Kshitij 2014
the techno-management fest
31st January - 3rd February

LAWS OF MOTION

TUTORIAL

Indian Institute Of Technology, Kharagpur

CONTENTS

1.The problem statement requires

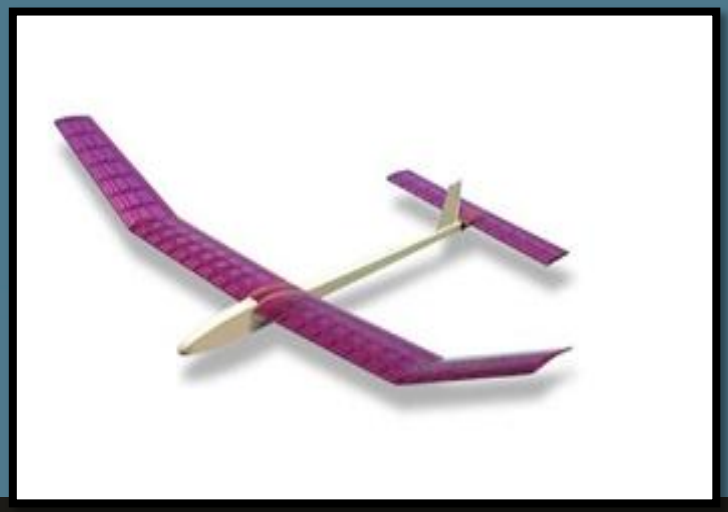
- Designing of a Remote Controlled electric powered aircraft which must take off from a runway strip, drop a load and land in a specified region.
- The details of the problem statement and other details related to the events can be found in: http://www.ktj.in/#Laws_of_Motion

2. Theory of flight

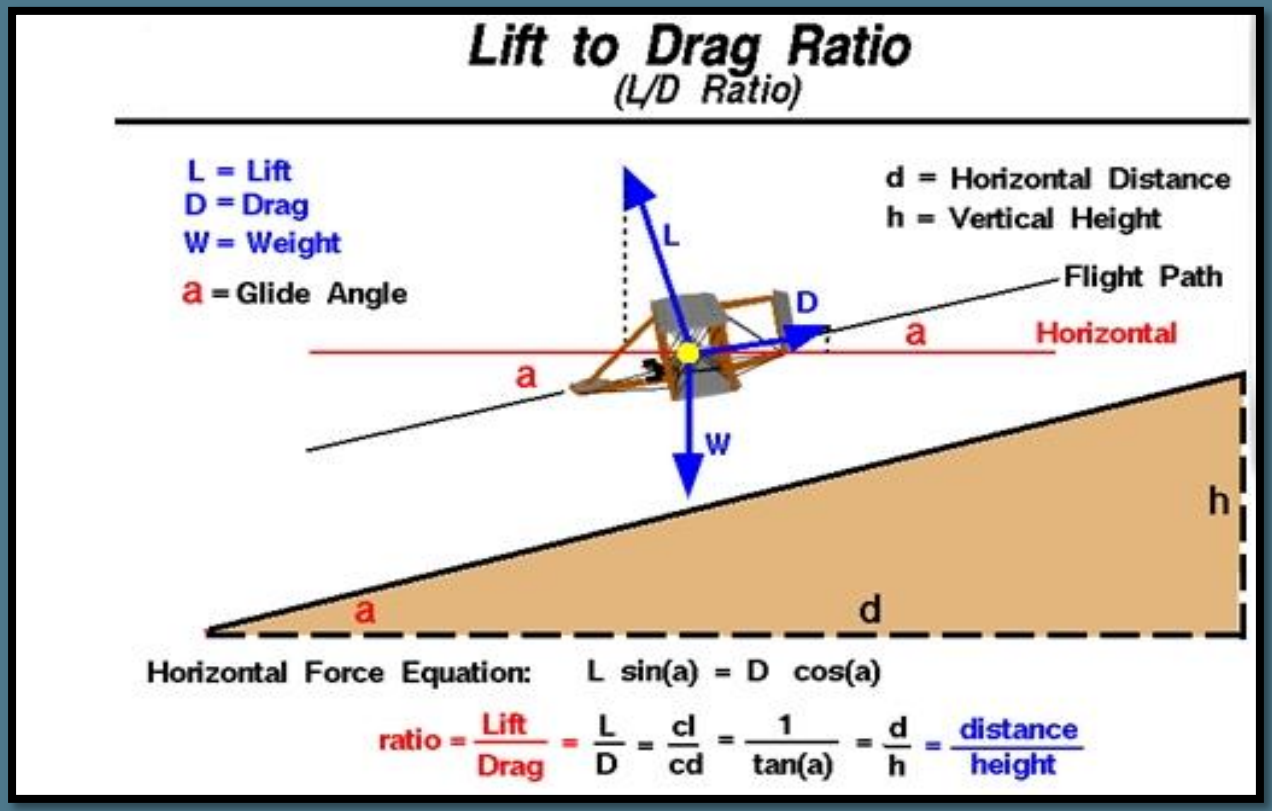
How to make your own remote controlled aircraft from scratch ?

3. What are the basic forces acting on an aircraft in flight?

- The ratio of Lift and Drag, describe the glide performance of the craft at given time.
- The more the value of L/D ratio the better would be the aircraft performance.



- For a non-powered aircraft, L/D ratio of 10-12 is preferred; whereas in case of a powered aircraft, L/D ratio of 6-8 is preferred.



Lift is directed perpendicular to the flight path and drag is directed along the flight path.

- Because lift and drag are both aerodynamic forces, the ratio of lift to drag is an indication of the aerodynamic efficiency of the aircraft.

- Under cruise conditions lift is equal to weight.

- A high lift aircraft can carry a large payload. Under cruise conditions thrust is equal to drag. A low drag aircraft requires low thrust.

Following is the equation indicates the relation between lift **L** and the lift coefficient **Cl**. Where, **r** => Air density **V** => Velocity **A** => Wing area

$$L = .5 * Cl * r * V^2 * A$$

Similarly, the drag equation relates the aircraft drag **D** to a drag coefficient **Cd**:

$$D = .5 * Cd * r * V^2 * A$$

Dividing these two equations give: **L/D** = **Cl/ Cd**

Hence, **lift to drag ratio** is equal to the **ratio of their corresponding constants**. **Lift and drag coefficients** are normally **determined** experimentally **using a wind tunnel**. But for some simple geometries, they can be determined mathematically.

4. Parts of aircraft

- The **wing** supports the aircraft.
- The **tail** surfaces provide stability.
- The **fuselage** holds the wing and tail in proper relationship to each other and also provides cockpit space for the motor and servos.

5. Lift generation

- Lift is generated on the basis of **Bernoulli's principle.**
- Cross section of a wing is known as an "***Airfoil".***
- **Upper edge of an airfoil is *longer than the lower edge***

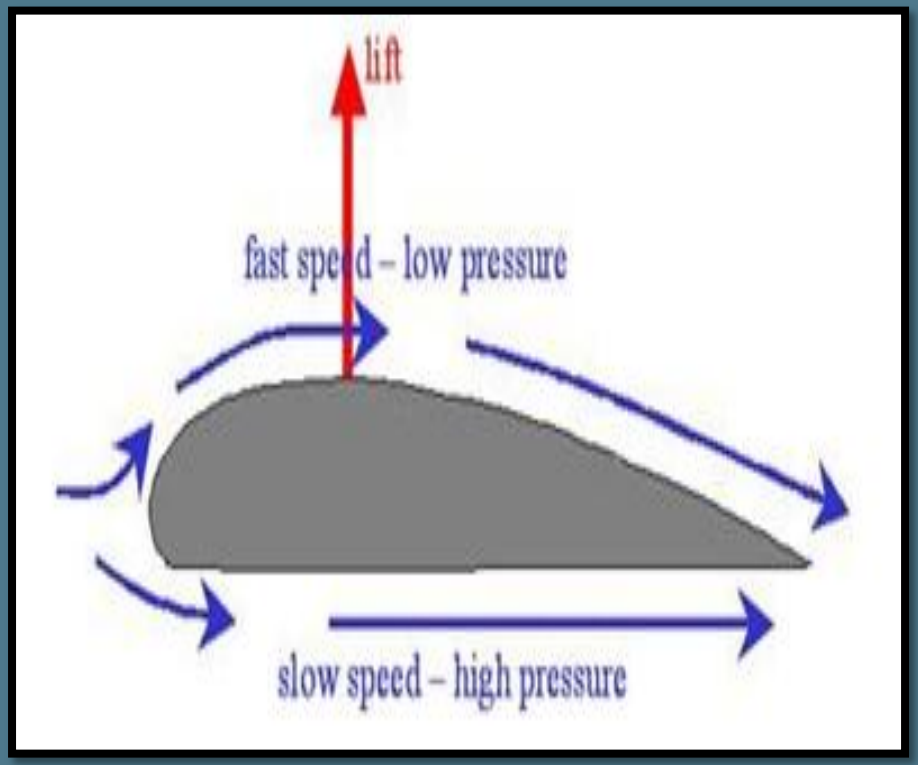
Time taken by air to travel through *both the edges* is **same**.

