FEYNMAN AEROSPACE

AIRCRAFT DESIGN INTERNSHIP

SUBMITTED BY
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TABLE ODF ACRONYMS

SR.NO	ACRONYM	TERM
1	MAV	MICRO AIR VEHICLE
2	C_L	COEFFICIENT OF LIFT
3	C_D	COEFFICIENT OF DRAG
4	AOA	ANGLE OF ATTACK
5	AR	ASPECT RATIO
6	MAC	MEAN AERO DYNAMIC CHORD

ABSTRACT

- The goal of this project was to design a small Radio-controlled aircraft. The Aircraft was not built Physically but only on 3D Design Software, we created a report that includes the step-by-step process for manufacturing it, as well as details about its design, analysis, and performance.

- To design the aircraft, we used software called SOLIDWORKS, which helped us create a virtual model of the Aircraft. Then, we analyzed its performance using another program called XFLR5.

- By the end of the project, we had a comprehensive report that provided all the necessary information to build the aircraft. Although we didn't physically construct it, our design fulfilled the goal of creating an efficient unmanned aerial vehicle for transporting medical supplies and other items.

INTRODUCTION

- The main objective of this project was to design, analyze, and potentially construct a Micro Air Vehicle (MAV). The aim was to gain a comprehensive understanding of the aerodynamics involved and make informed decisions regarding the selection of suitable motors and controllers for optimal MAV operation. To achieve this objective, a significant amount of research was conducted to determine the various parameters critical to the construction of the MAV.

- It was an individual project and was carried out with specific tasks. Once the initial research phase was completed, the data collected on various aspects of the project was put together to obtain the final design. The knowledge and expertise of the instructors helped to ensure a comprehensive and well-rounded final outcome.

AIRFOIL SELECTION

- AN AIRFOIL SHAPED BODY, MOVING THROUGH A FLUID, PRODUCES AERODYNAMIC FORCES, WHICH ARE LIFT AND DRAG HAND IT IS THE AIRFOIL GEOMETRY WHICH DETERMINES THE CHORD-WISE LIFT DISTRIBUTION OF A WING. THEREFORE, ONE OF THE IMPORTANT DESIGN PHASES OF MAKING AN AERODYNAMICALLY EFFICIENT MAV IS THE SELECTION OF THE APPROPRIATE AIRFOIL.
- In our project, the selection of the airfoil for the wing design involved performing an in-depth aerodynamic performance analysis of different airfoils. Our specific requirement was to find a "high lift, low Reynolds number" airfoil that would suit the characteristics and objectives of our MAV. We considered four different airfoils: AG25, AG26 , AG35 AND AG36 To evaluate their suitability, we utilized XFLR5 software, which allowed us to analyze the aerodynamic properties and performance of each airfoil.
- By conducting this thorough analysis, we aimed to identify the airfoil that would provide the desired high lift capabilities while operating at low Reynolds numbers, which are characteristic of MAVs. The selection of the optimal airfoil plays a critical role in achieving the desired flight performance, manoeuvrability, and efficiency of our MAV design.

AIRFOIL	$C_{L\,MAX}$	α	C_L/C_D AT α
AG25	1.197	9.2	53.6 AT 4.6
AG26	1.198	9.4	54.4 AT 4.5
AG35	1.257	9.5	50.32 AT 4.4
AG36	1.013	7^{O}	50.2 AT 4.5^{O}

TABLE 1:AIRFOIL PROPERTIES

AIRFOIL	C_L	α STALL	C_L/C_D	TOTAL
AG25	3	1	4	8
AG26	4	3	2	9
AG35	4	3	4	11
AG36	5	4	5	14

TABLE 2 : POINT BASED SYSTEM FOR AIRFOIL SELECTION

C_L BEHAVIOR OF THE AIRFOILS IS AS FOLLOWS :

