DRONE DEVELOPMENT CHALLENGE 2024

DESIGN REPORT

TEAM ID: DDC2024048 **TEAM NAME:** VALHALLA

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Date: **19 February 2024**

SAEISS DRONE DEVELOPMENT CHALLENGE 2024

Certification of Qualification

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Statement of Compliance

As Faculty Advisor:

- I certify that the registered team members are enrolled in collegiate courses.
- I certify that this team has designed, constructed and/or modified the radio-controlled airplane with the intention to use this aircraft in the **SAEISS Drone Development Challenge 2024** competition, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.
- I certify that this year's Design Report has original content written by members of this year's team.
- I certify that all reused contents have been properly referenced and is in compliance with the University's plagiarism and reuse policies.

19/02/24

Signature of Faculty Advisor

19-02-2024

Date

Signature of Team Captain

19-02-2024

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❖ INTRODUCTION AND BACKGROUND

The purpose of this project is to enter a remote controlled (RC) aircraft into the Society of Automotive Engineers India Southern Section (SAEISS) Aero Design competition. Students were tasked to employ knowledge of aerodynamics, structural mechanics, control systems, electrical engineering, and design principles to create an airworthy submission.

❖ MOTIVATION

UAVs are truly marvellous inventions with great potential. They can be found in delivery services to national defence. In the last few years, large Multinational corporations and even countries have started investing a considerable number of resources for the construction of unmanned aerial vehicles (UAVs), or drones. These devices immediately found a great deployment in the society opening an incredible number of new opportunities as useful tools to address a variety of societal challenges, including agriculture and forest analysis, identifying property boundaries, surveying construction sites or corridors for roads and railroads, flooding and coastal erosion assessments, building information management, disaster planning and handling, surveys in remote or undeveloped areas, and the delivery of goods. The possibilities of digitalisation and technology development address societal challenges such as making societal sectors and domains more ecosystem friendly, efficient and competitive. This project will work to define societal challenges and ways to address them using applications of drone technology.

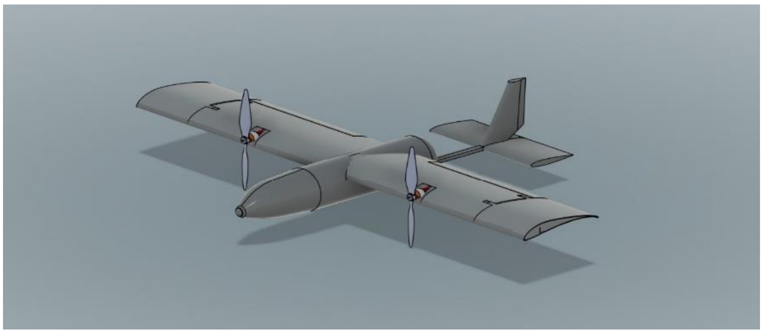


Fig 1. 3D Model of Aircraft

❖ LIST OF SYMBOLS

Symbol	Description
AR	Aspect Ratio
C_L	Coefficient of Lift
Cd	Coefficient of Drag
T_{min}	Minimum Thrust
V_{stall}	Stall Velocity
V_{TO}	Take-off velocity
A_d	Deceleration
V_{TD}	Landing velocity
W_L	Landing Weight

❖ POWER PLANT SELECTION

1. Motor Selection

Thrust calculation:

Total weight = 3kg = 3000g

Consider a Thrust to Weight ratio of 0.9

Thrust required = 0.9 x weight = 0.9 x 3000g = 2700g = 2.7kg

Power calculation:

Power required in watts = (Weight of aircraft in grams) / 4

= 3000 / 4 = 750W

kV calculation:

Take pitch speed as 65 MPH (Ps)

KV = (Ps x 1056) / (v x Pp) {V: Voltage | Pp: Propeller pitch}

= (65 x 1056) / (11.1 x 4.5)

= 1374.174 ~ A high KV motor is required

Considering the above calculations the following motor configuration is deemed to be ideal for the flight.

Element	Specification	Weight
Motor	DYS D3536-5 1450KV / 7.4~14.8V Shaft Diameter: 5mm Stator Diameter: 36mm Max Continuous Power: 655W Max Continuous Current: 45A Max RPM: 16095	102g

From the datasheet of the specified motor (DYS D3536 1450 kV BLDC Motor), the following performance is available for a propeller of 10” x 4.5”.

Voltage(V)	RPM	Throttle	Current(A)	Power(W)	Efficiency	Thrust(g)
11.1 V	16095	100%	33.2	368.4375	3.74	1380

2. Propeller Selection

Propeller Diameter: $\frac{2\times\sqrt{Wing\ \ Area}}{\sqrt{\pi\times Aspect\ \ Ratio}} = \frac{2\times\sqrt{385.31"}}{\sqrt{\pi\times\frac{46.024"^2}{385.31"}}} = 9.446" \sim$ **10"**

{Aspect Ratio: (Square of Wing Span) / (Wing Area)}

Propeller Pitch: (P_s × 1056) / (16095) = 4.26" ~ **4.5"**

Considering the motor loading and its datasheet a 10" x 4.5" propeller is selected.

3. ESC Selection

Maximum current drawn by the motor is 33.2 A as per the datasheet.

Considering 120% of the maximum current we get 39.84 A

An ESC capable of handling 11.1V (3S) and the maximum motor current is required.

Considering the above calculations the following ESC specification is deemed to be ideal for the flight.

Element	Specification	Weight
ESC	ReadytoSky 40A 2-4S ESC Burst Current: 60A Constant Current: 40A	34g

4. Battery Selection

Considering the weight requirements of the power plant, a battery of 2200 mAH capacity is considered.

C-rating calculation:

C-rating required = maximum current requirement of motor in mA / battery capacity in mA

= 80000 / 2200 = 36.36C ~ 40C

Considering the above calculations the following LiPo battery pack specification is deemed to be ideal.

Element	Specification	Weight
Battery	2200mAH - 3S (11.1V) - 40C LiPo	175g

Flight time estimation:

Efficiency of a battery = (3.3 / 4.2) x 100 = 78%

Taking a battery of 2200 mAH, the effective battery amp is: 78% of 2200 = 1716 mAH

The maximum motor amp consumed is 33.2mAH for one motor. So, for 2 motors, it equals 66.4AH.

Flight time = (Effective battery Amp / Maximum motor Amp) x 60

= (1.716/66.4) x60

= 1 minutes 33 seconds (at 100% throttle)

The specifications of power plant components are as shown below:

Element	Specification	Weight
Motor	DYS D3536-5 1450KV / 7.4~14.8V Shaft Diameter: 5mm Stator Diameter: 36mm Max Continuous Power: 655W Max Continuous Current: 45A Max RPM: 16095	102g
ESC	ReadytoSky 40A 2-4S ESC Burst Current: 60A Constant Current: 40A	34g
Battery	2200mAH - 3S (11.1V) - 40C LiPo	175g
Propeller	10” x 4.5”	22g

❖ FUSELAGE SELECTION

The primary function of a fuselage is to carry the payload safely while having the lowest weight possible while adhering to safety norms. There are three distinct parts of the fuselage: nose, centre, and rear. These will carry different loads depending on the purpose of the aircraft. The central part of the fuselage is reinforced more than the latter as it is expected to come under various forces. Keeping in mind the complex forces that come into play while on flight, the monocoque type of fuselage is selected with a 3D Printed PLA and the skin and bulkheads are reinforced using aluminium frame.

