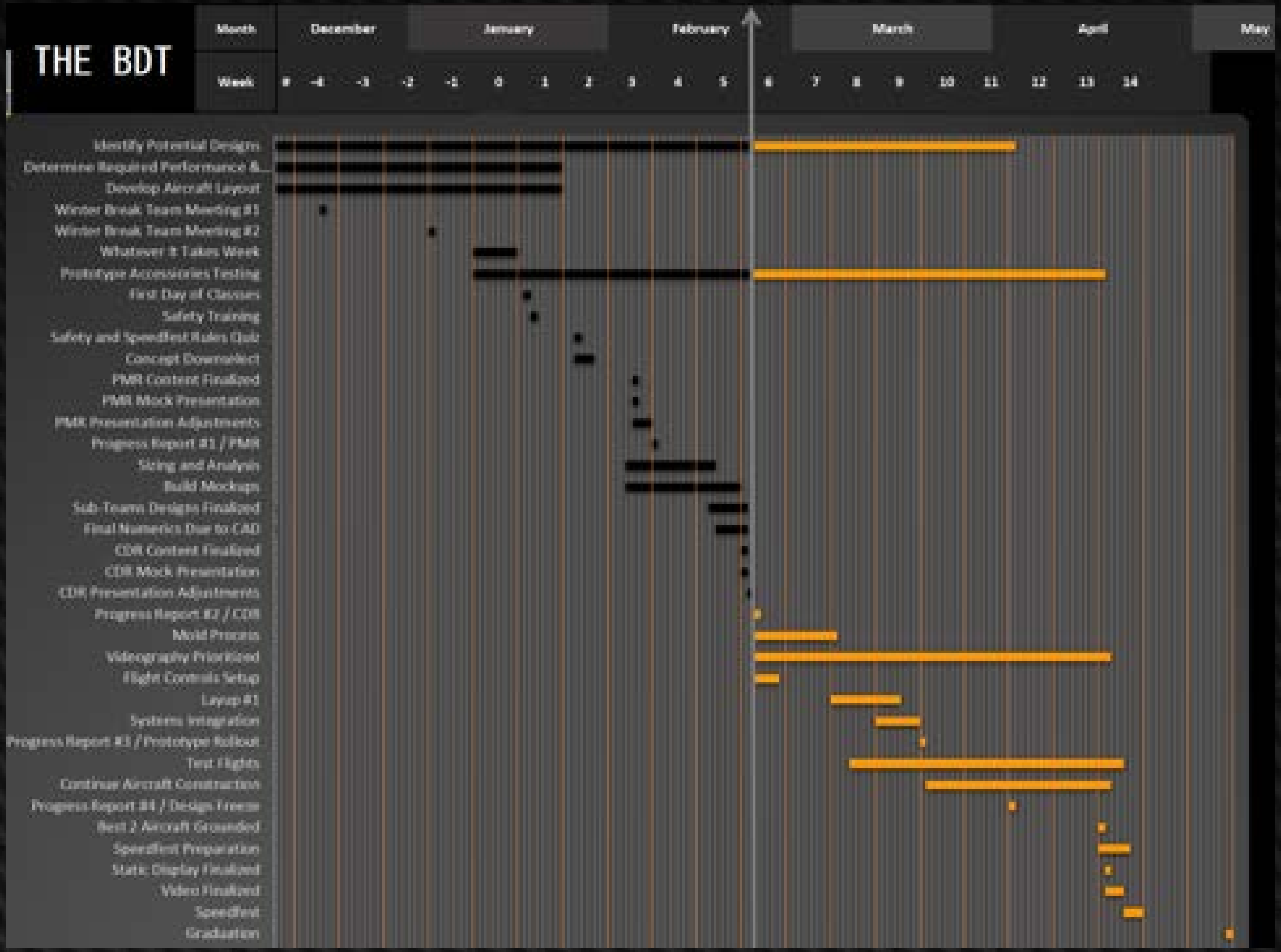
OSU BLACK
2021

Critical Design Review

OUTLINE

1. PROJECT UPDATE
   - Schedule
   - Speedfest Challenge & Concept of Operations
   - PDR Recap
   - Updated Design
2. Aerodynamics Design
3. Propulsion System
4. Structural Layout
5. Marketing

SCHEDULE


THE BDT
Month
December
January
February
March
April
May
Week
-4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Identify Potential Designs
Determine Required Performance &...
Develop Aircraft Layout
Winter Break Team Meeting #1
Winter Break Team Meeting #2
Whatever It Takes Week
Prototype Accessories Testing
First Day of Classes
Safety Training
Safety and Speedfest Rules Quiz
Concept Downselect
PMR Content Finalized
PMR Mock Presentation
PMR Presentation Adjustments
Progress Report #1 / PMR
Sizing and Analysis
Build Mockups
Sub-Teams Designs Finalized
Final Numerics Due to CAD
CDR Content Finalized
CDR Mock Presentation
CDR Presentation Adjustments
Progress Report #2 / CDR
Mold Process
Videography Prioritized
Flight Controls Setup
Layup #1
Systems Integration
Progress Report #3 / Prototype Rollout
Test Flights
Continue Aircraft Construction
Progress Report #4 / Design Freeze
Best 2 Aircraft Grounded
Speedfest Preparation
Static Display Finalized
Video Finalized
Speedfest
Graduation

SPEEDFEST 2021 OBJECTIVES

- DESIGN A HIGHSPEED, AEROBATIC, JET HOTLINER IN THE 30N CLASS, THAT IS RELIABLE AND FAST TO ASSEMBLE
- FIT IN A BOX OF MAXIMUM SIZE 6FT PER SIDE
- FLY AS MANY FLAGS AS POSSIBLE IN 3 MIN IN A FIGURE 8 PATTERN
- FLY A 4 MIN AEROBATICS SHOW
- DESIRABLE FOR PURCHASE BY HOBBYISTS
- UNIT COST UNDER $3,000 WITH A THRESHOLD PRICE OF $5,000

DESIGN METHODOLOGY

KEEP IT SIMPLE

- FEWEST COMPONENTS
- FEWEST MOLDS
- EASY ACCESS OF COMPONENTS

KEEP IT LIGHT

- DESIGN FOR PURPOSE
- INTENTIONAL USE OF STRUCTURE
- USE THE RIGHT MATERIAL

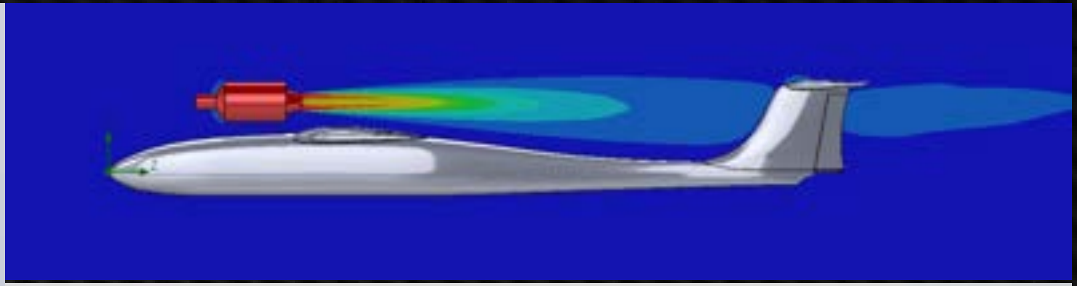
MAKE IT LOOK GOOD

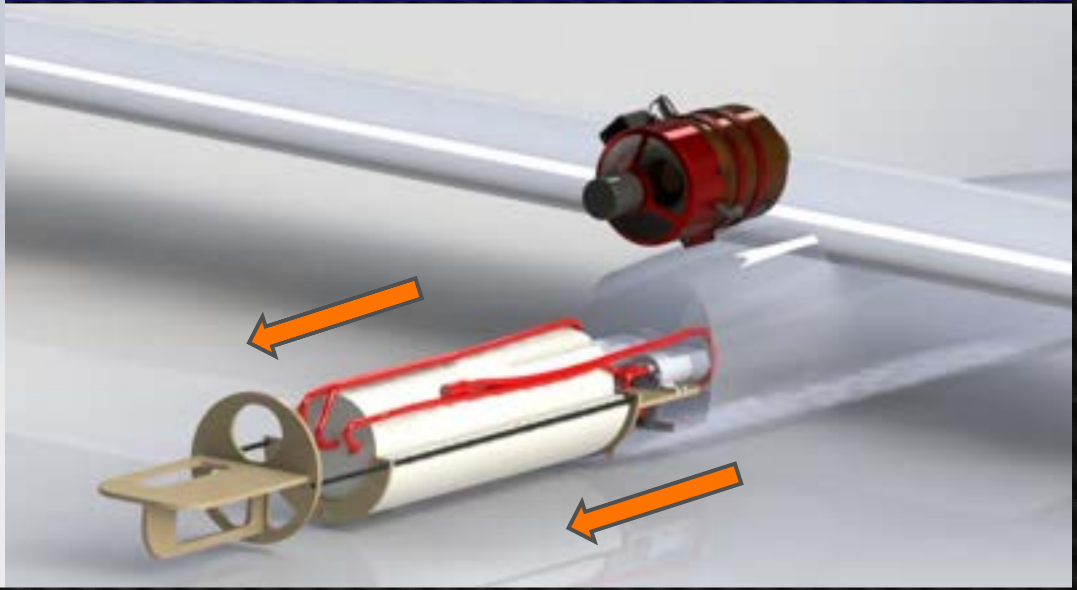
- FIT FOR PURPOSE
- ATTENTION TO DETAIL

PDR RECAP

- THE TURBINE HOTLINER
  - EXTERNALLY MOUNTED ENGINE
  - SLEEK, STREAMLINED DESIGN
  - INTENTIONAL JETWASH IMPINGEMENT FOR EXTREME MANEUVERABILITY & HAND LAUNCH
  - SIMPLE, USER FRIENDLY DESIGN

UPDATED DESIGN





AERODYNAMICS

Since PDR

1. Hand launching capabilities testing
2. Final wing geometry and sizing
3. Selection of airfoil
4. Tail sizing and airfoil selection
5. CFD analysis for jet wash considerations
6. Control surface and servo sizing

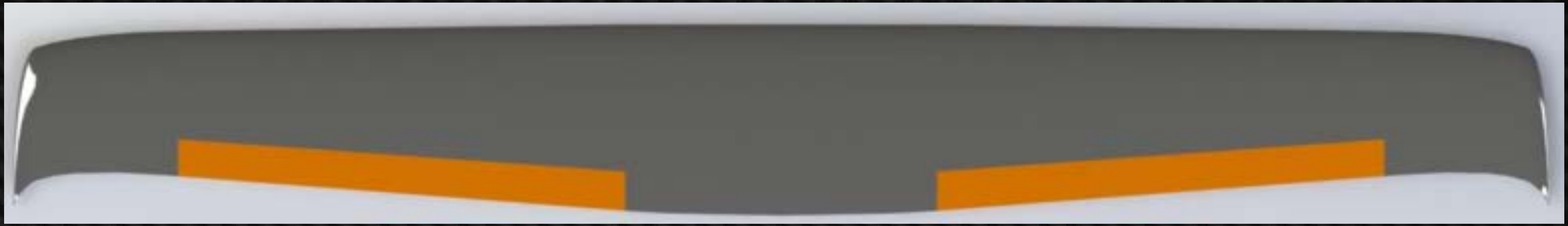
HAND LAUNCHING

- Testing revealed a comfortable hand launch speed of 25 ft/s
- This constraint, coupled with span constraints, guided wing area decisions
- Designed for 0 wind speed launch to ensure wide consumer use

WING GEOMETRY AND SIZING

- Span Constraint
  - Lays flat in truck bed
  - Span less than 5.5 ft
- Flag estimates at ~31.3 flags

S (ft^2)	b (in)	Sweep (deg)	Taper Ratio
3.25	66	2.0	0.7



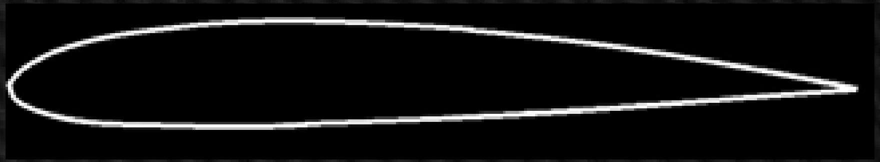
WING AIRFOIL SELECTION

Ashfall 300

- 11° stall angle
- Advantageous drag polars in our primary operating environment
- Custom airfoil optimized for pylon racing

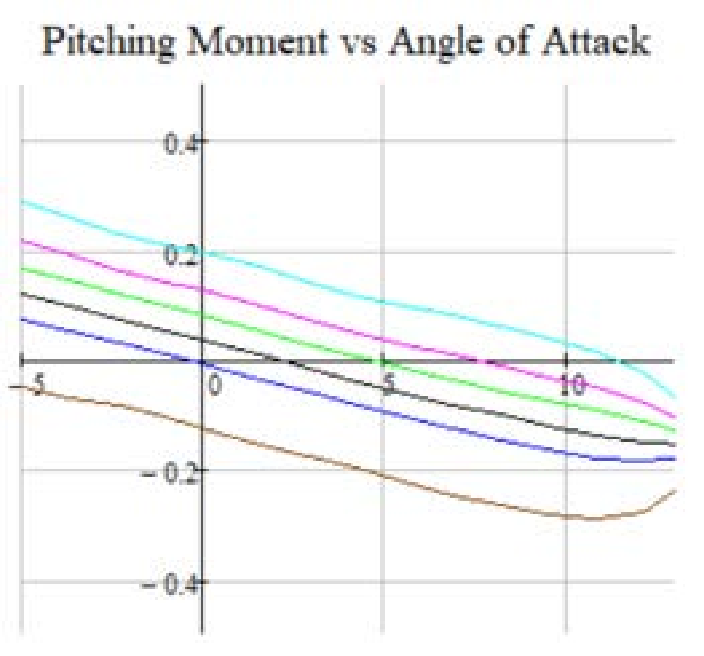
Ashfall 400

- Increased stall angle (12°)
- Improved hand launch at the expense of a fraction of a flag
- Custom airfoil optimized for hand launch



