Indian Institute of Technology Kanpur

UAV design methodology & Approach

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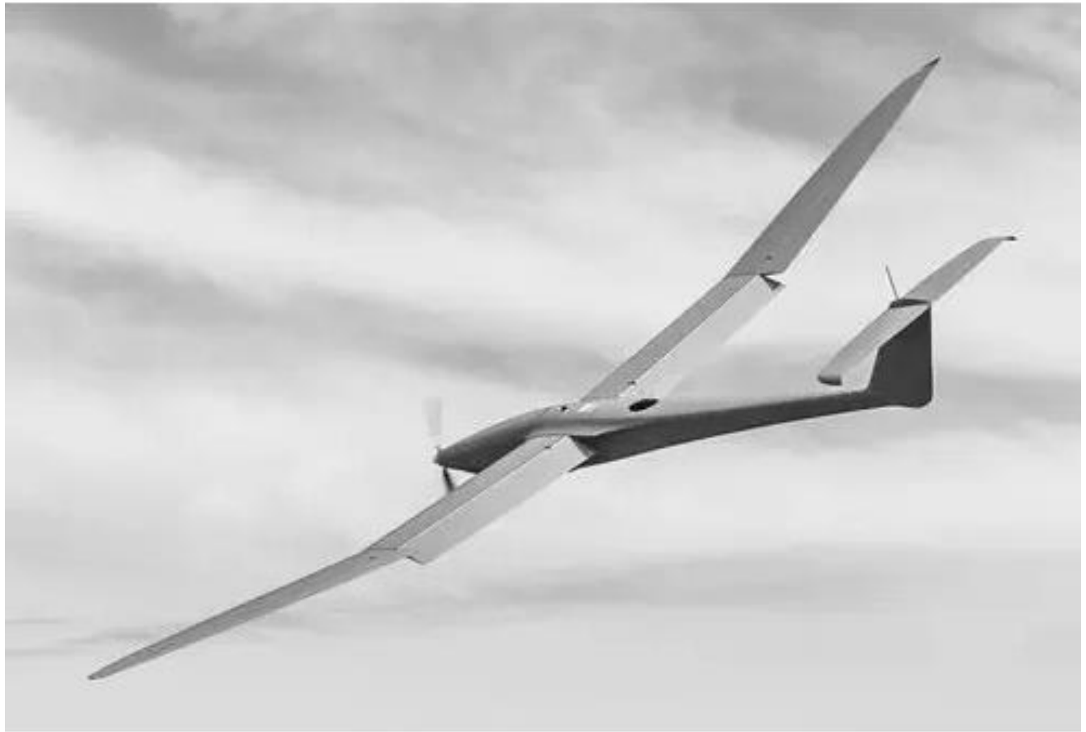
Similar class UAV

Strix 400 EOS Tech. France



Specifications:

Endurance : Solar powered

MTOW: 8 kg

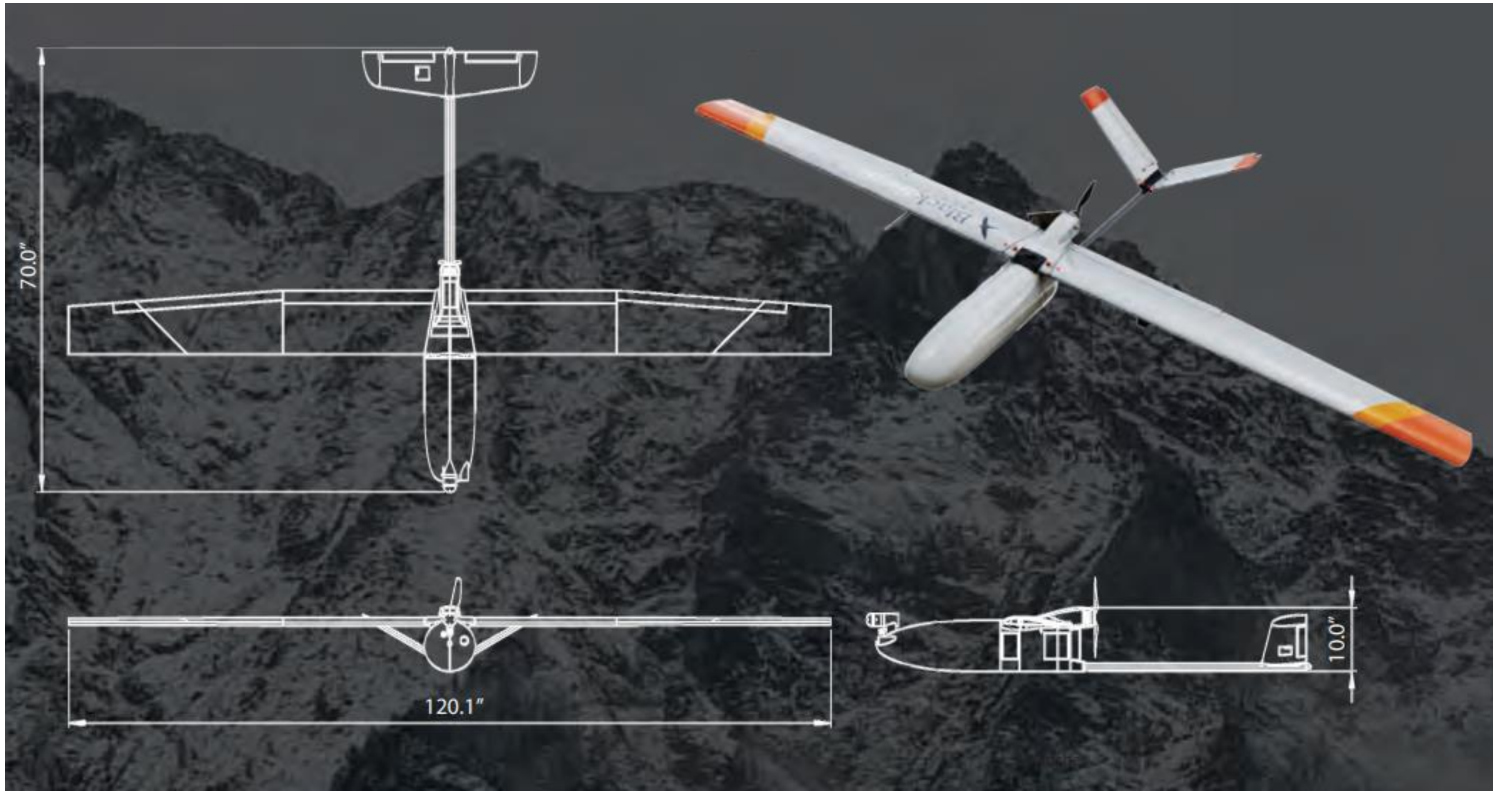
Cruise speed:18 m/s

Stall speed: 10.6 m/s

Max speed: 33 m/s

Similar class UAV

Black Swift S2 (USA)



Specifications:

