Indian Institute of Technology Kanpur

UAV design methodology & Approach

Guide: Prof. Abhishek

Presented by:
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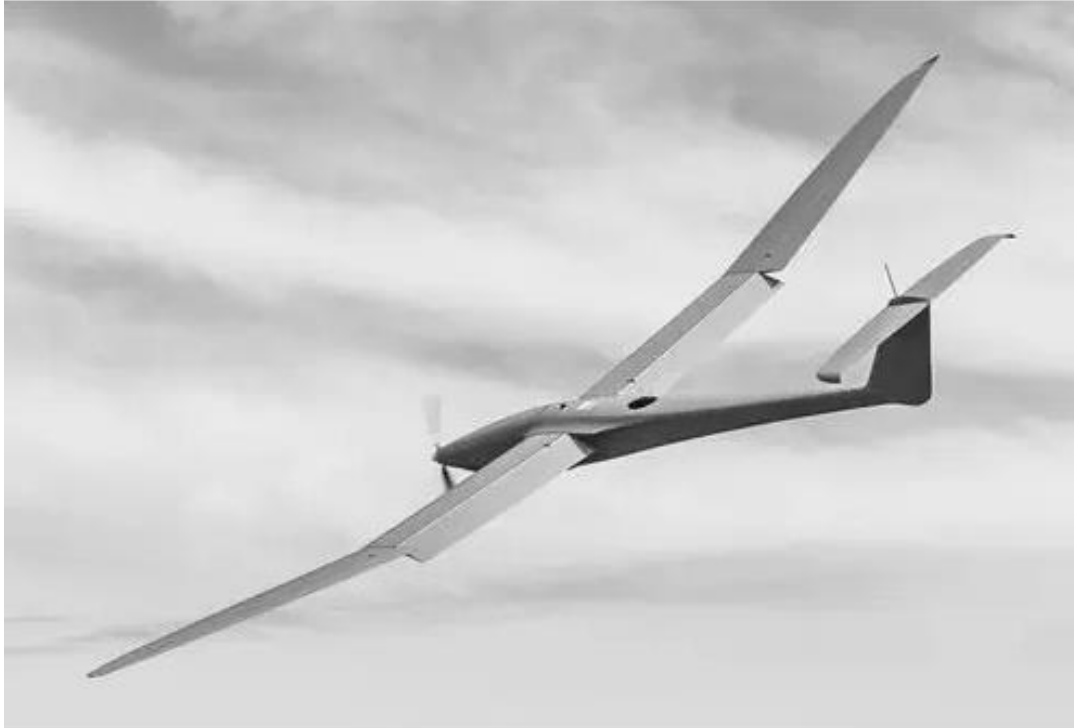Karan Kumar Tiwari (22101028)

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
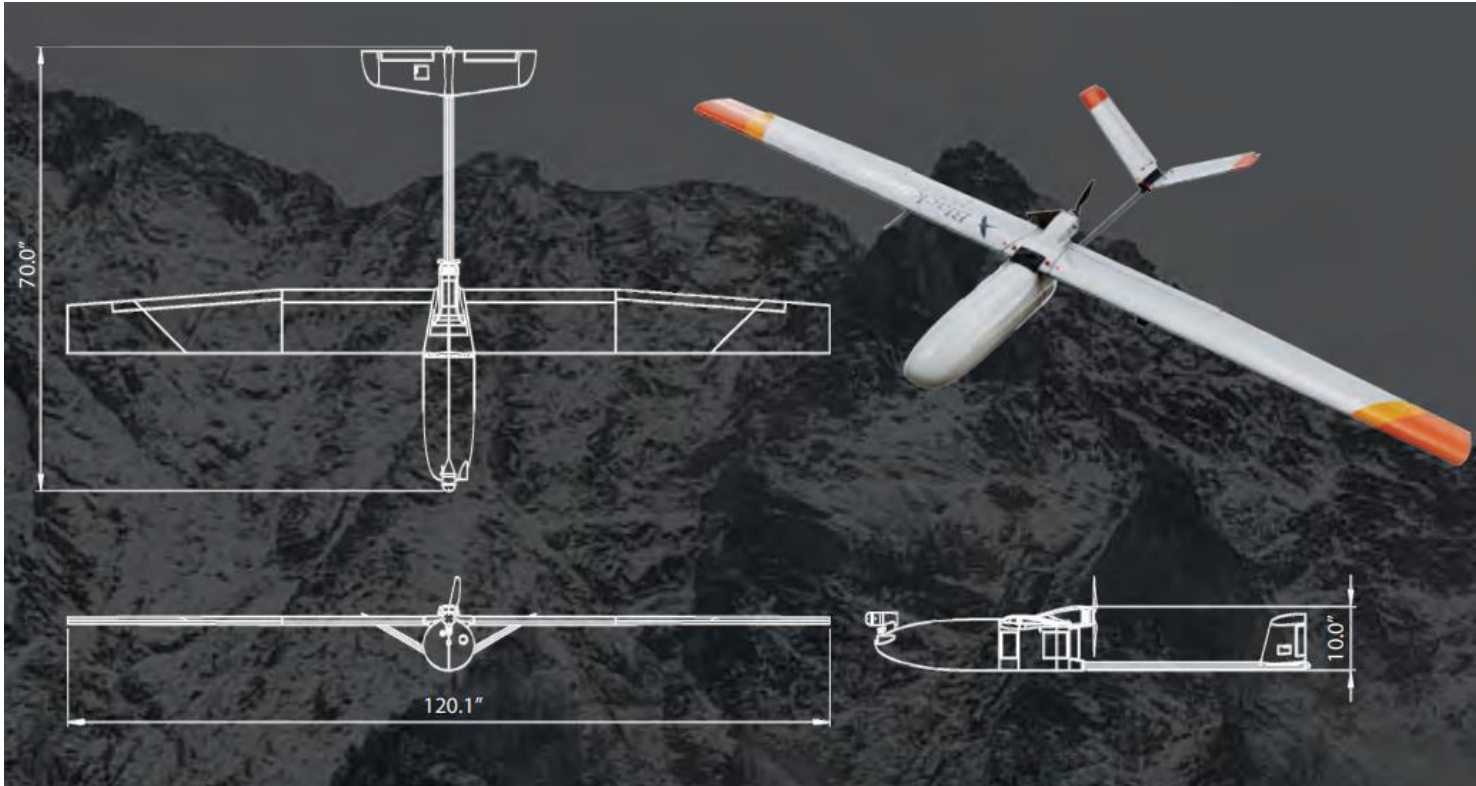
Black Swift S2 (USA)