TAIL SIZING

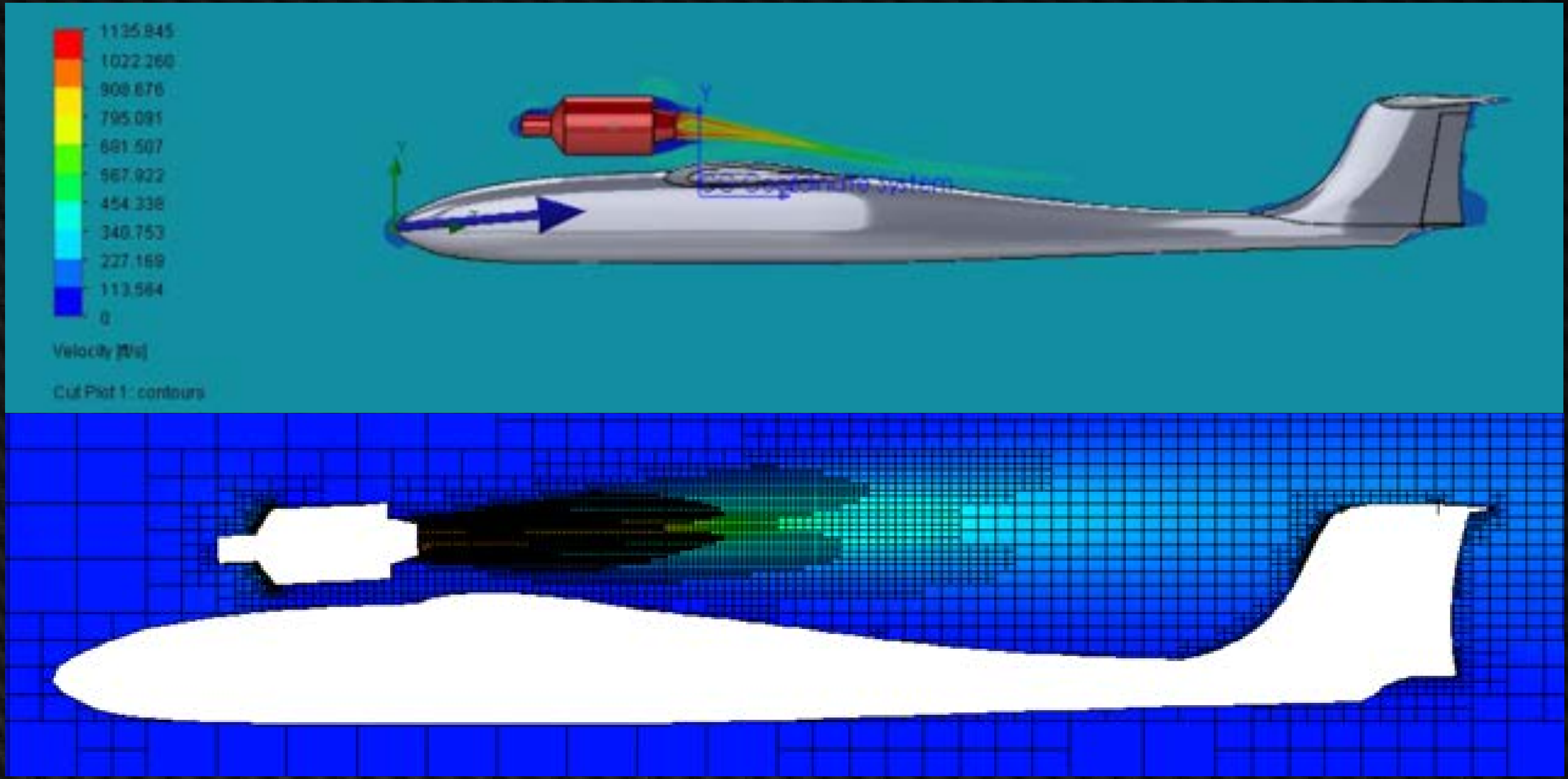
Surface	Area (ft^2)	Span (in)	Above Centerline (in)	Tail Volume Coefficient	Static Margin (Launch)	Static Margin (Cruise)	Sweep (°)	Incidence (°)
Horizontal Tail	0.4	12	6.5	0.5	13.2%	21.1%	2	-2
Vertical Tail	0.25	6.5	2.17	0.03	153.0%	201.0%	-	-



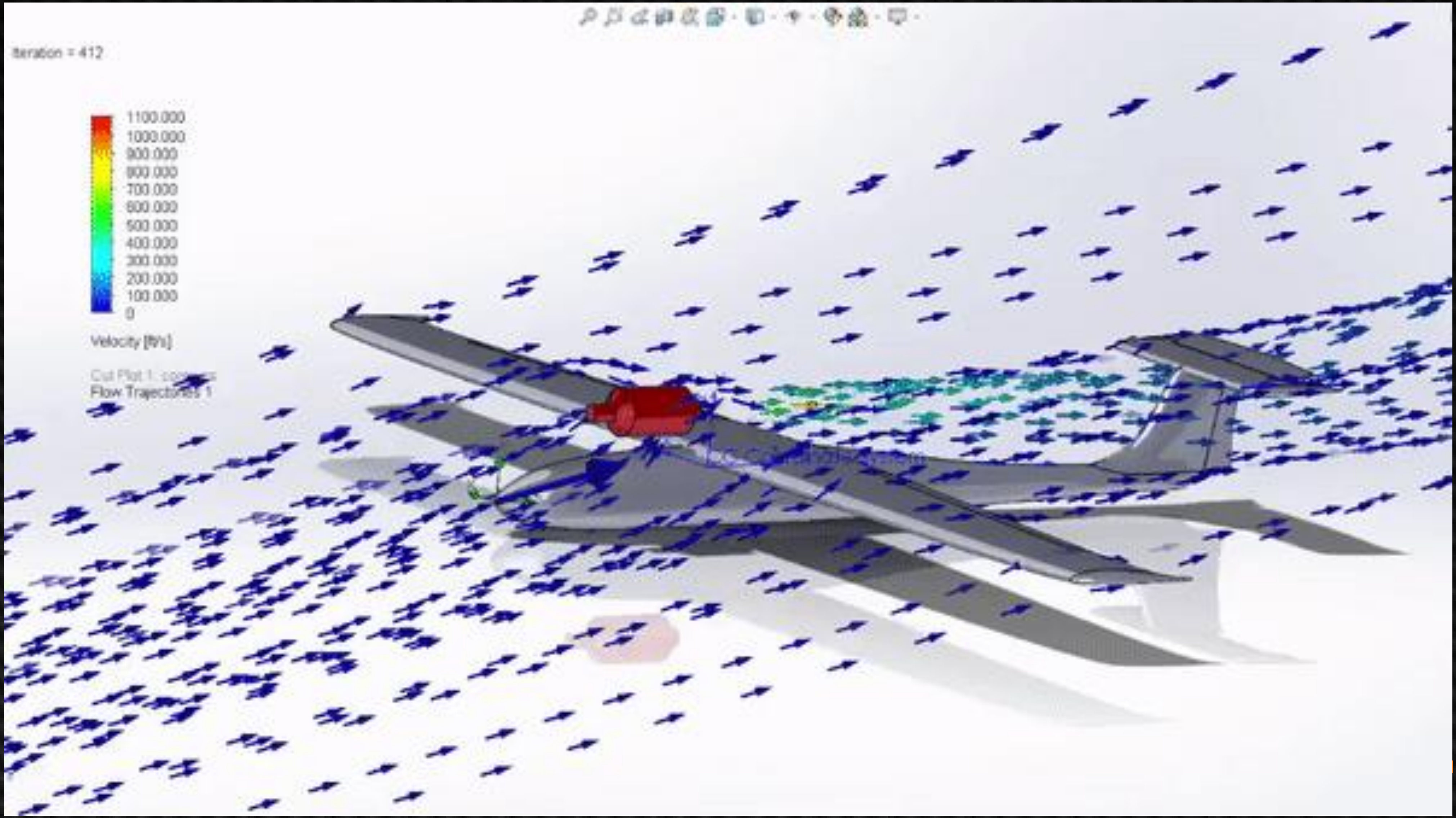
- NACA 0010

JET-WASH CONTRIBUTIONS

- ELEVATOR AUTHORITY
- COANDA EFFECT



FLOW SIMULATION



CONTROL SURFACE AND SERVO SIZING

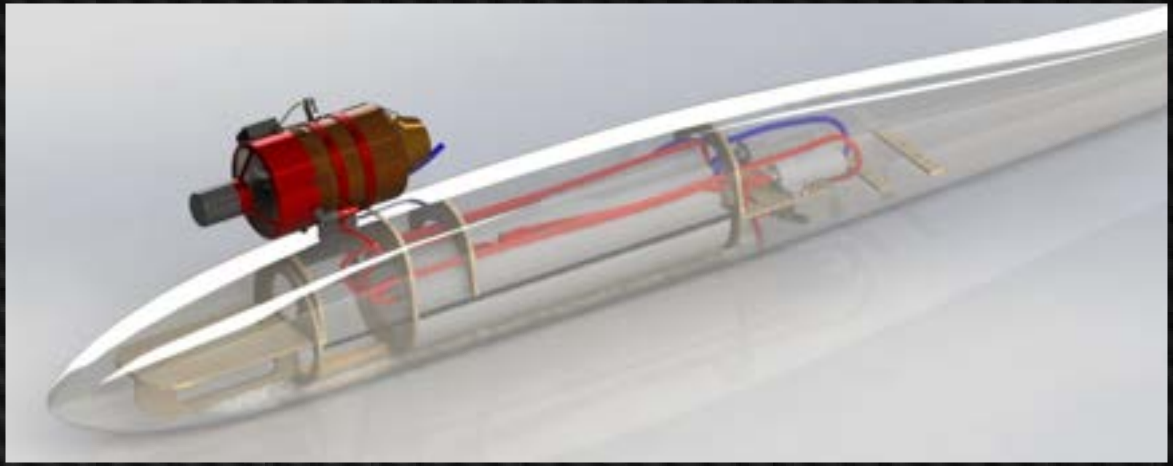
Surface	Chord (in)	Span (in)	ΔH Servo (ozf * in)	Servo Selection
Flaperons	1.44	21.0	127	205 oz-in, Mini, BLS
Elevator	1.56	10.2	32	D85MG Micro, 32 Bit, Metal Gear Servo
Rudder	1.44	5.16	21	

AERODYNAMICS NEXT STEPS…

- Assist structures with lay-ups
- Configure Avionics
- Continue analysis for possible improvement on final design

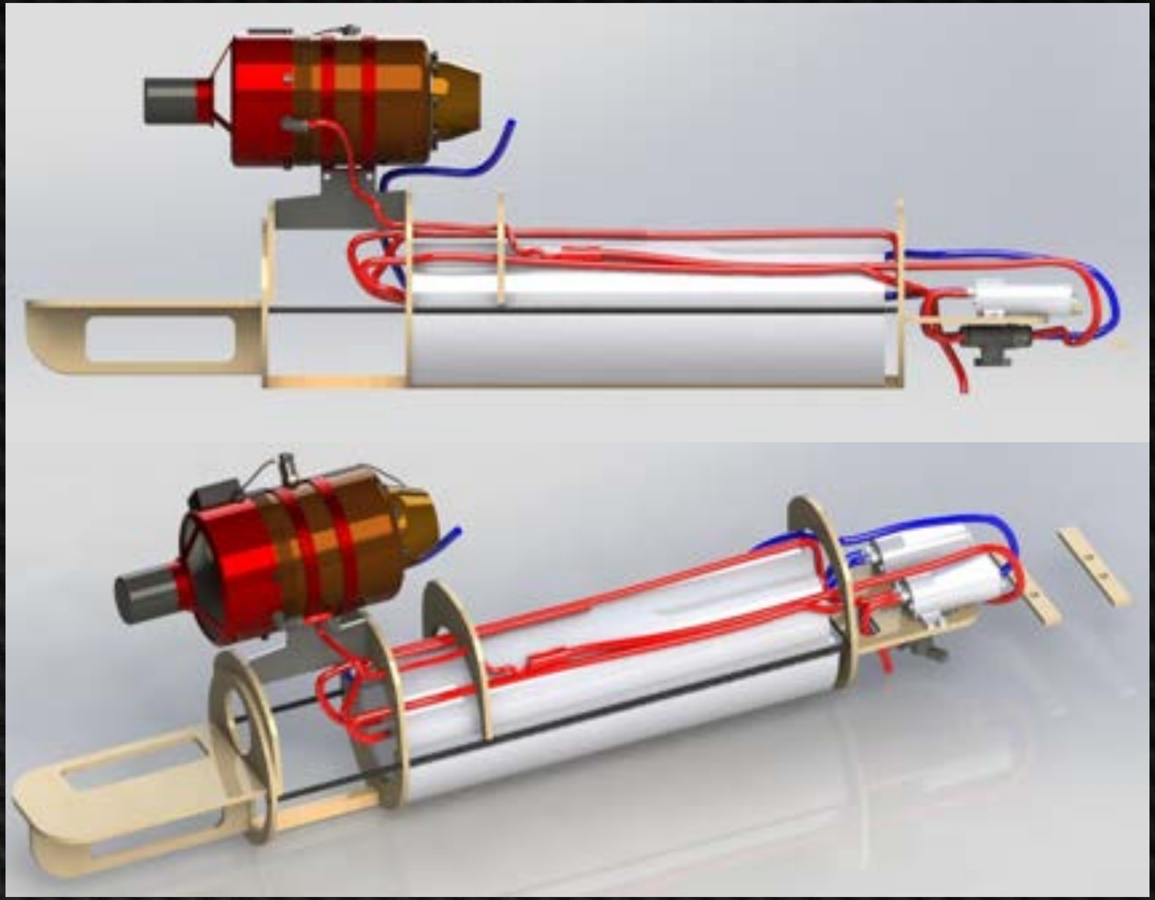
PROPULSION

- Since PDR:
  - Layout improvements/Developments
  - Engine Mounting
  - Heat Testing
  - Fuel Consumption Testing
  - Tank Sizing
  - Smoke Testing
  - Nozzle Development
  - Environmental Impact Considerations



Propulsion System Layout

- K30G3 Engine
  - Thrust: 6.61 lbf @ 59 °F
  - Fuel consumption: 120 g/min
  - Weight: 1 lbf
- Forward Top Engine Mount
  - Optimal Ease of Access and attachment
    - Fuel tank and fuel pump slide out nose cone
  - Heat control and diversion easily managed



