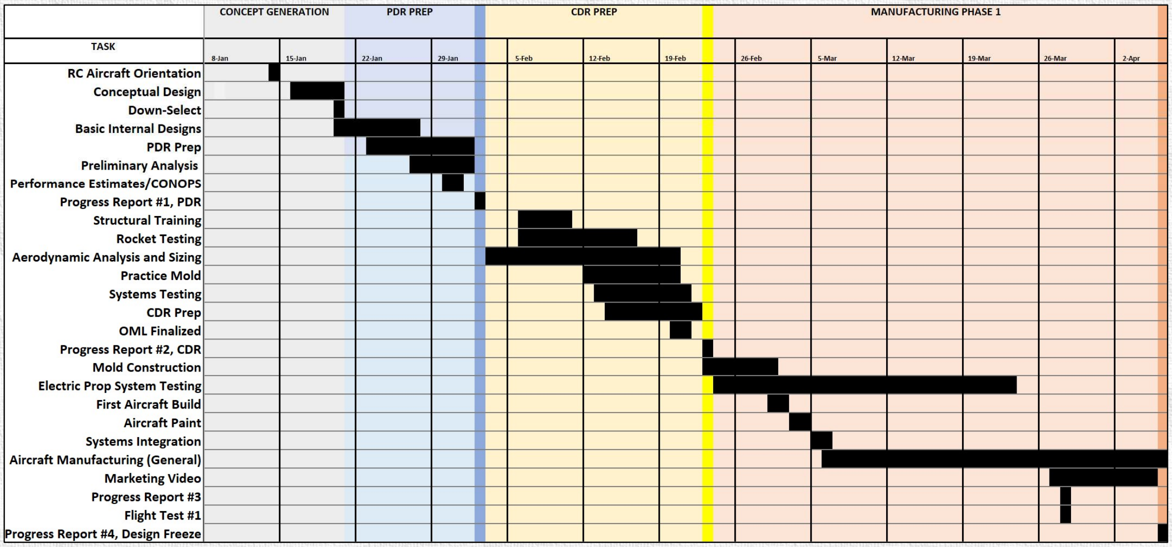
SPEEDFEST XII BLACK TEAM

CRITICAL DESIGN REVIEW

Team Structure

- **Chief Engineer** Killian Kane
  - **Aerodynamics** Tuyen Nguyen
    - Mark Ovsyannikov
    - Isaiah Richmond
    - Xamran Shamsi
  - **Propulsion** Austin Green
    - Andrew Acupan
    - Tyler Funk
    - Molly Lammes
    - Thomas Nine
    - Blake Tonquest
    - Haleigh Woodbridge
  - **Structures** Garrett Smith
    - Ashley Anderson
    - Skyler Cuthbertson
    - Trey Mandrell
    - Timothy Nelsen
    - Tom O'Connor
    - Justin Sam
    - Clint Weathers
  - **CAD** Newton Quach
    - Michael Cuthbertson

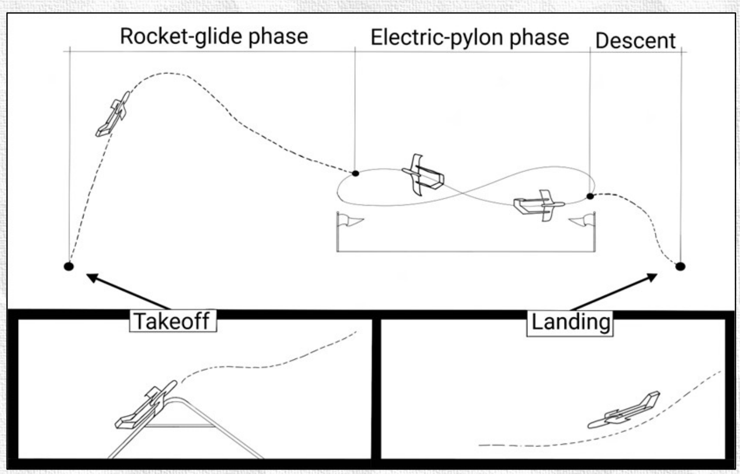
Integrated Master Schedule



Mission Profile

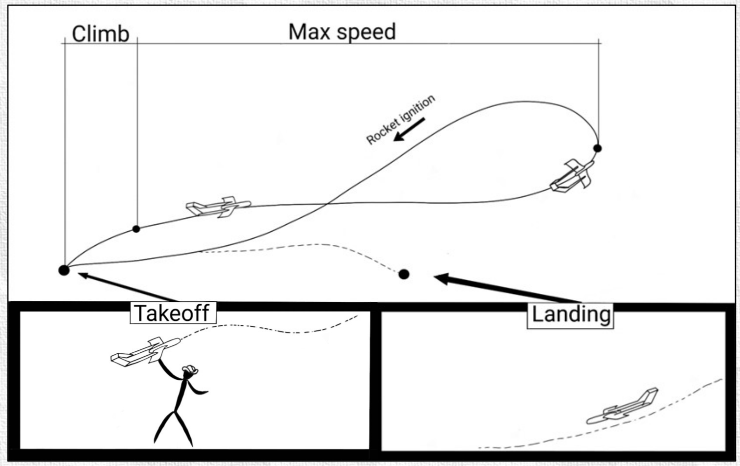
Pylon Racing (1st Place: 15 pts, 2nd Place: 10 pts)

- Rocket-glide phase
  - Time begins on visible rocket ignition
  - Time ends on first use of electric propulsion
- Electric-pylon phase
  - Must collect the maximum number of flags in available time
  - Time is based on the gliding time from previous phase
- Total points based on number of flags collected



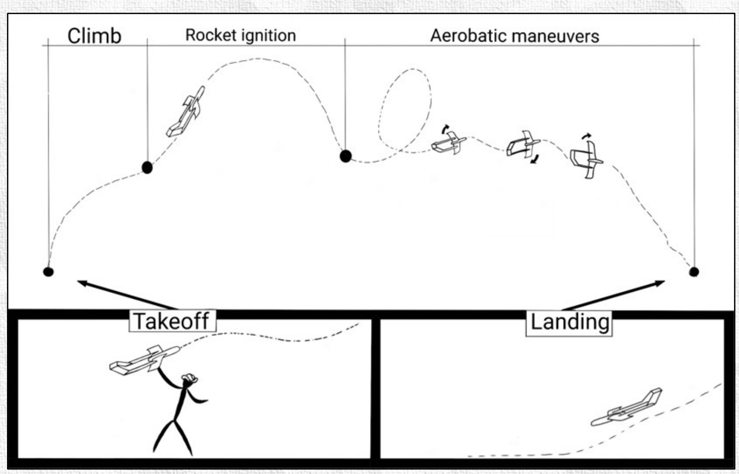
Mission Profile

Max Speed (1st Place: 15 pts, 2nd Place: 10 pts)
- Total points based on maximum speed reached within 10 seconds of launch



Mission Profile

Endurance/Flight Demonstration (5 pts)
- Sustain flight for a minimum of four minutes (all or nothing)

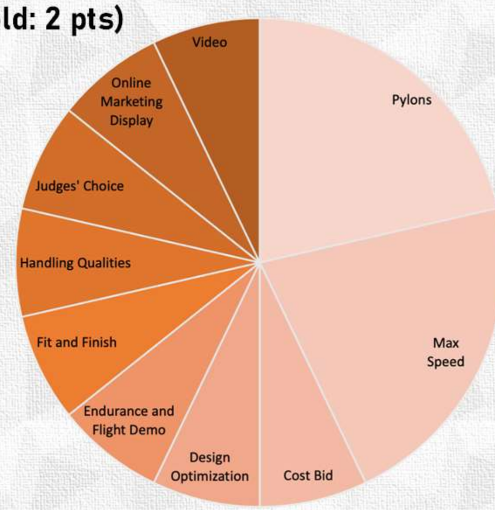


Mission Profile

Unit Cost Bid (Objective: 5 pts, Threshold: 2 pts)
- Based on projected cost of 100^{th} unit
- Threshold: $3000
- Objective: $2000

Aircraft Design (0-5 pts Each)
- Fit and Finish
- Handling Qualities
- Design Optimization

Marketing (0-5 pts Each)
- Online Marketing Display
- Video
- Judges Choice (all or nothing)



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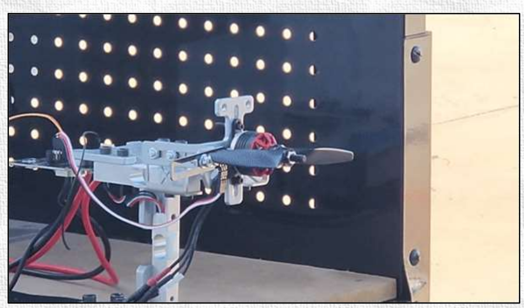
Unique Challenges

Rocket Integration
- CG changes during burn
- Exhaust plume impingement

Limited Propulsion System
- Electric, powered with 5S LiPo battery
- 40A Fuse
- 80 N-s total rocket impulse

Glide Endurance and Racing
- Long glide time
- High top speed
- Controllability



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PDR Solution

Lightweight

Low Profile Drag

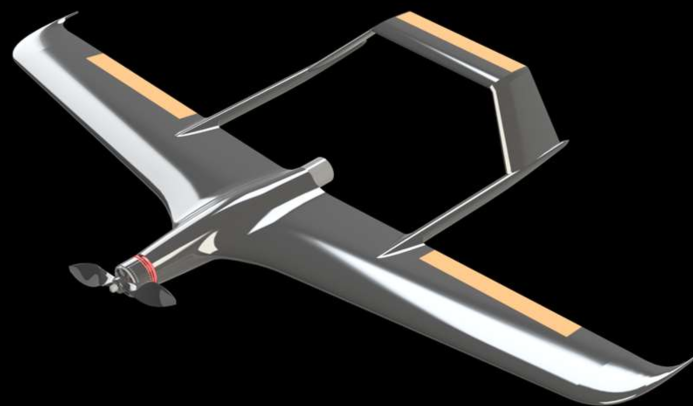
Good Control Authority

Favorable Stall Characteristics

Minimal Exhaust Impingement

Rocket Near CG

CG Ahead of AC



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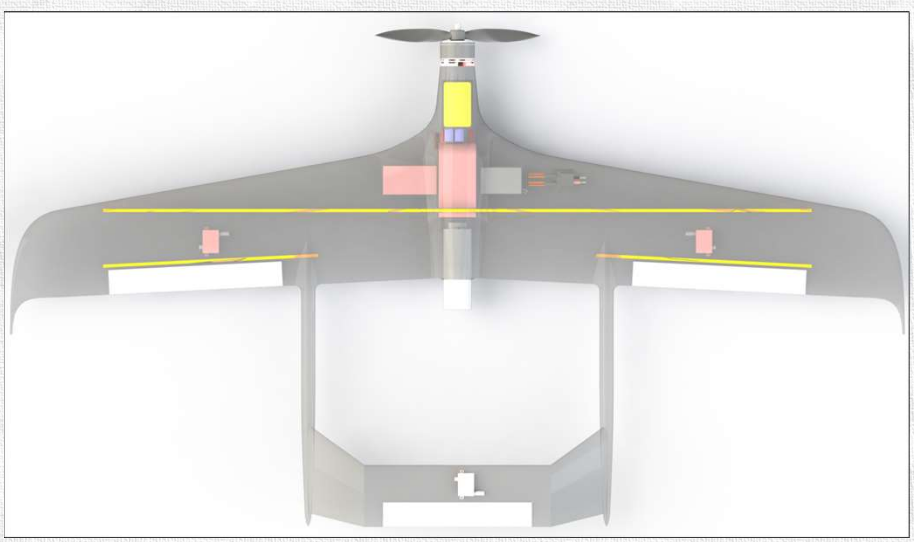
PDR Layout



