AEROTHON 2021

TEAM NAME – ARMS4VALOUR

COLLEGE – BANGALORE INSTITUTE OF TECHNOLOGY

TEAM NUMBER- 056

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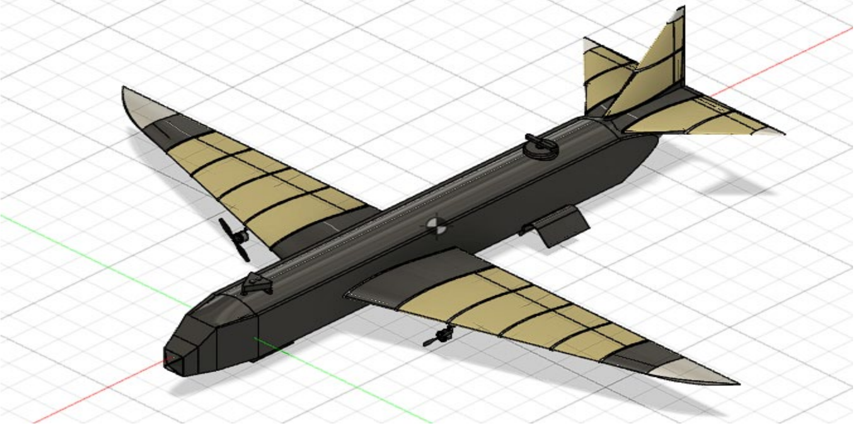


TABLE OF CONTENTS

LIST OF FIGURES AND TABLES:

LIST OF SYMBOLS AND ACRONYMS:

W - Weight

ρ - Density

L - Lift

D - Drag

V_∞ - Velocity

α - Angle of attack

C_{Lo} - Coefficient of lift at O angle of attack

C_{Do} - Coefficient of drag at O angle of attack

C_L - Coefficient of lift

C_D - Coefficient of drag

S - Surface area

λ – Tapper ratio

b - Wing span

K - Wing induced drag factor

a.r -Aspect ratio

D_{TOTAL}-Total drag

T_{Rmin} - Minimum Thrust required

V_{Rmin} - Minimum velocity required

R/C - Rate of climb

Dh - Difference in head

St/S - Surface ratio of tail and wing

$X_{e.g}$- Center of gravitymass

I_w - Initial wing setting angle

Dt - Difference in time

P_A - Power Available

P_R - Power required

T_A - Thrust available

γ -Angle b/w free stream velocity and horizontal axis

N_p - Efficiency of propeller

P_S - Power of shaft

$\overline{C}$ - Mean aerodynamic chord

X_{acw} -Aerodynamic center of wing

C_R - Root chord

C_t - Tip chord

$C_{L\alpha}$ - Coefficient of lift at angle

e - Ostwald's Efficiency

X_{act} - Aerodynamic center of tail

C_m - Pitching moment coefficient

C_{mo} - Pitching moment at O angle of attack

$C_{m(a/c)}$-Pitching moment of aircraft

$C_{m\alpha}$ - Pitching moment at angle of attack α

C_{mw}- Pitching moment of wing

C_{mt}- Pitching moment of tail

$X_{n.p}$ - Neutral point

I_t - Initial tail setting angle

1.0 INTRODUCTION:

I. Objective:

To design a fixed wing UAV accustomed for real life application of safe and timely delivery of drugs even in remote areas by incorporating reliable, advanced, efficient technology by inducing innovation, analysis in design methodology and also satisfying set parameters.

II. Air vehicle design requirement:

S.No.	Requirements
1.	Minimum Endurance – 3 Hrs
2.	Payload – 6 Kg
3.	Maximum Weight – 50 Kg
4.	Max Speed – 150 km/hr
5.	Above Sea Level (ASL) – 6000m

Table 1: Design Requirement

III. Mission profile:

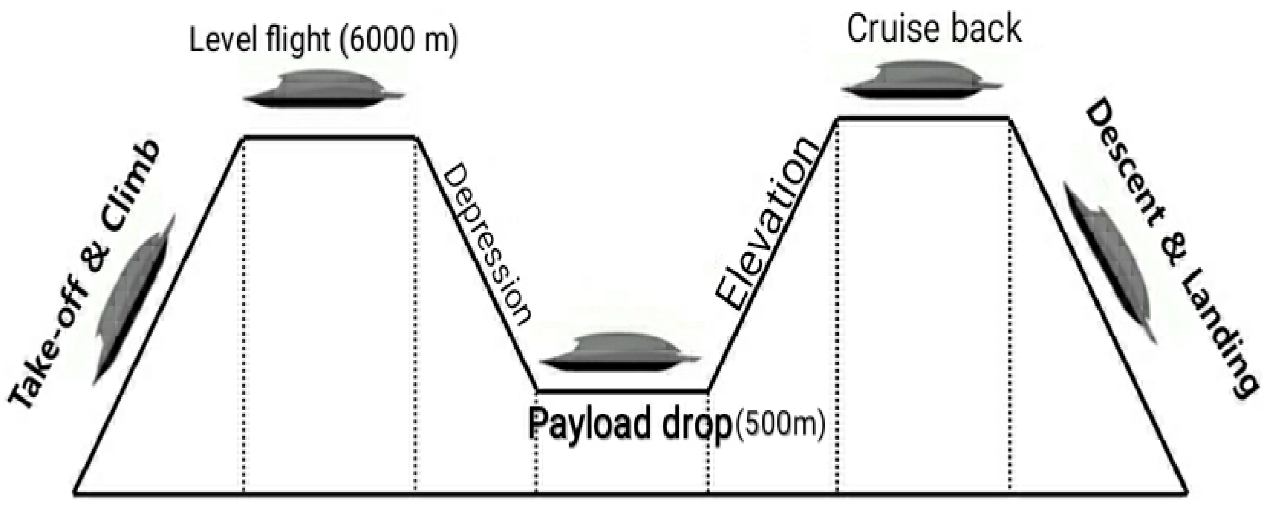


Figure 1: Mission Profile

2.0. CONCEPTUAL DESIGN:

2.1. RESEARCH:

According to the mission requirements, the model aircraft made should be capable of

lifting as much weight as possible while at the same time maintaining a very less weight of itself and being easily deployable.

I. Aerobatic performance is of a lesser priority compared to good lifting qualities at low speed and stable configuration, which are the primary factors to be considered.
II. As such, initial weight estimation led to air foil selection and wing dimensions.
III. These parameters were used to generate aerodynamic values such as lift, drag, and flight velocity.
IV. Stability and propulsion analysis were performed to determine necessary electronics requirements and their placement in the aircraft.
V. Several important trade-offs were done while deciding the servo motor control surfaces
VI. Usage and analysis of air foil shapes for determination of lift and moment coefficients, And Pressure distributions
VII. Electronics and radio control, GPS based autonomous operation and dynamic re-tasking from ground control
VIII. Payload drop mechanism
IX. Work budgeting and time delegation
X. launch and landing method
XI. Aerodynamics and the loads derived from aerodynamic considerations

2.2. DESIGN ANALYSIS & REVIEW PROCESS:

Design Analysis – compared with similar design or projects/concepts of uav

We arrive at a wide variety of wing aero foils, wing positions, tail types and many other aspects in designing an aircraft, carefully looking about all the internal and external factors influenced by the design. After choosing a design, we revisited the last set of options again to achieve a design that could potentially increase the efficiency and effectiveness of applications.

Design analysis factors:

Operating conditions	Application of UAV	Efficiency
Strength of structure	Maximum lift	Minimum drag
Maximum thrust	Propulsion type	Stability
Maximum takeoff weight (Mtow)	Powering system	Flight conditions

After Review process of side-by-side comparison of all best available design solutions and listing out all the positive and negative points.

Design Result:

- the fixed wing UAV is made with NACA 63-212 Airfoil fuselage and wing .
- A Conventional Tail and tapered wing planform with adequate wing twist and airfoil variance is incorporated in design.
- the aircraft is powered by Three 13000mAh 6S 25C/50C Lithium Polymer Battery (Li-po) Packs connected in parallel and propelled by two 1050 KV Brushless DC Motor.
- A ribbed structure of aluminium 7075 is used for the fuselage, Air foils, support structures and landing gear shaft ,CFRP sheets for outer covering of wings and tail and Medium compound rubber for landing wheels
- A 9 channel transmitter and receiver are used for controlling the throttle and control surfaces of the aircraft. The aircraft weighs a total of 12kg (predicted) with payload.
- Landing gear which can engage and disengage are incorporated to the UAV
- Sensors and Servo for aileron, rudder and elevator control surfaces are used for stable flight cruise.

2.3) DESIGN SELECTION PROCESS:

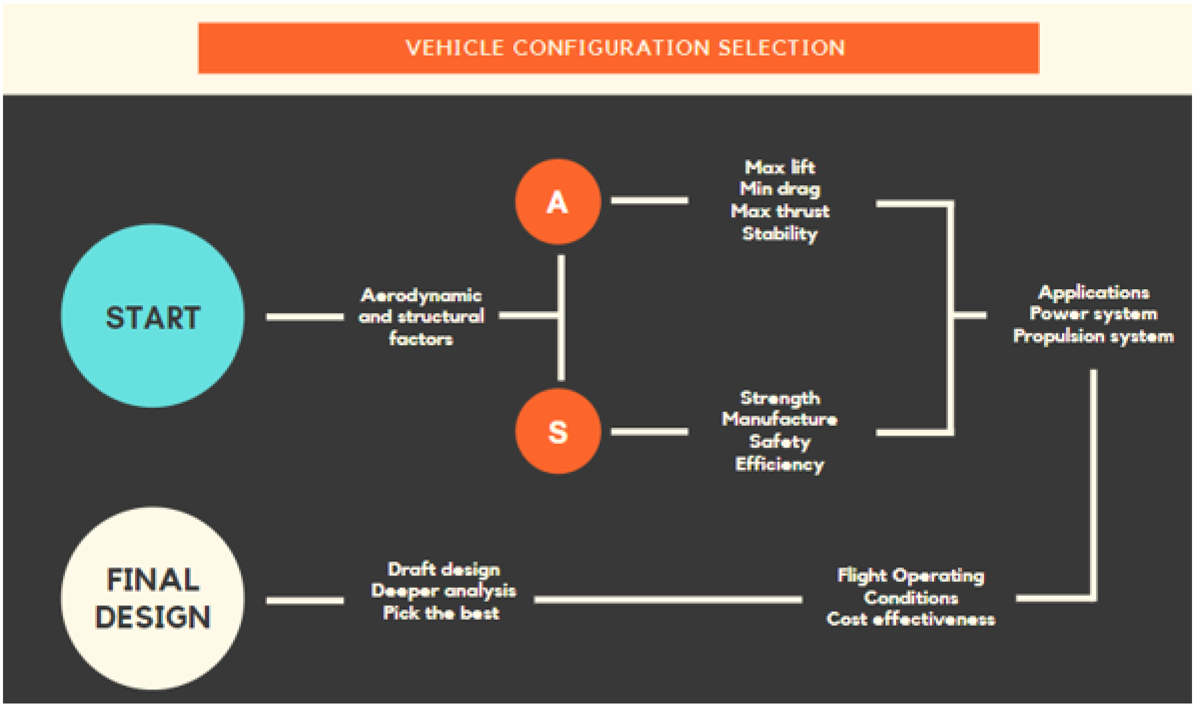


Figure 2: Design Selection Process

The final design from all the options considered is restricted by the following factors:

1. Safety of parts
2.complexity of design
3. Fuel consumption (service ceiling at half fuel)
4.all weather operational
5. Feasibility to design & manufacture
6.Cost effectiveness

3.0) PRELIMINARY & DETAILED DESIGN:

3.1) Wing Selection:

(refer appendix 3.1 for fuselage layout and other figures)

I. **Wing Location:**

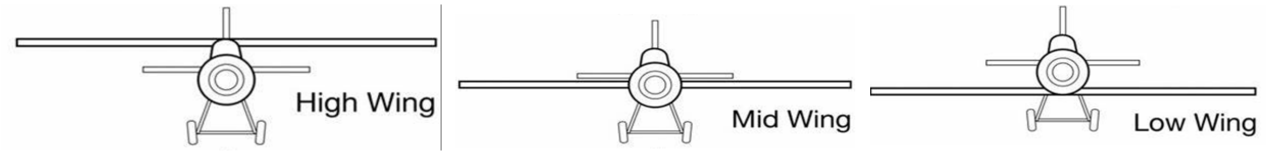


Figure 3: Types of Wing location

Preference: Mid Wing; a wing structure fixed at the middle region of fuselage

Reason:

1. Position of landing gear, drug delivery payload
2. To aerodynamically support the entire flight on a wing fixed at middle
3. To support the conventional tail stabilizers on rear end of the flight for better control of the flight

II. **Aspect ratio:**

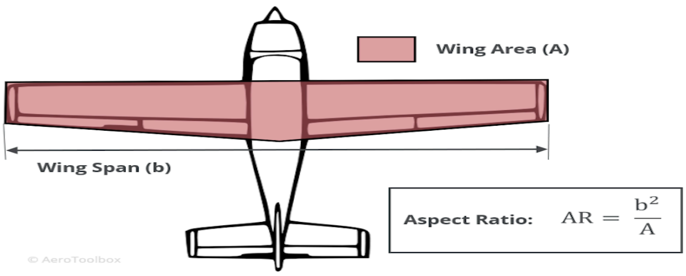


Figure 4: Aspect Ratio

Aspect Ratio: It is the ratio of wing span to the mean chord of the wing.

