Design of UAV's and MAV's - AS5213

AS5213

Group - 13

Design Report

Problem Statement

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Contents

List of figures

Important Equations

- Lift

$$Lift = \frac{1}{2} * C_L * \rho * A * V^2 \tag{1}$$

- Drag

$$Drag = \frac{1}{2} * C_D * \rho * A * V^2 \tag{2}$$

- Drag coefficient

$$C_D = C_{D0} + k * {C_L}^2 \tag{3}$$

$$k = \frac{1}{\pi * e * AR} \tag{4}$$

- Drag coefficient

$$C_D = C_{D0} + k * {C_L}^2 \tag{5}$$

$$k = \frac{1}{\pi * e * AR} \tag{6}$$

- Power in cruise

$$P = D * v \tag{7}$$

$$P = \frac{1}{2} * (C_{D0} + (\frac{1}{\pi * e * AR}) * {C_L}^2) * \rho * A * V^3 \tag{8}$$

- Turn rate

$$w = \frac{g * \sqrt{n^2 - 1}}{v_\infty} \tag{9}$$

- Turn radius

$$w = \frac{{v_\infty}^2}{g * \sqrt{n^2 - 1}} \tag{10}$$

Symbolic notations

C_L = Co-efficient of lift

C_D = Co-efficient of Drag

n = Load factor

ρ = Density

A = Section area

AR = Aspect ratio

1 Mission objective

1.1 Problem Statement

Monitoring and surveillance (MS) encompass the observation and analysis of extensive areas of interest. This broad term applies to various contexts, such as protected regions like wildlife sanctuaries and coral reefs, as well as areas prone to natural disasters, where real-time data collection enhances predictive capabilities for anticipating and responding to such occurrences.

1.2 Why this problem needs attention

Monitoring wildlife sanctuaries is crucial for several reasons, as it helps in the conservation and protection of biodiversity. Here are some key reasons why monitoring wildlife sanctuaries is important:

- **Biodiversity Conservation:** Wildlife sanctuaries are designated areas to protect and conserve the natural habitats of various species. Regular monitoring allows authorities to assess the health and diversity of the ecosystems within these sanctuaries. It helps in identifying any threats or changes in biodiversity, allowing for timely interventions to protect endangered species.
- **Illegal Activities:** Wildlife sanctuaries are often targeted by poachers, illegal loggers, and other criminal activities. Monitoring helps in detecting and preventing such illegal activities, safeguarding the flora and fauna within the sanctuary.
- **Habitat Health:** Monitoring helps in evaluating the overall health of the habitat, including factors such as water quality, vegetation cover, and soil conditions. This information is essential for managing and maintaining a balanced ecosystem.
- **Population Dynamics:** Tracking the population dynamics of various species within a sanctuary is crucial for understanding their behavior, reproductive patterns, and overall health. It aids in implementing effective conservation strategies, such as habitat restoration or reintroduction programs.
- **Climate Change Impact:** Wildlife sanctuaries are not immune to the impacts of climate change. Monitoring helps scientists and conservationists understand how climate change affects different species and ecosystems. This knowledge is vital for adapting conservation strategies to mitigate the effects of climate change.
- **Research and Education:** Monitoring provides valuable data for scientific research, helping researchers better understand ecological processes, species interactions, and the overall functioning of ecosystems. This information can also be used for educational purposes, raising awareness about

the importance of wildlife conservation.

- **Adaptive Management:** Regular monitoring allows for adaptive management, where conservation strategies can be adjusted based on the changing conditions within the sanctuary. This flexibility is essential for addressing emerging threats and challenges.
- **Policy and Planning:** Monitoring data contributes to evidence-based decision-making in the development of policies and management plans for wildlife sanctuaries. It helps authorities allocate resources effectively and implement measures that are grounded in scientific understanding.

In summary, monitoring wildlife sanctuaries is essential for maintaining the health and balance of ecosystems, protecting endangered species, and ensuring the long-term sustainability of biodiversity. It plays a vital role in conservation efforts and supports the broader goals of preserving natural habitats and promoting ecological integrity.

1.3 Mission Statement

To tackle this issue, we propose a lightweight monitoring/surveillance UAV with rapid turnaround times. The vehicle would fly around and over a designated area of interest and acquire important data - primarily in the form of pictures and terrain information - over long spans of time.

1.4 Requirements

- One of the most important aspects that will drive the design of such an aircraft will be endurance. We wish to fly for uninterrupted periods of time.
- Rapid turnaround time aiding in quick re-deployment.
- House good quality instruments for image capture and terrain estimation.
- Lightweight.

The following section details about a prospective mission profile for our aircraft.

