aeroKLE

AERO-DESIGN TEAM



# Recruitment Material

# 2026

# PREFACE

This document is only an abstract of a subset of important topics. It is intended only to guide you towards the required topics and help you realize our expectations during the interview. This document alone is not sufficient to get through our recruitment process. Explore this document thoroughly, self- learning is the key ingredient of success.

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# 1. Introduction to aerial vehicles

Aerial vehicles are any machines supported for flight in the air by buoyancy or by the dynamic action of air on its surfaces, especially powered airplanes, gliders, and helicopters.

(To explain you further in detail we have considered an example of a typical plane.)

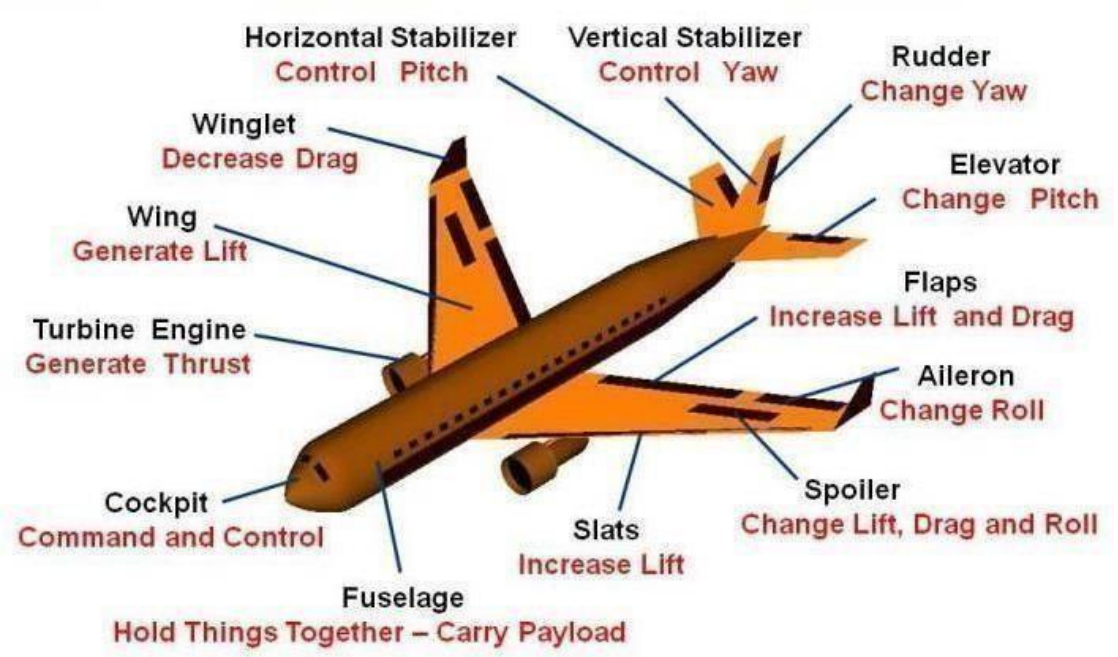



*Figure 1 : Different parts of an airplane and their functions*

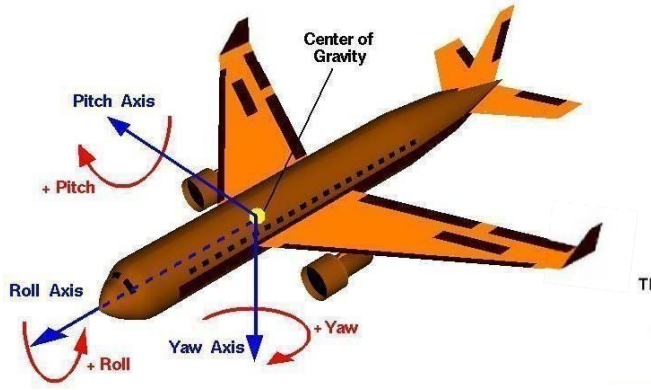



*Figure 2 : Aircraft Motions and Principle axes*

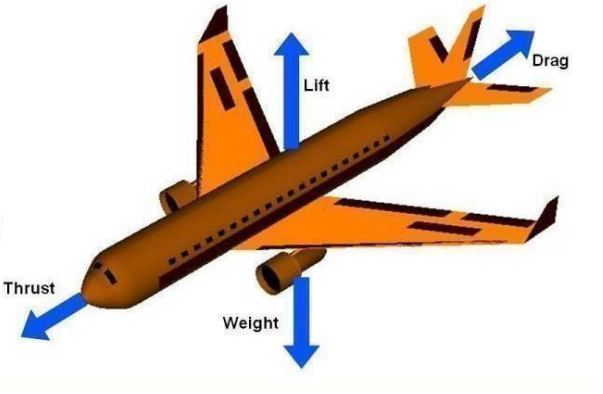



*Figure 3 :Forces acting on plane in cruise*

Major subsystems of an aerial vehicle

1. Lifting part - Wing
2. Main body - Fuselage
3. Stabilizing part -Empennage
4. Power unit - Propulsion

Details regarding each sub-system are mentioned below and supported reference link are given for the same to explore more in detail

Ever wondered how it is possible to fly at 30,000 ft with 50 tones!? That's the power of STRUCTURE AND AERODYNAMICS.

These two topics play a major role in every sub-system

## 2. Wing

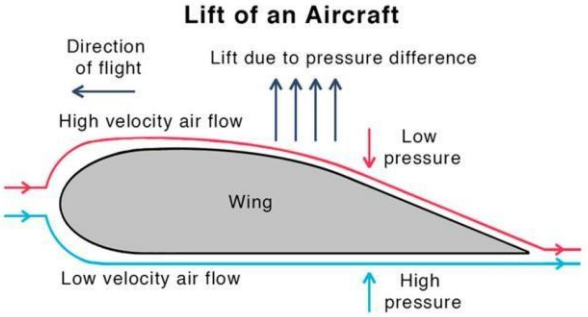
The wing is a primary lift producing part of the Aircraft. It is an aerodynamic structure that has a streamlined cross-section called an **airfoil**. Wing additionally provides lateral stability to the aircraft, which is essential for flight safety.

So how does a wing produce lift? What is the principle behind it? It's Bernoulli's Law.

### 2.1. Airfoil Lift

An airfoil creates lift by speeding up the air above it and slowing down the air below it. Faster air on top means lower pressure; slower air underneath means higher pressure. This pressure difference pushes the wing upward, creating lift.

*Figure 4: Principle of Bernoulli's law*




**Wing design**

1) Calculations 2) Airfoil selection 3) Planform and Configuration

4) Structural design 5) Material Selection 6) Analysis 7) Construction

### 2.2. Calculations

Most of the calculations involved in the wing design are done for cruise condition as it is the longest phase of the flight journey. The two formulas listed below are generally used in wing calculations.

$$\boldsymbol{L} = (1/2)\,\boldsymbol{\rho A V^2 C_L}$$

*Equation 1: Formula for lift*

$$\boldsymbol{D} = (1/2)\,\boldsymbol{\rho A V^2 C_D}$$

*Equation 2: Formula for drag*

where $\boldsymbol{\rho}$ is the density of the fluid, v is the free-stream velocity of the fluid, $\boldsymbol{C_L}$ is Co-efficient of Lift, $\boldsymbol{C_D}$ is Co-efficient of Drag, A is Wing surface area, L is Lift in newtons, D is Drag in newtons.

## 2.3. Airfoil Selection

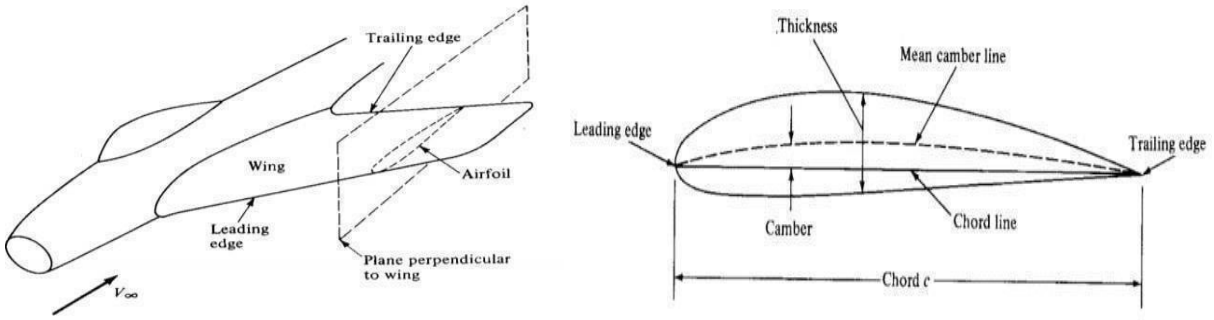



*Figure 4 : Airfoil and its parameters*

Planes like Boeing and Airbus may have their custom airfoils. However, during the preliminary design stage, the standard practice is to choose the airfoil from a large number of airfoils whose geometric and aerodynamic characters are available in aeronautical literature.

