

AERO VEHICLE DESIGN

Mission Profile 19

ASSIGNMENT 1

MQ1C-GRAY EAGLE



Submitted By

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AERO 20-A

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LESSON - STATEMENT

The MQ-1C Gray Eagle is a medium altitude long endurance (MALE) Un-manned aircraft system (UAS). It was developed by German Atomics - Aeronautical Systems (GA-ASI's) for United States Army as an upgrade of General Atomics MQ-1 Predator.

The MQ-1C Gray Eagle, an advanced variant of the renowned Predator series, stands as pinnacle of modern unmanned aerial vehicle (UAV) technology. Its sleek design and formidable capabilities evoke a sense of awe and admiration in aerospace community and beyond. However, it's not just the Gray Eagle's versatility and adaptability make it a formidable asset across a spectrum of missions. Whether conducting its cutting edge technology nested within its frame that truly sparks curiosity. Equipped with array of sensors, communications systems and advanced avionics, this UAV represents a paradigm shift in intelligence, surveillance and reconnaissance (ISR) capabilities. Its ability to provide real time high resolution imagery and actionable intelligence is nothing short of remarkable, offering commanders a decisive edge on battlefield.

Beyond its technical powers, the Eagle Gray embodies a shift in the way we perceive aerial operations. As a remotely powered aircraft, it challenges traditional notion of manned flights. Its ability to operate for extended duration with minimal logistical

footprint underscores its significance as a force-in-enabling persistent surveillance and rapid response capabilities that were previously unattainable.

Concluding the all points:

- ① The MQC-Gray Eagle exudes a sense of power and sophistication with its sleek design and impressive 56-foot wing span.
- ② Equipped with state-of-the-art sensors and communication systems, it possesses superhuman-like intelligence to gather critical information in real-time.
- ③ With a length of 28 feet and a payload capacity of over 1,000 pounds, it showcases remarkable adaptability and versatility.
- ④ Despite being unmanned, the Gray Eagle is dependable and ready to tackle any mission, from reconnaissance to precision strike.
- ⑤ It stands as a symbol of human ingenuity and innovation, pushing the boundaries of what's possible in modern aerial warfare.

CONCLUSION:-

In conclusion, the MQC-Gray Eagle UAV stands as a testament to innovation and ingenuity in aerospace engineering. Its sleek design, advanced technology, and unparalleled capabilities make it a symbol of excellence in the realm of unmanned aerial vehicles, capturing the imagination of those who witness its impressive performance in action.

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EAGLE PERFORMANCE PARAMETERS

Parameter	Value
Maximum Mach	0.26
Maximum speed (knots)	167
Cruise Mach	0.228
Cruise speed (knots)	135
Cruise Altitude (ft)	29000
Range (nm)	1000
Ceiling (ft)	29000
Wing Loading (lb/ft ²)	24.5
Take-off Distance (ft)	2300 ft
Landing Distance (ft)	1800
Endurance	25

GRAY-EAGLE ENGINE SPECIFICATIONS

Parameter	Values
Power Plant	Thielert centurion 1.7 Heavy Fuel Engine, 165 HP
Number of Engines	1
Engine Power	165 hp
BSFC	0.37 - 0.39 lb / hp-hr

PERFORMANCE - I PARAMETERS

Performance Parameters	Requirement
Max. Mach	0.23
Payload (lbs)	600
Endurance (h)	28
Ceiling (ft)	25000
Range (nm)	650
Max. Take-off Weight (lbs)	3000
Take-off distance (ft)	1000
Landing distance (ft)	850

GRAY-EAGLE GENERAL SPECIFICATIONS

Parameter	Value
Length	28
Wingspan (ft)	56 ft
Aspect Ratio	20
Height (ft)	9.8
Wing Area (sq. ft)	150
Payload Weight (lb) internal	575
Max. Takeoff Weight (lb)	3600
Fuel Capacity (lb)	575
Crew	0

