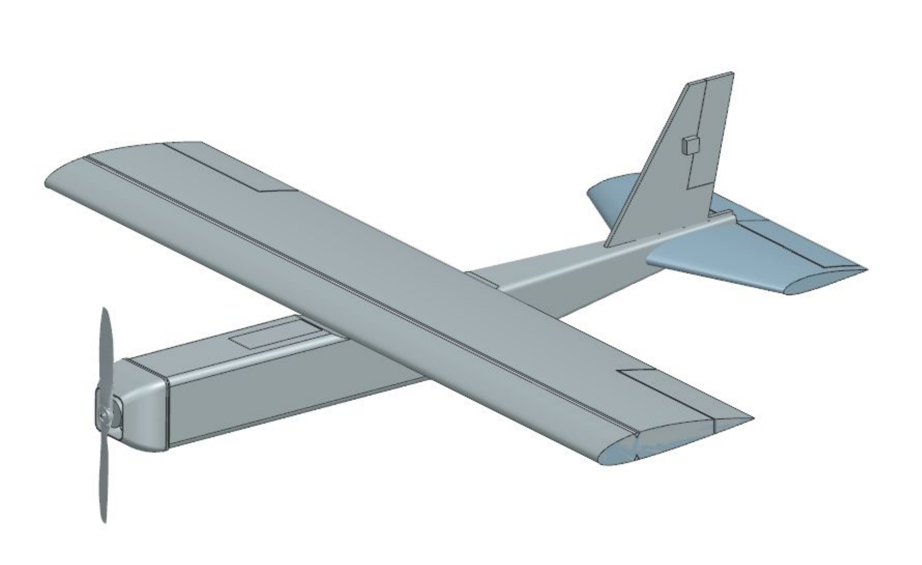
Conceptual Design Review



AAE 451 - Senior Design; Aircraft Desig

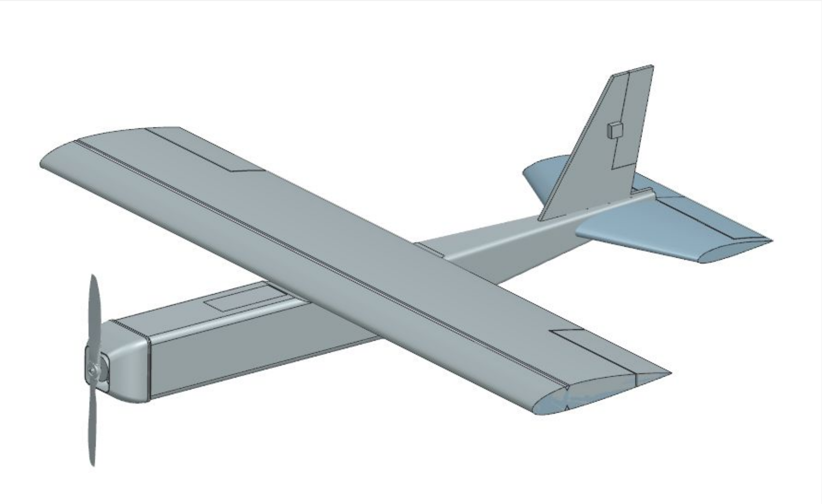
Team 5 - Lamarvelous

By Nathen Carey, Aidan Doyle, Mike Flanagan, Max Gorlich, Jose Lara, Ashwin Nathan, and Dhruv Wadhwa

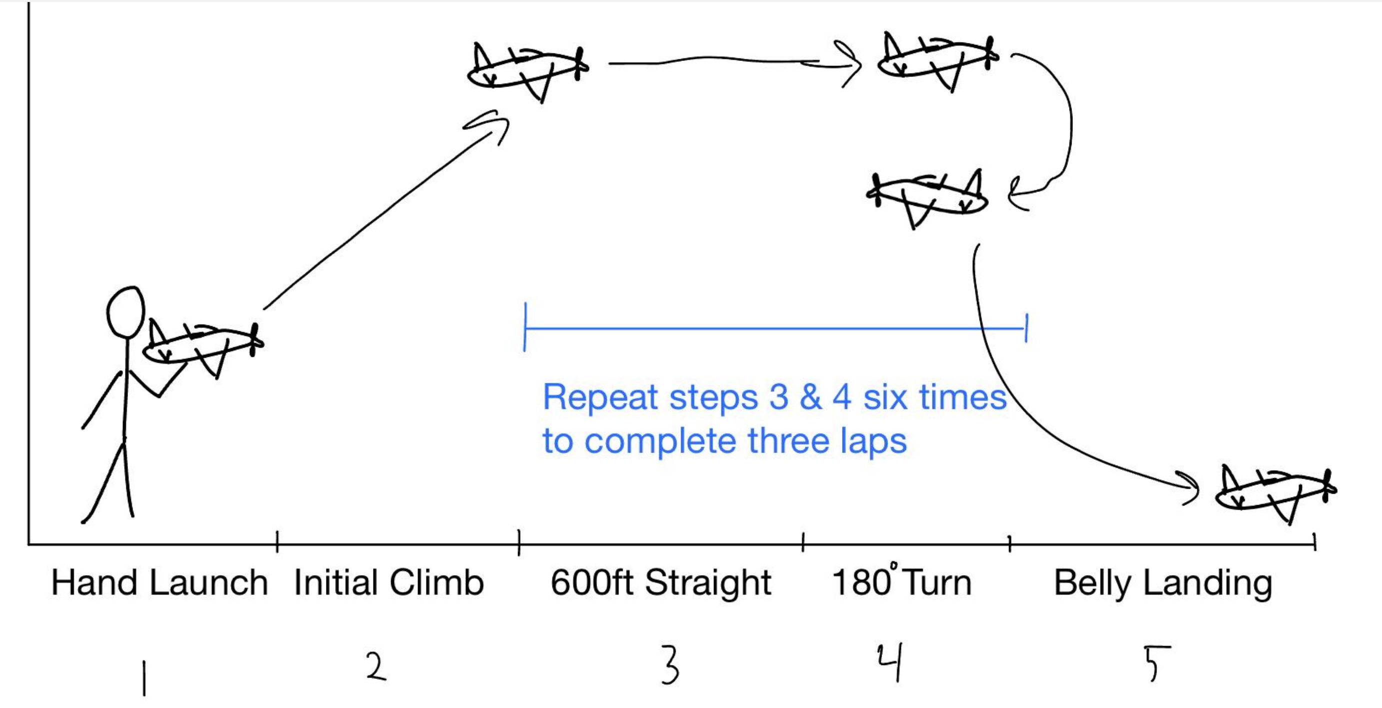
Executive Summary

In this project, our team will design, build, and fly a remote-controlled aircraft around a preconceived flight course. There are several project milestones that we will utilize to show the progression of our design and share any and all major engineering decisions we make. This project milestone is the Conceptual Design Review (CDR).

