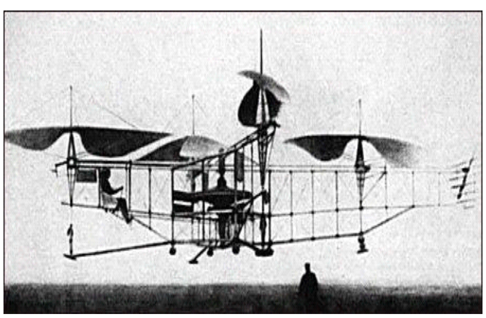
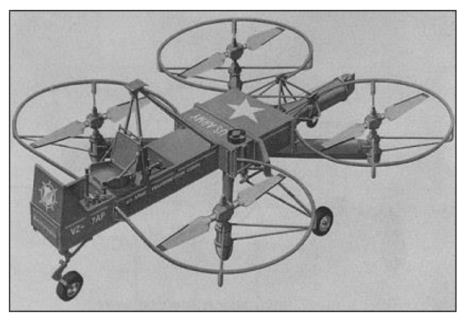
Lecture Notes-UAV principles & components

Background

Balloons can be considered as the oldest platform for aerial observations. As early as in 1858, Tournachon aboard a hot-air balloon to capture aerial photographs of Paris. In 1882 E.D Archibald, an English meteorologist, used kites for aerial photography. One of the most exciting experiments was the use of a pigeons’ breast to mount a small camera from the Bavarian Pigeon corps, as proposed by J. Neubronner. Etienne Oehmichen experimented with rotorcraft designs in the 1920s. Among the six designs he tried, his helicopter No.2 had four rotors and eight propellers, all driven by a single engine. An aircraft, with six bladed rotors at the end of an X-shaped structure was developed by Dr. George de Bothezat and Ivan Jerome. The Curtiss-Wright company designed the Curtiss-Wright VZ-7, which was a VTOL aircraft, for the United States Army. The VZ-7 was controlled by changing the thrust of each of the four propellers. In the past 10 years many small quad copters have entered the markets that include the DJI Phantom and Parrot AR Drone. This new breed of quad copters is cheap, lightweight. In the 20th Century, military research precipitated many widely used technological innovations. Surveillance satellites enabled the Global positioning system (GPS), and defense researchers developed the information swapping protocols that are fundamental to the Internet. Drone/UAV falls into a similar category. Designed initially for reconnaissance purposes, their para-military and commercial development was often out of sight of the public. Understood in such sense, drones came into first use after World War II (year 1939-1945) when unmanned jets, such as the Ryan Firebee (a documentary about the Firebee and the use of early drones in the Vietnam War), started field operation. Since then, the number of drones in military use increased substantially enough that the New York Time decided to refer to it as a new paradigm for warfare. A far-reaching array of civil markets and applications are likely to surface over the next few years for UAVs presenting a massive business opportunity for the companies involved.



Oemichen-1920



De Bothezat Helicopter-1923

Introduction

Unmanned aerial vehicles are designed and assembled based on the requirements and can be classified into two categories- fixed-wing and rotorcraft or multirotor or rotary wing UAVs. Fixed-wing UAVs have limitations in terms of complex designs, difficult stabilizing mechanism, requirement of a long runway and difficult to operate in hilly terrain. However, they have advantages in terms of long endurance and large payload capabilities. On the other hand, multirotor UAVs use vertical takeoff and landing and have been found more appropriate in hilly and complex terrain. However, unlike most fixed wing models of UAVs, the rotary wing models generally have a much shorter flight time. This is because the specific energy of chemical based energy source such as gasoline is way higher than an electric/electrochemical based energy source such as a Lithium-Ion battery or an alkaline battery.

Fixed Wing UAV

Rotary wing UAV (RUAV)/Multirotor

Rotary Wing UAV

Rotary Wing or a rotorcraft UAV is an aircraft which relies on a rotor to move wings which in turn generates lift allowing the aircraft to fly. An example of a rotary wing aircraft is the Helicopter. In case of a rotary wing aircraft, the wings connected to the rotor mast moves. This rotating movement of the propellers/rotors generates the necessary velocity over the airfoil to generate lift. Since the velocity over the wings is generated by moving the rotors, RUAVs are capable of VTOL (Vertical Take-Off and Landing). The VTOL capability of the RUAVs allow them to be used in areas where there is lack of space or where focus on a certain area is required for an extended period of time. The presence of the rotary wing model also ensures very high maneuverability and the ability to hover in a set point in space for a long time. However, unlike most fixed wing models of UAVs, the rotary wing models generally have a much shorted flight time. Most rotary wing based UAVs are multirotor, with generally more than one rotor.

