Chapter 1

Introduction

1.1 MIST EAGLE EYE :

The UAV is an acronym for Unmanned Aerial Vehicle, which is an aircraft with no pilot on board. UAVs can be controlled aircraft flown by a pilot at a ground station .Recent advancement in communications, solid-state devices and battery technology have made small, low cost fixed wing UAVs which can provide important information for low-altitude and high resolution applications such as scientific data gathering, surveillance for law enforcement and homeland security, precision agriculture, forest fire monitoring, geological survey and many more scientific and commercial applications. Among these purposes, the purpose of this project is mainly reconnaissance.

An unmanned Aerial Vehicle (UAV) using NACA-4415 profile is a balanced design, possessing good demonstrated flight handling qualities, practical and affordable in manufacturing requirement while providing a high vehicle performance. The aerodynamic characteristics of the UAVs have many similarities than that of the monoplane configuration. Due to the UAV's potential for carrying out many tasks together without direct risk to the crew or humans in general, they are ideal for testing new concepts to analyze the further increase of the vehicle's capability.

To perform various tasks more efficiently, UAVs require higher lifting force with a smaller size. As such, the concept of development of all lifting vehicle technology would bring good result for research on designing future UAV. The fuselage of UAV might be a good source of lifting force. Hence, this paper will investigate and analyze the structural design and flight test of UAV having aero foil shaped fuselage, named **MIST EAGLE EYE**.

1.2 Background of the research work :

To build and fly a UAV using NACA 4415 with aerofoil shaped fuselage has not been performed practically in the field of UAVs. Such research should be done for the development of this sector so that various operations including reconnaissance can be accomplished with more accuracy and efficiency. The theoretical research has been made by our supervisor. So, our target was to focus on the practical construction of UAV and the test flight through which the comparison between theoretical and practical work can be done.

The design of an aircraft draws on a number of basic areas of aerospace engineering. These include aerodynamics, propulsion, light-weight structures and control. Each of these areas involves parameters that govern the size, weight and performance of an aircraft. Our main design criteria as instructed by our supervisor, was to design a UAV having aerofoil shaped fuselage. We used NACA 4415 aerofoil for our design. In this paper we have focused on structure and design analysis and flight test.

1.3 Objectives:

- To design and manufacture a UAV having an aerofoil (NC 4415) shaped fuselage.
- To utilize the advantages of extra lift due to aerofoil shaped fuselage during flight operation.
- To study and analyze the corresponding aerodynamic effects during flight test.
- To ensure smooth take-off, stable flight and safe landing.
- To keep the weight of the UAV as low as possible and not more than 1200 gm.
- To keep the manufacturing cost as low as possible.
- To incorporate aerofoil shaped horizontal stabilizer in addition to aerofoil shaped fuselage.
- To build a UAV capable of reconnaissance mission.
- To install surveillance or spy camera on the body of UAV.

1.4 Outline of This Projects

Goal setting

⇩

Market Analysis

⇩

Theoretical design

⇩

Construction of main body

⇩

Electrical equipment and control system

⇩

First flight test and analysis

⇩

Second flight test with design corrections and analysis

⇩

Third flight test with spy camera

Chapter -2

Literature review

2.1 A Brief History of UAVs:

Using bats to carry incendiary bombs into enemy territory wasn't a good idea, and it wasn't the first bad idea in the history of unmanned aerial vehicles (UAVs). During the American Civil War, an inventor patented an unmanned balloon that carried explosives that could be dropped after a time-delay fuse mechanism triggered the basket to overturn its contents. Air currents and weather patterns made it difficult to estimate for how long to set the fuse, and the balloon was never successfully deployed.

By 1883, the first aerial photograph was taken using a kite, a camera and a very long string attached to the shutter-release of the camera. In 1898, this technology was put to use in the Spanish-American War, resulting in the first military aerial reconnaissance photos.

World War I saw the development and testing of various radio-controlled unmanned aircraft, but none emerged from the testing phase in time to be used before the war ended.

In the 1930s, the British Royal Navy developed a primitive, radio-controlled UAV: the **Queen Bee**. The Queen Bee could be landed for future reuse and could reach speeds of 100 mph (160 km/h). Instead of being used offensively though, the Queen Bee primarily served as aerial target practice for British pilots.

During World War II, Nazis developed a UAV to be used against nonmilitary targets. The **Revenge Weapon 1**, an unmanned flying bomb better known as the V-1, could reach speeds of almost 500 mph (804 km/h), carry 2,000 pounds (907 kilograms) of explosives and could travel 150 miles (241 kilometers) before releasing its ordnance. Its wingspan was about 20 feet (6 m), and it measured nearly 25 feet (7.6 m) long. In towns and cities across Britain, the V-1 was responsible for more than 900 civilian deaths and 35,000 injured civilians.

In the 1960s and 70s, the United States flew more than 34,000 surveillance flights using the **AQM-34 Ryan Firebee**, a UAV launched from a host plane and controlled by operators within that plane. The U.S. also employed UAVs called Lightning Bugs that were released from airborne C-130s for missions over China and Vietnam. Engineers from the manufacturer operated the aircraft with a joystick control.

In the late 1970s and 80s, Israel developed the **Scout** and the **Pioneer**, which represented a shift toward the lighter, glider-type model of UAV in use today. The Scout was notable for its ability to transmit live video with a 360-degree view of the terrain. The small size of these UAVs made them inexpensive to produce and difficult to shoot down.

The U.S. acquired Pioneer UAVs from Israel and used them in the Gulf War. On at least one occasion, Iraqi soldiers attempted to surrender to one of the UAVs as it flew overhead.

Although UAV technology saw sporadic development throughout the 20th century, it wasn't until the Predator drone arrived on the scene that unmanned aerial vehicles earned a permanent place in the arsenal. To understand the Reaper, it'll help us to know a little about its direct predecessor, the MQ-1 Predator. We'll read about this landmark UAV next.

2.2 Aerodynamics:

Aerodynamics is the way air moves around things. The rules of aerodynamics explain how an airplane is able to fly. Anything that moves through air reacts to aerodynamics. A rocket blasting off the launch pad and a kite in the sky react to aerodynamics. Aerodynamics even acts on cars, since air flows around cars.

2.3 Four Forces of Flight:

The four forces of flight are lift, weight, thrust and drag. These forces make an object move up and down, and faster or slower. How much of each force there is changes how the object moves through the air.

2.4 Weight:

Everything on Earth has weight. This force comes from gravity pulling down on objects. To fly, an aircraft needs something to push it in the opposite direction from gravity. The weight of an object controls how strong the push has to be. A kite needs a lot less upward push than a jumbo jet does.

2.5 Lift:

Lift is the push that lets something move up. It is the force that is the opposite of weight. Everything that flies must have lift. For an aircraft to move upward, it must have more lift than weight. A hot air balloon has lift because the hot air inside is lighter than the air around it. Hot air rises and carries the balloon with it. A helicopter's lift comes from the rotor blades at the top of the helicopter. Their motion through the air moves the helicopter upward. Lift for an airplane comes from its wings.

2.6 Drag:

Drag is a force that tries to slow something down. It makes it hard for an object to move. It is harder to walk or run through water than through air. That is because water causes more drag than air. The shape of an object also changes the amount of drag. Most round surfaces have less drag than flat ones. Narrow surfaces usually have less drag than wide ones. The more air that hits a surface, the more drag it makes.

2.7 Thrust:

Thrust is the force that is the opposite of drag. Thrust is the push that moves something forward. For an aircraft to keep moving forward, it must have more thrust than drag. A small airplane might get its thrust from a propeller. A larger airplane might get its thrust from jet engines. A glider does not have thrust. It can only fly until the drag causes it to slow down and land.

Lift and weight are two of the four forces acting on an airplane; the other two are drag and thrust

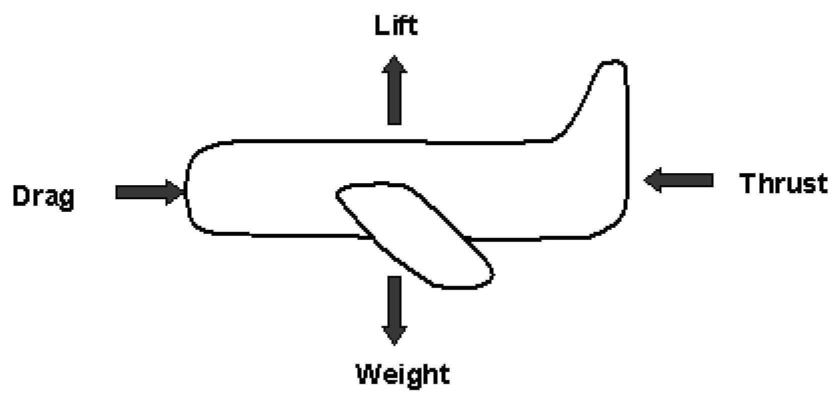


Figure 2.1: Forces acting on an aircraft

2.8 Aerofoil:

An airplane wing has a special shape called an aerofoil. As a wing moves through air, the air is split and passes above and below the wing. The wing's upper surface is shaped so the air rushing over the top speeds up and stretches out. This decreases the air pressure above the wing. The air flowing below the wing moves in a straighter line, so its speed and air pressure remains the same.

2.9 Geometry of Aerofoil:

The airplane generates lift using its wings. The cross-sectional shape of the wing is called an airfoil. A typical airfoil and its properties are shown in Figure , and are also described below.

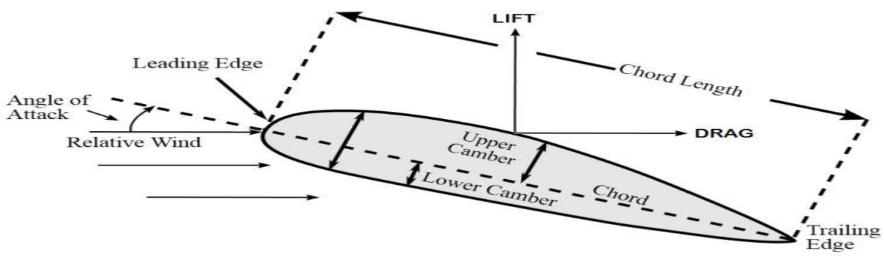


Figure2.2: Typical Aerofoil (Cross-Sectional Shape) of an Airplane Wing

2.10 Expiation of How It Works (Lift is Produced):

The wings provide lift by creating a situation where the pressure above the wing is lower than the pressure below the wing. Since the pressure below the wing is higher than the pressure above the wing, there is a net force upwards.

To create this pressure difference, the surface of the wing must satisfy one or both of the following conditions. The wing surface must be:

1. Cambered (curved); and/or
2. Inclined relative to the airflow direction.

Several airfoils are shown in Figure . However, the airfoils shown in Figure are useless without viscosity.

Viscosity is essential in generating lift. The effects of viscosity lead to the formation of the starting vortex which, in turn is responsible for producing the proper conditions for lift.

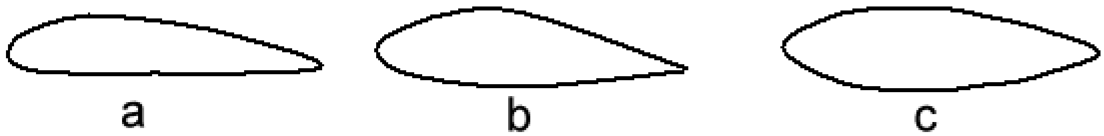


Figure 2.3: A Few Different Aerofoils
Note: There Are An Infinite Number of Possibilities; i.e. a) Flat Bottom; b) Slightly Curved Bottom; c) Symmetrical

2.11 How Lift is Generated by an Aircraft?

- Whether the speed of the wings itself in the air mass, or the movement of the air mass relative to the wings. the wings have a relative speed to the air mass.
- The air strikes against the inclined wing and speeds up over the wing. This movement of air (upwards and over the wing), is called up wash.
- Up wash restricts the random movement of air, causing the molecules to flow in a relatively streamlined manner and, thus speeding it up.
- As explained earlier, high speed motion of air causes its static pressure over the airplane wing to decrease.
- This creates an area of low pressure over the airplane wings and a relatively higher pressure under them.
- This pressure differential exerts an aerodynamic force on the wing which basically has two components; lift and drag.
- The lift component acts perpendicular to the direction of the airflow.
- Drag is parallel to the airflow.

Various airfoil shapes and designs have been researched, each having a different effect. The most efficient for the production of lift by airplane wings is called a "well-cambered airfoil," having a curvature near the leading edge on the upper surface of the wing.

2.12 Aerofoil Characteristics:

Lift, drag, stall and angle of attack are important concept to understand of an aerofoil characteristics.

2.13 Lift vs. Angle of Attack:

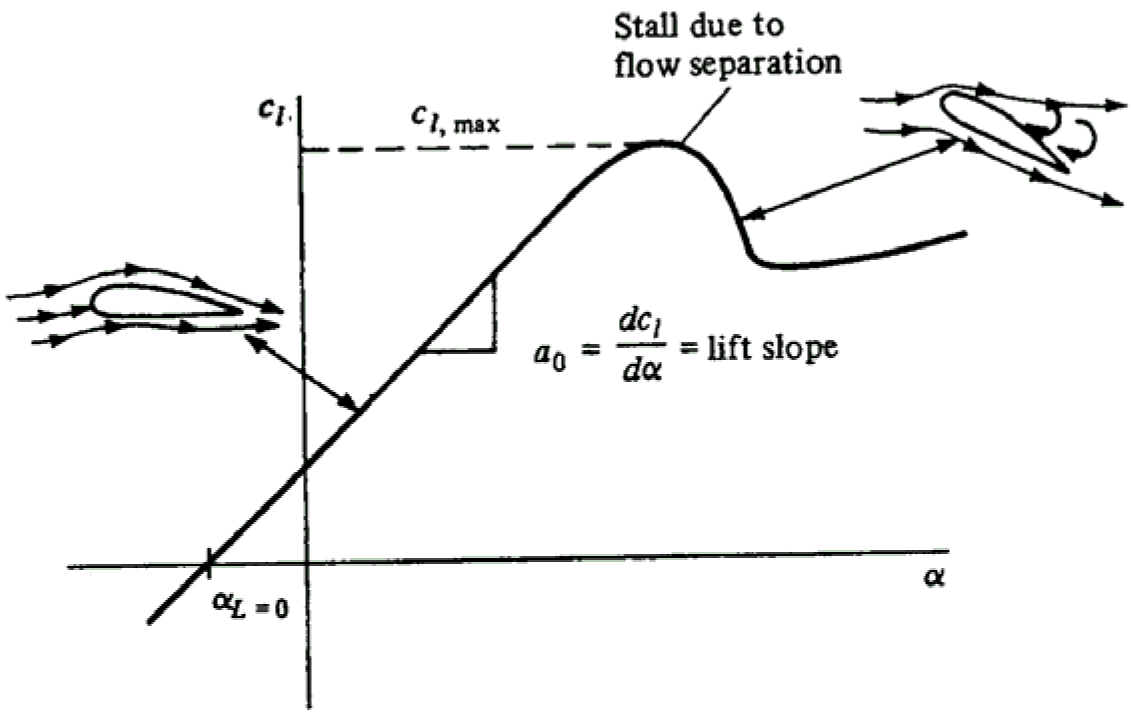


Figure 2.4: Lift vs. angle of attack

As a wing moves through the air, the wing is inclined to the flight direction at some angle. The angle between the line and the flight direction is called the angle of attack and has a large effect on the lift generated by a wing. When an airplane takes off, the pilot applies as much thrust as possible to make the airplane roll along the runway. But just before lifting off, the pilot "rotates" the aircraft. The nose of the airplane rises, increasing the angle of attack and producing the increased lift needed for takeoff.

2.14 Drag vs. Angle of Attack:

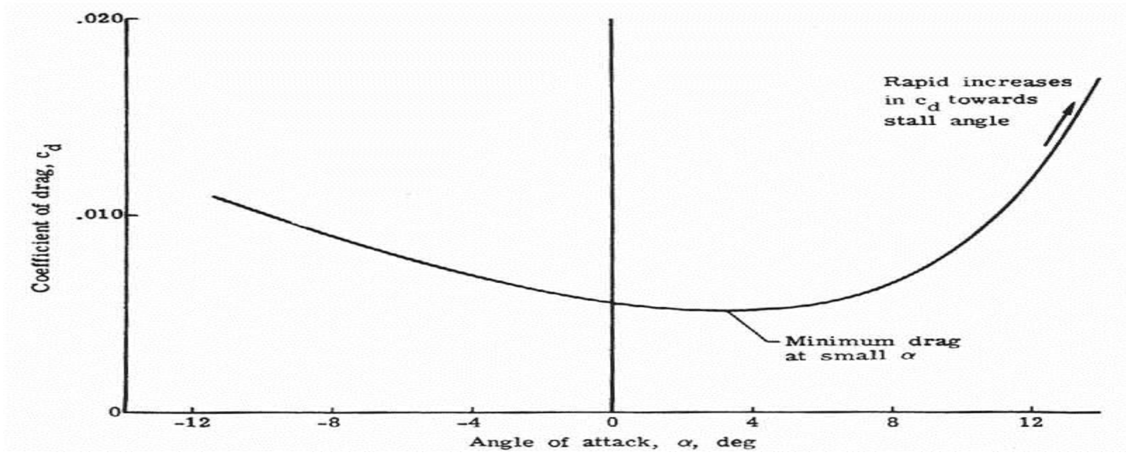


Figure 2.5: Drag vs. angle of attack

As a wing moves through the air, the airfoil is inclined to the flight direction at an angle. The angle between the line and the flight direction is called the angle of attack and has a large effect on the drag generated by the wing.