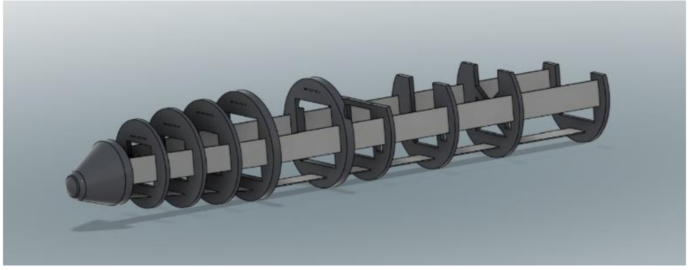


Fig 2. Fuselage Design

❖ WING SELECTION

The primary design of a rectangular wing with a short wingspan was rejected, keeping in mind the need for higher lift. As an alternative, a rectangular wing that could bring good aerodynamic characteristics of high lift was achieved by increasing the wingspan with foldable wings at both ends. The high wing design will give the aircraft the desired stability and clearance. A lightweight material Expanded Polyethylene sheet reinforced with aluminium plate is used as the wing base.

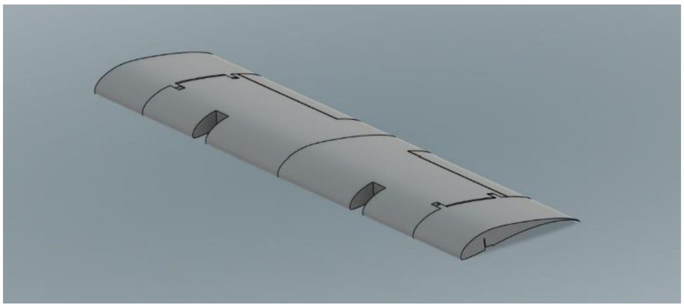


Fig 3. Rectangular Wing Design

❖ EMPENNAGE SELECTION

The tail in a conventional aircraft often has two components, horizontal tail and vertical Tail. Here conventional tail design was selected since it is the most widely used layout in commercial aircrafts and it provides sufficient lift and stability with the benefit of being lightweight. The aerofoil chosen for the empennage was NACA 0012 due to its no lift capacity at 0° angle of attack.

Horizontal stabilizer area	=	**0.00036 m²**
Elevator area	=	**0.00015 m²**
Vertical stabilizer area	=	**0.000126 m²**
Rudder area	=	**0.00003 m²**

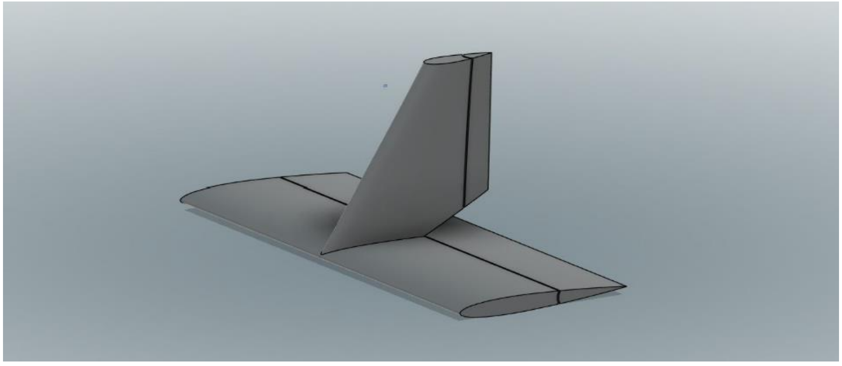


Fig 4. Empennage Design

❖ WING CONFIGURATION

- **AIRFOIL SELECTION**

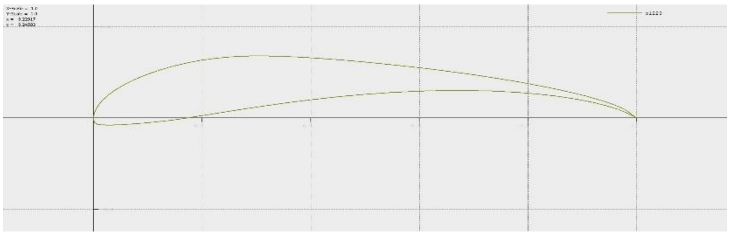
Considering the need to reduce drag and generate more lift at low speeds, SELIG s1223 is selected as the airfoil. Its high lift coefficients and low drag coefficients can be advantageous for the aircraft. Moreover, it has good stall characteristics as compared to other airfoils.

Here we evaluate the performance and characteristics of an airfoil by looking at the following graphs:

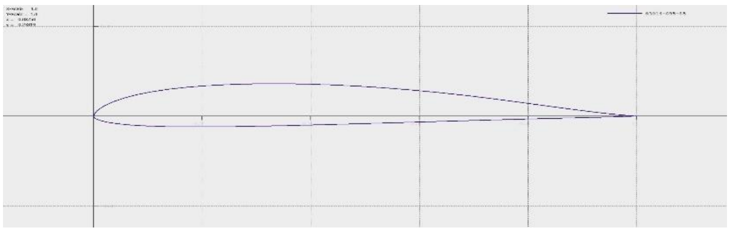
1. The variations of lift coefficient versus the angle of attack.
2. The variations of the lift coefficient versus the drag coefficient
3. The variations of the lift-to-drag ratio versus the angle of attack.

The following air foils were compared at 12.2° angle of attack-

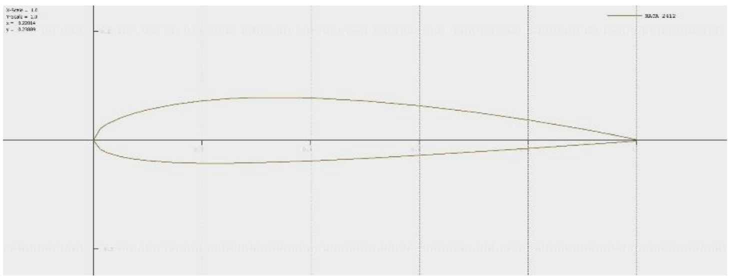
selig s1223 selig s3014 NACA 2412



Name: s1223



Name: s3014



Name: NACA 2412

Fig 5. Comparison of airfoils

- **AIRFOIL ANALYSIS USING XFLR5**

Airfoil was analysed using XFLR5 and airfoil tools software with Reynolds no of 180057. The final airfoil to be selected was determined through a percentile-based scoring system where the most desirable airfoil in each figure of merit was given the maximum score.