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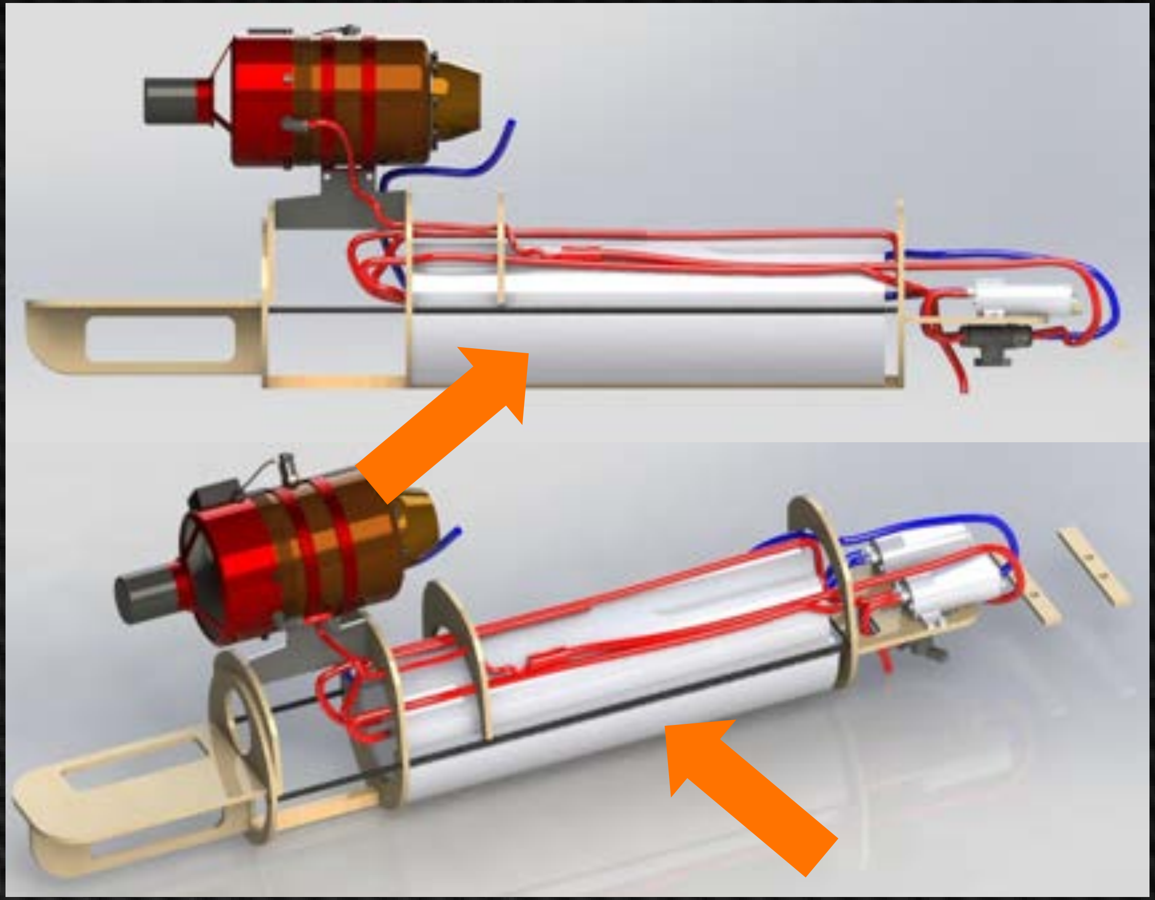
  - Semi-Cylindrical Fuel tank
    - Max Fuel Cap: 0.66 L
    - Max Smoke Cap: 0.16 L



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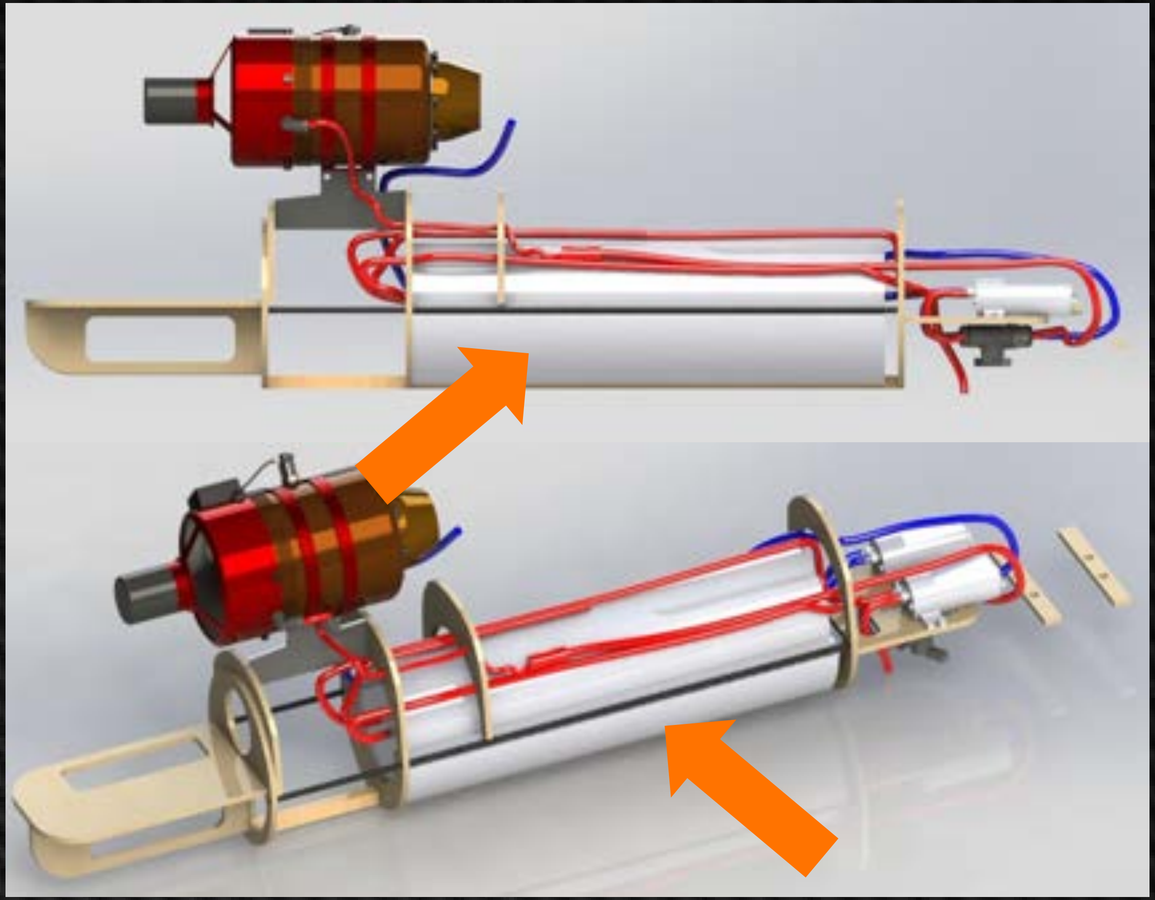
  - Filter/Clunk Combo



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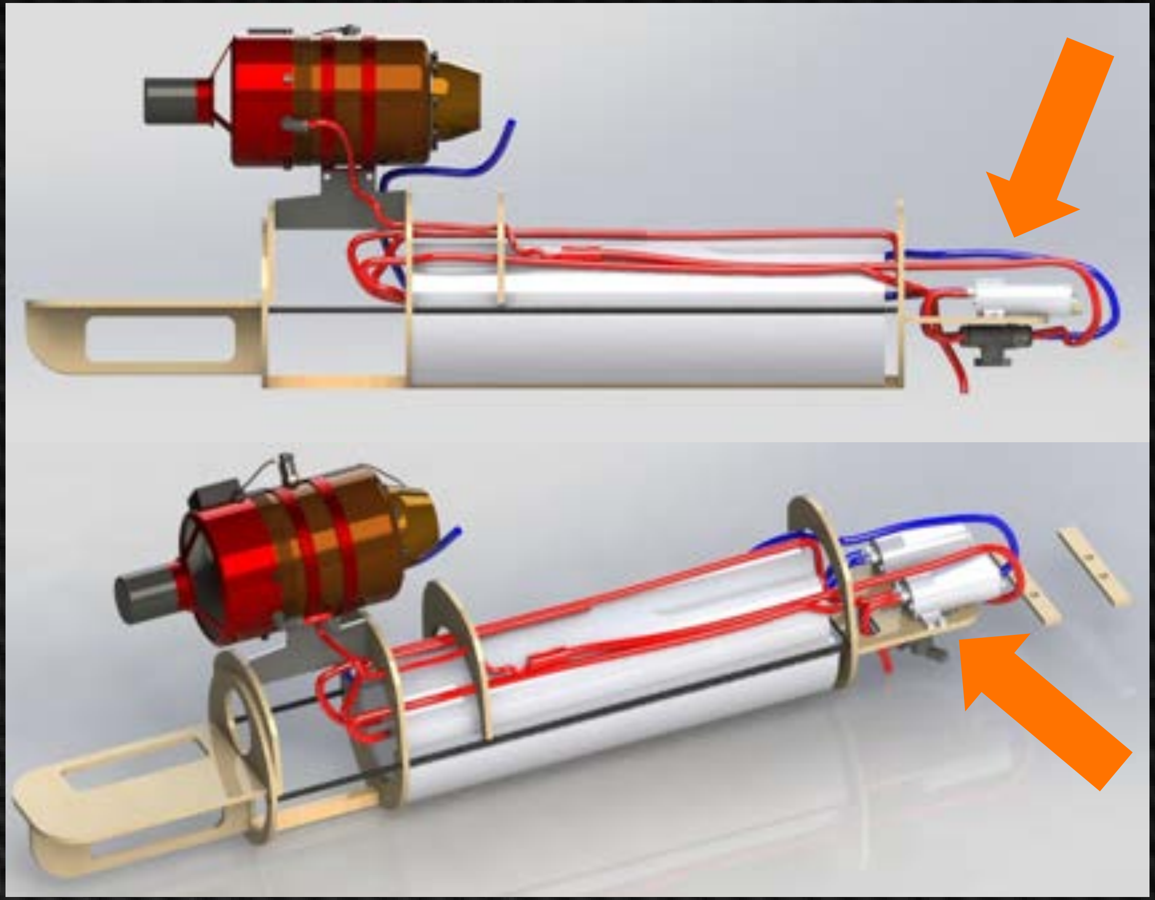
    - Pumps and Valves Aft of Tank on sled tray



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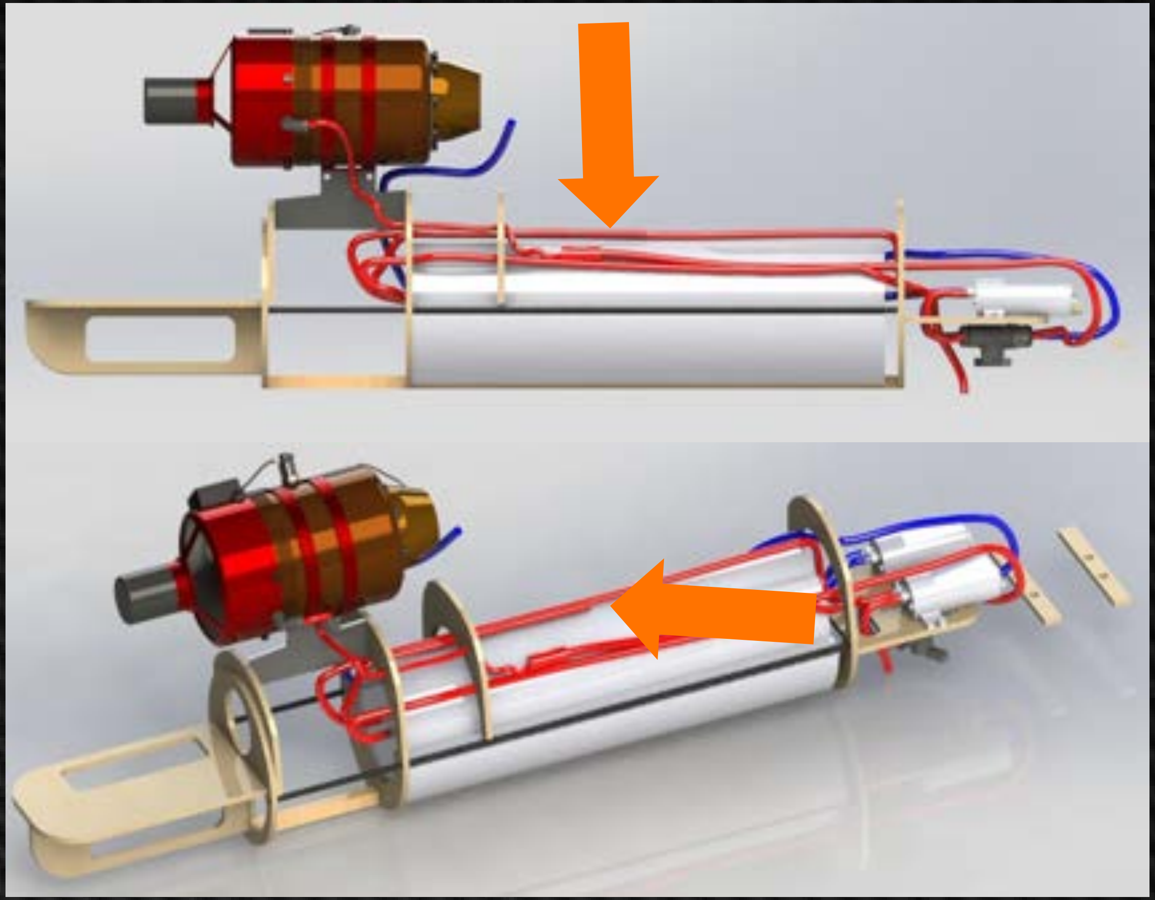
  - Fueling access directly under wing