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

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

1.32m

2.1 m
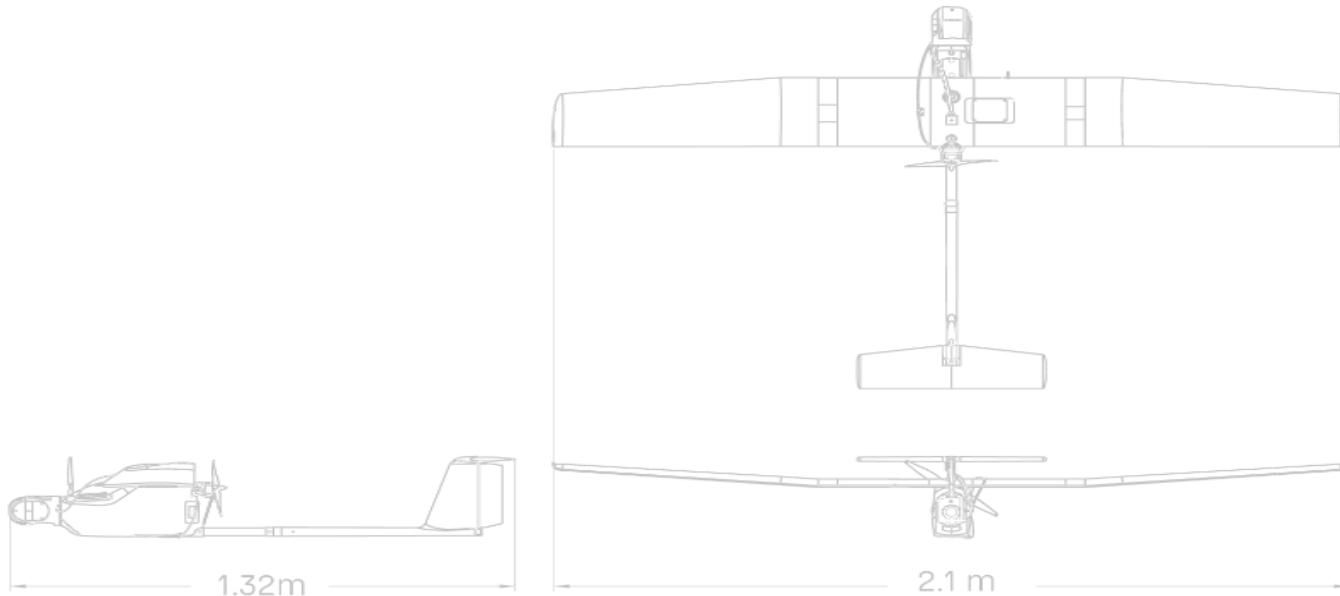
Horus FT-100

Specifications:

Endurance :2 hrs.

MTOW: 8 kg

Wingspan:2.7m

Length: 1.9m

Max speed: 22 m/s

AR-3000 RPAS (Avartek Finland**)**

Specifications:

Range: 20 km

MTOW: 9.5 kg

Wing Span: 3 m
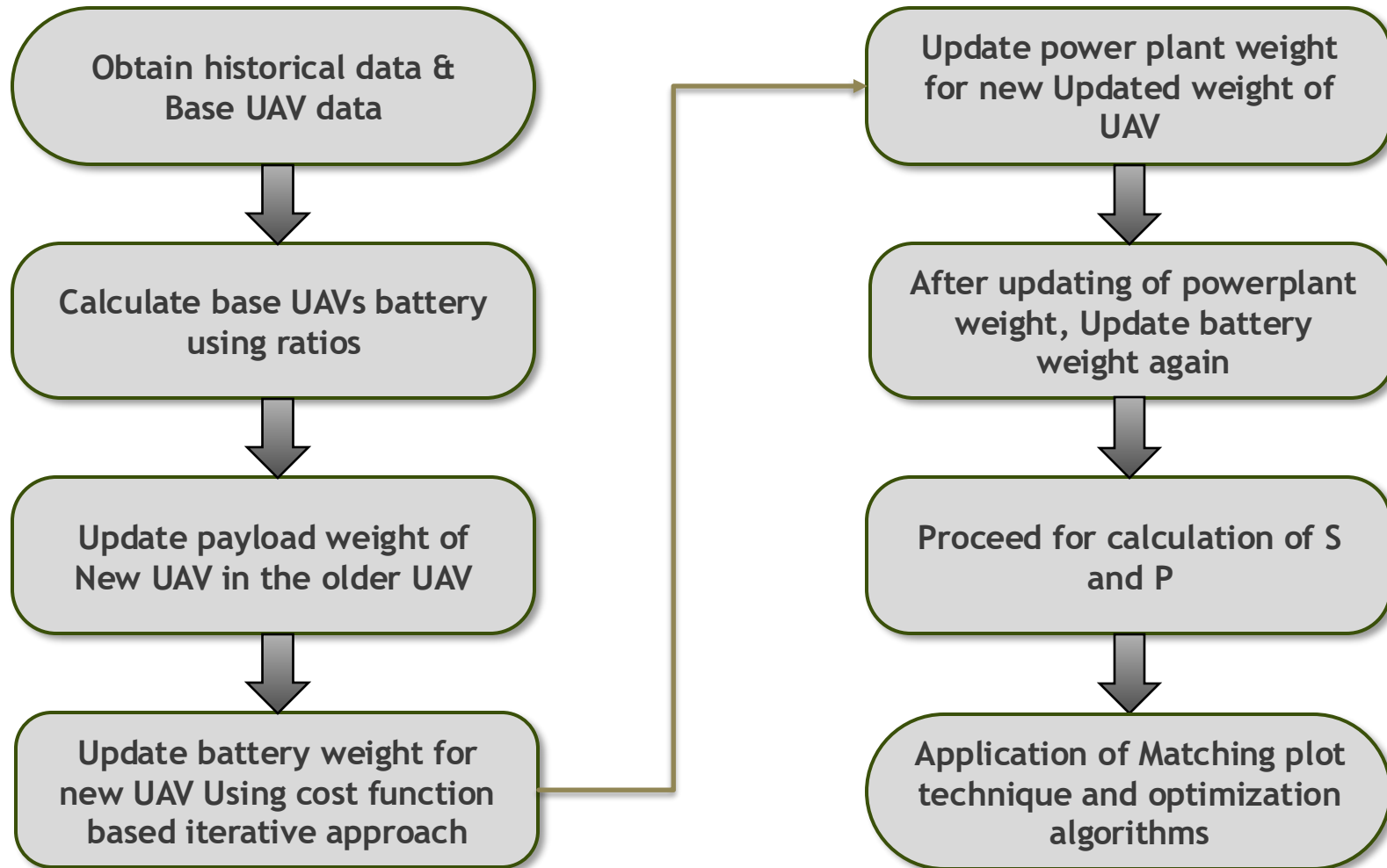
- Two significant weight ratios play a role in our estimation process.

