# UAV For Forest Surveillance


AS5100
Group-9
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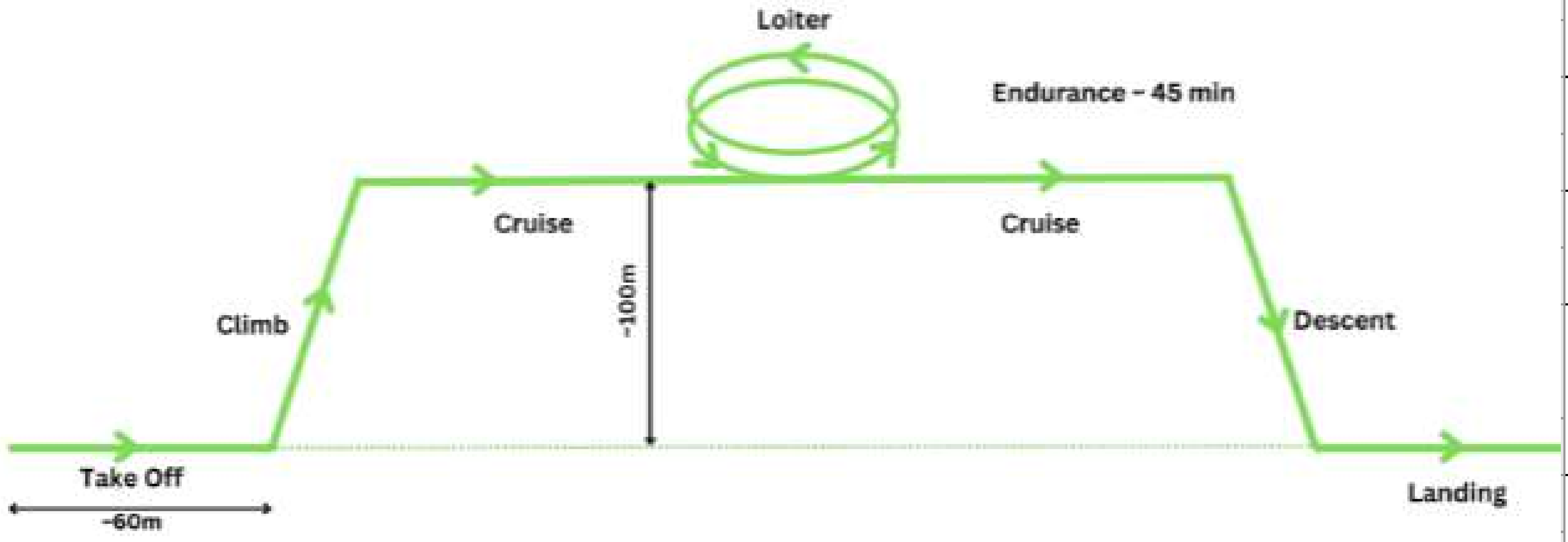
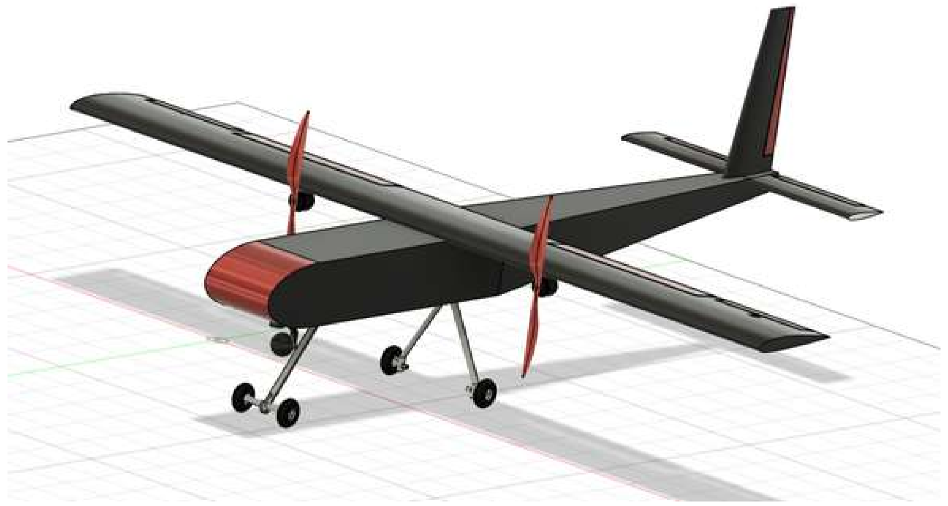
# Aerodynamic Review

- Surveillance of Forest areas to detect Forest Fires
- To aid in rescue operations
- Helps in keeping poaching and smuggling in check