The Airfoils lift characteristics are highly influenced by its shape and the shape of the airfoil is defined using following geometrical parameters.

1)Mean Camber line 2) Leading-edge 3) Trailing edge 4) Chord 5) Thickness Classification of airfoil based on their shape:

1) Under cambered 2) Symmetric 3) Flat bottom 4) Reflex

*Table 1 : Different airfoil characteristics and their applications*

| Airfoil Type | Key characteristics | Applications |
|---|---|---|
| Cambered | High L, High D, negative $C_M$ | Wings on high endurance UAVs, RC sailplanes |
| Flat bottom | Moderate L, Moderate D, less negative $C_M$ | Wings on short range UAVs, RC sports plane |
| Symmetrical | low L, low D, zero $C_M$ | Long range, Horizontal and vertical tail, Aerobatics |
| Reflex | Moderate L, Moderate D, positive $C_M$ | Flying wings |

Where L is Lift, D is Drag, $C_M$ is Pitching moment coefficient

## 2.4. Planform and configuration

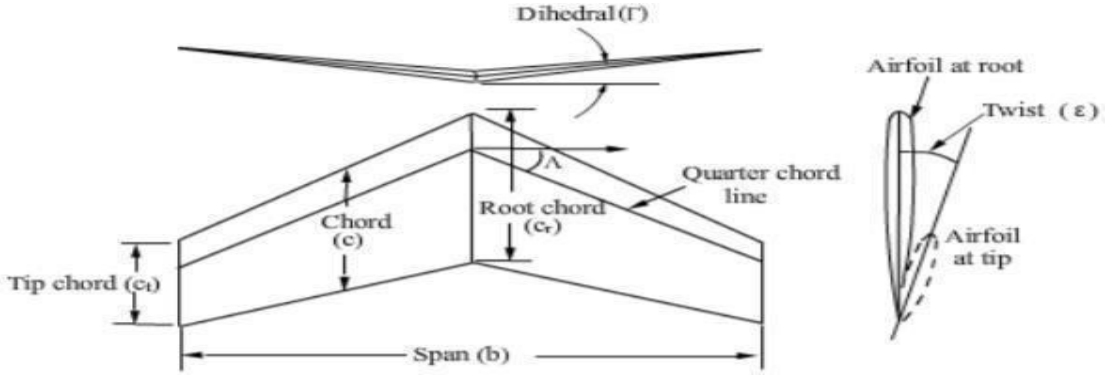



*Figure 5 : Planform Details*

Selection of appropriate planform is very important in the design process, as wing planform contributes significantly to the aircraft's aerodynamic performance and overall stability. There are different types of wing planforms few of which are mentioned below.

1) Rectangle 2) Swept (back/forward) 3) Elliptical 4) Tapered

5) In/Out tapered 6 ) Custom planform by optimization using software

### 2.4.1 Wing planform parameters

1) Aspect ratio (A.R) 2) Taper ratio 3) Swept ratio 4) Mean aerodynamic chord

Control surfaces present on the wing

1) Ailerons 2) Flaps 3) Spoilers

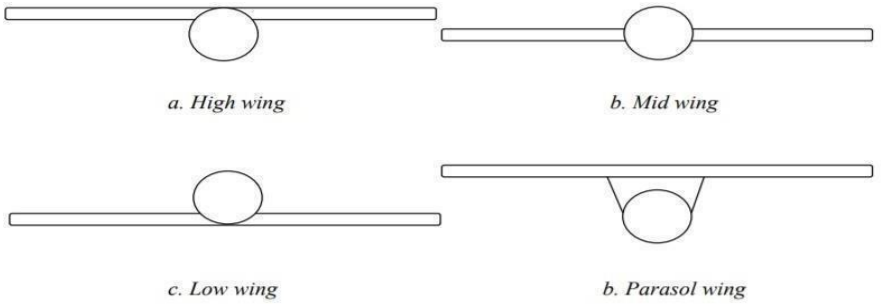



*Figure 6 : Wing types based on the position*

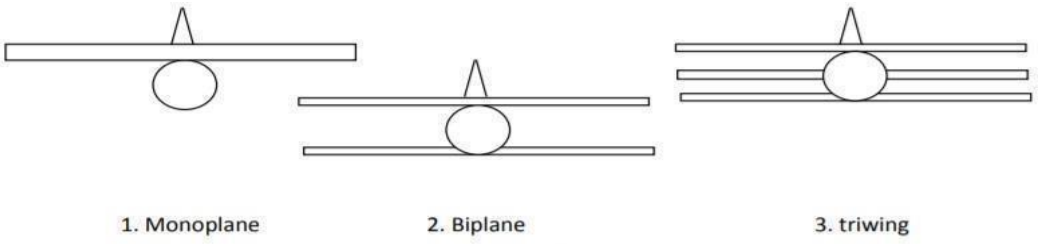



*Figure 7 : Wing types based on number of wings*

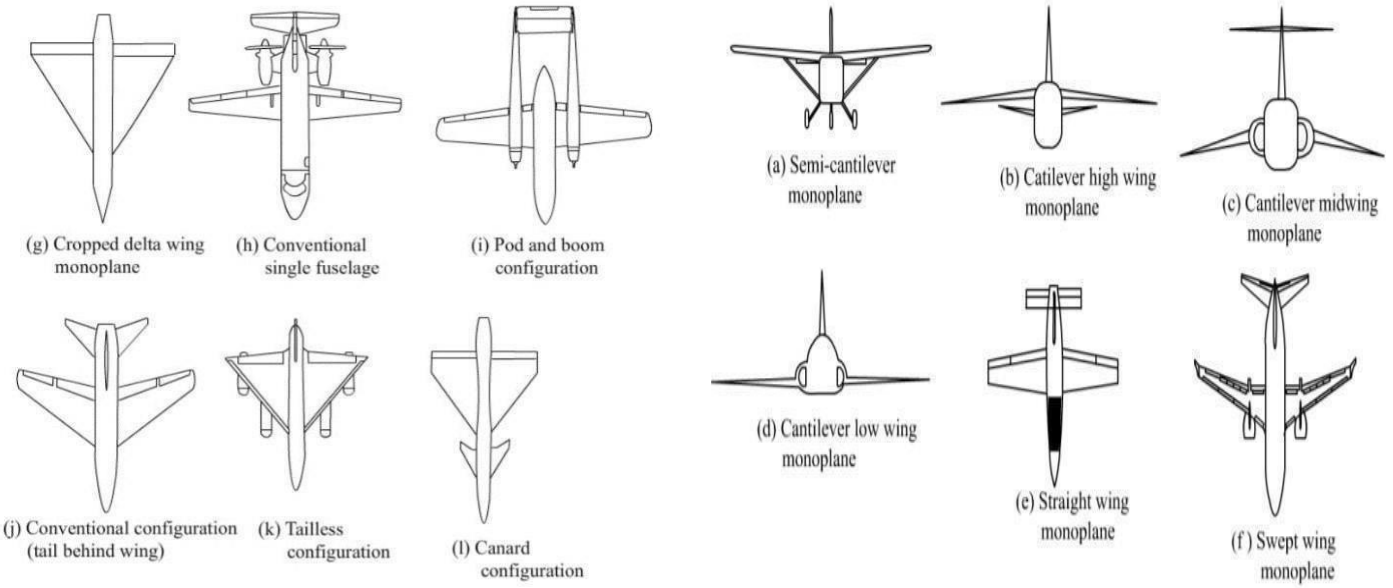



*Figure 8 : Various configurations in airplanes*

There are various ways to increase a wing's performance, for example hedral, wing fence, wingtip, etc.