Platform Geometry:

Section 1:

$S_1 = b\ (C_r+C_t)/2$

$S_1 = 0.916\ (0.45+0.15)/2$

$\mathbf{S_1 = 0.2751\ m^2}$

Section 2:

$S_2 = b(C_r+C_1)/2$

$= 0.234\ [(0.15 + 0.08)]/2$

$\mathbf{S_2 = 0.0269\ m^2}$

$S = s_1 + s_2$

$= 0.2751 + 0.0269$

$\mathbf{= 0.302\ m^2}$

Total surface area = 2s →

$\mathbf{S = 0.604\ m^2}$

To find X C.G of plane

$A.R = b^2 / S$

$= (2.3)^2 / 0.604$

$= 8.75$

$K = 1 \div (\pi.e.ar)$

$= 1 \div \pi\ .\ 0.8 \times 8.75$

$= 0.045$

Aspect Ratio=8.75

K=0.045 b=2.3 S=0.604

Preference: High Aspect Ratio Wing

Reason:

1. Lower induced drag
2. Position of propellers
3. Position of mid wing
4. Position of important sensors

III. Taper ratio:

Taper Ratio (λ): It is the ratio of tip chord length (C_t)to root chord length (C_r)of the wing, a chord is an imaginary straight line joining the leading edge and trailing edge of an aerofoil.

The distance between trailing edge and the point of intersection of chord and leading edge.

$\lambda_1 = C_t/C_r$

$= 0.15/0.45$

$\mathbf{= 0.33}$

$\overline{C}_1 = (2\div3)C_r\,[(1+\lambda_1+\lambda_1^2)\div(1+\lambda_1)]$

$=2\div3 \times 0.45\,[(1+0.33+0.33^2)\div(1+0.33)]$

$\mathbf{=0.324\ m}$

$\lambda_2 = C_t/C_r$

$= 0.08/0.15$

$\mathbf{= 0.53}$

$\overline{C}_2 = 2/3\ C_r\,[(1+\lambda_2+\lambda_2^2)\div(1+\lambda_2)]$

$= 2/3\times0.15 \times [(1+0.53+0.53^2)\div(1+0.53)]$

$\mathbf{= 0.118\ m}$

→

Mean Aerodynamic Chord:

$\overline{C} = \overline{C}_1 S_1 + \overline{C}_2 S_2 / S$

$= (0.0891 + 0.00317) / 0.302$

$\mathbf{\overline{C} = 0.3055}$

$\mathbf{\lambda_1 = 0.33}$

$\mathbf{\lambda_2 = 0.53}$

$\mathbf{C_1 = 0.324\ m}$

$\mathbf{C_2 = 0.118\ m}$

$\mathbf{C = 0.3055\ m}$

Aerodynamic Centre:

$X_{acw} = C_r - 0.75\overline{C}$

$= 0.45 - 0.2291$

$\mathbf{= 0.2209\ m}$

IV. Airfoil selection:

(refer appendix-3.1 Airfoil Characteristics graphs of NACA 63-212)

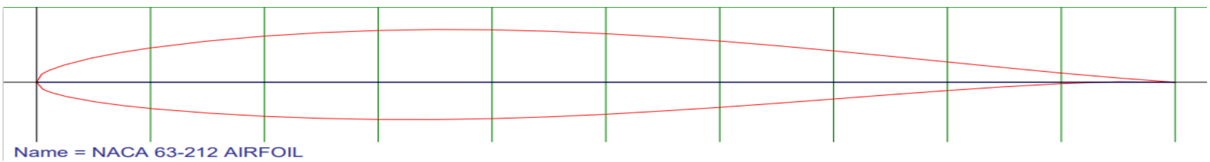


Fig 5: NACA 63-212 Airfoil

W_T = 12 kg = 117.6N

ρ = 0.7 (At 6000 m above Sea Level)

L = 137N

V_∞ = 36 m/s

Air foil - NACA 63 - 212 (6 Series)

At $\alpha = 3°$

$C_1 = 0.5$, $C_L = 0.20$, $C_D = 0.01$

$L = 1/2\ \rho V_\infty^2\ SC_L$

$137 = 1/2 \times (0.7) \times (36)^2 \times (5) \times 0.5$

S =0.604 m²

Preference: NACA 63-212 AIRFOIL
Reason:

1. Stable Cl vs Cd graph plots
2. Straight line slope between Cl vs α
3. Favorable graph plotting's for a stable flight in Cl/Cd vs α
4. Straight line slope between Cl/Cd vs α
5. U curve indicating minimum drag in Cd vs α
6. Suitable curves for a flight operation in Cm vs α
7. Stable flight operations at necessary given conditions
8. Airfoil serves the applications of the given task

Other alternatives considered were: NACA 6412, NACA 2412

V. Wing planform:

The wing skeleton is situated at mid region of the fuselage also called as mid wing structure.

Planform refers to the shape and layout of the fuselage and wing of a fixed wing aircraft. The four common wing planforms are: Rectangular, Elliptical, Tapered & Sweptback.

Tapered Wing: This is a modification of the rectangular wing where the chord is varied across the span to approximate the elliptical lift distribution. While not as efficient as the elliptical lift distribution, it offers a compromise between manufacturability and efficiency.

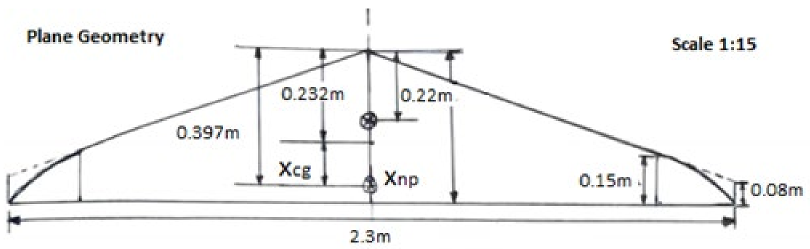


Fig 6: Wing planform

Reasons behind tapered wing planform:

1. Tapered wing form provides stability and stiffness to the wing

2. Tapered wing form provides good weight distribution over the wing
3. Lateral control is easy for tapered wing unlike elliptical wing
4. Rectangular wing stalls very easily compared to tapered wing
5. Elliptical wing, stalling characteristics are a still a worry.

Hence a tapered with adequate wing twist and airfoil variance provides nearly same efficiency as elliptical wing.

I. **Wing twist =0°**

3.2) Sizing of Horizontal & Vertical tail:

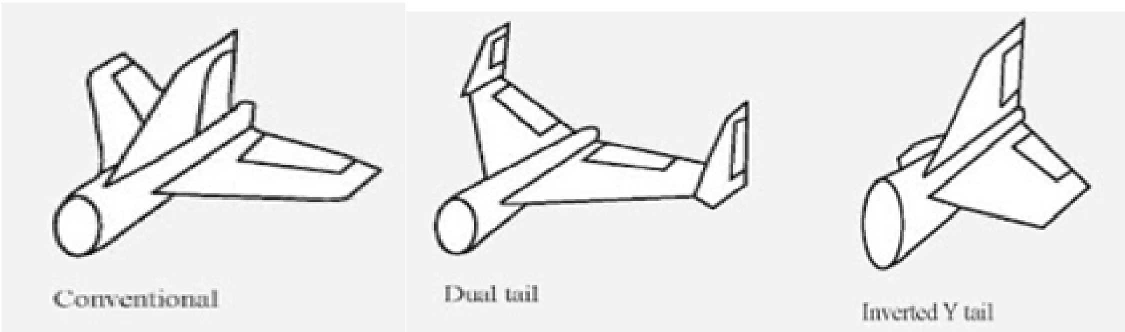


Fig 7: Types of Tail

Preference: Conventional Tail
Reason:

1. Has better mounting options to accommodate space for other applications at rear end
2. Provides better control over flight in stalls
3. Provides better safety and reduce chances of grounding due to any kind of damage during ground or flight operation
4. Suitable for long flight, low-speed flight applications with payload

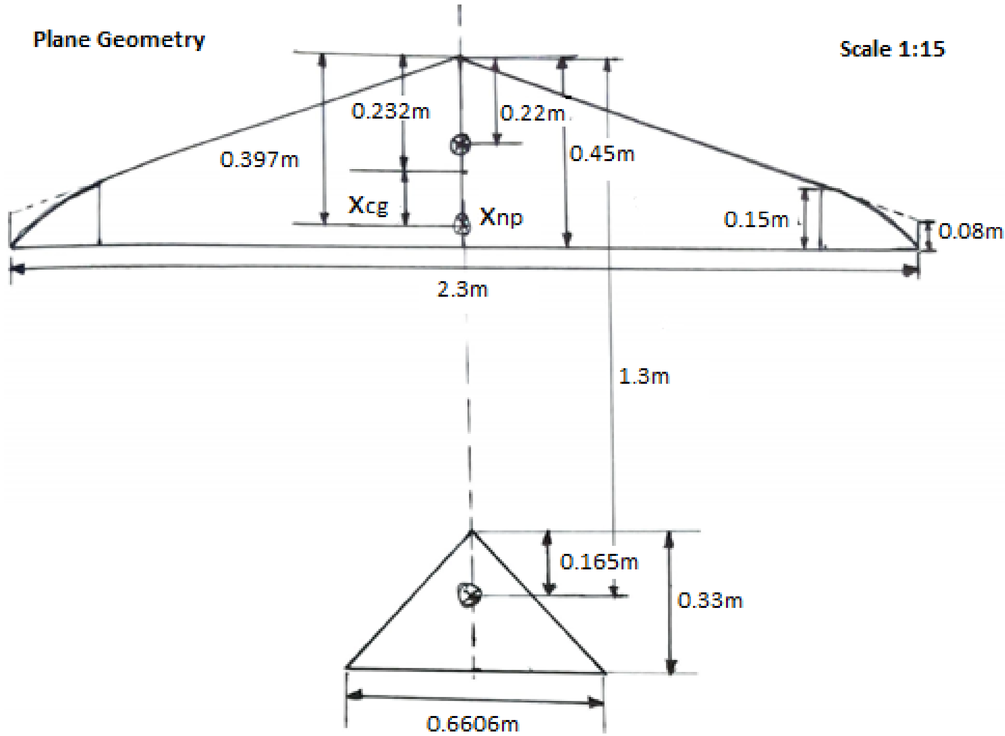


Fig 8: Plane Geometry

Tail:

$C_R = 0.33$

$S = 1/2 \times b \times C_R$

$= 1/2 \times 0.6606 \times 0.33$

$= \mathbf{0.1089m^2}$

$\lambda_2 = C_t/C_r$

$= 0/0.33$

$= \mathbf{0}$

→

$\overline{C} = 2/3\ C_r\ [(1+\lambda_2+\lambda_2^2)/(1+\lambda_2)]$

$= 2/3 \times 0.33 \times [(1+0+0/1+0)]$

$= \mathbf{0.22m}$

Aerodynamic centre:

$= C_R - 0.75\ \overline{C}$

$= 0.33 - 0.75 \times 0.22$

$\mathbf{x_{act} = 0.165m}$

3.3) AIRCRAFT PERFORMANCE:

- **DRAG ESTIMATION:**

$D = 1/2\ \rho V_\infty^2 C_{Do}$ (Profile)$+1/2\ \rho V_\infty^2 S\ K\ C_L^2$ (Induced)

$= 1/2\ (0.7)\ (36)^2\ (0.604)\ (0.01) + 1/2\ (0.7)\ (36)^2\ (0.604)\ (0.045)\ (0.5)$

= 5.821

$D_{total} = D_{fuselage} + D_{h.tail} + D_{v.tail} + D$

$= (0.1)\ D + (0.2)\ D + (0.1)\ D + D$

= 8.145 N

$\mathbf{D_{total} = 0.831\ kg}$

- **POWER REQUIRED FOR MISSION:**

$P_A = \eta_P X P_S$

P_A =Power available & P_S= Power of shaft

$P_A = T_A \times V_\infty$

$= 24.478 X 36$

= 881.208 watt

Assume η= 60%

$P_A = \eta_P X P_S$

$881.208 = 0.6 \times P_S$

$\mathbf{P_S = 1468.68\ watt}$

3.4) PROPULSION SELECTION:

I. Power system:

Designing a flexible power distribution system will minimize fuel waste, also enable the system to function efficiently with your evolving mission requirements.

There are various ways to power the flight:

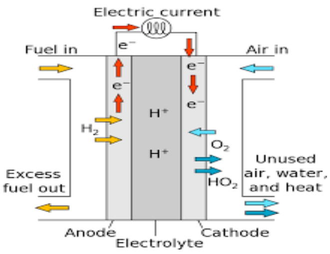


Fig 9.1: Hydrogen fuel cells

Fig 9.2: Solar cells

Fig 9.3: Li-po battery

Fig 9: Types of Cells

Fuel cells (Hydrogen fuel cells):

Pros- High Efficiency, good reliability, less Noise, greatly reduces CO2 emissions.

Cons- Expensive to manufacture due the high cost of catalysts (platinum) & Hydrogen is expensive to produce and not widely available.

Gallium arsenide (GaAs) Solar cells:

Pros- Cleanest and limitless energy source, lightweight solar cells higher absorption coefficient, efficiency, thickness, flexibility, and weather resistance.

Cons- Can be powered only during the day.

Batteries (Lithium polymer batteries):

Lithium-based, have higher energy density, higher voltage per cell

LiPo batteries are very lightweight and pliable, and can be made to almost any size or shape, become smaller and lighter.

They can be charged anywhere, in most cases can be transported without limitations, nothing can be spilled or inflamed, and 're-fuelling' is done easily by exchanging the battery blocks.

Keeping all these things into consideration we choose Li-po batteries to power our UAV.

II. Motors:

The use of motors for UAVs is to spin the propellers of UAV to fly.