- 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

Obtain historical data & Base UAV data

Calculate base UAVs battery using ratios

Update payload weight of New UAV in the older UAV

Update battery weight for new UAV Using cost function based iterative approach

Update power plant weight for new Updated weight of UAV

After updating of powerplant weight, Update battery weight again

Proceed for calculation of S and P

Application of Matching plot technique and optimization algorithms

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:

$$0.15 < \frac{W_{st}}{W_{to}} < 0.4 \quad (\text{ Structural weight ratio})$$

$$0.05 < \frac{W_{pr}}{W_{to}} < 0.2 \quad (\text{propulsion system weight ratio})$$

❑ **Update Payload weight of New UAV :**

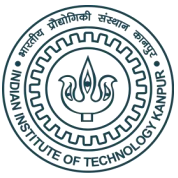a) Updating payload weight of new UAV in the base UAV and recalculate W_{TO}
As

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

❑ **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.

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

and for equilibrium L=W and T=D ,

$$T = W/(L/D)$$

Substituting in eq (1) we get..

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

for battery weight, using SED (specific energy density**)**

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

❑ **Initial power Calculation for the UAV:**

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

Note: Initially selecting a propulsion system such that the required power is delivered at the 50% of the maximum power.
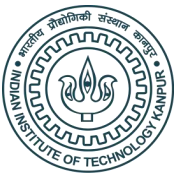
Initial weight estimation Round-1

❑ **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..

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

❑ **Update Battery Weight again for new 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.
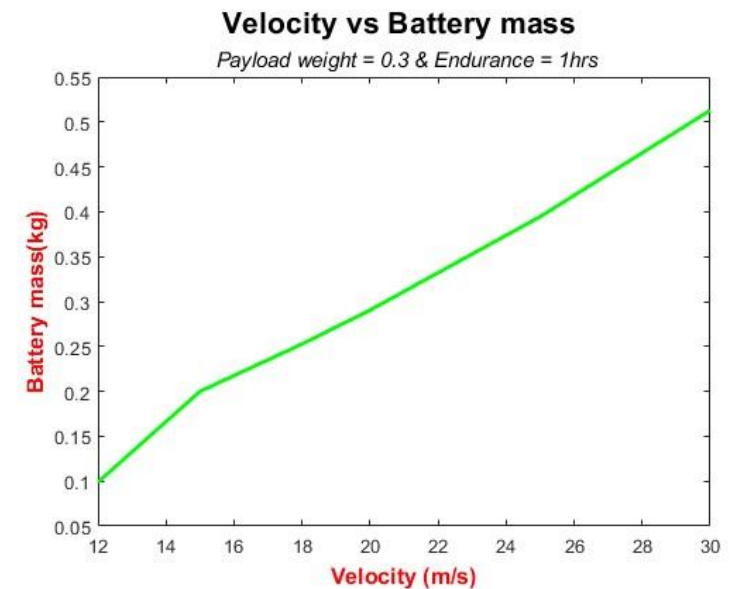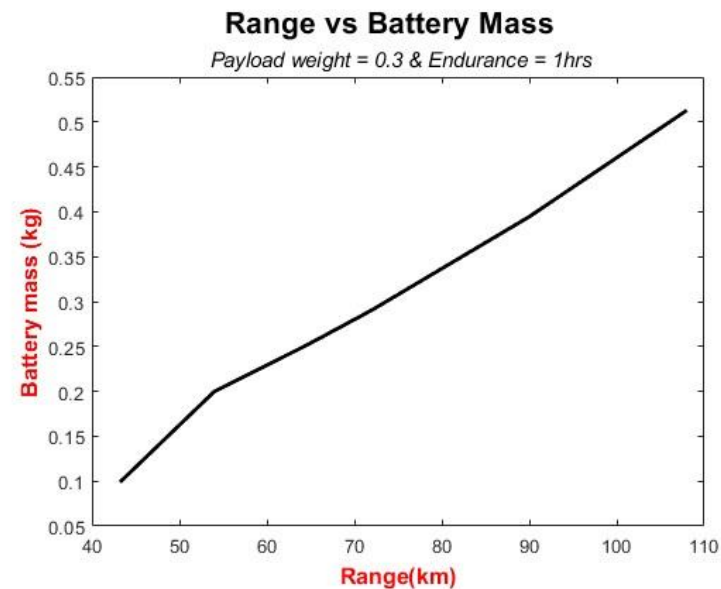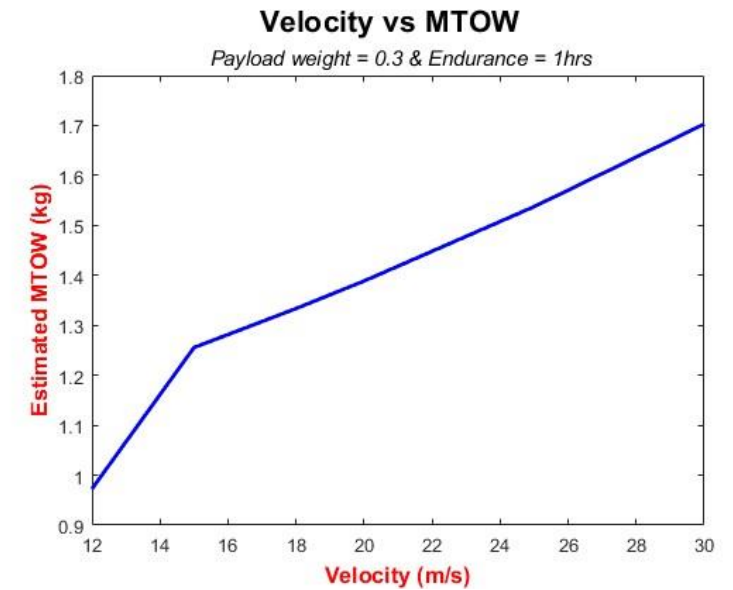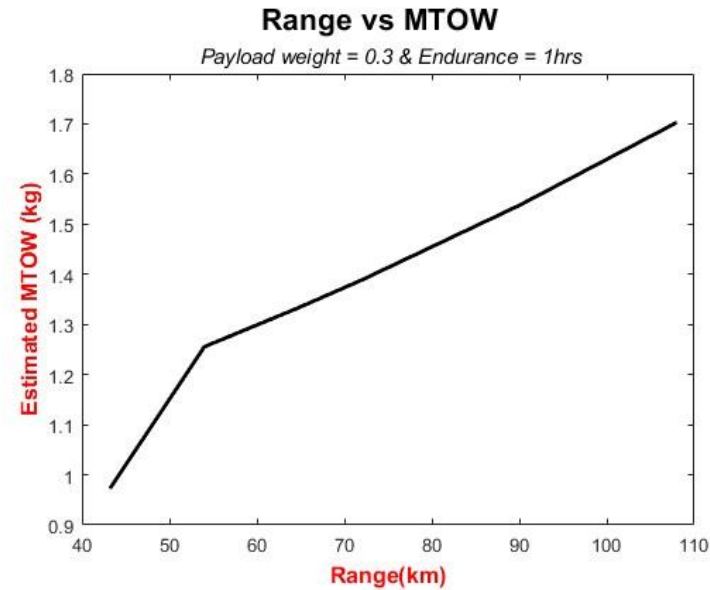
Variation of Range, MTOW, Battery weight

Payload weight = 0.3kg

Endurance = 2 hrs.

