EXPT NO	NAME OF THE EXPERIMENT
1	Create a paper plane model and calculate the Range and Endurance of the same.
2	Sketching the detailed configuration of Aircraft (Fighter or Commercial)
3	Fabrication on types of wing configuration-Foam or Balsa wood
4	Fabrication of glider using balsa wood (unpowered)
5	Calculate the CG of the modelled Glider & Assessing the aerodynamic performance parameter i.e. Range & Endurance
6	Flight testing on the gliders (belly landing)
7	Design & Fabrication of Ornithopter
8	Design & Fabrication of Lighter Than Air Concepts (Para Gliding)
9	Visualization on the concept of landing.
10	Sugar candy solid propellant
11	Design & Fabrication of powered gliders
12	Case Study on Aircraft Crash Investigation

ELEMENTS OF AERONAUTICS		Semester	3
Course Code	**BAE302**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 8-10 Lab slots	Total Marks	100
Credits	04	Exam Hours	3
Examination nature (SEE)	**Theory**		

Course objectives: This course will enable students to

- To know the history and basic principle of aviation.
- To understand the foundation of flight, aircraft structures, material aircraft propulsion.
- To develop an understanding stability of an aircraft along with its different systems.

Teaching-Learning Process (General Instructions)

These are sample Strategies; that teachers can use to accelerate the attainment of the various course outcomes.

1. Teaching in classroom through Chalk, Talk and ICT
2. Assignment of Home/field work on real-life problem
3. Adoption of Project-based/Activity Based learning
4. Practising the foundational knowledge

PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	Create a paper plane model and calculate the Range and Endurance of the same.
2	Sketching the detailed configuration of Aircraft(Fighter or Commercial)
3	Fabrication on types of wing configuration-Foam or Balsa wood
4	Fabrication of glider using balsa wood (unpowered)
5	Calculate the CG of the modelled Glider & Assessing the aerodynamic performance parameter i.e. Range & Endurance
6	Flight testing on the gliders (belly landing)
7	Design & Fabrication of Ornithopter
8	Design & Fabrication of Lighter Than Air Concepts (Para Gliding)
	Demonstration Experiments (For CIE)
9	**Visualization on the concept of landing**
10	**Sugar candy solid propellant**
11	**Design & Fabrication of powered gliders**
12	**Case Study on Aircraft Crash Investigation**

Course outcomes (Course Skill Set):

At the end of the course, the student will be able to:

- Appreciate and apply the basic principle of aviation.
- Apply the concepts of fundaments of flight, basics of aircraft structures, aircraft propulsion and aircraft materials during the development of an aircraft.
- Comprehend the complexities involved during development of flight vehicles.

EXPERIMENT 1

Aim: Create a paper plane model and calculate the Range and Endurance of the same.

Tools: A4 Sheet, Scale, Tape & Timer

Introduction: The origin of folded paper gliders is generally considered to be of ancient China, although there is equal evidence that the refinement and development of folded gliders took place in equal measure in Japan. Certainly, manufacture of paper on a widespread scale took place in China 500 BCE. It is impossible to ascertain where and in what form the first paper aircraft were constructed, or even the first paper plane's form.

For over a thousand years after this, paper aircraft were the dominant man-made heavier-than-air craft whose principles could be readily appreciated, though thanks to their high drag coefficients, not of an exceptional performance when gliding over long distances. The pioneers of powered flight have all studied paper model aircraft in order to design larger machines. Leonardo da Vinci wrote of the building of a model plane out of parchment, and of testing some of his early ornithopter, an aircraft that flies by flapping wings, and parachute designs using paper models. Thereafter, Sir George Cayley explored the performance of paper gliders in the late 19th century. Other pioneers, such as Clément Ader, Prof. Charles Langley, and Alberto Santos-Dumont often tested ideas with paper as well as balsa models to confirm (in scale) their theories before putting them into practice.

With time, many other designers have improved and developed the paper model, while using it as a fundamentally useful tool in aircraft design. One of the earliest known applied (as in compound structures and many other aerodynamic refinements) modern paper plane was in 1909.

Procedure:

Step 1:

Crease a piece of letter-sized paper in half lengthwise. Get a piece of printer paper that’s a rectangle and lay it on a flat surface. Fold the paper in half lengthwise so the paper looks like a long rectangle. Crease the fold with your fingernail before unfolding the paper again

Step 2:

Bring the top corners toward the center crease. Once the paper is flat again, grab one of the top corners and fold it toward the crease you just made to form a triangle. Press along the fold with your fingernail so the fold stays in place. Repeat the fold along the other top corner so the top of your paper forms a point

Step 3:

Fold the angled top edges toward the crease again. Grab the new top corner on one side of your paper and fold toward the crease to form a long triangle. Run your fingernail across the fold to secure it in place. Fold the other top corner in the same way so your piece of paper looks like a large triangle.

Step 4:

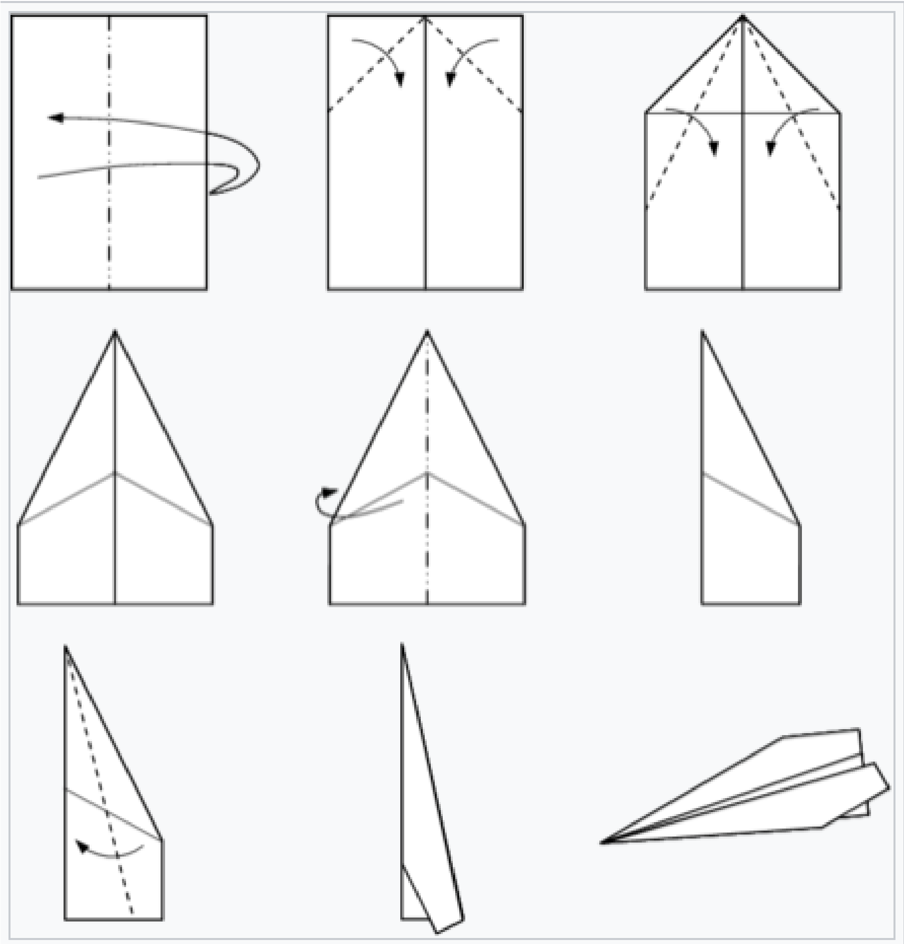
Fold the paper along the centerline. Use the first crease you made as a guide for making your next fold. Fold the airplane in half along the crease so the triangles you made are on the inside. Slide your fingernail across the crease so the fold stays in place.

Step 5:

Crease the angled side toward the center fold to create the wings. Bring the angled side of the paper to the fold you just made down the middle. Crease the paper with your knuckle or fingernail. Flip the paper airplane over to create the wing on the other side. Once both sides are creased, unfold them slightly so the plane is flat on top.

Make sure your wings are symmetrical to one another so your plane stays level when you throw it. It can fly far if thrown correctly. The best way to throw is to grab the bottom of it between the back and middle. Keep your arm completely level or slightly tilted up while stepping forwards and swinging it ahead. Then let go. It takes some practice to master, but the better you get, the faster and further your paper airplane will go.

Make different designs and fly.



Result: the plane built is found for its range & endurance and noted.

Instruction: Use the given A4 sheet and build any other paper plane design and paste it in Record book.

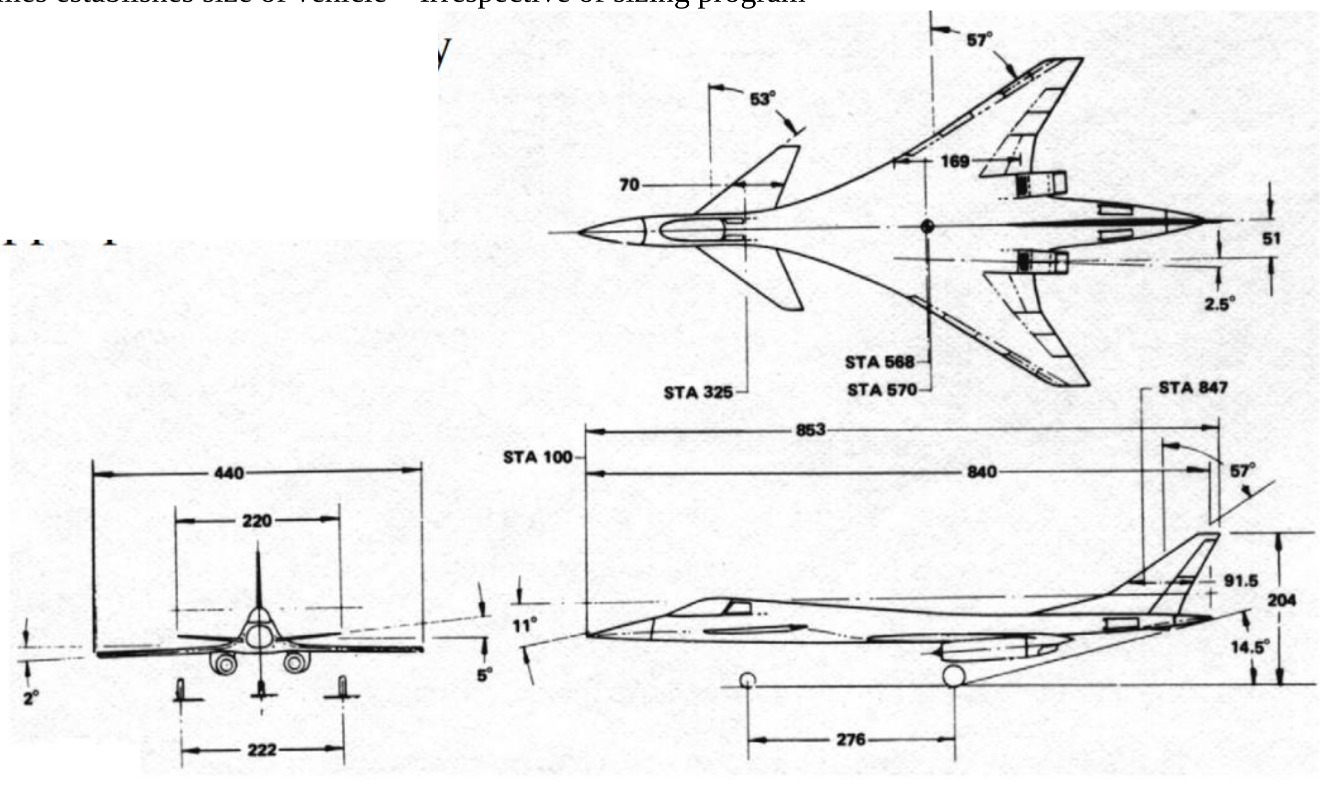
EXPERIMENT 2

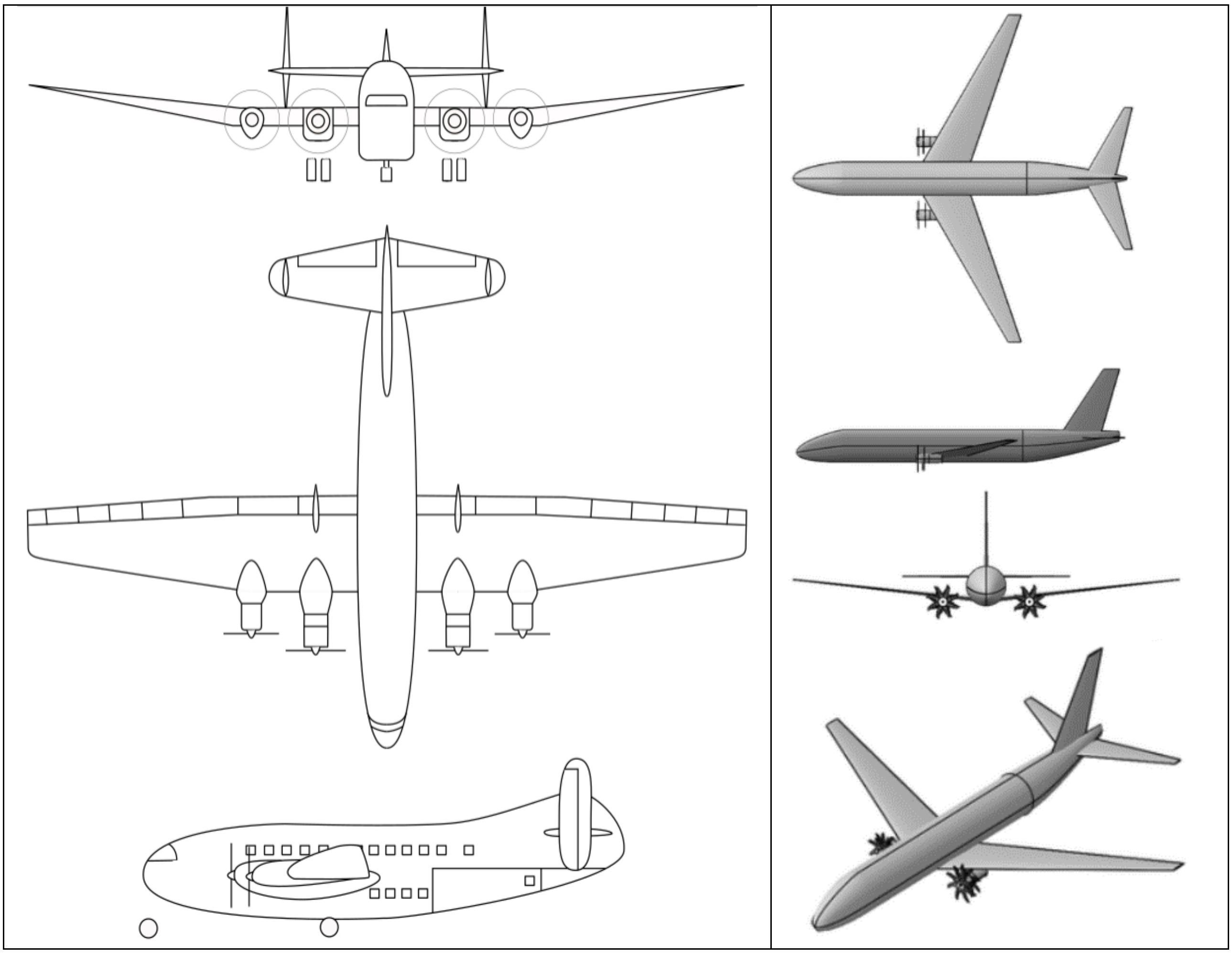
Aim: Sketching the detailed configuration of Aircraft (Fighter or Commercial)

Tools: Drawing Sheet, pencil, set square, drafter and other geometry stationeries.

Introduction: Aircraft configurations vary widely and can describe an aircraft's aerodynamic layout or specific components. **Conventional Configurations:** Cantilevered monoplane wing. Separate horizontal and vertical tail surfaces. Control via ailerons, elevators and rudder. Discrete fuselage to provide volume and continuity to airframe. Retractable tricycle landing gear. Minimum no. of power plants needed to meet power and operational requirements.