Electrical energy → Mechanical energy

Selecting a Drone Motor: Thrust > Weight to achieve lift

Types of motors:

1. Electric motors: Pros- Uses permanent magnet, and an electric current through a conducting wire creates a magnetic field around that wire. Cons- heavier.

2. Permanent magnet motors:

Pros- Reliability, efficiency and cooler operating temperatures.

cons-use neodymium magnets, rare-earth material, makes PMSM motors expensive.

3. DC motors: pros- They are powered by DC current from sources such as batteries or power supplies.

For our UAV we are going with BRUSHLESS DC MOTOR because BLDCs are more efficient, these motors require electronic speed controller (ESC) to operate.

Motor for our range of thrust is **AVIONIC PRO C3536 KV1050 Brushless motor** and T brushless motor. We choose avionic motors - more efficient.

Fig 10: Motor

Fig 11: Propeller

These motors are made from the highest quality magnets, casing and bearings this at the best available quality of motors at such a great value in the market till date.

Specification of the motor:

I. Stator Diameter: 28.0 mm (1.102 in)
II. Stator Thickness: 16.0 mm (0.63 in)
III. Motor KV: 1050 RPM / Volt
IV. No-Load Current (Io): 1.6 Amps @ 10 volts
V. Max Continuous Current: 36 Amps
VI. Max Continuous Power: 570 Watts
VII. Weight: 116 Grams
VIII. Overall Shaft Length: 52.5 mm (2.067 in)
IX. Max LiPo Cell: 3-4 S

(refer appendix 3.4 For load test table)

III. Propeller:

The propellers which can be used are 8*3.8 E. Propellers are always categorized according to the length and the pitch. Pitch is the distance travelled by drone in one single prop rotation. Here, 8*3 means 8 is the length and 3 is the pitch. The propellers with lower pitches produce more torque, therefore, the motor can operate on less current.

IV. Electronic speed controllers:

An ESC or an Electronic Speed Controller controls the brushless motor movement or speed by activating the appropriate MOSFETs to create the rotating magnetic field so that the motor rotates. The higher the frequency or the quicker the ESC goes through the 6 intervals, the higher the speed of the motor will be. **Here, ESC= 40A, to drive the motor efficient.**

3.5) MATERIAL SELECTION:

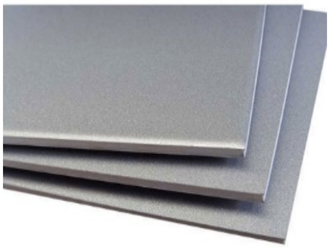


Fig 12.1: Aluminium 7075

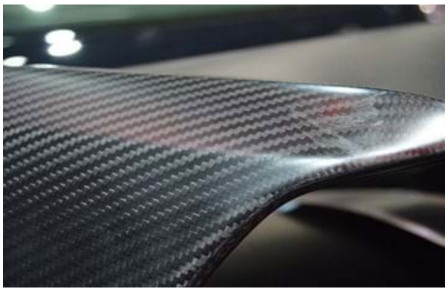


Fig 12.2: CFRP sheets

Fig 12.3: Medium compound rubber

Fig 12: Materials Used

I. **Aluminium 7075:**
   A. We preferred using Aluminium 7075 for the Air foils, support structures and landing gears. Other alternatives considered were: Aluminium 6061, Titanium & AA 2198.
   B. Reason for selection of this material:
      a) Aluminium 7075 is extensively used in the field of engineering, commercially available.
      b) It has good mechanical properties which include high specific strength, offers significant reduction of weight which is the main concern in aero industruy and our primary requirement in our UAV.
      c) Adding different alloys into this material increases its strength significanty.
      d) Above all the materials mentioned Aluminium 7075 is significantly cheaper.

II. **Carbon Fiber Reinforced Polymer (CFRP):**
   A. We have used carbon fiber reinforced polymer sheets for outer surface covering of wings, horizontal and vertical stabilizer. Other alternatives considered were: PLA composite, Glass fiber & Kelver.
   B. Reason for selection of this material:
      a) Strength to weight ratio is very huge when compared to all other material which becomes the primary reason for us to select this material.
      b) Other reasons are its radiolucdncy, durability, low thermal expansion, corrosion-resistance and vibration resistance.
      c) Less weightage results in less economical fuel consumtion thus more performance.

III. **Medium Compound Rubber:**
   A. We have used medium compund rubber to cover the landing wheels. Other alternatives considered were: Ni-Ti alloy, Bridgestone & Pirelli
   B. Reason for selection of this material:
      a) Soft compound rubber has good traction but is very bad at durability
      b) Hard compund rubber has very good durability but very bad traction

Considered medium compound rubber which provides balanceed effect between traction and durability

3.6) DETAILED WEIGHT BREAKDOWN (CG & STATIC MARGIN):

To find x_{cg} of plane:

$CL_{\alpha(2d)} = (0.26)/[2.5\times(\pi/180)]$

$= 0.26/0.043$

$= 5.95$

$CL_{\alpha(3d)} = (CL_{\alpha(2d)})/\ [1+(\ CL_{\alpha(2d)}/\ (\pi.e.ar\ )]$

$= 5.95/[1+(5.95/(\pi\times0.8\times8.75)]$

$= 5.95/1.270$

$= 4.685$

$\varepsilon_o\ = 2C_{low}\ /(\pi.e.ar\ )$

$= (2\times0.20)\ /\ (\pi\times0.8\times8.75)$

$= 0.081$

For stable flight:

Condition 1:

$c_{mo} > 0$

If $i_t = 0.0181$

$C_{mo(ac)} = C_{moacw} + c_{low}\ (\ \bar{x}_{cg} - \bar{x}_{acw})\ -\eta$

$\times\ st/s\ C_{lat}\ (i_t\text{-}\ \varepsilon_o\ )(\ \bar{x}_{acw\text{-}}\text{-}\bar{x}_{cg}\ )$

$C_{mo(ac)} = C_{moacw} + C_{low}\ (\ \bar{x}_{cg}\text{-}\ \bar{x}_{acw})$

$0 < -0.004+0.2\ (\ \bar{x}_{cg}\text{-}\ \bar{x}_{acw})$

$\bar{x}_{acw}\ = x_{acw}\ /\ \bar{c}$

$= 0.2209/0.3055$

$= 0.723\text{m}$

$0.004 < 0.2\ (\bar{x}_{cg} - 0.723)$

$\bar{x}_{cg} > 0.923\text{m}$

$x_{cg} = \bar{x}_{cg} \times \bar{c}$

$= 0.923\times0.3055$

$= 0.282\text{m}$

$= 28.2\text{cm}$

→

Condition 2:

$C_{m\alpha}<0$

$C_{m\alpha(ac)} = C_{law}\ (\ \bar{x}_{cg} - \bar{x}_{acw})\ -\eta \times st/s\ (\ \bar{x}_{acw\text{-}}\text{-}\bar{x}_{cg}\ )$

$c_{lat}\ (1\text{-}\ dt/d\alpha)$

$0 > 4.685\ (\bar{x}_{cg} - 0.723)\ -0.95\ \times0.18$

$(\ \bar{x}_{acw\text{-}}\text{-}\bar{x}_{cg}\ )\ 4.685\ (0.5739)$

$0 > 4.685\ (\bar{x}_{cg} - 0.723) - 0.0981\ (5.90 - \bar{x}_{cg}\ )$

$1.302 > \bar{x}_{cg}$

$x_{cg} = \bar{x}_{cg} \times \bar{c}$

$= 1.302 \times 0.3055$

$= 0.397\text{m}$

$= 39.7\text{cm}$

$1.302 > \bar{x}_{cg} > 0.92\text{m}$

$0.282 > x_{cg} > 0.397\text{m}$

$28.2\text{cm} > x_{cg} > 39.7\text{cm}$

$C_{mo} = C_{m\alpha(ac)} + C_{law}\ (\bar{x}_{cg} - \bar{x}_{acw})$

$= 0.04 + 0.2\ (1.236\text{-}0.723)$

$= 0.0626$

$C_{m2} = 4.685\ (\bar{x}_{cg} - 0.723) - 0.981\ (5.90 - \bar{x}_{cg})$

$= 4.685\ (1.236 - 0.723) - 0.0981\ (5.90 - 1.236)$

$= 1.9458$

$I_w = C_{mo}\ /\ C_{m2}\ x(180/\pi)$

$= (0.026/1.9458)\ X\ (180/\pi)$

$= 1.843$

Therefore, we will set the wing at 1.843^0

3.7) Flight Envelope:

A chart of speed versus load factor (or V-n diagram) is a way of showing the limits of an aircraft's performance. It shows how much load factor can be safely achieved at different airspeeds. In aerodynamics, the flight envelope defines operational limits for an aerial platform with respect to maximum speed and load factor given a particular atmospheric density. The flight envelope is the region within which an aircraft can operate safely.

If an aircraft flies 'outside the envelope' it may suffer damage; the limits should therefore never be exceeded.

Significance of V-N diagram: **(refer appendix -3.7)**

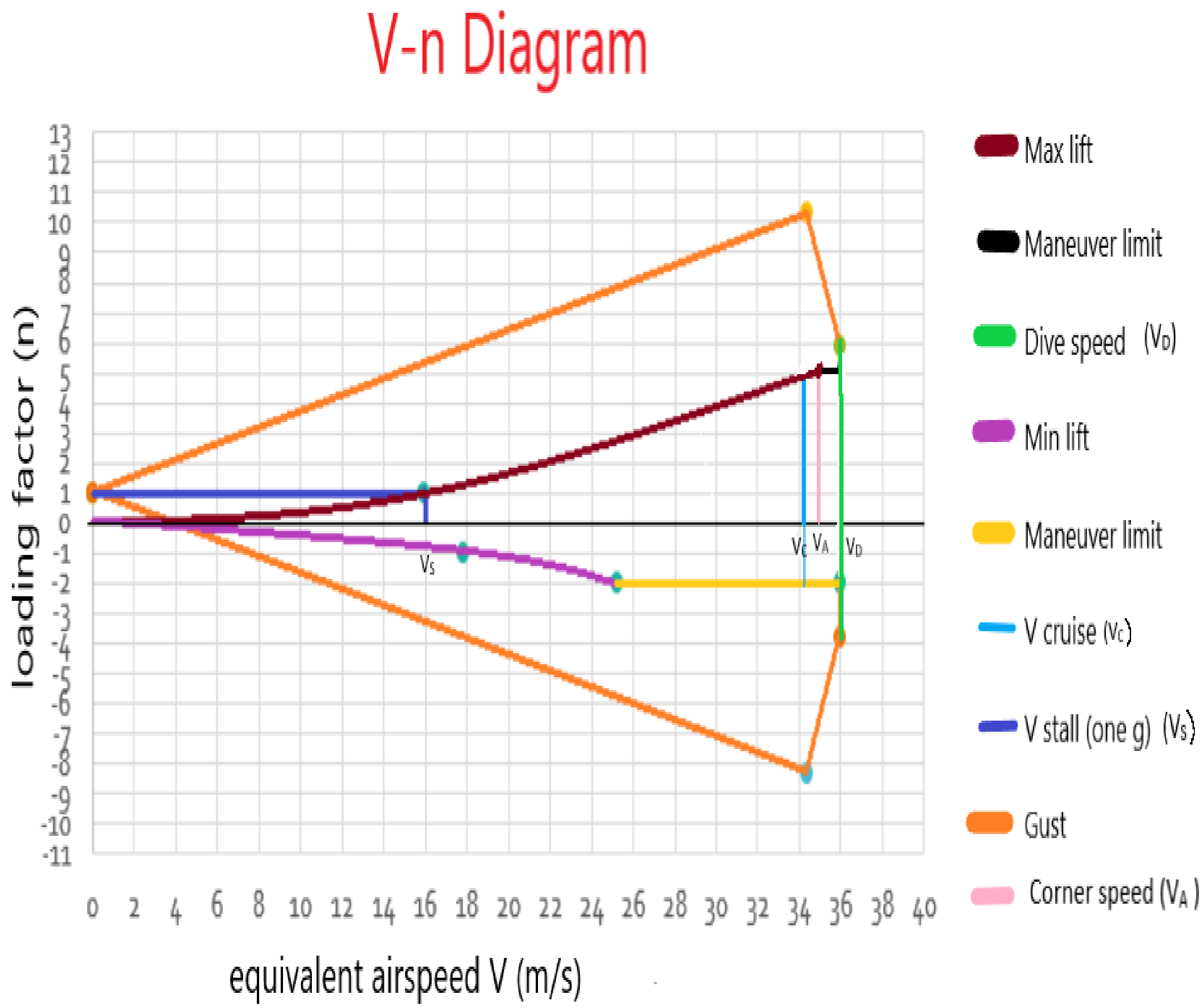
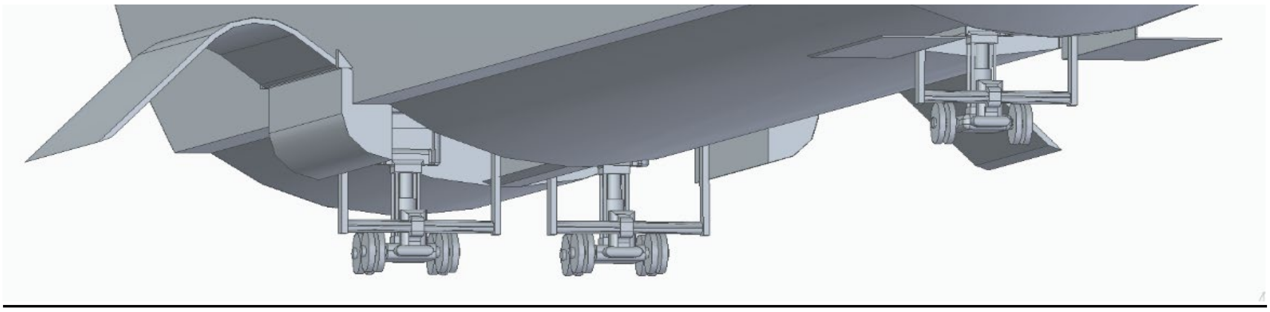


Fig .13 V-n DIAGRAM

3.8) Landing Gear:

Landing gear which can engage and disengage are incorporated to the UAV instead of fixed landing gears to avoid unnecessary drag during flight due to hanging wheels.