- Detail the final design of our chosen RC Aircraft
  - Sizing
  - Weights
  - Structures
  - Aerodynamics
  - Propulsion
  - Stability/Controls
- Objectives + High Level Requirements
- Discuss down-selection process
- Cost
- Fabrication/Manufacturing Plan

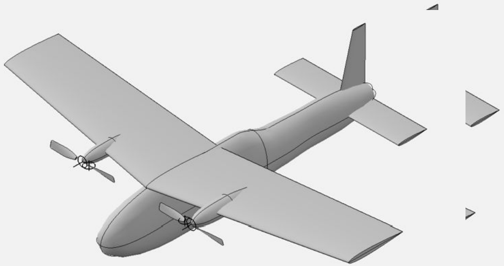


Project Objective and High Level Requirements

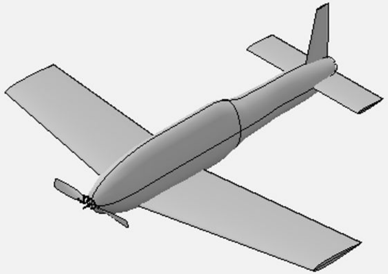


Best Aircraft Concept: Downselection

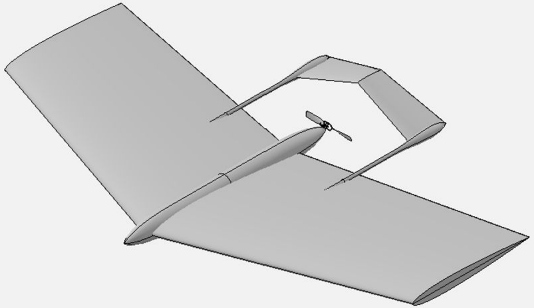
SRR+SDR Final Concepts:



High Wing, Twin Tractor



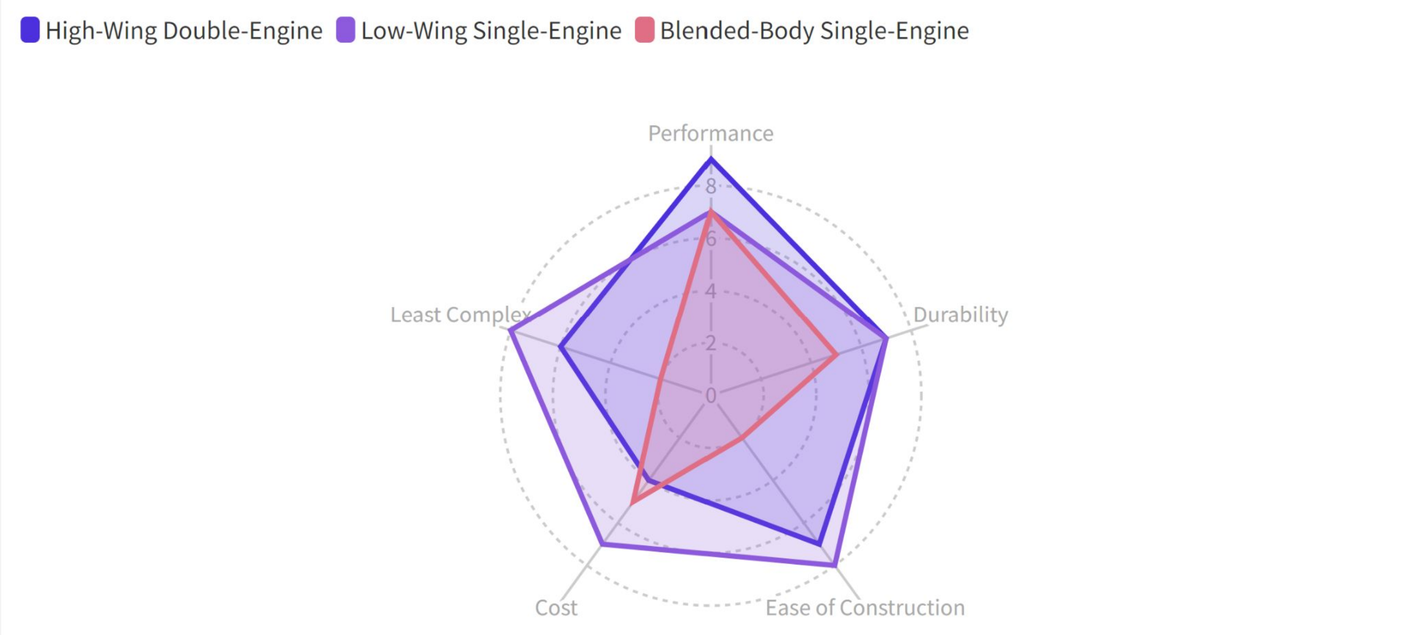
Low Wing, Single Engine Puller



Blended-Body Single-Engine Pusher

Best Aircraft Concept: Downselection

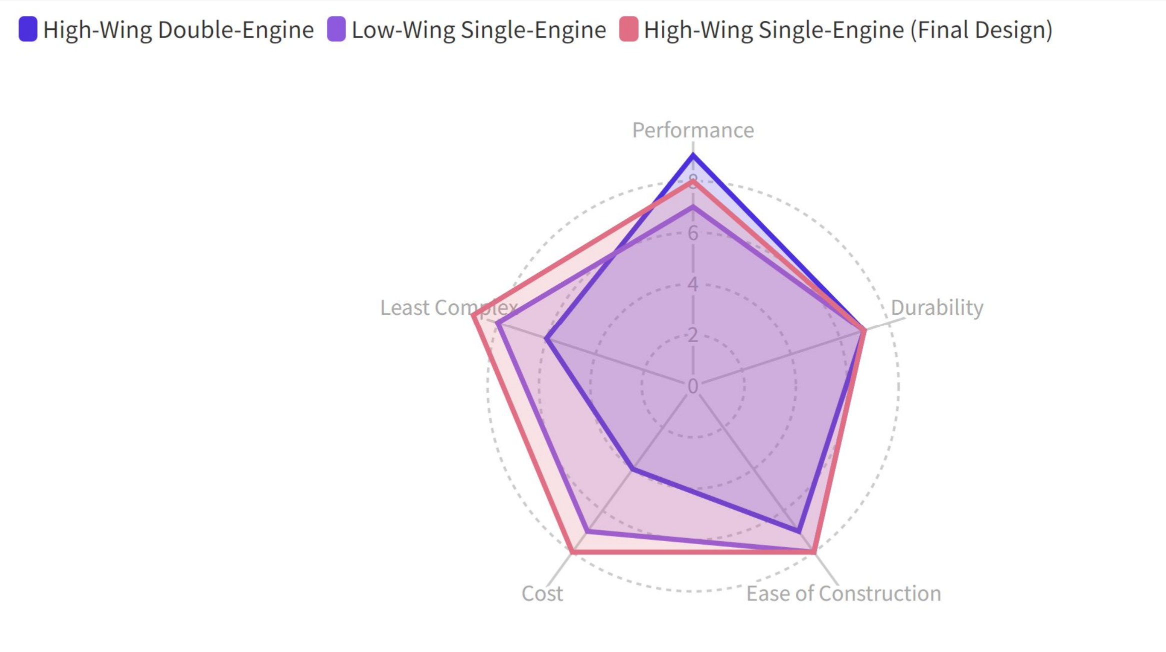
Eliminated Blended Body due to high complexity and high difficulty of construction