The basic rule of thumb in design of a copter is that the weight of copter should be half of the total thrust generated by the motors for hover condition at 50% of throttle

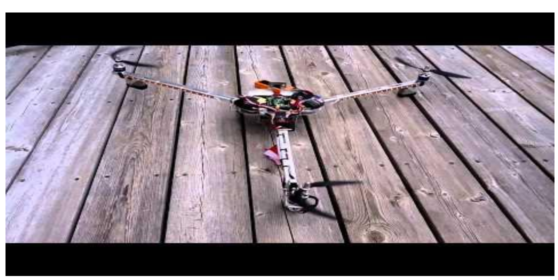
Total Thrust = 2 x All uplift weight (AUW)

Types of RUAVs

Multirotors comes in various forms and configurations. Hence, a classification of multirotors is required for easy identification of these flying machines. Multirotors can be classified as below:

Tri copter:

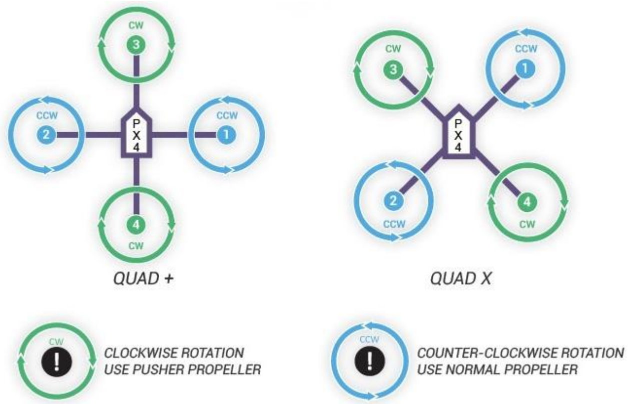
A three motor multirotor system, also known as a Tri copter is a multirotor with three rotors. The rotors are generally placed in a Y-configuration.



Tri copter

Quad copter

A Quad copter, as the name suggests, is a multirotors with four motors to generate lift. It is more stable than a Tri copter and can carry heavier loads due to the presence of the extra motor. There are two main configurations to a Quad copter, the + (Plus) configuration and the X configuration, with the X configuration being way more popular due to reasons given below. The X configuration provides more thrust and has a higher speed than a + configuration. This is because in case of The + configuration, only one rear motor is present to provide thrust in a particular direction while in case of the X configuration, two motors are present. In case of the + configuration, a FPV (First Person View) or any camera for that matter is generally obstructed by the propellers while in case of the X configuration, the region between the two propellers provide a clear view. The Quad copter is by far the most popular multirotor due to its mechanically simple design, efficiency, maneuverability and cost effectiveness.



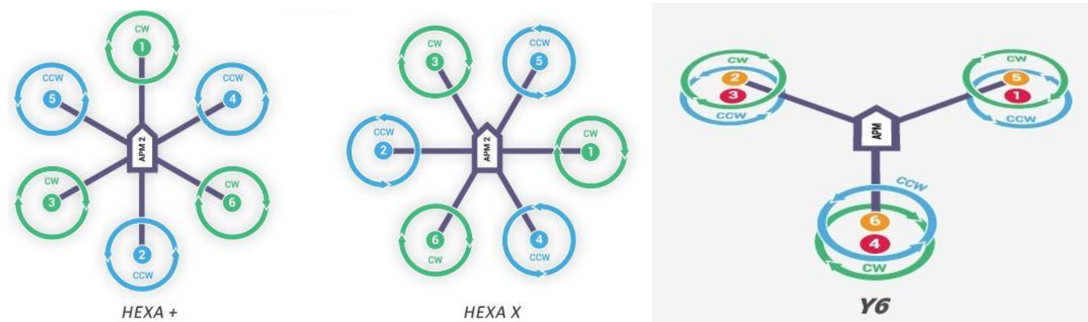
Quadcopter Configuration

DJI Inspire 1

Hex copter

A Hex copter is a multirotor with 6 motors. Due to the large number of motors, a Hex copter is more stable and can carry heavier loads than a Tri copter or a Quad copter. However, the extra motors mean extra ESCs and a larger battery which adds to the overall cost of the system. The increased price, stability and control makes the Hex copter to be more popular amongst the professionals and less popular amongst the hobbyists where price is a main factor. There are several configurations of a Hex copter. There are three primary configurations to a Hex copter, the I or + configuration, the V or X configuration and the

Y6 configuration. The placement of the motors and their orientation for the +, X and Y6 configuration can be observed below.

