Unmanned Aerial Vehicle

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MECHANICAL ENGINEERING
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Challenge

Design and build an original aircraft that meets all the 2023 SAE Aero Design West Competition requirements

Flight Scoring Method:

$$FS = Flight\ Score = \frac{W_{Payload}}{2} + PBB$$

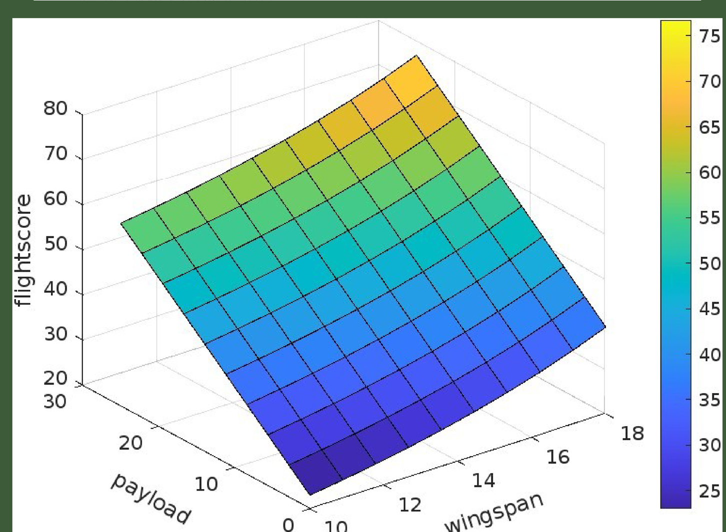
$$PPB = Payload\ Prediction\ Bonus = MAX\left(5 - \left(W_{payload} - P\right)^2, 0\right)$$

$$WS = Wingspan\ Score = 2^{\left(1+\frac{b}{5}\right)}$$

$W_{Payload}$ = Regular Boxed Cargo Weight (lbs)

b = Aircraft Wingspan (ft)

P = Predicted Payload



Visualization of potential flight score with a given wingspan and payload

Challenging Requirements:

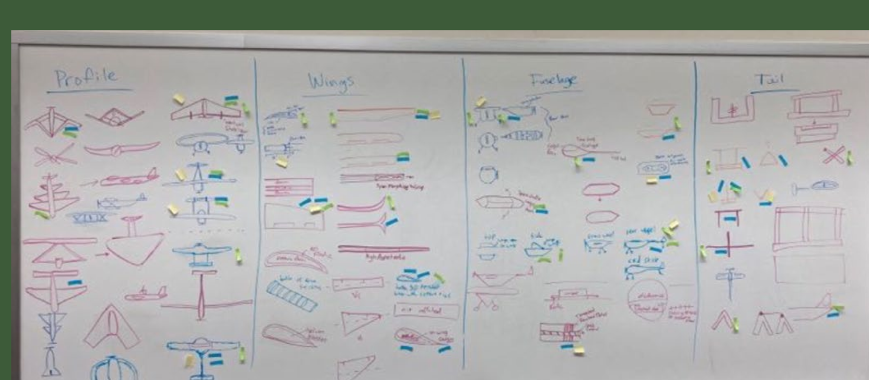
- Minimum 10 ft wingspan
- No part may measure longer than 48" (modular)
- Power system limited to 750 W
- Rear landing gear must be controllable
- Aircraft total weight must be less than 55 lbs including payload
- Takeoff distance less than 100 ft
- Landing distance less than 100 ft
- Must be flyable both loaded and unloaded
- Aircraft physical measurements and weights must match submitted drawing