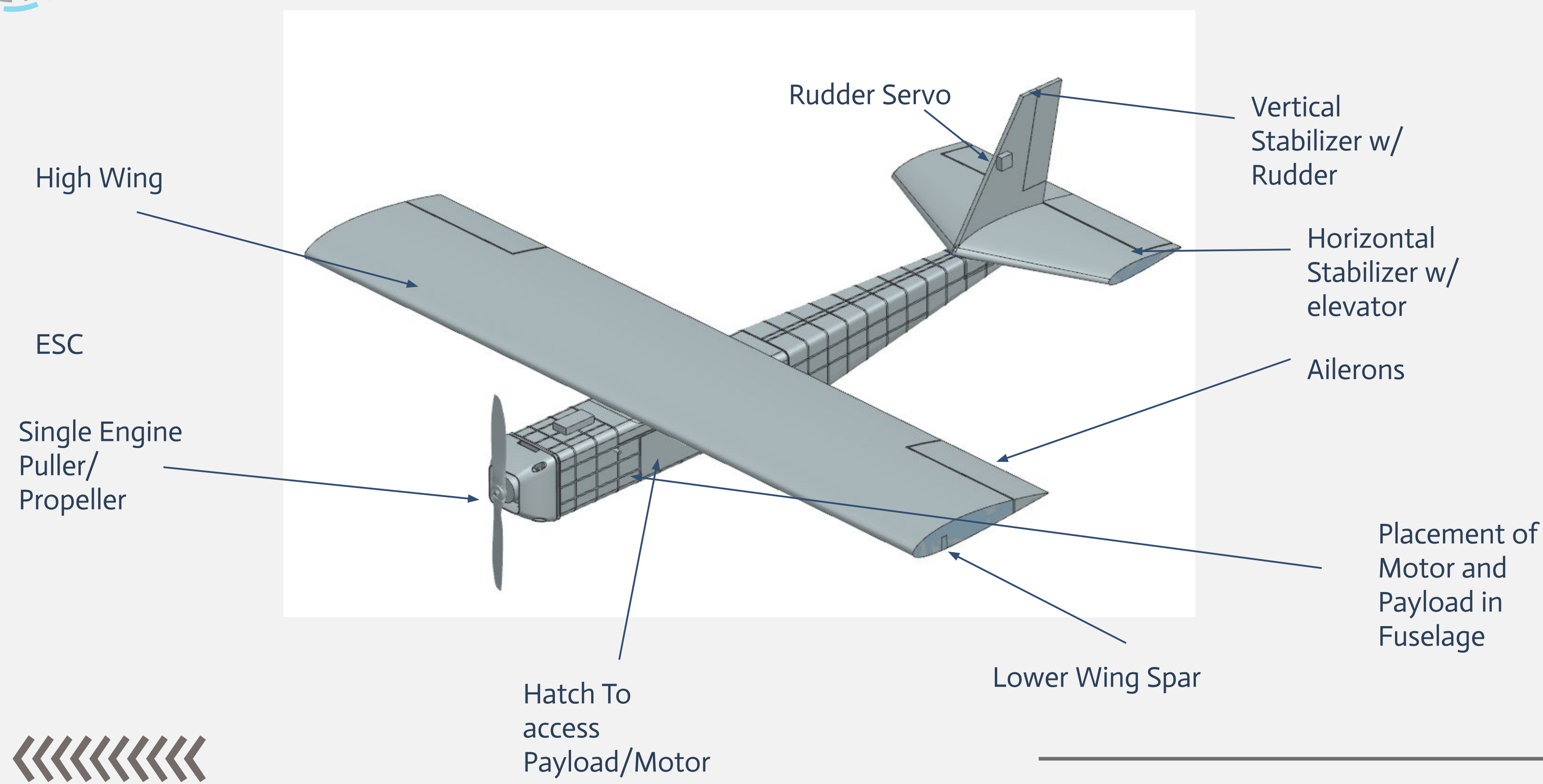


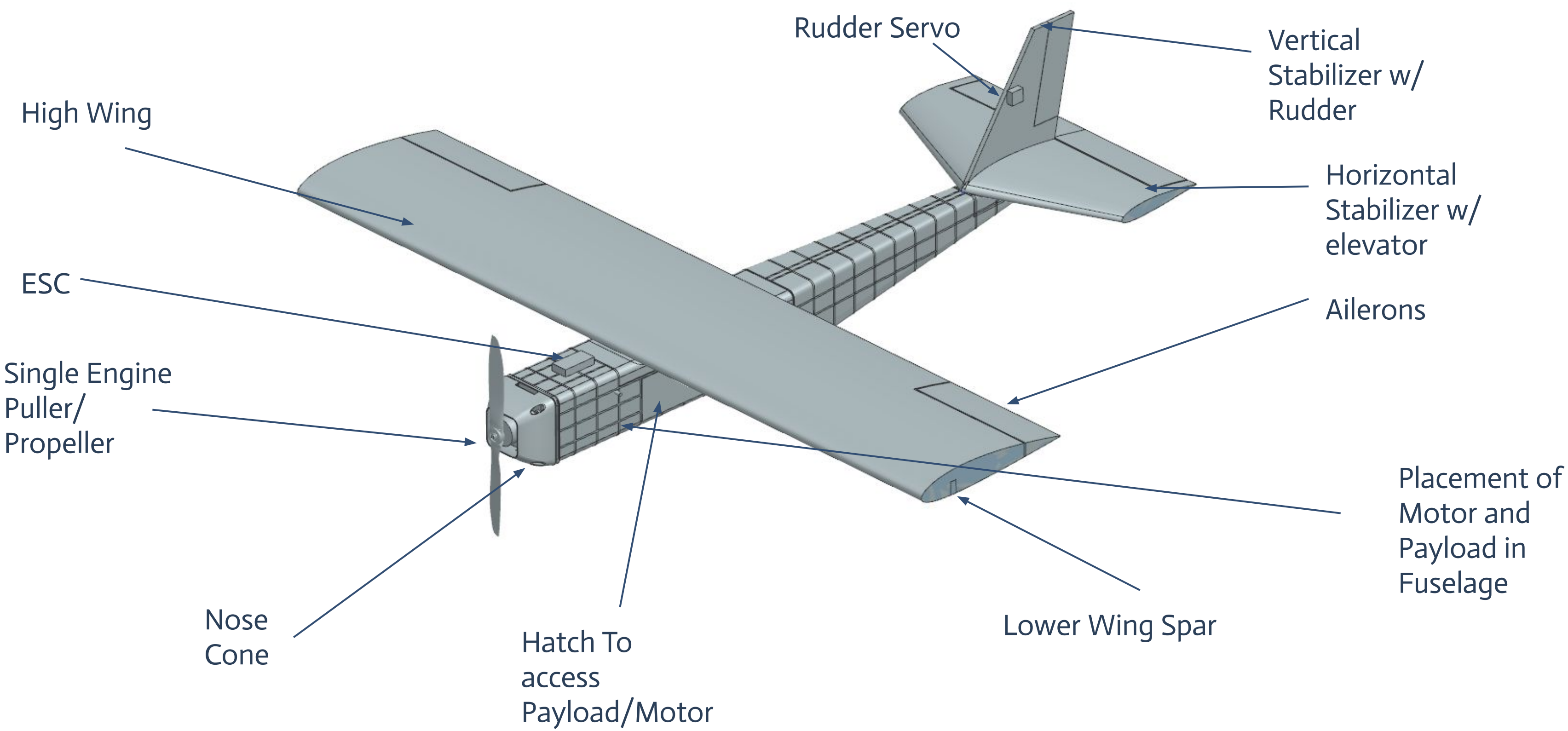
Best Aircraft Concept: Downselection

Decided to Combine other two designs.

- Single Engine Puller for easier construction and less complexity
- High wing allowing better grip for hand throwing take-off



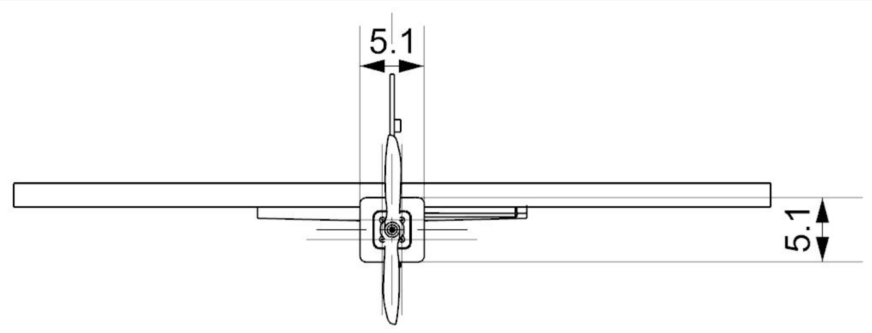

Rudder Servo
Vertical Stabilizer w/ Rudder
High Wing
Horizontal Stabilizer w/ elevator
ESC
Ailerons
Single Engine Puller/ Propeller
Placement of Motor and Payload in Fuselage
Lower Wing Spar
Hatch To access Payload/Motor