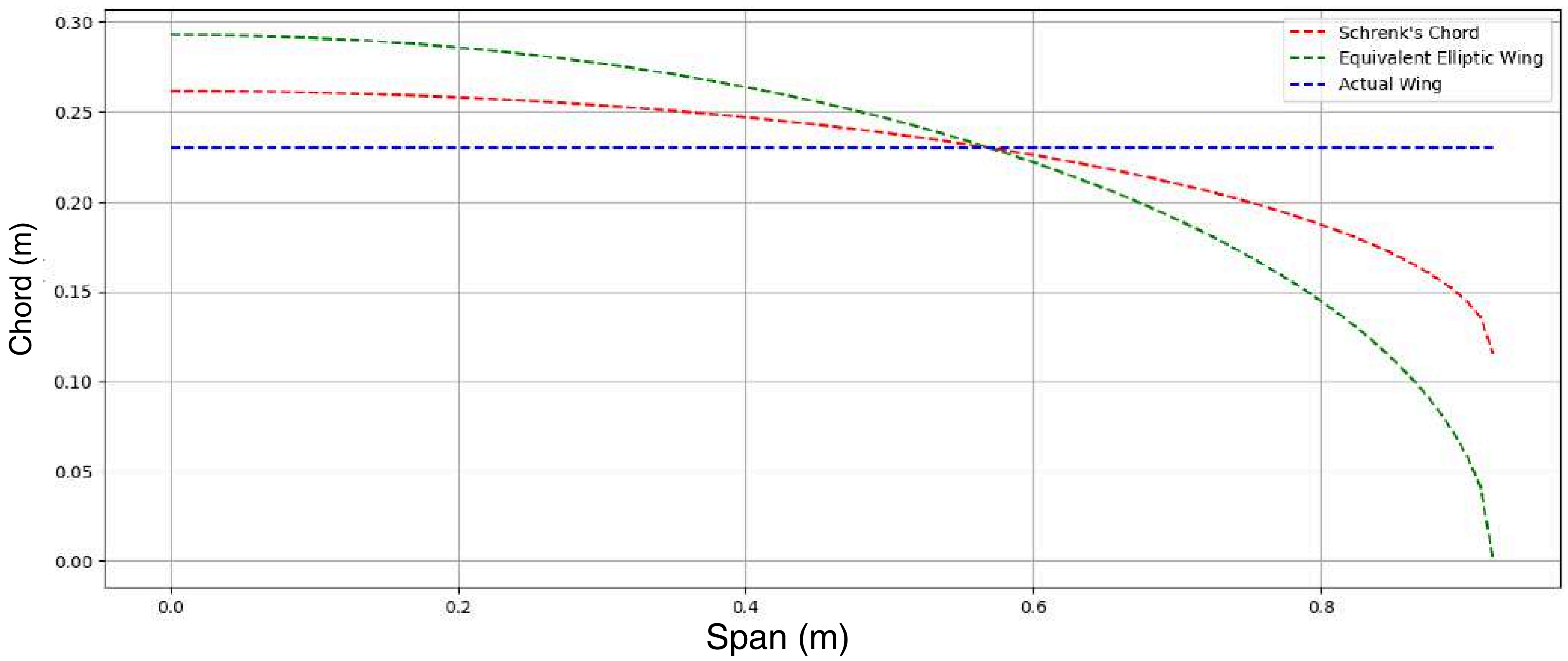

Mission Profile

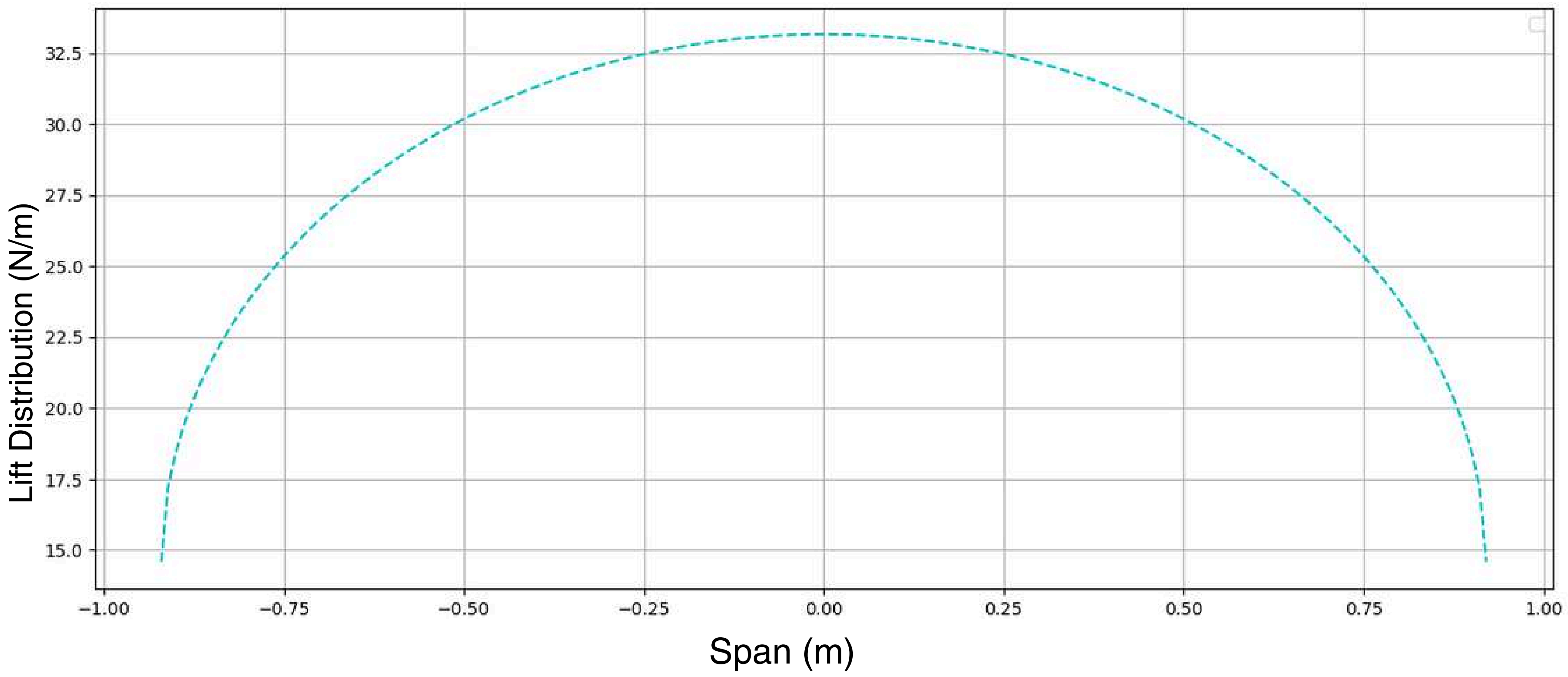


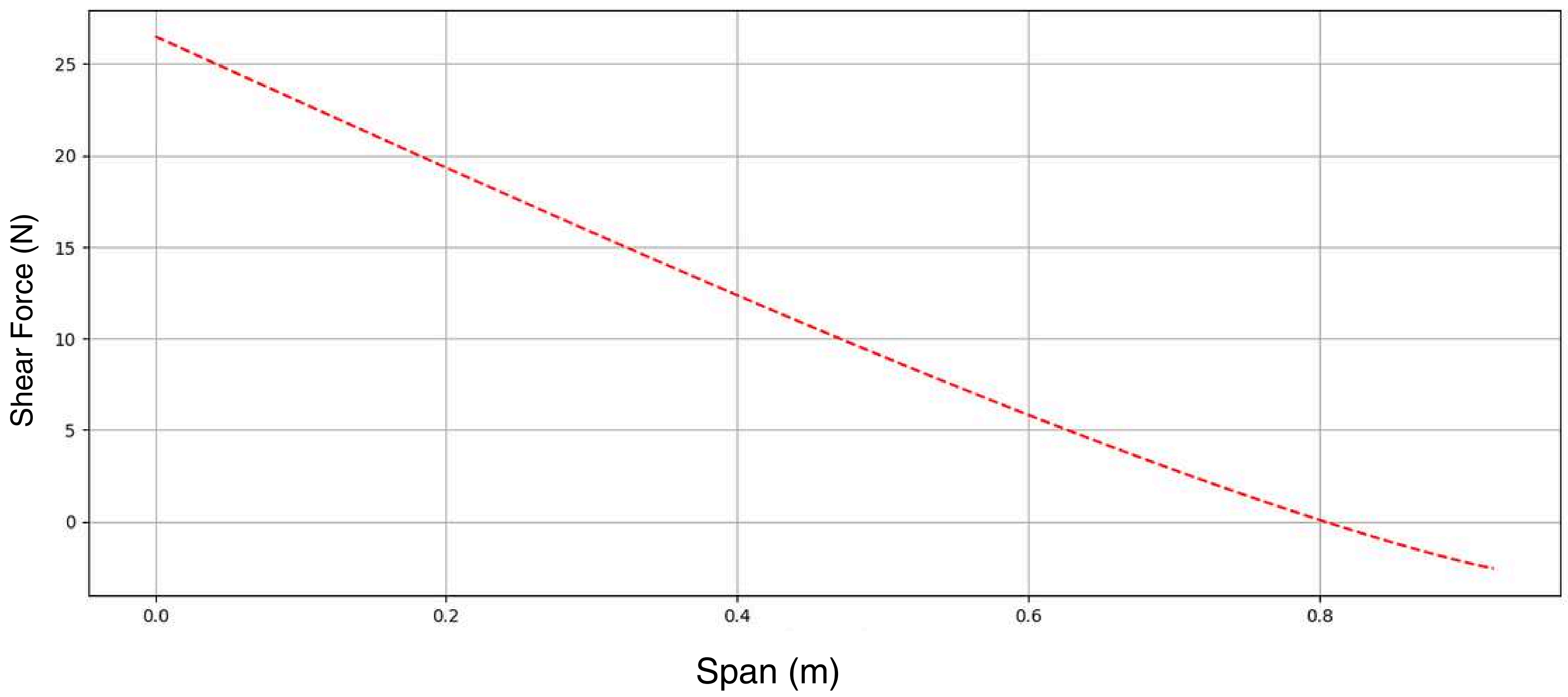
| UAV DETAILS | |
|---|---|
| Wing Span | 1.84 m |
| Wing Chord | 23 cm |
| Total Length | 1.69 m |
| DTOW | 5.47 Kg |
| Aspect Ratio of Wing | 8 |
| Wing Airfoil | NACA2412 |
| Tail Airfoil | NACA0012 |

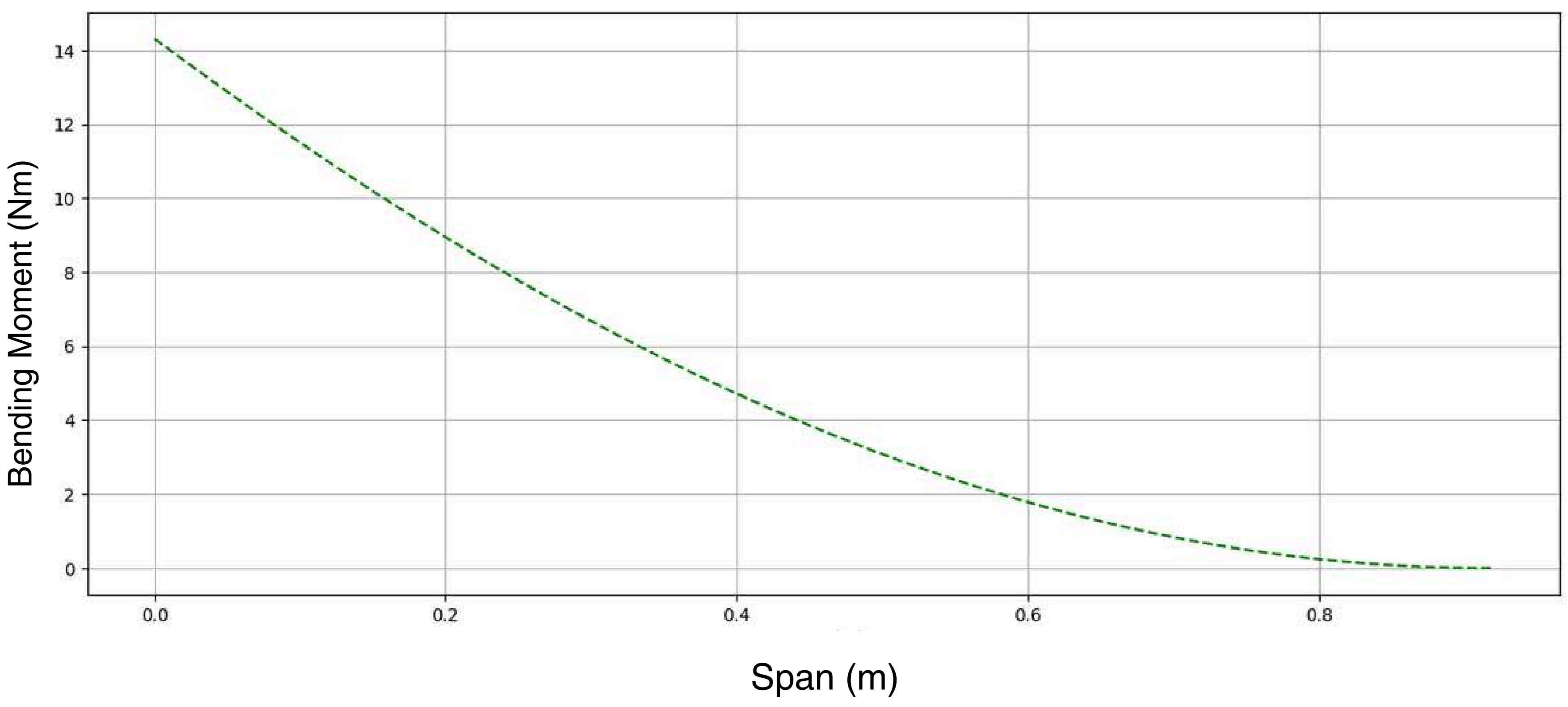
| MISSION DETAILS | |
|---|---|
| Cruise Speed, $V_{cr}$ | 20 m/s |
| Cruise Altitude | 100 m |
| Maximum Cruise Speed, $V_{max}$ | 25 m/s |
| Takeoff speed, $V_{TO}$ | 12.86 m/s |
| Stall Speed, $V_{stall}$ | 12.2 m/s |
| Corner Velocity, $V_{corner}$ | 19.29 m/s |
| Red Line Speed | 30 m/s |
| Positive Limit Load Factor $n_+$ | 2.5 |
| Negative Limit Load Factor $n_-$ | -1 |
| Lift Coefficient at zero AOA, $C_{L_0}$ | 0.2 |
| Cruise Lift Coefficient, $C_{L_{cr}}$ | 0.53 |
| Maximum Lift Coefficient | 1.5 |
| Ostwald's efficiency, e | 0.82 |
| Parasitic Drag, $C_{D_0}$ | 0.023 |