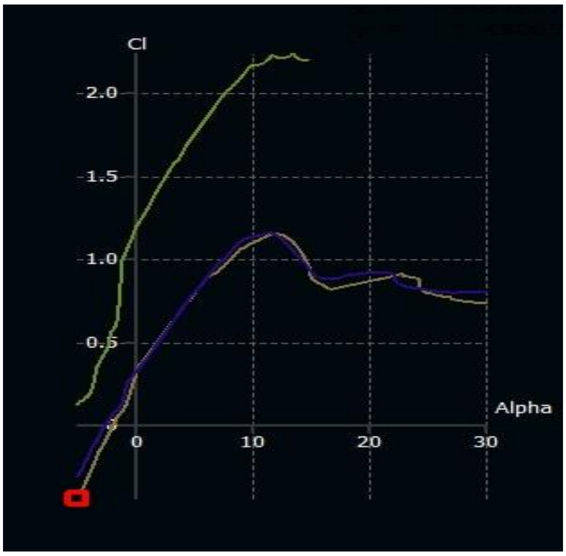


Fig 6. C_l vs Alpha

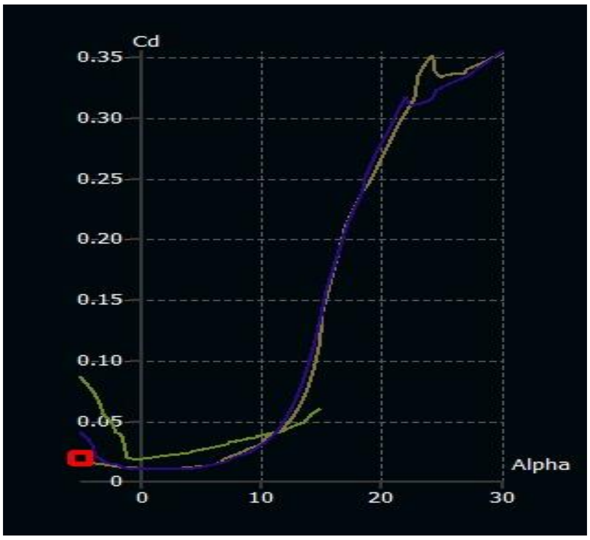


Fig 7. C_d vs Alpha

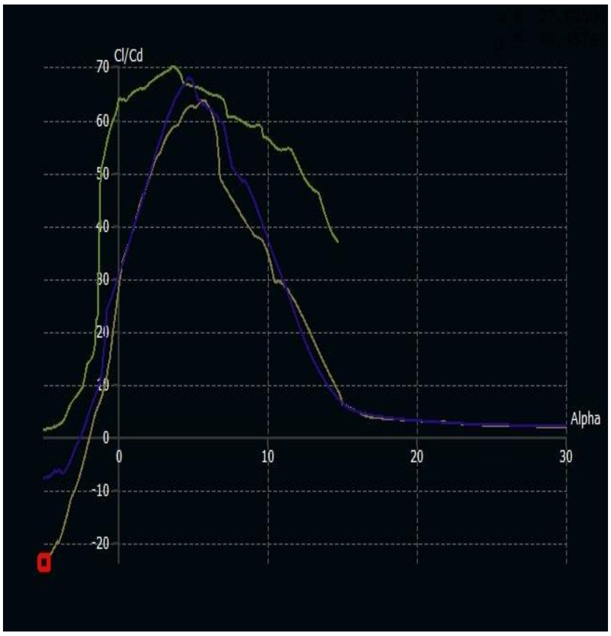


Fig 8. C_l – C_d vs Alpha

From the above table it is clear that Selig S1223 is the clear choice. NACA 2412 and S3014 airfoil faces early stall due to which it is rejected. The airfoil which has the best result is the C_l (lift coefficient)-C_d (drag coefficient) graph and it would be the best choice for designed aircraft because C_l / C_d ratio is an important factor to take-off. Aircraft which have an airfoil that provides the highest C_l value when C_d value is low, will have an easy take off. In our analysis S1223 provides the best lift while maintaining a low drag. Hence S1223 foil which has the best graph result is chosen.

FIGURE OF MERIT	SCORE OF FACTORS	S1223	NACA 2412	S3014
C_l vs α	60	60	36	24
C_l - C_d vs α	20	20	12	8
C_d vs α	20	20	11	10
Total	**100**	**100**	**59**	**42**

❖ CFD REPORT

CFD is a computerised method of solving fluid flow problems. It uses a process called Discretization to convert partial differential equations into discrete counterparts that the computer processors can solve. The software uses Navier–Stokes's equations to solve an algebraic matrix in each cell through iterations until the difference (residual) is small enough. There are many CFD software available. In our case we have used the CFD solver of ANSYS FLUENT. The mesh and set-up are as shown below:

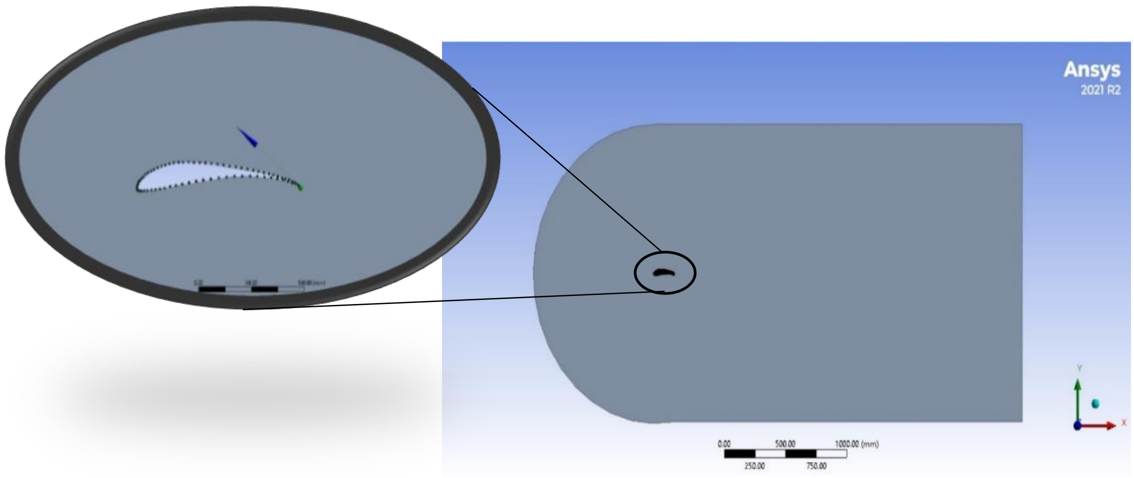
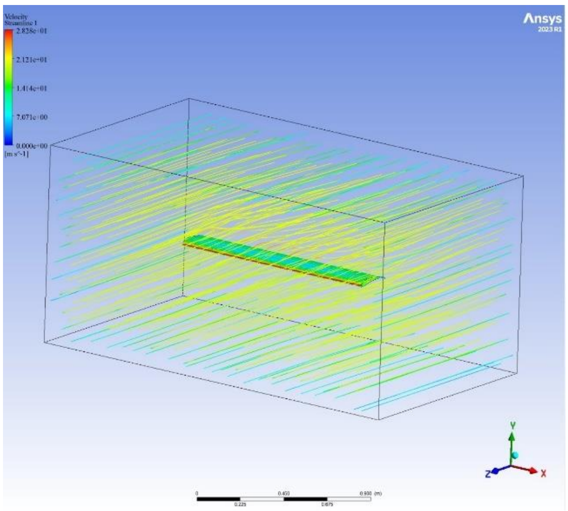