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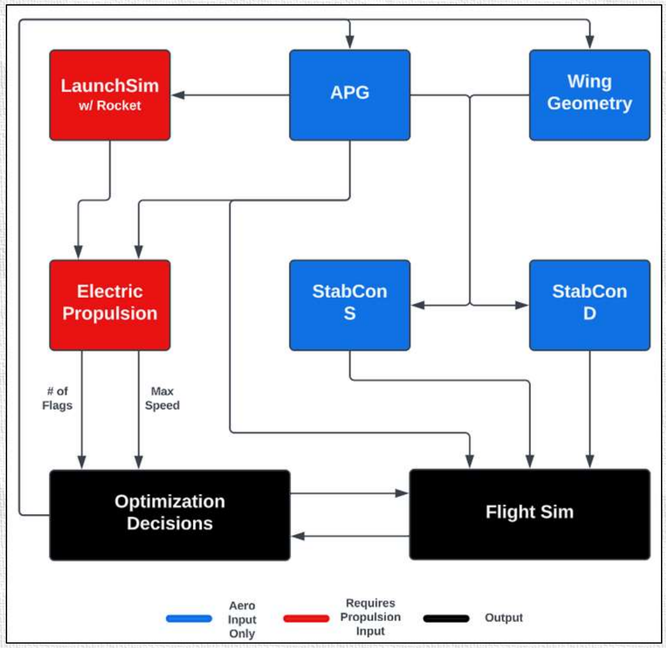
Analysis Procedure



Optimization
- Airfoil
- Wing Area
- Aspect Ratio

Sizing
- Wing
- Fuselage
- Horizontal and Vertical Tails
- Control Surfaces: Ailerons and Elevators

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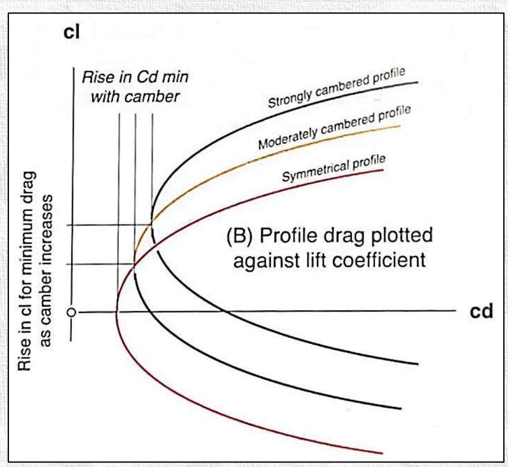
Airfoil Type

Airfoil Selection Objectives
- Low Reynolds number: 300,000 – 500,000
- Maximize C_L / C_D and $C_L^{1.5} / C_D$
- Minimize drag at turns
- Optimize airfoil characteristics: camber and thickness



The Influence of Camber Profile Drag

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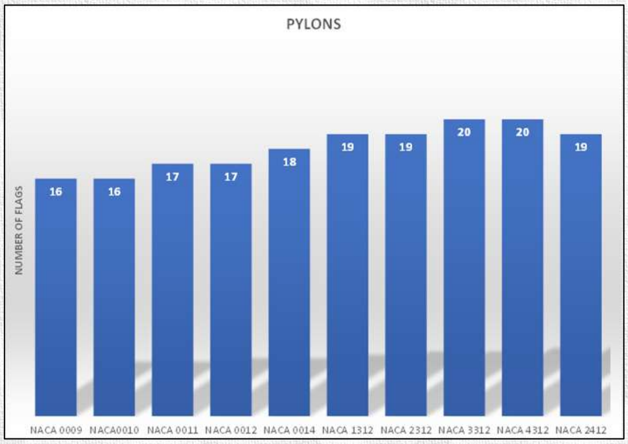
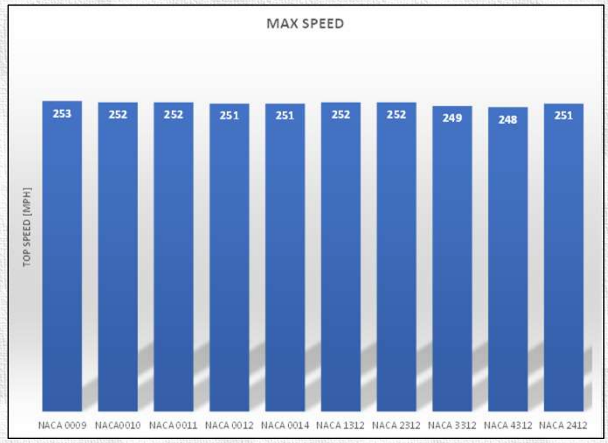
Generic Airfoil Comparison





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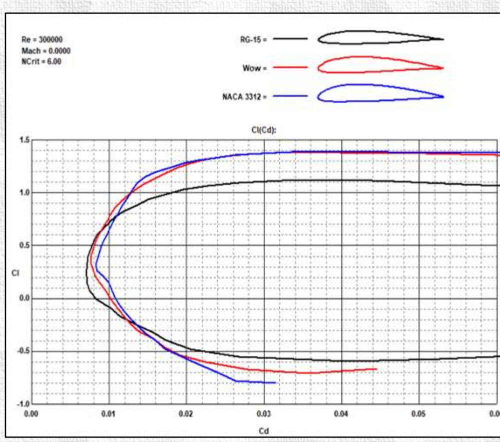
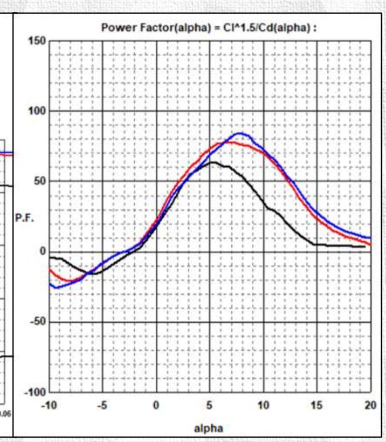
Benchmarked Airfoils

RG-15
- Max thickness 8.92% at 30.2% chord
- Max camber 1.76% at 40.3% chord
- Pylons: 18 flags
- Max speed: 251 mph

Wow
- Max thickness 11.12% at 27.9% chord
- Max camber 2.75% at 40.2% chord
- Pylons: 19 flags
- Max speed: 250 mph





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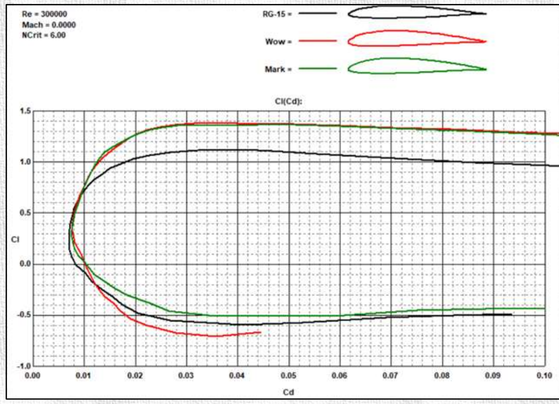
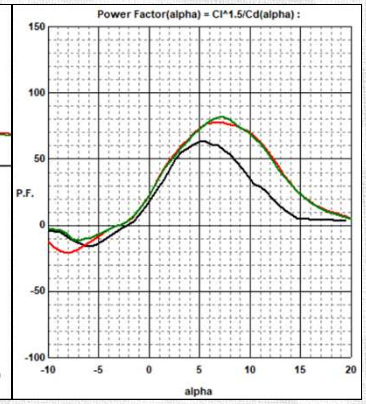
Preliminary Airfoil Design

Mark
- Max thickness 10.59% at 30.9% chord
- Max camber 2.52% at 40.2% chord
- Pylons: 25 flags
- Max speed: 256 mph





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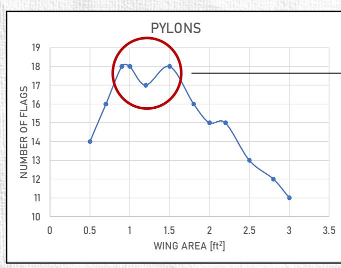
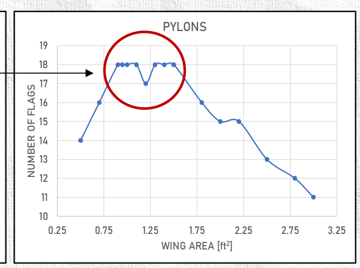
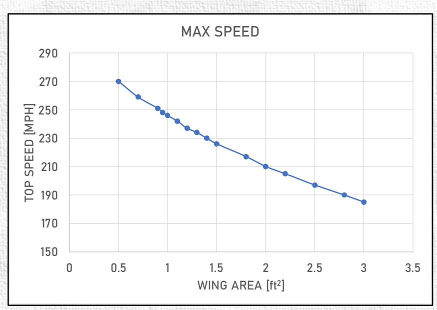
Wing Area

Wing Area (ft^2)	Altitude (ft)	Glide time (s)	Turn G load	$t_{straight}$ (s)	t_{turn} (s)	# Flags	Top speed (mph)
0.5	682	120	10.6	7.9	3.8	14	270
0.7	612	128	12.1	8.2	3.1	16	259
0.9	554	133	13.1	8.4	2.7	18	251
0.95	540	132	13.3	8.5	2.8	18	248
1	528	131	13.4	8.6	2.6	18	246
1.1	504	132	13.7	8.7	2.5	18	242
1.2	481	129	13.9	8.9	2.4	17	237
1.3	461	129	14.1	9	2.3	18	234
1.4	442	127	14.1	9.1	2.3	18	230
1.5	424	124	14.2	9.3	2.2	18	226
1.8	377	119	14.3	9.6	2.2	16	217
2	350	114	14.3	9.9	2.1	15	210
2.2	326	110	14.2	10.1	2	15	205
2.5	294	103	13.9	10.5	2.0	13	197
2.8	267	97	13.7	10.9	2.0	12	190
3	251	92	13.5	11.1	2.0	11	185







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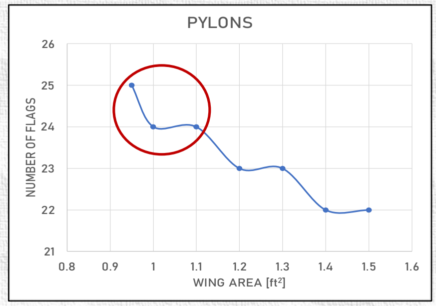
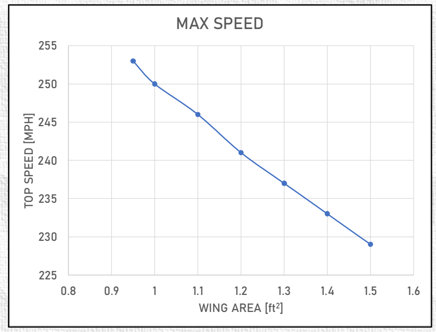
Wing Area

Wing Area (ft^2)	Wingspan (ft)	Altitude (ft)	Glide time (s)	Turn G load	$t_{straight}$ (s)	t_{turn} (s)	# Flags	Top speed (mph)
0.95	2.757	624	170	15.4	8.6	2.1	25	253
1	2.828	607	168	15.4	8.7	2.2	24	250
1.1	25.150	575	166	15.7	8.8	2.1	24	246
1.2	3.098	546	162	15.7	9	2	23	241
1.3	26.000	520	160	15.9	9.1	2	23	237
1.4	26.325	495	156	15.8	9.3	1.9	22	233
1.5	3.464	473	152	15.8	9.4	1.9	22	229





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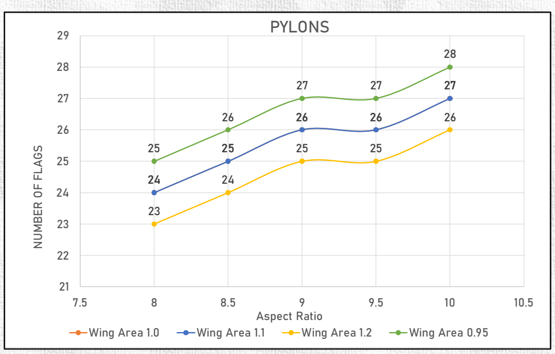
Aspect Ratio



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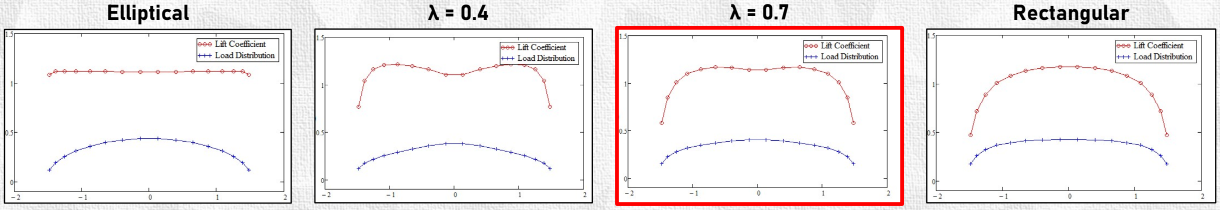
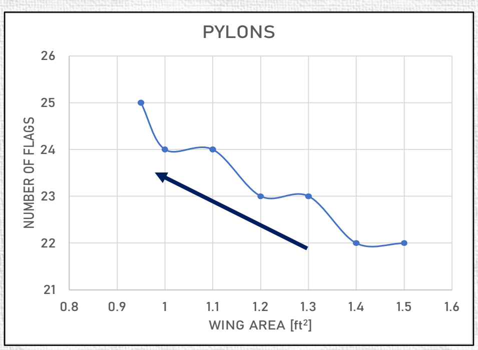
Taper Ratio