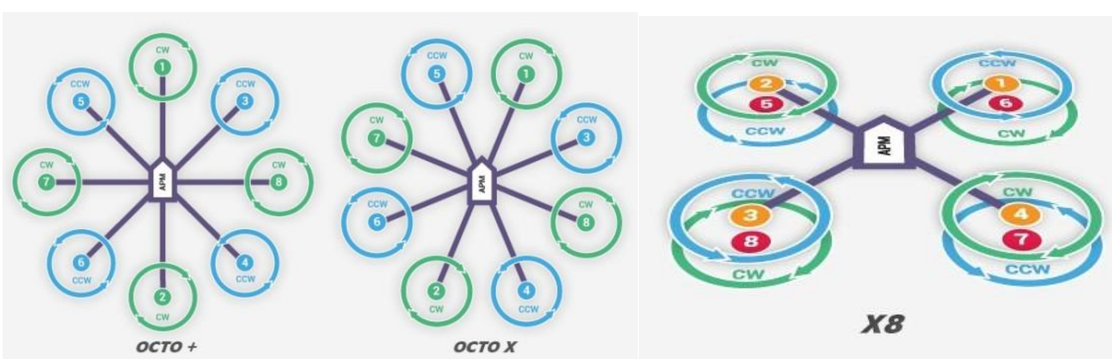


Hex copter Configurations

Hex copters also can function and fly home safely in case of any motor failure due to the number of motors present, however, the large number of parts present also increases the likelihood of a failure occurring.

Octocopter

An Octocopter is a multirotor with 8 motors. Due to the even larger number of motors than a Hex copter, it is more stable and is able to carry heavier loads. The even greater number of motors means even more expensive due to the additional number of motors and ESCs and a larger and heavier battery to support and power all the motors. This added mass generally leads to an increased weight of the structure with a commercially available one being approximately 4 kilograms. The large number of motors also allows the Octocopter to fly even in case of motor failure. However, the increased number of parts also increases the chances of failure of individual parts. There are three main configurations of an Octocopter, the + configuration, the X or V configuration and the X8 configuration. The advantages and disadvantages of the + and X configurations for multirotors hold constant for Octocopters as well.



X , + and X8 Octocopter Configurations

Parts of a Multirotor

A multirotor can be divided into five main sections, the frame, the propulsion, the power, the flight control system and the ground station and an additional section which is not required for flight, but for a mission in general, the payload.

Frame

The frame of a multirotor can come on various forms and can be made in various ways. These frames are generally made from plastics through the injection mould technique. Metals are also used as the main base where the arms or booms (circular arms) are attached to. The arms or booms are made from plastics or composite materials such as fiberglass and carbon fiber.

Most multirotors used by hobbyists and professionals use store made frames. This is because of the cost effectiveness of a store bought frame is very high as most of the desired configuration of a multirotor is already available in the market. The time taken to manufacture and fabricate along with the costs to procure the desired materials makes making one’s own frame impractical.

Carbon Fiber Frame

Plastic Frame

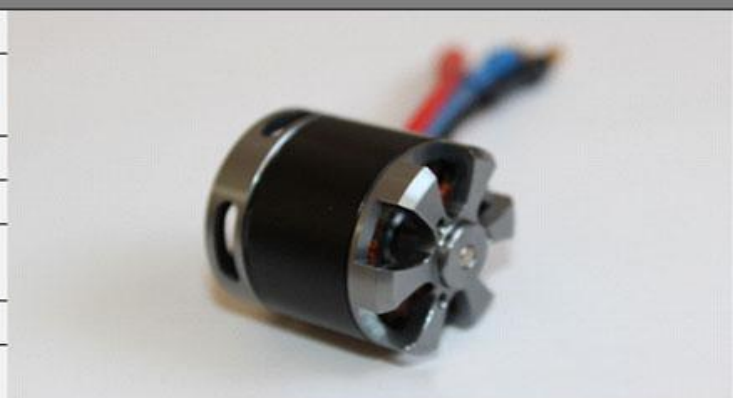
Propulsion

The propulsion system of a multirotor is responsible for moving the multirotor system. The multirotor system relies on motors and the shaft work it provides to the propellers to move. The components and parts required to move a multirotor system include the propellers, brushless motors and ESCs (Electronic Speed Controller). A propeller converts a rotating motion into forward motion. The propellers are divided based on the diameter. A larger diameter propeller will generate more lift than a propeller at the same angular velocity as it covers a larger area per rotation. However, due to the larger size, more torque will be required to move the propeller at the same angular velocity. Similarly, a larger propeller cannot change its angular velocity quickly because it has a larger inertia compared to a smaller propeller due to its greater mass. This makes a larger propeller not so popular among people who perform acrobatics with their multirotors.

