Conceptual Design Review

PLEASE NEGLECT AIR RESISTANCE

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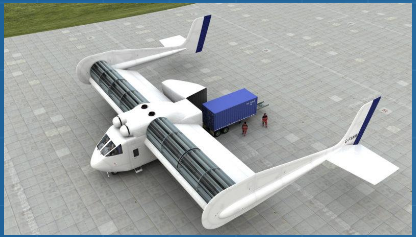
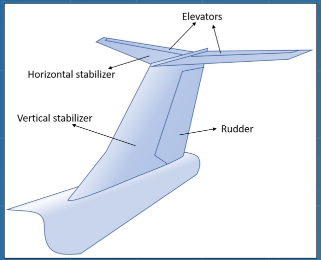
MISSION STATEMENT

"Utilize our knowledge of **aerodynamics, structures, and materials** to design, build, and fly a radio-controlled airplane to complete the particular mission of **loaded and unloaded flight** and **maximize total score** by considering **payload, take-off distance, speed, cost, and uniqueness**."

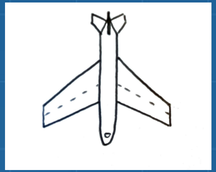
EARLY BRAINSTORMING


Fan Wing

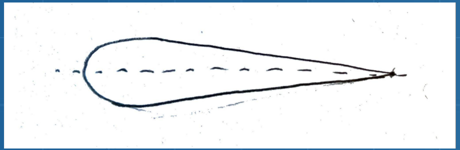


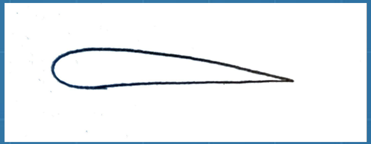
T-Tail

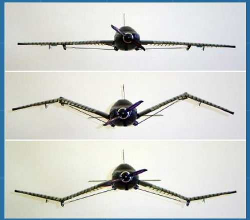

H-esque Tail

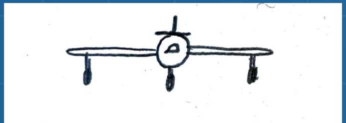

Forward Sweep


Low-Wing Dihedral

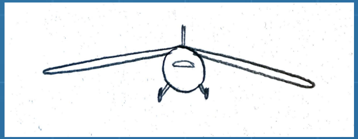

Symmetric Airfoil

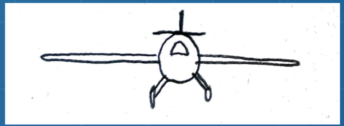

Flat-Bottomed AIrfoil

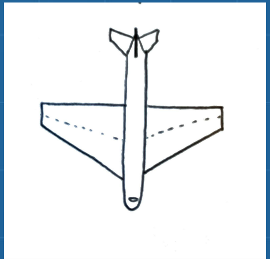

Gull Wing


Wing Landing Gear


Flying Wing


High-Wing Anhedral


Fuselage Landing Gear


Backward Sweep

DESIGN DRIVERS

Textbook Suggested Mission Requirements

(extracted from T. C. Corke, Design of Aircraft)

1. The aircraft purpose or mission profile
2. The type(s) and amount of payload
3. The cruise and maximum speeds
4. The normal cruise altitude
5. The range or radius with normal payload
6. The endurance
7. The take-off distance at the maximum weight
8. The landing distance
9. The purchase cost
10. The other requirements considered important

Design Score Equations

Our Design Criteria

1. Maximized Golf Balls Carried
2. Maximize Uniqueness
3. Minimize Take-Off Distance
4. Maximize Durability
5. Minimize Cost
6. Maximize Ease of Manufacture
7. Maximize Speed
8. Minimize Bank Radius

DESIGN DRIVER OPTIMIZATION

Equations to Optimize

$$S_{Flight} = \frac{1000}{(t_1 - 18.4)^{1.2}} + \frac{1000}{(d_1 + 8.76)^{1.7}} + \frac{1002}{t_2} + \frac{300}{(d_2 + 7.93)^{1.2}} + 50 \cdot \frac{1}{2}\left[1 + erf\left\{\frac{\ln N - \ln 12}{0.75 \cdot \sqrt{2}}\right\}\right]$$

$$S_{cost} = 1 - erf\left\{\frac{\$ - 250}{35.54\sqrt{2.4}}\right\}$$

$$S_{uniqueness} = \frac{Points}{5}$$

Mathematical Assumptions

- t_1, t_2, d_1, and d_2 are proportional to N
- *Points* and *$* can be optimized independent of N
- $t_1, t_2, d_1, d_2, N > 0$

Results

S_{Flight}

- A code was created to minimize the inverse of the S_{Flight} function for the given constraints.
- Additional golf balls do not realistically decrease the score until $\boldsymbol{N > 35}$.

S_{cost}

- Cost score is maximized by minimizing *$*.

$S_{uniqueness}$

- Uniqueness score is maximized by maximizing uniqueness points.