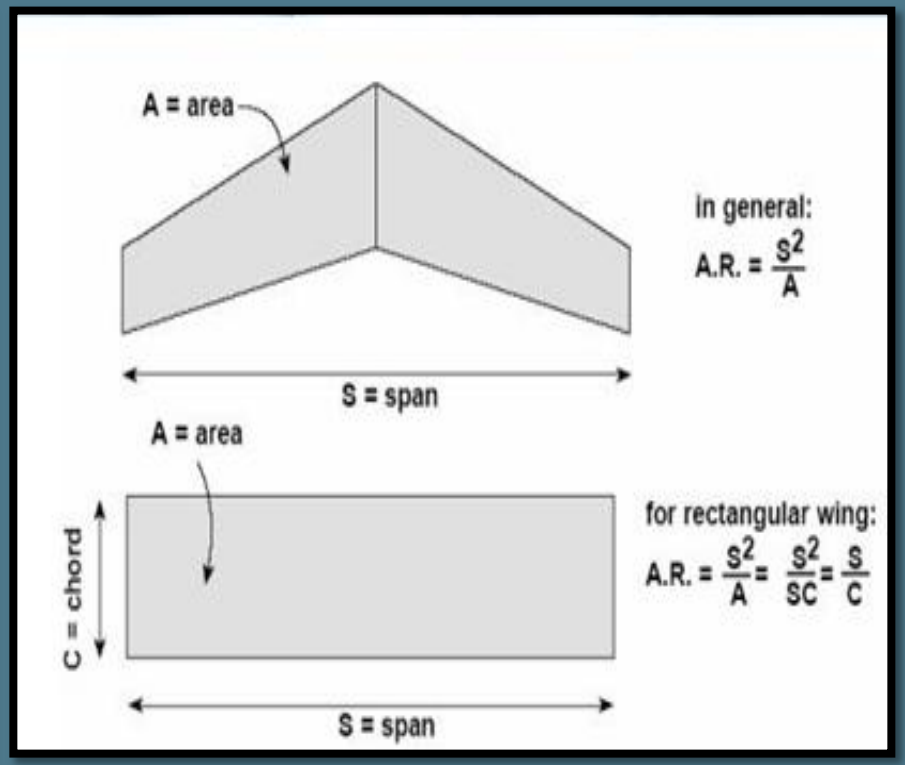
- Bernoulli's principle :**PL+ℓvL2 /2=PU+ℓvu2/2**.
- Hence the air through smaller length acquires **lesser speed**, hence **higher pressure**.

Lift can be assumed to be acting at aerodynamic centre of airfoil.

- Aspect ratio =S^2/A.
- Higher aspect ratio reduces drag, leading to higher efficiency.

LAWS OF MOTION

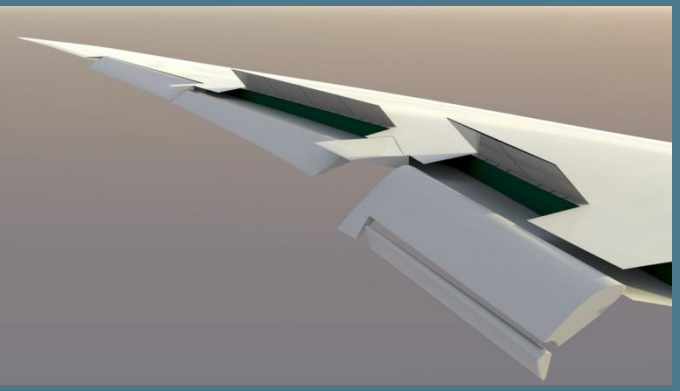


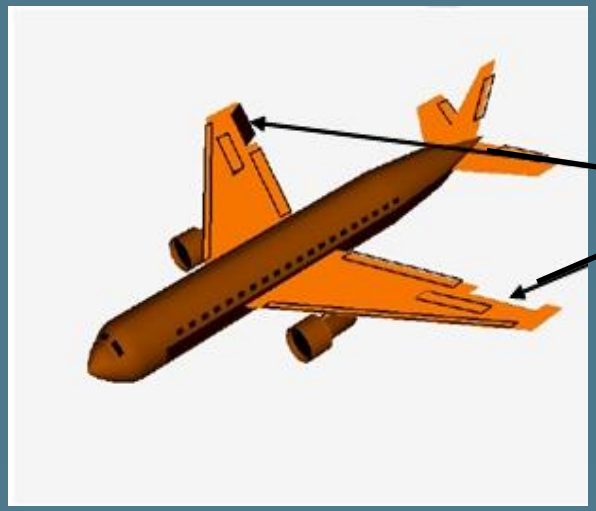


6. Three basic control surfaces:

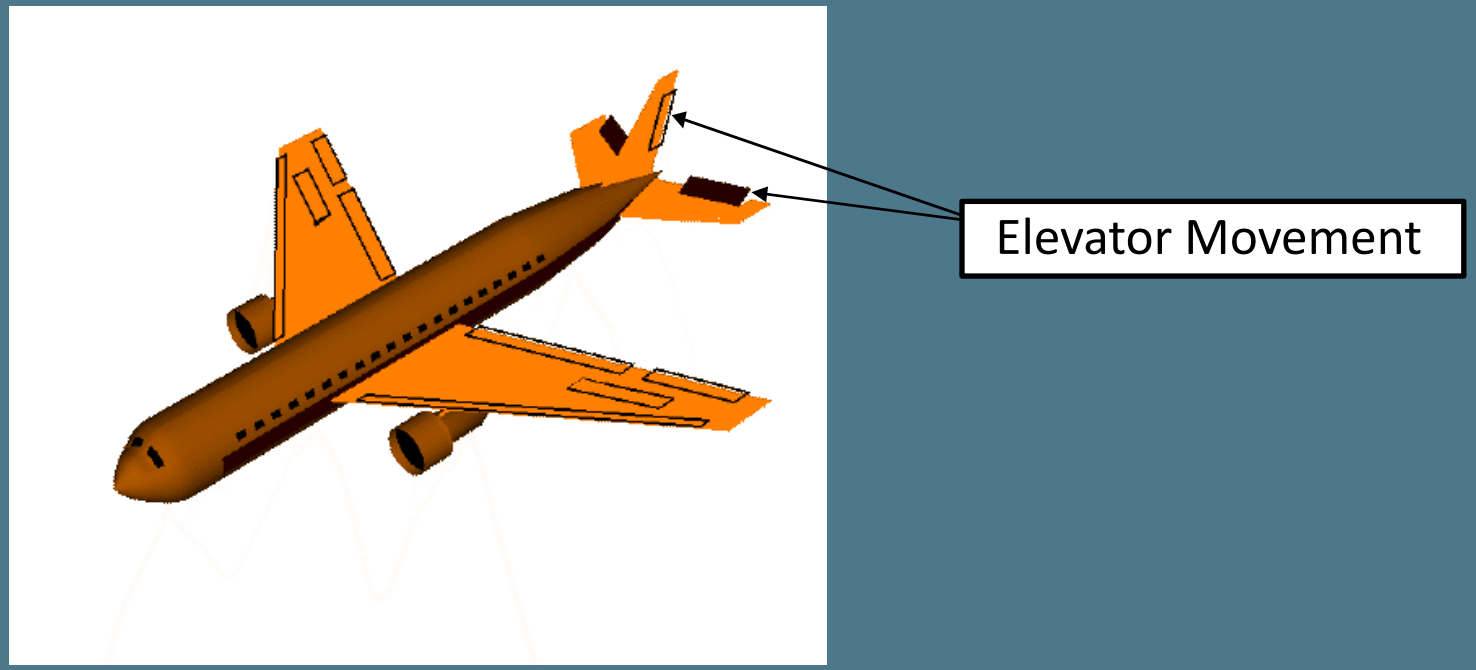
- Ailerons.
- Elevators.
- Rudder.