The motors which move these propellers are brushless DC motors. Brushless motors have fixed coils made out of copper or other conductive materials with a permanent magnet surrounding it. The outer shell is connected to the permanent magnet which moves when power is supplied. In a traditional brushed motor the outer permanent magnet is fixed while the coils move. These brushless motors provide larger torque, better efficiency, longer life and lower noise due to the lack of connecting parts which would have otherwise lead to wear and tear of the material. The brushless motors available in the market are divided primarily based on their Kv rating. The Kv rating of a brushless motor determines the RPM (Rotations Per Minute) of the motor per volt applied when there is no loads attached. For example, a 1100Kv motor will rotate at 1100 RPM when 1 Volt is applied. This RPM will increase to 2200 when 2 Volts is applied. A lower Kv rating will provide a motor with larger torque with lower RPM while a higher Kv rating will provide a motor with lower torque but with larger RPM. The datasheet of AS-2824 brushless motor is given. It is to be noted that most datasheets provide the thrust provided by common propellers at different voltages/power.

Model: AS-2824 brushless motor

Technical Datas	
KV	1100
Motor Dimension(Dia.× Len)	28*24.5mm
Shaft Diameter	3mm
Weight	49.5g
Idle current(10)@10v(A)	0.2
No.of Cells(Lipo)	2-4S
Max Continuous current(A)180S	10A
Max Continuous Power(W)180S	110W



Test parameters : AS-2824 KV1100

Prop	Voltage(V)	Amps(A)	Watts(W)	Thrust(G)	RPM	Force efficiency (G/W)
8040	11.1	2.4	24.68	286	6980	12.1
	11.1	5.3	57.24	465	9420	8.4
	14.8	1.8	28.31	302	7330	10.5
	14.8	5.6	80.5	558	10310	6.8
9050	11.1	1.8	19.4	234	4750	13.2
	11.1	6.3	71.2	549	7280	6.85
	14.8	2.9	43.4	385	6210	9.4
	14.8	9.8	138.1	812	8860	5.3
10*4.5	11.1	2.4	27.4	330	4200	11.4
	11.1	7.8	88.2	575	5650	6.2
	11.1	10.9	118.7	690	6070	5.1

Brushless Motor Datasheet

Power

The battery is the source of all power in a multirotor. The most popular battery in the RC (radio Controlled) Flight community is the LiPo (Lithium Polymer) battery. LiPo batteries come in many shapes and sizes and are very light, have a very large specific energy (compared to other electrochemical energy sources) and have a very high discharge rate, and to top it off, it is rechargeable. These features make it very popular in the RC Flight community. The light weight is a primary factor in determining components where minimum weight is concerned such as flight. The high discharge rate means it can handle the large loads and current draws required by motors in RC Planes and Multirotors. The ability to recharge allows the user to use the same battery for a large number of battery cycles. However, a LiPo battery cannot be charged conventionally. A special LiPo battery charger is required. This LiPo battery charger will evenly charge all cells in the battery. The even charging of the cells in the battery will ensure the battery can be used for a larger number of charge cycles.

Item		Specifications	Remark
Nominal Capacity		1100mAh	0.2C_5A discharge
Nominal Voltage		3.7V	Average Voltage at 0.2C_5A discharge
Charge Current		Standard：0.2 C_5A； Max：1C_5A	Working temperature：0~40℃
Charge cut-off Voltage		4.20±0.03V	
Discharge Current		Continuously: 0.2C_5A； Max：2C_5A	Working temperature：0~60℃
Discharge cut-off Voltage		2.75V	
Cell Voltage		3.8~3.9V	When leave factory
Impedance		≤130mΩ	AC 1KHz after 50% charge
Weight		Approx: 24 g	
Storage temperature	≤1month	-20~45℃	Best 20±5℃ for long-term storage
	≤3month	0~30℃	
	≤6month	20±5℃	
Storage humidity		65±20% RH	