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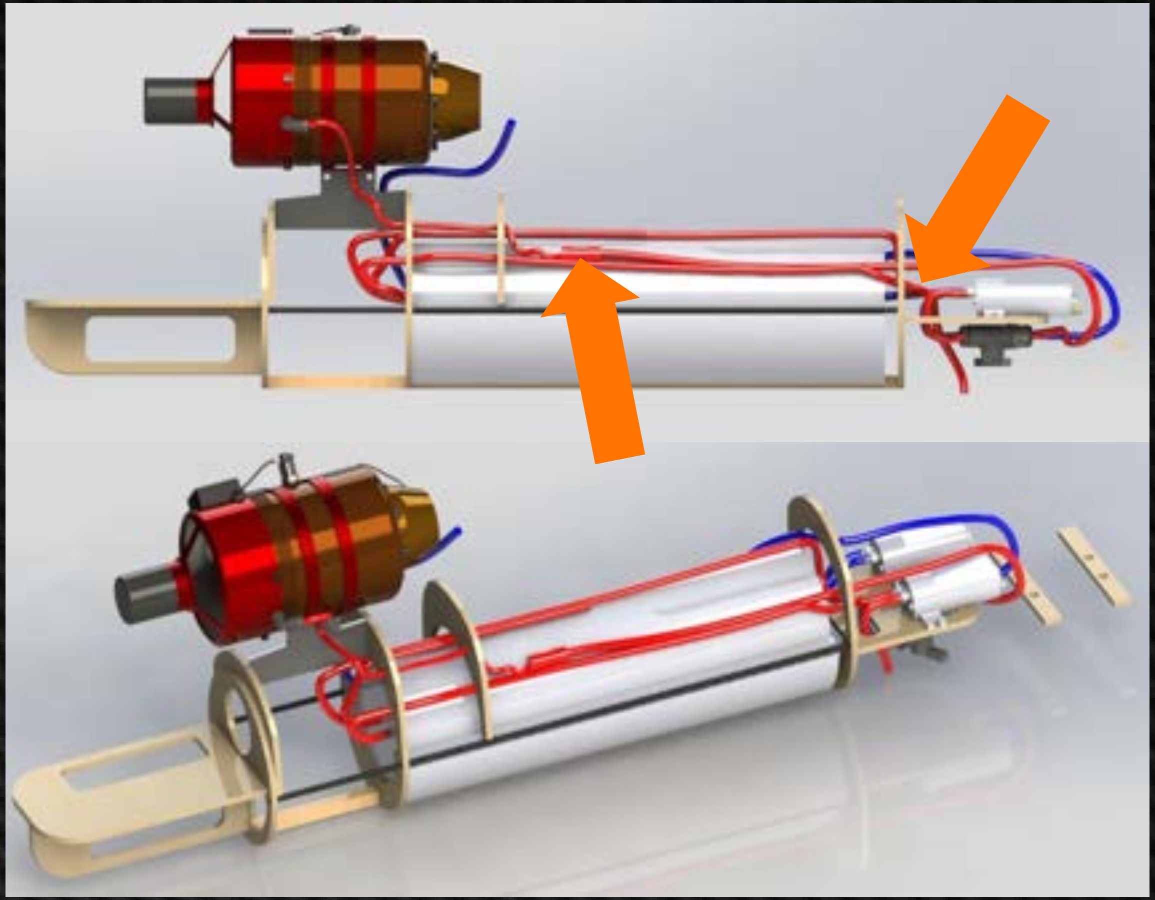
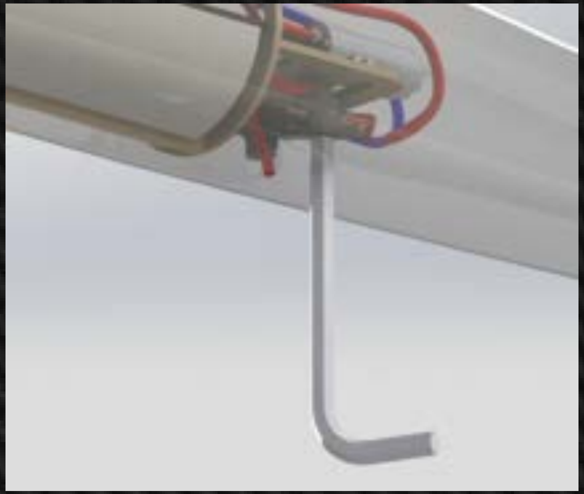
  - Fueling access directly under wing
  - Quick disconnects from tank and vent for sled tray



LAYOUT ADDITIONAL DETAILS

- Majority of plumping stays with sled
    - Fixed to tank via printed clips
- Permanent and Removable plumbing separated by quick connects
- Access to Valves through small fuselage holes
- Fueling performed through wing mount access
- Slack allowed in the lines



HEATING FROM ENGINE

Testing fuselage directly behind engine
Layup 1.5" below centerline of thrust

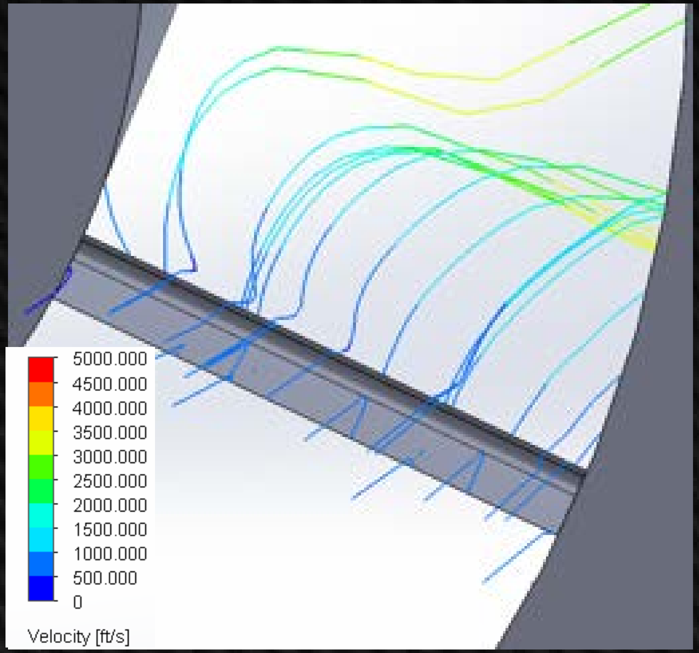
Testing tail in jet wash, 15" behind nozzle exit

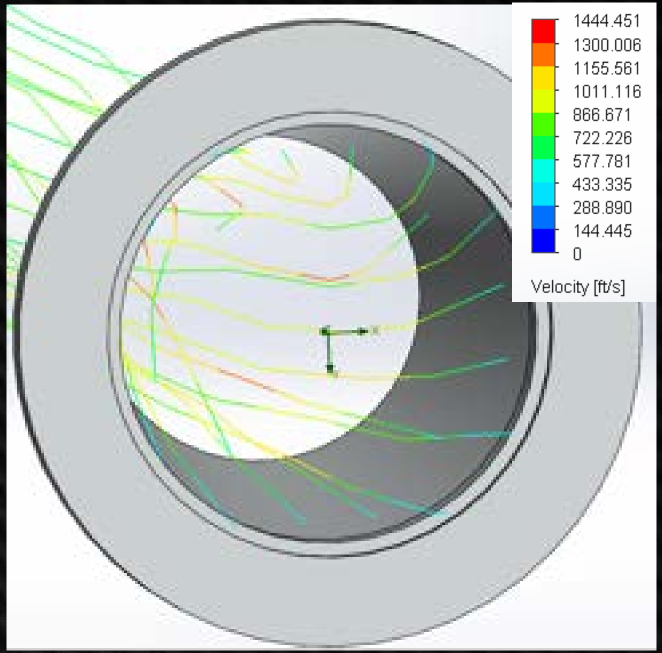
Heat Mitigation

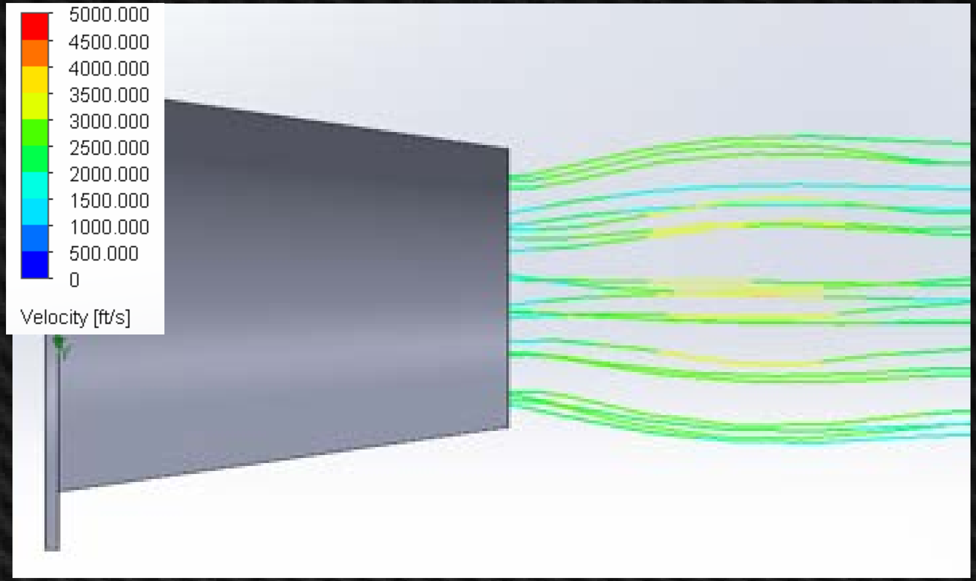
- WB400/CS215 distorts at 200°F
- Fuselage and Wing Safe at 1.5" below thrust centerline
- Significant damage at less than 0.5" from centerline
  - Image on the right shows results of layup directly in exhaust
- Tail Requires more Testing to confirm impact
- Prevention Measures
  - Balsa core
  - Heat paint in mold
  - Aluminum Foil in layup

NOZZLE

- Stator blades added to straighten flow
- Nozzle PCA shows for Mach 0.9 nozzle exit diameter of 1.06" will be near perfect expansion
- Manufacturing
  - 3D printing – Velo 3D







ENGINE MOUNT

- Mounted into major bulkheads
- Materials
  - Aluminum
  - Stainless Steel
- Ring design allows for easy engine swap

Fuel Consumption

- Testing performed to determine an accurate fuel burn rate
  - Tank Vol. Worst Case: 0.66 L
  - Avg Fuel Vol. Estimate: 0.48 L

Full Throttle	
Maximum	117.9 g/min
Minimum	54.4 g/min
Average	86.1 g/min

Variable Throttle	
Average	75.6 g/min

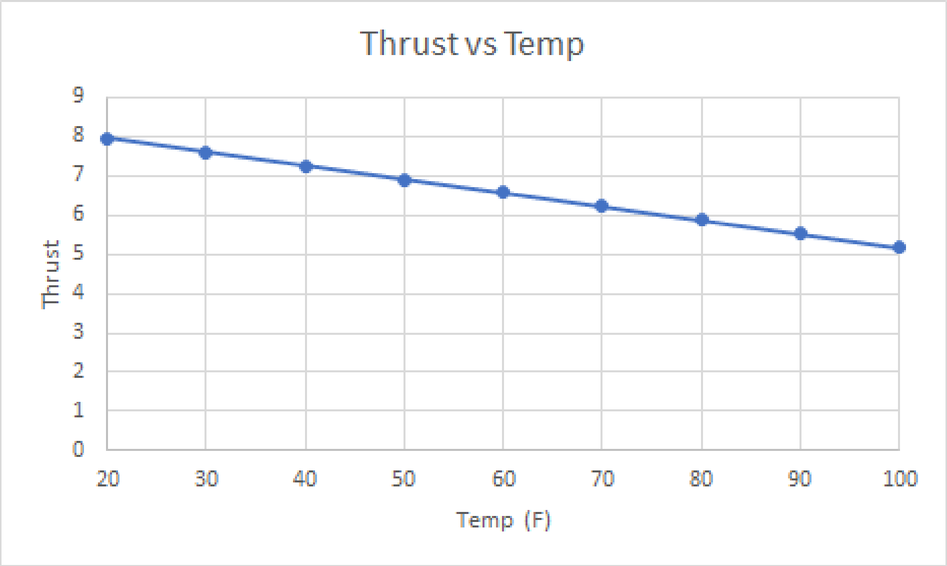
120 g/min at full throttle per manufacturer

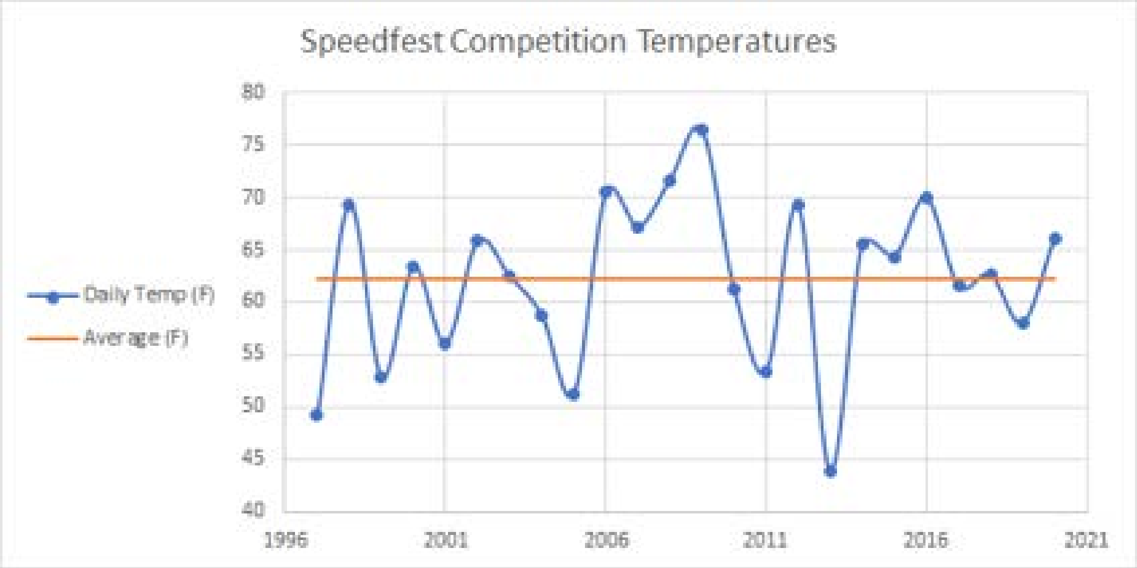
SMOKE

- Fuel as smoke tests produce subpar results
- Moving to safe plan:
    - Using a separate 0.16 L fuel tank for smoke oil
    - Separate pump and plumbing system for oil
- Kynetic R/C Smoke Oil

ENVIRONMENTAL CONSIDERATIONS

- Thrust variance Expected with competition day temperature
  - Best: 7.1lbf
  - Worst: 6.0 lbf
  - Average: 6.5lbf





PROPULSION NEXT STEPS

- Tail Heating Testing
- Environmental Testing
- Thrust/SFC Testing
- Nozzle Testing
- Smoke Oil Testing
- Temperature Probing
- 3D Tank Design/Testing
- Finishing Touches on Layout