# Lift Distribution - Schrenk's Method



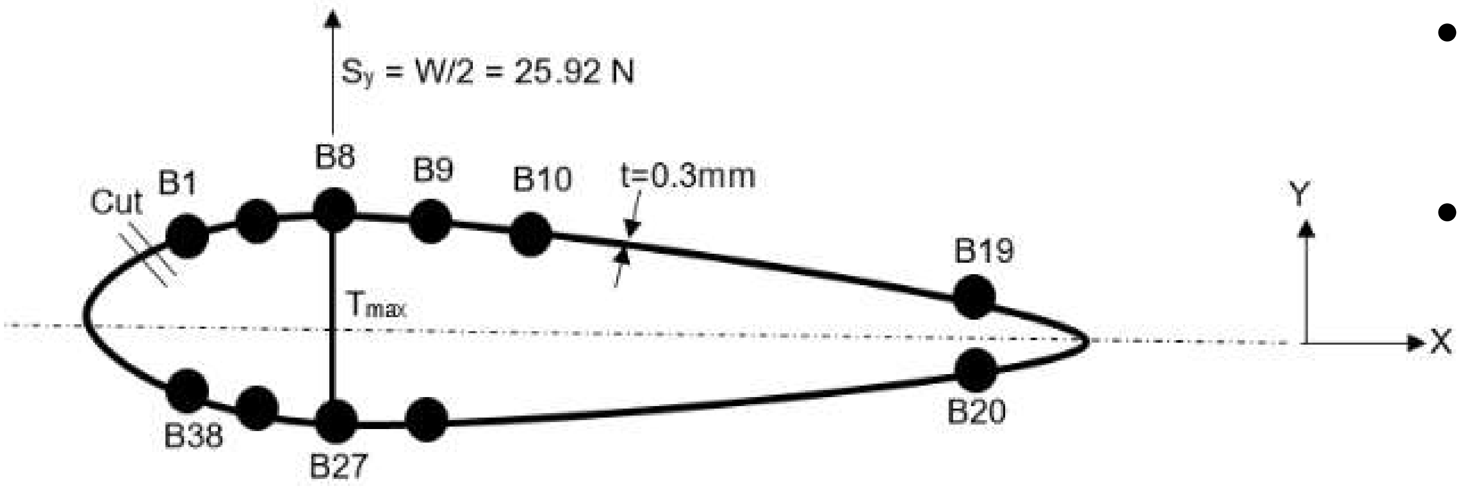
# Spar Design

Design Criteria;

$$\sigma_{allowable} \leqslant \frac{\sigma_{yield}}{k \times f \times n \times \eta_{fatigue}} \implies \sigma_{allowable} = \frac{\sigma_{yield}}{10.5} = \frac{M_{max} \times t_{max}}{2 \times I_{total}}$$

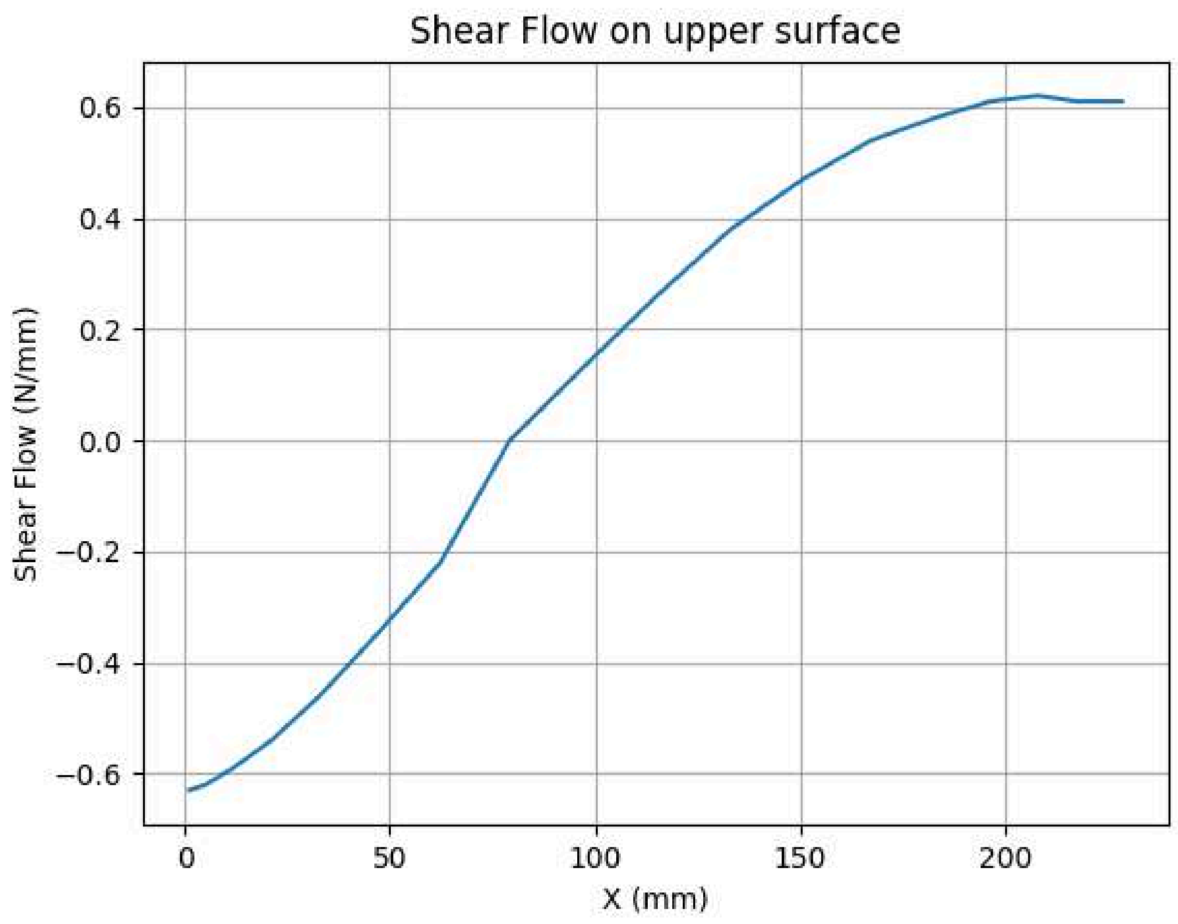
- Al-6061 (Yield Stress = 270 MPa) for skin, of uniform thickness 0.5mm.
- $I_{total} = 8.78 \times 10^{-9} m^4$
- $I_{skin} = 24.35 \times 10^{-9} m^4$ (20 individual skin sections for calculation)
- $I_{spar} = -15.57 \times 10^{-9} m^4$
- Hence, no spar is required. However, we will attach 'Root-Rib' of wing via a flat plate. This plate is attached to the bulkhead.