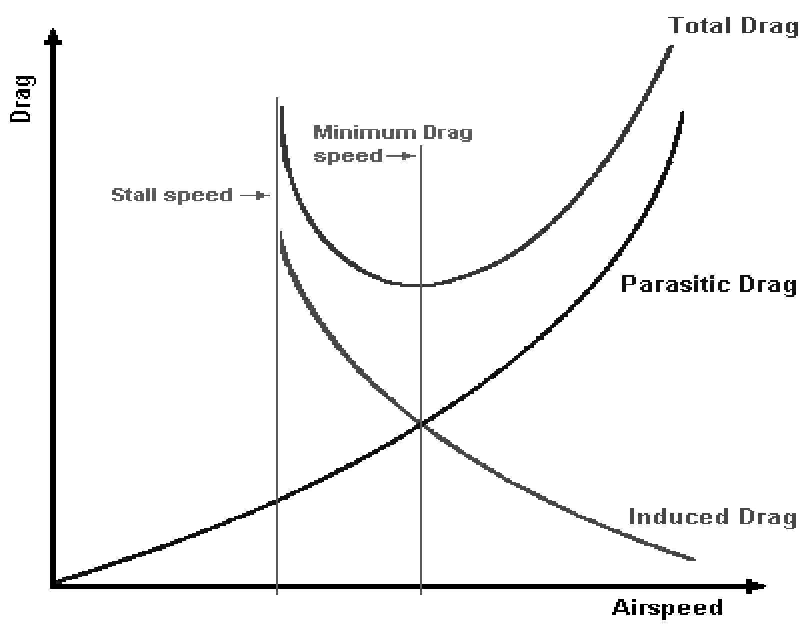


Figure 2.6: Drag vs. Airspeed

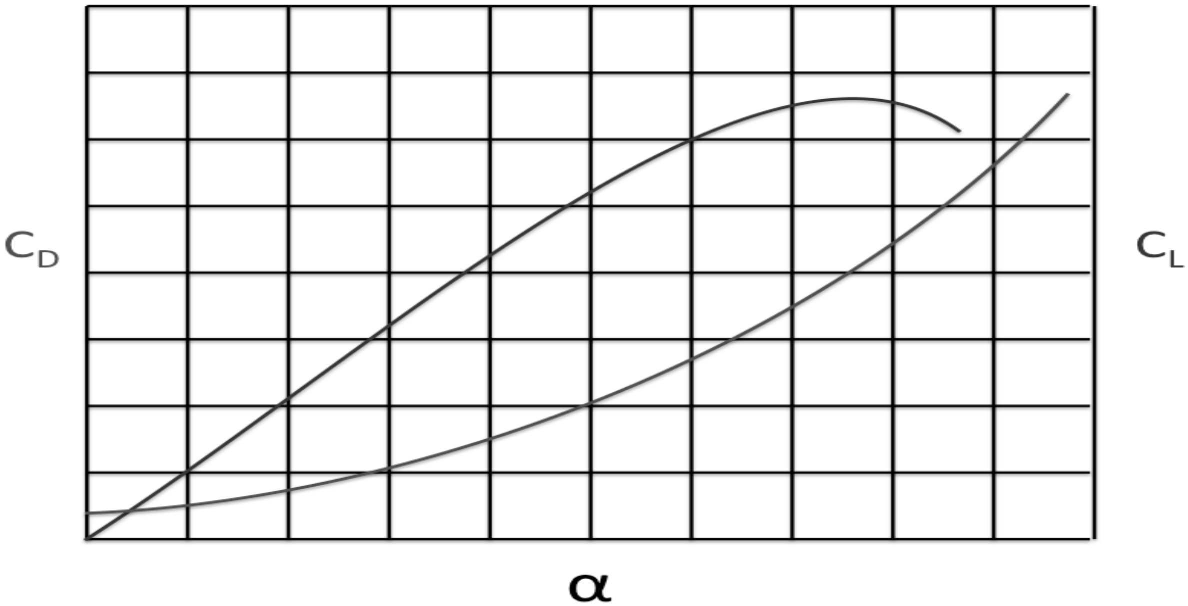


Figure 2.7: Change of Drag co-efficient and lift co-efficient with angle of attack.

2.15 Stall:

A stall is a condition in aerodynamics and aviation where the attack increases beyond a certain point such that the lift begins to decrease. The angle at which this occurs is called the critical angle of attack. This critical angle is dependent upon the profile of the wing, its plan form, its aspect ratio, and other factors, but is typically in the range of 8 to 20 degrees relative to the incoming wind for most subsonic airfoils. The critical angle of attack is the angle of attack on the lift versus angle-of-attack curve at which the maximum lift coefficient occurs.

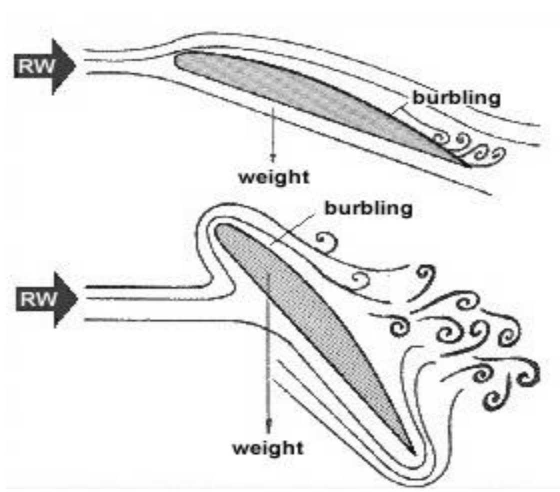


Figure 2.8: Aerofoil approaching and entering a stall

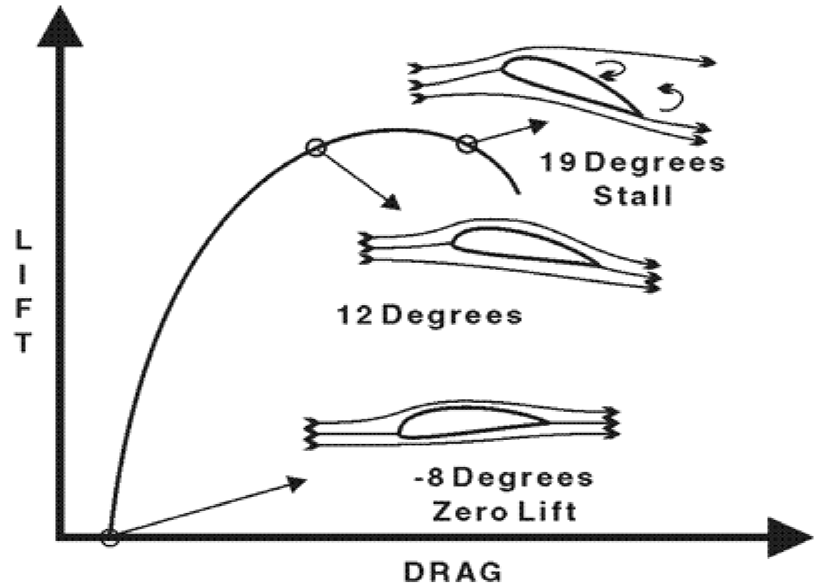


Figure 2.9: Lift vs. Drag

2.16 Centre of Gravity:

An airplane in flight can be maneuvered by the pilot using the aerodynamic control surfaces; the elevator, rudder, or ailerons. As the control surfaces change the amount of force that each surface generates, the aircraft rotates about a point called the center. The center of gravity is the average location of the weight of the aircraft. The weight is actually distributed throughout the airplane, and for some problems it is important to know the distribution. But for total aircraft maneuvering, we need to be concerned with only the total weight and the location of the center of gravity.

An airplane is a combination of many parts; the wings, engines, fuselage, and tail, plus the payload and the fuel. Each part has a weight associated with it which the engineer can estimate, or calculate, using Newton's weight equation:

$$w = m * g$$

Where w is the weight, m is the mass, and g is the gravitational constant .The total weight of the aircraft is simply the sum of all the individual weights of the components. Since the center of gravity is an average location of the weight, we can say that the weight of the entire aircraft W times the location cg of the center of gravity is equal to the sum of the weight w of each component times the distance d of that component from the reference location:

$$W * cg = [w * d] (fuselage) + [w * d] (wing) + [w * d] (engines) +...$$

The center of gravity is the mass-weighted average of the component locations.

2.17 Balancing RC Planes:

Correctly balancing the RC plane is so important for safe flying, because any deviation from the model's Centre of Gravity (CG) can potentially result in the model being quite uncontrollable**.**

Every RC airplane (and all other aircrafts) has a specific CG position, it's the mean point where all gravitational forces act upon the plane and hence the point where the model balances fore-aft correctly. Balancing a radio control plane correctly about its Centre of Gravity is so important because a very badly balanced plane will, at best, be hard to control. At worst, the plane will crash within seconds of getting airborne.

2.18 Basics of an UAV:

Fuselage, wing, horizontal stabilizer, vertical stabilizer are important components of a UAV. The control surface of UAV is aileron, elevator and rudder. It has also electrical parts.

2.19 Basic Parts of RC Plane:

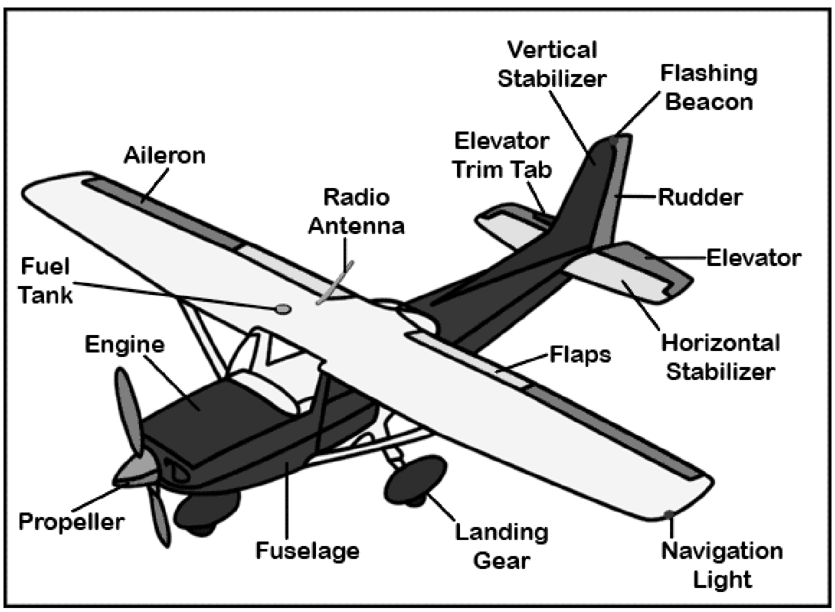


Figure 2.10: Basic parts

2.20 Fuselage:

Airplanes are transportation devices which are designed to move people and cargo from one place to another. Airplanes come in many different shapes and sizes depending on the mission of the aircraft. The airplane shown on this slide is a turbine-powered airliner which has been chosen as a representative aircraft.

The weight of an aircraft is distributed all along the aircraft. The fuselage contributes a significant portion of the weight of an aircraft. The center of gravity of the aircraft is the average location of the weight and it is usually located inside the fuselage. In flight, the aircraft rotates around the center of gravity because of torques generated by the elevator, rudder, and ailerons. The fuselage must be designed with enough strength to withstand this torques.

2.21 Wing:

A wing is a type of fin with a surface that produces aerodynamic force for flight or propulsion through the atmosphere, or through another gaseous or liquid fluid. As such, wings have an airfoil shape, a streamlined cross-sectional shape producing lift.

A wing's aerodynamic quality is expressed as its lift-to-drag ratio. The lift a wing generates at a given speed and attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift.

2.22 Aileron:

Ailerons can be used to generate a rolling motion for an aircraft. Ailerons are small hinged sections on the outboard portion of a wing. Ailerons usually work in opposition: as the right aileron is deflected upward, the left is deflected downward, and vice versa. This slide shows what happens when the pilot deflects the right aileron upwards and the left aileron downwards.

The ailerons work by changing the effective shape of the airfoil of the outer portion of the wing. As described on the shape effects slide, changing the angle of deflection at the rear of an airfoil will change the amount of lift generated by the foil. With greater downward deflection, the lift will increase in the upward direction. Notice on this slide that the aileron on the left wing, as viewed from the rear of the aircraft, is deflected down. The aileron on the right wing is deflected up. Therefore, the lift on the left wing is increased, while the lift on the right wing is decreased. For both wings, the lift force (Fr or Fl) of the wing section through the aileron is applied at the aerodynamic center of the section which is some distance (L) from the aircraft center of gravity.

This creates a torque

$$T = F * L$$

about the center of gravity. If the forces (and distances) are equal there is no net torque on the aircraft. But if the forces are unequal, there is a net torque and the aircraft rotates about its center of gravity.

2.23 <u>Horizontal Stabilizer:</u>

At the rear of the fuselage of most aircraft one finds a horizontal stabilizer and an elevator. The stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The horizontal stabilizer prevents up-and-down, or pitching, motion of the aircraft nose.

2.24 <u>Elevator:</u>

The elevator is the small moving section at the rear of the stabilizer that is attached to the fixed sections by hinges. Because the elevator moves, it varies the amount of force generated by the tail surface and is used to generate and control the pitching motion of the aircraft.

The elevators work by changing the effective shape of the airfoil of the horizontal stabilizer. As described on the shape effects slide, changing the angle of deflection at the rear of an airfoil changes the amount of lift generated by the foil. With greater downward deflection of the trailing edge, lift increases. With greater upward deflection of the trailing edge, lift decreases and can even become negative as shown on this slide. The lift force (F) is applied at center of pressure of the horizontal stabilizer which is some distance (L) from the aircraft center of gravity. This creates a torque

$$T = F * L$$

on the aircraft and the aircraft rotates about its center of gravity. The pilot can use this ability to make the airplane loop. Or, since many aircraft loop naturally, the deflection can be used to trim or balance the aircraft, thus preventing a loop. If the pilot reverses the elevator deflection to down, the aircraft pitches in the opposite direction

2.25 Vertical Stabilizer:

At the rear of the fuselage of most aircraft one finds a vertical stabilizer and a rudder. The stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The vertical stabilizer prevents side-to-side, or yawing, motion of the aircraft nose.

2.26 Rudder:

The rudder is the small moving section at the rear of the stabilizer that is attached to the fixed sections by hinges. Because the rudder moves, it varies the amount of force generated by the tail surface and is used to generate and control the yawing motion of the aircraft. This slide shows what happens when the pilot deflects the rudder, a hinged section at the rear of the vertical stabilizer.

The rudder works by changing the effective shape of the airfoil of the vertical stabilizer. As described on the shape effects slide, changing the angle of deflection at the rear of an airfoil will change the amount of lift generated by the foil. With increased deflection, the lift will increase in the opposite direction. The rudder and vertical stabilizer are mounted so that they will produce forces from side to side, not up and down. The side force (F) is applied through the center of pressure of the vertical stabilizer which is some distance (L) from the aircraft center of gravity. This creates a torque

$$T = F * L$$

On the aircraft and the aircraft rotates about its center of gravity. With greater rudder deflection to the left as viewed from the back of the aircraft, the force increases to the right. If the pilot reverses the rudder deflection to the right, the aircraft will yaw in the opposite direction. We have chosen to base the deflections on a view from the back of the aircraft towards the nose, because that is the direction in which the pilot is looking.

2.27 Aerodynamic Center (AC):

- Both Lift and Drag forces act from AC. It is important for aircraft design.
- AC is the point on airfoil where pitching moment does not vary with AOA.
- AC, unlike centre of pressure (CP), does not move with changes of AOA. AC is at quarter chord point.

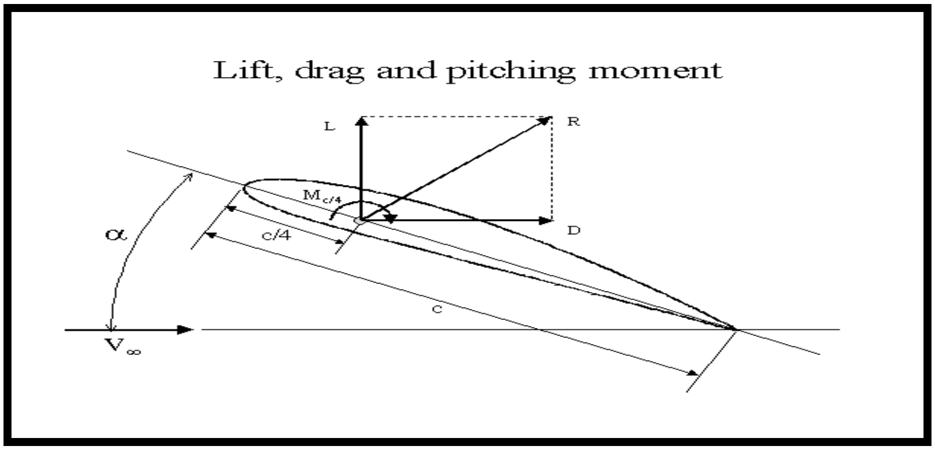


Figure 2.11: Aerodynamic center

2.28 NACA 4415:

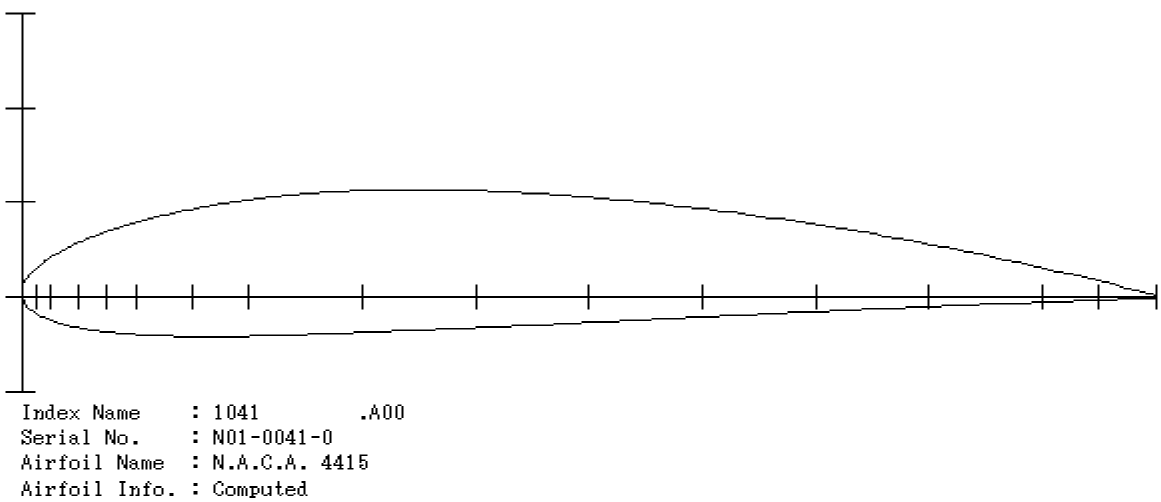


Figure 2.12: NACA 4415 profile

NACA 4415 airfoil
Max thickness 15% at 30.9% chord.
Max camber 4% at 40.2% chord

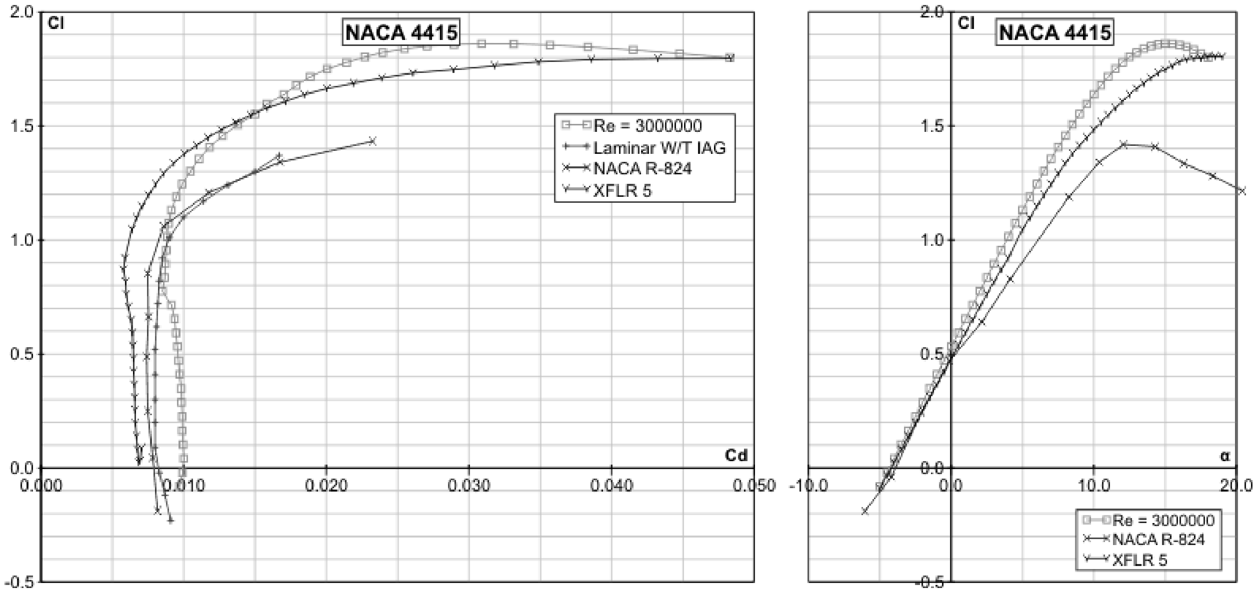
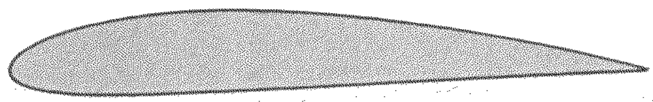