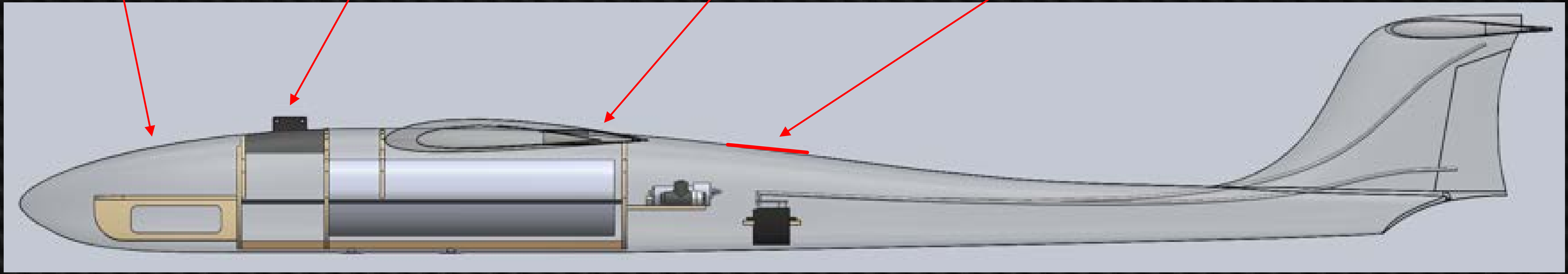
STRUCTURES

Since PDR

1. Wing spar prelim design
2. Wing structural layout
3. Refined wing mount design
4. Finalized servo placement
5. Refined fuselage structural layout
6. Weight and CG estimates
7. Accessory mount location determined
8. Prelim proof of concept designs built

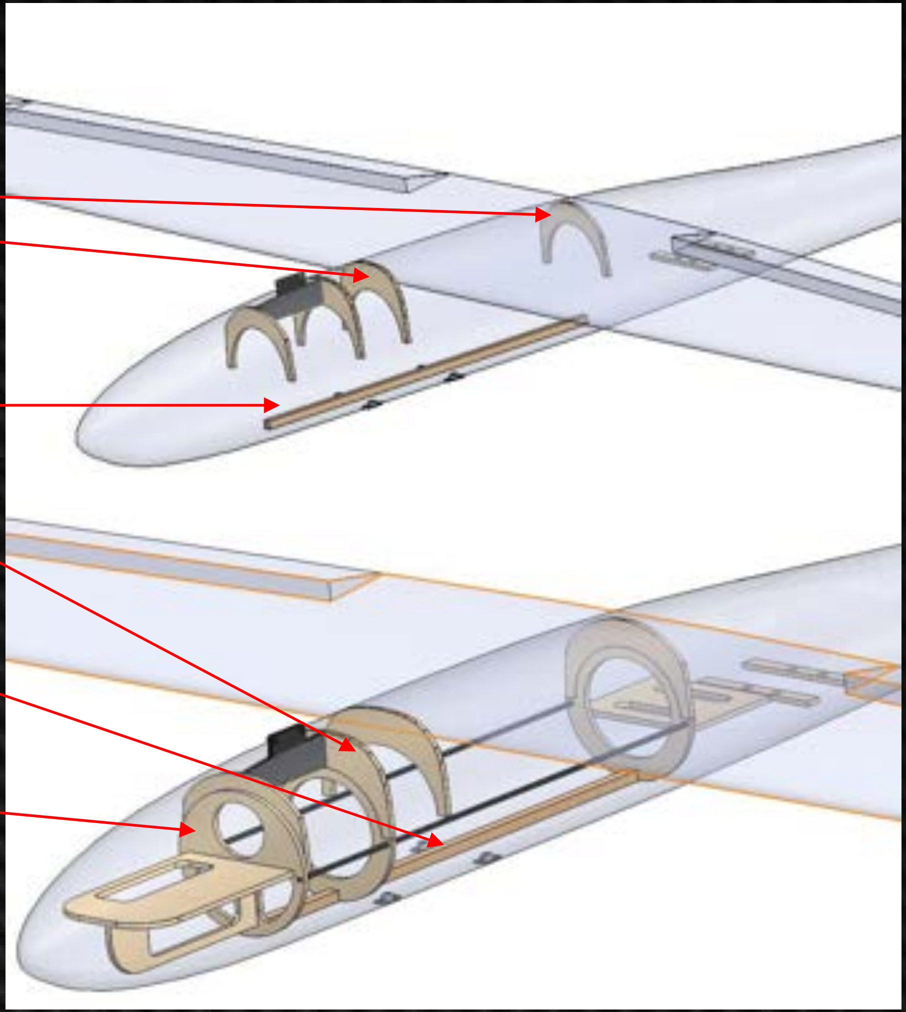
FUSELAGE LAYOUT

- Nose cone
- Avionics tray
- Engine mount
- Fuel tank
- Wing-fuselage mounting hub
- Fuel pump
- Servos and push rods
- Hatch



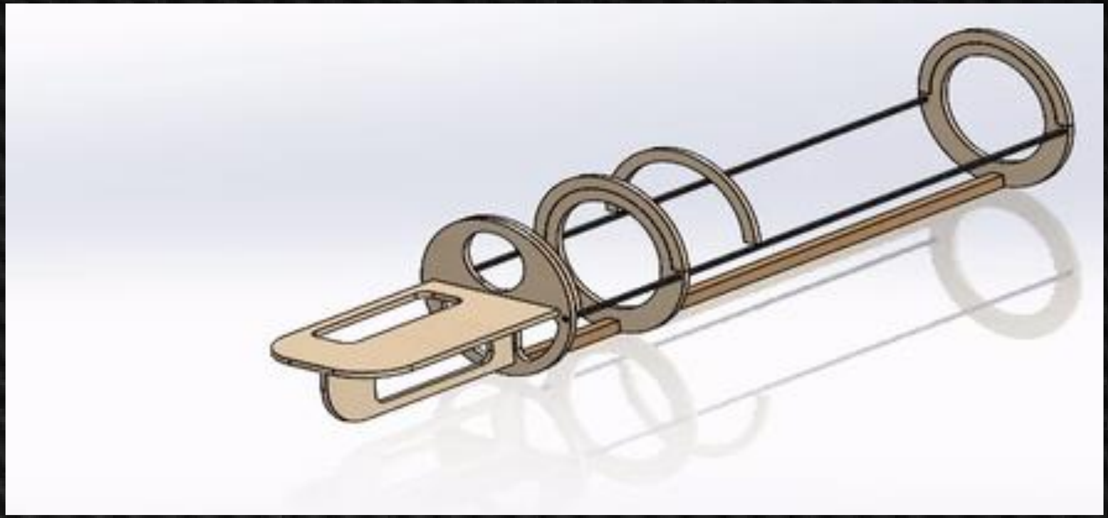
Internal Fuselage Design

- Permanent Bulkheads
  - Wing attachment
  - Engine mount structure
- Guide bar
  - Support for landing
  - Protect fuel tank
  - Guide removable tray
- Sliding Bulkheads
  - Strengthen Half Bulkheads
  - Hold avionics and fuel systems



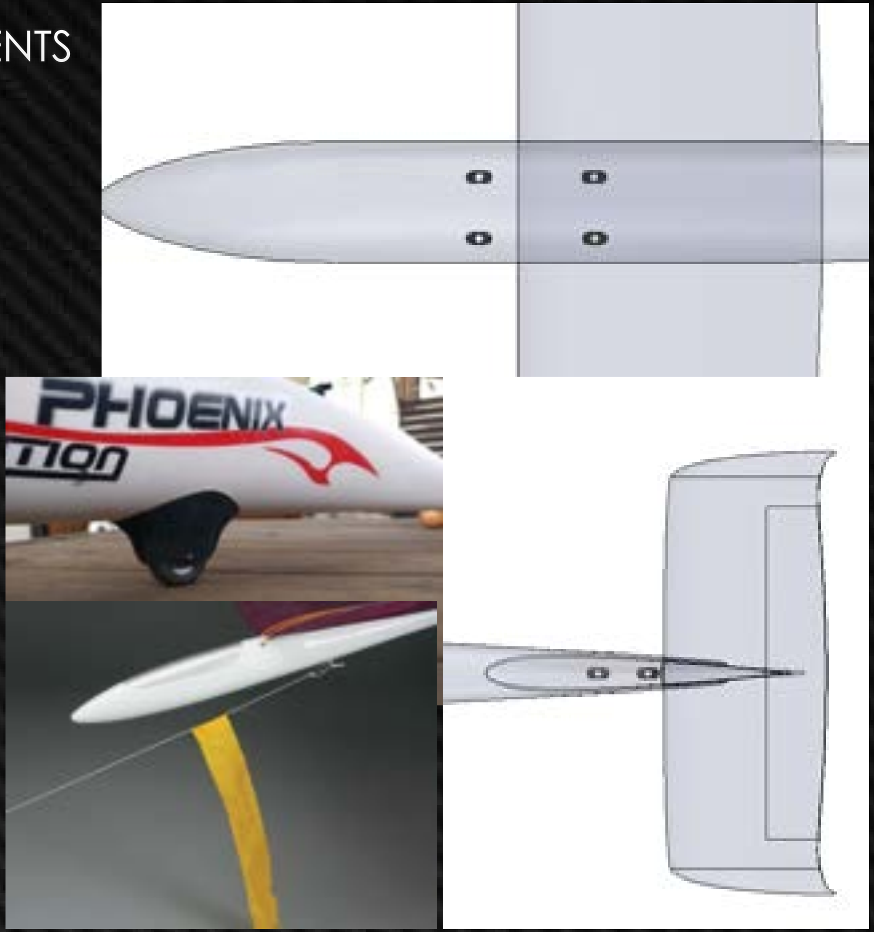
INTERNALS TRAY

- Direct access to all internals
- Less hatches required
- Optimization of internal components
  - Larger fuel tank
- More options for internals layout
- Follows guide for perfect fit
- Avionics Tray fastens to bulkhead



ACCESSORY MOUNT

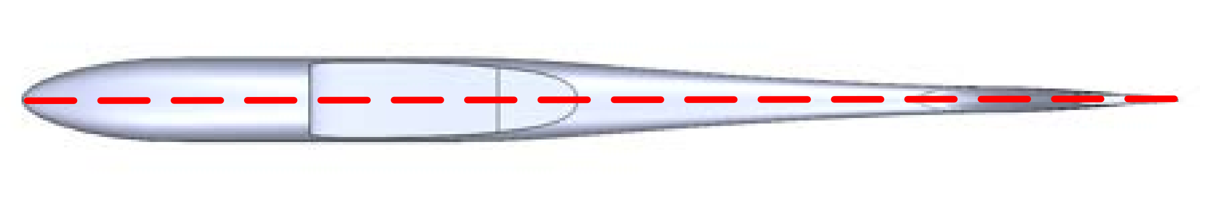
- Marketable mounting point for additional components
- Options:
  - High-start hook
  - Landing gear
  - Camera
- Custom mounts can be made for all options
- Attach with 4 Click Bonds
  - Located on bottom of fuselage
  - These will be inserted in the layup process



FUSELAGE MANUFACTURING

- Material
  - Bulkheads and Trays
    - Aircraft grade plywood (1/8" thickness)
  - Skin
    - Scored Divinycell Foam (1/8" Thickness)
- Layup
  - Mold split to have left and right fuselage
  - Start with 4-part layup
  - Use of unidirectional carbon fiber for tail stiffening