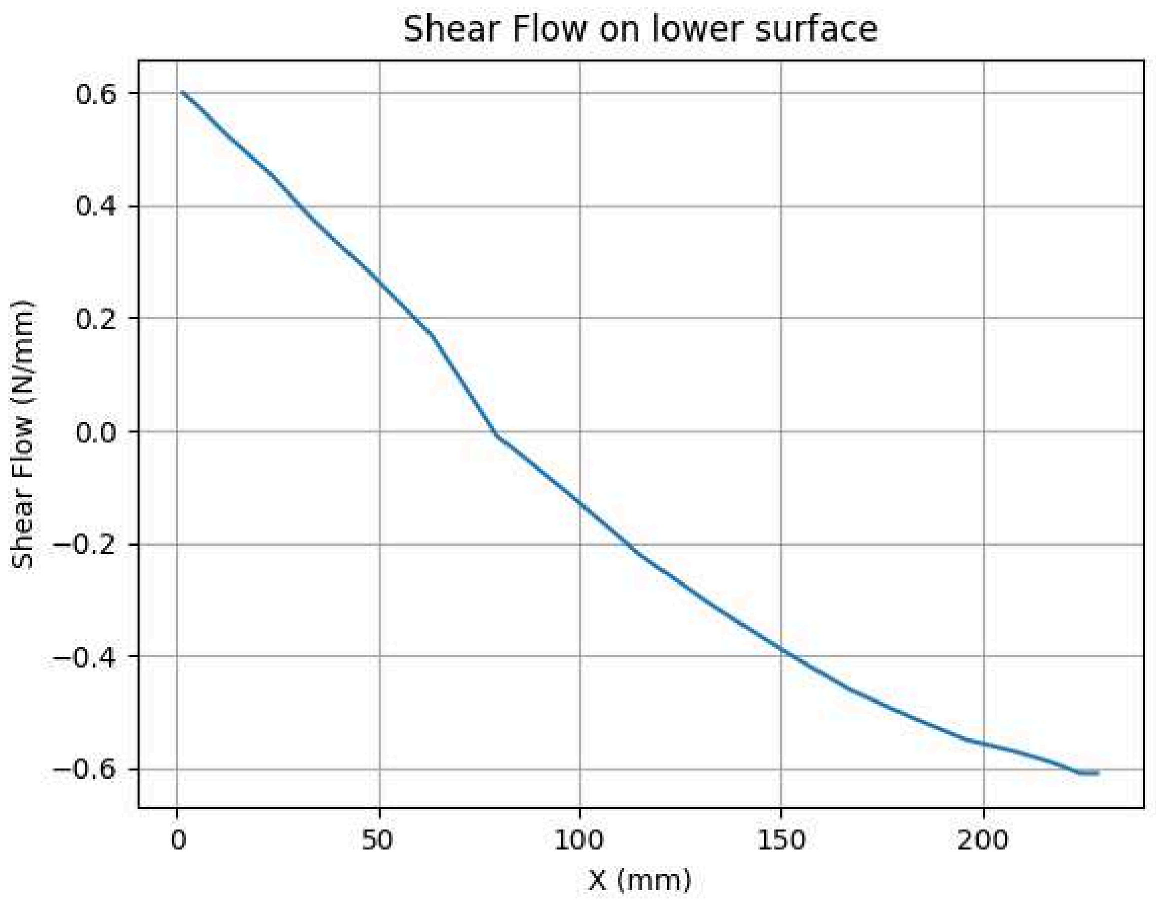
# Stringers



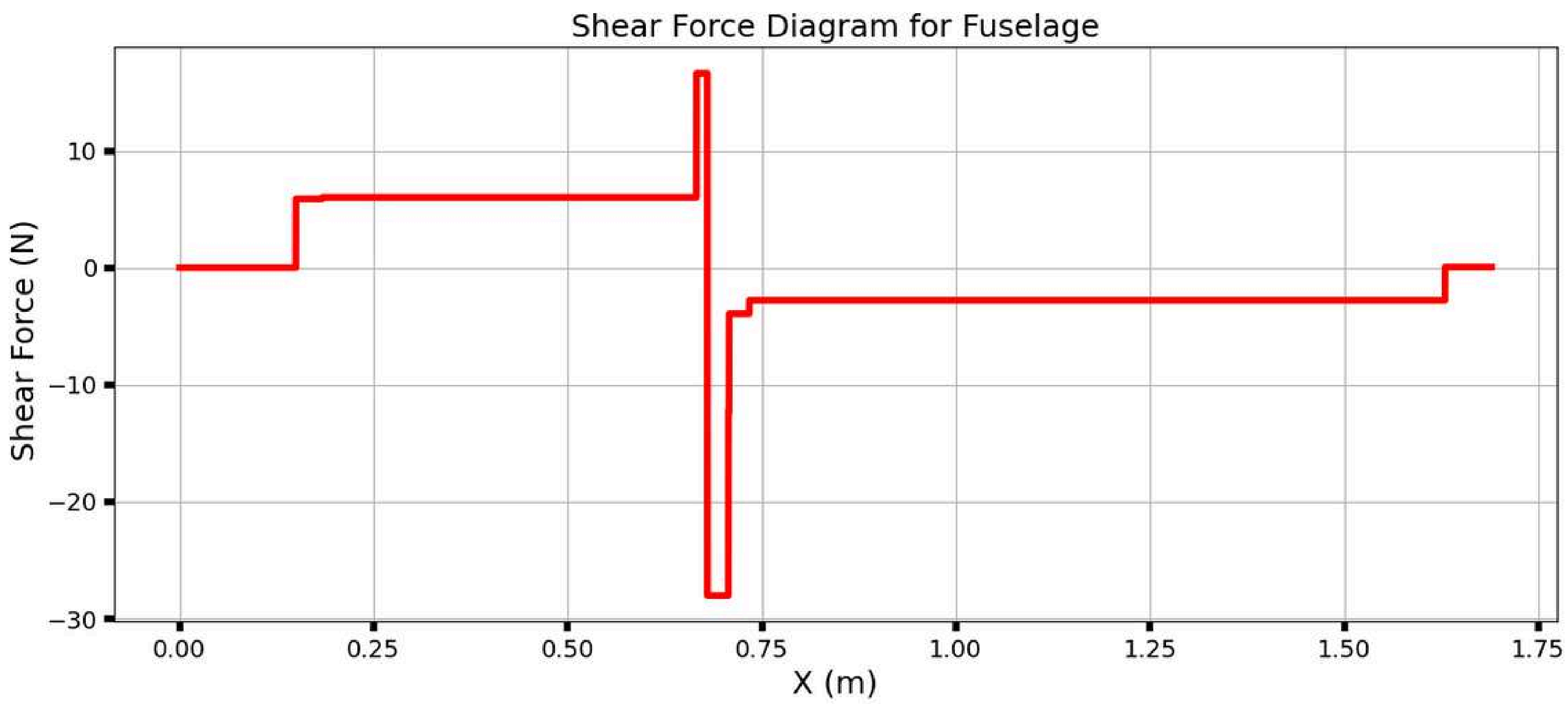

$$N_{cr} = \frac{K\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$$

- Top and bottom surfaces of airfoil were divided into 20 strips for idealization and shear flow calculation.
- The Force per unit area in the idealized section corresponding to the maximum shear flow and bending stresses is **8.11 N/sq.mm** and **7.07 N/sq.mm** in the two panels respectively whereas the critical buckling load per unit area is **9.81 N/sq.mm** and **9.11 N/sq.mm** respectively. Stringers are **not** required as the critical buckling load we have is lesser than the calculated one.

