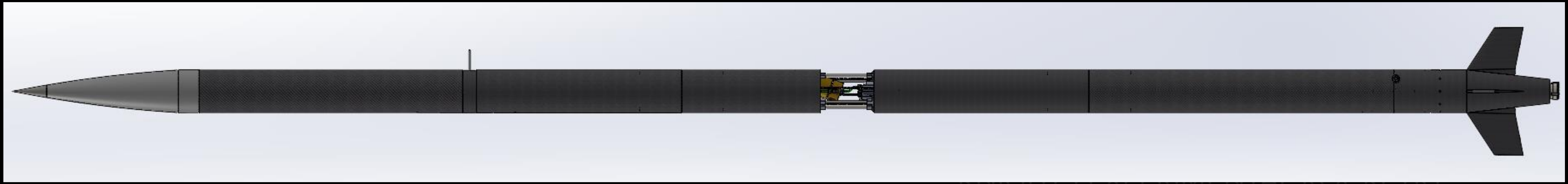
KNIGHTS EXPERIMENTAL ROCKETRY

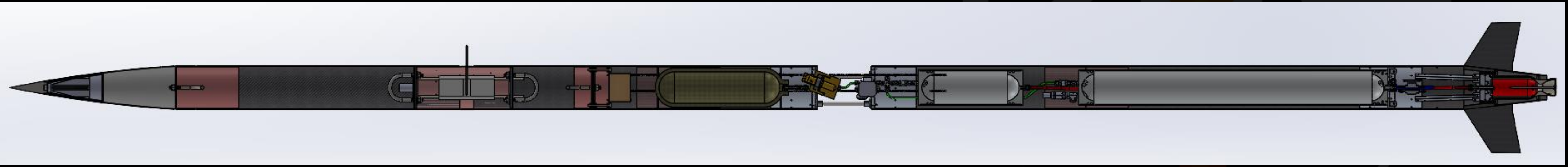
KXR

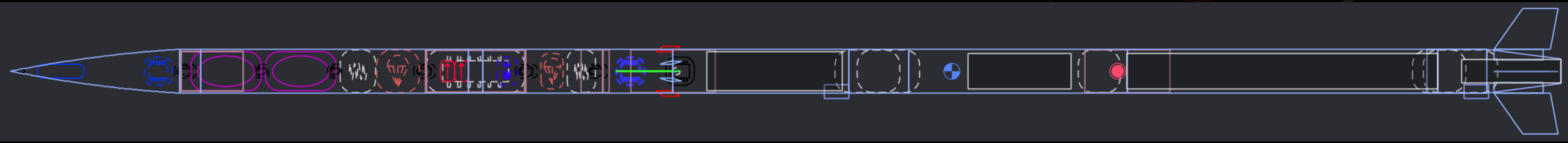
at UCF

Aerostructures CDR
FAR10k Basilisk

Aerostructures System



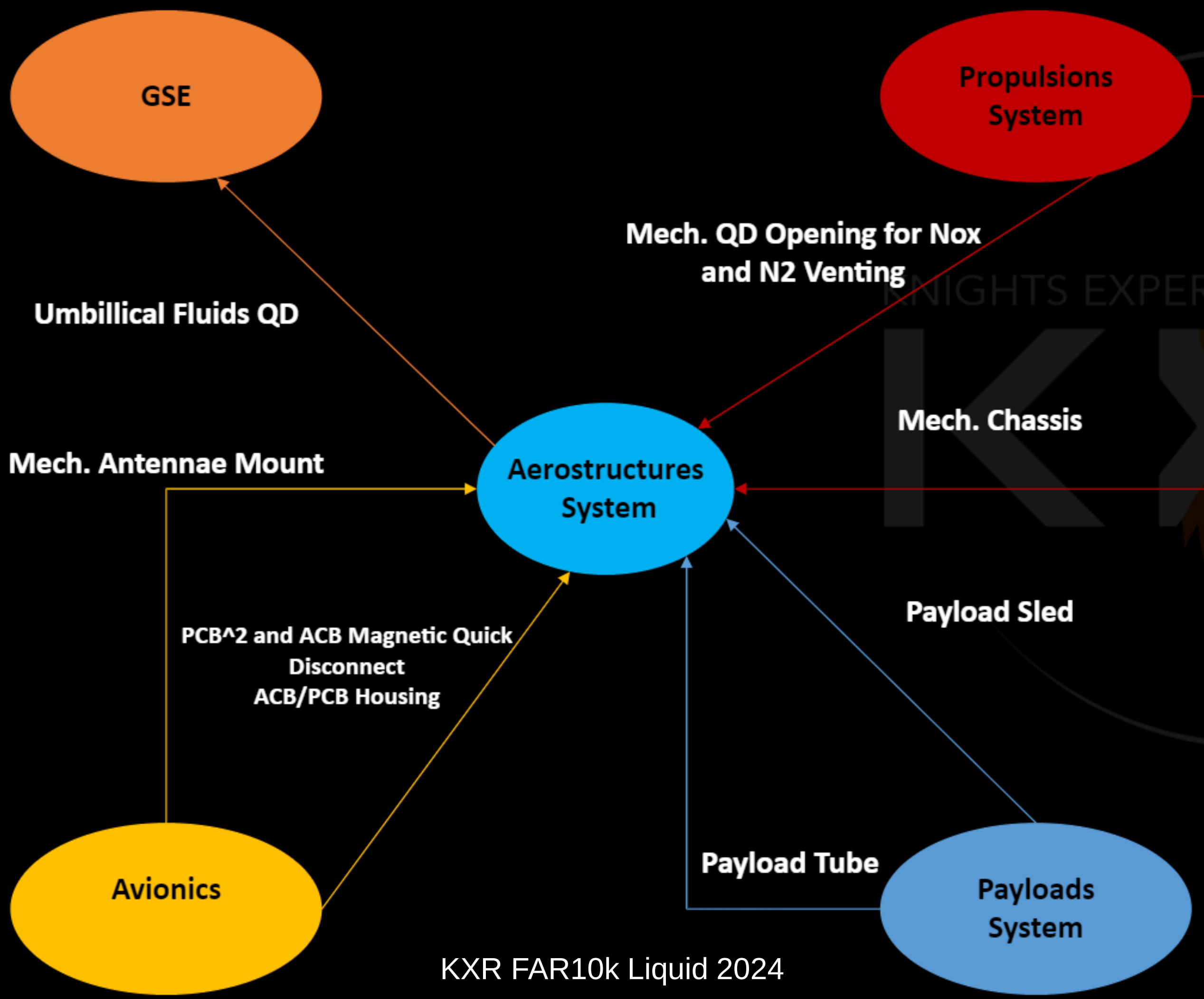




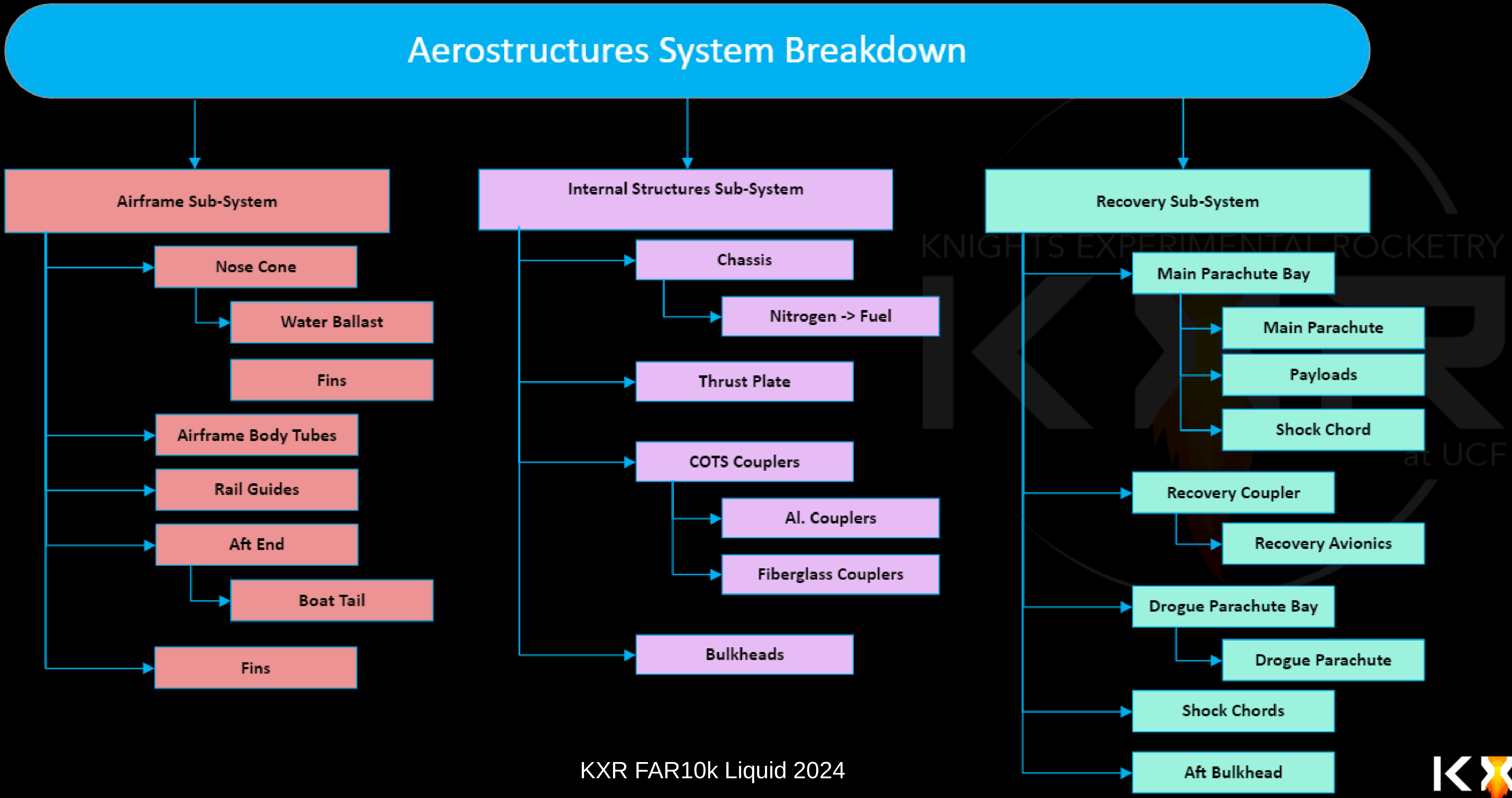
CAD and Open Rocket

KXR FAR10k Liquid 2024

Aerostructures Interface Diagram



Aerostructures Architecture



Aerostructures Function

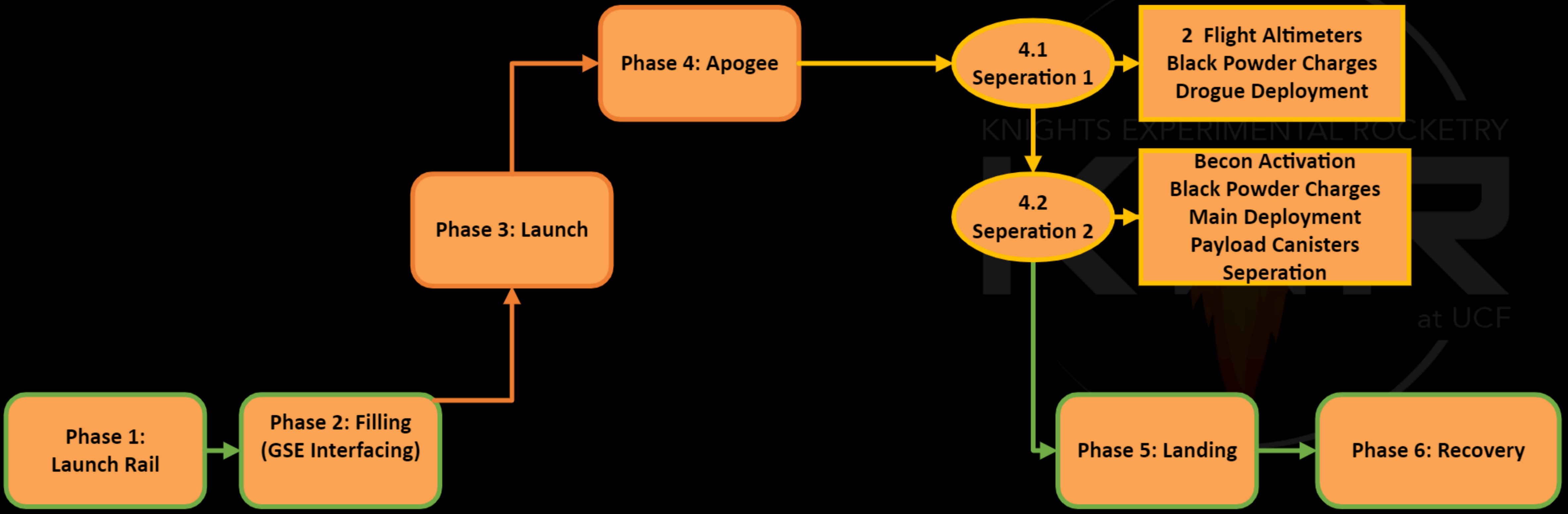
- Package all vehicle systems into a:
  - Flyable
  - Light Weight
  - Aerodynamic Structure

- Main interface for all systems of the vehicle

Aerostructures System Verification Plans

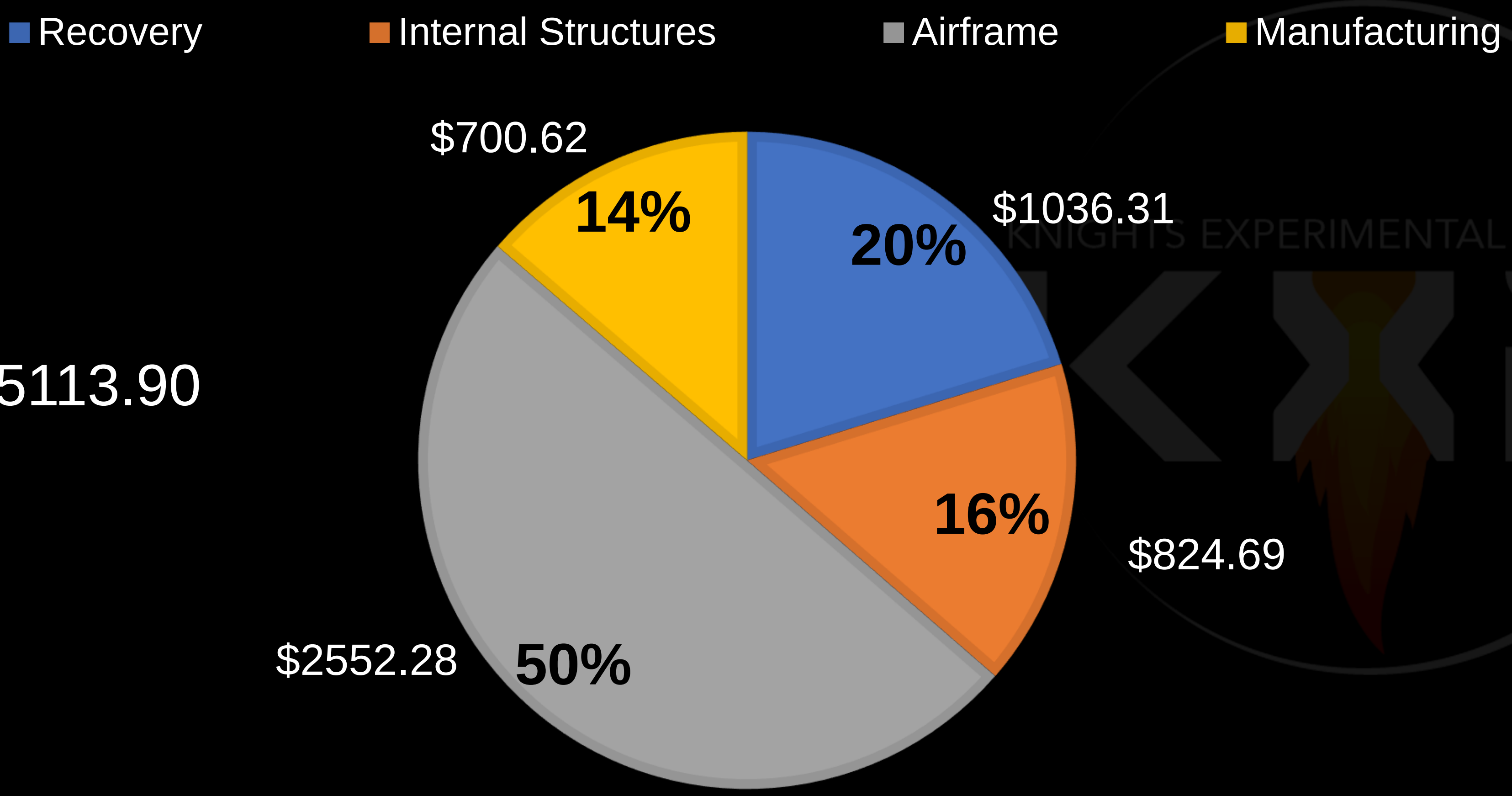
- Visual/Digital Inspection of System Interfaces
  - Accurate CAD Assembly
- FEA and ANSYS Component Load Analysis (Analysis)
- Test Article
  - Airframe and Fin Test Coupons Tested In UTM
- Dry Fitting Components (Demonstration)
- Confirmation of Dimensions and Mass (Inspection)
- Dual Deploy Recovery System Test (Test)
  - Black Powder and Shear Pin Tests

Aerostructures CONOPS



Aerostructures System Cost

Total: $5113.90



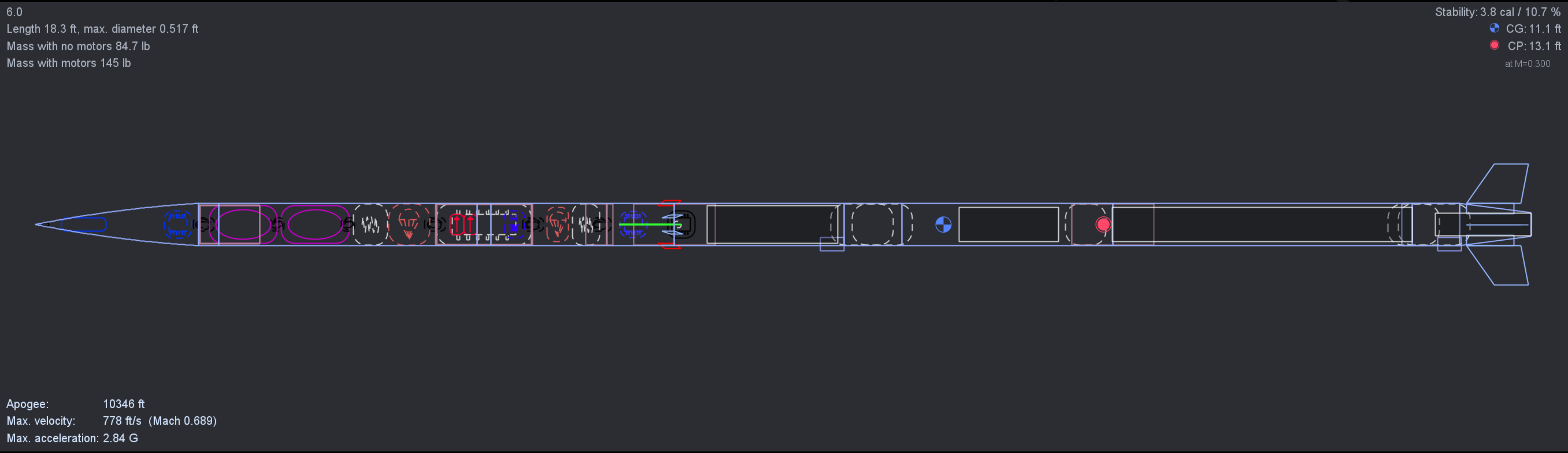
Aerostructures TPM's

Measure	TPM Value	Units	Verification Method
Snatch Force	1954	lbf	Demonstration
Max Bending Moment	7173	lb-in	Analysis
Max Compressive Load	21309	lbf	Analysis
Lateral Shear	122	lbf	Analysis
Drag Coefficient	0.75	n/a	Analysis

Aero TPMS Cont. (Dimensions)

Measure	TPM Value	Units	Verification Method
Total Length	18.3	Ft	Inspection
Inner Diameter	6	in	Inspection
Total Wet Mass	145	lbf	Inspection
Dry Mass	66	lbf	Inspection
Stability	12% (3.8)	CAL	Simulation

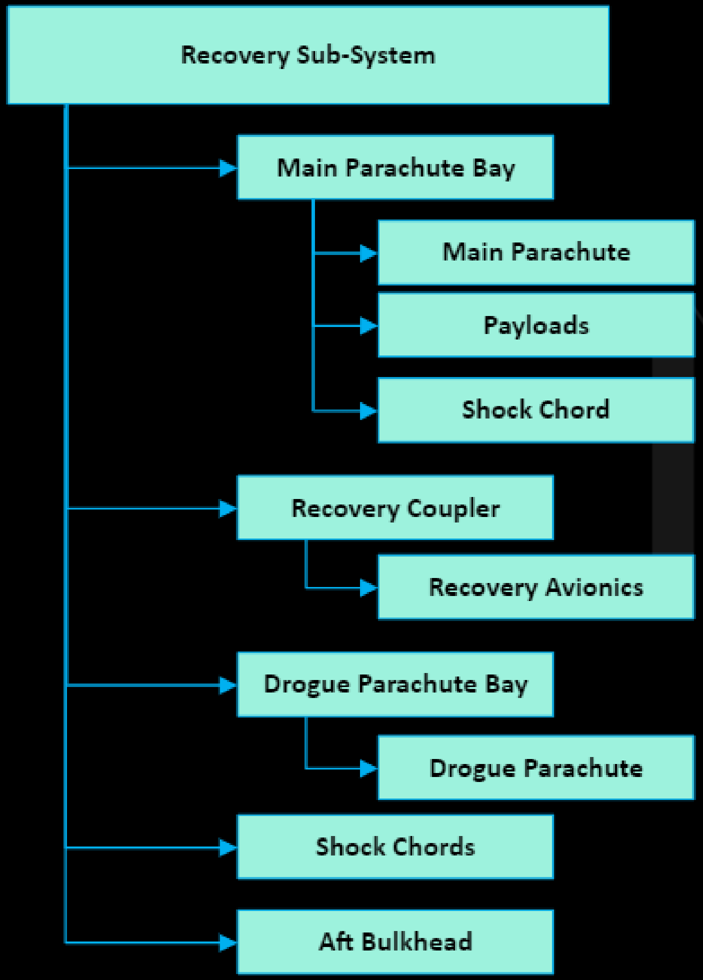
Aerostructures TPM's



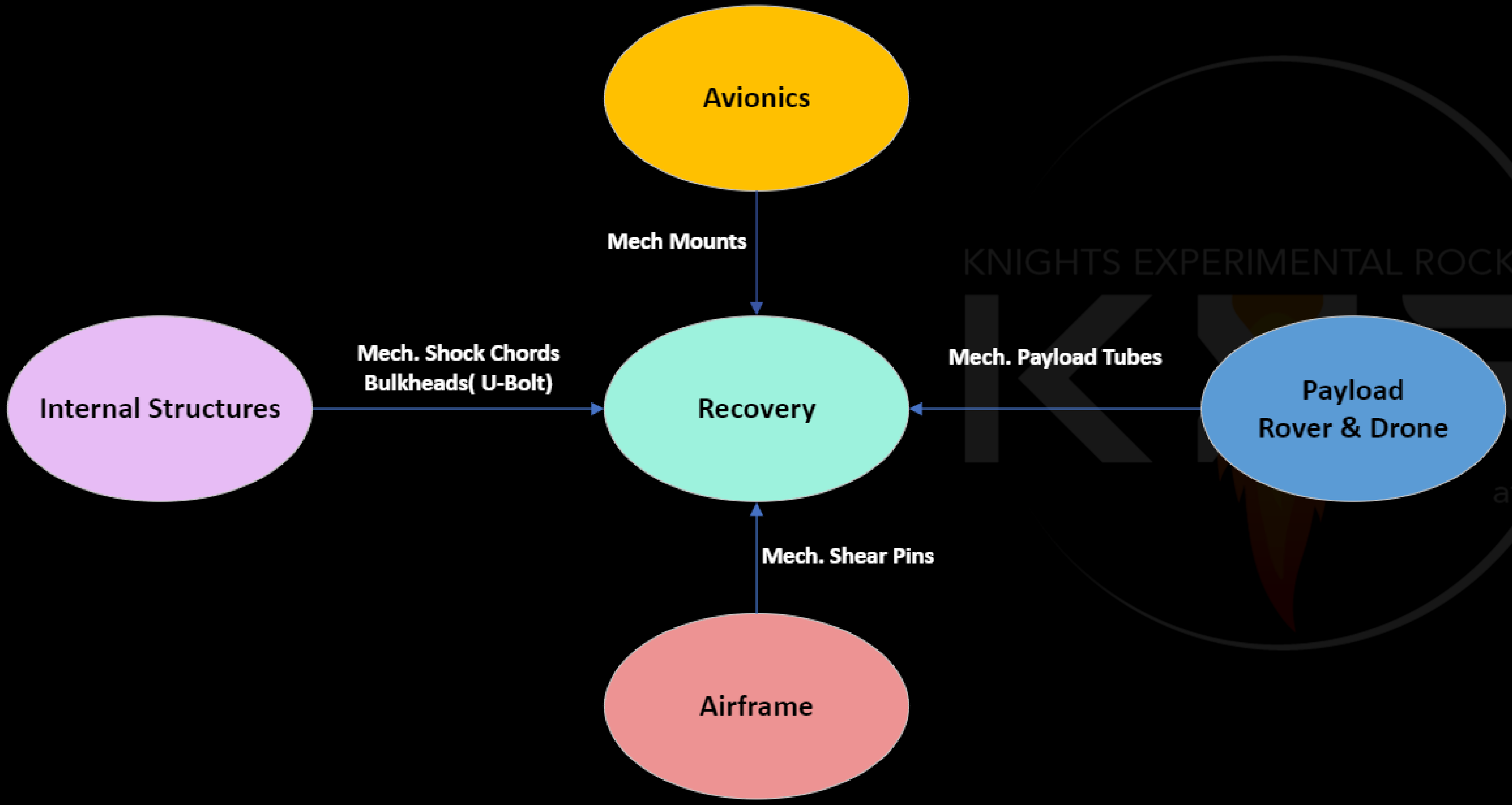
Aerostructures System FMECA

Sub-System	Failure	Criticality	Effect	Mitigation
Recovery	Failure to Recover	Medium	Failure to Deploy Parachutes and Payload	Testing Campaign and Designed Redundancy
Internal / External	Structural Failure During Flight	High	Rapid Unscheduled Disassembly	FEA and Hand Calculations. Coupon Testing
Flight Dynamics	Instability During Flight	Medium	Rocket Becomes Instable During Flight	Design and Testing of Fin Coupons