Concepts

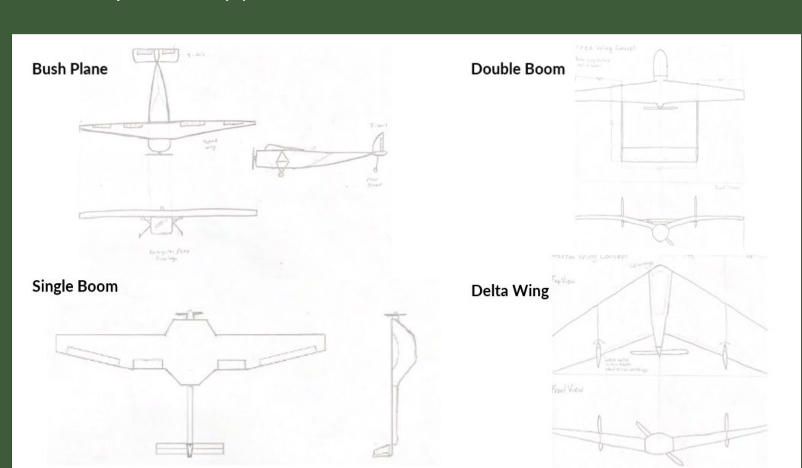
Using the design requirements as a guide, hundreds of ideas were generated through multiple brainstorming sessions and external searching

Selection Process:

- Open vote to weed out obvious losers
- Remaining concepts passed through scoring matrix
- Final 4 concepts run through selection matrix
- Winning concept passed on to prototype and test



Results from brainstorm session



Hand sketches of final 4 concepts

Selection criteria were derived from SAE competition rules and other factors that were determined by the team to be essential for the team's success.

Selection Matrix

Grade:	1 Bad	2 Ok	3 Average	4 Good	5 Excellent

Selection Criteria	Bush Plane	Double Boom	Single Boom	Delta Wing
Easy to Build	3	3.6	4.2	2.6
Modularity	2.6	4	4.4	2.4
Structurally Sound	3.8	3	2.6	4.2
Easy to Repair	2.4	3.8	4	2.6
Light Weight	1.8	3.6	4.4	3.2
Payload Adjustablility	4.4	2.4	2.4	3.2
Aircraft Must Fit into a Shipping Container	2.8	3.8	3.8	2.2
Aircraft Must Fly Both Empty and Weighted	4	3.2	3.2	4.8
Individual Part's Primary Axis Length	2.4	4.2	3.8	2.8
Totals:	**27.2**	**31.6**	**32.8**	**28**

Selection matrix used on final 4 designs

Prototyping and Analysis

The winning concept from the selection matrix went through several prototyping phases. Two prototyping iterations are shown above.

Left:
- Foam board wing
- Foam board fuselage

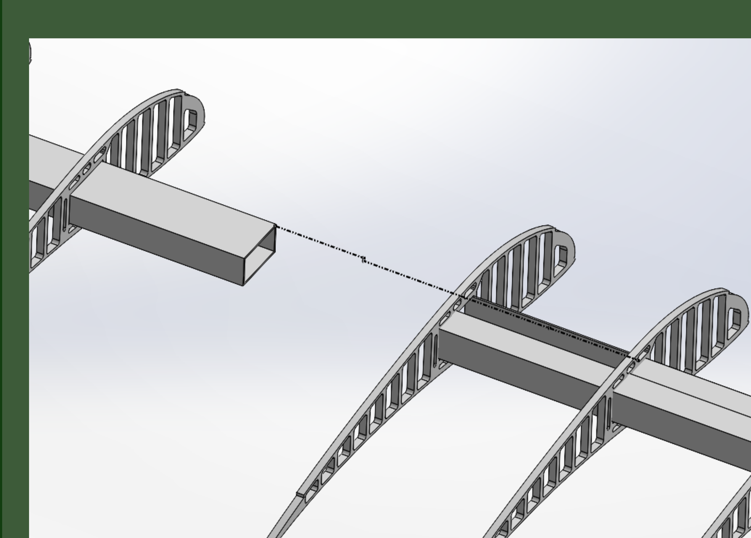
Right:
- Improved rib-and-spar wing construction
- Redesigned and lengthened fuselage

The Selig S1223 airfoil is designed for high lift and low Reynolds number applications, perfect for the design requirement of this project.

