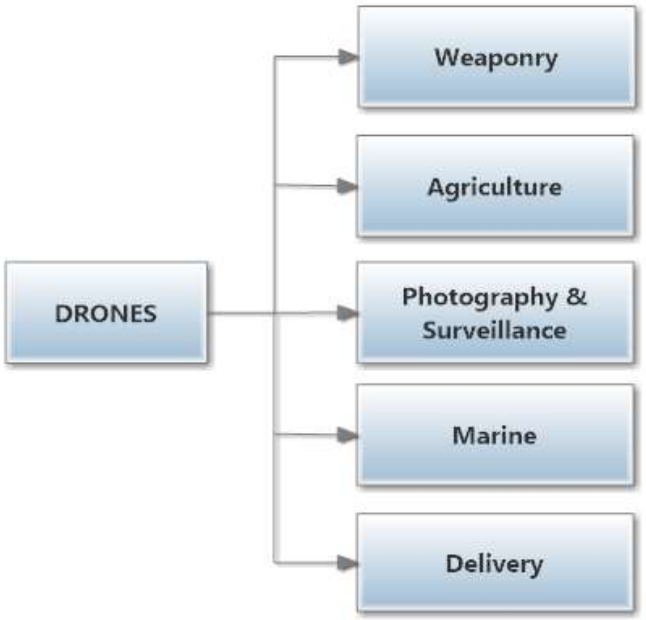

Fig -2: Classification of drone on the basis of application.

3.1 Weaponry

When there happened a transition from drones which have pilot on board to a pilotless drone, the number of application that this aerial vehicle can be used also increased. One such example was weaponry since this demands no direct human interaction. Development of this type of drone was a great support and best option for military related operations such as reconnaissance, attacks etc. The very first discovery in this sector happened around 1940's by two scientists, Lee De Forest who was basically a technologist on radio devices in collaboration with a TV engineer called U A Sanabria. They named this technology as Robot Television Bomber and they claimed it as the easiest and feasible method used as a flying explosive. The whole system consists of two aircrafts named as "robot plane" and "control plane". Robot plane is one in which carries large quantity of bombs, radio receiver and television transmitter in the main body of the aircraft. Second one the control plane, which is a piloted aircraft for controlling the other airplane. They flew at a distance of 10 miles away from the other one. Now the question arises how the controller will get information about the movement. This is achieved with the help of television commutator in the "robot plane" and the signals were received by the controller section which eventually guides the robot above the subjected target. Controlling section is carried out by a super high frequency radio. Nowadays, it is possible to note different type of modes in the remote controllers of drone to perform specific operation but in that time, different selector circuits were used for different operations.

Avenger (Predator C) was developed exclusively for US military from the manufacturer called "General Atomic Aeronautical systems" and made their first flight on 2009. They were the third advanced compact Ariel Bombardment vehicle in the Predator Series-Predator A and Predator B.

Also, they had come up with two variants, one is sea avenger and another Avenger ER. One of its interesting features which adds more value to this drone is that, they can give rapid result while doing any type of reconnaissance like investigation, scanning, survey, exploration, observation etc. Internal section consists of engines "Pratt and Whitney PW545B turbofan" which has less consumption rate, together they produce 4,800 pounds of installed thrust. Its storage capacity in terms of weapons is about 3,000 nuclear, chemical munitions. Consequently, this airship had set a new benchmark among the emerging Remotely Piloted Aircraft (RPA).

Fig -3: Predator C Avenger.

Source: Adapted from PREDATOR C AVENGER Datasheet, General Atomics Aeronautical Systems, Inc.

Wing Loong is another type of unmanned motorized vehicle developed supremely for "People's Liberation Army Air Force (PLAAF)" manufactured by Chengdu Aircraft Design & Research Institute (CADI), a part of People's Republic of China. The concept arose around 2005 and they progressively worked for long 4 years and on 2009 they had made their first test flight. Apart from being used for carrying missiles and other explosives it also served for disaster surveillance, environmental preservation and so on. Moving on to its structural details it had a height of 2.77m, 9.05m length and the distance between two wingtip or typically wing span distance of 14m. If its structure is observed then it can be noted that it has a bulged portion around its head, and this is the place where data transfer takes place with the help of antenna. Satellite communication is used for data transmission. In terms of technology they are highly advanced by the usage of radars, infrared cameras, sensors, laser designators and options for data collection in low light and even night time.