LiPo 1100 mAh Specification

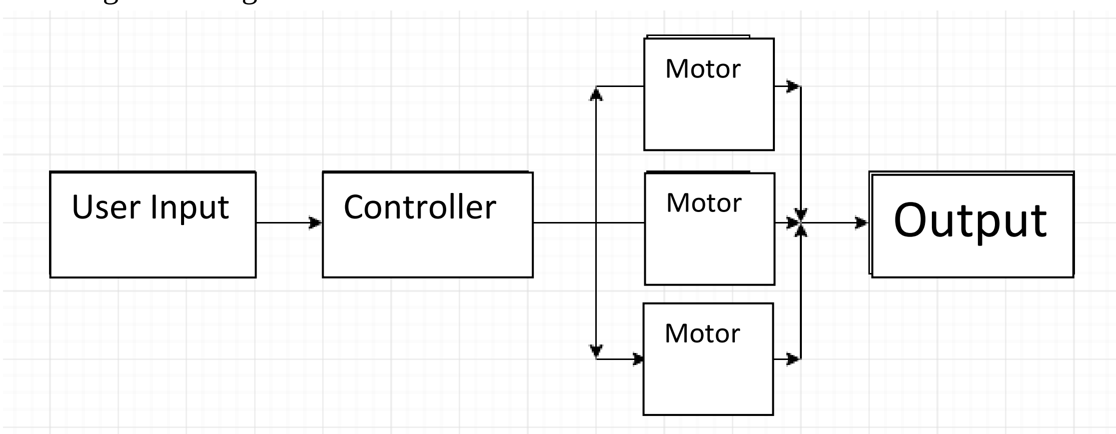
Above figure shows the datasheet/specifications of a 1100 mAh LiPo battery. LiPo batteries are very fragile and precaution must be taken while handling, storing or using them.

Turnigy LiPo Battery

Imax charger

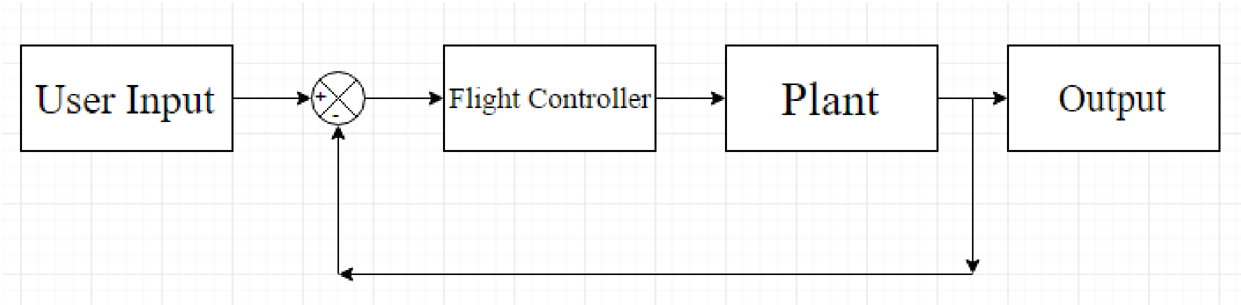
Flight Control System

The flight control system of a multirotor system is the heart and the brain of the multirotor. A multirotor is a very complex system with multiple variables any outputs. The flight controller gathers the input from the user and converts it into signals which will then be distributed to the motors which will in turn provide the desired output. A simple block diagram of the flight controller is given in Figure below.



Flight Controller Block Diagram

We can observe in above figure that the controller distributes the commands from the User to the motors to provide the desired output. An example of the controller coming into play is when the user wants to turn the multirotor about its yaw axis. To achieve such an output, the controller commands certain motors to turn faster while slowing down the others to create the necessary output. However, the multirotor does not always respond the way it is expected to due to external interferences. This interference or noise will create an unstable and unsteady flight of the multirotor. To counter these interferences and noise, a feedback control mechanism is implemented in almost all multirotors. A feedback control mechanism uses the error between the input and the output to provide extra input commands to the motors to correct the error. A block diagram showing a feedback control mechanism is shown in Figure below.



Block diagram of a Feedback Control Mechanism

Ground Station

The ground station is responsible for communication between the multirotor and the user. It is what connects the user to the multirotor. It can come in various forms such as a simple transmitter to an elaborate setup of computers with receivers with imaging and sound capabilities for UAVs such as the Predator. The 2.4 GHz transmitter coupled with its receiver is the most commonly used ground station for a simple multirotor system. The transmitter works in the 2.4 GHz frequency band primarily due to government regulations. FCC or the Federal Communications Commission has set the 2.4 GHz band as licensing is not required to operate radio frequencies at this band. This is because the FCC was required to keep the electromagnetic waves of different wavelengths separated based on their function and uses. Due to this, frequencies already in use by TVs, and radios were out of the question. A more commercially and popular electric equipment which uses electronic waves were considered and the 2.4 GHz band was chosen.