Recovery Component Breakdown



Recovery Interface Diagram



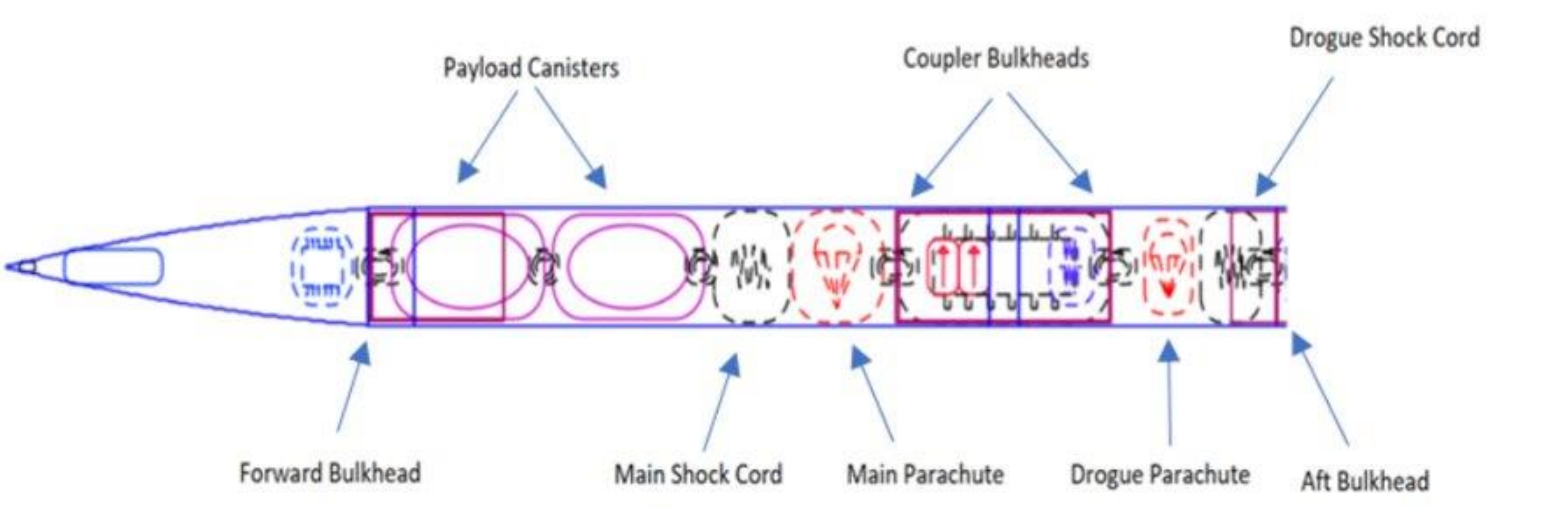
Recovery Functional Requirements

Requirement	Requirement Type	Verification Method
The Recovery System **shall** have redundancy	Functional	Demonstration
The Recovery System **shall** be visible during descent	Functional	Demonstration
The Recovery System **shall** have a dual-deploy system	Functional	Inspection
The Recovery System **will** create a safe controlled descent for the vehicle	Functional	Demonstration

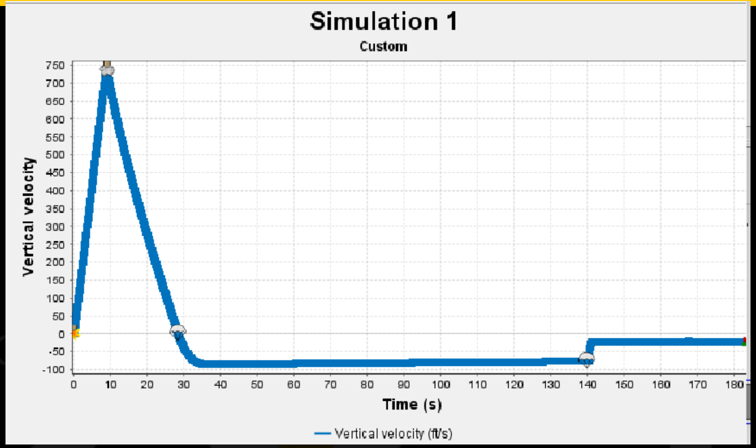
Recovery TPM's

Measure	TPM Value	Units	Verification Method
Snatch Force	1953.439059	Lbs.	Demonstration
Size of Recovery compartment	36” main+11” drogue	in	Inspection
Packing Length of Chutes	199.9	cu. in.	Inspection
Descent Rate	D: [75] M: [20]	Ft/s	Test
Shock Chord Length	1345	In	Inspection

Recovery Breakdown



Main Chute



- We are using a Skyangle Classic Cert 3 XXL as our main parachute
  - Uses 4 shroud lines
  - CD of 2.92, which gives us a final descent speed at 21.4 ftps
  - Deploys at 800ft
  - Total flight time of 220s (3 minutes 40 seconds)
  - Used OpenRocket to validate, using coordinates of the launch site, 100 degree ambient temperature and up-to-date vehicle characteristics
- We are attack the parachutes with fisherman knots and quick links
- We are using DB-XXL Main Deployment Bag as our fire blanket
- Deploy velocity at 76ftps

Drogue

We are also looking at reusing a parachute from another project as our main to save costs; final decision is pending on our final cost vs budget and discussions with the other projects.

- Descent speed of 75fps
- Coefficient of Drag 1.87
- Deploys at apogee
- Nominal deploy velocity at 0 ftps, horizontal velocity expected to be below 100 fpts, will depend on angle off the rail and wind

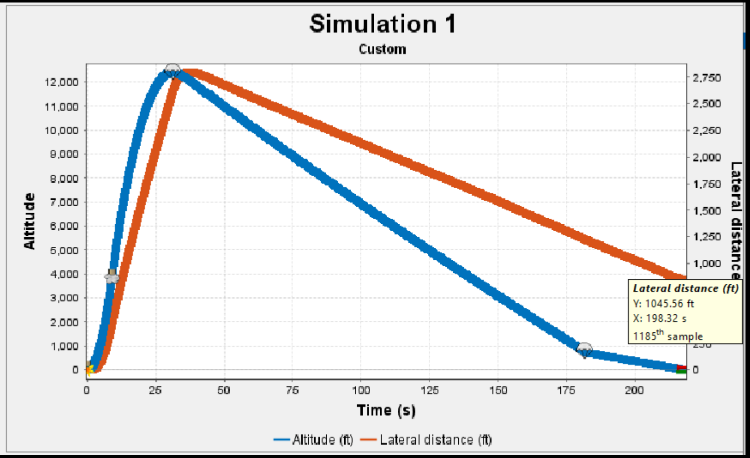
- Used OpenRocket to find a parachute in acceptable price range with a descent speed of 75ftps
- We attach the Drogue shroud lines to the quick link through Alpine Butterfly Loop
- We are using Medium SkyAngle Deployment Bag as our fire blanket.

Parachute Drift Analysis

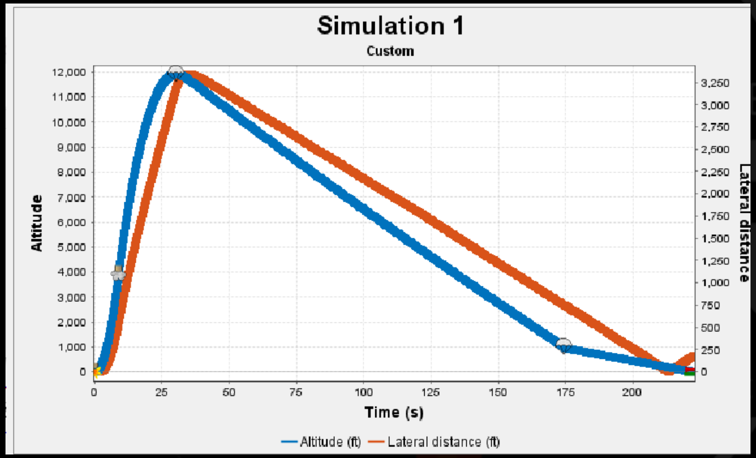
According to National Oceanic and Atmospheric Association, for **Mojave, CA:**

- Max Windspeed 13mph
- Average Windspeed 7mph

Both drift simulations take weathercocking into account with a 90* launch angle, the real radius will depend on launch angle of the rail and if the rocket remains straight off the rail

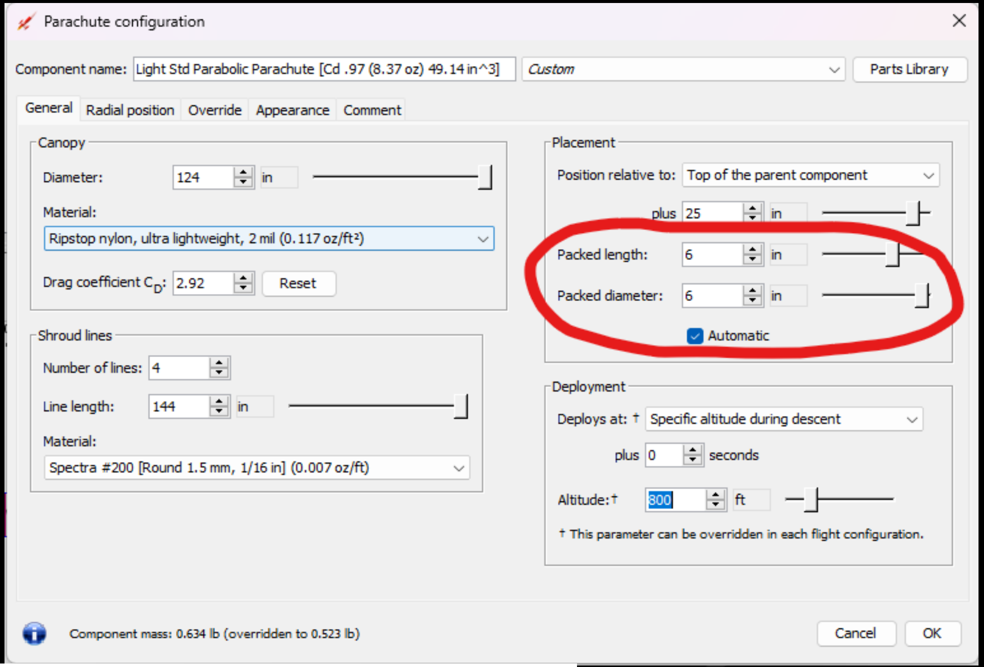


Average Windspeed:
Expected drift radius of under 1000 ft with wind conditions of 7.5mph

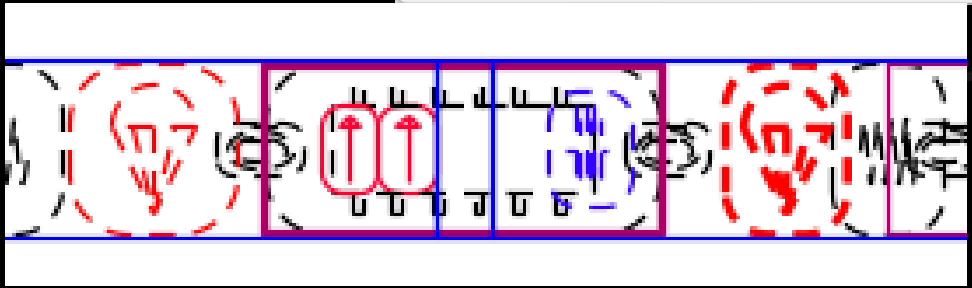


Peak Windspeed:
Expected drift radius of under 500 ft with wind conditions of 13mph

Parachute Packing lengths

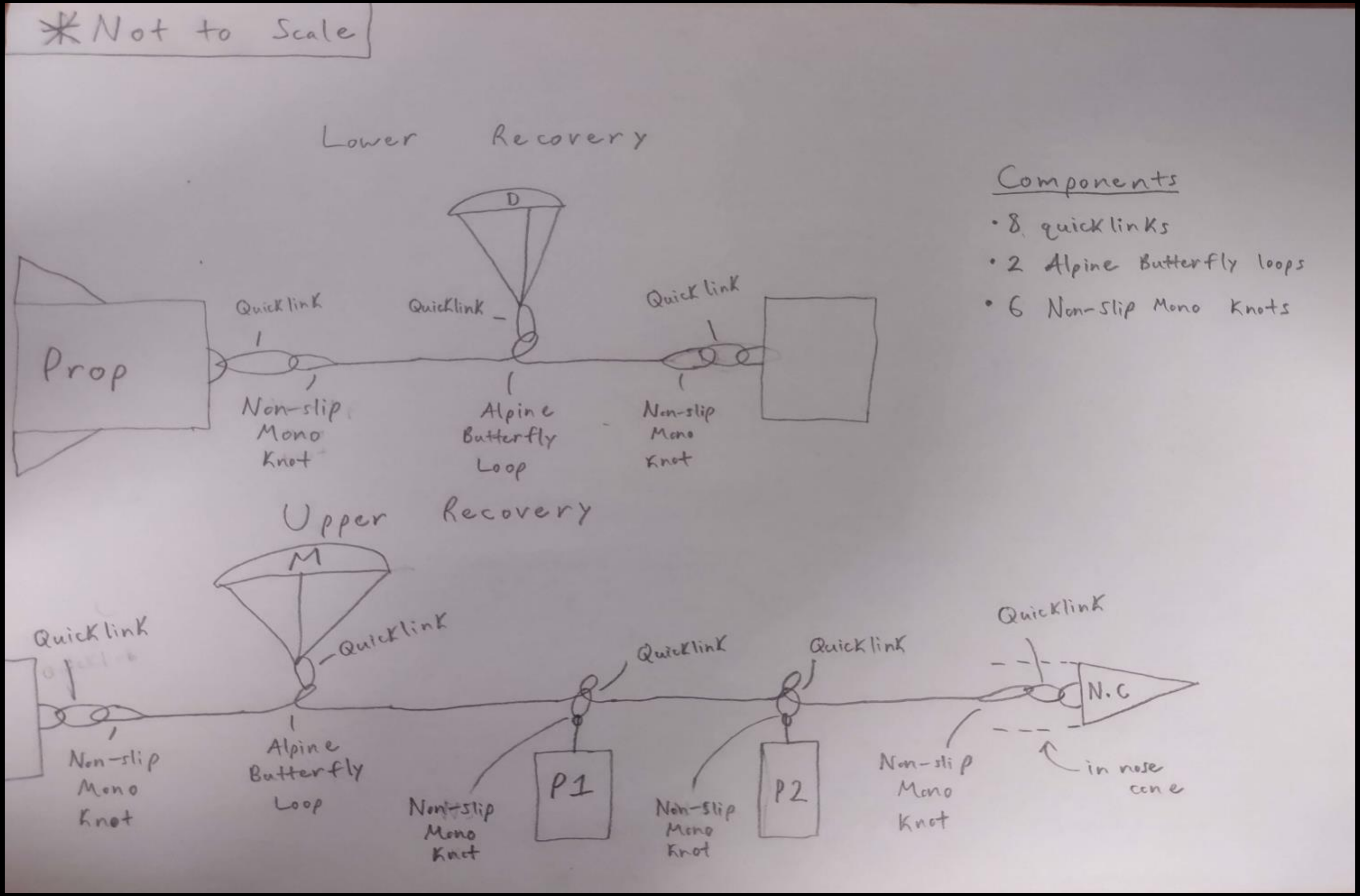


Drogue chute packing volume:
Under 3 inches in length in a 6" airframe



Main chute packing volume:
6 inches in length in a 6" airframe

Shock Cords



The recovery system will contain:

- 117 ft of ¼ " Kevlar shock cord
- 8 quick links
- 4 Alpine Butterfly Loops
- 4 Non-slip Mono Knots

Each knot will be epoxied for extra strength.

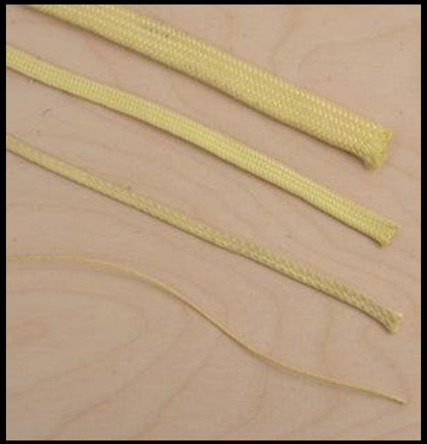
These components will provide the best chance of the system working as intended and not failing during execution.

Shock Cords

- We are using quick links and two types of fisherman knots to prevent tangling of the payloads.
- There will be rails developed by payloads inside to prevent tube knocking.
- We will have a beacon in the main compartment, but we are waiting on LTI for dimensions.

Material	Safety Factor
¼" Kevlar shock cord	1.5
½" Quick link	1.69

¼" Kevlar shock cord
Max Load 3000 lbs
Price: $143.52 (144 yards)



1/2 in. Zinc-Plated Quick Link
Max Load 3,300 lbs
Price: $50.16 (8)

Non-Slip Mono Knot

Alpine Butterfly Loop

- Order of hitting the ground: The bottom of the rocket (prop), coupler, nose cone, payloads

Shock Cords

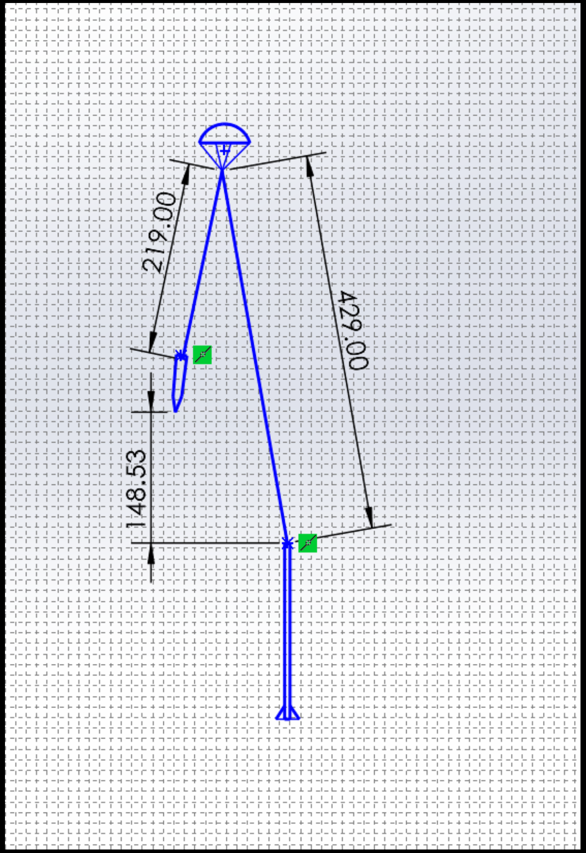
Drogue:
Total Shock cord length (3 x length of Rocket): 648"

Drogue to upper body: 219"

Drogue to lower body: 429"

Clearance from upper body to lower body: 140" (Safety Factor of 2)

Rocket length: 216"



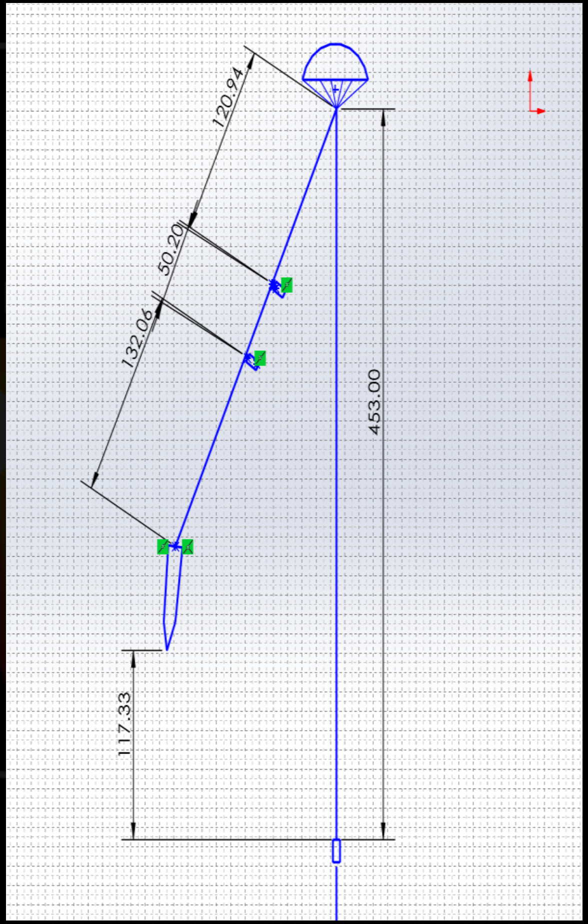
Main:
Total Shock cord length (3.5 x length of Rocket): 756"

Parachute to Payload 128"