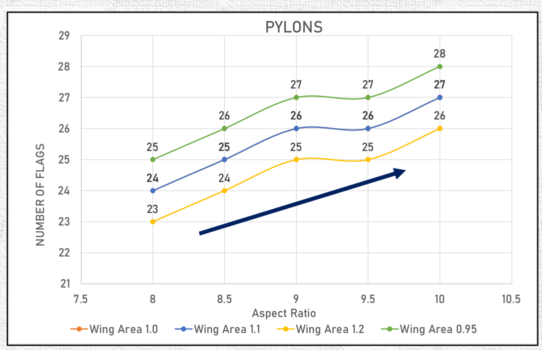
Elliptical | λ = 0.4 | λ = 0.7 | Rectangular



Optimum point between stall characteristics and ideal lift distribution

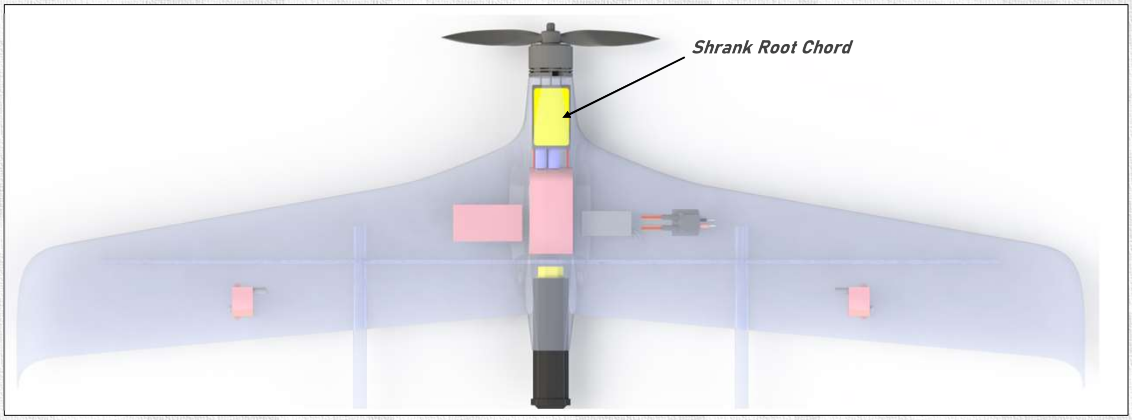
Aerodynamic Design Recommendations





Minimize Planform Area
Maximize Aspect Ratio
Taper Ratio 0.6-0.7

Layout Changes



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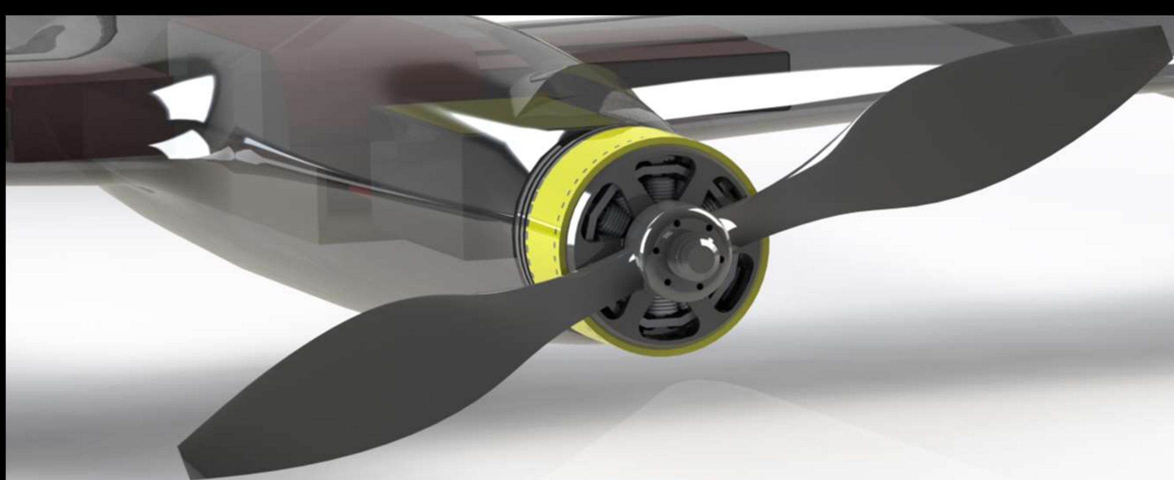
Meanwhile…



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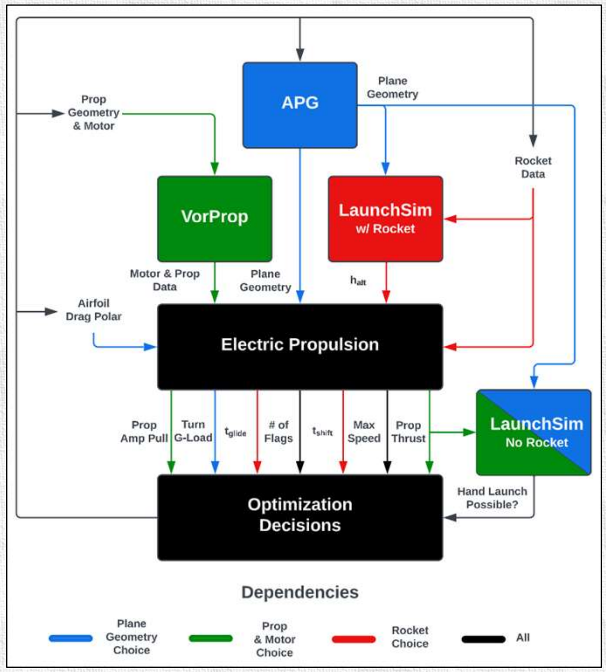
Propulsion Mathcad

- Created a master "Version Control" sheet to keep all results (flags, speed, volts, static thrust) in one space
- First draft had no direction and was a mess
- Next draft had more direction, but every variable changed, propulsion separated into groups and was assigned an aerodynamics team member
- Per Dr. Arena, the next draft was much more direct by only varying P/D, kV (and therefore diameter), and the rocket motors used



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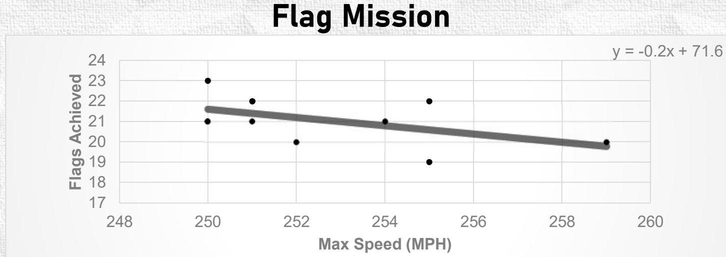
Mathcad Outputs

Flag and Speed Mission	Trendline (23 flags, 250 mph)	Top Performance (25 flags, 275 mph)
Motor (KV)	1300-1500	1950 Note: pulls 170 amps
Propeller (P/D)	1-1.2	1.5
Diameter (in)	5.5-8	6

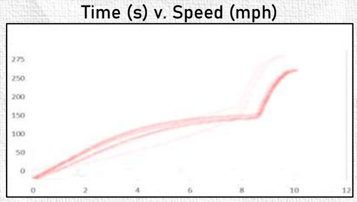
To find an optimal propeller and electric motor, Mathcad iterations varying P/D, motor kV, and propeller diameter were necessary to see trends in those resulting in high performance. Rocket motors had little effect on the trends explored.

Flag Mission

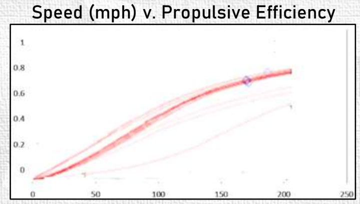


Speed Mission

Time (s) v. Speed (mph)



Speed (mph) v. Propulsive Efficiency



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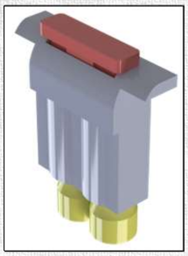
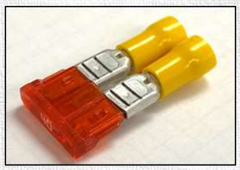
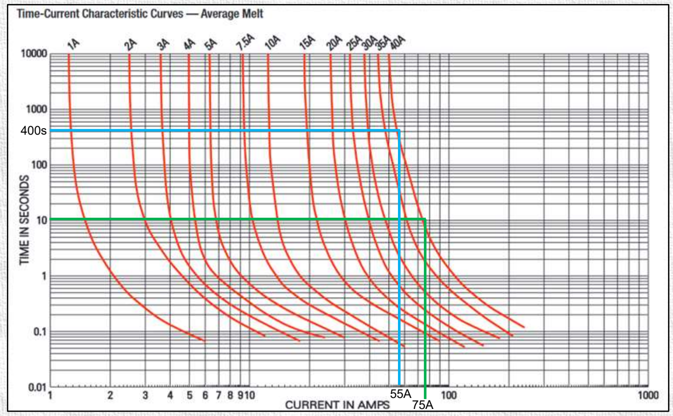
Fuse Data

- Any duration over 150 seconds will be considered “infinite” lifetime for the fuse
- Manufacturer data suggests that constant 55A is extremely reasonable
- 75A constant amp draw is reasonable for a 10 second flight







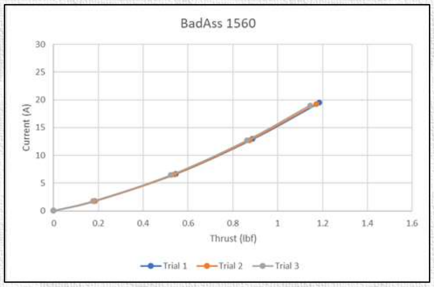
Electric Propulsion

- Maximum continuous amp pull of 55A
- Propeller size is dependent on kV of the motors
- Looking to benchmark and test a variety of sizes to achieve a 1-1.2 Pitch/Diameter
- Exploring folding prop options

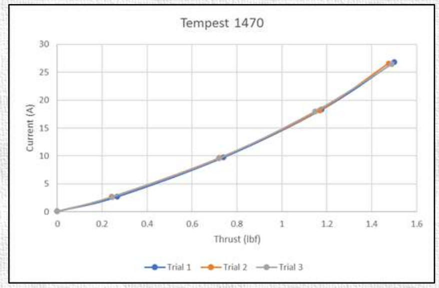
- Final Mathcad outputs gave us these final options

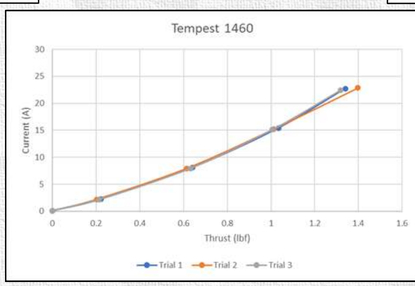
Motor	Type	KV	Max Cont. (W)	Max Draw (A)	Diameter (in)	Length (in)	Weight (oz)	Price (USD)
Badass 2814	Outrunner	1560	1200	65	1.102	0.551	4.13	$56.99
Tempest 2820	Outrunner	1460	1035	70	1.102	0.787	4.83	$39.99
Tempest 2826	Outrunner	1470	1515	82	1.102	1.023	5.96	$42.99

Dyno Testing



- All motors tested with an APC 7.25x6 trimmed propeller





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Rocket Motor Background

Class Background
- E and below are considered low-powered
- F and G are mid-powered
- H and above are high-powered
- A-G do not require National Association of Rocketry certification

Rocket Motor Codes
- Each rocket has a designated code
- For example, F40W-4
    - "F" indicates the class
    - "40" indicates the average thrust in Newtons
    - "W" indicates the propellant type (usually only affects burn color)
    - "4" indicates the delay of time, in seconds, until the ejection charge ignites

Class	Total Impulse (N*s)
A	1.26-2.50
B	2.51-5.00
C	5.01-10.00
D	10.01-20.00
E	20.01-40.00
F	40.01-80.00
G	80.01-160.00