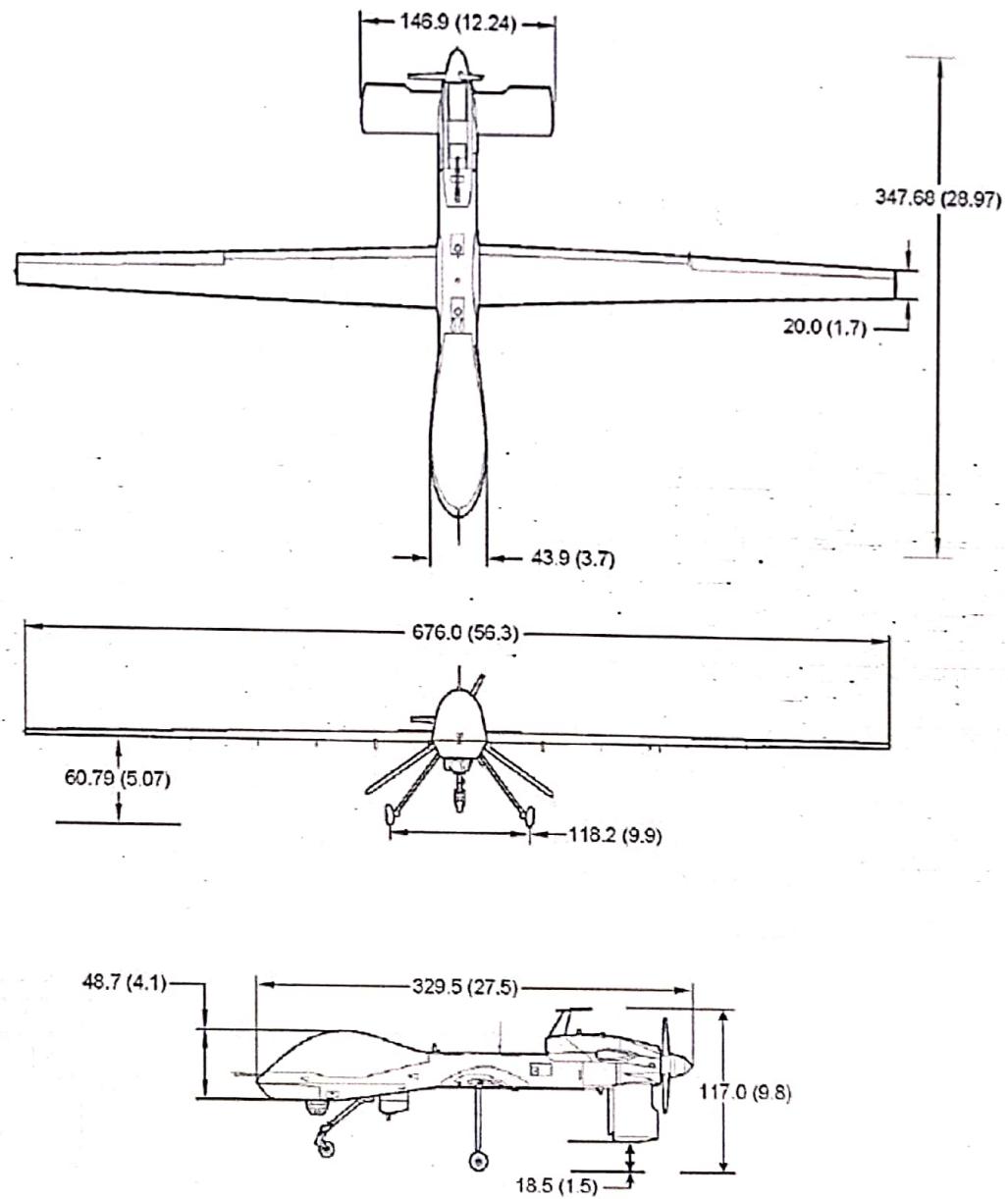
ION OF AIRCRAFT
Gray Eagle is selected
has highest score
design requirement

SELECTION OF AIRCRAFT

C- Gray Eagle is selected as our reference aircraft as it has highest score which means it is closest to design requirement.

MISSION PROFILE	PERFORMANCE PARAMETER	MOCIC Gray Eagle			EADS Harfang			Wing Loong I					
		Requirement	Weighting	Value	Score	Requirement	Weighting	Value	Score	Requirement	Weighting	Value	Score
Man. Mach.	0.23	15	0.18	11.74	0.25	13.08	0.17	11.09	1.09	0.23	0.23	15	
Payload	600	15	450	11.25	5.75	14.38	550	13.75	880	10.23	440	11	
Endurance	28	10	24	8.57	2.5	8.93	2400	8.57	32	8.75	20	7.14	
Ceiling (ft)	25000	10	25000	10	29000	8.62	25000	10.0	26000	9.62	24600	9.84	
Range (nm)	650	15	675	14.44	1000	9.75	540	12.46	810	12.04	2200	4.43	
MTOW (lbs.)	3000	15	2249	11.25	3600	12.50	2756	13.78	9260	4.86	2535	12.68	
Distance (ft)	Take-off	1000	10	2000	5	2300	4.35	2700	3.70	2600	3.85	2625	3.87
	Landing	850	10	2000	4.25	1800	4.72	2600	3.27	2550	3.33	2625	3.24