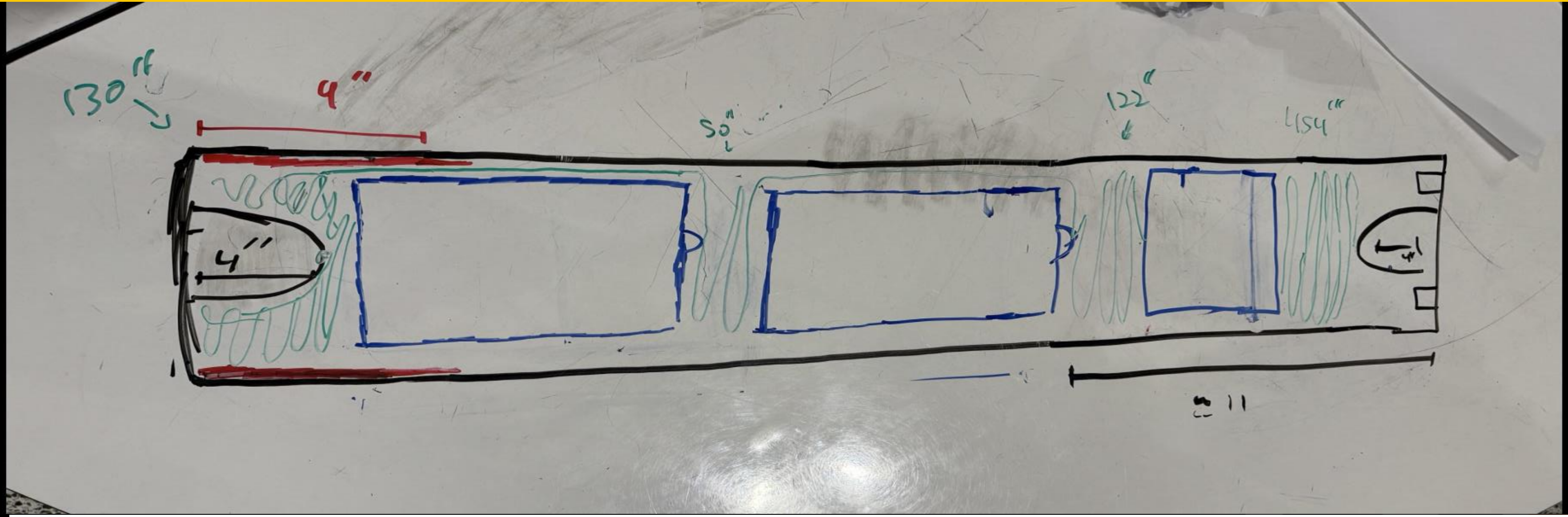
Distance between payloads: 50" Sf(3)

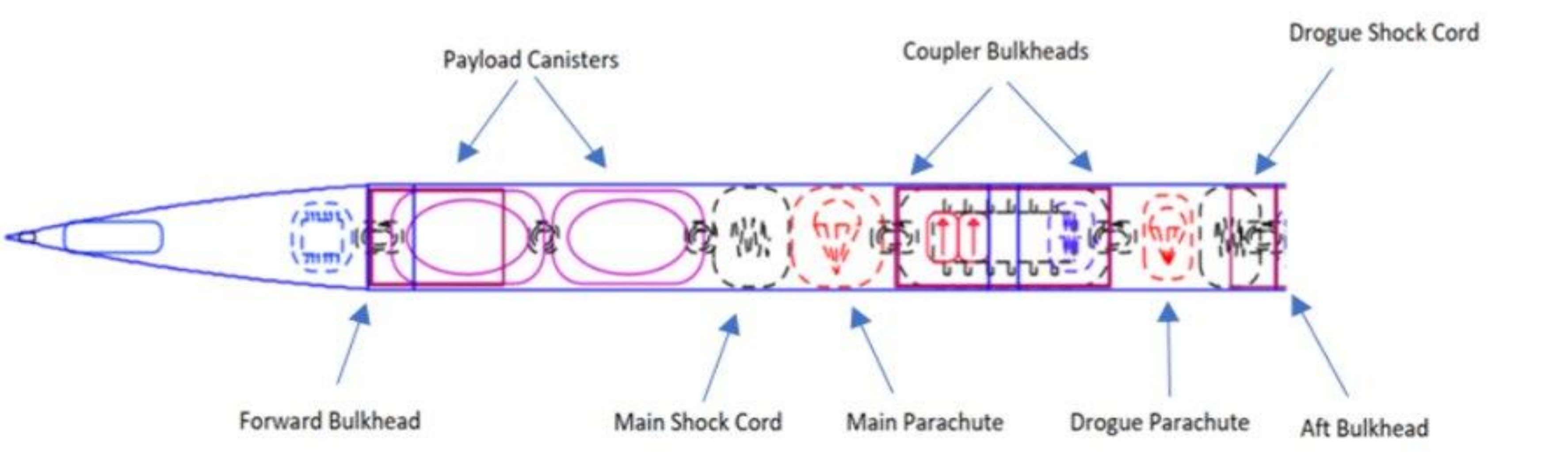
Payload to Nosecone: 113" Sf(1.5)

Nosecone to Coupler: 176" Sf(1.7)



Recovery and Payloads Interface





Payload dimensions

- 5.5" Diameter
- Rover Canister: 11" length
- Drone Canister: 11"

Recovery Dimensions

- 6" Diameter
- 36" Length

Shock Cord Length

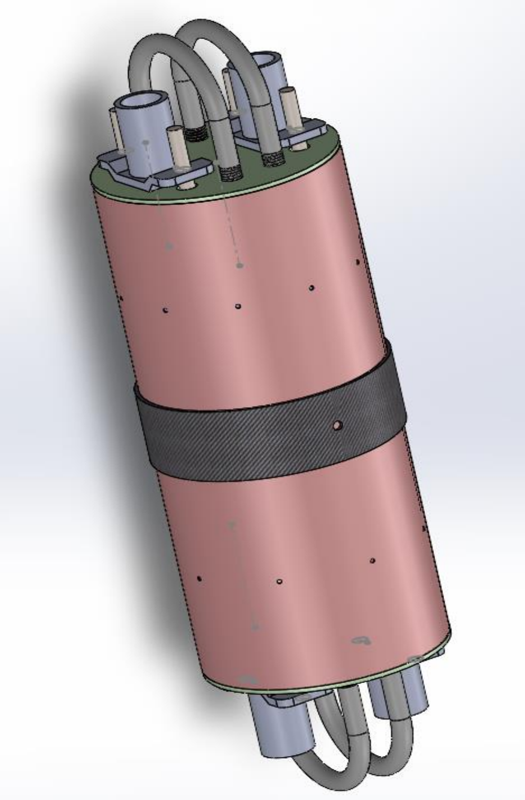
- 117 ft of ¼ " Kevlar shock cord

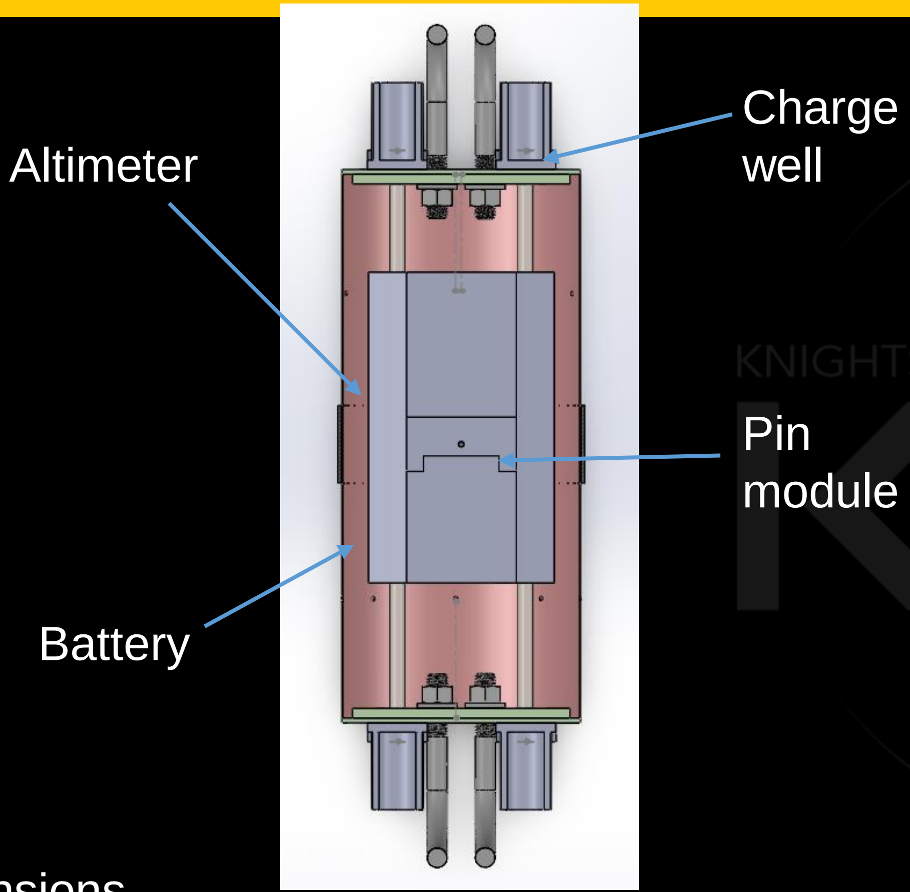
Available space for Recovery after Payloads: 14" length

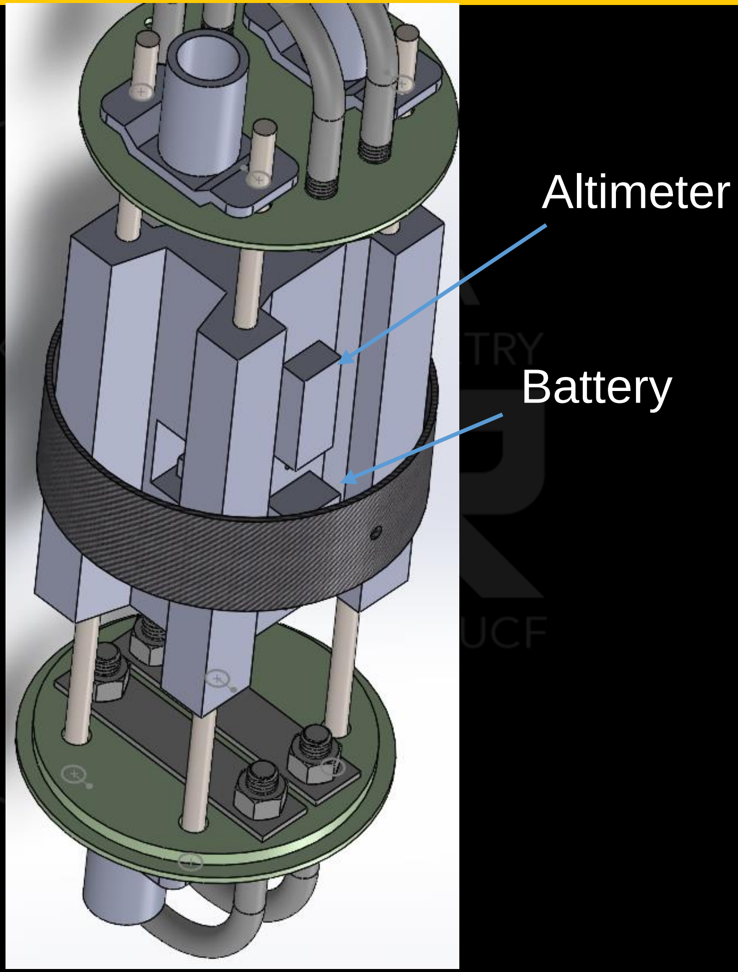
FMECA

Part	Failure	Criticality	Effect	Mitigation
Shock Chords	Snap	High	No Controlled Descent	Apply Safety Factor
Quick Links	Snap	High	No Controlled Descent	Apply Safety Factor
Shock Chords	Snap due to stress caused by heat	High	No Controlled Descent	Kevlar Shock Cord (heat resistant)
Shock Chords	Tangling With Payloads	High	Damage to the Rocket	Rail System for Payload
Shock Chords	Improper Shock Cord Lengths	Medium	Damage to the Rocket	Verify Lengths via Testing prototype
Shock Chords	Damage to Body Tube	High	Shredding of Shock Cord	Wrap or cover area of body tube where shock cord lies with duct tape.

Recovery Coupler







Dimensions
- Outer Diameter 5.998"; Inner Diameter 5.820"
- 14.25 inch length

Coupler Costs

Material	Dimensions	Cost
G12 Fiberglass tube	Outer Diameter 5.998"; Inner Diameter 5.820"	$99.00 madcowrocketry.com
4 Zinc-Plated Threaded Rod	3/8 in.-16 tpi x 24 in. Zinc-Plated Threaded Rod	$3.47 Home depot
High-Strength Steel Nylon-Insert Locknut (20 pack)	Grade 8, 3/8"-16 Thread Size	$4.50 Mcmaster.com
18-8 Stainless Steel Washer (100 pack)	3/8" Screw Size, 0.406" ID, 0.875" OD	$7.33 Mcmaster.com
PVC Pipe	3/8 in. x 5 ft. White PEX-B Pipe	$2.97 Homedepot
Shearpins (100 pack)	Nylon Pan Head Screws Phillips, 4-40 Thread, 1/2" Long (100 pack)	$8.97 Mcmaster.com
Helical Insert (10 pack)	18-8 Stainless Steel Helical Insert, 4-40 Right-Hand Thread, 0.280" Long (10 pack)	$4.71 Mcmaster.com
	Total	

Recovery Coupler

- Shear pins
- 10 Nylon Pan Head Screws Phillips for Main parachute deployment
- 8 Nylon Pan Head Screws Phillips for Drogue parachute deployment
- Helical inserts to prevent thread stripping

Bolt Selector (select yellow box for dropdown)

	Bolt Type	Max Force (lbs)	Min Force (lbs)	MinorA (in^2)	Max Stress (psi)	Min Stress (psi)
Drogue	#4-40	76	50	0.005191238	14640.05201	9631.613167
Main	#4-40	76	50	0.005191238	14640.05201	9631.613167

Inputs

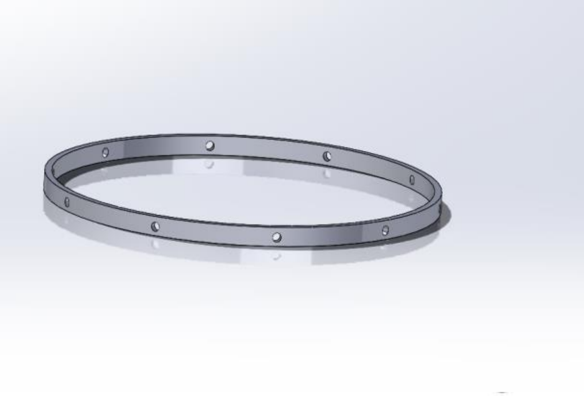
Rocket ID (drogue) (in)	Rocket ID (main) (in)	Empty Length (drogue) (in)	Empty Length (main) (in)	Launchpad Height (ft)	Rocket Apogee (ft)
6	6	11	30	2762	16000

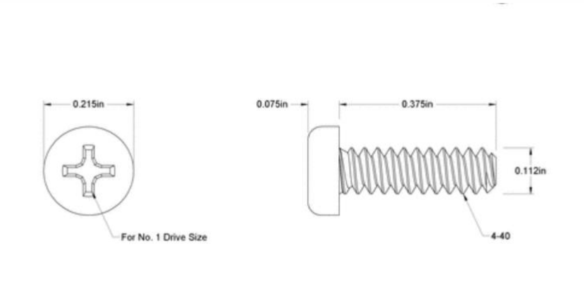
Calculated Outputs

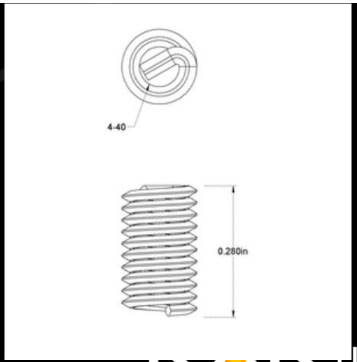
Temperature1 (F)	Temperature2 (F)	Atm. Pressure1 (psi)	Atm. Pressure2 (psi)	Ref Area Drogue (in^2)	Ref. Area Main (in^2)	
49.16728	-7.79272	13.30169173	7.127427439	28.27433388	28.27433388	< Temp/Pressure equations work up to 36152ft above sea lvl

Drogue	
Drag Top (lbs)	66.49
Drag Bottom (lbs)	105.81
Delta Drag (lbs)	39.31984546
Sep. Force (lbs)	174.57321
Bolt Safety Factor	1.5
Bolts	4.277861109
Bolts (rounded w/ SF)	**8**
Black Powder Safety Factor	2
Black Powder (grams)	3.448608579
Black Powder (SF) (grams)	**6.9**

Main		
Drag Top (lbs)	49.67	< Add up drag below and above separation point (where it shears) to find your drag diff.
Drag Bottom (lbs)	105.81	
Delta Drag (lbs)	56.13761346	
Sep. Force (lbs)	174.57321	
Hanging Section Weight (lbs)	20	< Weight of section being held by main shear bolts after drogue deployment
Bolt Safety Factor	2	
Bolts	4.614216469	
Bolts (rounded w/ SF)	**10**	
Black Powder Safety Factor	1.8	
Black Powder (grams)	11.75662016	
Black Powder (SF) (grams)	**21.2**	

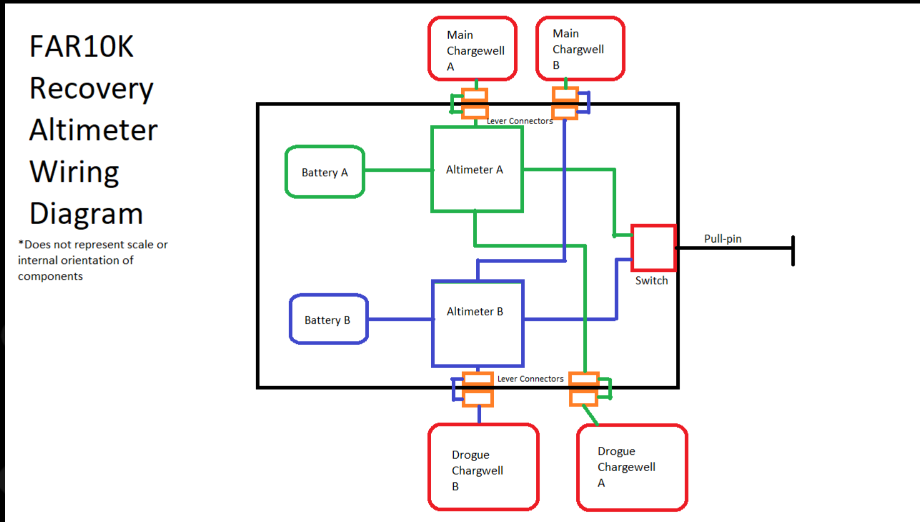


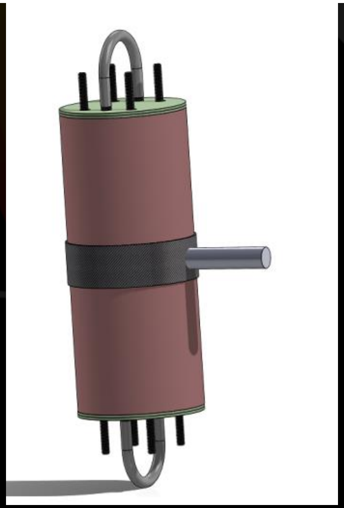




Recovery Avionics General Architecture

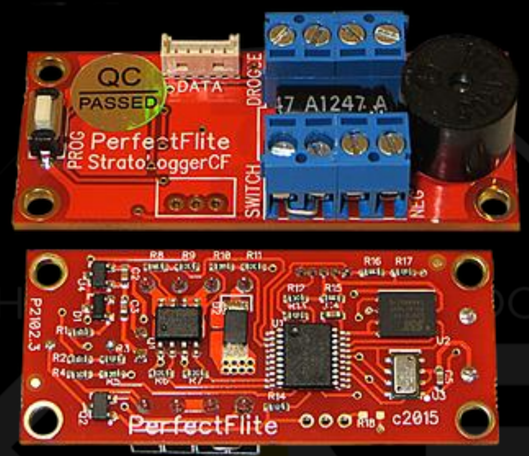
- Recovery system will use a fully dual redundant avionics system to deploy parachutes
- Both altimeters are fully able to deploy both parachutes
- Both powered by 9v batteries
- Nominal powered-on period of over 15 hours
- Avionics sit on a sled within the recovery coupler
- A pull-pin will activate the avionics system before flight, accessible from outside of the coupler; through vent hole

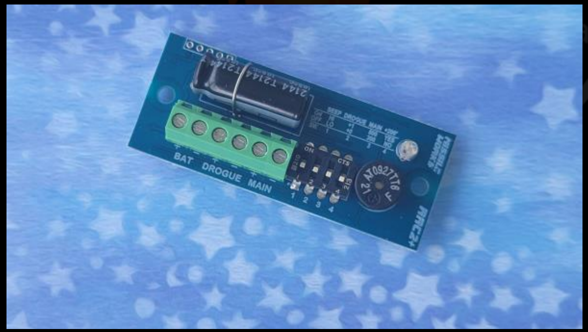




Recovery Avionics - Altimeters

- Stratologger CF – Already owned by KXR
  - 1.5mah consumption, over 100 hours of nominal life
  - Samples atmosphere 20 times per second
  - Dual-Deploy computer
- Missileworks RRC2+ - Already owned by KXR
  - 35mah consumption, 15 hours of nominal life
  - Dual-Deploy computer
- Back-up: Stratologger



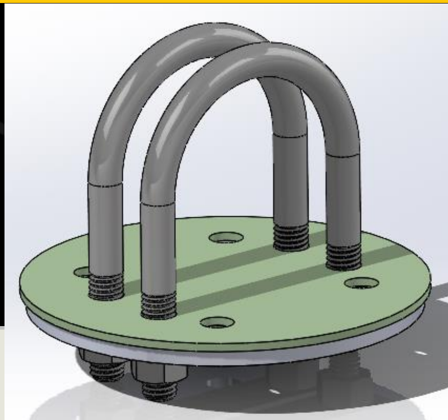


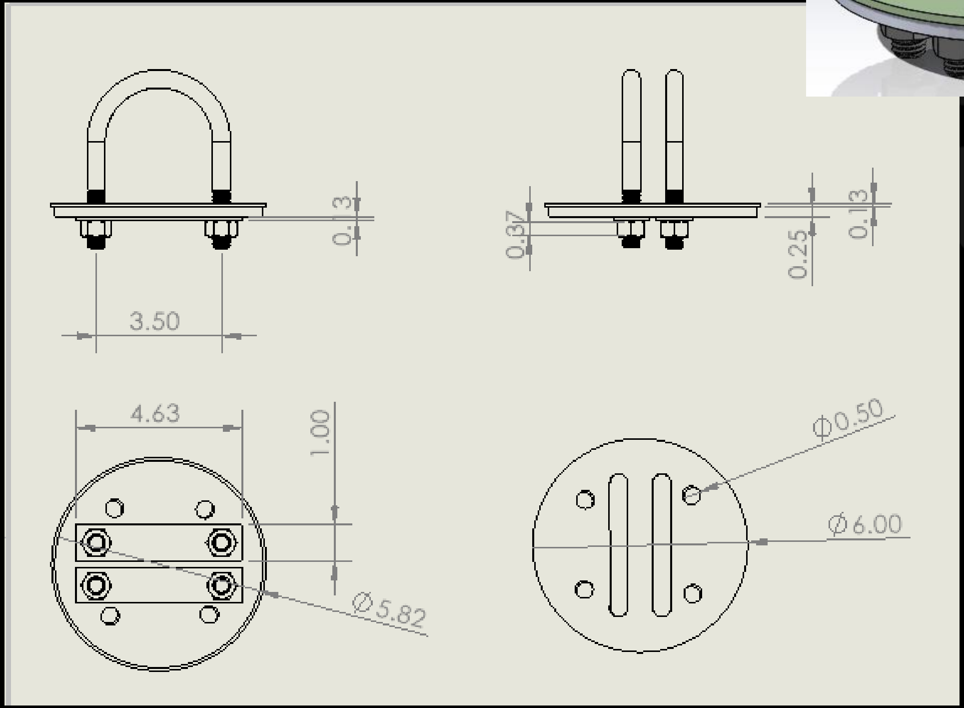
FMECA

Part	Failure	Criticality	Effect	Mitigation
Threaded Rods	Shearing	High	Coupler Failure	PVC Piping to cover the rods, stronger nuts to withstand snatch force.
Altimeters	Detonating charges late	High	Parachute(s) deploy at high velocity or too late	Ground testing of altimeters
Altimeters	Does not detonate charges	High	Parachute(s) do not deploy	Ground testing of altimeters
Parachute	Parachute failure (rip, does not unfold)	High	Unsafe descent	Proper packing procedure, analysis of velocity at deployment