2 Mission profile

2.1 Mission phases

- **Take-off** - Accelerating on the runway until liftoff and subsequently retracting the landing gear.
- **Climb** - Rise to the desired altitude required for the mission.
- **Cruise** - Level flight till the area of interest.
- **Loiter** - It is the most important aspect of our mission and most of the UAV's flight time is spent in loiter mode.
- **Descent** - Dropping altitude to ground level.

- **Landing** - Deployment of landing gear and deceleration to a halt.

2.2 Mission info-graphics

Given figures try to depict trajectory of mission of a UAV in a scenario that is according to the mission profile.

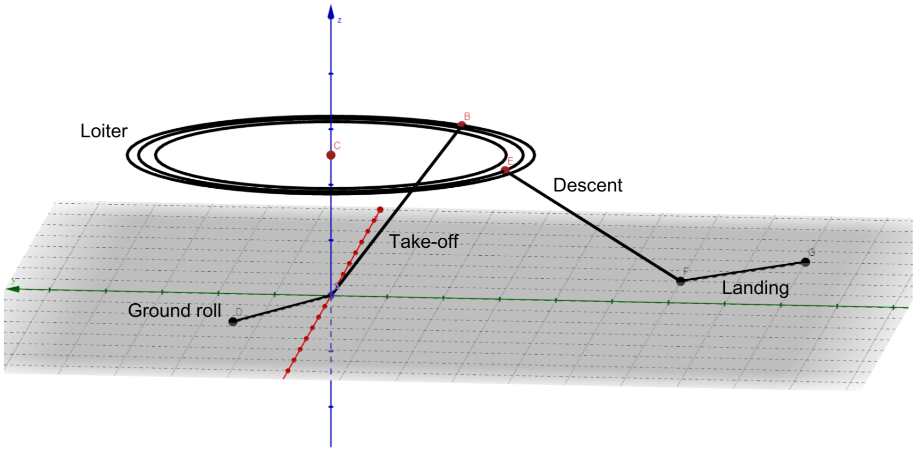


Figure 1 – Geometric view

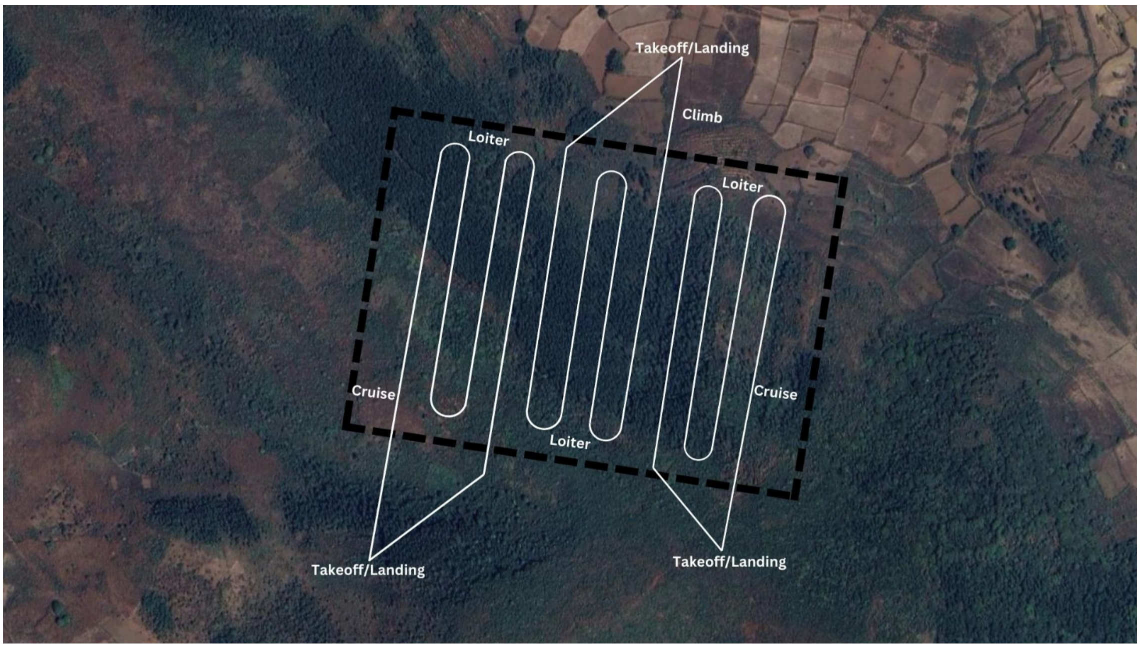


Figure 2 – Terrain / Geographic view

3 Estimation of parameters:

A general estimate of desired flight parameters (Range, approximate cruise speed, endurance was estimated as follows:
Average area of a forest in India is 1 million hectares, which is 10^4 km^2. Let us approximate a forest to be of an approximate square geometry of 100 km x 100 km.