Overall view:



(2 Rear Wheels) **(1 Front Wheel)**

Fig 14: Landing Gear

I. **Engagement & Disengagement:**

Mechanism of landing gear:

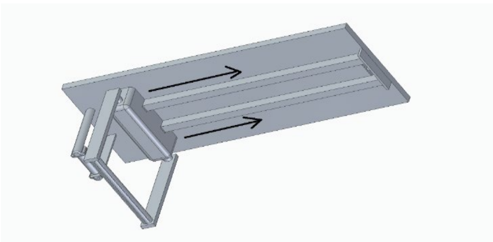


Fig 15: Sliding Bar Open

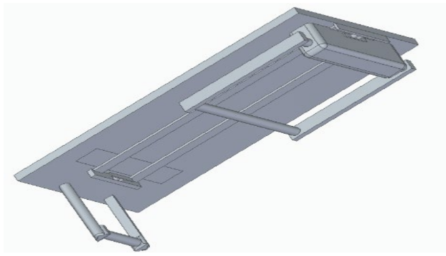


Fig 16: Sliding Bar Closed

A sliding bar runs along the slots provided on landing gear mount with the help of motorized motion. By the sliding action of bar, the connecting rod generates rotational motion which is later connected to wheel hub.

A motor handles the sliding mechanism hence its electronically controlled by the battery. The connecting rod further translates rotational motion back to sliding motion which helps to pull back the wheel hub into the fuselage.

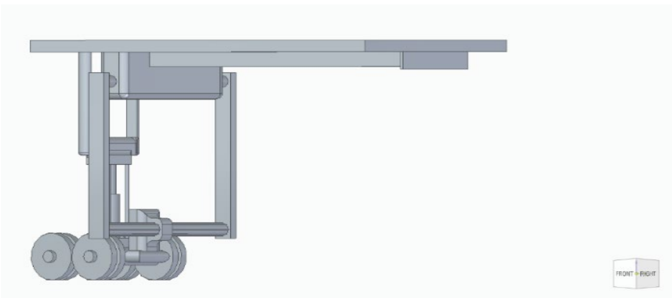


Fig 17: Wheel [Engaged]

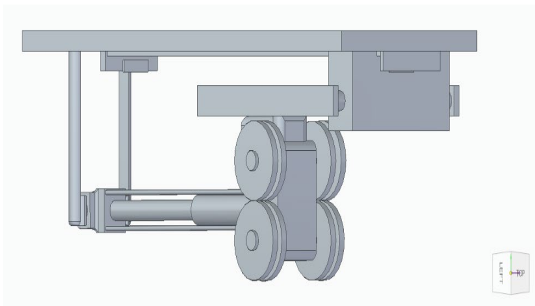


Fig 18: Wheel [Disengaged]

II. **Suspension & Hub:**

Hydraulic pistons are used to absorb the landing impact, four spring rods are also used for same purpose. The combination of piston and spring rods helps us achieve the suspension mechanism for our UAV.

(a) Single Hub (Front Wheel Hub) = Capacity of 4 wheels (2 each side)
(b) Dual Hub (Rear Wheel Hub) = Capacity of 8 Wheels (4 each side)

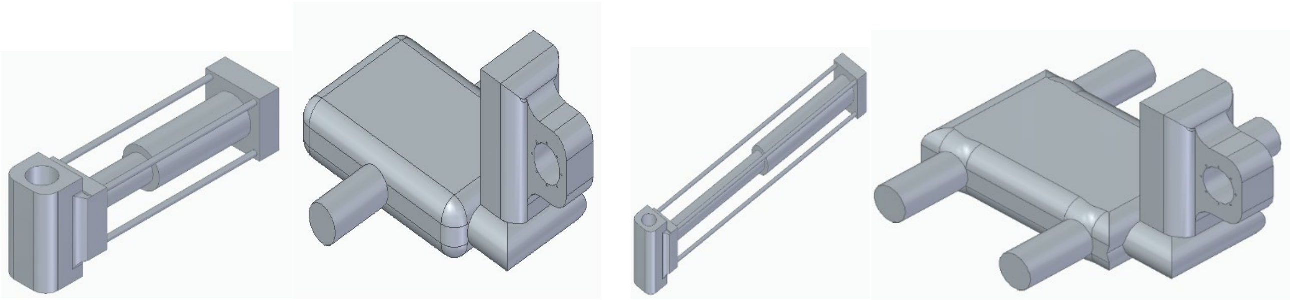


Fig 19: Suspension & Hubs

III. Wheels:

Front = 1 Single Hub = 4 wheels (4*1) [20 mm diameter]

Rear = 2 Dual Hub = 16 wheels (8*2) [20 mm diameter]

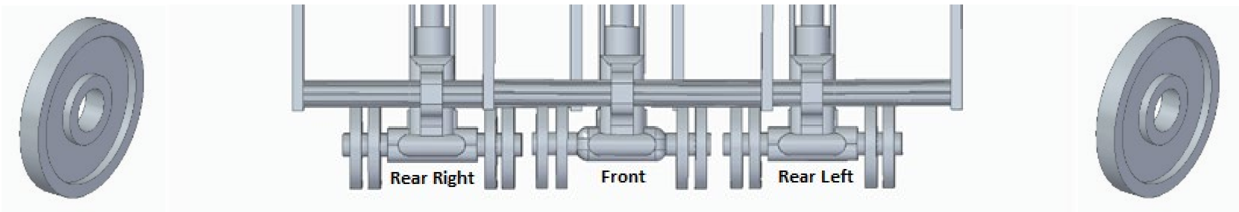


Fig 20: Wheel View

(refer 3.8-appendix for door mechanism of landing gear)

IV. Actuators:

We have used actuators in Landing Gears mechanism.

An actuator is a **device** that uses a form of power to convert a control signal into mechanical motion. the actuator creates specific motions depending on the purpose of the machine.

Few types:

a) Electric actuators are compact, relatively quiet, offer very precise positioning
b) Pneumatic actuators due to pressure losses and air compressibility

Preference: Servo actuators are electric actuators that use additional circuitry and a closed-loop feedback mechanism to provide additional precision and control even during motor motion.

(refer 3.8-appendix for more info on types of actuators)

3.9) STABILITY AND CONTROL:

Sensors:

Sensors play a vital role in the movement of the UAV to enhance the operation of the vehicle or to gather data.

Sensors used in our UAV are as follows:

Gyroscope, Accelerometer, Barometer Magnetometer, GPS sensor, inertial measurement units and Current Sensors Tilt Sensors.

(refer 3.9- appendix for detailed information on sensors)

Servo sizing:

Drag force analysis on the up going and down going ailerons/flaps/elevator/rudder gave the required clue for the servo motors,

we have assumed velocity of' air hitting the aileron reduced by half (in actuality, the change is less than half) for factor of safety.

I. **Aileron:**

Area of the aileron= $0.052m^2$

Angle = 45^0

Force * Distance = Torque

16.64 * 3 = 49.92 kg-cm

II. **Elevator:**

Area of the elevator = $0.056m^2$

Angle = 45^0

Force × Distance = Torque

17.97 * 3.5= 62.85 kg-cm

III. **Rudder:**

Area = $0.021m^2$

Angle = 45^0

Force ×distance = Torque

6.713 × 3.5= 23.495kg-cm

Based on the torque, the selected servos are:

I. **Servo for aileron and elevator**: Savox SH-1350 Super Torque Mini Digital

Fig 21: Servo

Features:

a) The coreless motor has brought above average performance and ensures smoother, faster, and more efficient operation.
b) The metal case allows for smoother operating temperature, environmentally friendly.

Specification:

a) Dimensions(mm): 35.0 X 15.0 X 29.2
b) Weight(g): 26.0
c) Speed (@6.0V sec/60): .11
d) Torque (@6.0V oz.-in): 63.9kg-cm

II. **Servo for rudde**r: Savox SH-1357 Super Speed Mini Digital Servo

Specification:

a) Dimensions (mm): 35.0 X 15.0 X 29.2
b) Weight (g): 26.0
c) Speed (@6.0V sec/60): .07
d) Torque(@6.0Voz-in):34.7kg-cm

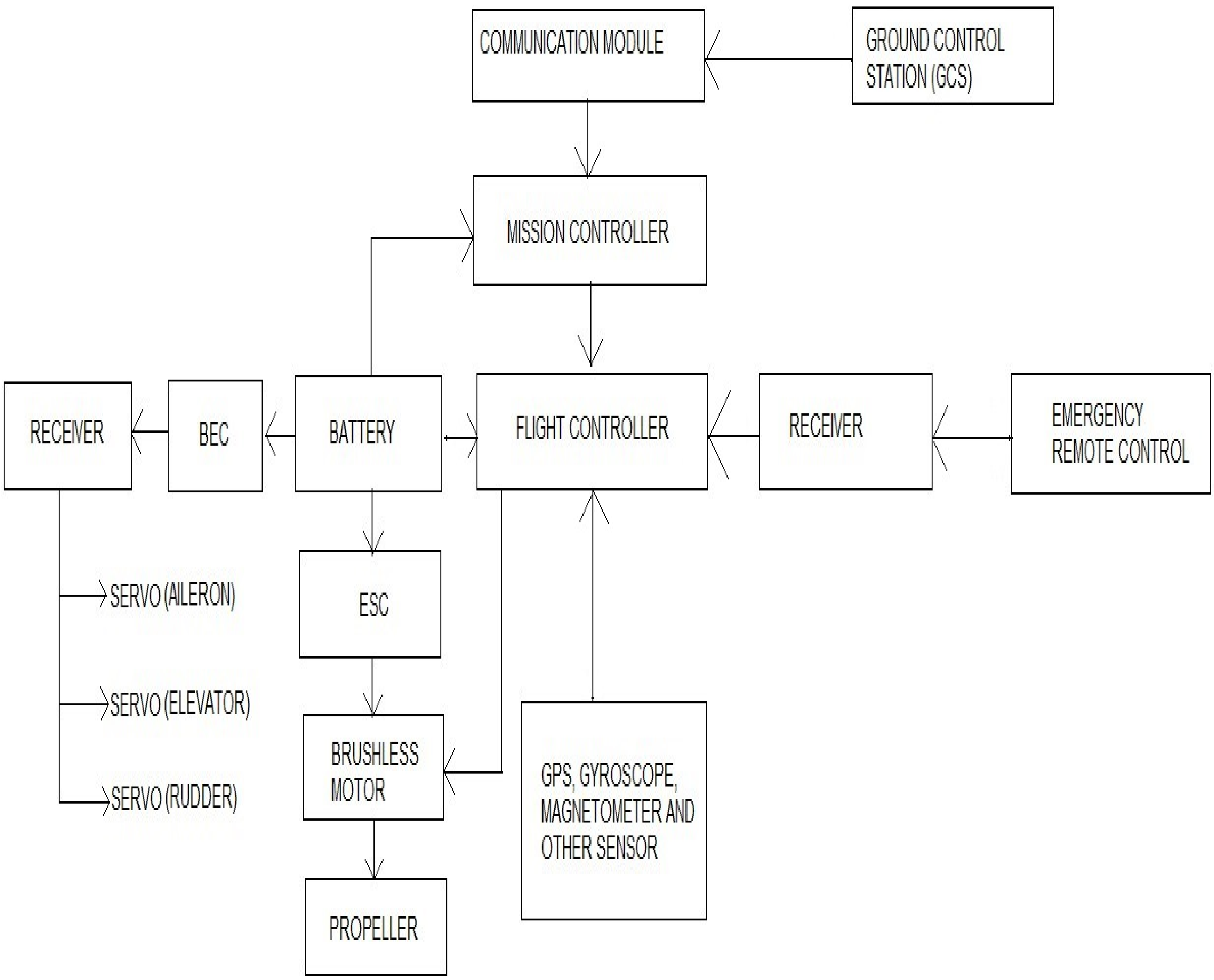


Fig 22: architecture of telementry and ground control

ELECTRICAL SYSTEM			
SL NO	NAME OF THE COMPONENT	SPECIFICATION	QUANTITY
1	LiPo Battery	13000mAh	3
2	9XR TRANSMITTER	2.4 GHz DSM2	1
3	RECEIVER	PAIRED WITH TRANSMITTER	1
4	SERVO	TORQUE 49.92 KG-CM SAVOX SH-1350	1
5	SERVO	TOORQUE 62.85 KG-CM SAVOX SH-1350	1
6	SERVO	TORQUE 23.495 KG-CM SAVOX-1357	1
7	MOTOR	AVIONIC PRO C3536 KV1050 BRUSHLESS MOTOR	2
8	ELECTRONIC SPEED CONTROLLER	40AMP BEC CIRCUIT (2A,50V)	1
9	SWITCH	DPST 30A FUSE	1

Table 2: Specification of components

3.10) Endurance Calculation:

Endurance expresses the capacity and requirements of energy for the flight to function completelly, it gives us the measure of battery capacity, flight time, energy consumption, etc.