Aileron movement showing right wing down and left wing down movement known as **banking**.

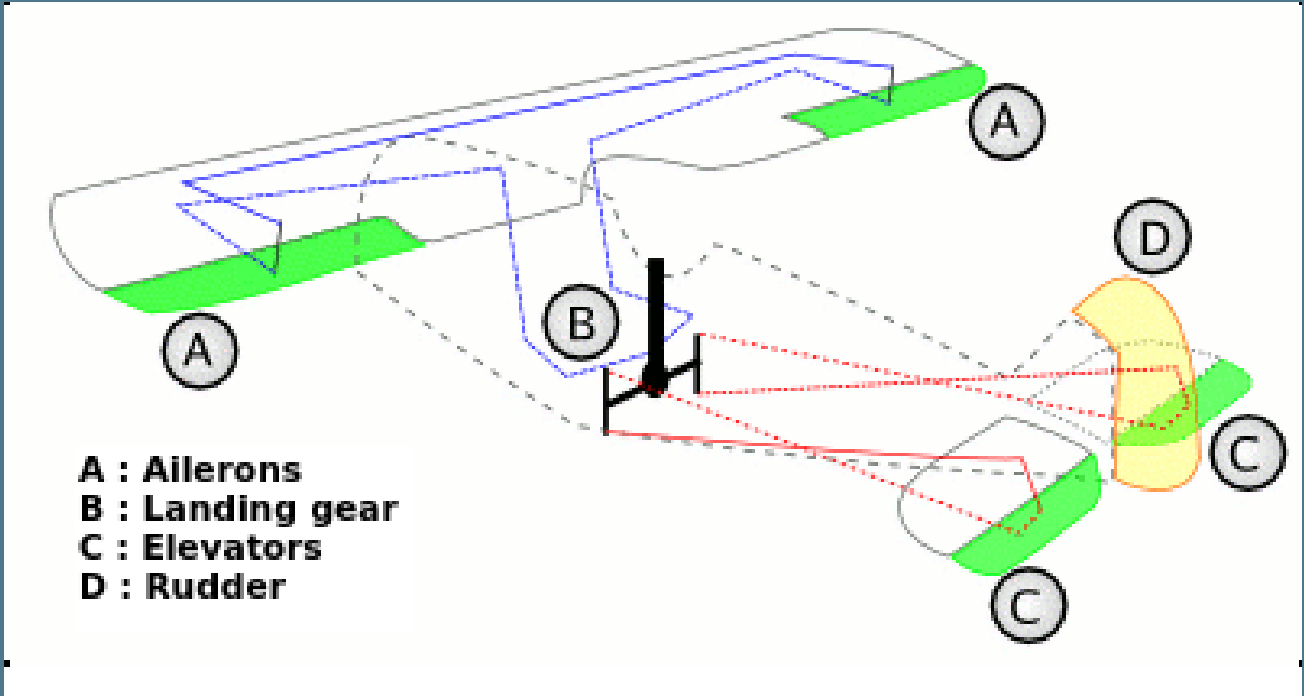




Elevator movement showing nose up and nose down movement of aircraft



7. Control Surfaces of a aircraft

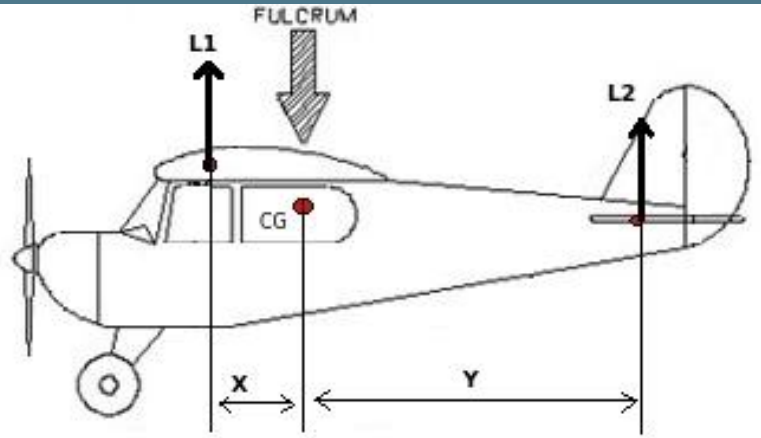


8. Stability

- It is the ability of the aircraft to reject any in-flight disturbance like sudden gust or downwash.
- A stable aircraft always remains in steady flight (constant heading and speed) irrespective of any disturbances.
- Dihedral wing configuration is used to give aircraft inherent roll stability.
- Similarly proper C.G placement gives us pitch stability.

Now that we've understood the basic theory of aircraft lets start making one.

9. Trimmed Flight



L1 * X = L2 * Y (must hold)

L1 : Lift from main wing
L2 : Lift from tail
X : Distance between CG and aerodynamic centre of main wing
Y : Distance between CG and aerodynamic centre of horizontal stablizer

10. Steps to make an aircraft

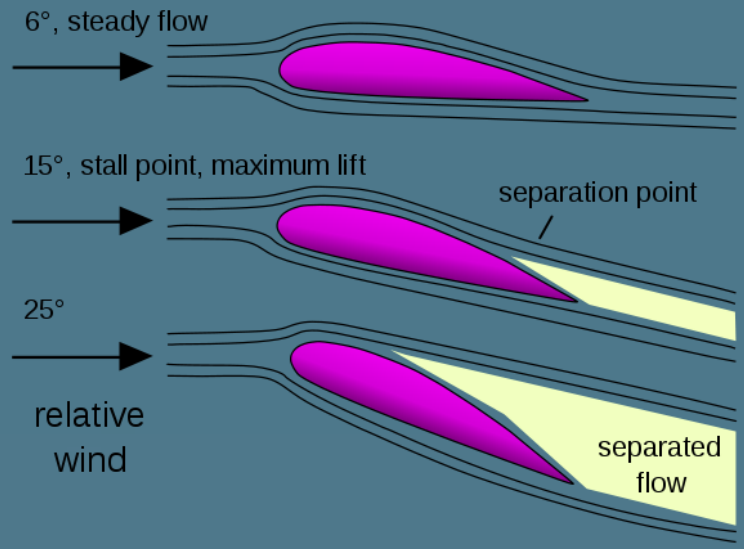
- Decide the span of the wing according to the weight it has carry, aspect ratio and hence the cord length.

- Look for an airfoil which has these basic features:
    - Low Reynolds's no.
    - High L/D ratio.

  Following database will help you choose an appropriate airfoil. Link for the database:
- www.ae.uiuc.edu/m-selig/ads/coord_database.html
- Look for low Reynolds's no. or sailplane airfoil.
- Make sure the airfoil design is simple and not very difficult to fabricate .
- Softwares like *javafoil* can be used to find lift coefficient of airfoils.

Stall Angle :

- A **stall** is a reduction in the lift coefficient generated by a foil as angle of attack increases.
- This occurs when the critical angle of attack of the foil is exceeded.
- The critical angle of attack is typically about 15 degrees, but it may vary significantly depending on the fluid, foil, and Reynolds number.



- 15 degrees angle which is known as Angle of Attack after which the lift suddenly decreases
- One can judge stall angle by using soft wares like java foil

11.Structures

- Next step is Choosing material for construction, balsa wood and high density thermocole, construction foam , Styrofoam.
- Reinforcements for additional strength and preventing damage while landing .
- Covered with polymer sheets, butter paper .