Procedure: Establish reference lines • Use the Final Initial Sketch as guide • In Side View (side elevation) – Draw crew station or passenger envelope – Establish required view-over-nose from pilot’s eye (forward vision line) – If military, draw radome & radar sensor, draw in-flight refueling system – If general aviation, draw nose shape to either enclose specified engine (1 engine) or baggage (2 engine) – Allow sufficient volume for retracted nose wheel.
In Planview (top elevation) • Establish fuselage width at pilot’s shoulder (a min.) or passenger cabin width • Draw radome and radar (if military) or engine or baggage compartment (if civil) • Establish A/C length and locate cg • Draw wing and establish mean aerodynamic chord 9mac). Locate wing on drawing placing mac on cg as function of aerodynamic layout (to start) • Establish spar locations - these will locate major load bearing bulkheads on the fuselage • Locate and draw engines.
Planview 2: Establish • Crew station or cabin envelope – Vision requirements – Ingress/egress provisions • Engine location & propeller diameter (if prop) • Inlet type, location & orientation (if jet) • Nozzle type & location (if jet) • Nose shape & envelope to house baggage (if civil) or radar/reconnaissance equipment (if military or commercial) • Wing and spar locations • Control surfaces & their fixity points • Landing Gear locations & fixity points • Stowage for retractable systems • Proper tip-back & turnover angles • Fuel tankage – balance.
Gun installation & weapon carriage (if military) – Make sure weapons are to scale! – Make sure gun has clear bullet path! • Passenger & cargo volume requirements (if commercial) – Doors & emergency exits – Lavatories & kitchen facilities – Cargo ramp & floor height from ground • Oft times establishes size of vehicle – Irrespective of sizing program





Typical Commercial aircraft (Br-763, also known as Breguet deux-ponts)

Result: Typical Commercial or Military aircraft with all the 3 views are drawn.

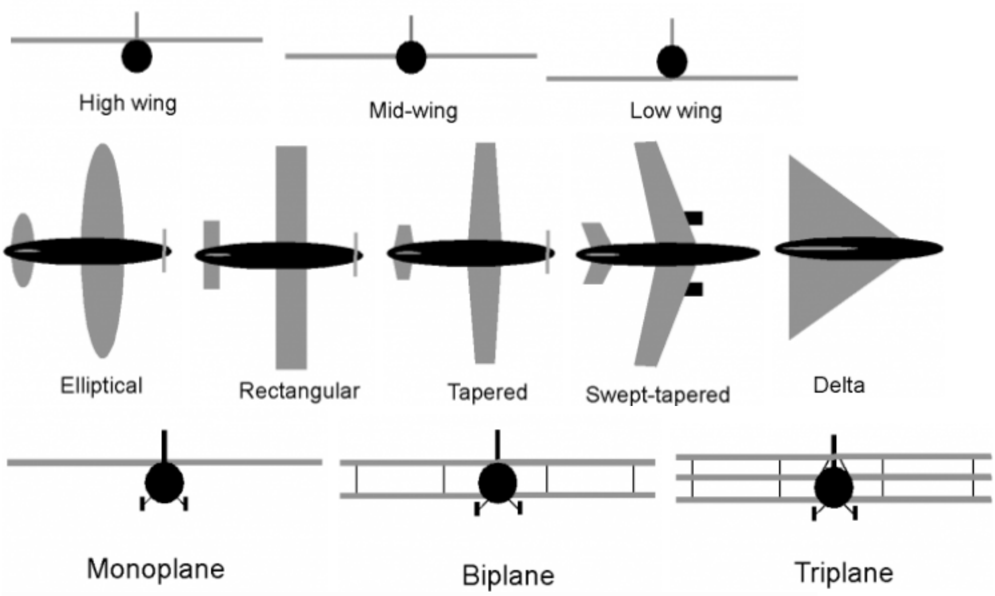
Instructions: Use a separate A4 or A3 sheet and draw all the three views of the aircraft and paste it in Record book.

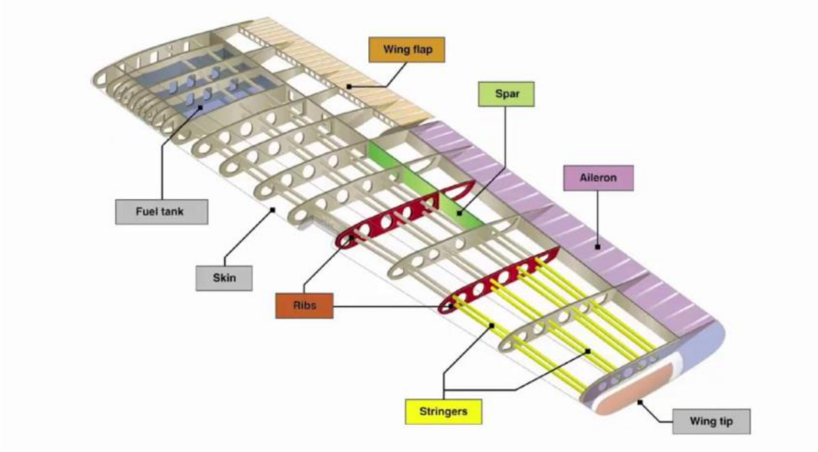
EXPERIMENT 3

Aim: Fabrication on types of wing configuration-Foam or Balsa wood

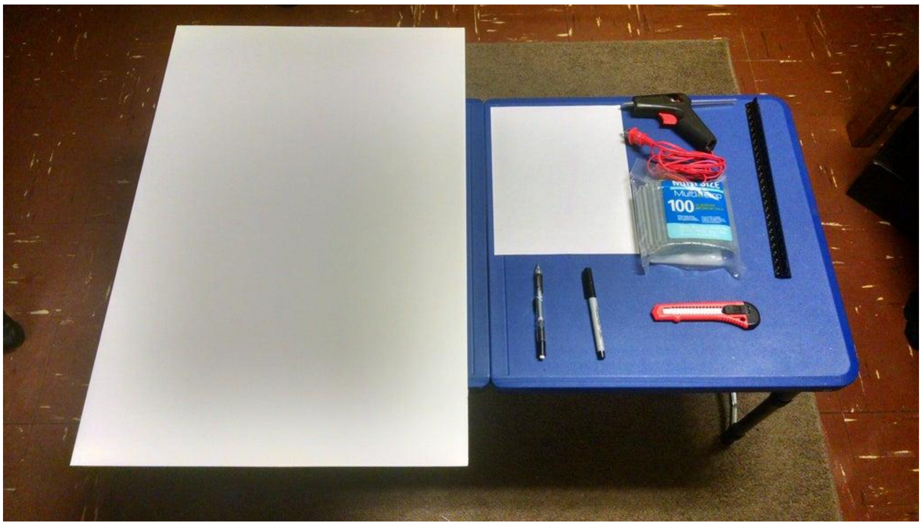
Tools & Material: Foam board or Balsa wood, cutter, hacksaw, scale, markers, glue, clamps.

Introduction: There are various configurations of wing based on vertical location, shape and numbers.

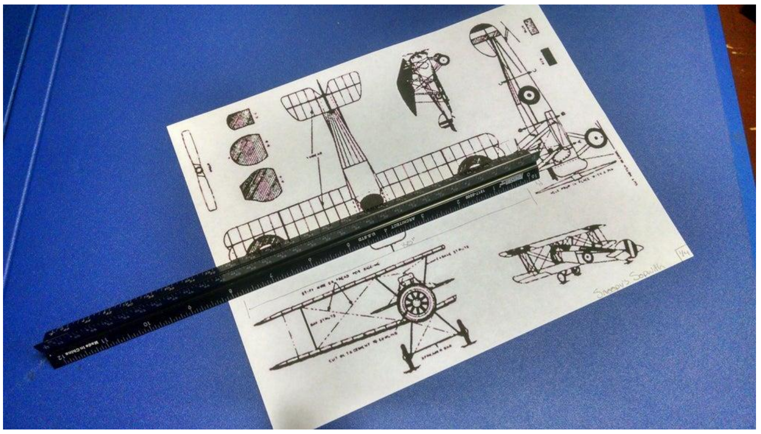




Materials: 1/8 inch foam board, 1 sheet of printer paper, Ruler, Pen, Pencil or Marker, Cutter, Hot glue gun and Hot glue sticks.

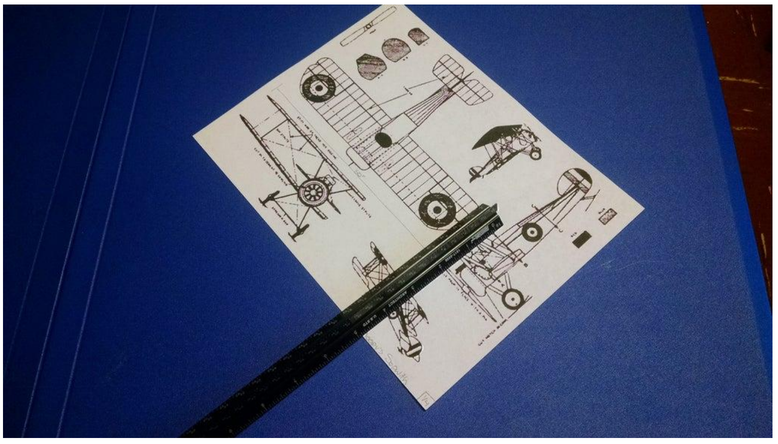


Step 1: Determine the Wingspan.



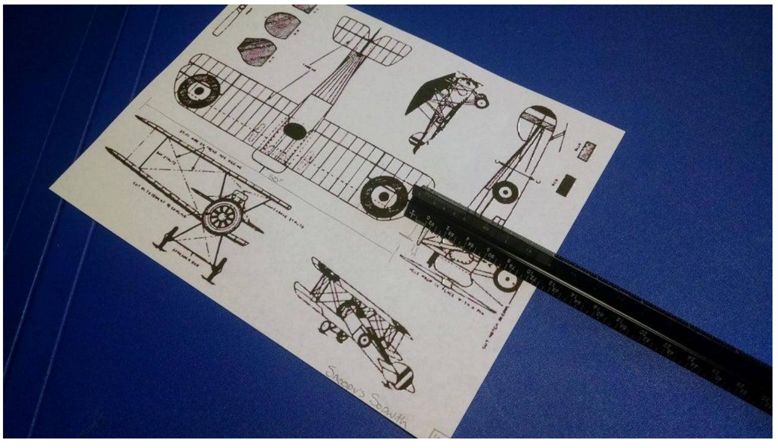
Determine the wingspan of the aircraft for which you are constructing the airfoil. In this example, we will be scaling our aircraft to a 30 inch wingspan.

Step 2: Determine Chord Length.



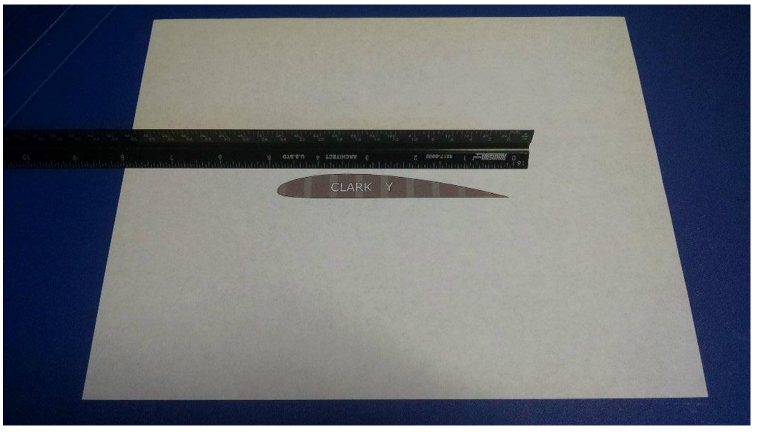
Determine the chord length of the airfoil based on the span. The chord length of a wing is the distance from the leading edge to the trailing edge of the airfoil. In our case, we are going to make our airfoil chord 5 inches.

Step 3: Determine Airfoil Shape.



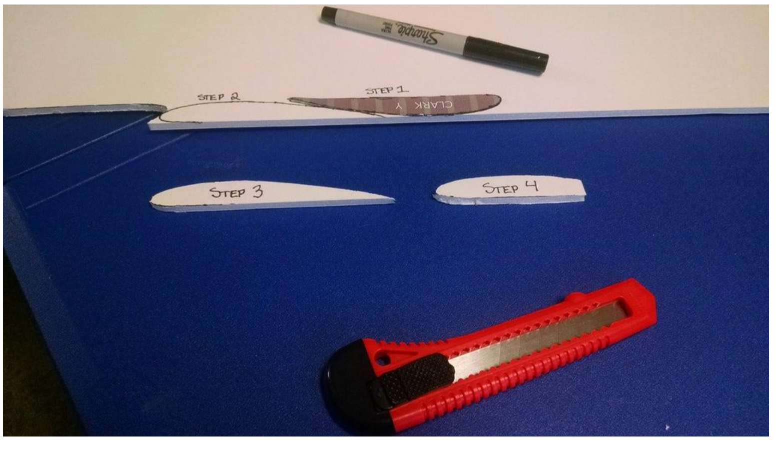
Determine the desired shape of the airfoil. This can be accomplished by selecting a nominal thickness for the wing or, if building a scale aircraft, by measuring the airfoil from a drawing. In this example, we will be using the Clark Y airfoil.

Step 4: Create an Airfoil Template.



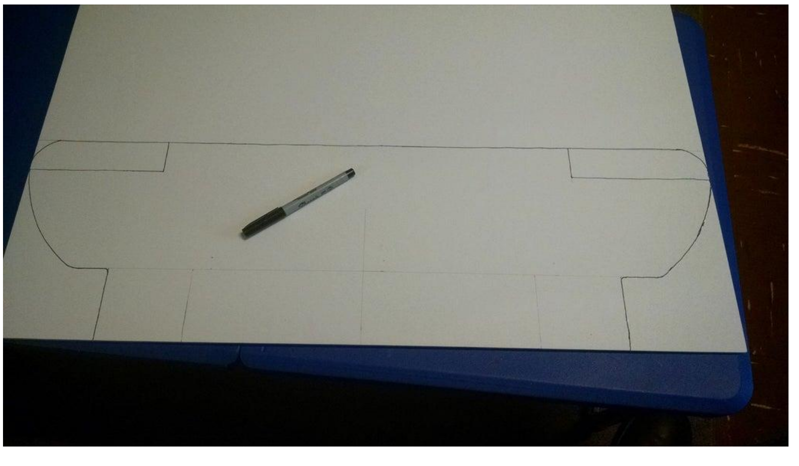
Create a template for your airfoil using a sheet of printer paper.

Step 5: Cut Airfoil Ribs.



Cut the desired number of airfoil ribs from the foam board using the template created in step 4. Then cut the back third of each rib off. This is done to create clearance for the ailerons.

Step 6: Draw the Shape of Your Wing Skin.



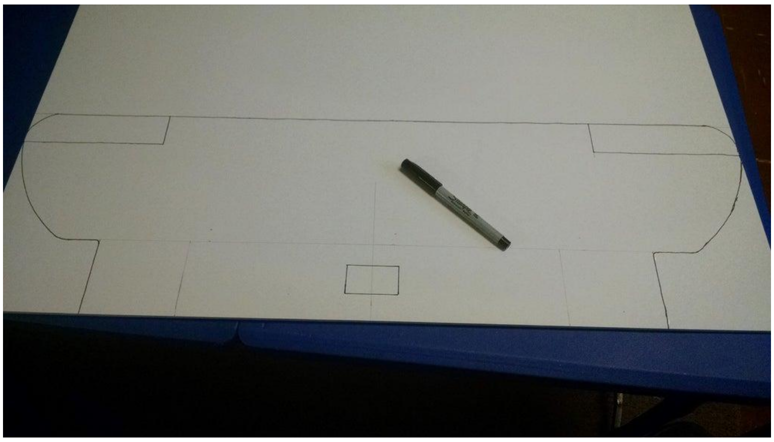
Trace the shape of the wing skin on the sheet of foam board.

Things to keep in mind:

The airfoil is created by folding the skin around the airfoil ribs we cut, so make sure to cut enough material to make it all the way around the airfoil rib.