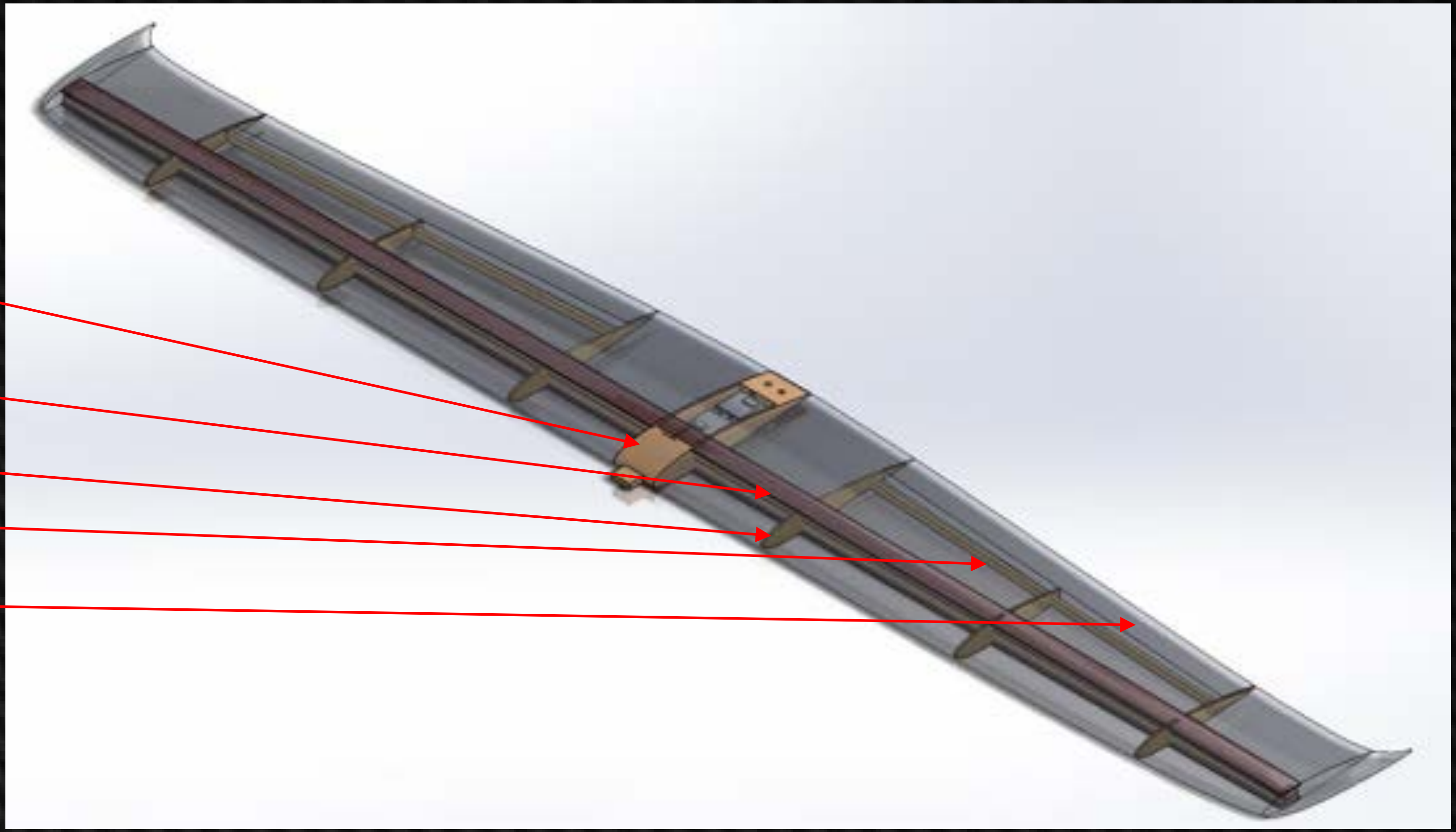
LEFT/RIGHT-HAND FUSELAGE



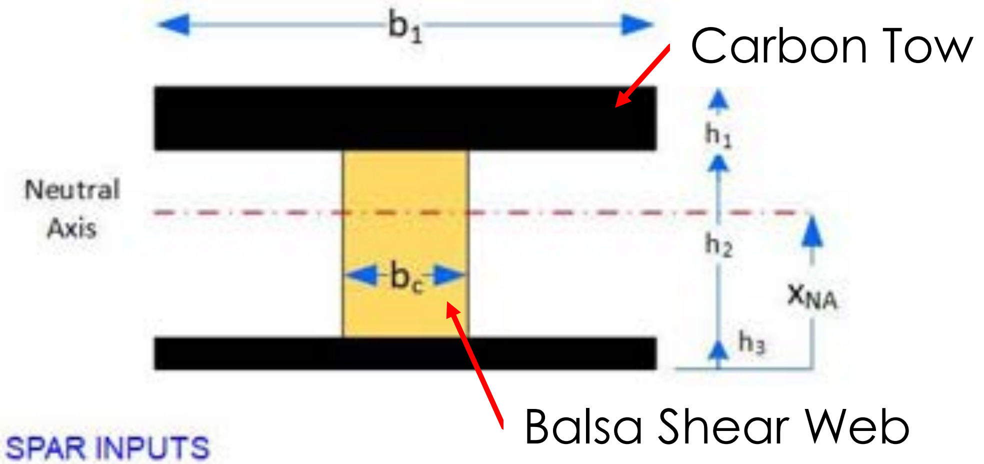
FUSELAGE AND VERTICAL TAIL

WING LAYOUT

- Wing Mounting Hub
- Main Spar
- Ribs
- Shear Web
- Control surface



MAIN SPAR DESIGN



SPAR INPUTS

$h_1 = 15 \cdot 0.005$ Spar cap thickness (compression) [in]

$h_3 = 15 \cdot 0.005$ Spar cap thickness (tension) [in]

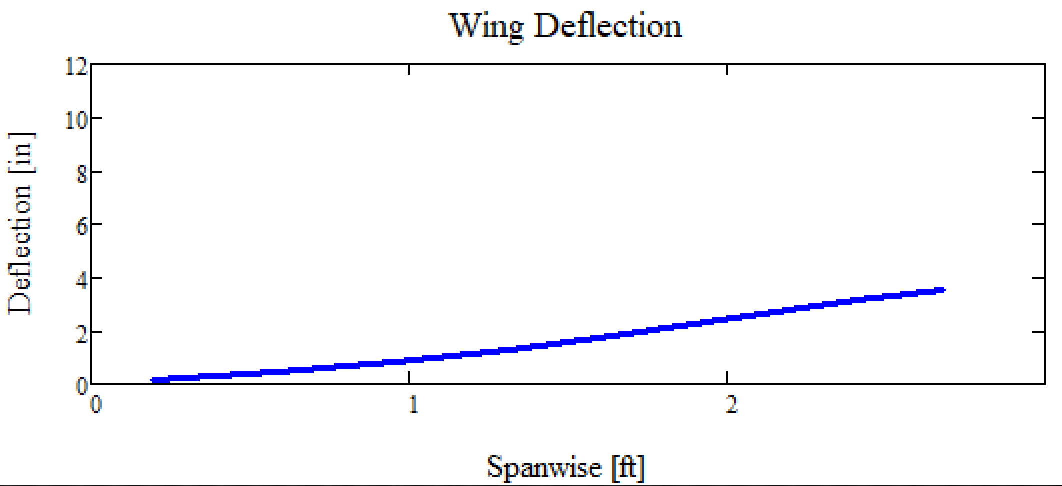
$b_1 = 1$ cap width [in]

$b_c = 0.6875$ core width [in]

$V = 330$ V Airspeed [ft/s]

$\alpha g = 15.2$ Angle of attack

$W = 6.8$ Weight of plane (if g load needed)



$\frac{L(\alpha g)}{W} = 82.7$ g load. The highest g-load possible for the wing will be a near-stall α, and the highest speed V.

$h_{2root} = 0.88$ Core Height [in]

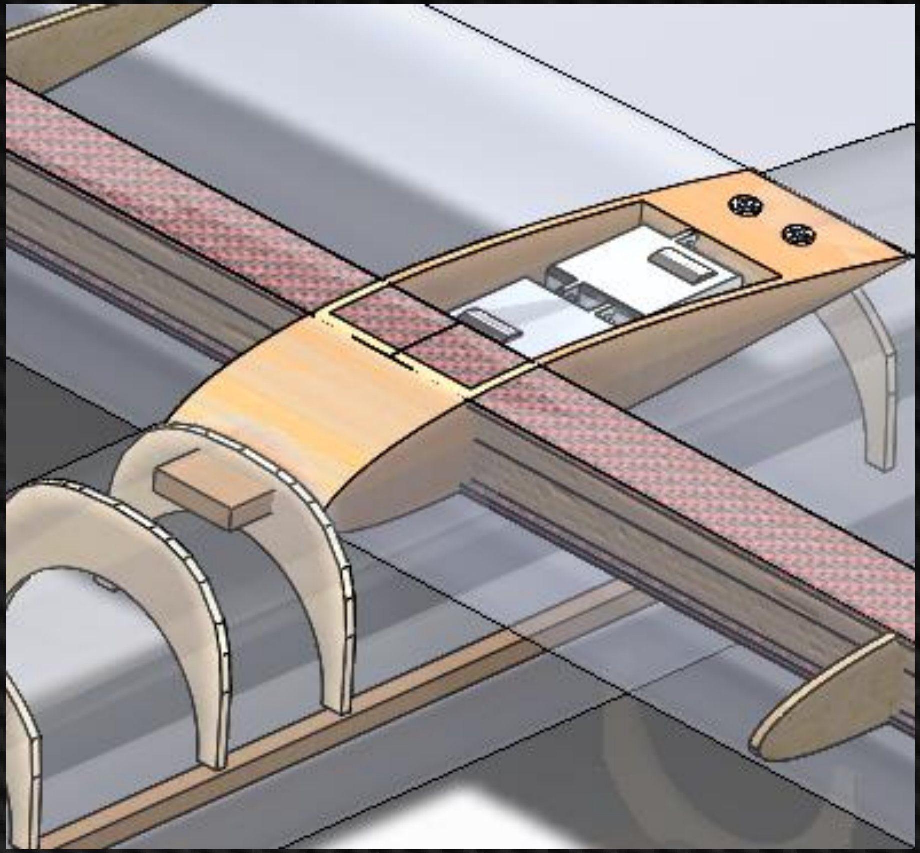
$L(\alpha g) = 562$ Lift [lb]

$V_s = 281$ Root Shear Force [lb]

$M_r = 4107$ Root Bending Moment [in-lb]

WING MOUNT DESIGN

- LE Tab
  - Slotted bulkhead for tight fit
- TE Camloc Quarter Turn Fasteners
  - Quick assembly
  - Composite versions for easier bonding during molding
  - Strong clamping force
  - Possible "wiggle room"



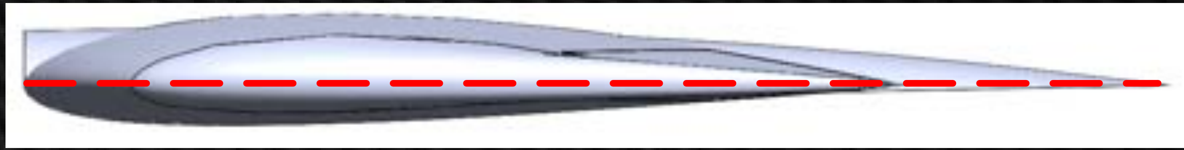
Wing Servo Placement

- Flaperon Servos
  - Located in the wing-fuselage mounting hub
  - Control rods run internally through the wing
- Elevator/Rudder Servos
  - Located within the fuselage aft of the fuel tank
  - Control rods run internally through the tail

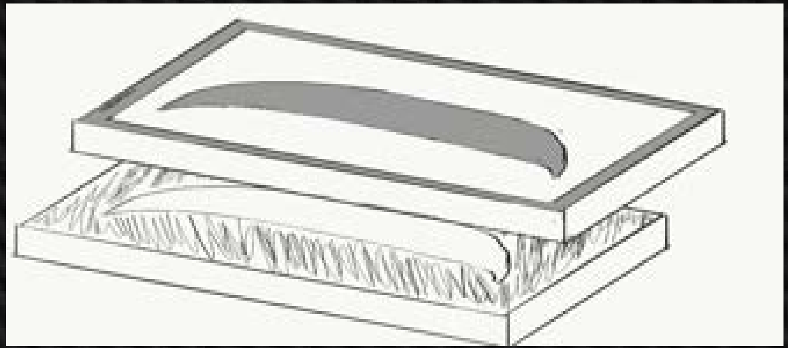
WING MANUFACTURING

- Material
  - Spar
    - Balsa Wood (11/16" thickness)
    - Unidirectional Carbon Fiber (1" wide)
    - I-beam caps
  - Ribs
    - Aircraft Grade Plywood (1/8" Thickness)
  - Skin
    - Balsa Wood core (1/16" thick)
- Layup
  - Asymmetric Airfoil
  - Mold split for top and bottom of wing
  - Control surfaces cut from the layup

TOP/BOTTOM WING

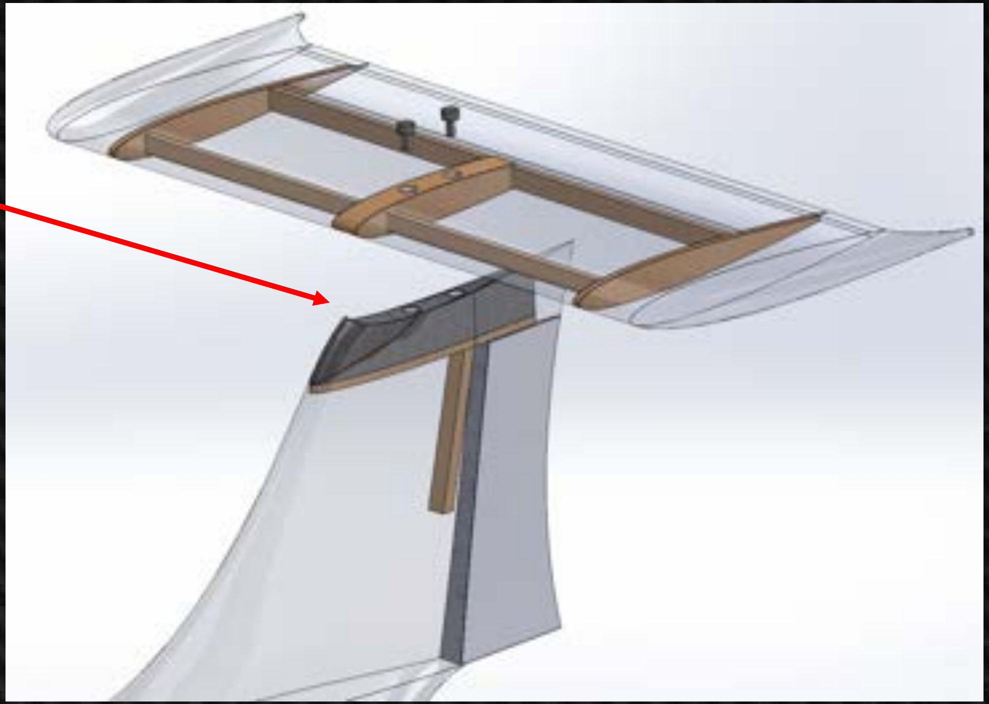


WING

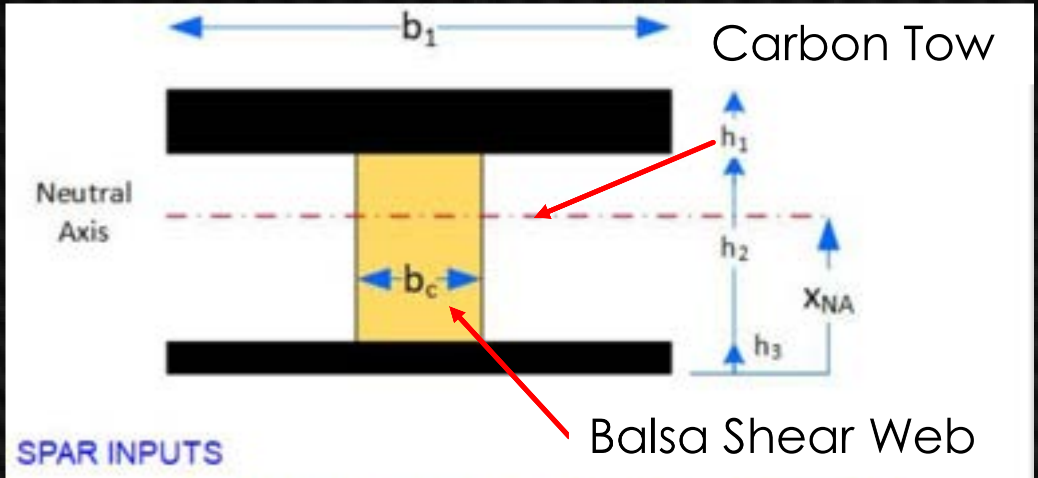


EMPENNAGE LAYOUT

- HORIZONTAL-VERTICAL MOUNTING POINT
  - CONTACT POINTS TO BE MADE OF A "SHOWER-DRAIN" EPOXY MIX
  - THREADED METAL BUSHINGS MOLDED INTO THE EPOXY MIX FOR BOLTING
  - WIDENED BASE AT THE TOP OF THE VERTICAL TAIL FOR MORE STABLE MOUNTING
- RIBS AND SPARS
  - MINIMAL