Energy requirement estimation:

Time of flight (t) = 3 hours 180min =10800 seconds

Total drag D= 8.145N

Max velocity = V_∞ = 36 m/s.

a) Power demand (Specific fuel consumption) = D x V_∞ x 293 Joules/s
b) Energy required = Power demanded x t = D x V_∞ x t = 3,166,776 Joules
c) For a battery with voltage rating 25V (6 cell battery)
d) Battery capacity in mAh = (Energy required x 1000 / (Voltage x 3600) = 35186mAh
e) Three 13000mAh 6S 25C/50C Lithium Polymer Battery Packs connected in parallel can be used for powering the plane (accounting for a factor of safety of 10%)

Endurance = **Battery capacity / Power demand**

= (3 x 13 x 25 x3600)/293

=11979.52s

= **3hours 20minutes**

3.11) OTHER REQUIRED CALCULATION OF UAV :

$W_T = 12$ kg

$= \underline{117.6N}$

$\rho = 0.7$(At 6000 m above Sea Level)

$L = \underline{137N}$

$V_\infty = \underline{36 \text{ m/s}}$

Airfoil - NACA 63 - 212 (6 Series)

At $\alpha = 3°$

$C_l = 0.5$

$C_L = 0.20$

$C_D = 0.01$

$L = 1/2\ \rho V_\infty^2\ SC_L$

$137 = 1/2 \times (0.7) \times (36)^2 \times (5) \times 0.5$

$S = \underline{0.604 \text{ m}^2}$

→

RATE OF CLIMB

For climb

dh= 6000 m

dt =20 x 60

R/C= dh/dt

=6000 /20 x 60

=5 mls

P_A= Power Available

P_R=Power required

$R/C = P_A - P_R / W$

$5 = T_A V_\infty - DV_\infty / W$

$5 = 36\ (T_A - 8.145) / 117.6$

thrust available

$T_A = \underline{24.\ 478 \text{ N}}$

$\text{Sin}(\gamma) = T_A - D / W$

$=244.478 - 8.145 / 117.6$

$\gamma = \text{Sin}^{-1}(0.138)$

$\gamma = \underline{7.93^\circ}$

TOTAL SURFACE AREA

$S = 2S$

$= 2 \times 0.302$

$S = \underline{0.604\ m^2}$

THRUST REQUIRED ,VELOCTIY REQUIRED

$T_{Rmin} = W \times \sqrt{4\ K\ C_{do}}$

$=1/7.6 \times \sqrt{4} \times 0.045 \times 0.01$

$=4.989\ N + [\ (0.1)\ D + (0.2)\ D + (0.1)D]$ –Error

$= \underline{7.31}$

$V_{Rmin} = [\sqrt{2(W/S\ x\rho\ )}]\ x\ (K/C_D)^{1/4}$

$= [\sqrt{2}\ (117.6/0.604\ x0.7)]\ \ x\ \ (0.045/0.01)^{1/4}$

$=\underline{34.35 m/s}$

For level flight / Cruise flight

$T = D$

$T_R=8.145\ N$

$T_R \rightarrow$ Thrust required

$L = W$

$= 117.6\ N\ T_{Rmin}=7.31\ N$

$V_{Rmin}=34.35\ m/S$

→

SERVO SIZING

- **Aileron**

Area of the aileron = 0.052m2

Angle = 45°

Area × cos (angle) =

= 0.052* 0.707

=0.0367m2

Velocity = 36 m/s (plane velocity)

To find acceleration:

v = u + at

v = 18m/s

u = 36m/s

t = 1m/s

a= (v-u)/t

a= -18m/s

Velocity × Area × density = Mass per second

36× 0.0367 ×0.7 = 0.9248

Mass * acceleration = Force

0.9248* 18 = 16.64N

Force * Distance = Torque

16.64 * 3 = 49.92 kg-cm

Using same method and formulas ,

We have calculated torqe for elevator and rudder.

4.0) Computer Aided Design Details:

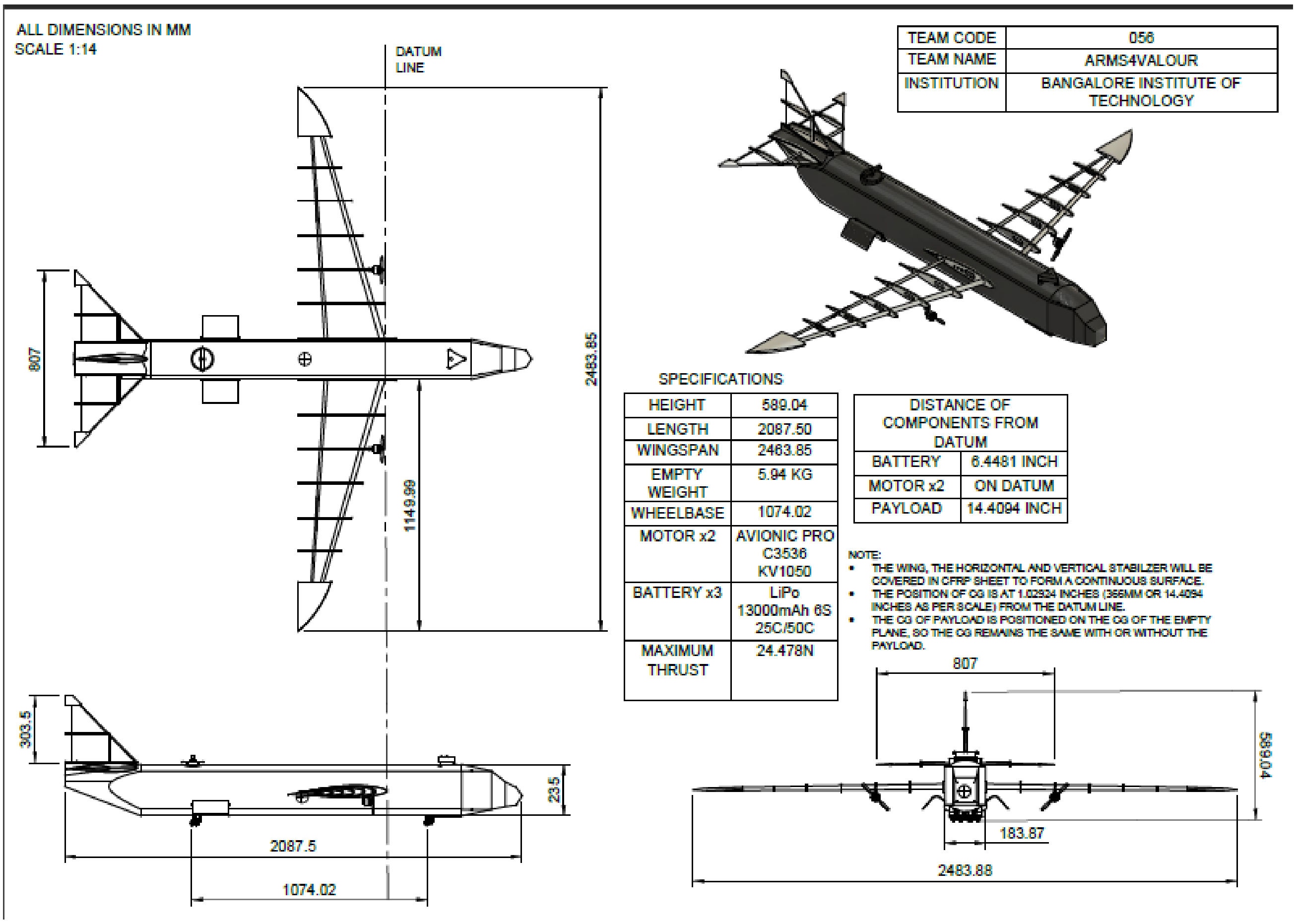


Fig 27: Team Arms4Valour UAV Drawing with 3D

(refer last page for cad image in A3 size)

5.0) Computational Analysis:

I. CFD Analysis:

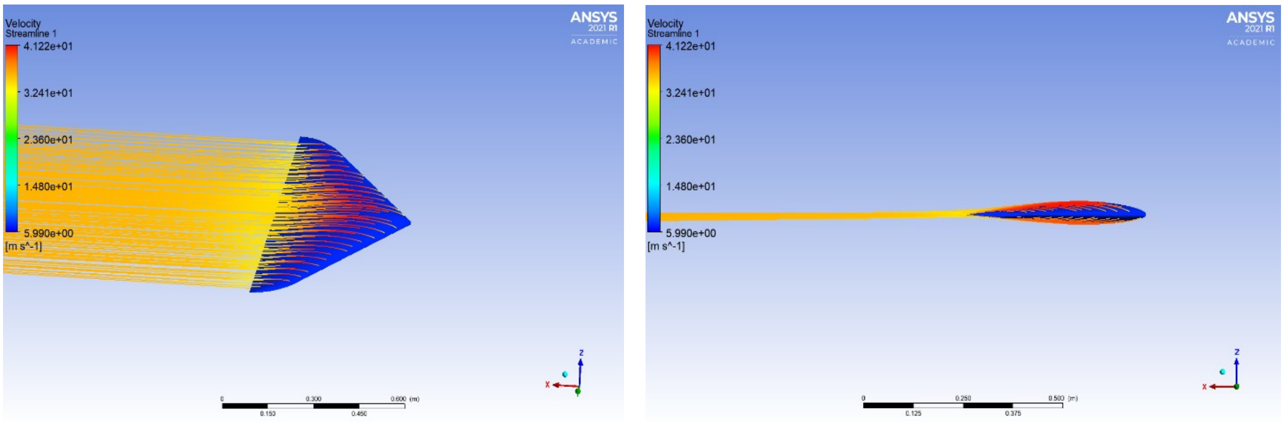


Fig 23: CFD analysis with streamline velocity from air generated at body

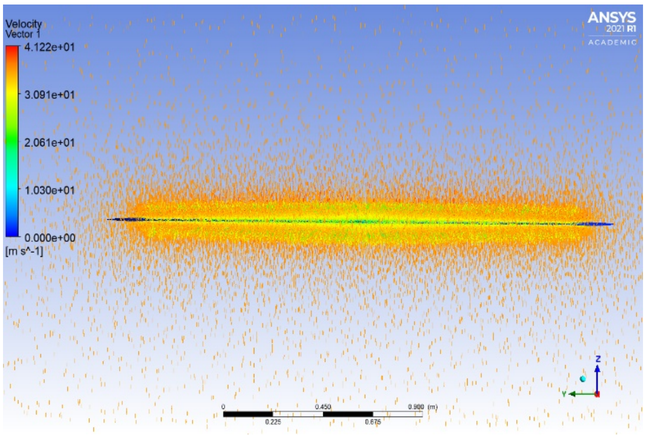


Fig 24: CFD analysis of velocity vector generated at the body (Front View)

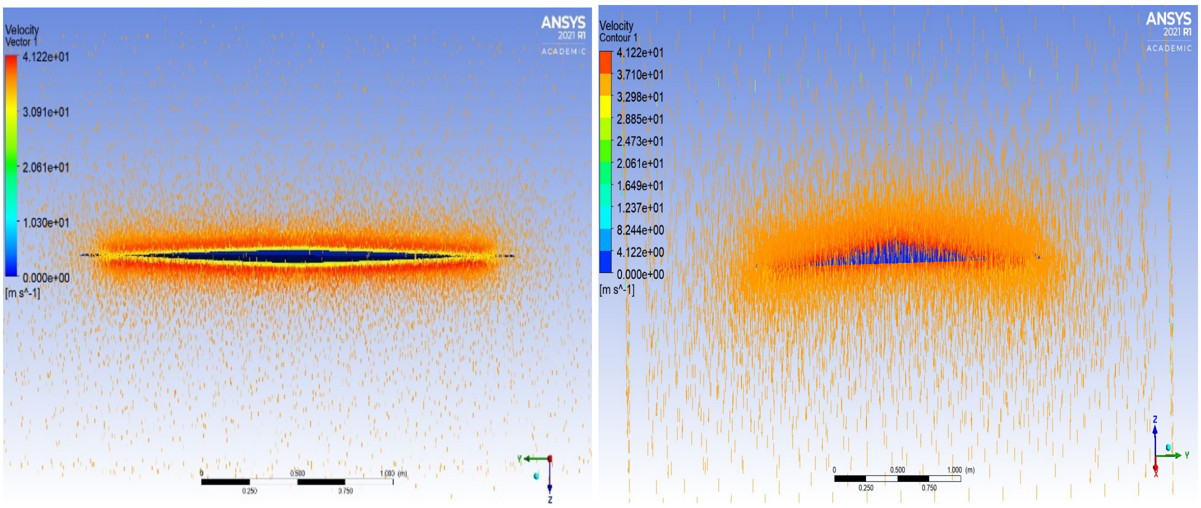


Fig 25: CFD analysis of velocity vector generated at the body (Behind View)