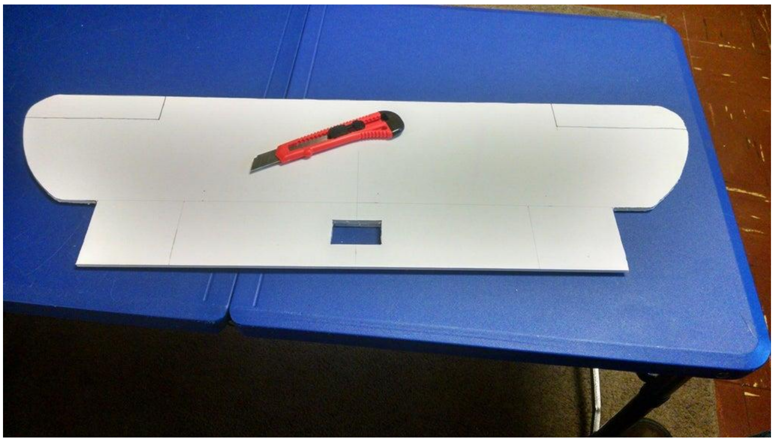
The rear third of the airfoil rib has been removed so the material BELOW the wing only needs to extend to the cut line of the airfoil rib.

Step 7: Draw an Access Panel for Servo Wires.



In RC aircraft, control surfaces such as ailerons, elevators and rudders are controlled by small electronic actuators called servos. These servos are controlled by the flight control board or receiver by servo wires. Trace an access hole in the bottom center of the wing to run servo wires through.

Step 8: Cut the Wing Skin From the Foam Board.

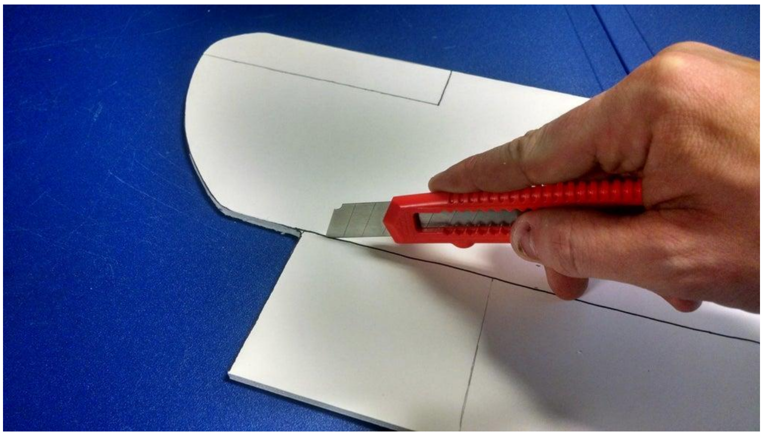


Carefully cut out the wing skin and access panel but DO NOT cut the ailerons yet.

Step 9: Mark the Leading Edge.

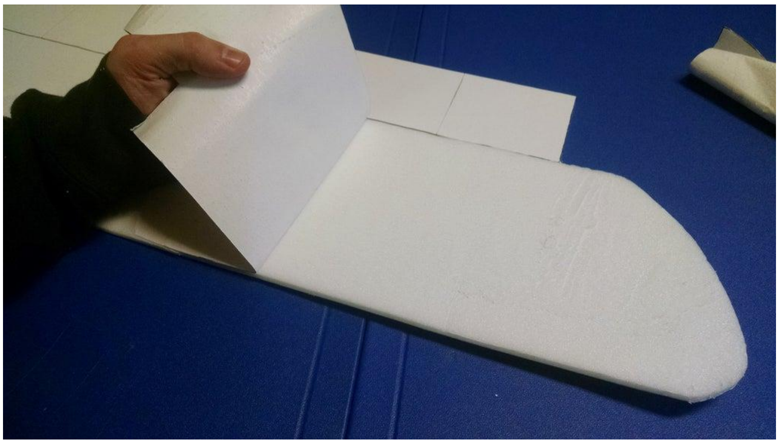
Draw a straight line across where the leading edge of your airfoil rib will be.

Step 10: Score the Leading Edge Line.



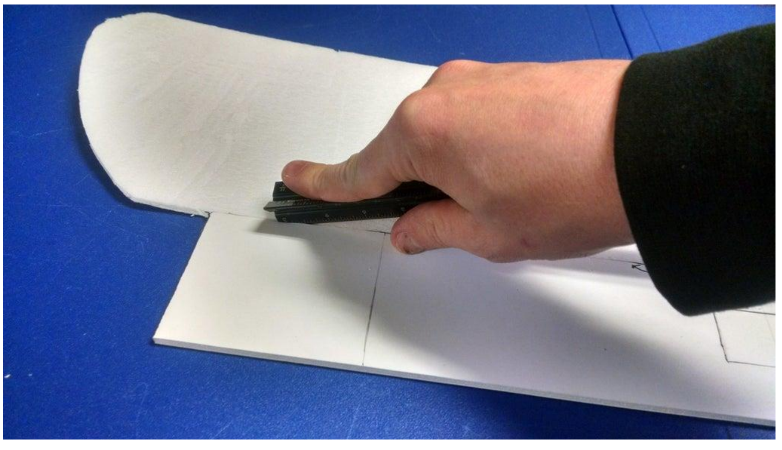
Using the box cutter, cut along the line making sure only to cut through one side of the paper and not the foam!

Step 11: Remove the Paper From the Upper Surface.



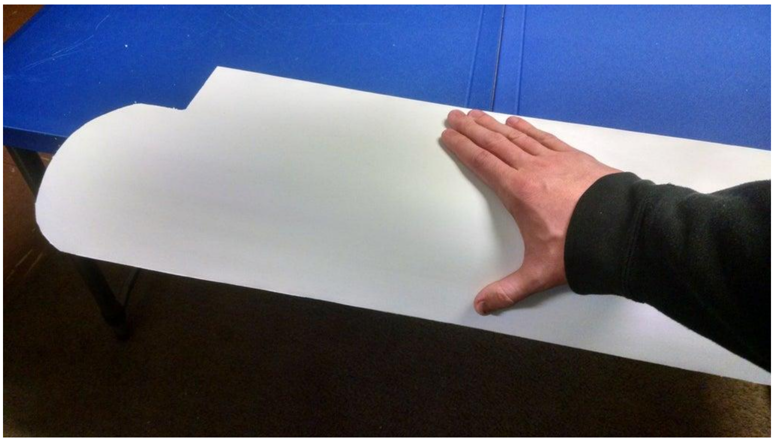
Carefully peel the separated piece of paper off of the upper surface of the wing.

Step 12: Crease the Leading Edge Line.



Run your ruler along the edge of the papered section, pressing firmly to create a crease in the foam.

Step 13: Bend the Upper Half of the Wing Skin.



Carefully bend the upper portion of the wing skin to create a permanent bend in the board. This is to ensure the skin will form around the airfoil ribs.

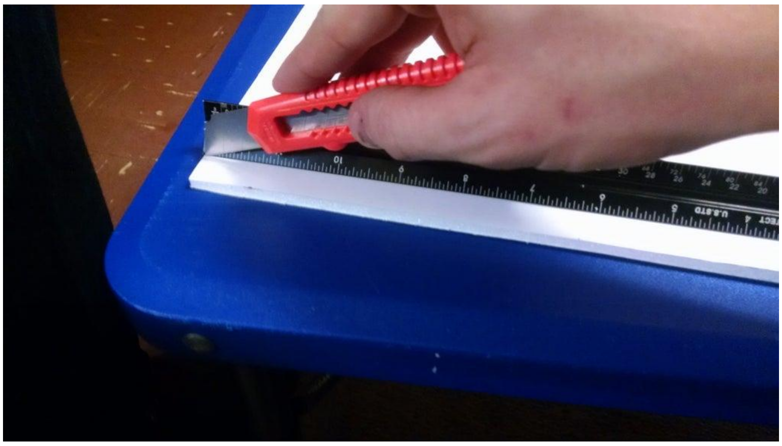
Step 14: Glue the Ribs in Place.

Place the airfoil ribs in the desired location of the papered portion of the foam board and glue them down using a bead of hot glue.

Step 15: Create a Path for Servo Wires.

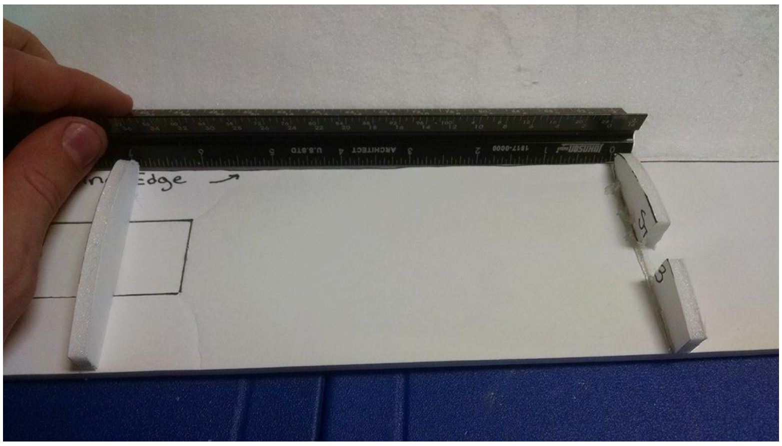
Cut a gap in the outer ribs to create a channel for servo wires.

Step 16: Cut the Wing Spar.



The next step is to cut the wing spar. The spar is the element of a wing that gives it its rigidity and strength and carries the majority of the load. Cut a strip of foam board as long as your wing and as wide as the thickest part of your airfoil ribs.

Step 17: Measure Spar Length.



Measure the distance between the ribs.

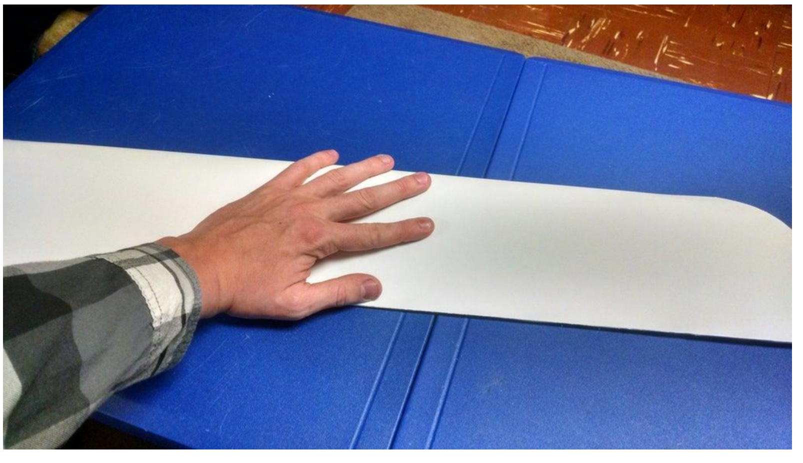
Step 18: Cut the Spar to Length.

Take the foam strip that was cut in step 16 and cut from it the lengths of measured in step 17. Be sure to make 90 degree cuts!

Step 19: Glue the Spar in Place.

Glue these pieces vertically between the ribs. This makes up your wing spar.

Step 20: Check to Ensure Your Wing Skin Is Large Enough.

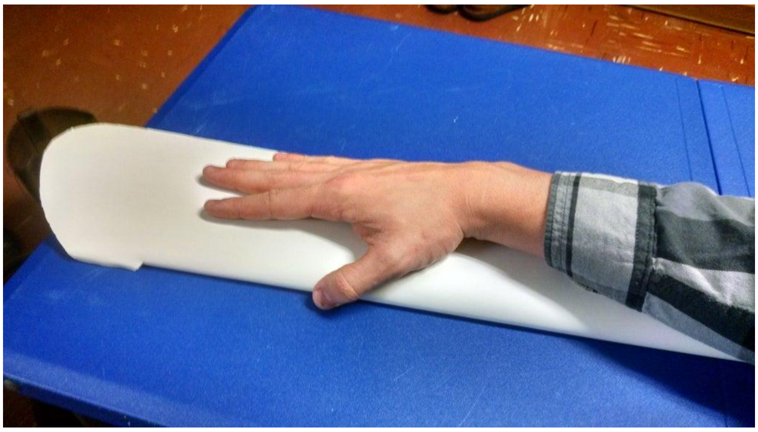


Once the glue dries, wrap the non-papered section of the wing over your spars. Ensure there is enough wing skin left to cover the upper surface of the wing. Note: You should have plenty of extra foam board hanging over at the trailing edge of the wing.

Step 21: Add Glue to the Wing Structure.

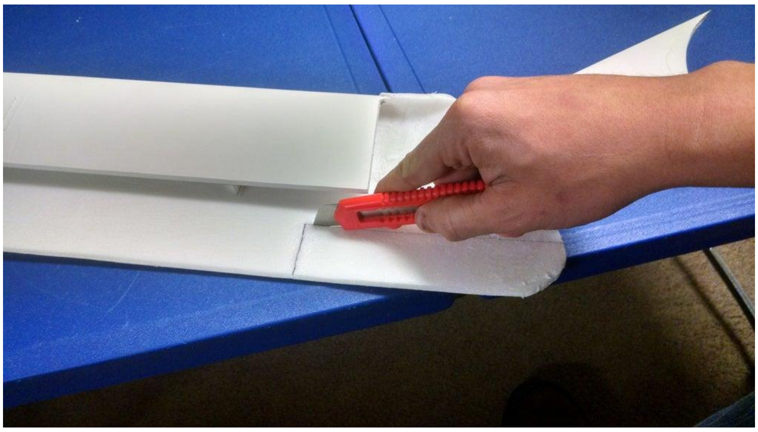
Open the wing back up and place a bead of hot glue on the top of your airfoil ribs and spar. Note: You need to do this step quickly before the glue cools!

Step 22: Wrap the Skin Over the Structure.



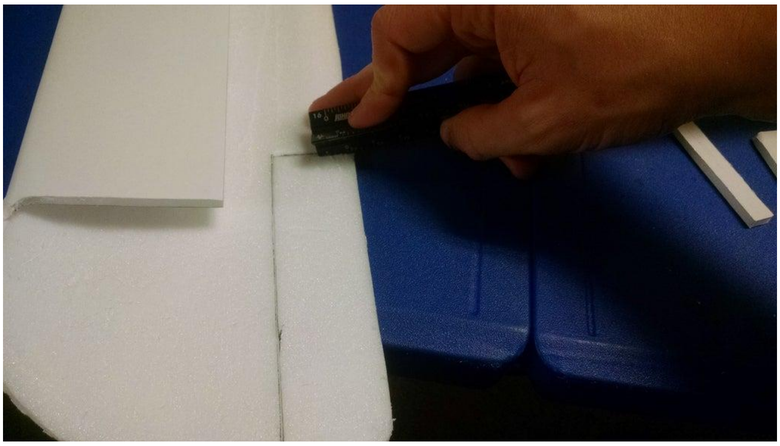
Before the glue cools, quickly wrap the non-papered portion of the wing up and over the airfoil ribs and apply pressure while the glue cools.

Step 23: Cut the Ailerons Free.



Using the box cutter, cut your ailerons free. Note: Only cut completely through the foam board on the cuts perpendicular to the spar. The cuts parallel with the spar should have the foam core cut from beneath the wing, but the top paper should be intact.

Step 24: Create a Gap for Aileron Clearance.

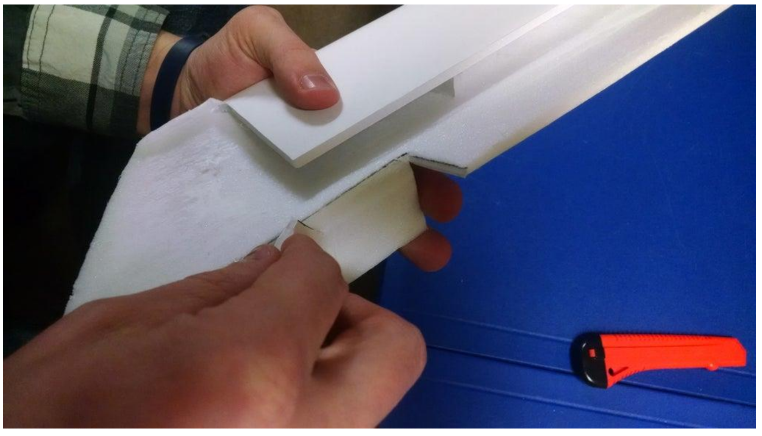


Run a ruler down the perpendicular cuts to create a gap and prevent the aileron from rubbing.