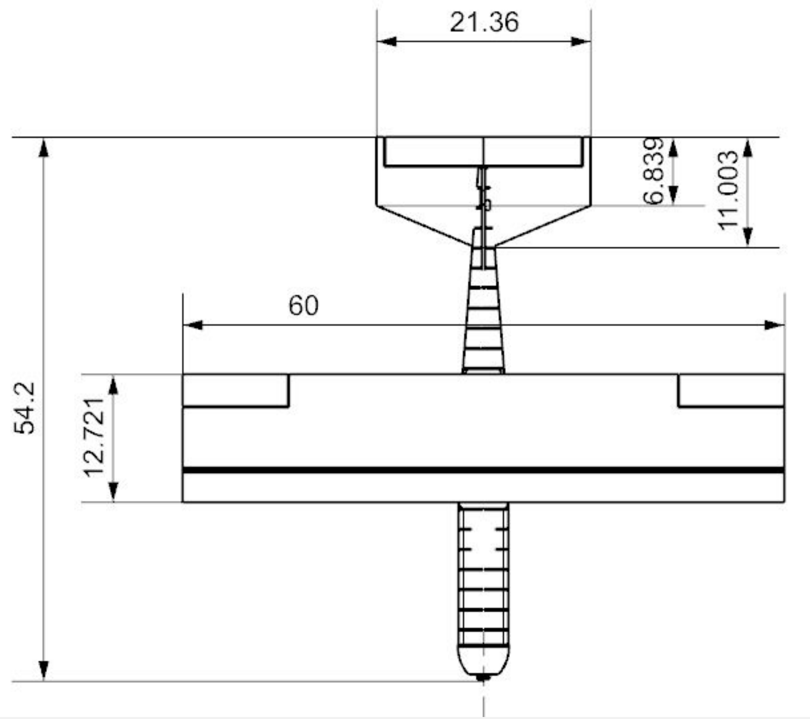

Rudder Servo
Vertical Stabilizer w/ Rudder
High Wing
Horizontal Stabilizer w/ elevator
ESC
Ailerons
Single Engine Puller/ Propeller
Placement of Motor and Payload in Fuselage
Nose Cone
Hatch To access Payload/Motor
Lower Wing Spar

Best Aircraft Concept: Design Parameters

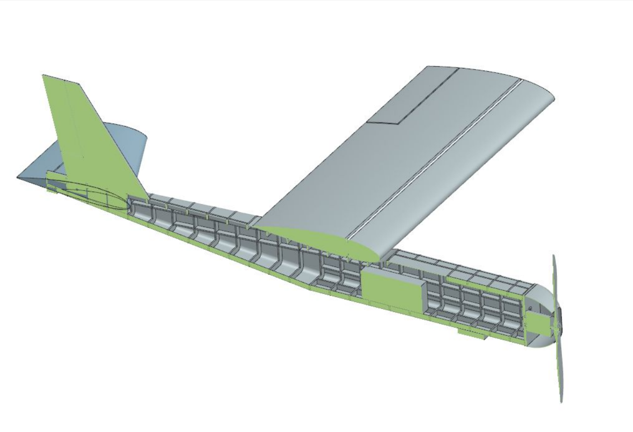
Gross Weight	7.6 lbs / 50% increase is 11.4lbs
Payload	1.136 lb_f
Wing Loading	1.445 lb_f / ft^2
Wing Area	5.31 ft^2
Wing Aspect Ratio	4.71
Thrust to Weight ratio	1.31/ 0.87 for 50% increase in weight
Cost	$380.47

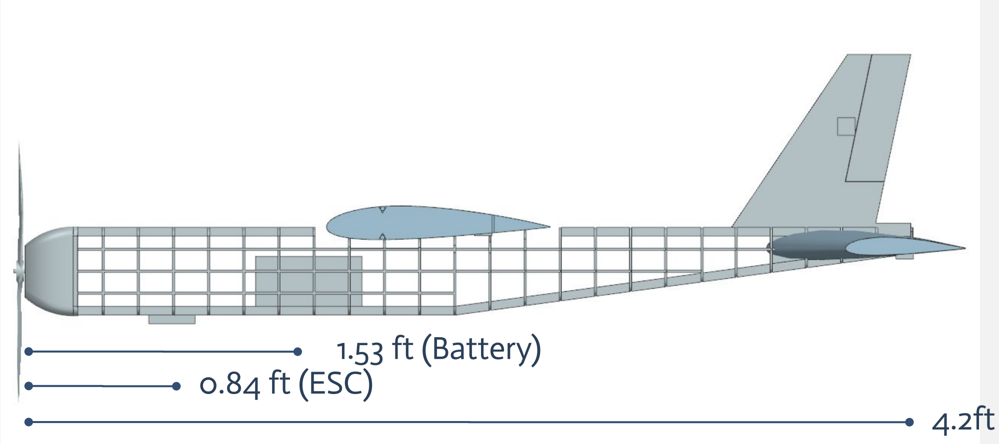
Advanced Aircraft Description: External Layout





Advanced Aircraft Description: Internal Layout



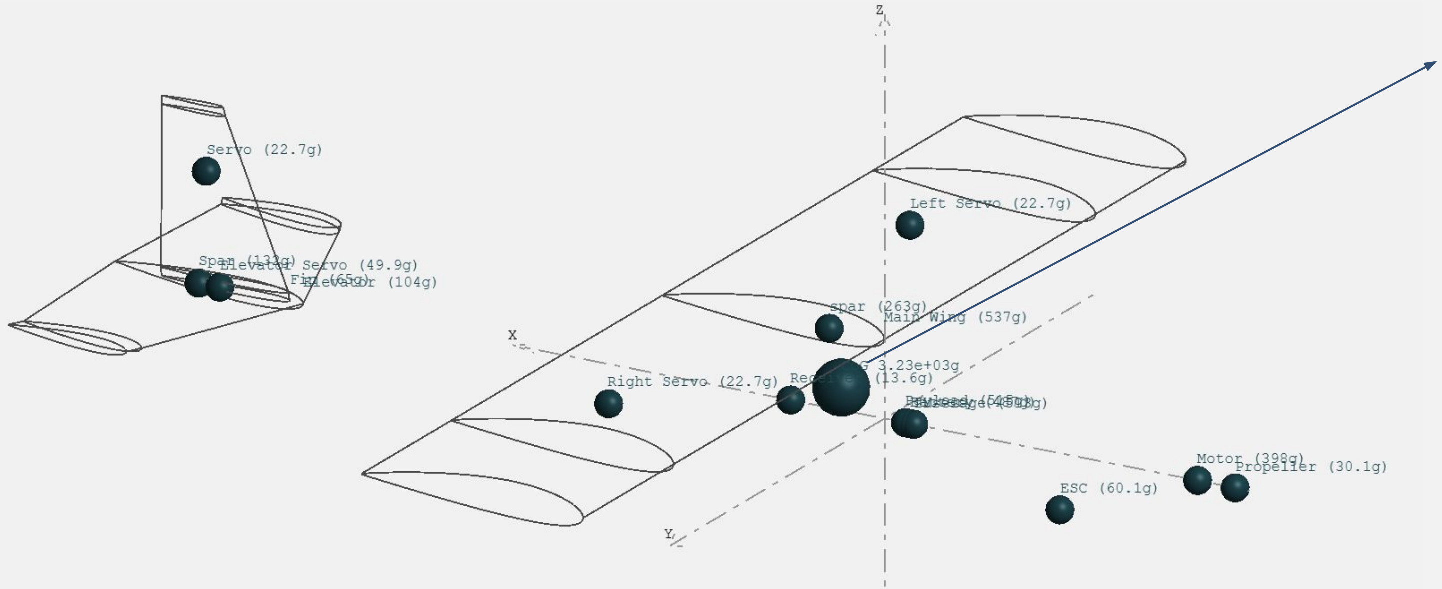


Weights and Balance: Group Weight Statement

	Weights(lbs)	Location(ft)	Moment(ft-lbs)
Structures	3.41		7.42
Wing	1.76	1.68	2.96
Tail	0.66	4.5	2.97
Fuselage	0.99	1.5	1.49
Propulsion	1.08		0.39
Motor	0.88	0.18	0.16
ESC	0.13	0.84	0.11
Propeller	0.07	1.68	0.12
Equipment	0.29		0.96
Aileron servos	0.10	2.28	0.23
Elevator	0.11	4.2	0.46
Rudder Servo	0.05	4.1	0.21
Receiver	0.03	2.13	0.06
Total Empty Weight	4.78		8.77
Useful Load	2.21		3.41
Payload	1.14	1.58	1.8
Battery	1.07	1.5	1.61
Total Gross Weight	6.99		12.18