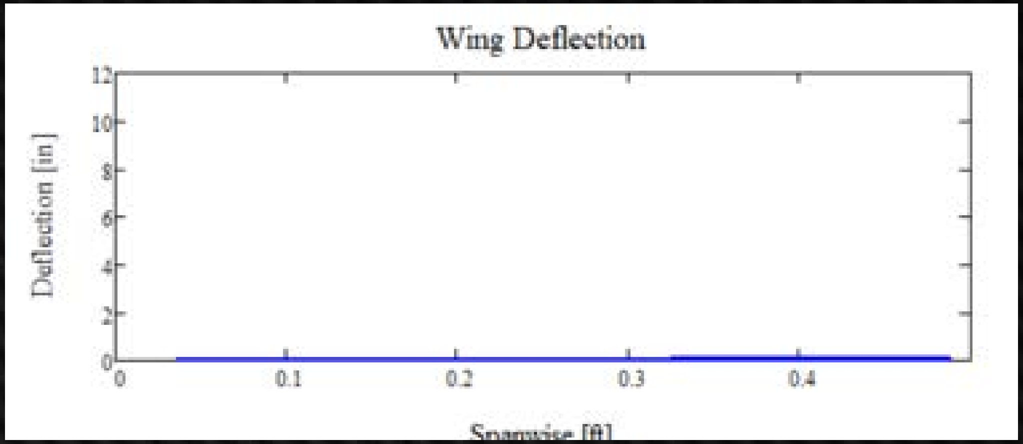
HORIZONTAL TAIL SPAR DESIGN



SPAR INPUTS

$h_1 = 2 \cdot 0.005$	Spar cap thickness (compression) [in]
$h_3 = 2 \cdot 0.005$	Spar cap thickness (tension) [in]
$b_1 = \frac{3}{8}$	cap width [in]
$b_c = \frac{1}{8}$	core width [in]

$V = 330$	V Airspeed [ft/s]
$\alpha g = 15.2$	Angle of attack
$W = 6.8$	Weight of plane (if g load needed)



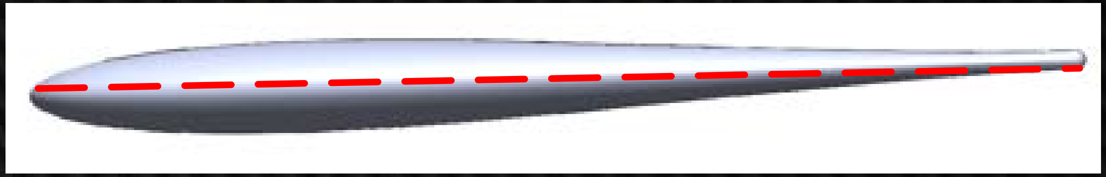
$\frac{L(\alpha g)}{W} = 5.3$ g load. The highest g-load possible for the wing will be a near-stall α, and the highest speed V.

$h_{2root} = 0.59$	Core Height [in]
$L(\alpha g) = 36$	Lift [lb]
$V_s = 18$	Root Shear Force [lb]
$M_r = 47$	Root Bending Moment [in-lb]

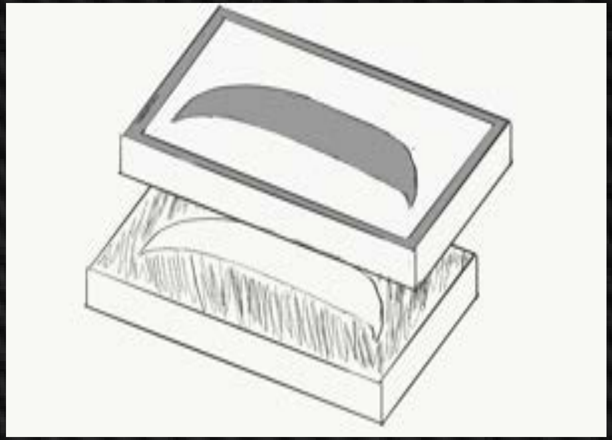
HORIZONTAL STABILIZER MANUFACTURING

- Material
  - Ribs
    - Aircraft Grade Plywood (1/8" Thickness)
  - Skin
    - Balsa Wood core (1/16" thick)
- Layup
  - symmetric Airfoil
  - Mold split for top and bottom of the tail
  - Control surfaces cut from the layup

TOP/BOTTOM HORIZONTAL TAIL

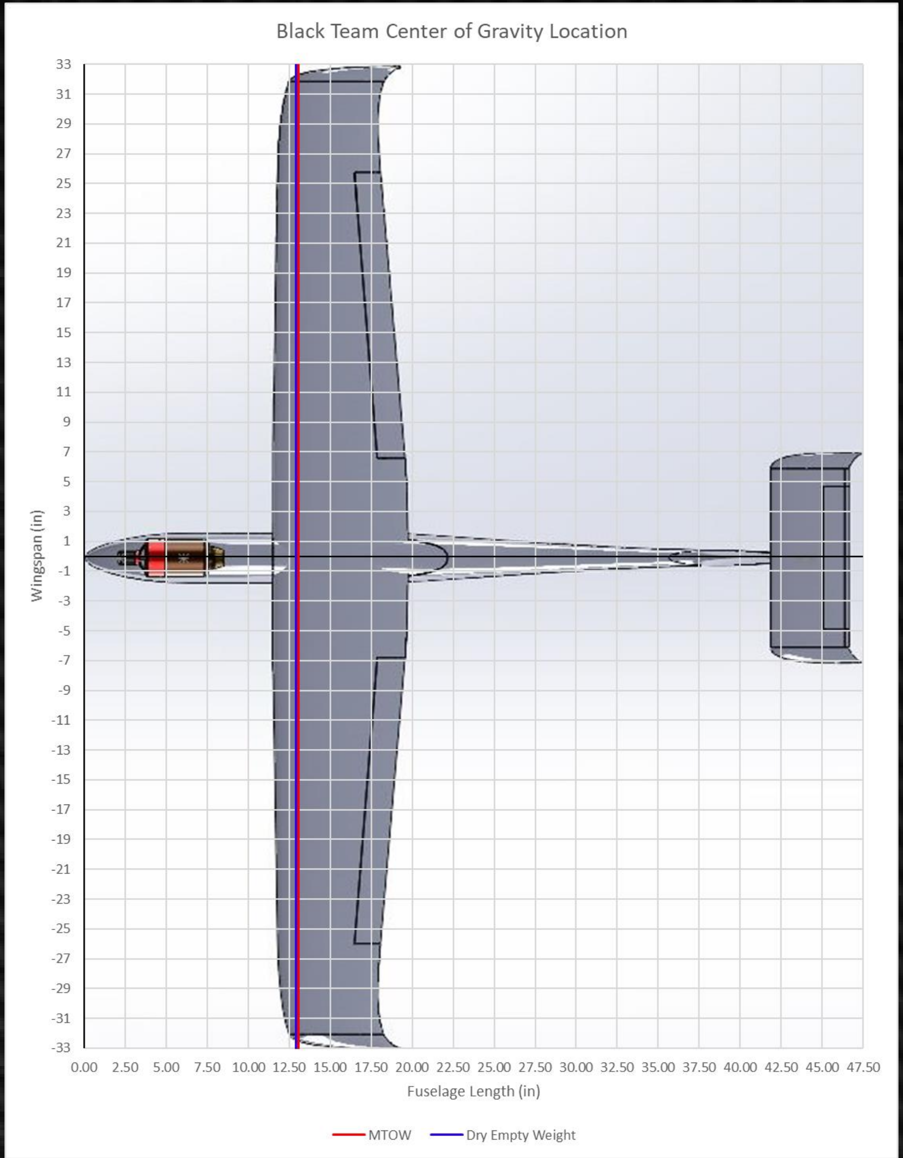


HORIZONTAL TAIL



WEIGHTS AND BALANCES

- Maximum Takeoff Weight (RED LINE)
  - ~6.5 lbs
  - CG: 18.9% of chord
- Dry Weight (BLUE LINE)
  - ~5.3 lbs
  - CG: 17% of chord



BOX

- Constraints
  - Must not exceed 6 feet in L, W, or H
  - Fit wing-span of 5.5 feet within
  - Transportable in a pick-up bed
- Features
  - Light and sturdy
  - Foam form fitted to plane components for support
  - Convenient packaging and access to components

Manufacturing Challenges

- Wing-Fuselage Mounting
  - Snug fit
- T-Tail (Horizontal-Vertical Mounting)
  - Strength
- Internals Tray
  - Smooth sliding
  - Proper alignment
- Customizability
  - Compact design that allows for potential expansion

POST CDR PLANS

- Complete outstanding training (if any)
- Begin manufacturing and prepping plugs/molds for layup
- Start work on Prototype #1
- Build and test
  - Wing
    - Spar
    - mount interface
  - Horizontal Stabilizer
    - Spar
    - Mount interface
  - Internals Tray
  - Permanent Bulkheads