12.Controls

- Ailerons are used for roll control, usually ailerons are not preferred in aircrafts as it leads to decrease in altitude.
- Rudders are used to control heading.
- Elevators are used to control altitude.
- We generally use both ailerons and rudder control for easier turning airfact

13.Making a Balsa wood aircraft

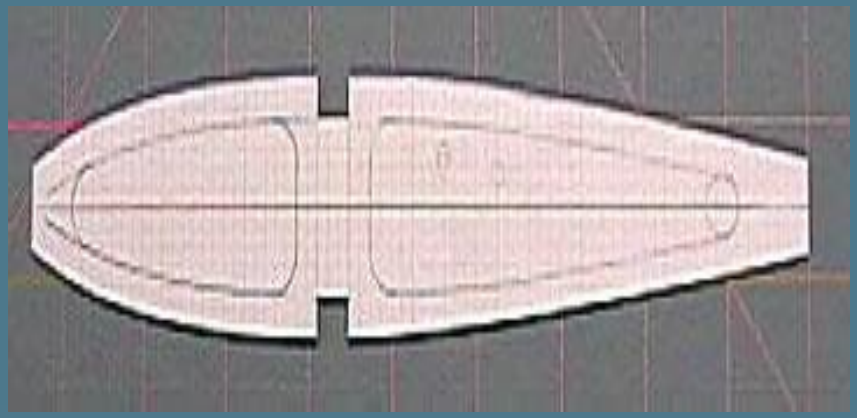
The four basic components are:

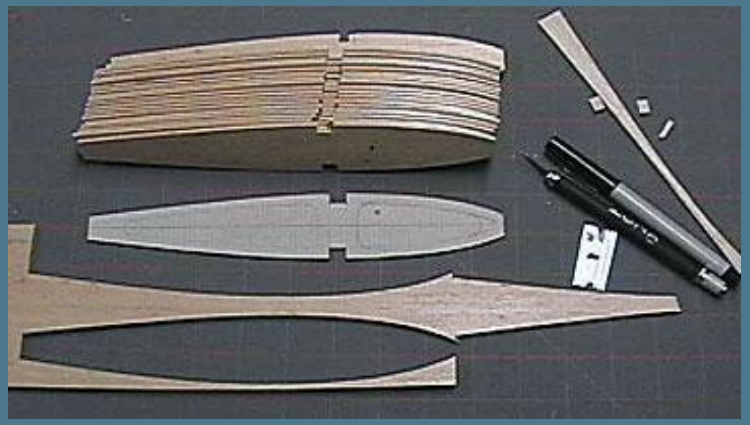
1. The wings.
2. The Fuselage.
3. The rudder.
4. The stabilizer and elevator.
5. The landing gear.

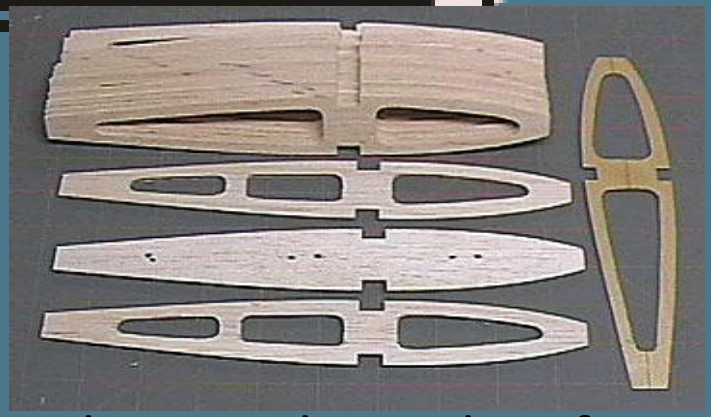
Making Ribs

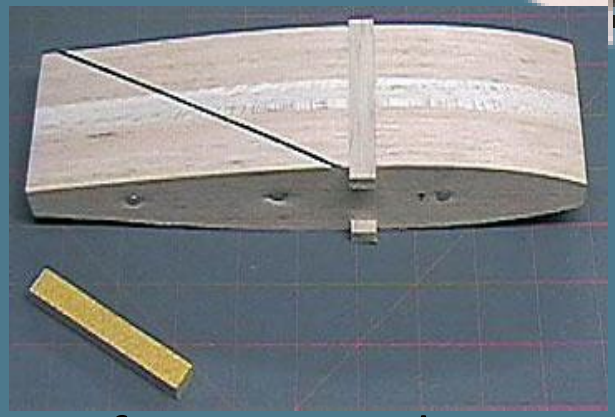
- Ribs incorporate the airfoil shape of the wing, and the skin adopts this shape when stretched over the ribs.

- Number of ribs varies depending on the size of the wing and the required structural strength.







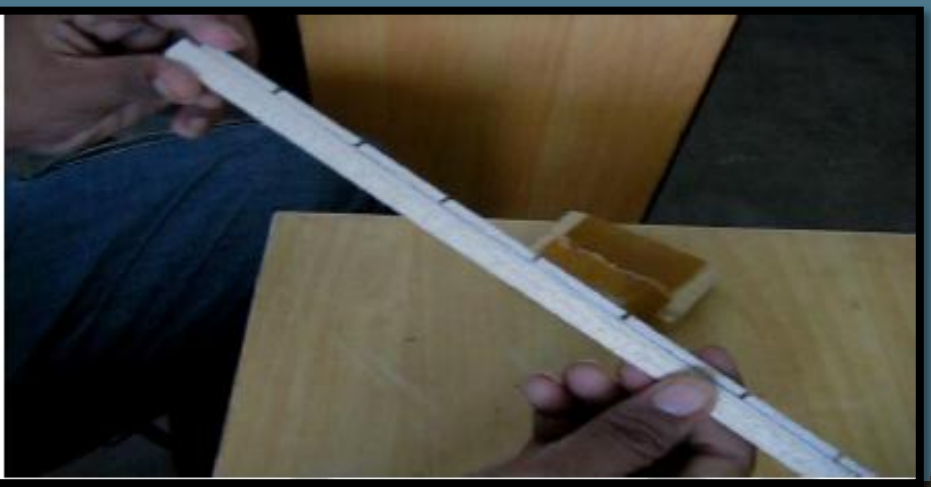


Ribs must have slots for span wise reinforcements known as **spars**.

13.Leading & Trailing edges

- **LEADING EDGE** :The forward most part of the wing running the full span of the wing. Normally the leading edge is a stick of balsa.

- **TRAILING EDGE** :The backward most part of the wing running the full span of the wing.



LAWS OF MOTION

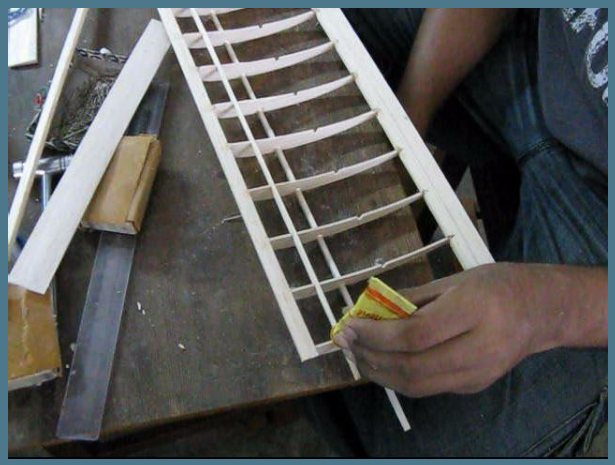
14.Making Wings

- Make slots in leading and trailing edge.

- Ribs are placed in these slots and glued.

- Spars are placed along span-wise direction , they provide strength against bending stresses.