On 2015 developers of Wing Loong came up with the improvised and advanced version called as Wing Loong II. One of the main changes was in terms of the number of hardships, in the base version there were only 2 hardship but in the latest version one single wing consist of 3 hardships so total 6 hardships which increased the number of missiles they can carry. They also had undergone commendable structural changes like, height increased to 4.1m, length has become 11m and wing span of 20.5m [2].

3.2 Agricultural Drones

Agricultural sector is very important when it comes to the prosperity of a country. Proper care should be given at the time of growing crops. For this manual surveillance is the best option, but this could be impractical with large area of land. A solution to this problem can be achieved with the help of Drone technology particularly known as Agricultural Drones. With the help of this type of drone's farmers can spray pesticides, surveying, mapping, detect infectious parts precisely.

For the growth of any type of crop, water is an important constituent. It is also necessary to consider that each and every individual crop gets uniform concentration of water. By 'spraying' water, it could be achieved very easily. Nowadays drones specified for this purpose are available in the market. One such example XAG P Series which is designed to operate in different topographical land such as hills, forests, plains and so on. Spraying is done with a part called "rotary spraying disc" which produces water droplets of micro size. They are also automatically controllable with help of 4G network, ACB1 connection, and downloaded android/iOS apps. By using these much of advancements it is possible to program flying and spraying parameters on the controller. Spraying can be done in four variant patterns, standard pattern, spot/spiral pattern, free pattern, wave pattern. It has also got the option to select a particular area of land for spraying, were it can reduce the wastage of water caused by choosing unwanted regions. To store the liquid, a "Smart Tank" is used which utilize Bluetooth as a communication link between the flying system and controlling unit. Display of controlling unit gives a couple of information about the amount of water available in the "Smart tank" and flow rate. In combination with this tank there is a refiller (ALR5) which works automatically and simultaneously to fill the storage unit with reference to the data collected from the cloud. It employs Lithium-Polymer batteries (B12620/B12800) having a volume of 620Wh/800Wh. Batteries come up with an auto preheat option for cold domains. Parallel to this, it has the provision of rapid charging. XAG P can do the work equivalent to that of 100 laborers with an efficiency of 14Ha/Hr. A single man can operate 5 P series drone at the same time.

AGRAS MG IP Series - another innovative agricultural drone introduced into the market. It has got 8 rotors with high redundancy that is, if any one of the rotors fails the system provides a safe flight during their operation and also it has the capability to divert the control signal in case of any emergency. These drones introduced a new generation tele command which is entirely different from other controllers in terms of their structure, operation and specifications. The controlling range is about 3km and offers highly accurate video transmission without compensating their quality. It has also got the features like replaceable batteries, 4G wireless communication and so on. There are three radars incorporated with the system, amongst one plays the role of obstacle detection such as power lines, tress, birds in a 15m range even in night. AGRAS MG IP Series occupies two antennas which serves the purpose of resistance against electromagnetic interference. AGRAS MG IP Series have two operational modes from the authentic controllers one is

"Multi Aircraft Controller mode" where operator can control two drones simultaneously and "Banked turning" is the next one which improves the efficiency of the system up to 20%. Subsidiary to these two modes, three commonly seen modes are also there; "A-B Route Operation Mode", "Manual Operation Mode", and "Manual Plus Operation Mode". In case of payloads it is equipped with 123˚ wide angle cameras mainly FPV. Air Board is yet another type of agricultural drone specially meant for spraying fertilizers in fields. This one was developed by a cluster of scientists who had a long work experience of about 50 years in the field of "robotics" and "electro mobility". Mainly people opt helicopter to spray fertilizers in their vegetation but the usage of Air Boards can reduce the expenditure to half. It can be used for spraying pesticides, bactericides, fungicides etc. Depending on the application there is an option to change the nozzle. A user-friendly software is installed in it which makes easy interface between drone and humans. Farmers also have an option to get information about the battery life, route map, moving speed etc. Like other drones it has features like obstacle detection sensors, radar sensors, cameras, redundant batteries. It had also come up with a vibrant battery package such as "Battery Management System (BMS)" and Protection Circuit Module (PCM). For the sake of safe travel 2 GPS were also included in the system. At a single flight it can cover up to 70 hectares of land with a time limit of one hour and pesticide quantity of 100 litres. This drone falls under the category of compactable drones, these are foldable and can be transported easily[3]–[6].

