ARCHERFISH

Project Manager: Jasmine Cheng

CAL POLY
SPACE SYSTEMS

AGENDA

1. Overview
   - Mission Scope
   - Concept of Operations
   - Top Level Requirements
2. Fluids
3. GSE
4. Aerodynamics
5. Structures
6. Recovery
7. Avionics
8. Testing
9. Budget

OVERVIEW

Mission Scope

- **Mission Objective:** To launch an experimental pump-fed bi-propellent liquid rocket.
- **Mission Success Criteria:**

1. Successful, complete launch and recovery of rocket
2. Student technical and teamwork development!

- FAR Ten Cents per Foot Contest, launch end of May – Early June

OVERVIEW

Open Rocket Model

Liquid Bi-Propellant Rocket
- **Oxidizer:** Nitrous Oxide
- **Fuel:** Ethanol
  - Pressurized By GN2
- **OF Ratio:** 2.6
- **Target Thrust:** 400 lbf

- **Wet Mass:** 93.0 lbs
- **Dry Mass:** 73.2 lbs
- **TWR:** 4:1
- **Overall Length:** 122 in (10' 2")
- **Diameters:**
  - Top: 6.20" Outer | 6" Inner
  - Bottom: 6" Outer | 5.75" Inner

- **CG Location:** 74.6 in
- **CP Location:** 85.3 in
- **Stability:** 1.73 caliber
- **Max Apogee: ~13000ft**

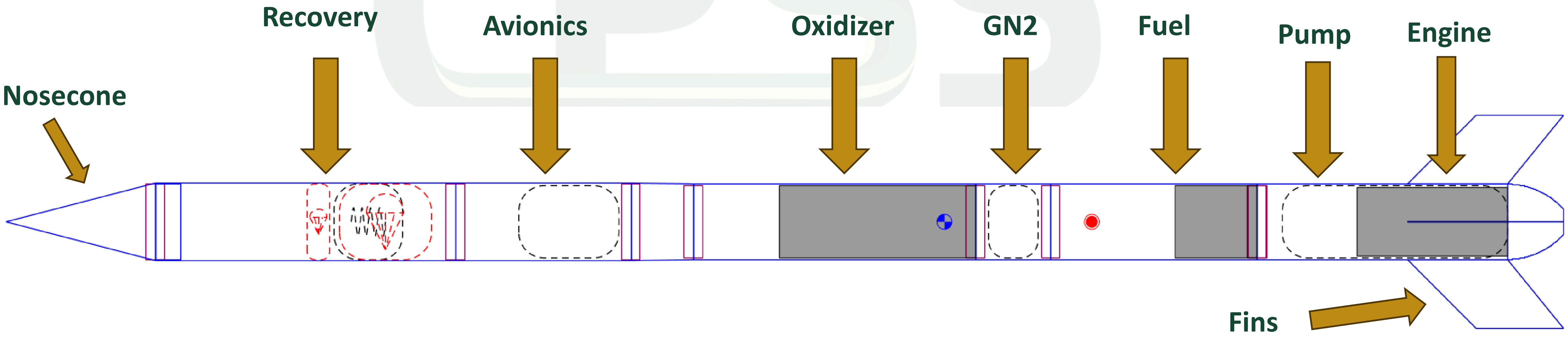


Fig 0.1 Open Rocket Model

OVERVIEW

CAD Model (Full)

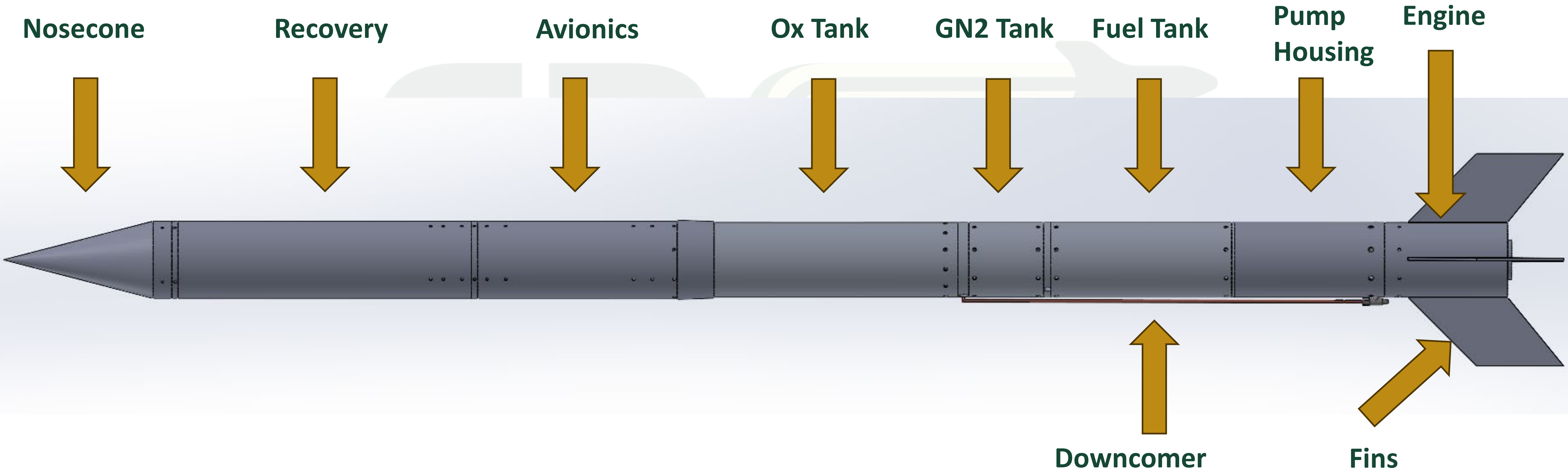


Fig 0.2 Full External CAD

CONOPS

Graphic + Phases

- Phase 1: Filling

  Ox tank and air tank fill

- Phase 2: Launch

  Pump turns on

  Line cutters ignite

  C-motor ignition

- Phase 3: Apogee + Drogue Deployment

  Coasts to an apogee of ~13000 ft

  Detect deployment at apogee

- Phase 4: Main Parachute

  Detect deployment altitude of 1000 ft

- Phase 5: Landing

  Archerfish lands safely

  GPS transmits location

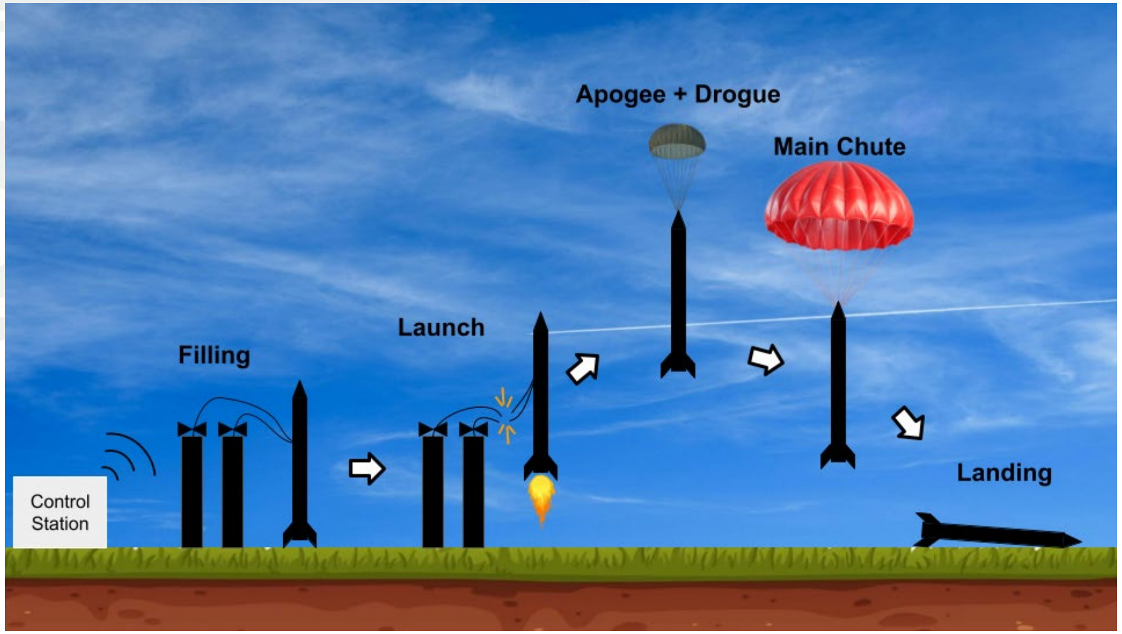


Fig 0.3 Concept of Operations

REQUIREMENTS

Top Level

RBS	Requirement	Rationale
1	The rocket shall be a pump-fed bipropellant liquid rocket	This is the primary mission of this rocket.
2	The rocket shall be fully recoverable	Components and materials are expensive, post launch analysis becomes much more difficult if the rocket is in bad condition afterwards. This is also a FAR requirement.
3	The rocket shall be structurally stable	Components and materials are expensive, post launch analysis becomes much more difficult if the rocket is in bad condition afterwards
4	The rocket shall maintain static stability throughout flight	A stability caliber that's too low allows the wind to easily change trajectory or cause tumbling, lowering apogee or potentially mission failure. A too high stability caliber increases the rocket's sensitivity to disturbances and makes it difficult to recover from them, changing the trajectory and lowering apogee.
5	The rocket shall have an avionics system	This is a FAR requirement and is also necessary for several functions of the rocket

Note: FAR Requirements in Appendix

REQUIREMENTS

Second Level

RBS	Requirement	Rationale
1.1	The rocket shall have an engine that produces 400 lbf	The rocket cannot move otherwise
1.2	The rocket shall have a thrust to weight ratio greater than 3:1	The rocket cannot move otherwise
1.3	The rocket shall have a pump for the rocket fuel	This is a requirement for a rocket to be pump-fed
1.4	The rocket will use Nitrous Oxide and Ethanol	This is a FAR Ten Cents Per Foot challenge requirement
2.1	The recovery system shall deploy without damaging the rocket	This needs to occur for a successful recovery system
2.2	The drogue chute shall deploy at apogee	This needs to occur for a successful two stage recovery system
2.3	The main parachute shall deploy below 1,000 ft	This needs to occur for a successful two stage recovery system

REQUIREMENTS

Second Level (Cont'd)

RBS	Requirement	Rationale
3.1	All parts of the rocket shall stay intact as designed throughout the internal systems	Components and materials are expensive, post launch analysis becomes much more difficult if the rocket is in bad condition afterwards
3.2	The rocket body shall be able to support the weight of all internal systems	The rocket will fall apart if the rocket cannot support its own weight
3.3	The rocket shall have a minimum FOS of 1 during entire flight	Components and materials are expensive, post launch analysis becomes much more difficult if the rocket is in bad condition afterwards
4.1	The rocket shall have a stability caliber of 2. 5 +/- 0.5 OR 15%	See RBS 4
5.1	The rocket shall have a telemetry system	This is a FAR requirement
5.2	The avionics stack shall stay in one piece throughout the flight	The avionics system will likely not work if damaged

FLUIDS

- Pump
- Bulkheads and Tanks
- Valves
- Injector
- Propulsion

FLUIDS – PUMP

Presented by: Tony Casagrande and Tate Manley

PUMP REQUIREMENTS

Design Criteria

1. Head Rise >= 400

Derived from main requirements -> needed for proper engine pressure = 350 psi

2. 0.26 kg/s Mass flowrate

Derived from main requirements for engine -> supports 400 lbf

3. P_{Req} <= 10000 Watts

Derived from capabilities of batteries and choosing a realistic amperage / voltage from past pumps (~50V @ 200 amps)

4. N = 30000 RPM

Based on capabilities of current motor, soft requirement as different motor can be selected

PUMP DESIGN

Overall Design Parameters / Considerations

- Low Specific Speed + High Head Rise ➔ **Centrifugal Pump with Barske Impeller**
- **Single Stage:** Simplicity/Cost
- **No Inducer:** Small Net Specific Suction Head Require (NPSHR) for impeller
- **Bearings + Sealing:** High speed ball bearings + compressed graphite/PTFE packing rope + Springs and Seal-Plunger

*5.21 [GPM]

Parameters	Value
Fuel Mass Flow	0.26 [kg/s]*
Head Rise	500 [psi]
RPM	30000
Specific Speed (Ns)	350
NPSHR	10 [psig]

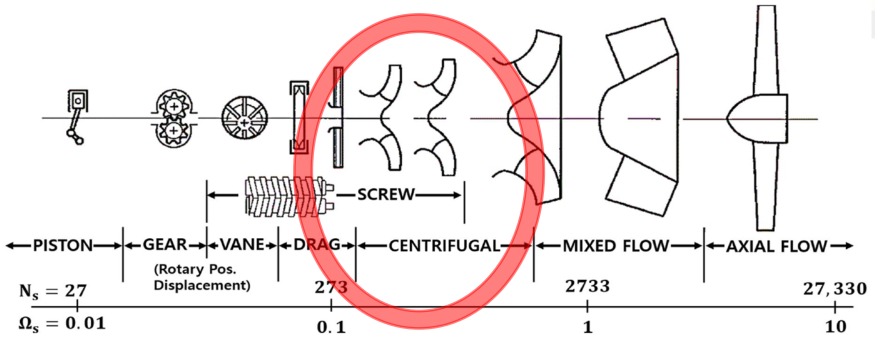


Fig 1.1 Pump Types

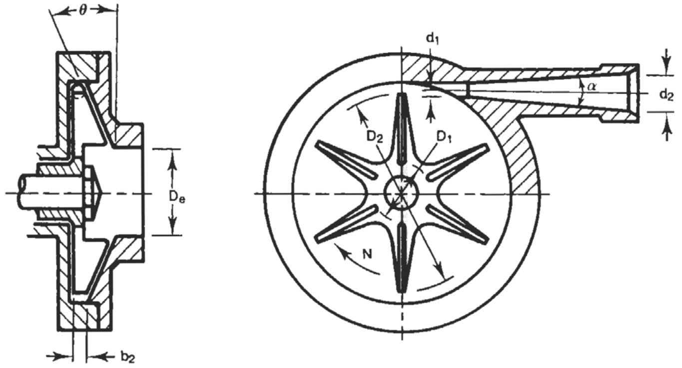


Fig 1.2 Barske Pump

PUMP DESIGN

Overall Design and Parameters/Considerations

- **Volute:** Concentric bowl (No gain with Volute collector at <400 Ns)
  - Prior pump
- **Motor:** CASTLE 2028 SENSORED MOTOR - 800KV (FOC CAPABLE)
- **Materials:**
  - Volute/Diffuser + Casing: 3D Printed Aluminum
  - Impeller: 3D Printed Stainless (316)
  - Motor Mount: SLA Resin
- **Overall Size (Pump Hardware):**
  - Impeller Diameter = 2 [in]
  - Overall Length = 10.4 [in]
  - Overall Diameter = 3.5 [in]

Parameters	Value
Motor Voltage	9 - 50.4 [V]
Motor Amperage	<= 200 [A]

BP2 LEARNINGS

BP2 Pump Curve -> Flowrate Issue Solved!

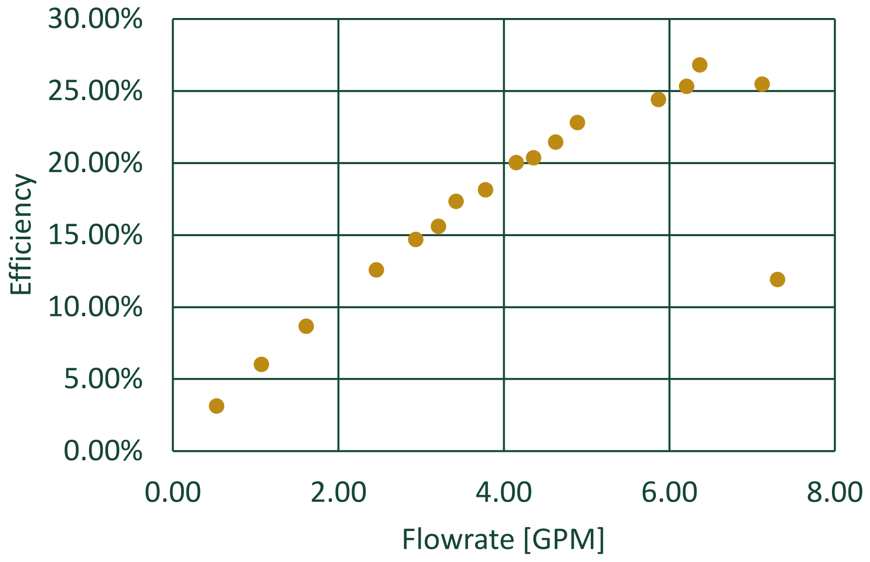


Fig 1.3 BP2 Efficiency Curve

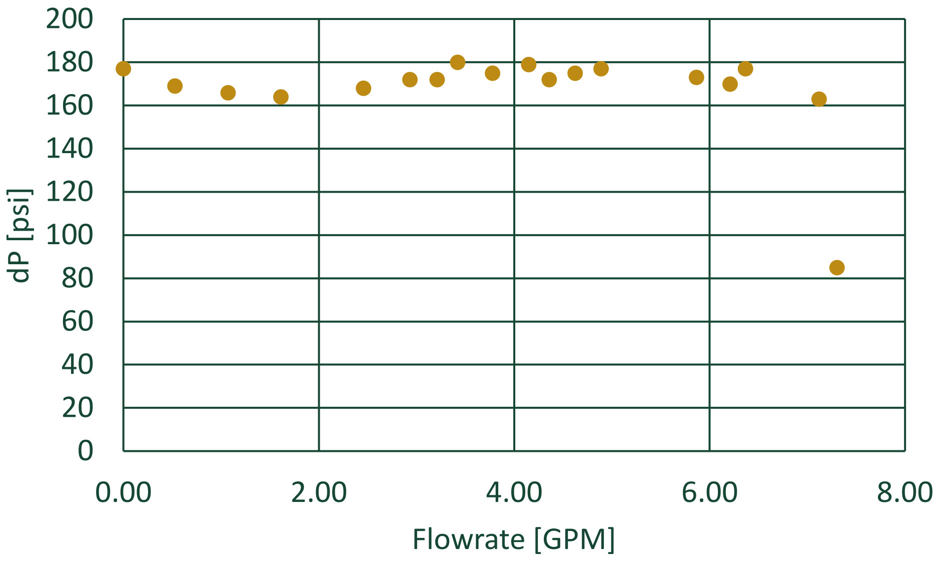


Fig 1.4 BP2 Pump Curve

Head Rise	Flow Rate	Mass Flow (Ethanol)	Power	Efficiency
175 [psi]	6.2 [GPM]	0.31 [kg/s]	1800 [W]	26.8%

INTEGRATED DESIGN

AP1 -> Actual Design Views

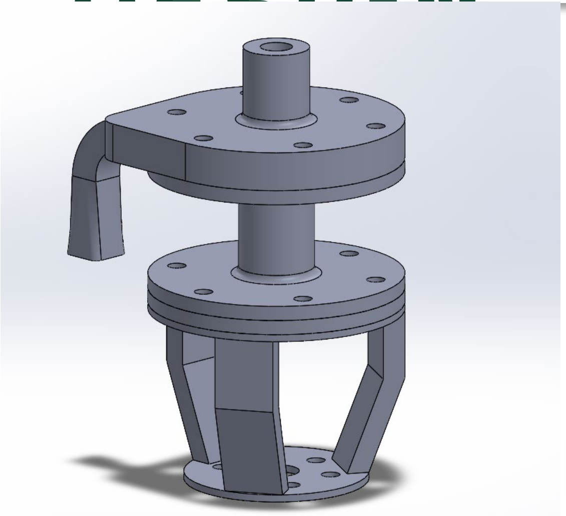


Fig 1.6 AP1 Full Assembly

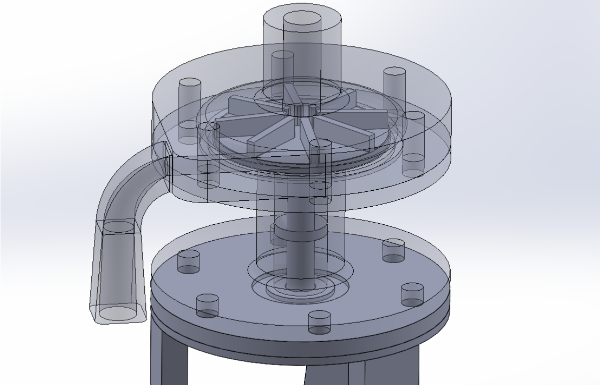


FIG 1.7 AP1 Impeller housing

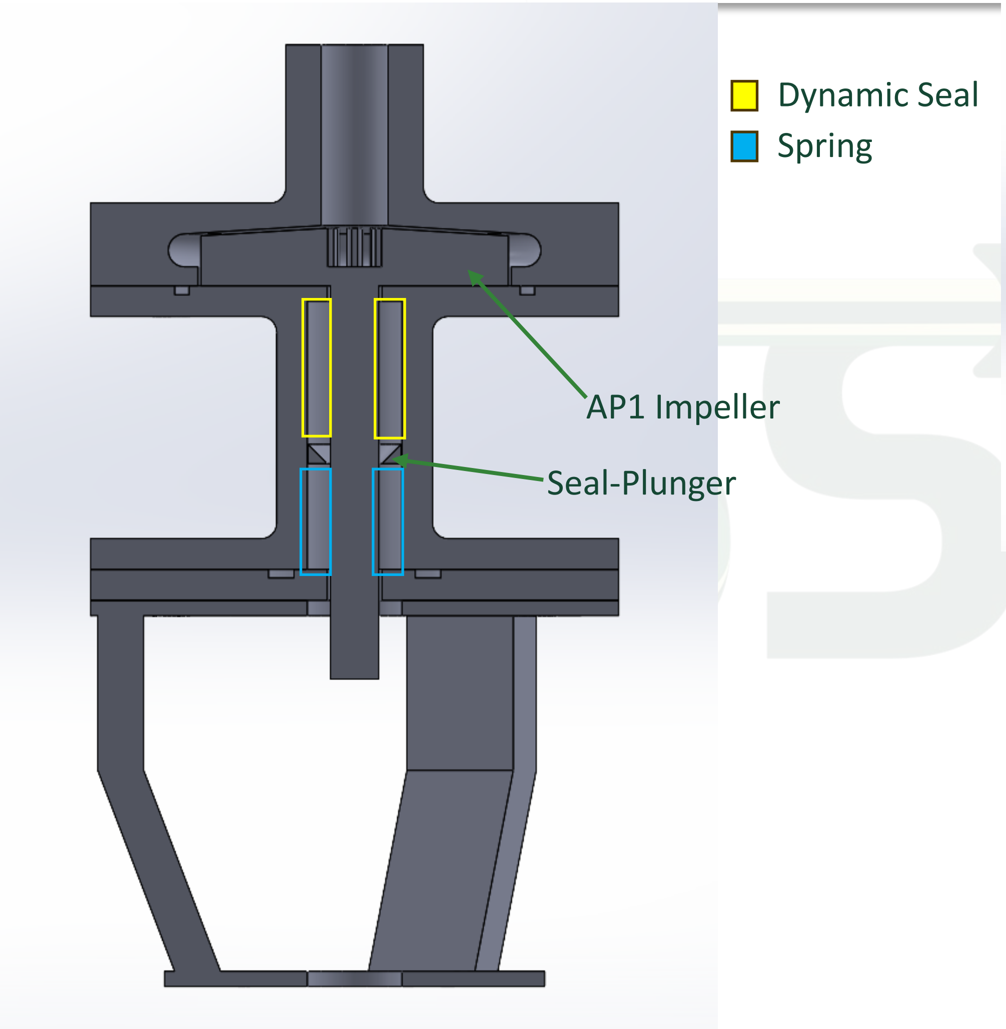


FIG 1.5 AP1 Section View

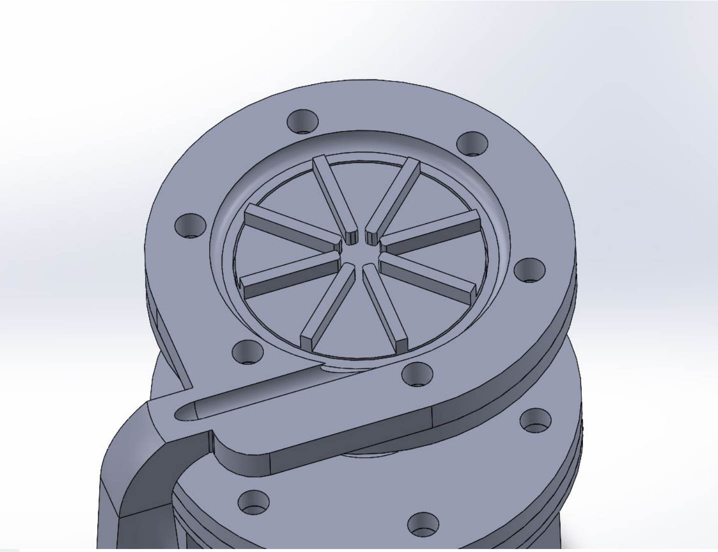


FIG 1.8 AP1 Impeller Chamber

PUMP MOUNTING

Plan for Integration

Integrate with bottom of fuel bulkhead

- Blind threaded hole w/ thread locker (2nd retention) on bulkhead
- Nut with threaded rod (x6)

Will also interface with electronics mounts

- Motor Controller / Batteries
- Mounts attached to spacer or directly to pump casing/bulkhead

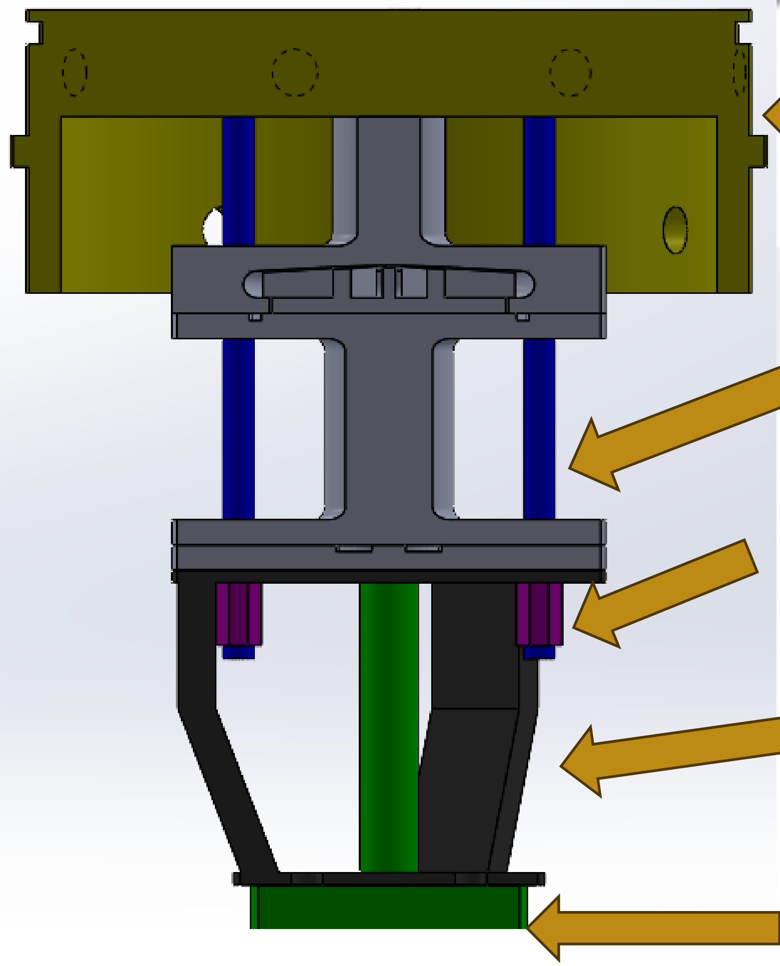


FIG 1.9 Mounting Section View

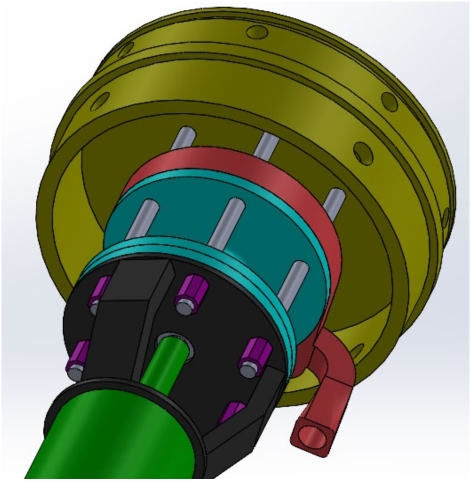


FIG 1.10 Isometric Mount View

PUMP ELECTRONICS

Wiring Diagram

Key Features

- **PWM Command** from Engine Controller (0-100% RPM)
- **FOC Motor Controller** – Motor Curve Optimized Automatically
- **XT60**: 60A continuous, 180A peak
- **Battery**:
  - 2x Drone batteries in series – 2x 6s (22.2V each)
  - Size: **5000 mAh minimum** – uses ~12% of capacity for 10s spin at 10000W.
  - C rating: >= 50 (for worst case of 200A)
- **Weight:** <= 6 lbs (Motor + Controller + Batteries + Mounts)

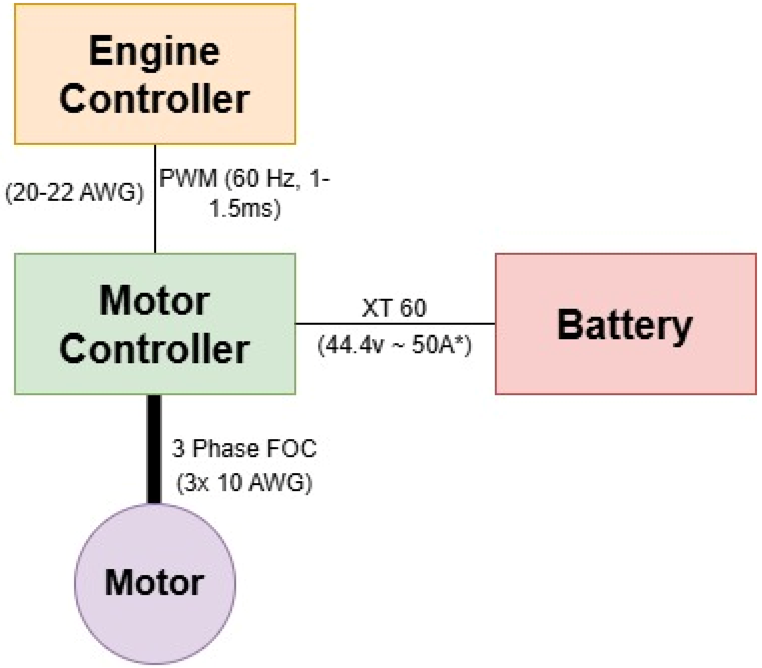


Fig 1.11 Flight Pump Wiring Diagram

FUTURE STEPS

To-Do

- **Design –** Update design with feedback
- **Manufacture –** Casing, Impeller, Mounting, etc.
- **Testing –** Test AP1 (Pump curve + Integrated Hot Fire Test)

Fig 1.12 BP2 Integrated for Testing

FLUIDS – BULKHEADS AND TANKS

Presented by: Devin Chen, Gustavo Chavez, Joshua Chung, Sloan Robbins

BULKHEAD REQUIREMENTS

Design Criteria

RBS	Requirement	Rationale	Verification
1	Design OX tank for 750 psi MEOP (1500 psi for FS 2) Fuel tank for 100 psi MEOP (200 psi for FS 2) GN2 tank for 100 psi MEOP (200 psi for FS 2). This means that the bulkhead will also have to be rated to these pressure with a factor safety of 2	This is to ensure that the pressure vessel will be able to withstand pressures than may result from unexpected temperature fluctuations which would allow for higher-than-normal pressures.	SolidWorks FEA, Hand Calculations, and pressure vessel testing
2	All Bulkheads are to be manufactured out of 6061 T6 Aluminum and need to be manufactured in house	The material constraint is due to 6061-T6 aluminum being lightweight while being strong enough to withstand the pressures in the system, they are also much more affordable than other material that have these properties.	
3	All bulkhead should meet or safely be below the allowable weight so that the thrust to weight ratio of 4.51	A too low of a TWR leads to stability issues during launch and flight	
4	All bulkheads must have a tab in the middle	Provides space for check values to ensure no gases/ liquids will mix.	