VIEW DIAGRAM

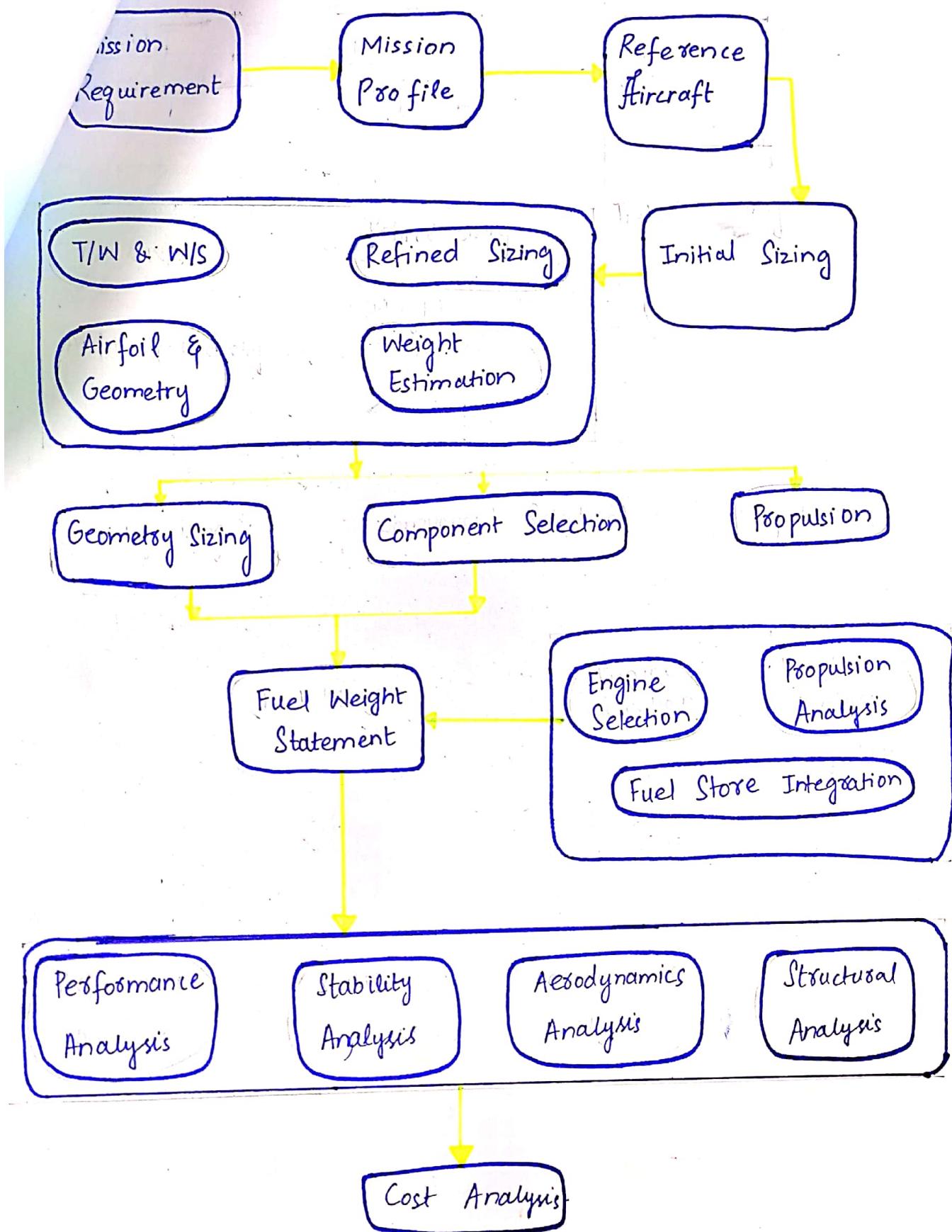


NOTE:

DIMENSIONS = INCHES.

DIMENSIONS INSIDE () = FEET.

INDIVIDUAL AIRCRAFT LOADING WILL AFFECT
OVERALL HEIGHT AND GROUND CLEARANCE.