Step 25: Cut a Bevel for Aileron Movement.

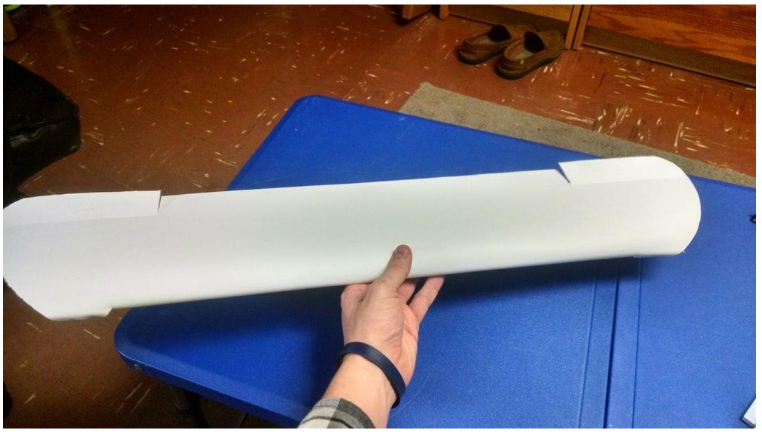
Using the paper as a hinge fold the aileron up and cut away the foam at a 45 degree angle making sure not to cut through the paper.

Step 26: Reinforce the Aileron Hinge With Hot Glue.



Run a bead of hot glue in the crevice you just created in step 25. Then use a piece of scrap foam as a squeegee to remove the excess glue. This helps reinforce the hinge point of the aileron. Note: Do not close the hinge until the glue has completely cooled or the aileron will become inoperative.

Step 27: Completion



Result: RC wing is ready to have the servos installed and be attached to your aircraft!

EXPERIMENT 4

Aim: Fabrication of glider using balsa wood (unpowered)

Tools & Materials 1 x balsa piece of 3.2 x 76 x 914 mm (1/8" x 3" x 36"), 2 x balsa smaller pieces of 3.2 x 10 x 914 mm (1/8" x 2/5" x 36"), Hot glue, cutter, hacksaw, Metal (or plastic) ruler.

Introduction: A glider is a fixed-wing aircraft that is supported in flight by the dynamic reaction of the air against its lifting surfaces, and whose free flight does not depend on an engine.[1] Most gliders do not have an engine, although motor-gliders have small engines for extending their flight when necessary by sustaining the altitude (normally a sailplane relies on rising air to maintain altitude) with some being powerful enough to take off by self-launch.

There are a wide variety of types differing in the construction of their wings, aerodynamic efficiency, location of the pilot, controls and intended purpose. Most exploit meteorological phenomena to maintain or gain height. Gliders are principally used for the air sports of gliding, hang gliding and paragliding. However some spacecraft have been designed to descend as gliders and in the past military gliders have been used in warfare. Some simple and familiar types of glider are toys such as paper planes and balsa wood gliders.

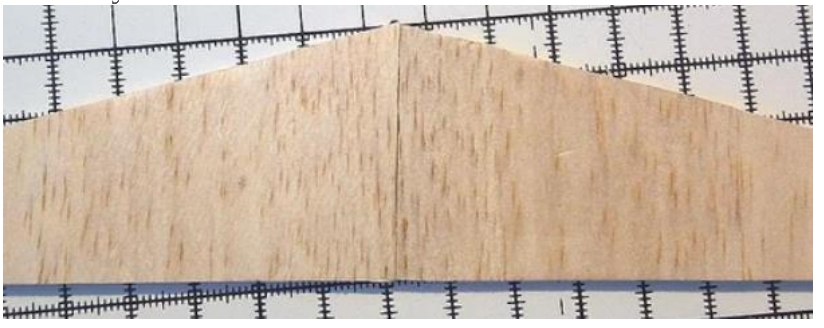
Procedure:

Step 1: Prepare the pieces.

1. Cut out from the big balsa piece three small pieces of 40 mm at the longest side, as seen in the picture, so you will have three pieces of 3.2 x 76 x 40 mm.
   . They will be the parts for the tail.
2. Cut the leftover big balsa piece in two equal parts. They will be the wings.
3. Cut out from each of the big parts a piece of 80 mm. They will be the end of the wings.

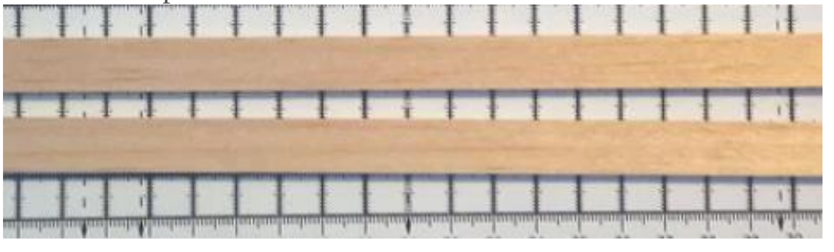
Step 2: Prepare the Tail.

1. Cut a triangle out from each of the three 40 mm pieces, 20 mm side and as long as the longest part as shown in the picture. Keep the small pieces for later.
2. Stick together two of the three pieces by the 40 mm side with hotglue. Don't put too much and as the hotglue gets cold remove the leftover hotglue from the top side.
3. With the help of one of the squared pieces for the wings, that forms 90º, stick the third piece by the 40 mm side again to the other two. It has to be exactly at the middle as shown in the picture. Also well aligned so the plane flies straight. Use again enough hotglue and remove what is more than necessary.



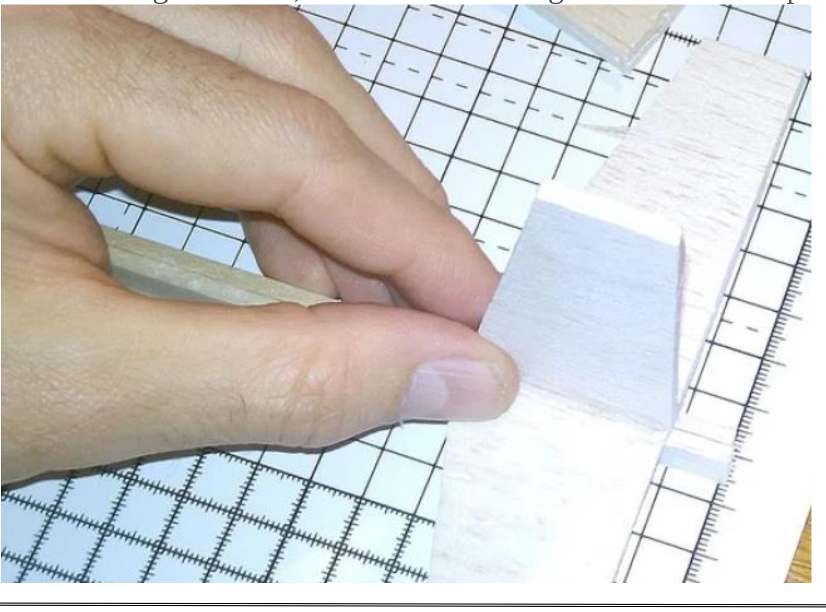
Step 3: Prepare the fuselage

1. Measure 400 mm twice with the thin balsa piece and cut them.
2. Stick them together with hotglue. Don't put too much, just enought to hold them.
3. At 10 mm from one end measure 40 mm as this will holds the center of the tail.
4. Measures also 3 mm deep on that 40 mm measured before.
5. Cut out that part with a cutter.



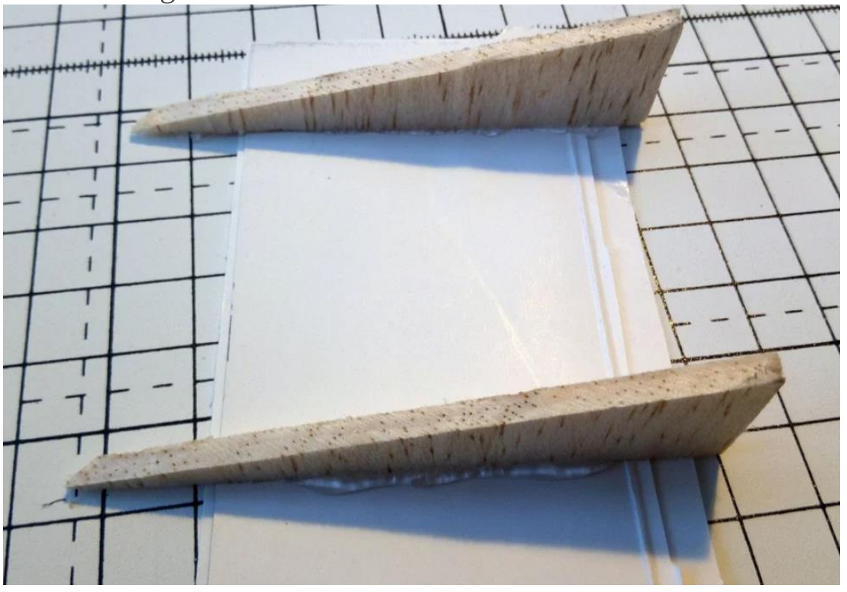
Step 4: Place the tail on the fuselage

1. Now insert the tail on the place we made on the fuselage.
2. It has to be well aligned so you can see the fuselage follows the main line while the long rear part of the tail is perpendicular.
3. Use enough hotglue to stick them together.
4. Put also hotglue below, between the fuselage and the bottom part of the tail.



Step 5: Form the Wings, stick the wings to the Fuselage

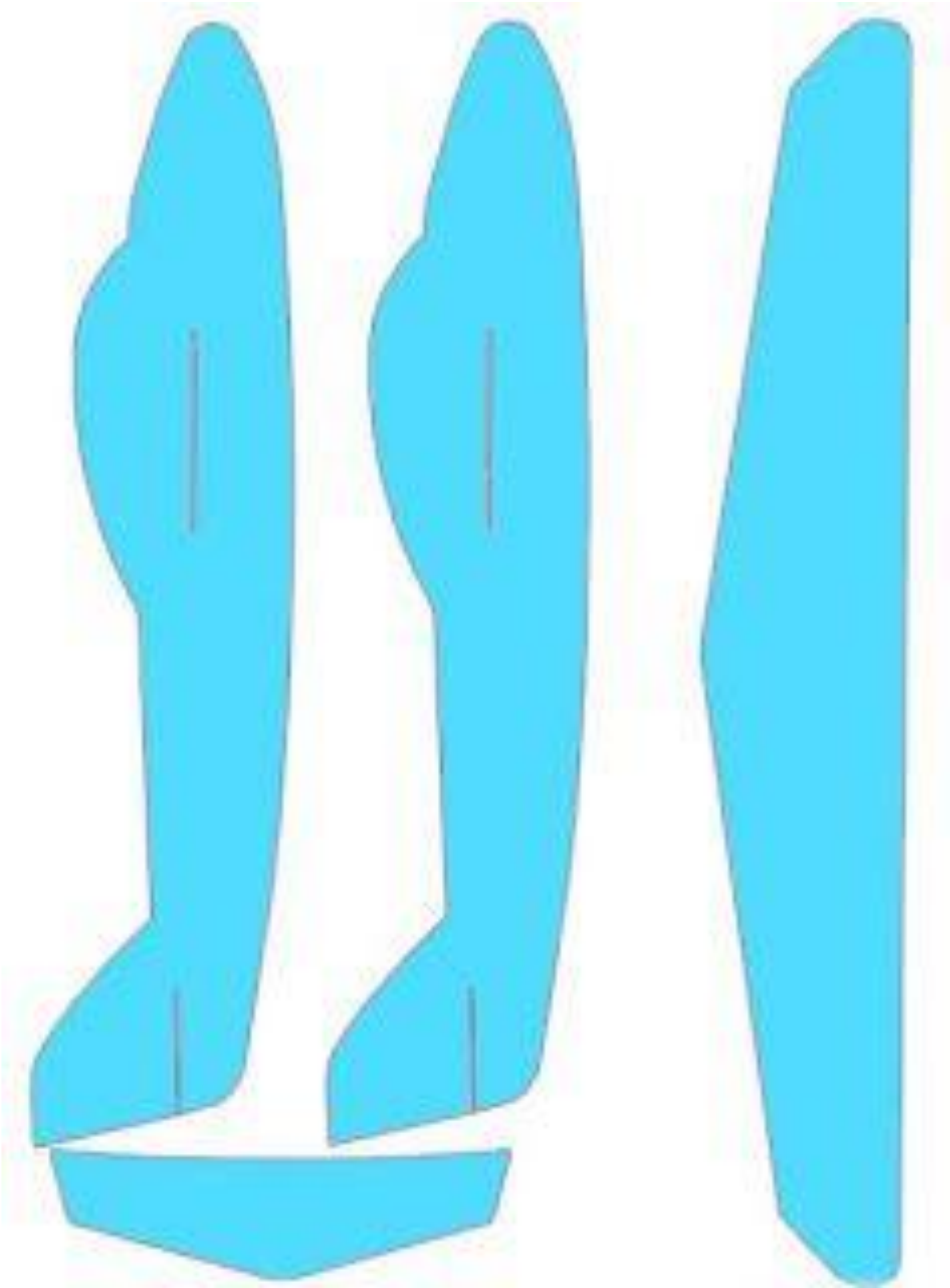
1. Stick two of the small triangles on a thin cardboard. They have to be parallel to be well aligned, as shown in the picture. It will be the angle base.
2. Cut a thin triangular part along the parts for the wings. It gives more surface to stick them together.
3. Stick first one end of the wing to its main wing, use the angle base (step 1 above) to form an angle between them. This shape of the wing gives stability when flying. Don't use too much hotglue and remove what is not needed.
4. Stick the whole finished wing to the fuselage. Again help yourself to keep the wing perpendicular to the fuselage.



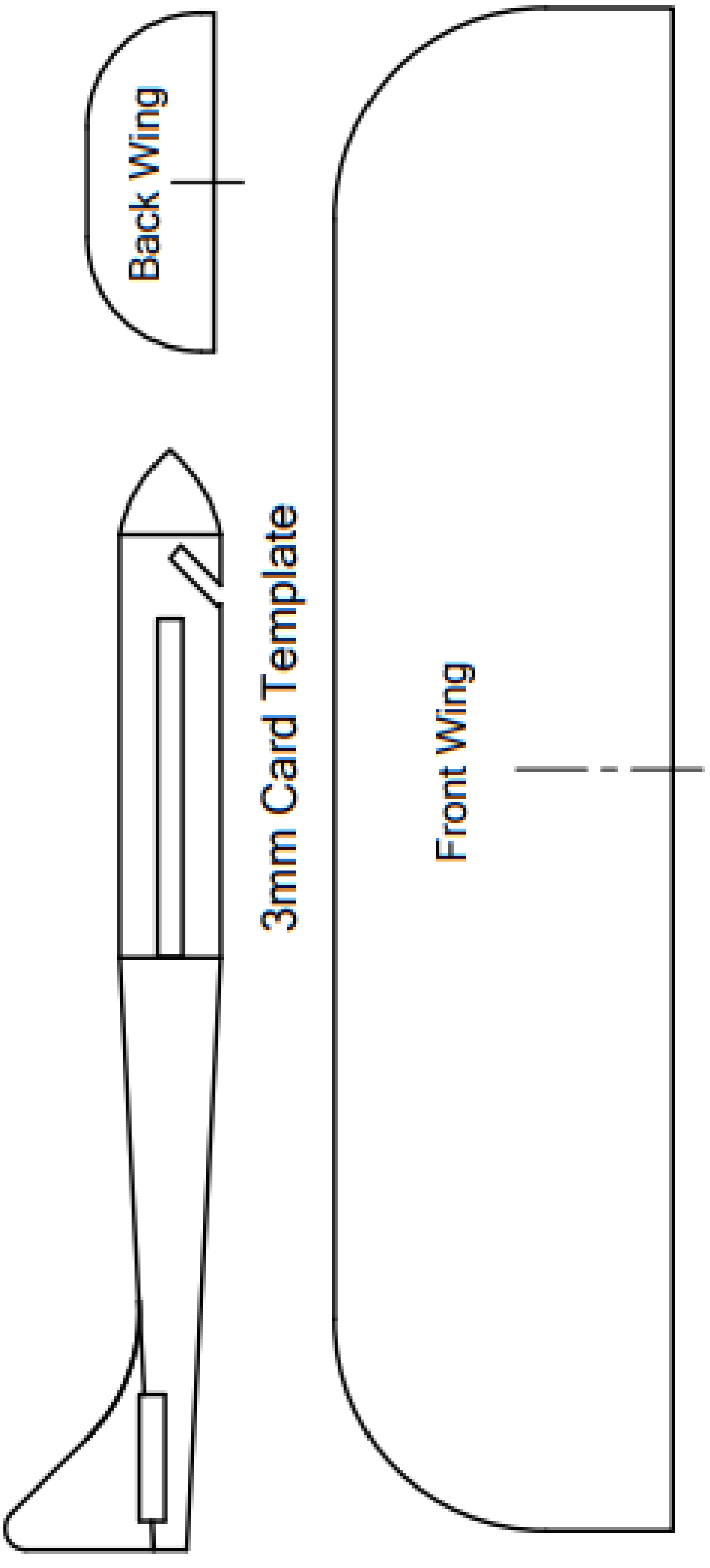
Result: Balsa Glider is ready to be flown.