Fig 9.a. Boundary conditions in 2D Model



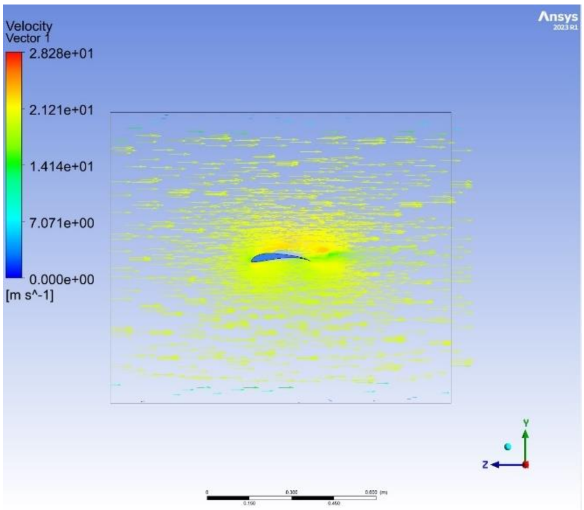


Fig 9.b. Boundary Conditions in 3D Model

Fig 9.c. Boundary Conditions in 3D Model (Side View)

The wing is enclosed in a rectangular enclosure to act as a wind tunnel and specify the boundary conditions. Boolean operation was done to subtract the wing from the enclosure.

- **MESH**

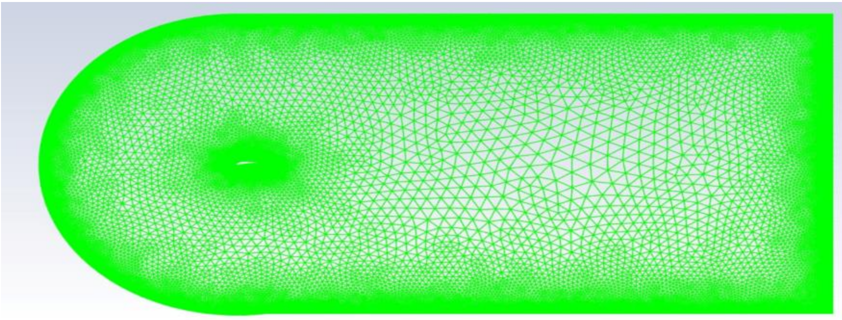


Fig 10. Mesh Analysis

Element size was set containing predominantly triangular mesh. Edge sizing was given to further refine the mesh.

- **RESULTS**

Velocity streamlines were plotted as shown below.