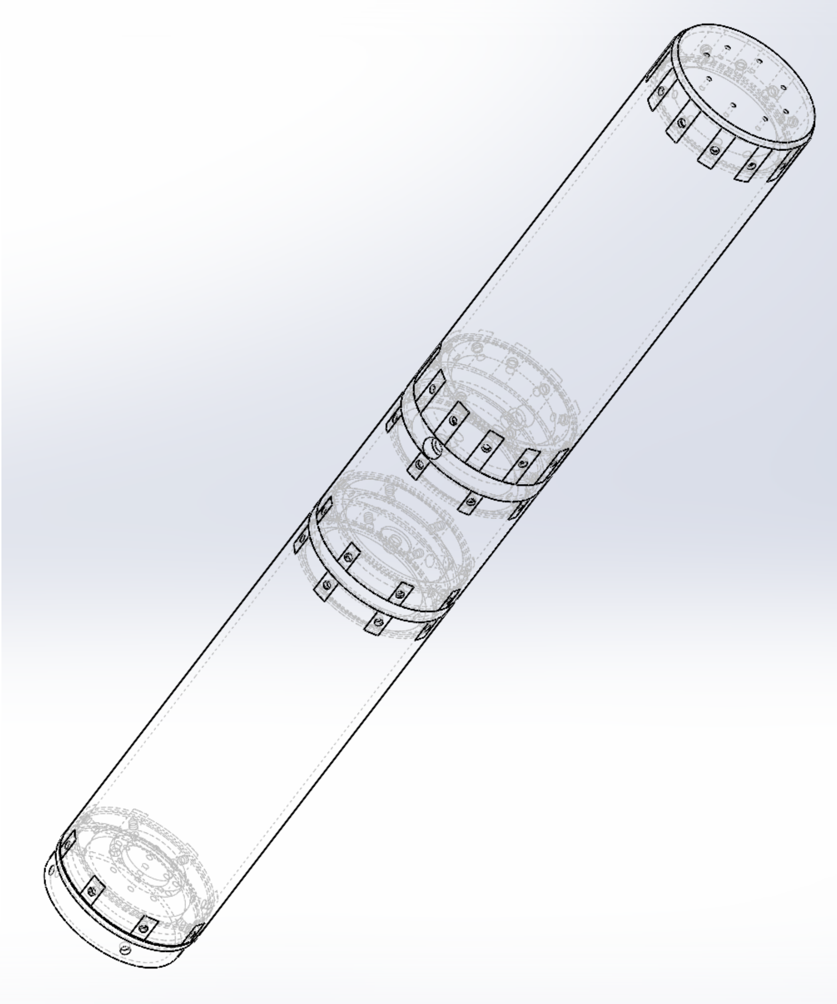
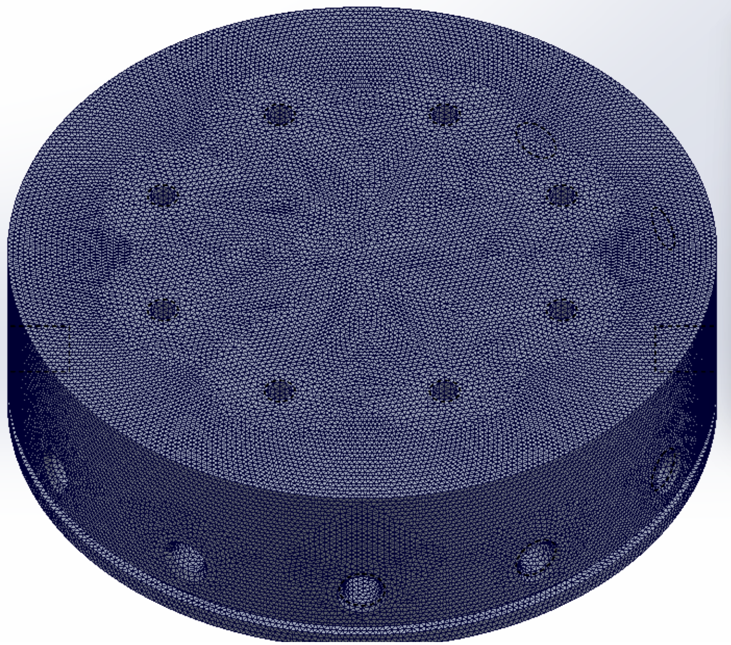


Fig 2.1 Tank Assembly

BULKHEADS

FEA Approach



Mesh Details

Study name	Static 2* (-Default-)
DetailsMesh type	Solid Mesh
Mesher Used	Blended curvature-based mesh
Jacobian points for High quality mesh	16 points
Max Element Size	0.05 in
Min Element Size	0.0025 in
Mesh quality	High
Total nodes	2444731
Total elements	1763139
Maximum Aspect Ratio	4.463
Percentage of elements with Aspect Ratio < 3	100

Fig 2.2 OX Sample Bulkhead Mesh

- Sufficiently high mesh quality to capture stress concentrations.
- Simulated at pressures far higher than application for safety. (e.g., 1500psi for a bulkhead with 750psi tank pressure)
- Simulated with maximum von Mises scale being a full order of magnitude lower than actual yield strength.
- Bulkheads under 2 pressures simulated with both pressures individually and together, highest stress result shown.
- 0.0015in maximum displacement

BULKHEADS OX

CAD/FEA

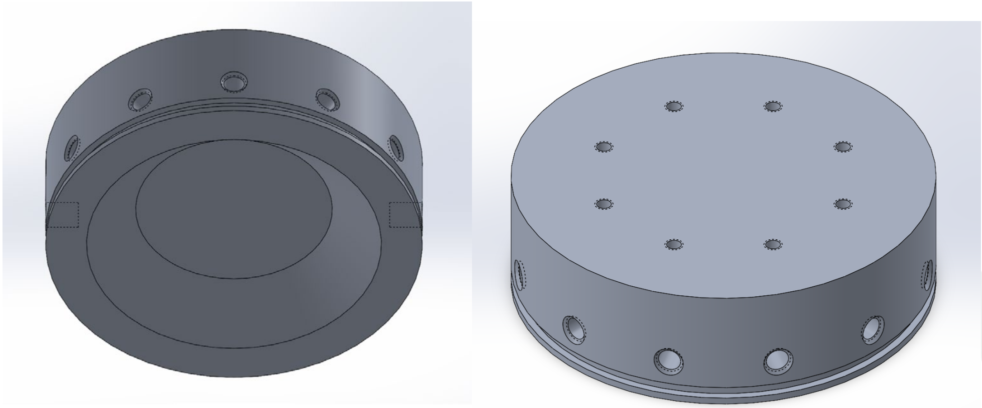


Fig 2.3 OX Bulkhead Model

Dimensions:
Height: 1.75 in
Width: 5.75 in OD

Mass = 3.52 lbs.

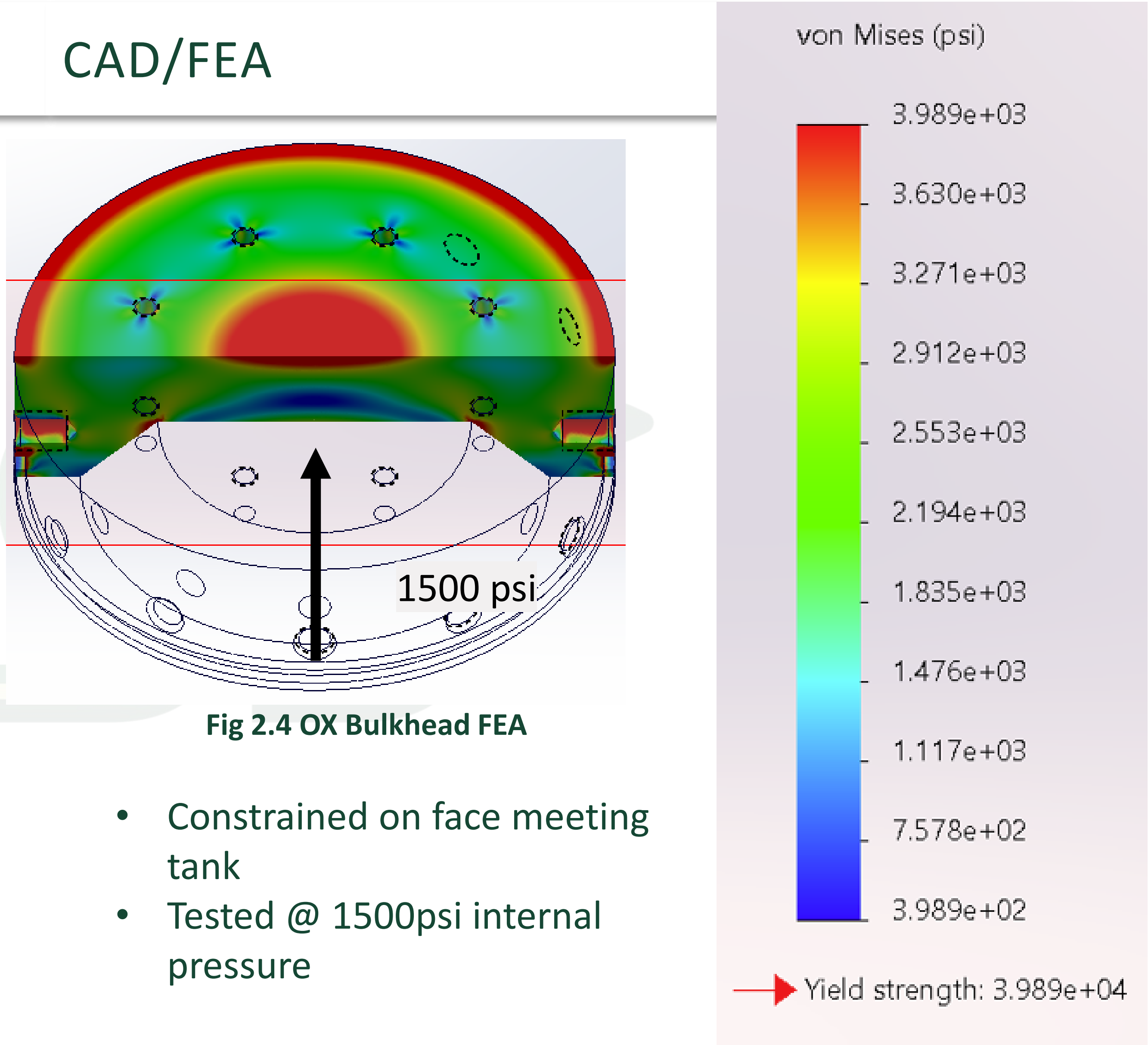


Fig 2.4 OX Bulkhead FEA

- Constrained on face meeting tank
- Tested @ 1500psi internal pressure

BULKHEADS OX/GN2

CAD/FEA

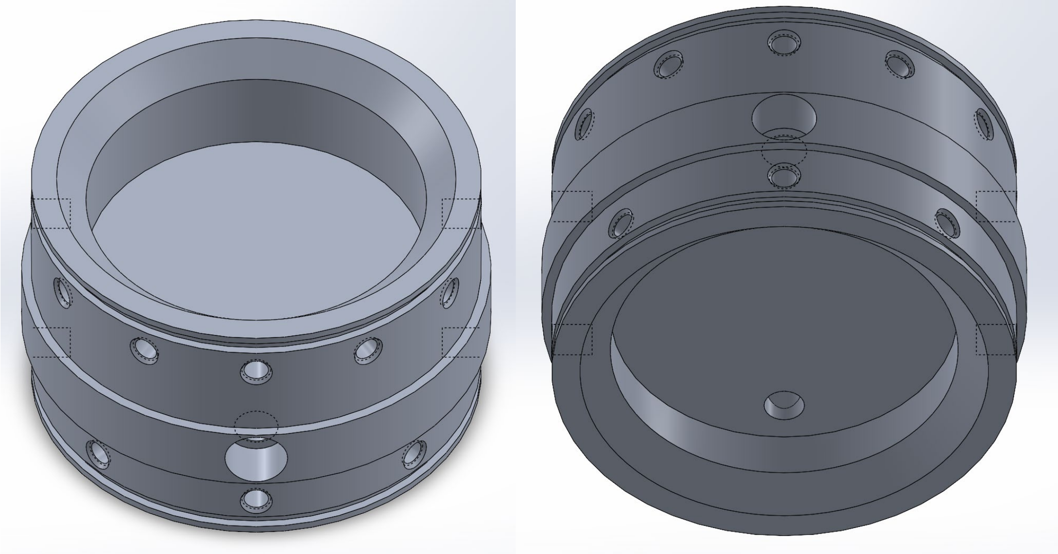


Fig 2.5 OX and GN2 Bulkhead Model

Dimensions:
Height: 3.6255 in
Width: 6.00 in
OD

Mass = 5.02 lbs.

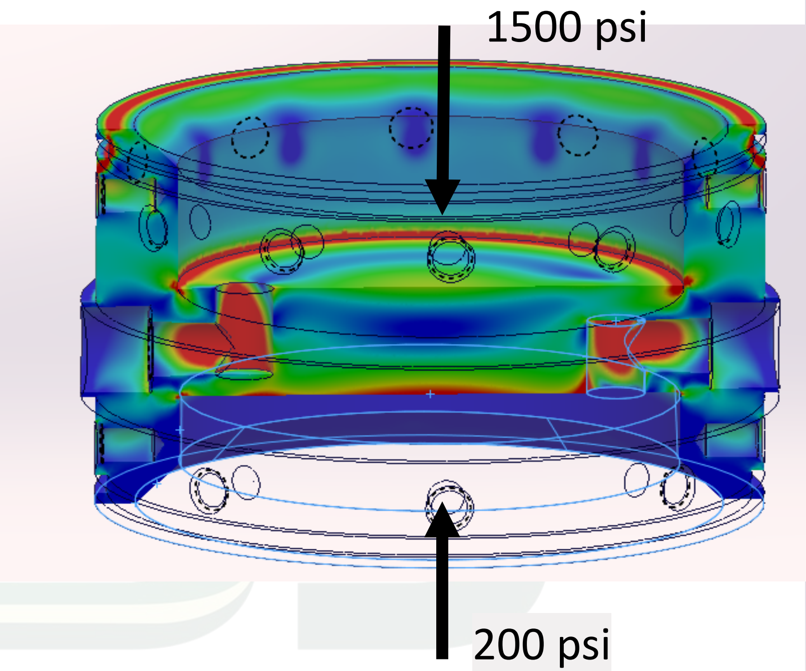
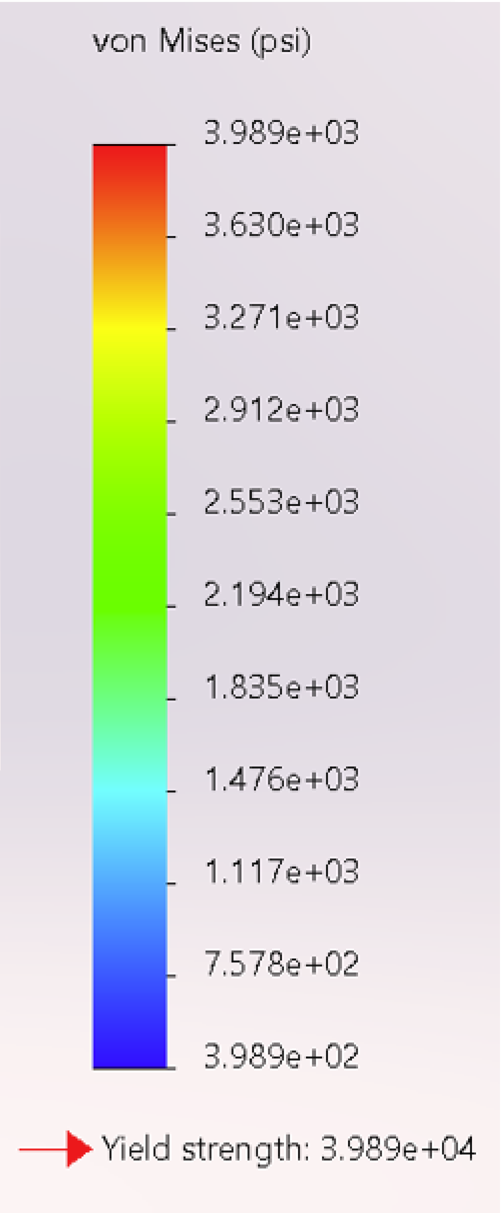


Fig 2.6 OX and GN2 Bulkhead FEA

- Constrained on faces meeting tanks
- Tested @ 1500psi



BULKHEADS GN2/FUEL

CAD/FEA

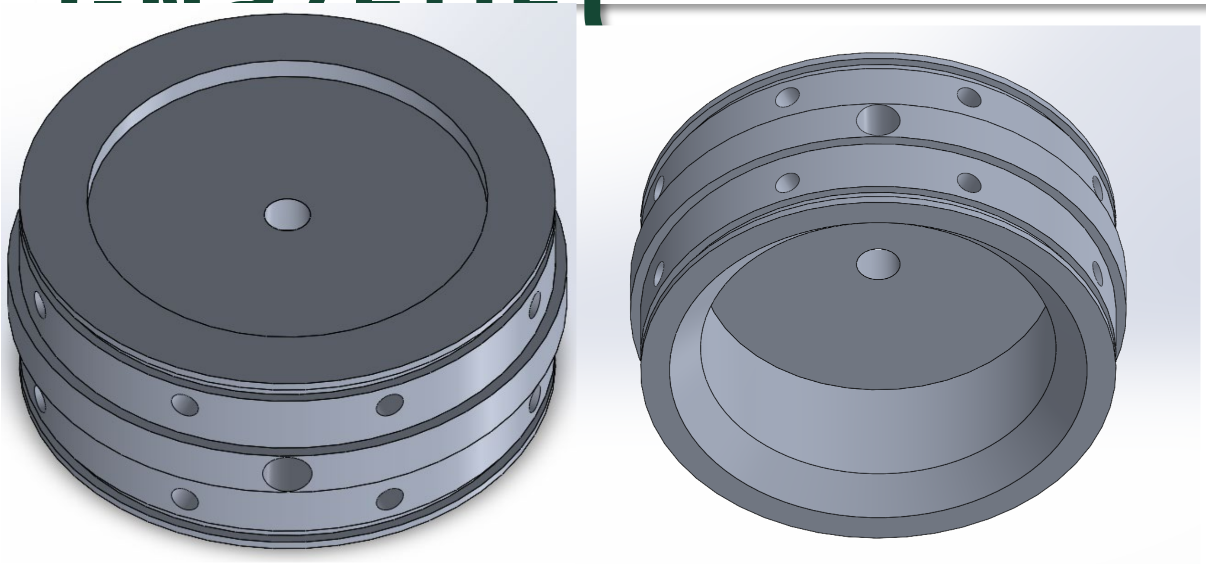
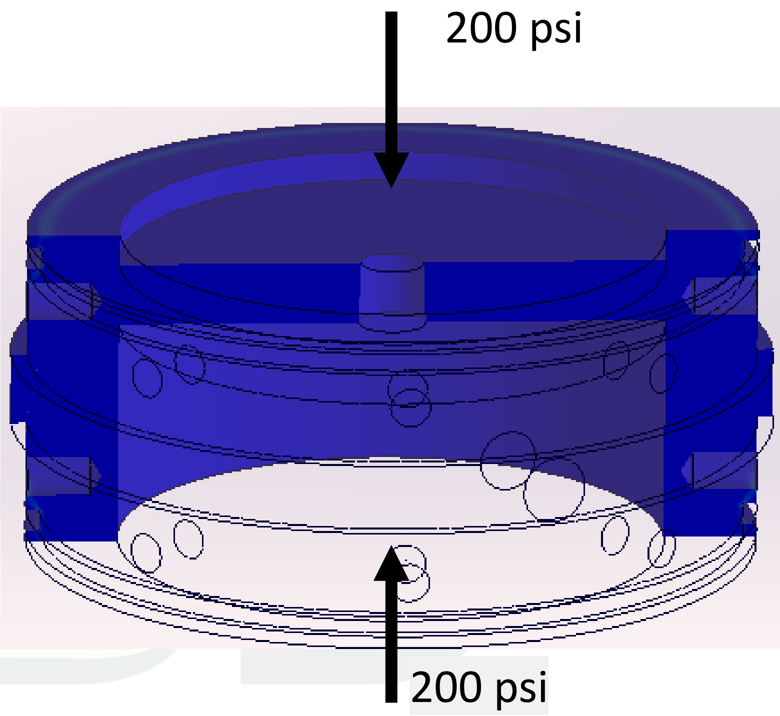


Fig 2.7 OX and GN2 Bulkhead Model

Dimensions:
Height: 2.587 in
Width: 6.00 in OD

Mass = 3.19 lbs.



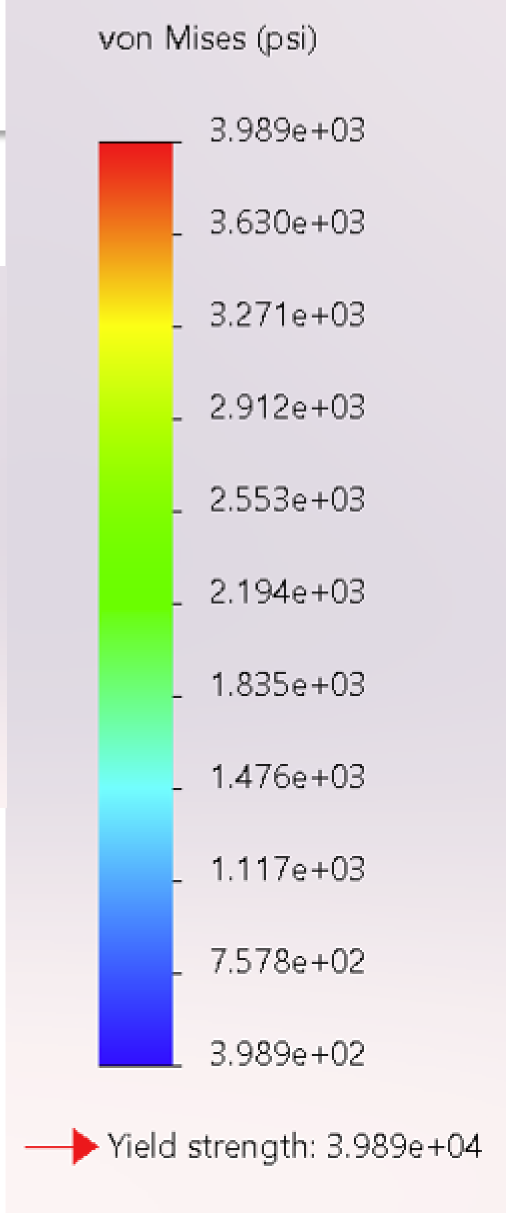


Fig 2.8 GN2 and Fuel Bulkhead FEA

- Constrained on faces meeting tanks
- Tested @ 200psi

BULKHEAD BOTTOM FUEL

CAD/FEA

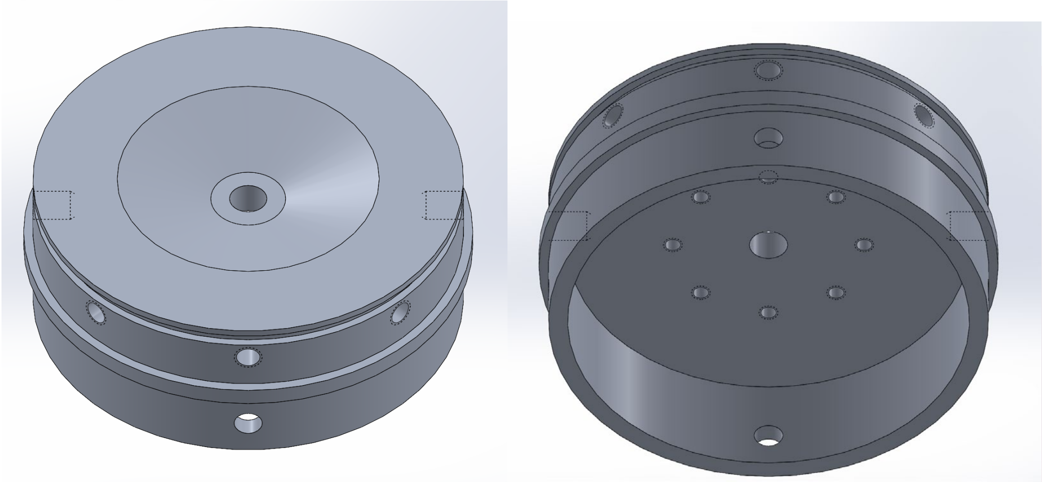


Fig 2.9 GN2 and Fuel Bulkhead Model

Dimensions:
Height: 2.587 in
Width: 6.00 in OD

Mass = 2.54 lbs.

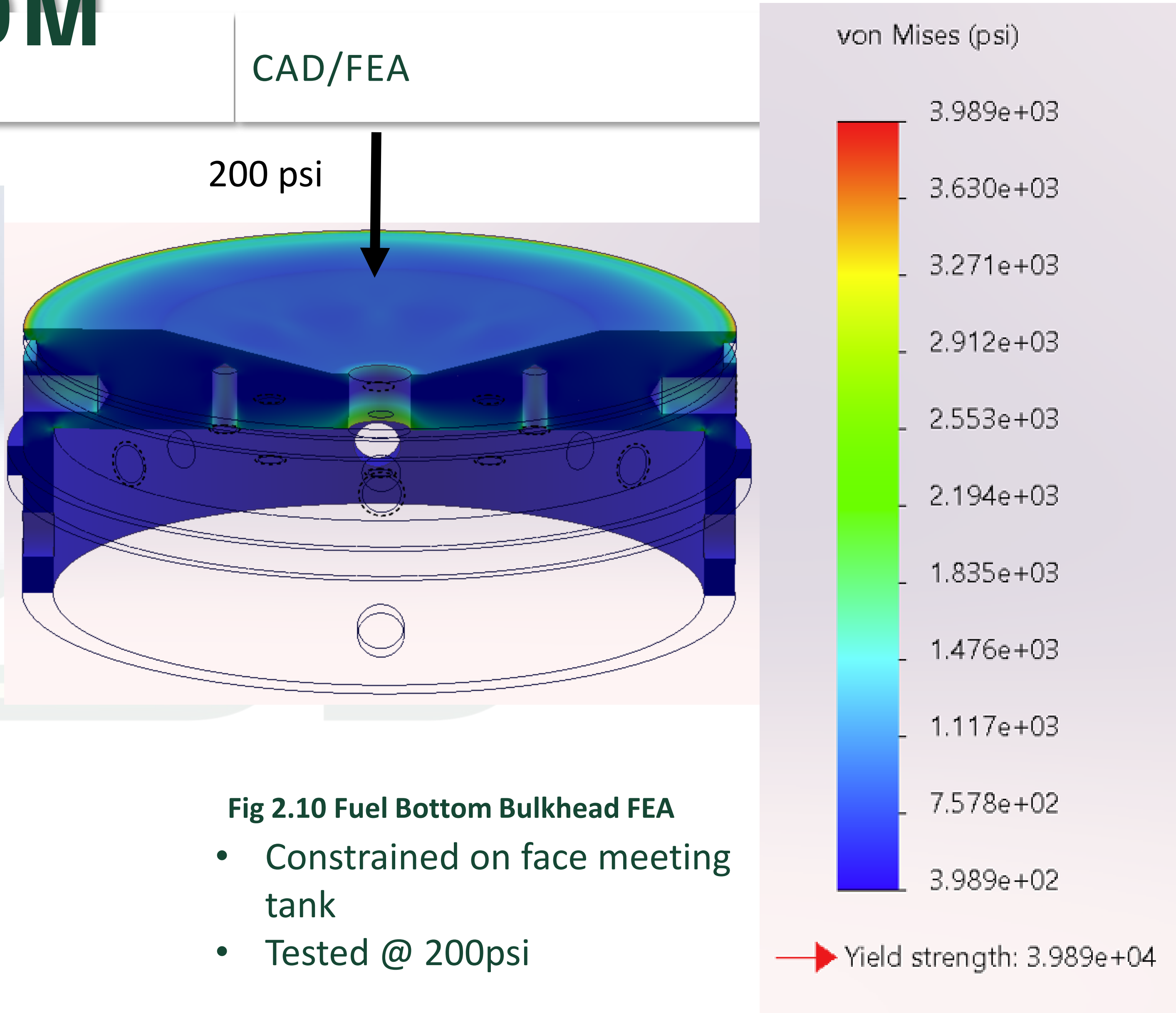


Fig 2.10 Fuel Bottom Bulkhead FEA

- Constrained on face meeting tank
- Tested @ 200psi

BULKHEAD CALCS

Bolts

Shear Stress (Num Bolts):

$$\frac{\frac{\frac{\pi}{4} * (ID^2 * MEOP_{tank})}{0.75 \; * UTS_{bolt}}}{FS * \frac{\pi}{4} * (D_{bolt,minor}{}^2)} = num\ bolts$$

Num Ox Bulkhead bolts:
10.2002 --> 12 bolts

Num Fuel Bulkhead bolts:
1.3327 --> 8 bolts

Num Air Bulkhead bolts:
1.3327 --> 8 bolts

https://www.mcmaster.com/92620A621/

Bolts Used:

3/8-16 Grade 8 Steel Bolts

5/8in long

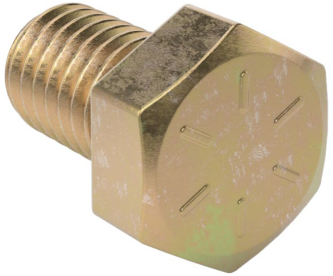


Fig 2.11 Grade 8 Steel Bolt

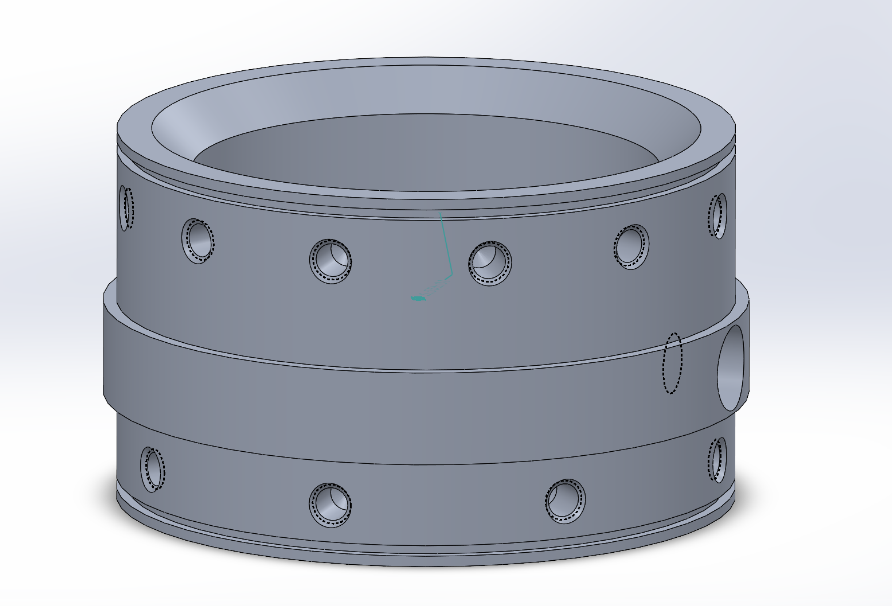


Fig 2.12 OX and GN2 Bulkhead Model

BULKHEAD CALCS

Bolts

Tear Out Stress(Tank Wall):

$$\frac{D_{bolt,minor}}{2} + \frac{\frac{\pi}{4} * D_{tank,inner}{}^{2} * MEOP}{num\ bolts\ * \frac{USS}{FS} * 2 * t_{tank}} = Bolt\ Pos_{tank}$$