RC Transmitter and Receiver

Payload

The payload is the driving factor being the construction of a UAV. This payload can come in various forms such as a FPV (First Person View) camera for hobbyists, a high quality video camera for professional aerial photography and videography, multispectral and hyperspectral cameras for remote sensing, goods for the newly proposed AMAZON drone delivery system and LIDAR (Light Detection And Ranging) for surveillance and 3-D mapping. Payloads define the requirements and the requirements define the parameters of a UAV. However, payloads are not necessary for the construction of a UAV. A multirotor UAV can be constructed simply to understand the physics and the working of a multirotor system and the theory behind how it works. A UAV is a very unstable system with requires a complex feedback control mechanism and hence has been a source of study for many control engineers.

Amazon Drone Delivery system

A multirotor with LIDAR

Fixed-Wing UAV

A fixed-wing UAV is essentially a plane without a pilot or any other human on board. The wing generates lift when air flows over it. To generate the required airflow, a form of propulsion to move the aircraft forward is required. This propulsion is usually done by a propeller attached to a chemical engine or a motor. Due to this, a fixed-wing UAV requires a conventional runway to take off and land. The thrust produced by the propeller allows the UAV to move at high horizontal speeds effectively allowing the UAV to cover a large distance in a short amount of time. The aerodynamic properties of a wing also enable a fixed-wing UAV to have a stable unpowered flight allowing the UAV to land safely in case of loss of power. The efficiency of a fixed-wing UAV is also very high as it is capable of carrying heavier loads when compared to rotary wing aircrafts at the same power.

The generation of lift in a fixed wing is generated by the difference in pressure on the upper and lower surfaces of the wing. This difference in pressure is generated by the difference in flow speeds over the two surfaces of the wing. Bernoulli's principle states that the total pressure in a system is constant for a steady, inviscid and incompressible flow. Therefore, we can write the equation of pressure in a system as $P + \frac{1}{2}\rho V^2 + \rho gh = constant$, where P is the static pressure, $\frac{1}{2}\rho V^2$ is the dynamic pressure and ρgh is the hydrostatic pressure. As the hydrostatic pressure will remain constant as the height difference between the top and the bottom layer of the wing is negligible, we get the following equation, $P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$. Therefore, from this equation, we can derive the equation of lift generated by a wing of surface area A to be $L = \frac{1}{2}\rho V^2 A C_l$. Therefore, the lift of a fixed wing aircraft is dependent on its velocity.

However, due to the requirement of a runway to takeoff, a fixed-wing UAV cannot be used in places where there is not enough space. The constant need for a horizontal motion to generate lift also makes the design unfavorable when focus on a certain non-moving body/area is required. The fixed-wing design while being stable is not very maneuverable and makes it not practical to use the fixed-wing design when the UAV will be flying in and around obstacles.

The fixed-wing UAV can be divided into subparts based on the wing configuration and the wing shape, etc. The wing configuration can be high wing, medium wing, low wing flying wing, with a swept wing, elliptical wing or a swept wing design which has their own advantages and disadvantages. In a high wing configuration, the wings of the aircraft are placed on top of the fuselage. This configuration provides a greater clearance for the wing from the ground. The high wing configuration also provides a better visibility from the cockpit to the ground and generates a little more lift due to the top of the fuselage being a part of the wing. The high wing configuration is also considerably more stable than the other configurations. However, the position of the wing causes the downwash to severely affect the tail of the plane. The increased stability also means the plane is not as maneuverable. Hence, due to the above characteristics, the high-wing design is generally implemented on airplanes with the objective to have a long duration, stable and efficient flight.