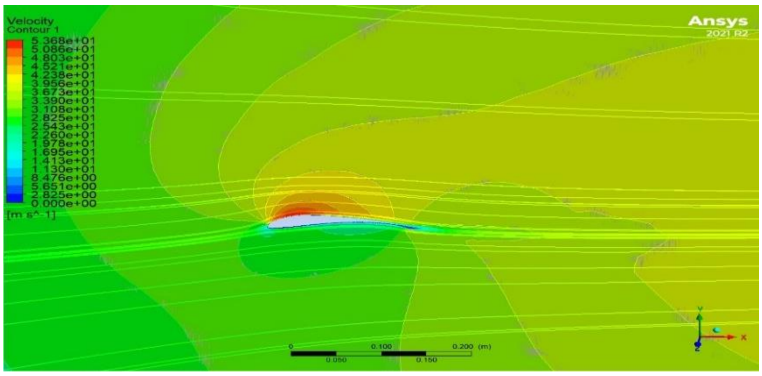


Fig 11.a. Angle of Attack 0°

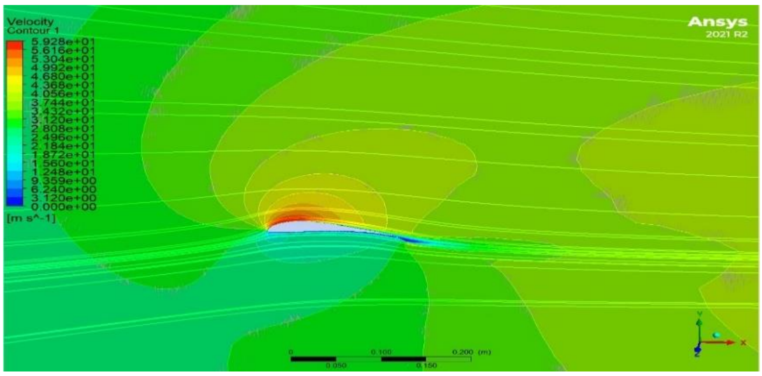


Fig 11.b. Angle of Attack 6°

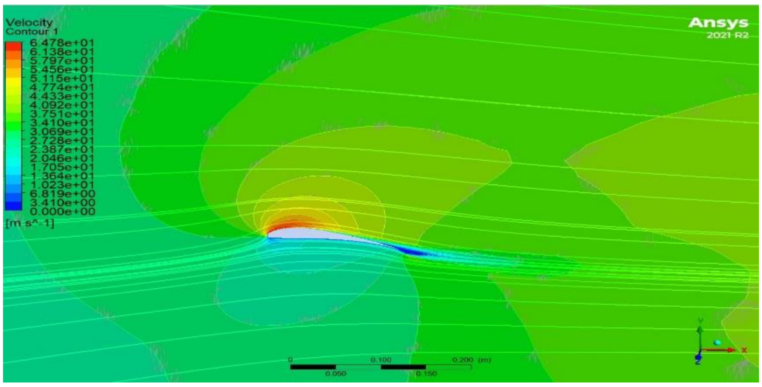


Fig 11.c. Angle of Attack 10°

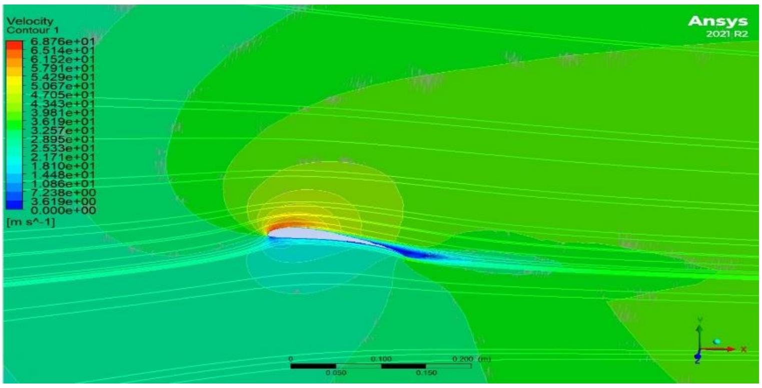


Fig 11.d. Angle of Attack 12.2°

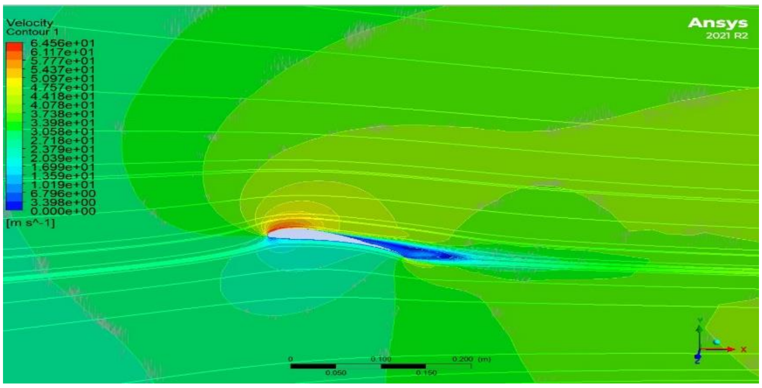


Fig 11.e. Angle of Attack 12.5°

It has been observed from this study that lift force required to lift the aircraft at take-off velocity was at 12.2° degrees. The wing was producing a lift force of 42.3792 N, which leaves enough room even after considering the weight of payload & aircraft at take-off velocity. Therefore, it is calculated that, an angle of 12.2 degree is the least angle required for the aircraft to get airborne.

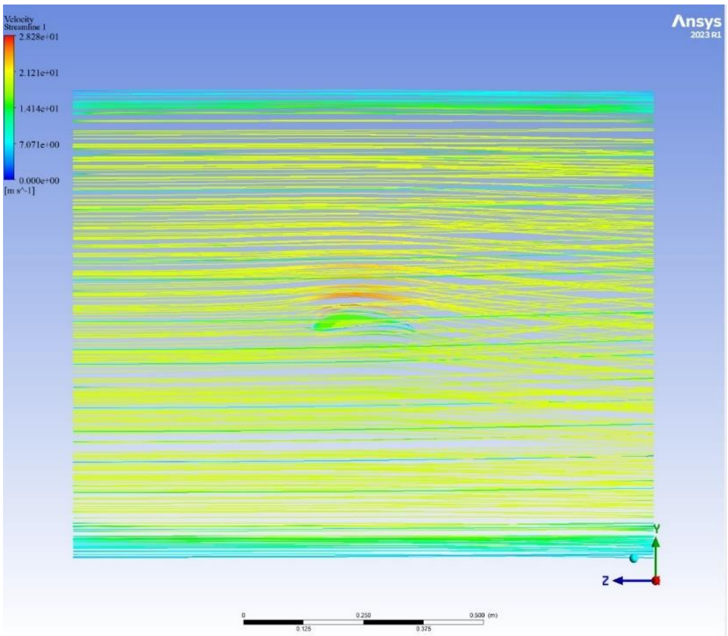


Fig 12.a. Side View of Angle of Attack

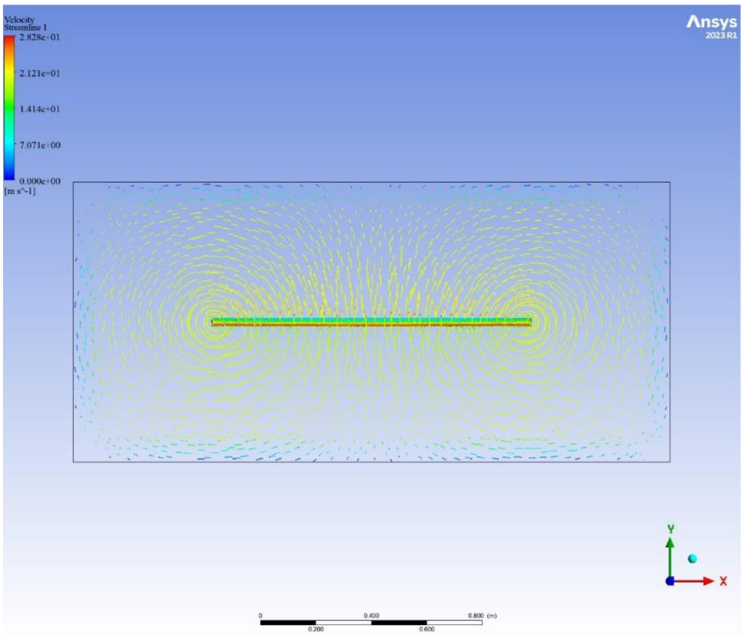


Fig 12.b. Frontal View of Angle of Attack

The 3D Model Analysis shows the airflow around the wings and gives us a basic idea of the aerodynamics of the wing and aerofoil selection and thus helping us figure out the performance of the wing in normal flight conditions.

- **3D ANALYSIS OF AIRCRAFT**

By doing the 3D analysis of aircraft in Ansys, we get the following results;