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Rocket Motor Requirements

Rocket Motor
- 80 N-s impulse or less
- Single rocket design
- Single-use or reloadable
- Known brands
- Short burn time

Ignition Switch
- Soldered to ESC
- Ignited from 5S LiPo battery
- Designed to be single-use

Name	Burn Time (s)	Avg Thrust (lb)	Impulse (N-s)	Total Mass (g)	Propellant Mass (g)	Cost (USD)
AeroTech F40W-4	2.1	8.57	80	126	37.9 (30% of total)	$24.60
AeroTech F50-6T	1.4	12.33	76.8	85	37.9 (44.6% of total)	$29.44
Cesaroni P24-3G (F51)	1.5	11.24	75	95	33.0 (34.7% of total)	$23.03

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Rocket Testing

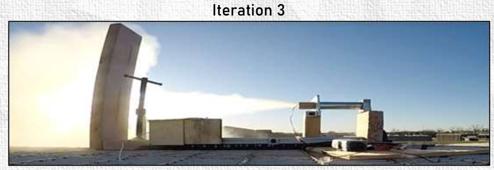
Goals
- Verify burn time of rockets
- Determine the heat of the flow and effects on different material samples
- Study the rockets for any other concerns that could affect the mission and safety of the audience

Test Stand Alterations
- First iteration was too long
- Second test stand made more stable and accurate to design
- Third version was condensed and provided all the data needed
- Fourth iteration added a backstop for safety and raised rocket to better simulate flow on tail

Iteration 1

Iteration 2

Iteration 3



Iteration 4

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Rocket Testing Results

- Determines how high the tail needs to be
- Determines what parts need to be heat proofed
- Illustrates heat expansion of the rocket
- Future testing includes heat and pressure out the front of the rocket

Model	Location 1	Temp 1 (°F)	Location 2	Temp 2 (°F)
F40	3oz and Balsa (4")	98.3	Carbon Fiber (10")	76.4
F25-T1	3oz and Balsa (4")	94.28	Carbon Fiber (10")	171.14
F25-T2	3oz and Balsa (4")	218	Carbon Fiber (10")	87.2
Estes	Flow (10")	272.5	Kevlar (10")	N/A
F10	Flow	N/A	Kevlar (10")	N/A
F40	Casing	123	Kevlar (10")	N/A

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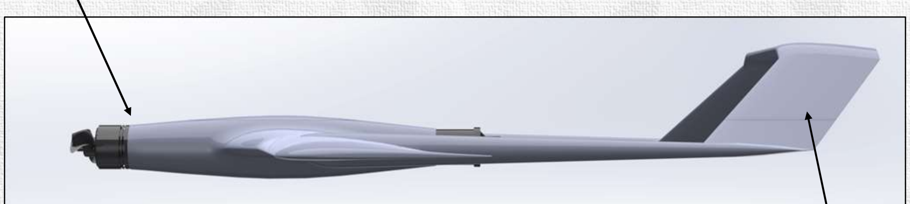
Layout Validation



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Simultaneously…

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Structural Benchmarking: Skin Materials

Material	Density (kg/m^3)	Modulus of Elasticity (GPa)	Tensile Strength (MPa)	Pros	Cons
Fiberglass (3oz)	1124.9	70	62.1-124.1	Light, Durable, Affordable	Weak
Tooling Glass (7.5oz)	2208.86	67.6	49.8	Strong, Affordable, Fatigue Resistance	Heavy
Kevlar/Aramid	1210-1320	70-112	58.6-72.4	Yellow, Fatigue Resistance	Expensive, Heavy
Carbon Fiber (twill)	1600	55.82	717	High Strength to Weight Ratio, Low Thermal Expansion, Fatigue Resistance	Expensive
Unidirectional Carbon Fiber	1800	255	5033	Very Strong in Single Load Direction	Expensive, No Out-of-Plane Strength

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Structural Benchmarking: Core

Material	Density (kg/m^3)	Modulus of Elasticity (GPa)	Tensile Strength (MPa)	Pros	Cons
Balsa Wood	160	1.8-6.4	4.9-17.6	Light Weight, Strong, Easy to Cut	Highly Flammable, Poor Durability
Polycarbonate 1/16"	1200	2360	64.5	Durable, Moldable	Low Melting Point
Divinycell	60	75	1.8	Light, Moldable	Weak
Honeycomb	29	0.023	0.62	Light	Difficult to Work With, Thick
Polyetherimide (PEI)	1380	7680	131	Strong, Machinable, Heat Resistant	Dense, Expensive, Conductive
Foam Board	450	2.92	3.32	Easy to Cut, Affordable	Weakest, Heavy

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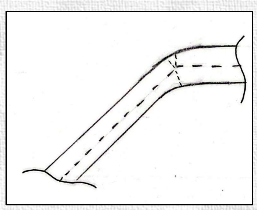
Building the Practice Mold

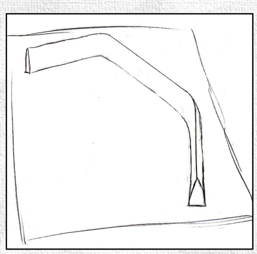
Manufacturing Issues

- Eliminating negative CNC draft angles
  - Front/Back airfoil parts
  - Break up into smaller parts
  - Flexible foam
- Assembling positive tail plug

Solutions

- 3D print "Mason" corners
- CNC top/bottom airfoil halves
- Use parting board as jig to build positive plug





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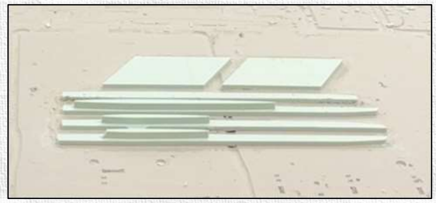
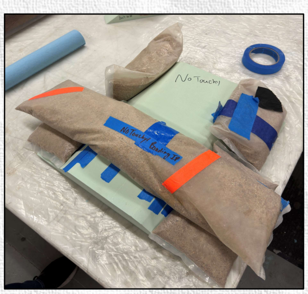
Practice Tail - CNC

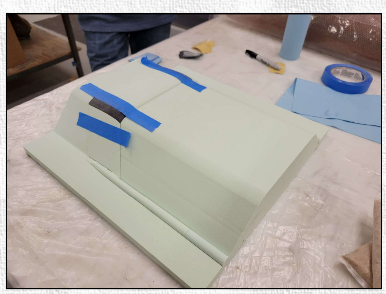
- Small CNC parts have quality issues on thin edges
- Tail complexity required 10+ pieces to be CNC'd including top/bottom halves



Practice Tail - Sanding and Bonding

- Bonded the two pieces of the negative mold together
- Sanded to remove machine marks
- Bonded the halves of the tail plug
- Applied and sanded drywall compound to fill gaps
- Bonded the whole tail together





Practice Tail – Removing the Bonded Plug

Issues
- Positive plug bonded to parting board
- Broke apart immediately

Solutions
- Needed much more colloidal
- Laid release tape and thin plastic sheeting in parting board

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Making the Mold






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Here Comes the Boom

First Tail Layup
- One boom 3oz and Carbon @ 90°
- Second boom 3oz and Two Carbon @ 90°
- Surprising torsional rigidity

Second Tail Layup
- Both booms Carbon @ 90° and Unidirectional Carbon

Final Sizing
- Carbon @ 45° and Unidirectional Carbon per half of boom
- Diameter increased
  - Max Diameter: 1 inch
  - Min Diameter: 0.5 inch


First tail layup


Second tail layup

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Lessons Learned

- Increase boom diameter
- Attaching tails to booms at 45° angles is difficult
- Increase trailing edge thickness
- Leave a flange on mold for chromate
- Thin edges chip on CNC
- More colloidal when bonding pieces
- 3D printing worked well for replacing complicated geometry
- Tail airfoil increased to 14% minimum thickness
- Non-planar mold method feasible
- Use less tool coat
- Use less release

Nearly no problems encountered were a result of using a non-planar mold

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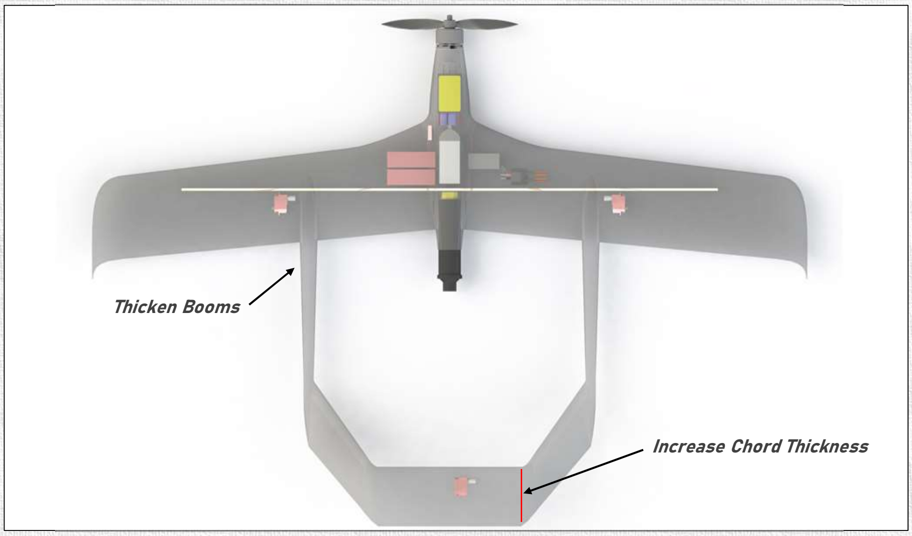
Layout Changes



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Concurrently…

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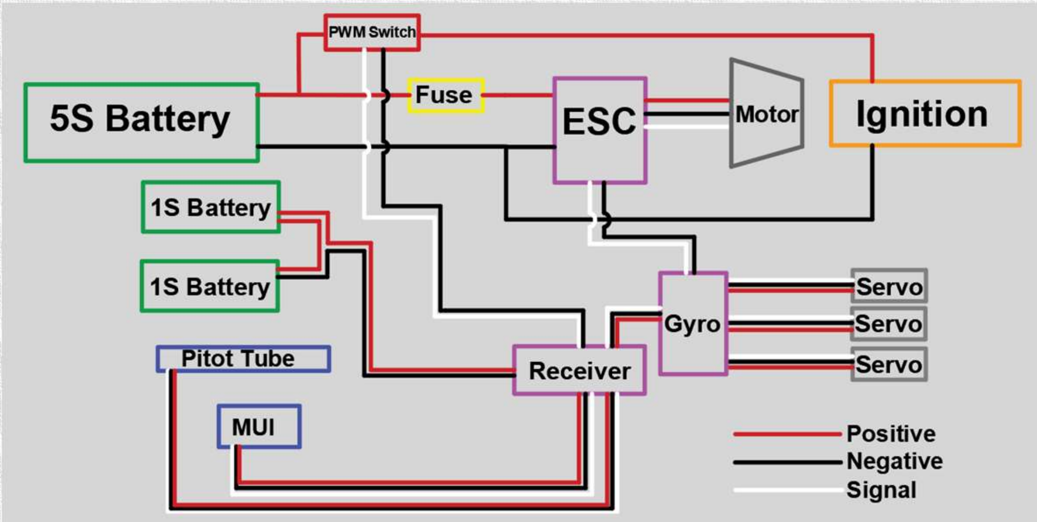
Updated Circuit Layout