DESIGN DRIVER OPTIMIZATION

Conclusion

- The maximum score will be obtained by attempting to be **above average in all categories rather than extraordinary in any single category** at the expense of the others.
    - Specifically, the target number of golf balls will be ***N* = 35**, which is **above the ‘23-’24 average of *N* = 30.6**.
    - This gain will outweigh the score loss in *t* and *d*.
- Ease of manufacture will be prioritized to maximize cost score.
- Extra time work will be put into the conceptual design phase to maximize uniqueness.

DESIGN DRIVER WEIGHTING

Figures of Merit	Quantitative Weight
Number of golf balls	16
Uniqueness	10
Take-Off Distance	13
Durability	8
Cost	13
Ease of Manufacture	20
Speed	15
Bank Radius (min)	5

WEIGHT ESTIMATE

Initial Historical Estimate:

From 2023-2024 Data:

- Average Unloaded Weight per Golf Ball = **0.242 lbs**
- Average Loaded Weight per Golf Ball = **0.344 lbs**
- Estimated Unloaded Weight to Carry **35** Golf Balls = **8.487 lbs**
- Estimated Loaded Weight to Carry **35** Golf Balls = **12.031 lbs**

$$W_{unloaded} \approx 8.5 \text{ lbs}$$

$$W_{loaded} \approx 12.0 \text{ lbs}$$

PRELIMINARY WING DESIGN: MOUNTING

Figures of Merit	Weight (%)	High Wing	Low Wing	Mid Wing
Number of golf balls	16	5.0	1.0	3.0
Uniqueness	10	3.0	3.0	3.0
Take-Off Distance	13	4.0	3.5	3.0
Durability	8	3.5	3.0	4.0
Cost	13	3.0	3.0	3.0
Ease of Manufacture	20	3.0	3.0	3.0
Speed	15	2.0	5.0	3.0
Bank Radius (min)	5	1.0	5.0	3.0
Total	**100**	**3.24**	**3.15**	**3.08**

High Wing design was chosen because the increased stability would optimize carry-weight.

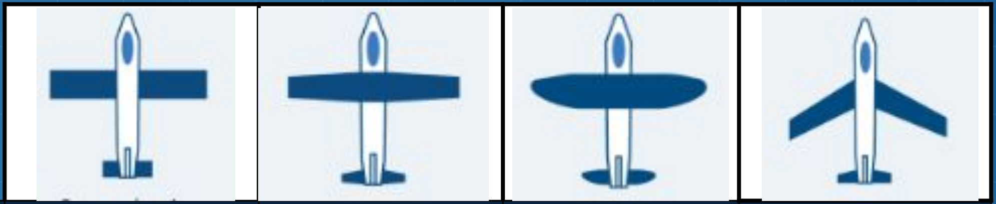
PRELIMINARY WING DESIGN: CONFIGURATION




Figures of Merit	Weight (%)	Anhedral	Dihedral	Gull Wing	Straight Wing
Number of golf balls	16	4.0	3.0	4.0	5.0
Uniqueness	10	4.5	3.0	5.0	1.0
Take-Off Distance	13	4.0	3.5	4.0	3.0
Durability	8	4.0	4.0	2.0	4.0
Cost	13	3.5	3.5	2.0	4.0
Ease of Manufacture	20	3.5	3.5	1.0	5.0
Speed	15	3.0	5.0	3.0	3.0
Bank Radius (min)	5	5.0	4.0	2.0	2.5
Total	**100**	**3.79**	**3.66**	**2.83**	**3.71**

Anhedral design was chosen to maximize the uniqueness to the design, roll maneuverability.

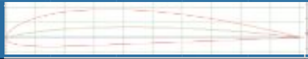
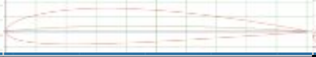
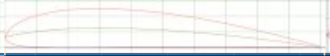
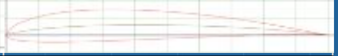
PRELIMINARY WING DESIGN: WING SHAPE



Figures of Merit	Weight (%)	Rectangular	Trapezoidal	Elliptical	Swept Wing
Uniqueness	12	1.0	4.0	5.0	5.0
Take-Off Distance	20	4.0	3.5	4.0	3.0
Durability	15	4.0	4.0	3.0	4.0
Cost	13	4.0	3.5	3.0	4.0
Ease of Manufacture	20	5.0	4.0	1.0	2.0
Speed	15	3.5	5.0	4.5	5.0
Bank Radius (min)	5	3.0	4.0	2.5	3.0
Total	**100**	**3.72**	**3.99**	**3.24**	**3.62**

Trapezoidal wing was chosen because the increased lift (closer to elliptical) and uniqueness outweighs the added difficulty of manufacturing.

PRELIMINARY WING DESIGN: AIRFOIL

Figures of Merit	Weight (%)	Clark Y	NACA 2213	N-22	SD7037
Uniqueness	10	3.0	4.0	3.0	5.0
Ease of Manufacture	20	5.0	3.0	5.0	2.0
Cl, max	14	1.2	1.0	1.5	1.3
Cd at Cl, max	14	1.2	1.1	1.5	1.2
Clo	14	0.1	0.7	3.0	1.2
Cdo	14	1.2	1.2	1.5	1.0
Max L/D	14	1.3	1.1	1.3	1.3
Total	**100**	**2.0**	**1.7**	**2.5**	**1.7**

N-22 design was chosen because it has the best lift performance, is flat on the bottom making it easy to manufacture.