MTOW: 9.5 kg

Cruise speed:18 m/s

Stall speed: 12 m/s

Range: 90-110 km

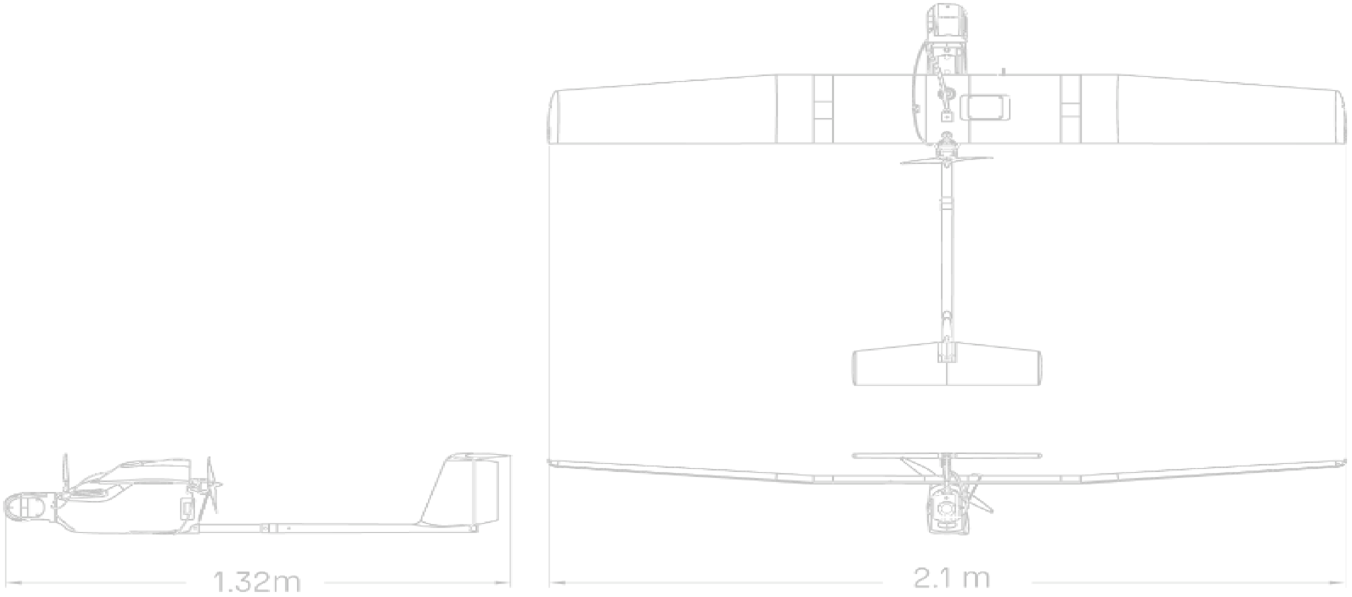
Payload weight:2.3 kg

Wingspan: 3 m

Ceiling :6 km

Similar class UAV

TEKEVER AR4



Specifications:

MTOW: 5 kg

Endurance: 2 hrs.

Cruise speed:15 m/s

Range: 90-110 km

Payload weight:1 kg

Wingspan: 2.1 m

Length: 1.35m

Similar class UAV

Horus FT-100

Specifications:

Endurance :2 hrs.

MTOW: 8 kg

Wingspan:2.7m

Length: 1.9m

Max speed: 22 m/s

Similar class UAV

AR-3000 RPAS (Avartek Finland)

Specifications:

Range: 20 km

MTOW: 9.5 kg

Wing Span: 3 m

Historical /Base data

•Two significant weight ratios play a role in our estimation process.

•Structural Weight Ratio (Wr_str) varies between 0.15 and 0.4. For this study, we have assumed it to be 0.25."

•Propulsion Weight Ratio (Wr_pr) varies between 0.05 and 0.2. We have taken it as 0.125.

•The base weight (W_b) of a similar UAV is 5.5 kg.

•The payload weight (W_p) is 1 kg.

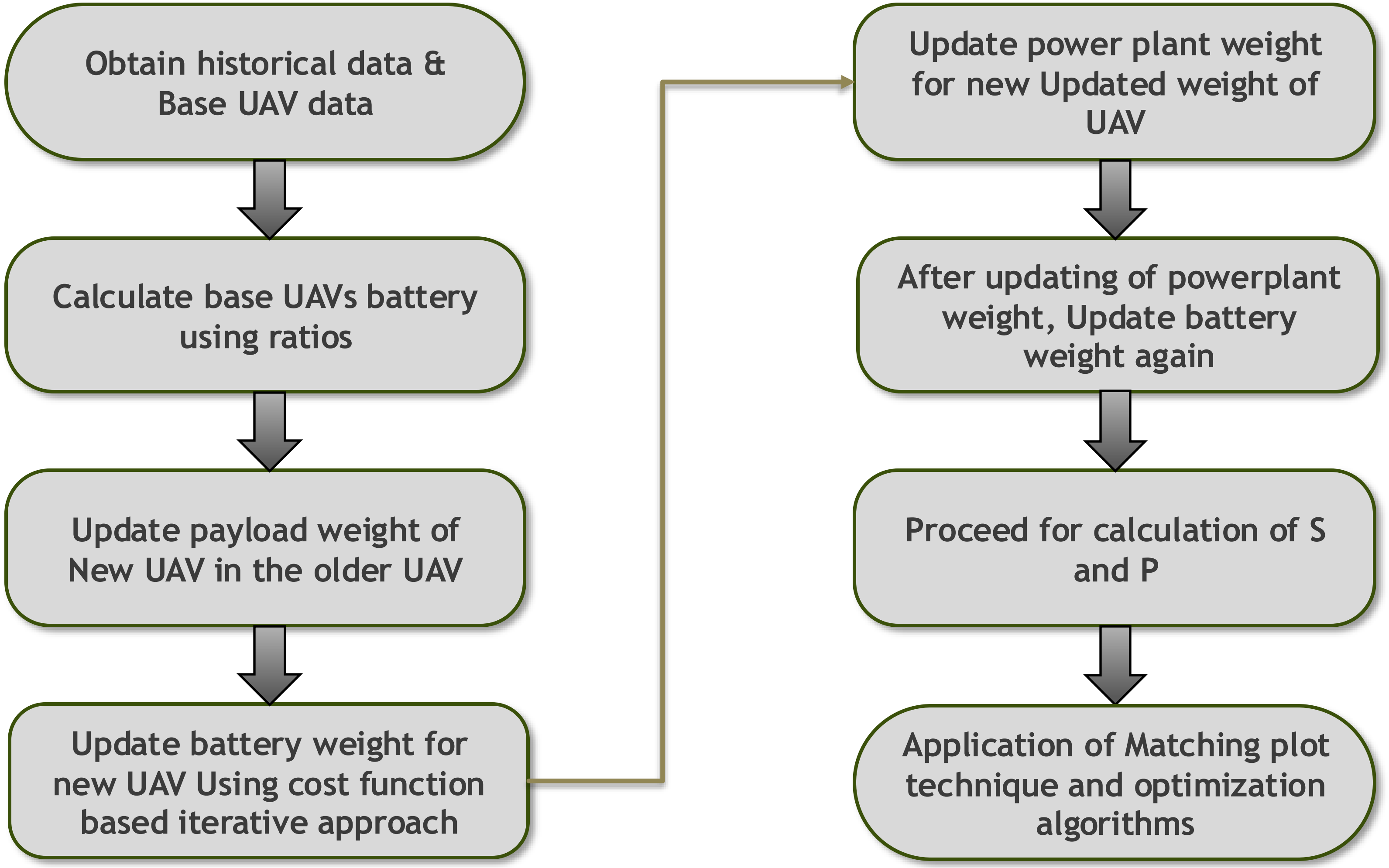
•Taking Aerodynamic efficiency (L/D) 10.

•Taking Specific energy density (SED)=100.

•Battery efficiency = 0.7

•(Motor + ESC + Propeller) combined weight = 0.3 kg

Initial weight estimation using iterative approach



Initial weight estimation Round-1

❑ Historical and Base UAV data:

Taking a similar weight class, configuration and mission UAV as Base UAV.

Weight ratios from historical data:

$$\mathbf{0.15 < \frac{Wst}{Wto} < 0.4}$$ **(Structural weight ratio)**

$$\mathbf{0.05 < \frac{Wpr}{Wto} < 0.2}$$ **(propulsion system weight ratio)**

❑ Update Payload weight of New UAV :

a) Updating payload weight of new UAV in the base UAV and recalculate W_{TO} As

$$\mathbf{W_{TO} = \left(\frac{W_{st}}{W_{To}}\right) W_{TO} + \left(\frac{W_{pr}}{W_{TO}}\right) W_{TO} + W_{Payload} + W_{Battery}} \quad \textbf{(eq.1)}$$

❑ Update Battery Weight for new UAV using cost function based Iterative approach:

a) Assuming a value for (L/D), we calculate Battery weight to propel our UAV.

$$\text{Energy required} = P_r * \Delta t \quad \textbf{(eq.2)}$$

Initial weight estimation Round-1

and for equilibrium L=W and T=D ,

T = W/(L/D)

Substituting in eq (1) we get..

$$\text{ER} = \frac{\boldsymbol{W_{TO} * V_{\infty} * \Delta t}}{\boldsymbol{L/D}} \qquad \textbf{(eq 3)}$$

for battery weight, using SED (specific energy density)

$$\boldsymbol{W_{battery} = ER/(\prod_{i=1}^{n} n_i * SED)} \qquad \text{(eq 4)}$$

❑ Initial power Calculation for the UAV:

Power required= $\frac{\boldsymbol{W_{TO} * V_{\infty}}}{\boldsymbol{L/D}}$

Note: Initially selecting a propulsion system such that the required power is delivered at the 50% of the maximum power.