Instruction: Calculate the CG as mentioned in Expt. 5.
After some flights your plane will crash and eventually it could get broken, **add a dumping system and reinforce that part below the wings. make the plane more aerodynamic** cut some top front part of the wings to give it a rounded shape. At the top rear part of the wings you can cut also but more flat. At the tail do the same as shown in the pictures.

Alternate Designs/Templates



Alternate Designs/Templates



EXPERIMENT 5

Aim: Calculate the CG of the modelled Glider & Assessing the aerodynamic performance parameter i.e. Range & Endurance

Tools: Two tape rolls, string, scale, pencil, stop clock, Meter tape.

Introduction: When the glider or airplane is flying properly, the lift of the wings will be directly over the weight of the airplane. In order for your plane to fly properly, you must know how to locate the wing in relation to the weight. The weight acts through a point which we call the Center of Gravity, abbreviated CG. You must know how to locate the CG in order to properly balance your plane for flight. The plane will balance at its CG, but that balance must be in proper relation to the wings lift for good flight. In gliders, clay is used to add ballast. Using ballast is an easy way to change the glider center of gravity, but by using ballast the total mass increases.
We have gravity pulling down at the center of gravity, and air pushing up at the center of lift. In a properly designed glider, the center of gravity is in front of the center of lift so that the nose of the glider drops.
We can balance an object using a string or an edge. The point where the object balances is the centre of gravity. Another method involves suspending the object from different points and drawing vertical lines from these points.

Range: It is defined as the max distance covered by an aircraft on a tank of fuel. After launching the glider landing distance is measured using a tape from the point of launch.

Endurance: It is defined as the maximum time an aircraft can stay in air on a tank of fuel. After launching the glider timer is turned on and glider landing the time is taken to know the endurance.

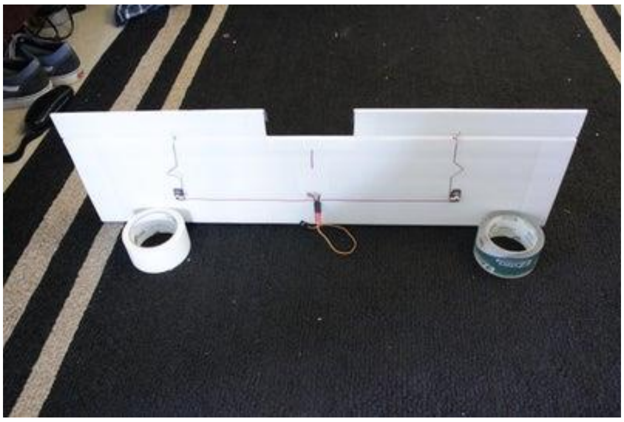
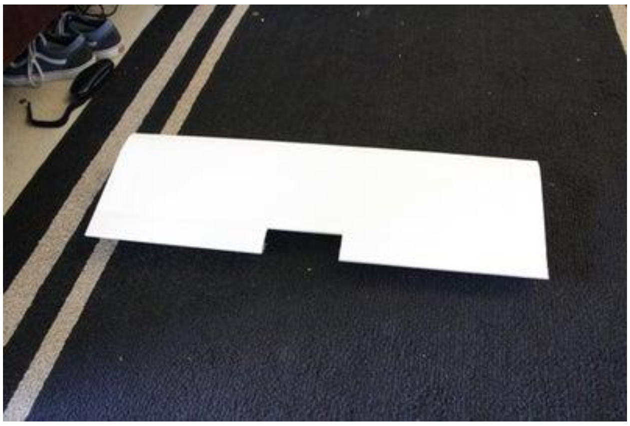
Procedure for CG. Method1:
Balancing the Plane:

1. If you through now the glider it will fall down from the back, that's because the back weights more, but that's normal.
2. We need to counter balance that with some weight at the front tip of the plane.
3. Use some plasticine or little coins. Add some and weight the plane holding it at 1/3 at both sides of the wings, as shown on the pictures above. The plane will keep itself balanced.
4. This part requires some patience as you don't want to add too much weight.
5. Through the plane several times and repeat the previous steps until the plane glides



Procedure for CG. Method2: Grossly the glider should balance on two fingers placed near the base of the wings and at 1/3 distance from leading to trailing edge. A horizontal hand launch (if weight allows) should permit fine tuning. If nosing up, move the CG forward until if follows a gentle downward slope. Elevator should be horizontal.

CG of the glider is found using the same method as for RC airplane.

Glider /RC model with all the electronics, including the motor, propeller, battery, ESC and the receiver is taken to see where the center of gravity. This step has to be done after ALL pieces have been loaded into the plane. If you forget something then you will have to re calculate the CG.

Lay down two rolls of tape (pic 1).

Balance the wing on top of the tape (pics 1 & 2).

Place the fully loaded fuselage on top of the wing and drag it forward or backwards until it balances perfectly on wing. After it balances move it forward just a tiny bit until the nose it a bit lower than the tail.

The CG will be a 1/3 the way back from the front of the wing, or where the airfoil is at it's highest. 1/3 the way back from the front. Make a small mark on the wing 2.3" back from the front of the wing. Lay your ruler along the wing and measure from the very front of the fuselage to the mark you made.

Keeping the plane balanced measure how far back the front of the wing is from the front of the fuselage. Here you can draw a line and now you know how far up to place your wing.

Result: CG of the glider is marked on the glider and the range in meters and endurance in seconds are noted.

Instruction: Grossly the glider should balance on two fingers placed near the base of the wings and at 1/3 distance from leading to trailing edge. A horizontal hand launch (if weight allows) should permit fine tuning. If nosing up, move the CG forward until if follows a gentle downward slope.

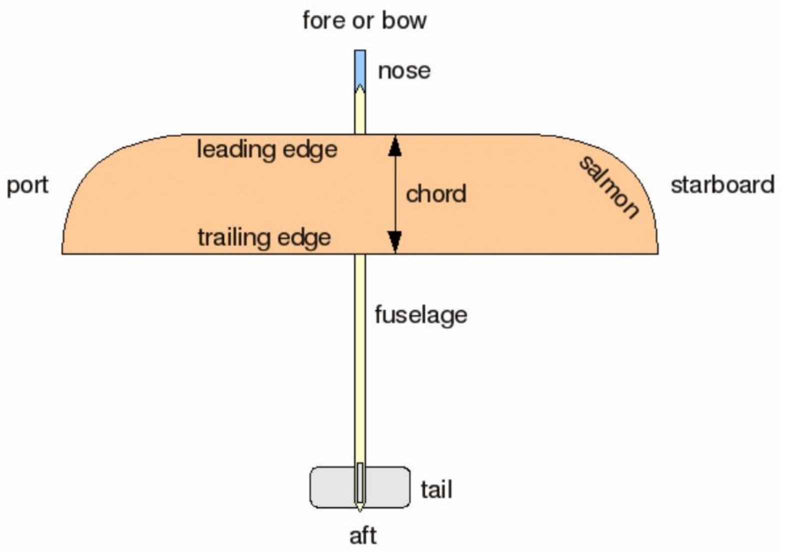
EXPERIMENT 6

Aim: Flight testing on the gliders (belly landing)

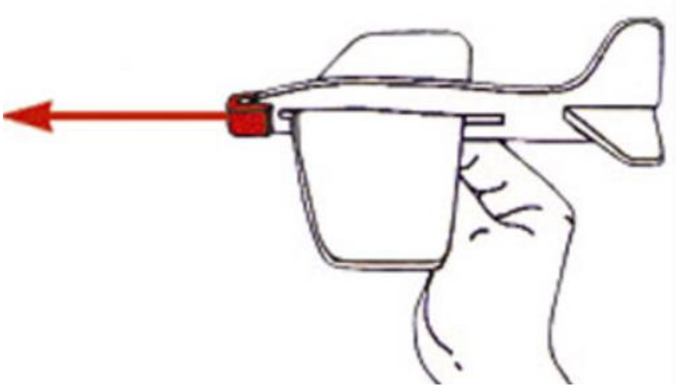
Tools: Glider

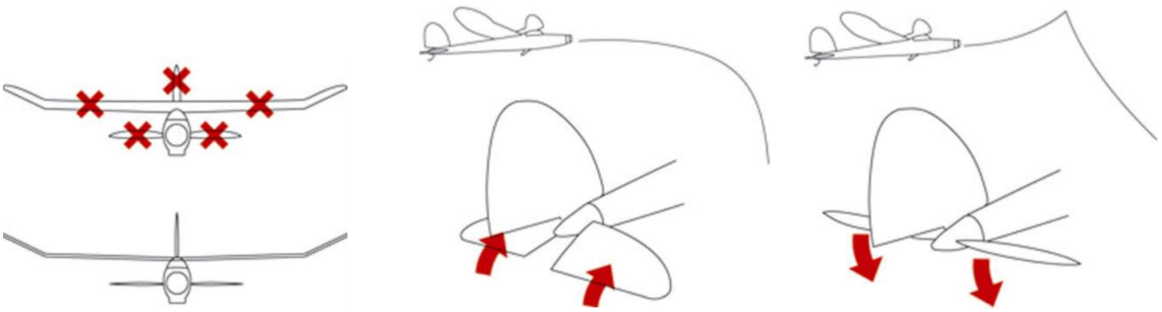
Introduction: Glider has only three main forces acting on it: lift, drag, and weight. In aircrafts. Belly landing is also known as gear-up landing, is an emergency landing technique in which an aircraft lands without extending its landing gear. It is a last resort option for pilots when they are unable to deploy the landing gear due to technical or mechanical failure. However, belly landings come with significant risks, and the management of the landing requires careful planning and execution. Belly landings pose significant risks. It can cause Structural damage, Fire or explosion, Injury to passengers and crew in aircrafts.

Where as in gliders, its only belly landing, since there is no undercarriage. Sufficient measures to be taken in the design of glider such that at the time of landing, there are no structural damage. Maintain a landing attitude until the end of roll, not just touchdown. There is no need to actively 'land' the glider by flying it on at speed, as this is likely to result in a bounce and ballooned landing.



Procedure:
Hold the plane on the underside of the fuselage and throw out straight in front of you. In the open always fly into the wind.





Align the wings and the elevator. The plane should fly straight and cover about 10 m if correctly adjusted.

If the plane flies straight ahead and the dives nose first, bend the back of the elevator upwards 1 – 2 mm. If the plan begins to climb then dives vertically, bend the back of the elevator downwards 1 – 2 mm.

Result: Sufficient measures is taken such that at the time of landing, there are no structural damage

EXPERIMENT 7

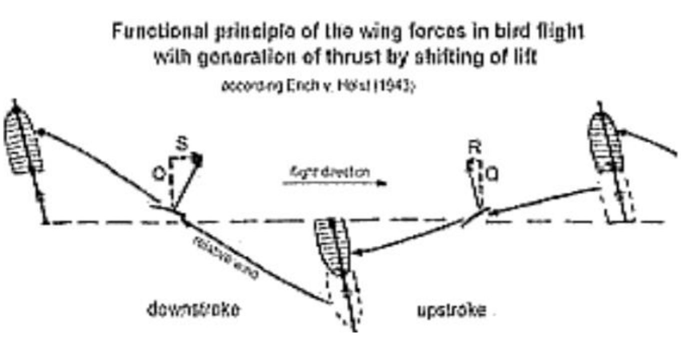
Aim: Design & Fabrication of Ornithopter.

Tools: carbon fiber frame, Teflon material, Electronic Circuit

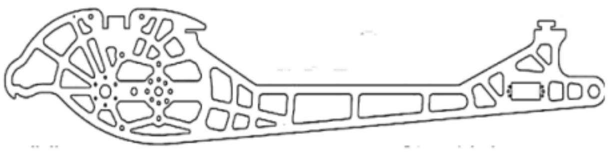
Introduction: The ornithopter is a mechanically designed robot that uses a flapping wing mechanism to achieve flight. These designs are inspired by natural aviators such as birds and insects known for their ease of flight and maneuverability in the open sky. However, achieving this feat has presented a challenge due to the complexity of understanding its working dynamics. They autonomously vary the flapping rate and adjust the orientation of their tail to sustain steady flight in the atmosphere. Many experiments were conducted to develop the precise mechanism, to help thoroughly understand the dynamics of its machinery, and solving the enigma of its sustained flight in the air. The main objective of the project is to mimic the fluttering actions of a natural bird and understand its flight patterns. Recreating a sizeable model capable of manifesting the same functions as a bird but with other additional features such as surveillance, image capturing. These improvements have wide applications in the military field, research field, and general public applications. This model can be controlled over a long distance using a remote control. Hence, the altitude and the model speed can be controlled by the same. The interest rate on this subject has increased in developing ornithopter based on different aviators. Different methodologies were initiated to comprehend how to maintain long-range coverage, use of solar energy to recharge its power source and to sustain longduration flight and working time.

PROBLEM DEFINITION AND METHODOLOGY: The basic methodology used in this model is a flapping wing mechanism. They hold the key features required for flight of the prototype. Although it is seen to be impossible to achieve the exact moment of wing actions through mechanical behavior of a model certain aspects can be mimicked to insurance working. Moreover, even when the shape of wings add on to their behavior in air. For example,the shape of a swallow wings are different from that of a pelican. Swallows are quick to cover short distance and sharp turns but pelicans can last longer, this is due to the wingspan. So selection of the wing shape is crucial pertaining to the type of application required for themodel. The selection of material also has a huge effect in working of the prototype. Many factors should be added to generate the most precise type of materials used.

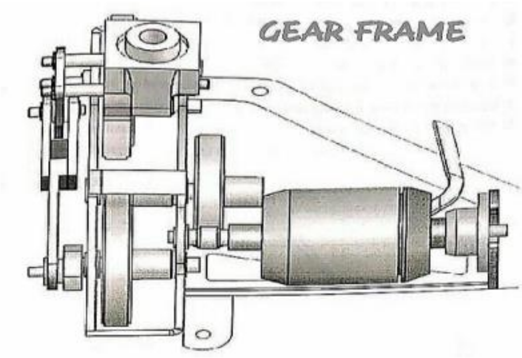
OPERATING PRINCIPLE OF WINGS The general principle of wings called for the increase in pressure below the ring then on top of the wing in an aero plane. But in the flapping of birds the upper stroke is slower than the downward stroke to ensure its flight. During this downward stroke the pressure is more in the mid part of the wing and the outwards when compared to the part closer to the body. As the main focus of the pressure should be in the middle they are shaped point towards the end. However, most of the pressure acts atthe middle part ofthewing.This inturnhelps thebirdtoexertthepressurerequiredenough to lift them off the ground.