**2.5. Important Aerodynamics terms**

| | | |
|---|---|---|
| 1. Wing loading | 2. Wing twist | 3. Wing incidence angle |
| 4. Center of pressure | 5.Aerodynamic center | 6. Pitching Movement of the airfoil |
| 7. Swept angle | 8.Stall Angle and velocity | 9. Mean aerodynamic chord |
| 10. Roll Stability | 11. Angle of attack | 12. Flightpath angle |
| 13. Lift co-efficient ($c_l$) | 14. Drag co-efficient ($c_d$) | 15. Moment co-efficient($c_m$) |

*(The co-efficient are available at airfoiltools.com)*

*(All the co-efficient are in 2d)*

*Equation 3 : Approx. formula for 3d coefficient*

$$C_{L(3d)} = \frac{C_{l(2d)} \times A.R}{A.R + 2}$$

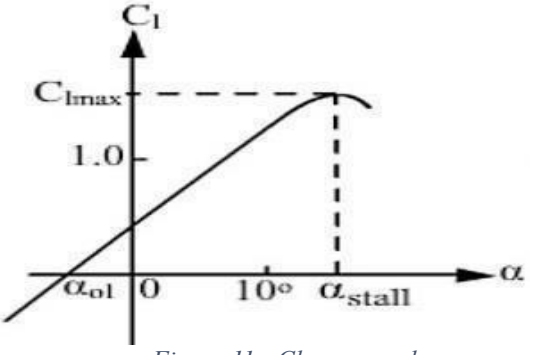



*Figure 11 : Cl vs α graph*

$$C_{D(3d)} = C_{Dmin} + kC_L^2$$

$$K = \frac{1}{\pi \times A.R \times e}$$

*(where e is Oswald efficiency taken to be as 0.9)*

## 3. Fuselage

Fuselage is the main body of the aircraft which houses all the components including the payload. The payload can either be passengers, cargo, missiles, etc. and connect with other parts.

### 3.1. Sizing

The length of the fuselage - 60-75% of Wingspan. The length from propeller to CG of the plane should be around 33.4% of fuselage length. Fuselage height and width is 10% to 15% of fuselage length (it might vary differently for different aircraft).

### 3.2. Design and construction

Important terms

1) Formers 2) Stiffeners/stringers 3) Skins 4) Longerons

Fuselage holds the most of the aircraft components along with the payload. Fuselage may experience very high loads during rough landing or short-takeoff. Hence, it should be designed carefully to bear all the loads without adding much weight to the system. Fig 13,14,15 shows the standard fuselage construction techniques which are followed by the aerospace industries.

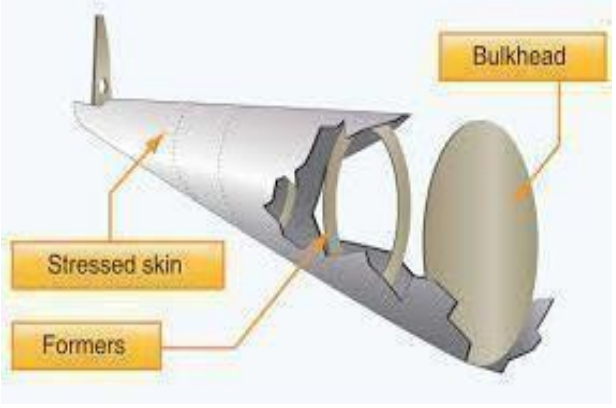



*Figure 13: Monocoque Structure*

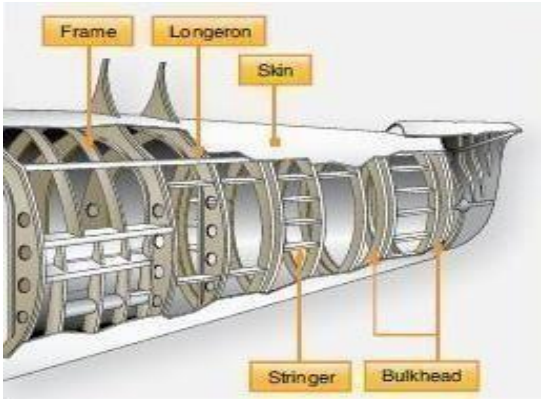



*Figure 14: Semi - Monocoque Structure*



*Figure 15: Truss Structure*

### 3.3. Undercarriage

Undercarriage refers to the landing gear. The main purpose of the landing gear is to withstand landing impact. There are many different configurations of landing gear each having its own pros and cons.

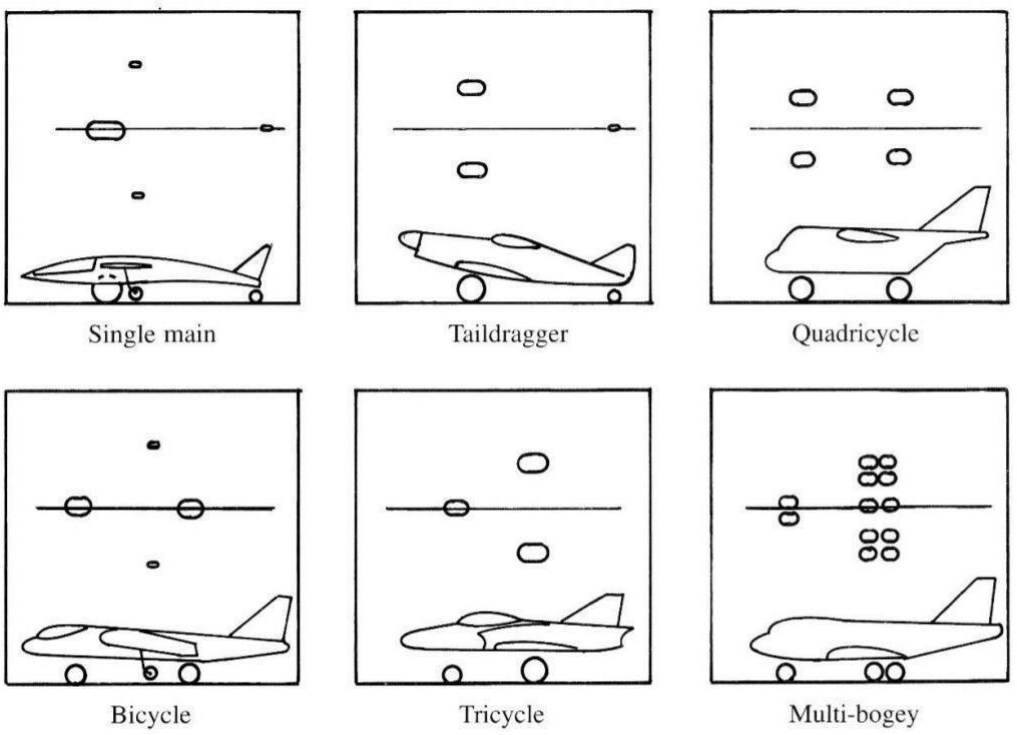



*Figure 16: Types of landing gear*

## 4. Empennage

### 4.1. Introduction to the empennage

The empennage is one of the most important components of an aircraft, which is commonly known as the tail. The tail mainly consists of horizontal and vertical stabilizers. The vertical stabilizer is equipped with a rudder and the horizontal stabilizer is equipped with an elevator.

#### 4.1.1 Vertical Stabilizer

The vertical stabilizer, located at the back of the fuselage, prevents side-slip and keeps the aircraft stable in yaw. It is mounted upright because this position helps generate lift that counters unwanted banking and avoids the instability that would occur if it were placed underneath. The movable back portion of the stabilizer is the rudder, which the pilot uses to control yaw.

### 4.1.2 Horizontal Stabilizer

A horizontal stabilizer is used to maintain the aircraft in longitudinal balance, on trim it exerts a vertical force at a distance from the Centre of Gravity, so the summation of pitch moments about the Center of Gravity is zero. The vertical force exerted by the stabilizer varies with flight conditions, in particular, according to the aircraft lift coefficient.

Another role of a horizontal stabilizer is to provide longitudinal static stability. Stability can be defined only when the vehicle is in trim. It refers to the tendency of the aircraft to return to the trimmed condition if it is disturbed. The elevator serves to control the Pitch axis. In the case of a fully movable tail, the entire assembly acts as a control surface.