DESIGN PROCEDURE

"INITIAL SIZING"

Design of aircraft begins with sizing of an aircraft. It is to determine its size and weight. For every aircraft, there is a different mission profile which has different segments. For sizing these segments should be considered individually.

TAKOFF WEIGHT BUILD-UP:-

This equation summarises the take-off weight build-up.

$$W_0 = W_{\text{crew}} + W_{\text{payload}} + W_{\text{fuel}} + W_{\text{empty}}$$

Fuel weight and empty weight can be expressed as fractions of total take-off weight (w_f/w_0) and (w_e/w_0).

$$W_0 = W_{\text{crew}} + W_{\text{payload}} + \left(\frac{w_f}{w_0}\right)W_0 + \left(\frac{w_e}{w_0}\right)W_0$$

$$W_0 - \left(\frac{w_f}{w_0}\right)W_0 - \left(\frac{w_e}{w_0}\right)W_0 = W_{\text{crew}} + W_{\text{payload}}$$

$$W_0 = \frac{W_{\text{crew}} + W_{\text{payload}}}{1 - \left(\frac{w_f}{w_0}\right) - \left(\frac{w_e}{w_0}\right)}$$

EMPTY-WEIGHT ESTIMATION:-

We will use historical trends given by Raymer. As our aircraft is MALE UAV, so category of UAV-TacRecce has been selected from the given data.

$$W_e/W_0 = A W_0^C k_{vs}$$

JAV-Tac Recce 8 UCAV	A	Almetric	C
	1.67	1.47	-0.16

However, the table from which this data is taken is given at the end.

calculate empty weight fraction.

$$\frac{w_e}{w_0} = A w_0^c k_{vs}$$

$$A = 1.67, \ c = -0.16, \ k_{vs} = 1.$$

$$\boxed{\frac{w_e}{w_0} = 1.67 \times w_0^{-0.16}}$$

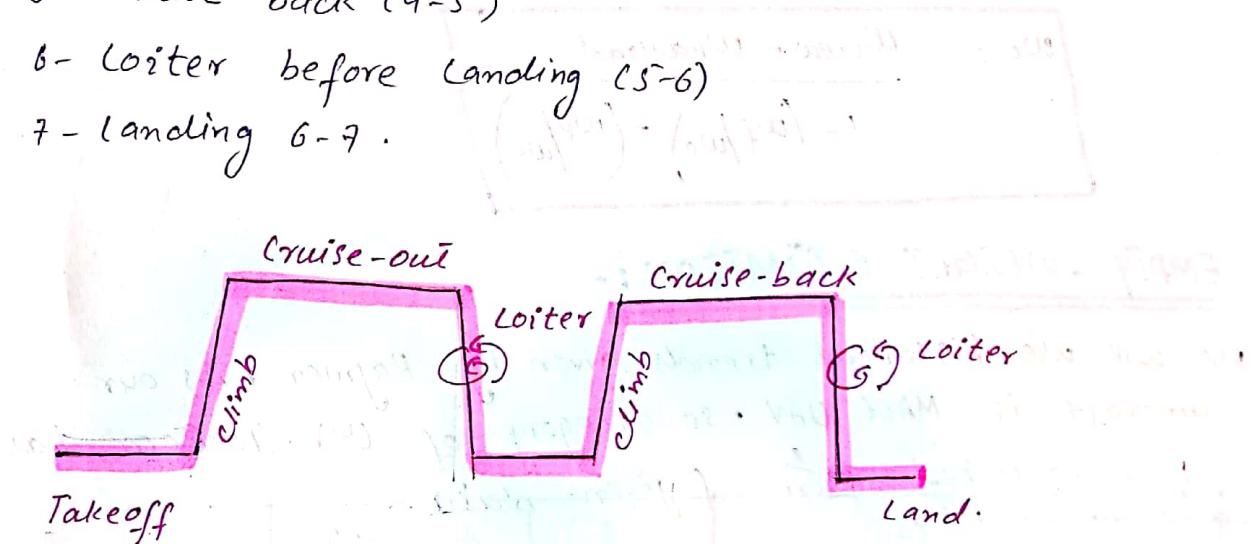
FUEL-WEIGHT-ESTIMATION :-

To calculate fuel fraction, we need specific mission profile.

Mission-profile :-

Generally, mission profile of MALE (UAV) is to take off, climb, cruise out, loiter, cruise back and land.