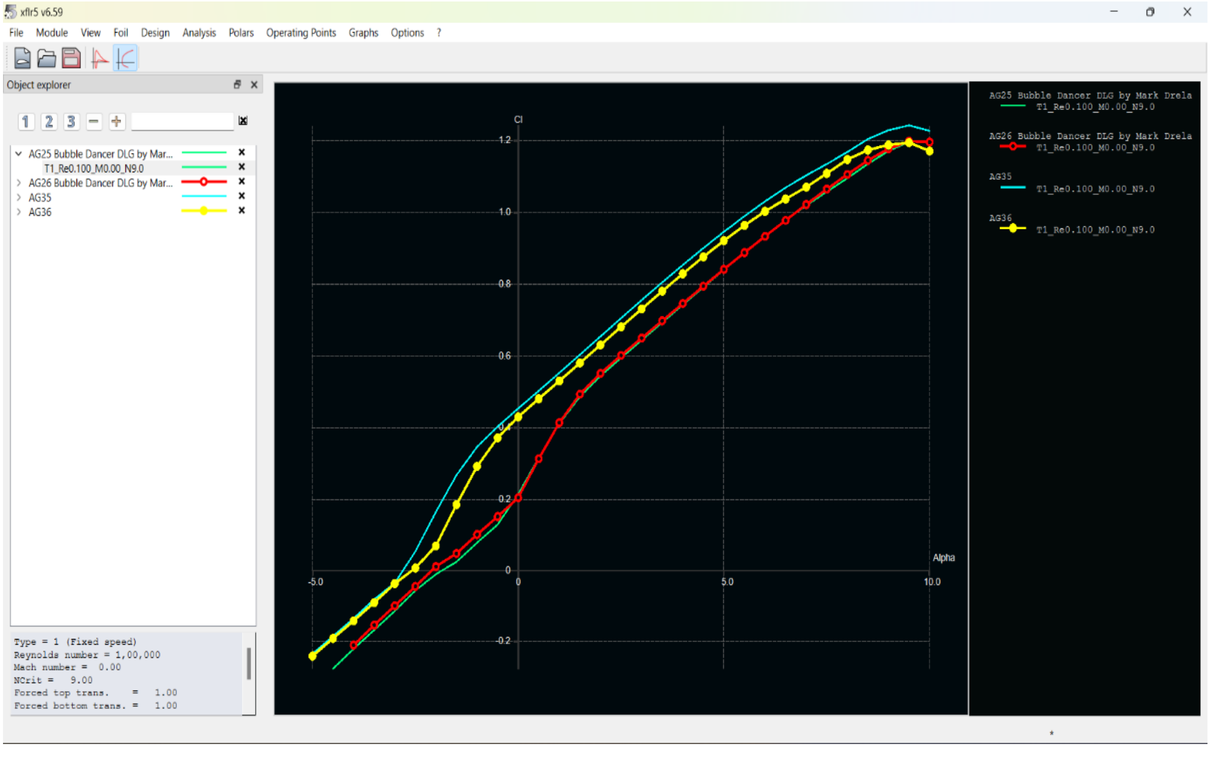


FIGURE 1: C_L CHARACTERISTICS FOR AG25 , AG26 , AG35 AND AG36 AIRFOILS