Tear Out Stress(Bulkhead):

$$\frac{D_{bolt,minor}}{2} + \frac{\frac{\pi}{4} * D_{bulkhead,inner}{}^{2} * MEOP}{num\ bolts * \frac{USS}{FS} * 2 * L_{bolt}} = Bolt\ Pos_{bulkhead}$$

Tank Wall:	Ox Bulkhead:	Air and Fuel Bulkhead:
0.9531in	0.3983in	0.2156in

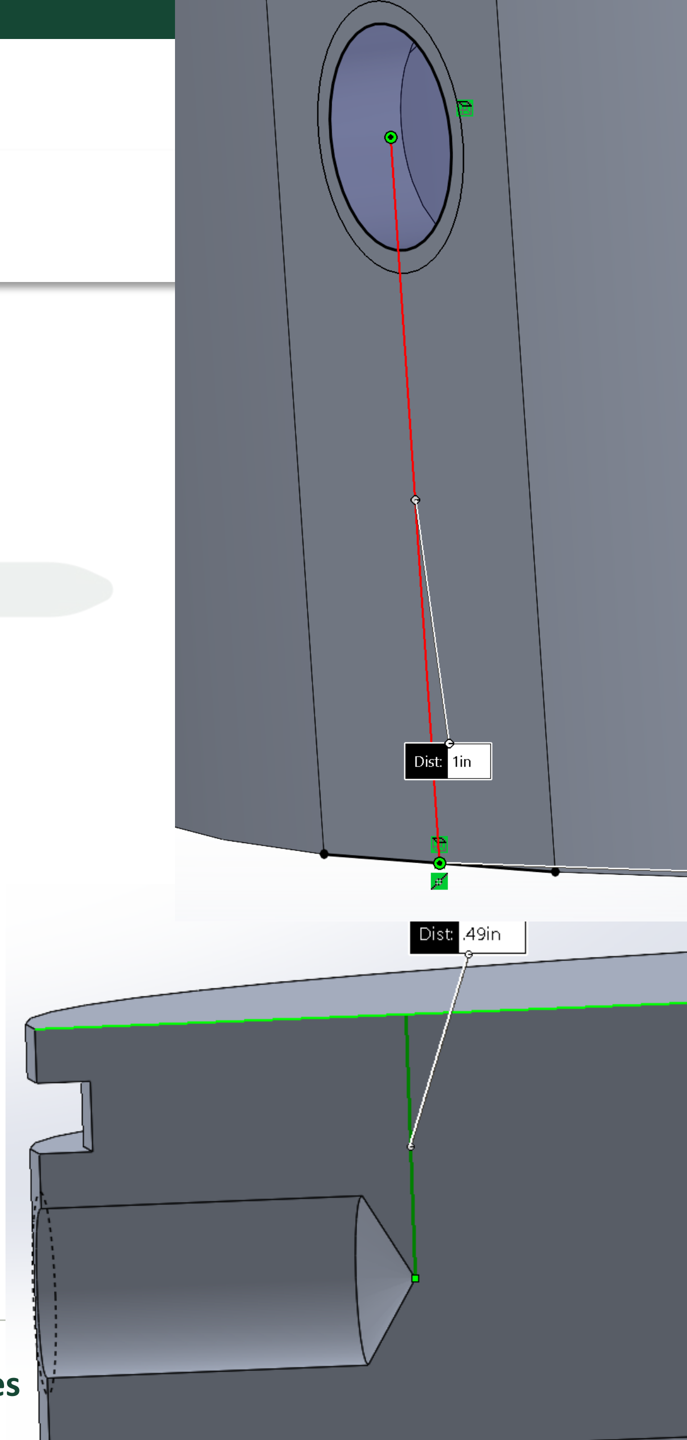


Fig 2.13 Bulkhead Bolt Distances

BULKHEADS

O-Ring

Series 2-255 O-Rings

Material: Viton®

Sizing:

- OD > 5.75in
- ID < 5.75in

Fractional(in)	Actual(in)	Gland Dimension(in)
OD: 5 7/8	OD: 5.887	Depth: .115
ID: 5 5/8	ID: 5.609	Width: .196
Width: 1/8	Width: .139	

TANKS REQUIREMENTS

Design Criteria

RBS	Requirement	Rationale	Verification
1	Design OX tank for 750 psi MEOP (1500 psi for FS 2) Fuel tank for 100 psi MEOP (200 psi for FS 2) GN2 tank for 100 psi MEOP (200 psi for FS 2). This means that the bulkhead will also have to be rated to these pressure with a factor safety of 2	This is to ensure that the pressure vessel will be able to withstand pressures than may result from unexpected temperature fluctuations which would allow for higher-than-normal pressures.	SolidWorks FEA, Hand Calculations, and pressure vessel testing
2	Sized to a 10 seconds of burn time	Gives us a basis for how much fuel and OX we need to pressurize too in order to reach 10 seconds.	
3	Static Vent in Ox Tank (Unknown Hole Size)	Prevents pressure buildup during filling and to provide a constant, controlled way to release excess pressure	
4	Tank Lengths: OX 14.5", GN2 3.6", Fuel 15.16"	Lengths used to allow for enough fuel with pressures rated for the tanks.	

CPSS

TANK CAD

OX/Air/Fuel

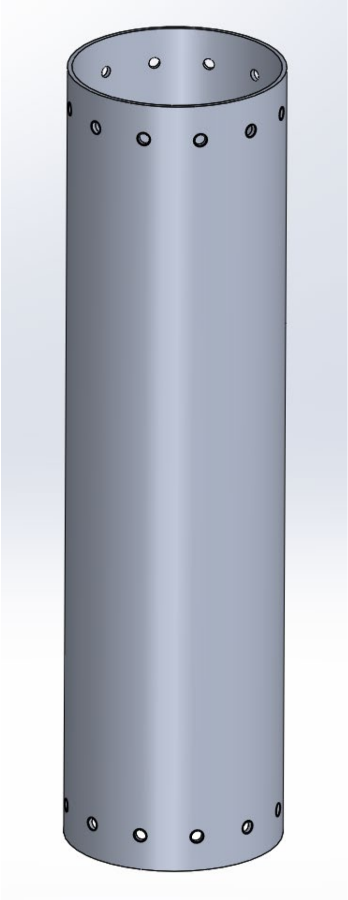


Fig 2.14 OX Tank

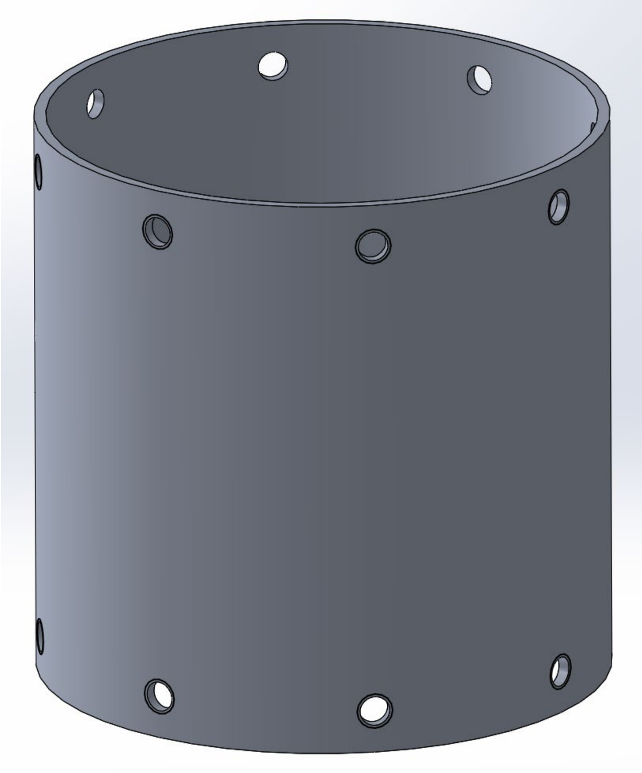


Fig 2.15 GN2 Tank

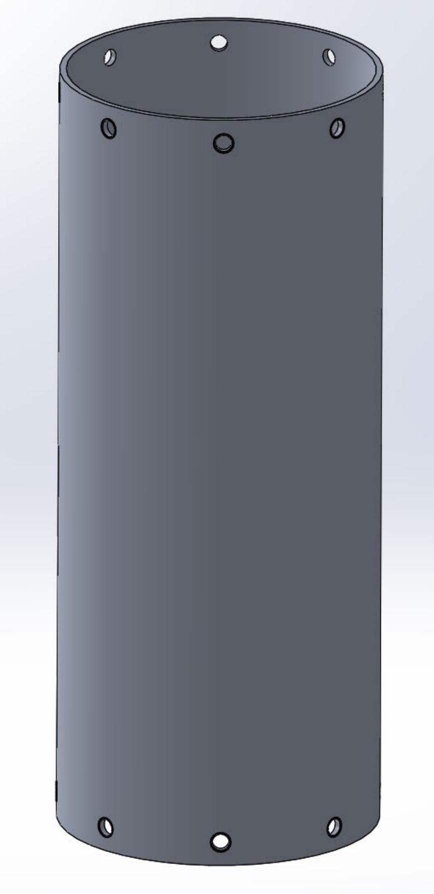


Fig 2.16 Fuel Tank

$$\sigma_h = \frac{PD}{2t} = \frac{1500 * 6}{2 * 0.125} = 36000 \text{ psi}$$

$$\sigma_{yield} = 40000 \text{ psi}$$

Lengths:
OX Tank: 22.5in
GN2 Tank: 6in
Fuel Tank: 14.5in

DOWN PIPE CAD

OX to Manifold

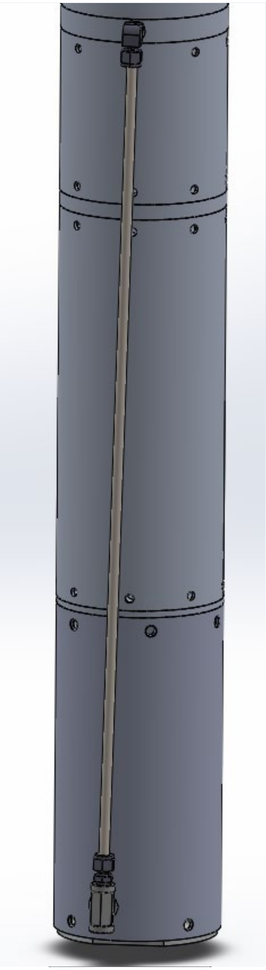


Fig 2.17 Downcomer

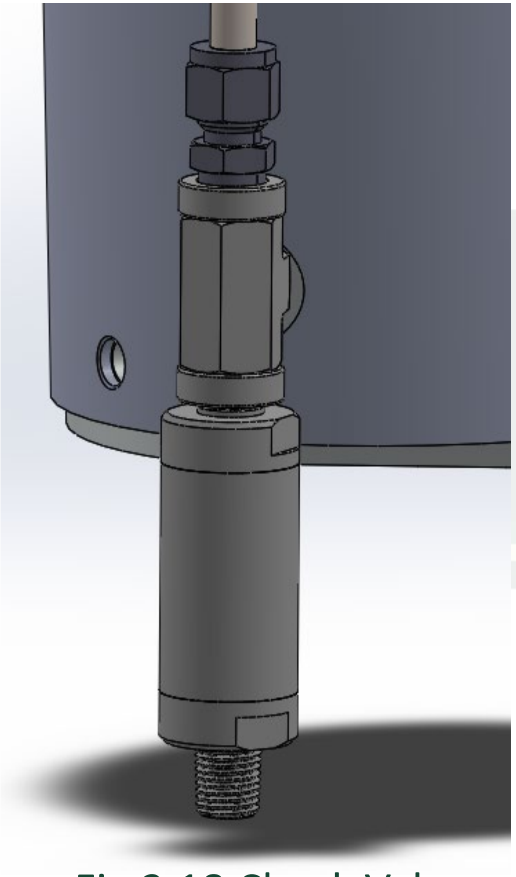


Fig 2.18 Check Valve

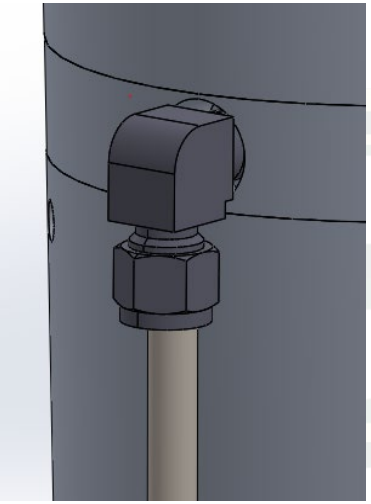


Fig 2.19 Downcomer Fitting

OX Down Pipe:

Pipe Material: Aluminum Rated for 3200psi

Length: 29.5in

Fittings: ¼ NPT T Male and 2 Female

¼ NPT Female to Swage 3/8 Male Straight

¼ NPT Female to Swage 3/8 Male Elbow

¼ to ¼ NPT Check Valve: Rated for 3000psi

BULKHEAD AND TANK BOM

	Description	Part Number	Unit Price	Quantity	Subtotal	Taxes	Shipping	Total
1	6in OD 24in Length Stock	R36	$297.81	2	$570.62	$26.80	$16.20	$613.62
2	6in OD 5.875ID 35 in Length Tubing		$36.41	1	$96.89	$2.64	$10.51	$110.04
3	Bolts	92620A621	$16.15	2 packs (100)	$32.30	$0	$0	$N/A
4	O-Rings	9464K554	$7.62	4 packs (8)	$30.48	$4.55	$11.23	$78.56
							TOTAL:	**$802.22**

FLUIDS – VALVES AND INJECTOR

Presented by: Shiv Patel and Kevin Quintana

VALVE REQUIREMENTS

Design Criteria

- The Injector Valve shall prevent the flow of fluid during Closed state
- The Injector Valve shall allow for the flow of fluid during Open State
- The Plunger must remain in the system for the duration of the vehicle's flight
- Line cutters shall be triggered and allow the Plunger to slide

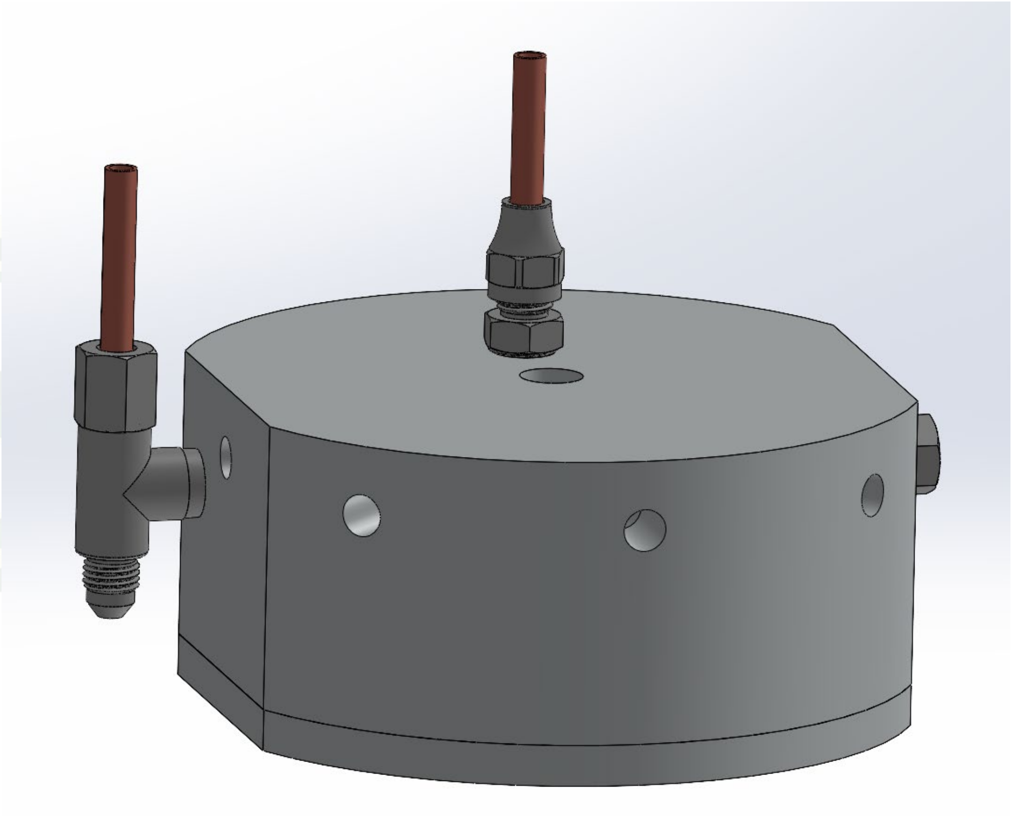


Fig. 3.0

INJECTOR VALVES

Isometric + Cross-sections Views

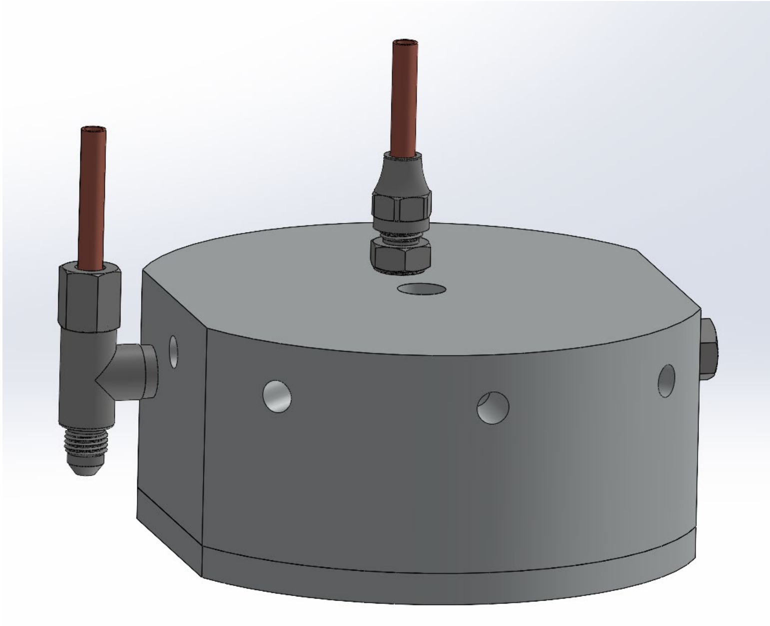


Fig. 3.1

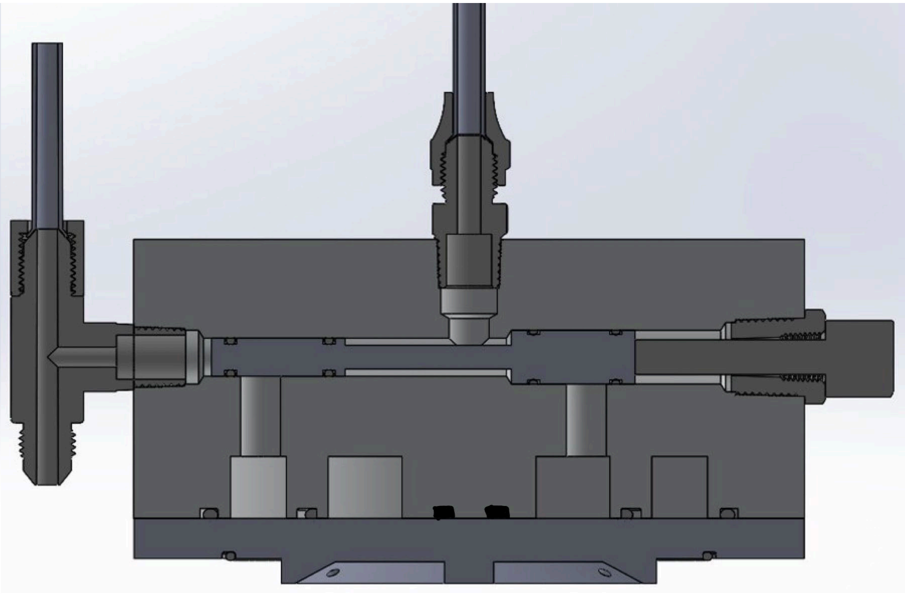


Fig. 3.2a

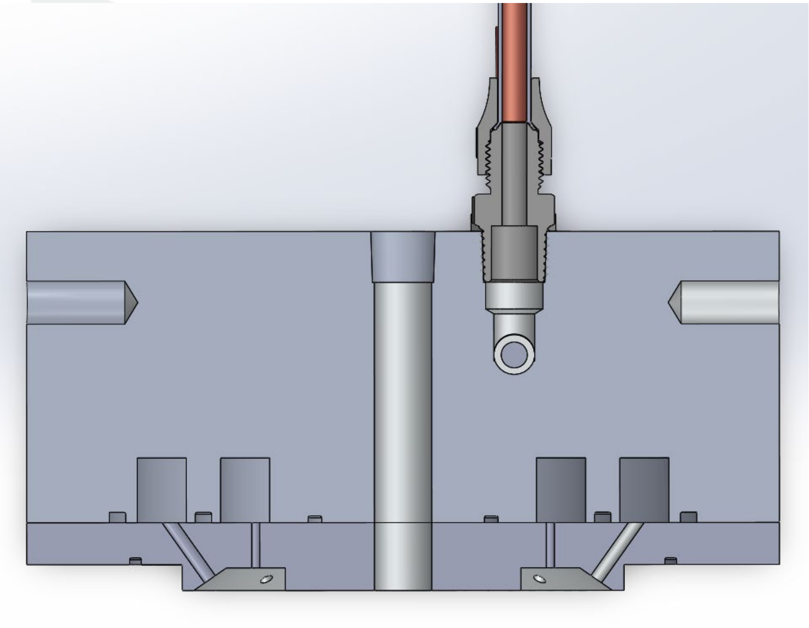


Fig. 3.2b

VALVES

Injector Valves + Manifold

- Line cutters trigger mechanical transition from Closed to Open State
- Reducer in place to prevent Plunger from falling off during flight
- Igniter is in the center, Inlet and Exit ports are offset 0.85" from center
- 5.75" OD, 2.25" Tall, ¼" NPT Ox and Fuel Inlets, Deburred Exit Holes, 6061 Aluminum

Closed State
(no fluid flow past Plunger)

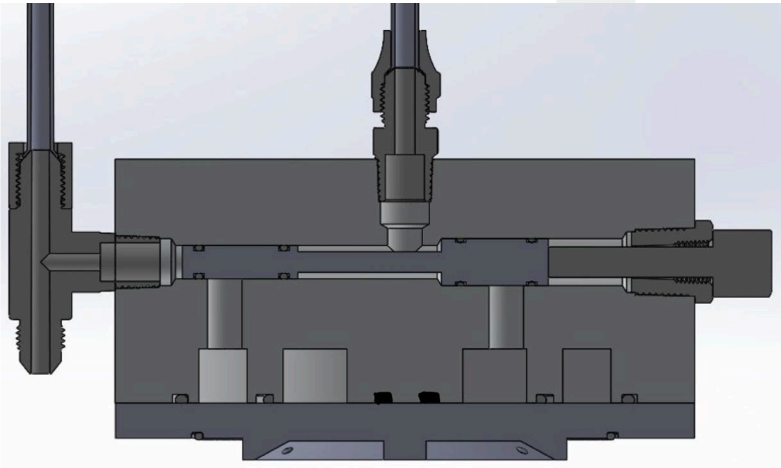


Fig. 3.3

Open State

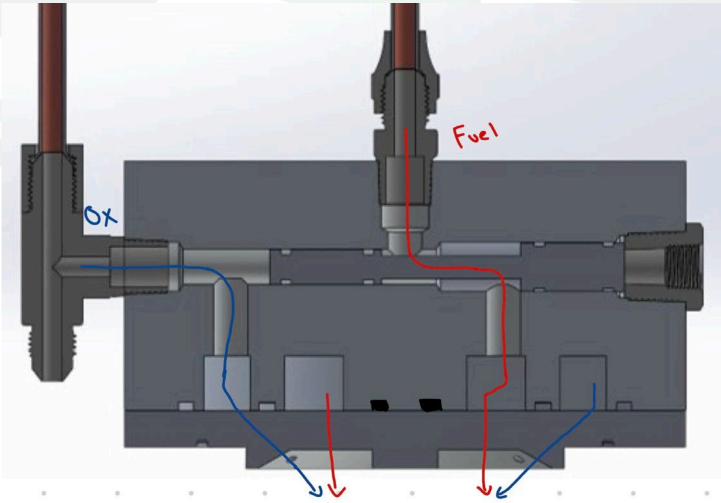


Fig. 3.4

Fig. 3.5: Line Cutters

INJECTOR MANIFOLD

FEA Simulations

- Very little deformation is observed

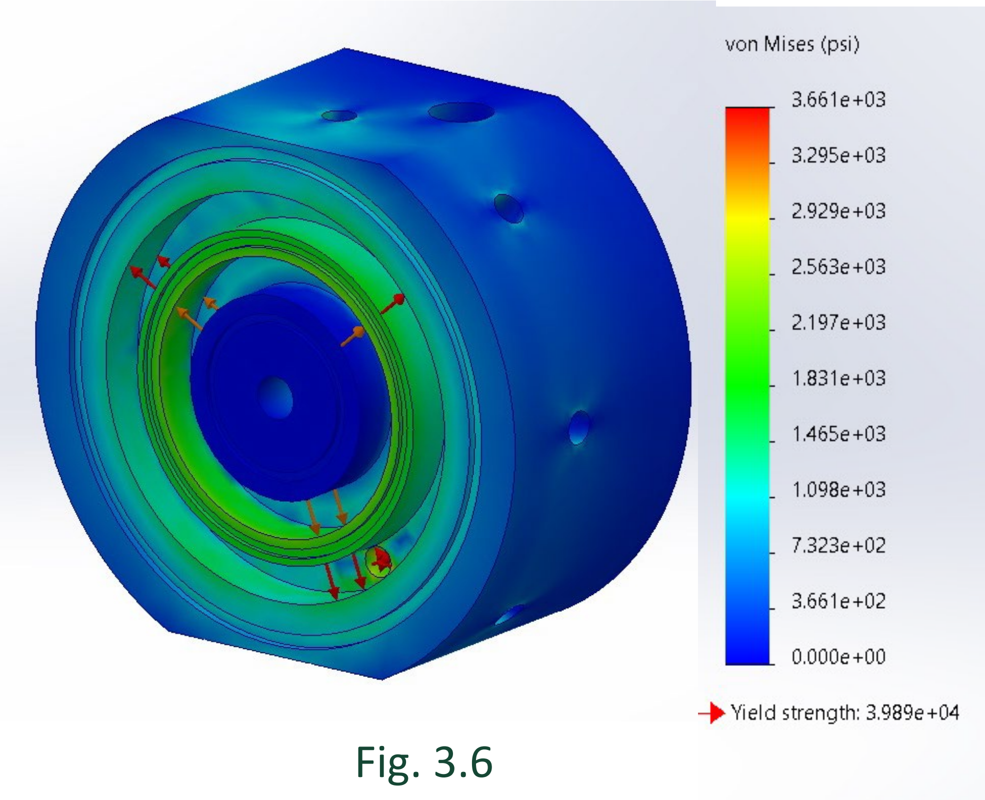


Fig. 3.6

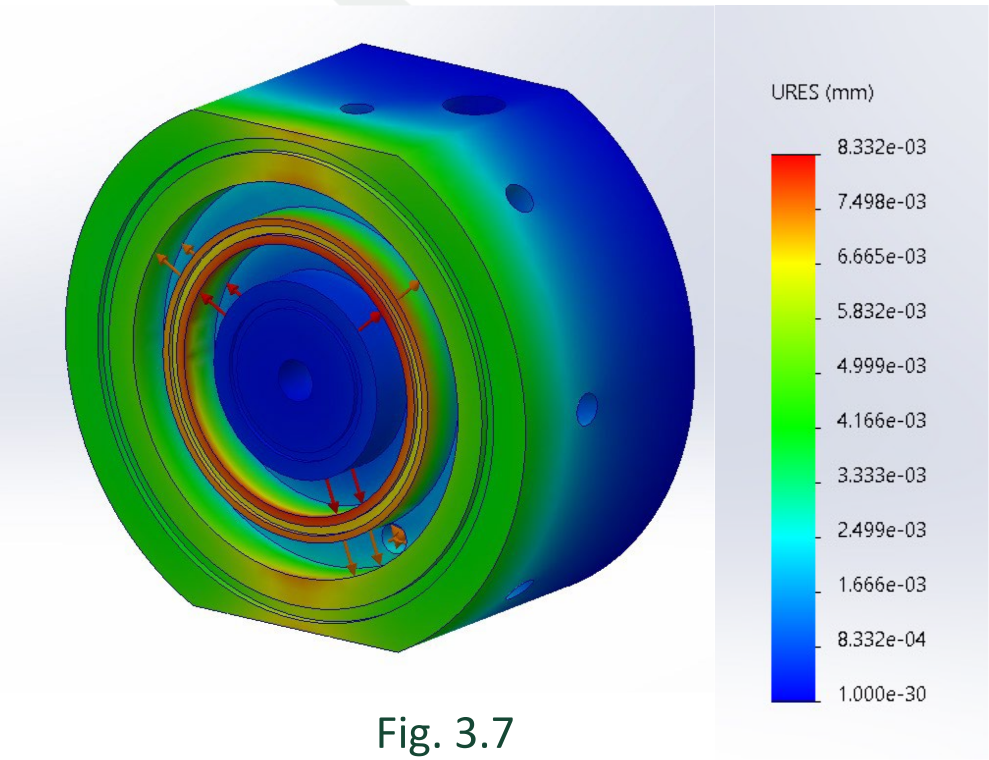


Fig. 3.7

VALVES BOM

	Description	Part Number	Supplier Link	Unit Price	Quantity	Subtotal	Taxes	Shipping	Total
1	Plunger: ½" dia. x 3.25" long Aluminum Stock	N/A	Midwest Steel and Aluminum	$9.40	1	$9.41	$	$19.88	$29.28
2	Manifold & Injector: 5.75" dia. x 3-1/4" long Aluminum Stock	N/A	Midwest Steel and Aluminum	$143.48	1	$143.48	$	$24	$167.48
3	O rings	TBD	McMasterr Carr	$ TBD	TBD	$	$	$	$
4	3/8"-16 Thread, 1-3/4" Long Aluminum Hex Head Screw	93306A913	McMaster Carr	$10.05	1	$10.05	$	TBD	$10.05
5	3/8 Male x 1/8 Female NPT Bushing (Reducer)	4464K641	McMaster Carr	$7.12	1	$7.12	$	TBD	$7.12
6	45 Degree Flare Nut	TBD			1				
7	45 Degree Flare to ¼" NPT Fitting (Fuel)	TBD			1				
8	Line Cutters	TBD			1				
								TOTAL:	$213.77

CPSS

NEXT STEPS

- Begin manufacturing to validate Two Phase Flow results
- Testing Closed and Open State sealing and transitions
- Validating Valve Timings to ensure we have an Ox Lead (to prevent a hard start)

PROPULSION

Presented by: Brandon Muck

ENGINE DESIGN

Nozzle Design Parameters

- **Engine Requirements**
  - Burn Time: 10 s
  - Max Thrust: 400 lbf
  - Chamber Pressure: 350 psi
  - Propellant: N2O (Oxidizer) / Ethanol (Fuel)
  - O/F Ratio: 2.6 : 1
    - Fuel Rich
  - Mass Flow: 0.94 kg/s
    - Oxidizer: 0.68 kg/s
    - Fuel: 0.26 kg/s
  - Ambient Pressure: Δ0.13 atm
    - (0.93 to 0.80) atm
  - Exit Pressure: 5.42 psi
  - Pressure Thrust: -43 lbf

Sizing (Off The Shelf):

- Expansion Ratio: 7.49
- Contraction Ratio: 11.39
  - Chamber Diameter: 3.375"
  - Throat Diameter: 1.000"
  - Exit Diameter: 2.737"
  - Converging Half Angle: 60°
  - Diverging Half Angle" 15°
- L*: 1.42 m
- C*: 1360 m/s
- Nozzle Type: Conical