3.3 Drones for Photography and Surveillance

All humans are gifted with a beautiful nature consisting of animals, plants, terrains such as mountains, hills, plains etc. From decades photographers are capturing images and are creating beautiful frames of it. Now consider a situation in which you can flew with a bird and can encapsulate every single movement of it or to record majestic sunset or sunrise from an elevated region. Also, surveillance of regions which are compact, volcanic, ignited, unhygienic, affected by disasters. All these can be achieved with the autonomous technology like that of a drone. Currently in market a wide variety of drones using high quality payloads are available. Payloads are typically, cameras that come in combination with these unmanned motorized vehicles.

Fig -4: Drone's used in Agricultural application. (a) Air Board, (b) AGRAS MG IP Series, (c) XAG P series.

Source: Adapted from (a) Air Board [Online image] from https://www.airboard.co/agriculture-drone/, (b) AGRAS MG IP Series [Online image] fromhttps://www.dji.com/mg-1p, (c) XAG P series [Online image] from https://www.xa.com/en/pseries.

One such drone is called Typhoon H. This is a compact sized drone that is used for aerial photography as well as videography. It has a round trip span of about 25 minutes and uses CGO3+ 4K UHD camera. Since it is mainly used for capturing quality is a factor that needs to be given great importance. It provides 4K ultra high definition video,12 megapixel still images, flexible 360˚ movement, wide angle etc.

DJI Mavic Pro is one of the most compactable drones in the industry. It is a quadcopter with elegant design. In the sake of making it compactable it is designed to be small with a weight under 16 ounces. In terms of compatibility they can be folded up and easy to carry. The drones discussed till now in this paper is controlled by remote controllers, mobile applications etc. Sometimes these types of controlling methods may be vulnerable to noise interference and even the control can be restricted by electromagnetic radiation. These problems can be easily solved by gesture recognition.

DJI Mavic Pro have gesture mode incorporated with it. What it needs to be done is to make a gesture of a frame with our hands, then drone will immediately take a selfie. Another technology it has been using is mainly designed for obstacle detection and named it as "Flight Autonomy". This technology offers comprehensive and accurate obstacle sensing by the help of multiple sensors which can spot object at a range of 15m from the drone, apparently, they scan their domain in a 3D fashion. This technology also uses the help of 5 extra cameras & satellite positioning (GPS and GLONASS). Since this is a compactable drone it uses unambiguous 3 axis gimbal camera with this it can capture 4k video at every frame per second and also it enables to shot pictures quickly by the cameras. In addition to all these features it has 3 intelligent flight modes such as 'trace' for following the entity either from front or in an annular way. Next one 'profile' mode for flying close to entity or target such as a moving person. Last one 'spotlight' mode and these modes has been appreciated by most of their customers which record every angle changes of the moving target and captures cinematic shots.

Now let's move to a technology that have been developed by the Intel's drone group which is known as Intel's Falcon 8+ System. This system mainly consists of "Intel's Falcon 8+ UAV", "Cockpit" and "Payloads". It comes under the category of octocopter. Coming to the structural details of drone – Intel Falcon 8+ UAV has a V shape with carbon frames for support. This is a highly redundant type of drone which provides three alluring features of sophisticated batteries, sensing and communication. The central portion consist of "IMU (Inertial Measurement Unit) Chips", and two batteries. These batteries are called "Intel's Power Pack" having 4000

mAh power. An integrated Battery Management System (BMS) which provide power to both the drone and controller system is also incorporated. The working of Intel's Falcon 8+ is based on "Astec Trinity Technology" which offers stability, accuracy, altitude, inclination and lot more aids. Intel's cockpit is highly advanced having a tablet combined with controller. It consists of joysticks for circular, left, right movements. Use of payload makes it meaningful to its applications. For each application there will be dedicated payloads. For inspection mapping and surveying they use Sony Alpha 7R which is a DSLM camera. If inspection is taking place regions that are thermally affected then most preferred camera is Panasonic Lumix TZ71 which is an infrared camera that clearly gives information about the position, orientation. It is very much flexible and give 180˚ full motion. For communication GPS and GLONASS satellites are used [7]–[10].