Recovery Bulkheads

- Materials: G10 (FR4) Fiber glass plate, Black Oxidized Steel U-bolts, ½ " nuts and washers, wire quick connect, and wood Bulkhead lip
- Safety factors:
  - U-bolt- 1.02 - Excel calculated
  - Bulkhead Plate: 13.7 - Excel calculated
  - Shear force per bolt: 211 – Excel calculated
- Due to the low SF there will be 2 U-bolts to counteract it
- With 2 U-bolts the force will be distributed over a larger surface area
- Forces: Snatch - Bolt shear (1389 PSI), Shear Force per bolt (14.27 PSI)



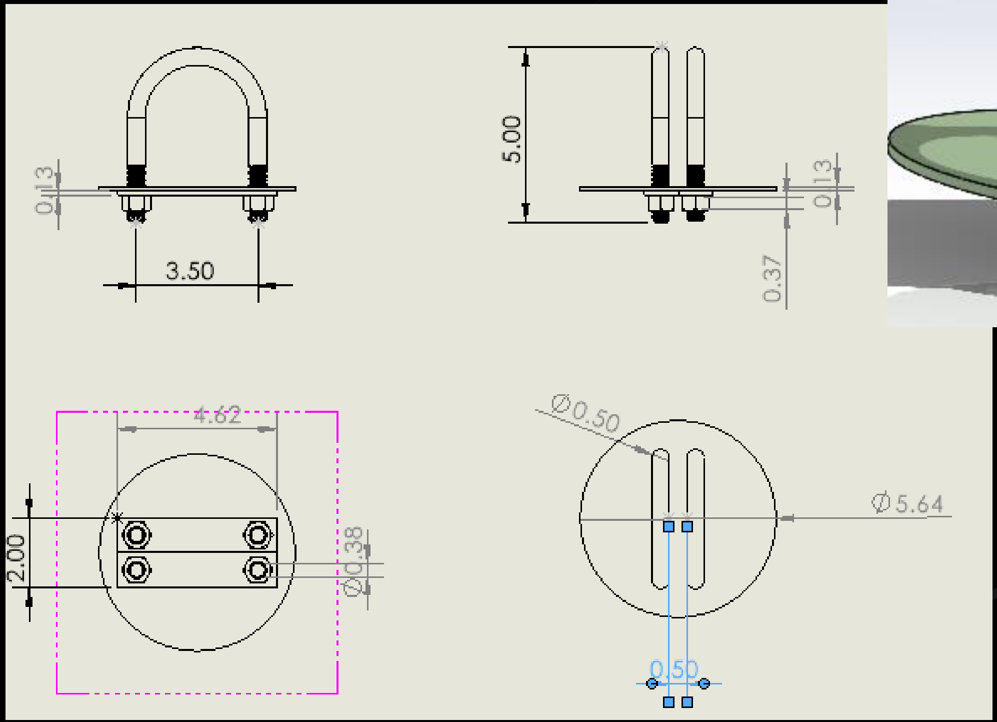


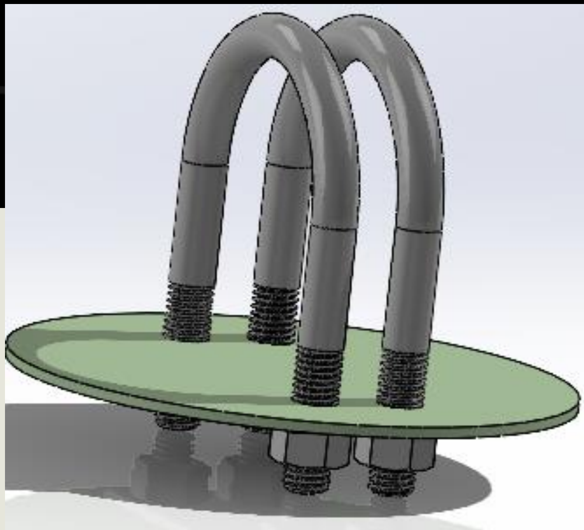
$$F = 0.5 * r * v_d^2 * C_d * A_m$$

Snatch Force (N)	Snatch Force (lbs)	SF	Focre*SF (lbs)
5606.019256	1260.283264	1.55	1953.439059

Recovery Bulkheads

- Attachments:
  - Recovery Coupler – 3/8" rods with lock nuts to secure
  - Body Bulkheads – secured in place by G12 couplers in body sections
- Verifications – Excell calculators and physical tests
  - Using values from open rocket, other calculators, and manufacturers
  - Physical Test
- Forces applied:
  - Main areas: U-bolt, threads, and bulkhead plate
  - Transfer of Forces: Quick link > U-Bolt > back plate > Lip > BH Plate





FMECA

Part	Failure	Criticality	Effect	Mitigation
U-bolt	Snaps	High	Vehicle Disassembly	The U-bolt has a Safety factor 1.02 thus 2 U-bolts are being used
Bulkhead Plate	Bolt Tear	High	Vehicle Disassembly	13.7 Safety Factor on the Bulkhead

Bulkhead Cost

Part	Quantity	Cost
U-bolt/nuts(2)/back plate	8	$46.53
G10(FR4)	1x0.125" x 12" x 24" sheet	$42.11
Nuts ½ in	16	$11.04
Washers ½ in	16	$11.04
Wire quick connect	2	$12.99
Hardpoint wood	1 2ft x 4ft plank	$5.15

Black Powder

- Calculated Black powder by using values from open rocket (Fin height root chord Tip Chord & Pressure Base and Friction Coefficient) plugging into the aerodynamics forces we get drag top and bottom for drogue and main.
- Then we use drag top and bottom and use the black powder calculator
  - We used black powder safety values of 2 for drogue and 1.8 for main
  - Bolt safety of 1.5 for drogue and 2 for main.
  - We also got Rocket ID, length and hanging sections weight from Open rocket
- We will be using 6.9 Grams of black powder for the drogue and 21.2 grams of black powder for the Main

Bolt Selector (select yellow box for dropdown)	Bolt Type	Max Force (lbs)	Min Force (lbs)	MinorA (in^2)	Max Stress (psi)	Min Stress (psi)
Drogue	#4 40	76	50	0.005191238	14640.05201	9631.613167
Main	#4 40	76	50	0.005191238	14640.05201	9631.613167

Inputs

Rocket ID (drogue) (in)	Rocket ID (main) (in)	Empty Length (drogue) (in)	Empty Length (main) (in)	Launchpad Height (ft)	Rocket Apogee (ft)
6	6	11	30	2762	16000

Calculated Outputs

Temperature1 (F)	Temperature2 (F)	Atm. Pressure1 (psi)	Atm. Pressure2 (psi)	Ref Area Drogue (in^2)	Ref. Area Main (in^2)	
49.16728	7.79272	13.30169173	7.127427439	28.27433388	28.27433388	< Temp/Pressure equations work up to 36152ft above sea lvl

Drogue	
Drag Top (lbs)	66.49
Drag Bottom (lbs)	105.81
Delta Drag (lbs)	39.31984546
Sep. Force (lbs)	174.57321
Bolt Safety Factor	1.5
Bolts	4.277861109
Bolts (rounded w/ SF)	8
Black Powder Safety Factor	2
Black Powder (grams)	3.448608579
Black Powder (SF) (grams)	6.9

Main		
Drag Top (lbs)	49.67	< Add up drag below and above separation point (where it shears) to find your drag diff.
Drag Bottom (lbs)	105.81	
Delta Drag (lbs)	56.13761346	
Sep. Force (lbs)	174.57321	
Hanging Section Weight (lbs)	20	< Weight of section being held by main shear bolts after drogue deployment
Bolt Safety Factor	2	
Bolts	4.614216469	
Bolts (rounded w/ SF)	10	
Black Powder Safety Factor	1.8	
Black Powder (grams)	11.75662016	
Black Powder (SF) (grams)	21.2	

Coefficient Inputs

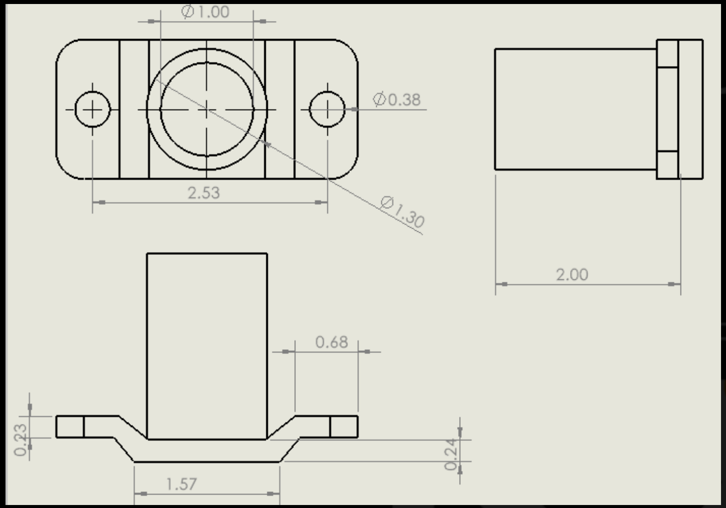
Componen	Pressure Cd	Base Cd	Friction Cd	Total Cd	Drag (lbf)	Cn α	Cn	Lift (lbf)
Nose Cone	0.04	0.00	0.03	0.07	26.20	0.00	0.00	0.00
nose cone shoulde	0.00	0.00	0.01	0.01	1.96	0.00	0.00	0.00
payload body tube	0.00	0.00	0.06	0.06	21.51	0.00	0.00	0.00
ecovery switch rin	0.00	0.00	0.01	0.01	1.96	0.00	0.00	0.00
ower recovery tub	0.00	0.00	0.04	0.04	14.86	0.00	0.00	0.00
n mount	0.00	0.00	0.03	0.03	13.30	0.00	0.00	0.00
trogen valves mou	0.00	0.00	0.02	0.02	6.26	0.00	0.00	0.00
fuel tube	0.00	0.00	0.02	0.02	7.04	0.00	0.00	0.00
fuel valves mount	0.00	0.00	0.02	0.02	6.26	0.00	0.00	0.00
ox tube	0.00	0.00	0.06	0.06	21.51	0.00	0.00	0.00
cc mount	0.00	0.00	0.02	0.02	6.26	0.00	0.00	0.00
trapezodial fin set	0.02	0.00	0.01	0.03	9.78	0.00	0.00	0.00
boat tail	0.00	0.07	0.02	0.09	20.55	0.00	0.00	0.00
Total	0.05	0.07	0.31	0.44	157.44	0.00	0.00	0.00

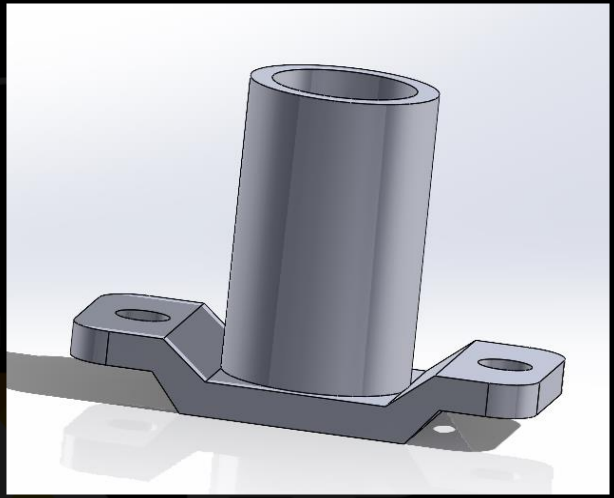
Constant Inputs

Density of air at sea level	Max velocity	outer diameter	Cross-sectional Area	α (angle of attack)	Fin Area	g	Fin Root Chord	Fin Tip Chord	Fin Height
slugs/ft^3	ft/s	ft	ft^2	degrees	ft^2	ft/s^2	ft	ft	ft
0.00238	1001.00000	0.51667	0.32844	0.00000	0.18960	32.17405	0.58	0.38	0.40

Charge Wells

- 3D printed charge wells, Wing nuts 3/8", electrical tape, E-match, quick connect, and Wiring
- Charges will be packaged in fingers of gloves
- Then be placed in in well with electrical tape to secure it to the E-match and prevent any movement
- Igniting the charge – the wires from the altimeter will be run through a quick connect to a small hole in the bottom of charge well





PM(g)	BD(g/cm^3)	PV (cm^3)	PV(in)	Actual Volume
21.1	1.7	12.4117647	0.757412	1.570796327
				0.964367295
2.356194				

PV = PM / BD P V = PM /B D Where PV is the Powder Volume (m^3) PM is the powder mass (g) BD is the bulk density (g/m^3) To calculate the powder volume, divide the powder mass by the bulk density.

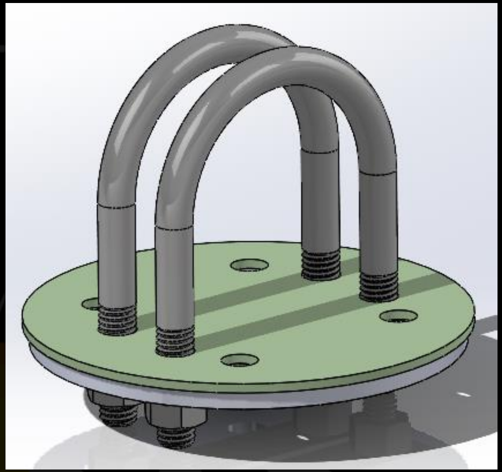
KXR UCF

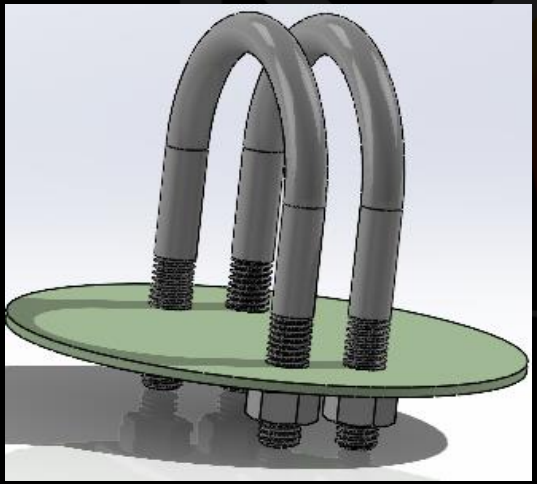
FMECA

Part	Failure	Criticality	Effect	Mitigation
BP Fuse	Fails to ignite	High	Separation fails	Proper wiring
BP Amount	Too much BP	High	Separation fails	BP testing
BP Amount	Too little BP	High	Separation fails	BP testing

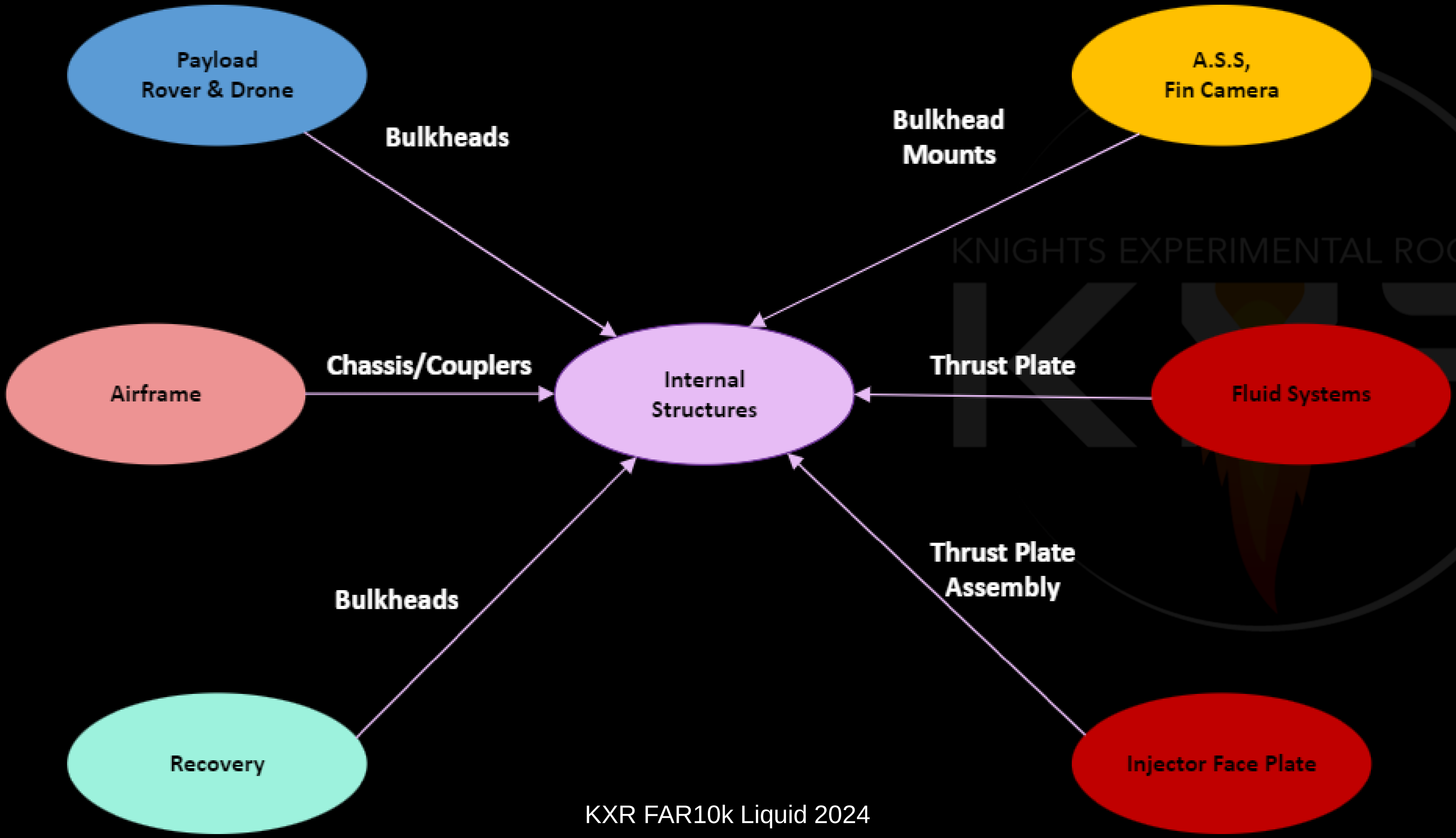
Recovery System Manufacturing

- Bulkheads
  - Made from G10 fiberglass
  - Bulkheads will be designed through CAD
    - The drawing file will be sent to a fabrication center to be laser cut
  - U-bolts will be bought from McMaster
- Switchbands
  - Made from carbon fiber pre-preg
  - The 2" band will be cut from the lower recovery tube and the nitrogen tank tube
    - These tubes can be manufactured longer than needed to allow the switchbands to be cut from them





Internal Structures Interface Diagram



Internal Structures Functional Requirements

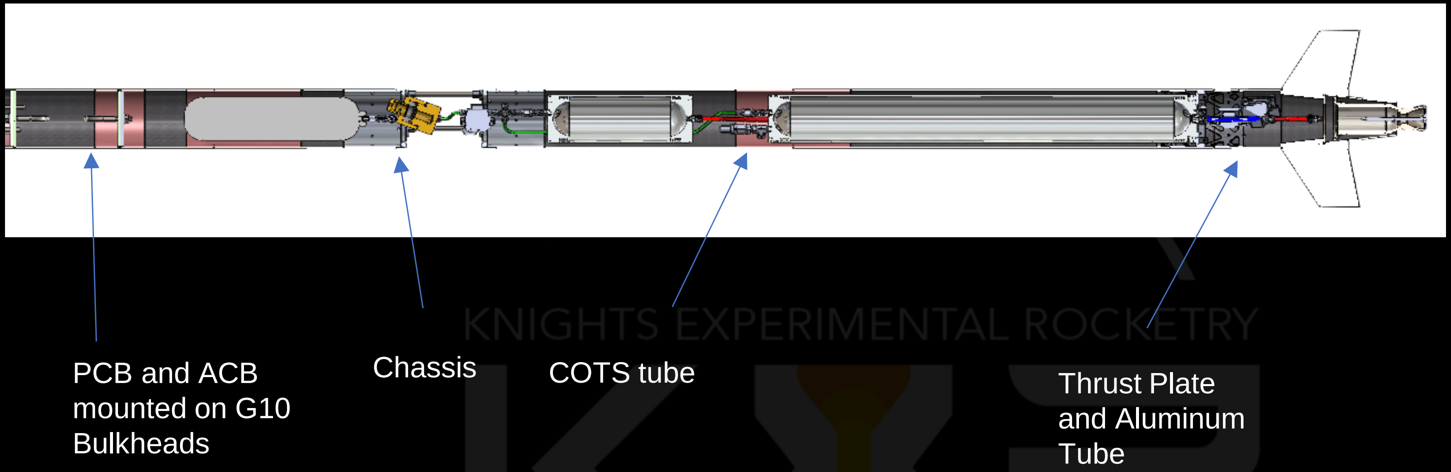
Requirement	Requirement Type	Verification Method
The Ɨnternal Structures sub-system **shall** support and protect the **Propulsion** and **Payload** systems	Functional	Analysis
The internal Structures sub-system **shall** withstand the loads and vibrations acting on the rocket	Functional	Analysis
The Internal Structures sub-system **shall** house and provide access to the internal components of the vehicle	Functional	Inspection
The Internal Structures sub-system **shall** allow separation between motor, payload and recovery section of the vehicle.	Functional	Inspection
The Internal Structures sub-system **shall** withstand the weight of the propulsion system [64 lbs] and the payloads [10 lbs]	Functional	Analysis

Internal Structures Technical Performance Measures

Measure	TPM Value	Units	Verification Methods
Total Compression Loads	16,941.311	psi	Force Calculator (Aero Loads)
Snatch Force	1,260.283 (No S.F) 1,953.439 (S.F 1.55)	lbf	Force Calculator (Snatch Force)
M1 Bending Max M2 Bending Max	-3,726.961 5,742.241	psi	Far Force Calculator (Aero Forces)
G Force	2.84	G's	Open Rocket
Shear Force (V1) Shear Force (V2)	67.690 221.527	lbf	Force Calculator (Aero Force Loads)
Bearing Stress (Tensile) Bearing Stress (Compression)	2,367.805 68,105.684	psi	Force Calculator (bolt sizing)

Internal Structures Component Breakdown

- Internal Structures Sub-System
  - Chassis
    - Nitrogen -> Oxidizer
  - Thrust Plate
  - COTS Couplers
    - Al. Couplers
    - Fiberglass Couplers
  - Bulkheads