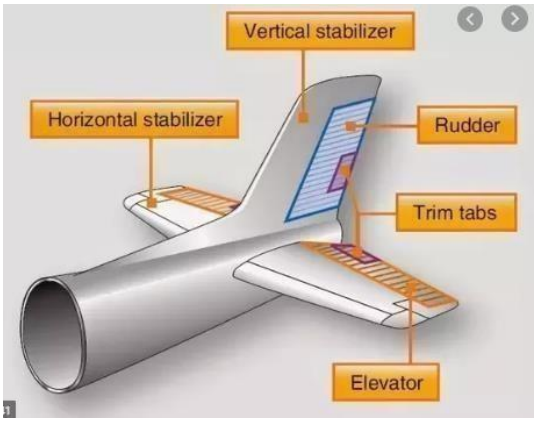



*Figure 17: Control surfaces on a tail*

### 4.2. Formulae

$$C_{HT} = \frac{L_{HT} S_{HT}}{C_w S_w}$$

*Equation 1 : Horizontal tail coefficient*

$$C_{VT} = \frac{L_{VT} S_{VT}}{b_w S S_w}$$

*Equation 2 :Vertical tail coefficient*

Where $c_{HT}$, $c_{VT}$– Horizontal and vertical tail volume coefficients.

$S_{HT}$,$S_{VT}$– Horizontal and vertical tail area.

$L_{HT}$,$L_{VT}$– Moment arm i.e. the distance from CG of the aircraft to AC of the tail.

$S_W$–Area of the wing. $b_W$ – Wingspan $c_W$-Mean aerodynamic chord of the wing

A study from basic RC Aircraft design suggested values for $C_{HT}$ are between 0.3 to 0.5 and $C_{VT}$ lies between 0.04 to 0.07 for subsonic or low-speed Aircraft.

### 4.3. Different tail configuration

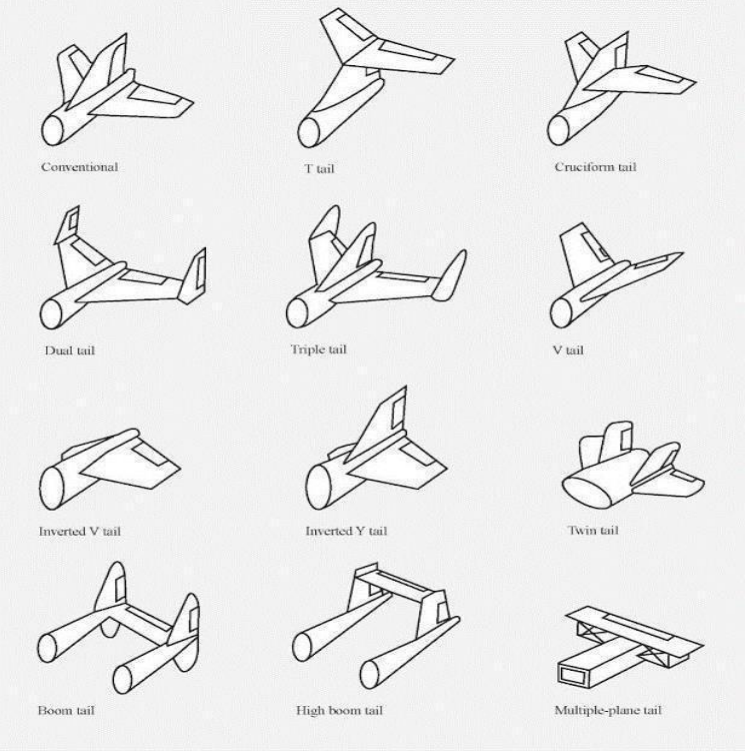



*Figure 18: Different tail configurations*

Each tail configuration has its pros and cons.

*Have you seen the V configuration tail! Wondered how it works?*

### 4.4. Aerodynamic important terms

1) Downwash on tail
2) Wing shadow
3) Tail incidence angle
4) Tail volume co-efficient
5) Moment arm
6) Aspect ratio
7) Elevator power
8) Static stability
9) Directional stability
10) Roll stability
11) Side slip
12) Moment

## 5. Structural design

The structure & construction techniques of the tail are similar compared to the wing. the ribs are so arranged to obtain a uniform wing surface. The main spar is present to hold all the ribs in their actual position and to bear the loads acting on the tail. Other spars help to support the structure.

### 5.1. Important parts in a structure (wing and tail)

1) Ribs
2) spar
3) fixture
4) control surfaces (Ailerons, Flaps)

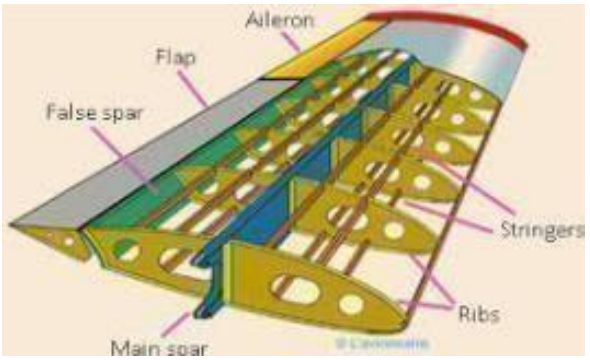



*Figure 19: Structural view of a win*

## 6. Analysis

The planform characteristics ($c_l$, $c_d$, $c_m$) are analyzed using XFLR5 or other airfoil tools. The plane structural analysis is done using the FEM method using tools like ANSYS, where the stress and loads are analyzed. The flow analysis of the wing is done using the CFD method using tools such as Simflow (open foam), ANSYS (fluent) where the overall lift, drag, moment, vortex and downwash is analyzed.

## 7. Materials

The material is the main and important aspect of any design. The material should be able to withstand the load on the design at any time and should weigh as low as possible and be strong (high strength to weight ratio).

Properties of materials

1)Youngs modulus
2) Tensile / Compressive strength
3) Flexural or bending strength
4) Density

## 8. Propulsion and Avionics

Electronics are the soul of any UAV without which they won't make it to the sky. There are a bunch of components you must know about:

1) Batteries:
   Li-Po (Lithium-Polymer) batteries are a type of lithium-ion battery that use a polymer electrolyte instead of a liquid one. They are commonly used in RC planes, drones, and portable electronics where low weight and flexible form factor are important. A single Li-Po cell typically operates between 3.7 V (nominal) and 4.2 V (max), and packs use cells connected in series.

Li-ion (Lithium-ion) batteries use a liquid electrolyte. They offer high energy density, good lifespan, and stable performance, making them widely used in drones, laptops, EVs, power banks, and smartphones. Their voltage range is also about 3.6–4.2 V per cell.

2) BLDC Motor/ Brushless DC Motor:

As the name suggests brushes are absent and hence in this case, commutation is implemented electronically with a drive amplifier that uses semiconductor switches to change current in the windings based on rotor position feedback.

The advantage of a BLDC motor includes high efficiency, longer operating life, higher speed ranges, better speed versus torque characteristics, faster dynamic response and noiseless operation. In addition, the ratio of torque to the size of the motor is higher, making it useful in application where space and weight are critical factors.

3) Servo Motor:

Servo motor is a type of motor that is specialized for high response, high precision positioning. Most servo motors can rotate only 90° either side.

4) Propellers:

A propeller's size can be expressed as either a 4-digit number or in the format of diameter × pitch. For example:

6045 = 6.0 in. x 4.5 in. 3020 = 3.0 in. x 2.0 in.

The initial number represents the diameter (measured from tip to tip), and the subsequent number denotes the pitch, typically measured in inches. Pitch determines thrust: larger pitch for more thrust but less stability, and smaller pitch for higher speed and stability but less thrust.

5) ESC:

An Electronic Speed Controller (ESC) is a device that regulates the power of an electric motor, allowing it to throttle from 0% to 100%. An ESC is made up of three key components. A BEC/voltage regulator, a Processer and the switching consisting of FETs (field effect transistor). The BEC/voltage regulator is a division of the ESC that will send a set amount of power back to other components.

6) Transmitter and Receiver:

Transmitter, as the name suggests, transmits information which is carried by a radio frequency signal, which is called a carrier signal. This signal is carried out through a particular frequency which is received by a receiver. The receiver converts the information carried by the signal to a usable form.

7) Flight Controller:
   A flight controller (FC) is a small circuit board of varying complexity. Its function is to direct the RPM of each motor in response to input. A command from the pilot for the multi-rotor to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.