Figure 2.13: lift co-efficient vs. Drag co-efficient and Lift co-efficient vs. angle of attack for NACA 4415

Table 1. NACA 4415 Aerodynamic Parameters Summary

CASE	Re num	C_{lmax}	dC_l/d□□	C_{mo}
Clean	$1.0x10^6$	1.47	0.097	-0.097
Clean	$1.5x10^6$	1.45	0.092	-0.096
Clean	$2.0x10^6$	1.47	0.094	-0.096
k/c=0.0019	$1.0x10^6$	1.14	0.088	-0.083
k/c=0.0019	$1.5x10^6$	1.21	0.091	-0.081
k/c=0.0019	$2.0x10^6$	1.21	0.095	-0.081
Clean VG's	$1.0x10^6$	1.83	0.105	-0.095
Clean VG's	$1.5x10^6$	1.87	0.109	-0.096
k/c=0.0019 VG's	$1.0x10^6$	1.53	0.101	-0.091
k/c=0.0019 VG's	$1.5x10^6$	1.54	0.104	-0.092



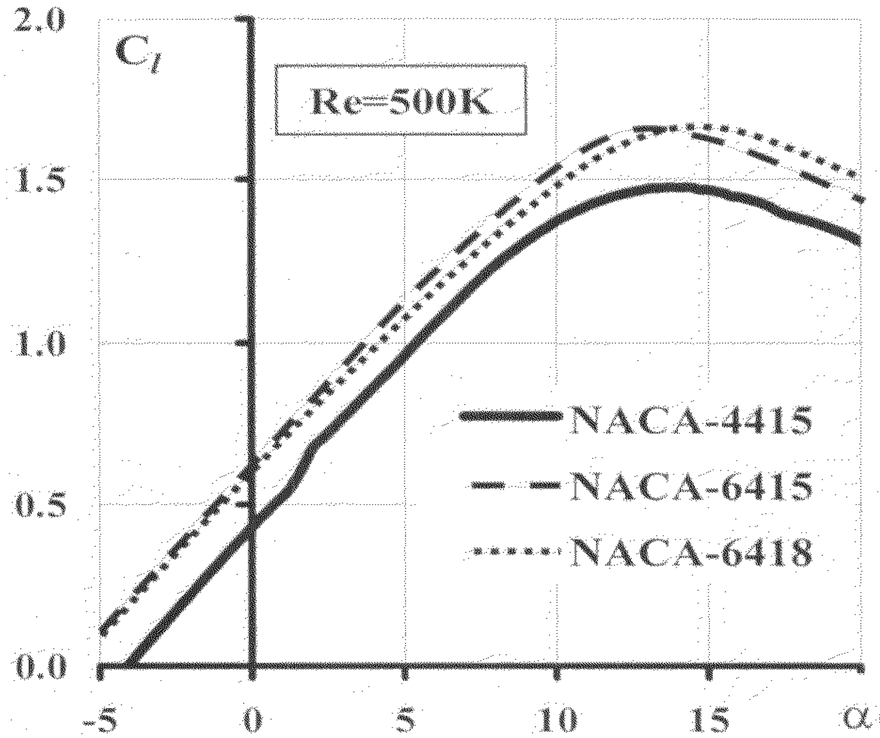


Figure 2.14: Comparison of lift co-efficient of different NACA aerofoils

Chapter 3

Design details

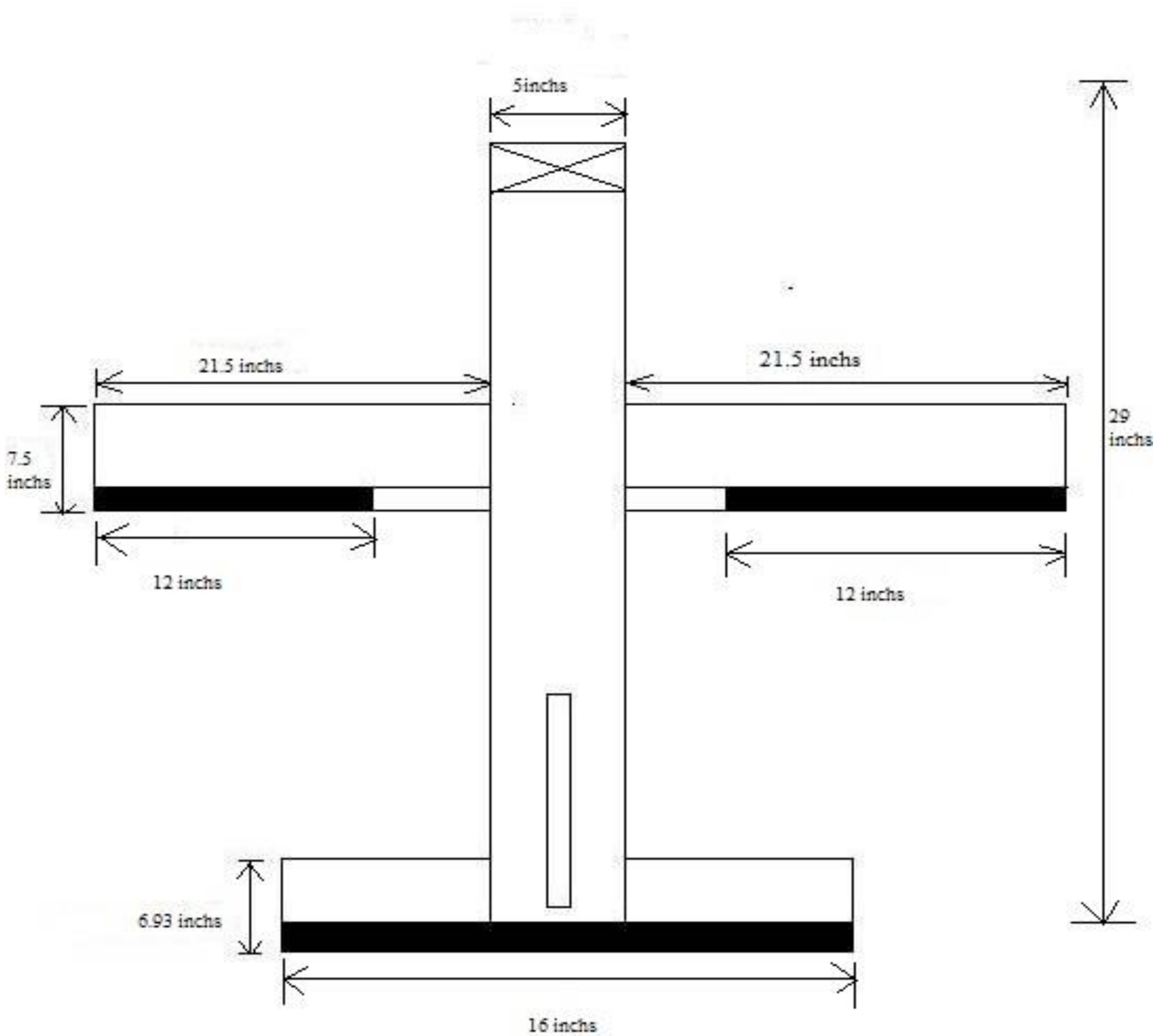


Figure 3.1: Top View of MIST EAGLE EYE

3.1 Wing Design:

Wing design is the most important part in constructing an UAV. The design of other parts such as fuselage, horizontal stabilizer, vertical stabilizer depends on the wing design.

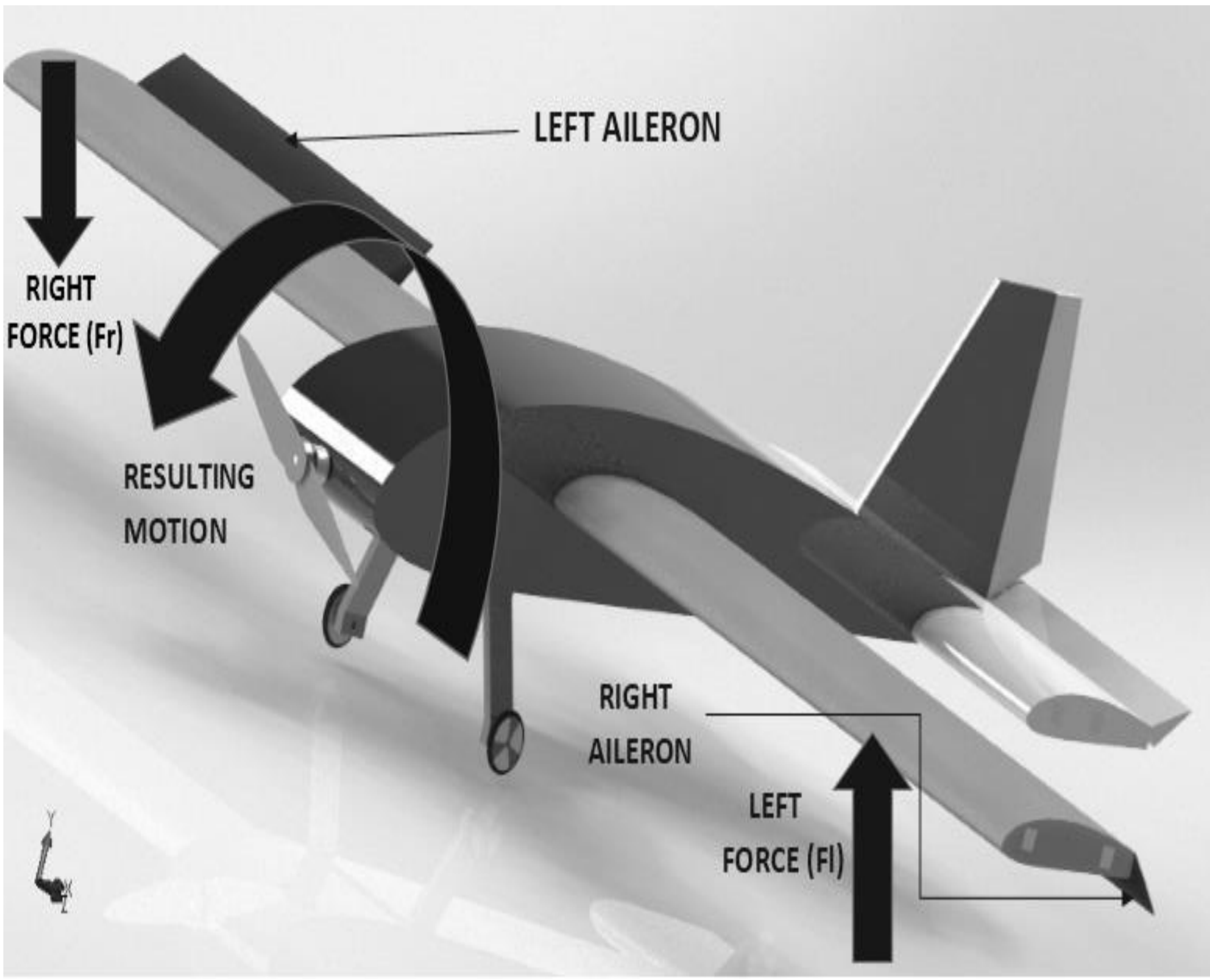


Figure 3.2: Aileron motion control in our UAV

3.2 Number of Wings:

Wing is a part of aircraft, which contributes more lift. There are two types of wings

i. Monoplane – Is an aircraft with the one fixed wing.
ii. Biplane - Is an aircraft with two set of wings.
   The monoplane design has been universally adopted over Multiplan Configuration because of airflow interference between adjacent wings Reduce efficiency.

3.3 Advantages:

- Fixed wing configuration.
- Due to only one set of wings, the drag is less.
- Weight is less, since monoplane has only one wing.
- Smooth flow of air around the wing.
- Load factor is high.
- Small head resistance due to the entire absence of vertical supporting post.
- Load distribution is varying according to the section it makes structurally advantage, due to dihedral configuration.
- Cost effective as only one set of wings is present.

3.4 Disadvantages:

- Presence of only one set of wings makes the lift to be comparatively less.
- As airfoil shaped fuselage is used which produces as much as 20% to 25 % extra lift, the desired lift performance is achieved with monoplane configuration.

3.5 Aspect Ratio:

Aspect ratio is an indicator of the general performance of an aircraft wing. In aerodynamics, the aspect ratio of a wing is defined as the square of the span divided by the wing chord. It is a measure of how long and slender a wing is from tip to tip. For “high” aspect ratio aircraft wing indicates long, narrow wings, whereas a “low” aspect ratio wing indicates short and stubby. Higher aspect ratio has the effect of a higher rate of lift increase, as angle of attack increases, than lower aspect ratio wings. This provides the pilot an added advantage of enjoying quick control surface response. MIST EGLE EYE has a higher aspect ratio.
The wing platform area with a rectangular shape is defined as the span times the mean aerodynamic chord.

3.6 Several Rectangular Wings with The Same Platform Area But Different Aspect Ratio:

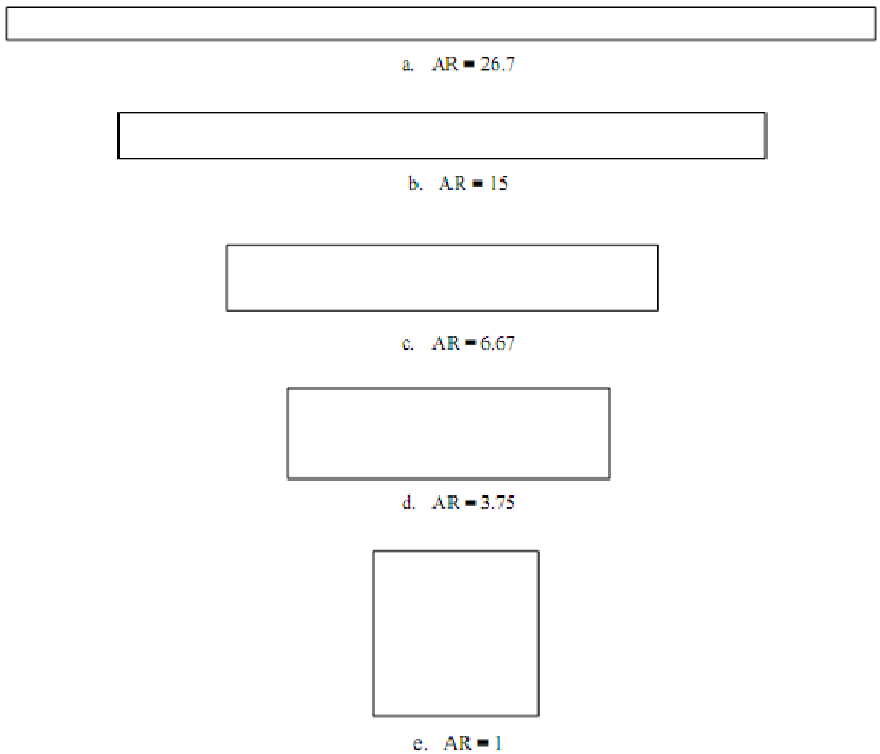


Figure 3.3: Change of aspect ratio with wing span and chord length.

3.7 Aspect Ratio Effect on The Stall and Angle of Attack of RC UAV:

The graph below on the x-axis is Wing Angle of Attack in degrees and on the y-axis is the Wing Lift Coefficient (CL). Lift curve of different RC Airplanes Wings are drawn with increasing Aspect ratio. Here to note, that the maximum Lift coefficient is considered the same for all the RC Airplanes Wings with different Aspect Ratio. From the graph, we can see that an RC Airplane with small Aspect Ratio stalls at a higher Angle of Attack. On the other hand we can see that when the Aspect Ratio of the RC Airplane Wing is increased the wing stalls at a lower Angle of Attack. So, from this we can conclude that a wing with a smaller value of Aspect ratio stalls at a higher Angle of Attack and a wing with a higher Aspect Ratio stalls at a lower value of angle of attack. Now, we know that Aspect Ratio is defined as,
(Wing Span*Wing Span) / Wing Area or b^2 /S.

When the value of Aspect Ratio is higher, the wing reaches the maximum lift coefficient at a smaller angle of attack. Further, increase of the angle of attack will cause the flow separation and the wing will stall. When the aspect ratio is smaller, higher values of angle of attack are required to achieve the maximum lift coefficient and thus the wing stalls at a higher value of Angle of Attack. In our UAV MIST EAGLE EYE we have utilized the advantage of higher aspect ratio.

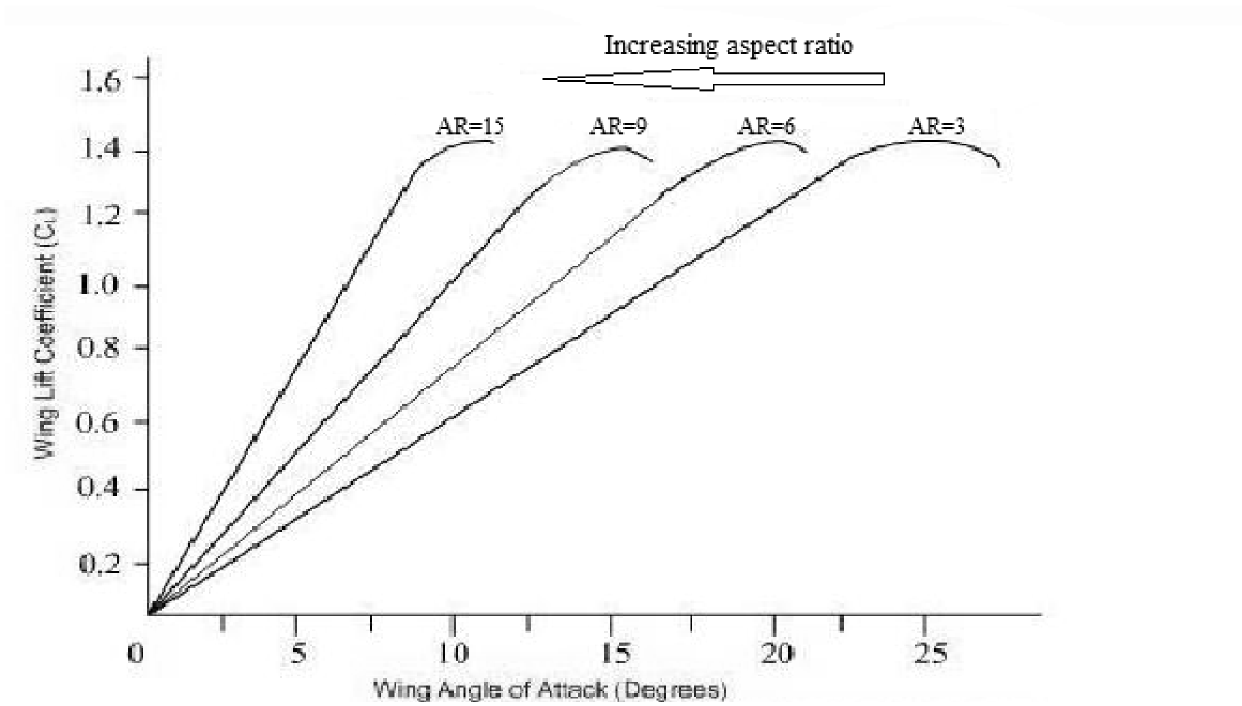
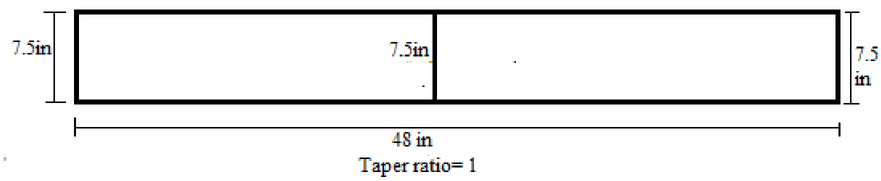


Figure 3.4: Effect of aspect ratio on stall

3.8 Taper Ratio:

The taper ratio of a wing is simply the tip chord divided by the root chord. High aspect ratio wings with low taper ratio (tip chord much less than root chord) are extremely prone to tip stalls so it is best to avoid using both on the same wing. as we have used high aspect ratio in the design we have kept the taper ratio 1 (same root and tip chord).