Chassis Technical Performance Measures

Measure	TPM Value	Units	Verification Methods
Total Compression Loads	16,941.311	psi	Force Calculator (Aero Loads)
Snatch Force	1,260.283 (No S.F) 1,953.439 (S.F 1.55)	lbf	Force Calculator (Snatch Force)
M1 Bending Max M2 Bending Max	-3,726.961 5,742.241	psi	Far Force Calculator (Aero Forces)
G Force	4.24	G's	Open Rocket
Shear Force (V1) Shear Force (V2)	67.690 221.527	lbf	Force Calculator (Aero Force Loads)
Bearing Stress (Tensile) Bearing Stress (Compression)	2,367.805 68,105.684	psi	Force Calculator (bolt sizing)

Airframe Shear Stress

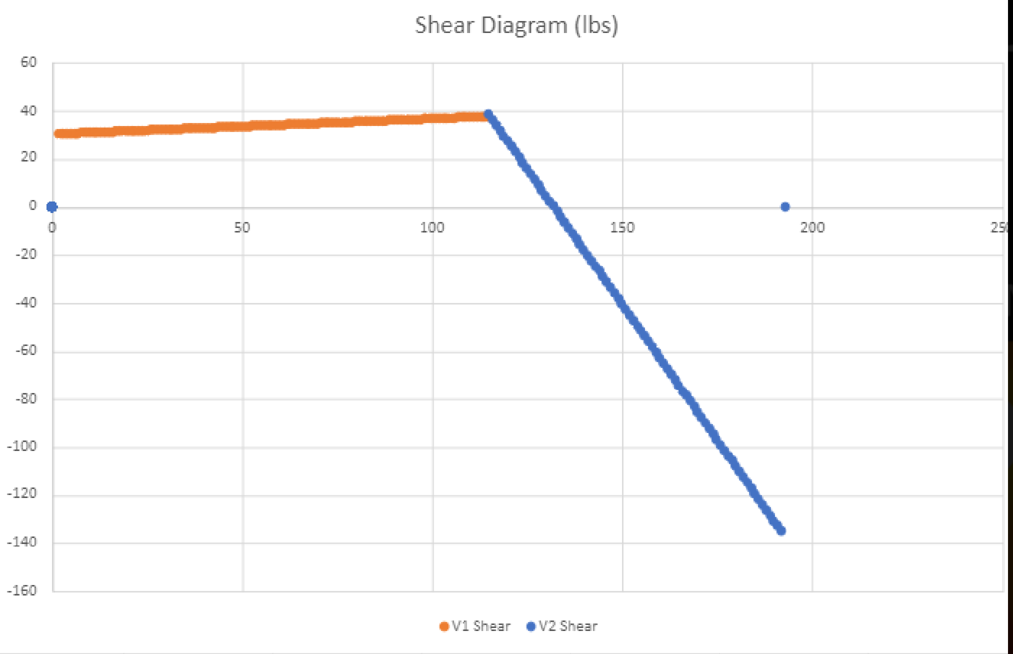
Equations from Nakka rocketry assume a distributed load acting on the body during flight.

$$w_2 = \frac{N_F(2x_2 + x_1) - N_N\, x_1}{x_2^2 + x_1\, x_2}$$

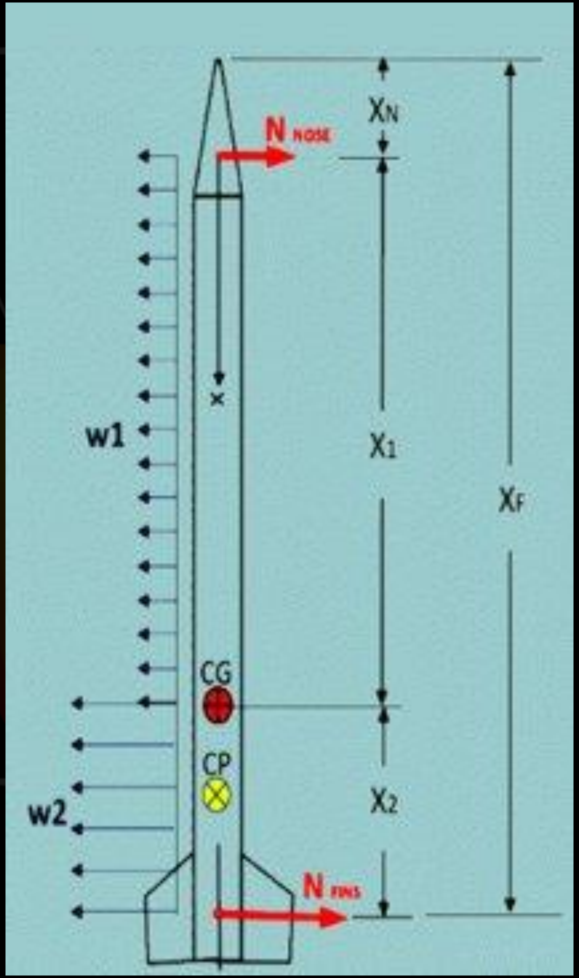
$$w_1 = \frac{N_N + N_F - w_2\, x_2}{x_1}$$

$$V(x) = N_N - w_1\, x \qquad 0 \le x \le x1$$

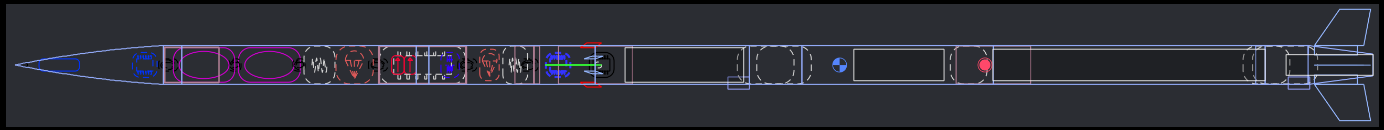
$$V(x) = V_1 - w_2(x - x_1) \qquad x1 < x \le L$$



Body Tube Loads			
Distributed load W1 (lb/in)	Distributed load W2 (lb/in)	Lateral Shear V1 (lbf)	Lateral Shear V2 (lbf)
-0.064303376	2.256670282	37.79152609	121.91



Airframe Bending Stress

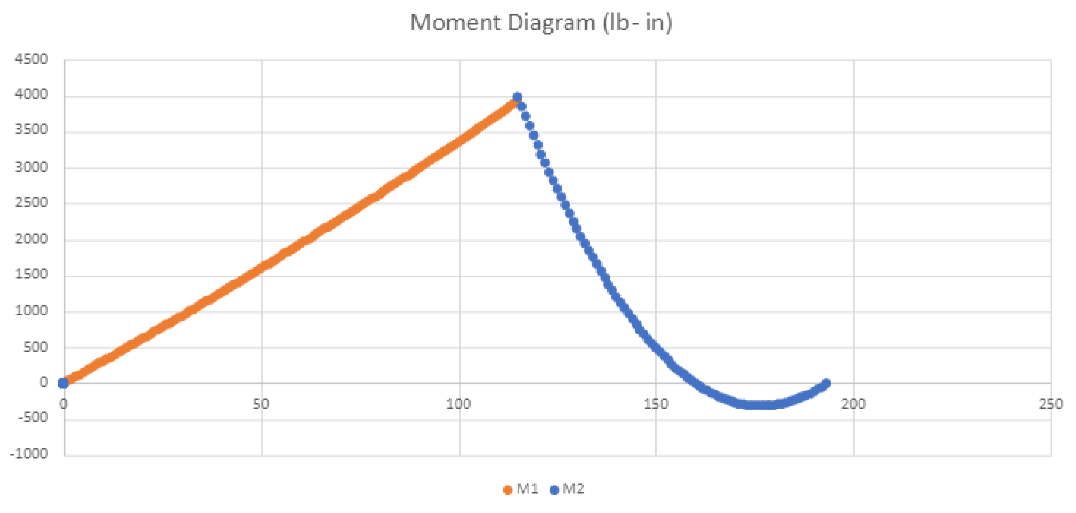


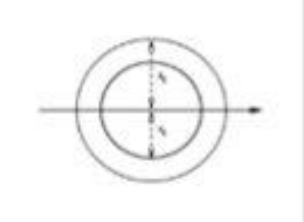
The **bending moment (M)** as a function of x is given by:

$$M(x) = N_N x - w_1 \frac{x^2}{2} \qquad 0 \le x \le x1$$

$$M(x) = V_1 x + w_2\left(x_1 x + \frac{1}{2}L^2 - \frac{1}{2}x^2\right) - L(V_1 + w_2 x_1) \qquad x1 < x \le L$$

$$f_{b\,max} = \frac{M}{Z}$$





$$S = \frac{\pi(r_2^4 - r_1^4)}{4r_2} = \frac{\pi(d_2^4 - d_1^4)}{32d_2}$$

Calculator:

Section Modulus Hollow Round Center Neutral Axis Calculator

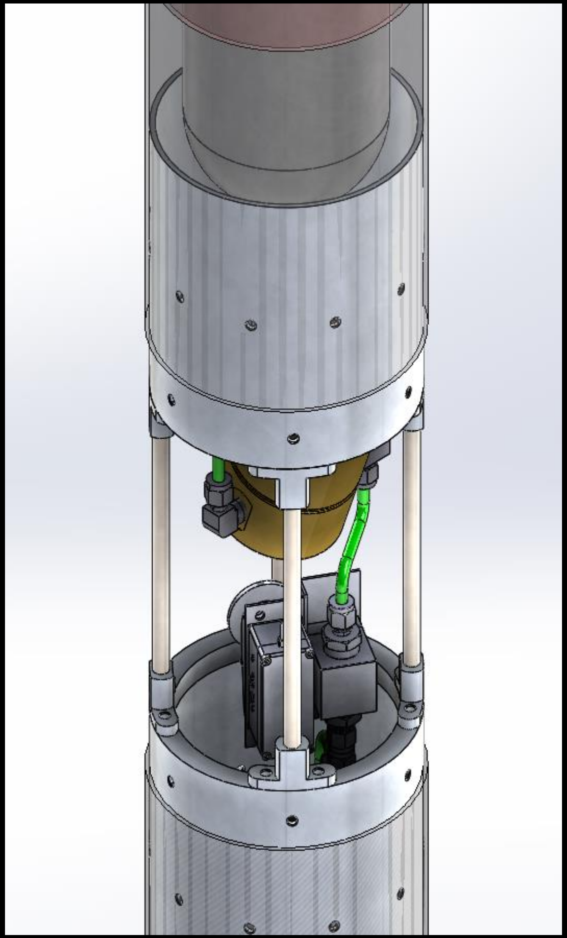
NA indicates neutral axis

Max Bending Stress on Body (PSI)	
M1 Bending Max	-2493.867483
M2 Bending Max	1927.620763

Forward Moment/Bending Moment		
M1 Max Moment (lb in)	Max Forward Bending Moment (lb in)	Location of Max Forward Bending (in)
3917.964997	-7172.619099	115.00

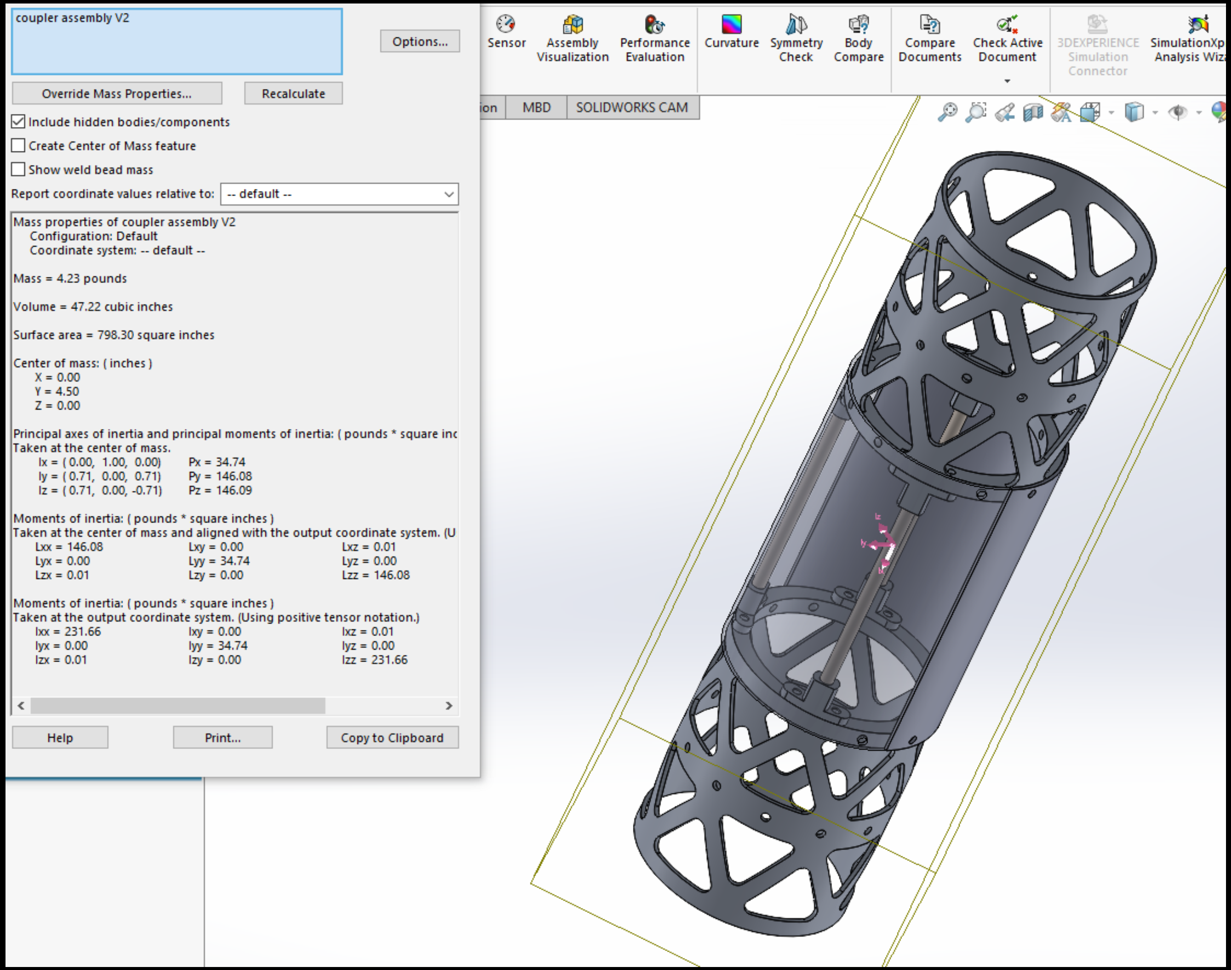
Aft Moment/Bending Moment		
M2 Max Moment (lb in)	Max Aft Bending Moment (lb in)	Location of Max Aft Bending (in)
3986.169714	5544.035357	115

Chassis



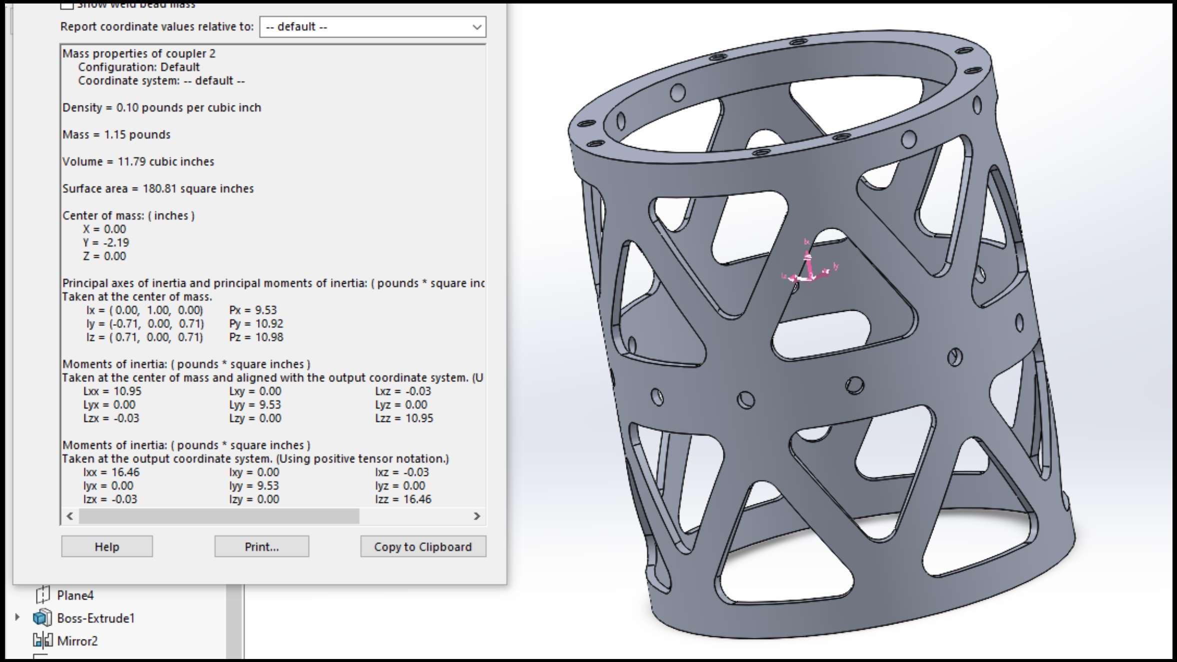
- Aluminum Coupling Section goes between the nitrogen tank and the fuel tank
- 8" long steel threaded rods provide an opening for access to regulator to avoid moving the entire tube and wearing out threads
- Aero panels can cover up the exposed plumbing and take little load during flight
- The panels will be made out of 3D printed polycarbonate

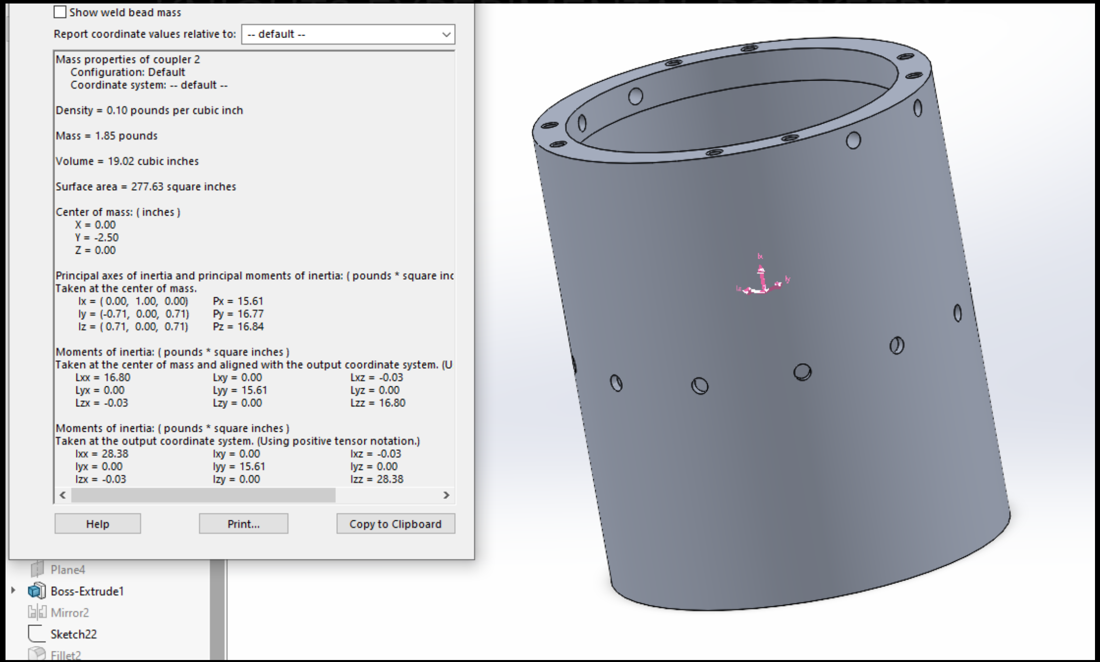
Design Evolution



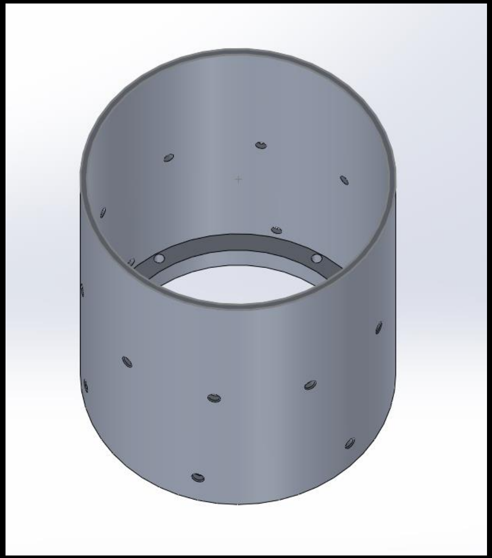
Weight Loss

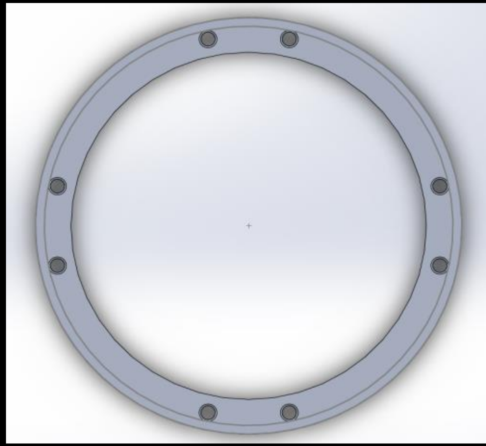
- Original: 1.85 lbs
- Lightened: 1.15 lbs
- Weight loss of 0.7 lbs per coupler, or 40%
- Adds up to almost 3 lbs across all couplers



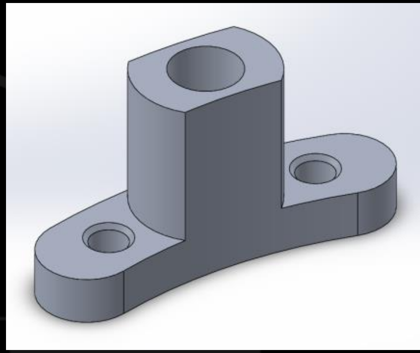


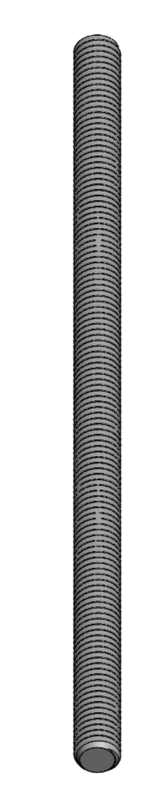
Chassis





Item	Material	Stock and Machining Costs	Quantity	Total	Resource
Chassis	6061 T6 Aluminum	$75 for stock 3 hours per coupler $35 hourly	1	Estimated $360	Quotes provided by UCF Machine Shop
3/8" threaded rods	Steel	$4.24	4	Estimated $18	https://www.homedepot.com/p/5-8-in-11-tpi-x-12-in-Zinc-Plated-Threaded-Rod-802017/204274006





FMECA

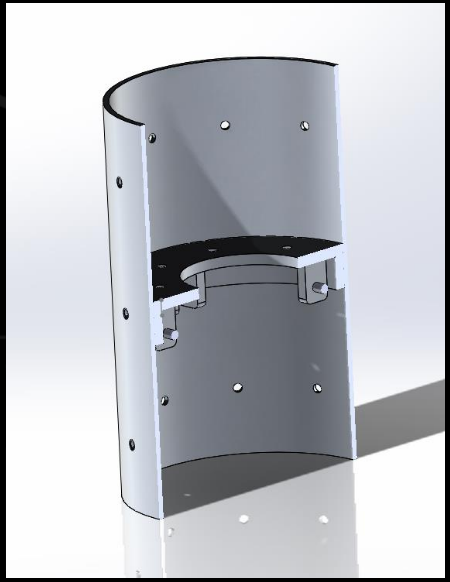
Part	Failure	Criticality	Effect	Mitigation
Coupler Tube	Bolt tear out	High	Joined sections of the airframe come apart during flight	6" shoulder length on carbon tubes
Coupler Tube	Bearing Stress	High	Bolt connections become loose during flight	Bigger bolts and better material for those bolts
Threaded Rods	Buckling	High	Component bends and fails during flight	Using different strut geometry, increasing the number of threaded rods or the diameter
All	Galvanic corrosion	High	Oxidizes the Aluminum	We will apply a coat to the Aluminum to stop the corrosion