Range vs MTOW
Payload weight = 0.3 & Endurance = 2hrs

Velocity vs MTOW
Payload weight = 0.3 & Endurance = 2hrs

Range vs Battery Mass
Payload weight = 0.3 & Endurance = 2hrs

Velocity vs Battery mass
Payload weight = 0.3 & Endurance = 2hrs

Chord length= 0.2 m

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

a) AG35
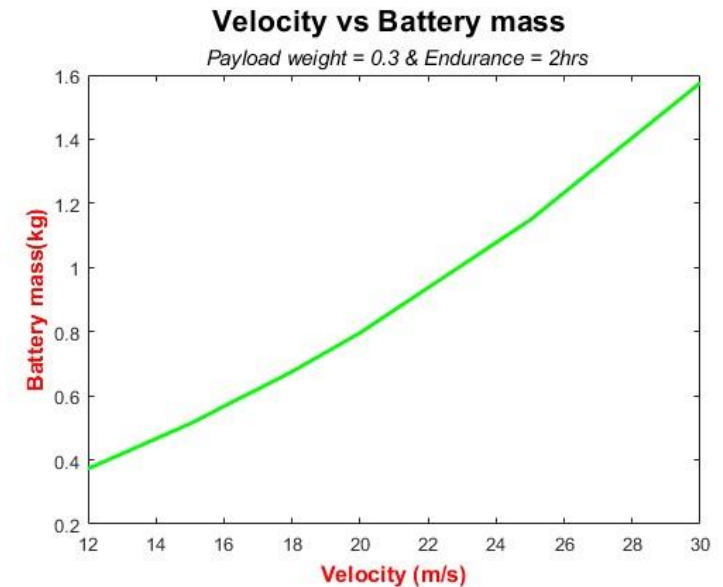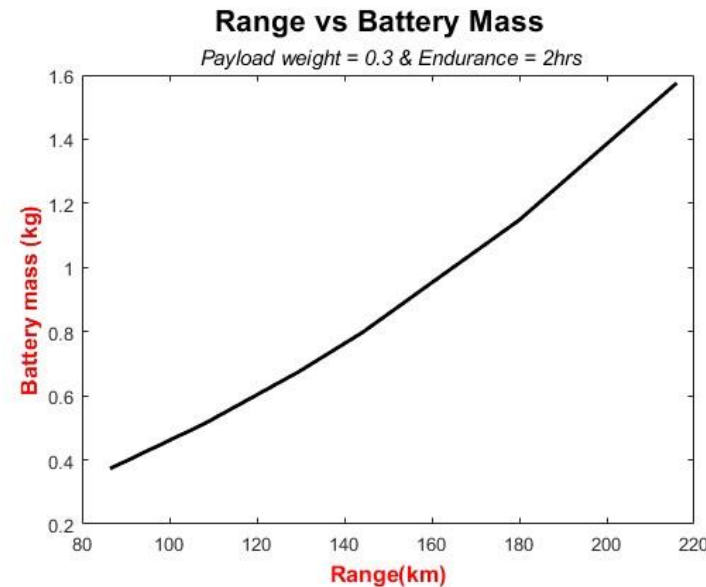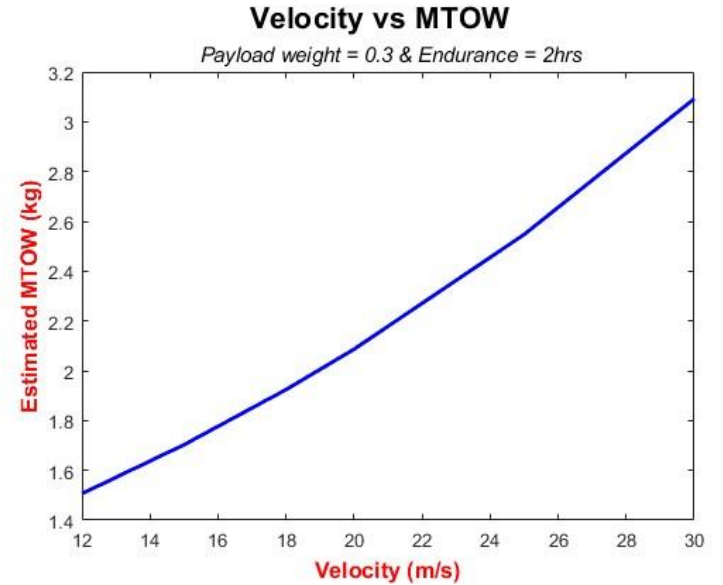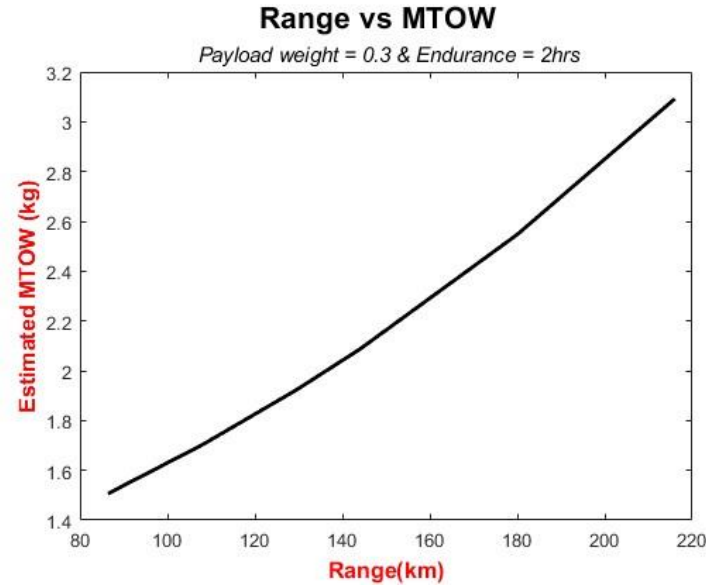
b) Eppler 214