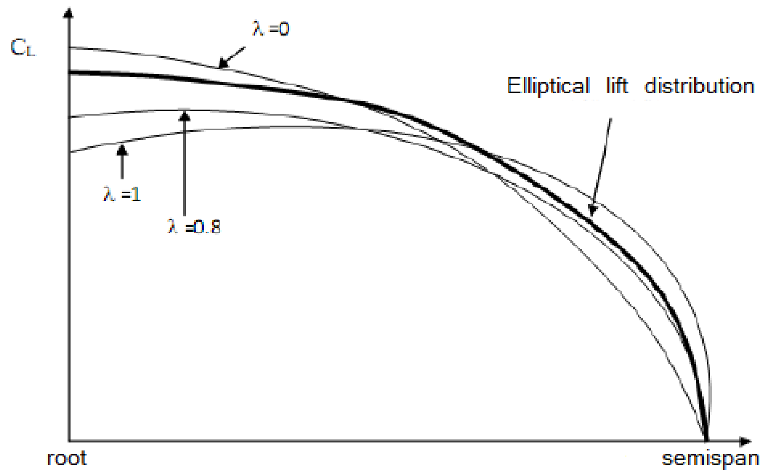


Figure 3.5: Typical effect of taper ratio on lift distribution

From the above studies and discussions, the most preferred wing design for a RC plane will be a monoplane. The RC plane should be made monoplane as a monoplane offers less drag and less weight when compared to other models. Taper ratio is chosen close to 1 so as to provide a high aspect ratio plane.

3.9: Calculation of Aileron:

Aileron length and width varies in proportion with wing span and wing chord respectively. In this part aileron length and width used in our UAV are given below:

- Wing span = 48" (Used in our UAV)
- Wing chord = 7.5" (Used in our UAV)
- Aileron length = 1/4 × wing span

= 1/4 × 48"

= 12"

- Width of the aileron = 1/4 × wing chord

  = 1/4 × 7.5"

  = 1.875"

- Area = 12" × 1.875"

= 22.5 $inch^2$

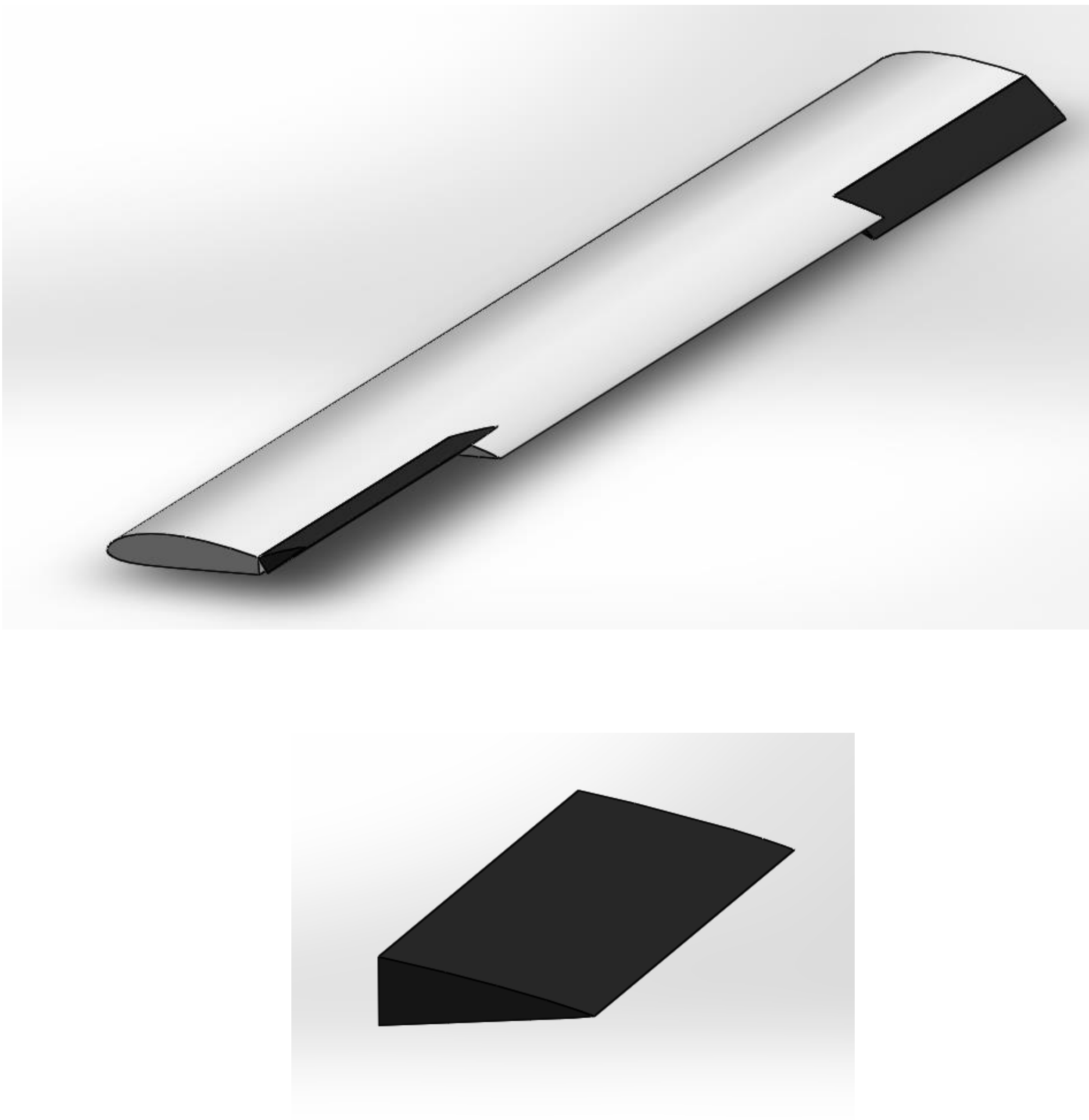


Figure 3.6: Aileron used in our UAV

3.10: Calculation of Horizontal Stabilizer:

Horizontal stabilizer area depends on wing area. It is usually 20-30% of wing area. Various dimension of horizontal stabilizer used our UAV are given below:

- Horizontal stabilizer area = 0.3 wing area

  = 0.3 × 360 $inch^2$

  = 108 $inch^2$

- Horizontal stabilizer span = 1/3 wing span

  = 1/3 × 48"

  = 16"

- Horizontal stabilizer chord = 1/3 horizontal stabilizer span

  = 1/3 × 16"

  = 5.33"

- Elevator area = 20 to 30% of horizontal stabilizer area

  = 0.25 horizontal stabilizer area

  = 0.24 × 108 $inch^2$

  = 25.9 $inch^2$

- Elevator length = Horizontal stabilizer span =16"

- Elevator width = 25.9/ 16"

  = 1.6"

3.11: Calculation of Vertical Stabilizer:

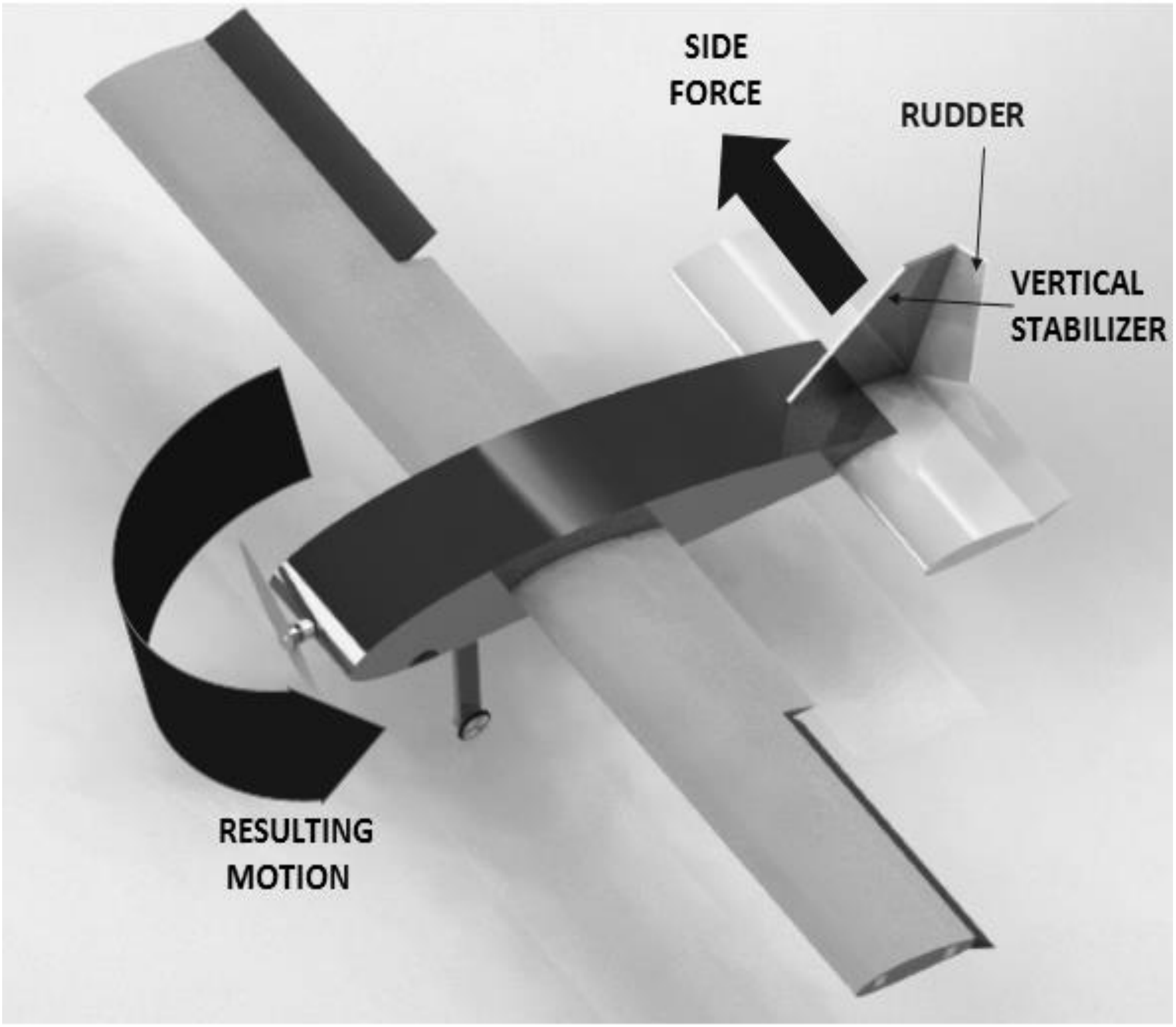


Figure 3.7: Motion control of rudder in our UAV

Vertical stabilizer area related to the horizontal stabilizer area.

- Fin area = 33% of stab area

  $= 0.33 \times 108\ inch^2$

  $= 35.64\ inch^2$

- Fin length = 0.15 wing span

  = 0.15 × 48"

  = 7.38"

- Width = 0.33 fin length

  = 0.33 × 7.38"

  = 2.5"

- Rudder length = fin width

  = 2.5"

- Rudder width = 1/2 rudder length

  = 1/2 × 2.5"

  = 1.25"

Chapter 4

Structural Materials selection and construction

4.1 Materials Used in Assembly:

- Balsa sheet
- Cork sheet
- Balsa square bar
- Two part epoxy adhesive
- Electrical communications equipment
- Covering paper
- Others

In the construction of “MIST EAGLLE EYE” balsa sheet has been used to make the ribs of wing , ribs of fuselage , ribs of horizontal stabilizer ; vertical stabilizer and control surfaces while cork sheet is mainly used to construct the main body .

4.2 Balsa Sheet:

- Balsa is a wood that is famous worldwide. And while its density and mechanical values can vary significantly depending on the growing conditions of any particular tree, it is generally the lightest and softest of all commercial woods, ranging from 8 to 14 pounds per cubic foot. Yet despite its softness, Balsa is technically classified as a hardwood, rather than softwood, since it has broad leaves and is not a conifer.

- Balsa has excellent sound, heat, and vibration insulating properties, and is also incredibly buoyant: in fact, “Balsa” is the Spanish word for “raft.”

Figure 4.1: Cutting of ribs according to design specifications.

- Its outstanding strength to weight ratio enables to construct durable models that fly in totally realistic manner. Balsa also absorbs shock and vibration and can be easily cut, shaped and glued with simple hand tools.

4.3 Balsa in a Brief:

- **Common Name(s):** Balsa
- **Scientific Name:** Ochromapyramidale
- **Distribution:** Tropical regions of the Americas; also grown on plantations
- **Tree Size:** 60-90 ft (18-28 m) tall, 3-4 ft (1-1.2 m) trunk diameter
- **Average Dried Weight:** 9 lbs/ft^3 (150 kg/m^3)
- **Specific Gravity (Basic, 12% MC):** .12, .15
- **Janka Hardness:** 90 lb$_f$ (390 N)
- **Modulus of Rupture:** 2,840 lb$_f$/in^2 (19.6 MPa)
- **Elastic Modulus:** 538,000 lb$_f$/in^2 (3.71 GPa)
- **Crushing Strength:** 1,690 lb$_f$/in^2 (11.6 MPa)
- **Shrinkage:** Radial: 2.3%, Tangential: 6.0%, Volumetric: 8.5%, T/R Ratio: 2.6

4.4 Properties of Balsa :

- **Color/Appearance:** Heartwood tends to be a pale reddish brown color, though it is not commonly seen in commercial lumber. Most boards/blocks of Balsa are from the sapwood, which is a white to off-white or tan color, sometimes with a pink or yellow hue.
- **Grain/Texture:** Balsa has a medium to coarse texture with open pores and straight grain.
- **End grain:** Diffuse-porous; large pores in no specific arrangement; solitary and radial multiples of 2-3; growth rings indistinct; rays visible without lens; parenchyma typically not visible with lens.

- **Rot Resistance:** Sapwood is rated as perishable, and is also susceptible to insect attack.

- **Workability:** Generally very easy to work with virtually no dulling effect on cutters; yet because of its extremely low density, fuzzy surfaces can be a problem when using dull cutters. Balsa generally should not be used to hold nails, with glue being the preferred method of joining. Balsa stains and finishes well, though it has a tendency to soak up large quantities of material on the initial coats.

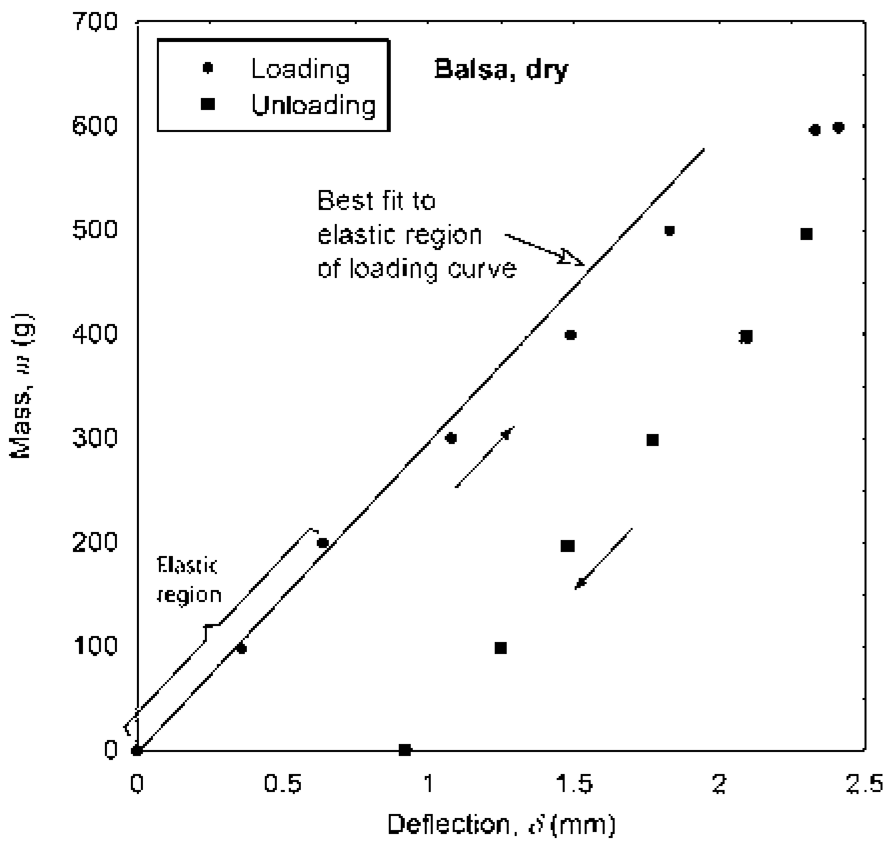


Figure 4.2: Physical properties of Balsa

- **Odor:** No characteristic odor.

- **Allergies/Toxicity:** Although severe reactions are quite uncommon, Balsa has been reported to cause skin irritation. See the articles Wood Allergies and Toxicity and Wood Dust Safety for more information.

- **Pricing/Availability:** High quality Balsa (that is, Balsa with a very low density) can be rather expensive when purchased at hobby stores or other specialty outlets. Larger boards and lumber sold through typical hardwood dealers is hard to find, but generally has a better cost per board-foot than other sources.

- **Sustainability:** This wood species is not listed in the CITES Appendices or on the IUCN Red List of Threatened Species.

4.5 Common Uses:

- Buoys,
- rafts,
- surfboards,
- model airplanes,
- musical instruments,
- packing/transport cases,
- core stock in sandwich laminations,
- Fishing lures.