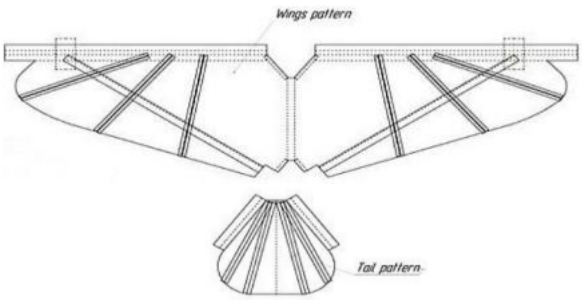
Body: The body is made from a carbon fiber frame where the electronic components are attached. The slots are cut out based on the dimension of each components and predetermined locations. These Efficient slots are already cut help keep the electronic components fixed in place. The carbon frame is used as it is lightweight and has high durability in the presence of slightly strong wind



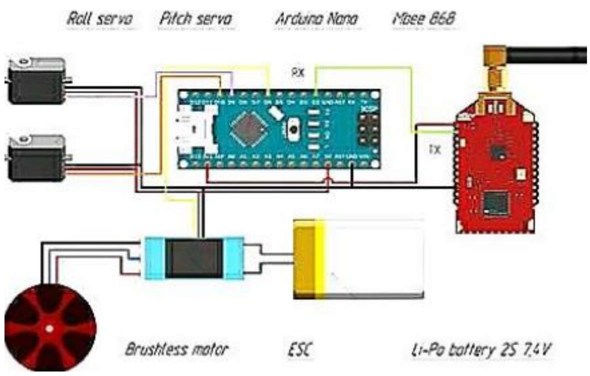
Gear Mechanism: The gear mechanism was determined based on the number of teeth required on the gear. This was calculated based on the required flapping rate per second that is 5 up and down strokes per second to maintain flight. An external battery is connected to the gear mechanism as the power source. Furthermore, the flapping rate can increase or decrease based on the flight needs of the ornithopter.



Wings: The material used for wink are carbon fiber rods and Teflon sheets. They have the durability as well as lightweight features. The carbon fiber rods are placed in crisscross manner and are stitched not the fabric. The exoskeleton of the wings are almost shaped like the exoskeleton of bat wings. This pattern provides much more flexibility in maintaining the pressure distribution throughout the wing.



Electronic Circuit: Electronics makeup for the controlling and other part behavior of the prototype for the operator to control its movements. This comprises of all the electronic components into including the Arduino board, speed controller, servo motor, polymer batteries and other components. The motion of control takes place with the operator sending signals via the remote control to the model using RF signals already coded into the Arduino board. The speed and direction can be controlled by a speed controller and a servo motor. The controller sends and receives radio frequency signals to operate the prototype. Long range can be maintained by using a distinct range of RF frequency already programed into the system to avoid unwanted interruptions.



Result: The ornithopter is one of the most promising models which has infinite capabilities from surveillance to crop protection. Furthermore, many numbers of attachments can be added as a result of increasing the functional abilities of the ornithopter

EXPERIMENT 8

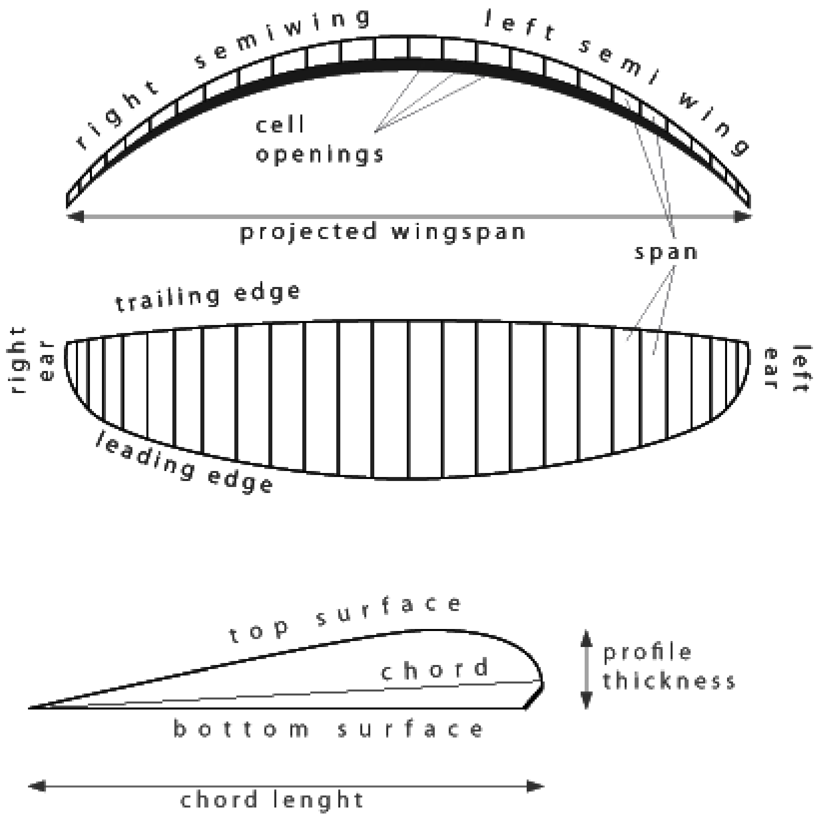
Paraglider structure

The paraglider consists of a wing, which is connected to the pilot by a harness via lines, risers and carabineers.

Paraglider wing

The wing of the paraglider has close to ellipse shape, when seen from above and has **left and right semi wing** (the directions are always chosen in relation to the flight direction). The wing consists of **cells**, divided by walls. The front of the wing is called the **leading edge** and this is where the cell openings are located. This is where the airflow enters and inflates the wing with air. The back part of the wing is called trailing edge. The outtermost area of each semiwing is called an ear, which ends with a **wing tip**. The distance between wing tips is called **wing span**.

The inflated wing has an arc shape, when seen from both the front and behind. There is a difference between the projected wing span of an inflated wing and the wing span of a spread on the ground wing. There is also a difference between the projected surface and the surface of a wing. The projected surface area is the one which carries the load, no matter how big the surface of laying on the ground wing.



Wing elements viewed from in front, above and a profile section

Each semi wing consists of set of profiles, formed by the shape of cell walls. The profile has **upper and bottom surface**. The distance between the front and back part of each profile is called a **chord**. The mail characteristics of a profile are **chord length, maximal profile thickness and its position**.

Paraglider suspension

* distributes the weight of the pilot along the wing surface; gives a shape to the wing
*sets the balanced angles of attack at different wing sections (central section, ears) by changing the, line length construction, in flight angle of attack control.

The suspension consists of **lines, risers and carabineers**.

The lines are attached to the numerous **attachment points** at the connection of cell walls with the bottom surface of the wing.

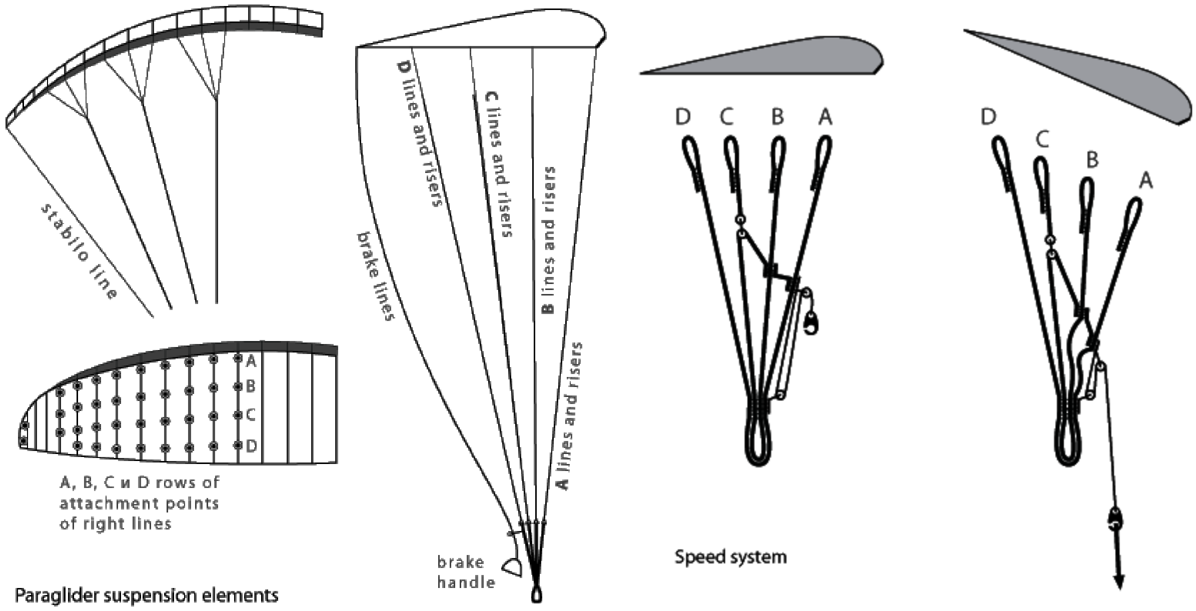
As lines make drag, the paraglider constructors strive to reduce their overall length – for example the use of diagonals between cells improves the load distribution and reduces the amount of attachment points.

Laternally (if seen from behind), the lines are divided to left and right, according to which semi wing they are connected to. The wing tip is connected to a **stabilo line**, which has different color and is pulled to clear canopy and lines cravats.

Longitudinally (if seen from the side), the lines are in parallel divided to **A, B, C and D lines**. The A lines are the closest to the leading edge and the D lines are the furthest. The closest to the trailing edge are the **brake lines** (control lines).

The lines that lead directly from the wing surface, are grouped together and united into a thicker line, thus making up the A,B,C,D lines. Finally the lines are connected to the corresponding **A, B, C and D risers**, through triangular metal elements called **maillons**. The risers are stitched together in an ear, where the carabineer connects them to the pilot's harness.

There is a short riser with a pulley connected to the last riser. The brake line goes through it and connects to the **brake handle**(control handle). This way, the control remains within the reach of the pilot's arms if he releases it by accident.



Paraglider suspension elements

Speed system

Some modern and sportive paragliders have rigid elements in their construction and may not have C or D lines and risers.

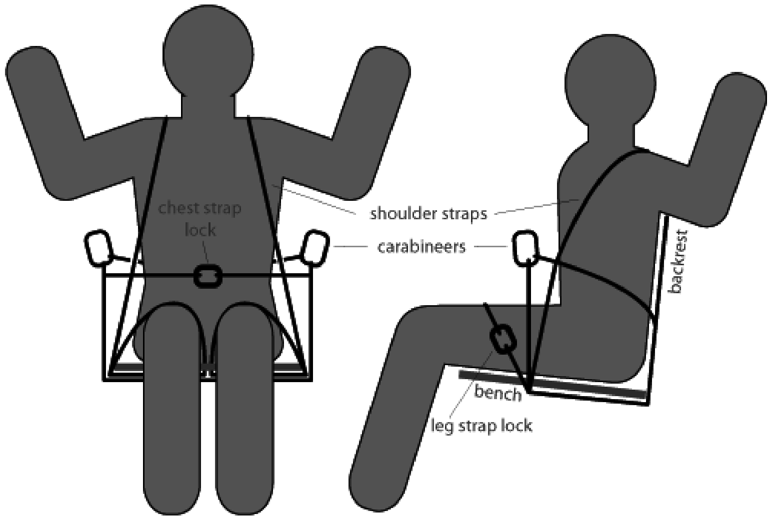
The risers are made in such a way, that the pulling of a pulley system on the A riser, pulls consecutively A, B, C and D risers downward and thus reduces the angle of attack. This is called a **speed system**. Some paragliders have **trimmers**, which pull or release the last risers and also have an effect of controlling the angle of attack.

Paragliderharness

The paraglider harness envelops the pilots body and transfers his weight to the wing through the carabineers, risers and lines. The harness should: hold the pilot body in all positions (even upside down); allow the pilot to control the wing by shifting his weight sideways; allow mounting and easy use of a speed system; have active safety devices (rescue parachute) and passive safety devices (protectors); allow comfortable position to the pilot lasting for hours; allow enough freedom of movement (fast running on take off and landing, easy entering and exiting).

Usually, the harness has a rigid seat plate where the pilot sits. Bellow the seat plate the main riser webbing is run. Stitched into this webbing is the loop that holds the carabineers, which attach the pilot to the wing. There are additional loops running from the harness to the carabineers, which give the pilot shoulder and back support. The pilot is secured in the harness by locking a chest belt (strap) between the carabineers and leg belts (straps).

The leg strap locking is very important because there are still lethal cases of pilots who slipped down from the harness. Most of modern harnesses have their chest strap attached to the leg strap with an additional strap which prevents the falling of the pilot if he forgets to lock the leg straps. Some producers also use combined chest-leg straps.



Paraglider harness construction

The beginner's harnesses are sitting type, while the experienced pilots try to reduce their body drag and use laying type of harness with a streamlined bag for their legs.

To avoid leg tingleness by the bench edge after hours long flying, some harnesses can be equipped with a **stirrup**, which carries part of legs' weight. It also allows for better body position control and easy entering and exiting of the harness on take off and landing. Usually a sling connects the stirrup with the speed system, which makes it easy to find and work with pilot's legs. It's important not to use the speed system as a stirrup.

Except some special harnesses (lightweight for hiking, acrobatics and others), the harnesses are equipped with a back protector, which protects the pelvis and the back spine against serious injuries.

The **back protector** consists of a molded piece of plastic foam, which must conform to an industry standard thickness. It is placed in a tight cover within the harness, ensuring it is always in the correct position to protect the pilot. It will absorb and distribute the energy from an impact. The same principle is used for the additional **airbag systems**. These harnesses allow the bottom portion to be filled with air when in flight, but a one-way valve at their entrance traps the air creating a cushion in the even? of an impact.

The paragliding harness producers decide where to place the rescue parachute compartment – under the seat, at the back or in a separate container attached to the chest or side straps (front container, side container). The rescue parachute handle should be at a convenient place, where it's easy to reach, pull and throw the rescue parachute. The rescue parachute compartment and the whole rescue system should not be too tight for difficult pull out or too lose for sporadically dropping and opening. The rescue parachute belt is connected to the harness behind the pilot shoulders via additional risers. Thus, during the parachute descent, the pilot body leans ergonomically slightly forward and ready for better absorbing of the impact.

Strength of paragliding materials?

To fight fear, the beginner pilot has to trust the wing that they are strapping themselves to.

The paraglider sail is made of synthetic fabric (Skytex, Galvanor) which is reinforced against tearing. The producers choose different fabric thickness (g/m2) and properties for different parts of the wing (upper surface, bottom surface, ribs, leading edge). The fabrics are mechanically woven, colored and impregnated with thorough quality control.

The fabric impregnation with special coating protects it against UV rays and reduces its **porosity** (air tightness). The fabric reduces its quality with time, usage, exposure to sun, mechanical friction (take offs, landings). At the end of a **wings lifespan** (about 500 hours or flights), most of the fabric porosity is worn out, which causes rapid ageing of fabric threads. The fabric condition is monitored by counting airtime and by porosity and bettsometer checks.

Depending on the suspension construction, the producers use lines with different thicknesses. The most common materials are Kevlar, Dyneema, Aramid and Polyester. 0.8 mm thick line holds 80 kg, 2.2 mm – 220 kg. The paraglider lines outlast the fabric lifespan, except if damaged. This is not valid for the unsheathed “competition” lines, which are more exposed to external influences (UV, H2O, etc.) and have to be replaced every 150-200 hours. Throughout normal usage, due to external influences, the lines change their length and have to be checked for deviations periodically. Often the moisture causes 2-5 cm shrinkage of sheathing of lightly loaded C and D lines, which changes the profile curvature and angle of attack. Such deviations are slightly perceivable at beginner’s gliders, but can cause dramatic changes in flight modes and behavior of high performance models with thin and sensitive profiles.

The lines are connected to the risers via triangular steel mayons. They have thread and screw which allows them to open to replace lines. 3 mm Stainless Oval Maillon holds longitudinally 800 kg and 160 kg laternally. The risers are made of polyester strap, which holds over 1100 kg The pilot weight is carried mainly by left and right ? and B risers.

It is measured that a 25 m2 wing, loaded with 75 kg pilot, has 16 kg force on each A riser and 10 kg force on each B riser.