3.4 Drone for Marine Use

Drone are devices that can move over any nook and corner and collect information/data. For the same purpose invention of a new drone happened with an added advantage of water repellence and named as Splash drone 3+. It is the most authentic and adaptive water proof drone that had discovered yet. This type of drone is highly adaptive and can be utilized for various aquatic and other applications ranging

from filming, fishing to rescue and research. It makes use of a versatile technology called as Swell Pro exclusive ventilation technology. The presence of reinforced ABS fibre makes it waterproof. It is also corrosion resistant throughout its lifespan, so that it can be one suitable for marine use. To make it anti corrosive Splash drone 3+ is anticipated with special coating which will offers high salt water resistance and extreme power for take-off from water and heavy rain. It has the power and navigation capability when it flies up in

Fig -5: Drone's used in Photography and Surveillance application. (a) Intel Falcon 8+, (b) Mavic Pro, (c) Typhoon H.

Source: Adapted (a) Intel Falcon 8+ [Online image] from https://www.intel.com/content/www/us/en/products/drones/falcon-8.html, (b) Mavic Pro [Online image] from https://www.dji.com/mavic,(c) Typhoon H [Online image] from https://us.yuneec.com/typhoon-h-overview winds by Beaufort force 4 (18mph/28kmh) with gusts force 6 (31mph/49kmh). It is fused with well-built propulsion system and sensors which will provide substantial sensitivity and accuracy. Propellers design is in such a way that motor can be fixed without the help of tools, it is also light and stiff so that it can efficiently transform the power onto thrust. Splash drone 3+ have the capability to resist chopping waves that can invert the drones. This is done with the help of patented power-flip feature.

3.5 Drone designed for delivery.

By the discovery of this type of drone called Amazon Prime by the Amazon CEO Jeff Bezos started the new application in the drone history. It is a multirotor miniature type aerial vehicle. These are capable to fly with packet to the customers one at a time. It will reach the destination within 30 minutes from the order. This new technology has some sort of restrictions too as packet should need to be fix in the carton box, the packet weight must be lesser than 5 pounds and their delivery location should be around 10 miles from the Amazon Centre [11].

4. COMPARSION OF VARIOUS DRONES

Some of the striking parameters and purposes of the drones are given Table 1- 5. These parameters make them distinct and variant from each other. In weaponry application the payload capacity is of at most important, Predator C Avenger

Fig -6: Splash drone 3+

Source: Adapted from Splash drone 3+ [Online Image] from https://www.swellpro.com/waterproof-splash-drone.html

Fig -7: Amazon Prime Air.

Source: Adapted from Amazon Prime Air [Online Image] from https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011 is the best among the drones reviewed and it has a capacity of 1588 kg.

Table -1: Drones used in Weaponry

Name of Drone	Performance Parameters	Exceptional Purpose
Predator C Avenger	1. Flight Speed – 400 KTAS 2. Flight Time – 18 Hours 3. Elevation – 50,000 ft 4. Fuel capacity – 7,900 pounds 5. Payload Capacity – 1588 kg 6. Comprehensive Weight – 8255 kg	1. Two ground controllers 2. Hybrid non - skid break 3. Housed by two payloads
Wing Loong I	1. Flight Speed – 280 km/hr 2. Flight Time – 20 Hours 3. Payload Capacity – 200 kg 4. Comprehensive weight – 1,100 kg	1. Autonomous takeoff and landing 2. Dual redundancy 3. Electronic Monitoring 4. Carry two missiles.
Wing Loong II	1. Flight Speed – 370 km/hr 2. Flight Time – 20 Hours 3. Payload Capacity – 400 kg 4. Comprehensive Weight – 480 kg	1. GPS utilized 2. Use of infrared cameras and sensors 3. Carry up to "12 laser guided bombs" or "missiles"

Comparison of various drones used in Agriculture applications is given in Table 2. From table 2, it is clear that when it comes to the Flight speed AGRAS MG IP Series outperforms other drones. Other distinct features are listed in the table.