c) S1223
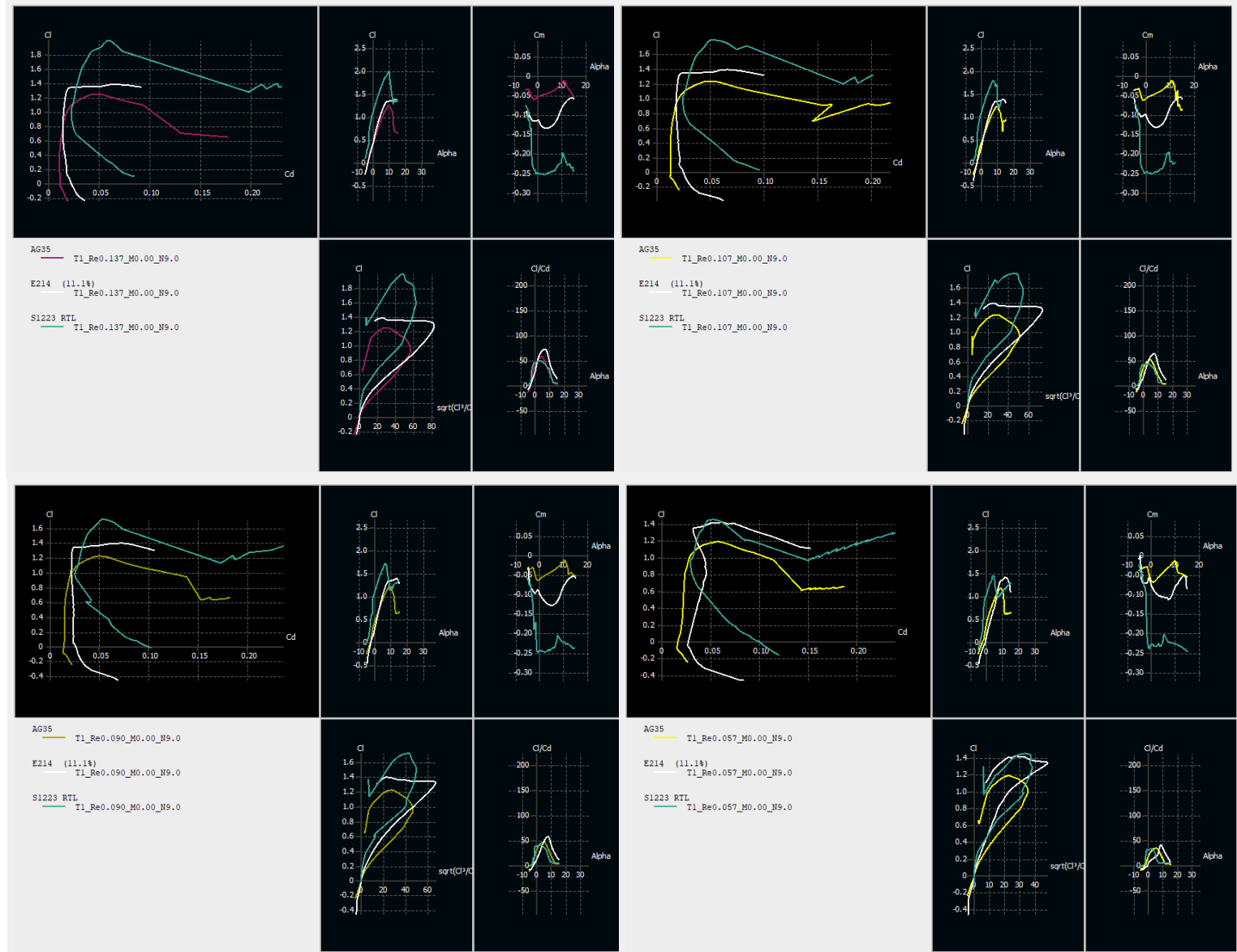
Selected airfoil behavior at V=20m/s

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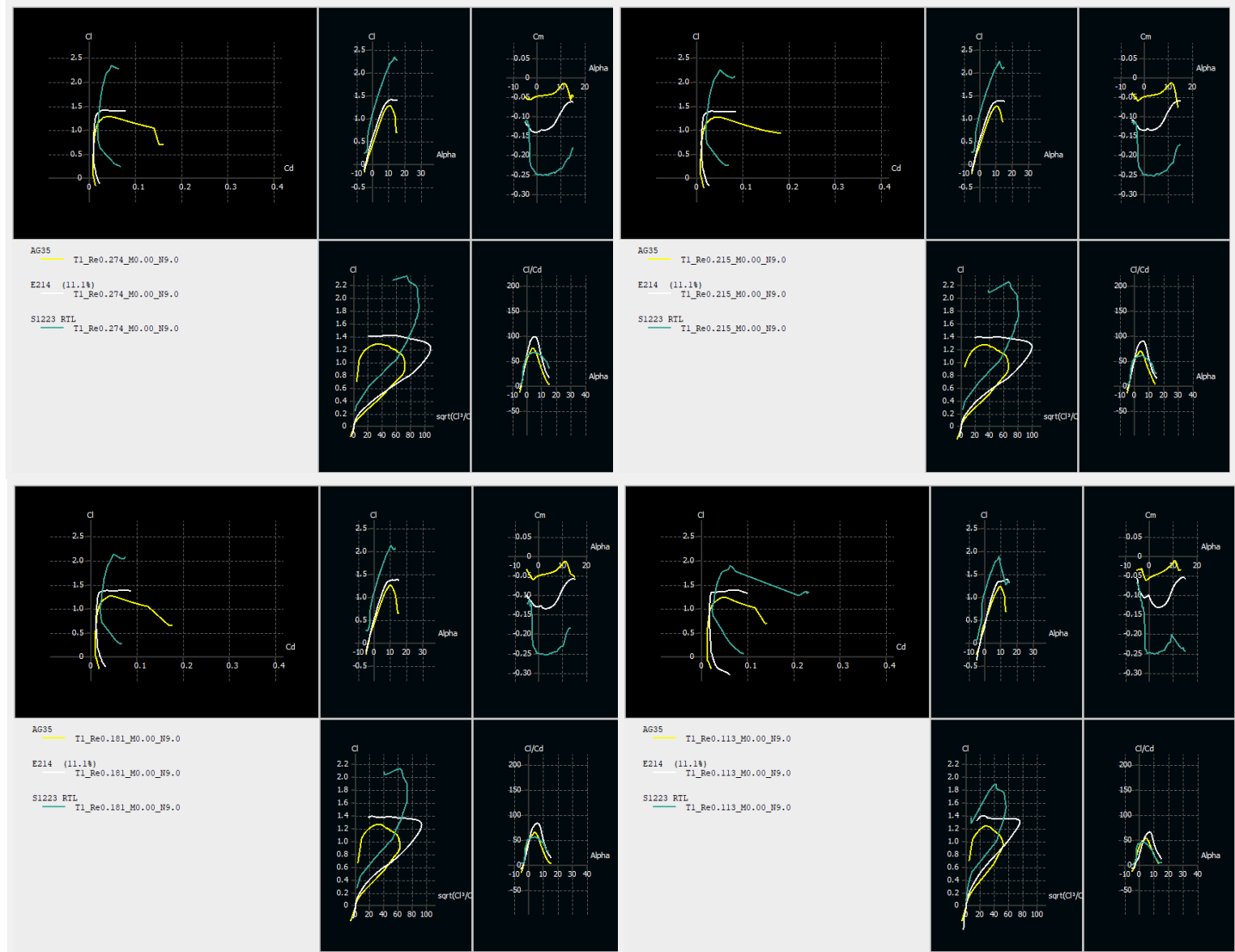
Surface area requirements