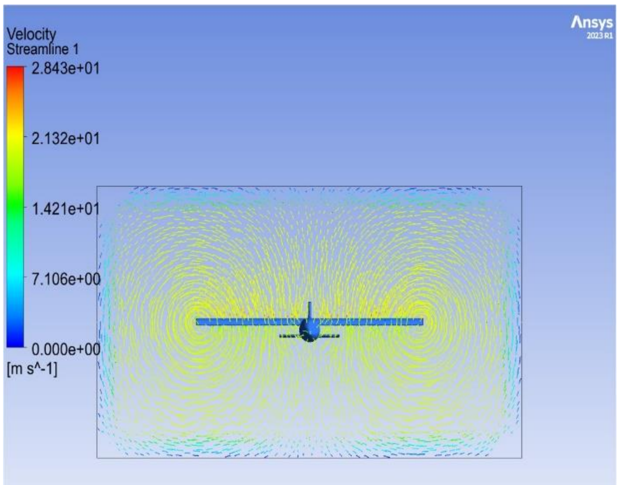


Fig a: Velocity Streamline

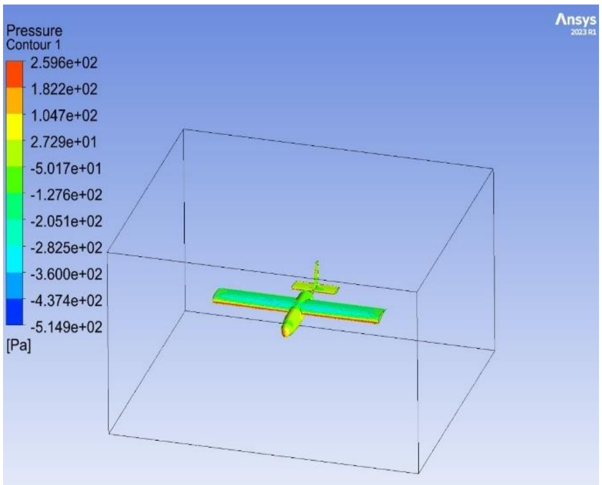


Fig b: Pressure Contour

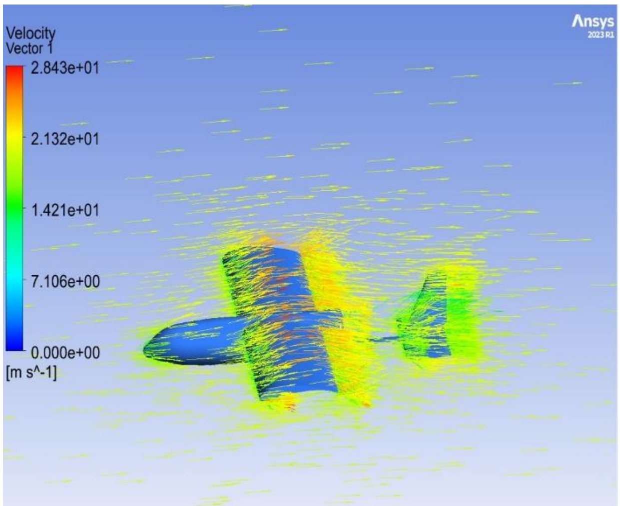


Fig c: Velocity Vector

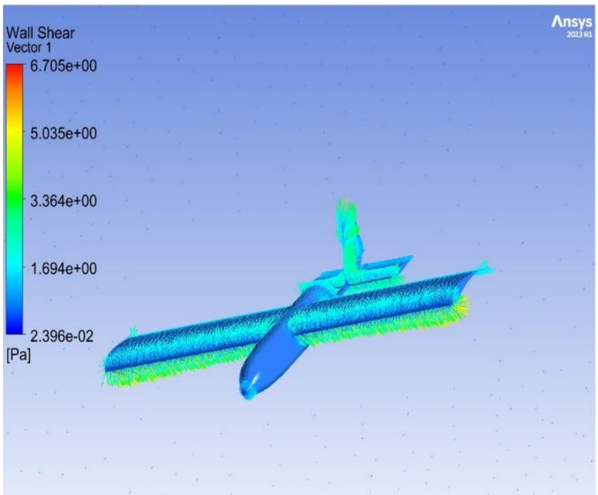


Fig d: Wall Shear Vector

❖ STRUCTURAL ANALYSIS

The structural analysis helps to determine the cause of a structural failure. The purpose of the structural analysis is to design a structure that has the proper strength, safety, and rigidity. The materials used in the following analysis are 3D Printed PLA, Expanded Polyethylene Sheet and Aluminium alloy. Their properties are:

Table 1: 3D Printed PLA	
PROPERTY	VALUE
Elastic Modulus	3.5 GPa
Poisons Ratio	0.37
Shear Modulus	1.2 GPa
Yield Strength	50 MPa
Mass Density	1.25 g/cm^3

Table 2: Expanded Polyethylene Sheet	
PROPERTY	Value
Elastic Modulus	15 MPa
Poisons Ratio	0.45
Shear Modulus	5 MPa
Yield Strength	100 kPa
Mass Density	20 kg/m^3

Table 3: Aluminium 1060 Alloy	
PROPERTY	VALUE
Elastic Modulus	68.9 GPa
Poisons Ratio	0.33
Shear Modulus	25.2 GPa
Yield Strength	55 MPa
Mass Density	2.7 g/cm^3

❖ FUSELAGE ANALYSIS

A force of 400N was applied on the fuselage while maintaining the top end of the fuselage fixed. The material is made of 3D Printed PLA due to its low weight along with aluminium alloy for its relative strength. The following results were obtained:

- **STRESS ANALYSIS**

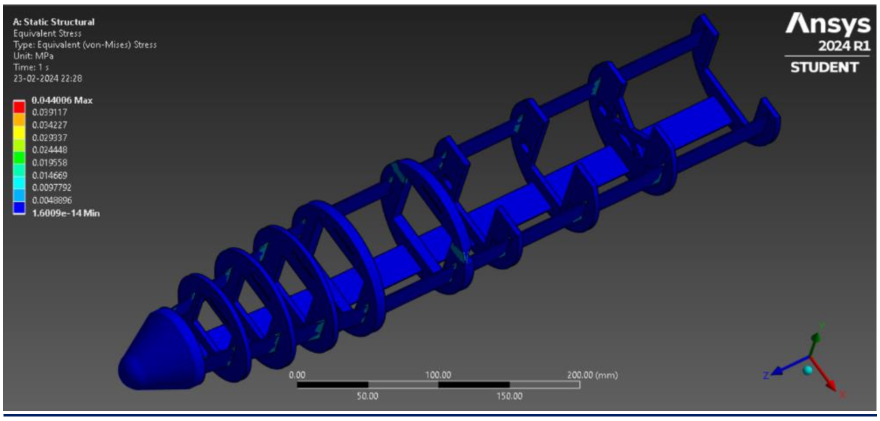


Fig 13. Stress Analysis of Fuselage

The above analysis predicts the behaviour of our fuselage under the load. From the result we can see that the fuselage would not fail. The maximum stress induced on the material was 4.4006e-002 MPa which is larger than the yield stress of PLA. Thus, we reinforce the material with aluminium plates with a yield strength of 55 MPa. The minimum stress is 1.6009e-014 MPa and the average stress induced is 1.3246e-003 MPa. From the above analysis and compensatory support, it is very clear that the material will not yield.

- **DISPLACEMENT ANALYSIS**

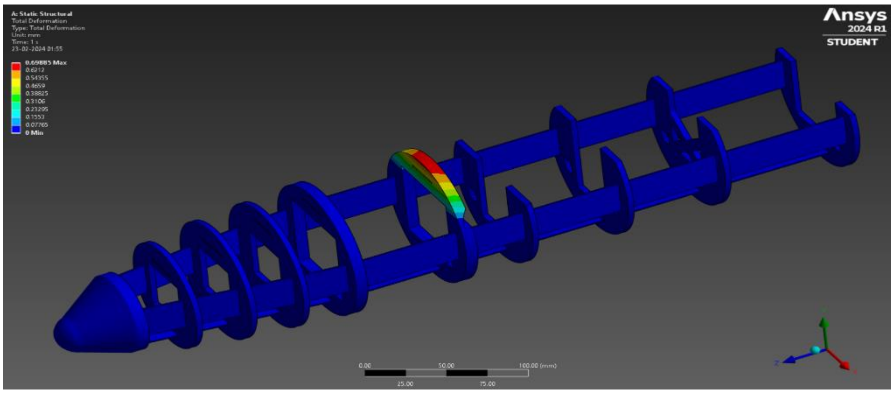


Fig 14. Displacement Analysis of Fuselage

Here the maximum Displacement of the fuselage was found to be 0.69885 mm which is very less when we consider the overall dimension of the fuselage. The minimum deflection is found to be 0 mm which assures the structural safety of the structure. The average deflection of 1.797e-002 mm infers the fact that material shows very little deformation throughout.