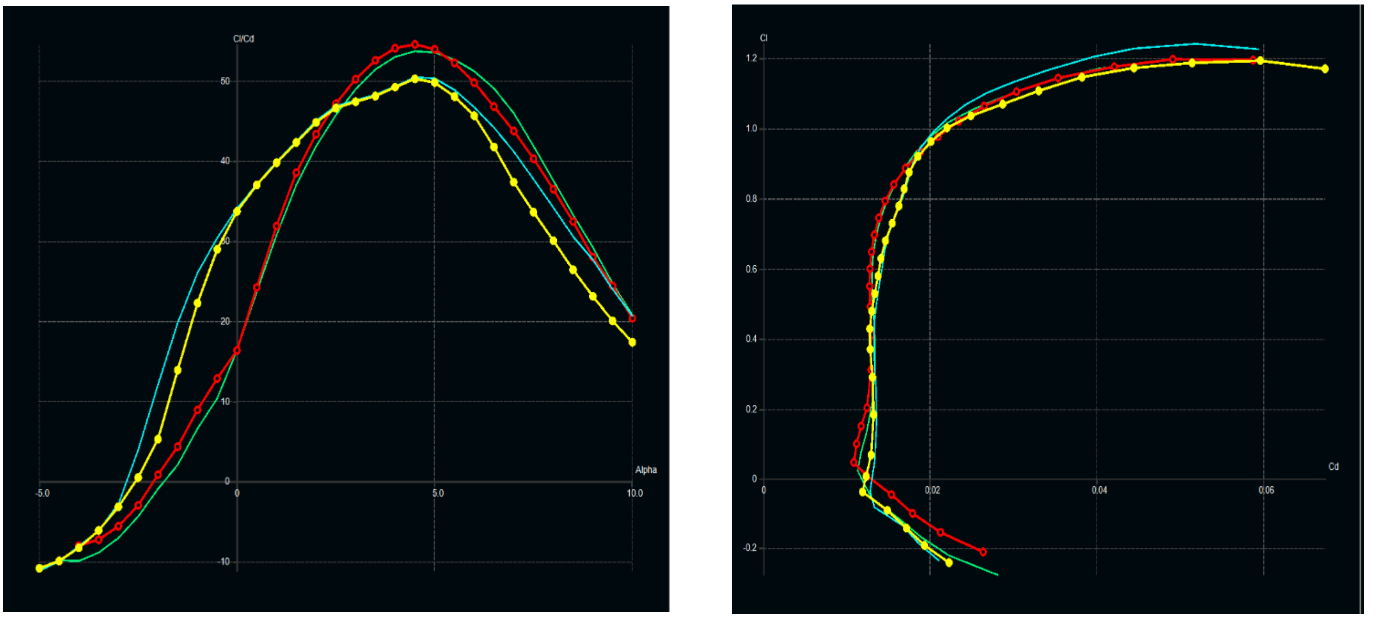
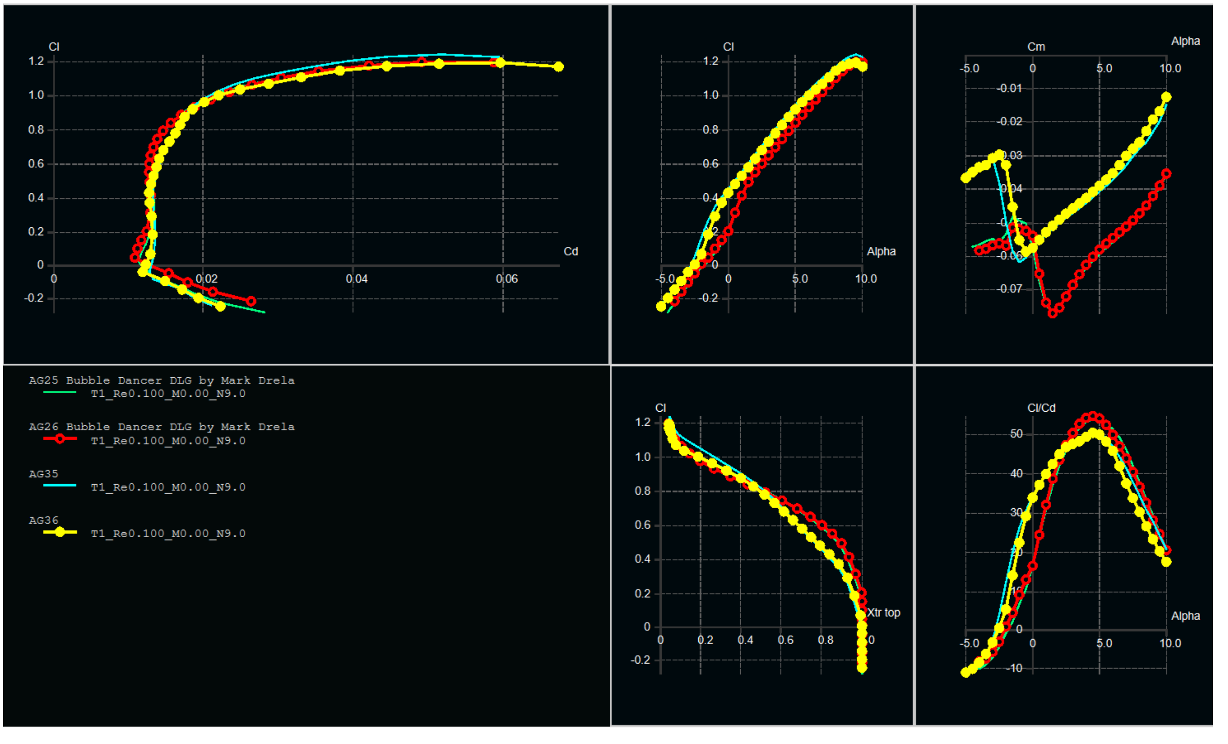
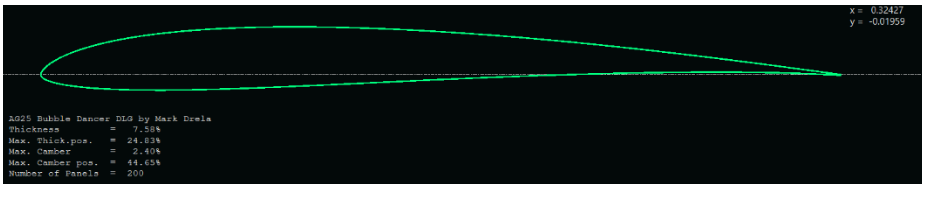