Considering a solution for surveillance of forests using a UAV as per our mission statement, we plan a model where 15 UAV's in the skies for a duration can suffice for the surveillance of the entire forest.

Now considering forest to be an approximate square geometry of 100 km x 100 km, field of vision of each UAV spanning about 3 km of ground, the forest can be classified to 33 strips each of 100 km length and 3.3 km width. The 15 UAV's in the model would be monitoring about 2 strips each.

Consider the following parameters:

- Endurance of each UAV = e hr's
- Speed of each UAV corresponding to maximum time of flight = s km/h

We can thereby develop a relation:

$$e * s = 200 \tag{11}$$

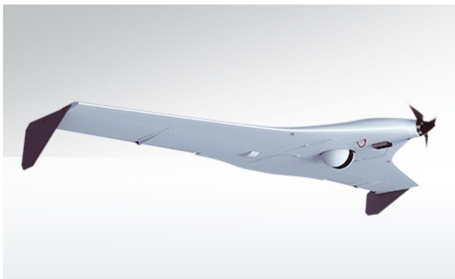
Now, choosing/fixing the preferred range for one of the above parameters wihh thereby give out the range of the other. We choose the flight speed to be in the range 10 - 25 m/s (36 - 90 km/h) which implies the endurance of each UAV should be around 2.2 - 5 hours.

Thereby we proceed ahead to research on UAV's with an endurance of about 2 - 5 hours and flight speeds of about 10-25 m/s.

4 UAV Study

4.1 Data of similar UAV's

Data of UAV's which are used actively in environments with the same natural prospects as our problem statement have been collected and analysed. The following are the images of the UAV's.
Each of their sources is linked in the caption of the figure



(a) ZALA 421-04M

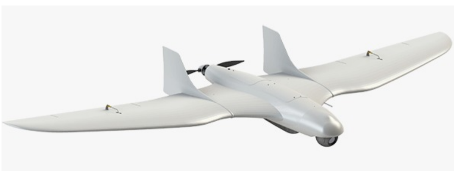
(b) Crex B

(c) Vrabac

(d) Borey 20

(e) Albatross

(f) Boeing Insitu



(g) A1-CM Furia

(h) TAI-Pelikan

(i) TAI-Marti

(j) RQ-20 Puma

Figure 3 – Similar UAVs. (References are contained within image captions).

4.2 Parameters for selection, Categorization and classification of UAV's

A substantially produced UAV was categorized similar to the UAV we aim to design for out problem statement based on following paramenets:

- **Weight** : UAV's with an ideal weight of 5-20 kg.
- **Endurance** : An endurance of at least 1hr is expected considering it's used for surveillance purposes. Following our estimations, UAV's with endurance in range 2-5 hours are considered.
- **Operational height / Ceiling** : UAV's with an operational height of 150 m - 1 km were considered with a maximum ceiling of around 2 km - 3 km. These parameters are considered keeping in view that the UAV would be required to perform several tasks related to imaging and detection.
- **Speed** : UAV's with operational speeds in the range 10-25 m/s, to ensure the quality and resolution of the data collected through camera and sensor modules is not compromised.

4.3 Further information on data of similar UAV's

4.3.1 Ceiling

In certain UAV's from the above mentioned list, exact details of ceiling wasn't mentioned in catalogue, hence the data provided is the data of the suggested operational ceiling provided by the company.

4.3.2 Range

In certain UAV's their range is restricted based on the farthest for which a smooth data transmission is possible which is majorly dependent on communication modules (LoRa etc) and antennae used (Omni, Yagi, uni etc) and not on power-plant. Considering communication an important prospect, we proceeded with the available data of range.

Range of certain UAV's wasn't specified, in those scenarios, we estimated the maximum possible range based on cruise speeds, endurance, MTOW.

4.4 Comparison chart

The following table has data of UAV's with similar mission profiles and with similar parameters like operational ceilings, range and endurance. All the UAV's listed are fixed wing and are manufactured on a substantial scale and are widely available for commercial purchase.