Initial weight estimation Round-1

- **Updating propulsion system weight (Motor+ ESC + Battery):**

a) Updating propulsion weight W_{PS} of new UAV in the base UAV and calculating W_{TO}

As..

$$\mathbf{W_{TO}} = \left(\frac{\mathbf{W_{st}}}{\mathbf{W_{To}}}\right)\mathbf{W_{TO}} + \mathbf{W_{PS}} + \mathbf{W_{Payload}} + \mathbf{W_{Battery}}$$

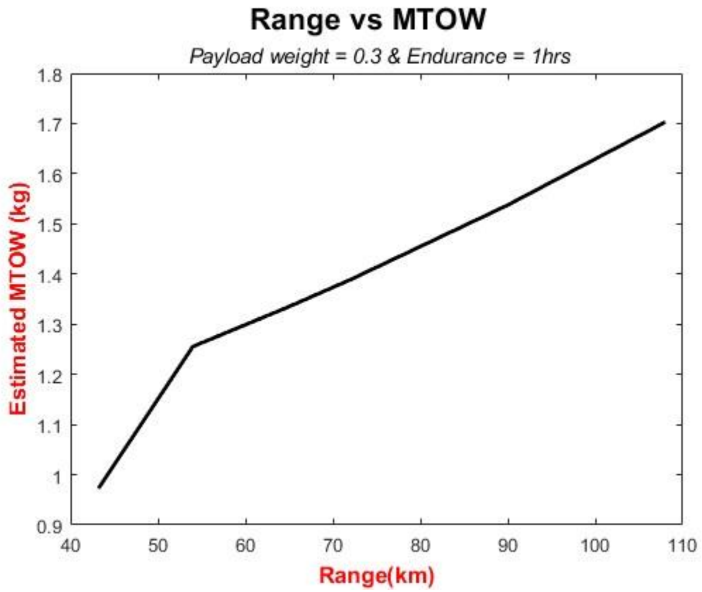
- **Update Battery Weight again for new $\mathbf{W_{TO}}$ using cost function based Iterative approach**

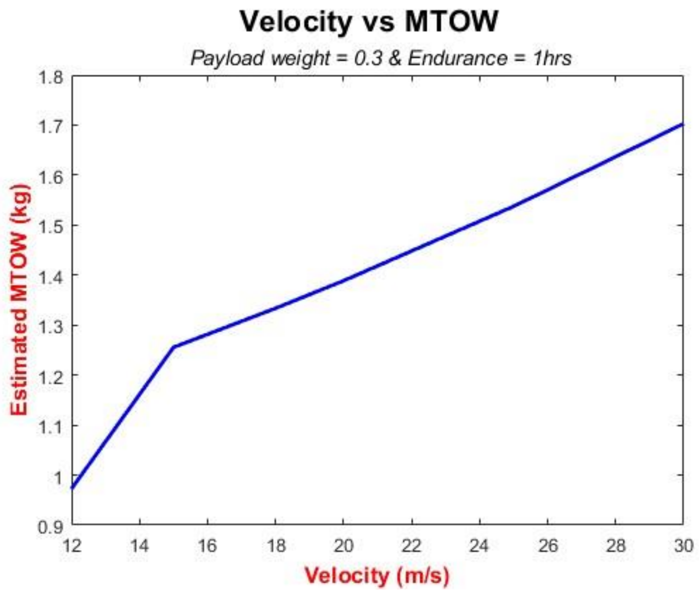
- Initial UAV weight after first round of iteration

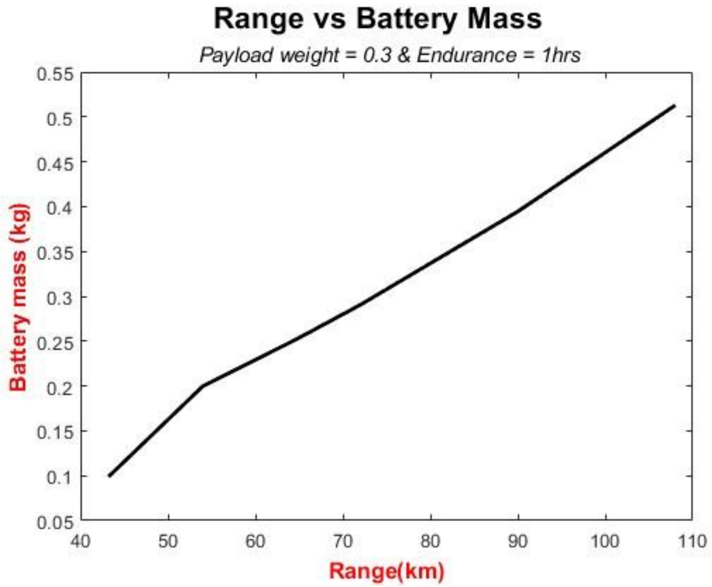
Variation of Range, MTOW, Battery weight

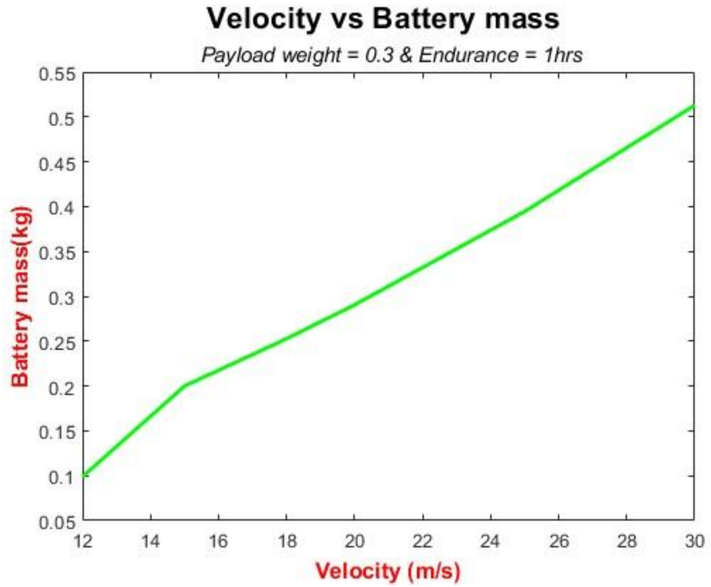
Payload weight = 0.3 kg

Endurance = 1hrs.