### 8.1. Important Electrical terms

There are a few electrical terms that one needs to be aware of while sizing the propulsion system:

1) Kv of motor: A Kv value is the no-load rotational velocity of a motor per 1 V of input. Kv values are reported in units of [RPM/V].
2) Current rating of motor: The current rating of a motor is the amount of current that the motor draws from the battery.
3) Torque of motor: The torque is the twisting force that makes the motor running and the torque is active from *0%* to *100%* operating speed.
4) Capacity of a battery: The battery capacity represents the maximum amount of energy that can be extracted from the battery under certain specified conditions.
5) C rating of a battery: It is a rating of how quickly energy can be discharged from a battery. The rating is combined with a battery's capacity to determine the maximum discharge.

### 8.2. Important Avionic terms

Avionic is the electronic system used on aircrafts that are programmed to perform specialized tasks. Some of the important terms regarding Avionic are:

1) Sensors: These are devices whose purpose is to detect events and send the data to other electronics.
2) GPS module: GPS or Global Positioning System module is a device that contains processors and antennas that directly receive data from satellites through dedicated RF frequencies.
3) Microcontroller: A microcontroller is a compact integrated device designed to govern a specific operation in an embedded system.
4) Flight Computer: A flight computer is the high-level processing unit that handles advanced decision-making and autonomy in a drone. It runs complex algorithms

such as computer vision, mapping, obstacle avoidance, path planning, and mission control (Eg; Raspberry pi 3,4,5 , NVIDIA Jetson Nano, Vicharak Axon)

5) Ground Station: A ground station is the control hub on the ground that allows operators to monitor and manage a drone's flight. It displays live data such as GPS position, battery level, camera feed, and mission status. Through the ground station, users can plan waypoints, send commands, adjust settings, and track the drone in real time. It acts as the communication link between the drone and the pilot, especially during autonomous or long-range missions.
6) IMU: IMU or Inertial Measurement Unit is an electronic device that measures a body's angular velocity, specific force, acceleration and its orientation. It includes sensors like gyroscopes, accelerometers and sometimes magnetometers.
7) Image recognition: The technology that is used to identify various objects, places and people in digital images is known as image recognition.

### 8.3. Important Structural terms

1)Weight of the components

2) Material

3) Heat discharge

4) Size of component

5) Fixture

### 8.4. Important Aerodynamic terms

1)Flight time
2) Endurance range
3)Maximum thrust
4) Maximum velocity
5)Minimum thrust required
6) Maximum flight path angle
7) Pusher/puller configuration
8) Gyroscopic effect
9) Thrust to weight ratio

## 9. Different flight Stages

1) Take-off (hand launch, power take-off)
2) Ascent phase
3) Cruise/Loiter condition
4) Descent phase
5) Landing (belly landing)

## 10. Assembly of different parts of the plane

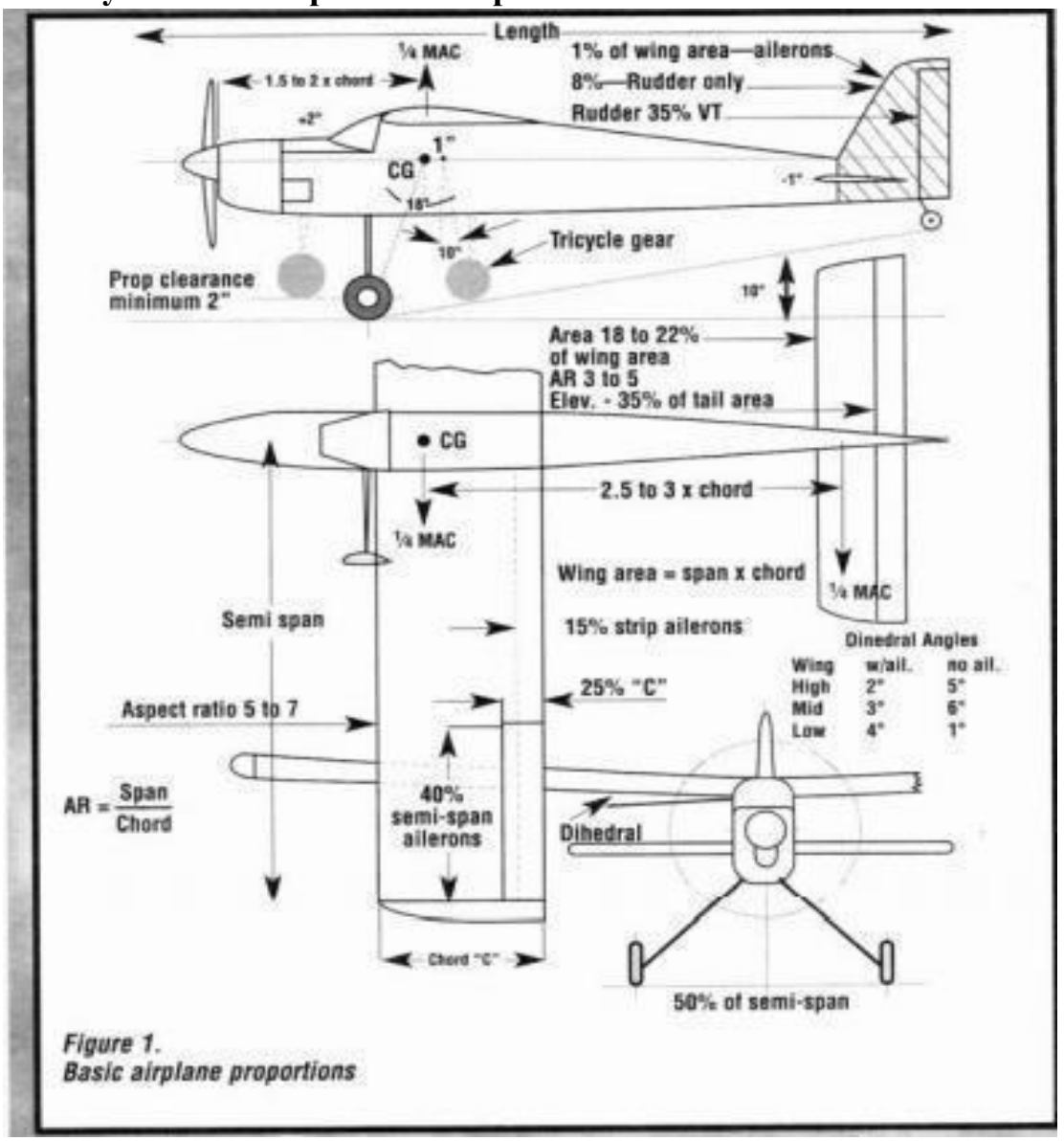



*Figure 20: Basic proportionally for assembly of RC plane (Andy Lenon)*

It's very important that the weights of components are placed well, the CG is maintained through-out the flight and the moment across the CG in cruise condition is zero

# 11. Drones

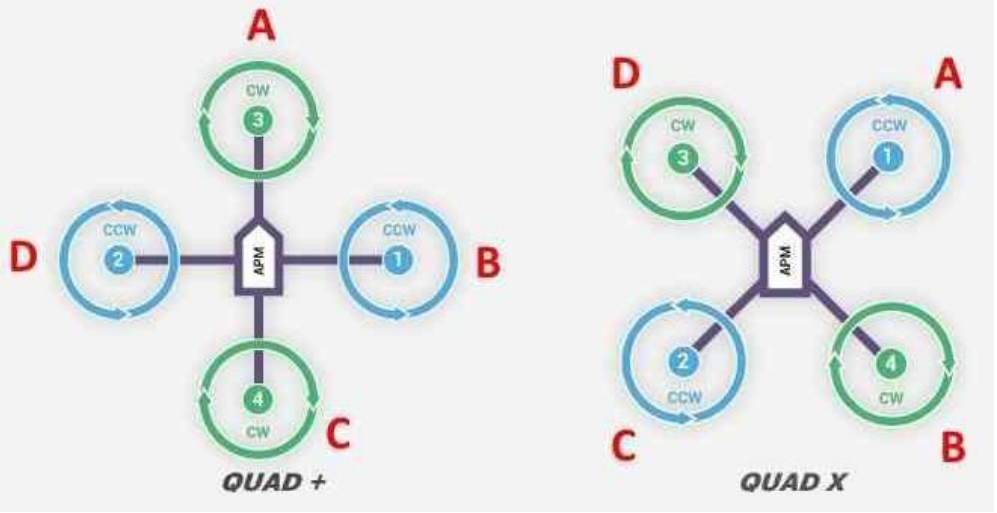
### 11.1.1 Types of drones based on the number of Propellers

A number of propellers are provided to drones. More propellers improve the stability of drones and load-carrying capacity but such drones need more battery power to drive more motors to get high power. A quadcopter is a more popular drone.