4.6 Why Balsa Wood So Light?

The secret to balsa wood's lightness can only be seen with a microscope. The cells are big and very thinned walled, so that the ratio of solid matter to open space is as small as possible. Most woods have gobs of heavy, plastic-like cement, called lignin, holding the cells together. In balsa, lignin is at a minimum. Only about 40% of the volume of a piece of balsa is solid substance. To give a balsa tree the strength it needs to stand in the jungle, nature pumps each balsa cell full of water until they become grid-like a car tire full of air. Green balsa wood typically contains five times as much water by weight as it has actual wood substance, compared to most hardwoods which contain very little water in relation to wood substance. Green balsa wood must therefore be carefully kiln dried to remove most of the water before it can be solid. Kiln drying is tedious two week process that carefully removes the excess water until the moisture content is only 6%. Kiln drying is also kills any bacteria, fungi, and insects they have been I the raw balsa wood.

In fact, balsa wood is often considered the strongest wood for its weight in the world. Pound for pound it is stronger in some respects than pine, hickory, or even oak.

Balsa wood is only about the third or fourth lightest wood in the world. However, all the woods which are lighter than balsa are terribly week and undesirable for any practical use.

Species	*Weight Lbs./Cu. Ft.*	*Stiffness Strength*	*Bending Strength*	*Compression Strength*
Balsa	8	72	70	75
Balsa	10	100	100	100
Balsa	14	156	161	149
Spruce	28	230	260	289
Yellow Pine	28	222	277	288
Douglas Fir	30	241	291	341
Hickory	50	379	638	514
Oak	48	295	430	366
Basswood	26	261	288	288
Black Walnut	37	301	506	512

Table 4.1: Strength of balsa wood compared to other woods

For our project, balsa sheet is used of the specifications given below:

Specifications:	
Width	4 inch.
Length	16 inch
Thickness	3 mm
Amount used	7 pieces
Type	sealed

4.7 Balsa Square Bar:

Figure 4.3: Balsa square bar

- The balsa square bar has been used as spur. This provides more strength and rigidity to the body frame.

Width: 4 mm

Length: 12” length

4.8 Cork Sheet:

- Aerofoil made of cork sheet is used between the ribs in wing, fuselage and horizontal stabilizer for strength and uniform covering surface. It is also used in making the wing root fillets.
- Chemically, it is known as polystyrene. Because of its light weight, it is easily stored, handled and installed on job sites. Due to its design flexibility and versatility, it can be cut in to sheets, slabs, or any design requirement to meet specific building code standards. It can be cut to shape with ordinary tools to assure tight joints thus reducing heat loss. The mechanical properties of polymer include its strength, elongation, modulus, impact, strength and toughness.
- The cork sheet has been selected to construct the main body because of its light weight and flexibility, as weight is a major concern to build a UAV. It can be easily glued. No special equipments or cutters are needed to shape it to the desired design.

- A drawback of cork sheet in UAV is that, the landing gears cannot be installed or attached to it properly which makes the attachment of the landing gear with main body weaker.
- The same difficulty was also faced while mounting the propeller motor at the front side of the fuselage. For a safer and better flight, the stiff mounting of the motor is very important.

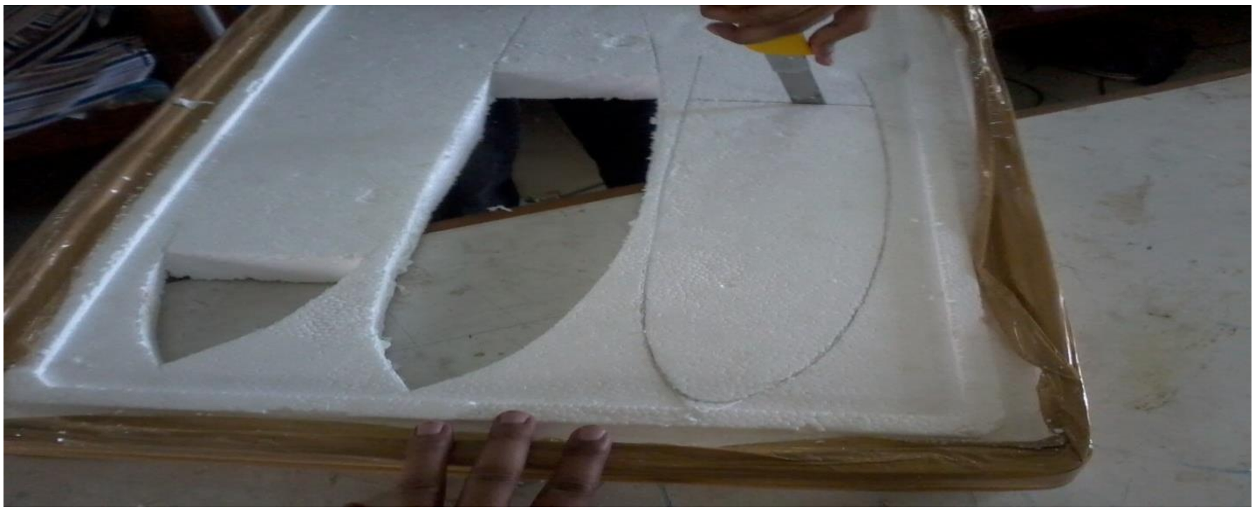


Figure 4.4: Cutting of polystyrene (cork sheet).

4.9: <u>Common Modelers Tools For Cutting And Shaping Balsa Wood And Cork Sheet:</u>

Balsa is a very “friendly” wood to work with-so light, so soft, so easily worked into so many things. You don’t need heavy duty power saws and sanders like you would if working with hardwood. in fact, even with an extensive power shop at their disposal. According to the professional model builders to cut and shape the balsa sheets manually for the model airplane, the recommended tools are:

A knife or razor blade works well for cutting balsa sheet and sticks up to 3/16” thick. A razor saw of sizes thicker than 3/16” can be used. Replacement blades on hand must be kept as blades do wear out and a dull blade can make it impossible to do a good job.

Figure 4.5: Balsa cutting procedure

4.10 Sandpaper:

Sandpaper or **glass paper** is generic names used for a type of coated abrasive that consists of a heavy paper with abrasive material attached to its surface. Despite the use of the names neither sand nor glass are now used in the manufacture of these products as they have been replaced by other abrasives. Sandpaper is produced in different grit sizes and is used to remove small amounts of material from surfaces, either to make them smoother (for example,

in painting and wood finishing), to remove a layer of material (such as old paint), or sometimes to make the surface rougher .

- Sandpaper is used to smoothen the surface of the components made by balsa and cork sheet. Sandpaper works very well on them and helps to achieve desired surface with more perfection.

- **S** indicates a good **starting point** for typical sanding.

- **F** indicates a good **stopping point** so that you can proceed with the rest of the finish.

	Ultra Coarse		Coarse		Medium		Fine		Ultra Fine	
	Grit									
Material	60	80	100	120	150	180	220	320	400	600
Hardwood/Birch Plywood				S					F	
Hard balsa/Lite Ply						S			F	
Medium Balsa							S			F
Contest balsa								S		
Fiberglass, Plastics and metals									S	

4.11 Laser Cutting Machines For 3-D Thin Sheet Parts:

Laser cutting is the high speed cutting with a narrow kerf width that results in superior and enhanced quality, higher accuracy and greater flexibility. In fig. 1 schematic is shown the laser cutting.

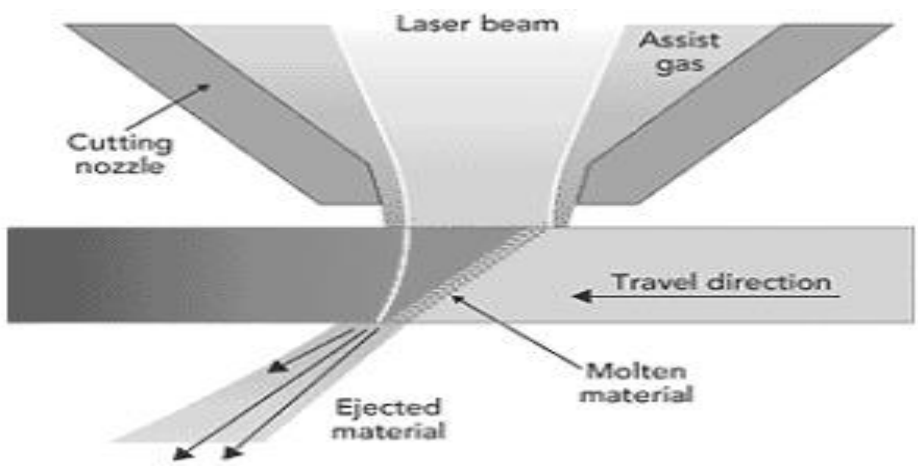


Figure 4.6: Laser cutting

By combining the laser beam and the machine providing motion, in addition to the applied numerically controlled system, it is possible to provide for a continual sheet cutting along the predetermined contour. The laser beam can cut very hard or abrasive materials. Cutting with lasers is a very cost effective process with low operating and maintenance costs and maximum flexibility.

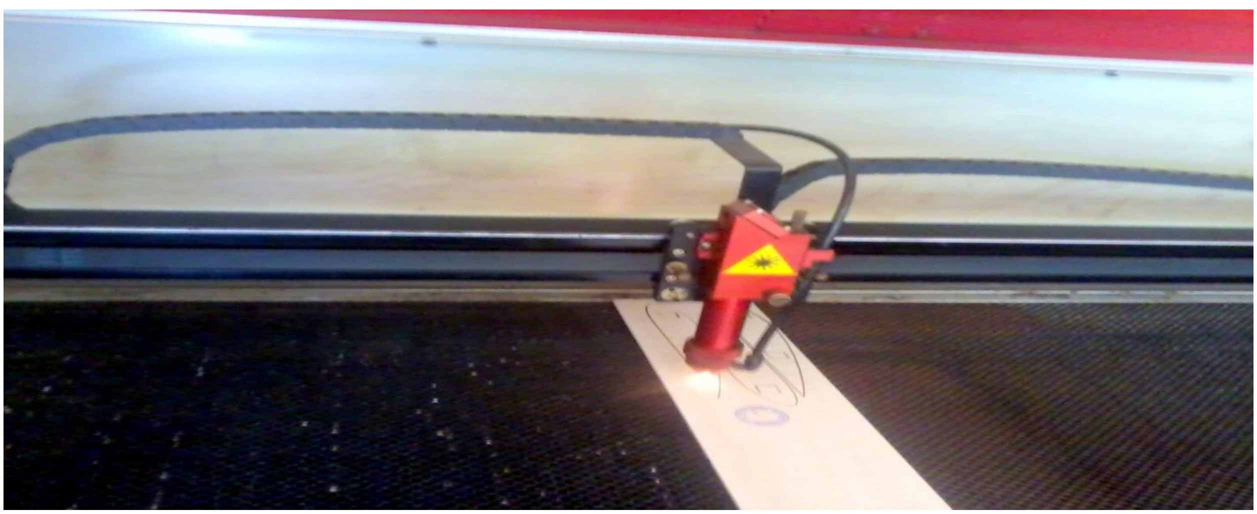


Figure 4.7: CNC laser cutting machine(a)

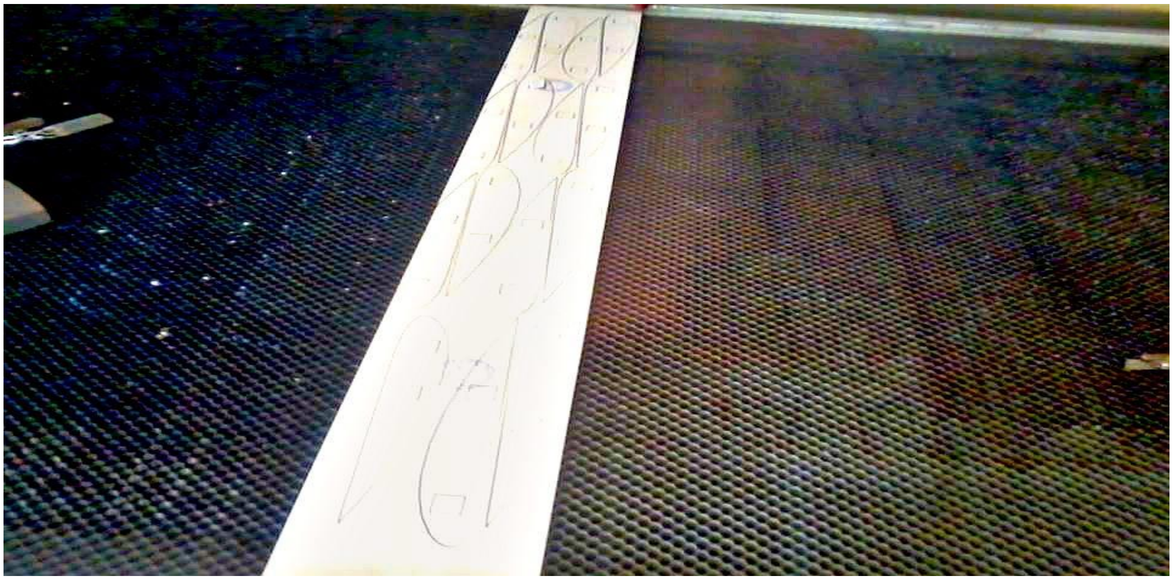


Figure 4.8: Laser cutting(b)

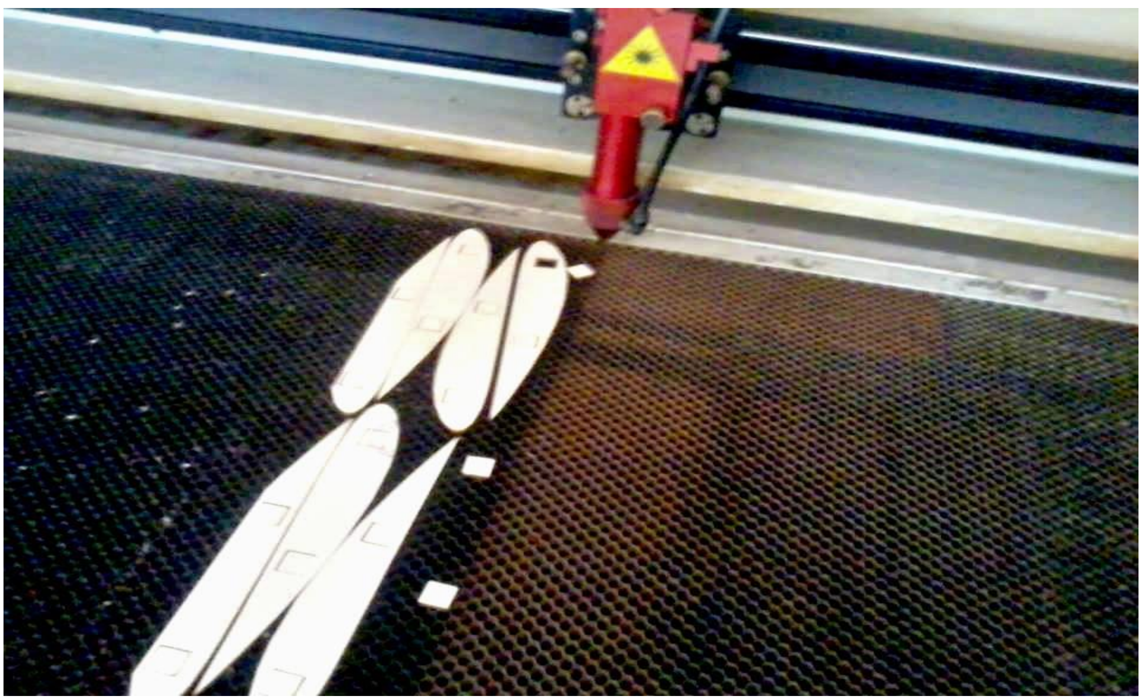


Figure 4.9: laser cutting(c)

4.12 Covering Paper:

60 CM WIDE COVERING FILM - TRANSPARENT RED

- **Brand:** MMRC Tech Ltd.
- **Product Code:** Film-Trnt Rd
- **Specifications:**

Width: 60cm

Length: 1 meter

Color: Transparent Red

4.13 Rapid 3 Ton 4 Min Epoxy (V-Tech):

Brand: MMRC Tech Ltd.
Product Code: Epoxy- 4 min

4.14 Properties of EPOXY Adhesive:

Fast setting, non-shrinking, clear color epoxy adhesive that exhibits a remarkable combination of properties, high mechanical strength, excellent resistant to most chemical and reliable heat resistant. Easy to machine, non-conductive & can be handled after 2 hrs

- Color : Clear

Chapter 5
Body assembly

5.1 Considerations Before Assembly:

- Unmanned air vehicles represent the most dynamic growth sector of the aerospace industry. In fact, UAV spending will more than double over the next decade, from $4.9 billion to $11.5 billion annually.

- The major difference is the shear size comparison, which also drives facility needs and capital and tooling needs, as well. But, other major factors include components that make the aircraft unmanned, as well as the all-important payload that currently provides high-resolution video. Another major aspect that separates manned from unmanned aircraft is the modular nature of the unmanned aircraft.

- The assembly depends on the expectation of the UAV. Rapid prototyping and proof of concept vehicles can be built similar to model airplanes. Balsa stick construction was the choice of us for a smaller UAV and limited use foam tools for layups was done .

- Depending on the platform, UAVs can be as simple as a high-performance model airplane or as complex as a modern manned aircraft. Additionally, the different types of components are dependent on the size and mission performed by the UAV. In most cases, the larger the UAV, the more capable and versatile its payload and the more involved the assembly process.

Figure 5.1: aileron

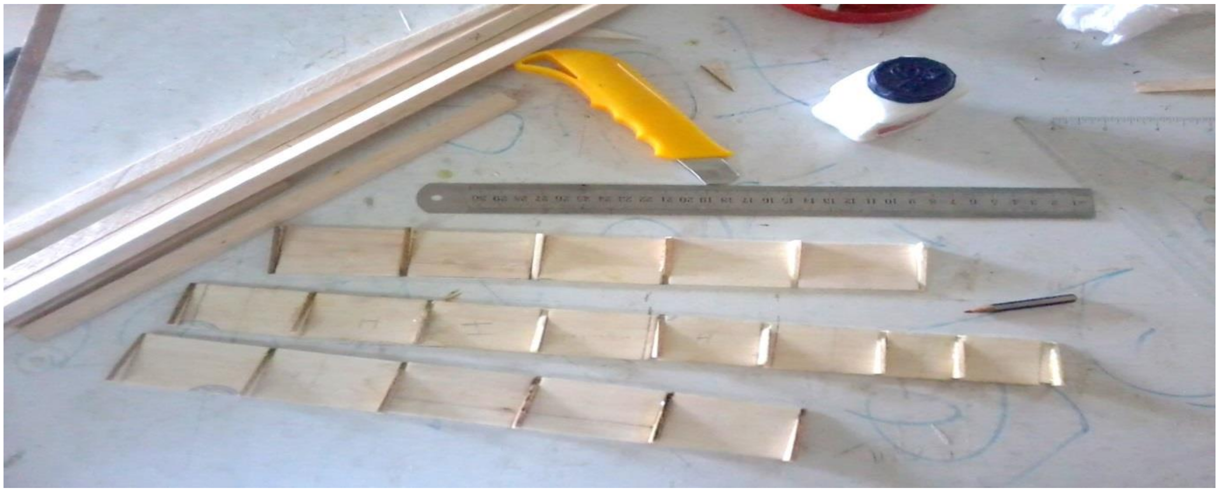


Figure 5.2: fabrication of control surfaces

There are approximately seven major process groupings consisting of composites, bonding, electrical assembly, mechanical assembly, integration, static UAV test and flight testing. Surrounding these process groupings are a number of certification processes that provide a high level of quality and ensure conformance to all contractual requirements. The major components are fuselage, outer wings, center wing, tail section, tail booms, payload, engine, landing system, batteries, landing equipment and electrical communications equipment.