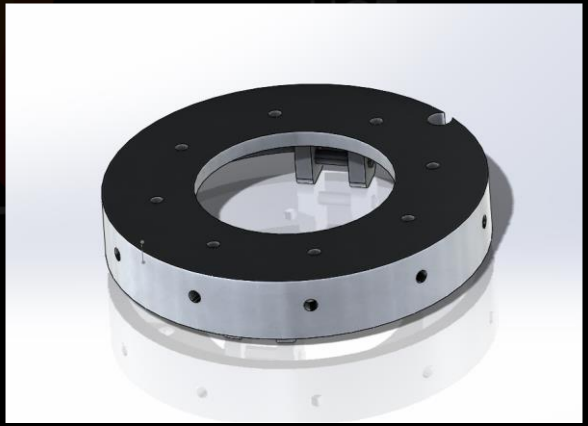
Thrust Plate TPMs

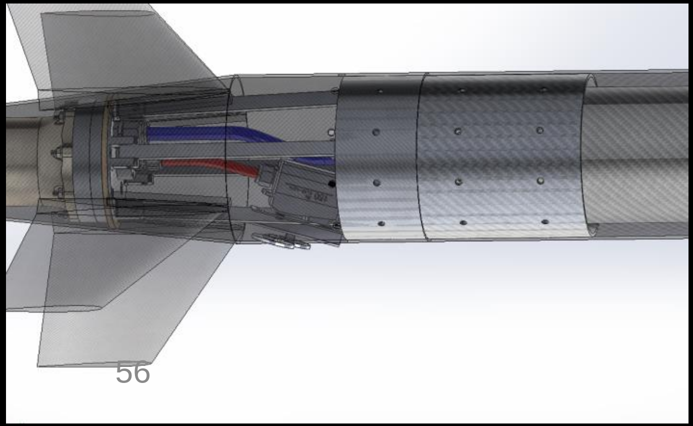
Measure	TPM Value	Units	Verification Methods
Total Compression Loads	16,941.311	psi	Force Calculator (Aero Loads)
Snatch Force	1,260.283 (No S.F) 1,953.439 (S.F 1.55)	lbf	Force Calculator (Snatch Force)
G Force	2.84	G's	Open Rocket
Thrust Force	539.991	lbf	Force Calculator (Aero Force Loads)
Bearing Stress (Tensile) Bearing Stress (Compression)	2,367.805 68.105.684	psi	Force Calculator (bolt sizing)
Shear Stress (Tensile) Shear Stress (Compression)	1,396.641 15,234.508	psi	Force Calculator (bolt sizing)

Thrust Plate

- Thrust Plate interfaces with aluminum struts coming from the injector
- Aluminum coupler tube attaches to the thrust plate in the middle to allow for attachment of the boat tail and one of the main body tubes
- The oxidizer bulkhead is attached, flushed with the thrust plate
- An indent of 3/8" is made to allow the fuel line to pass through







Thrust Plate Cost Breakdown

Part	Material	Stock and/or Machining Costs or	Quantity	Total	Link (not hyperlink)
Thrust Plate	6061 T6 Aluminum	Estimation of 20-35 dollars for stock 3.5 to 4 hours of machining time Hourly Machine Charges of 35 dollars	1	Estimated $170 dollars	Quotes from UCF machine shop
Aluminum Tube (6x.125x5.75)	6061 T6 Aluminum	$44.37	1	$44.37	https://www.metalsdepot.com/aluminum-products/aluminum-round-tube

Compression and Tensile Stresses

Thrust Force (lb)	Tube Cross-sectional Area (in^2)	Engine Thrust Compression (PSI)
539.9910813	1.257755468	429.3291462

Force Drag (lb)	Tube Cross-sectional Area (in^2)	Compressive Drag (PSI)
429.0488383	1.257755468	341.1226181

Mass (lb)	Max Gs	Tube Cross-sectional Area (in^2)	Mass inertia compression (PSI)
145	2.84	1.257755468	14243.23844

Engine Thrust Compression (PSI)	Max Bending Stress on Body (PSI)	Compressive Drag (PSI)	Mass inertia compression (PSI)	Total Compressive (PSI)
429.3291462	1927.620763	341.1226181	14243.23844	16941.31097

Main

Snatch Force (N)	Snatch Force (lbs)	SF	Focre*SF (lbs)
5606.019256	1260.283264	1.55	1953.439059

Drouge

Snatch Force (N)	Snatch Force (lbs)	SF	Focre*SF (lbs)
347.5449334	78.13120915	1.5	117.1968137

- Compression Loads are calculated using equations from Nakka Rocket

$$f_{cm} = \frac{m\, g\, (1 + G_{max})}{A_c}$$

- Compressive stress due to mass inertia

$$f_{ca} = \frac{F_D}{A_c} \qquad \text{[Equation 11]}$$

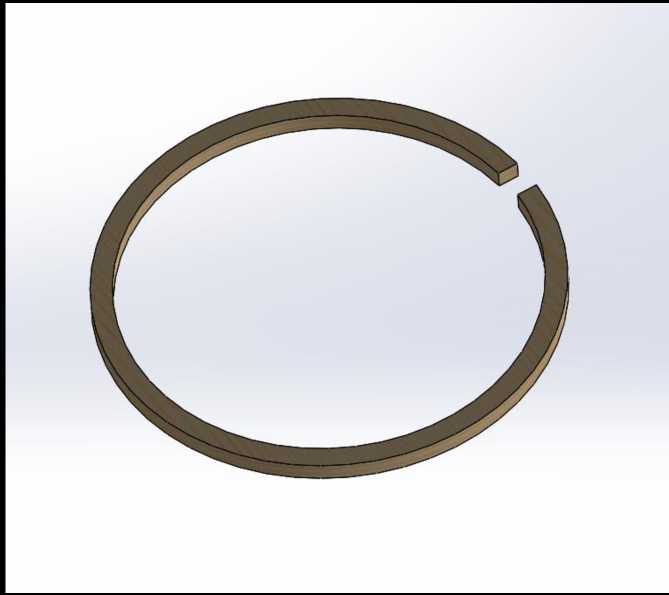
- Compressive stress due to drag force

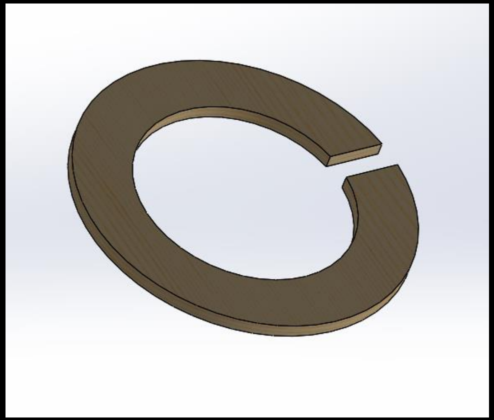
- Tensile stress from snatch force during recovery

FMECA

Part	Failure	Criticality	Effect	Mitigation
Coupler Tube	Bolt Shear	High	Thrust Plate and or joined sections of the airframe come apart	6" shoulder length on body tubes 3" of shoulder length into the boat tail
Coupler Tube	Bearing Stress	High	Bolt connections become loose	Bigger bolt diameter or stronger material
Thrust Plate	Bolt shear	High	Propulsion system connections become loose during flight	Using bigger bolt diameter and stronger material
Thrust Plate	Deformation	High	Propulsion system could collapse into the airframe	Adding thickness to the thrust plate or changing material

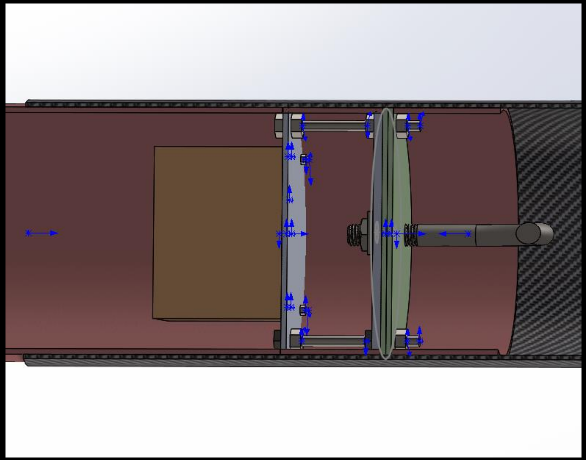
Centering Rings



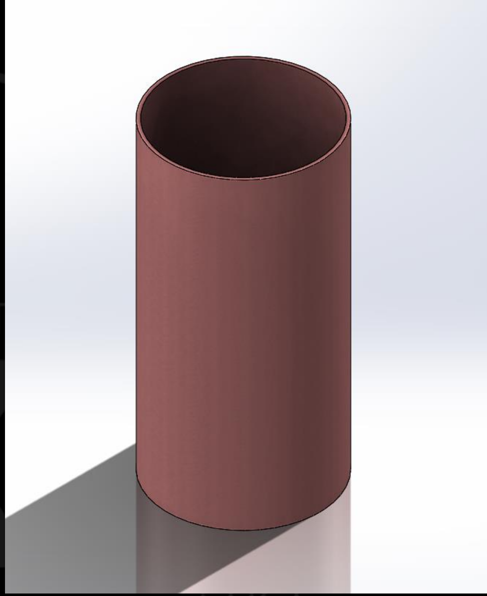


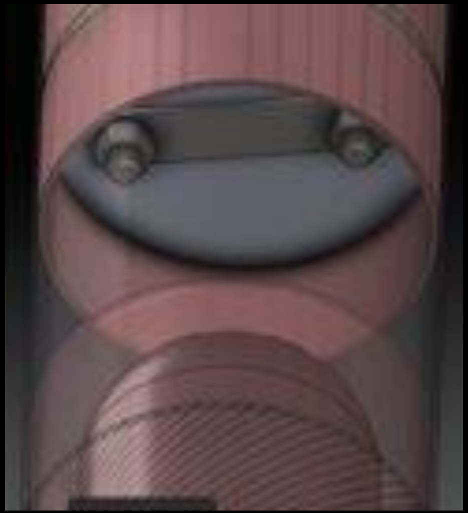
- To prevent translation of the tanks and the combustion chamber centering rings will be placed around the propulsion system.
- Centering rings will be placed around the combustion chamber as well as the fuel and oxidizer tank.
- Will be cut out of plywood
- Cost: $40 for a sheet of plywood

COTS Couplers/ Bulkheads



- Sections that won't require a chassis near the propulsion system will be joined together using fiberglass couplers
- Above the nitrogen tank, two bulkheads will secure the PCB and the ACB using fiberglass couplers and G10 plates
- These bulkheads will also be used to secure two cameras providing a horizon view during flight and a camera pointing down towards the fins





Item	Full Item Description	Cost	Quantity	Total	Link (not hyperlink)
G12 Fiberglass coupler tube	6” fiberglass tube	$60.00 each	2	$120.00	https://www.compositewarehouse.com/index.php?route=product/product&product_id=125

FMECA

Part	Failure	Criticality	Effect	Mitigation
Centering Rings	Cracking or disassembly	Medium	Risks the propulsion system sloshing inside the airframe	Multiple centering rings and/or thicker wood
Bulkeads	Cracking or disassembly	Medium	PCB, ACB, and cameras could risk collapsing inside the airframe	Using larger bolts to support the bulkhead

Bolt Bearing Stress

Compressive Loads Aluminium	
Bearing Stress (psi)	Saftey Factor
68185.68485	0.527970058

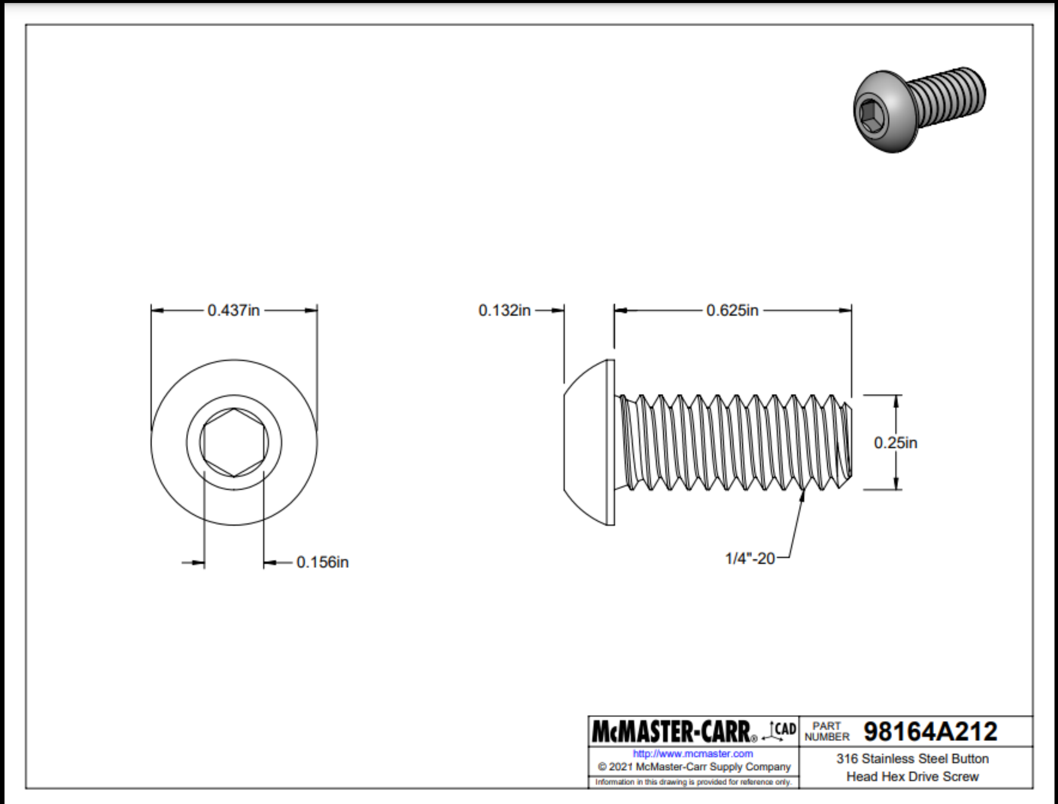
Tensile Loads Aluminium	
Bearing Stress (psi)	Saftey Factor
2367.80492	15.20395523

Bolt Sizing		
Bolt Type	Wall thickness (in)	SF of Bolts
1/4 - 20	0.2	1.75

Airframe will be secured using 10 ¼-20 steel bolts at all jointing sections.

$$f_{br} \leqq \frac{S_{br}}{S.F.}$$

$$f_{br} = \frac{F_s}{D_m\, t}$$



Bolt Tear Out

Bolt Diameter (in)	Edge distance (in)
0.25	0.5

Bolt Diameter (in)	Minimum Edge distance (in)
0.25	0.375

- Minimum Edge distance was calculated for aluminum couplers on the chassis and on the aft end

Compressive Loads Bolts

Number of Bolts	Num Bolts With SF	Num of Bolts to even Number
6.165516932	10.78965463	10

Shear Stress Per Bolt (PSI)	Shear Force per Bolt (lb)	SF of Bolts
15234.50842	2130.802652	1.62192402

$$F_{max} = f\,\frac{M}{D}$$

$f = 2/5$ for ten fasteners

Shear Stress Average = Applied Force / Area
or
Shear Stress ave.= $F/(\pi r^2)$
or
Shear Stress ave.= $4F/(\pi d^2)$

Where:

Edge Distance

$$E \geq 2 \times d_{bolt}^{major}$$

$$E \geq 2 \times 0.25$$

$$E = 0.5$$

Minimum Distance from Edge

$$E_{min} = E - \frac{d_{bolt}^{major}}{2}$$

$$E_{min} = 0.5 - \frac{0.25}{2}$$

$$E_{min} = 0.5 - 0.125$$

$$E_{min} = 0.375in$$

Tensile Loads Bolts

Number of Bolts	Num Bolts With SF	Num of Bolts to even Number
0.565231209	0.989154616	1

Shear Stress Per Bolt (PSI)	Shear Force per Bolt (lb)	SF of Bolts
1396.641954	195.3439059	17.69187518

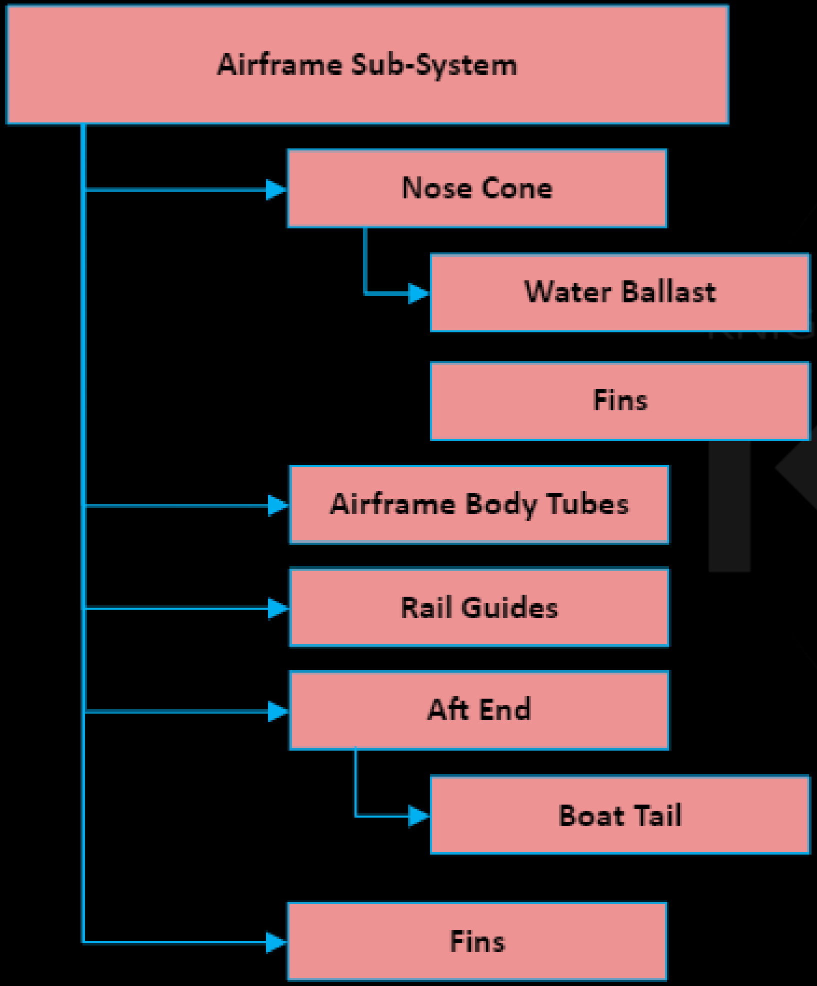
Max # of bolts: $n_{bolts} = \frac{F_{bulk}}{F_{bolt}^{max}} =$

Max Force one bolt can take: $F_{bolt}^{max} = \tau_u \cdot A_{bolt}$

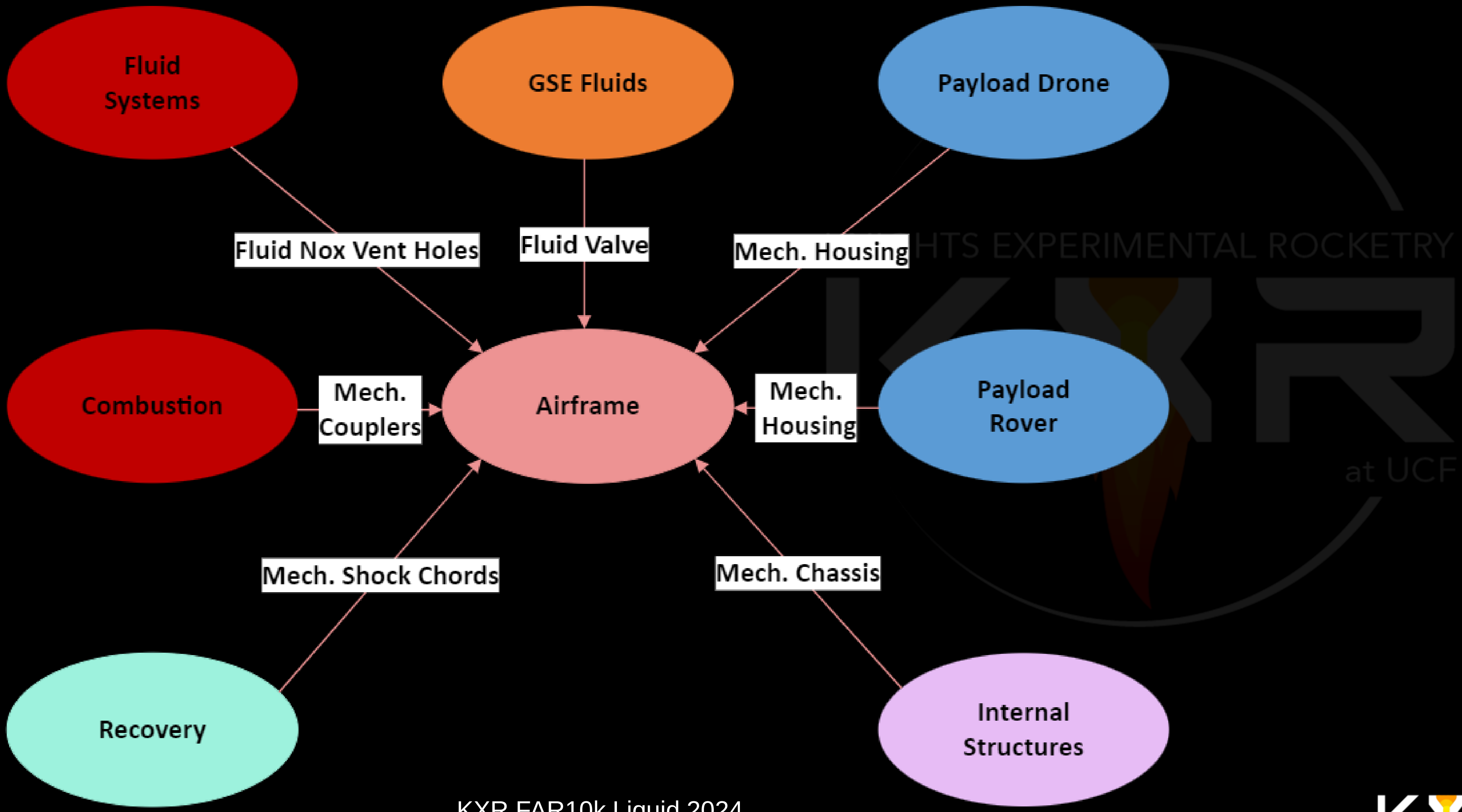
Internal Manufacturing

- Chassis
  - Will purchase stainless steel threaded rods, which we will cut to specified lengths
  - The coupler adapter ("feet") of the struts will be machined out of 6061 aluminum in the machine shop
  - 6 hours to machine
  - 8 pieces in total
- Thrust Plates
  - Will be machined out of 6061 aluminum in the machine shop
- Bulkhead Rings
  - Will be made from COTS G12 couplers
    - We will cut the rings from the coupler and post-process as necessary