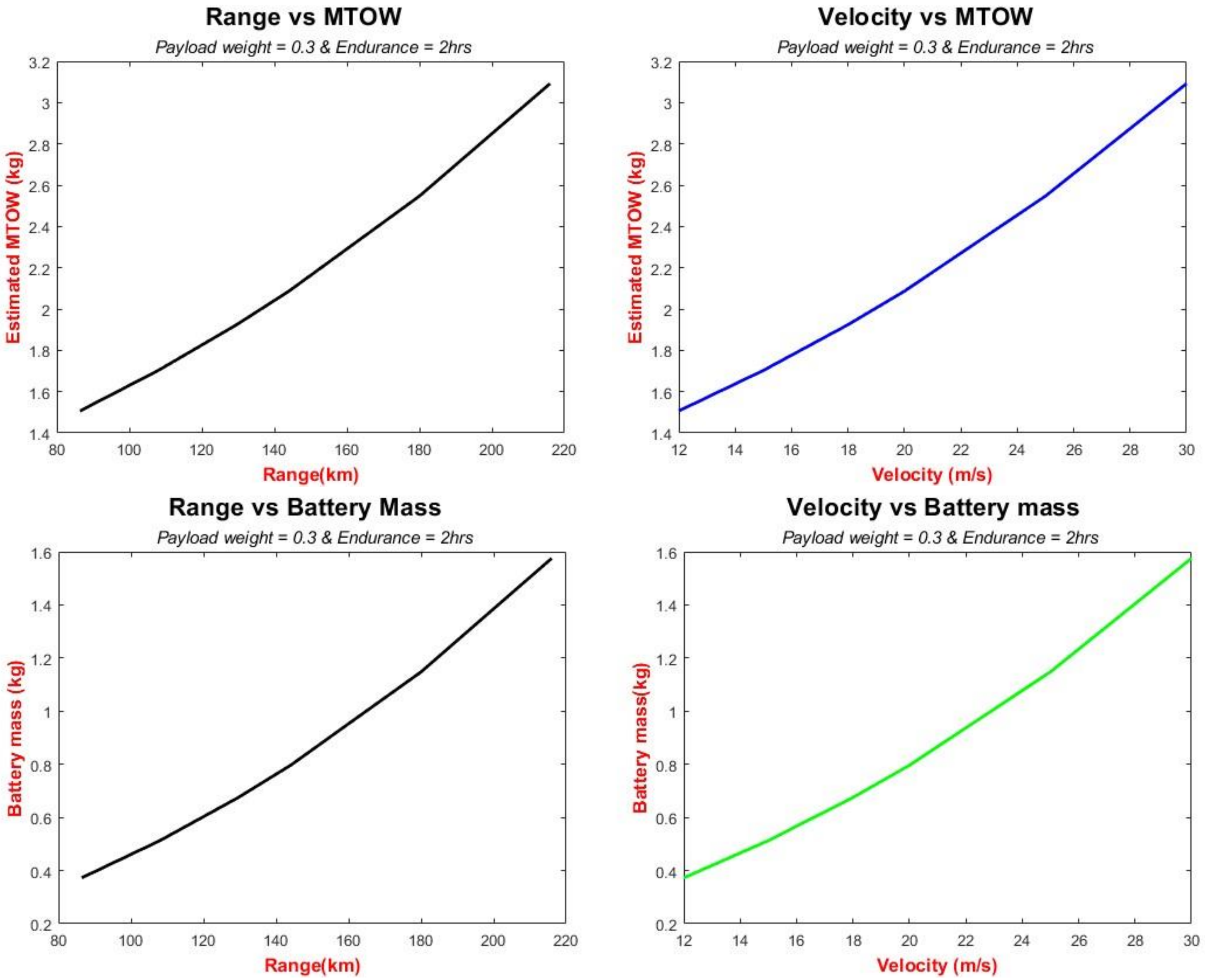




Variation of Range, MTOW, Battery weight

Payload weight = 0.3kg

Endurance = 2 hrs.



Selected airfoil behavior at V=10m/s

H E L I C O P T E R   L A B

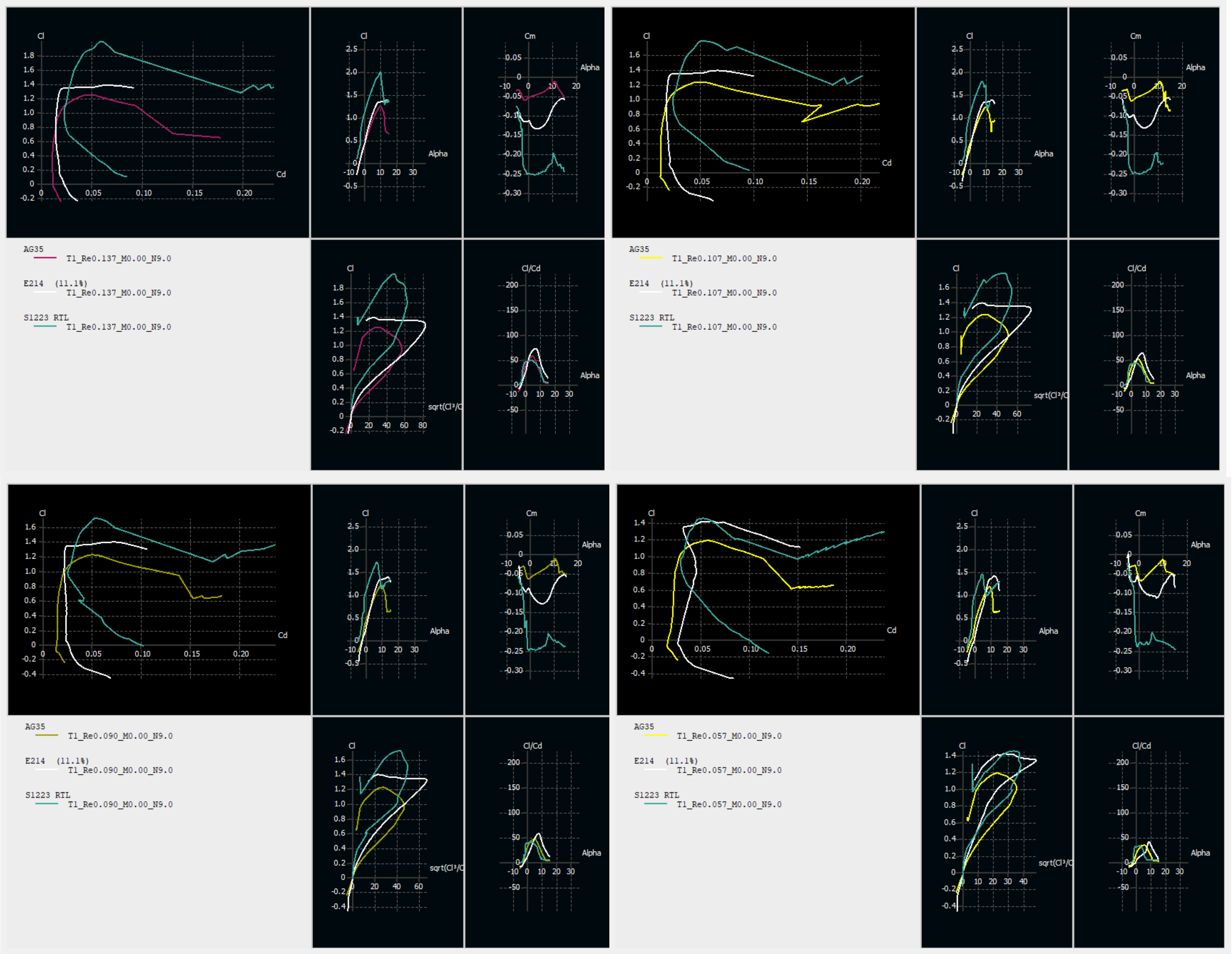
Chord length= 0.2 m

- Several airfoils are compared for the following process, only three are showing competitive behavior.