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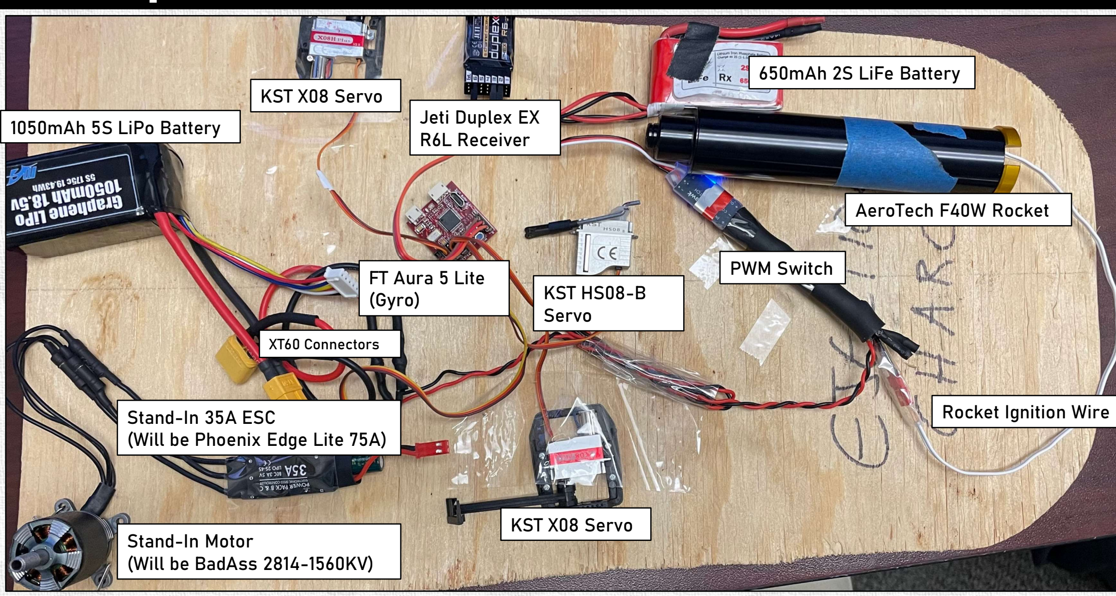
Mock-Up Internal Circuit



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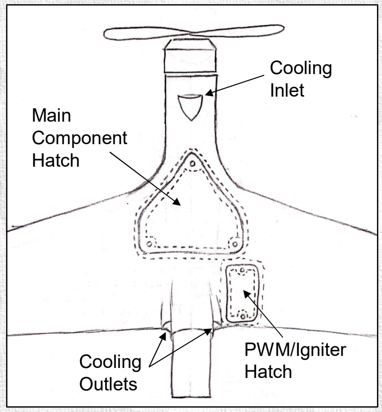
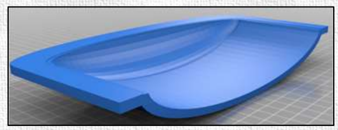
Integration Considerations

Frequency of Removal
- Batteries (5S and 2S)
- Rocket and Ignition
- Fuse (Externally Accessed)
- PWM Switch
- ESC
- Receiver
- Motor
- Servos and Wires

Component Cooling
- Inlets on top, behind motor
- Exact cooling requirements unknown. If more is needed, additional external scoop(s) will be added.

Internal Structure
- Avoids structural members





Battery Requirements

- 5S and 2S for propulsive and control components, respectively
- Looking to minimize size, weight, and thus capacity
- "MaxAmps" brand provided an excellent weight and size per capacity
- Considering slightly sacrificing weight to increase capacity; improving battery chemical reaction
- 1000mAh minimum 5S capacity
- Two 1S batteries in series to save weight and space – testing will provide more information

5S Battery

1S Battery

5S Battery

Brand	Capacity (mAh)	Weight (g)	Length (in)	Width (in)	Height (in)	Price (USD)
Ovonic	1300	187	2.87	1.46	1.38	$29.99
MaxAmps	1050	152	2.68	1.38	1.38	$79.99
MaxAmps	1300	177	2.68	1.57	1.38	$89.99
MaxAmps	1450	242	2.68	1.87	1.38	$99.99

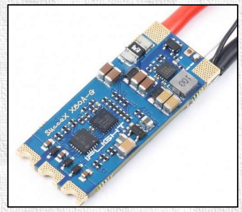
2S Battery

Brand	Capacity (mAh)	Weight (g)	Length (in)	Width (in)	Height (in)	Price (USD)
Tattu	650	43	2.24	1.22	0.47	$10.99
Happymodel 1S (x2)	650	32	2.36	1.42	0.31	$9.98

ESC Requirements

- Pull 75-100 amps in burst
- Telemetry capable
- Performance valued over size
- Lightweight

Avian 100A



BL Heli SucceX 80A

Phoenix Edge Lite 75A

ESC	Dimensions (mm)(WxLxH)	Weight (g)	Amperage (A)	Price (USD)
Avian 100 Amp Brushless Smart ESC, 3S-6S	35 x 76 x 33	126	100-119	$99.99
Phoenix Edge Lite 75 Amp 2S-8S	31 x 66 x 22	81	75	$115.95
iFlight SucceX X80A 32bit BLHeli_32 2S-8S X-Class ESC	17 x 40	8.1	80	$63.99

Receiver/Stabilization Requirements

- Jeti brand for compatibility
- Integrated telemetry
- Altimeter capabilities
- 7 or 4 channels – depending on gyro

Jeti Assist

- Integrated into receiver
- Saves space laterally at the cost of thickness

Separate Gyro

- Benefit of launch assist to help mitigate torque
- Only a 4-channel receiver is needed, 6-channel receiver for additional systems

Flite Test Aura Lite 5

Jeti Duplex EX R6L

Jeti Duplex REX 7 Assist

Receiver	# Channels	Dimensions (mm)	Weight (g)	Price (USD)
Duplex REX 7 Assist	7	42 x 28 x 11	13	$155
Duplex EX R4L	4	40 x 18 x 6	5	$59
Duplex EX R6L	6	40 x 20 x 7	8	$79

Servo Options

- High torque and speed
- Low size and weight
- Some “leftovers” from previous years; will test to confirm viability and use as available

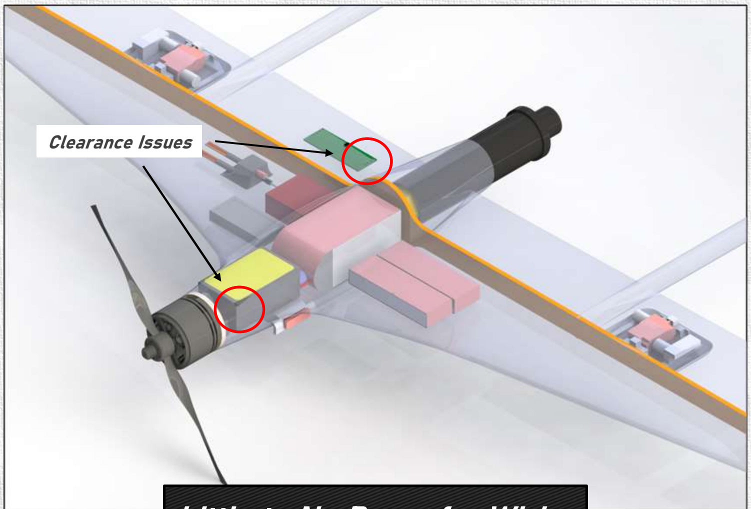
Name	Dimensions (in)	Weight (oz)	Torque (oz/in)	Speed (seconds @ 60 degrees)	Price (USD)
KST HS08-B High Torque Coreless Slim LV/HV Digital Servo	0.99x0.93x0.31	0.39	69	.21/.13/.141	$50.00
KST X08 Metal Gear Digital Micro Servo	0.63x0.93x0.31	0.32	72	.17-.13	$42.99

Summary

- Still deciding on rocket based on availability, weight, and if better numbers are desired over more
- Prop will be decided on per mission basis and still working to find best P/D
- Two 1S batteries are in testing to see if comparable to 2S for sizing

Part	Selected
5S	MaxAmps 1050mAh 5S
2S	2x – Happymodel 650mAh 1S
Motor	BadAss 2814-1560kV
Propeller	Working to optimize for each mission and trim propellers
Rocket	Cessaroni P24, Aerotech F40, Aerotech F50
ESC	Phoenix Edge Lite 75 Amp 2S-8S
Receiver	Jeti Duplex EX R6L
Gyro	FT Aura Lite 5
Servo	KST HS08-B High Torque Coreless Slim LV/HV Digital Servo
Pitot	Jeti MSpeed EX
PWM	Elechawk RC Switch
Fuse	Mouser 504 ATC 40A

Skin Thickness and Tolerance



Little to No Room for Wiring

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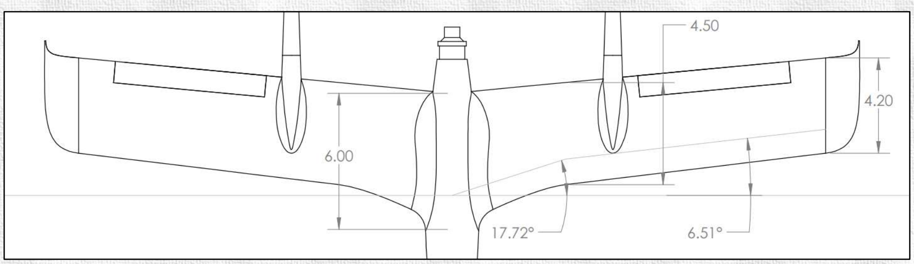
Solution: Poly Taper and Sweep



Poly-tapered

- Root chord: 6 in
- Wingspan: 3 ft
- Poly taper location: 0.28
- Taper ratios: 0.75 (from root to ϵ_t) and 0.93 (from ϵ_t to tip)

Poly-swept

- Sweep angle: 17.7 degrees (from root to ϵ_t) and 6.5 degrees (from ϵ_t to tip)

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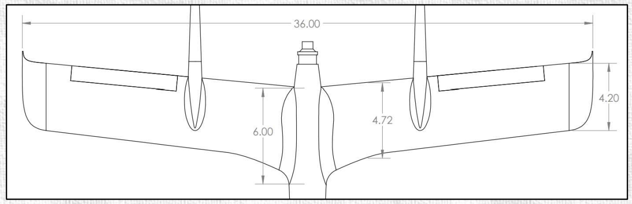
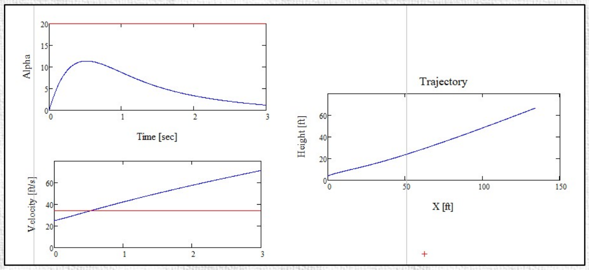
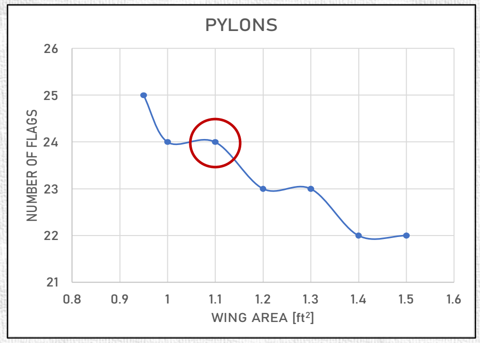
Solution: Wing Area

- Lower stall speed
- Ability to hand launch
- Maintain aspect ratio and internal volume







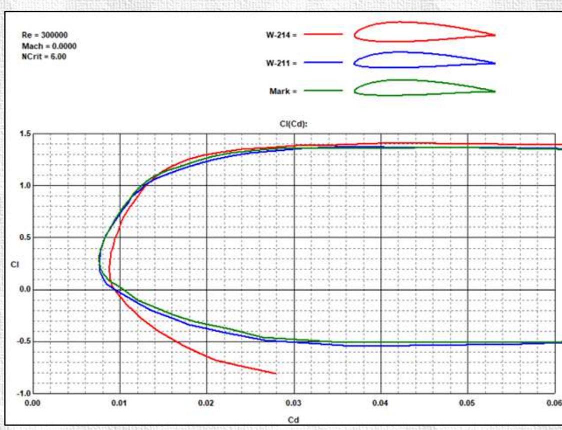
Solution: Refined Airfoil

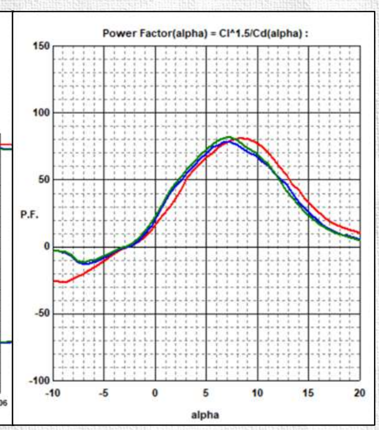
W-211

- Max thickness 11% at 30.5% chord
- Max camber 2.43% at 37% chord

W-214

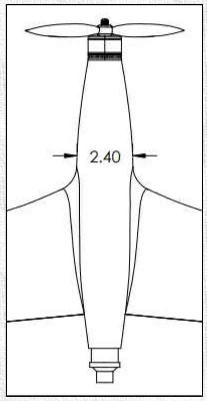
- Max thickness 14% at 30.4% chord
- Max camber 2.43% at 36.5% chord