Figure 5.3: Body assembly

➢ Before starting the assembly, the following items are made available:

- 5 minute epoxy,
- Hot glue,
- Popsicle sticks,
- AnXacto knife or a razor blade,
- Those tiny jeweler's screwdrivers,
- Paper towels,
- Paper
- Packing tape.

Figure 5.4: Top view of initial body assembly

White foam is glued to white foam. To make a stronger bond some small circular holes are poked with one of the smaller jeweler screw drivers throughout the two pieces that are glued. The holes are kept small, and kept well within the center of the gluing surface. When covering it with epoxy, these holes are made sure to be filled with epoxy. This allowed the epoxy to bind to a greater surface area and almost create the equivalent of a rivet into that surface.

5 min. epoxy is used for anything that is supposed to make a permanent bond. The two part epoxy is mixed, and a Popsicle stick is used to apply it to both of the surfaces to glue together. The epoxy is easy to spread thin, but it's better to have a little extra than too little. After about 3-4 minutes the epoxy starts to become unusable. When the surfaces are covered in epoxy, wing is pressed with a little force onto the plane. Excess glue will likely shoot out the sides. With a paper towel the excess glue is removed. Once all of the excess is removed, the wing is properly aligned.

Chapter 6
Electrical components and assembly

6.1 Electrical Communication Equipment's:

- Electric / Propeller motor,
- Servos motor,
- Lipo battery.
- Electronic speed controller(ESC)

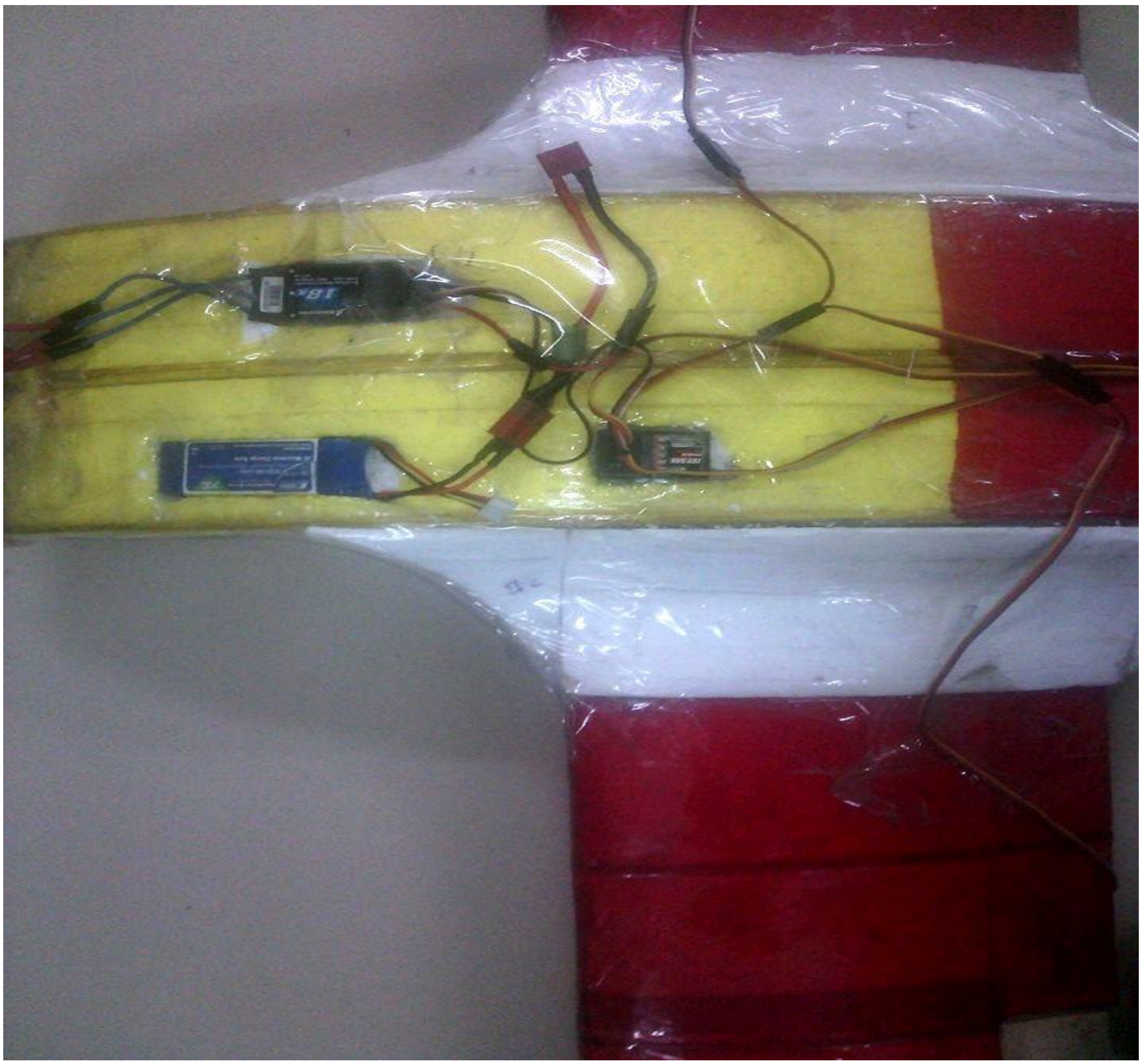


Figure 6.1: The electrical equipments of MIST EAGE EYE

6.2 Electric Motor:

- model : EMAX 1200KV Outrunner Brushless Motors
- Brand: EMax
- Product Code: CF-2822

6.3 Features:

It is the very high power delivered by these small and very robust, but light weight (39g) brushless motors with rotating case suitable for all models of 300-400 size. The CF2822/CF2812 motors offer extremely high efficiency and high load capability for their weight. EMAX motors with the high quality of manufacturing, reliability and performance are the best out runners available in the market.

6.4 Specifications:

No. Of cells	2-3 Li-Poly
RPM/V	1200 RMP/V
Max. efficiency	82%
Max. efficiency current	7 -16 A (>75%)
No load current / 10 V	0.9 A
Current capacity	16 A/60 s
Internal Resistance	150 mohm
Stator Dimensions	22x10 mm
Shaft diameter	3 mm
Weight	39 g
Recommended model weight	200 -600 g

6.5 Recommended Propellers Without Gearbox:

APC 7X4

APC 8X3.8

APC 9X4.5

APC 10X5

Among this APC 10X5 has been used for this project.

6.6 Transmitter:

The Transmitter is the most visible part of the system .A rectangular box with an antenna protruding from the top and the left and right control sticks or joysticks.

6.7 Receiver:

The Receiver is a small electronic unit that is capable of receiving the signals given by the transmitter. The receiver will only act on signals sent to it by its transmitter; most modern systems are capable of being operated with many other systems in the same flying area without interfering with one another.

The receiver will have output terminals for sending the signals received to the servos -these are electronic components that convert the current sent by the receiver to a movement - to move a rudder, aileron or an elevator. A point to note is unlike the earlier systems or simpler toy RC systems, the current sent out by the receiver is proportional to the movement of the control sticks on the transmitter so finer control can be exercised, not simply 'all or nothing ' control of an elevator or other control surface. To use the example of a radio controlled toy car, where the front wheels can be steered full left or full right or straight ahead, proportional controls enable the wheels to be steered in degrees, either a small correction or a full turn to the left or right and anything in between.

6.8 Transmitter and Receiver:

Hobby King 2.4Ghz 6Ch Tx & Rx V2 (Mode 2)(THROTTLE ON THE LEFT)

Hobby kings T6A 2.4 Ghz systems is an entry level transmitter offering the reliability of 2.4 GHz signal technology and a receiver with 6 channels.
This transmitter requires a PC to modify any of the channel variables including mixing and servo reversing.

6.9 Key Features:

6-channel 2.4GHz transmitter with servo reversing.
Easy to use control for basic models.
Includes 6-channel receiver
Trainer system option.

6.10 Included:

1 x 2.4 GHz transmitter
1 x 2.4Ghz Receiver
1 x Bind Plug.

6.11 Servos:

A servo is a device for moving a part of the model. Usually servos operate the rudder and elevator on a three channel model and the aileron as well on a four channel model. The throttle may be operated by a servo or on electric models it may be operated by a speed controller called an 'electronic speed controller' that plugs into the receiver. It connects the control rods.

TOWER PRO MG90S 9G / 1.5KG / 0.10SEC ECO MICRO SERVO

Brand: Tower Pro
Product Code: TPMG90S

6.12 Specification:

Weight: 13.4g
Dimension: 22.8*12.2*28.5mm
Stall torque: 1.8kg/cm (4.8V) - 2.2kg/cm (6.0V)
Operating speed: 0.10sec/60degree (4.8v) - 0.08sec/60degree (6.0V)
Operating voltage: 4.8-6.0V
Temperature range: 0- 55deg
Servo Plug: JR (Fits JR and Futaba)

6.13 ESC:

The Electronic Speed Controller (ESC) is the device that regulates the electricity going from the battery to the motor. If there was no ESC, then the battery would just be directly to the motor, and only one speed would be available: Full Throttle. Doing other things with UAV, like landing, being able to control throttle is a necessity. This is what the ESC provides.

How the ESC knows how much throttle is required to supply to the motor:
The Tx sends the information about throttle position to the receiver. The ESC actually has a small 3 pin connector (like the servos have), and this connector plugs into the channel 3 slot on your receiver. The receiver then sends the throttle information over this wire to the ESC. The ESC now knows how much throttle the pilot wants to give to the motor, and it is able to regulate the power due to being in between the battery and motor.

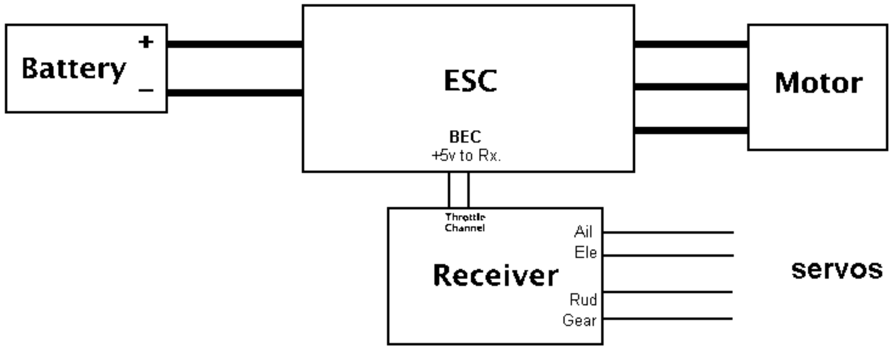


Figure 6.2: Schematic diagram of electric system.

As shown in the above diagram, the ESC directly connects to the battery. Connectors are chosen, and soldered. The battery connector must match the battery. All battery connectors consist of two wires –

a positive (red)

a negative (black).

Aside from the battery connector, and the wire that goes to the receiver, the ESC has a set of wires running to our electric motor. Usually, these colors are red, black and blue. The motor will also have three wires extending from it, and they will often be the same color. The wiring can sometimes be inconsistent, and the motor will actually run in reverse. When the motor is reverse, the airflow from the propeller is in the wrong direction. To fix this, the connection is simply swapped between any two wires. In other words if these connections cause the motor to run in reverse: red1 to red2, blue1 to blue2, black1 to black2, then swapping the configuration tothis

would fix it: red1-blue2, blue1-red2, black1-black2. Since the ESC is connected to the battery, it will actually power all the other components on the plane. The motor is obviously powered via its direct connection to the ESC, and the receiver is powered via the ESC's 3 pin connector that is plugged into the CH 3/Throttle port on the receiver. Once the receiver has power, it will then pass some on to the servos that are spread out through the plane.

The Turnigy 15 is an advanced switching DC-DC regulator which will supply a constant 8A or more with short bursts of up to 15amps. The Turnigy UBEC plugs into a 2 or 3 Cell Lipoly pack and supplies a constant 5 or 6v to receiver. Voltage status indicator lights on the pack show whether your 2 or 3 cell pack is Full, half charged or low. The system includes an anti-short circuit and overheats function with a thin metal shield cover, reducing noise. Also included is an output filter to reduce noise, an on/off switch and a step down regulator adapter.

TURNIGY 8-15A UBEC FOR LIPOLY

Brand: Turnigy
Product Code: Turnigy UBEC

6.14 Specifications of ESC:

Output (Constant): 5v/8A or 6v/8A
Input: 6v-12.6v (2-3cell lipo)
Size: 42x39x9mm
Weight: 34g
Quiescent Current: 60mA
Type: Switching
LED indicator (2 or 3 cell)
Full: 7.8~8.4v / 11.7v~12.6v
Incrementing down to:5.4~6.6v / <9.9v

6.15 Battery:

There are many different types of batteries out there, like Nickel Cadmium (NiCd), Nickel Metal Hydride, Lithium (Li) and Lithium Polymer (LiPo). Since Lithium Polymer (LiPo) batteries are the current standard for electric aircraft, we have used this for the UAV.

There are four main factors to be aware of regarding batteries

- Number of Cells (Voltage)
- Capacity (mAh)
- Discharge Rate (C-rating)
- The Battery Connector

6.16 <u>Battery Connectors:</u>

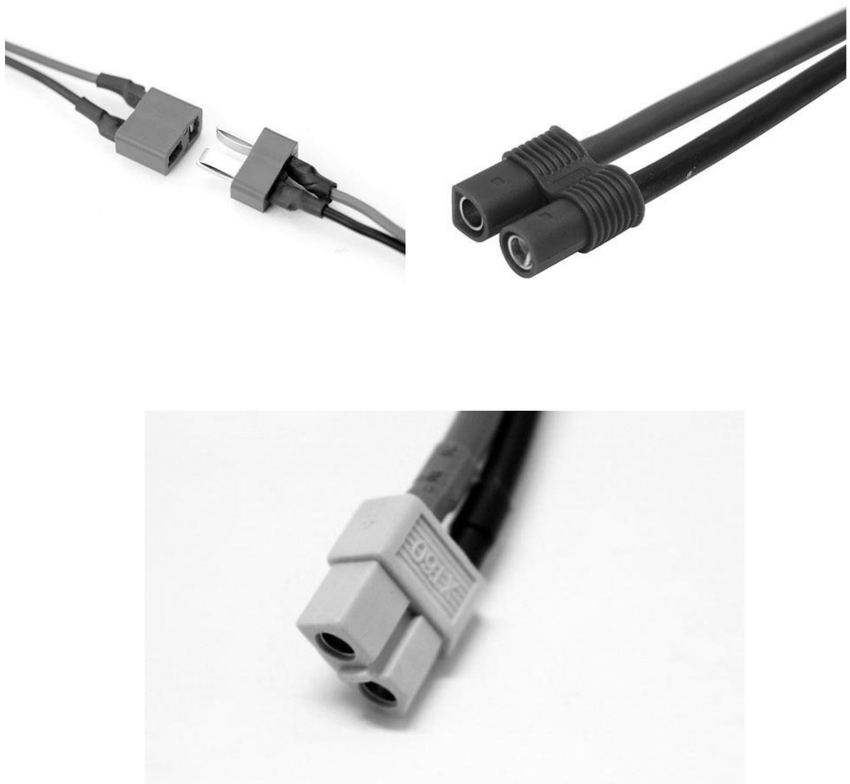


Figure 6.3: Connectors

The JST-XH balance connector (shown above) is usually found on the majority of LiPo batteries. The balance plug is used exclusively during the charging process as a way to ensure all cells inside the battery are charged evenly. It’s also the preferred connection for battery meters, as it provides a direct measurement of the voltage for each cell. The JST-XH balance connectors will vary in size, depending on how many cells you have. A 2S battery will have a 3 pin connector, while a 6S batter will have a 7 pin connector

Servo connections (320mm)

Servo connections00101 L320mm

When the standard servo wire isn't long enough to reach, these extension cables are used that come in a variety of sizes.

Servo Extensions 00101 L165mm

Y-Cable 200mm

It is dividing signal from receiver to 2 servos. Y-Harness Cables to connect 2 servos to 1 channel on your receiver like in a dual-aileron application.

6.17 Propeller:

Figure 6.4: propeller

There are two factors that determine and rate propeller performance. They are the diameter and the pitch. The diameter is merely how long the propeller is. Pitch determines how much air is moved with each turn of the propeller. Propeller sizes are expressed as: 10x7 or 11x6. The first number is the diameter, the second is the pitch.

The variables of motor speed, motor torque, pitch and diameter are all interconnected. If speed is desired, a lower diameter and higher pitched propeller is used. If acceleration is wanted with the ability of changing direction on a moment’s notice, a high diameter and lower pitched propeller is used.

Figure 6.5: Propeller of MIST EAGLE EYE

The propeller should be supported by the electric motor that . The higher the diameter and pitch, the more stress there is being put on the motor. Motors mounted with an incorrect propeller size can draw massive amounts of power. This extra power draw can damage battery, ESC is fried and melted with electric motor.

6.18 Propeller Direction and Pusher vs Puller Props:

Figure 6.6: pusher propeller

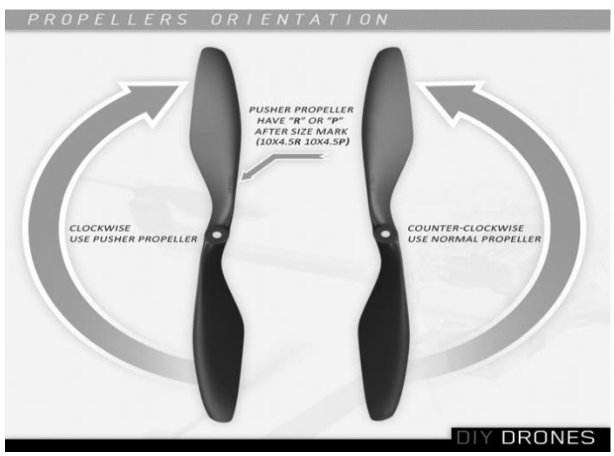


Figure 6.7: Pusher vs. puller propellers

Puller props are the standard propeller, and pusher props are used in specific circumstances. These are not actually designed for pushing or pulling the aircraft. They are actually designed for twin engine planes due to something called torque roll. All planes create a torque roll effect due to the rotation (for a puller prop, it's a counter-clockwise rotation). Torque roll with a puller prop will cause the plane to roll left on its own. This usually only happens at low speeds. The pilot must counter this effect by rolling to the right.

This is usually manageable on single engine planes. So, we have used puller propeller.

6.19 Mounting the Motor and The Propeller:

Figure 6.8: Motor mounting accessories

The motor is screwed in to a specially made plate of wood. After the motor is mounted the propeller is loaded. In order to do this a collet prop adapter is used, which is a common adapter used today. The prop adapter is sized to fit that motor. The base of the adapter is fitted snuggly onto the motor shaft, or it will fail to grip onto the motor shaft. Once the base of the prop adapter is fitted onto the motor shaft, there is a second piece that will slide onto the base of the collet adapter. This piece puts pressure on the bottom of the adapter, clamping it onto the motor shaft. The propeller will slide into this piece, and force it in place. Finally, the propeller and the base of the prop adapter are secured into place.