- 1- Warmup and take off (0-1)
- 2- climb (1-2)
- 3- Cruise out
- 4- Loiter for surveillance (3-4)
- 5- Cruise back (4-5)
- 6- Loiter before landing (5-6)
- 7- Landing (6-7).



Mission Segments (w_i/w_{i-1})

Warmup and take off	0.970
climb	0.985
Landing	0.995

(2)

Warmup and take off = $0.970 = w_1/w_0$ (provided by Raymer)

climb = $\frac{w_2}{w_1} = 0.985$ (provided by Raymer)

Cruise-weight-Fraction =

Breguet-range-equation.

$$R = \frac{V}{C} \frac{L}{D} \ln \left(\frac{w_i-1}{w_i} \right)$$

$$\frac{w_i}{w_{i-1}} = \exp \left(\frac{-RC}{V(L/D)} \right)$$

Now,

$$R = \frac{V}{C} \frac{L}{D} \ln \left(\frac{w_3}{w_2} \right)$$

$$\frac{w_3}{w_2} = \exp \left(\frac{-RC}{V(L/D)} \right)$$

Range

$$R = 650 \text{ nm}$$

$$R = 3.95 \times 10^6$$

Cruise velocity

$$M = V/a$$

$$a\bar{t} = 25000 \text{ ft.}$$

$$M = 0.207 \text{ (Cruise Mach)}$$

$$V = 0.207 \text{ (602)}$$

$$V = 124.614 \text{ m/s}$$

$$V = 210.3 \text{ ft/s}$$

$$\alpha = 602 \text{ l/mois}$$

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for

SPECIFIC FUEL CONSUMPTION:-

Since our engine is piston driven propeller, we will need to find an equivalent specific fuel consumption.

c_{bhp} = equivalent braking specific fuel consumption.

$$c = c_{bhp} \times \frac{V}{550 \times \mu_p}$$

From typical values from Raymer.

For piston prop. $c_{bhp} = 0.4 \text{ (cruise)} = 0.5 \text{ (loiter)}$.

for cruise $\mu_p = 0.8$

$$c = c_{bhp} \times \frac{V}{550 \mu_p} = (0.4 \times \frac{210.3}{550 \times 0.8})$$

$$c = 0.1912/\text{h}$$

for loiter

$$c = c_{bhp} \times \frac{V}{550 \mu_p} = 0.5 \times \frac{210.3}{550 \times 0.8}$$

$$c = 0.2390/\text{h}$$

	Cruise	Loiter
Jet	0.866 l/D _{man}	l/D _{man}
prop	l/D _{man}	0.866 l/D _{man}

- OUT

Dynamic efficiency estimation (C_D)_{max}.

Can calculate it from reference aircraft now.

$$C_D = C_{D0} + k C_L^2$$

for C_{D0} ,

$$C_{D0} = C_{fe} \frac{S_{wet}}{S_{ref}}$$

S_{wet} = wetted area.

C_{fe} = skin friction drag.

$$\log S_{wet} = C + d \log W$$

For single propeller driven aircraft.

$$C = 1.0892$$

$$d = 0.5147$$

$$C_{fe} = 0.0055$$

$$\log S_{wet} = 1.0892 + 0.5147 \log (3000)$$

$$S_{wet} = 756.61 \text{ ft}^2$$

$$C_{D0} = 0.0055 \times \frac{756.61}{150}$$

$$\boxed{C_{D0} = 0.0277.}$$

For k , Oswald efficiency according to Raymer.

$$e = 0.8.$$

$$A_{ref} = 20.9.$$

Since aircraft is subsonic it can be assumed.

$$k = k_1 + k_2 + k_3 = \frac{1}{\pi e A_{ref}} = \frac{1}{3.14 \times 0.8 \times 20.9}$$

$$K = 0.019$$

As

$$\left(\frac{L}{D}\right)_{max} = \frac{1}{\sqrt{4CD_{0,0} \times K}}$$

$$\left(\frac{L}{D}\right)_{max} = \frac{1}{\sqrt{4 \times 0.0277 \times 0.019}}$$

$$\left(\frac{L}{D}\right)_{max} = 21.79$$

from equation

$$\frac{w_3}{w_2} = e^{-39.5(10^6) \times \frac{0.1912}{3600}} \\ = e^{-210.3 \times 21.79}$$

$$\frac{w_3}{w_2} = 0.95525$$

Loiter for Surveillance :-

MALE UAV's are for long endurance.