The paraglider and harness tests require them to stand up to 10 G (10? the pilot weight), without destruction of construction or its elements (tearing of lines, stitches, fabric, risers, breaking of carabineers, etc.).

Paraglidercare

Taking good care of your paraglider prolongs its lifespan and gives you safety and comfort in the air. The main reasons for ageing and weakening of paraglider materials are environmental and mechanical influences. The **environmental influences** are due to sunlight (UV), atmospheric moisture and temperature changes. The **mechanical influences** affect the materials strength and structure and are due to:normal and extreme flight loadings;into the ground friction at take off, landing, folding and unfolding;deformations and frictions at folding and transporting; catching and hooking of branches, bushes thorns, roots, stones, rocks and others, which together with stepping on the sail and the lines can cause tears and damage.

Despite our casual care of things in everyday life, in aviation good care is more then a must:

– **do not expose to sunlight unnecessary the wing, lines, risers and harness are all susceptible to UV damage. This is because they are made of petrol based synthetic materials, which quickly age by exposure to UV rays. The thin paragliding fabric is especially vulnerable!**

– **avoid ?oisture**: If your paraglider gets wet make sure you dry it completely before storing. The moisture helps the dust and small particles to penetrate deep into the materials, which accelerates their abrasion. The moisture causes deformation of materials and often shrinkage of lines. Moisture also can causes fungus and mould to grow. If you dip the paraglider in salty water, then wash it with plenty of fresh water, because the salt acts abrasively and chemically on the fabric and lines. The paragliders are usually not washed out of dirt, but if needed then use soft cloth or sponge without soaps and chemicals; **avoid extreme temperatures** , because they influence the fabric coating and shorten the paraglider lifespan. The heat generated by car left in strong sun can deform the plastics inside the wing. Low temperatures combined with moisture can damage lines and fabric (breaking of micro fibers when water turns into ice) and reduce their strength;

– **avoid unnecessary friction** into the ground or other surfaces. Even the dry grass works like a sandpaper!

– **clean the paraglider** periodically from dust, sand and objects in the cells. Most wings have special velcro openings at the wing tips, but check the other cells too;

– **remove insects** and especially grasshoppers when folding the wing after a flight. They don’t like eating synthetics, but they love their freedom and make holes on their way to it;

Generally **be gentle with the paraglider**: **be careful not to step on the sail or the lines**, because you can damage them, especially if there are stones or solid objects bellow;

– check carefully if pulling of the wing for take off won’t catch the sail or the lines into stones, roots, bushes, etc, which may tear or damage the wing. If wind moves your wing on the take off, then check again for possible catching. Be ready to stop pulling the paraglider if you feel it's caught somewhere. The best is to inflate the canopy several times before taking off, in order to sort out the wing and the lines, to check the terrain and the conditions, to smoothen the take off. **do not let the wing fall on its leading edge** after landing (there are cases of broken ribs and cells due to the pneumatic shock);**fold the wing cell by cell** by keeping the rigid elements parallel to each other without bending them too much when rolling the canopy. Regularly change the central cell which you use as a base to fold the rest cells in order to avoid ageing of fabric due to frequent bending (when we want to tear a piece of paper at certain place we bend it several times there). Do not fold the paraglider too tight. When packing the paraglider, use the principle of **material diversification** – for example leave the risers with their metal elements in a protective bag against friction into the fabric during transport. Use the velcro strap outside the inner glider bag. The rolling of folded cell by cell wing starts from the trailing edge toward the leading edge. Don't be inpatient and don't push hard the fabric to kick the air faster toward the leading edge openings;**acrobatic flying** causes high overloading of the paraglider and the resultant deformations do not restore completely;**store the paraglider** at dry and dark place at moderate temperature; paragliding producers recommend **periodic checks of condition of the paraglider** in specialized test centers(http://test.skynomad.com/bg/).

ParagliderRepair

The most common damage to a paraglider is: torn fabric big >10 cm small < 10 cm damaged line sheathing; broken line unpicked or broken stitches. Small rips up to 10 cm can be repaired with a special rip stop adhesive sticker, which usually comes with every new glider. **A strip of repair tape slightly bigger than the tear is cut with rounded corners.** This helps prevent ungluing by dust and pollution. The area around the tear is cleaned with moist soft cloth and let to dry. The broken parts are matched together and the sticking patch is glued on them. It's good to have a solid base bellow to allow good pressurizing of the sticker to the fabric with a solid object (a finger nail). If the ripped part is 2-10 cm big, then sticking on both sides is recommended. Bigger rips are taped and stitched. Occasionally a tear is so big it requires the replacement of the whole cell, which can be done by the manufacturer or specialized repairmen centers. Tears close to stitching at cell's borders also require specialized repairmen.

The most dangerous type of rip is located at the top surface near the leading edge, where most of the aerodynamical force is created and where the highest wing loadings are.

The line sheathing rips are not dangerous, unless the line core is damaged too. It is possible to join temporarily the broken sheathing ends by gluing them with a sticker. Still, these lines should be replaced sooner as they're vulnerable to further damage and environmental influences. The damaged line is replaced with an identical supplied by the producer or made by a specialist according to the producer specifications and after a symmetry check with the other semi wing.

Tying up a broken line is not allowed because knots can reduce the strength by up to 40% and because the shortening of lines changes the profile and compromises the safety.

Partly torn or worn out risers or speed system elements have to be replaced completely.

Deformed or non-operational elements like mayons, carabineers or pulleys have to be replaced.

EXPERIMENT 9

Aim: Visualization on the concept of landing.
A visualization of the concept of "landing" could be depicted as a downward-angled line representing the aircraft's descent, with a gradual curve towards the ground as it approaches the runway, culminating in a solid horizontal line signifying touchdown, often with a subtle "bump" to represent the impact with the ground; key elements could include:

Visual Elements:

Trajectory Line:

A thick, curved line starting at a higher point (representing cruising altitude) and gradually sloping downwards, with the final part becoming nearly horizontal to represent the final approach and touchdown.

Landing Zone:

A rectangular area on the ground, shaded differently to indicate the runway, with markings to depict the landing threshold and center line.

Aircraft Silhouette:

A simple silhouette of an airplane, positioned along the trajectory line, with the angle of the aircraft changing as it descends, potentially showing the flaps extended during landing approach.

Altitude Markers:

Small vertical lines along the trajectory line to indicate decreasing altitude as the aircraft descends.

Ground Features:
Optional details like trees or buildings near the runway to provide context and scale.
Variations and Considerations:

Perspective:

Top-down View: A flat view looking down on the landing path, showing the full trajectory and runway clearly.

Side-profile View: A 3D perspective showing the aircraft approaching the ground at an angle, highlighting the descent profile.
Dynamic Elements:

Animated Landing: A moving animation of the aircraft progressing along the trajectory line, showing the gradual descent and touchdown.

Landing Gear Deployment: Visual representation of the landing gear extending as the aircraft nears the ground.

Data Representation:
Speed Indicator: A gauge or numerical value indicating the aircraft's decreasing speed during the landing approach.

Glide Slope: A dotted line representing the ideal descent angle for a stable landing.
Application:

Educational Purpose:

To visually explain the different stages of an aircraft landing process, including the approach, flare, and touchdown.

Flight Simulator Training:

A more detailed visualization could be used to practice landing maneuvers in a simulated environment.

Infographic Design:

A simplified visualization could be incorporated into an infographic explaining the basics of aircraft landing.

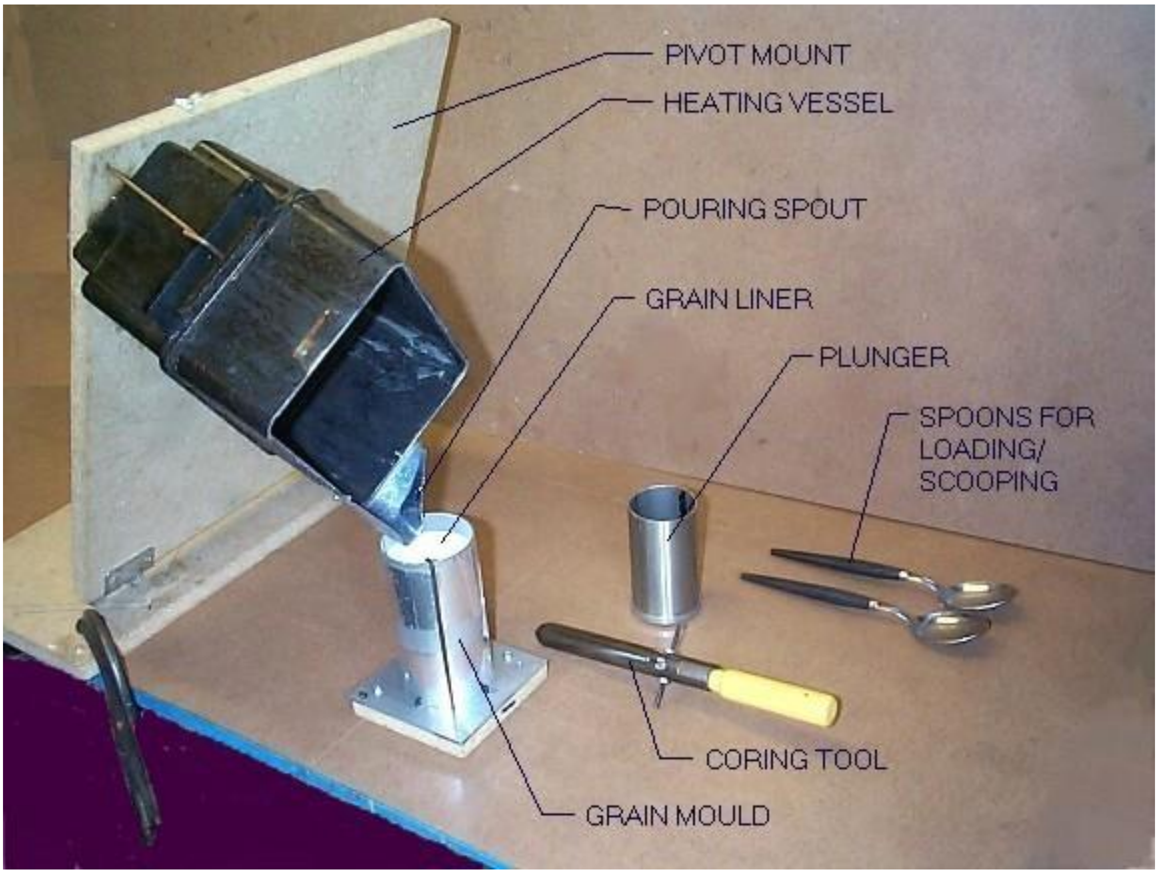
Flight simulator with pilot in front of projection screen and operator at rear console

EXPERIMENT 10

Aim: Sugar candy solid propellant

Tools: Scale balance, table sugar, corn syrup, salt, beaker, hot plate, mortar, drill, dowel rod, igniter, safety gear.

Introduction: Rocket candy is a type of fuel used for model rockets that is made from sugar and an oxidizer. Rocket candy, aka caramel candy, is called such because of its sugar content and appearance of caramel. Because of its oxidizer content it obviously should not be consumed.



Procedure:
Step1: Take all the ingredients: Oxidizer, Potassium Nitrate, types of fuel: Sucrose (table sugar), and Fructose (Corn Syrup)

Step2: Heat: Turn on your hot plate to around 350 F and allow it to heat up.

Step3: Add your ingredients to the beaker. Stir continuously until the mixture is a uniform consistency. Then stir occasionally so that the sugar doesn't burn.

Step 4: Turn the heat up. Once the mixture has thinned out a little (after about 5-10 mins) increase the heat to 500-600 F. Stir more often than before.

Step 5: Remove from Heat. Once the mixture stops bubbling and has turned a caramel color (after about 15-20 mins) turn off the hot plate and remove the beaker from the heat. Pour your mixture onto wax paper and let cool.

Step 6: Cool the fuel. Once the fuel has cooled and hardened break it into smaller pieces. You will notice the fuel has lost some weight due to water boiling off.

Step 7: grind the fuel. Using a mortar and pestle, grind your fuel into a powder. This step is important. The fuel must have a small grain size so that it can be properly mixed and packed.

Step 8: Add Metal Oxide. Add 5-10% by weight of a metal oxide. This increases the burn rate of your fuel turning it from a smoke bomb into a rocket engine. The easiest metal oxide to use is Iron oxide (rust). There are plenty of great tutorials on Instructables.com on how to make rust. It follow the instructions and add the rust to your fuel and mix.

Step 9: Pack the Motors. Take the motor casing from a used rocket motor and fill it with your fuel. I used the B size rocket motors which take around 6g of fuel to fill. While packing you should periodically pack down the fuel in the motor. Do this by sliding the dowel rod into the open end and tapping it down with a hammer.

Step 10: Drill a nozzle. Once the motors are packed, use a drill to drill a nozzle down the center of the motor. It should be slightly smaller than the hole in the motor casing nozzle and about 2/3-3/4 the depth of your fuel.

Step 11: Blast off. You are now finished. Put your motor into an appropriate size rocket, install an igniter, and fire it off.

Result: After the successful launch of the rocket, the time taken by the rocket to get back to the ground is noted.

⚠️ Safety Warning

- **Only proceed if local laws allow amateur rocketry and propellant manufacturing.**
- Work in a **well-ventilated** area.
- Use **PPE**: safety goggles, gloves, lab coat.
- Keep a **fire extinguisher** nearby.
- Never work alone.

Warnings:
Making rocket fuel is dangerous. There is potential for personal injury including poisoning and burning. This is to be conducted outside under Faculty supervision and in an open air environment. The creator of this instructable is not personally responsible for any injury resulting from the creation or use of this rocket candy. All safety precautions should be followed including those of the manufacturers of the rockets themselves. Take care, while fun, rockets are still dangerous.

EXPERIMENT 11

Powered Gliders

A foot-launched powered hang glider (FLPHG), also called powered harness, nanolight, or hangmotor, is a powered hang glider harness with a motor and propeller often in pusher configuration, although some can be found in tractor configuration. An ordinary hang glider is used for its wing and control frame, and the pilot can foot-launch from a hill or from flat ground, needing a length of about a football field to get airborne, or much less if there is an oncoming breeze and no obstacles.

Adding propulsion

While powered microlights (ultralights) developed from hang gliding in the late 1970s, they were also a return to the type of low-speed aircraft that were common in the earlier years of aviation, but which were superseded as both civil and military aircraft pursued more speed.[1] For a second time in aviation history, during the 1970s, motorization of simple gliders, especially those portable and foot-launched, became the goal of many inventors and gradually, small wing-mounted power packs were adapted. These early experiments went largely unrecorded, even in log books, let alone the press, because the pioneers were uncomfortably aware that the addition of an engine made the craft liable to registration, airworthiness legislation, and the pilot liable to expensive licensing and probably, insurance. Inventors from Australia, France and England produced several successful microlight motor gliders in the early 1970s[2] and very few were portable wings.

Systems

Currently, there are two harness configurations: prone (face down) and sitting. Both configurations allow the pilot to takeoff and land on their feet. Foot-launched powered hang glider (FLPHG) harnesses are built around a light metal frame with the engine and propeller mounted on the rear in a pusher configuration. Current powered harnesses weigh 22–32 kg (50-70 lb) not including the safety parachute and fuel, and fold neatly into a 1.5 metres (4.9 ft) long harness bag with a handle. Most powered harnesses in production are equipped with the Radne Raket 120 two stroke engine which is based on Husqvarna XP3120 chainsaw parts. It has a displacement of 118 cubic centimetres (7.2 cu in) and produces about 15 hp (11 kW) at 8900 RPM if equipped with a tuned exhaust; when coupled to a 1:3.5 belt-driven reduction drive and a 52" x 22" propeller, it produces about 100 lbf (440 N) of static thrust. For heavy pilots or pilots operating from higher than 1,500 metres (4,900 ft) MSL fields, a powered harness equipped with an 18 hp (13 kW) engine is recommended.[38]

Cruiser powered Hang Glider with Rotax 582 Engine and Aeros Stil 17 Wing

EXPERIMENT 12

Aim: Case Study on Aircraft Crash Investigation
A case study on an aircraft crash investigation report would typically analyze a real-life plane crash, examining the detailed investigation report to identify the probable cause of the accident, contributing factors, and safety recommendations derived from the findings, often highlighting key aspects like pilot error, mechanical failure, weather conditions, air traffic control issues, and systemic problems within the airline or regulatory body, with the goal of understanding the chain of events leading to the crash and preventing similar incidents in the future.
Example Case Study: The Tenerife Airport Disaster (1977)

Accident Summary:
Two Boeing 747s collided on the runway at Tenerife Airport, resulting in the deadliest aviation accident in history with 583 fatalities.