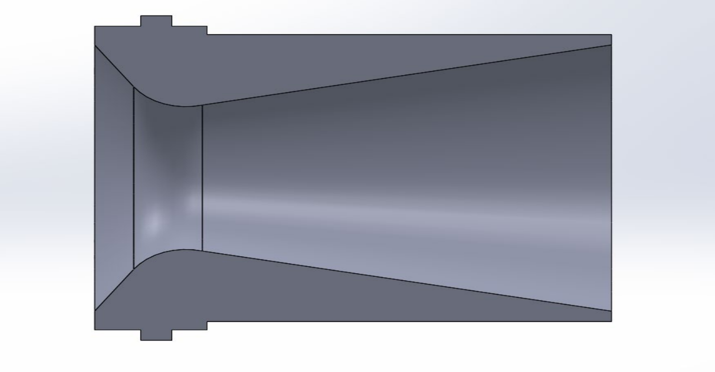


Fig 4.3: Nozzle Geometry

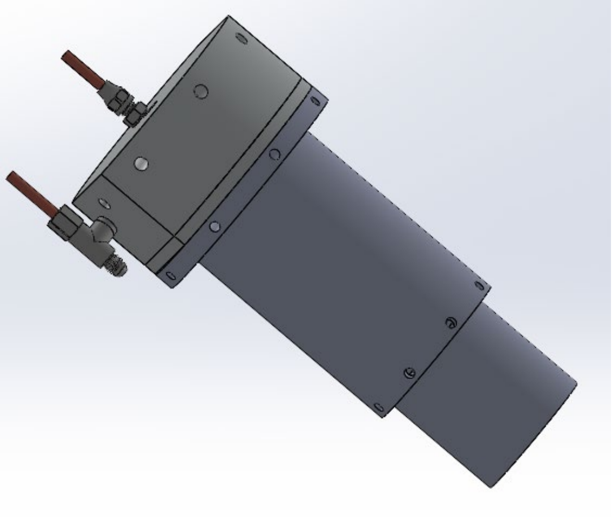


Fig 4.4: Engine-Injector Assembly

ENGINE DESIGN

Nozzle Choice

Stratum Engine Design:

- Commercial Single-Throat nozzle
  - Supplied by RCS Rocket Motor Components
  - Molded Glass Phenolic Nozzle
  - Ablatively Cooled
- Used in previous year in static testing (300lbf)
  - Tested in cold flows & 8 hot fires
  - Proven thermal performance
  - Pre-sized Ablative Lining
    - Store Bought

Fig 4.1: Stratum Engine Nozzle

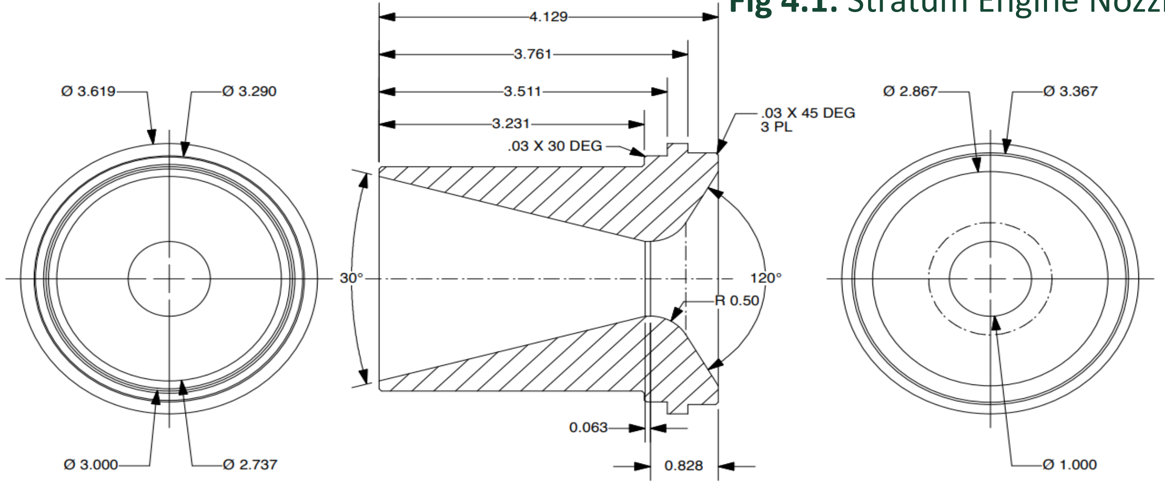


Fig 4.2: RCS Engine Drawing

THRUST CURVE

Halfcat Sim v1.3.8 and Thrust Curve Tool

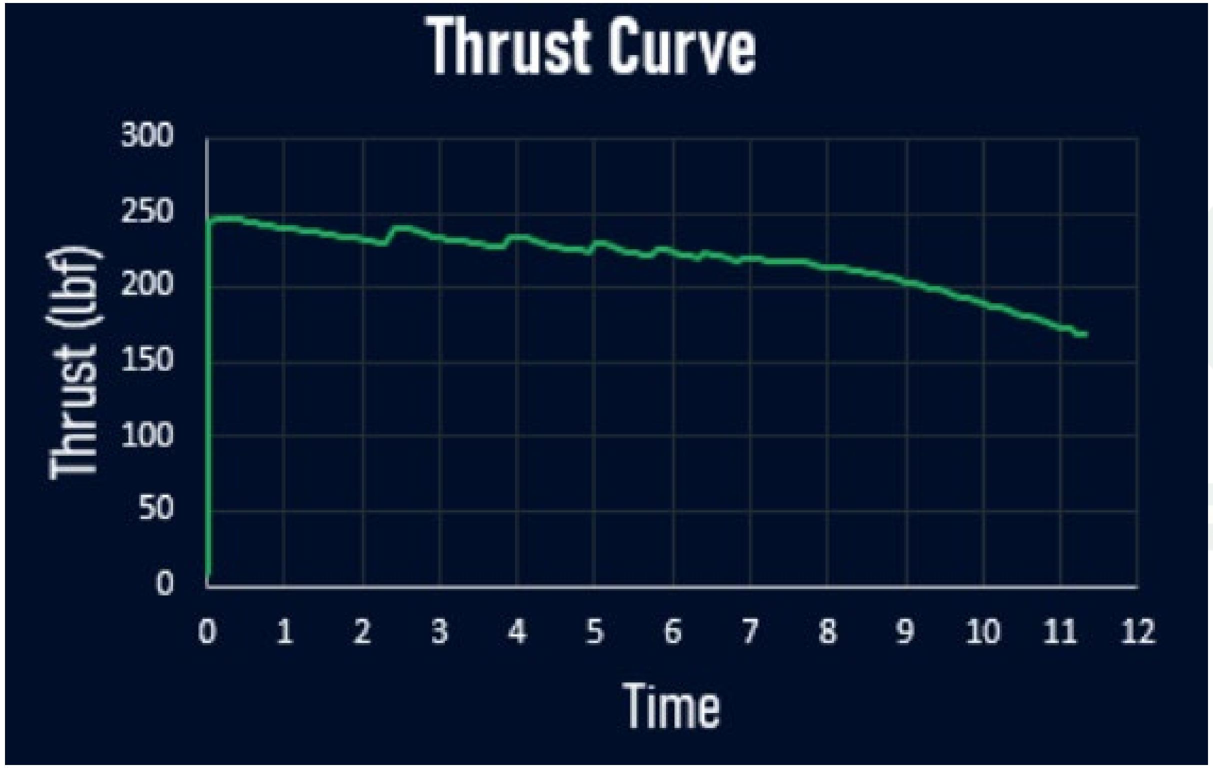


Fig 1.3 Current Stratum Geometry– HalfCat Sim

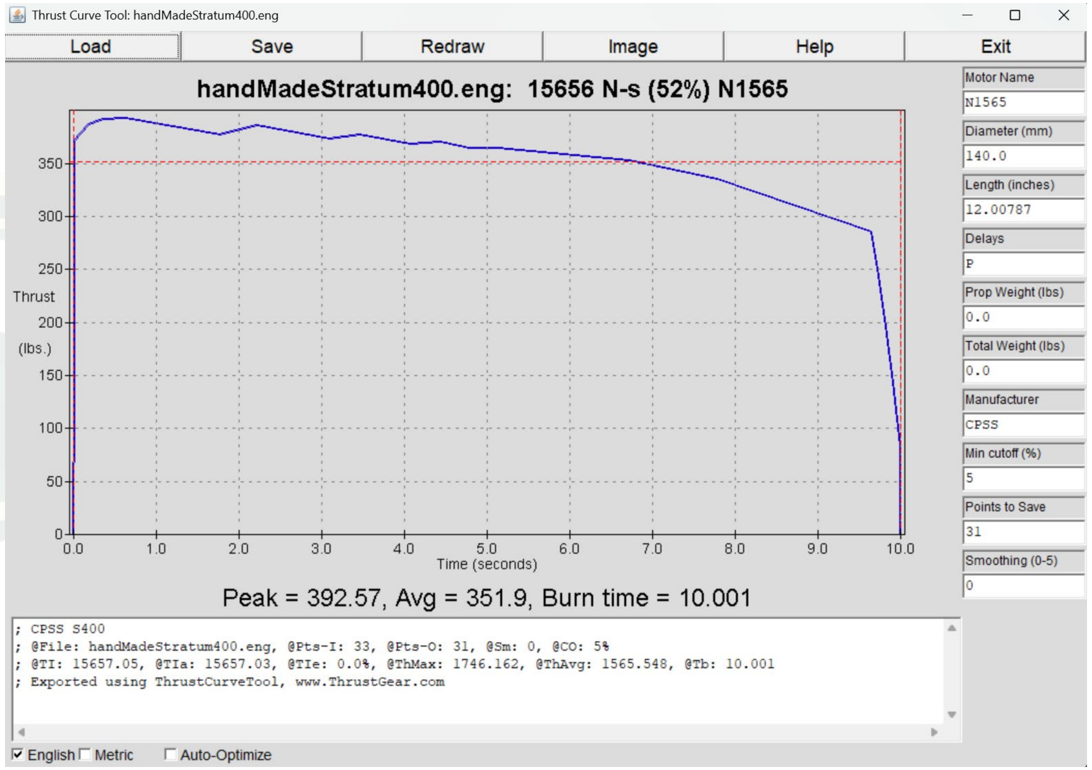


Fig 1.4 400 lbf

ENGINE DESIGN

Manufacturing Plan

- Chamber Sleeve
  - Turn / Bore Stock to Sleeve Dimensions
    - Upper
      - 5.75" OD / 3.61" ID
    - Lower
      - 4" OD / 3.61" ID
  - Upper Retaining Ring
    - Bore x8 .25" Radial Holes
      - 0.5" Depth
      - Thread with ¼"-20 tap
- Lower Retaining Ring
  - Turn / Bore Stock to 3.61" OD / 3" ID
  - Bore x8 .25" Radial Holes
    - .25" depth
    - Thread with ¼"-20 tap

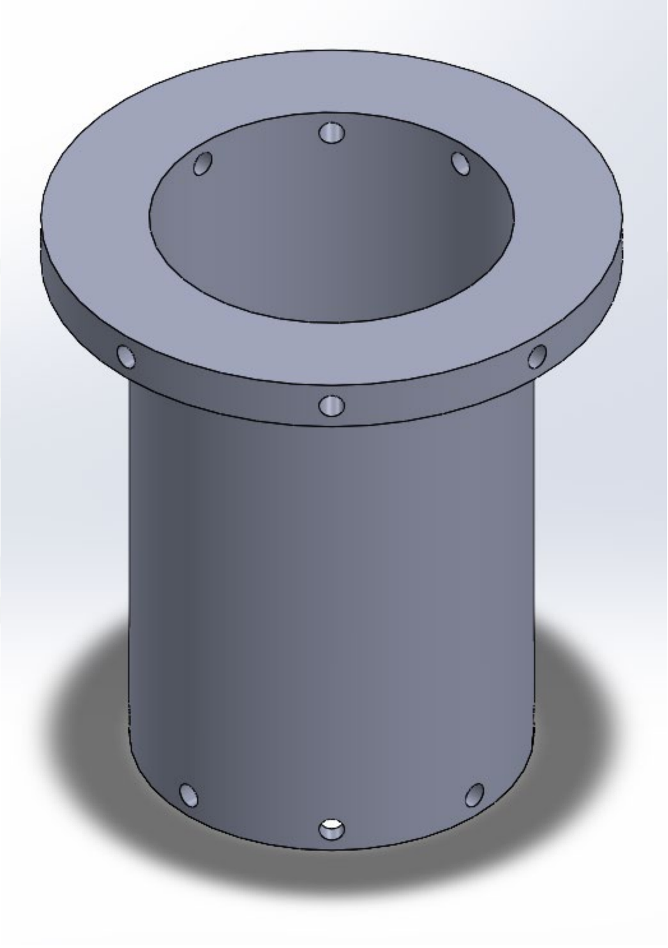


Fig 4.6: Chamber Sleeve

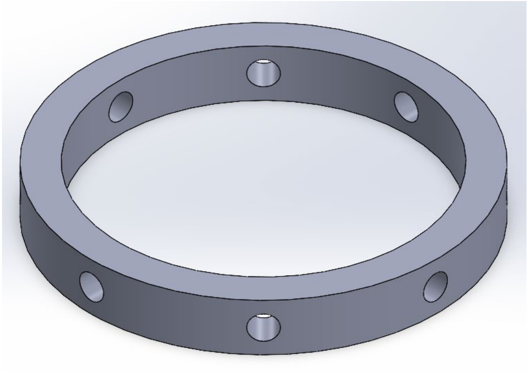


Fig 4.7: Retaining Ring

ENGINE DESIGN

Assembly Plan

- Injector Integration
    - Chamber Sleeve
        - Upper Retaining Ring
            - 5.75 OD
            - ¼"-20 High Strength Hex Screws
                - X8 Radially Bolted to Body Shell
- Bottom Retaining Ring
    - Material for lip of nozzle to sit on
    - ¼"-20 High Strength Hex Screws
        - X8 Radially Bolted to Chamber Sleeve
- Nozzle / Ablative
    - Ablative sits on top of nozzle lip
    - JB Weld RTV Silicon applied on OD of sleeve

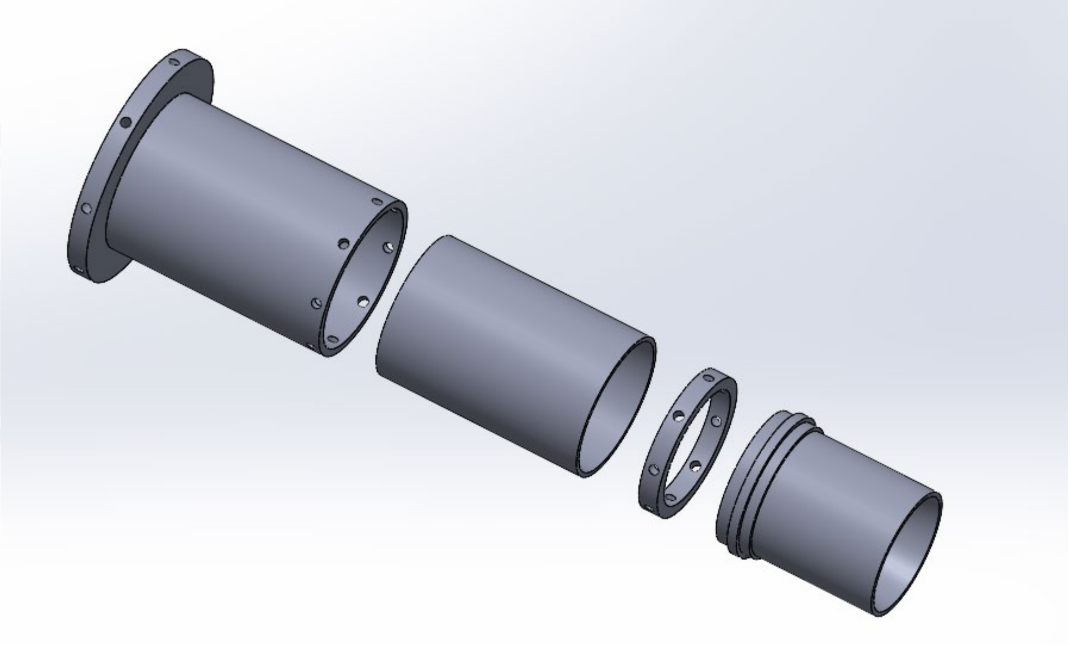


Fig 4.5: Exploded Engine Assembly

ENGINE DESIGN

Force Calculations

Component	Criticality	Analysis Type	Yield FoS	Ultimate FoS	Margin of Safety
Aluminum sleeve	1	Hand Calcs	1.8	2	4.710926346
Flange for Nozzle	1	SOLIDWORKS FEA	1.8	2	12.37882133

Bolts Upper Retaining Ring

Component	Failure Mode	Criticality	Analysis Type	Yield FoS	Ultimate FoS	Margin of Safety
Upper Retaining Ring Bolts	Bolt Shear	1	Hand Calcs	1.8	2	1.291238318
	Tear Out	1	Hand Calcs	1.8	2	1.539045534
	Bearing	1	Hand Calcs	1.8	2	2.872884996

Bolts Lower Retaining Ring

Component	Failure Mode	Criticality	Analysis Type	Yield FoS	Ultimate FoS	Margin of Safety
Lower Retaining Ring Bolts	Bolt Shear	1	Hand Calcs	1.8	2	2.845074663
	Tear Out	1	Hand Calcs	1.8	2	0.695172514
	Bearing	1	Hand Calcs	1.8	2	2.59531072

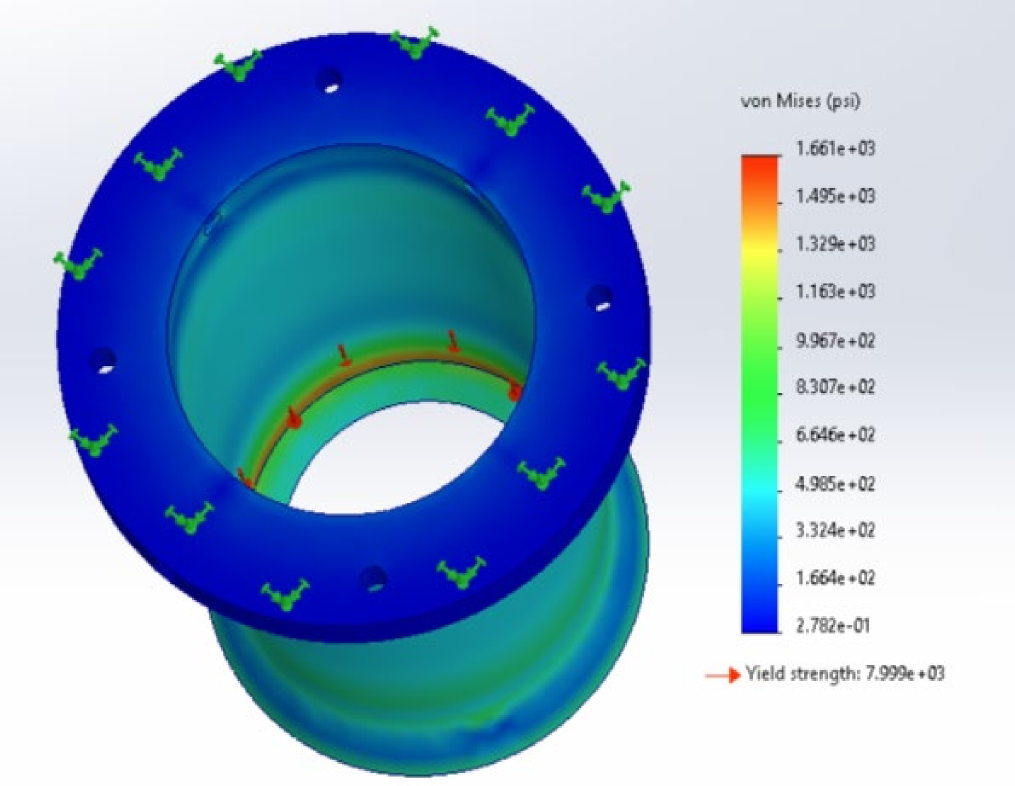


Fig 4.8: Stress Analysis of Bottom Retaining Ring

ENGINE BOM

	Description	Part Number	Unit Price (Estimates)	Quantity	Subtotal	Taxes	Shipping	Total
1	RCS 98mm Nozzle	01880	$89.99	1	$89.99			$107.09
2	RCS 13" 98mm Phenolic Motor Liner	03040-2	$19.99	1	$19.99	+ 9%	+ 10%	$23.80
3	C-Class Motor	NA	$14.00	1	$14			$16.55
4	JB Weld Hi-Tem RTV Silicone 11oz	NA	$9.40	1	$9.40	+ 9%	+ 10%	$11.19
5	5.75" dia x 6.25" long 6061 Aluminum Round Bar	NA	$252.31	1	$52.91	+ 9%	+ 10%	$300.00
6	3.61" OD, 3" ID 6061 Aluminum Retaining Ring	NA	$18.80	1	$18.80	+ 9%	+ 10%	$22.37
7	¼-20 High Strength Hex Bolts	NA	$12.44	1	$12.44	+9%	+10%	$14.40
							TOTAL:	**$498.46**

GROUND SYSTEM EQUIPMENT

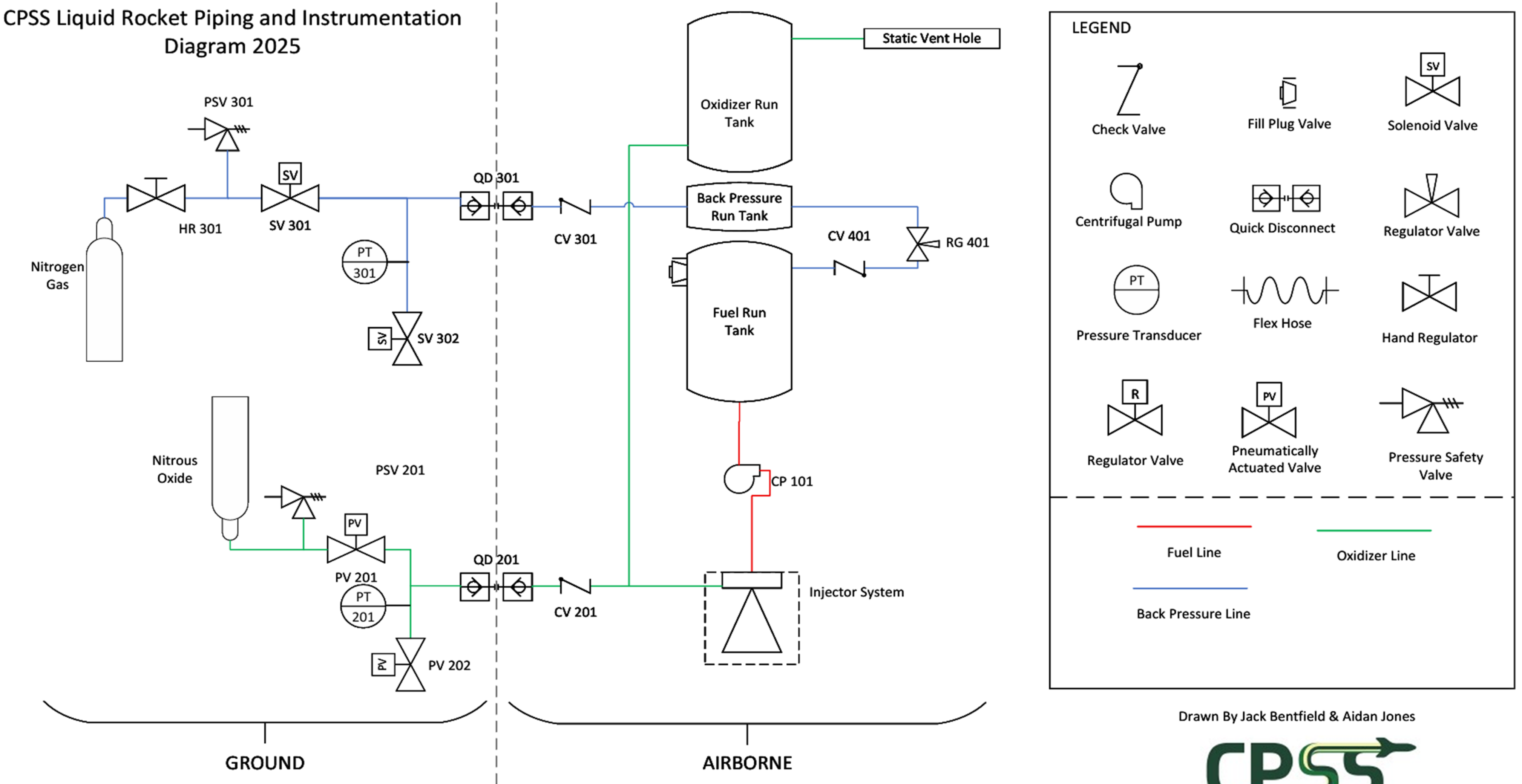
Presented by: Arjan Reyes

OVERALL SYSTEM

- Communication between components
  - Onboard computers (TOM, engine controller)
  - GSE controller
  - Main computer
  - Control Box
- Safety
  - Fill, pressurize, dump, and launch system efficiently
  - Ability to abort launch without sacrificing entire rocket
  - Fill station will fail into a safe mode if control or power are lost
- R&D Implementation
  - Utilize TOM in new ways

Content: more context behind what separation mechanism is used for (specify for valves, etc.)

FLUID SYSTEMS/P&ID



SEPARATION MECHANISM Design

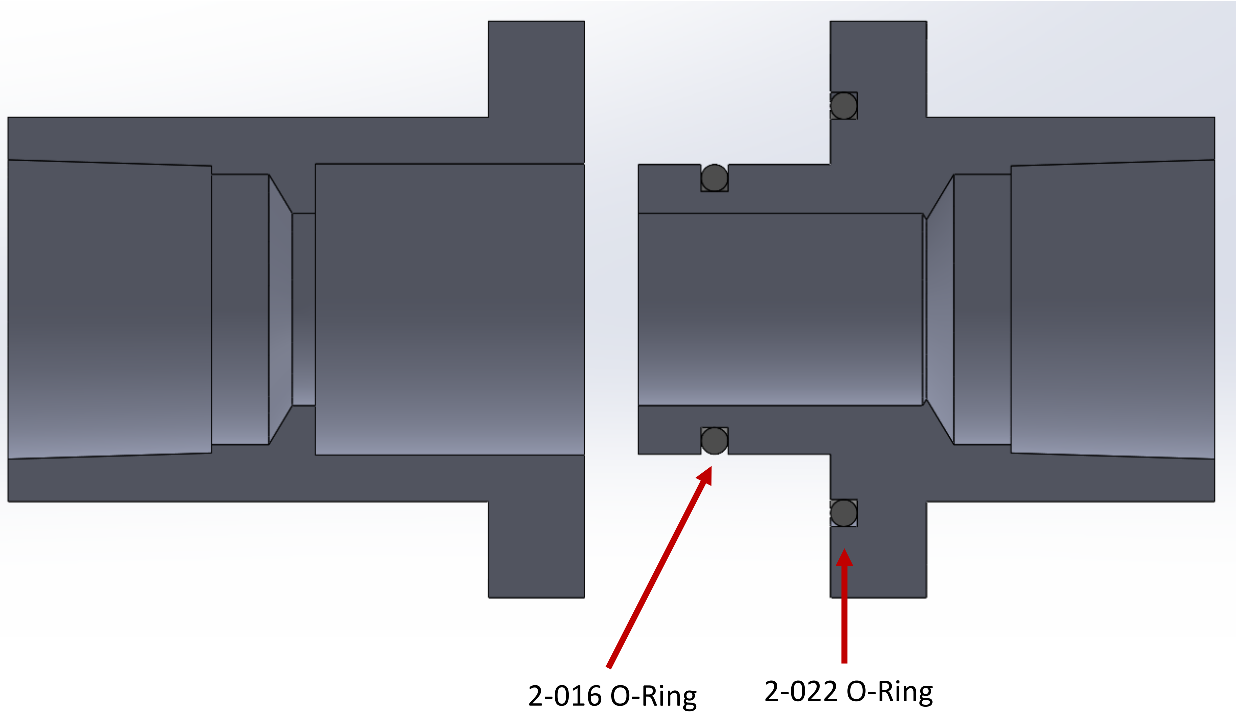


Fig 5.1 Quick Disconnect with Plunger Mechanism

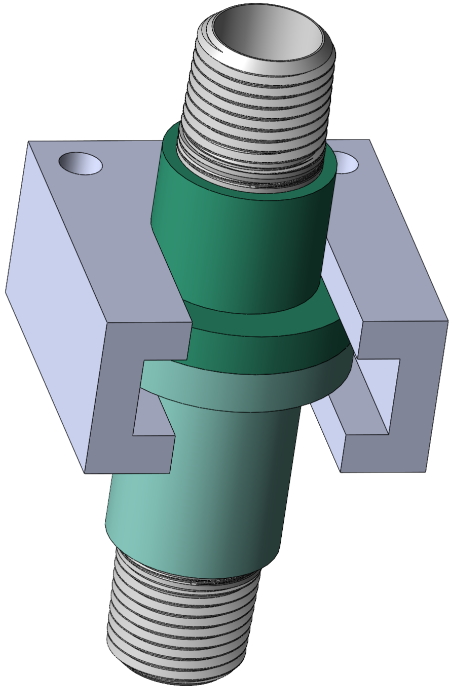


Fig 5.3a QD U-clip Connection

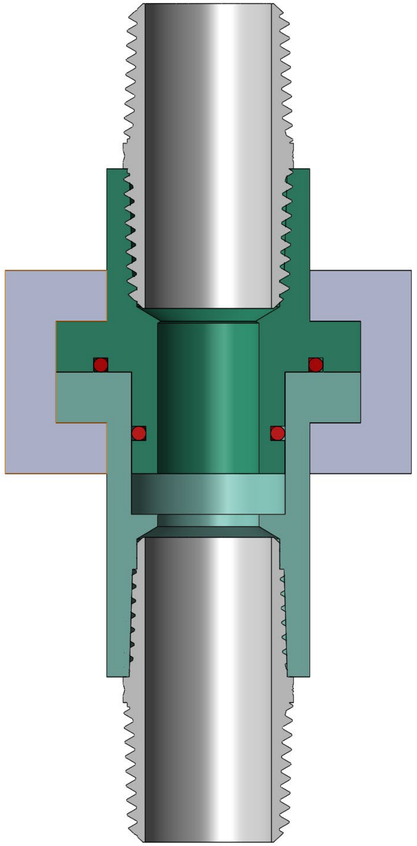
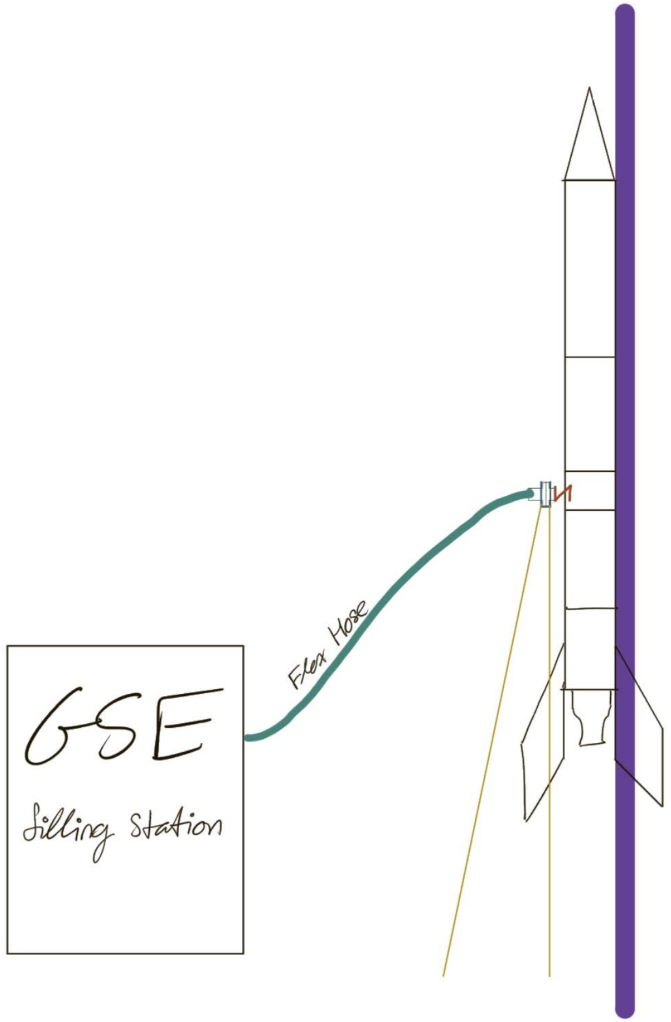
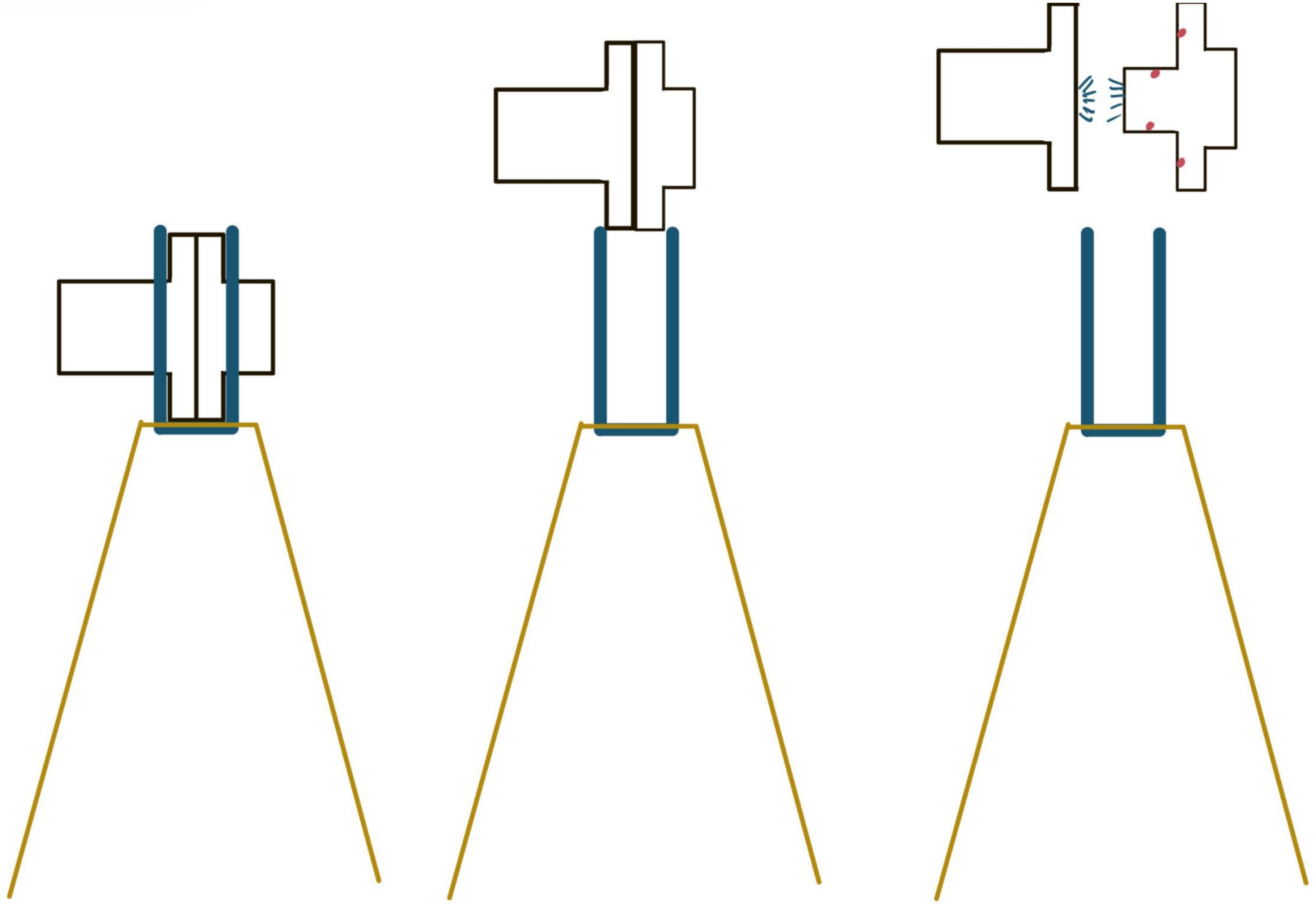