- Bicopter
- Tricopter
- Quadcopter
- Hexacopter
- Octacopter

### 11.1.2 Working Principle of Quadcopter

A quadcopter has four propellers at four corners of the frame. For each propeller, speed and direction of rotation are independently controlled for balance and movement of the drone. In a traditional quadrotor, all four rotors are placed at an equal distance from each other. To maintain the balance of the system, one pair of rotors rotates in a clockwise direction and the other pair rotates in an anti-clockwise direction. To move up (hover), all rotors should run at high speed. By changing the speed of rotors, the drone can be moved forward, backward, and side-to-side.




## 11.2 Forces and Moments Acting on a Drone

When a drone moves in the air, various forces act on it. The resultant force will decide its movement. There are major forces acting on a drone

- **Weight**
- Due to the mass of the drone, the body mass force always acts in the direction of gravity
- Higher the weight of the drone, more power is required to lift and move the drone
- Weight of drone = mass of drone × acceleration due to gravity

- **Lift**:
- The vertical force acting on the drone is called lift
- This force is due to pressure differences across the drone (in the vertical direction). Hence, the speed, size, and shape of the propeller blade decide the amount of lift force
- Lift is essential to lift the body against the gravity
- To create this force, all four propellers run at high speed to lift the drone
- **Thrust**
- The force acting on the drone in the direction of motion is called thrust. However, for drone dynamics, it is normal to the rotor plane.
- During hovering, the thrust is purely vertical. If thrust is inclined then the drone will tilt forward or backward.
- This force is essential to move the drone in the desired direction at equal speed
- To get desired motion, two propellers have been given high speed
- **Drag**
- The force acting on the drone in the opposite direction of motion due to air resistance is called drag
- This may be because of pressure difference and viscosity of air
- To reduce the drag, the aerodynamic shape of the drone is selected.

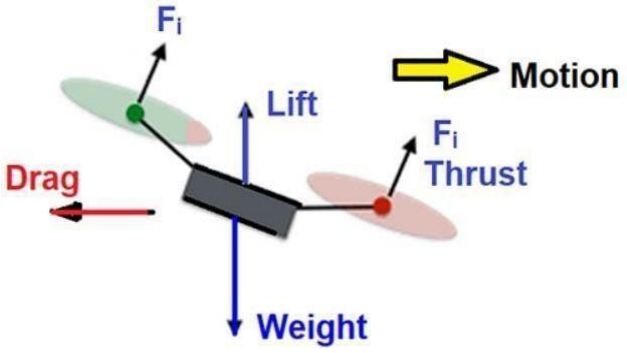



*Figure 21:forces acting on drone*

## 11.3 Quadcopter Dynamics

- The movement of drone are classified into four types based on the relation motion between four propellers: 1) throttle, 2) Pitch, 3) Roll, and 4) Yaw
- The details of quadcopter dynamics are explained in many references

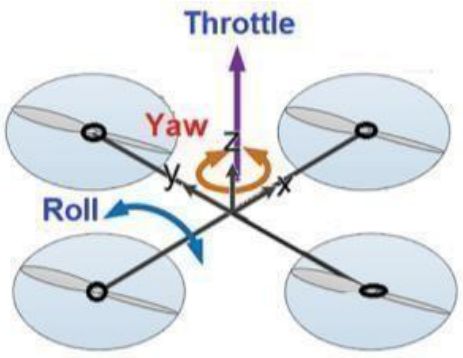


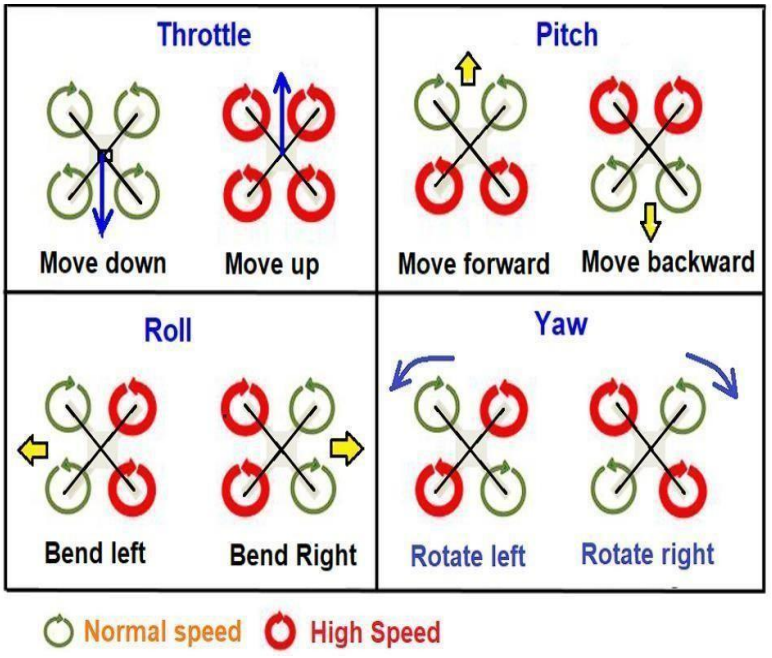

*Figure 22: drone dynamics*

- **Throttle/Hover**: Up and down movement of the drone is called throttle
- If all four propellers run at normal speed, then the drone will move down
- If all four propellers run at a higher speed, then the drone will move up. This is called the hovering of a drone

- **Pitch:** Movement of a drone about a lateral axis (either forward or backward) is called pitching motion
- If two rear propellers run at high speed, then the drone will move in a forwarding direction
- If two front propellers run at high speed, then the drone will move in the backward direction

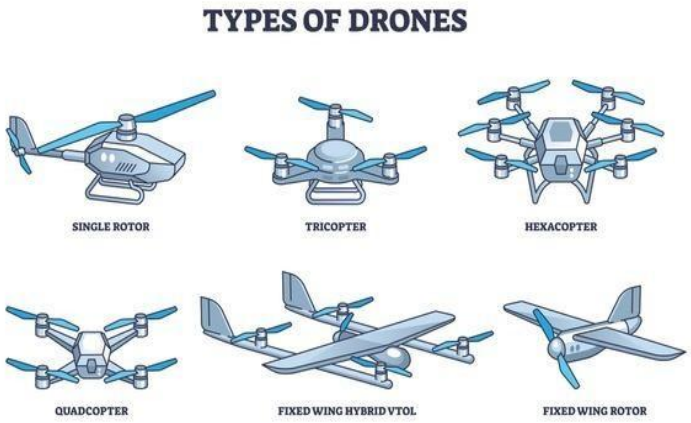
- **Roll:** Movement of a drone about the longitudinal axis is called rolling motion
- If two right propellers run at high speed, then the drone will move in the left direction
- If two left propellers run at high speed, then the drone will move in the right direction

- **Yaw:** The rotation of the head of the drone about the vertical axis (either the left or right) is called Yawing motion
- If two propellers of a right diagonal run at high speed, then the drone will rotate in an anti-clockwise direction
- If two propellers of a left diagonal run at high speed, then the drone will rotate in a clockwise direction.



## 11.4. Drone Frame Structure

- The frame is the primary load-bearing structure of the drone.
- Common materials: PLA/ABS (for prototyping).
- Goals of the frame:
- High stiffness
- Low weight
- Vibration resistance
- Ability to carry payloads safely




**Different parts of Drone:**

**a) Motor Mounts**

- Securely hold the motor in position.
- Designed to resist vibration and bending.
- Must maintain proper alignment for smooth propeller rotation.



**b) Propeller Guards**

- Protect the propellers and surroundings from accidental hits.
- Should be lightweight and removable.
- Designed to deform without breaking under small impacts.



**c) Landing Gear**

- Provides safe landing and protects electronics.
- Types: Retractable, Foam-based.
- Must absorb impact and prevent tipping.