Selig S1223 airfoil.

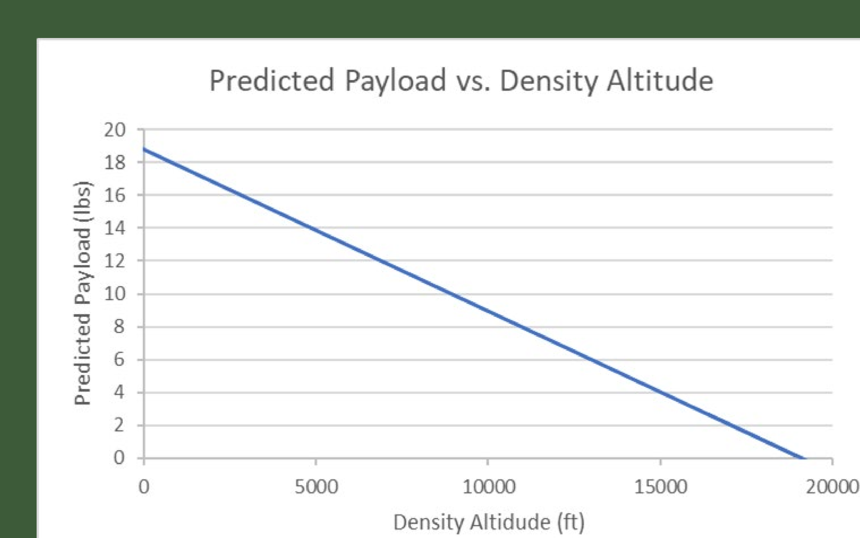
Airfoil Analysis:
- Airfoil data was collected using preexisting data tables that were produced using an MIT code named XFOIL
- Lift calculations were done to determine the ideal wingspan, chord length and needed windspeed

Chord	Ch	Velocity (	Velocity (m	Re	Max C_l	Crit AOA (de	Estimated Lift (lbf)	Max C_d	Estimated Drag	Estimated Fuse
20	0.51	10	4.470272687	150281	2.2901	12.25	14.63568548	0.03956	1.265164136	1.022533507
		12.5	5.587840858	187852	2.2901	12.25	22.86825856	0.03956	1.976818963	1.597708605
		15	6.70540903	225423	2.2901	12.25	32.93029233	0.03956	2.846619306	2.300700392
		17.5	7.822977202	262994	2.2901	12.25	44.82178678	0.03956	3.874565167	3.131508866
		20	8.940545373	300565	2.2901	12.25	58.54274192	0.03956	5.060656544	4.09013403
		22.5	10.05811354	338136	2.2901	12.25	74.09315775	0.03956	6.404893439	5.176575881
		25	11.17568172	375707	2.3534	14	94.00141427	0.04107	8.20909553	6.390834421
22	0.56	10	4.470272687	165310	2.2901	12.25	16.09925403	0.03956	1.39168055	1.022533507
		12.5	5.587840858	206637	2.2901	12.25	25.15508442	0.03956	2.174500859	1.597708605
		15	6.70540903	247964	2.2901	12.25	36.22332156	0.03956	3.131281237	2.300700392
		17.5	7.822977202	289291	2.2901	12.25	49.30396546	0.03956	4.262021683	3.131508866
		20	8.940545373	330618	2.2901	12.25	64.39701612	0.03956	5.566722198	4.09013403
		22.5	10.05811354	371945	2.3534	14	83.75526011	0.04107	7.314304117	5.176575881
		25	11.17568172	413272	2.3534	14	103.4015557	0.04107	9.030005083	6.390834421
24	0.61	10	4.470272687	180338	2.2901	12.25	17.56282258	0.03956	1.518196963	1.022533507
		12.5	5.587840858	225422	2.2901	12.25	27.44191028	0.03956	2.372182755	1.597708605
		15	6.70540903	270506	2.2901	12.25	39.5163508	0.03956	3.415943167	2.300700392
		17.5	7.822977202	315590	2.2901	12.25	53.78614414	0.03956	4.6494782	3.131508866
		20	8.940545373	360674	2.3534	14	72.19308616	0.04107	6.304585367	4.09013403
		22.5	10.05811354	405758	2.3534	14	91.36937467	0.04107	7.979240855	5.176575881
		25	11.17568172	450842	2.3534	14	112.8016971	0.04107	9.850914636	6.390834421