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

- 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

Surface area VS Altitude
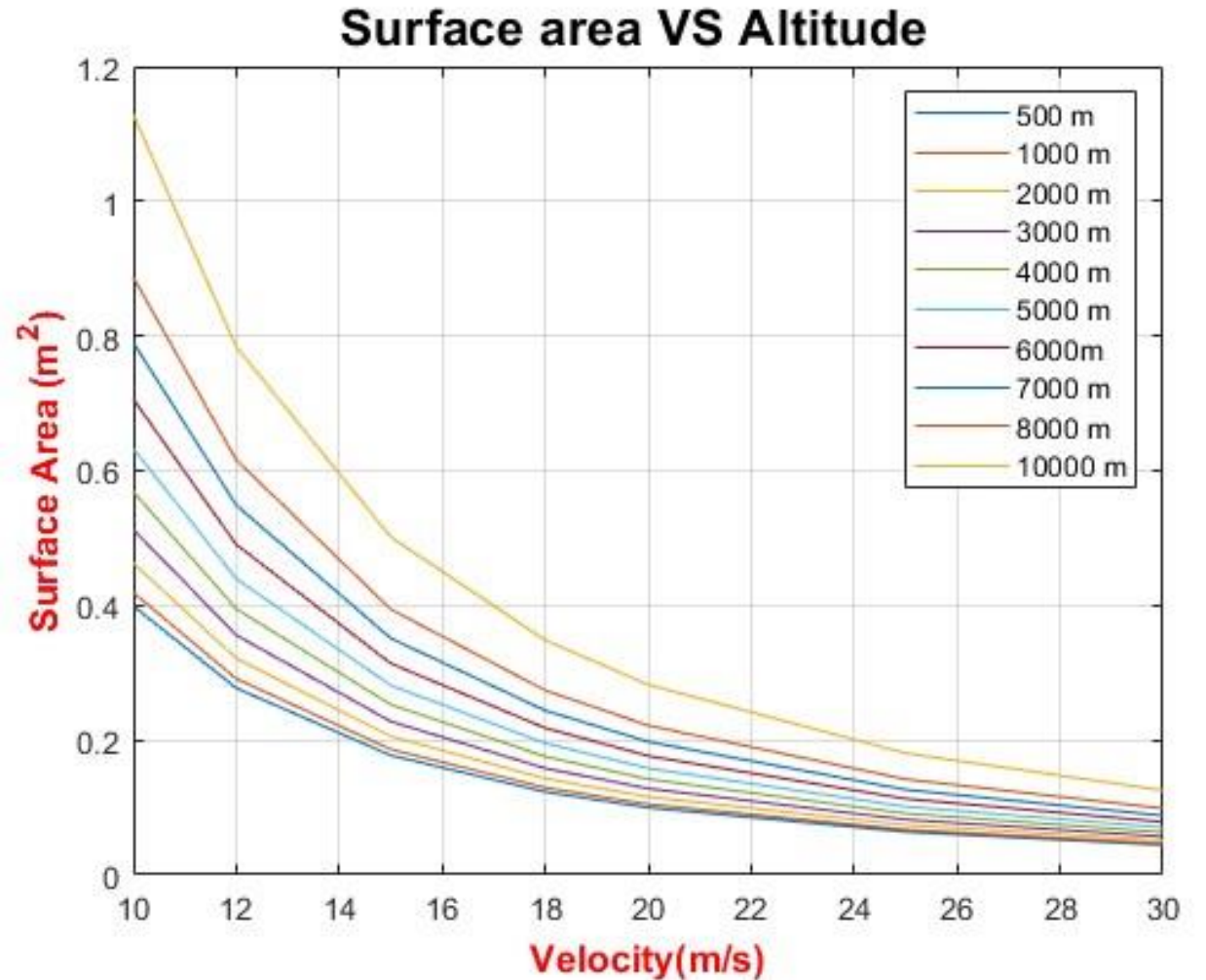
Velocity estimation at various Altitudes

Stall velocity VS Wing Planform Area
At different Altitudes
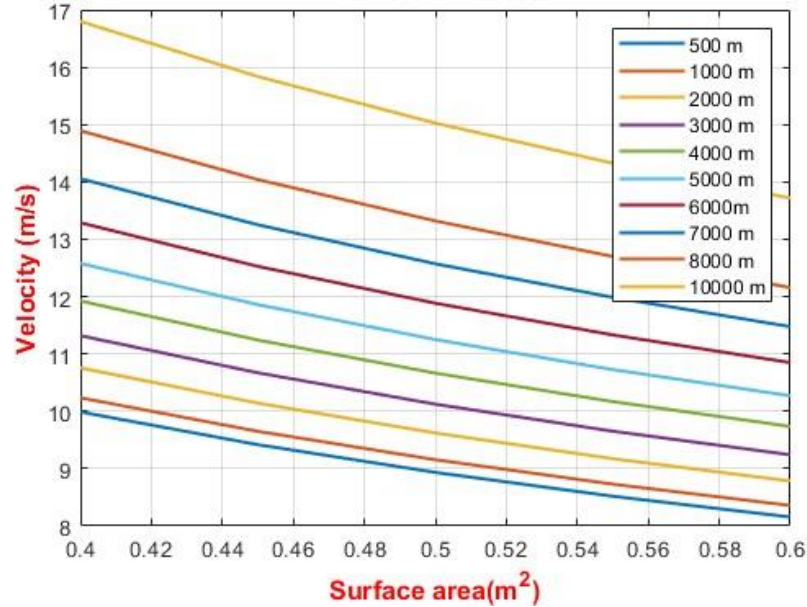
Design velocity VS Wing planform Area
W.r.t Altitudes
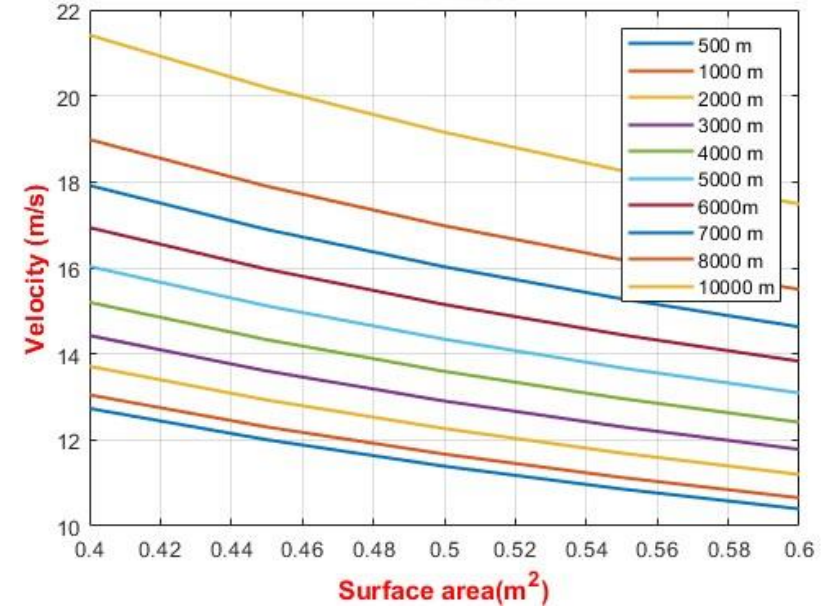
Possible velocities for cruise at 5000 m:
- V_{stall} = 13 m/s
- V_{cruise} = 15m/s