**d) Central Hub**

- Central load-bearing structure
- Holds arms and motors in alignment
- Houses electronics safely
- Reduces vibration to sensors
- Absorbs minor crash impacts
- Provides battery/payload mounting point



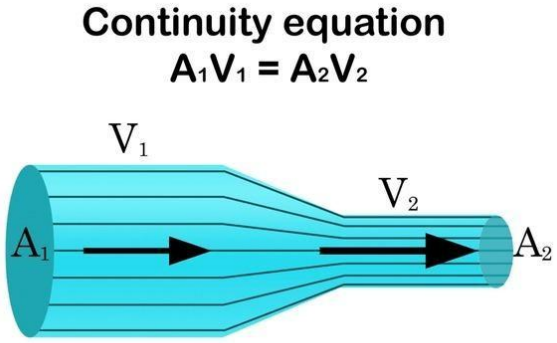
## 11.5 Basic Mechanical Design Considerations

- Weight Distribution: Balanced for stable flight.
- Ease of Assembly: Modular parts preferred.
- Maintenance Accessibility: Components should be quick to replace.
- Structural Integrity: Withstand crashes and vibrations.
- Payload Mounting: Must be strong, vibration-free, and centered.

## 11.6 Pressure & Fluid Flow Basics

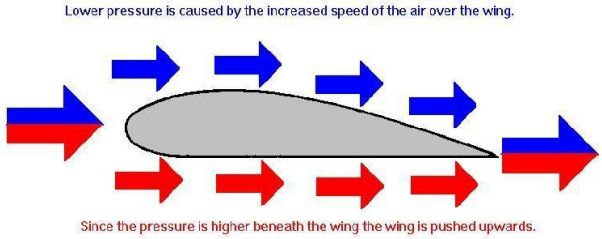
### 11.6.1Continuity Equation

The continuity equation explains that when air flows through a smaller area, its speed increases. This relationship ensures mass conservation in airflow. It helps explain why air accelerates over curved wing surfaces. Faster airflow reduces pressure as per Bernoulli's principle. Together, these concepts explain lift generation.



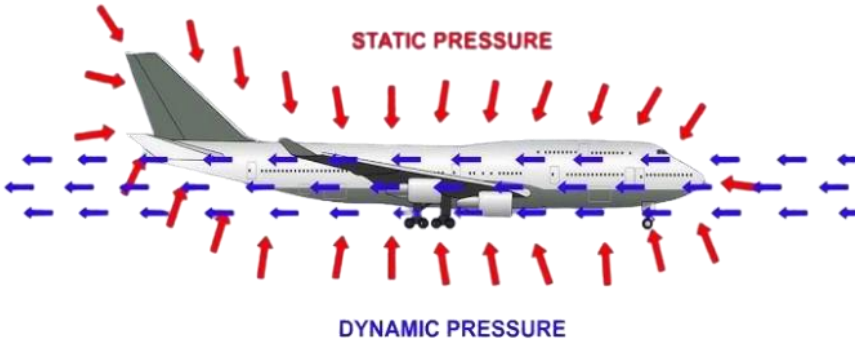
### 11.6.2 Pressure Difference Creating Lift

Lift is created because air pressure above the wing is lower than below it. Wing shape and angle of attack help control this pressure difference. A stronger pressure difference means more lift generated. If angle of attack becomes too high, the flow separates and lift decreases. Managing this difference is key to stable flight.




### 11.6.3 Static & Dynamic Pressure

Static pressure is the pressure of still air, while dynamic pressure increases with airspeed. An aircraft's sensors use both pressures to determine airspeed accurately. Total pressure is the sum of static and dynamic pressure. Understanding these helps in airspeed measurement systems. Dynamic pressure also affects lift and drag forces.




## 11.7 Materials and manufacturing methods

### 11.7.1 Common Materials Used in Drones



PLA/ABS

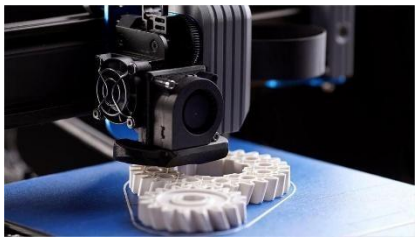


Carbon Fiber



Brich Ply

### 11.7.2 Manufacturing Processes Used in Drones



3D Printing



Laser Cutting

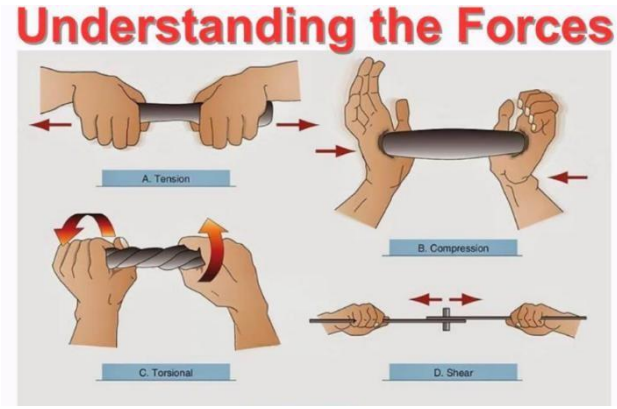


CNC Routing

## 11.8 Basic Mechanical Terms

### 11.8.1 Stress

Stress is the internal force per unit area in a material when a load is applied. Different parts of a UAV experience tension, compression, torsion, and bending stresses. Excessive stress may cause failure or deformation. Engineers calculate stress to ensure components are strong enough. It is a key concept in structural design.




### 11.8.2 Strain

Strain is the measure of deformation caused by stress. It expresses how much a material stretches or compresses relative to its original length. Strain helps determine whether materials behave elastically or plastically. Too much strain can lead to permanent damage. Designers choose materials with safe strain limits.

### 11.8.3 Elastic vs Plastic Deformation

Elastic deformation is temporary—materials return to their original shape after the load is removed. Plastic deformation is permanent, occurring when stress exceeds a material's elastic limit. Understanding this helps prevent structural failures in UAVs. Designers ensure parts operate within the elastic region. This improves durability and safety.

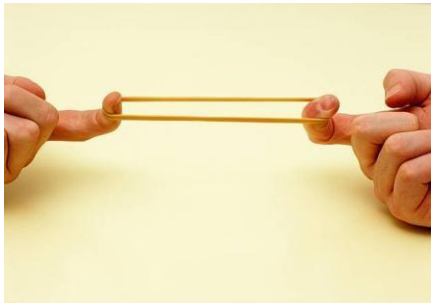


*Fig :Rubber in Tension( Elastic)*



*Fig :Deformation (Plastic)*

### 11.8.4 Factor of Safety (FoS)

Factor of Safety is extra strength included in a design beyond the expected maximum load. It compensates for uncertainties like manufacturing defects or unexpected forces. Higher FoS increases reliability but may add weight. Engineers choose appropriate FoS depending on the component's importance. It ensures the UAV remains safe and functional.

| Modulus | What it measures | Basic relation | Formulas |
|---|---|---|---|
| Young's modulus (E) | Resistance to change in length | Longitudinal stress / Longitudinal strain | $E = \frac{\sigma}{\varepsilon}$ |
| Bulk modulus (K) | Resistance to change in volume | Pressure change / Volumetric strain | $K = \frac{-\Delta p}{\Delta V/V}$ |
| Modulus of rigidity (G) | Resistance to change in shape due to shear | Shear stress / Shear strain | $G = \frac{F \times l}{A \times \Delta x}$ |

## 11.9 Avionics in Drone

### 11.9.1 Thrust Force and Kv Value

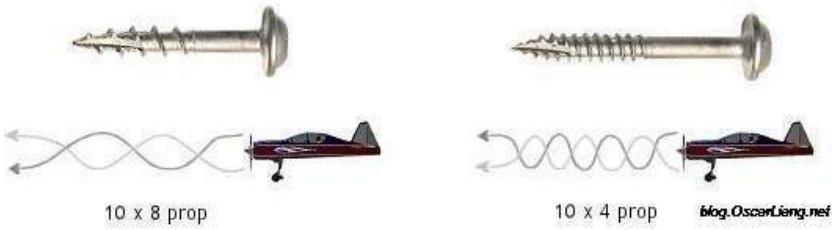
A "Kv" value, is the no-load rotational velocity of a motor per 1 V of input. Kv values are reported in units of [RPM/V]. For example, an unloaded motor with a Kv value of 2300 would spin at 2300 RPM if we applied 1 V to it.

On one hand, this gives us an idea of how "powerful" a motor is and how fast it can spin: A "large" Kv value will spin *really* fast but will do so without much torque behind it. On the other hand, a "small" Kv value will spin pretty slow, but will do so with a lot of torque.