Fig 5.b Separation Mechanism Assembly

SEPARATION MECHANISM Diagram





GSE BOM

	Description	Part Number	Unit Price	Quantity	Subtotal	Link	Taxes	Shipping	Total
1	pneumatic valves	C26NRXC8SC	$264.00	2	$528.00	Assured Automation	+ 9%	+ 10%	$633.07
2	1500 psi Pressure Transducer		$79.00	2	$158.00	www.dataq.com	+ 9%	+ 10%	$189.44
3	1/4" 750-1500 PSI Relief Valve	SRV60-S-4T-S6	$147.82	2	$295.64	www.sprayerdepot.com	+ 9%	+ 10%	$354.47
4	316 Stainless Steel Check Valve	1874N15	$62.35	2	$124.70	www.mcmaster.com	+9%	+10%	$149.52
5	GN2 hand regulator	FHS4	$295.77	1	$295.77	www.ebay.com	+ 9%	+ 10%	$354.63
6	solenoid valves	JFHSV00022	$95.99	2	$191.98	ussolid.com	+ 9%	+ 10%	$230.18
7	3 way 2 position solenoid valves	3V210-08-24VDC	$24.65	2	$49.30	www.electricsolenoidvalves.com	+ 9%	+ 10%	$59.11
8	Polyurethane Tubing	5648K25	$16.25	11	$178.75	https://www.mcmaster.com/	+9%	+10%	$214.32
								TOTAL:	**$2,184.75**

GSE BOM

	Description	Part Number	Unit Price	Quantity	Subtotal	Link	Taxes	Shipping	Total
9	QD aluminum stock 1ft of 2" round	R32	$41.56	1	$41.56	www.metalsdepot.com	+ 9%	+ 10%	$49.83
10	Clip Stock 6" of 0.5"x2" aluminum flat	F4122	$10.68	1	$10.68	www.metalsdepot.com	+ 9%	+ 10%	$12.81
11	1/2" NPT male to male fittings		$11.99	1	$11.99	amazon.com	+ 9%	+ 10%	$14.38
12									
13									
14									
15									
16									

TOTAL: $77.01

BREAK

10 Minutes - Return at __:__

AERODYNAMICS

Presented by: Brayant Silva and Juan Godina

AERODYNAMICS

Nose Cone

- Shape: Conical
- Length: 12 in
- Inner Diameter: 6 in
- Wall Thickness: .2 in
- Neck length: 2 in

Manufacturing Method:

Wet layup using carbon fiber on mold

2D cutout for 3D shape

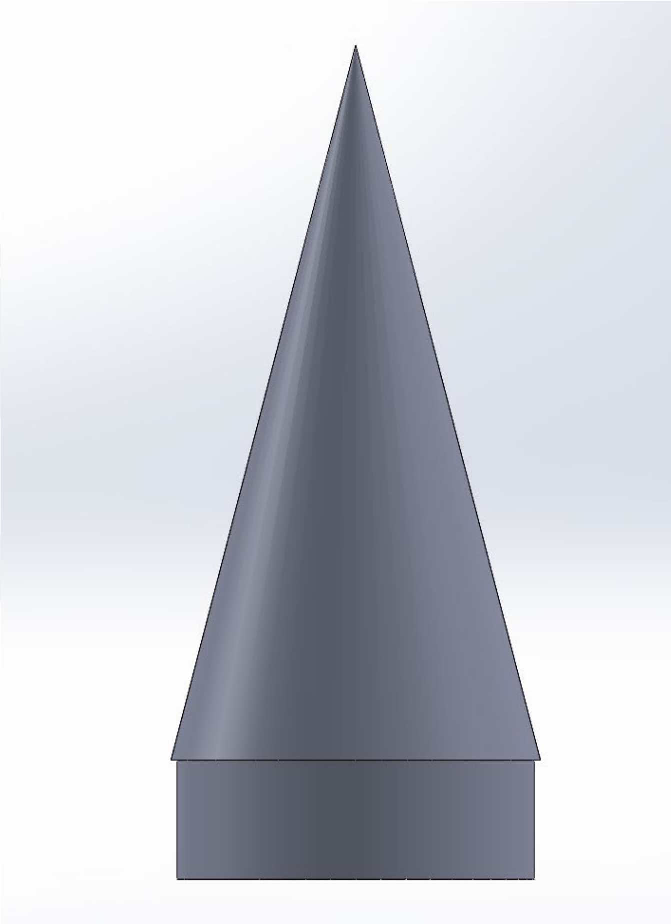


Fig 6.1 Nose Cone

AERODYNAMICS

Fins

- Root Chord: 8 in
- Tip Chord: 7 in
- Height: 5.5 in
- Thickness: 0.2 in
- Fin Flutter Safety Margin: Mach 1.7
- Manufacturing Method: prepreg layup and waterjet cut

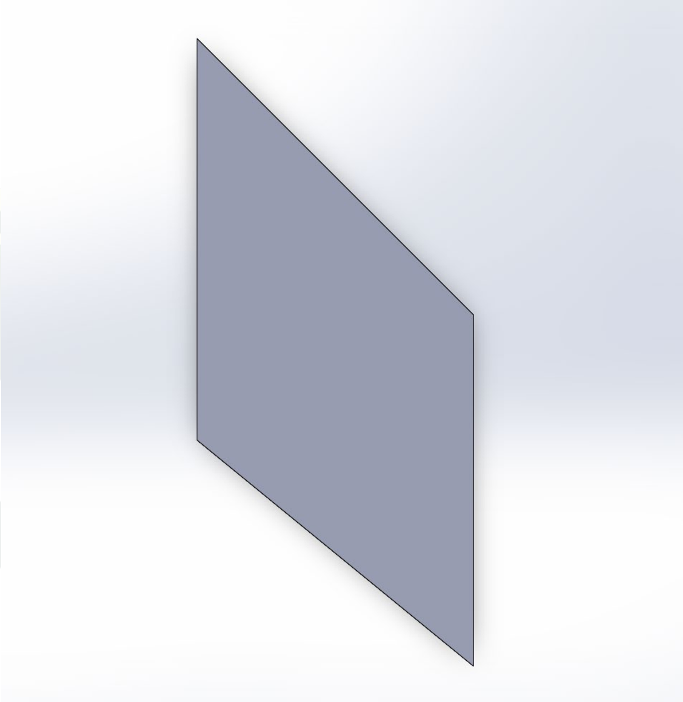


Fig 6.2 Fin

AERODYNAMICS

Fin Adapter

- Length:9.6 in
- Outer Diameter: 6.0 in
- Inner Diameter: 5.75 in
- Manufacturing Method: carbon fiber wet layup

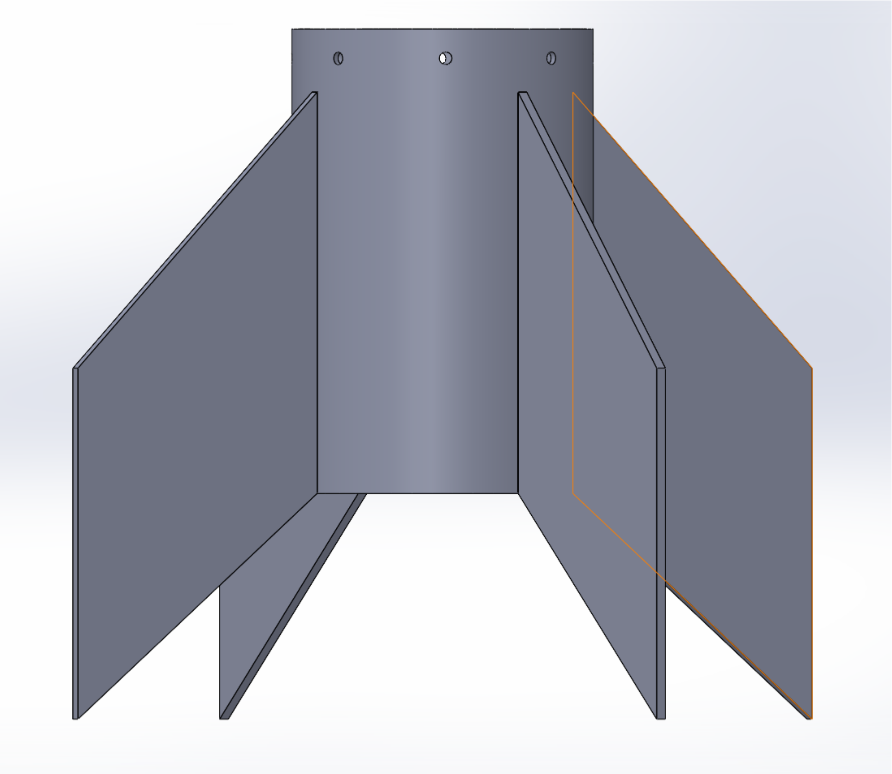


Fig 6.3 Fin Can

STAR-CCM+ CFD

- **Aerodynamic Analysis Goals**
  - Predict drag coefficient trends across the expected Mach range
  - Compare CFD-derived drag to OpenRocket and RASAero models
  - Quantify sensitivity of trajectory predictions to drag uncertainty

CFD MODELS

- **Flow & Solver Setup**
  - 3D Flow, Compressible RANS
  - Steady-state simulations
  - Ideal gas air model
  - Turbulence model: k-ω SST
- **Boundary Conditions**
  - Freestream Mach number prescribed
  - No-slip wall on rocket surface
- **Simulation Scope**
  - Mach sweep: M = 0.1 -0.8
  - Primary outputs: drag coefficients

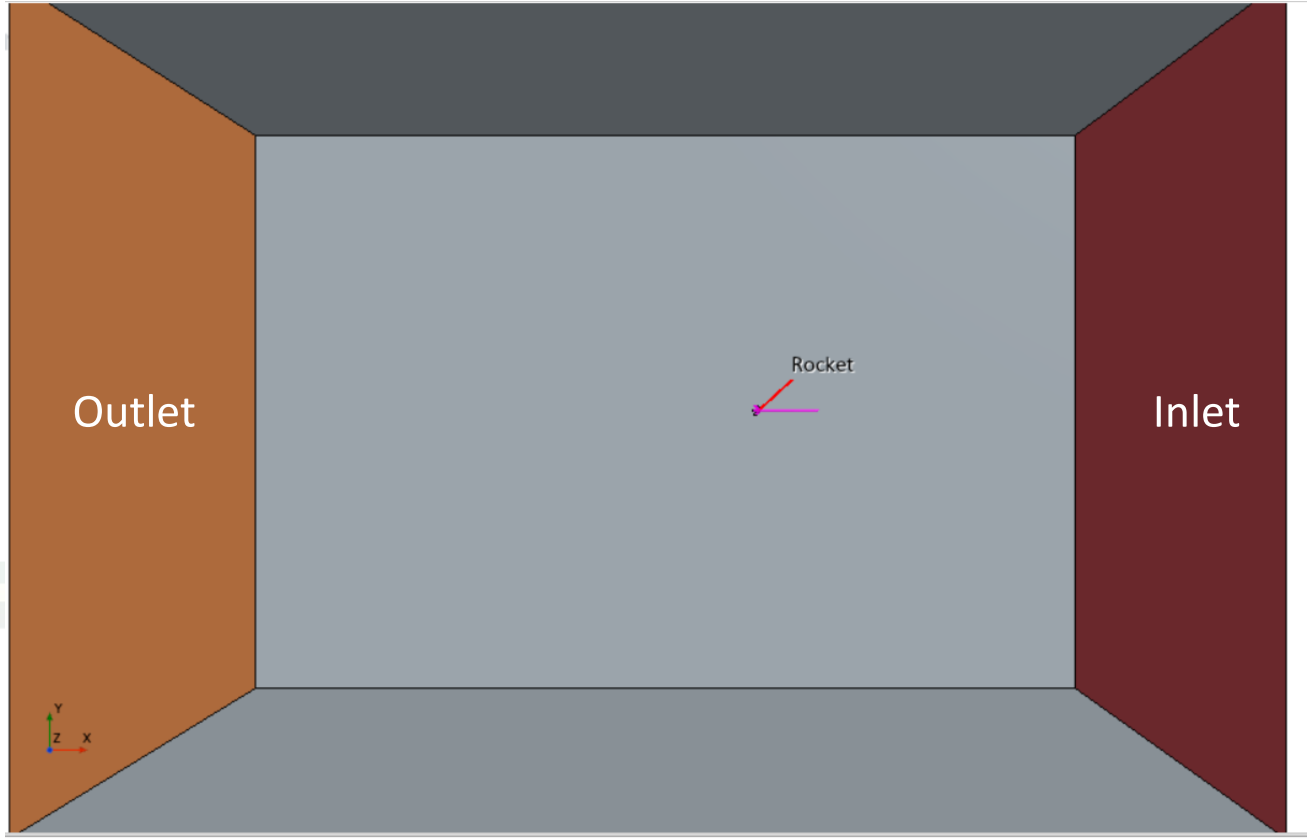


Fig 6.4 Flow Domain

CFD MESH

- **Mesh Parameters**
  - 3D Automated Polyhedral Mesh
  - Near-wall prism layers
- **Custom Controls**
  - Wake refinement downstream of rocket
  - Nose Cone Refinement
- **Grid Convergence**
  - Local refinement studies on wake and nose regions
  - Global size refinement to verify CD convergence

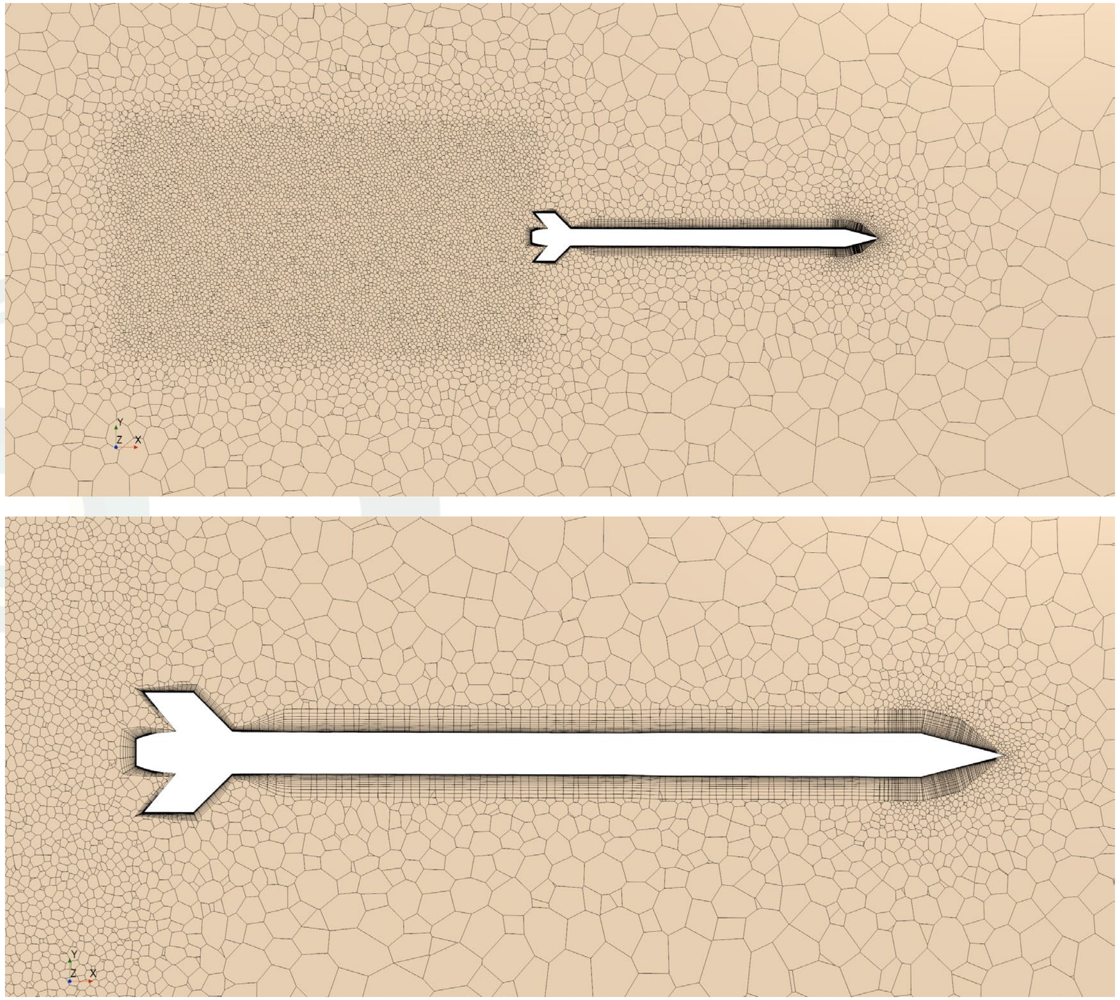


Fig 6.5 Rocket Mesh

CFD RESULTS

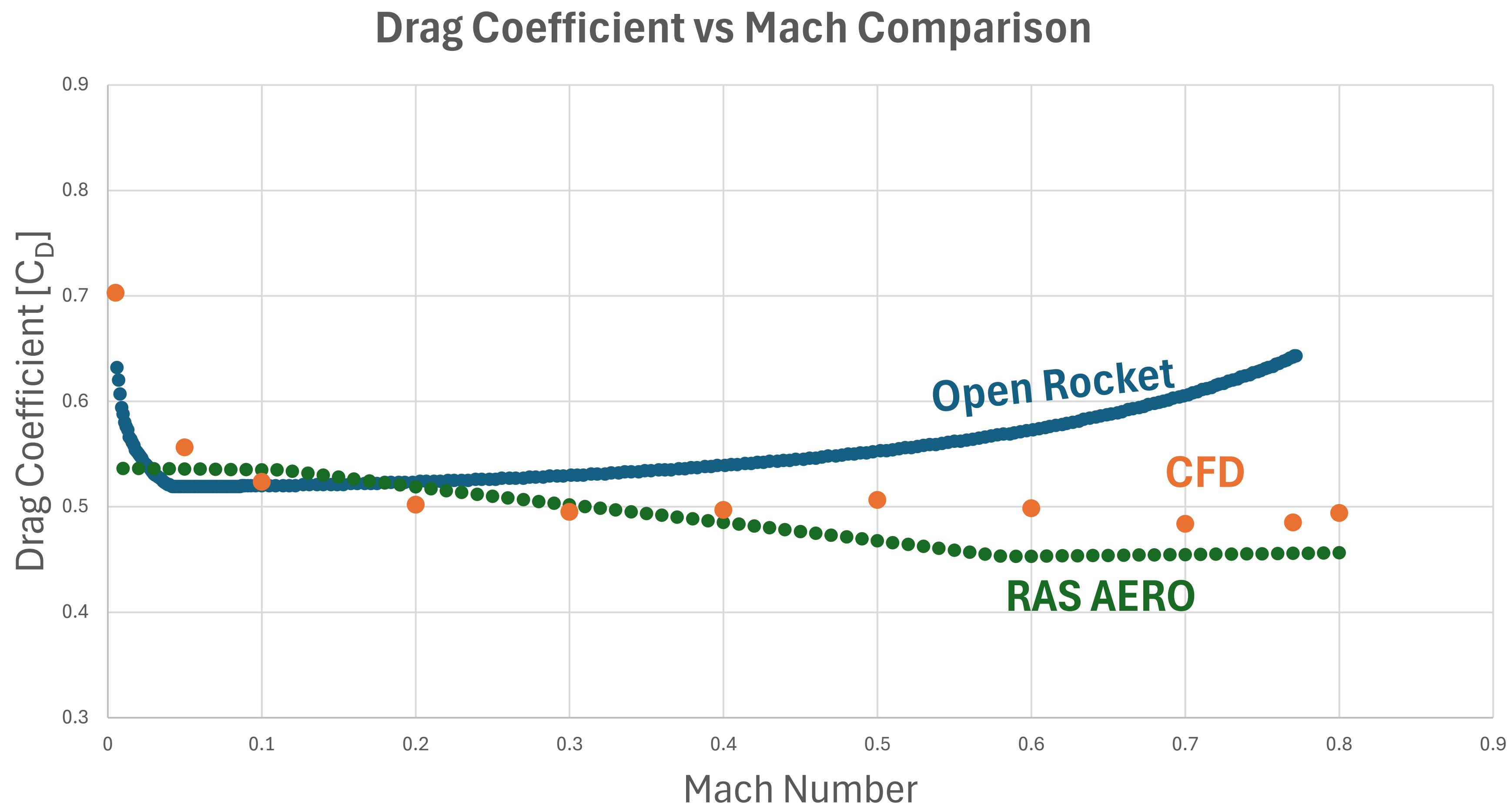


Fig 6.6 Drag Comparison

ALTITUDE SENSITIVITY

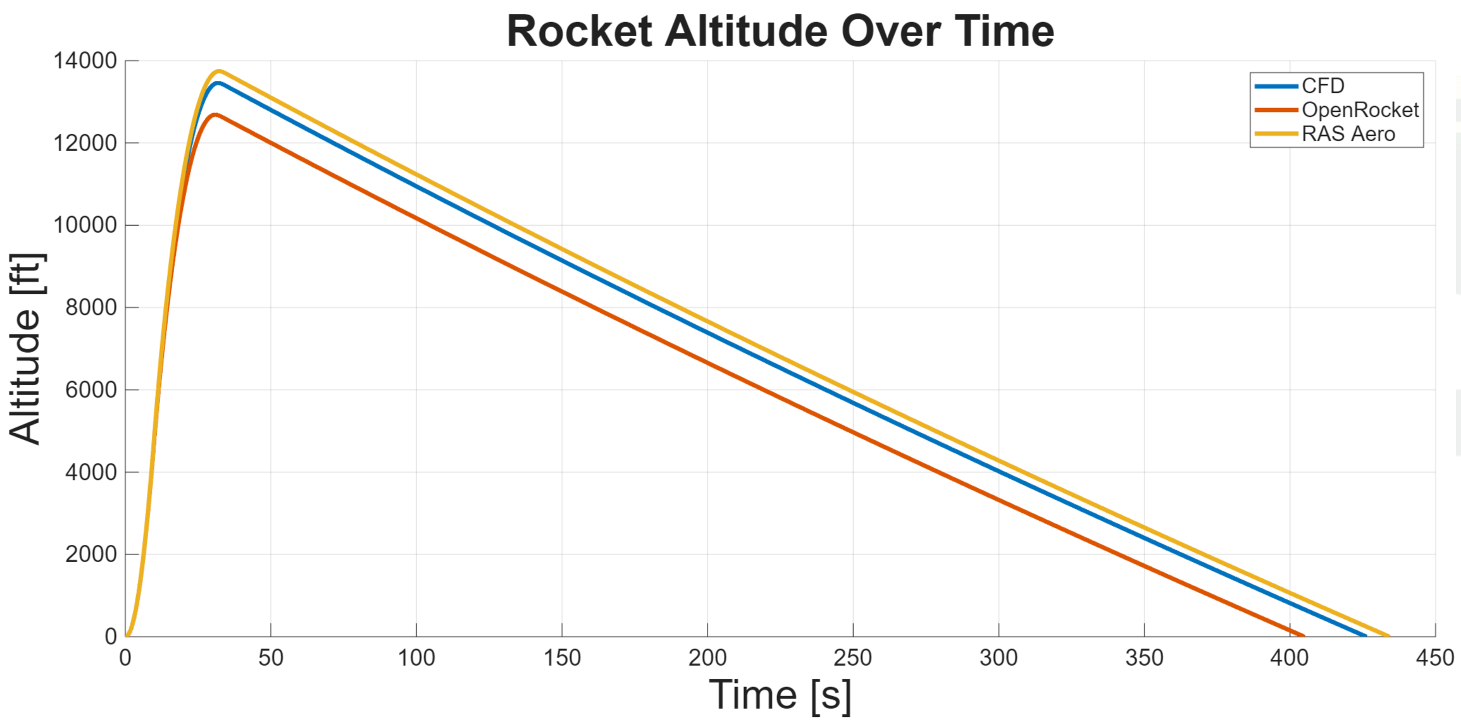


Fig 6.7 Altitude Sensitivity to Drag

Results

- **OpenRocket Cd:**
  - Apogee: 12690 ft
- **RASAero Cd:**
  - Apogee: 13745 ft
- **CFD Cd:**
  - Apogee: 13460 ft

Data Spread

- **Max Spread:**
  - 1058 ft
- **Deviation From Mean Apogee:**
  - ±4%

ALTITUDE PLOTS

MATLAB

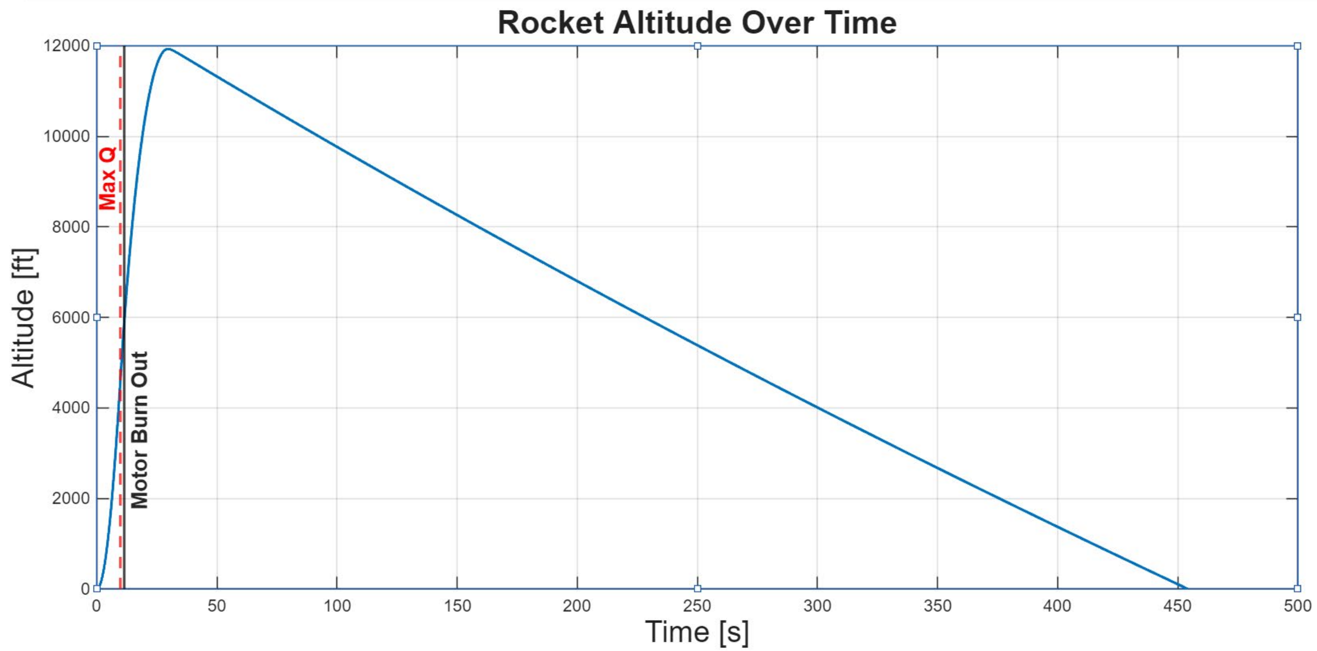


Fig 6.8 MATLAB predicted trajectory

- **Results:**
  - Apogee: 11930 ft
  - Max Velocity: 843 ft/s [Mach 0.77]
  - Max Acceleration: 104.7 ft/s^2
  - Time to Apogee: 29.6 s
- **Assumptions made:**
  - Temperature: ISA
  - Wind Speed: 10 mph
  - Atmospheric pressure: ISA