PRELIMINARY WING DESIGN

Taper Ratio, λ	Aspect Ratio, AR	Area, S (ft^2)	Wingspan, b (ft)	Root Chord, c_r (ft)	Tip Chord, c_t (ft)
0.4	6	5.227	5.6	1.333	0.533

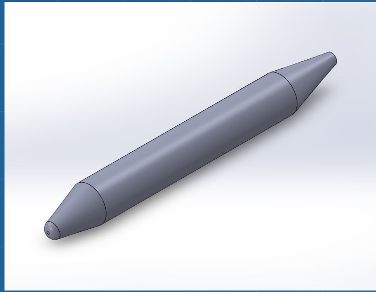
- Wingspan was chosen based on 2023-2024 data.
- Wing area gives max wing loading of 2.296 lb/ft^2 which matches published values online.
- Taper Ratio was chosen as 0.4 because it is the optimal.
- Taper ratio gives a mean aerodynamic chord of 0.99 ft.
- No sweep will be added to the wings.
- Plane will use traditional ailerons.

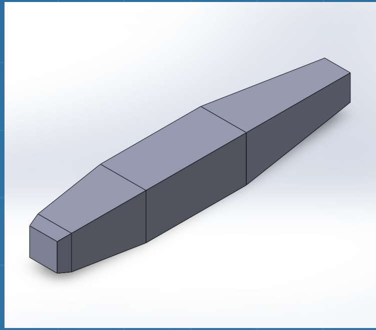
MATERIAL CONSIDERATIONS

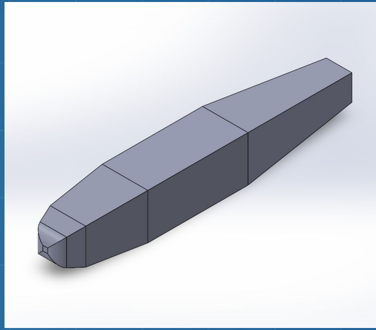
  

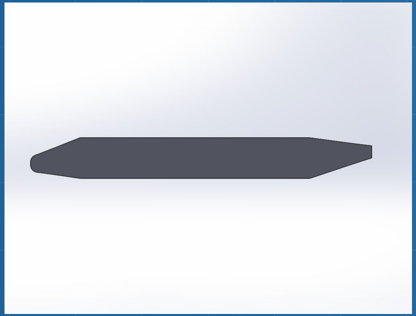
Figures of Merit	Weight (%)	Wood	Fiberglass	Carbon Fiber
Weight	15	4.0	2.0	2.0
Strength	20	2.0	3.5	5.0
Manufacturability	25	5.0	3.0	2.0
Cost	18	4.0	2.0	1.0
Interface	22	5.0	3.0	3.0
Total	**100**	**4.07**	**2.77**	**2.64**