❖ WING ANALYSIS

- **DISPLACEMENT ANALYSIS**

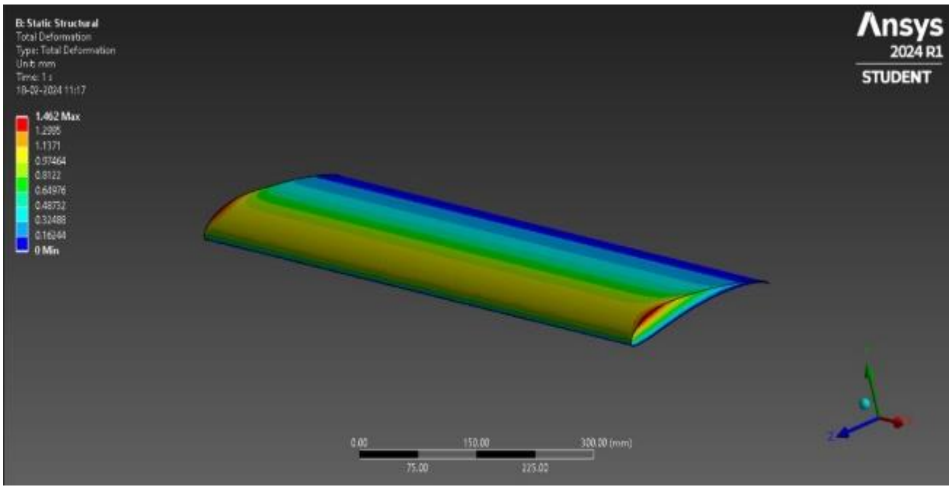


Fig 15. Displacement Analysis of Wing

Here the maximum Displacement of the wing was found to be 1.462 mm which is very less when we consider the overall dimension of the wing. The minimum deflection is found to be 0 mm which assures the structural safety of the structure. The average deflection of 0.64976 mm infers the fact that material shows very little deformation throughout.

- **STRESS ANALYSIS**

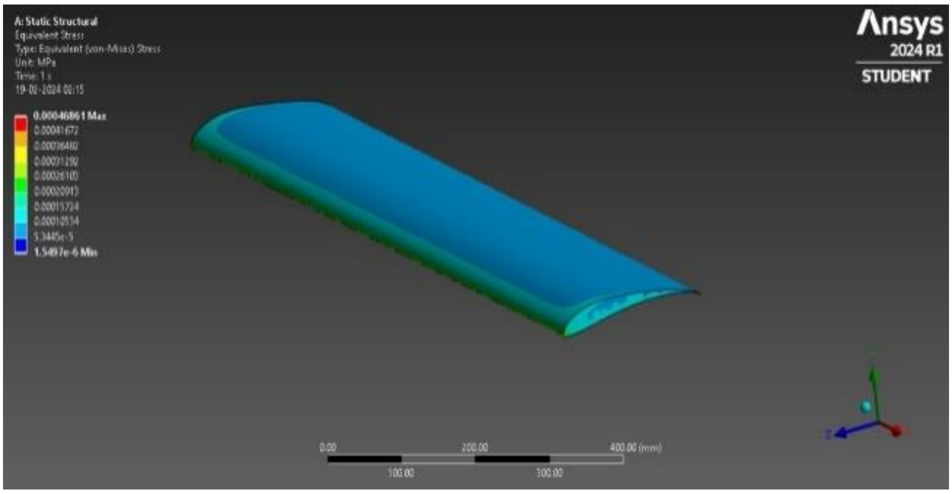


Fig 16. Stress Analysis of Wing

The above analysis predicts the behaviour of our wing under the load. From the result we can see that the wing would not fail. The maximum stress induced on the material was 0.00046861 MPa which is very much less than the yield stress of EP Sheet. The minimum stress on the wing is $1.5497e^{-6}$ MPa and the average stress induced is 0.00020913 MPa. From the above analysis and compensatory support, it is very clear that the material will not yield.

❖ PERFORMANCE REPRESENTATIONS

Aircraft Empty Mass (Excluding Payload) = **1.5 kg**

Payload considered = **1.5 kg**

Total Weight of UAV (W) = mass × acceleration due to gravity

= **29.43 N**

Total Wing Area of UAV = **0.2408 m²**

Aspect Ratio = (Wing Span)² / (Wing Area) = **5.497**

$$\text{Wing Cube Load} = \frac{Mass\ in\ grams}{(Wing\ area\ in\ decimeters)^{1.5}}$$

$$\text{Wing Cube Load} = \frac{3000}{(24.082)^{1.5}} = \mathbf{25.38\ g/dm^3}$$

This shows that the wings will be able to produce enough lift to fly the UAV.

- **TAKE-OFF PERFORMANCE**

$$V_{stall} = \sqrt{\frac{2 \times W}{\rho \times S \times Clmax}} = \sqrt{\frac{2 \times 29.43}{1.225 \times 0.2408201635 \times 2.205}}$$

$$= \mathbf{9.5124\ m/s}$$

Take off velocity, $V_{TO} = 1.2 \times V_{stall}$ = **11.4149 m/s**

Lift produced with Take off velocity 11.4149 m/s and at an Angle of Attack of 12.2° and a C_{lmax} value of 2.205.

Lift Produced $= 0.5 \times \rho \times V_{TO}^2 \times s \times C_l$ = **42.3792 N**

As the lift force is greater than the total weight of the UAV, the upward net lift force will cause the UAV to fly.

Drag (D) $= 0.5 \times \rho \times V_{TO}^2 \times s \times C_d$ = **0.3652 N**

- **CRUISE PERFORMANCE**

$$V_{cruise} = \sqrt{\frac{2}{\rho \times Cd}} = \sqrt{\frac{2}{1.225 \times 0.019}} = \mathbf{9.2697\ m/s}$$

$$\text{Lift at } V_{cruise} = \text{Weight of UAV} = \mathbf{29.43\ N}$$

- **LANDING PERFORMANCE**

$$V_{TouchDown} = 1.3 \times V_{stall} = \mathbf{12.3662\ m/s}$$

❖ WEIGHT BUILD-UP

The table below shows the weight build-up used by the team to track the weight of individual components. It was used during the identification of potential sections of UAV for weight reduction.

SL. NO.	COMPONENT	WEIGHT (kg)
01	Frame	0.096 Kg
02	Tail Boom	0.062 kg
03	Empennage	0.007 kg
04	Fuselage	0.110 kg
05	ESC (x2)	0.068 kg
06	Receiver	0.015 kg
07	Servos (x4)	0.044 kg
08	Battery	0.175 kg
09	Propeller (x2)	0.022 kg
10	Motor (x2)	0.204 kg
11	Glue and Plastics	0.100 kg (approx.)
12	Control Arms	0.008 kg
13	Control Rods	0.012 kg
14	Screws	0.010 kg
15	Velcro	0.018 kg
16	Vinyl Wrap	0.300 kg
17	Ballast	0.100 kg
18	Empty Weight	1.331 kg
19	Payload Fraction	1.669 kg
Total		3 kg

❖ INNOVATION

- **FOLDABLE WINGS**

Introduction:

The innovation aims to address two critical challenges faced while building RC planes- maximizing aerodynamic performance and overcoming storage and transport limitations. To achieve this, we have developed an innovative foldable wing configuration that offers a larger wingspan during flight for increased lift generation while providing convenient folding capabilities for compact storage and transport.