Weights - XFLR5 View

Center of Gravity



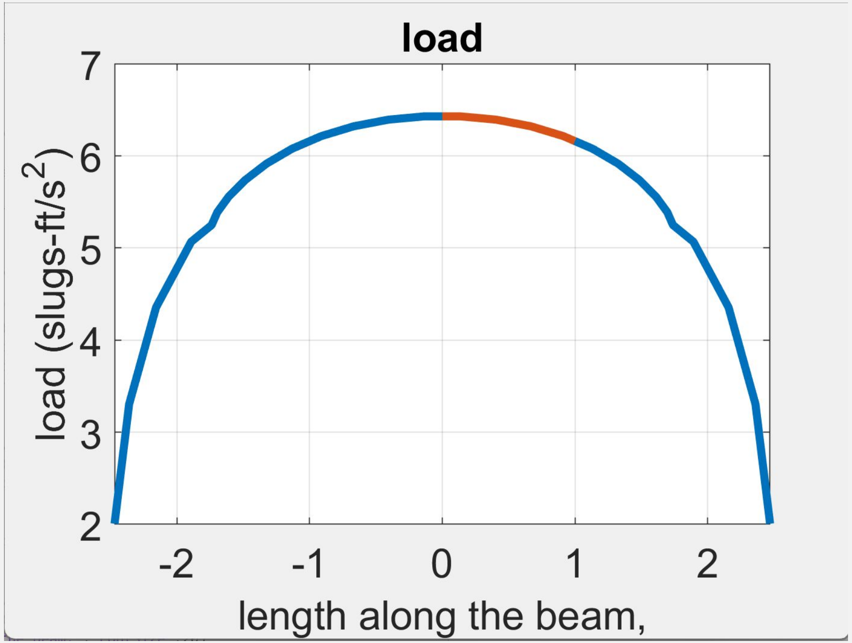
CG is 1.89ft Aft of Nose
CG 0.053ft Forward from the Wing Quarter Chord

Structures - Material Selection

Structure	Materials	Reasoning
Fuselage	Balsa Wood	Light but relatively strong material, easy to manufacture, relatively low in cost
Wing - NACA 2415	Foam with Aluminium Spars	Easy to manufacture, low in cost. Spars add structural integrity at low cost and weight.
Horizontal Stabilizer - NACA 0012	Foam with Aluminium Spars	Similar reasoning to wing.
Vertical Stabilizer	Balsa Wood	Stronger than foam, singular control surface so needs to be more rigid to allow for increased controllability.

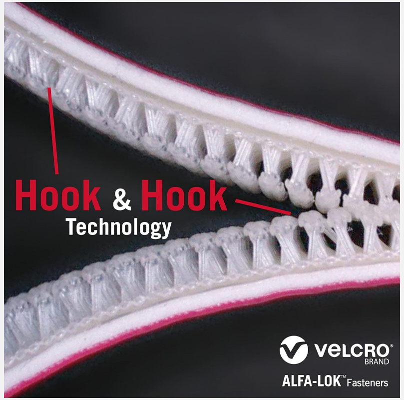
Structure: Critical Load Paths

- To assist with structural integrity, we will utilize ribs in the fuselage.
- In the wings, we will utilize two thin aluminum rods as spars.
  - Minimizes cost and weight.
- Horizontal Stabilizer will feature a structure similar to the wings.



Structure: Wing Fuselage Intersection

- Velcro
  - Hook and Hook
- Rubber Bands
  - Stretch across wings in x shape
  - Connect to pins



Surface Area of wing in contact with fuselage: 60in^2
Max Weight capacity of Velcro: 2.5 lbs/in^2

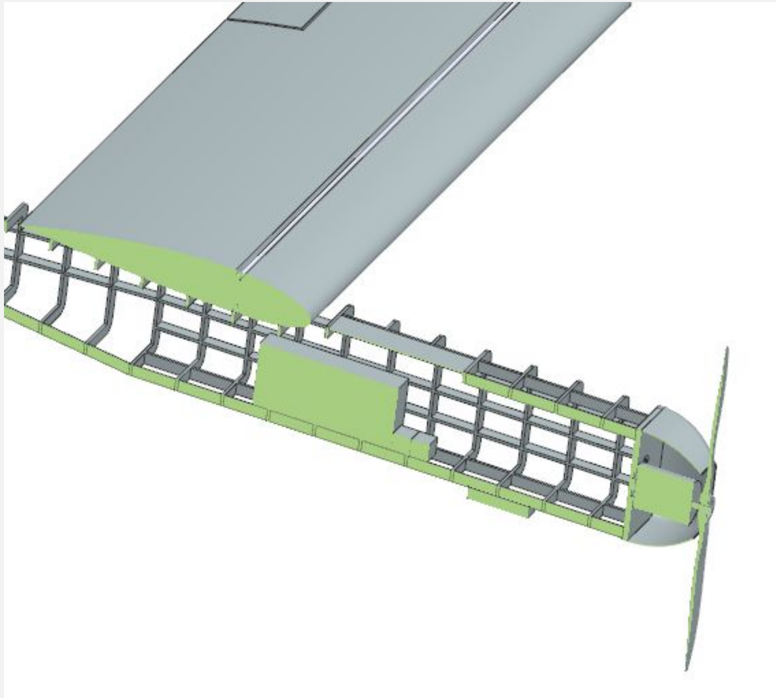
Max Weight possible: 150 lbs

Weight of Aircraft: 7.62 lbs
Factor of Safety: 1.5
Minimum allowable design weight: **11.4 lbs**

Estimated Max force expected: **≈ 7 lbf**

Structure: Payload and Battery Placement

- Small box located between leading edge and nose of the plane
- Will hold both payload and battery.
- Small velcro strips within box will keep items in place.
- ESC on outside of plane to avoid overheating

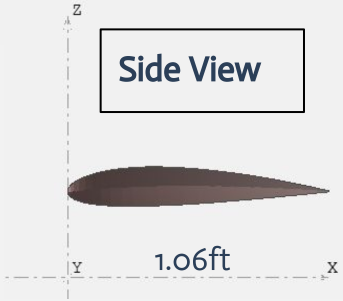


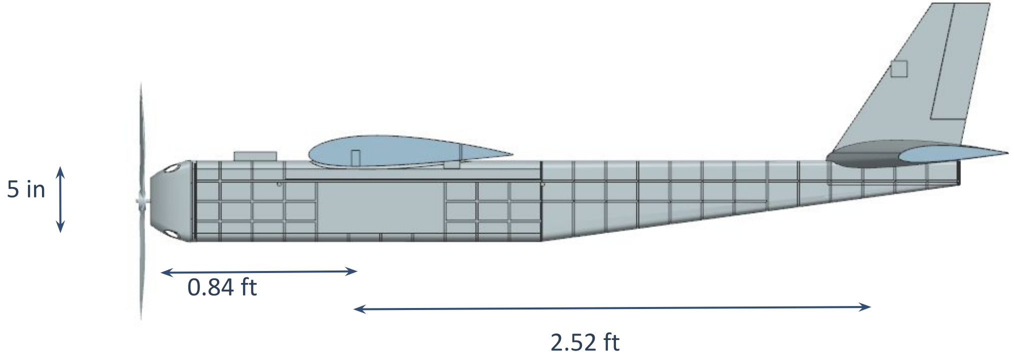
Aerodynamic Design: Wing Design

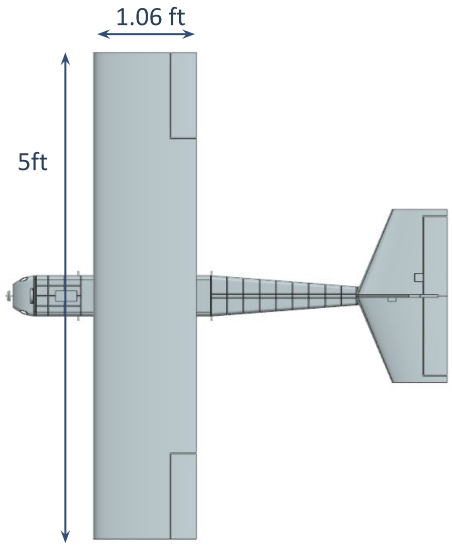
WING DESIGN	
Span	5 ft
Chord	1.06 ft
Area	5.31 ft^2
Airfoil	NACA 2415
Aspect Ratio	4.71
Taper	NONE
Sweep	NONE
Dihedral	NONE