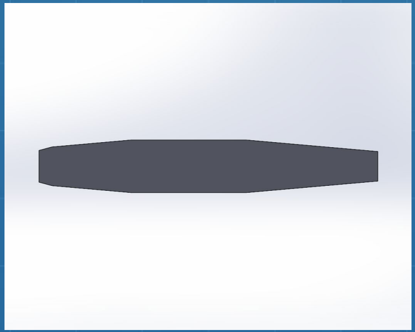
PRELIMINARY FUSELAGE DESIGN

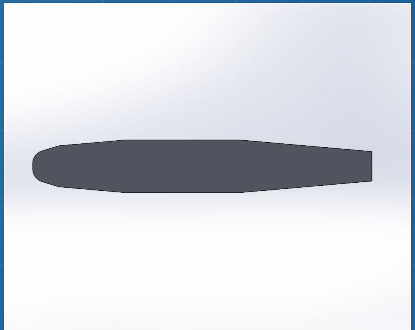




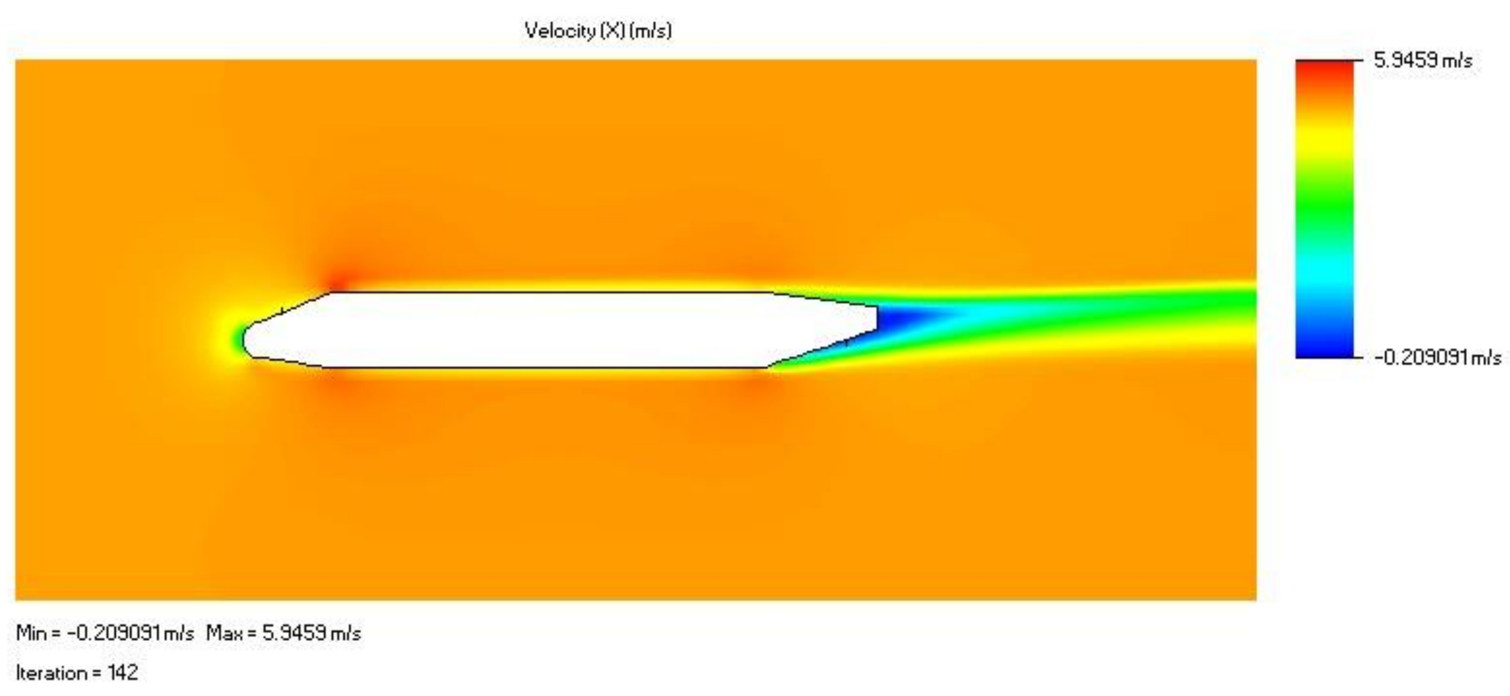








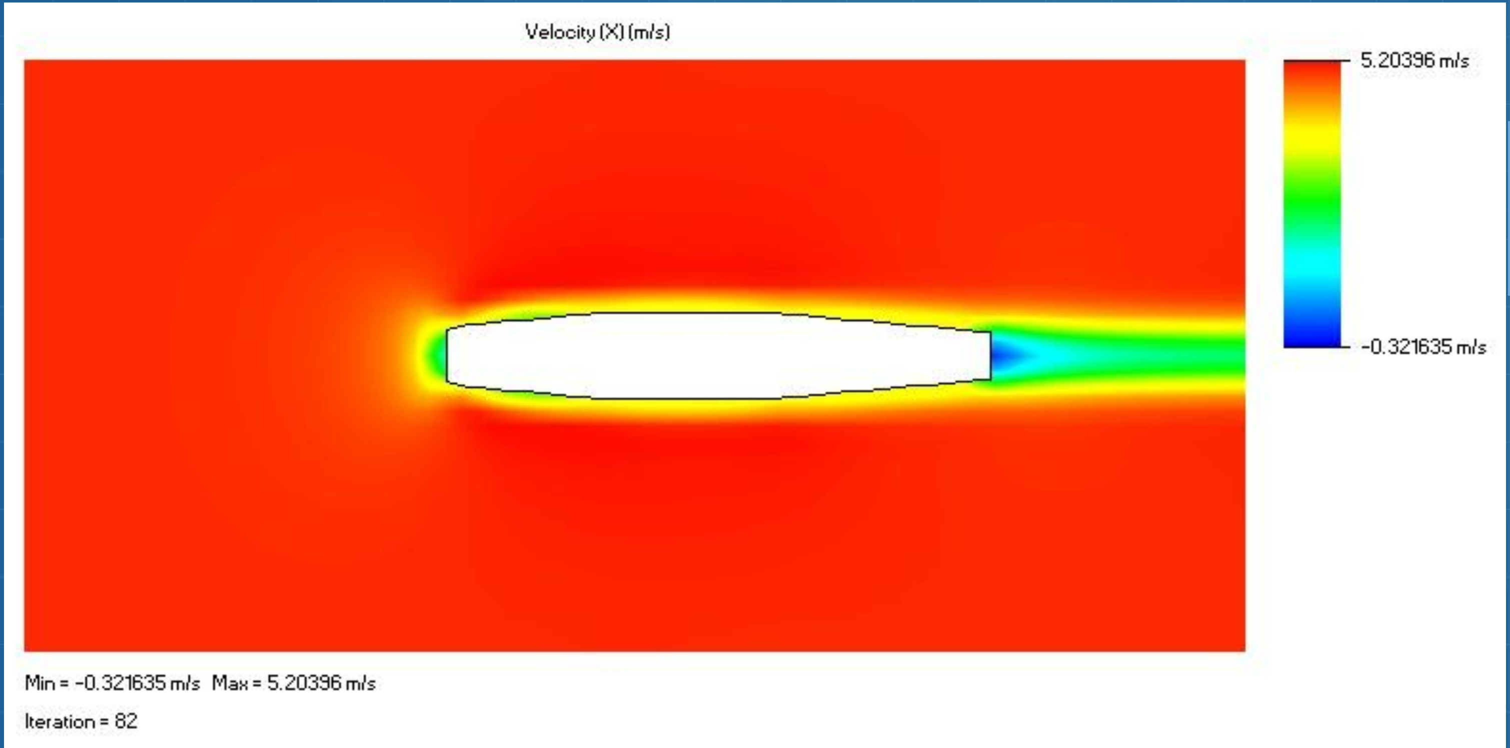
CYLINDRICAL FUSELAGE RESULTS



SOLIDWORKS RESULTS

C_{D0}	Drag (N)
0.072	0.024

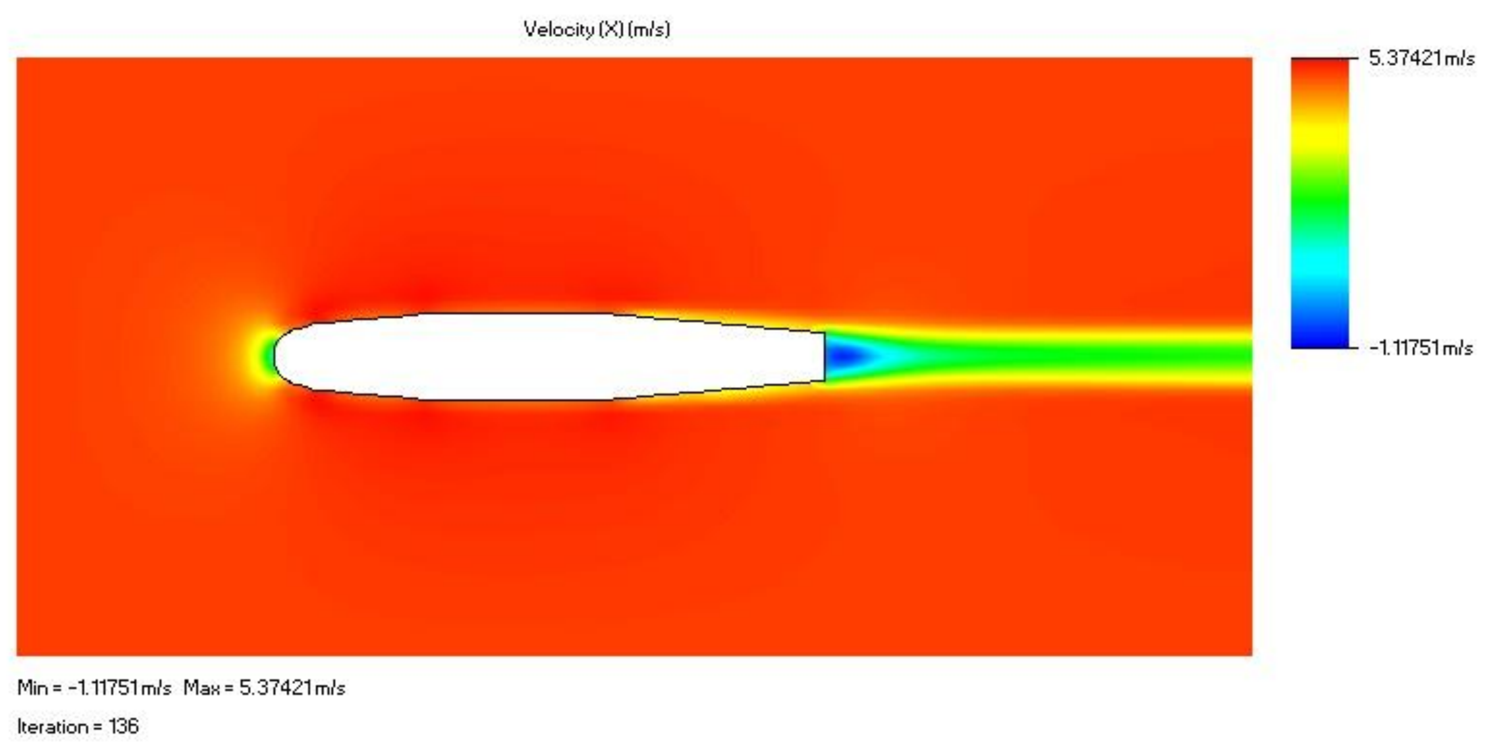
RECTANGULAR FUSELAGE RESULTS



SOLIDWORKS RESULTS

C_{D0}	Drag (N)
0.283	0.173

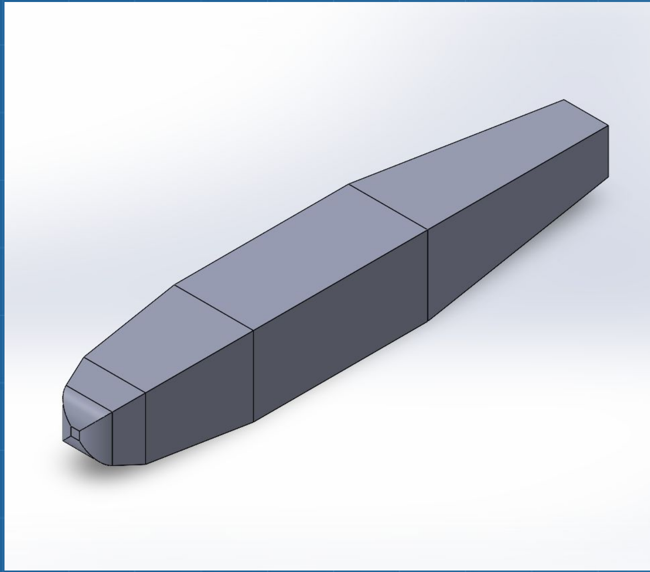
RECTANGULAR (NOSE CONE) RESULTS

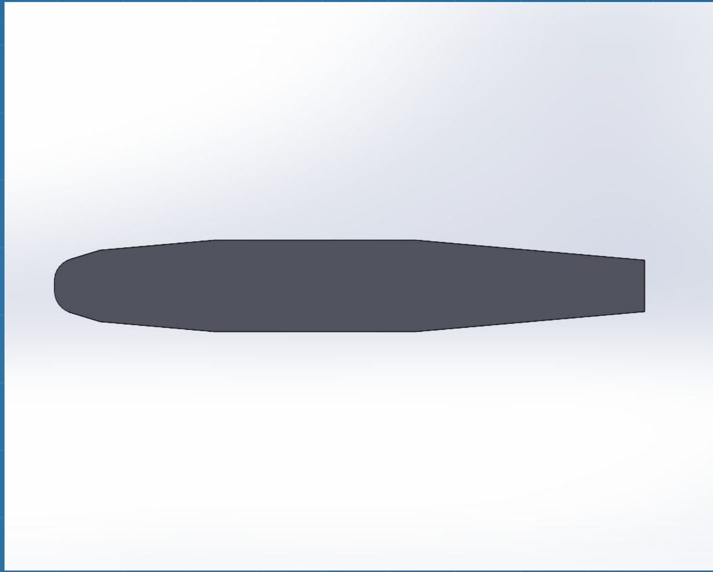


SOLIDWORKS RESULTS

C_{D0}	Drag (N)
0.068	0.041