$$\frac{w_4}{w_3} = e^{-\frac{EC}{(L/D)_{loiter}}}$$

Specific fuel consumption = $C_{loiter} = 0.2390/h$.

endurance = $E = 14 \text{ hrs}$ (general mission profile).

aerodynamic efficiency = $(C/L)_{loiter} = 0.866 (C_p)_{max}$.

$$(C/L)_{loiter} = 0.866 \times 21.79$$

$$\frac{w_4}{w_3} = e^{-\frac{14 \times 0.2390}{18.87}}$$

$$\frac{w_4}{w_3} = 0.8375$$

se - Back

$$\frac{w_5}{w_4} = 0.95525$$

Loiter- Before Landing

time before landing is assuming 1 hour.

$$\frac{w_6}{w_5} = e^{-1 \times 0.2390}$$

$$\frac{w_6}{w_5} = 0.9874$$

Landing

Provided by Raymer, $\frac{w_7}{w_6} = 0.995$

Segment	Fraction	Value
Warmup and take off	w_1/w_0	0.970
climb	w_2/w_1	0.985
cruise - out	w_3/w_2	0.95525
Loiter	w_4/w_3	0.8375
Cruise - back	w_5/w_4	0.95525
Loiter before landing	w_6/w_5	0.9874
Landing	w_7/w_6	0.995

$$\frac{w_f}{w_0} = \frac{w_1}{w_0} \times \frac{w_2}{w_1} \times \frac{w_3}{w_2} \times \frac{w_4}{w_3} \times \frac{w_5}{w_4} \times \frac{w_6}{w_5} \times \frac{w_7}{w_6}$$

$$\frac{w_f}{w_0} = 0.970 \times 0.985 \times 0.9553 \times 0.8375 \times 0.9553 \times 0.9874 \times 0.995$$

$$\frac{w_f}{w_0} = 0.7174$$

Also, to cater for 6% trapped and reserved fuel.

$$\frac{w_f}{w_0} = 1.06 \left(1 - \frac{w_f}{w_0}\right)$$

$$= 1.06 \left(1 - 0.7174\right)$$

$$\frac{w_f}{w_0} = 0.3$$

CREW AND PAYLOAD WEIGHT

Since, it is a UAV, it has no crew.

$$w_{crew} = 0$$

according to mission profile it will have

$$w_{payload} = 600 \text{ lb}$$

payload of

TAKE-OFF WEIGHT ESTIMATION

Note that we have calculated all the fuel and empty weight fraction, we can calculate take-off weight.

$$w_0 = \frac{w_{crew} + w_{payload}}{1 - \frac{w_f}{w_0} - \frac{w_e}{w_0}}$$

using hit and trial method in MATLAB.
The Matlab code is attached at the end.

$$W_0 = 2646 \text{ lb}$$

W_0 (Guess)	W_0 (Obtained)
3000	2541
2541	2683
2683	2634
2634	2650
2650	2645
2645	2647
2647	2646
2646	2646

ERROR

and the error value is calculated as.

$$\% \text{Error} = \frac{3000 - 2646}{3000} \times 1000 = 11.8\%$$

$$\boxed{\% \text{Error} = 11.8\%}$$

The error is under limit of 12% which is good. As we will do refined sizing the error is expected to further reduced. The reason for that is this is crude sizing. The mission profile needs to be further refined and segments should be well-defined. A lot of assumptions were also taken into calculations because initially we need to see take-off weight of aircraft. Anyhow, this is not all bad.

as it is very close to required take off weight
shy of 11.8%.

CONVERGENCE

TRADE-STUDIES

Trade study is important part of conceptual design, the evaluation and refinement of conceptual design with the customer. Trade studies are done by changing different parameters like range and payload one at a time by keeping other constant to see their effect on weight, which is then analyzed. We will do three trade-off studies.

- 1 - Range trade off
- 2 - Payload trade off
- 3 - Composite material trade off.

RANGE - TRADE

For range off only cruise segment need to be calculated for every range and then takeoff weight is calculated.

Range (nm)	Weight (lb)
350	2148
400	2211
450	2326
500	2403
550	2496
600	2553
650	2646
700	2703
750	2815

CONVERGENCE GRAPH FOR INITIAL SIZING



In the previous figure, we can see that from increasing more fuel is required and thus takeoff weight increases.

PAYLOAD WEIGHT TRADE

In payload trade, the segment weight fractions, fuel fraction is unchanged. In take off weight estimation, only payload weight is change. The table is obtained by iterations.