II. Structural Analysis:

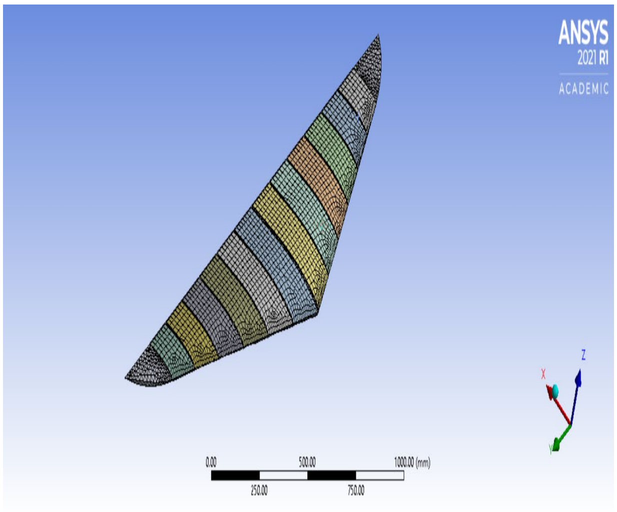


Fig 26: Meshing of Wing Structure

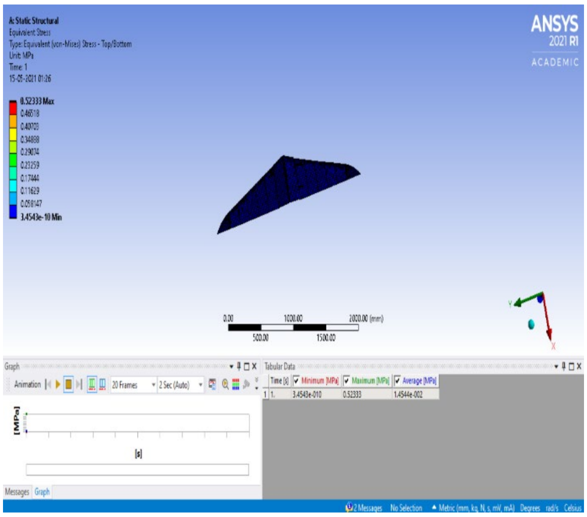


Fig 27: Stress Analysis for Wing structure

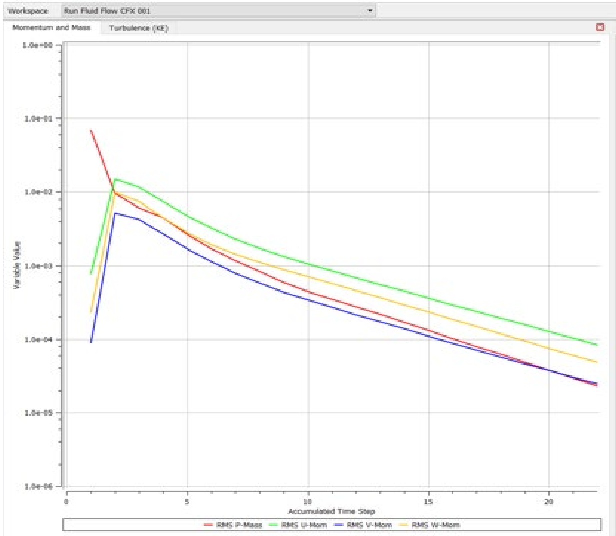


Fig 28: Mass and Moment

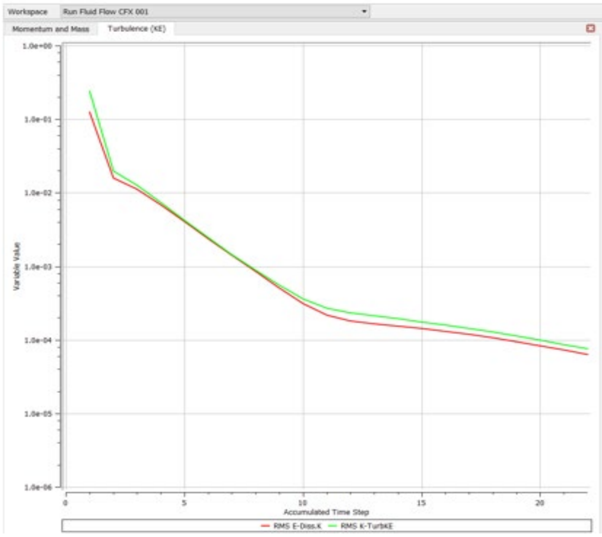


Fig 29: Turbulence

6.0) OPTIMIZED DESIGN:

I. Wings:

NACA 64-212 airfoil was given preference over other airfoils mainly because of drag bucket. Reducing drag is very important as it needs to be reduced as much as possible for a flight. A flight with lower drag at same conditions is always preferred. It also facilitates the trim of wing at higher angles of attack, as we know the flight stalls at higher angles of attack often; it's important to reduce the chance of stalling and increase the control of the flight to overcome from stalling.

II. **Centre of gravity:**
We faced lots of challenges while placing the center of gravity due to a lot of factors like location of battery, location of landing gears and other important mechanism. It was also important to keep the center of gravity within optimum limits or else it might've led to instability of the flight.

III. **Landing Gear:**
Mechanism of engaging and disengaging the landing gear was a huge challenge we faced due to small size of our flight and it always looked easy when it comes to fixed landing gear. A lot of concepts such as suspension, turning, shock absorbers, etc. had to be studied. Another challenge was finding solutions for opening/closing landing gear compartment, after a lot of research we could finally arrive with solutions using actuators and motorized motion.

IV. **Tail:**
A conventional tail was chosen after a lot of thinking and analysis as we had other ideas like dual tail and inverted Y tail. A dual tail was our goal but due to challenges we faced in mounting and enabling the control in each part of stabilizers, we chose the conventional tail.

V. **Payload Delivery:**
Achieving the application of payload delivery was very carefully done as it involved a lot of challenges such as parachutes, airbags, compartments, material build, cooling effect and opening/closing of capsules. Under ideal conditions, we firstly began but then we also tried to achieve water tight and air tight system for the contents of payload. Having airbags also enables floating of payload over water, this might help in places of water floods.

VI. **Battery:**
Choosing an ideal battery to serve all the functions and power all the systems was the biggest challenge we faced, as we couldn't eliminate any particular system because we wanted to make sure our flight had all round capacity and operating at non ideal conditions as well.

7.0) PRACTICAL APPLICATION AND FEASIBILITY:

Objective: Accomplishing the delivery of a minimum of 6kg payload

7.1. PRINCIPLE AND WORKING:

The Unmanned Aerial Vehicle serves an important application such as not only payload delivery but also providing cold storage solution to the payload or capsule, this can be potentially used for delivering medicines and drugs that need to be delivered in isolated regions without breaking the cold chain supply. It also facilitates landing the payload in flooded regions due to presence of airbags and system of air and water tight mechanism.

7.2. SPECIFICATION:

Payload weight = 7 kg, Length = 400 mm, Width = 152.80 mm, Height = 119.31 mm

Volume = 54, 76,885.8 mm^3, Location = within fuselage, Dropping Height = 500m,

Descent Speed = 5 mps, Time taken to land = 100 seconds approx.

7.3. EXTERNAL AND INTERNAL STRUCTURE:

I. Isometric view:

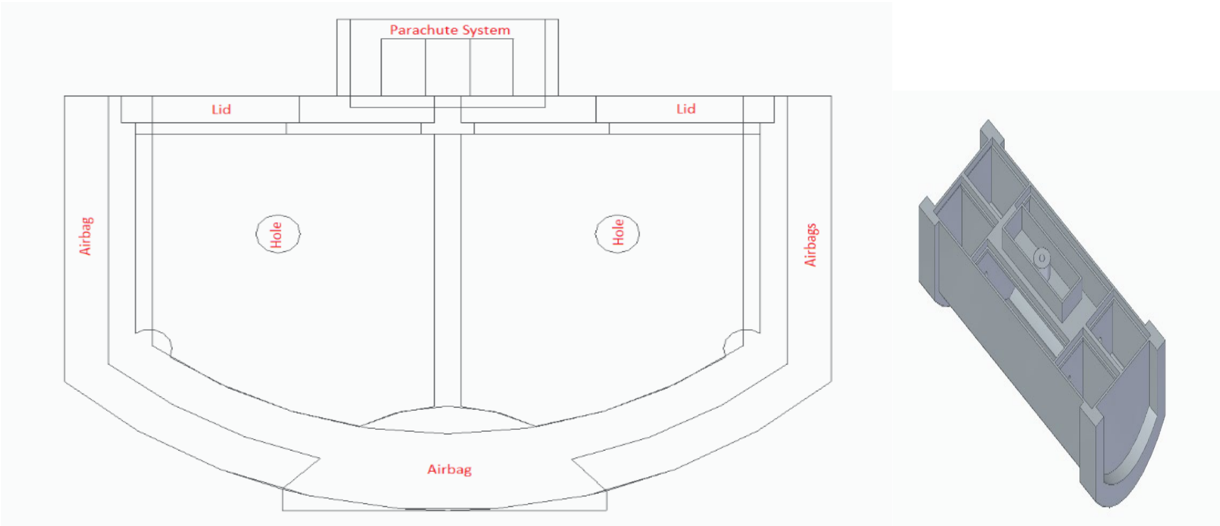
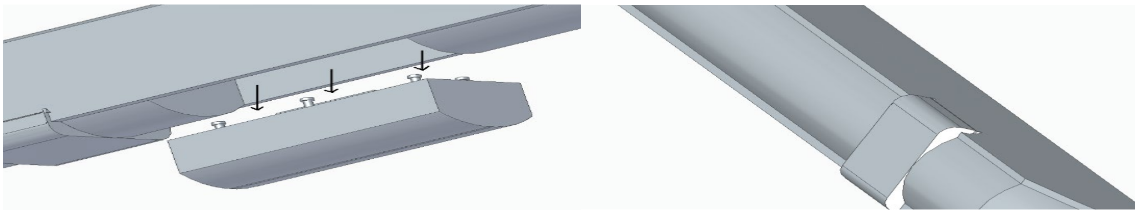


fig .30 internal 2d structure of payload

7.4. DROPPING MECHANISM:

Sliding Doors are used to house the payload safely into the fuselage, the doors close after dropping with the help of pneumatic actuators to avoid unnecessary sudden hollow gaps in fuselage. On opening the door, the fuselage is dropped and closes after the activity of delivery.



7.5. OPENING/CLOSING OF CAPSULE:

To access the payload, lids are used for opening and closing the capsule. These lids fit on the access paths of each subsection. Lids are tightly secured into the access paths using multipurpose adhesive gum, which can be removed easily after the capsule lands. A small amount of heat and 100%/99% IPA alcohol or some WD-40 on a cotton swab can be used according to situation to remove the adhesive.

These adhesive packing provides air tight and water tight conditions to contents of the capsule hence making it very useful in harsh conditions.

Lids:

7.6. LANDING AND AIRBAGS:

Parachute system is used to reduce the descent speed to desired safe value,. This mechanism is opened immediately after dropping the capsule, the air bags are deployed to reduce the impact load on landing.

The airbag reduces the chances of damage to both the capsule and its contents. The parachute section can be independently detached from the capsule after landing.

Diameter of parachute = 275.78 cm, Impact Force = 70 Newton

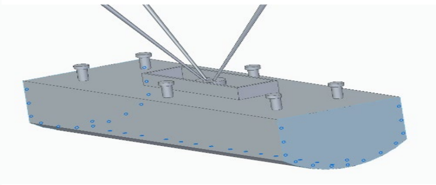
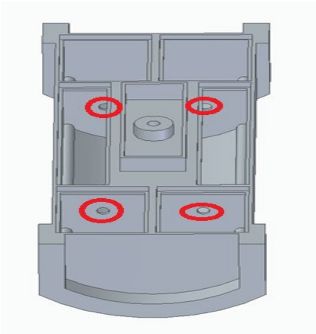
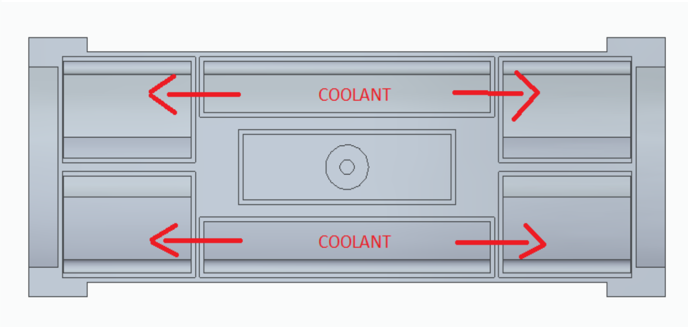


FIG.31 Parachute system **FIG.32Airbag system:**

7.7. OPTIONAL COOLING SYSTEM:





Optional cooling system is made available by having coolants such as dry ice, liquid nitrogen or any coolant stored primarily in sub section 3 and 4 respectively.

For safety reasons, dry ice or solid carbon dioxide is most preferred coolant for cooling action as it sublimes safely releasing cold vapours of carbon dioxide into sub-sections containing the contents of capsule.

8.0) INNOVATION:

To compile all the innovations we used, here is a list of ideas and solutions we have incorporated:

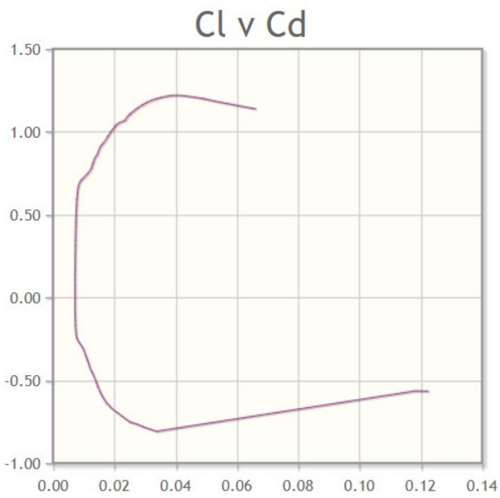
1. Landing gear with simpler mechanism instead of complex hydraulic piston for engaging and disengaging the gear mechanism
2. Maintaining cold chain supply to payload contents incase of important drugs and medicines
3. Enabling trimming of wings at higher angles of attack by applying NACA 64-212 airfoil
4. Advanced battery system to cater all needs of UAV to perform in few non-ideal conditions
5. Incorporating Anti Collison sensors and other necessary sensors for safety of UAV
6. Introducing air and water tight system to the payload by providing adhesive locking mechanism that can be opened by few sets of given solutions.
7. Incorporating a certain type of propulsion system to cater the thrust needed for flight operation with or without payload with a considerate factor of safety.
8. Landing gear with both horizontal and vertical shock absorbers to absorb both longitudinal and lateral impact load faced during landing
9. A system of gyroscopes and leveler mechanism are introduced to provide better flight control and stability
10. Selection of most suitable Materials based on factors like cost, manufacturing, ease of detection of damage, environmental factors, dielectric resistance and lightweight.