Wing Mount Bolt

Wing mount Nut
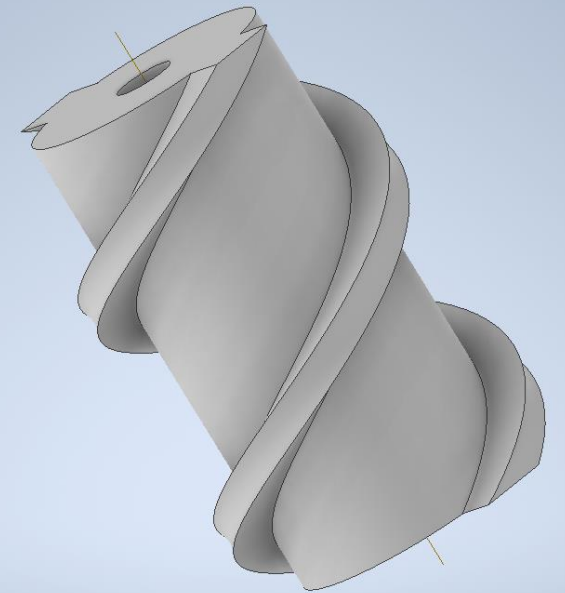
The mechanism is based on nut and bolt mechanism.
As the nut is rotated on bolt, the nut moves linearly similarly As the 'Wing mount nut' moves on the 'Wing mount bolt', the wing mount nut moves up or down.
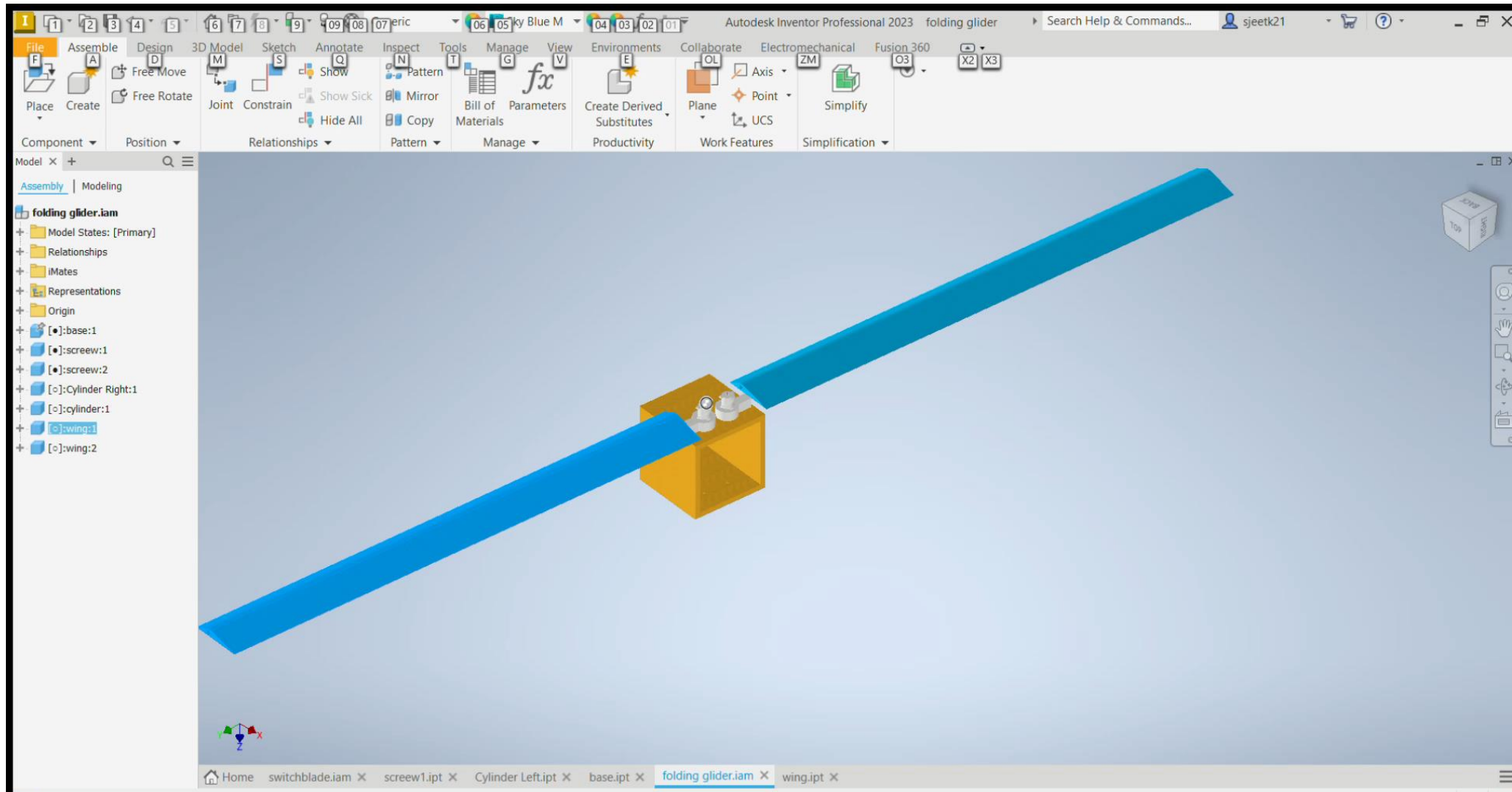
Advantage:-
- Simple mechanism
- Easy to fabricate
- Less Complex
- Minimum maintenance
- Easy to operate with servos and Springs.