ALTITUDE PLOTS

OpenRocket

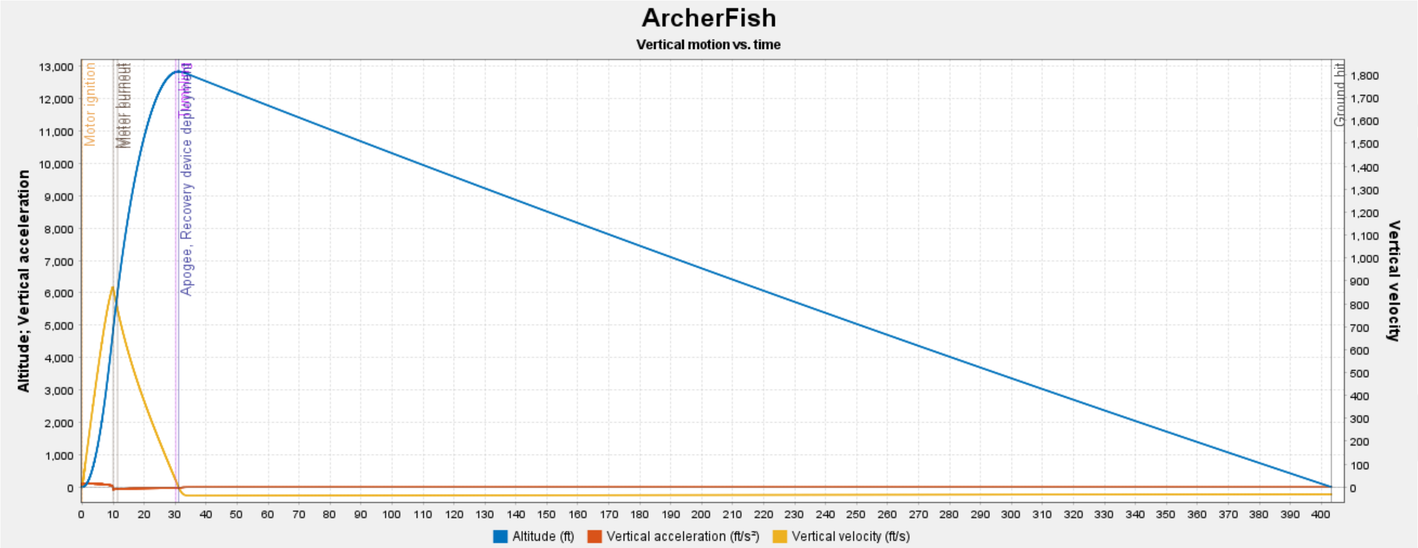


Fig 6.9 OpenRocket predicted trajectory

- **Results:**
  - Apogee: 12720 ft
  - Max Velocity: 873 ft/s = [Mach 0.77]
  - Max Acceleration: 105 ft/s^2
  - Time to Apogee: 31 s
- **Assumptions made:**
  - Temperature: 90 F
  - Wind Speed: 10 mph
  - Atmospheric pressure: 27.3 inHg

WIND ANALYSIS

Average Wind @ FAR: 13.3 mph

No Wind

- Average Apogee: 12873 ft
- Average Maximum Velocity: 873 ft/s
- Average Maximum Acceleration: 105 ft/s^2
- Average Time to Apogee: 31.1 s

Low Wind-10mph

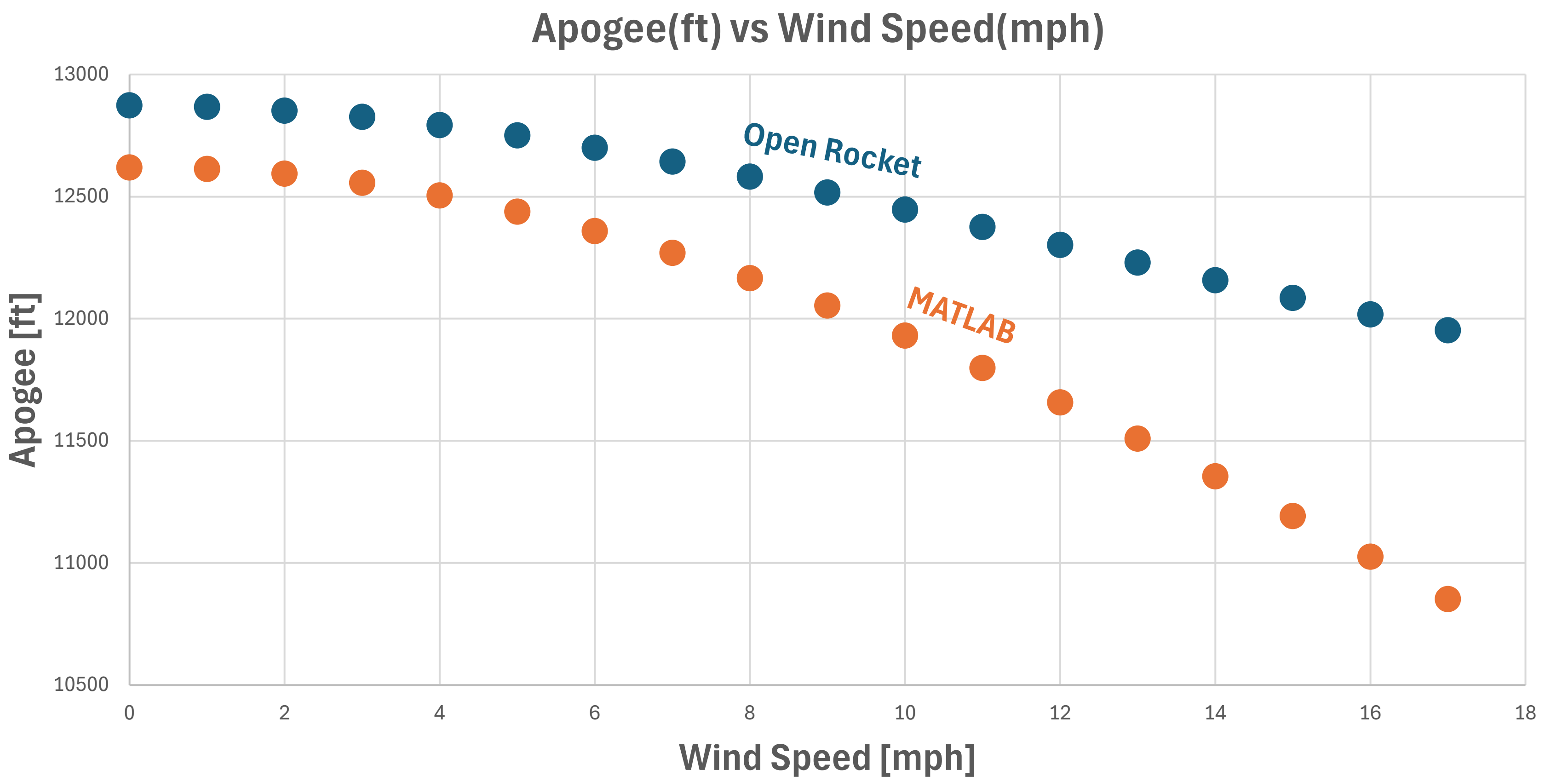
- Average Apogee: 12750 ft
- Average Maximum Velocity: 873 ft/s
- Average Maximum Acceleration: 105 ft/s^2
- Average Time to Apogee: 31 s

- **Mid Wind-20mph**
  - Average Apogee: 12446 ft
  - Average Maximum Velocity: 871 ft/s
  - Average Maximum Acceleration: 105 ft/s^2
  - Average Time to Apogee: 30.7 s

- **Big Wind-30mph**
  - Average Apogee: 12085 ft
  - Average Maximum Velocity: 868 ft/s
  - Average Maximum Acceleration: 105 ft/s^2
  - Average Time to Apogee: 30.2 s

WIND ANALYSIS

Graphic



AERODYNAMICS BOM

	Description	Part Number	Supplier Link	Unit Price	Quantity	Subtotal	Taxes	Shipping	Total
1	Vaccuum Bag		Link	$3.33	50	$166.5	$	$	$
2	Heat-Shrink Tape		Link	$22.88	2	$45.76	$	$	$
3				$		$	$	$	$
4				$		$	$	$	$
5				$		$	$	$	$
6				$		$	$	$	$
7				$		$	$	$	$
8				$		$	$	$	$
								TOTAL:	**$212.26**

NEXT STEPS

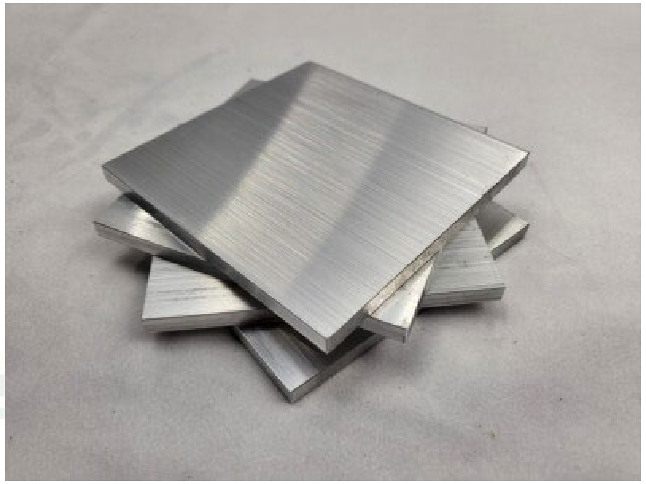
- Start Composite Manufacturing
- Collect real weights as parts get manufactured

STRUCTURES

Presented by: Timothy Barry

MATERIAL CHOICES

- 6061 Aluminum
  - Great Strength to Weight Ratio
  - Easy to machine and work with
  - Familiarity with it overall as a club
- Fiberglass
  - Required for avionics signals to get through
  - Still great overall strength
- Carbon fiber
  - Low density, high tensile strength
  - Have hours of layup experience with it
  - Still have a large amount of donated material
  - Good for bonding with epoxy



MAIN BODY

Body Tubes

- Recovery (Carbon Fiber)
  - Inner Diameter: 6in
  - Wall Thickness: 0.1in
  - Length: 24in (approx.)
  - Manufacturing Method: Composite Layup

- AV Bay (Fiberglass)
  - Inner Diameter: 6in
  - Wall Thickness: 0.1in
  - Length: 14in (approx.)
  - Manufacturing Method: Composite Layup

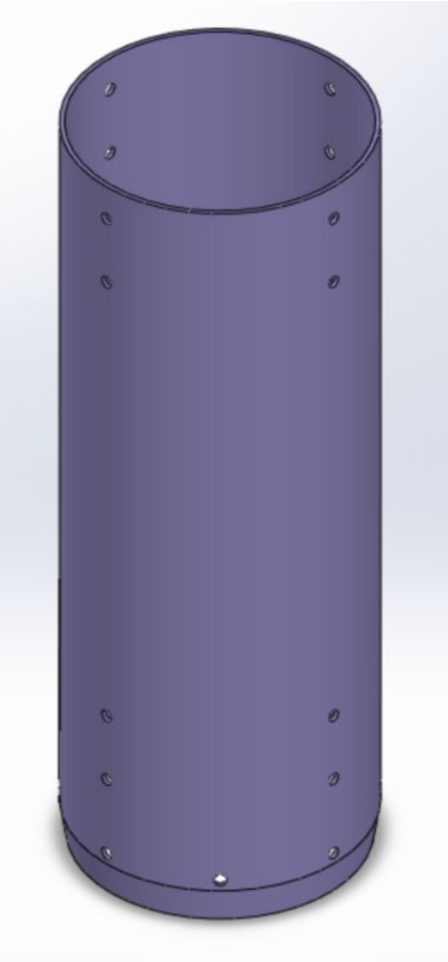


Fig 7.1 Avionics Tube

Fig 7.2 Recovery Tube

COUPLERS

Old Coupler Design

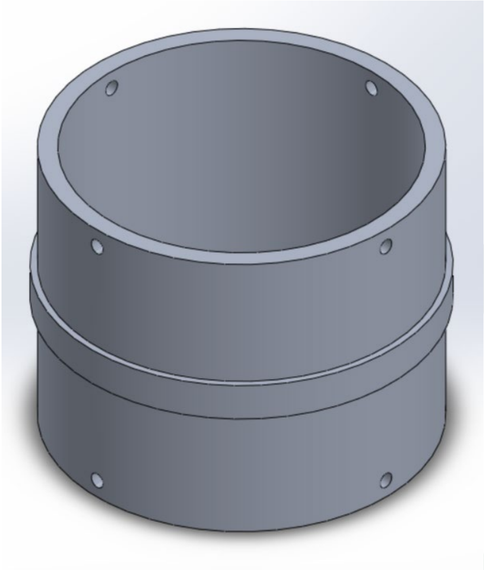
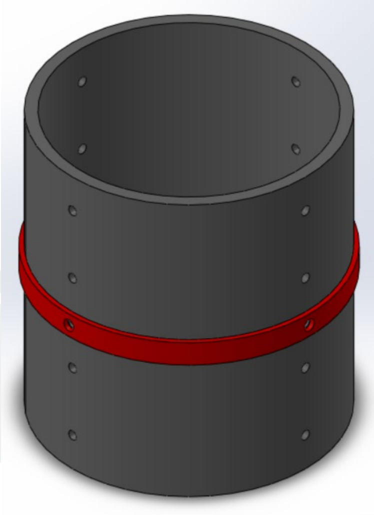


Fig 7.3 Forte/Fortissimo Coupler

- Machine out of hollow aluminum stock
  - Long time to manufacture due to lathe concentricity issues
  - Short length is believed to cause stiffness issues with last year's rocket

New Coupler Design



General Dimensions:
6” OD, 5.5”ID
4.5-6.5” Long

Fig 7.4 Example Coupler

- Still made from hollow aluminum stock
  - Ordered generally to length
  - Longer and more holes for more stiffness
- Coupler Band
  - Will replace metal lip that separates tubes
  - Changed from ABS to Fiberglass

BULKHEADS

Old Bulkhead Design

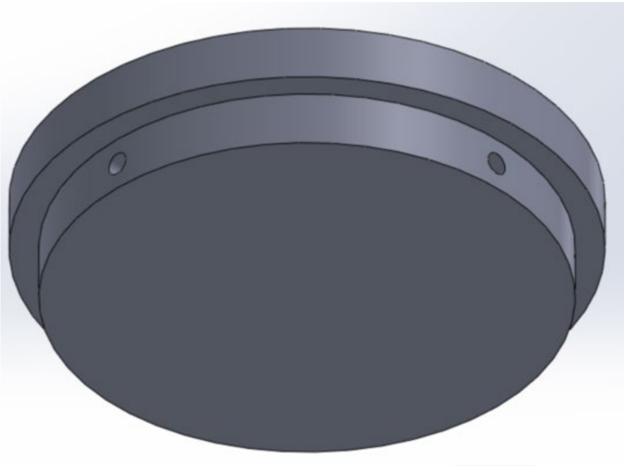
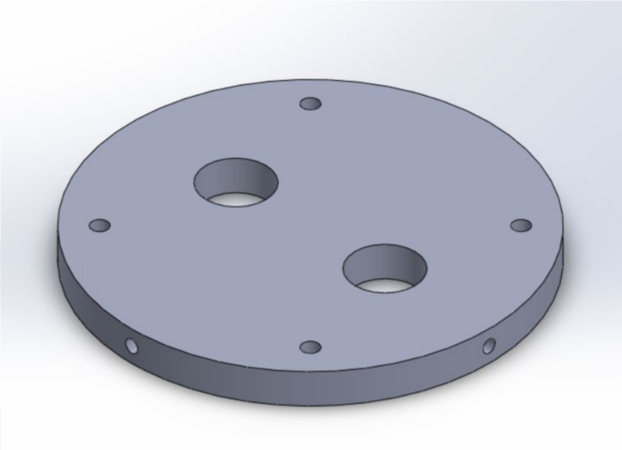


Fig 7.5 Generic Forte/Fortissimo Bulkhead

- Machine out of solid Aluminum
  - Very heavy, lots of wasted material
  - Long time to manufacture
- Difficult to line up with couplers and body tubes

New Bulkhead Design



General Dimensions:
5.5” OD
½” Thick

Fig 7.6 Example Bulkhead for the Recovery section

- Water jetted out of 1/2” Aluminum Sheet
  - Much lighter and faster to make
- Hybrid of Encore Couplers and last year's bulkheads
  - Inserted inside couplers
  - No need to line up with body tube first
- ¼-20 Screws for all holes

BULKHEADS CONT.

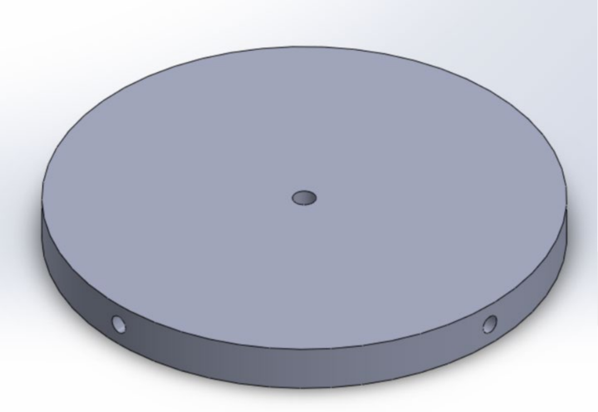


Fig 7.7 Nose Cone Bulkhead

- Hole for I-bolt for shock cord
- Four ¼-20 Holes to Secure Bulkhead
- Epoxy can be used around edges for a pressure seal

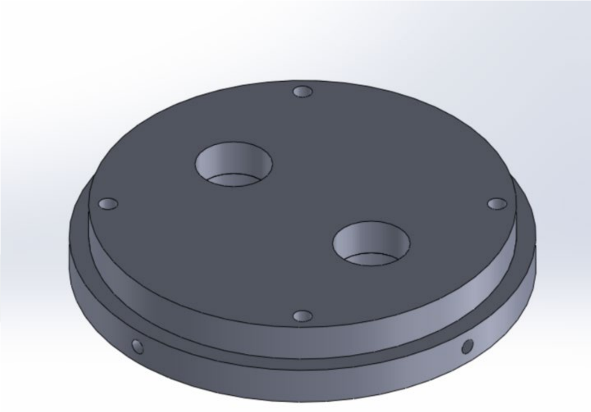


Fig 7.8 Recovery Bulkhead

- Made from two water-jetted pieces of ½" Aluminum Sheet
- Bolted Together
- Peregrine holes can be water-jetted out
- Is more like and can be installed like a bulkhead from last year
- Better for a pressure seal

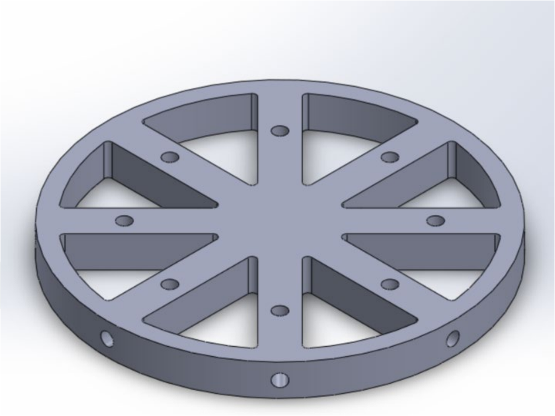


Fig 7.9 Fluids Adapter Bulkhead

- Designed to Secure Oxidizer Bulkhead to top half of rocket
- Eight ¼-20 Holes to Secure Bulkhead
- Highly important part to secure rocket together
- Pockets for weight reduction

Integration of Couplers and Bulkheads

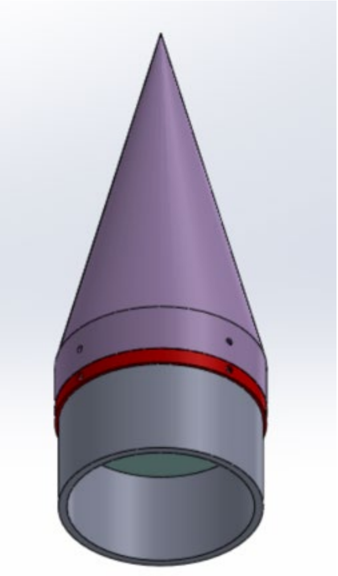


Fig 7.10 Nose Cone Bulkhead integration

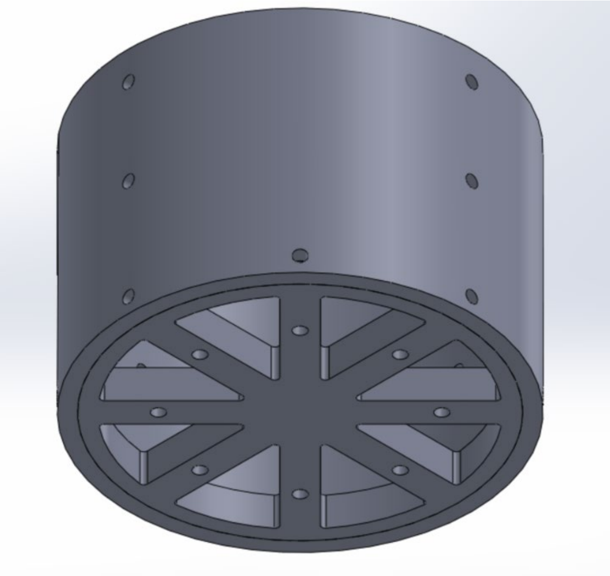


Fig 7.11 Fluid Adapter Bulkhead integration

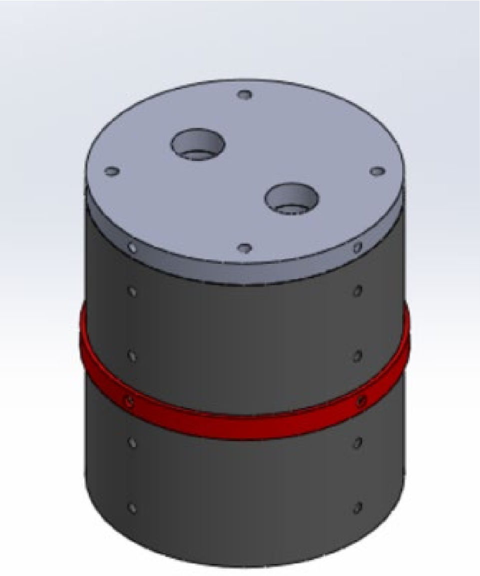


Fig 7.12 Full Recovery Coupler Assembly

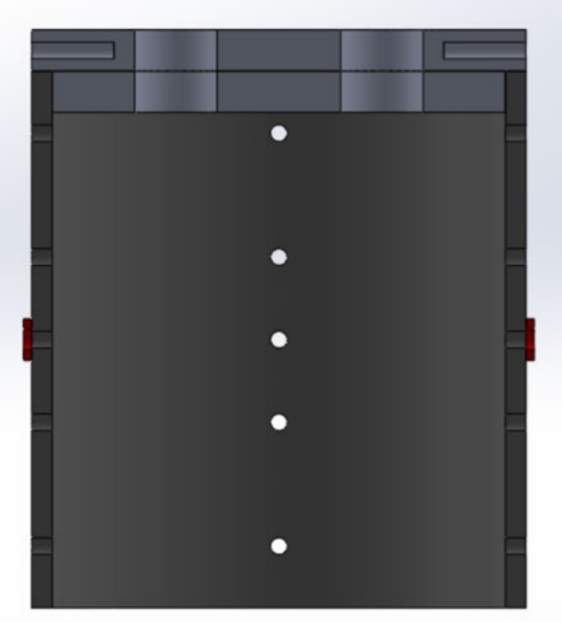


Fig 7.13 Recovery Coupler Cross Section

FORCE AND MOMENT CALCULATIONS

- Values are between those of Forte and Fortissimo last year
- Rocket is going faster (Around Mach 0.75)
- Overall, good safety factors
- Assumes a thicker wall thickness of around 0.1in

```
--- Structural Analysis Outputs ---
Maximum Bending Moment (M_max): -3693.917 lb-ft
Maximum Bending Stress (fb_max): -15413.7038 PSI
Safety Factor for Bending (Fiberglass): 19.4849
Minimum Wall Thickness (t_minimum): 0.00088571 in
Safety Factor for Bending (Carbon): 32.9327
Safety Factor for Fasteners: 9.7545
```

Fig. 7.14 Force, Moment and Safety Factor Values

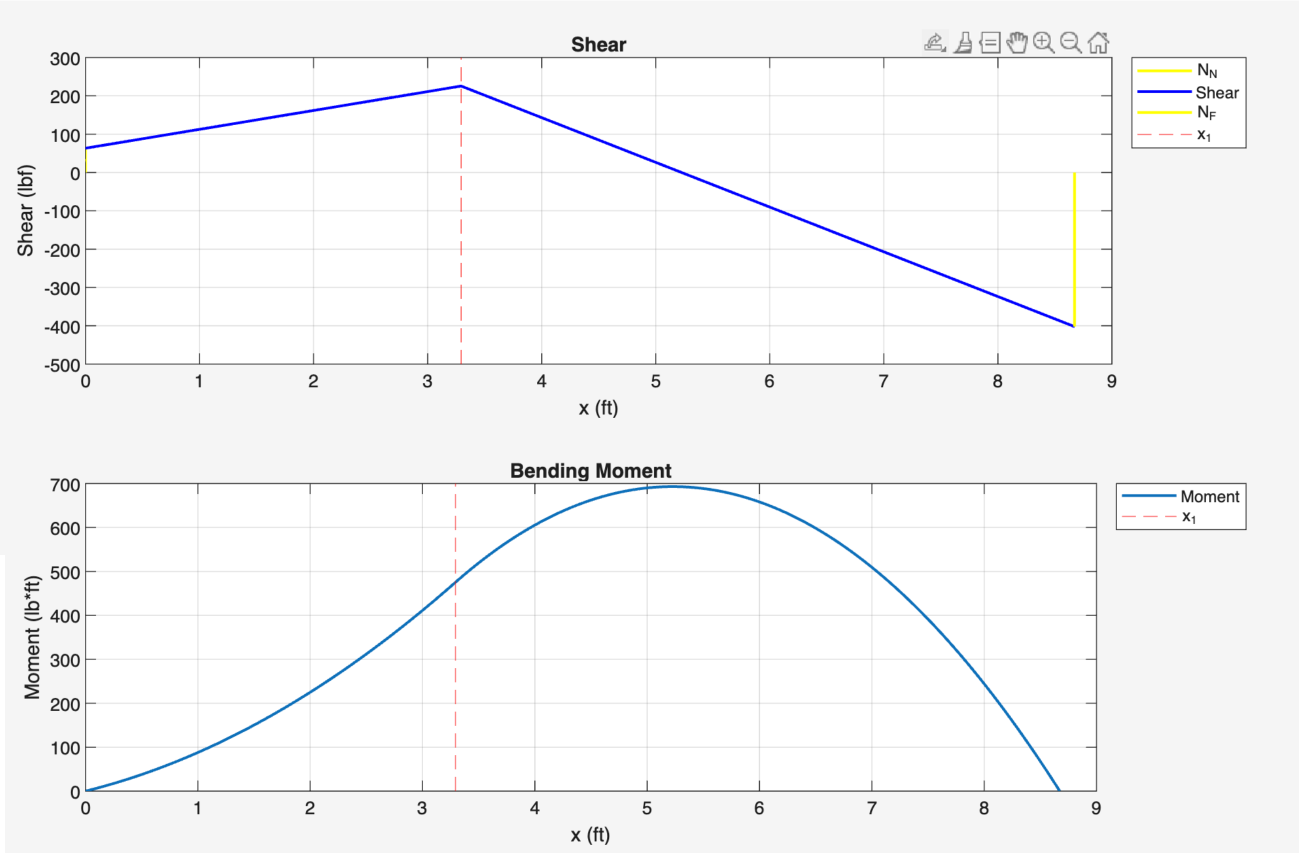


Fig. 7.15 Bending and Shear Diagrams for Archerfish

BOLTS

- General Bolt for all Bulkheads and Couplers
  - ¼-20 Bolt (Length Varies)
- Shear Safety Factor for Bulkheads: 4250

MANUFACTURING (COUPLERS)

- Overall Improved Processed
  - Couplers ordered cut generally to length
  - Should result in better end to avoid concentricity issues
- Still will need to face and likely turn down diameter a bit
- New Manufacturing Jig
  - Square Design to use in drill press
  - Should make it easier to hold couplers and have consistent hole locations
- Overall should be a faster process

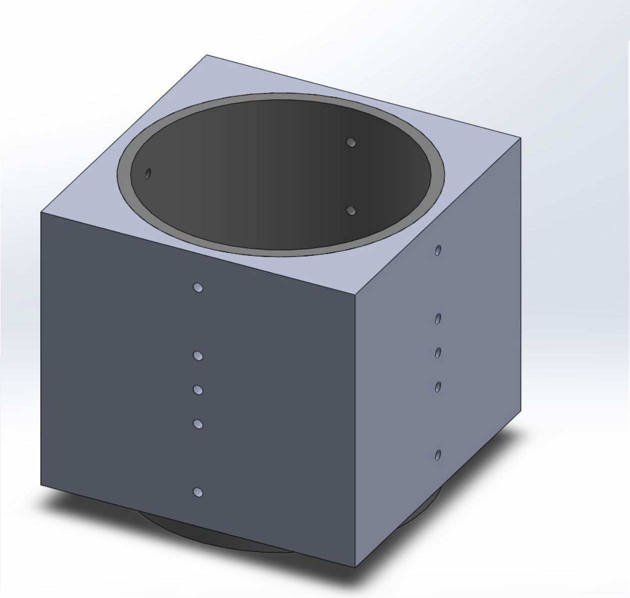


Fig 7.16 Isometric View of a coupler with a manufacturing jig

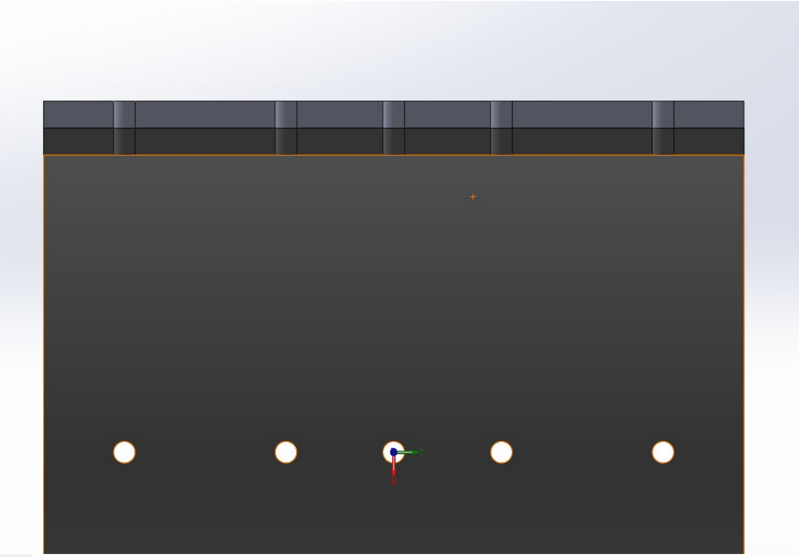


Fig 7.17 Sectional View of the Manufacturing Jig

MANUFACTURING (BULKHE

- Significant Improvements Made
  - Water Jetted from 0.5" Aluminum Plate
  - Cuts out additonal holes for like pergrines for recovery
  - Saves loads of time
- New Jig to hold bulkheads so we can drill holes in the drill press