Similar mission profile UAV's data									
S.no	UAV Designation	Empty weight	Powerplant weight	Payload weight	MTOW in kg	Endurance in hr	Range in km	Speed in m/s	Ceiling in km
1	Albatross	4.4	-	5.1	10	3	180	17 - 33	0.15 - 5
2	Boeing Insitu	14		5	26.5	1.5 - 4	250	18.9	-
3	AI-CM	3.5	-	0.6-1	5.5	3	200	18	-
4	TAI-Pelikan	20	-	6	35	6	320	33	1.52
5	TAI-Marti	9			12	1	-	27	0.9
6	RQ-20 Puma	4.2	-	-	7	2	15	10 - 23	0.15 - 3
7	Vrabac	6.17	1.3	1.5	9	1	50	17-33	0.3-0.5
8	ZALA 421-04M	3.47	1.03	1	5	1.5	15	17-27	3.6
9	CREXB	1.5	-	-	2.2	1.25	10	10	3.1
10	Borey 20 UAV	8.7	-	4	26	5	400	20	3.5

Table 1 – UAV Technical Specifications

In the above table consisting of data of different UAV's. All the data presented above has been collected from valid and reliable sources and the hyperlinks redirecting to the sources have been attached for all the UAV's.
All the weights mentioned are in kilograms. Exact data of power-plant weight of several UAV's wasn't available in the catalogues so approximations have been considered in a few cases based on the data of MTOW, Payload capacity and Empty weight.

5 UAV Mission Phases

Estimated durations for each of the phases of the mission are given as follows, this is only a preliminary flight estimate based on the mission profile

UAV Mission Phases and Duration's		
S.no	Mission Phase	Duration in minutes
1	Ground-roll	30 seconds
2	Climb and cruise	3 - 5 minutes
3	Loiter	2 - 4 hours
4	Descent	3 - 5 minutes
5	Landing	30 seconds

Table 2 – UAV Mission Phases and Durations

Cruise and loiter: After observing data from similar UAV's and making a detailed assesment of our mission profile, a cruise altitude of around 300m is found suitable. This altitude gives enough freedom and clearance to UAV's path from any natural disturbances and would be suitable to work with thermal sensors, imaging modules and other mapping equipment.

6 Payload selection

Visible camera : We have selected **DJI Zenmuse P1** based on several factors. It is specifically designed for aerial photography. It comes with an integrated 3-axis mechanical gimbal for image stabilization. It is also lighweight (**430g**) and cheap when compared to it's competition.

Figure 4 – DJI Zenmuse P1

Multispectral camera : For terrain mapping, complementing visible range camera we have chosen **Sequoia RedEdge P**, which is capable of capturing images in five spectral bands and also has a built-in thermal sensor. Also comes with an integrated gimbal which is simple to mount with the UAV. Weight of the camera is **460g**.

Figure 5 – Sequoia RedEdge P

LiDAR : LiDAR offers highly detailed 3D models of the terrain, including elevation, vegetation cover, and even small objects. For terrain with dense vegetation or uneven surfaces, LiDAR can penetrate foliage and capture accurate elevation data, while traditional visual mapping might struggle. We have chosen **RIEGL Mini VUX-UAV LiDAR** which weighs at **1.3 kg**. It is compact and lightweight, suitable for complex terrain and wildlife analysis.

Figure 6 – RIEGL Mini VUX-UAV LiDAR

Total payload weight $= 1.3 + 0.46 + 0.43 =$ **2.19 kg**

7 Power requirements and energy estimation

Estimation of power required by the UAV to complete the mission is vital in battery weight estimation, and battery selection. This plays a crucial role in estimating a lot of factors including the total weight.
The power required to perform the entire mission is broken down into segments relating it with power required during each phase of the mission, and it's estimated as follows:

7.1 Ground roll

To conservatively estimate energy requirements during ground roll, we assume the following;

- Taking Stall speed = 12m/s, we assume lift off speed to be 1.2 times the stall speed $V_{Liftoff} = 14.4m/s$
- In the real world, the UAV is expected to start from rest and then accelerate to this $V_{Liftoff}$. For our initial energy requirement estimation, we take the speed of the entire stretch to be $V_{Liftoff}$. This also ensures that friction is taken care of.

These assumptions are valid and give us more energy than would be needed in the real case, hence acting as a factor of safety. Moreover, this stage of the flight would account for less than 5 percent of the total energy requirement.

$$Power = Thrust \times Velocity$$

$$Power = Drag \times V_{Liftoff}$$

$$Power = \frac{W_{Total}}{\frac{L}{D}} \times V_{Liftoff}$$

$$Energy = \frac{W_{Total}}{\frac{L}{D}} \times V_{Liftoff} \times Time \tag{12}$$

7.2 Climb

Considering climb, the UAV should climb to an altitude of 300 m (Cruise altitude). After being airborne, the UAV should clear obstacles (most likely to be trees), hence distance travelled while airborne to safely clear an obstacle plays a crucial role as it determines the approximate length of airstrip required. We hence decided to consider a climb performance such that the distance travelled while airborne to safely clear an obstacle is not very large, Considering the parameters such that the UAV can takeoff on an airstrip as short as 100 metres,