Payload	Weight
200	1218.1
300	1602.5
400	1964.3
500	2310.8
600	2646.1
700	2972.7
800	3292.2
900	3605.7
1000	3914.2

From the next graph we can see that on increasing payload, take off weight increases.

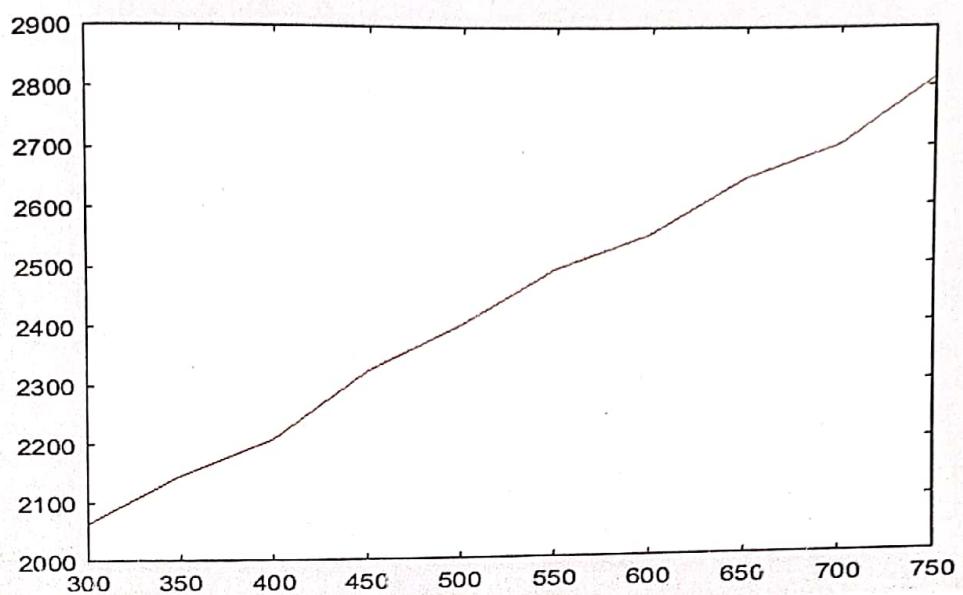
COMPOSITE MATERIAL TRADE

To see the effects of composite material, the empty weight fraction is reduced to 95% of its value. The take off weight and composite material trade comes out to be.

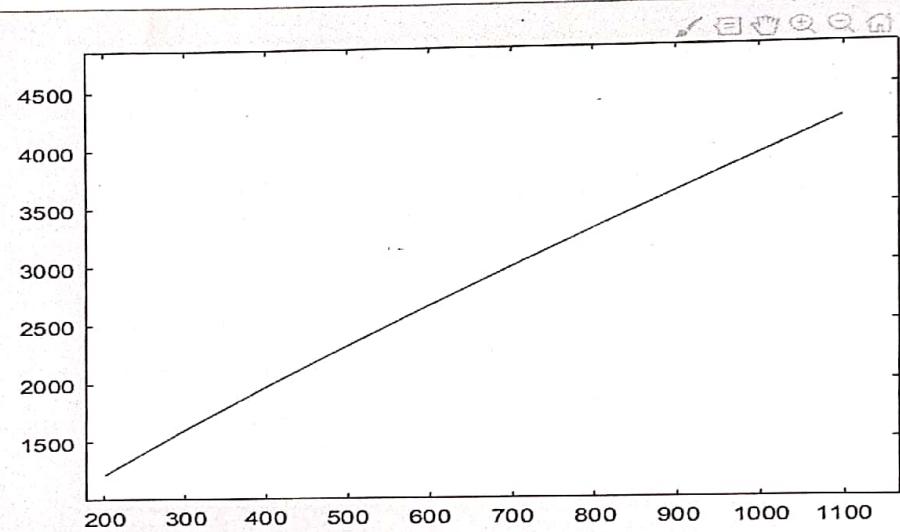
$$W_0 = 2450 \text{ lb.}$$

The plot is given on next page.