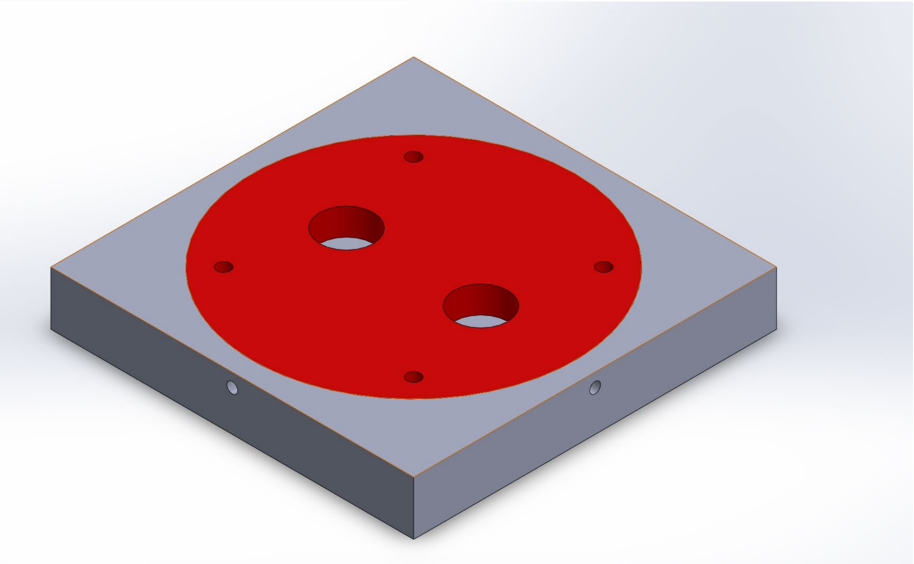


Fig 7.18 Isometric View of a Bulkhead with a manufacturing jig

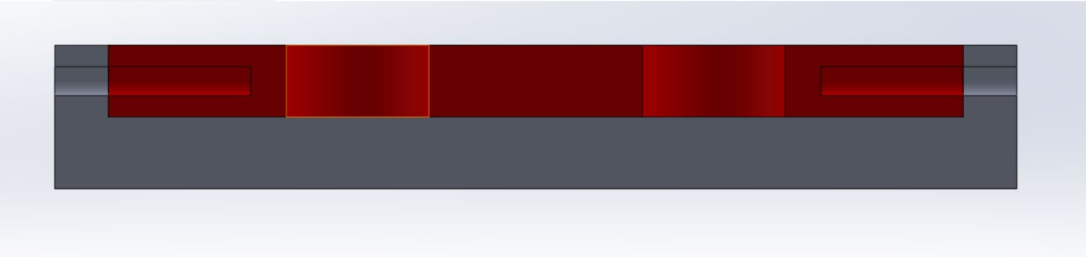


Fig 7.17 Sectional View of the Bulkhead Jig

NEXT STEPS

- Once Rail Button Placement is finalized perform analysis
- Pring Jigs and begin to manufacture parts

Fig 6.13 Figure of the next step above

PRELIMINARY STRUCTURES BOM

	Description	Part Number	Supplier Link	Unit Price	Quantity	Subtotal	Taxes	Shipping	Total
1	Aluminum Round Tubing (6" OD, 5.5ID, 6.5" long)	N/A	Link	$57.06	1	$57.06	$4.99	Combined	$
2	Aluminum Round Tubing (6" OD, 5.5ID, 5.5" long)	N/A		$51.77	1	$51.77	$4.53	Combined	$
3	Aluminum Round Tubing (6" OD, 5.5ID, 4.5" long)	N/A		$51.77	1	$51.77	$4.06	Combined	$
4	1/2" Aluminum Plate (18"x18")	N/A		$233.06	1	$233.06	$20.39	$26.45	$448.98
5	Bambu Lab White ABS Filament	Bambu Lab		$19.99	2	$45.98	$3.49	Unknown	$49.47
6				$		$	$	$	$
7				$		$	$	$	$
8				$		$	$	$	$
								TOTAL:	**$498.95**

RECOVERY

Presented by: Metztli Singha

RECOVERY LAYOUT

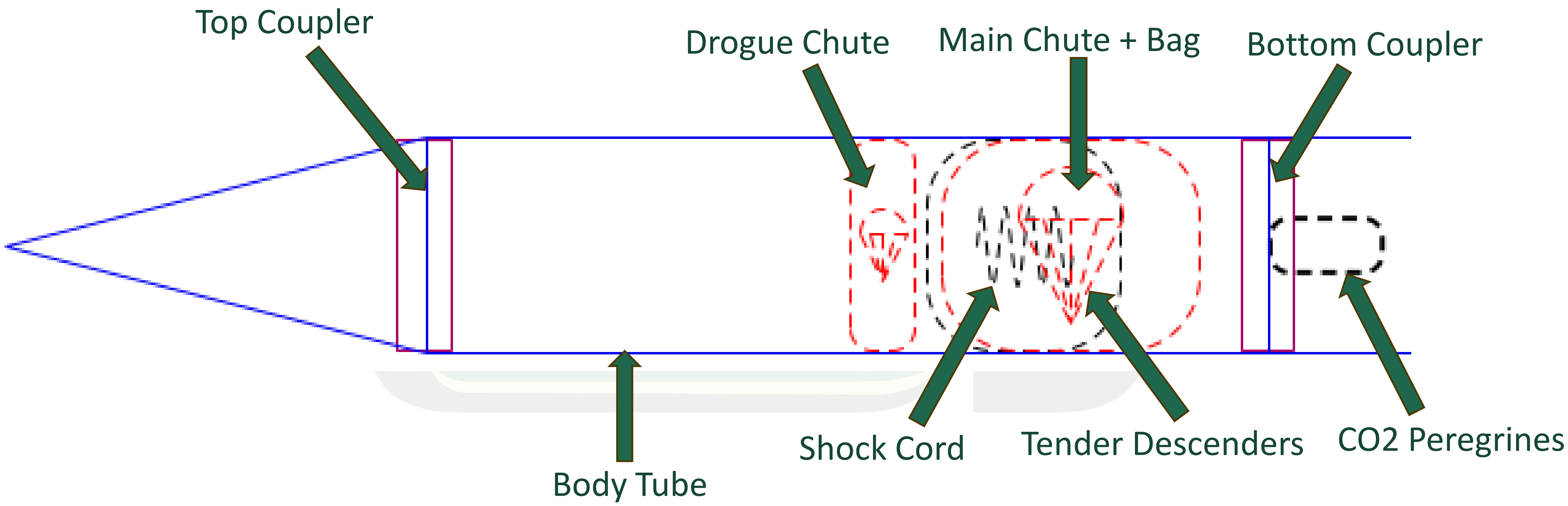


Fig 8.1 Recovery System Layout

INTERNAL COMPONENTS

Line Diagram

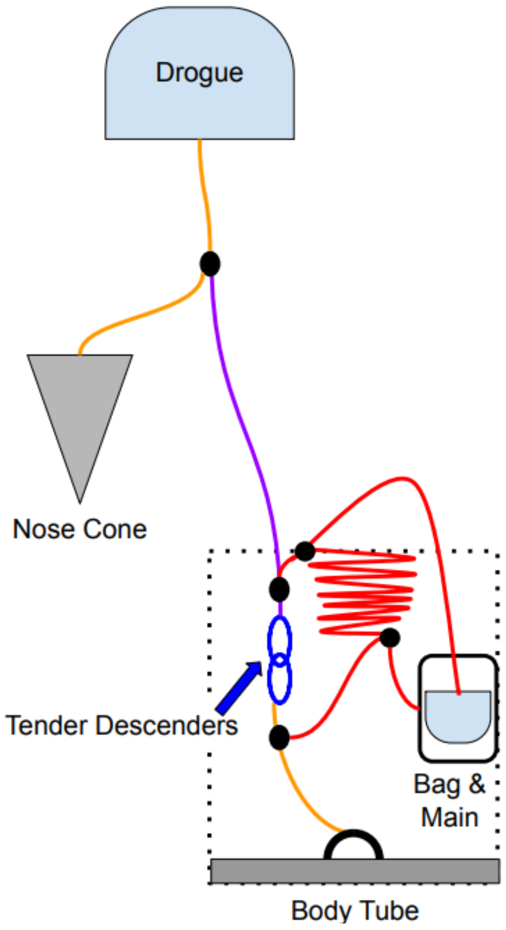


Fig 8.2 Before Tender Descender Ignition

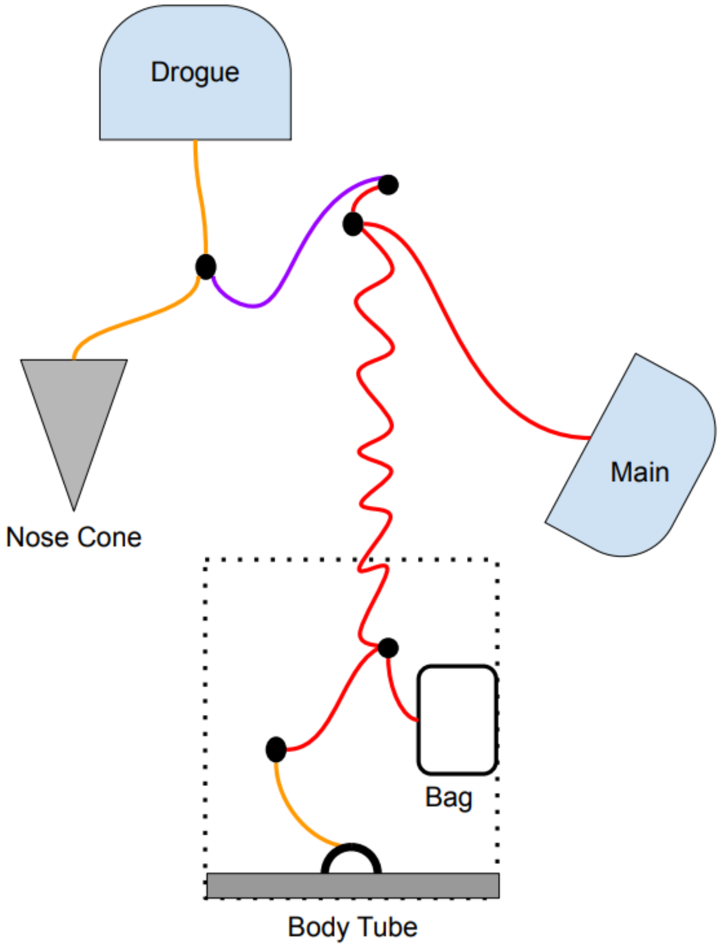


Fig 8.3 After Tender Descender Ignition

OUTER PROFILE

Body Tube & Couplers/Bulkheads

- Pressure vessel created from a carbon fiber body tube and aluminum couplers/bulkheads
  - Nose cone rests on the lid of the pressure vessel
- Bottom bulkhead will require four through holes
  - One 1/4" eyebolt secured with backing located in center of bulkhead
  - One small hole to allow wires to connect from tender descenders to avionics
  - Two holes to secure CO2 peregrines
- Top bulkhead will require one through hole
  - Another 1/4" eyebolt

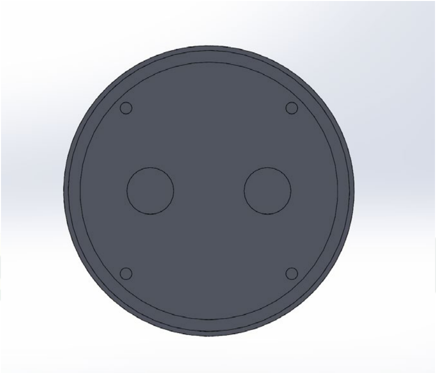


Fig 8.4 Top-down View of Bottom Coupler

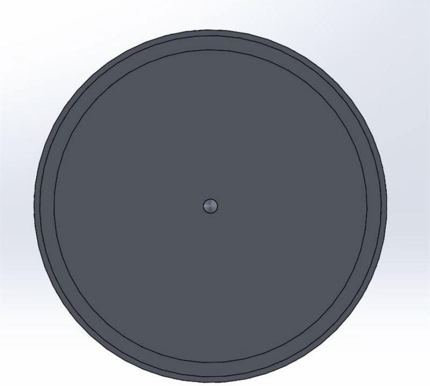


Fig 8.5 Top-down View of Nose Cone Coupler

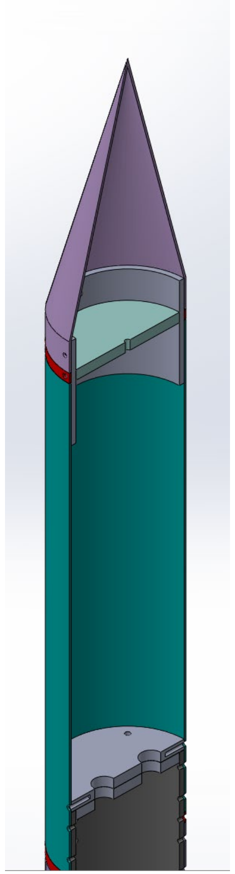


Fig 8.6 Sectional View of the Recovery Tube

INTERNAL COMPONENTS

CO2 Peregrines

- CO2 Peregrine Kits from Tinder Rocketry (12 g)
  - Placed around eyebolt, sticks through the bottom coupler
  - Two are used for redundancy
- Used to release drogue chute at apogee
  - CO2 will fill pressure vessel
  - Resulting pressure will force off top coupler and pull out the drogue

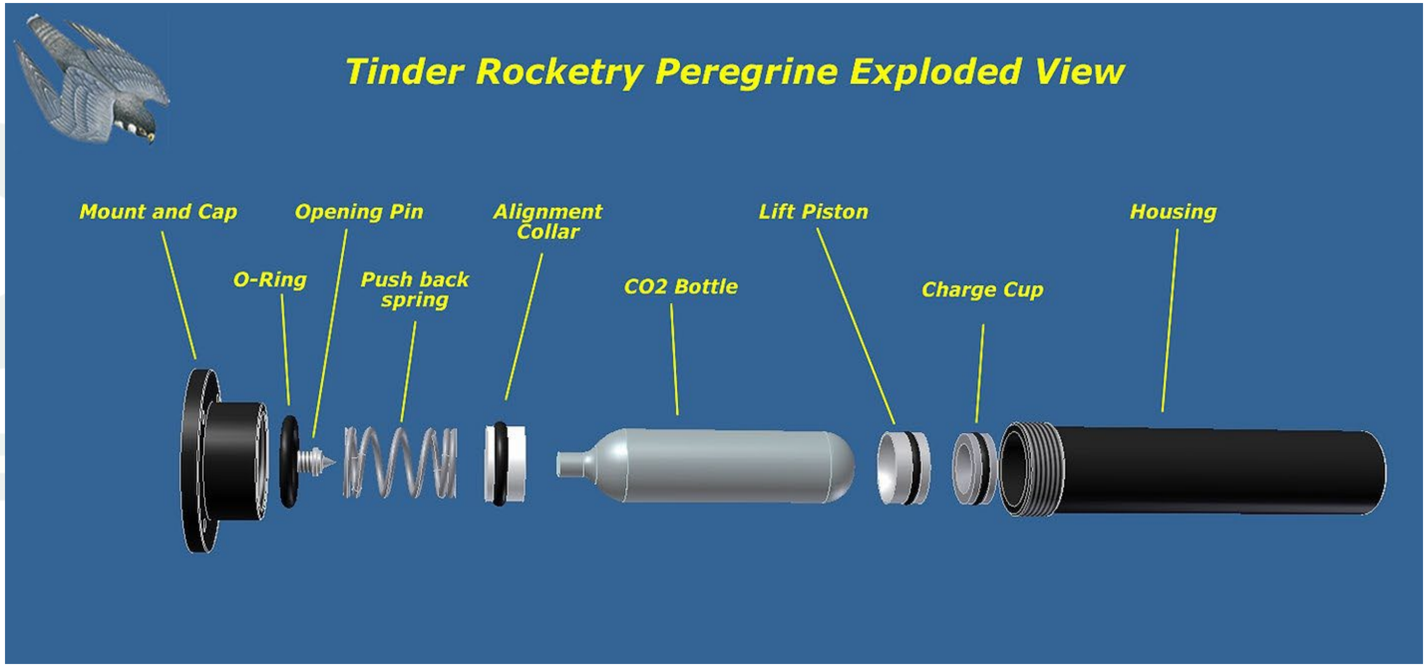


Fig 8.7 Labelled Diagram of CO2 Peregrines

INTERNAL COMPONENTS

Tender Descenders

- Tender Descenders from Tinder Rocketry
  - Placed in series, connects top portion of shock cord to eyebolt
    - Keeps main chute and main chute shock chord length inside body tube until deployment
  - Two tender descenders used for redundancy
- Used to release main chute
  - Will deploy at 1000 ft
  - Black powder within tender descenders will detonate upon receiving signal from avionics
  - Allows main chute to be pulled out of its bag by the drogue

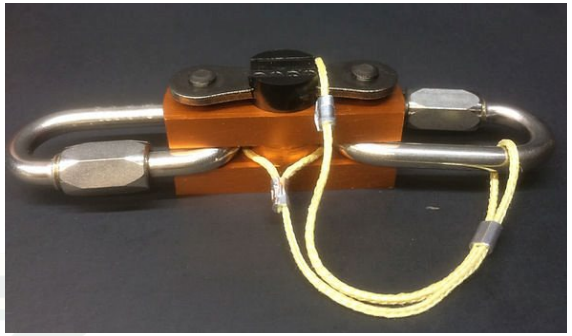


Fig 8.8 Fully Assembled Tender Descender

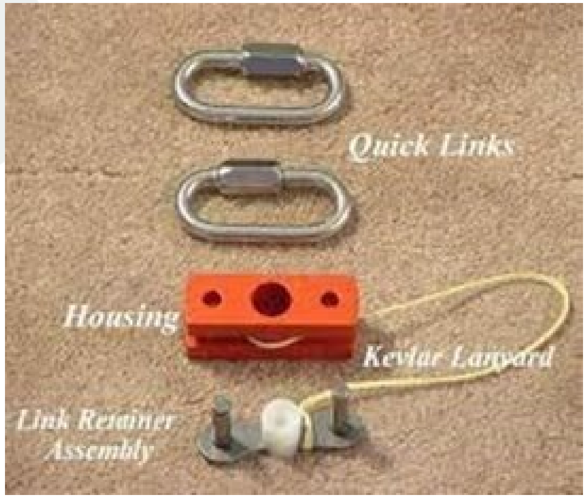


Fig 8.9 Labelled Parts of a Tender Descender

INTERNAL COMPONENTS

Altimeters & Related Avionics

- Egg Timer
  - Connected to CO2 peregrines and programmed to apogee
  - Connected to each tender descender and programmed to sense altitude of 1000 ft
  - Avionics system will serve as redundant system

- E-Matches
  - Used to ignite the pyrotechnics
    - Ideally 10 feet in length
  - Connects from Tender Descenders and Peregrines to avionics
    - Tender Descender wires route through bottom bulkhead/coupler

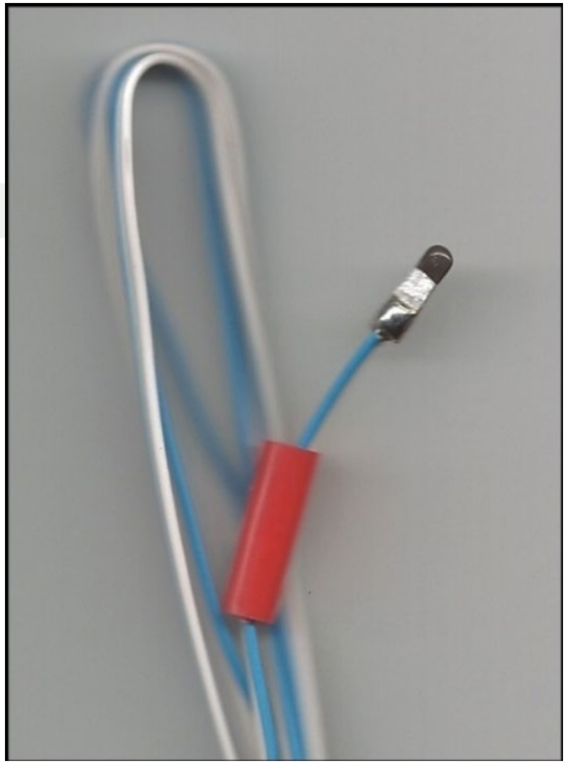


Fig 8.10 E-match from MJG Technologies

MATERIAL ANALYSIS

Shock Cords and Parachutes

Kevlar Shock Cords

- Stronger than nylon
- Lightweight
- Flexible and easy to handle
- ½ in. wide is ideal
- More prone to zippering and has less shock absorption than nylon

Fruity Chutes - Ripstop Nylon

- Lightweight
- Resists tearing and abrasions
- Elastic
- Absorbs shock during deployment
- More durable than standard nylon, especially when subjected to sudden forces
- **Fruity Chutes have a Cd of 2.2**

RECOVERY CALCS

Sizing and Descent

Parachutes + Shock Cords

Drogue Parachute

- 36" diameter Iris Ultra Standard

Main Parachute

- 144" diameter Iris Ultra Compact

Shock Cord

- 30.6 ft (9.33 m)

Packing Volume

- Needed: 292 in^3 (4770 cm^3)
- Available: 642 in^3 (10524 cm^3)

Velocity & Drift

Velocity

- Must be 15-20 ft/s
- Apogee Rockets Eq: 16.2 ft/s (4.94 m/s)
  - Weight 1.25x greater: 18.1 ft/s (5.52 m/s)
- Fruity Chutes Sim: 16.0 ft/s (4.87 m/s)

Drift

- For 5 mph winds:
  - 0.349 miles (0.563 km)
- For 20 mph winds:
  - 1.40 miles (2.25 km)

RECOVERY CALCS

Drogue Deployment

Nose Cone Force Exerted

- Drogue will deploy when rocket is in free fall
- If force of CO_2 can overcome force of the nosecone while stationary, then it can in free fall
- **Force of Nose Cone:**

  14.5 lbf (64.5 N)

  - Note: does not account for friction/latch forces

CO_2 Forces

- **Force for One Peregrine:**

  20.8 lbf (92.7 N)

- **Safety Factor: 1.44**
- With two peregrines, force is 41.7 lbf and SF is 2.87
- Ideally both peregrines deploy, but system will work with only one
  - Redundancy

RECOVERY CALCS

Pressure Vessel

- Thin-walled pressure vessel
  - Wall thickness to diameter ratio: 0.0162 < 0.10
  - Uses 24 g of CO2

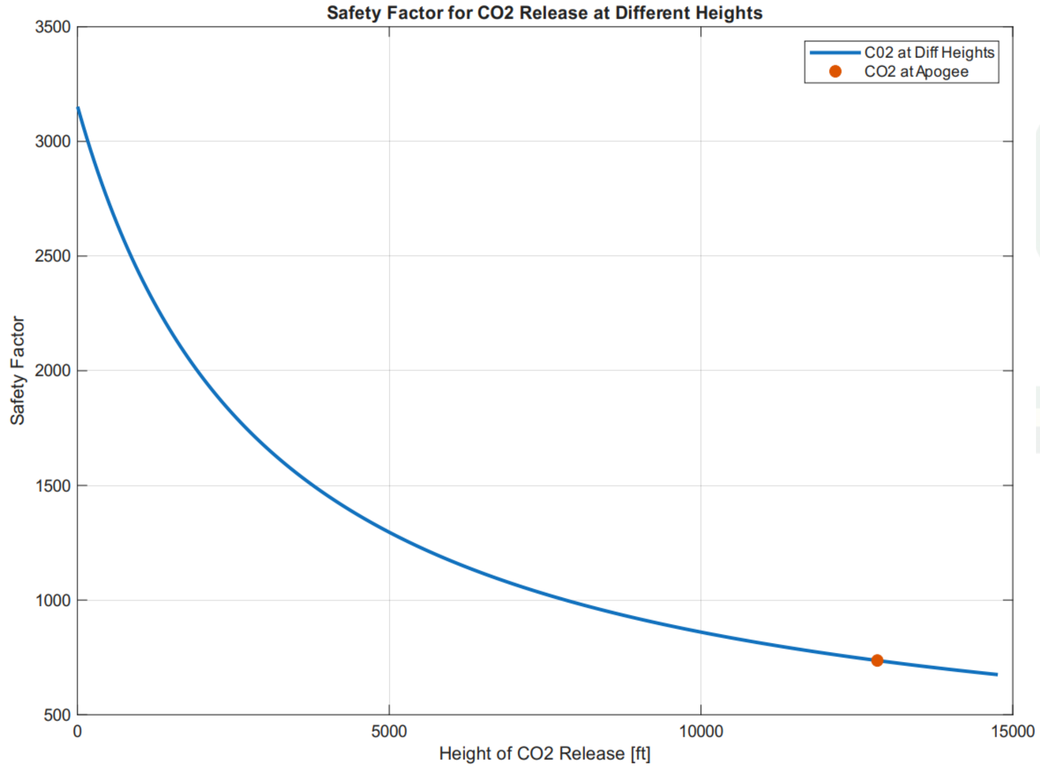


Fig 8.11 Safety Factor vs Height at CO2 Release

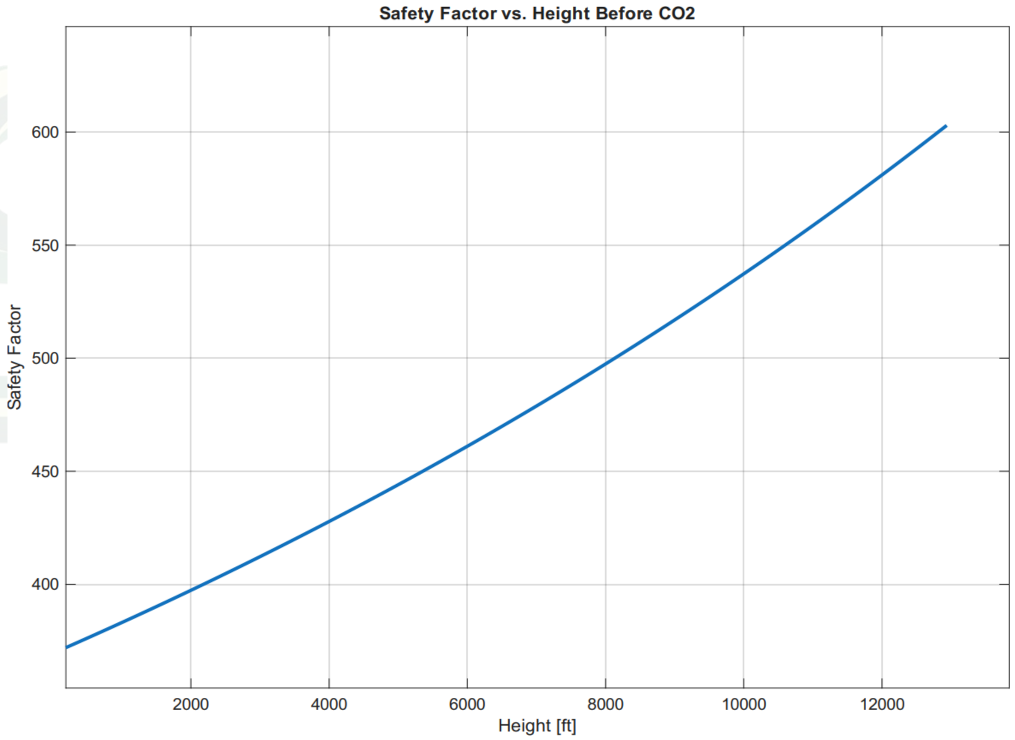


Fig 8.12 Safety Factor vs. Height Before CO2 Release

CPSS

PRESSURE VESSEL Clearance

- Target clearance: Will follow the recommended tolerance for a H7/h6 fit.
  - 0.001 inches of clearance
  - Coupler diameter goal: 5.999 to 6.001 inches
    - Realistically 0.005 - .01 in of clearance

Hole Basis	Shaft Basis	Type of Fit	Description
H11/c11	C11/h11	Clearance Fit	Loose running fit for wide commercial tolerances or allowances on external members.
H9/d9	D9/h9		Free running fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.
H8/f7	F8/h7		Close Running fit for running on accurate machines and for accurate moderate speeds and journal pressures.
H7/g6	G7/h6		Sliding fit not intended to run freely, but to move and turn freely and locate accurately.
H7/h6	H7/h6		Locational clearance fit provides snug fit for locating stationary parts; but can be freely assembled and disassembled.