Chapter 7

Mechanical components and assembly

7.1 Mechanical Components:

The receiver will receive input from the transmitter and tell all the mechanical components how to move. The mechanical components and their functions re elaborately explained in this section

7.2 Servos:

Figure 7.1: Servo motors.

The servo physically generates the force to move the control surfaces (like the rudder, aileron and elevator). We have used small micro servos and each of them weighs around 5g. Since our concern was to minimize weight we did not use larger servos. The main body contains the gears and electronics, while the servo arm (on the right) is held on by a small screw. Some servos are capable of pushing with more force than others. Aside from strength, hardiness is also an issue. The servos used in our UAV have plastic gears, and extra strain or impact can cause the gears to strip. Metal gear servos help solve this problem, as they are often much harder to strip down. Generally speaking, they will be more powerful and hardier servos. But as metal gear servos increase weight as well we did not use those to keep the weight of the UAV low.

Servos also come in digital and analog variants. The internal parts of these servos are practically identical, but there is a major difference in how the process the signal from the receiver. The end result is that digital servos have a faster response time and smoother acceleration when compared to analog servos. The big drawback is that they do use extra power, which might be a concern in case of long test flight. So, to decrease power consumption we have used analog servo motors.

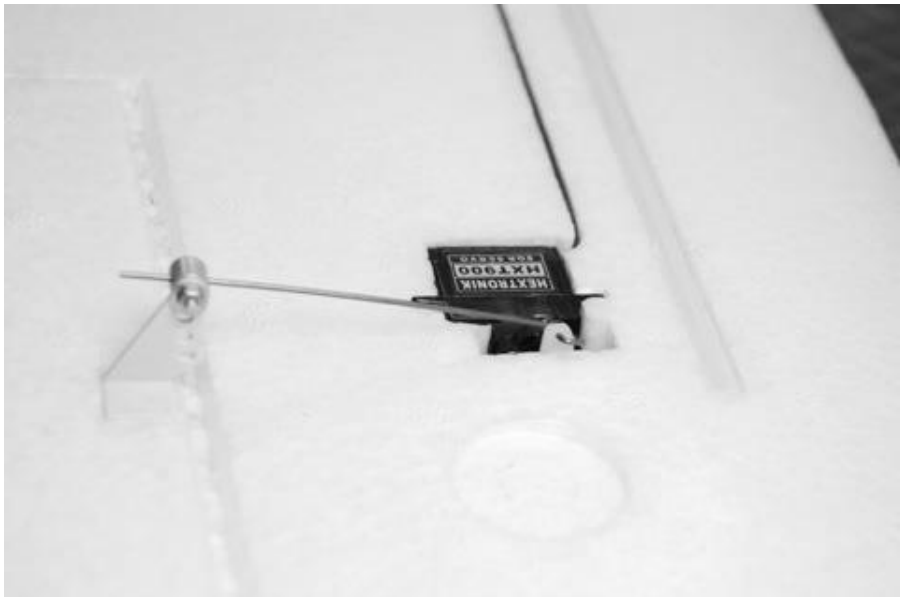


Figure 7.2: Analog servo motor.

Servos are positioned throughout the plane, but usually within a short distance of the surface they are trying to control. The aileron servos are embedded in the wings. Elevator control servo is placed in the horizontal stabilizer and rudder control is embedded in the fuselage towards the back of the plane.

Figure 7.3 Y-cable

Ailerons operate off of one channel, yet the ailerons are driven by two servos (one on each wing). Well, the servo wires are hooked into a Y-cable, pictured above. Both servo wires are plugged into the two female connectors, while the other end is plugged into the correct channel on the receiver. At this point, both servos will move in tandem. Since ailerons need to move in opposite direction, one servo is rotated/flipped over, to face the opposite direction, when it is glued to the wing. Now the arms on that flipped servo will move in the opposite direction of the servo on the other wing.

7.3 Pushrods and Control Horns:

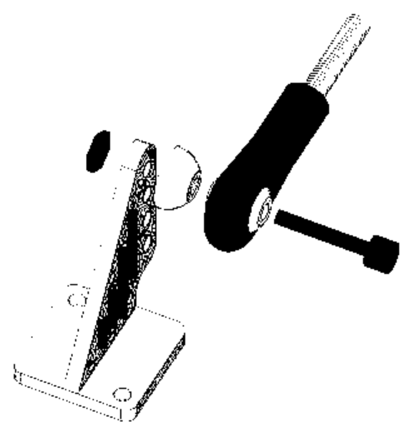


Figure: 7.4: pushrod and control horn

The servo is mounted a decent distance away from the surface its trying to move, so it needs some way to reach it. The pushrod is the item that extends the reach of the servo. Both ends have "Z-bend. The top of the pushrod has a little bend to it. This right-angle looking bend is the Z-bend. With some careful maneuvering, Z-bend portion is snaked into a hole on the servo arm.

The Z- bend on the other end is connected to a piece called a "control horn". This horn is glued and screwed into each control surface.

The receiver sends commands to the servo, and the servo arm moves back and forth. That servo arm is connected to the push rod, and it stays in place due to the Z-bend. The pushrod extends out to where the control horn is. As the servo arm moves, the pushrod moves, thus causing the horn and the attached surface to move.

There are ways to adjust *how much* the surface will move. Both the servo arm and the control horn have multiple holes to connect to. On the servo arm, the hole furthest away from the servo will result in the most movement of the control surface. The innermost hole on the servo arm has the least amount of movement. On the control horn its actually the opposite of this. The hole furthest away from the base of the horn will move the control surface the least. The innermost hole on the horn actually produces the most movement.

Figure 7.5: Front view of fully assembled MIST EAGLE EYE

Figure 7.6: Top view of fully assembled MIST EAGLE EYE

Figure 7.7: Side view of fully assembled MIST EAGLE EYE

7.4 Cost Analysis:

Item	**Cost(BDT)**
Balsa sheet(6 pieces)	1800
Cork (poly styrene) sheet	1200
Laser cutting	7000
Balsa square bar (2 pieces)	1000
Epoxy (3ton)	1200
Anti-cutter	425
Scissors	120
Weight machine	2000
Ply wood	600
Covering paper	900

Screw driver	300
Allen key	100
Servo motor (4 pieces)	1000
Steel wire	75
Connector (10 pieces)	1300
Servo wire	400
Cross filament tape	600
Li-Poly battery	2000
Transmitter receiver	5000
ESC	1500
Propeller	700
Li-Poly battery charger	2000
Y cable (2 pieces)	300
Plastic Horn (4 pieces)	100
Pilot fees	1500
Pen Camera	2200
Propeller motor	2500
Others	3000
Total	**40,820 BDT**

Chapter 8

Flight test overview and analysis

8.1 First Flight Test Overview:

A series of flight tests was carried out to evaluate the performance of our UAV. A pilot highly experienced and skilled in model RC plane control participated in the tests. Flight performance and pilot comments were recorded for each test. Tests were performed in conditions of calm winds of less than 5m/sec and sufficient visibility (1 km or more).

Straight flight and turn maneuvers then were performed to evaluate the handling qualities of the UAV. The problems faced during the flight test are stated below with proper analysis of the problems.

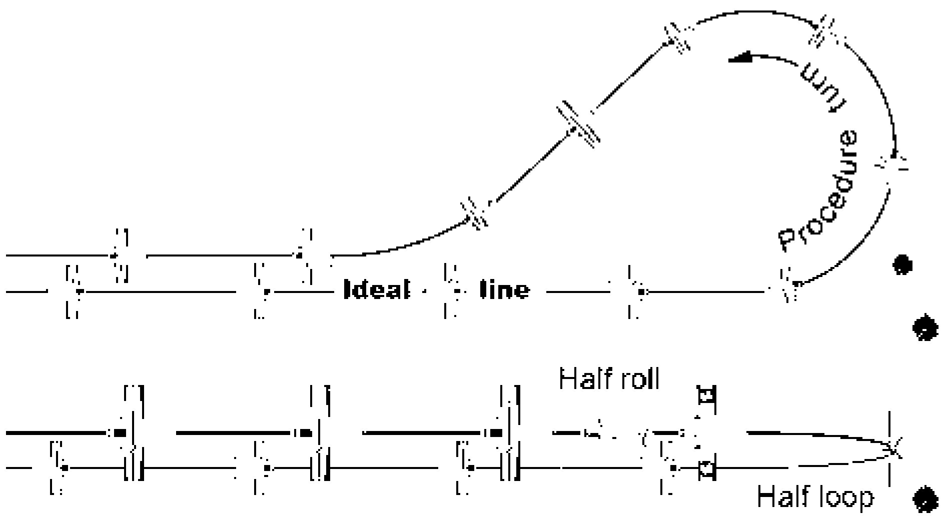


Figure 8.1: Straight flight and turn maneuvers

8.2 Effect of Aerofoil Shaped Fuselage on Lift:

- The main feature of this project is aerofoil shaped fuselage. NACA 4415 aerofoil is used the chord length of the aerofoil used in fuselage is 29 inches.
- The ribs are made of balsa wood and the main body is made of cork sheet. this structure would give necessary strength in combination with very light weight .
- In case of aerofoil shaped fuselage, the lift has increased to 15-20% of lift of cylindrical shaped fuselage. The application of aerofoil shaped fuselage is preferable if lift is the main consideration. The plane has gained better lift coefficient within short time after takeoff.

Figure 8.2: Aerofoil shaped fuselage

- But the use of aerofoil shaped fuselage with aerofoil shaped horizontal stabilizer has negative impact on controlling the aircraft by creating some troubles

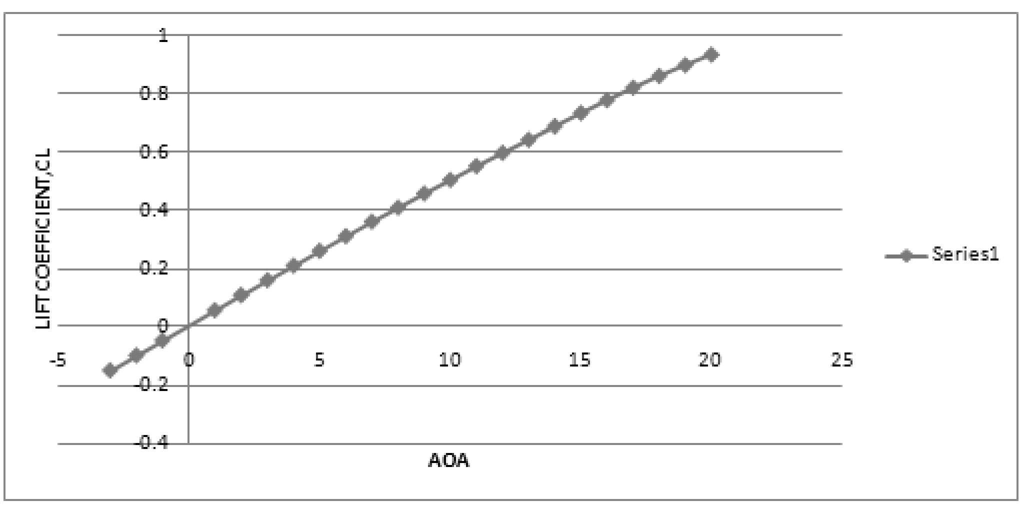


Figure 8.3 a: variation of lift force with angle of attack for velocity 20 m/s

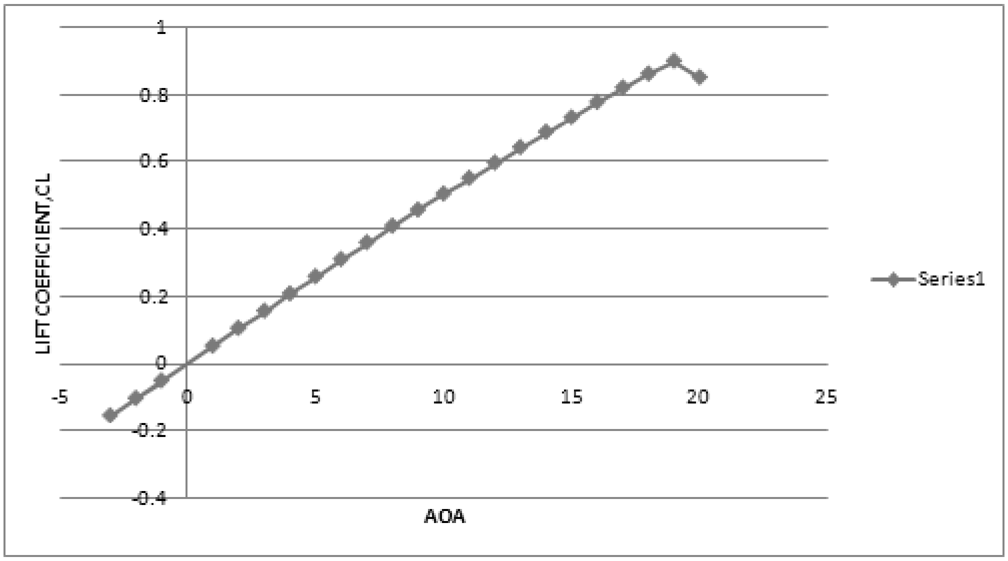


Figure 8.3 b: variation of lift force with angle of attack for velocity 30 m/s

The variation of drag force and coefficient of drag force with angle of attack for plane are shown in Figures respectively. The shape of the drag force vs. angle of attack for plane is parabolic. The drag force increases with the increase of angle of attack. In other words, the shape of the drag force coefficient vs angle of attack curve is parabolic. For velocity 10 m/sat 16◦ angle of attack the corresponding values of drag and coefficient of drag forces are 2.38 N and 0.23874.For velocity 20 m/sat 18◦ angle of attack the corresponding values of drag and coefficient of drag forces are 2.28 N and 0.28734.For velocity 30 m/sAt 19◦ angle of attack the corresponding values of drag and coefficient of drag forces are 3.13 N and 0.31314 respectively.

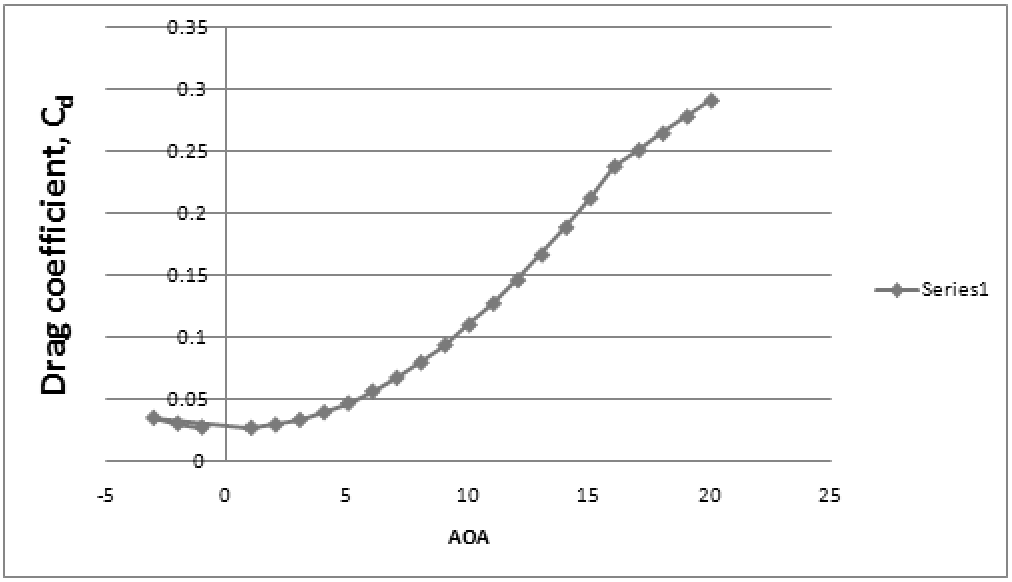


Figure 8.3 c: variation of drag force with angle of attack for velocity 10 m/s

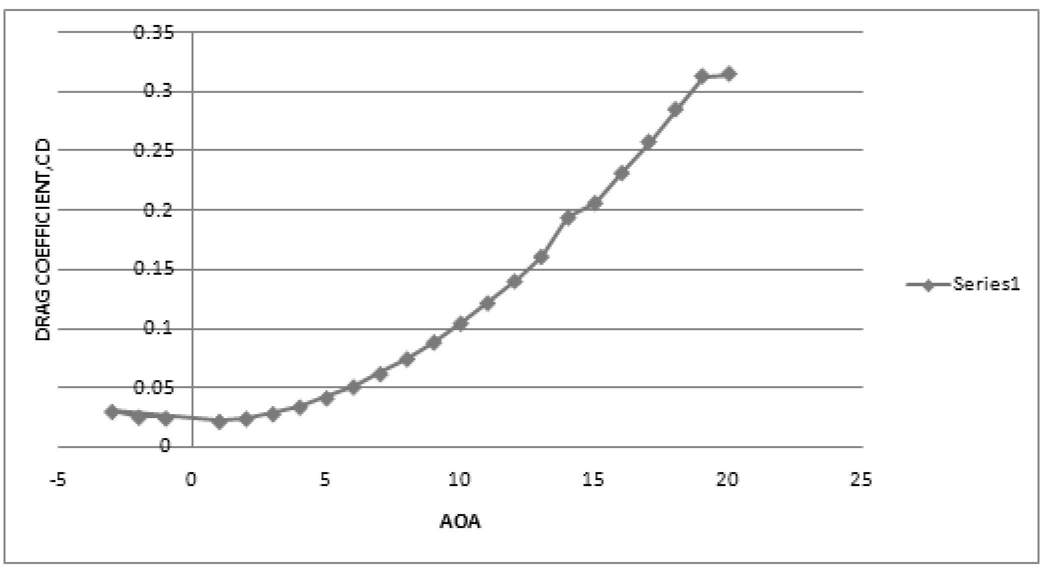


Figure 8.3 d: variation of drag force with angle of attack for velocity 30 m/s

Comparing Coefficient of draft (cd) with coefficient of lift (cl) shows the hyperbolic form. Which means it gives stability during lifting. For velocity 10 m/s, 20 m/s,30m/s CD VS CL graph are shown respectively.

8.3 Flight Troubles:

Insufficient longitudinal stability (stability in pitch).

Problems associated with C.G.

Sudden bumps

Overall unsatisfactory control

8.4 Flight Stability Analysis:

- An aircraft's stability is expressed in relation to each axis:
  lateral stability (stability in roll), directional stability (stability in yaw) and longitudinal stability (stability in pitch).
- Lateral and directional stabilities are inter-dependent.

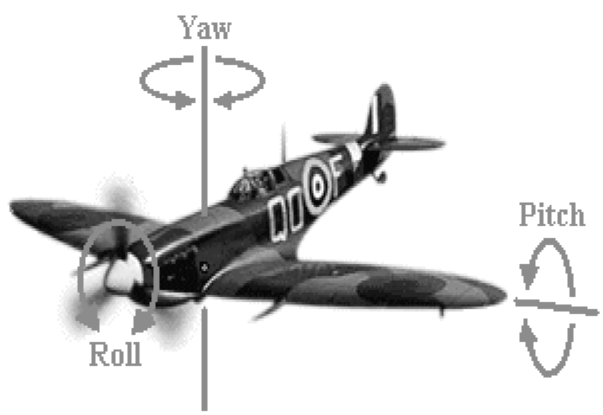


Figure 8.4: Aircraft movement

- Stability may be defined as follows:

  - **Positive stability:** tends to return to original condition after a disturbance.