FIGURE 2 : C_L vs C_D C_L/C_D vs α CHARECTERISTICS OF AIRFOILS



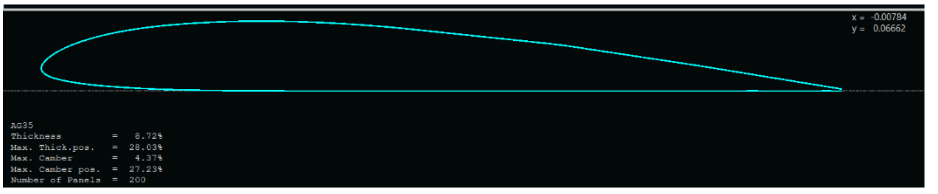
AIRFOIL PROPERTIES

AG36 AIRFOIL



AG25 AIRFOIL

AG26 AIRFOIL



AG35 AIRFOIL

Wing calculation and Planform selection

Formula for Total wing loading:

Wing Loading = Maximum Take-off/ Weight Lifting Area

- We wanted to find the best wing loading value for our aircraft, which is the weight of the aircraft divided by the wing area. We tested different wing loading values between 8 and12, and decided that a wing loading of 10 kg/m^2 was the most suitable. Based on this wing loading, we calculated the necessary lifting area to support a weight of 1.3 kg (our assumed aircraft weight), which turned out to be 1300 cm^2.
- Our Aircraft had a MAC of 25 cm and wing span of 150 cm. Therefore our wing area is approximately 3750 cm^2, which is obviously higher than our assumed wing area.
- Next, we considered different aspect ratios for the wings. The aspect ratio is the ratio of the wing's span to its average chord length. According to our aircraft's requirements, we aimed for an aspect ratio between 5 and 6.5. Taking into account the competition rules that specified a maximum wing span of 150 cm, and using the designed wing area of 3750 cm^2,we were able to calculate the aspect ratio (AR).

Formula for AR:

$$AR= SPAN^2/WING\ AREA$$

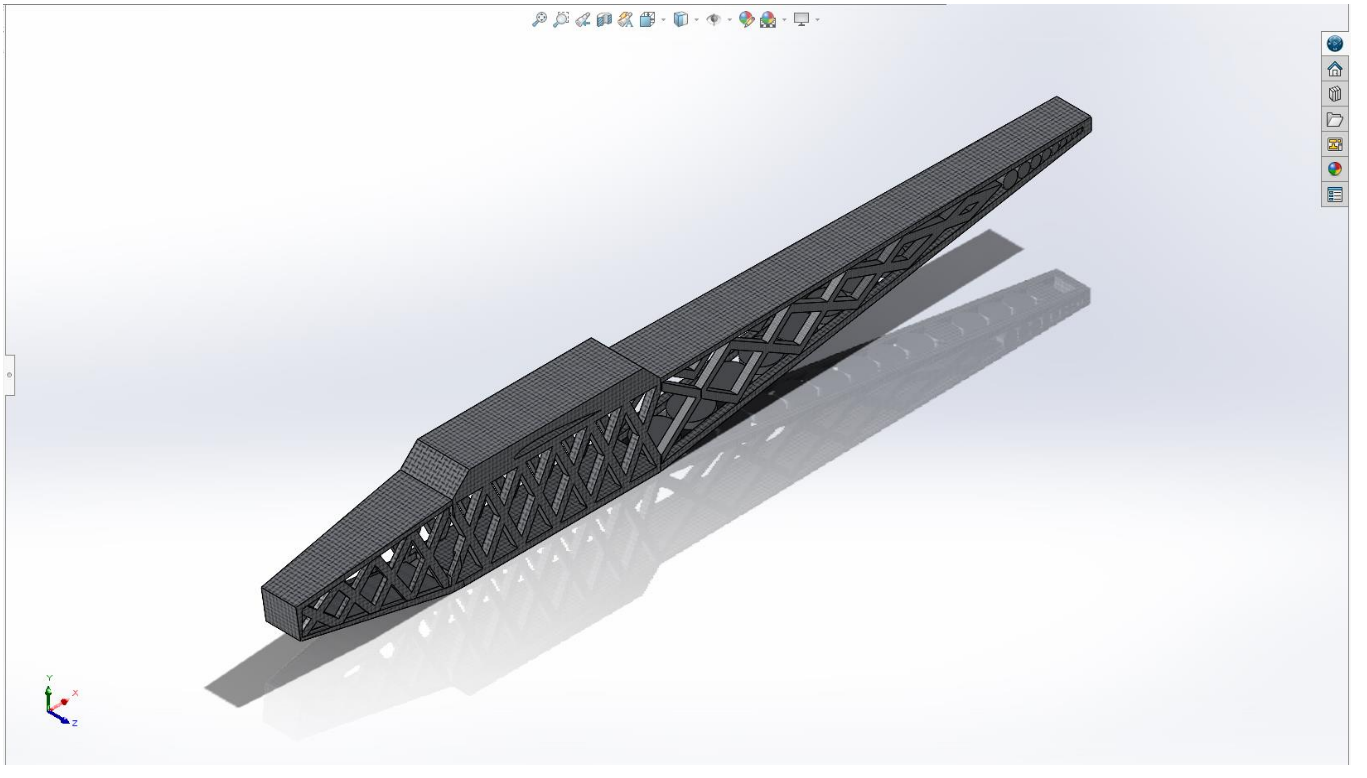
$$AR =150^2/3750=6$$

The compound planform was created with a root chord of 30 cm and tip chord of 20 cm fora span of 150 cm. A dihedral angle was added to the root of the wing for ease of handling , better stability and manoeuvring. A winglet was designed to reduce the turbulence at the wing tips for better aerodynamic efficiency, and stability.

The material for the aircraft Design was chosen to be PLA, the model was prepared in such a way that it can be 3D printed using the appropriate equipment.

FUSELAGE DESIGN

A fair amount of research amount was done for the fuselage design and it was found that for most RC plane a proportional length of fuselage is 80% - 85% of the wingspan. We also came to a conclusion that manufacturing a stream line design would be difficult therefore, so it was decided that we would be creating a boxy fuselage as shown below.



The material that we decided to use for the fuselage was Carbon Fibre. It was chosen over other allowed materials because it is light in weight and provided sufficient strength.

Wing Analysis

We used an underwing configuration, as it provides better flight efficiency and speed for racing manoeuvring.
We used XFLR5 software to analyze the wing of our aircraft. The analysis was conducted using VLM2 (Vortex Lattice Method) and a fixed speed polar, assuming a free stream velocity of 15 m/s. The analysis conditions are listed in the table below.

Table 3:Wing Analysis Conditions

s

PARAMETER	VALUE
SPEED	**15 m/s**
AOA	**-5 deg to 10 deg**
AIR DENSITY	**1.225 kg/m^3**
KINEMATIC VISCOSITY	**1.5x10^{5}m^2/s**

The results of the analysis indicated that our wing generated a maximum coefficient of lift of 1.013. The graph below illustrates how the coefficient of lift varies with the angle of attack.