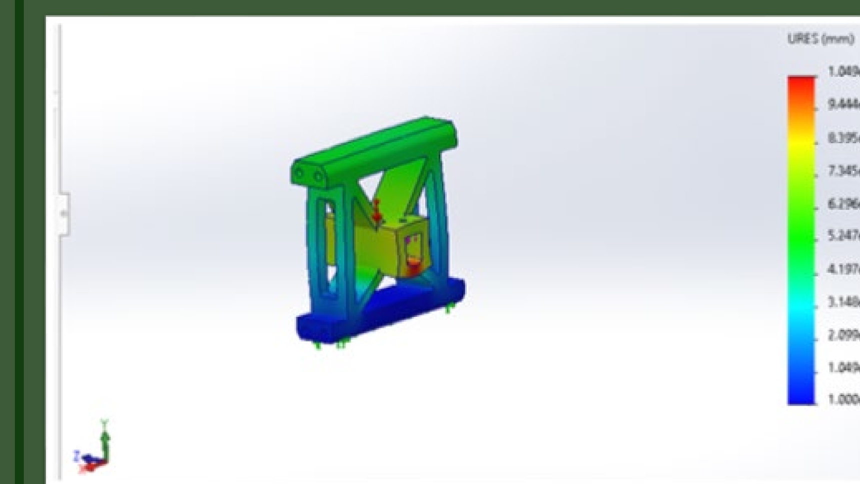


Wing construction and connection method

The construction method for the wings is known as a rib-and-spar construction



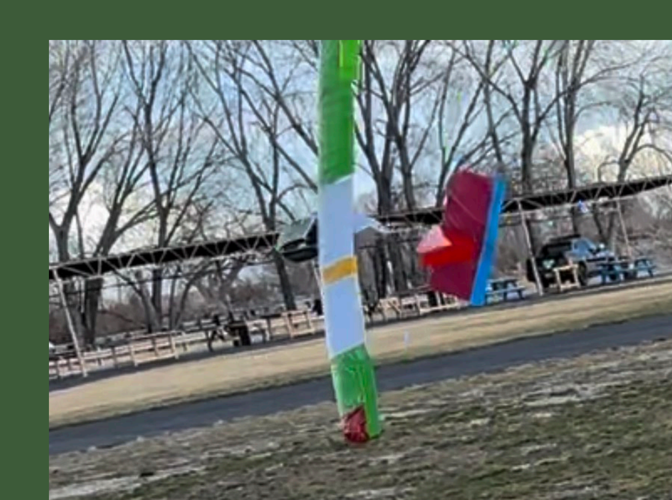
The Payload chart can be used to Predict the amount of weight that can be added to the UAV based on density altitude.



Analysis done on tail boom support to verify that the fuselage could handle the weight of the tail without interfering with the overall control of the UAV. The analysis also ensured that the other end of the boom could hold the payload plates. It verified that the support would not break in the event of a crash.

Results

Final design of the UAV



Flight Results:

- There were many attempts where the plane was damaged due to high winds
- The UAV was repaired and continued flight attempts were made
- Aircraft easily lifted off within 100 ft
- Aircraft was flown by a student pilot
- 95% of design requirements were fulfilled as planned
- With additional time and testing, aircraft controllability could be zeroed in

Coach: Dr. Matt Ballard