  - **Negative stability:** tends to increase the disturbance.

  -**Neutral stability:** remains at the new condition

  - **Static stability**: refers to the aircraft's initial response to a disturbance. A statically unstable aircraft will uniformly depart from a condition of equilibrium

  - **Dynamic stability**: refers to the aircraft's ability to damp out oscillations,which depends on how fast or how slow it responds to a disturbance. A dynamically unstable aircraft will (after a disturbance) start oscillating with increasing amplitude. A dynamically neutrally stable aircraft will continue oscillating after a disturbance but the amplitude of the oscillations.

  So, a statically stable aircraft may be dynamically unstable. Dynamic instability may be prevented by an even distribution of weight inside the fuselage, avoiding too muchweight concentration at the extremities or at the CG. Also, control surfaces' max throws may affect the flight stability, since a too much control throw may cause instability, e.g.Pilot induced oscillations.

  - Lateral stability is achieved through dihedral, sweepback, keel effect and proper distribution of weight. But our UAV has a straight wing. When the aircraft is disturbed, the fuselage weight acts like a pendulum returning the aircraft to the horizontal level.

- The tail fin determines the **directional stability**.
  If a gust of wind strikes the aircraft from the right it will be in a slip and the fin will get an angle of attack causing the aircraft to yaw until the slip is eliminated.

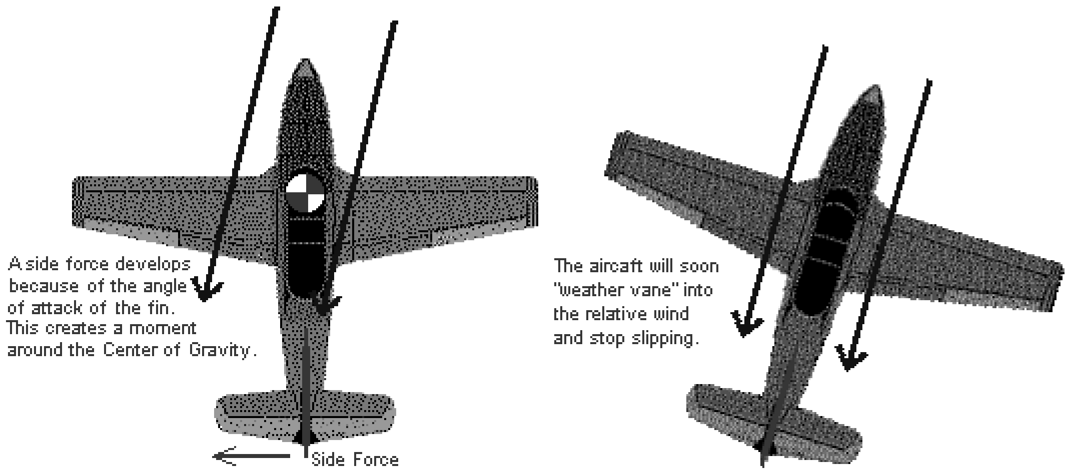


Figure 8.5: Aircraft stability

- **Longitudinal stability** depends on the location of thecentre of gravity, the stabilizer area and how far the stabilizer is placed from the main wing. Most aircraft would be completely unstable without the horizontal stabilizer.

- Our UAV has non symmetrical cambered aerofoil(NACA 4415).Non-symmetrical cambered airfoils have a higher lift coefficient, but they also have a negative pitching moment (Cm) tending to pitch nose-down and thus being statically unstable, which requires the counter moment produced by the horizontal stabilizer to get adequate longitudinal stability. As our UAV's fuselage and horizontal stabilizer both have non symmetrical cambered aerofoil (NACA 4415) negative pitching moment (Cm) problem was very much experienced during the flight test. The pilot found it really hard to control the longitudinal stability of the UAV. The stabilizer provides the same function in longitudinal stability as the fin does in directional stability.

- It is of crucial importance that the aircraft's **Centre of Gravity (CG)** is located at the right point, so that a stable and controllable flight can be achieved. In order to achieve a good longitudinal stability, the CG should be ahead of the **Neutral Point (NP)**, which is the Aerodynamic Centre of the whole aircraft. NP is the position through which all the net lift increments act for a change in angle of attack. Longitudinal stability is also improved if the stabilizer is situated so that it lies outside the influence of the main wing downwash. It has been found both experimentally and theoretically that, if the aerodynamic force is applied at a location 1/4 from the leading edge of a rectangular wing at subsonic speed, the magnitude of the aerodynamic moment remains nearly constant even when the angle of attack changes. This location is called the wing's Aerodynamic Centre.

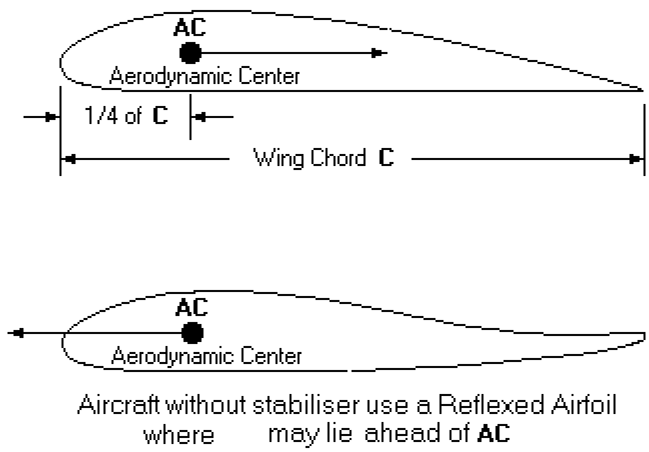


Figure 8.6 Relative position of AC and CP

- In order to obtain a good Longitudinal Stability the **Centre of Gravity CG**should be close to the main wings' **Aerodynamic Centre AC**.

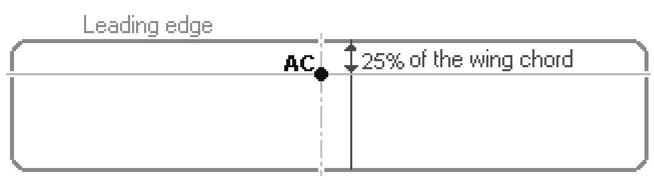


Figure 8.7: Relative position of CG and AC

- Stabilizers are therefore often staggered and mounted at a different height in order to improve their stabilizing effectiveness.

8.5 <u>Design Corrections:</u>

wing root fillet

tail area is doubled

strengthening the control surfaces

corresponding adjustment of the C.G.

8.6 Wing Root Fillet:

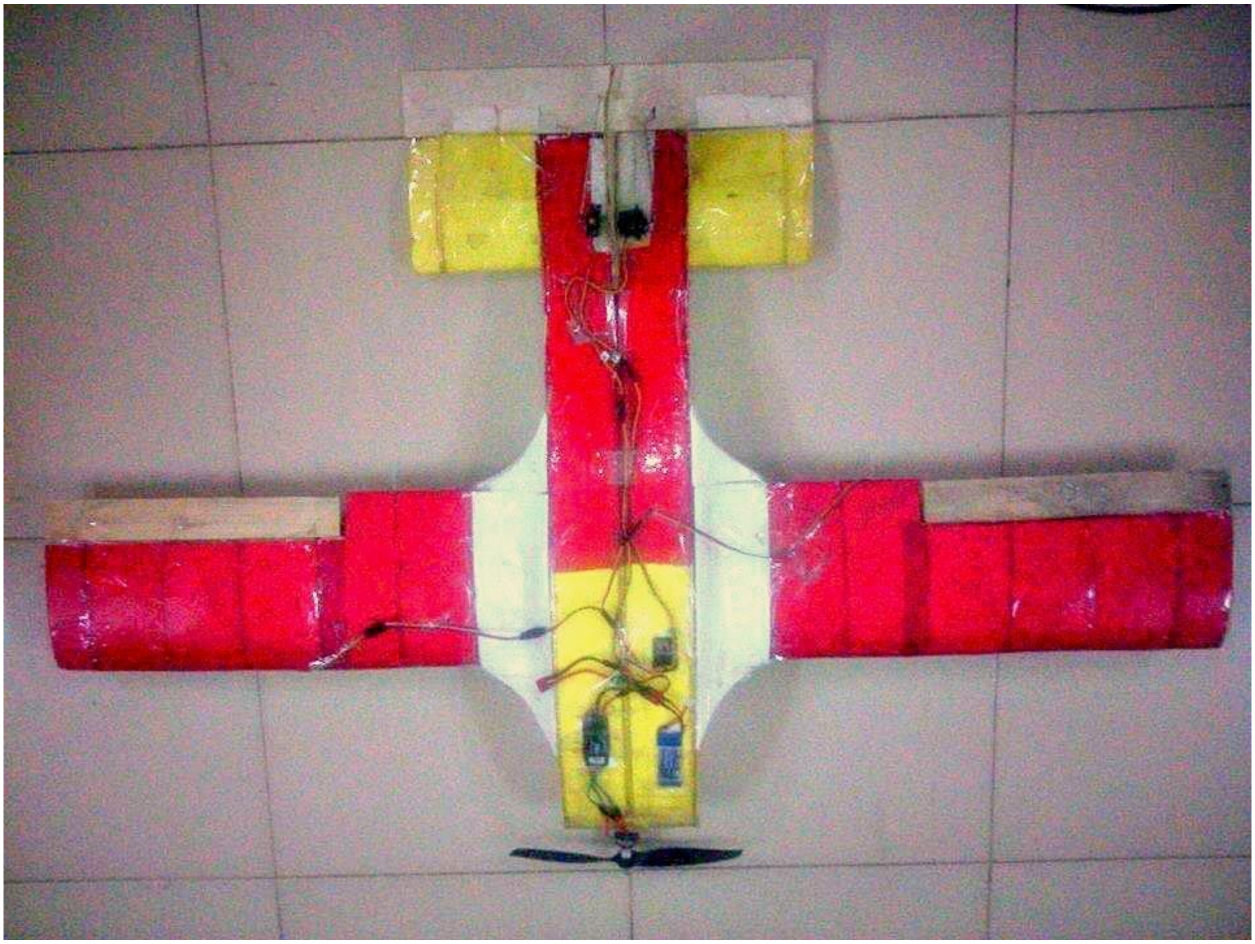


Figure 8.8: Top view of MIST EAGLE EYE wing root fillet

The purpose of wing root (et al) fairing on sub-sonic aircraft is primarily to reduce interface drag. When a wing is joined the fuselage without fairing, the boundary layers of each surface interact with each other causing an accelerated thickening of this layer and premature breakdown into turbulent flow. This results in an increase in form drag.

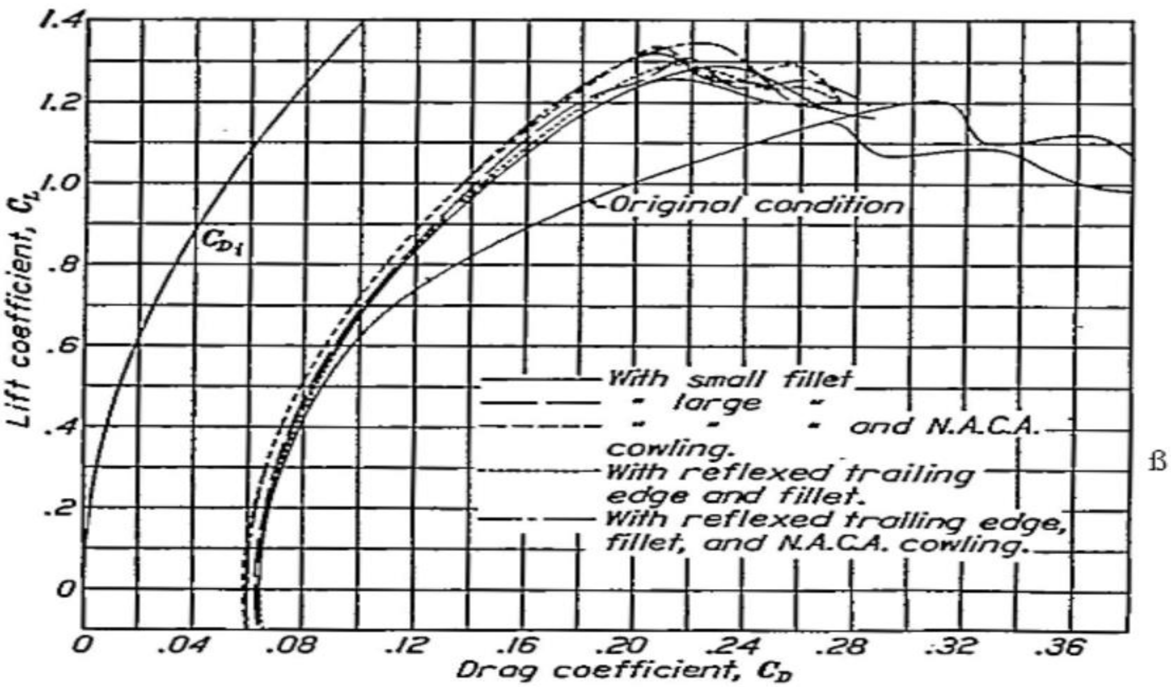


Figure 8.9: Effect of wing root fillet on lift co-efficient.

The common profile for a wing root fairing is a fillet that increases its radius as it progresses from the leading edge to the trailing edge. Once it has reached the trailing, a trailing fillet's radius may be several times that of the starting radius. The ending fillet is washed out with a trailing edge.

The increase in fillet radius is approximately logarithmic. The benefit that a wing root fillet gives a small aircraft—that doesn't cruise much faster than 100 knots—is dubious at best (though it sure looks good). As a matter of fact, adding a fat wing root fairing may have undesirable effects at the low-end of the speed curve and on may end up with a wing that has poor stall characteristics.

8.7 Tail Area is Doubled:

Static stability is proportional to the stabilizer area and the tail moment. Static stability is doubled if the tail area or the tail moment is doubled. Dynamic stability is also proportional to the stabilizer area but increases with the square of the tail moment,

Dynamic stability = (Tail moment) ^2

This means that the dynamic stability becomes 4 times if the tail arm length is doubled.

However, making the tail arm longer or increasing the stabilizer area will move the mass of the aircraft towards the rear, which may also mean the need to make the nose longer in order to minimize the weight required to balance the aircraft.

A totally stable aircraft will return, more or less immediately, to its trimmed state without pilot intervention. However, such an aircraft is rare and not much desirable. We usually want an aircraft just to be reasonably stable so it is easy to fly. If it is too stable, it tends to be sluggish in maneuvering, exhibiting too slow response on the controls.

Figure 8.10: MIST EAGLE EYE with increased tail area

8.8 Second Flight Test Observations and Analysis:

After implementing the design corrections the second test flight was executed in the same atmospheric conditions and environment. The flight was more stable with better control over it than the previous flight. The pilot appreciated the improved longitudinal stability (pitchingmoment).

- Buffeting was least when the fillet was used. The fillet reduced the amplitude of the stabilizer tip oscillations. It increased the maximum lift , reduced the minimum drag , increased the maximum lift-drag ratio of the plane and increased the effectiveness of the elevator about 40 percent .

- Improvement of the flow at wing root and doubling the area of the tail decreased the tendency of sudden bumping.

- Strengthening of the control surfaces resulted in pilot's better and easier control over the UAV.

- The corrections in design finally provided a clean and safe landing too.

8.9 Spy Pen Camera:

The spy pen is a discreet device that allows you to record your environment in both video and audio. It has a MicroSD card slot so one can store up to 16GB of recordings.

Features:

- Tiny size makes it ideal for a variety of uses such as hidden cam, spy cam, etc.
- USB 2.0 standard port, need no drive or circumscribed electric power source neither
- Real time recording in AVI video format
- Playback the video on your computer
- Video compression: AVI video format, 640 x 480
- Memory Capacity: support MicroSD or TF card up to 8GB (not included)
- Recording Mode: Continuous Recording until memory is full or manually off
- Adapter Type: USB adaptor charging cable
- Record time: up to 5 hours

- Size: 145 x 12 x 12mm
- MicroSD card not included. Comes with: Spy Pen, USB Cable, Manual
- Operating System: Support WINDOWS98/98SE/ME/2000/XP/Vista/7/8/MAS OS/ LINUX.

8.10 Third Flight Test:

Finally, our main objective of stable flight control with better lift co efficient was accomplished in our third flight. This time we successfully installed a spy pen camera on the body of the aircraft. The bird's eye view of the flight was captured by the pen camera. Now "MIST EAGLE EYE" was completely ready for reconnaissance mission.

Chapter 9

Recommendations and conclusion

9.1 **Limitations:**

1. The aircraft structure is heavier, due to the necessity of reinforcing wing root at the intersection with the fuselage.

2. The mid wing is more expensive compared withhigh and low.

3. Longitudinal stability is hampered as the stabilizer is situated such that it lies inside the influence of the main wing downwash.
4. Weak installation of landing gear
5. Due to the aerofoil shape of the fuselage, the mounting of the propeller motor got disturbed and the design needed to be compromised to a small extent.
6. During first flight test the longitudinal instability (pitching moment) was a big problem due to induced drag incurred by mid-wing configuration.
7. Due to budget limitation high quality spy camera could not be used

9.2 **Recommendation**:

"MIST EAGLE EYE" is a successful project as it has achieved all the predetermined goals using an aerofoil shaped fuselage has always been a challenging concept to implement,especially in terms of unmanned aerial vehicle. This sort of research is not performed practically quite often. aerofoil shaped fuselage gave 15-20% extra lift to the aircraft but the whole structure of the aircraft sometimes created control problem for the pilot . We have modified our design to minimize those difficulties to some extent but further design improvement can be made to increase the flight performance.

- Better surface finish can be ensured by using better foam sanding technology to reduce aerodynamic drag on the UAV.
- High wing configuration can give better performance
- To avoid stall at lower angle of attack wing of lower aspect ratio can be used although it reduces the lift of the aircraft
- A cowling covering the motor portion may be used in front of the fuselage. This cowling must be of a good aerodynamic shape so that it reduces the aerodynamic drag on the forward portion of the UAV .
- The landing gear should be rigidly mounted for safe landing even on rough surface.
- Linkage between servos and control surfaces should be more robust .link rods may be used instead of push rods with mechanism.
- Use of taper wing will provide

1. Lower Drag
   Helps with overall speed
   Better lift distribution

2. Improve maneuverability

9.3 Conclusion:

"MIST EAGLE EYE" team has successfully developed a project with the help of system engineering approach. The system engineering approach gives us the right way to apply our practical knowledge and fulfill our desired. It can also demonstrate different tasks regarding with the mission requirement and finally our aircraft launched in the sky without facing any critical situation after the required corrections.

This group has created a new era by developing this type of systematic project. The group also hopes that future students from Military Institute of Science and Technology will take part in studying and analyzing the performance of aerofoil shaped fuselage with newer modifications. This had been a unique experience of the project group in conceptualizing, designing, fabricating and finally accomplishing a successful flight test for reconnaissance.

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