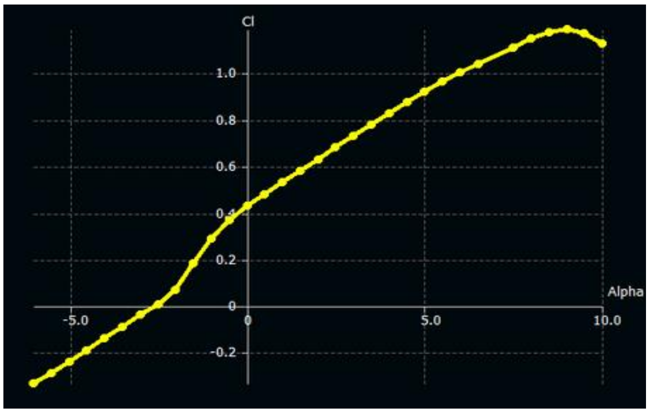


Figure 5: The variation of the coefficient of lift with angle of attack

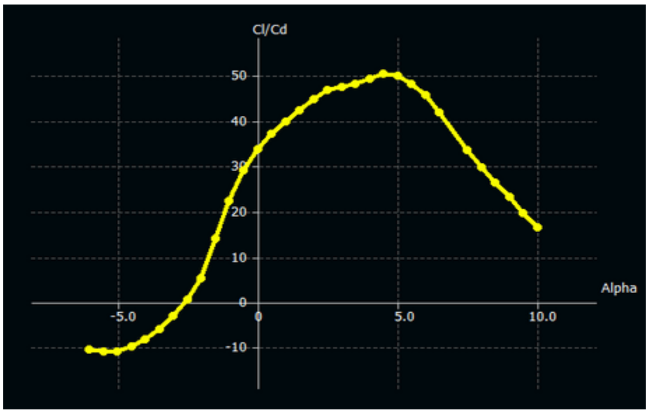


Figure 6: The variation of C /C with angle of attack

From the analysis, we observed that our wing planform performed exceptionally well in terms of lift generation within an angle of attack range of -5° to 10°. The wing achieved its highest lift coefficient of 1.013 at an angle of attack of 4.5°. This information provides valuable insight into the aerodynamic performance of our wing design

Avionics

- The avionics system used in the project was carefully selected to meet the specific requirements of the aircraft. The choice of the motor and propeller was crucial to ensure adequate thrust for hand launching and efficient take-off.
- For the motor, a Brushless Direct Current (BLDC) motor was chosen over a brushed motor due to its superior efficiency and torque per voltage. This decision aimed to increase the overall range of the aircraft and maximize its thrust capacity, which directly affects the payload it can carry. The selected motor had a rating of 1000kV, meaning it ideally runs at1000 revolutions per minute (rpm) for every 1 volt of voltage applied. However, it was found to run at around 800rpm per volt, with an efficiency of 80%.
- The propeller chosen was a 10x4.7 propeller with two blades, a 10cm length, and a pitch of47 degrees. This configuration struck a balance between stable and nimble flight while providing sufficient thrust for the intended payload.
- An Electronic Speed Controller (ESC) was employed to regulate the motor's speed and operation. The ESC accepted a PWM servo input signal with a nominal frequency of 50 Hz, where the pulse width ranged from 1 ms to 2 ms. When provided with a 1 ms pulse, the ESC would deactivate the motor, while a pulse width of 1.5 ms would result in the motor running at approximately half-speed. By adjusting the pulse width of the input signal, the ESC facilitated precise control over the motor's performance, enabling the aircraft to achieve the desired flight characteristics and responsiveness based on the pilot's commands.
- To power the motor, an 11.1V 3s lithium polymer battery with a capacity of 2200mAh was used. This battery choice struck a balance between weight and capacity, ensuring optimal performance without adding unnecessary weight to the aircraft.
- The servos utilized in the project were 9 gram SG90 servos with plastic gears. These servos were chosen to avoid adding excessive weight, as the forces acting on the control surfaces did not exceed the limits of the plastic gears. Each servo had a stall torque of approximately 2.5 kg-cm, which proved sufficient for controlling the ailerons, elevators,