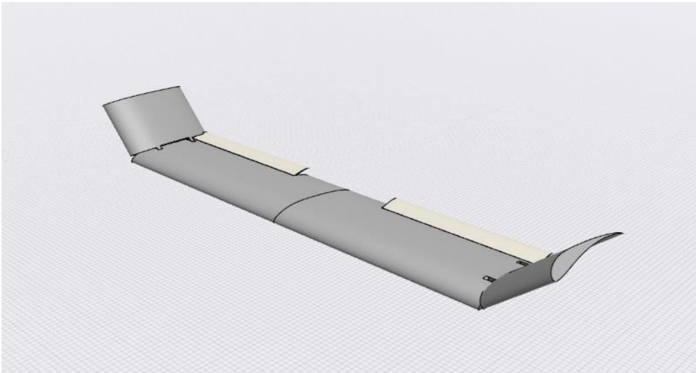


Fig 17. Foldable Wings

Innovation Description:

Our foldable wing configuration consists of a unique mechanism that allows the wings to be easily folded and unfolded as needed. During flight, the wings extend to their full span, providing maximum lift and stability for optimal aerodynamic performance. When not in use, the wings can be quickly folded to reduce the overall size of the aircraft, making it easier to store and transport. The use of Velcro provides stability and support to the locking mechanism during flight.

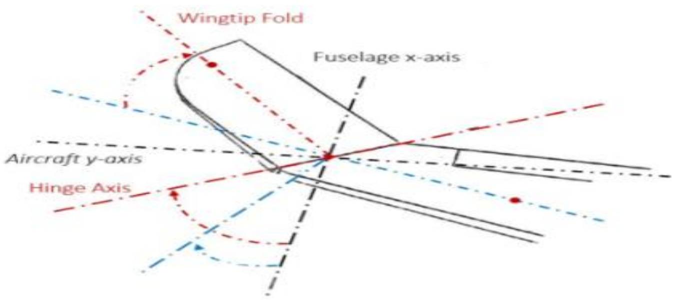
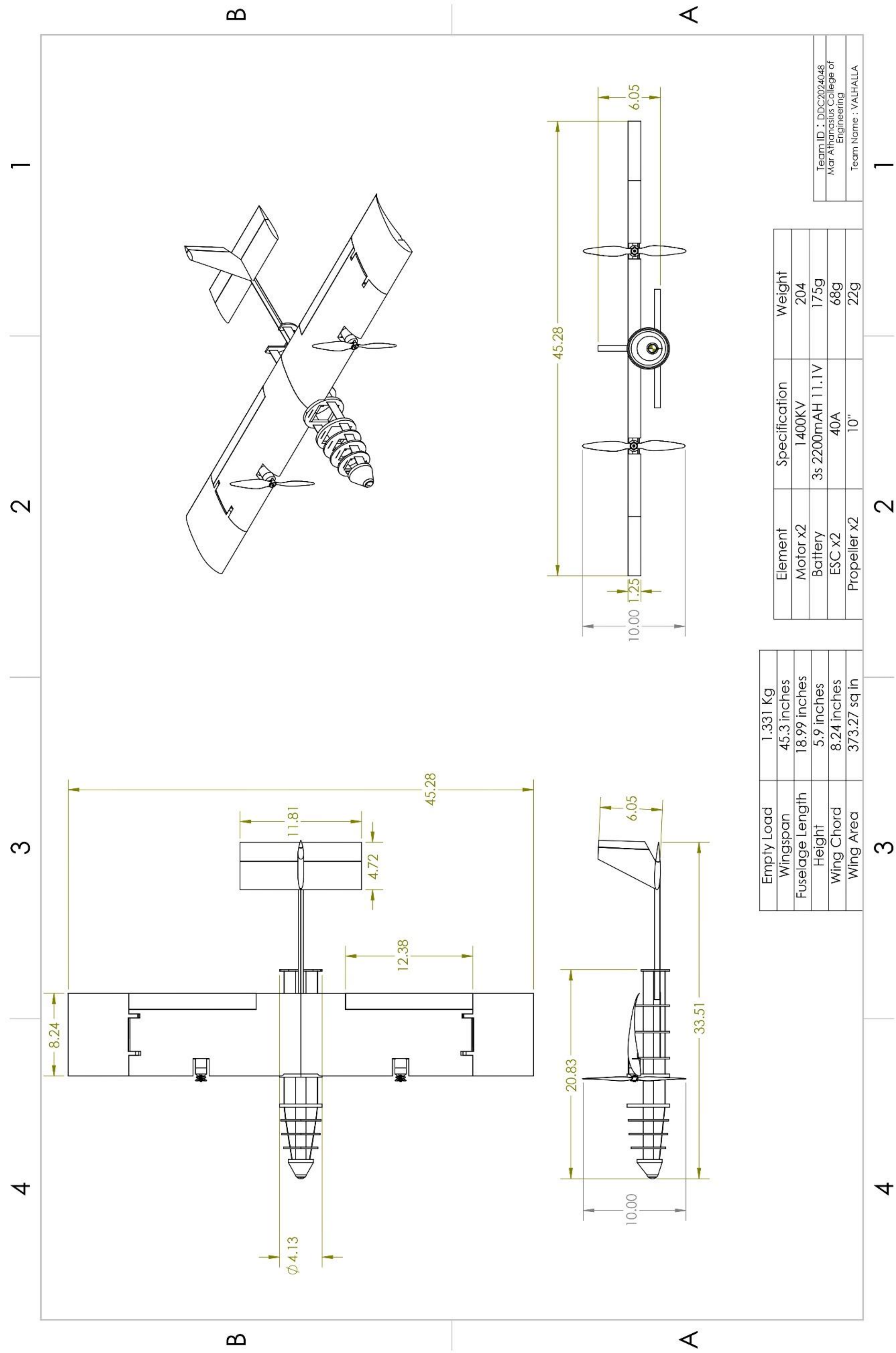


Fig 18. Descriptive Modelling of Foldable Wings

❖ 2D DRAWING


Team ID : DDC2024048
Mar Athanasius College of Engineering
Team Name : VALHALLA
Element | Specification | Weight
Motor x2 | 1400KV | 204
Battery | 3s 2200mAH 11.1V | 175g
ESC x2 | 40A | 68g
Propeller x2 | 10" | 22g
Empty Load | 1.331 Kg
Wingspan | 45.3 inches
Fuselage Length | 18.99 inches
Height | 5.9 inches
Wing Chord | 8.24 inches
Wing Area | 373.27 sq in
45.28
6.05
1.25
10.00
11.81
4.72
12.38
8.24
Ø4.13
20.83
33.51
A
B
1
2
3
4

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