F300; High Wing UAV

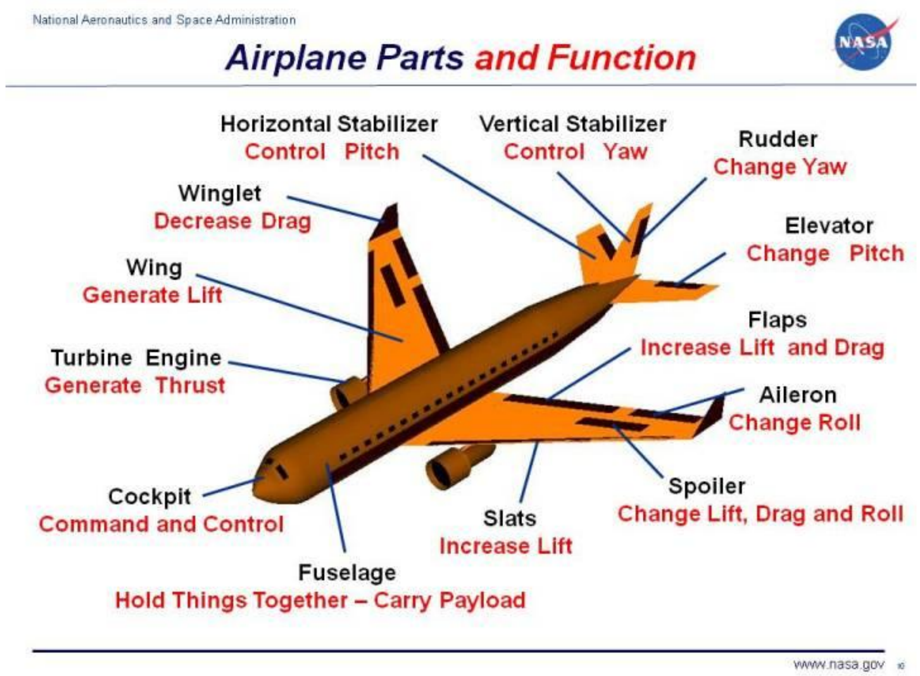
The Low-Wing configuration is when the wing is placed below the fuselage of the aircraft. A Low-Wing configuration is slightly unstable with a low clearance from the ground. The overall speed of the plane is also a little higher compared to a High-Wing model and more maneuverable due to the unstable nature of the design. Due to this, acrobatic planes tend to be of Low-Wing configuration. The Low-Wing configuration in a UAV can be observed in figure below.

Predator XP; Low-Wing Configuration

From the above figures, the general shape of a fixed wing UAV is very limited and static. The design can be broken up further depending on how the lift is generated. For example, a flying wing design will have no distinction between the fuselage and the wings, while a blended body will have a smooth transition between the fuselage and the wings, while finally, a lifting body will have no wings, but rather rely on the fuselage to provide lift at high speeds or high angle of attack.

Parts of a Fixed Wing UAV

A fixed wing UAV is very similar to a plane and can be divided into five main parts, fuselage, wings, empennage (tail), propulsion and undercarriage (landing gear).The fuselage is the main body where all other structural components are attached to. The wings are responsible for the generation of lift and some control of the plane. The empennage is responsible for the stability and control of the aircraft. As observed in Figure below, the pressure distribution is not even across any axis of the airfoil and thus creates a pitching moment in the plane. To counteract this moment from the wings, another form of lift is required to keep the plane stable. This lift comes from the horizontal stabilizers in the empennage of the plane. The vertical stabilizer in the empennage of the plane keeps the plane stable in the yaw axis. The wings and the empennage are also the location for of the control surfaces of the plane. On the wings, there are Slats, Spoilers, Flaps and Ailerons. The Slats and the Flaps change the chord length of the wing effectively changing the coefficient of lift of the plane, while the Spoiler increases the drag generated by the wing making it an effective air brake. The Aileron is responsible for the rotation of the plane around its roll axis. This rotation is achieved by raising the Aileron of one wing while simultaneously lowering the other. This changes the effective angle of attack producing more lift on one side while reducing the lift produced on the other side. This uneven distribution of lift across the two wings creates a rolling moment about the roll axis. On the horizontal stabilizer, the Elevators are located. The elevators are responsive for the pitching moment of the plane. This moment is achieved by raising or lowering the elevators on the horizontal stabilizers on the empennage of the plane. Similar to the ailerons, the angle of attack is changed when the position of the elevator is changed which leads to less or more lift produced by the horizontal stabilizers. Since the lifting forces act on the center of gravity of the aircraft, a pitching motion is created. Similarly, on the vertical stabilizer of the empennage, the rudder is located. The rudder is responsible for the movement of the plane in the yaw axis. This is moment is also created by changing the angle of attack to the oncoming wind, also known as the free stream, on the vertical stabilizer. The changing angle of attack causes a horizontal force to act on the vertical stabilizer. This force being away from the center of gravity of the plane instead creates a moment about the yaw axis of the plane. The propulsion is the type of engine or motor used to propel the aircraft forward. In case of a commercial plane such as the Airbus A380, it is a turbofan engine which relies on the thrust provided by the exhaust of the engine. In case of a smaller trainer plane such as the Piper PA-38-112 Tomahawk, a turboprop engine is used where the rotation of a propeller along a shaft is used to propel the plane forward. In case of many smaller fixed wing UAVs, a brushless electric motor is used to rotate a propeller to propel the aircraft forward. The undercarriage also known as the landing gear is responsible for asafe and smooth transition between flying on air and moving on the ground. There are primarily two types of undercarriages, retractable and non-retractable. A retractable undercarriage is retracted into the aircraft during flight reducing the number of protrusions on the aircraft effectively reducing drag. Most planes now have a retractable undercarriage while all planes which fly at transonic speeds or greater definitely have retractable undercarriage as parasitic and wave drag increases significantly as the aircraft approaches the speed of sound.