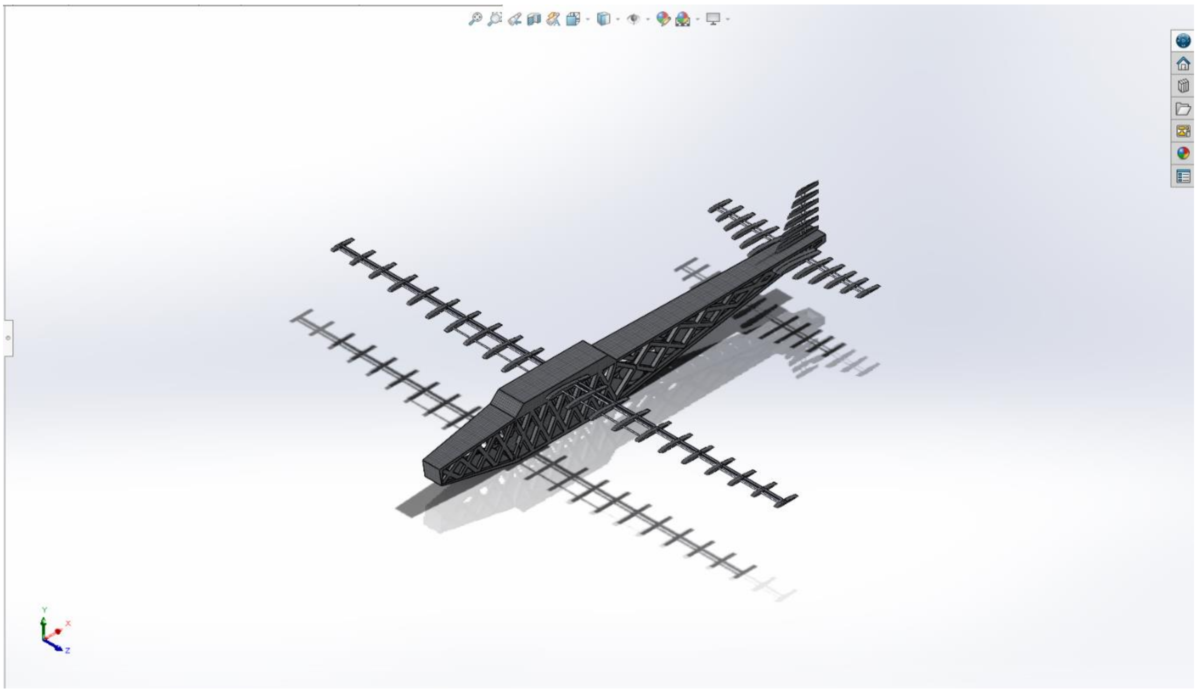
rudder, and payload release mechanism. The ailerons were actuated by two servos mounted beneath the wing, connected to ailerons through a 2cm horn and a 2:1 ratio linkage, providing smooth and precise flight corrections. Two additional servos mounted towards the tail controlled the elevator and rudder using 2cm horns and a 180-degree rotation limit .Placing the servos at the rear helped relocate the centre of gravity beneath the wing shoulder.

- All the servo operations and control were managed using a 6-channel radio transmitter and controller. For Landing gear, the under-wing has space for pushrods of 2mm in diameter and for a tail wheel at the end of the fuselage similarly.

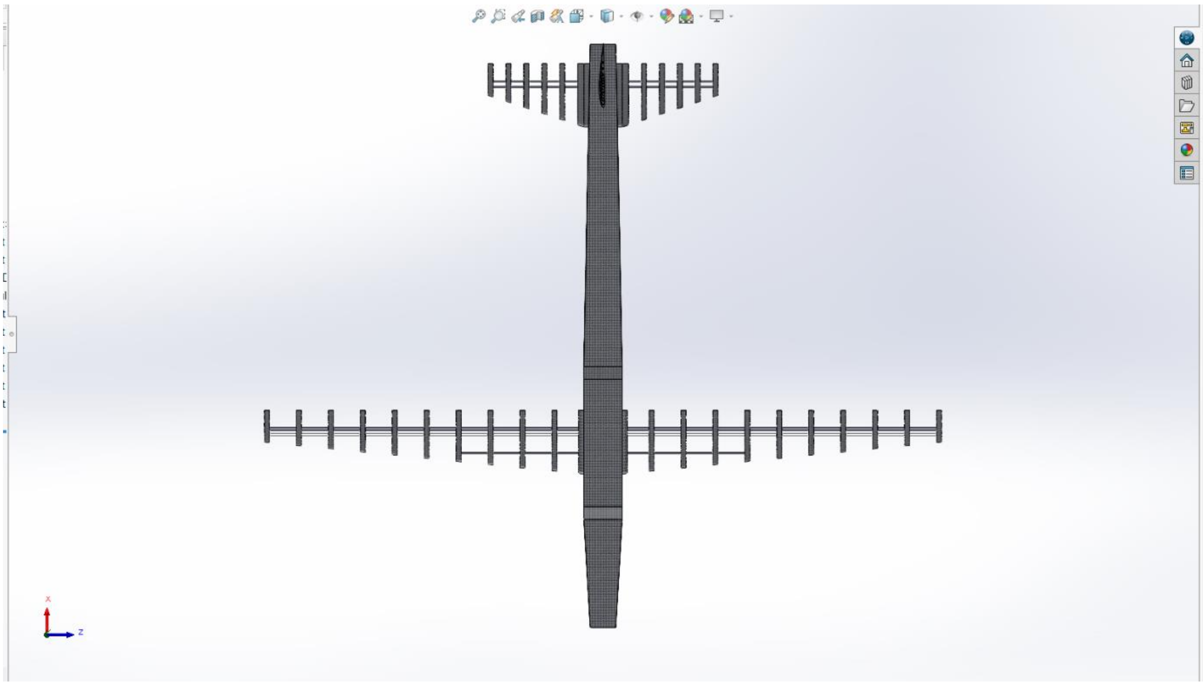
References

S.no.	TITLE
1	"Introduction to Flight" by John D. Anderson Jr."
2	"Aircraft Design: A Conceptual Approach" by Daniel P.Raymer."
3	"Principles of Aircraft Stability and Control" by M. V. Cook."
4	IJERT VOLUME 3 BY SHREYAS HEGDE