FUSELAGE PROPOSAL



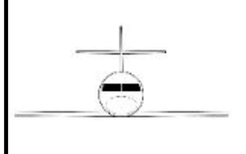


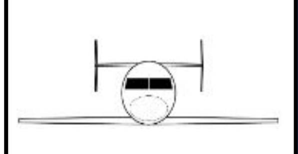
Dimensions:
0.492 ft x 0.492 ft x 4.232 ft
~ 1.024 ft^3

Needed golf ball volume (assuming 74% packing efficiency):
~ 0.140 ft^3

Rectangular fuselage with nose cone attachment was chosen to minimize the drag while increasing ease of manufacturing.

PRELIMINARY TAIL DESIGN

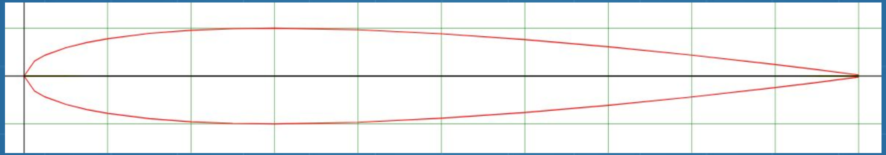



Figures of Merit	Weight (%)	V Tail	Cruciform	Conventional	T Tail	H Tail
Number of golf balls	16	1	2	4	5	3
Uniqueness	10	4	2	1	3	5
Take-Off Distance	13	3	4	5	2	1
Durability	8	1	2	5	3	4
Cost	13	5	2	4	3	1
Ease of Manufacture	20	2	3	4	5	1
Speed	15	5	3	4	2	1
Bank Radius (min)	5	4	3	5	2	1
Total	**100**	**3.03**	**2.66**	**3.96**	**3.39**	**1.96**

Conventional tail was selected as it is the most well rounded design, which matches our current requirements for a generalist plane.

PRELIMINARY TAIL DESIGN: AIRFOILS

The NACA 0010 was chosen for the vertical and horizontal stabilizers. The symmetrical design allows for easy elevator and rudder control implementation because there is no base lift at zero angle of attack.