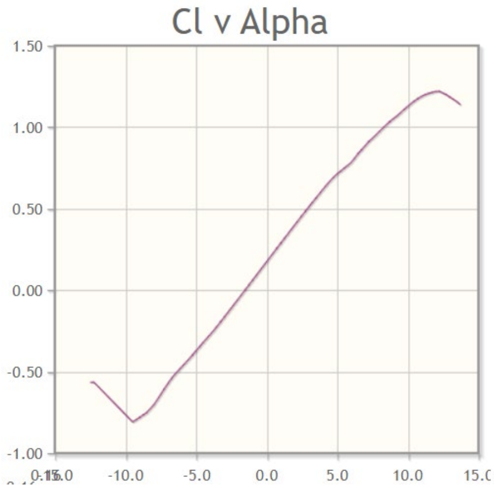
-- END --

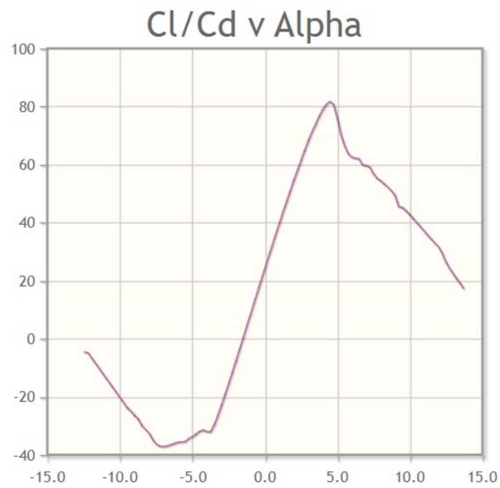
Appendix A:

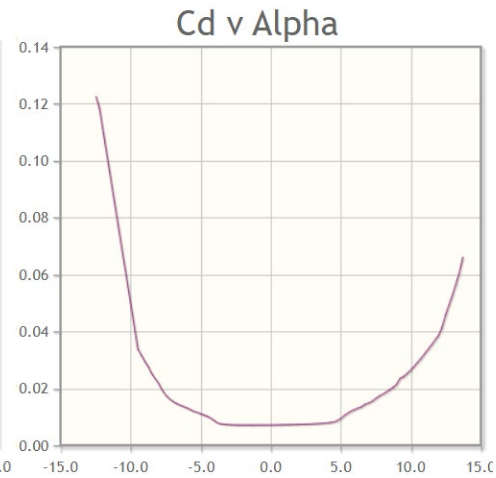
3.1) Wing Selection:

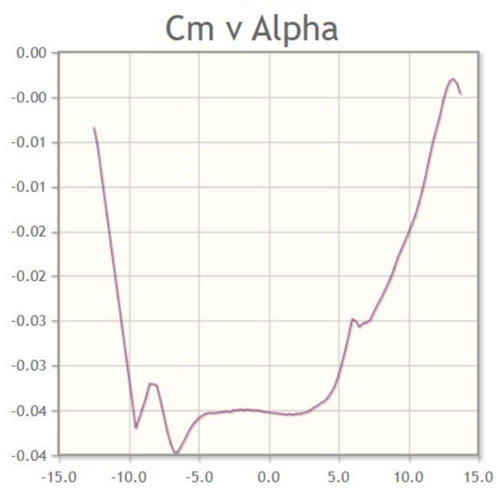
Airfoil Characteristics of NACA 63-212:





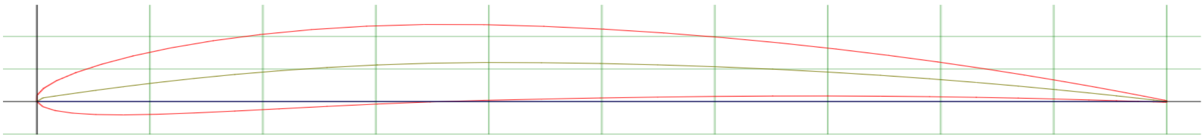




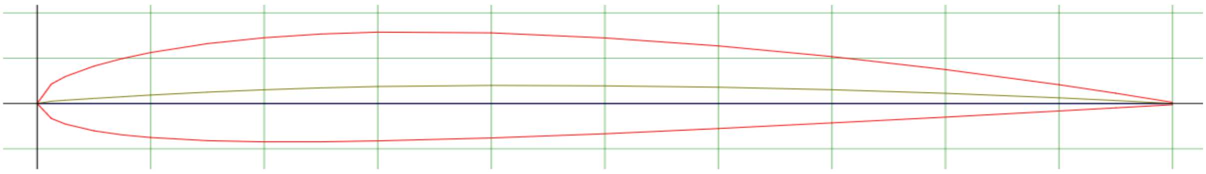


Other Alternatives instead of 63-212:

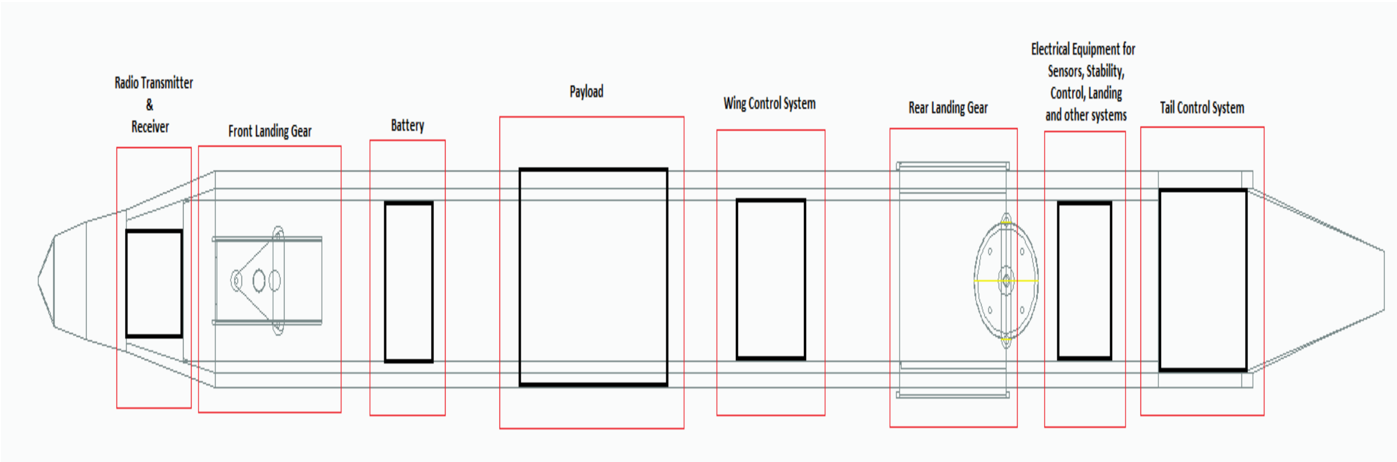
NACA 6412:



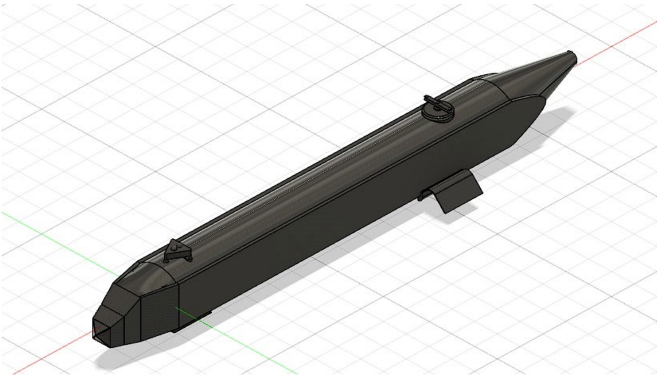
NACA 2412:



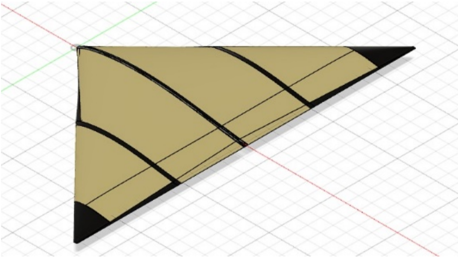
3.2) Fuselage layout

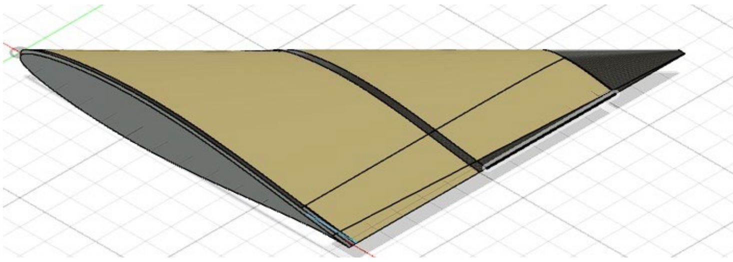


Fuselage:

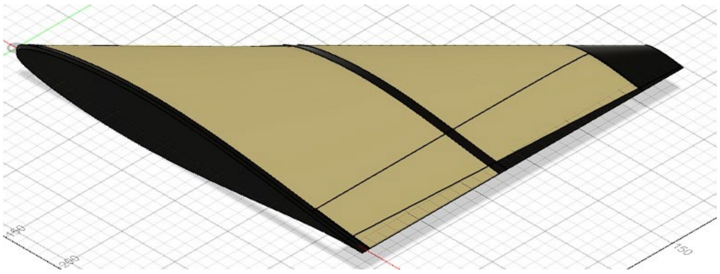


Horizontal Tail:





Vertical Tail:



3.4) Propulusion System:

Battery:

Table 3: Load Test Report

Voltage/V	PROP	PULL/g	CURRENT/A	ESC
11.1	9*3.8 E	920	13.9	30A
11.1	9*3.8 SF	1040	16.8	30A
11.1	9*4.7 SF	987	18.1	30A
11.1	10*5 E	1400	25.3	40A
11.1	11*5.5 E	1630	28.9	40A
11.1	11*7 E	1580	31.2	50A
11.1	12*6 E	2040	38	50A
14.8	8*3.8 SF	1350	21.2	40A
14.8	**8*3.8 E**	**1270**	**20.4**	**40A**
14.8	8*6 SF	1480	30.7	40A
14.8	9*3.8 SF	1780	28	40A
14.8	9*3.8 E	1560	23	40A
14.8	9*4.7 SF	1590	23.4	40A
14.8	9*6 E	1850	34.3	50A
14.8	10*5 E	2160	41	50A

I. Motor is selected based on the amount of thrust value
II. From calculations we know that the value of thrust is 24.278N = 2475.05g
III. Thrust is divided into two motors.

IV. On considering the above table, let's consider 1270g of thrust. We require two motors of same thrust specification.

3.7) Flight envelope

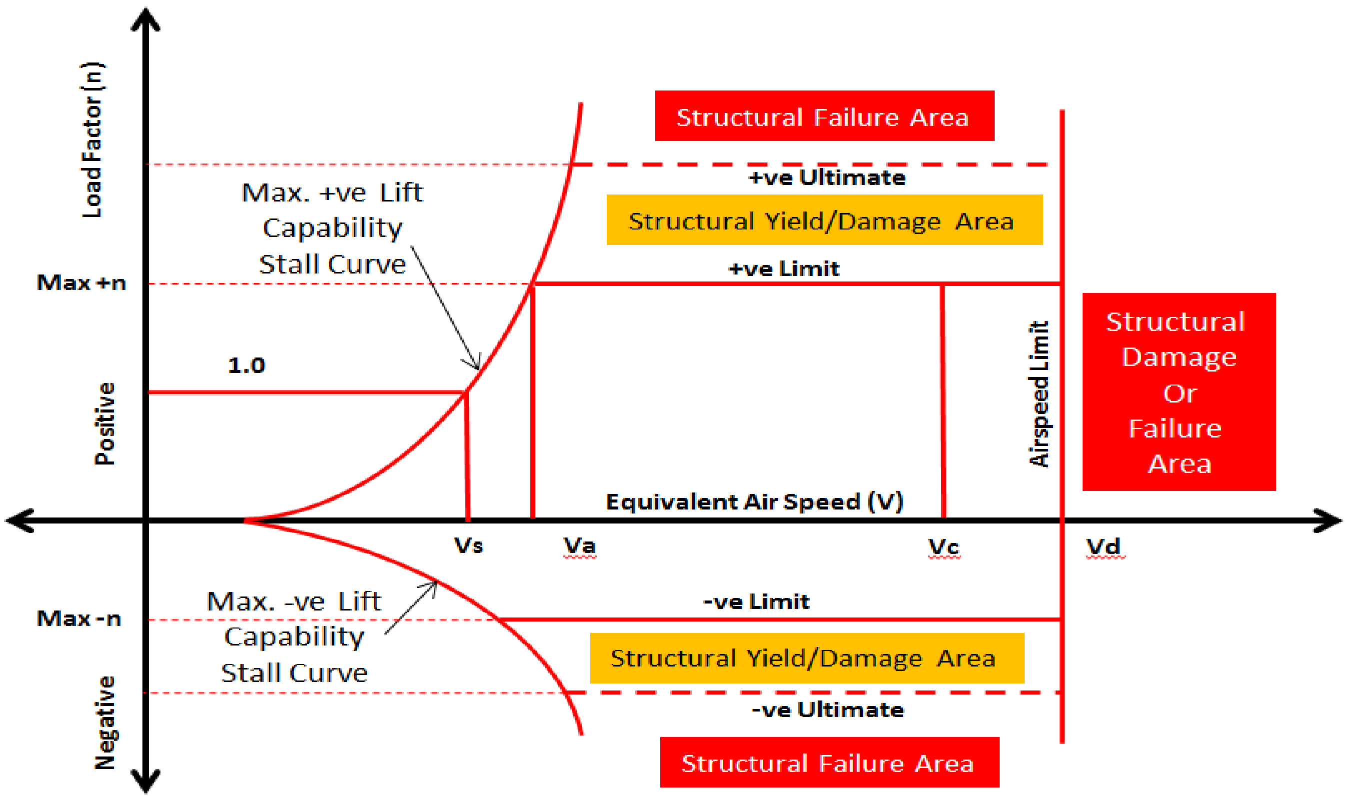


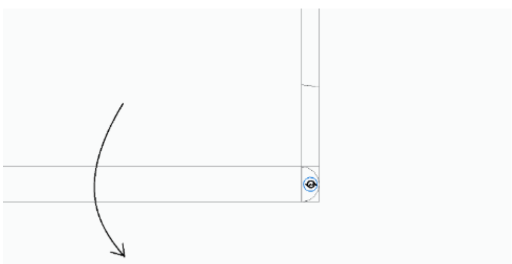
Fig . Significance of V-N Diagram

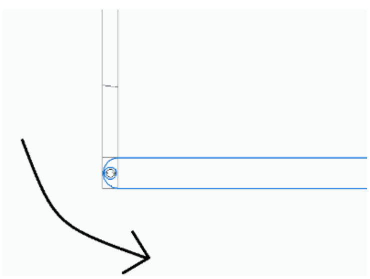
3.8) Landing Gear:

Mechanism of front landing gear compartment:

Internal Mechanism:

Open position: **Closed Position:**





Mechanism of rear landing gear compartment:

Closed position rear: **Open position rear:**

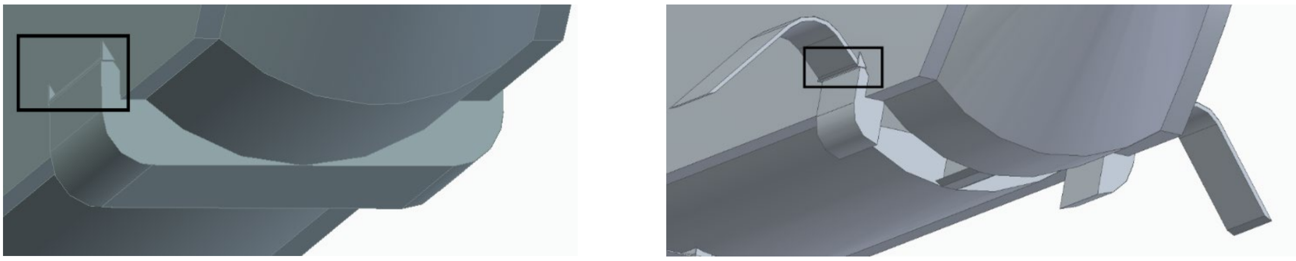


Fig : Rear Landing Gear Positions

Opening and closing of compartments is also motorized by the above rotational mechanism, the **position of the motor** is situated as shown below:

Actuators:

An actuator is a device that uses a form of power to convert a control signal into mechanical motion. The actuator creates specific motions depending on the purpose of the machine. Here in our UAV, we use actuators in Landing Gears.

Few types of actuators are as follows:

I. **Electric actuators**:
Electric actuators are motor-driven devices that convert electric current input into mechanical motion, either linear or rotary.
Electric actuators are compact, relatively quiet and easier to interface into electrical systems than pneumatic or hydraulic actuators. They offer very precise positioning and high repeatability.

II. **Pneumatic actuators:**
Pneumatic actuators use compressed air or other gases from an external compressor or a manual pump to move a piston within a cylinder.

Pros: Pneumatic actuators have a relatively simple construction and require little maintenance. Cons: Due to pressure losses and air compressibility and require a compressor to continually run and generate pressure even when no motion is required.

III. **Hydraulic actuator:**
Hydraulic actuators are similar in operation to pneumatic actuators, but use liquid to move a piston instead of gas. Cons: Loss of efficiency due to fluid leakage and they are bulky and more complicated

IV. **Servo actuators:**
Servo actuators are electric actuators that use additional circuitry and a closed-loop feedback mechanism to provide additional precision and control. Servos allow for precise control of position and velocity even while the motor is in motion.

Preference: Servo actuators are electric actuators that use additional circuitry and a closed-loop feedback mechanism to provide additional precision and control even during motor motion.

3.9) Stability & Control:

Sensors:

Sensors play a vital role in the movement of the flight to enhance the operation of the vehicle or to gather data.

Sensors used in our flight are as follows:

I. **Gyroscope:**

Gyroscopes work on the principle of conservation of angular momentum.

This helps in collecting information on the drone's roll, pitch, and yaw, and feeding back this information to the drone's proportional-integral-derivative (PID) controller.

II. **Accelerometer:**

The accelerometer of a drone works together with its gyroscope to determine changes in its position and movement using thermal sensing.

III. **Barometer:**

Barometers are sensors that measure air pressure. In drones, this air pressure information is used to determine the drone's altitude and maintain stable altitude.

IV. **Magnetometer:**

A drone can always determine the direction of the magnetic North and adjust its trajectory accordingly using this sensor.

V. **GPS sensor:**

A drone is outfitted with a GPS receiver that can receive signals from several GPS satellites.

VI. **Inertial Measurement Units:**

Inertial measurement units combined with GPS are critical for maintaining direction and flight paths. air traffic control.

VII. **Current Sensors:**

In drones, power consumption and use are important. Current sensors can be used to monitor and optimize power drain, safe charging of internal batteries, and detect fault conditions with motors or other areas of the system.

VIII. **Tilt Sensors:**

Incorporating both an accelerometer and a gyroscope, Tilt sensors help drones maintain level flight.

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Quora

Rocket reviews

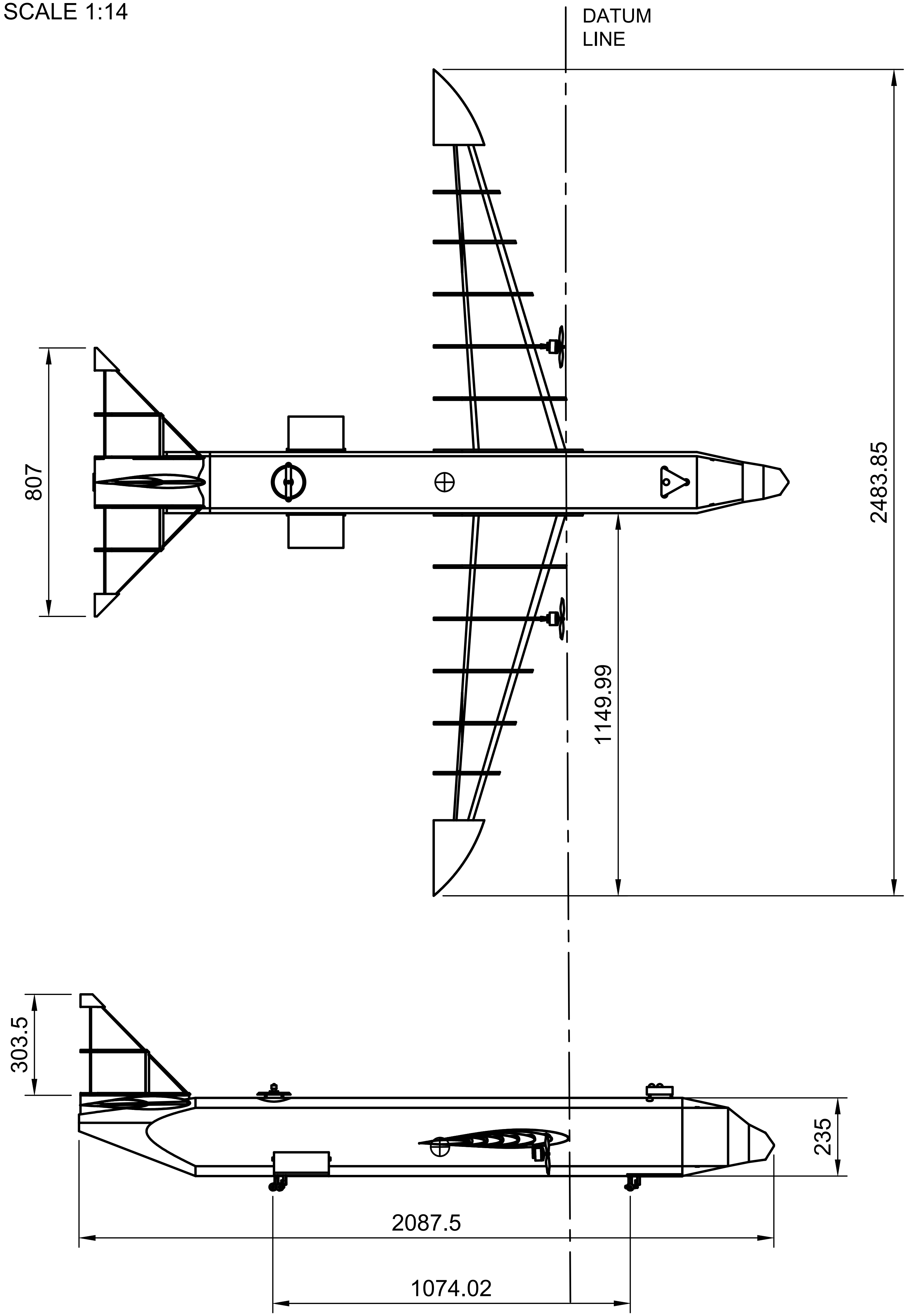
Rocket mime

Volvo vehicle safety using airbags

Airfoil tools

Principles of flight

ALL DIMENSIONS IN MM
SCALE 1:14



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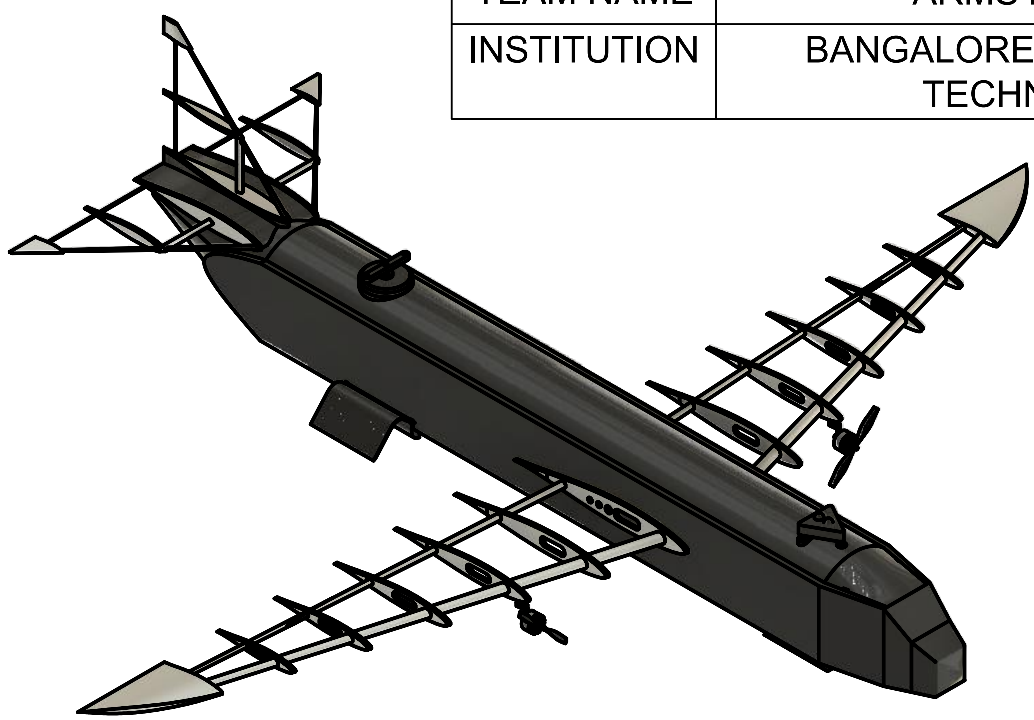
INSTITUTION	BANGALORE INSTITUTE OF TECHNOLOGY



SPECIFICATIONS

HEIGHT	589.04
LENGTH	2087.50
WINGSPAN	2463.85
EMPTY WEIGHT	5.94 KG
WHEELBASE	1074.02
MOTOR x2	AVIONIC PRO C3536 KV1050
BATTERY x3	LiPo 13000mAh 6S 25C/50C
MAXIMUM THRUST	24.478N

DISTANCE OF COMPONENTS FROM DATUM	
BATTERY	6.4481 INCH
MOTOR x2	ON DATUM
PAYLOAD	14.4094 INCH

NOTE:

- THE WING, THE HORIZONTAL AND VERTICAL STABILZER WILL BE COVERED IN CFRP SHEET TO FORM A CONTINUOUS SURFACE.
- THE POSITION OF CG IS AT 1.02924 INCHES (366MM OR 14.4094 INCHES AS PER SCALE) FROM THE DATUM LINE.
- THE CG OF PAYLOAD IS POSITIONED ON THE CG OF THE EMPTY PLANE, SO THE CG REMAINS THE SAME WITH OR WITHOUT THE PAYLOAD.