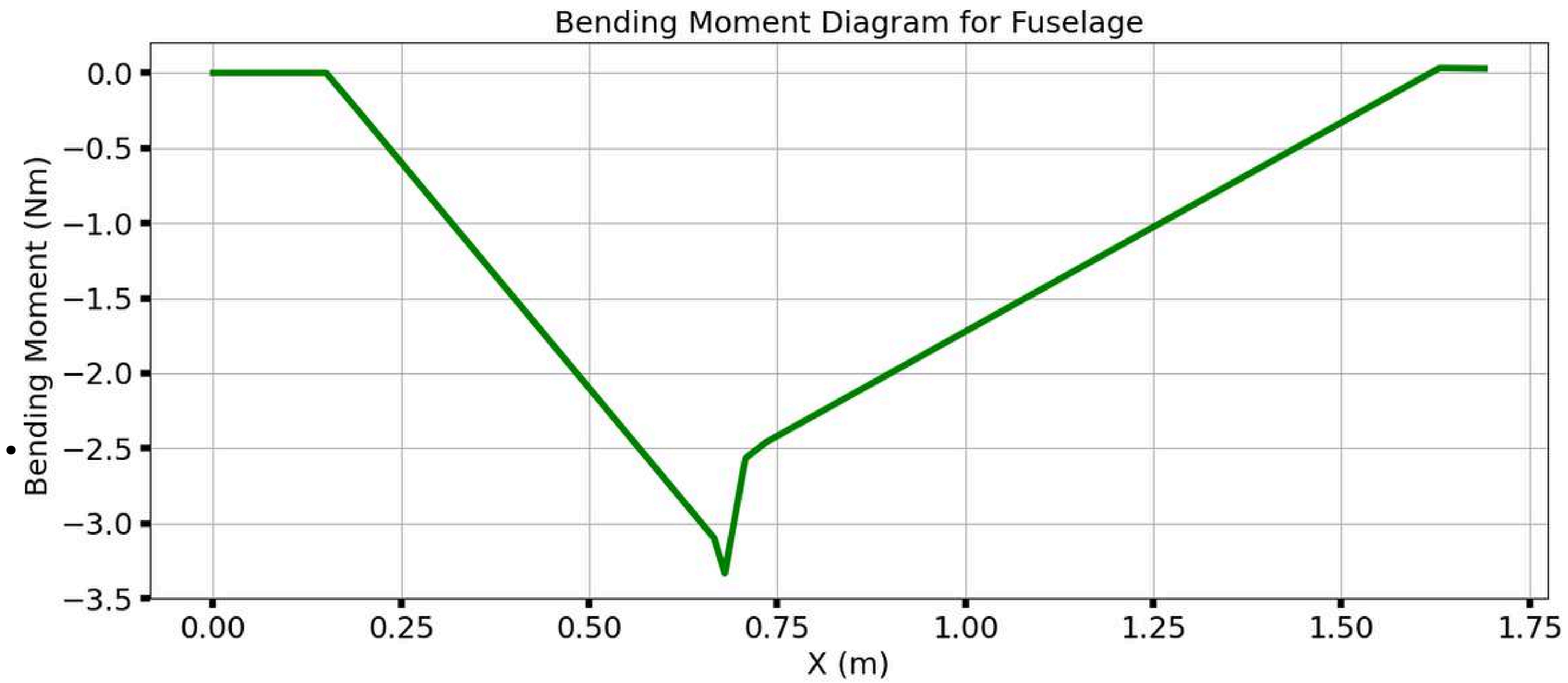


# SFD and BMD of Fuselage

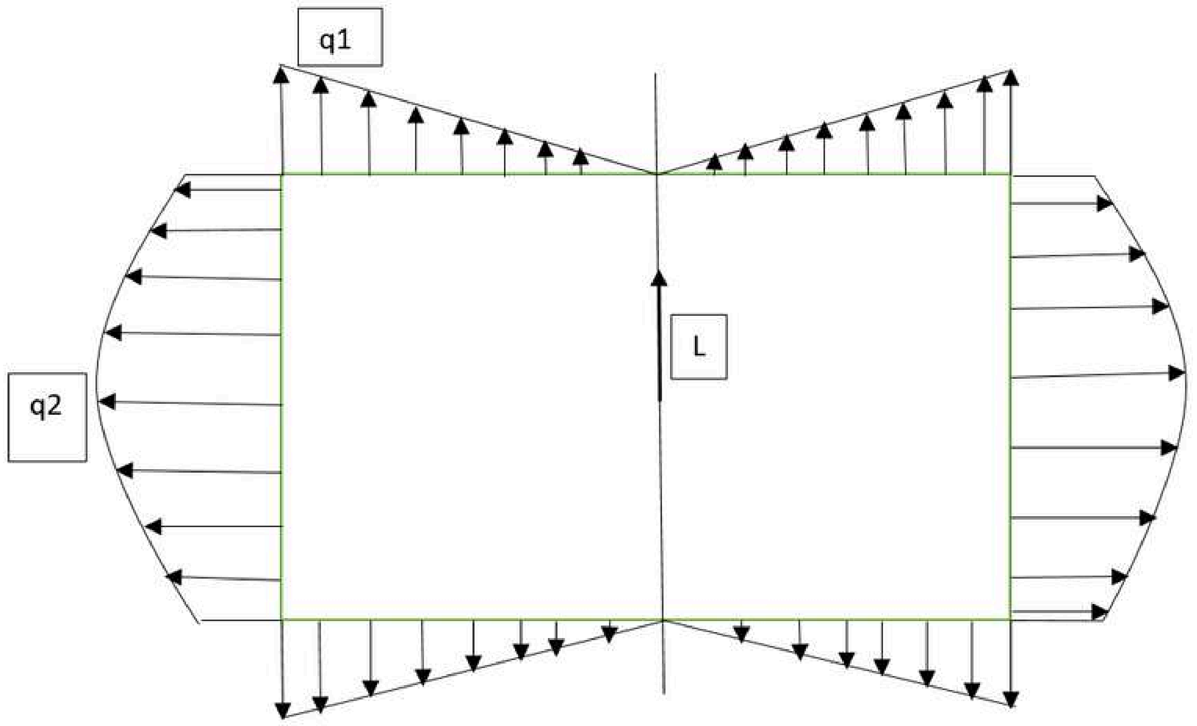



- Maximum |BM| is around 3.5 Nm.



# Longerons

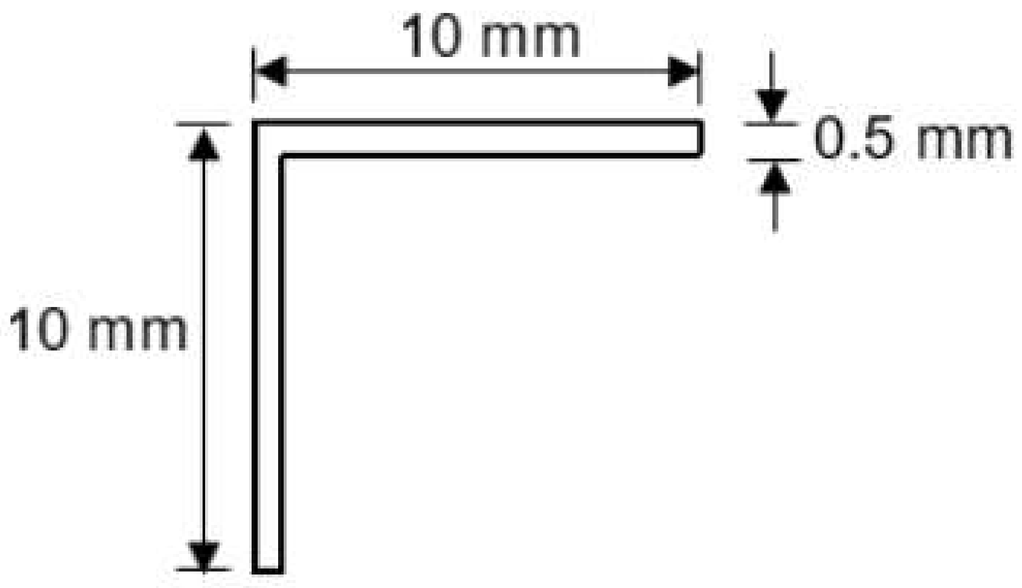
- For fuselage, $I_{skin} = 2[\frac{bt^3}{12} + bt(\frac{h}{2})^2 + \frac{th^3}{12}] = 996579.5mm^4$
- q1(s) = $\frac{Lhst}{2I_{skin}}$
- q2(s) = $q1(b/2) + \frac{L\,(h-s)st}{2I_{skin}}$




- Net force per unit area due to shear stress and bending moment is,

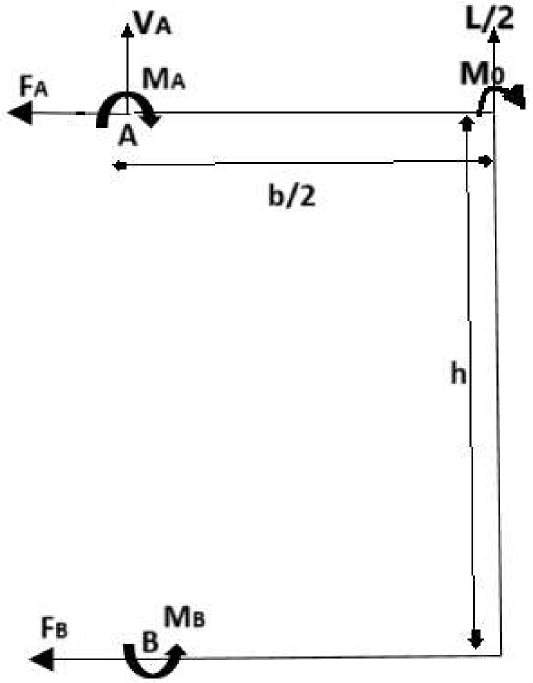
$$F_{net} = \frac{q}{t} + \frac{M_{max,fus}y}{I_{skin}}$$

- The maximum value of this comes out to be **0.58 N/sq.mm**.
- The allowable stress is **22.95 N/sq.mm**. Hence, no requirement of longerons. We will use 4 (x2) L sections at each corner, as longerons, to attach skin to the bulkheads.

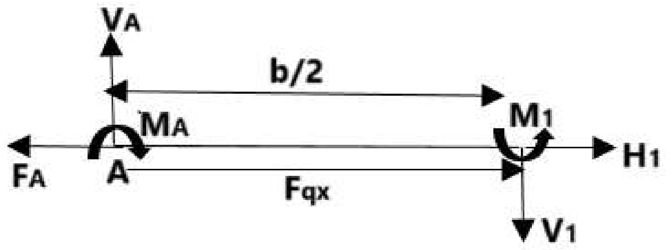


# Bulkhead Sizing

- We use the shear flow along the fuselage and calculate the bending moment on the bulkhead.




- Example for Top member




$$M_1 = M_A + V_1 x$$

$$H_1 = F_A - \frac{Lhx^2t}{4I}$$

$$V_1 = V_A$$

- Castigliano's second theorem,

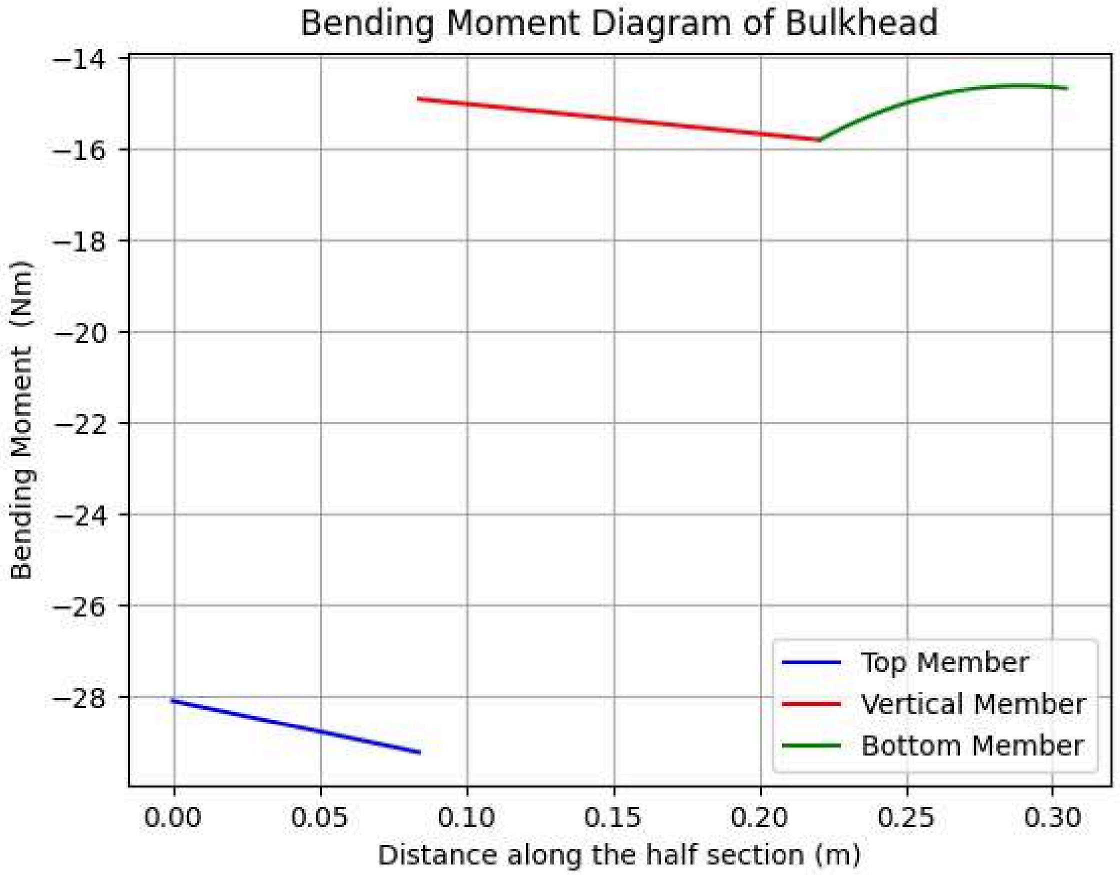
$$U_{bending} = \frac{1}{2}\int_0^L \frac{M^2}{EI}dx \qquad U_{shear} = \frac{1}{2}\int_0^L \frac{H^2}{EA}dx \qquad U_{axial} = \frac{1}{2}\int_0^L \frac{V^2}{GA}dx$$