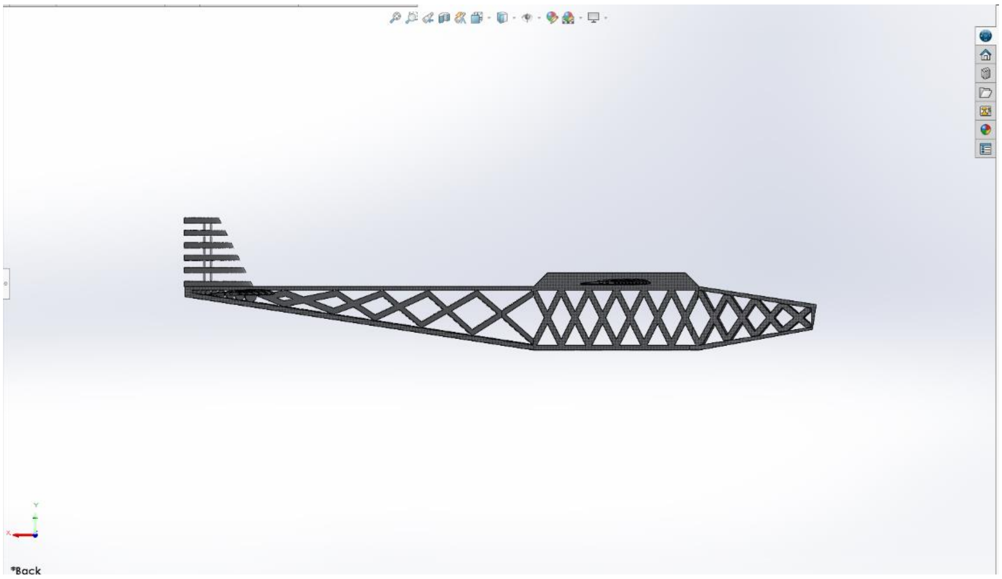
3D DESIGN OF AIRCRAFT



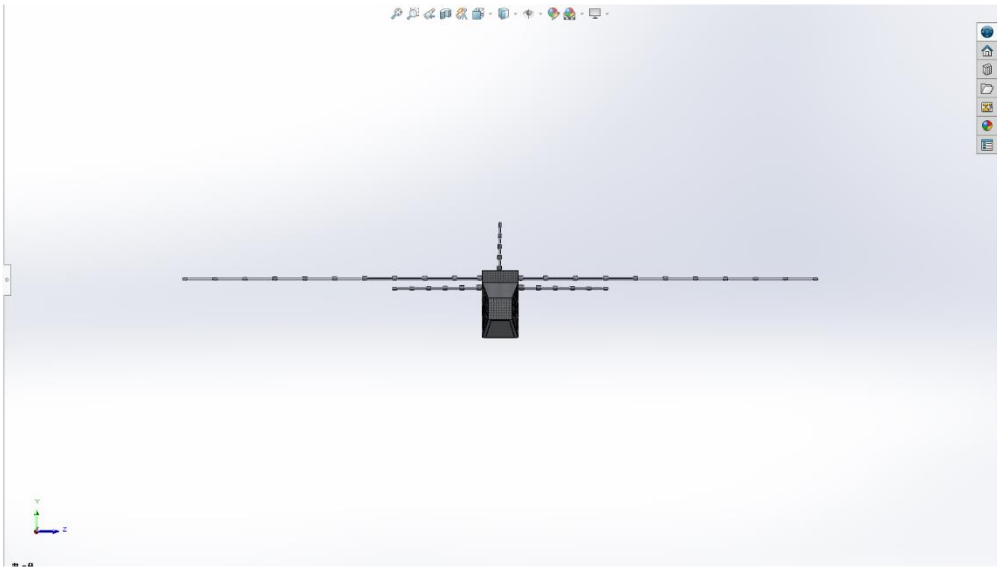
ISOMETRIC VIEW



TOP VIEW



SIDE VIEW



FRONT VIEW