Top View

Side View




5 in
0.84 ft
2.52 ft


1.06 ft
5ft

Aerodynamic Design: Drag Buildup

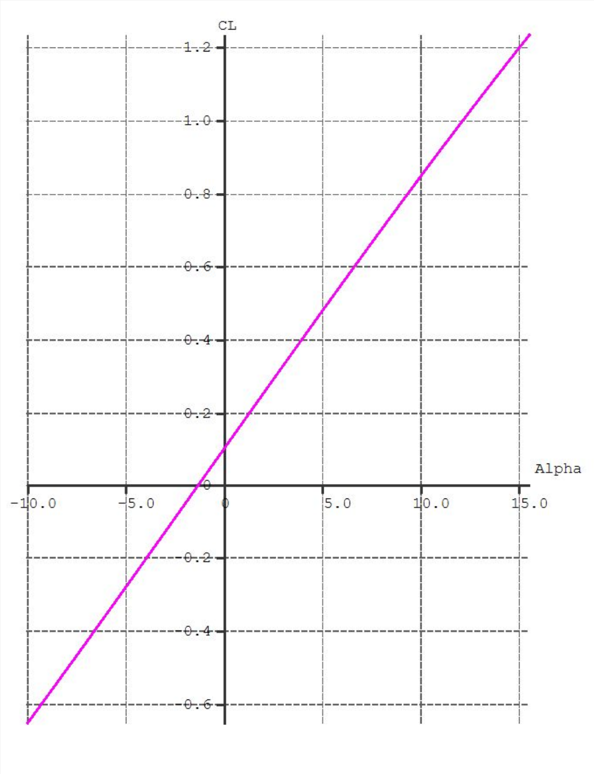
DRAG BUILDUP (IN CLASS METHOD)	
Parasitic Drag CDo	0.02042
Induced Drag at Cruise CDi	0.00891
Misc Drag CD,misc	0.08*CDo (8% of Parasitic Drag)
Total CD	**0.02933**

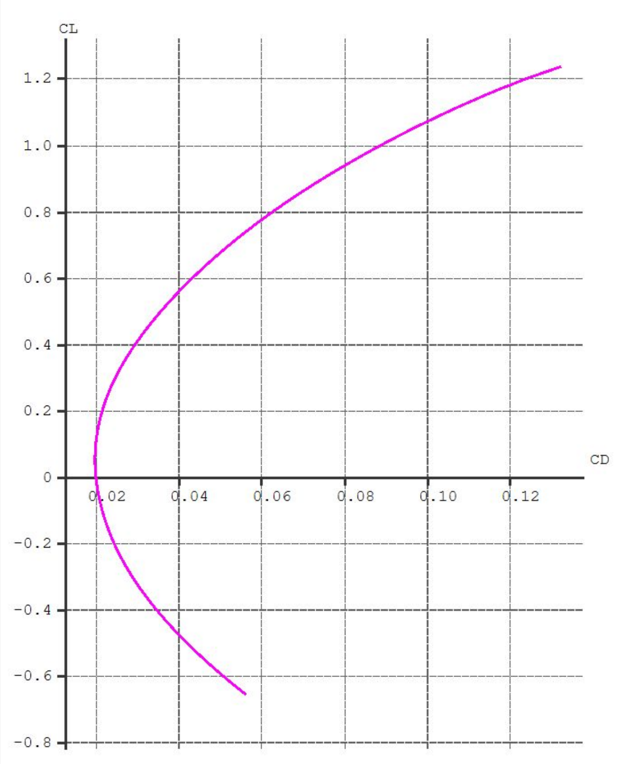
Drag Polar from XFLR5

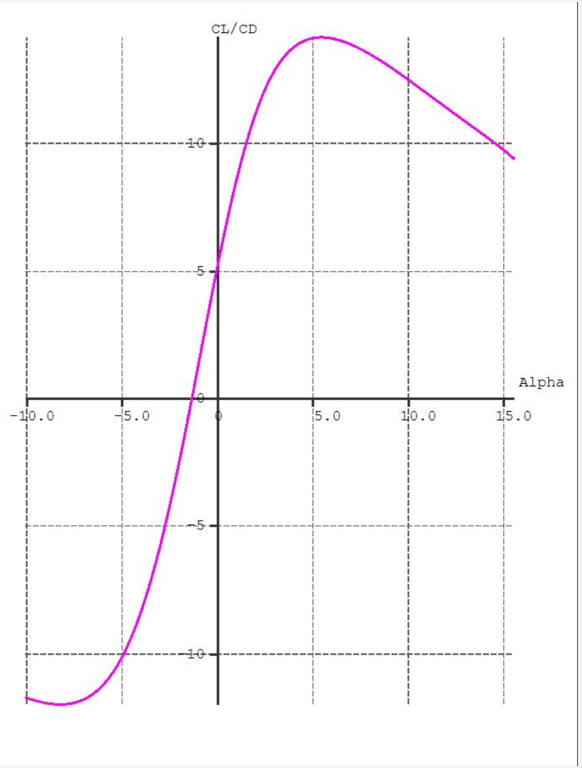
Aerodynamic Design: Lift, Drag, and Thrust

	Lift (lbf)	Drag(lbf)	Thrust Needed (lbf)	Thrust Available(lbf)
Takeoff	16.67	1.53	1.60	8.31
Cruise	7.67	0.92	0.92	8.99