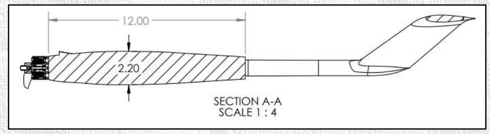




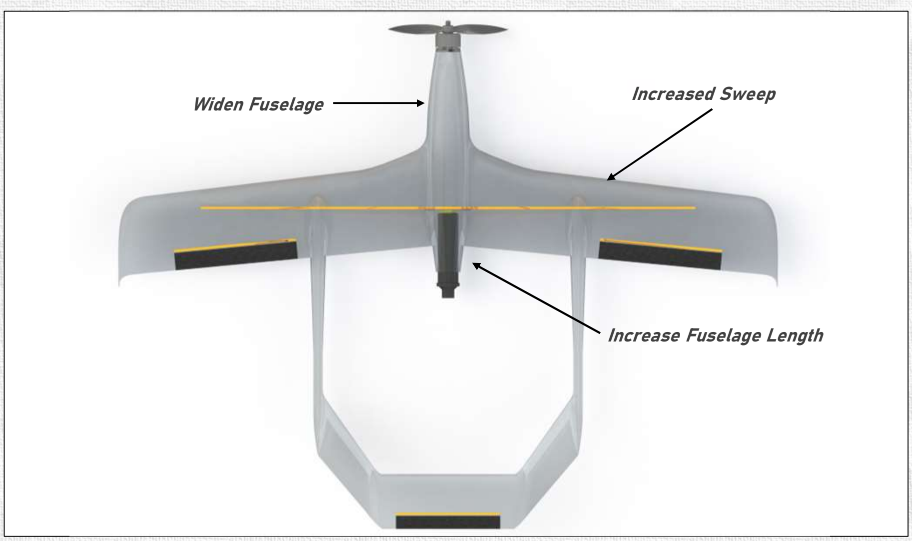
Solution: Fuselage Sizing

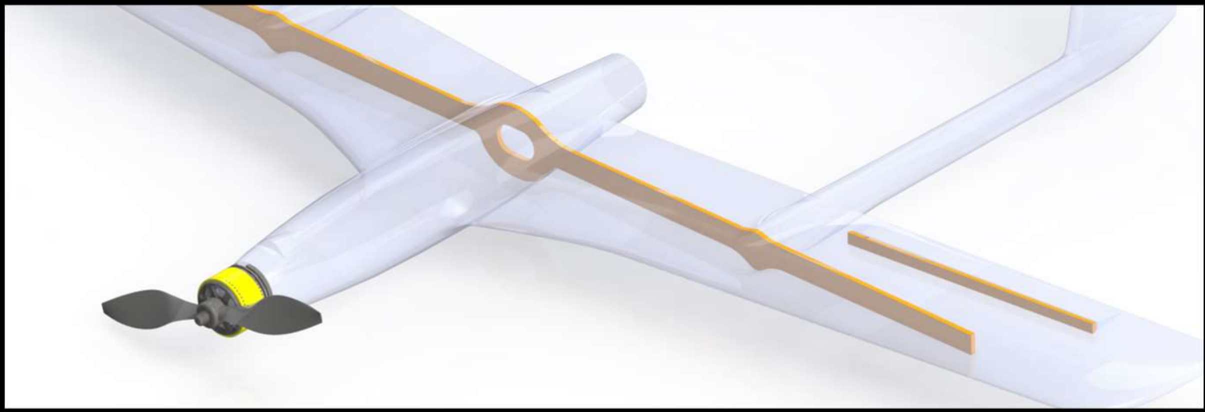
- Length: 1 ft
- Max Width: 2.4 in
- Max Height: 2.2 in
- Wetted Area: 55.9 in^2





Layout Changes





Contemporaneously…

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Structural Benchmarking: Internals

Material	Density (kg/m^3)	Modulus of Elasticity (GPa)	Tensile Strength (MPa)	Pros	Cons
Garolite (G-10)	1800	12 - 17	131	Flame Retardant, Strong, Electrical Insulation	Must be Machined
AL Tubing (6061-T6)	2770	68.9	290	Strong, Low Bending, Well Documented	Heavy, Difficult to Work With
Carbon Tubing	1600	234	4.14	Stout	Heavy, Expensive
Polyvinyl Carbonate (PVC)	1390	4.83	60	Cheap, Malleable After Heating, Impact Resistance	Heavy, Bendy, Poor Availability
PLA Filament	1240	3.5	59	Manufacturability	Low Heat Resistance
Balsa	160	1.8-6.4	4.9-17.6	Light Weight, Strong, Easy to Cut	Highly Flammable, Poor Durability

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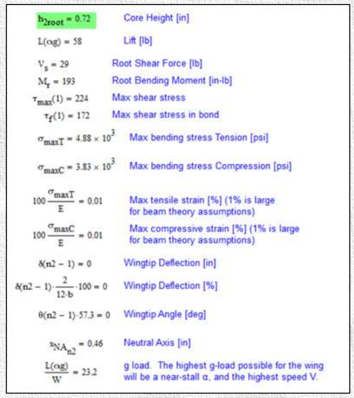
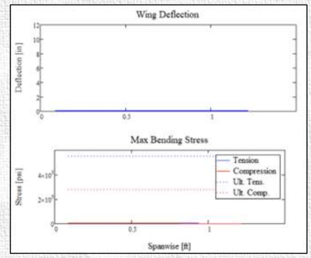
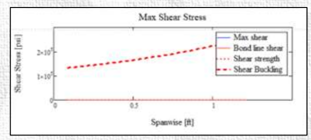
Spar Analysis

- After experimental testing with a composite spar demo, ultimate failure from a point load occurred at 46.9 pounds
- The anticipated ultimate failure load was 58 pounds







Spar Analysis

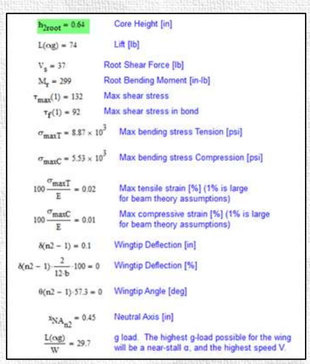
- Unidirectional carbon spar caps sized to 0.054 inch thick and 1.12 inch wide, these were the sizes we measured after folding the material provided in lab in half and adding resin to attach 6 layers each

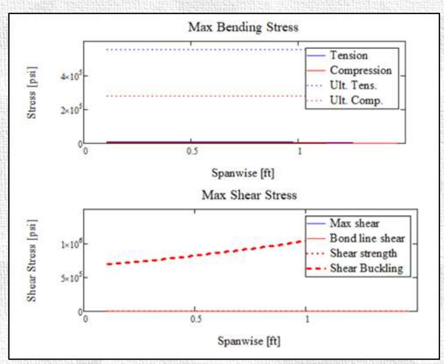
Original Web

- 1/8th inch balsa core
- Shear stress: 224 psi
- Total load: 58 lb
- Tested total load: 47 lb

Updated Web

- 1/4th inch balsa core
- Shear stress: 132 psi
- Total load: 74 lb
- Predicted tested total load: 60 lb



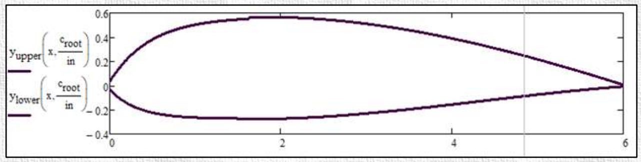


Wing Torsion

- Analysis of twist due to aerodynamic forces
- Primarily used to ensure aircraft skin would not fail due to torsion beyond spar tip

$$q_s = -(S_y/I_{xx})\int_0^s ty\, ds$$

$$\frac{d\theta}{dz} = \frac{q}{2A}\oint\frac{ds}{Gt}$$



Span Location of Twist: Wing Twist Due to Lift:

$$Span\_Location = \begin{pmatrix} 1.563 \\ 4.641 \\ 7.578 \\ 10.285 \\ 12.679 \\ 14.689 \\ 16.251 \\ 17.321 \end{pmatrix} \cdot in \quad \theta = \begin{pmatrix} -8.536\times 10^{-3} \\ -0.045 \\ -0.059 \\ -0.059 \\ -0.081 \\ -0.105 \\ -0.114 \\ -0.107 \end{pmatrix} \cdot deg$$

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Servo Mounting

- Internal Drive System Mounting is still planned
  - Mounted inside bubble protruding from wing underside
  - Similar weight to normal servo
  - Reduced parasitic drag
- Hatches located on servo mounting location for ease of maintenance
- Mounted at thickest point of the wing along the control surface

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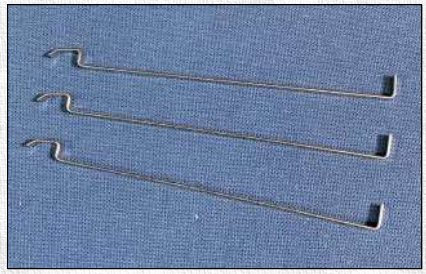
Rocket Retention



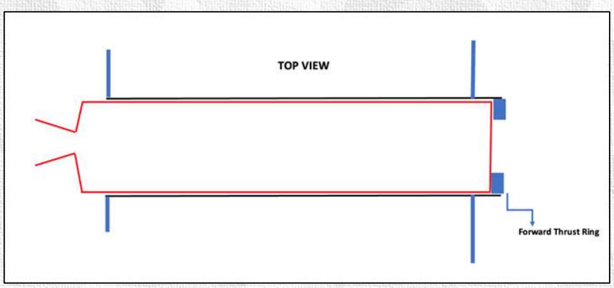
Engine Hook
- Mechanical spring retention of the rocket motor
- Lightweight
- Simple

Threaded Engine Retainer
- Mechanical retention
- Heavy
- Robust

Friction Fit
- Non-mechanical motor retention
- Extremely lightweight → strip of masking tape
- Less secure retention strategy

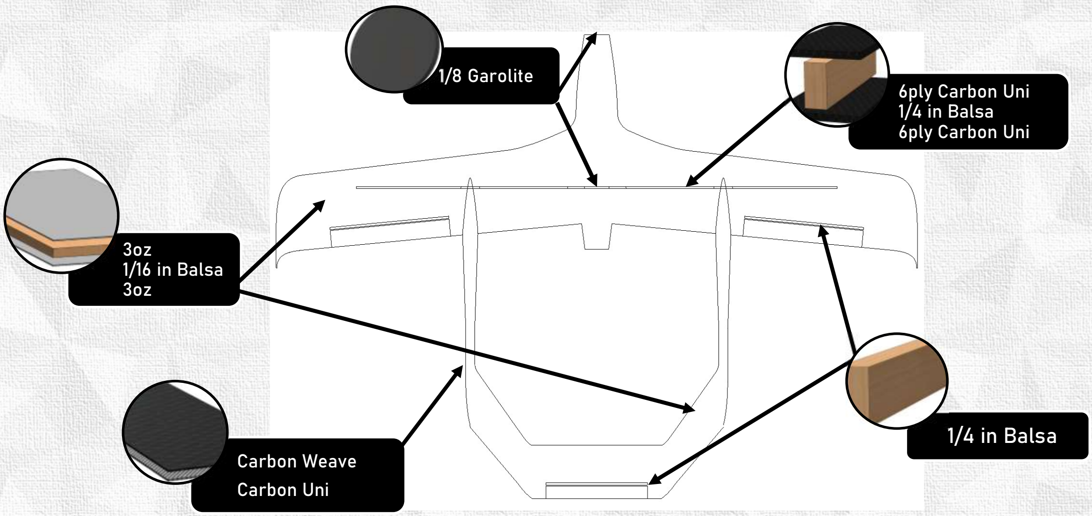
Rocket Mounting

Internal Bulkhead



- Thrust transferred through a forward bulkhead
- Bulkhead to be constructed from Garolite to ensure that the planes internals will not be harmed in the case of a malfunction