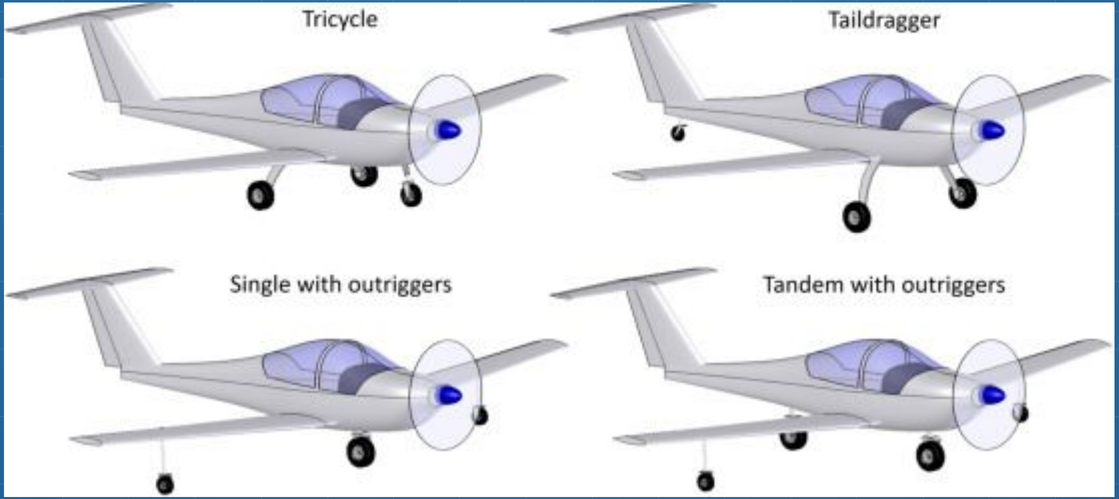
- -2 degree mounting angle for horizontal tail was chosen based on XFLR-5, but may change in future iterations.
- Rectangular shape was chosen.
- Traditional elevators and rudder will be used.

S_{HT} (ft)	S_{VT} (ft)	b_{HT} (ft)	b_{VT} (ft)	AR_{HT}	AR_{HT}
1.110	0.503	2.583	1.737	6	6

PRELIMINARY LANDING GEAR CONFIGURATION

Taildragger Landing Gear

- The team plans on purchasing this part, and as a result a trade study was not conducted.
- Since this part will not be manufactured, the simplest design was selected: the Taildragger best balances center of gravity and prevents tail strike



THRUST ESTIMATE

01 → 02 → 03 → 04

PROPELLER SELECTION

Propeller: Master Airscrew 12x6

NUMBER OF ENGINES

Single puller motor configuration

MOTOR SELECTION

Motor: E-Flite Power 46

THRUST

Actuator Disk Theory: Static Case ($V_\infty = 0$)