a) AG35

b) Eppler 214

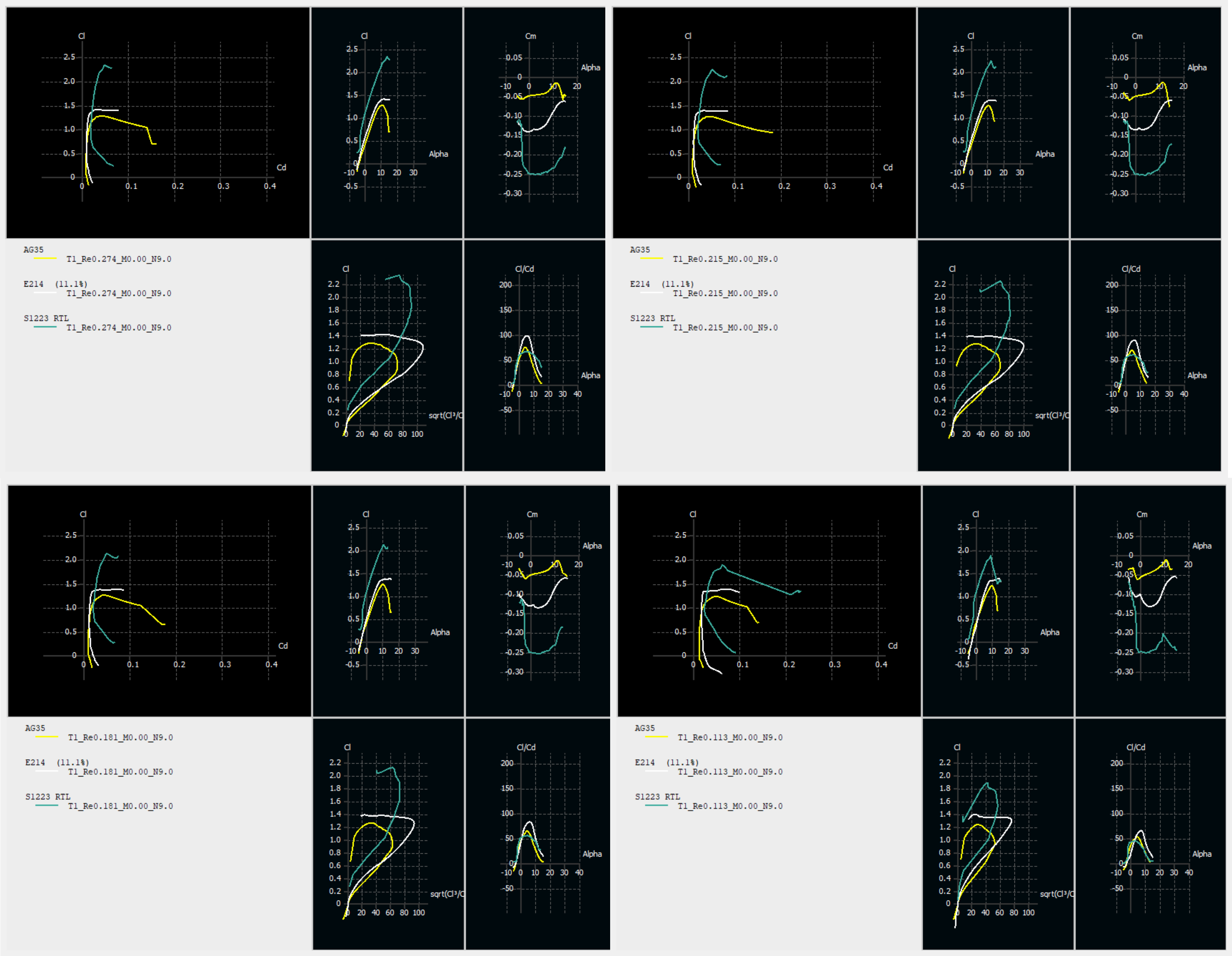
c) S1223



Selected airfoil behavior at V=20m/s

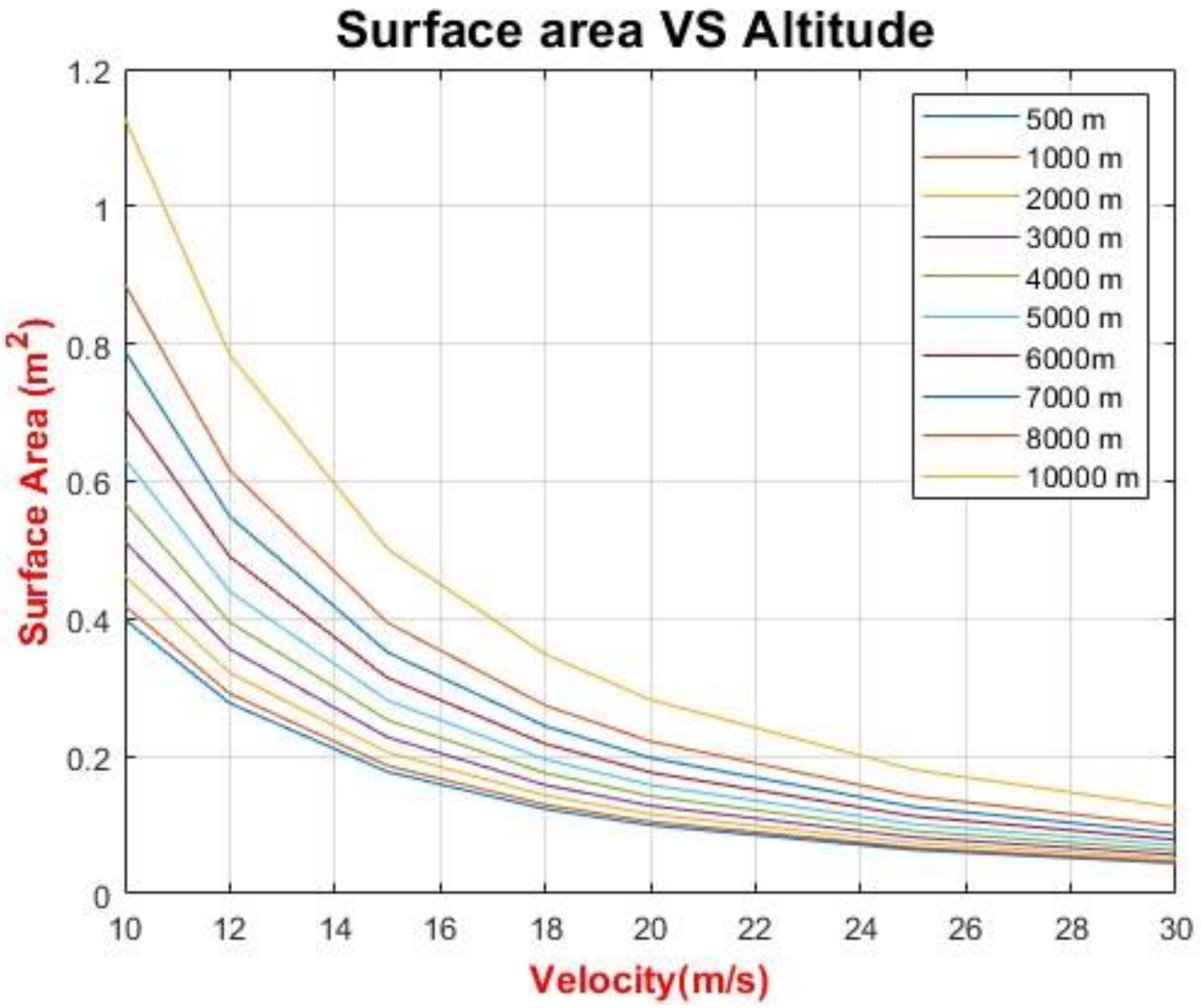
H E L I C O P T E R L A B

- In conclusion we get to see that E214 is having better performance, based on the design requirements.

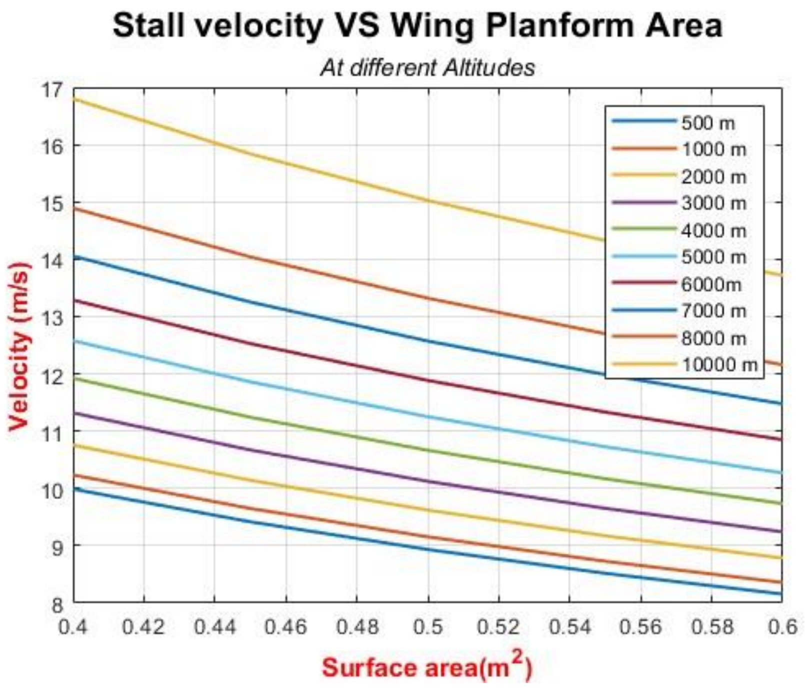


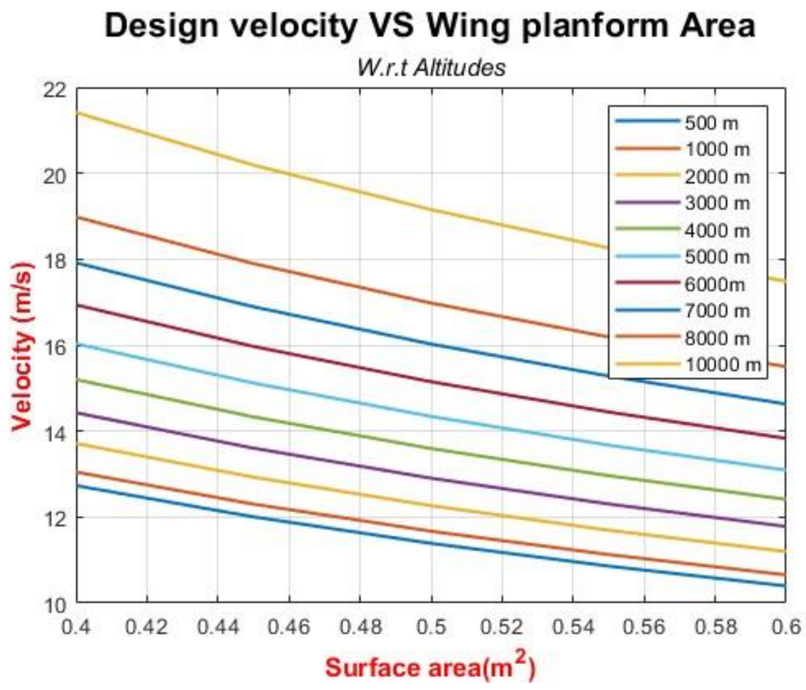
Surface area requirements

- The following graph shows the surface area requirements for the given vehicle.
- Here we have taken Cl_{max} as the coefficient of lift while calculating the Surface area.
- Given plot is for the design which provides:
    - 40-70 min endurance
    - 60-80 km range