- Since we have fixed ends, we can write,

$$\frac{\delta U_{total}}{\delta M_A} = 0 \qquad \frac{\delta U_{total}}{\delta F_A} = 0$$

- Similarly, solving for the vertical and bottom member, We get that

$F_A = 12.99N,\ M_A = -28.09Nm$ and $V_A = -13.415N$




$$M_{max} = 29.375Nm$$

$$\frac{My}{I} \leqslant \sigma_{allowable}$$

$$\frac{I}{y}req \geqslant 1142.55mm^3$$

- A C-section of 35 mm x 35 mm x 1 mm Cross section is sufficient

$$I = 23230.6mm^4,\ y_{max} = 17.5mm$$

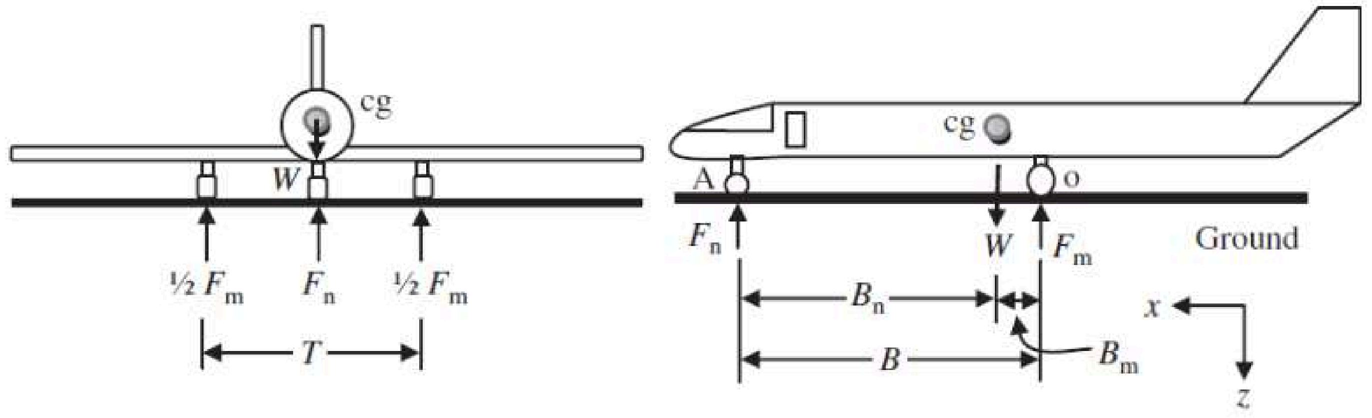
$$\frac{I}{y} = 1327.46mm^2$$

# Landing Gear Design

- From Aerodynamic report

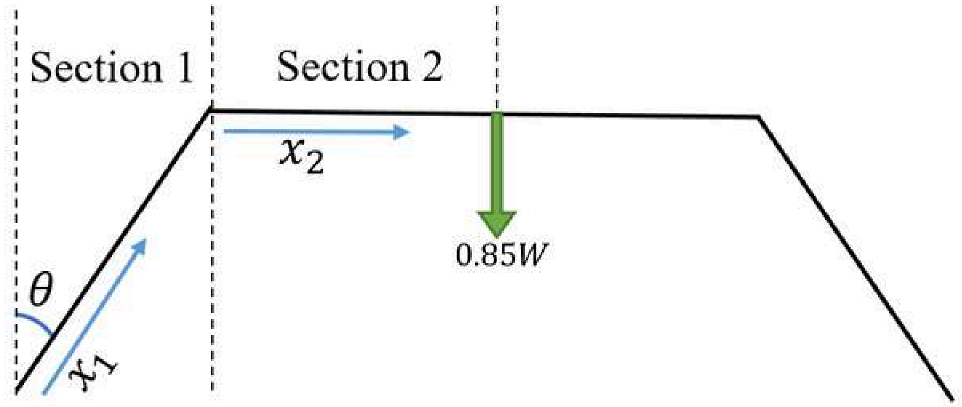
| Parameter | Value |
|---|---|
| Wheel Base | 55 cm |
| Wheel Track | 20.1 cm |
| Landing Gear Height | 21.56 cm |
| Clearance Angle | 16° |
| Tire Diameter | 6 cm |
| Tire Width | 1.98 cm |

- 85% load by Main Landing Gear
- 15% by Nose Landing Gear




- Main Landing Gear Design

**Longitudinal Analysis**

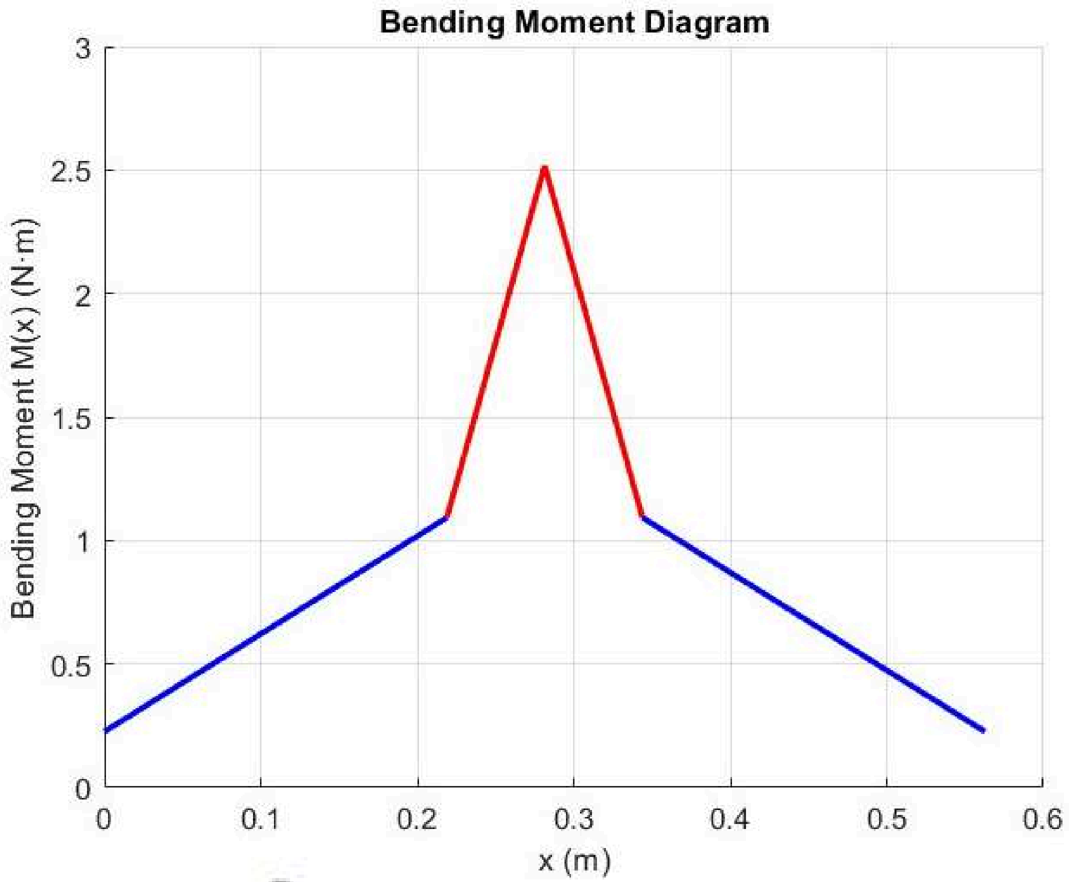



$$M_1 = M_0 + x_1 F \sin(\theta); \quad x_1 \in [0, L]$$

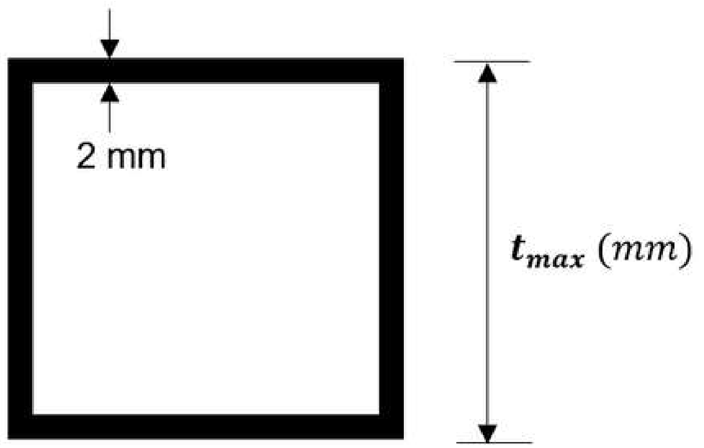
$$M_2 = M_0 + F(x_2 + L\sin(\theta)); \quad x_2 \in \left[0, \frac{T}{2} - L\sin(\theta)\right]$$

$$M_0 = F \times \frac{w_t}{2} \text{ (about ground)}$$

$$F = 0.85 \times \frac{W}{2}$$




- Maximum Bending Moment = 2.52 Nm.