Distance travelled while airborne = 100 m
Height of obstacle = 20 m

Height of obstacle is considered 20 m as after research, it is found to be the average height of a tree in Indian forests.

$$V sin(\theta) \times t = 20 \tag{13}$$

$$V cos(\theta) \times t = 100 \tag{14}$$

$$tan(\theta) = 0.2 \tag{15}$$

$$Climbangle = 11^0 \tag{16}$$

As most airfoil's stall around an angle of 15 degrees, a climb angle of around 11 degrees which we require according to the above approximation can be considered a safe climb angle as even in case of a disturbance due to horizontal wind, it has still has a margin where it may not stall. (Although direction of thrust vector, placement of wing, and airfoil affect this, climb at 11 degree angle can be taken as a safe approximate which would hold in extreme cases as well.)

Now coming to climbing to 300 m, as assumed, the UAV is expected to reach this altitude in around 2 minutes as mentioned in flight profile.

$$V(sin(11)) \times 120 = 300 \tag{17}$$

$$Climbvelocity(V) = 12.5m/s \tag{18}$$

Force due to drag on the UAV can be given as:

$$D = \frac{C_D}{C_L} \times W \tag{19}$$

Now power required can be estimated as:

$$Power = v \times \frac{C_D}{C_L} \times W + v \times W \times sin(\theta) \tag{20}$$

$$Power = 12.5 \times \frac{C_D}{C_L} \times W + 12.5 \times W \times sin(\theta) \tag{21}$$

The value of C_D/C_L is chosen 1/20 after taking reference from [4] page number 3.

7.3 Cruise and Loiter

After climbing to the required altitude, the next thing the UAV is required to do is reaching the desired location via level flight (cruise) followed by occasional level turns and then back to cruise. This phase is predominantly cruise. The following are the main considerations for power estimation:

- Cruise time = 2 hours
- Cruise altitude = 300 m

- Density of air = 1.188 kg/m^3
- Cruise speed = 20 m/s
- Angle of attack = 5^0

$$P_{cruise} = DV$$
$$P_{cruise} = D \times (\frac{L}{L}) \times V$$
$$P_{cruise} = \frac{W_0}{\frac{L}{D}} V$$
$$P_{cruise} = 20 \times W_0 \times \frac{C_D}{C_L}$$

The value of C_D/C_L is chosen 1/25 after taking reference from [4] page number 3.

7.4 Level turns

We fix to a turn rate of around 12 degrees per second, completing a turn in a span of 30 seconds. For turn, we choose the value of CL/CD of 20 for turn after refering to [4] page number 3
The turn is being taken at a bank angle of 30 degrees. Turn velocity can be evaluated as:

$$v = \frac{Tan(\theta) * g}{\omega} \tag{22}$$
$$v = 27m/s \tag{23}$$

Power during this phase evolves out to be:

$$P = \frac{C_D}{C_L} * W_0 * 27 \tag{24}$$

7.5 Descent

As shown in 21, we assume descent requirements are similar.

7.6 Landing

As shown in 12, we assume landing requirements are similar.

8 Battery

Recent developments in lightweight electric motor and battery design are making feasible the use of electric propulsion from storage batteries. In particular the improvement in rechargeable battery performance through use of Li–S (lithium sulphur) Li-Po (Lithium Polymer) technology has reduced the mass/energy ratio to about one-quarter that of other battery types. The resulting performance of a high-technology battery-motor combination may be seen to be marginally better than the rotary engine.

Considering these factors, a LiPo battery based propulsion system has been opted for our UAV. Other battery sources including ones such as Ni-Mh, Ni-Cd are compared less safer than LiPo, have less energy density and constitute substances which are toxic/poisonous to nature.