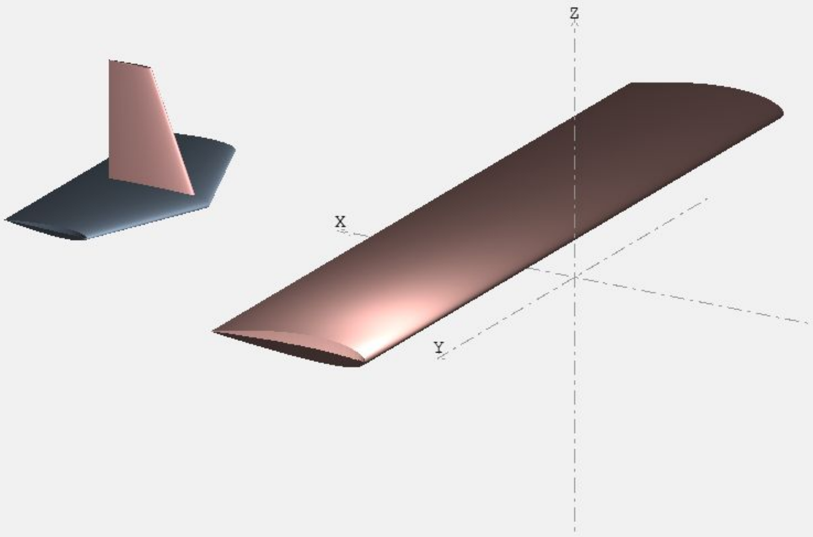
Aerodynamics - XFLR5 Plots

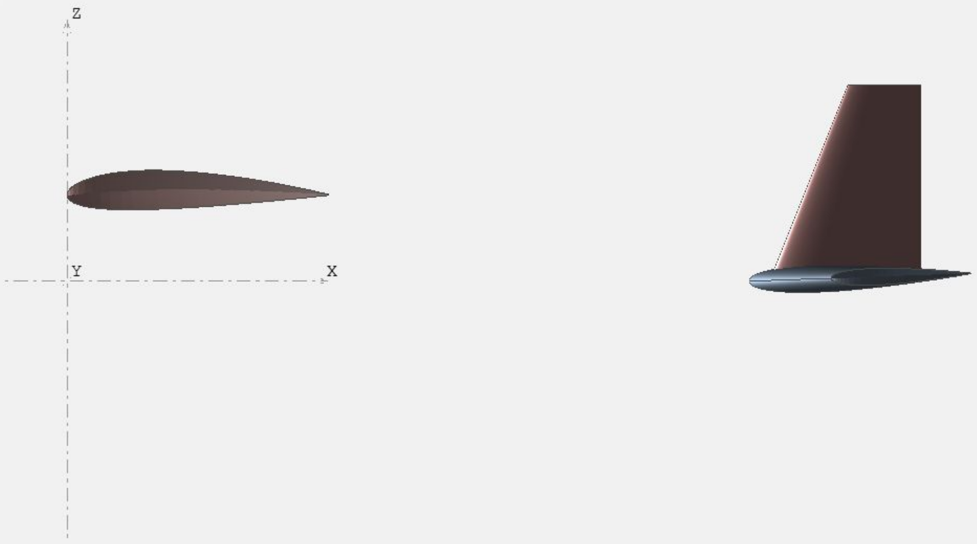






XFLR5 View





Mission Performance Discussion: Essential Characteristics

Takeoff Duration	1.1 sec
Climb Duration	10.63 sec
Cruise Duration	78.44 sec
Descent Duration	21.64 sec
Total Duration	111.8 sec

L/D_{cruise}	9.67
Cruise Altitude	200 ft

Takeoff Velocity	12.649 ft/s
Cruise Velocity	70 ft/s
Rate of Climb	18.8 ft/s

Takeoff Energy Consumption	40.25 J
Climb Energy Consumption	2,818 J
Cruise Energy Consumption	14,982 J
Descent Energy Consumption	4,788 J
Total Energy Consumption	22,628 J

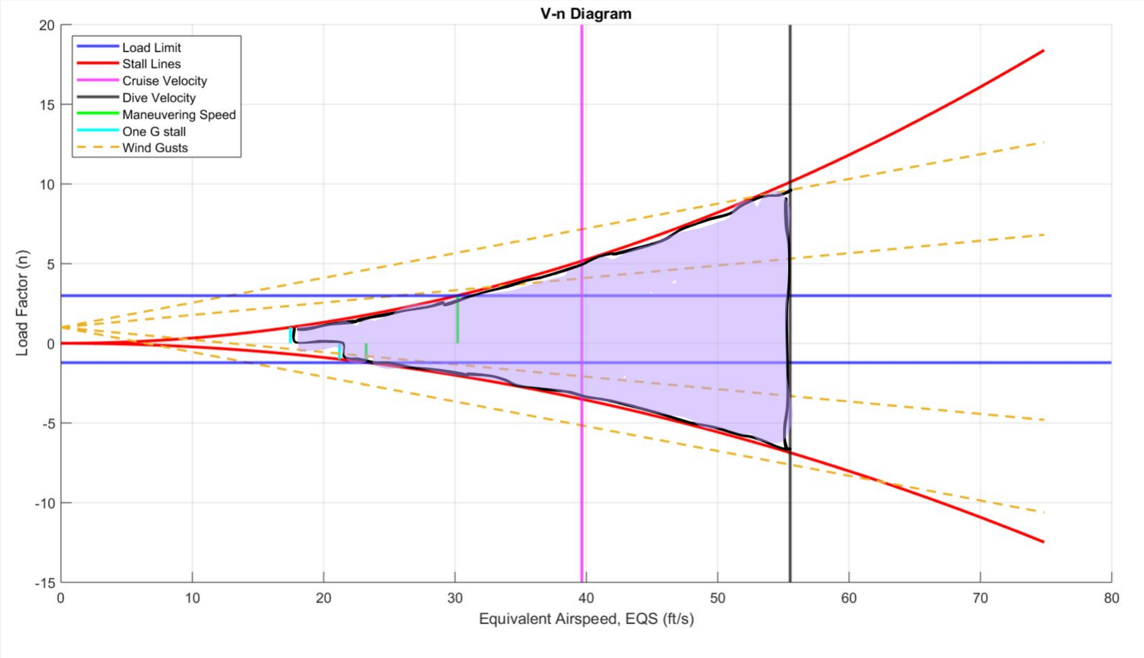
Mission Performance Discussion: Compliance Matrix

Requirement	Threshold	Target	Current Value
Cruise Speed	40 ft/s	70 ft/s	70 ft/s
Payload	0.284 lbs	2 lbs	1.14 lbs
Ease of Construction	We need to be able to construct the vehicle before the flight date.	Simple structural design using straight edges.	Using Velcro Wing Attachment
Storage and Assembly	Must fit inside a 30in x 30in x 60in container and be able to assemble on site.	Same as threshold.	Fits
Stability and Controllability	Easy to fly by an external pilot.	Intuitive controls and stable aircraft.	Stable
Range	3600 ft + 6 Turns + Initial Climb	1 Mile, 5280 ft	Meets Range Threshold
Cost	< $400	$300	380.47
Structural Durability	Must withstand flight conditions and a belly landing.	Same as threshold.	Meets except for propellor strike.

V-N Diagrams

Design Cruise Speed of 40 ft/s

Maneuvering Speed of 30 ft/s



Propulsion

https://www.rcelectricparts.com/80a-esc---classic-series.html

Propeller	
Model	APC 13x6.5E
Diameter [in]	13.0
Pitch [in]	6.5

Motor	
Model	Cobra 4130/12
Kv [rpm/V]	540
Max Current [A]	65
Max Power [hp]	1.93

LiPo Battery	
Brand	Liperior
Capacity [mAh]	3300
Discharge [C]	30
Cells	6S

ESC	
Brand	RC Electric Speed
Max Current [A]	80
Burst Current [A]	100
Voltage Range [V]	6-26
BEC Output	6 Amps at 5.5 Volts

Propulsion

Power Constraint	
Model Weight [lbf]	7.672
Safety Factor	1.5
Safety Weight* [lbf]	11.508
Power Required [hp]	1.03

Power Plant	
Max Current Draw [A]	51.38
Electrical Power [hp]	1.41
Mechanical Power [hp]	1.29
T/W*	0.87
Max RPM	10,152

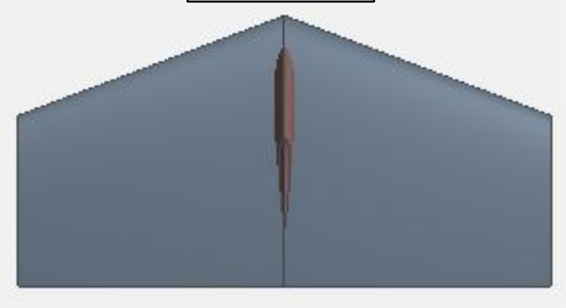
Calculations performed at 4 degree Celsius, 0 ft Altitude.
Max Thrust = 4540.5 grams = 10.01 lb_f

Stability and Control

We used Raymer Equations to size our horizontal and vertical stabilizers

Vertical Tail	Span = 0.80 ft c = 0.53 ft (taper = 0.65) c_t = 0.61 ft, c_r = 0.30 ft	AR = 1.5 Lv = 2.52 ft
Horizontal Tail	Span = 1.78 ft c = 0.76 ft (taper = 0.6) c_t = 0.57 ft, c_r = 0.94 ft	AR = 2.35 Lh = 2.52 ft