$$T_0 = {P_{engine}}^{2/3}(2\rho A_{disc})^{1/3}$$

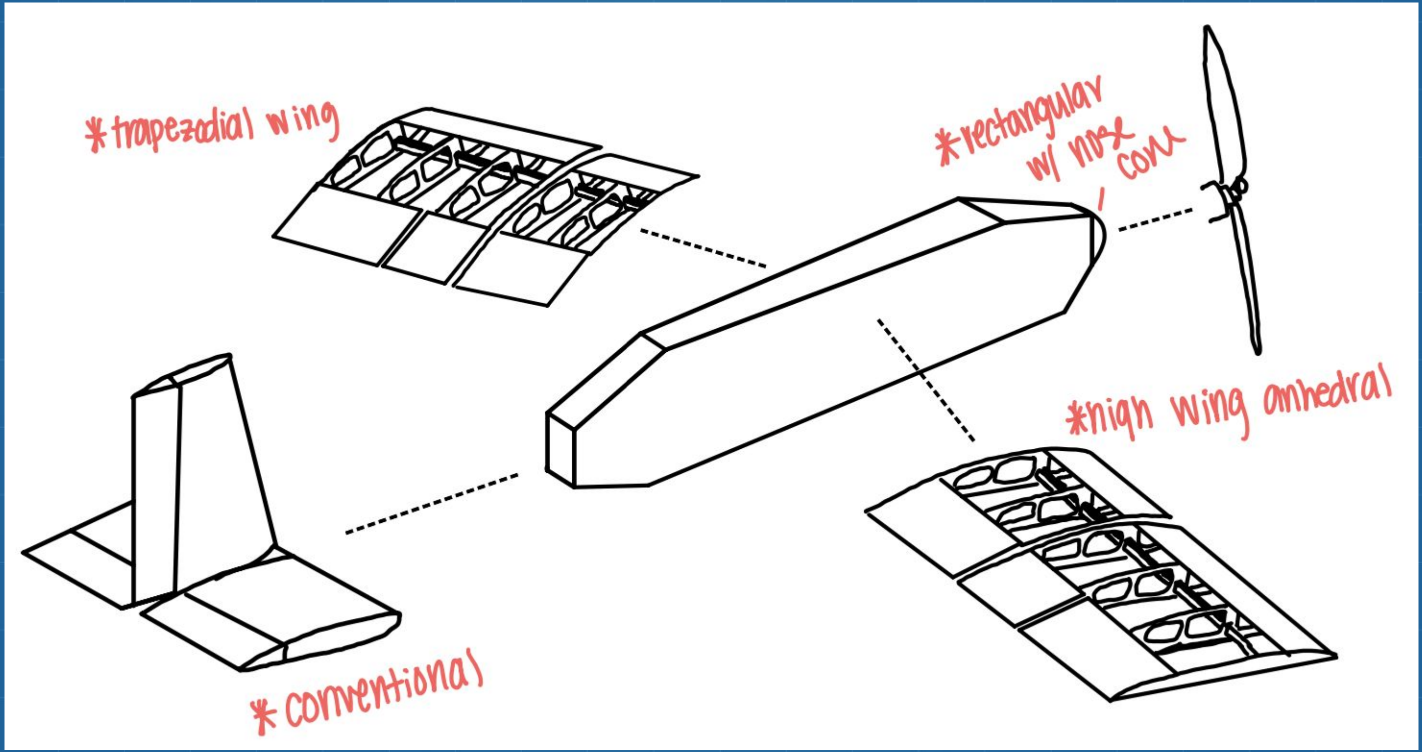
$P_{engine} = 0.53$ hp

$\rho = 0.0023$ slug/ft^3

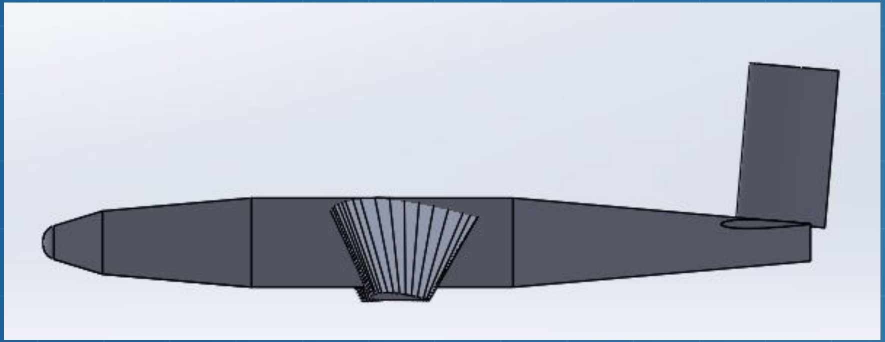
$A_{disc} = 0.78$ ft^2

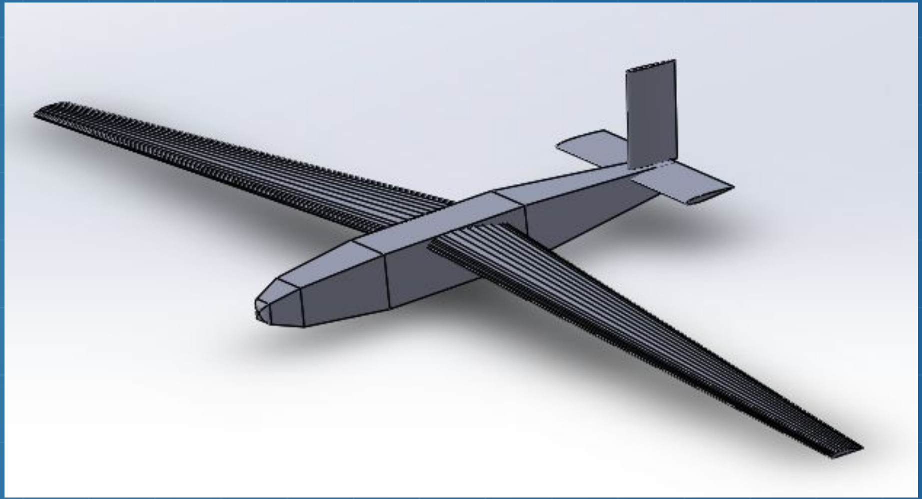
$$\boldsymbol{T_{theoretical} = 7.6 \text{ lbs}}$$

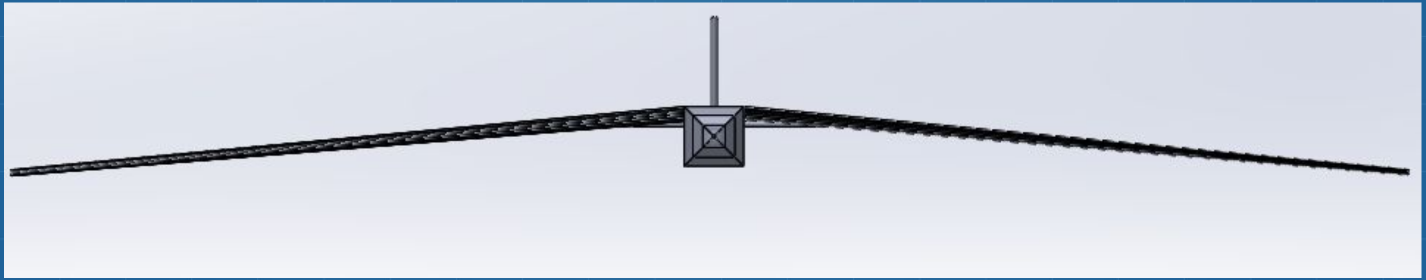
COMPLETE AIRCRAFT PROPOSAL



COMPLETE AIRCRAFT PROPOSAL







QUESTIONS
and
FEEDBACK