Airframe Component Breakdown



Airframe Interface Diagram



Airframe Functional Requirements

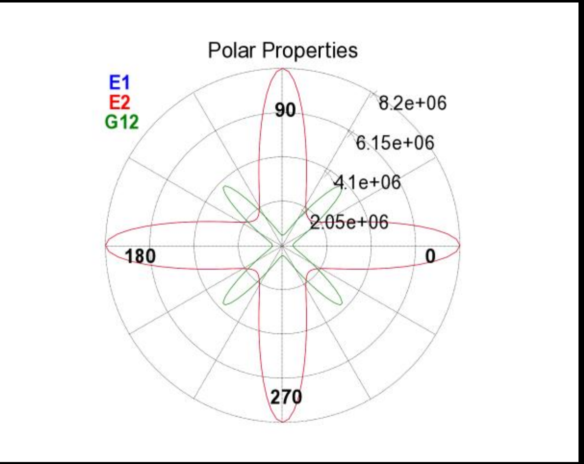
Requirement	Requirement Type	Verification Method
The Airframe Sub-system **will** be optimized for transonic speeds	Functional	Analysis
The Airframe Sub-system **will** provide stability in flight	Functional	Analysis
The Airframe Sub-system **will** withstand flight loads	Functional	Analysis

Airframe TPMS

Measure	TPM Value	Units	Verification Method
Snatch Force	1954	lbf	Demonstration
Max Bending Moment	7173	lb-in	Analysis
Max Compressive Load	21309	lbf	Analysis
Lateral Shear	122	lbf	Analysis
Drag Coefficient	0.75	n/a	Analysis
Vibrations (Flutter)	3120	ft/s	Test/Analysis

External Structures Lay-Up

- Body Tubes, Boat Tail & Fins: 3K 2x2 twill weave prepreg carbon fiber
- Nose Cone: Wet-Lay Fiberglass Sleeves
- Methods of calculations : The Laminator, Classical lamination theory, Force Calculator
- Simulation: Ansys ACP



Polar Material Properties

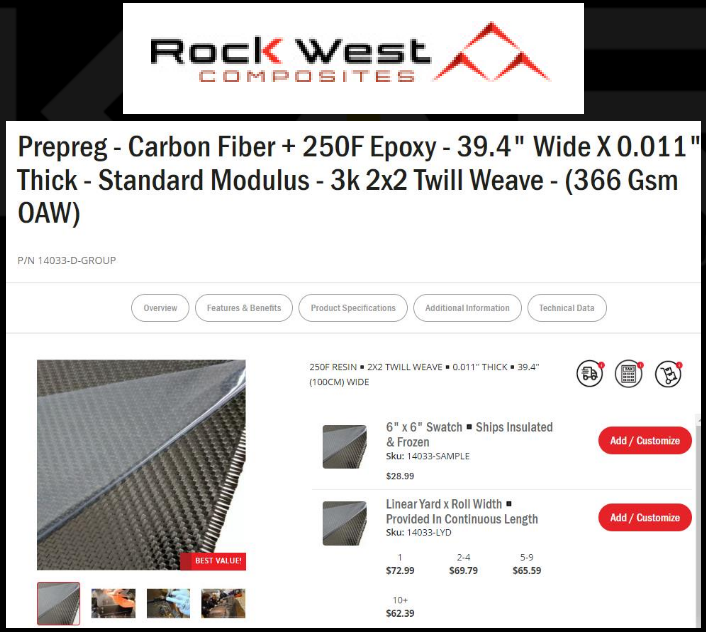
Analysis Results

Load Vector Scale Factors for Ply Failure
(For Applied (+) and Reversed (-) Loads)
****

Layer	Max Stress (+)	Max Strain (+)	Tsai Hill (+)	Hoffman (+)	Tsai-Wu (+)
1	4.98	4.98	4.98	4.98	4.98
2	4.98	4.98	4.98	4.98	4.98
3	4.98	4.98	4.98	4.98	4.98
4	4.98	4.98	4.98	4.98	4.98
5	4.98	4.98	4.98	4.98	4.98
6	4.98	4.98	4.98	4.98	4.98
Min	4.98	4.98	4.98	4.98	4.98

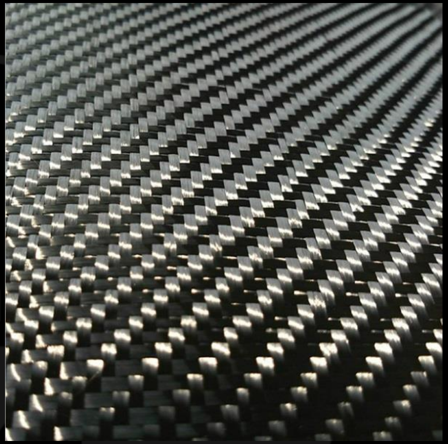
Layer	Max Stress (-)	Max Strain (-)	Tsai Hill (-)	Hoffman (-)	Tsai-Wu (-)
1	-5.30	-5.30	-5.31	-5.31	-5.31
2	-5.30	-5.30	-5.31	-5.31	-5.31
3	-5.30	-5.30	-5.31	-5.31	-5.31
4	-5.30	-5.30	-5.31	-5.31	-5.31
5	-5.30	-5.30	-5.31	-5.31	-5.31
6	-5.30	-5.30	-5.31	-5.31	-5.31
Min	-5.30	-5.30	-5.31	-5.31	-5.31

The laminator F.S

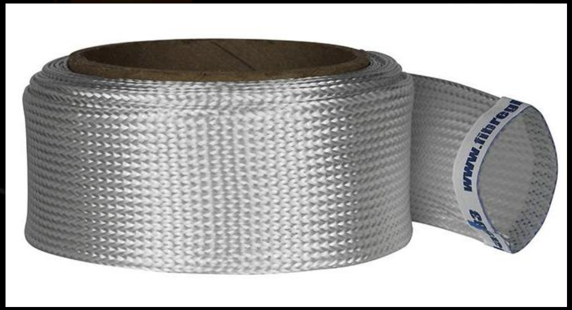


External Structures Lay-Up

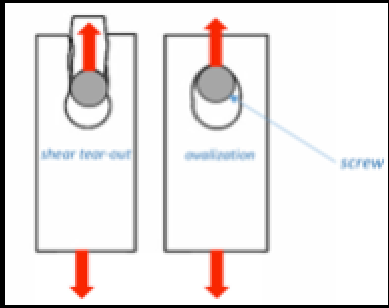
Item	Number of Plies	Ply Orientation	Method	Raw Composites Cost
Body Tubes	6	0	Rolling	$1277
Coupler Aero covers "skins"	2	0	Rolling	(integrated in Body tubes)
Nose Cone	6	45/45	Sleeves	$74.9
Boat Tail	8	0	Rolling	$234
Fins	24	0	Hand Laying	$399
Total (+ Tax & Handling)	-	-	-	$2310



3k 2x2 Twill CF

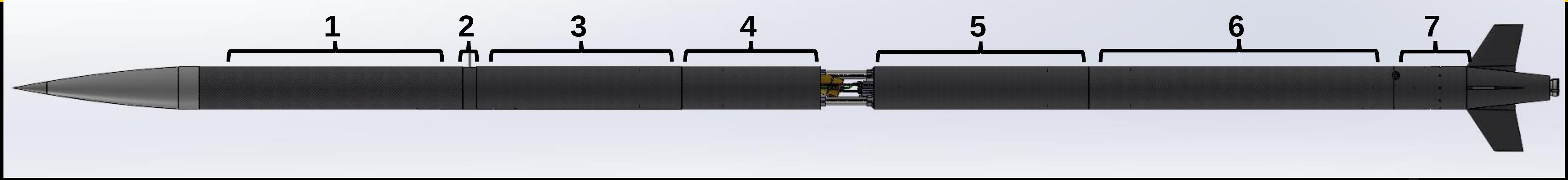


Bi-Axial FG Sleeve



Edge Distance S.F:
= Distance / Minimum Safe distance
= 3in / 0.375in = 8

Body Tubes / Design



1 Payload Body Tube	2 Recovery Switch Ring	3 Drogue Body Tube	4 Nitrogen Tank Tube	5 Fuel Tank Tube	6 Oxidizer Tank	7 Boat Tail

Body Tube FMECA

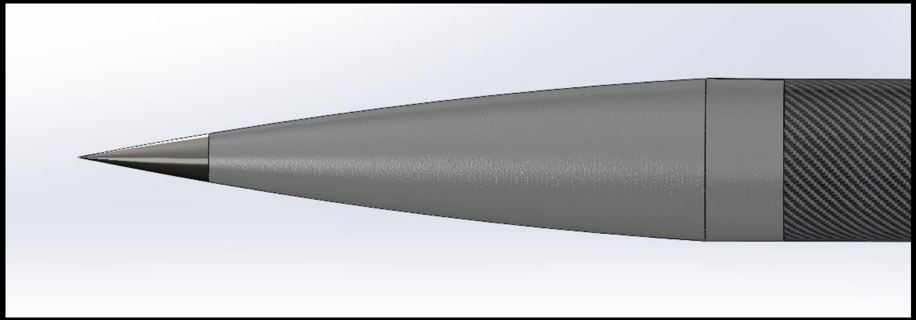
Part	Failure	Criticality	Effect	Mitigation
Body Tubes/Nose Cone/ Boat tail/ fins	Structural Failure	**High**	Complete Mission Failure	Verify Layup and add SF as well as coupon testing
Body Tubes / Nose Cone / Boat Tail	Bolt Shear/ Tear out	**High**	Complete Mission Failure	Optimize the bolt locations

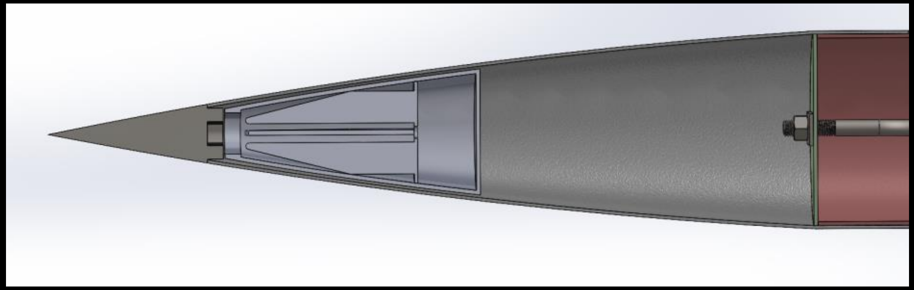
Nose Cone

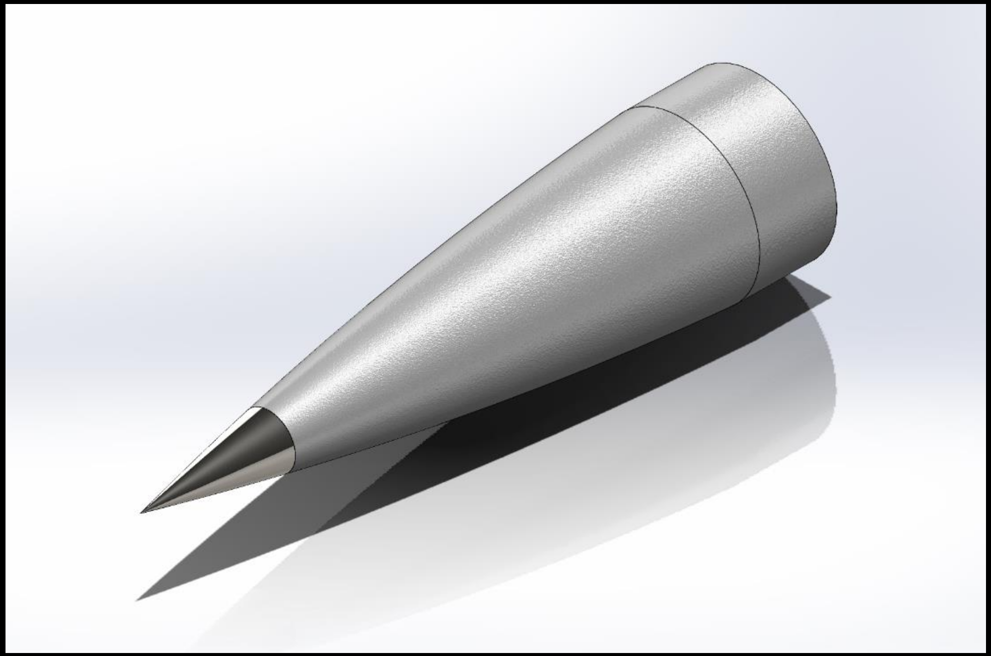
- Parabolic Nose Cone
  - Achieved lowest coefficient of drag between Fluent & OpenRocket with K = 0.7
- Steel Tip
  - Higher density than aluminum adds more stability
  - 1.56 lb

For $0 \leq K' \leq 1 : y = R\left(\frac{2\left(\frac{x}{L}\right) - K'\left(\frac{x}{L}\right)^2}{2 - K'}\right)$

R = 3.1 in
L = 24 in
K = 0.7







Nose Cone TPM

Measure	TPM Value	Unit	Verification Method
Dynamic Pressure	4.1	psi	Force Calculator
Normal Force	30.37	lbf	Force Calculator
Total Drag	96.45	lbf	Force Calculator / ANSYS
Bolt Tear Out (Min-Safe-Distance)	2	in	Force Calculator
Total Compressive Force	371	lbf	Force Calculator

$$Q = \frac{1}{2} * Rho * V^2{}_{Max}$$

$$N_{NOSE} = q\,A\,\alpha\,(C_{N\,\alpha})_N$$

$$D = \frac{1}{2} C_D \rho v^2 A_{ref}$$

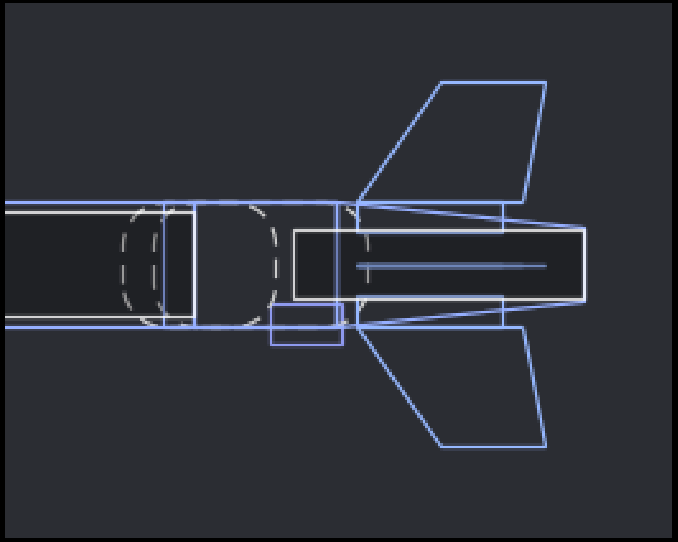
Nose Cone FMECA

Part	Failure	Criticality	Effect	Mitigation
Nose Cone	Fail to reduce drag	Low	Rocket doesn't reach estimated apogee	Keep iterating to produce the most optimized nose cone shape
Nose Cone	Crumples due to compressive load	High	Rockets drag is significantly increased	Design thickness according to calculations with a safety factor
Nose Cone	Breaks on landing impact	Medium	No more re-flyability (Point loss)	Design it to withstand impact with a safety factor

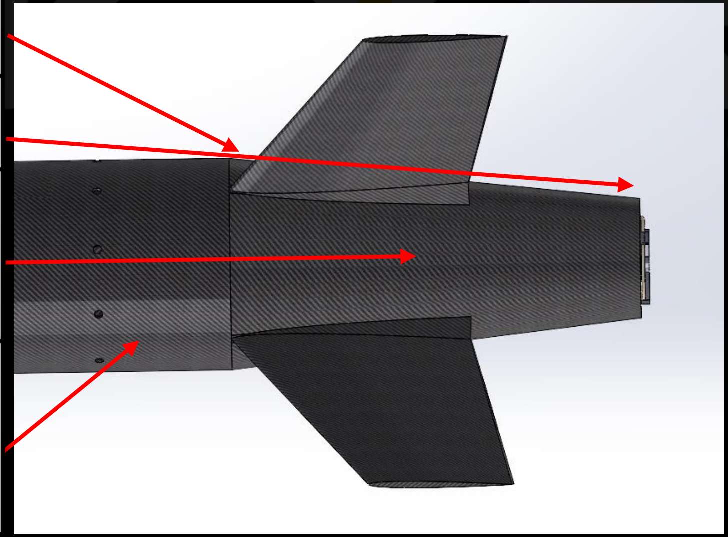
Boat Tail

- Lowest drag coefficient out of all three possible geometries.
  - The boat tail decreases our drag coefficient by 0.095.

Flat Aft	0 (0%)	0.132 (0%)	0.025 (0%)	**0.157 (0%)**
Boat Tail	0 (0%)	0.042 (0%)	0.02 (0%)	**0.062 (0%)**



Fore Radius	6.2 Inches
Aft Radius	3.5 Inches
Length of Taper section	12 Inches
Length of straight section	10.5 Inches



FMECA

Part	Failure	Criticality	Effect	Mitigation
Boat Tail	Fail to reduce drag	Low	Rocket doesn't reach estimated apogee	Keep iterating to produce the most optimized aft end shape
Boat Tail	Breaks upon ground impact	Medium	Rocket no longer has re-flyability (Point Loss)	Design to withstand ground impact with safety factor

Water Ballast

Function/ Performance:

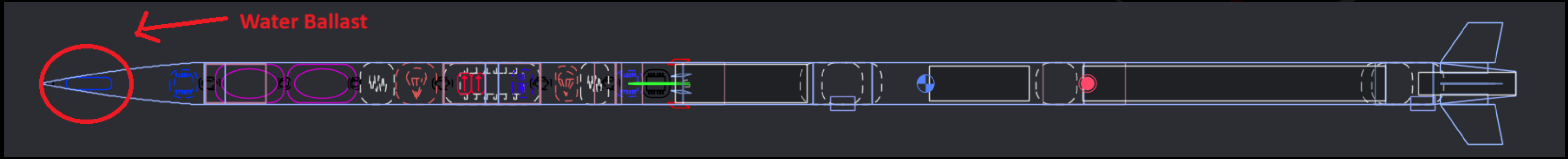
- Add weight for ascent
- Removed at descent or apogee
- Gain 1000 points
- Threaded Rod should sustain snatch force

Characteristics – TPM values:

- 500ml of water (1.1 lbs)
- Nose Cone Tip Weight (~1.6 lbs)

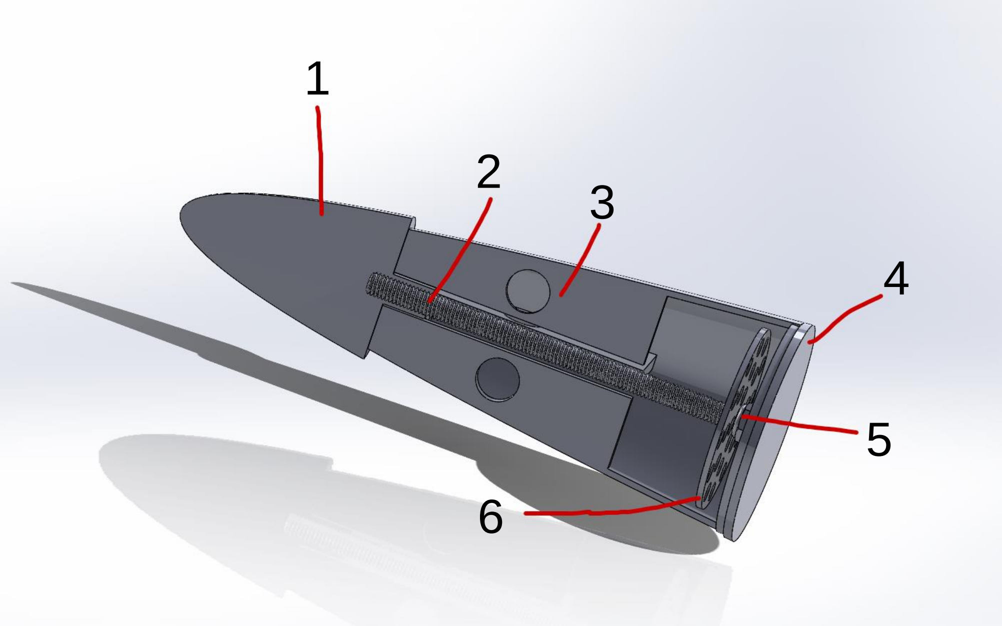
Geometry

- We're pursuing a trans-sonic and subsonic design until we get our actual values.



Water Ballast (cont'd)

Parts:
1 – Nose Cone Tip
2 – Threaded Rod
3 - Baffles
4 - Lid
5 – Lock Nut
6 – Mesh Plate



Materials: Polycarbonate 3d print for Water containment portion

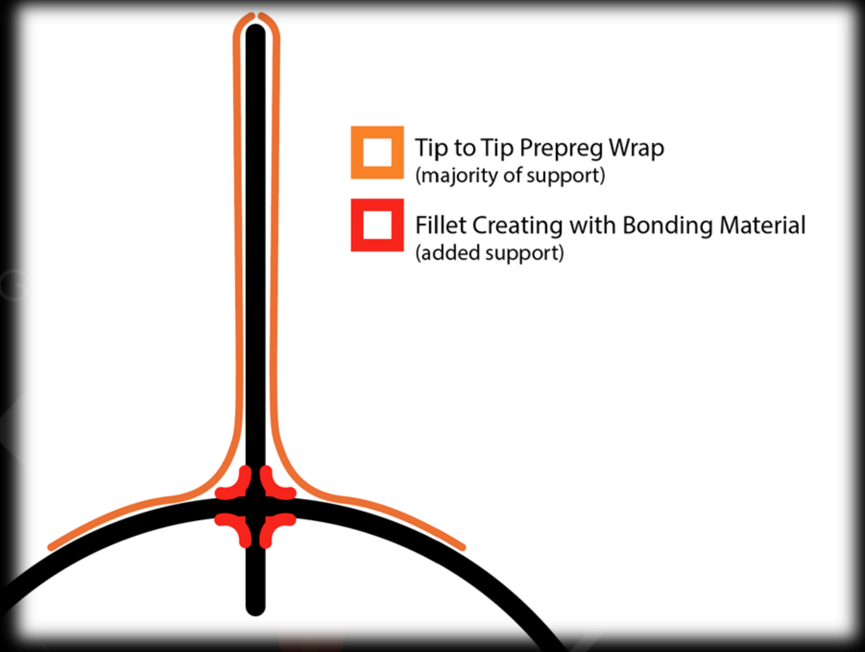
- Threaded rod
- Lock nut
- Nose cone tip made of steel

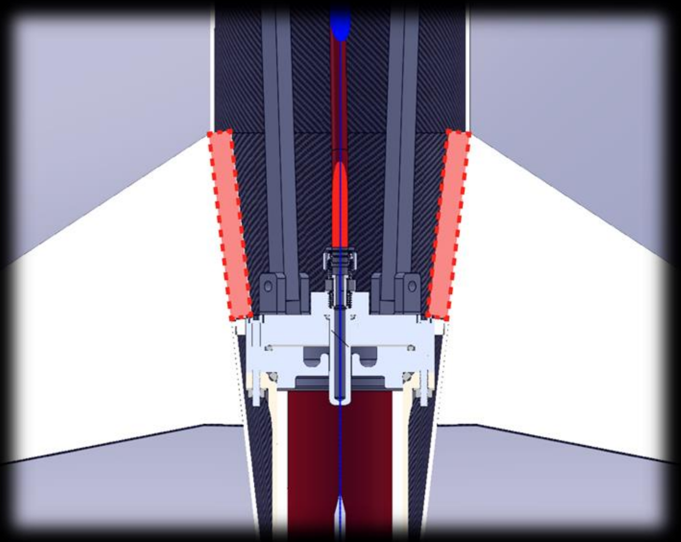
Water Ballast FMECA

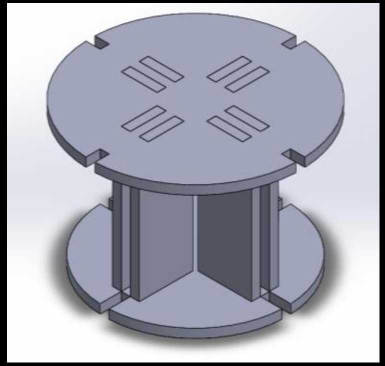
Part	Failure	Criticality	Effect	Mitigation
Nose Cone Tip	Fails to Detach	Low	Water fails to release	Tolerance between nose cone tip and water ballast is increased
Baffles	Threaded Rod crushes baffles	Low	Baffles are damaged	Baffle Width is increased
Lid	Fails to seal water	Low	Chance of damaging electronics	Epoxy is used to seal the Water Containment
Mesh	Mesh breaks	High	The nose cone tip can separate from the main rocket creating a safety problem	Mesh becomes thicker.