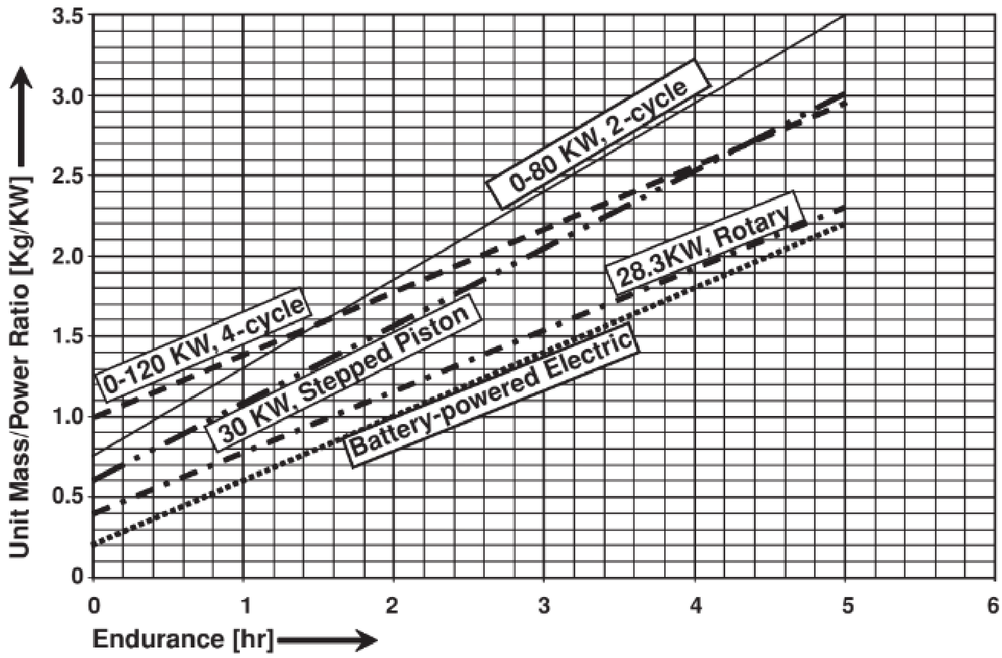


Figure 7 – Graph taken from Reg Austin Unmanned Aircraft Systems, page no. 290 [5]

8.1 Battery weight estimation

- From the energy requirements of each stage of flight, we get an estimate of the total energy required to carry out one cycle of our mission (In terms of the total weight of the aircraft).
- If we divide this quantity by the energy density rating (250 W h /Kg here) of an appropriate battery, we estimate the battery weight needed to carry out our desired mission.
- Dividing this value by the total weight of the aircraft, we get the battery weight fraction. This will serve as an input to the interactive weight estimation process.
- A 10% safety factor is considered in our energy requirement. Additionally, we've taken efficiencies of motor components and battery power delivery as 0.8 and 0.9, respectively.
- Fraction turns out to be 0.13

```
%% Energy and Battery Weight Fraction Estimation
Mass = 10; %(Can be anything, will be cancelled in the final
    battery weight estimation)
W = Mass*9.81;
LbyD = 10;

Ptakeoff = (W/(LbyD*2))*1.2*12;
Etakeoff = Ptakeoff*30;

P_climb = (12.5/(LbyD*2))*W + W*12.5*sind(11);
E_Climb = P_climb*120;

P_CruiseLoit = (20/(LbyD*2))*W;
E_CruiseLoit = P_CruiseLoit*2*60*60;

P_Turn = 27 * W/((2\sqrt(3))*25);
E_Turn = P_Turn*90;

Total_Energy = 2*Etakeoff + 2*E_Climb + E_CruiseLoit + E_Turn;

Battery_Energy_Density = 250; % W h/ Kg
Battery_Weight = Total_Energy*1.1/(0.9*0.8*Battery_Energy_Density
    *60*60);
Battery_Weight_Fraction = Battery_Weight/Mass;
display(Battery_Weight_Fraction);
```

9 Empty weight estimation:

We undertake empty weight estimation by looking at historical data from previous successful UAVs as shown in 5.
The generic form of how empty weight fraction varies with total weight is given by the relation:

$$\frac{W_{empty}}{W_{total}} = A{W_{total}}^{L} \tag{25}$$

Where A and L are some constant coefficients. It is important to note that L is expected to be a negative number to ensure convergence (Will be talked about in section 8.3)

9.1 Empty weight fraction vs Total weight

Plotting (from our data collection) the required values, we get the following:
Running an optimization (fmincon in MATLAB) that reduces the least squares error for input parameters A and L.

```
sol = fmincon(@(X) find_AL(X,MTOW,Empty_Weight./MTOW),[1,0]);
function cost = find_AL(X,MW,frac)
A = X(1);
L = X(2);
y = A*MW.^L;
error = (frac-y)./y;
cost = error*error';
end
```

Running the above script the appropriate Take of Weights and Empty Weight fractions, we get the following values:

$$A = 0.8993, L = -0.1594 \tag{26}$$

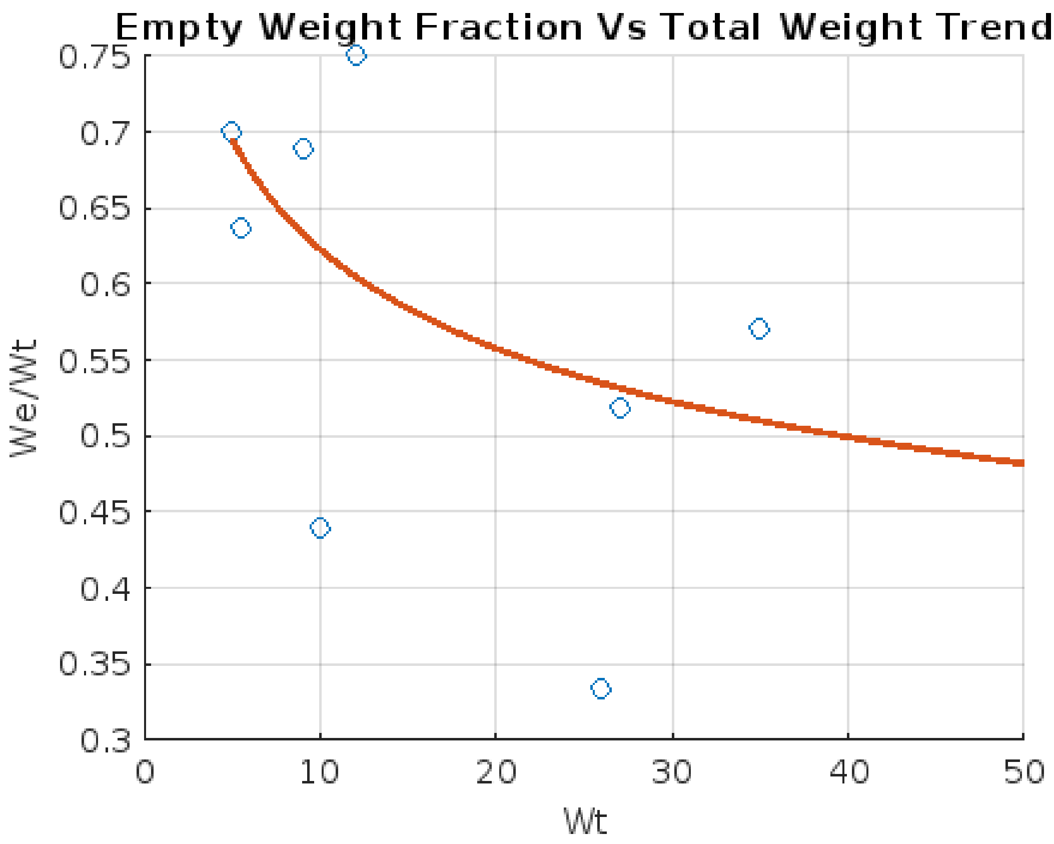


Figure 8 – Empty Weight Trend

9.2 Estimated total weight

With the values of A, L, and a battery weight fraction estimated, we are now ready to do an iterative preliminary weight estimation as given in Raymer <INSERT BIB>.
Before we do so, let us familiarize ourselves with the various quantities involved.

$$W_{total} = W_{empty} + W_{battery} + W_{payload} \tag{27}$$

Rearranging the terms, we get the following

$$W_{total}(1 - \frac{W_{empty}}{W_{total}} - \frac{W_{battery}}{W_{total}}) = W_{payload} \tag{28}$$

This expression gives us the algorithm that will be used to propagate our iterative process.

$$W_{totali+1} = \frac{W_{payload}}{(1 - \frac{W_{empty}}{W_{totali}} - \frac{W_{battery}}{W_{totali}})} \tag{29}$$

where i denotes the iteration number.
Executing the above algorithm until a user-specified convergence is achieved, we get the following plot.
Weight converges to **10.21 Kg**.

```
%% Iterative Loop to find initial estimate of weight
A = sol(1);
L = sol(2);
W_p = 2.5; % Kg (We have to find this)
Battery_Weight_Fraction; % (Calculated in Battery Estimation)

w1 = 5; % Kg (Just an initial guess)
i = 1;
diff = 10;
figure
array = [i w1];
hold on
grid on
while abs(diff)>0.00001
    empty_frac = find_empty_frac(A,L,w1);
    w2 = W_p/(1-Battery_Weight_Fraction-empty_frac);
    diff = (w2-w1)/w1;
    w1 = w2;
    i=i+1;
    array(i,:) = [i w1];
    if i>100
        break
    end
end
display(w1)

display(w1) % This is our initial weight estimate
```