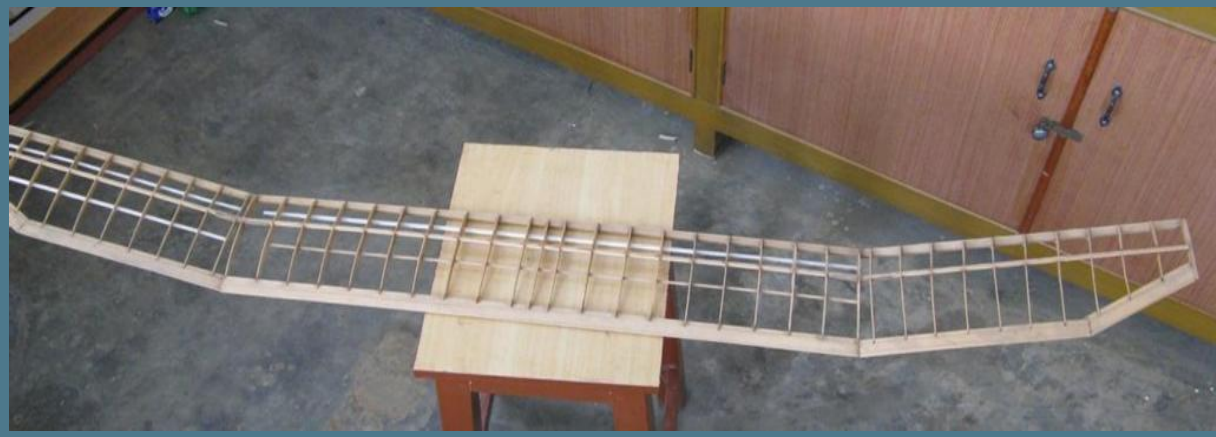
LAWS OF MOTION

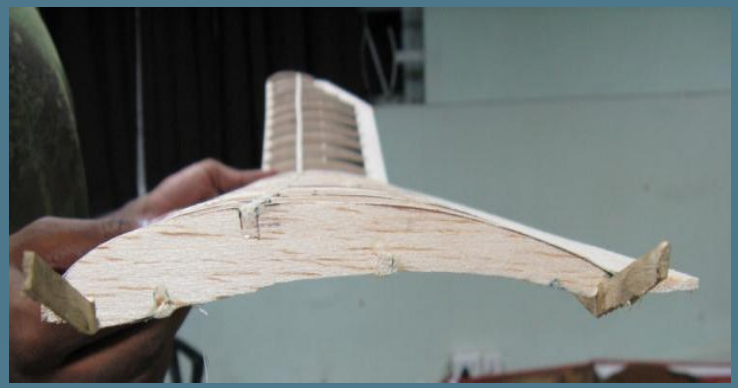



- Both leading and trailing edge are first glued and are later sanded to fair into the ribs.

- Skin of the wing is then tightly glued.

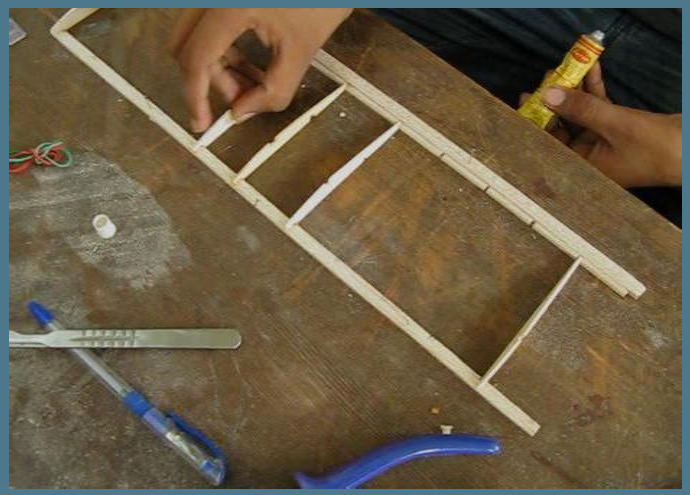
The extruding part are used to fix winglets at a certain angle to the main wing. This angle is called **cant angle**.

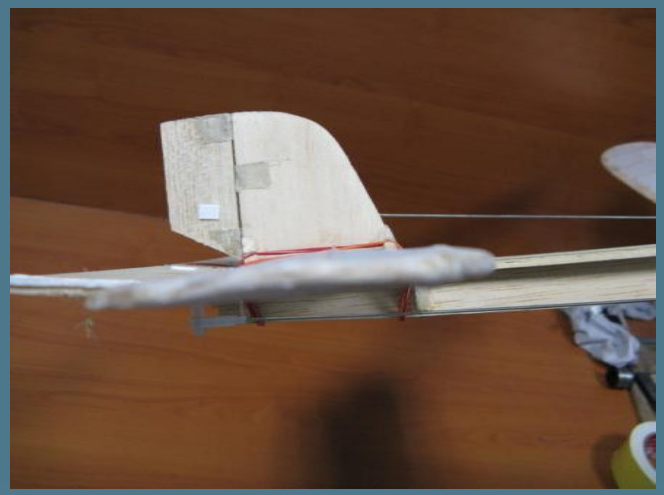




15.Horizontal tail plane

- Tail plane is made in the same way as the wings.
- Only difference being the airfoil used here is symmetric.
- Tail plane's rear portion are the moving control surfaces called **elevators**.
- Vertical tail plane is placed on top of the horizontal tail.





16.Fuselage

- The fuselage performs the function of holding the wing and tail in proper relationship to each other.
- It also houses the control-components viz. batteries, servos.
- Should be made with least weight.
- Care must be taken to place tail and wing in such a way so that.
- The front area of fuselage should be kept minimum for lower drag force.
- Width and height of fuselage should increase slowly and smoothly to decrease the drag.

17.Landing Gear

Landing gear help the aircraft to take off from the ground just like a real plane. Mount the landing gear on the fuselage using rod linkage which should be strong enough to sustain jerks during landing. The CG of the aircraft should be between the front and rear wheels.

Preferably small size landing gears are used to reduce air drag.

Some typical types of Landing gears are:

1. Tricycle Landing Gear

One wheel is in the nose of the aircraft and the other two, the main gear, are under the wing.

2. Tail-dragger Landing Gear

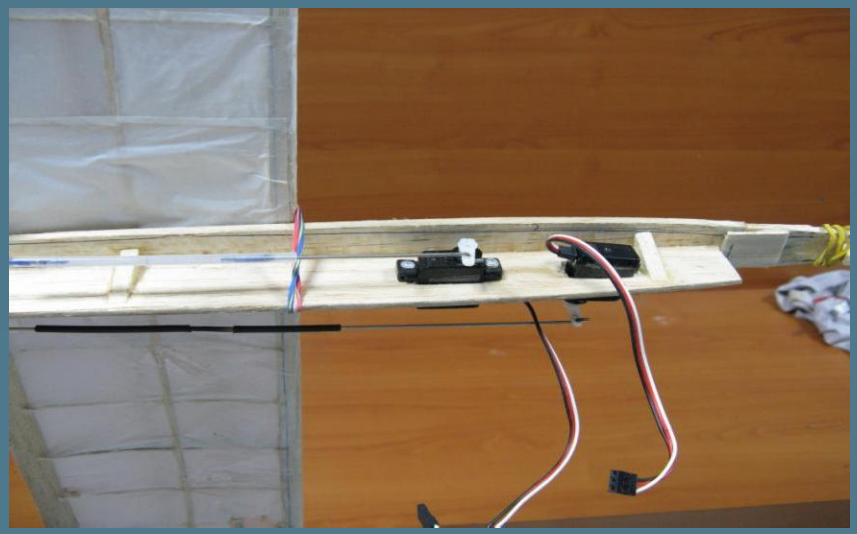
- Unlike the tricycle gear, this configuration causes the tail of the airplane to be in contact with the ground until the plane picks up speed.
- Typically the tail will rise off the ground and the plane will roll along on the mains for a bit before the plane gets airborne.
- This design is commonly seen on low-wing aircraft

3. Retractable Landing Gear

- Retractable landing gear can be either configuration and rely upon a mechanical or pneumatic system to raise and lower the gear.
- This equipment is used on scale aircraft to give the plane a realistic look while in the air. Retracts will allow the plane to fly faster due to reduced drag.
- A full-function RC plane will use a servo for each function, throttle, rudder, ailerons and elevator.
- A separate RC channel and servo must be dedicated to the retracts, so this means using a five-channel system.
- Video Link:http://www.youtube.com/watch?v=IwTXeKFRWgY

18.Controls

- Two servos can be fixed to the fuselage , one each for elevator and rudder.
- The servos and a 4.8-6 V battery is connected to a receiver
- The receiver can be controlled by a radio signal transmitter
- We use push rod linkages for controlling the control surfaces, one may also use magnetic actuators.