Velocity estimation at various Altitudes





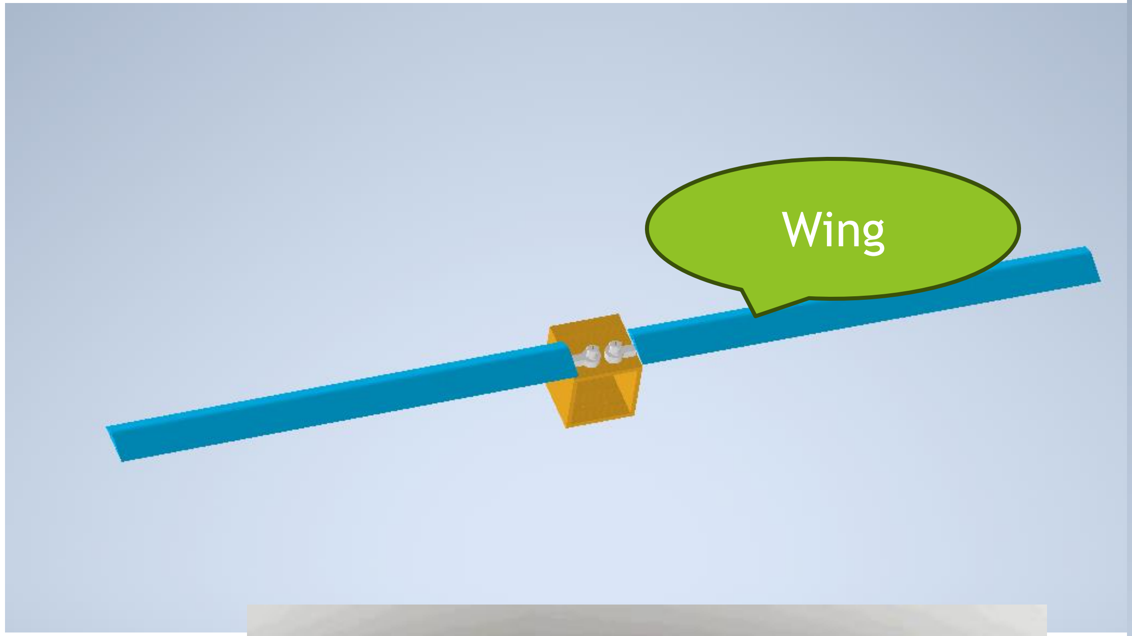
Possible velocities for cruise at 5000 m:

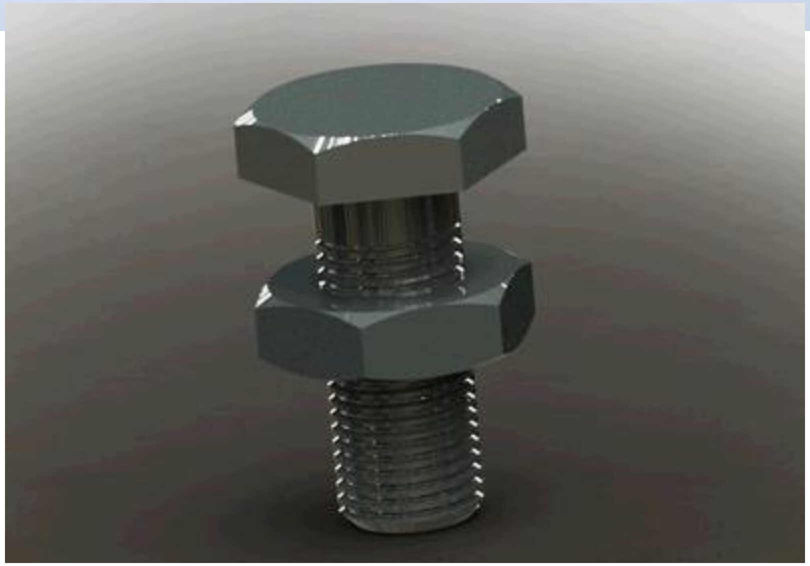
- V_{stall} = 13 m/s
- V_{cruise} = 15m/s