### 11.9.2 Propeller

A propeller "size" is reported as either a 4-digit number or as a **diameter** × **pitch** value. The 4digit method is simply a shortened form of the second. For example:
6045 = 6.0 in. x 4.5 in. 3020 = 3.0 in. x 2.0 in.

Again, the first number is the diameter (measured from tip to tip) and the second is the pitch. Almost always, these numbers are in inches. The **pitch** is how much the propeller translates in one rotation. The following images illustrates this:




Both propellers shown have a diameter of 10 inches but different pitches (on the left: 8 inches; on the right: 4 inches). In general, the larger the pitch, the greater the thrust force: the propeller "pulls" or "cuts through" more air per single rotation. However, a larger pitch also requires more power and is less stable. A smaller pitch can spin faster and is generally more stable, but produces less thrust force. Larger diameters increase the thrust force but take more time to change speed.

Oftentimes, motors and propellers are designated as being CW or CCW. For multi-rotors this is an important distinction because if the thrust force is in the wrong direction, the force direction is changeable.

### 11.9.3 BLDC MOTORS

As the name suggests brushes are absent and hence in this case, commutation is implemented electronically with a drive amplifier that uses semiconductor switches to change current in the windings based on rotor position feedback.



Advantage of Permanent Magnet Brushless DC Motor

- Better speed versus torque characteristics
- Faster dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

In addition, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors.

The BLDC motors consist of 3 main components: Stator, Rotor and Hall Effect Sensor.

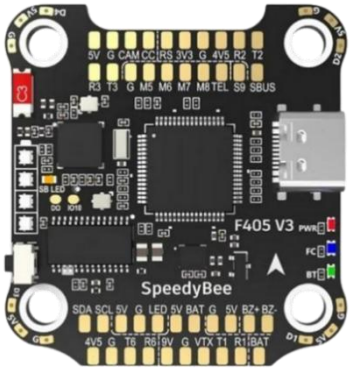
**Stator:**
Stationary part with windings placed in slots around the inner periphery to create magnetic poles.

**Rotor:**
Rotating part made of permanent magnets with alternating N and S poles.

**Hall Sensors:**
Sensors that detect rotor position to enable proper electronic commutation.



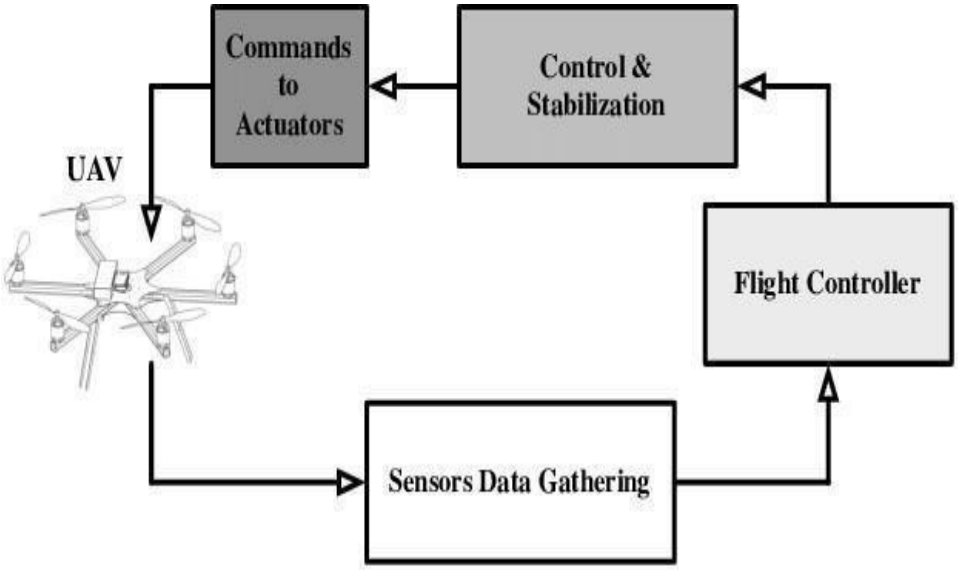

## 11.10 Flight Controller




The flight controller (FC) is the brain of the aircraft. It's a circuit board with a range of sensors that detect movement of the drone, as well as user commands. Using this data, it then controls the speed of the motors to make the craft move as instructed. Nearly all flight controllers have basic sensors such as Gyroscopes and Accelerometer. Some FC include more advanced sensors such as Barometer (barometric pressure sensors) and magnetometer (compass).

Its function is to direct the RPM of each motor in response to input. A command from the pilot for the multi-rotor to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.

The control of an aircraft requires a mathematical model that consider all flight characteristics associated with the motions of the aircraft. Analysis of the aircraft requires the study of phenomena such as lift, thrust, air resistance, wind and even the surfaces of the aircraft.



## 11.11 Computer Vision

Computer vision enables drones and multirotor to interpret their surroundings using onboard cameras and AI algorithms. It is used for tasks such as **object detection**, **person tracking**, **landing-pad detection**, **obstacle avoidance**, and **terrain following**. By converting raw images into meaningful information, infrastructure with high precision, perform surveillance, and autonomously recognize mission-critical targets. This makes drones far more intelligent than basic remote-controlled aircraft.

## 11.12 Autonomous Systems

Autonomous systems give drones the ability to execute complex missions with minimal human input. Using onboard sensors (GPS, IMU, LiDAR, cameras), path-planning algorithms, flight controllers, and safety logic, autonomous drones can **navigate**, **hover**, **avoid obstacles**, **follow waypoints**, **return-to-home**, and **perform automated delivery or monitoring missions**

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## 11.13 Simulations

Simulation allows engineers to test drone behaviour, control algorithms, computer vision models, and autonomous navigation in a safe virtual environment before deploying on real hardware. We can also simulate physics, sensors, weather, GPS drift, and environments, letting developers evaluate flight stability, tuning parameters, and mission planning without risking crashes

## 11.14 Electronics

**Resistors:**

These devices are used to limit the current in the circuit and also provide a sufficient voltage across them. They oppose current according to Ohm's law, where the voltage across a resistor is proportional to the current through it. Mathematically expressed as, V=IR.

**Capacitors**:

These acts as a storage tank in the circuits. These store energy in form of voltage for a short period of time, therefore stabilizing that voltage across any component.

**Diodes:**

A silicon diode in forward bias typically drops about 0.6–0.7 V. And if positioned to be in reverse bias the circuit is open. Therefore, it acts as a protection device in the circuits.

**Transistors (BJT/ MOSFETs):**

Transistors are semiconductor devices that function as controllable switches and are responsible for most control actions within electronic circuits and integrated circuits. They operate in three primary regions: cut-off, linear (active), and saturation, with the operating region determined by the voltages and currents applied to their three terminals. By appropriately biasing these terminals, the transistor can be driven between non-conducting and fully conducting states, or maintained in its active region, where it typically achieves its most useful and efficient performance.

## 11.15 Propulsion

The most basic formula used while selecting the propulsion system is Thrust-to-Weight ratio (T/W). For multirotor, we usually consider 2:1 and for planes it is in the range of 0.5 to 0.7.

## 11.16 Communication

Communication is the link that connects a drone to its pilot and the ground station. The transmitter sends information as a radio frequency signal, which is received by the receiver on the drone. The receiver converts it into electrical control signal and passes it to the flight controller, which directs the RPM of each motor accordingly. Telemetry is the reverse link, where the drone sends live telemetry data such as GPS position, orientation, altitude and speed back to the ground station. The ground station displays this data, along with mission status, so the operator can monitor the drone in real time and send commands or waypoints during autonomous missions. The range of this link depends on the frequency, transmitter power and antenna.

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## 12.References

Playlist Fundamentals of Aerodynamics

NPTEL course - youtube playlist

NPTEL course link

ANDY LENON

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*We hope you went through the whole document, and in case of doubts/queries feel free to contact us. Team aeroKLE is having great upcoming plans including Product Development and National/International Competitions. The team is also focused on Research and Development and are looking forward to publishing National/International level research papers on the fields of Unmanned Aerial Vehicles (UAVs), Machine Learning, Complete automation of flights, and many more. The team is aiming to work on many exciting projects using advanced technology such as Artificial Intelligence and the Internet of Things (IoT).*

***Looking forward to welcoming you to the team, HAPPY LEARNING!!***