Fig 8.13 Preferred mechanical tolerances Metric ISO 286 from Engineers Edge

BILL OF MATERIALS

Preliminary Recovery BOM

#	Item	Qty.	Price per Unit	Price (Total)	Source
1	Tender Descenders	2	$155	$310	Link
2	CO2 Peregrine Kit	2	$185	$370	Link
3	Parachute Bag	1	$69.36	$69.36	Link
4	Shock Cord (1 yd)	12	$7.69	$92.28	Link
5	E-Matches (10 ft)	1	$32.99	$32.99	Link
6	Parachute (144 in)	1	$965.89	$965.89	Link
	Total (Not including Tax/S&H)			$1840.26	

NEXT STEPS

- Help with manufacturing
- Start testing

AVIONICS

Presented by: Brian Payne and Aidan Sacco

SYSTEMS OVERVIEW

TOM 2.0

- Telemetry Operations Manager, responsible for sending GPS Location and Altitude to Mission Control

Flight Recorder

- Backup logging computer for data from TOM or Engine Controller

Engine Controller

- Controls the Engine's Fuel/Ox Pump

Mission Control

- Ground Communication station and Data Visualization

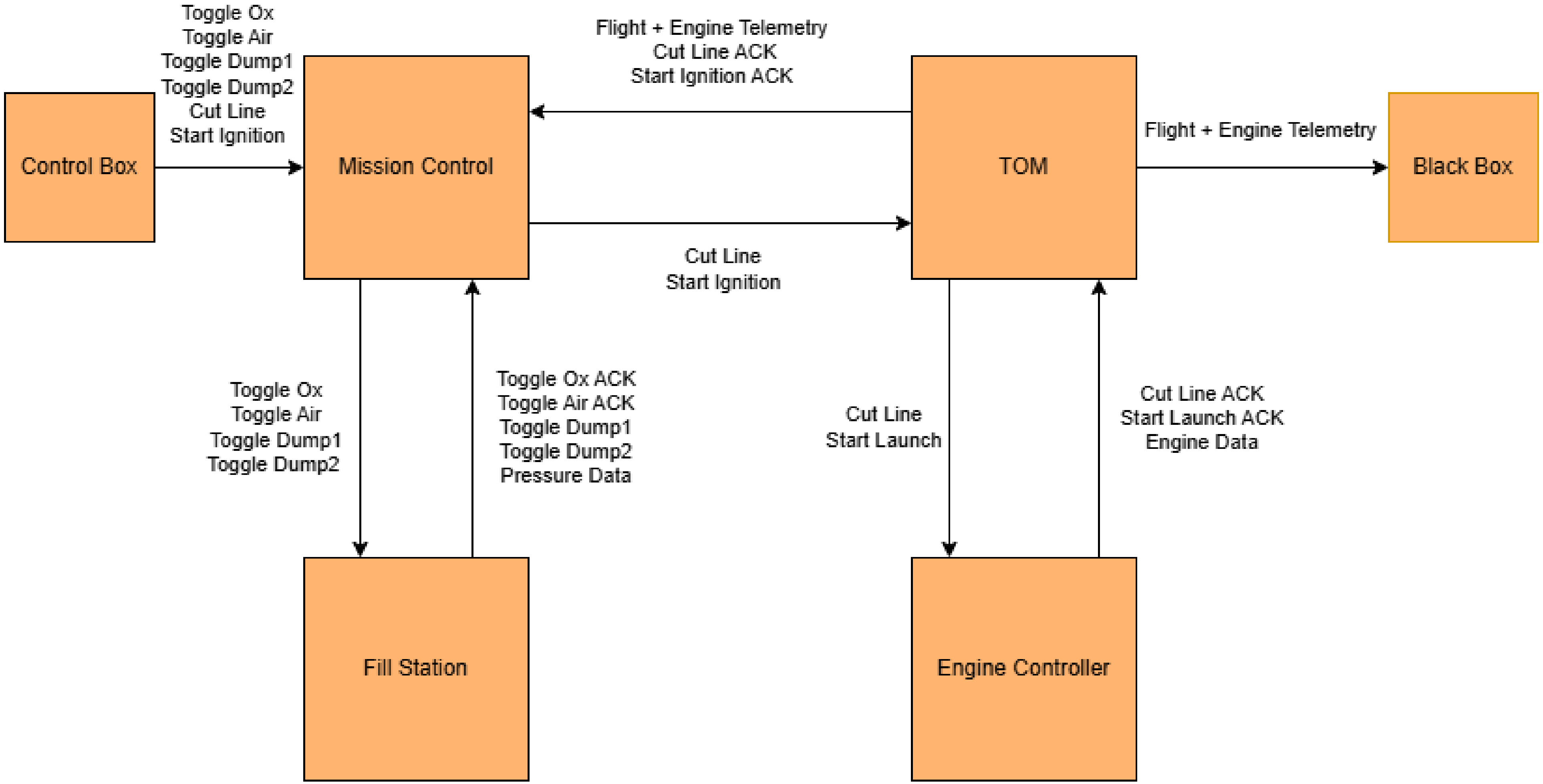
Control Box

- Human-in-the-loop controller where an operator presses switches to cause an effect in the system

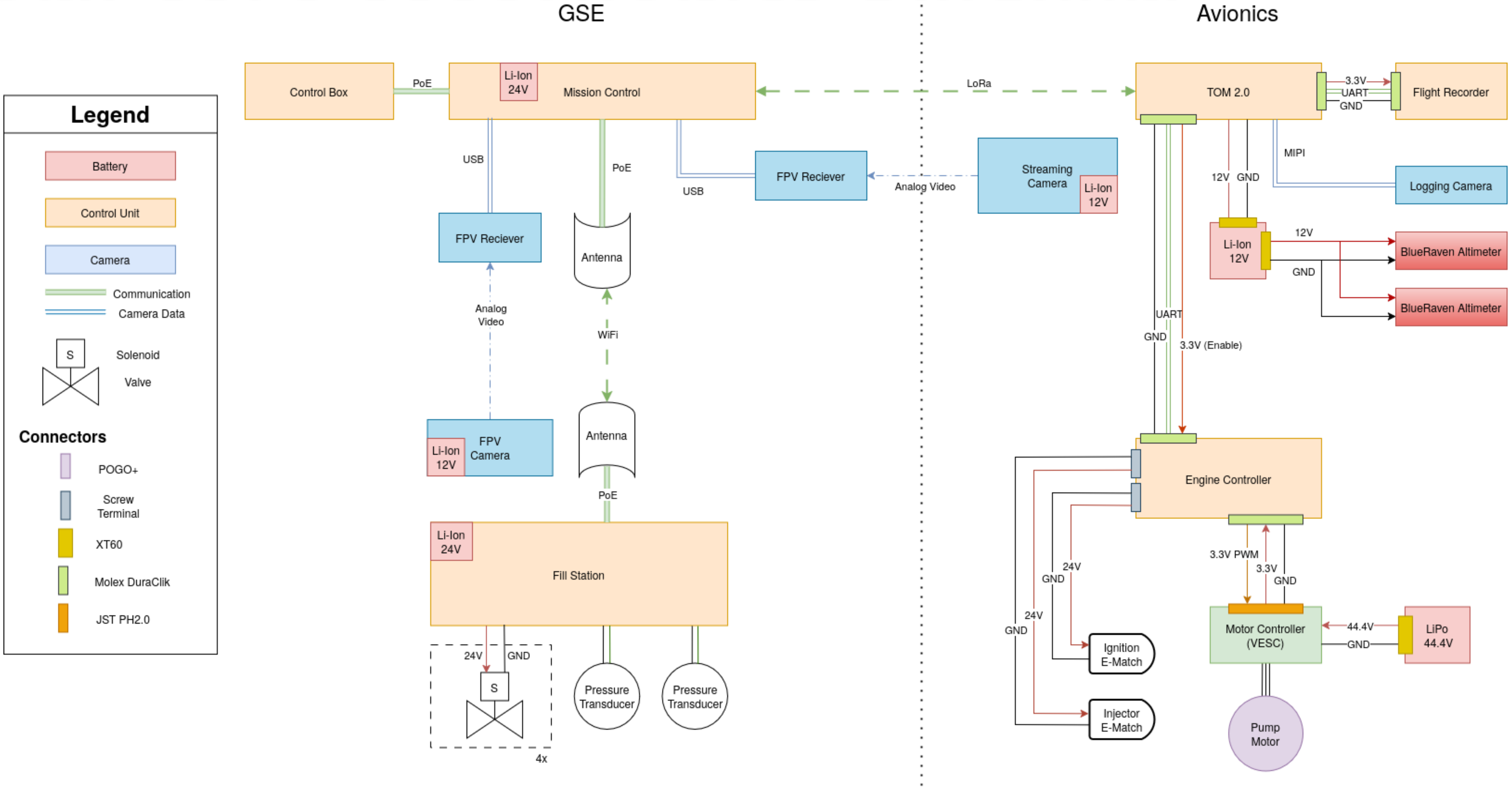
Fill Station

- Controls Oxidizer filling procedure

MESSAGE FLOW

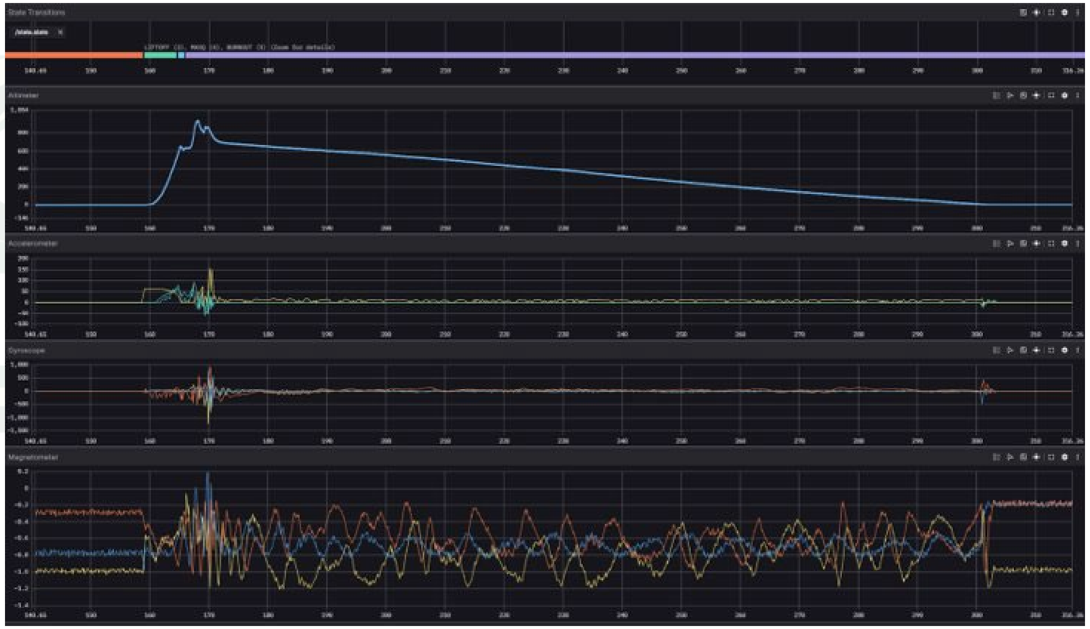


COMPLETE ELECTRONICS DIAGRAM



MISSION CONTROL

- Operator interacts with Control Box
  - Contains all buttons and switches needed to remotely operate fill station solenoids and ignition
  - Wired directly to Mission Control computer over Ethernet
- Acts as the Avionics communication "hub"
  - Facilitates ConOps by sending commands
  - Instructs Fill Station (over WiFi) to actuate solenoids for filling oxidizer
  - Instructs TOM (over LoRa) to Initiate launch sequence and gather telemetry
- Logs and visualizes telemetry data
  - Displays fill station and flight telemetry to the operator



MISSION CONTROL SYSTEM REQUIREMENTS

RBS	Requirement	Rationale	Traced From	Verification Method
0	Mission Control Shall remotely send commands to Fill Station and TOM to control the Sequencing of Launch	Launch sequence needs to be controlled by operators	Liquids Safety Procedure	HITL testing, demonstrate communication with other systems and response from other systems
0.1	Mission Control shall have an interface for the operators to send commands	Operators must be able to input commands	RBS 0	HITL testing, demonstrate interface results in sent commands
0.1.1	Mission control shall only send control signals to Fill Station and TOM when corresponding inputs are selected by the operator	All control signals should be controlled by operators	RBS 0.1	HITL testing, demonstrate interface results in sent commands. Test with various inputs that only correct signals are sent
0.2	Mission Control Shall communicate wirelessly with TOM and Fill Station	Operators must be able to execute commands from a distance	RBS 0	HITL testing, demonstrate communication with other systems over various distances
0.2.1	Mission Control Shall display pressure readings from the fill station	Operators must be able to read pressure in the tanks for go/no go procedures	RBS 0.2	HITL testing, demonstrate Mission control can receive pressure readings over a distance
0.3	Mission Control Shall display a video feed from Fill Station of the static release valve	Operators must be able to see static release Valve for determining go/no go	RBS 0	HITL testing, demonstrate video can be received over a distance from Fill Station
0.4	Mission Control shall send the following signals to Fill station: Toggle Ox, Toggle Air, Toggle Dump1, and Toggle Dump2	These are the signals fill station uses for fill procedure sequencing	RBS 0	HITL testing, demonstrate that signals get sent to and acknowledged by fill station
0.5	Mission Control shall send the following signals to TOM: CutLine, and Start Ignition	These are the signals TOM uses for launch sequencing	RBS 0	HITL testing, demonstrate that signals get sent to and acknowledged by fill station
1	Mission Control Shall receive, store and display telemetry data sent from TOM	This is necessary for data collection and recovering the rocket	Far Requirement	HITL testing, Demonstrate

FILL STATION

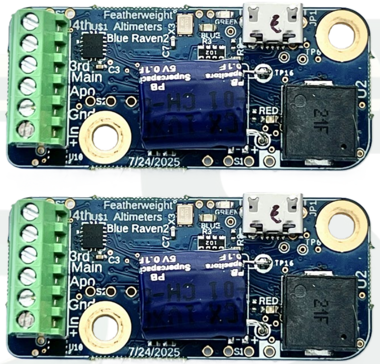
- Actuates Ox and Pressurization valves
- Sends pressure transducer data to mission control for visualization
  - Used for determining go/no go conditions
- Communicates with Mission control over wifi for signals to start/stop valve actuations
- Sends live video of static release valve to determine when oxidizer is done filling

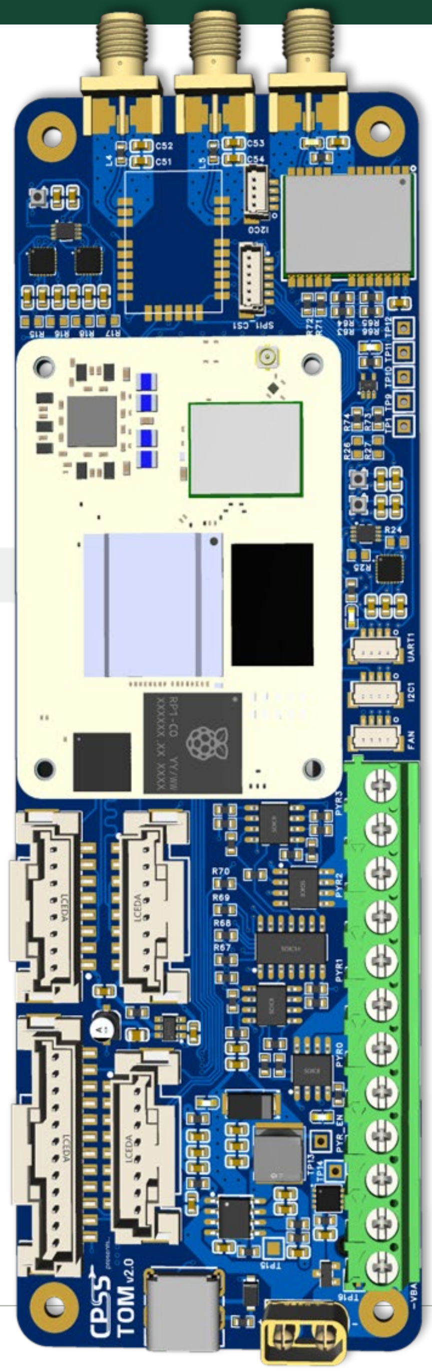
FILL STATION REQUIREMENTS

RBS	Requirement	Rationale	Traced From	Verification Method
0	The Fill Station shall control propellant filling and dumping operations	This is the primary mission of the Fill Station.	Mission Requirements	Hardware-in-Loop Testing
1.0	The Fill Station shall actuate 4 solenoid ball valves when commanded by Ground Station	This is necessary to control oxidizer fill, GN2 fill, oxidizer dumo, and GN2 dump.	Mission Requirements	Hardware-in-Loop Testing
1.1	The Fill Station shall be capable of actuating all 4 valves independently	Different Failure cases require different valves to be toggled	RBS 1.0	Hardware-in-Loop Testing
2	The Fill Station shall receive commands from Ground Station at distances up to 400 m	This is necessary to allow operators to control propellant operations from a safe distance per FAR requirements.	FAR Requirement	Field Range Testing
2.1	The Fill station shall only toggle valves upon receiving the corresponding signals from Mission Control	All valve control should be handled by operators through Mission Control	RBS 2	HITL testing, demonstrate interface results in sent commands. Test with various inputs that only correct signals are sent
3	The FIll Station shall provide visual monitoring of the pressure relief valve area	This is necessary to detect propellant venting during operations	Mission Control RBS 0.3	Field Testing
4	The Fill Station shall wirelessly transmit data from the pressure transducers to Mission Control	This is necessary data for operators to make decisions on possible failure cases	Mission Control RBS 0.2.1	HITL testing, demonstrate that correct pressure readings can be sent to Mission Control

AVIONICS BAY

- Logic center for Avionics during flight
- Contains TOM and Black Box Recorder
- Contains redundant COTS altimeters (Featherweight Blue Raven) for activating recovery
- Sends flight telemetry data to Misson control
- Relays messages from Mission Control to Engine Controller
- Receives engine data from Engine controller





AVIONICS BAY REQUIREMENTS (TOM)

RBS	Requirement	Rationale	Traced From	Verification Method
0	The system shall stream Telemetry data throughout the entire mission duration.	This is a FAR requirement.	FAR Requirement	Field Range Testing
0.1	The system shall include GPS latitude and longitude in telemetry.	This is necessary for recovering the rocket.	FAR Requirement	HITL testing, demonstrate correct GPS measurements
0.2	The system shall include altitude in telemetry.	This is necessary for preliminary scoring and scoring on system failure.	FAR Requirement	HITL testing, demonstrate correct Altimeter measurements over I2C with varying altitudes
0.3	The system shall send telemetry up to an altitude of 26400 ft	This is necessary to send telemetry throughout the mission duration.	Archerfish Requirement	Field Range Testing
0.4	The system shall send telemetry up to a distance of 4 miles.	This is necessary to send telemetry throughout the mission duration.	Archerfish Requirement	Field Range Testing
0.5	The system shall send telemetry at a minimum of 1Hz	This is necessary to maintain real-time telemetry.	Archerfish Requirement	Visual confirmation on mission control
1	The system shall fire the drogue parachute at apogee	This is a FAR requirement.	FAR Requirement	HITL testing with simulated flight data from Certs/previous launches/openrocket
1.1	The system shall fire the main parachute during descent at 1K ft AGL	This is a FAR requirement.	FAR Requirement	HITL testing with simulated flight data from Certs/previous launches/openrocket
2	The system shall collect IMU data for review	This is useful data that can be re-used for testing on future missions	Avionics Requirement	HITL testing, demonstrate correct IMU measurements over I2C with varying velocities
3	The system shall receive and relay the following signals from Mission Control to the Engine Controller: Launch and Cut Line	All launch and failure case procedures are controlled by operators through mission control and need to be passed to Engine controller which does not have wireless communication with Mission Control	Mission Control RBS 0.5	HITL testing, demonstrate communication between TOM and engine controller over UART on long wires. Test both with simulated data and Motor Controller in the Loop

AVIONICS BAY REQUIREMENTS (BLACK BOX)

RBS	Requirement	Rationale	Traced From	Verification Method
0	Black Box shall store data persistently	This is necessary for recovering data in the case of critical failure from the rocket	Mission Objective	HITL testing to verify storage is persistent after power on/off
1	Black Box shall receive data over a common interface from TOM	This is necessary to collect data for storage	Mission Objective	HITL testing, demonstrate functional communication with TOM
2	Black Box shall record data regardless of malformedness	Necessary for debugging if data collection/distribution is not correct	Mission Objective	HITL testing with simulated malformed datasets
3	Black Box shall fit in a volume with space 8cm x 5cm x4cm	This is the space allocated in the avionics bay	Mission Objective	Design

ENGINE CONTROLLER

- Performs timed launch sequence operations
  - Signaled by TOM over UART
  - Fires Line Cutter and Ignition e-matches
  - Sends a (constant duty cycle) PWM signal to enable the pump motor controller
- Sends pump data to TOM over UART
  - RPM for logging

ENGINE CONTROLLER REQUIREMENTS

RBS	Requirement	Rationale	Traced From	Verification Method
0	The engine controller will only turn on if the arming key is turned and an enable signal is sent from TOM	The engine controller needs to be completely off and isolated when the engine is not armed to provide redundancy and avoid early ignition on the pad	FAR requirements	Demonstrate engine controller only turns on when key is turned
1	The engine controller shall have a common wired interface with TOM	This is necessary for by-proxy communication with Mission control	TOM RBS 3	HITL testing, demonstrate functional, bilateral communication between TOM and engine controller and signals are relayed correctly
1.1	The engine controller shall be prepared to receive the following signals through the communication with TOM: Start ignition and Cut Line	These are the control signals for launch and failure cases	RBS 1	HITL testing, demonstrate functional, bilateral communication between TOM and engine controller and signals are relayed correctly
1.1.1	The engine controller will send the signal for the line cutter	This is a part of the rocket launch sequence and some failure cases	RBS 1.1	HITL testing, demonstrate signal works on output and corresponds to correct signal from TOM
1.1.2	The engine controller will send the signal for the Igniter	This is a part of the rocket launch sequence	RBS 1.1	HITL testing, demonstrate signal works on output and corresponds to correct signal from TOM
1.1.3	The engine controller will generate and output a PWM signal to the motor controller	This is the input to the motor controller to control the pump motor	RBS 1.1	HITL testing, demonstrate signal works on output and corresponds to correct signal from TOM
1.1.4	The Engine Controller shall turn on the ignitor, then send the PWM signal to the pump, then activate the line cutter only upon receiving the "start ignition" signal	This is the launch sequence and should only be started when operators are prepared to launch	RBS 1.1	HITL testing, demonstrate signal works on output and corresponds to correct signal from TOM
1.1.5	The Engine Controller will cut the line upon receiving the "CutLine" signal	This is a part of some failure cases	RBS 1.1	HITL testing, demonstrate signal works on output and corresponds to correct signal from TOM
2	The Engine Controller shall record data from the engine	This is data will be useful for future liquid engine designs	Archerfish Requirement	HITL testing, demonstrate engine controller can read data off of TOM
2.1	The Engine Controller shall send data over the common wired interface with TOM	This is how the data will be sent somewhere to be stored	RBS 2.1	HITL testing, demonstrate functional, bilateral communication between TOM and engine controller and data is relayed correctly. Test with simulated data and as full loop system including engine controller

TESTING

Presented by: Jasmine Cheng

REVISIONS

- **Line-cutter testing**
  - Find rope that works
  - No need to test carbon fiber rods effect on signal

- **Line-cutter Testing Attempts:**
  - Received: Line Cutters engaged, e-matches went off
  - Problems: Rope was not cut through

TESTING

Propulsion, Liquids, and GSE (1 of 3)

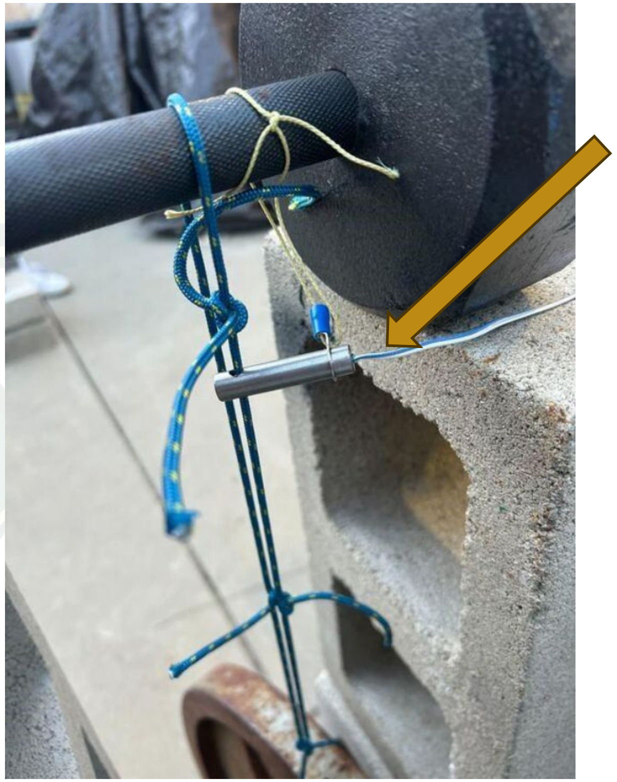
GSE:

Goal: Validate all electronics, solenoids, pneumatics, etc.

- Line Cutters
- Separation Mechanism Testing
- Filling Ox and Air controls (Tanks)
- Mission control and Fill Station Communication

Next Steps:

- Line Cutter Testing: Test new rope
- Continue manufacturing



Line Cutter

Fig 10.1 Line cutters in Example Testing Setup

TESTING

Cold Flows:

- Goal: Full Liquid System Cold Flow – Early Feb.

  Tanks, GSE, Valves, Bulkheads, Engine - Not on Bluegrass

- Valves:

  Hydrostatic Testing (Water Hand Pump)

  Full liquids system (See Fig. 10.3)

- Pump – Bluegrass

- Valves (Bluegrass, engine, line-cutters)

Fig 10.2 "Bluegrass" Test Stand

Fig 10.3 Picture of Test Stand to Mount Liquid System

TESTING

Propulsion, Liquids, and GSE (3 of 3)

Hot Fires:

Main Goal: Get Engine Data, Ensure Pump + Engine are integrated and produce desired results, valve timing

- Engine (no pump) - Bluegrass
- Pump + Engine - Bluegrass

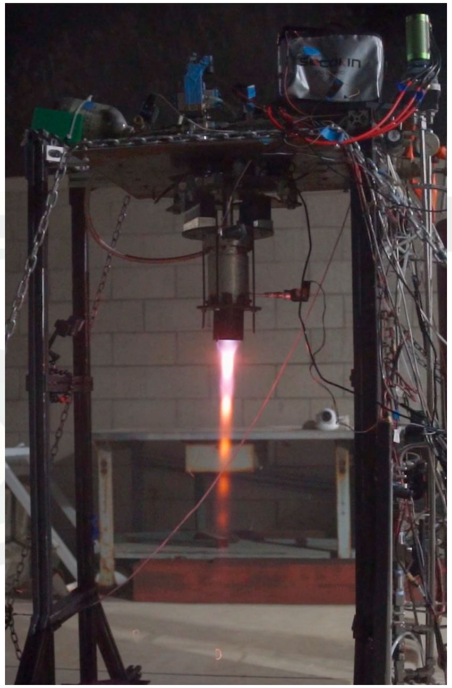


Fig 10.4 "Stratum" Hot Fire on Bluegrass

Fig 10.5 "Stratum" Hot Fire on Bluegrass

TESTING

Liquids Timeline

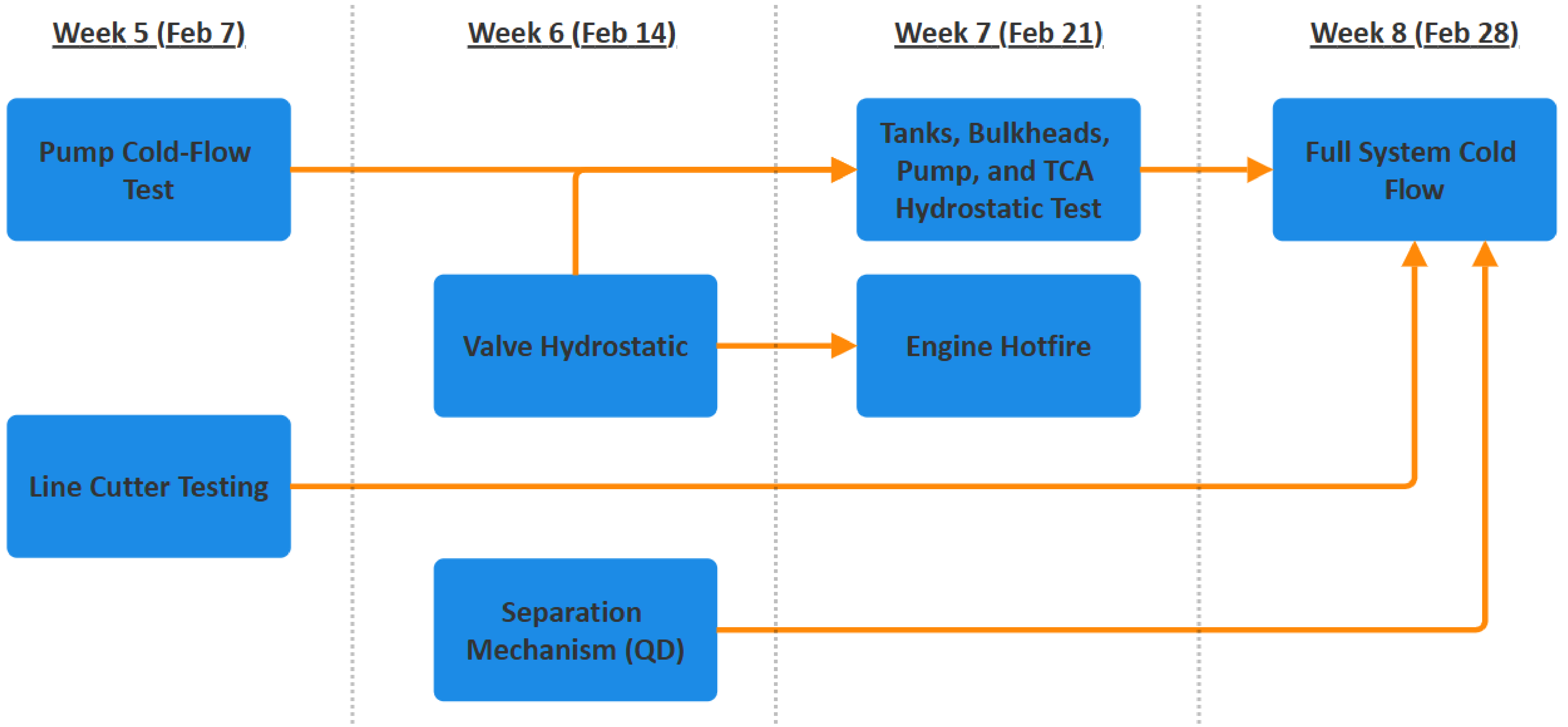


Fig 10.6 Fluids Testing Timeline

TESTING

Composites

- Compression load with load cell in the structures lab on carbon fiber tube

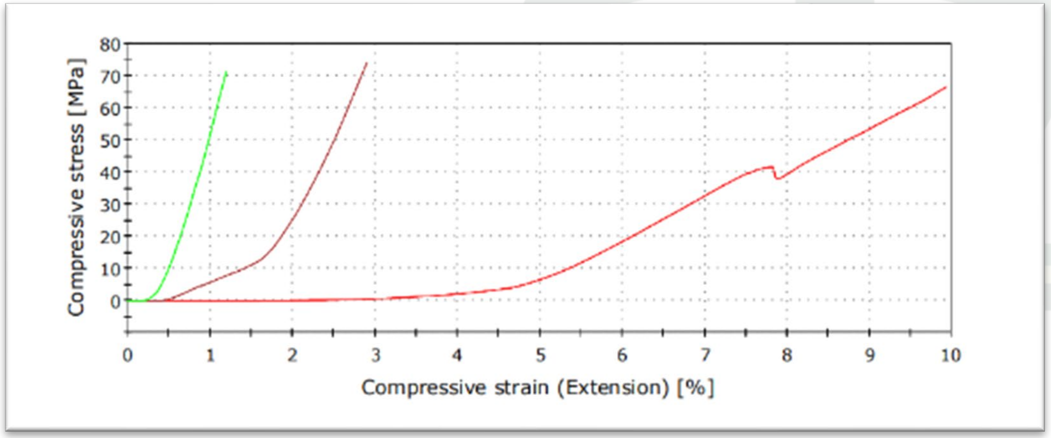


Fig 10.5 Strain vs Stress Curve

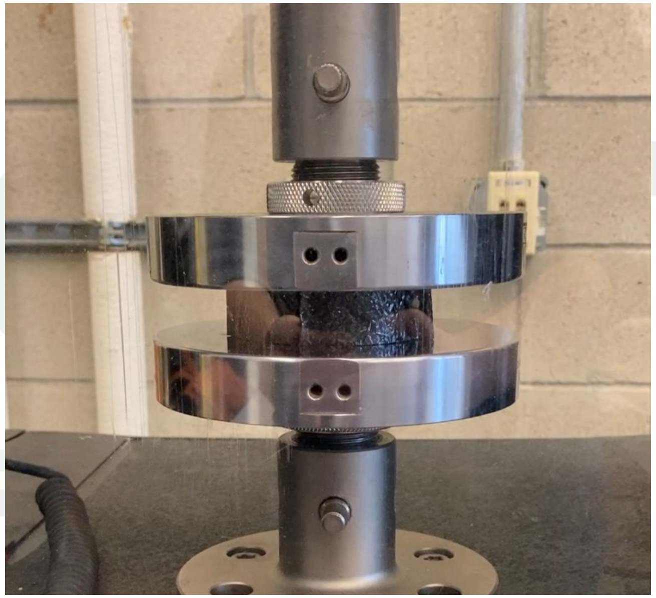


Fig 10.6 Carbon Fiber Tube Testing in Instron

Fig 10.7 Instron 5969

TESTING

Recovery

Peregrine Testing

- Previously tested system; testing will be combined in pressure vessel test

Pressure Vessel Testing

- Ensure the top coupler of the pressure vessel successfully separates from the body tube in a safe manner
- Combine with avionics system to ensure the stack can fire the peregrines

Tender Descender Testing

- Ensure the quick links of the TDs successfully detach from the housing

Fig 10.8 Successful Pressure Vessel Test

Necessary Next Steps:

- Safety procedure write ups
- Propulsion lab and black powder safety briefings

BUDGET

PROJECT BUDGET ESTIMATES (IN-PROGRESS)

Subsystem	Allotted Budget	Estimated Cost
Propulsion	$1200	$498.46
Fluids	$1900	$1045.58
Ground System Equipment	$2000	$2,261.75
Aerodynamics	$400	$212.26
Structures	$600	$498.95
Recovery	$875	$1840.26
Avionics	$500	TBD
Total	$7,475	$6358.26+ TBD

QUESTIONS?

Thank you

Cal Poly Space Systems

APPENDIX

FAR REQUIREMENTS

RBS	Requirement	Rationale
0.1	Altitude shall be determined by two commercially available recovery electronics	This is a FAR requirement
0.2	The system shall have dual deployment for recovery.	This is a FAR requirement
0.2.1	Drogue parachute shall deploy at apogee	This is a FAR requirement
0.2.2	The main parachute shall deploy below 1000 ft.	This is a FAR requirement
0.3	The system shall contain a tracker.	This is a FAR requirement. GPS telemetry, radio beacon, or other approved in advance
0.4	The system shall be recovered successfully.	This is a FAR requirement
0.5	Rocket must be rail or tower launched.	This is a FAR requirement
0.6	The rocket shall meet FAR/Mars safety requirements.	This is a FAR requirement
0.7	The system shall not exceed 250,000 feet in apogee.	This is a FAR requirement based on FAA COA