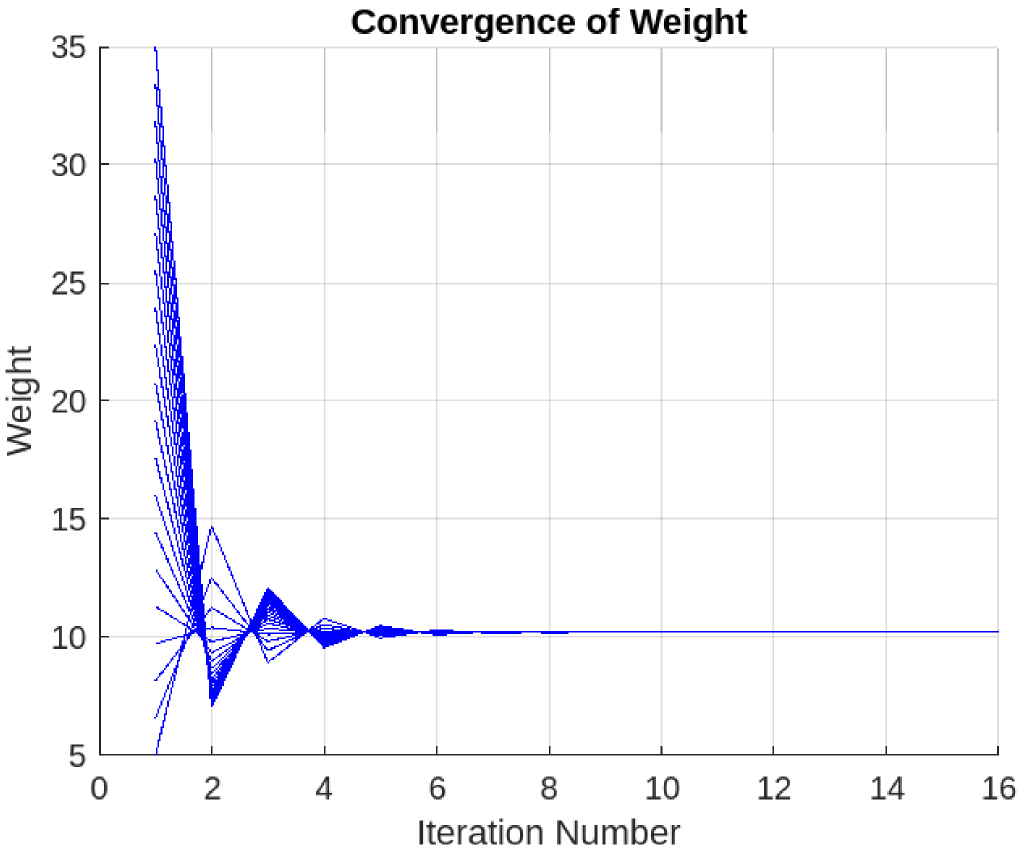


Figure 9 – Weight Estimate Convergence

10 Estimations and approximations:

The only estimate considered while evaluating the weight fractions of battery is the ratio of $\frac{C_L}{C_D}$. Other approximations and values are only to make the mission profile simpler and to design a system with parameters such that it's performance is better.

To give an example, velocity of UAV during climb is taken to be 12.5 and that value is reached while starting from a situation to have a shorter distance travelled while being airborne, in order to successfully clear an obstacle.

11 Week2 Contributions:

- Hrishav Das: Compiling data into Matlab Script, generating plots, takeoff, and landing power requirement formulation.
- Chandra Hasa: UAV data collection, payload selection, cruise and loiter power requirement formulation, document formatting.

- Balaji Naidu P: Climb and Turn performance and power requirements, Data collection and compilation, Performance and powerplant study of similar UAV's, document formatting.
- Avneesh Kumar: UAV data collection,design making and formatting,Payload instrument selection,document formatting.
- Vishwajeet Shukla:
- Karri Deepak:

References

[1] AeroExpo—The B2B marketplace for aeronautical material and products: Aircraft, ground support, airport terminal equipment, etc. (n.d.). Retrieved February 4, 2024, from https://www.aeroexpo.online/

[2] Introduction of versatile unmanned aircraft system: A combat power multiplier for the macedonian army. (n.d.). Retrieved February 4, 2024, from https://apps.dtic.mil/sti/citations/AD1210256

[3] Yangda fw-320 fixed wing vtol plane. (n.d.). Yangda Security. Retrieved February 4, 2024, from https://www.yangdaonline.com/yangda-fw-320-fixed-wing-vtol-plane/

[4] AERODYNAMIC PERFORMANCE COMPARISON OF AIRFOILS IN FLYING WING UAV, Seyhun Durmuş, Balikesir University, Edremit School of Civil Aviation 10300, Edremit, Balikesir, Turkey. from International Journal of Innovative Engineering Applications

[5] Reg Austin (2010). Unmanned Aircraft Systems. American Institute Of Aeronautics and Astronautics. from university of Pancasila repository

[6] Guayaquil, S. S. (2014, May 1). Surveillance uav. $https : //digital.wpi.edu/concern/student_works/p5547s99q?locale = en$

[7] Anderson, J.D (2010), Aircraft Performance & Design, Mc.Graw-Hill, New York, USA. from https://soaneemrana.org/onewebmedia/AIRCRAFT