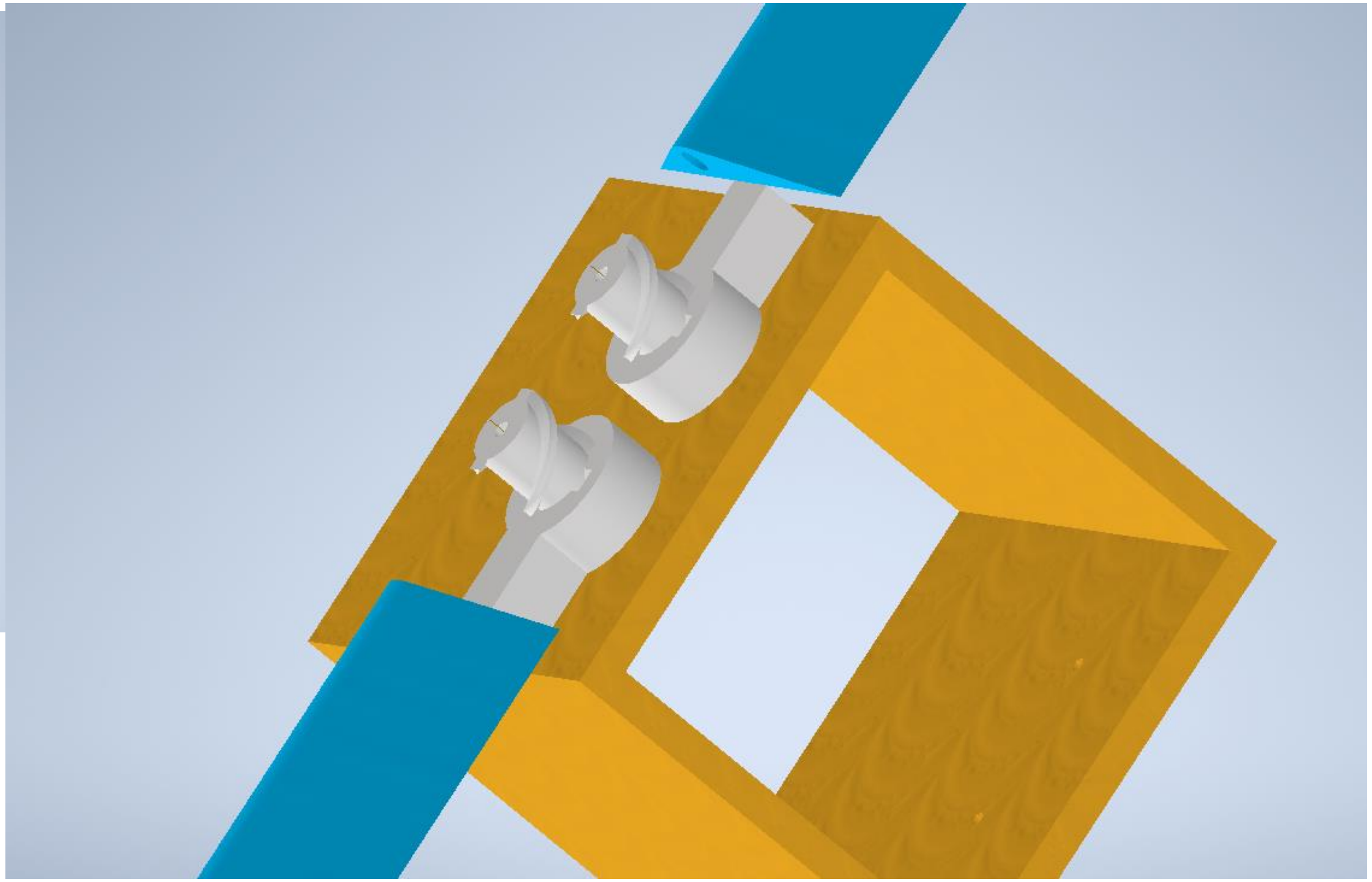
Stall velocity at a given altitude :-

for S= 0.4	500	1000	2000	3000	4000	5000	6000
Velocity @ S=0.4	10	10.2	10.8	11.3	11.9	12.6	13.3
Vcruise @ S=0.4	~~10.6~~ 11.4	11.8	12.3	13	13.5	14.3	15
Vstall @ S=0.5	8.9	9.15	9.62	10.12	10.66	11.24	11.88
Vcruise @ S=0.5	10.18	10.43	10.96	11.54	12.15	12.82	13.54
Vstall @ S=0.6	8.15	8.35	8.78	9.24	9.73	10.26	10.84
Vcruise @ S=0.6	9.3	9.52	10.01	10.53	11.10	11.70	12.36

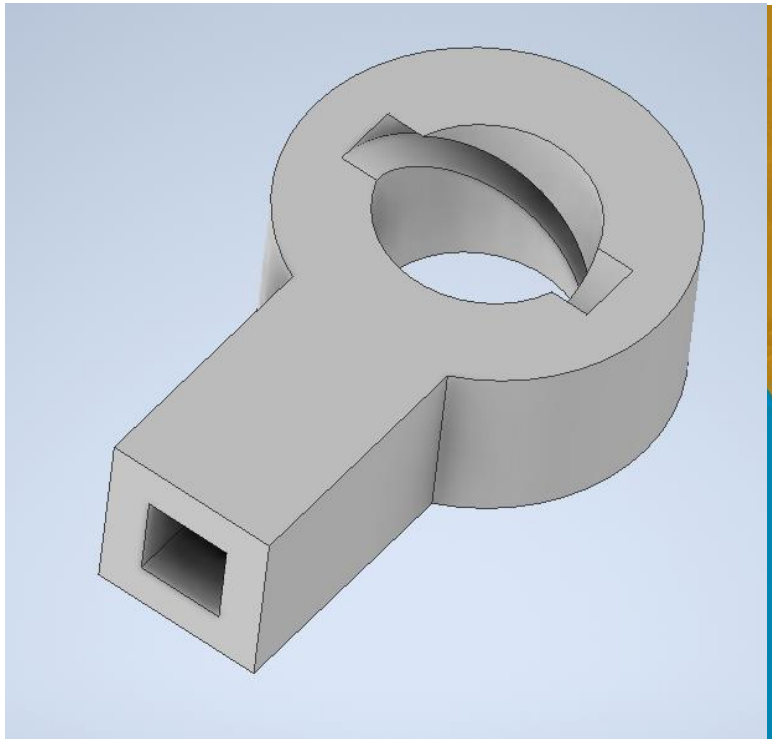
Preliminary Mechanism for Wing Deployment

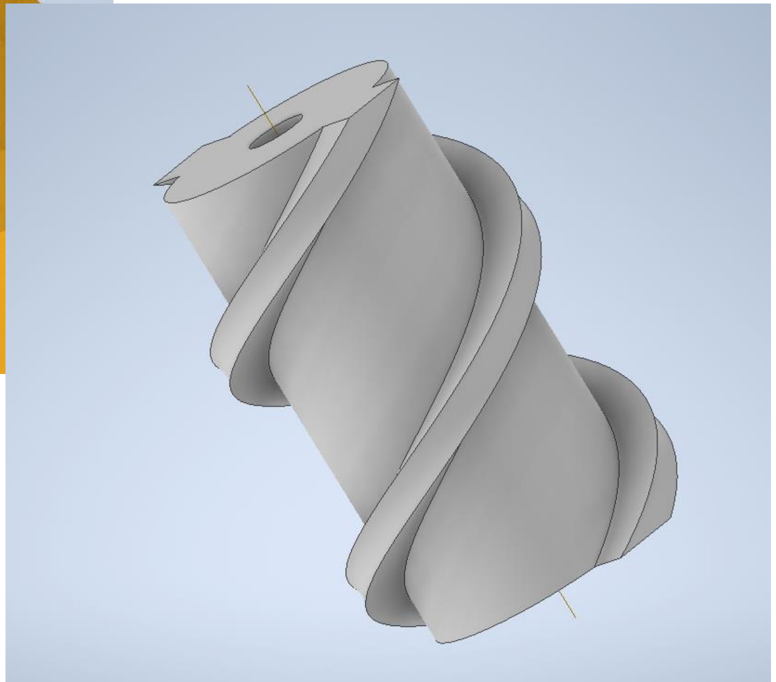






Preliminary Mechanism for Wing Deployment





Preliminary Mechanism for Wing Deployment

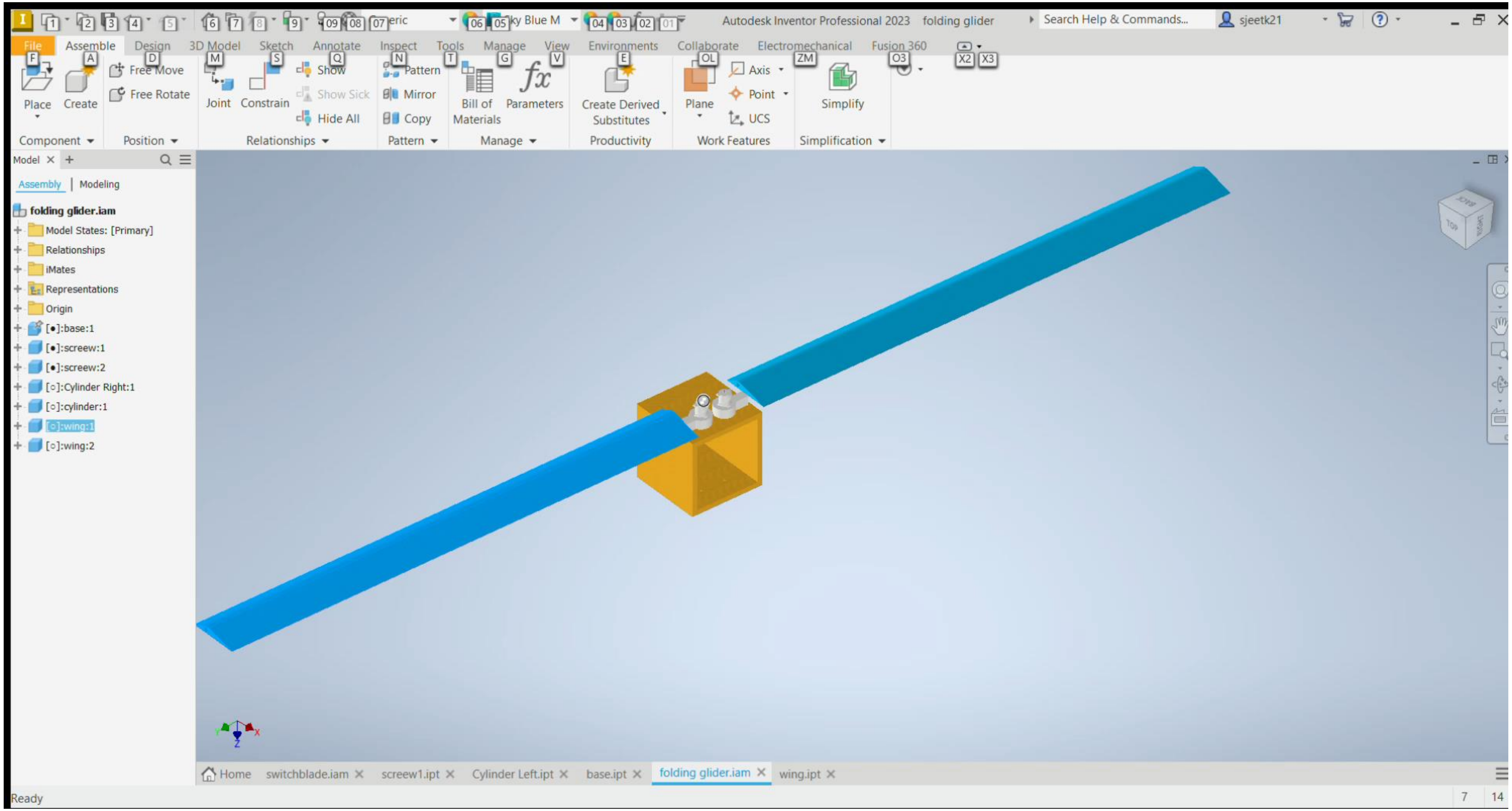
The mechanism is based on nut and bolt mechanism.
As the nut is rotated on bolt, the nut moves linearly similarly As the 'Wing mount nut' moves on the 'Wing mount bolt', the wing mount nut moves up or down.