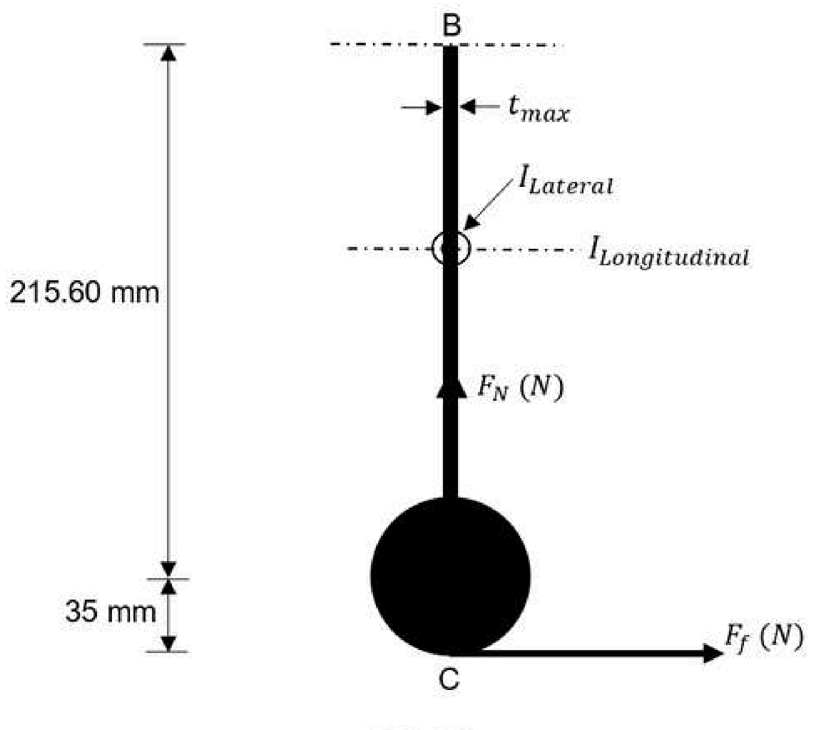



$$I = \frac{1}{12}\left({b_{out}}^4 - {b_{in}}^4\right) \implies t_{max} \geq 6.204 \text{ mm}$$

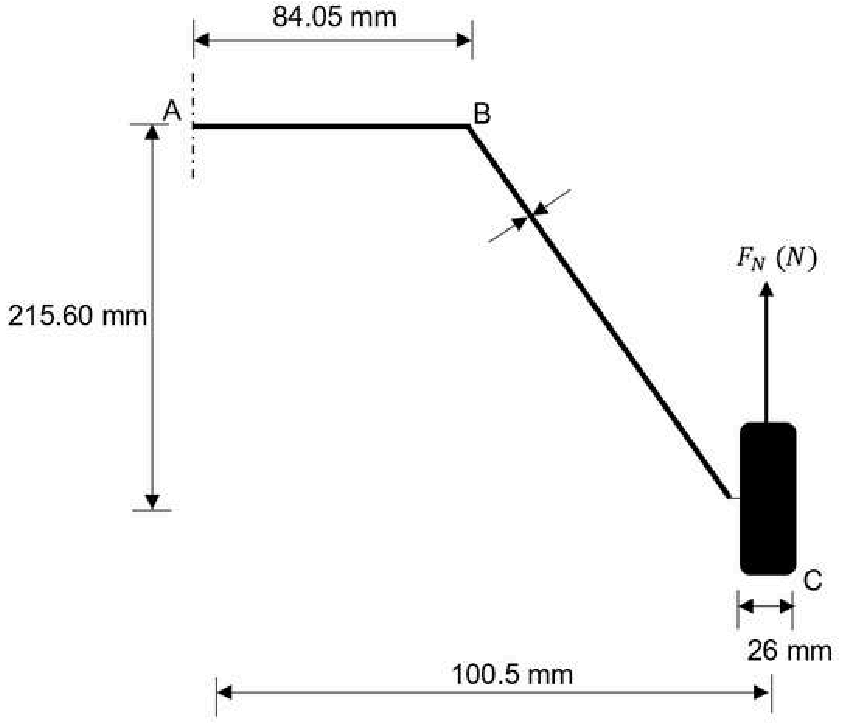
# Landing Gear Design

- Main Landing Gear

**Lateral Analysis**

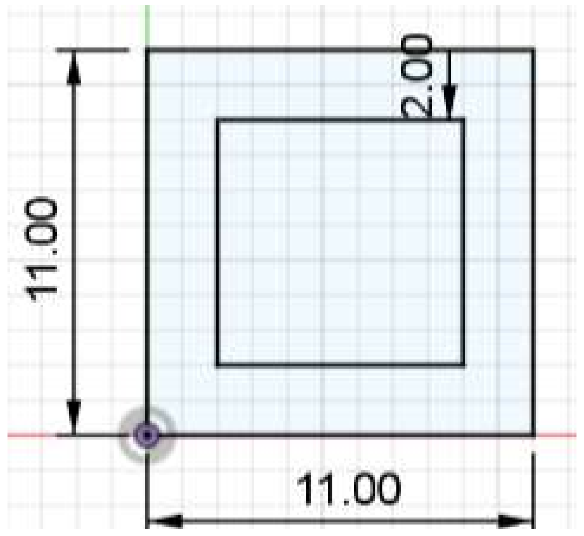



Side View




Front View

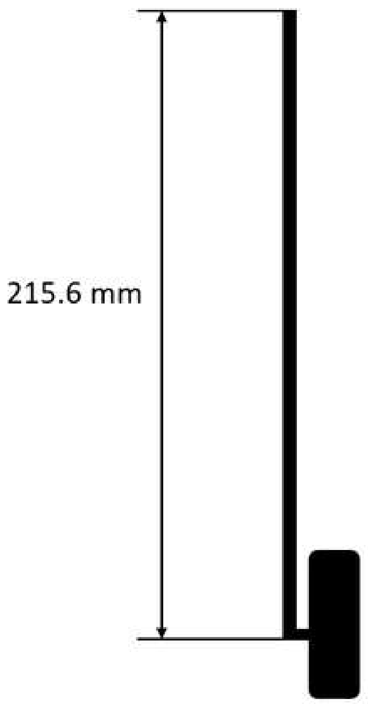
- Maximum Lateral moment is 10.085 Nm. We need hollow square section of side greater than 10.31 mm and thickness 2 mm.




*units are in mm

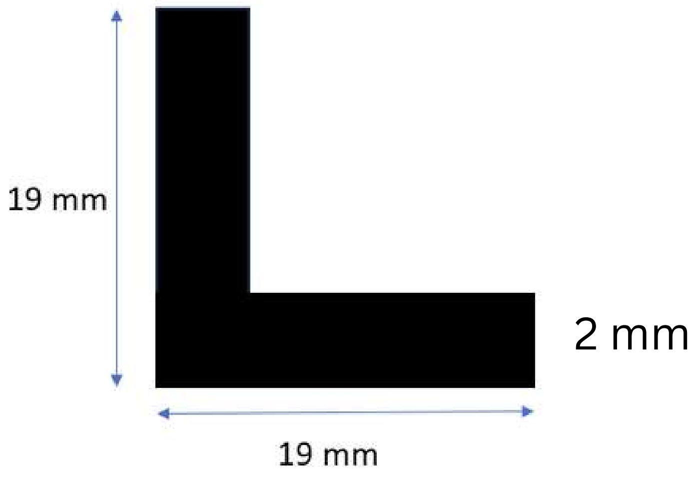
- Nose Landing Gear

**Buckling Analysis**




- Design should consider a factor of magnitude higher than the buckling stress. This includes Stress concentration factor = 2, Factor of safety = 1.4, fatigue factor = 1.5, Impact Factor = 1.5.

$$\sigma_{NLG} = \frac{0.15W}{A} \qquad \sigma_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