Table -2: Drones in Agriculture applications.

Name of Drone	Performance Parameters	Exceptional Purpose
XAG P Series	1. Flight Speed – 12 m/s 2. Flight Time – 600 sec 3. Spray Capacity – g.6 l/min 4. Battery Capacity – 620Wh/800Wh	1. Deduce pesticide usage to 30% 2. Preserves use of water up to 90% 3. Atom sized liquid droplets 4. 3 Inertial Measurement Unit (3 IMU) 5. Utilize 4G networks 6. Mesh Networking
AGRAS MG IP series	1. Flight Speed – 22 m/s 2. Battery Capacity – 6000 mAh 3. Temperature – 0 to 40°C	1. Carry liquid payload of 10 kg 2. Low latent 3. Automatic recording 4. 40 – 60 times speeder than the authentic way
Air board	1. Flight Speed – 7m/s 2. Flight Time – 12 min 3. Battery Capacity – 180Ah	1. Can cover 50 acres 2. Carry liquid payload of 100L 3. 50 times faster than the authentic way

When it comes to drones used for photography and surveillance the main factor to be considered is Flight time, battery capacity and quality of camera. In case of flight time DJI Mavic Pro offers 30 mins and it also has a combination of GPS and GLONASS and vision position system. Typhoon H has the largest battery but its flight time is less than that of DJI Mavic Pro.

Table -3: Drones in Photography & Surveillance applications.

Name of Drone	Performance Parameters	Exceptional Purpose
Typhoon H	1. Flight Time – 25 min 2. Battery Capacity – 8700 mAh 3. Temperature - -10°- 40°C 4. Video Resolution – 1080 p 5. Image Resolution – 12.4 Mega pixels	1. In built android tablet 2.Automatically controllable flight modes 3. Get highly resolute image at a distance of 150ft
DJI Mavic Pro	1. Flight Speed – 40m/h 2. Flight Time – 30 min 3. Battery Capacity – 2970mAh 4. Temperature Range - 32° to 140°C	1. Noise power reduction up to 60% 2. Combination of "GPS", "GLONASS" and "Vision position system"

		3. Extra 4 cameras for stability
Intel's Falcon 8+ UAS	Flight Time – 16 – 26 min Altitude – 13123 feet Battery Capacity - 2× 4000 Operating Temperature - -5°- 40°C	1. Most suitable one for challenging domains 2. Single flight can take 180° view of the entire region

Table 4 & 5 lists the main features of drones used in marine and delivery applications.

Table -4: Drones in Marine applications.

Name of Drone	Performance Parameters	Exceptional Purpose
Splash Drone 3+	1. Flight speed – 20 m/s 2. Flight Time – 20 - 30 min 3. Water proof level – 600mm deep 4. Battery Capacity – 1800mAh	1. Battery warning at three distinct level 2. Relocation facility in case of missing 3. Snow and rain repellent too

Table -5: Drones in Delivery applications.

Name of Drone	Performance Parameters	Exceptional Purpose
Amazon Prime Air	1. Flight Time – 30 min 2. Flight speed – 80.5 km 3. Battery Capacity – 10,000mAh	1. Use of SONAR 2. In cooperated thermal and depth cameras

5. CONCLUSION

Drones are one among the supreme aircraft of aviation industry in consideration with its anomalous parameters like flight speed, endurance, payload capacity etc. also with its widespread applications. The paper gives a history in the development of drones starting from the unmanned balloons to most modern Splash Drone 3+. Also, the paper discusses different types of drones that are employed in certain selected applications that has been used by mankind in their day to day life. A total of five applications were discussed and it is found that each drone has their own advantages and disadvantages. It can be concluded from the comprehensive comparison that, Predator C Avenger, XAG P Series, Intel Falcon 8+ System are found to be convenient in their respective field of applications. Much discoveries hadn't happened in the Marine and Delivery applications, so a clear-cut comparison can't be made.

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