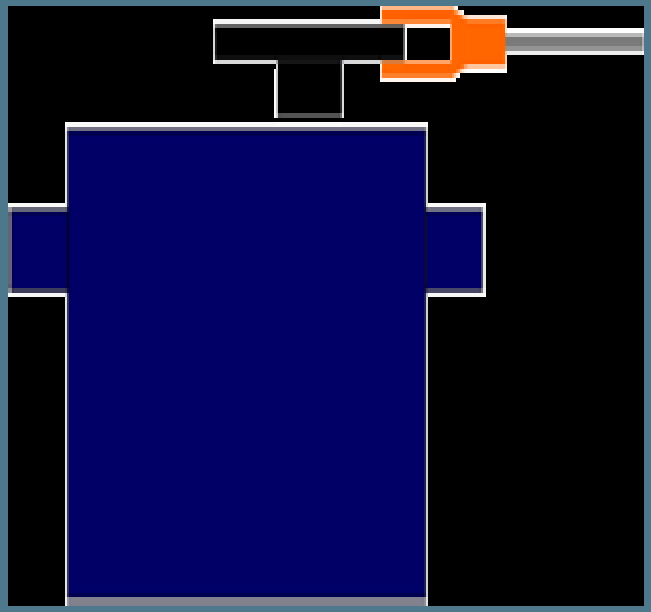
- Generally servo used for ailerons control is fixed on the wing itself.

Entire assembly is called a **pushrod system**.

It includes servo motors, control arms.

- It must align properly with the arm it connects to.

- Must be strong enough to transfer and withstand the maximum load requirement for the entire pushrod/control surface system.



Futaba RC (remote controllers) are available at most aero modelling outlets. They come along with a receiver which is mounted on the model aircraft.
For controlling a simple aircraft a simple 4 channel RC controller will serve the purpose.

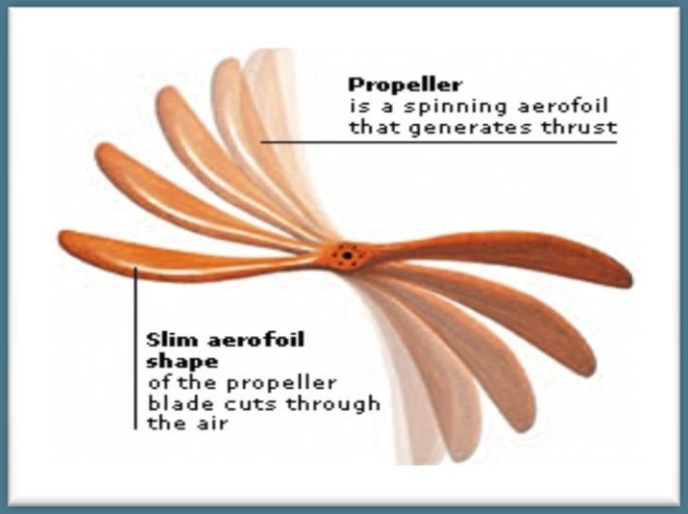
Receiver and Transmitter

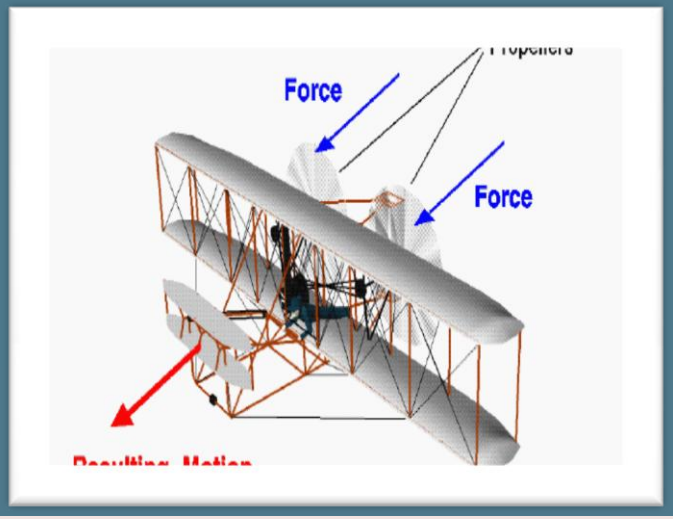
The receivers are mounted on the aircraft help in control. These are available along with the corresponding transmitters.
Each pair of transmitter and receiver operate at different frequencies.

19.Propulsion

- An aircraft can be propelled either using a **motor-propeller combination** or a **jet propulsion system**.
- Generally, *motor-propeller combination is preferred* in aero modelling.

A propeller, when rotated at high speeds by a sufficiently powerful motor, creates an airflow in the direction opposite to the heading, thus creating thrust.





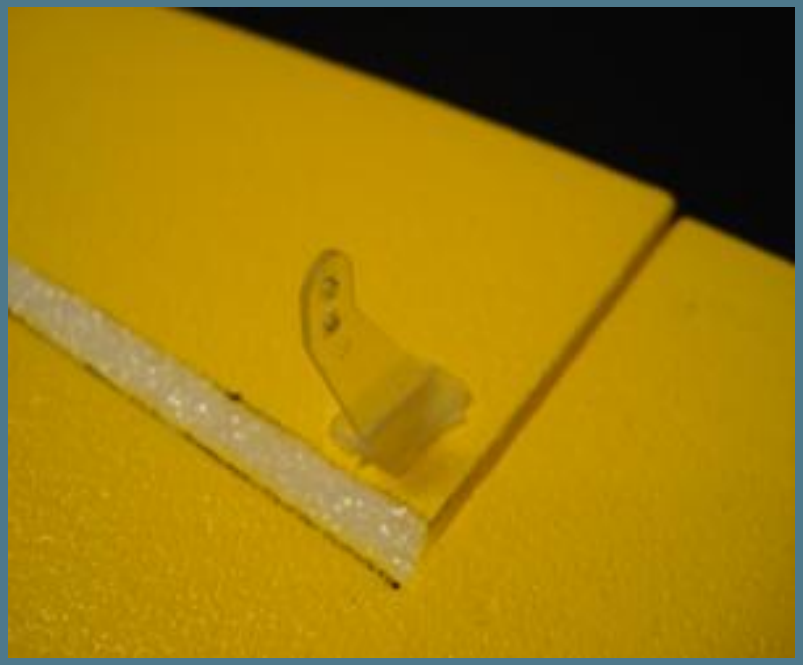
20. The Control Horns

In order to mount each of the control surfaces to their servos:

- First install control horns onto each of the control surfaces.
    - A variety if materials can be used to make these. One can use plastic control horns that are included in a GWS airplane kit.
    - These can also be cut-out from any stiff material.
- Cut slots for the horns on the side of the surface where you intend to mount the servo.
    - These slots should be located a short distance from the hinge of the surface.
    - The longer the distance the slot is from the hinge, the less the control surface will be able deflect.

It is important to select a location for the slots that will suit the needs of your airplane. You may mount it as close to the hinge as possible.