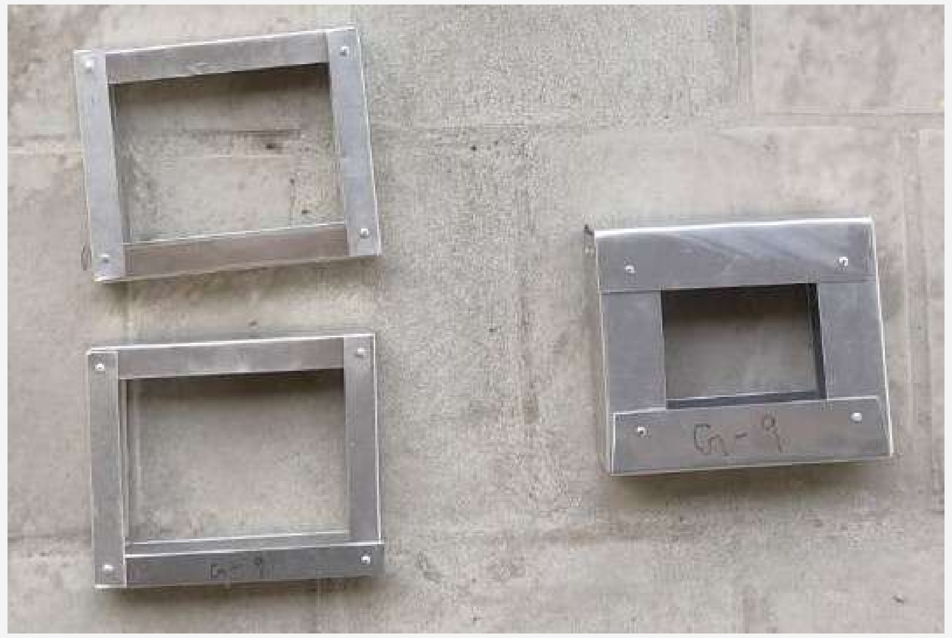



- K = 0.707, for fixed-pinned end
- We get I = 1.74 $mm^4$.
- We use the available L-section.

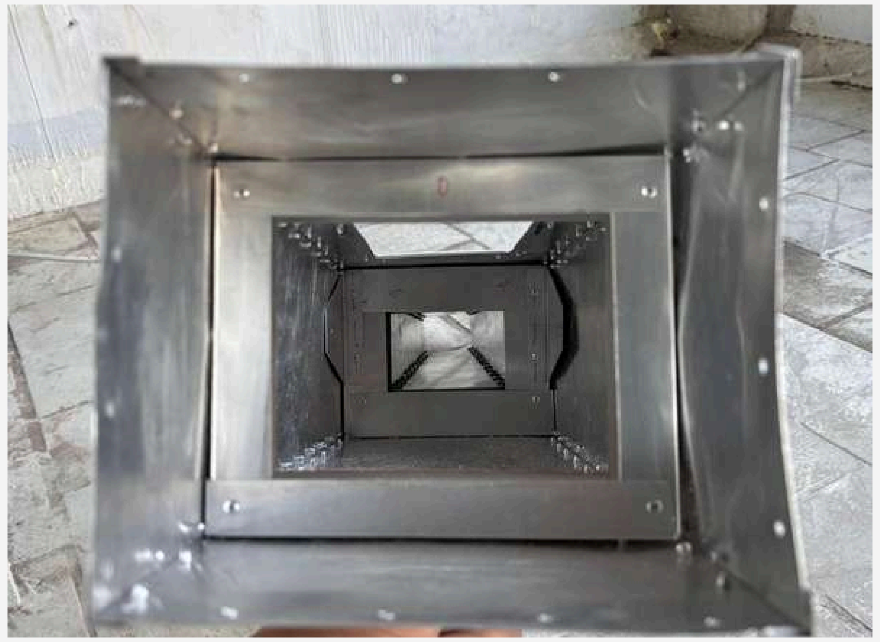
# Calculated Weights of Components

| Component | Number | Total Weight |
|---|---|---|
| • Longeron | 4 | 241.96 g |
| • Bulkhead | 3 | 523.23 g |
| • Main Landing Gear | 1 | 286.75 g |
| • Nose Landing Gear | 1 | 41.7 g |

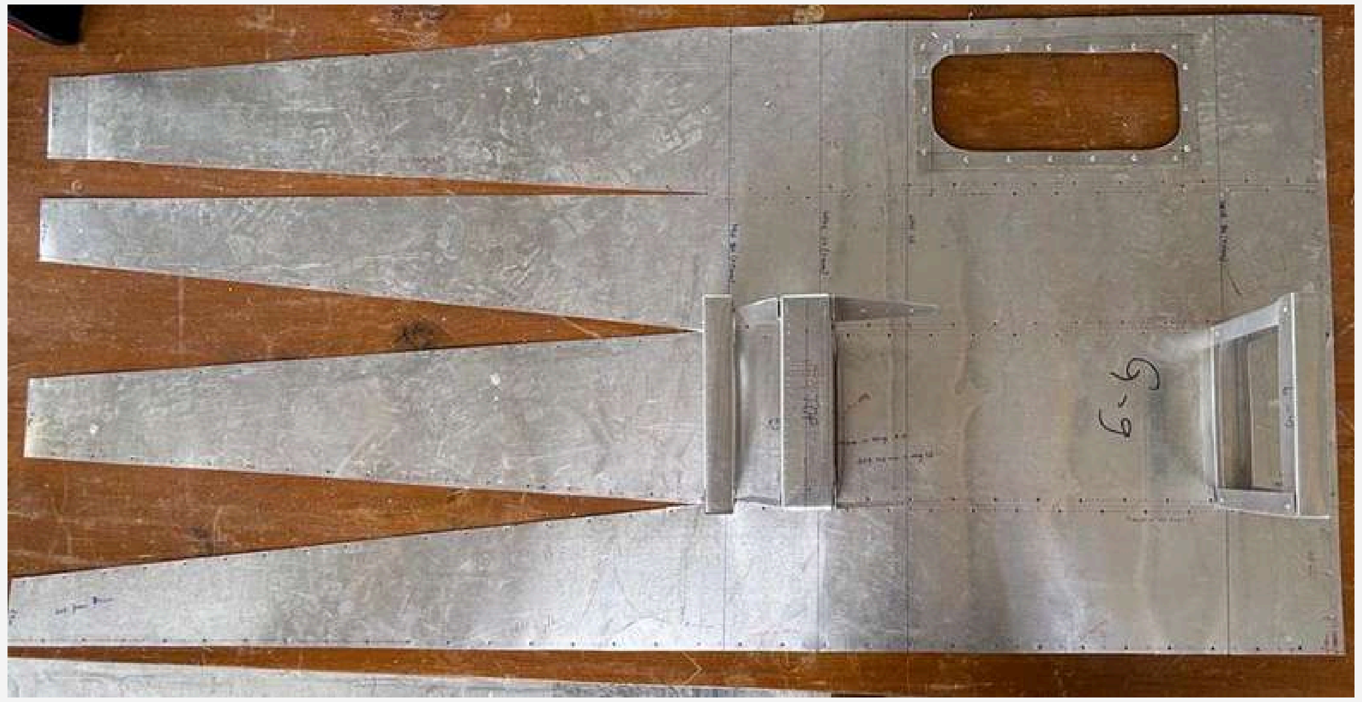
# Fabrication - Fuselage



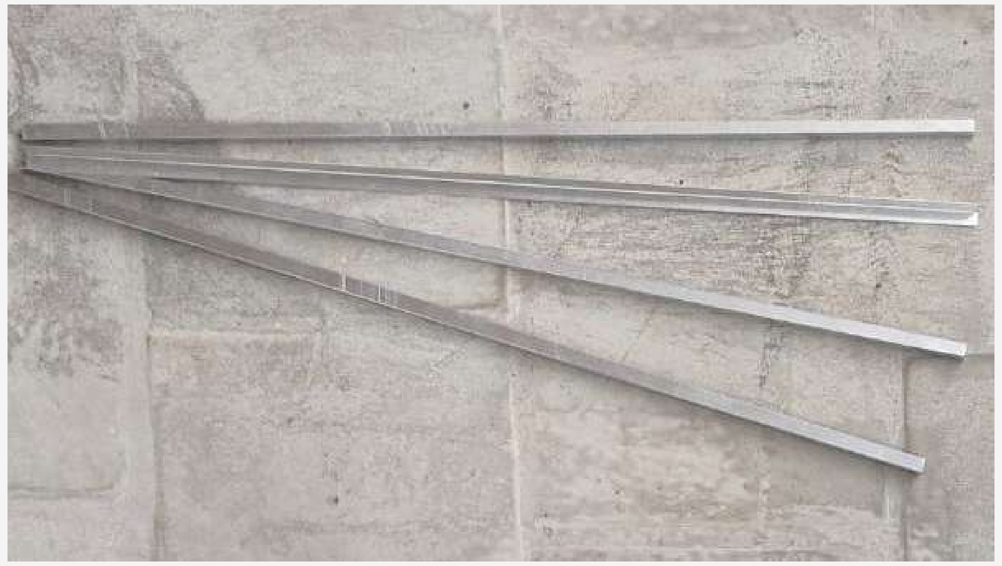
Bulkheads



Bulkhead Assembly



Fuselage before folding



Longerons

Nose Mount

Finished Fuselage

# Fabrication - Wing

Ribs of wing

Wing Adapter

Assembly showing coupler on the bulkhead

Wing-to-bulkhead coupler

Motor Mount

Finished Wing

# Fabrication - Tail and Landing Gear


Tail Adapter


Finished Tail


Finished Main Landing Gear


Finished Nose Landing Gear

# Fabrication - Finished Structure

Finished Structure of the UAV

# Thank you!