Composite Construction



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Stability and Sizing

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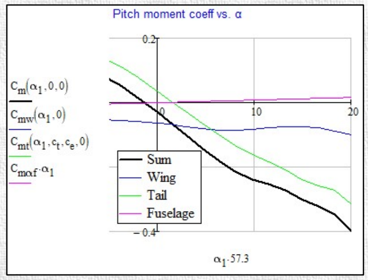
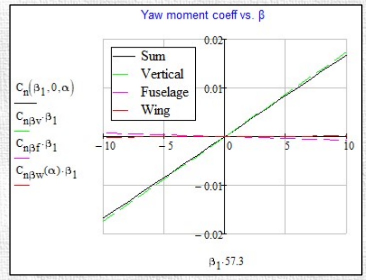
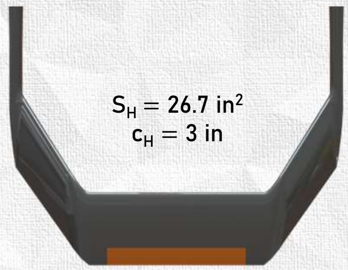
Tail Sizing

Objectives
- Pitch Static Margin: 10-15%
- Yaw Moment Coefficient: $C_{n\_\beta} > 0.05$
- Roll Stability: $C_{l\beta w} < 0$

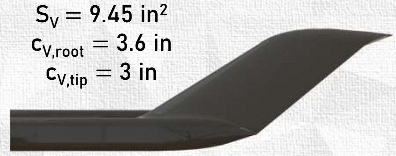
Outputs
- Pitch Static Margin: 27%
- $C_{n\_\beta} = 0.096$
- Yaw Static Margin : 276%
- $C_{l\beta w} = -0.037$
- $V_H = 0.56$
- $V_V = 0.03$







$S_H = 26.7$ in^2
$c_H = 3$ in



$S_V = 9.45$ in^2
$c_{V,root} = 3.6$ in
$c_{V,tip} = 3$ in

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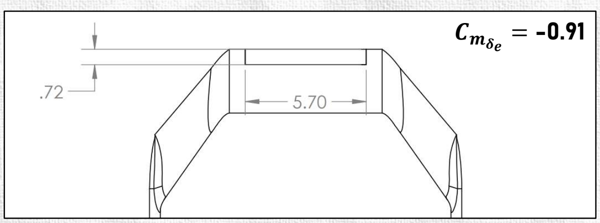
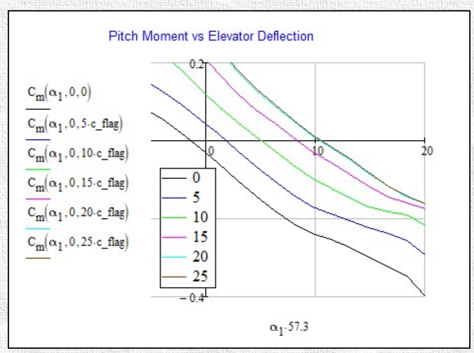
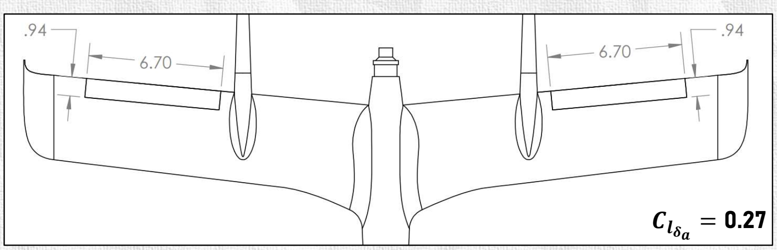
Control Surfaces



$C_{m_{\delta_e}} = -0.91$





$C_{l_{\delta_a}} = 0.27$

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Servo Confirmation

$\Delta H = 7 \cdot ozf \cdot in$ Hinge Moment
$\Delta H = 0.04 \cdot lbf \cdot ft$
$\Delta H_{servo} := 1.5 \cdot \Delta H = 11 \cdot ozf \cdot in$ Hinge Moment with FOS

Elevator torque

$\Delta H = 18 \cdot ozf \cdot in$ Hinge Moment
$\Delta H = 0.1 \cdot lbf \cdot ft$
$\Delta H_{servo} := 1.5 \cdot \Delta H = 27 \cdot ozf \cdot in$ Hinge Moment with FOS

Aileron torque

Surface	Chord (in)	Span (in)	Torque Required (oz-in)
Elevator	0.72	5.70	11
Aileron	0.94	6.70	27

- The previously chosen servos are still valid due to their strength

Name	Torque (oz/in)
KST HS08-B High Torque Coreless Slim LV/HV Digital Servo	72
KST X08 Metal Gear Digital Micro Servo	69

Final Sizing Summary

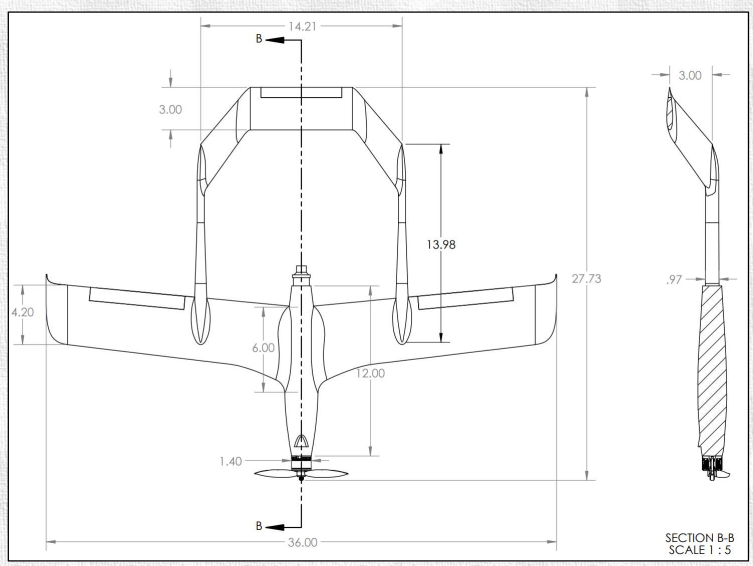
Wing
- Area: 1.13 ft^2
- Wingspan: 3 ft
- AR: 8

Fuselage
- Length: 12 in
- Max width: 2.4 in

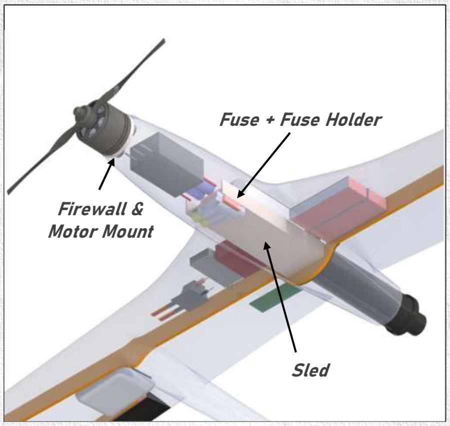
Horizontal Tail
- Area: 26.8 in^2
- Chord: 3 in

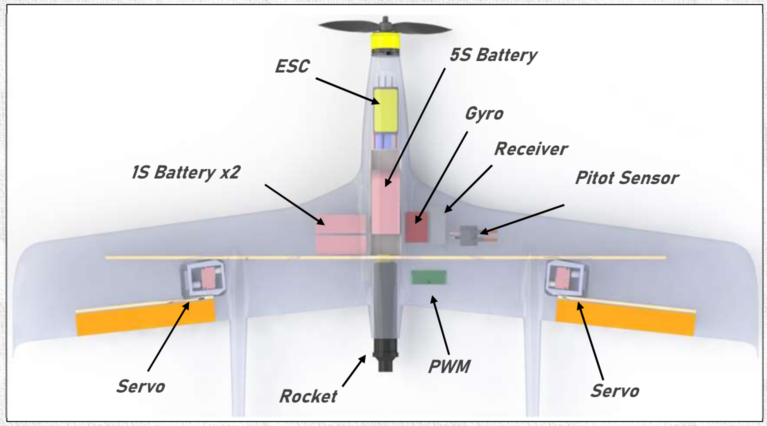
Vertical Tail
- Area: 9.45 in^2
- Span: 3 in

Boom
- Length: 14 in
- Max diameter: 1 in



Final Systems Layout





5S Battery secured by sled
Other components secured via Velcro

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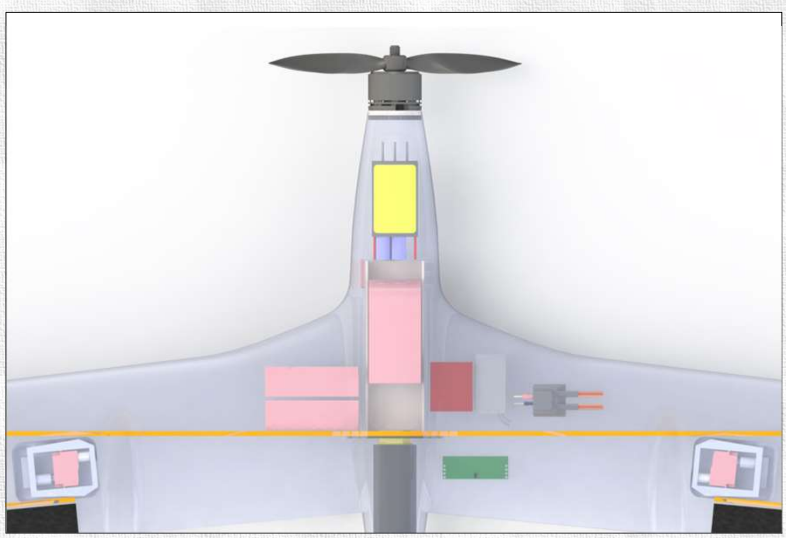
Weight Prediction

Upper Limit: 2.61
Lower Limit: 2.26



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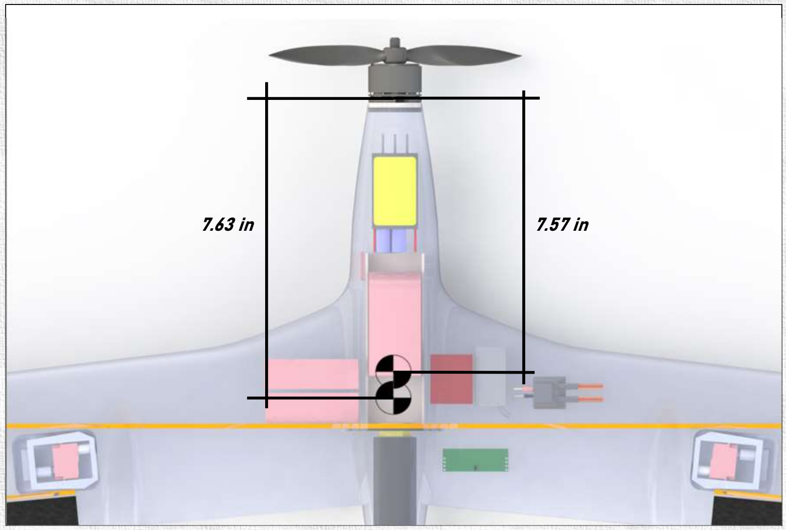
CG Shift

Rocket burn shifts CG 0.06 inches forward



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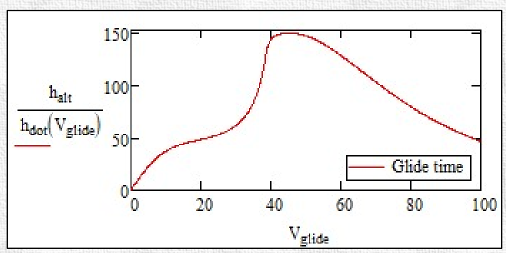
Mathcad (Theoretical) Performance