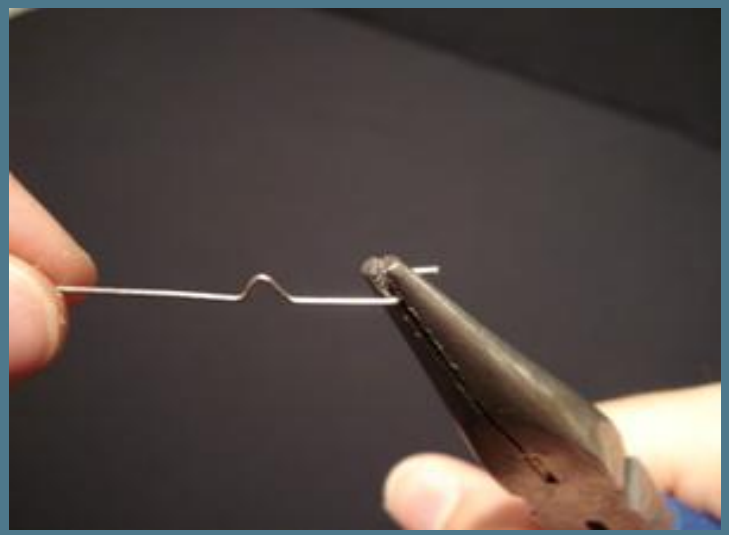
Once a slot is cut for the control horn, install the control horn by gluing it with hot-glue. A finished control horn is shown below:

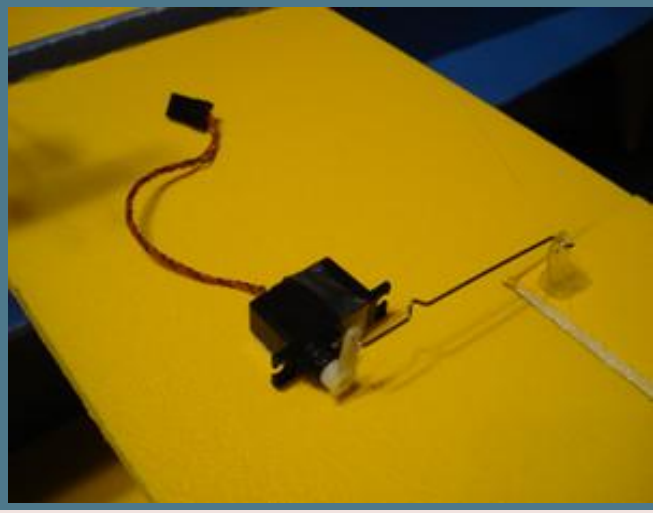


21.The Connecting Rods

Once the control horns have been installed, the metal connecting rods which connect the control horns to the servos must be formed. They are made by bending a thin metal rod into shape.

You may like to use needle-nose pliers to bend the rods into required shape (as in fig.). The v-bend included in the shape of the rod allows the length of the rod to be later adjusted by changing the shape of the bend. The completed shape of the rod is shown below.





22. Motors

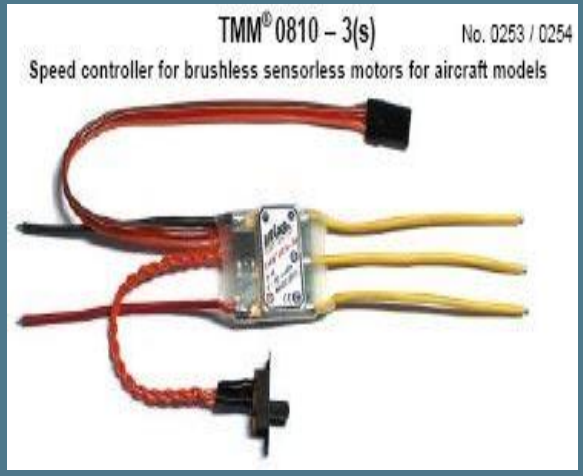
Two types of motors can be used:

1. brushed
2. brushless

- Brushed motors are more rugged, robust, cheaper and easier to use.

- Brushless motors are lighter, less prone to damage due to overheating.

- An electronic speed controller (esc) has to be used to control either of the motors.



The Servos

After the control horns are installed and their control rods are connected, the servos must be installed on the airplane and attached to the control rod.

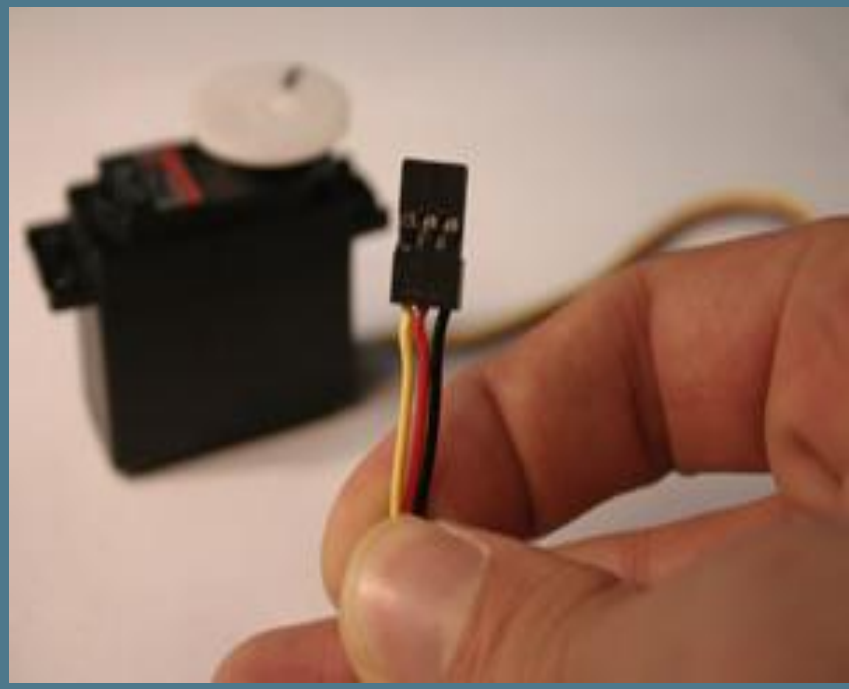
To attach the servos:

- You can use a strip of double-sided equal to the size of the servo.
- The tape is placed on the servo and the servo is placed on the airplane by pressing it onto the airplane firmly.
- When attaching the control rod to the servo, u can use the outermost hole of the servo arm. This gives the greatest amount of control deflection.
- If you would later like to reduce the amount of deflection, it will be done digitally with the transmitter.

Controlling Servos

Below is the most common kind of servo connector. It fits onto standard SIPP pins, and has three leads:

White: Signal
Red: Power (Positive)
Black: Ground

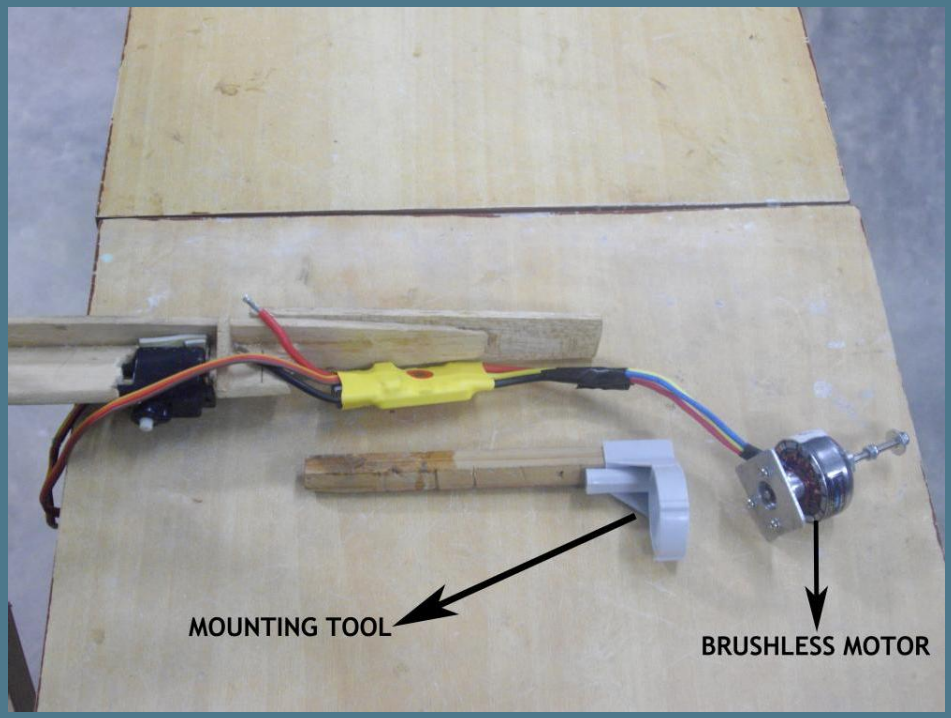


For an R/C aircraft, the most common power sources used are Nickel-metal hydride (Ni-Mh) or lithium-polymer (Li-Po).