Parts of a Fixed wing Plane

UAV Applications & Limitations

Applications

- Quick disaster assessment
- Crop estimation & damage assessment
- City/town planning
- Traffic management
- Aerial movies & videography-Film industry
- Industrial inspection-solar parks, wind parks, power line etc.
- Structural analysis- archaeology & heritage monument inspection
- First responders in accident, fire or crisis

Limitations

- Limited payload capacity
- Limited flight endurance
- Less area coverage
- Relatively costly
- Suitable for small study area
- Can not be operated during rain

Importance of UAVs in Remote Sensing

- Effective for real time mapping, survey and monitoring activities with high spatial and spectral resolution data.

- UAV data can be applied in combination with satellite data to produce better results e.g. Getting high-resolution images of interested area, getting localized images of satellite shadow zones.
- The potential of UAV product in the form of very very high-resolution (VVHR) images has enabled to gather detailed spatial information in studying unplanned settlements.
- UAVs can perform an efficient Survey for disaster prone or physically inaccessible areas, quick damage assessment of landslides, floods and earthquakes for enabling relief measures.

NESAC UAVs

The centre has three-multi rotor UAVs (a Quad Copter and two Hex Copters). Quad copter is a ready to fly UAV having a camera as a payload. Hex copter (HQ1) is assembled based on the requirements and can carry different payloads for different requirements. Hex copter (HQ 2) is ready to fly UAV having a camera and a multispectral sensor as a payload. All three Copters have a range of 2 Kms radius with clear line of sight communication. The copters are powered by lithium polymer batteries (LiPo batteries) which provides flight endurance from 20-40 mins. Hex copters can carry a payload up to 5 kgs based on the requirements. The center is also having a Fixed wing UAV which is under experimental stage.

Quad Copter

Hex Copter (HQ1)

Hex Copter (HQ2)

Fixed wing UAV

Flight planning & Data acquisition

Background:

Flight planning and data acquisition is the important part of UAV Remote sensing. If there are no proper flight planning techniques used the acquired data may have gaps after processing due to lack of fixed overlaps or different in heights etc. UAV data acquisition may be done in ways a) Manual flying b) Autonomous flying. In case of manual data collection we don’t have any control on front and side overlaps however we can fix height of flying and camera shutter speed. Once the height of flying and camera shutter speed is fixed we have fly the UAV such that sufficient overlap is maintained by looking at the live camera feed. In this case maintaining a constant overlap is difficult and we also end up in capturing more no of images for the required area as compare to autonomous mode. In autonomous mission planning we can define the percentage of front and side overlaps along with height and shutter speed to capture data precisely. The overall data acquisition and flight planning may be divided into following steps:

1. **Identification of the Area:**
   In the first step of any mission we have to create Area of Interest (AOI). As the mission planning varies for different areas such as: urban area, forest areas, rivers etc we have to study the terrain condition of the AOI and then fix the flight parameters such as flying height, overlaps etc. Flying height is also related to ground sampling distance (GSD) required for the acquired data. The GSD (m) at a fixed height can be defined as:
   $$GSD= (H/f)*u$$
   $$u= w/Sw=h/Sh$$
   where, H is flying height (m), f is focal length of the camera (mm), u is pixel size (um), W is width of CCD (mm), H is height of CCD (mm), Sw is no of pixels for W and Sh is no pixels for h.

2. **Mission Planning:**
   After identification of area is done a mission plan is prepared on the mission planning software and loaded into aircraft. The softwares used for mission planning are Pix4D capture, AirMap, DJI GS, Maps made easy etc. Figure No 1 & 2 on next page shows Autonomous mission planning for aerial and linear surveys respectably.

3. **Establishment of Ground control points (GCPs):**
   As the accuracy of data collected from UAV will depend on the accuracy of onboard GPS system which is in range of 5-10 m. To improve the accuracy further ground control point may established using DGPS or any other high accuracy instrument and the GCPs may be incorporated with the UAV data at the time of processing for generating high accuracy outputs such as DSM, DTM, contours, orthophoto etc.

Figure 1: Autonomous mission planning for required area

Figure 2: Autonomous mission planning for linear missions

4. Data Acquisition:

Once the mission plan is loaded in the UAV the acquisition process starts in a pattern as defined by user.