MARKETING

- Name: REDACTED
- Paint scheme
- Commercial
- Website

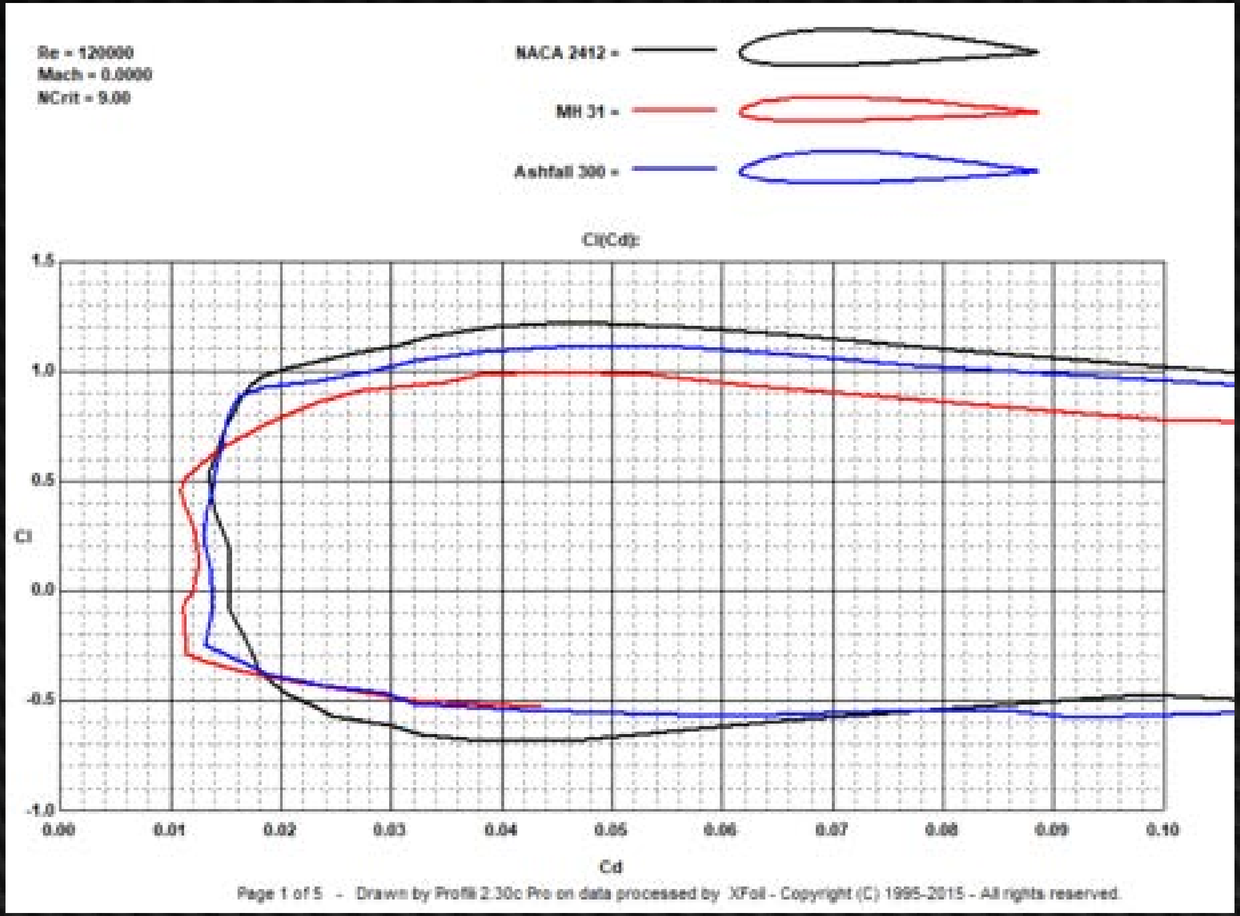
QUESTIONS

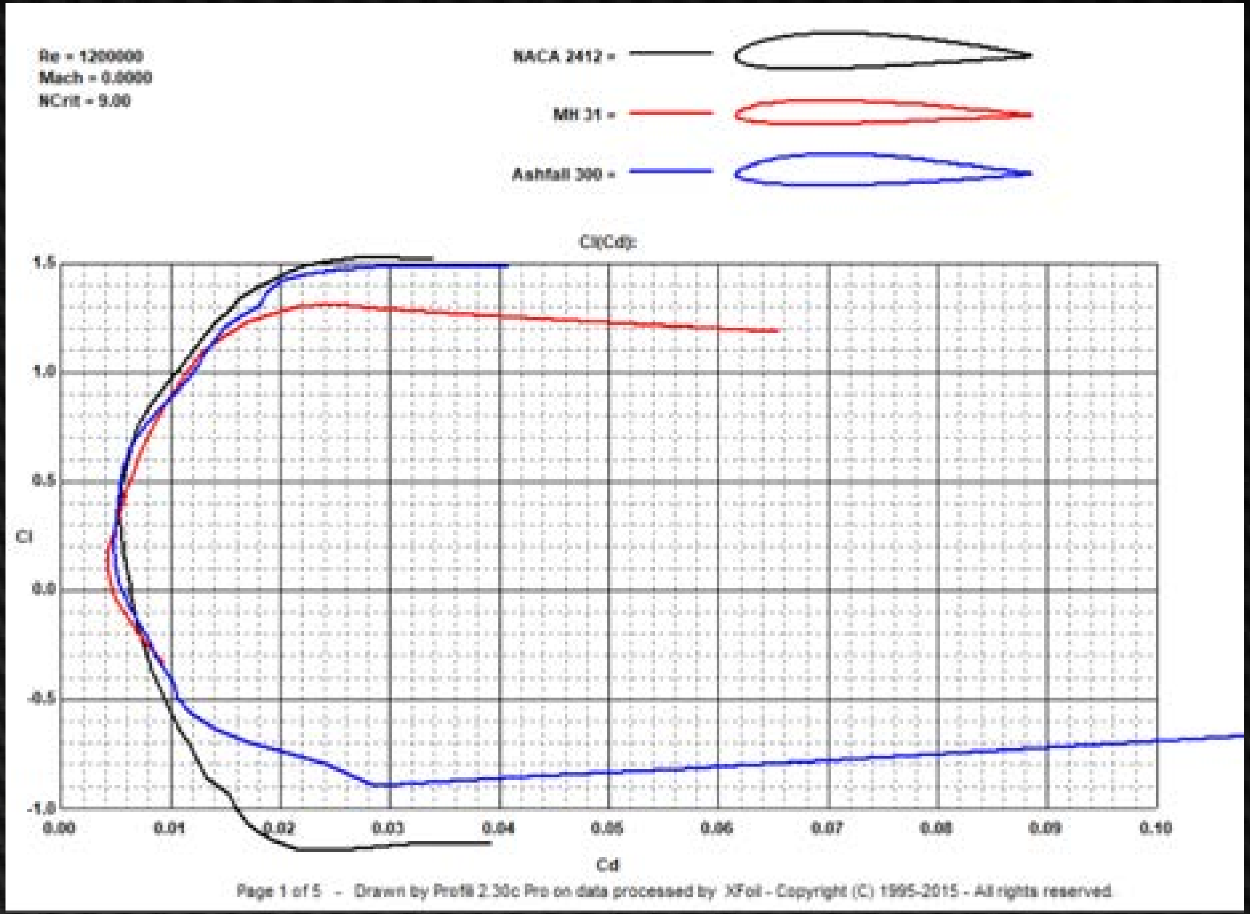
BACKUP SLIDES

AERO BACKUP SLIDES

AIRFOIL DRAG POLARS

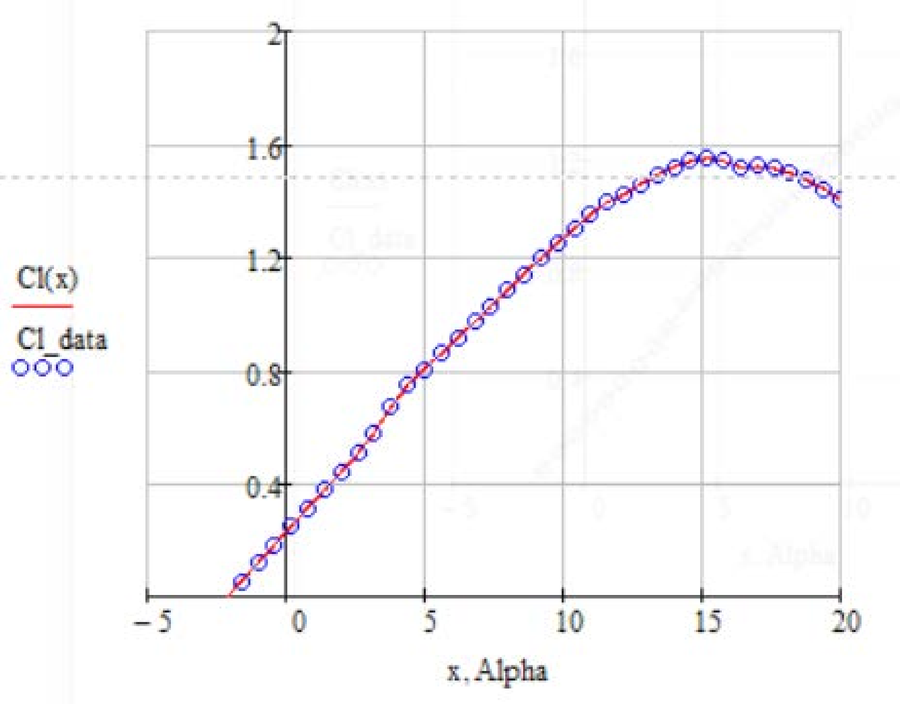
Ashfall 300 Comparison



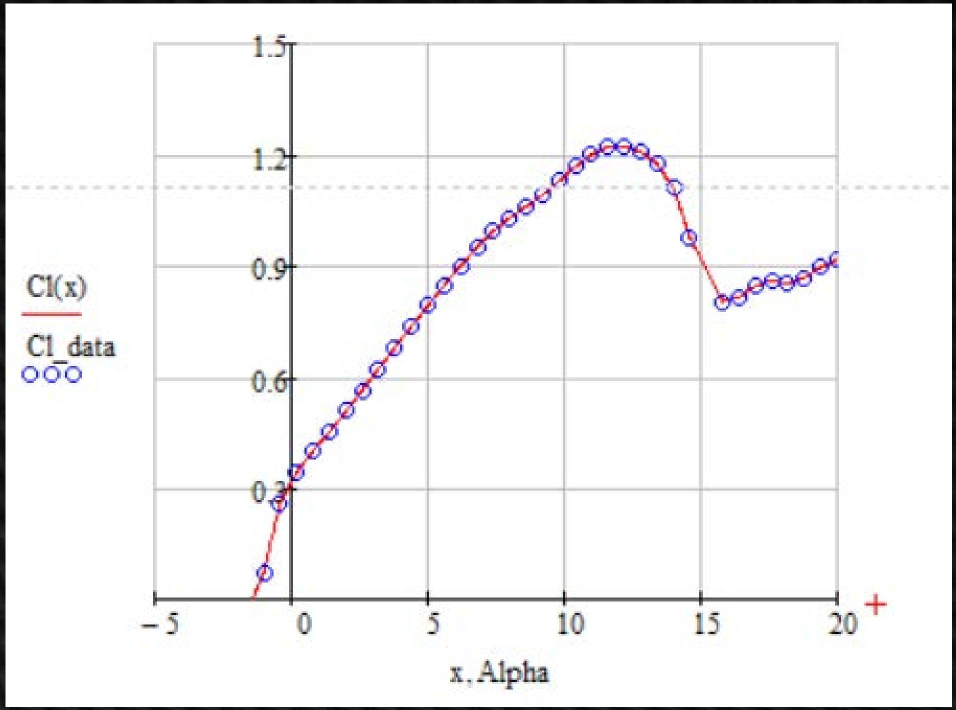


Ashfall 400

Cruise



Handlaunch



STRUCTURES BACKUP

TE Fastener Choices

Camloc Quarter Turn

- Pros:
  - Reliable
  - Strong Clamping Force
  - Simple and Small
  - Can be Flush
  - Variable Sizes
  - Composite Versions
- Cons:
  - Requires Tools
  - Not the fastest installation method
  - Possible Give/wiggle room

CORE MATERIAL CHOICES

FUSELAGE SKIN:

- SCORED DIVINYCELL FOAM (1/8" THICK)
  - EASIER FOR COMPLEX CONTOUR LAYUP
  - ADDED RIGIDITY -> *LANDING*

WING SKIN:

- BALSA WOOD (1/16" THICK)
  - LAYS UP WELL ON WING SURFACE
  - MORE FLEXIBLE -> *WING BENDING*

STRUCTURAL MATERIALS

Ribs and Bulkheads:

- Aircraft grade plywood (1/8" thick)
  - 5-ply adds rigidity
  - Light but strong

Spar:

- Unidirectional Carbon Fiber (1" wide)
  - Strong in tension
  - I-beam caps
- Balsa wood (various thicknesses)
  - Light
  - I-beam shear web

WINGTE MOUNT INTERFACE

- Composite shelf
  - Reinforced with plywood underneath
  - Plywood bonds with rear fuel tank bulkhead

WEIGHTS AND BALANCES

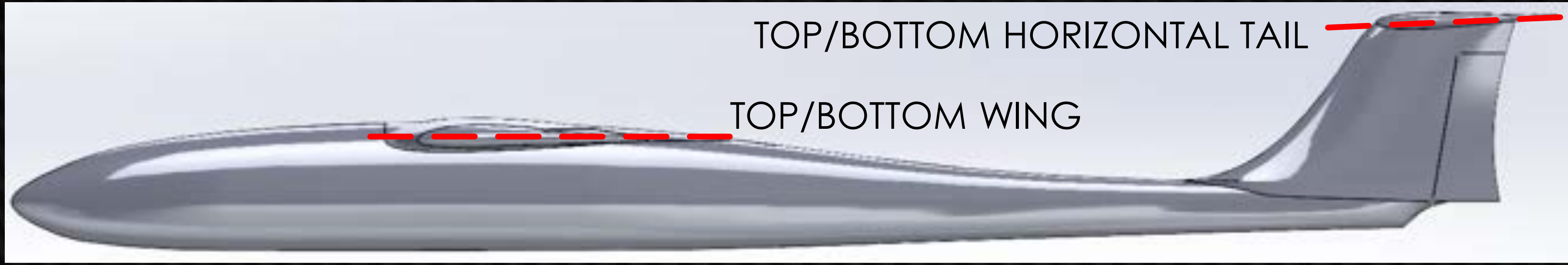
MTOW	
CG dist	13.07
wing start	11.5
chord	8.3
% chord	18.89%

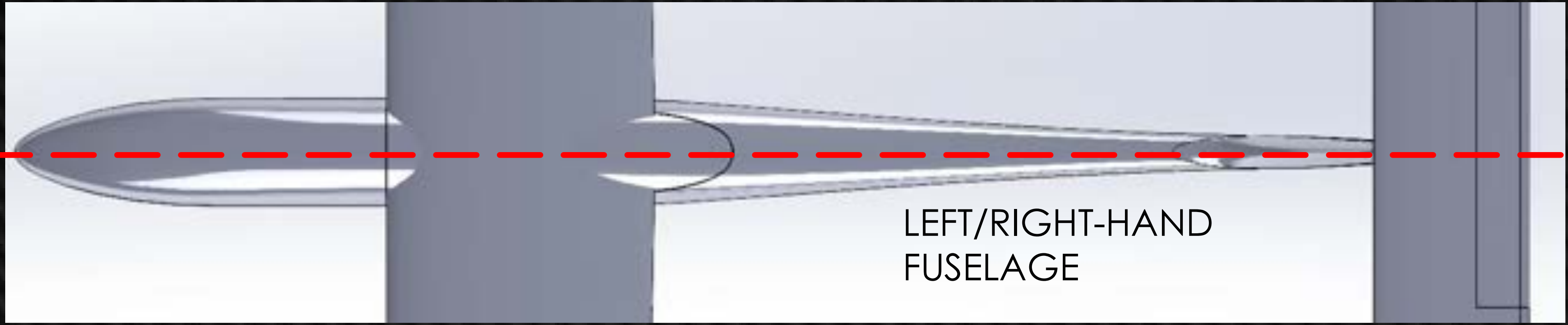
DEW	
CG dist	12.91
wing start	11.5
chord	8.3
% chord	17.04%

MTOW Horizontal Weights Distribution			
	Weight (lbf)	cg from aft of nose	W * c.g. length
ECU BATTERY	0.260	4.330	1.126
ECU	0.090	4.200	0.378
FUEL PUMP	0.100	20.250	2.025
SMOKE PUMP	0.200	20.250	4.050
FUEL FILTER	0.000		0.000
REVIEVER BATTERY	0.102	5.455	0.556
RECIEVER	0.030	5.825	0.175
AIRSPEED SENSOR	0.024	2.935	0.070
PITOT TUBE	0.022	1.000	0.022
ENGINE	1.010	7.500	7.575
SMOKE VALVE	0.030	20.000	0.600
FUEL VALVE	0.030	20.000	0.600
FUEL TANK	0.375	13.750	5.156
FUEL	1.200	13.750	16.500
SERVO 1	0.110	14.750	1.626
SERVO 2	0.110	16.500	1.819
SERVO 3	0.048	20.875	1.008
SERVO 4	0.048	20.875	1.008
SERVO 5	0.000	0.000	0.000
FUSELAGE	1.000	15.000	15.000
WING	1.710	15.000	25.650
TAIL	0.000	0.000	0.000
total structures	0.000		0.000
Sum	6.500		84.944
		CG for station 1	13.068

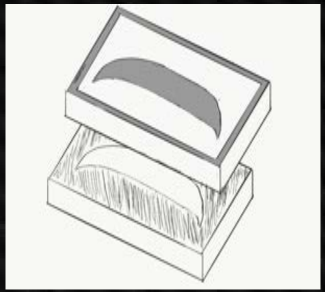
Dry Empty Horizontal Weights Distribution			
	Weight (lbf)	cg from aft of nose	W * c.g. length
ECU BATTERY	0.260	4.330	1.126
ECU	0.090	4.200	0.378
FUEL PUMP	0.100	20.250	2.025
SMOKE PUMP	0.200	20.250	4.050
FUEL FILTER	0.000		0.000
REVIEVER BATTERY	0.102	5.455	0.556
RECIEVER	0.030	5.825	0.175
AIRSPEED SENSOR	0.024	2.935	0.070
PITOT TUBE	0.022	1.000	0.022
ENGINE	1.010	7.500	7.575
SMOKE VALVE	0.030	20.000	0.600
FUEL VALVE	0.030	20.000	0.600
FUEL TANK	0.375	13.750	5.156
FUEL	0.000	13.750	0.000
SERVO 1	0.110	14.750	1.626
SERVO 2	0.110	16.500	1.819
SERVO 3	0.048	20.875	1.008
SERVO 4	0.048	20.875	1.008
SERVO 5	0.000	0.000	0.000
FUSELAGE	1.000	15.000	15.000
WING	1.710	15.000	25.650
TAIL	0.000	0.000	0.000
total structures	0.000		0.000
Sum	5.300		68.444
		CG for station 1	12.914

PLUG/MOLD COMPONENTS

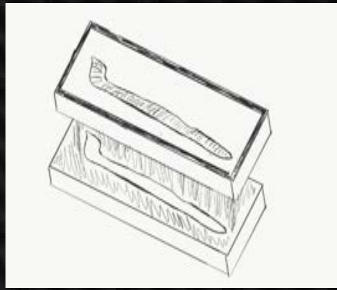




HORIZONTAL TAIL

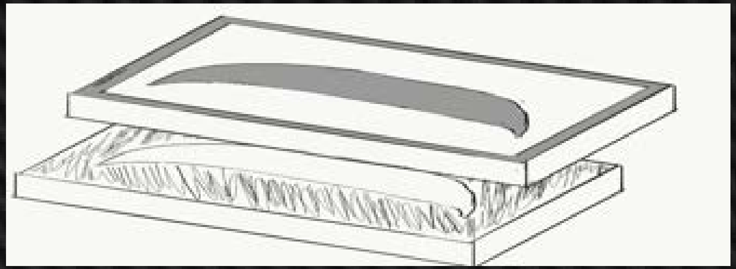


FUSELAGE AND VERTICAL TAIL



- Total Projected Mold Count:
  - 3 mold pairs
  - Less molds = cheaper tooling cost

WING



INTERNAL WING DESIGN

- Wing Mounting Hub
- Main Spar
- Ribs
- Shear Webs