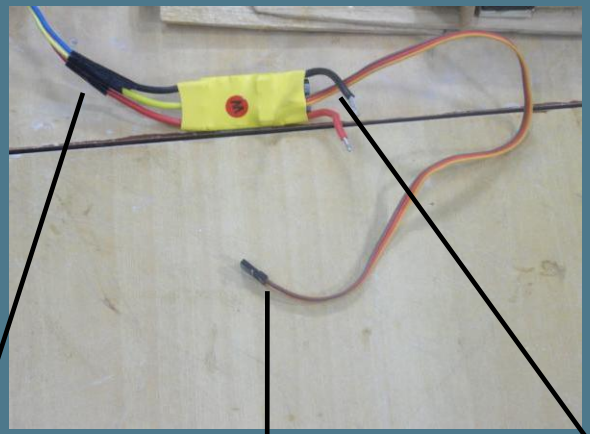
24.Mounting Mechanism

There are various mounting mechanisms, one of them is depicted through the following pictures.

The motor is mounted slightly downwards (2-3 degrees) for producing down thrust. Also it is made to point slightly to the right for balancing the moments produced.



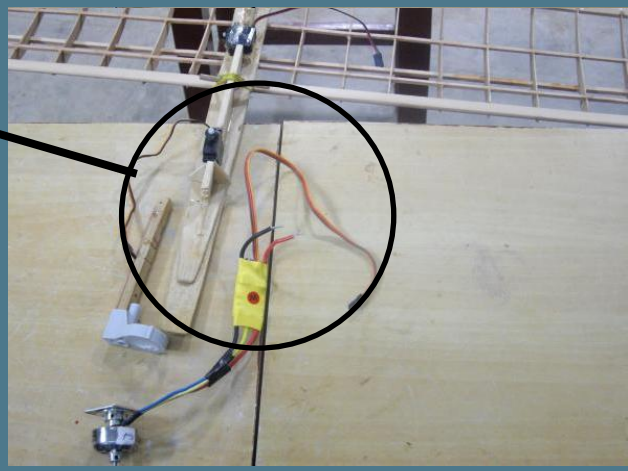
25.Electronics of the Aircraft



These are connected to the motor

This end goes to the receiver

These are connected to the battery



26.Take Off

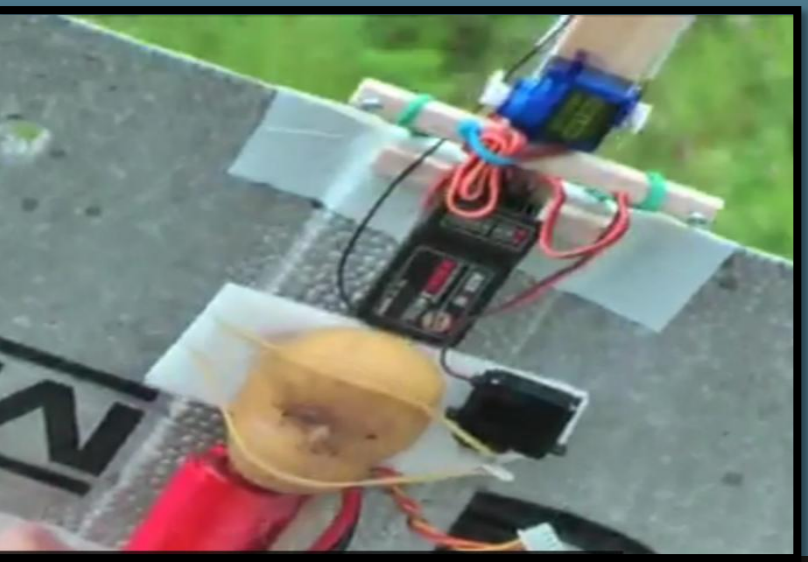
While it may seem daunting to the first-time RC pilot, it isn't too hard to take off successfully. With careful preparation and some practice, you'll soon be taking off with your RC plane and soaring into the skies.

- Bring the engine up to full speed.
- As the plane accelerates, you may need to use gentle pressure on the rudder to keep it going straight.
- As your plane picks up speed, it will begin to lift off.
- If your plane has elevators, give it just a little bit of up elevator now.

27. Payload

Dropping the payload can be done by attachment of an extra bay with the fuselage. The doors of the bay can open up the release and can be controlled by servo-activated mechanism.

Attach the bay near the center of gravity.
Try not disturbing the center of gravity of your aircraft.



Shown in the picture is the mechanism where you can use elastic material to drop the load.

Using a controlled box

In this mechanism, a box can be used which can be controlled to open up in air and drop the load.

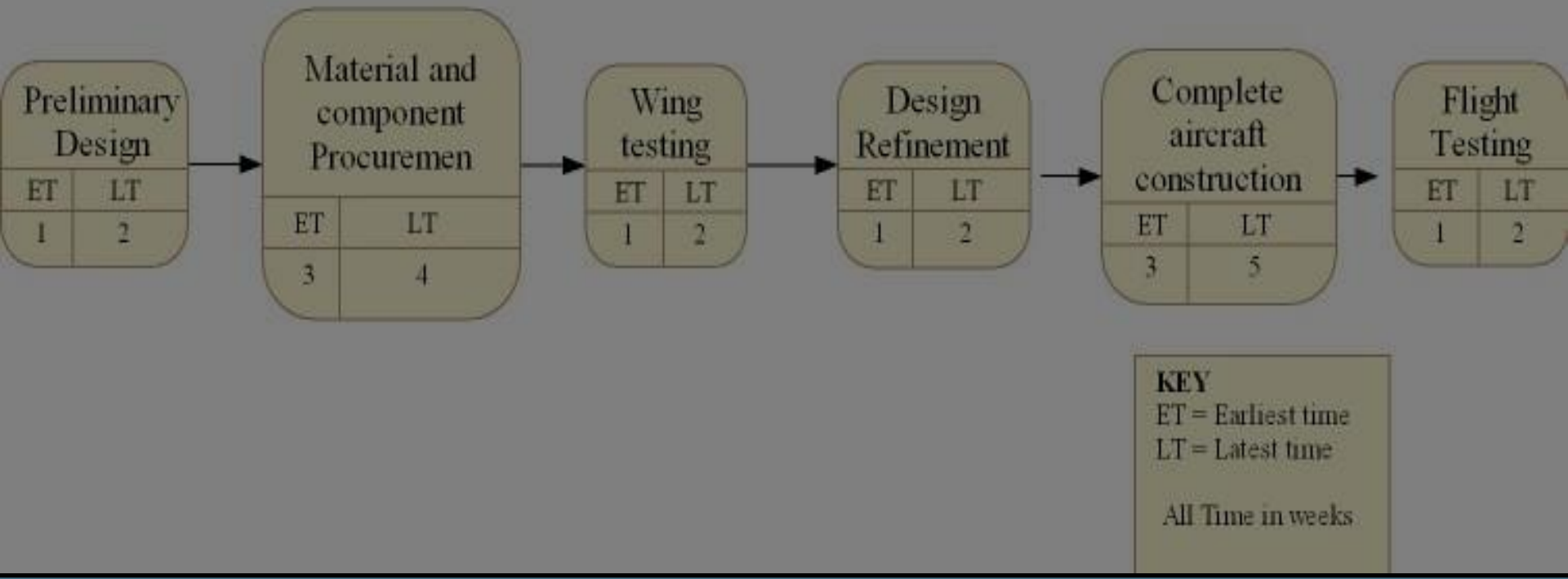
This is another view of controlled box.

Remember to give air gap at the end which could push the load to come out due of air pressure.

The bay can also be internally attached to the fuselage.

The flap can be controlled to open up or close down with the proper mechanism.

PERT CHART


Preliminary Design
ET 1
LT 2
Material and component Procuremen
ET 3
LT 4
Wing testing
ET 1
LT 2
Design Refinement
ET 1
LT 2
Complete aircraft construction
ET 3
LT 5
Flight Testing
ET 1
LT 2
KEY
ET = Earliest time
LT = Latest time
All Time in weeks

28.Video links

- http://www.youtube.com/watch?v=jv3D30RGT-g
- http://www.youtube.com/watch?v=ufmRpaObx0w&feature=related

One of the aircrafts in KGP

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