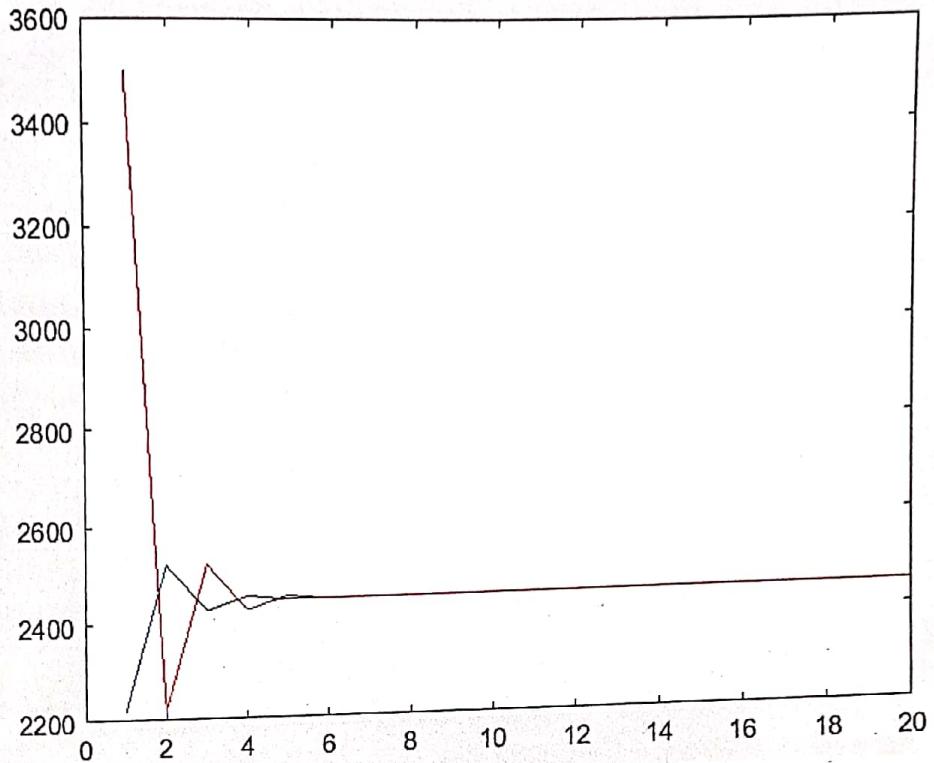
RANGE VS WEIGHT



PAYOUT VS WEIGHT



COMPOSITE TRADE-OFF



EMPTY WEIGHT FRACTIONS VS. W_0

$W_e/W_0 = AW_0^C K_{vs}$	A	(A-metric)	C
Sailplane—unpowered	0.86	{0.83}	-0.05
Sailplane—powered	0.91	{0.88}	-0.05
Homebuilt—metal/wood	1.19	{1.11}	-0.09
Homebuilt—composite	1.15	{1.07}	-0.09
General aviation—single engine	2.36	{2.05}	-0.18
General aviation—twin engine	1.51	{1.4}	-0.10
Agricultural aircraft	0.74	{0.72}	-0.03
Twin turboprop	0.96	{0.92}	-0.05
Flying boat	1.09	{1.05}	-0.05
Jet trainer	1.59	{1.47}	-0.10
Jet fighter	2.34	{2.11}	-0.13
Military cargo/bomber	0.93	{0.88}	-0.07
Jet transport	1.02	{0.97}	-0.06
UAV—Tac Recce & UCAV	1.67	{1.47}	-0.16
UAV—high altitude	2.75	{2.39}	-0.18
UAV—small	0.97	{0.93}	-0.06

K_{vs} = variable sweep constant = 1.04 if variable sweep = 1.00 if fixed sweep.

APPENDIX

User

$$W_o = \frac{(W_{crew} + W_{payload})}{(1 - W_f/W_0)} - \frac{W_e/W_0}{}$$
$$W_o = \frac{(0 + 600)}{(1 - 0.3 - 1.67 * W_o^{-0.16})}$$

Using hit and trial method in MATLAB,

$W_o = 2646$ lb.

write matlab code for it

ChatGPT

Certainly! Here's how you can implement the hit and trial method in MATLAB to solve the given equation for W_o :

```
matlab
Copy code
% Define the equation
equation = @(Wc) (600) / (1 - 0.3 - 1.67 *
Wc^(-0.16)) - Wo;
% Set tolerance for convergence
tolerance = 1e-6;
% Initial guess for Wo
guess = 2000;
% Perform hit and trial method
while abs(equation(guess)) > tolerance
    guess = guess + 0.1; % Increment the guess
    (you can adjust the step size)
end
% Display the result
fprintf('Wo = %.2f lb.\n', guess);
```