Key Contributing Factors:
Dense fog obscuring visibility on the runway
Miscommunication between pilots and air traffic control
Improper runway usage due to confusion regarding taxi instructions
Pilot error in decision-making under pressure

Investigation Findings:
The pilots of one aircraft were attempting to take off on the wrong runway, not realizing they were on a taxiway due to the fog.
The air traffic controller gave conflicting instructions, leading to confusion among the pilots
Inadequate runway lighting and signage contributed to the disorientation in the fog

Safety Recommendations:
Improved training for pilots on runway awareness and decision-making in low visibility conditions
Clearer communication protocols between pilots and air traffic control
Enhanced runway signage and lighting systems at airports prone to fog
Analyzing a Crash Investigation Report:

Data Collection:
Review the official accident investigation report, including details about the aircraft, crew, weather conditions, flight plan, cockpit voice recorder (CVR) transcripts, flight data recorder (FDR) analysis, and witness testimonies.

Timeline of Events:
Construct a chronological sequence of events leading up to the crash, highlighting critical decisions and actions taken by the crew.

Human Factors Analysis:
Examine pilot performance, including training, fatigue, decision-making, and crew coordination.

Technical Factors:
Investigate potential mechanical failures, system malfunctions, maintenance issues, and aircraft design flaws.

Environmental Factors:
Assess the impact of weather conditions like turbulence, fog, icing, and wind shear.

Organizational Factors:
Evaluate airline procedures, safety culture, training programs, and regulatory oversight.
Key Points to Consider in a Case Study:

Causative Factors:
Identify the primary and contributing factors that led to the crash, often involving a combination of human, technical, and environmental elements.

Lessons Learned:
Analyze the safety recommendations derived from the investigation and discuss how they can be applied to prevent future accidents.

Systemic Issues:
Highlight systemic flaws in the aviation industry that may have contributed to the accident.

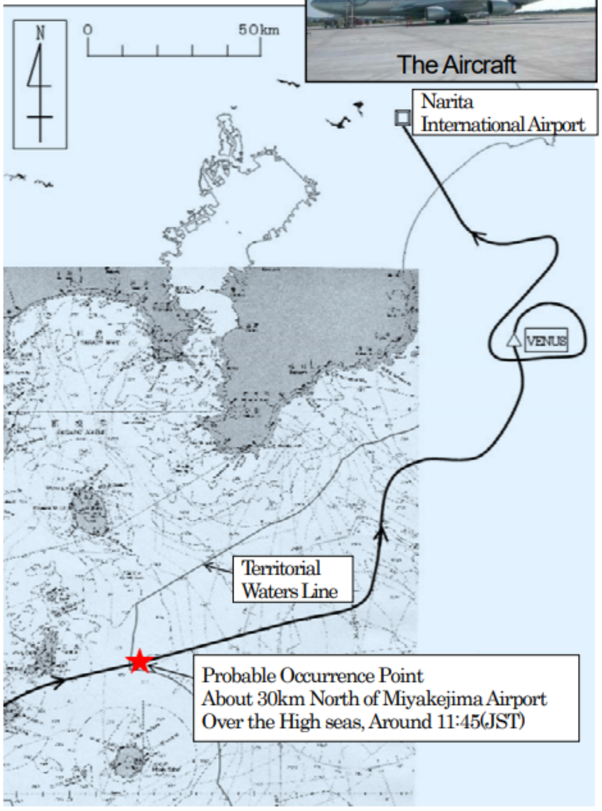
3. Case Studies of accidents

Case 1

Injuries suffered by passengers and cabin attendants from the shaking of the aircraft encountering turbulence during its descent in convective clouds

Summary : On Friday February 20, 2009, a Boeing 747-400, operated by Company A, took off from Manila (Ninoy Aquino) International Airport (Republic of the Philippines) bound for Narita International Airport (Japan) as the company's scheduled Flight. Around 11:45 Japan Standard Time (JST: UTC+9hr, unless otherwise stated, all times are indicated in JST on a 24-hour clock), the aircraft was hit by turbulence when it was flying at an altitude of 30,300 ft about 174 km south-southwest of Narita International Airport (about 30 km north of Miyakejima Airport). Four passengers sustained serious injuries while 27 other passengers and seven flight attendants (FA) sustained minor injuries.
There were 422 people on board, consisting of the pilot in command (PIC), 13 other crewmembers and 408 passengers.
The aircraft interior was partially damaged.

Estimated Flight Route



Events leading to the Accident

Around 08:47

The aircraft departed from Manila International Airport bound for Narita International Airport as the company's scheduled flight.

Around 11:30

The aircraft was instructed by the Tokyo Area Control Center (hereinafter "Tokyo Control") to descend from 37,000ft to 35,000ft, and the aircraft requested Tokyo Control to change its heading from 055° to 040° to avoid cumulonimbi.

Around 11:42

While descending from an altitude of approximately 34,000ft, the aircraft changed its heading to 080° based on instructions from Tokyo Control, and the aircraft began to jolt.

Around 11:44

The wind velocity began to change and dropped to approximately 100kt from approximately 150kt when the aircraft was descending by approximately 500ft from an altitude of approximately 30,700ft. At around that time, the bumpiness became intensified with altitude fluctuations.

When the Aircraft was descending at an altitude of about 30,300 ft, the vertical acceleration changed; from +1.36G to -0.52G, then to +1.70G. At that time, the pitch angle of the Aircraft decreased by about 0.5 degree in the nose-down direction and after the decrease, quickly increased by about two degrees in the nose-up direction.

Until landing, the vertical acceleration changed intermittently while decreasing, and the aircraft landed at Narita International Airport at around 12:19.

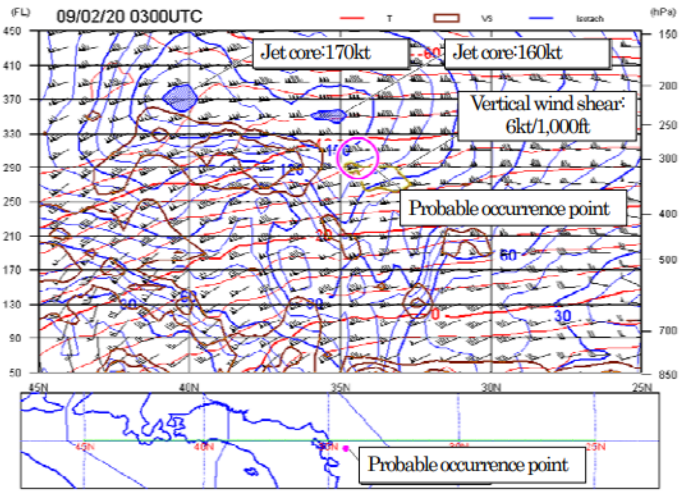
Meteorological Phenomena

Because warm and damp winds were blowing from the south into the low pressure near the Tokai region, generating unstable atmospheric condition. As a result, it is considered highly probable that clumpy convective clouds were developing there.

It is highly probable that clumpy convective clouds developed from the waters off the Tokai region to the Kanto region.

A vertical wind shear of 6kt/1,000 ft was observed amid jet stream near Latitude 35° N at an altitude of 26,000 to 30,000 ft. Therefore, it is considered highly probable that turbulent air was generated in the airspace near the place where the accident occurred.

Unit Conversion
1G : 9.807m/s²
1kt : 1.852km/h



Hourly Analysis Chart
1200JST 20 FEB 2009(Longitude 140°E) Some information was overlaid onto the JMA document.

Comparison of Situation in Forward and Aft Cabin Sections

In the briefing conducted at the Aircraft, the PIC briefed the all of FAs about the possible turbulence and requested them to observe the seat belt signs and have all duties finished prior to descent.

Situation in the forward and upper deck cabin sections

While the aircraft has 65 seats, there were 64 passengers 5 FAs responsible for these sections.

Situation in the middle and aft cabin sections

While the aircraft has 338 seats, there were 338 passengers and 6 FAs responsible for these sections.

The seats on the Aircraft were almost fully occupied. Passenger density was higher in the middle and aft cabin sections compared to the forward and upper deck sections. The number of passengers per one FA was about 13 persons in the forward and upper deck sections, while the number was far higher at about 56 seats in the middle and aft cabin sections. It is considered probable that it took longer to finalize post-service duties and confirm the safety of passengers in the middle and aft cabin sections.

The FAs of the forward cabin section took their seats earlier than usual after confirming the safety of the galleys and finishing their duties.

When the seat belt sign was illuminated, FAs in the upper deck confirmed whether the passengers fastened their seat belts and took their own seats with the seat belts fastened.

The aircraft became bumpy soon after the seat belt sign was illuminated. The FAs of the middle and aft cabin sections hurriedly tried to take the nearest jumpseats, they were not able to become seated.

In the middle and aft cabin sections where one FA had to take care of more passengers and more time was necessary for post-service clean-up and safety confirmation, it is considered probable that big bumpiness started before safety was fully confirmed after the lighting up of the seat belt sign.

There was intense shaking, and FAs who happened to be in the aisles were keeping themselves by holding on to the rack, and then crawling to the jumpseats. There were no injured persons in the forward cabin section, nor was there anybody screaming.

When the Aircraft dropped violently, nobody was standing in the upper deck, and all were safe.

In the mid cabin section, some unseated passengers fell on the floor after bumping their heads against the ceiling, and one of them was unable to move.

Some people, including FAs, were thrown upward to the ceiling, and many passengers were injured.

It is considered probable that when big bumpiness occurred, the passengers in the forward and upper deck sections had been seated with their seat belts fastened, while some passengers in the middle and aft cabin sections had left their seats or had not fastened their seat belts, or their seat belts had not been fastened properly.
The Aircraft encountered big bumpiness around 11:44:54, and a vertical acceleration of -0.52G was registered concurrently the pitch angle decreased followed by quick increase. It is considered probable that the aft section of the Aircraft sank suddenly corresponding to this pitch change and as a result it was subjected to a large negative vertical acceleration than in the forward.

Cabin ceiling

Armrest

Lavatory ceiling

It is considered somewhat likely that these factors led to more injuries in the middle and aft cabin sections.
Aircraft bumpiness might be greater in the aft cabin section than in the forward cabin section.
FAs in the aft cabin section are required to keep this in mind when they prepare in-flight service plans and confirm the safety of passengers.

With the PIC's pre-flight briefing all crewmembers had knowledge of anticipated turbulence during the descent. Therefore, like the FAs in the forward and upper deck sections did, it is considered probable that the FAs in other sections of cabin were able to confirm passengers' safety before the Aircraft encountered the turbulence.

Flight of the Aircraft

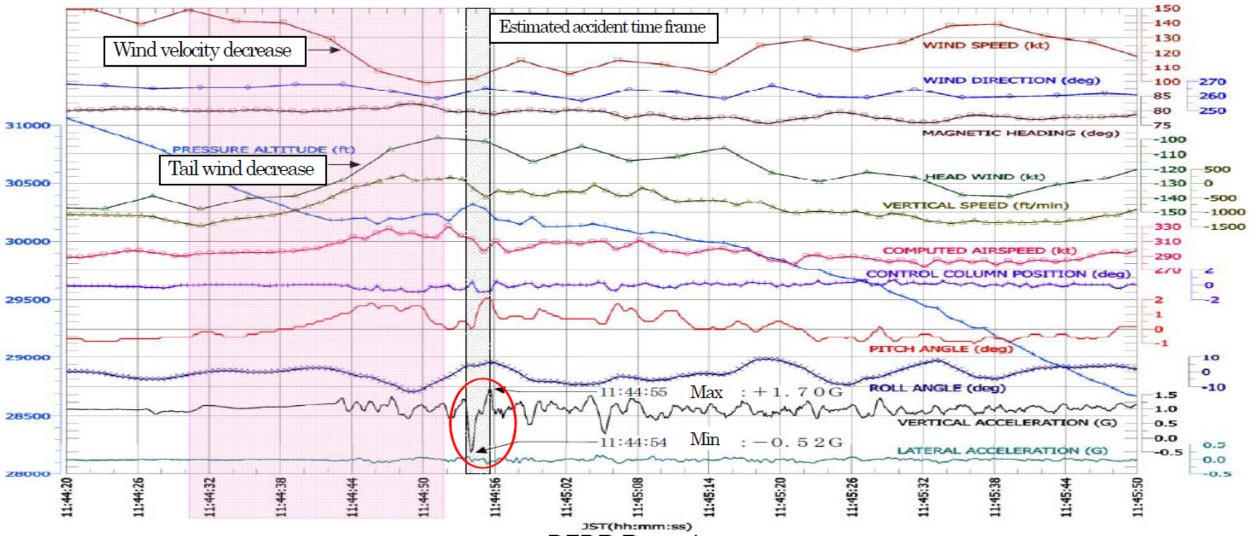
The aircraft requested permission to change its heading when it descended from the cruising altitude of 37,000ft to 35,000ft based on the instruction by Tokyo Control. It is highly probable that this was aimed to avoid cumulonimbi.

The Aircraft was instructed by Tokyo Control to descend to 18,000 and change its heading to 080° . Because clouds were observed in that direction, the Aircraft examined the clouds ahead with its radar, but there was no clear cumulonimbus on the radar screen. Therefore, it is considered highly probable that the Aircraft made a descent through the clouds keeping the direction as instructed.

According to the DFDR record concerning the vertical acceleration which indicates vertical bumpiness of flight, it is considered highly probable that the Aircraft encountered turbulence around 11:44:26 and the bumpiness began bigger from around 11:44:43 with the Aircraft's attitude change and then, reaching its culmination at 11:44:53 to 11:44:55 at an altitude of about 30,300 ft.

It is considered highly probable that this bumpiness resulted from the influence of the turbulence.

The wind velocity was 130 to 140kt in the vicinity of the airspace where the accident occurred. But the wind velocity that the Aircraft actually flew varied by about 50kt from about 150 kt to about 100kt. Therefore, it is considered highly probable that the Aircraft was influenced by the sudden large wind velocity change near the airspace where the accident occurred.



DFDR Records

Probable Causes: It is considered highly probable that this accident occurred when the Aircraft pitched greatly upon encountering a turbulence during its descent through a turbulent airspace of convective clouds near the front and below the jet stream, causing serious injuries to four passengers in the aft cabin section: who were not seated; who were not being buckled up; or if done so, who did it in an inappropriate manner.

It is considered somewhat likely that the following factors contributed to the serious injuries of aft cabin passengers: safety of passengers was not fully confirmed in the aft cabin section during the time frame between the seat belt sign illumination and the abrupt big aircraft pitching; and the aft cabin was exposed to a stronger negative vertical acceleration compared to the forward.

In order to Prevent Recurrence

- It is necessary for FAs to have common understanding about the indication of the seat belt sign and to take measures to call passengers' attention to the need of fastening seat belts properly and carefully listening to in-flight announcements.
- When an aircraft is anticipated to encounter turbulence, the cockpit crew should turn on the seat belt sign at the earliest possible time so that FAs may have enough time to finish their duties before the encounter, because a lot of time is necessary for them to provide services to passengers, clean up and confirm the safety of passengers.
- When informed by the PIC of the possible turbulence and the need to be seated during the descent, in the pre-flight briefing, FAs need to plan to finish in-flight services well before the anticipated encounter with turbulence. If the situation required, FAs need to consider discontinuing or canceling in-flight services. When the seat belt sign is illuminated, FAs are required to urge non-seated passengers to be seated and perform safety checks mainly by confirming their seat belt fastening manner. Accordingly, it is necessary to make plans while taking into account the time needed for these activities.

The investigation report of this case is published on the Board's website (issued on Dec. 16, 2011).
http://www.mlit.go.jp/jtsb/eng-air_report/N676NW.pdf
(This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.)