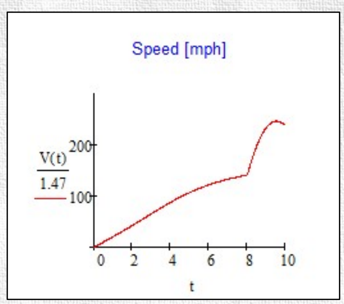
Pylons

- Altitude: 503 ft
- Glide time: 150s
- Flags: 21



Max speed

- Rocket ignition: 8s
- Speed: 248 mph



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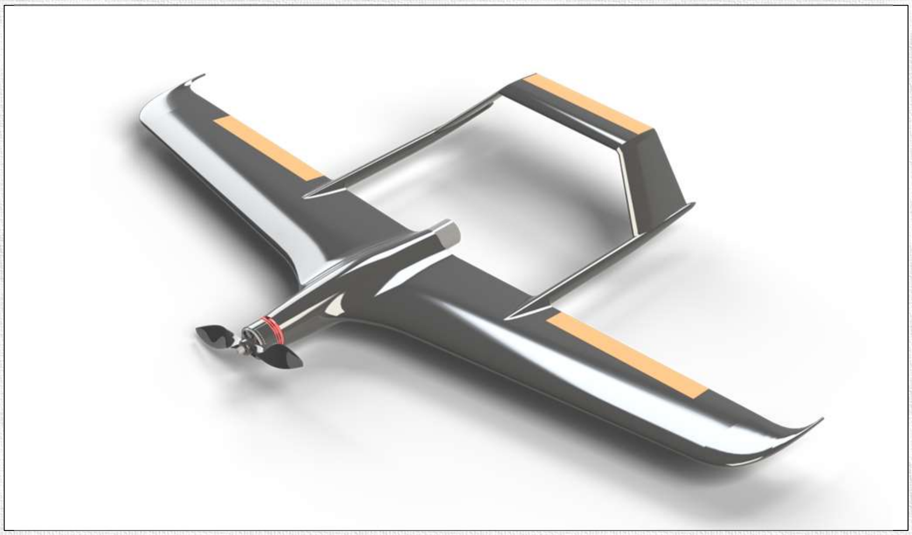
Where we started



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INTRODUCING…

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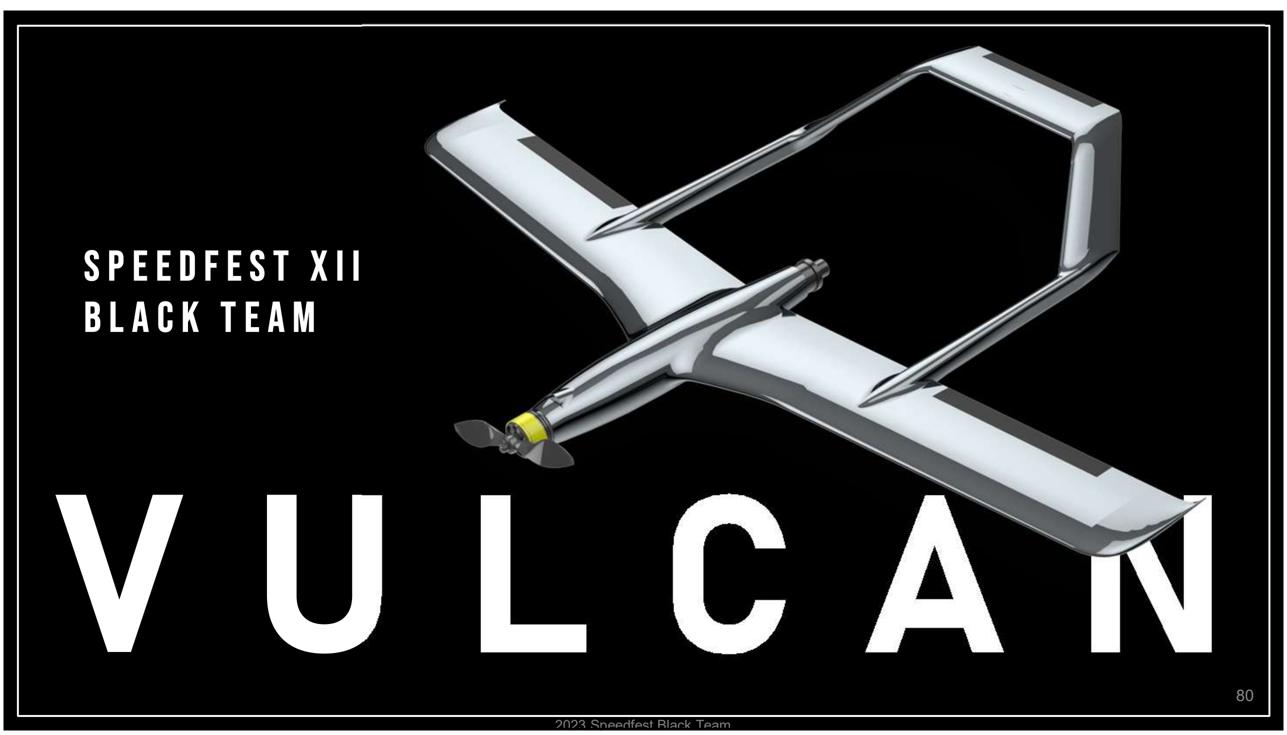
SPEEDFEST XII
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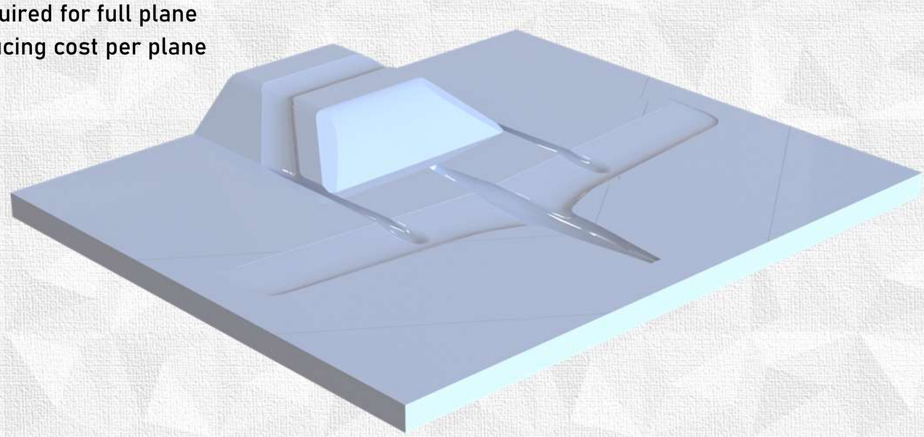
Manufacturing and Budget

- Non-planar mold with parting lines along the mid plane of wing and tail
- Front-load manufacturing time
- Less man hours required for full plane layup therefore reducing cost per plane



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Launch Rail

Initial Concept Downselect

- **Hand Launch**
  - Unsafe RATO
- **PVC Zero-Length Rail**
  - Lacked directional control/security
  - Awkward transportation
- **Pivot Locking Rail**
  - Heavy
  - Expensive
  - Limited transport options

Final Design

- Rifle bipod extendable legs
- 80/20 (1010) 1"x48" Rail
- Garolite Flame Diverter
- Adjustable launch angle
- Fits in a car, single person carry

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Launch Cart

Initial Concept

- Demonstrated basic functionality
- Primarily wooden construction
- Inspiration from fall-away rocket rail guides

Demonstration of Concept

- Proved functionality at small scale
- Smooth separation from aircraft

Final Prototype

- Secures aircraft in all 6 DOF relative to the launch cart
- Simple passive release mechanism
- Lightweight – 84 grams
- Additional rail buttons added to the edge slots

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Launch Cart Final Design

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Hand Launch Validation

- Outdoor throw trial conducted
- 2.6 lb brick approximately matching weight of plane
- Consistently 26-30 ft/s at a launch angle of 0-30
- Various throwers were able to achieve results
- Torque effects will be mitigated by the Flite Test Aura 5 Gyroscope

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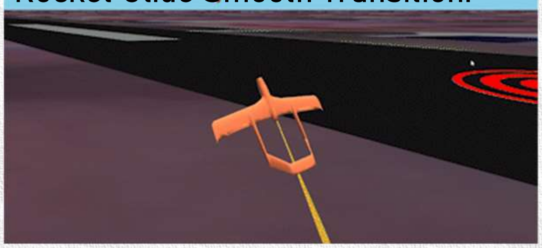
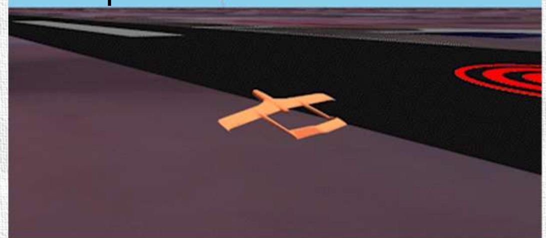
Flight Sim Demonstrations

Rocket Glide Max Height Stall:

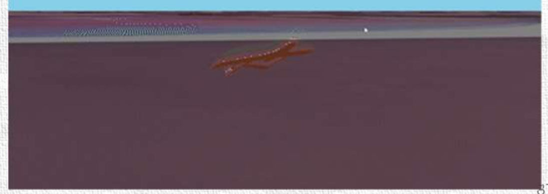
Rocket Glide Smooth Transition:



Max Speed Hand Launched:



Max Speed Launch Rail:



Launch Sim Parameters

Rocket Glide Max Height Stall

- 60-degree launch angle gave best performance
- Gains most height but stalls and falls some distance

Rocket Glide Smooth Transition

- 60-degree launch angle gave best performance
- Doesn't stall at top, but gains less height
- Produces similar results to stall tests

Max Speed Hand Launched

- 15-degree launch angle
- 27 ft/s launch speed

Max Speed Launch Rail

- 30-degree launch angle
- 30 ft/s launch speed
- 4 ft launch rail

Aircraft Performance

Rocket Glide
- Peak altitude of 483 ft
- Average glide time of 135 seconds
- Using this average glide time with EP Mathcad produces an average of 19 flags

Max Speed
- Average max speed of 208 kts or 240 mph
- Firing rocket at around 8 seconds is the most effective
- Climbing and then diving increases performance
- Diving time can vary

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Marketing – Name & Logo

- Roman God of Fire and the Forge
- Simple but captivating logo
- Wings give a sense of both mythology and aerospace
- Wings also form a "V"
- Name in "Roman Numeral" type font

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Social Media

- Added Facebook, YouTube, and LinkedIn
- Posted two new videos since PDR:
  - -What is Speedfest?
  - -Plane Name Reveal
- Many projects in the works

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Black Team App

iOS 16 only

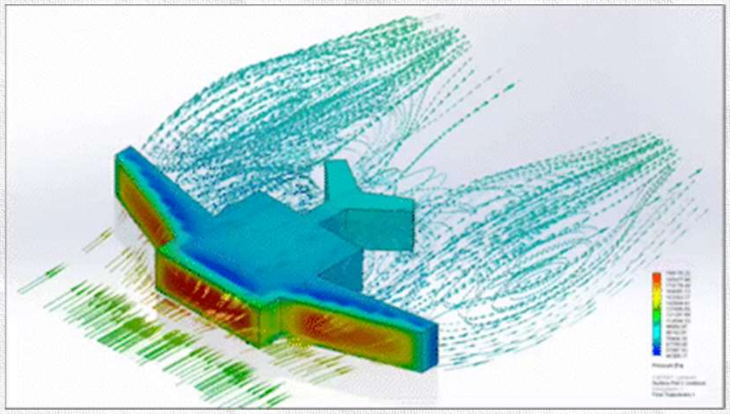
Outreach

School Visits
- Oklahoma Christian School (Feb 15th)
- Union High School (March 1st)
- Stillwater High School (March 8th)

Prospectives
- Visiting more schools
- Visiting other aerospace classes
- Tabling on campus

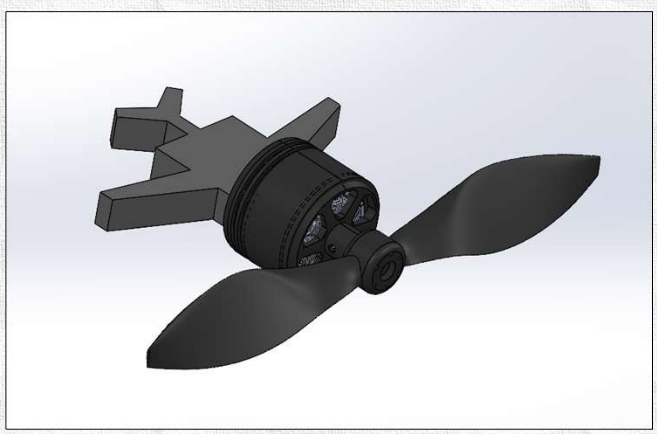
Aerodynamic Prospective

- Aerodynamic group members distributed between Structures and Propulsion
- Continue to iterate on control surface sizing



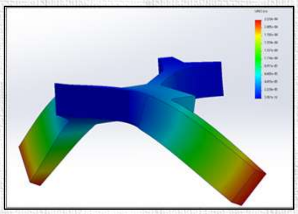
Propulsion Prospective

- Further rocket and propeller testing
- Finalize integration of the system
- Practice integration and soldering



Structure Prospective

- Thanks to the accomplishment of securing the duck, we will immediately begin the manufacturing of our mold tonight.
- We will experiment with using different materials to try and hit the sweet spot between rigidity and weight.



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Questions?

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