Advantage:-

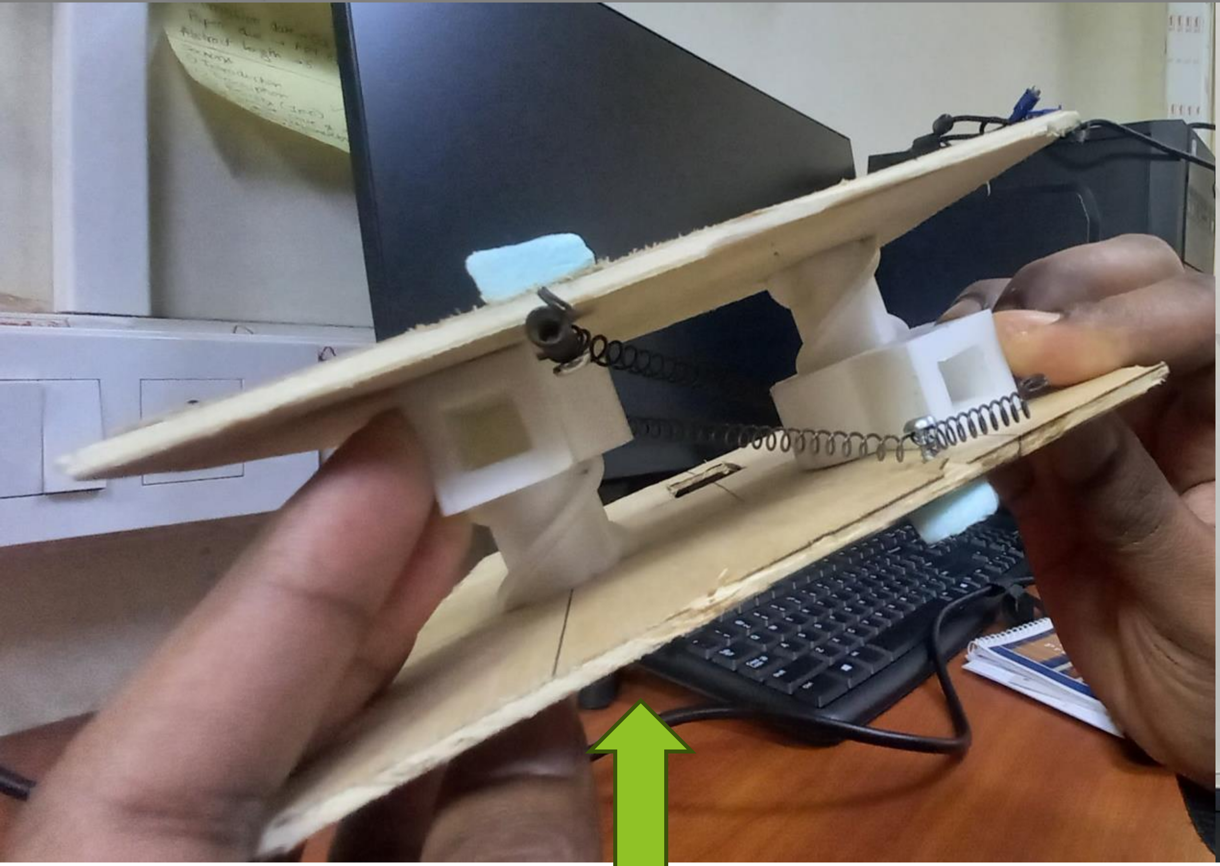
- Simple mechanism
- Easy to fabricate
- Less Complex
- Minimum maintenance
- Easy to operate with servos and Springs.

Preliminary Mechanism for Wing Deployment

Simulation



Preliminary Mechanism for Wing Deployment

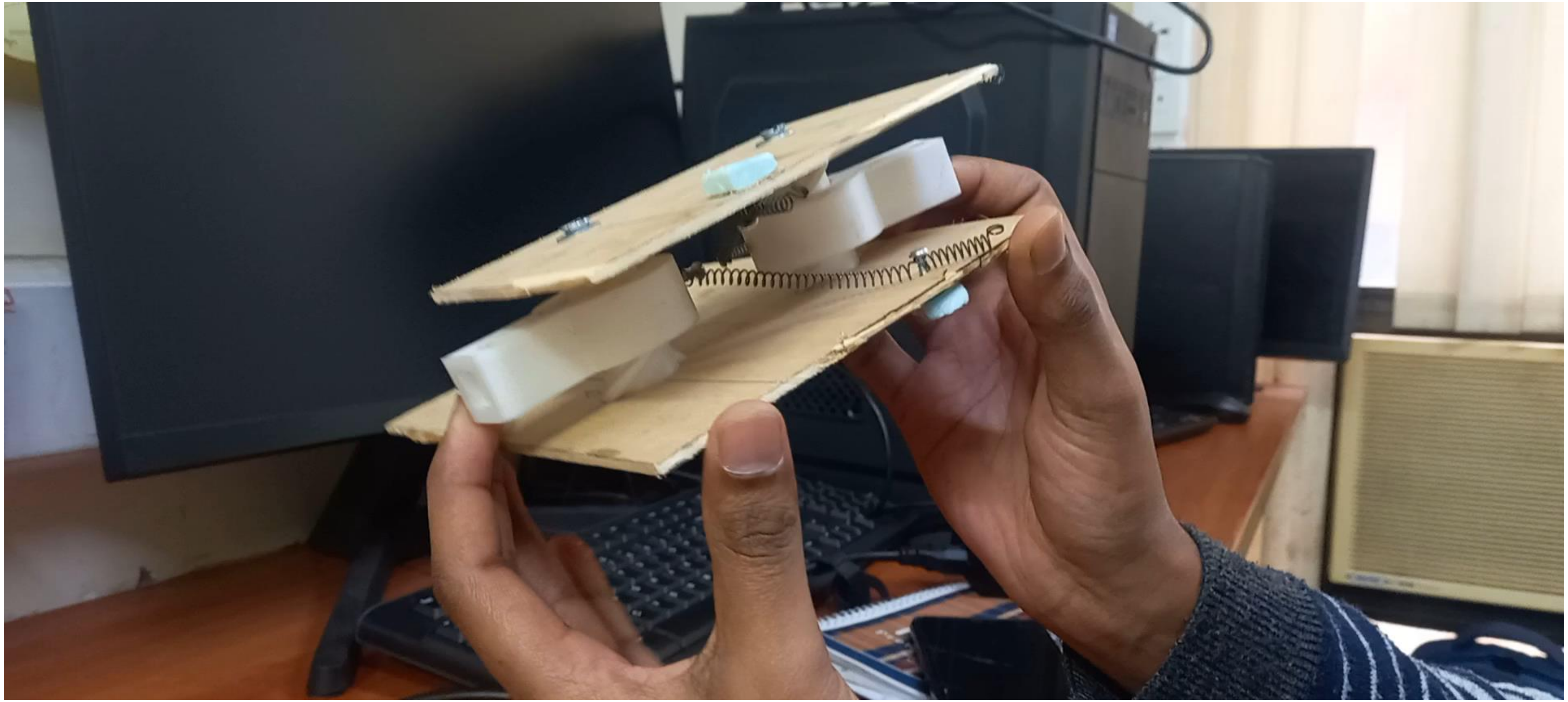


Folded Wing

Deployed Wings

Preliminary Mechanism for Wing Deployment

Actual Working of mechanism




Thank You