Preliminary Mechanism for Wing Deployment

Simulation

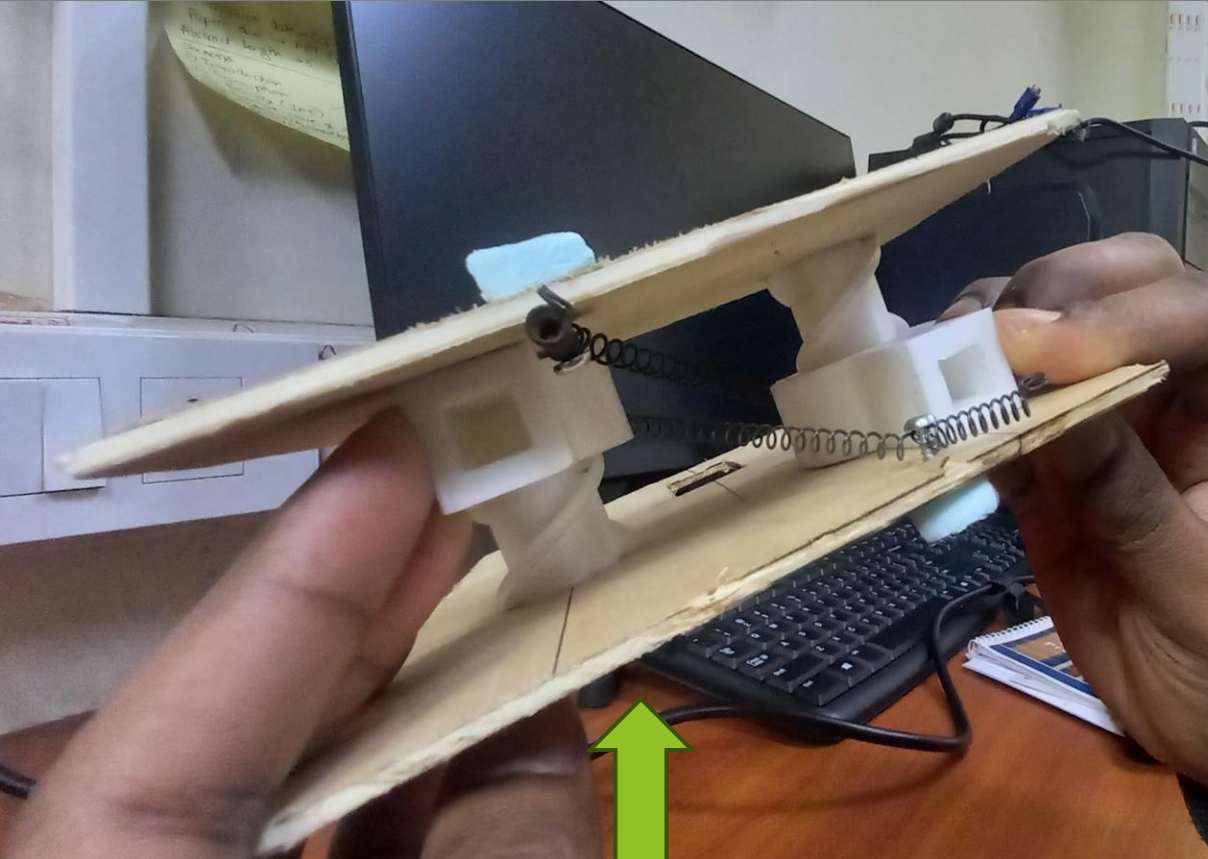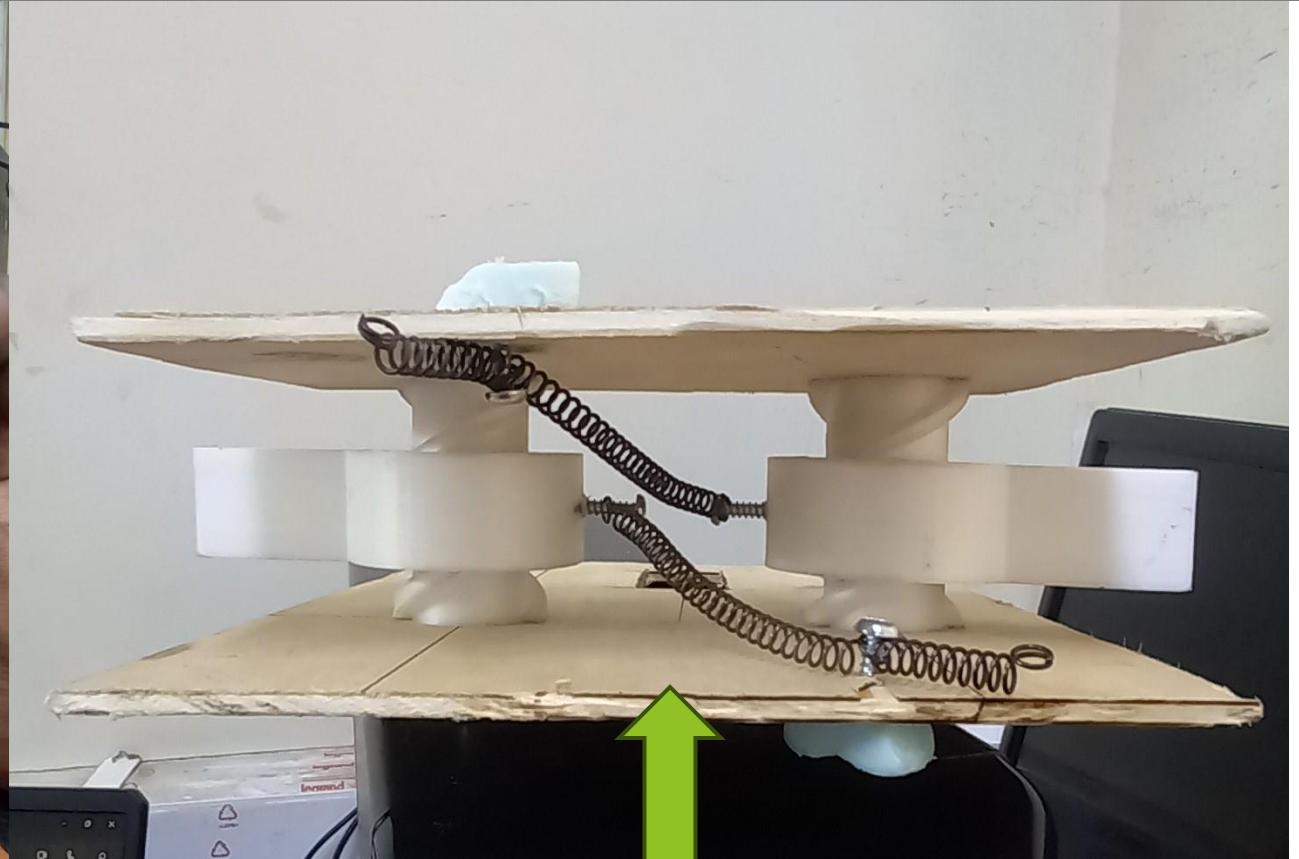# Preliminary Mechanism for Wing Deployment

Folded Wing

Deployed Wings

Actual Working of mechanism

Thank You