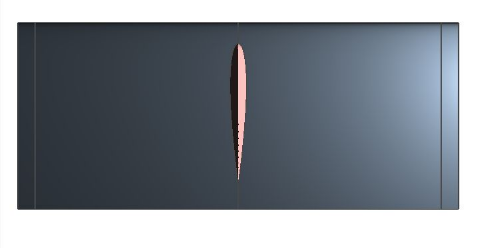
Top View



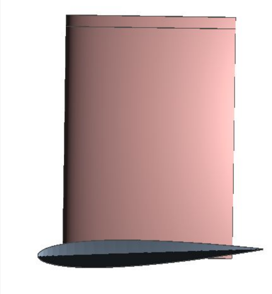
Side View

We used Raymer Equations to size our horizontal and vertical stabilizers

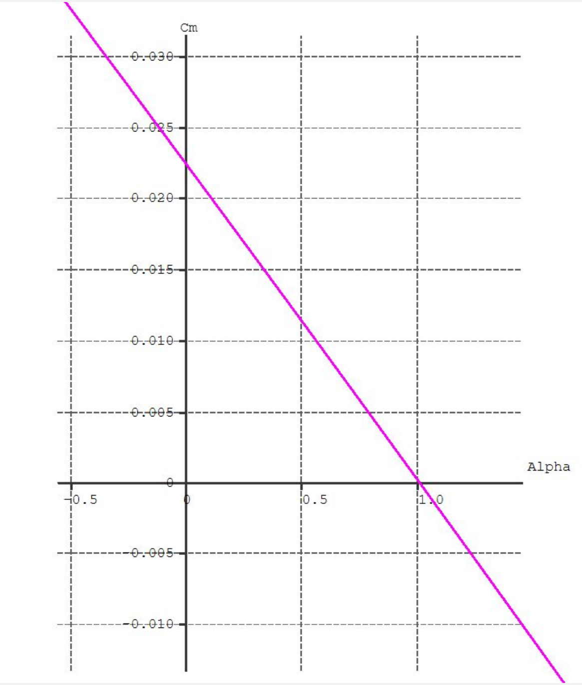
Top View



Side View



Stability and Control



Positive $C_{m,o}$, negative $C_{m,alpha}$

Longitudinal Stability prerequisite met.

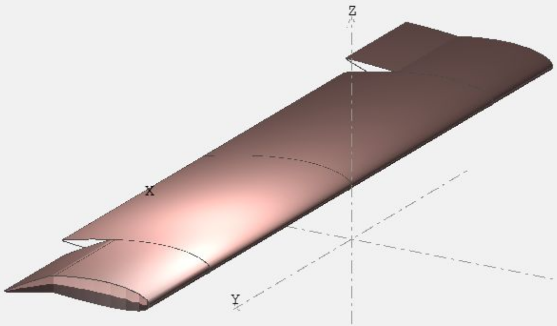
Neutral Point x_{NP} = 0.524 ft (aft of LE)

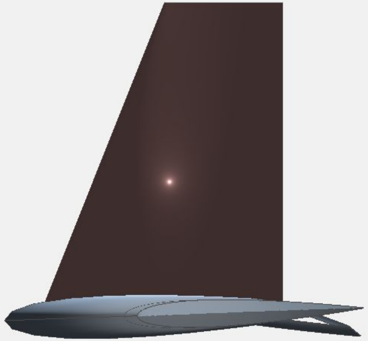
Static Margin = $(x_{CG} - x_{NP})$ = -.31 -> 31%

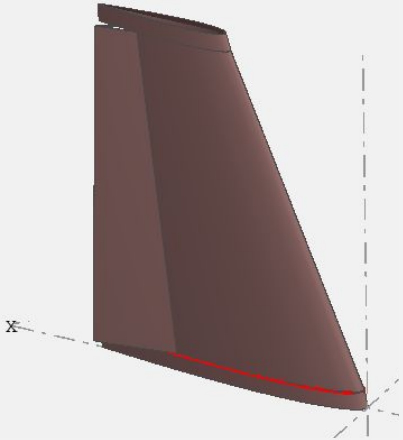
Control Surface Sizing

Ailerons → 35% span of wing, 25% chord of wing
Rudder → 90% span of Horizontal Tail, 30% chord of Horizontal Tail
Elevators → 92.5% span of Vertical Tail, 32.5% chord of Vertical Tail

	Span	Chord
Ailerons	1.75 ft	0.27 ft
Rudder	0.72 ft	0.16 ft
Elevator	1.65 ft	0.25 ft







Servos Sizing and Placement

Elevator:
1 x HS-311 Standard Voltage Resin Gear 24T Analog Sport Servo

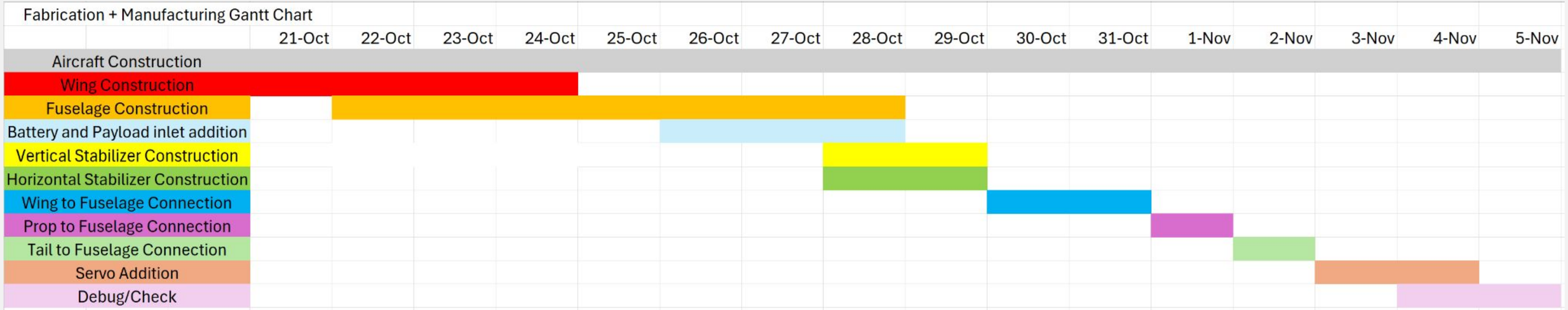
Ailerons and Rudder:
3 x EMAX ES08MA II 12g Metal Gear Servo

Servo	Count	Stall Torque (oz-in)	Weight (oz)	Max Current (mA)	Voltage (V)	Cost per Servo ($)
HS-311	1	42-49	1.51	800	4.8 - 6	13.49
EMAX ES08MA II	3	21-28	0.42	500	4.8 - 6	7.75

Aircraft Cost

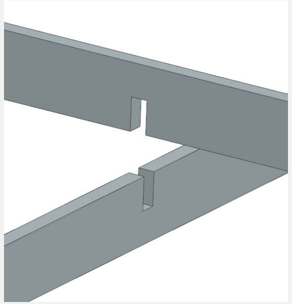
Budget Sector	Number of Components	Total Cost ($)
Propulsion	4	193.7
Control	4	58.22
Structure	7	128.55
Total	15	380.47

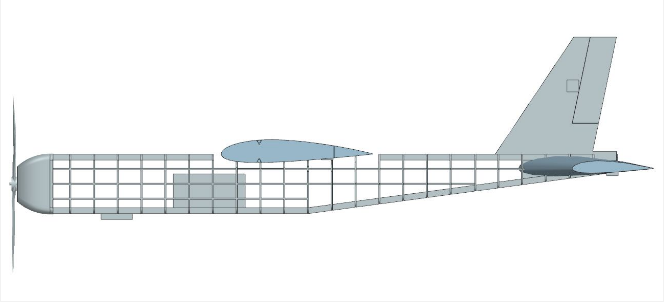
Fabrication Gantt Chart



Manufacturing Method

- Wing
  - Foam Cutter
    - Airfoil
    - Spar channels
  - Glue
    - Spar into channel
- Horizontal Stabilizers
  - Foam Cutter
    - Tapered airfoil
  - Hand cut
    - Fit around ribs of fuselage
- Fuselage
  - Laser Cut
  - Glue together
- Vertical Stabilizers
  - Laser Cut
- Control Surfaces
  - Cut out same process as their main component
  - Hinge to help support control surface
  - Servo arm attached hinges





References

Simons, Martin. Model Aircraft Aerodynamics. 5th ed., Special Interest Model Books, 2015.

Lennon, Andy. Basics of R/C Model Aircraft Design: Practical Techniques for Building Better Models. Air Age Media, 2005.

"Building with Foam." RC Groups, Verticalscope Inc. www.rcgroups.com.

"Selecting Materials for RC Plane Construction." RC Airplane World www.rc-airplane-world.com/

Thank you! - Questions?