Fin Cage Component Breakdown

- Our rocket will alternatively use fillets on each corner of contact for the fin tabs, as well as tip to tip pre preg wrap to support each fin
- This decision was made for the sake of simpler integration with the CC and thrust plate
- A support will be made and laser cut for holding the fins in place while they cure, then will be removed.







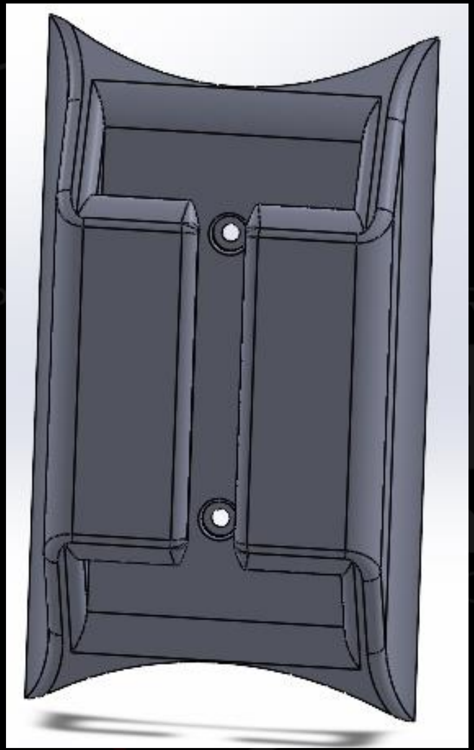
Fin tabs are inserted into an internal and external centering jig for manufacturing

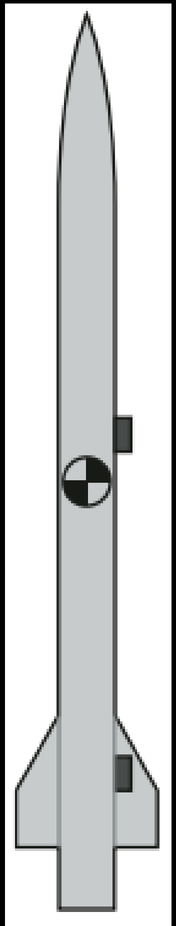
Rail Guides Component Breakdown

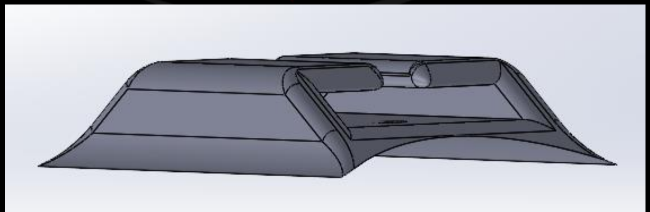
Function/ Performance:

- Hold rocket to rail
  - Supports rocket so stability can effectively develop
  - Prevents any misalignment of trajectory during launch
- Permanent feature, now a part of rocket and influences flight character

- Upstream guide: ~115 inches from the nose tip
- Downstream guide: ~205 inches from the nose tip







Item	Full Item Description	Cost	Quantity	Total	Link (not hyperlink)
Polycarbonate filament	Black PC Filament 1.75 mm 3D Printer Filament 1 KG Spool 2.2LBS Dimensional Accuracy +/- 0.05mm 3D Printing Polycarbonate Material	$25	2	$50	CC3D global
Screws	Alloy steel socket head screws.1-72. Item number 91251A068	$7.23	1	$7.23	McMaster-Carr
nuts	High strength steel hex nuts. Item number 94895A815	$10.92	1	10.92	McMaster-Carr
Graphene powder	Lucky Line 4.5 Grams of Dry Lock Lubricant Graphite Powder for Pin Tumbler Locks, 1 Tube (95001)	$3	2	$6	Lucky Line

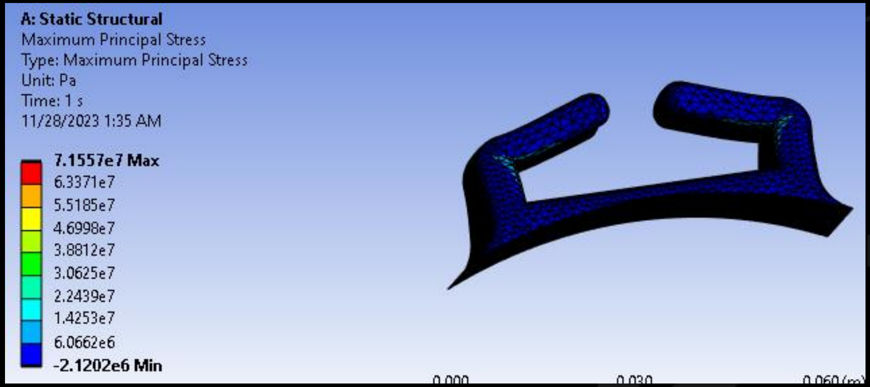
Rail Guides Component Breakdown

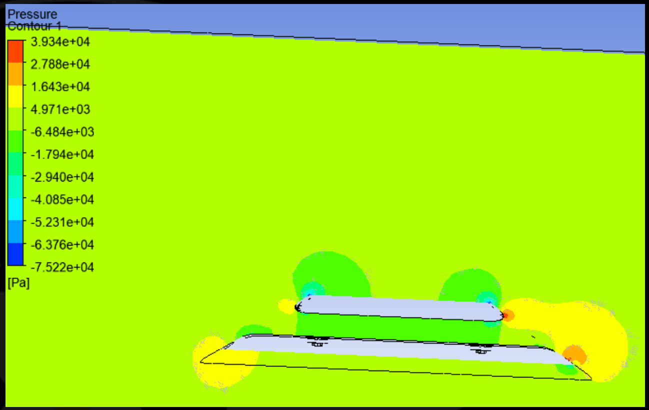
Designed and evaluated at 600lbs

Estimated Factor of Safety of 2.78

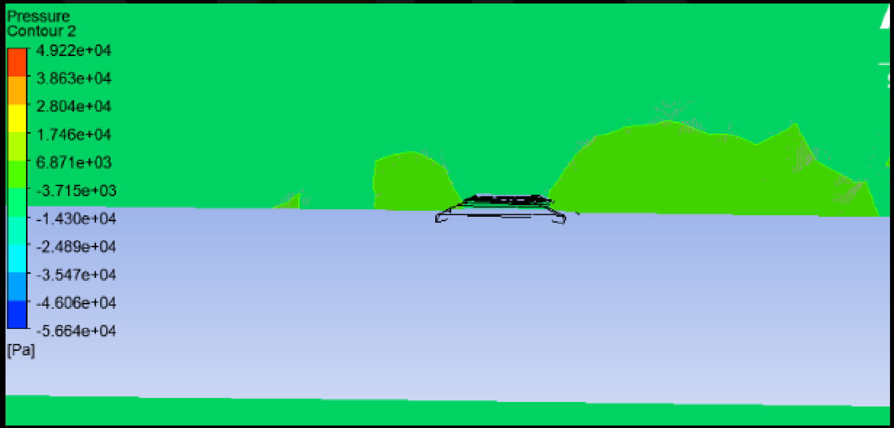
$$P_f L_f + P_a L_a - \mu \left| P_f + P_a \right| R_T = 0$$

- Back plate will be utilized





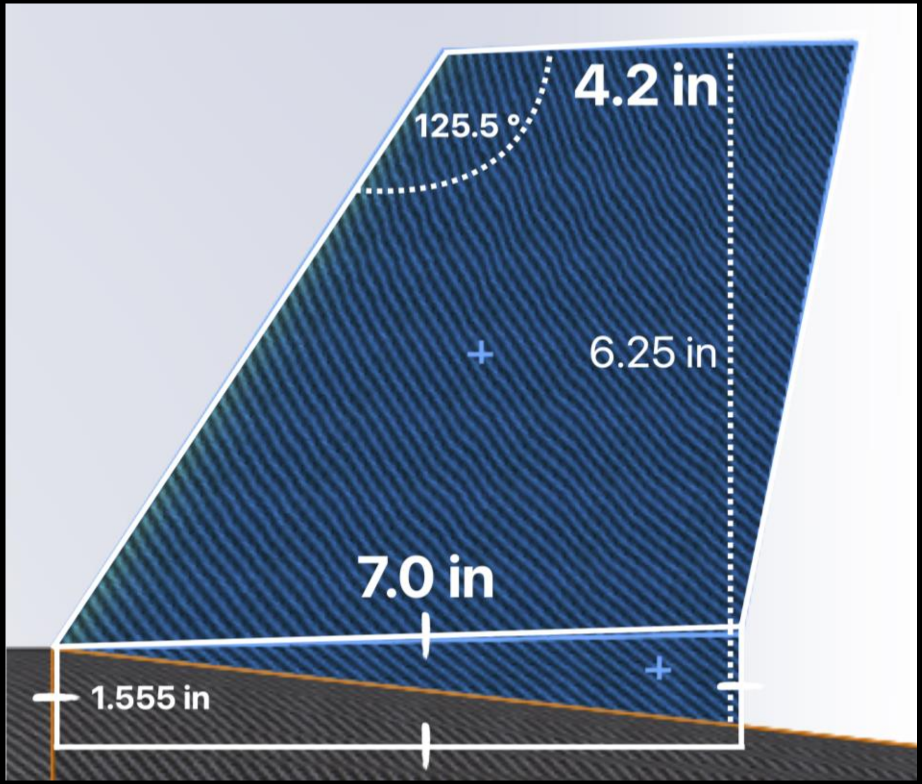
Measure	TPM Value	Units	Verification Method
Resisted launch force	600	lbf	Testing
Mount length	4	inches	Demonstration
Mount height	1	inches	Demonstration
Drag from mount	4000	Pa	Analysis



FMECA

Part	Failure	Criticality	Effect	Mitigation
Bolt	Bolt tear out	High	Rail guides shear off, rocket fails to develop stability. Launch failure	Choose bolts with high strengths, design guides to be thick on face with rocket. Employ back plate
Rail guides	Flange failure	High	Rail flanges tear off, rocket fails to develop stability. Launch failure	Thicken flanges to withstand high safety factor

Fins

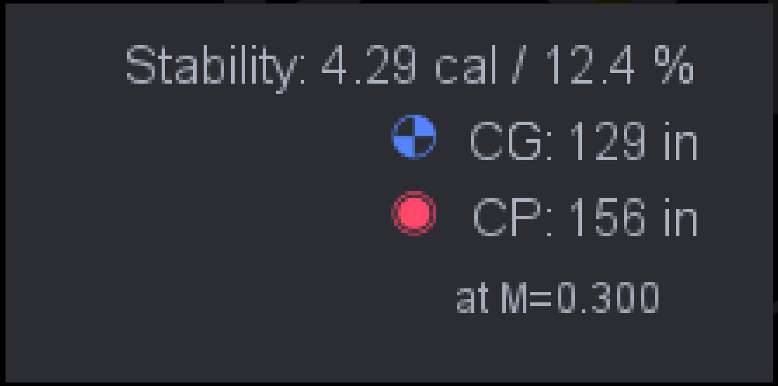


Function/ Performance:

- Shall resist all loads and vibrations experienced in flight.
- The fins shall provide passive stability to the vehicle.

Characteristics – TPM values:

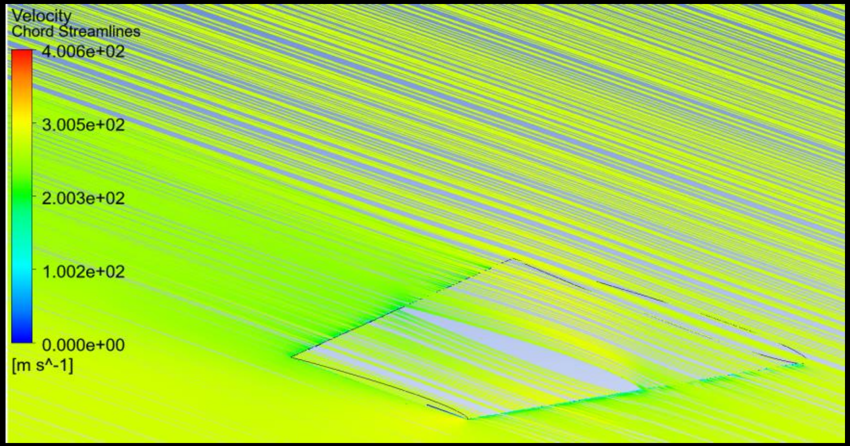
- Pressure [11.66 psi]
- Fin flutter velocity [3055 ft/s] - safety factor of [3.92]

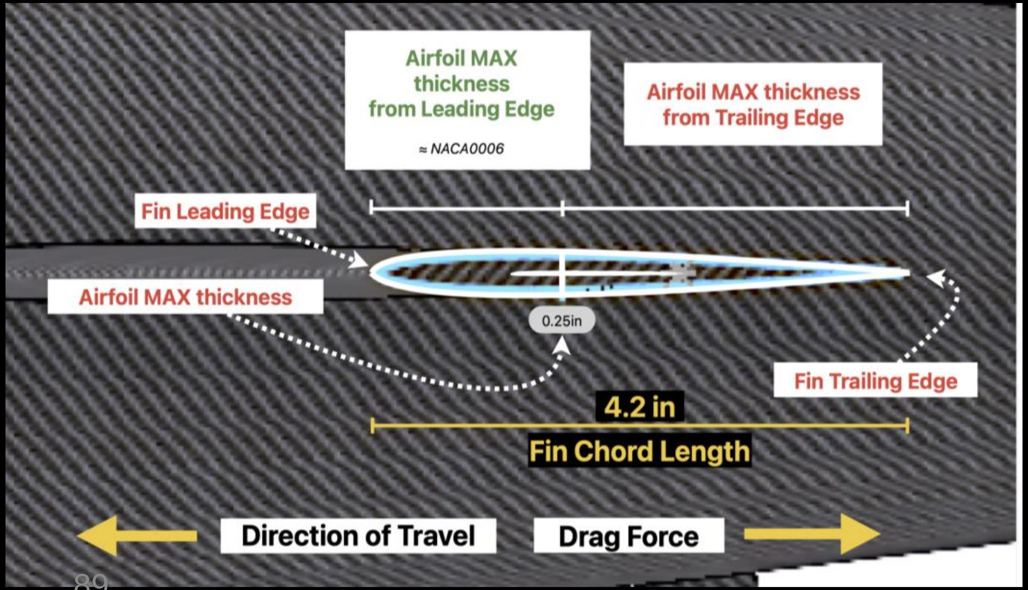


Fins

Part	Failure	Criticality	Effect	Mitigation
Fin	Flutter	High	Vibration	Make thicker/Shorter
Fin	Drag	Low	Decreased Apogee	Airfoil
Airfoil	Manufacturing	Medium	Time/Budget	Tolerance

Airfoil





Function/ Performance:

- Airfoil should minimize the aerodynamic forces acting on the vehicle.

Characteristics – TPM values:

- Pressure [11.66 psi]
- Fin flutter velocity [3055 ft/s] - safety factor of [3.92]

Drag coefficient	Value
Pressure Cd	1.15E-04
Viscous Cd	1.51E-04
Total (drag) Cd	2.66E-04

$$y_t = 5t\left[0.2969\sqrt{x} - 0.1260x - 0.3516x^2 + 0.2843x^3 - 0.1015x^4\right],$$ [5][6]

where:

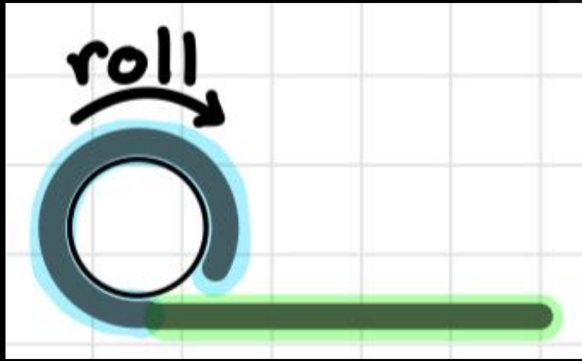
x is the position along the chord from 0 to 1.00 (0 to 100%),

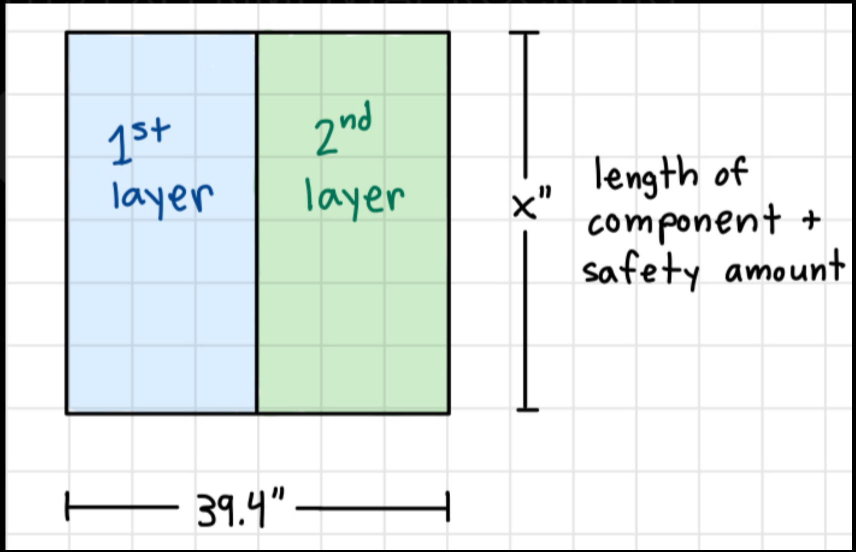
y_t is the half thickness at a given value of x (centerline to surface),

t is the maximum thickness as a fraction of the chord (so t gives the last two digits in the NACA 4-digit denomination divided by 100).

Airframe Manufacturing

- Tubes
  - Made of 3k 2x2 twill weave prepreg carbon fiber
  - Roll the prepreg around a 6 in. metal mandril to build up layers and form the tube
    - Width of pre-preg is 39.4 in, which is twice the circumference, so one sheet will have 2 layers
    - Roll 3 sheets in total to make 6 plys
  - Cure tube in autoclave and post-process as necessary
  - Will need to manufacture 5 separate tubes*
    - Payload body tube: 38 inches
    - Recovery switch band: 2 inches
    - Lower recovery tube: 27 inches
    - N tank tube: 19 inches
    - Fuel tube: 31 inches
    - OX tube: 44 inches

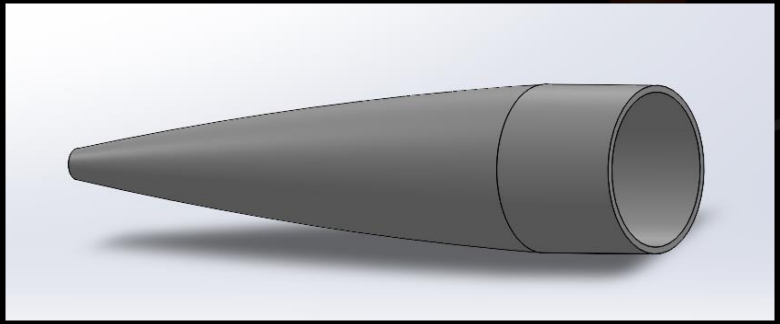




*the recovery switch band (length/material) will be added and cut from the lower recovery tube piece

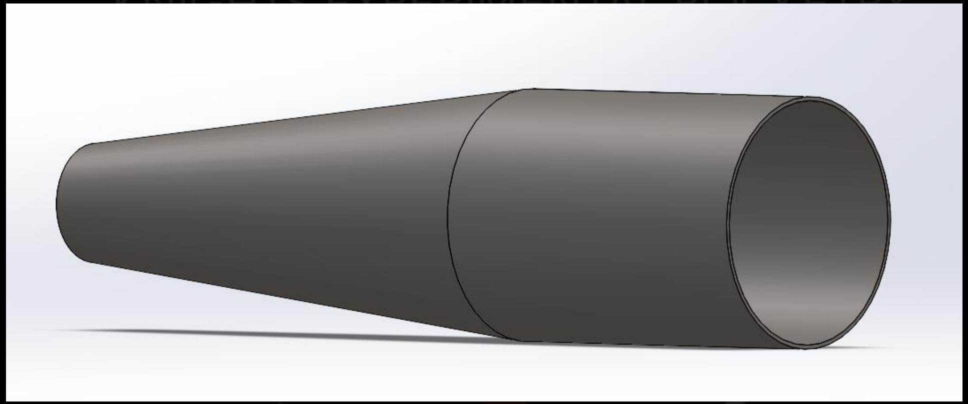
Airframe Manufacturing Contd.

- Nose Cone
  - Mold: Male mold; 3D-printed out of PLA plastic with extra length on ends as safety factor for material
    - Will take about 5 days to print
    - Will be printed in separate sections due to the size constraints of the 3D printer
      - These will be glued together, most likely with E6000
  - Wet-lay fiberglass sleeves over the 3D-printed male mold, according to lay-up schedule
  - Composite will be vacuumed and sealed in Autoclave
- Tip machined from 2 in. diameter steel rod
    - Will take 1-2 days to machine
- Water Ballast
  - 3D printed out of PLA
    - Will take only a few hours to print
  - The COTS threaded rod will be cut to size by us



Airframe Manufacturing contd.

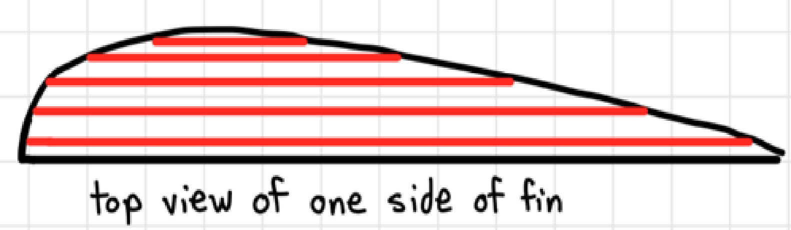
- Boat Tail
  - Made from carbon fiber pre-preg
    - Will 3D print a male mold out of polycarbonate plastic (PCP)
      - It will be 3D printed in separate sections due to size constraints of the 3D printer, glued together most likely with a high temp. epoxy
  - Will need to apply 8 layers of prepreg
    - Cure composite in the autoclave
  - Then, insert the fins with epoxy and fillet them to the tail cone
    - May need a high temp epoxy/glue

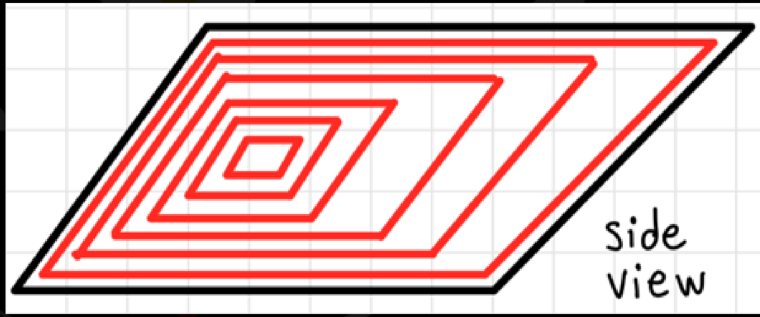


  - Then the tail cone will go back into the autoclave and cure to cement the fins in place

Airframe Manufacturing Contd.

- Fin Cage
  - The material will be G10 fiberglass
    - The parts will be laser cut at a fabrication center and then assembled by us
- Fins
  - Will be tapered, swept, trapezoidal and made from layered pre-preg
    - There will be a total of four fins.
    - The measurements are as follows:
      - Root chord – 7.5in
      - Tip chord – 5in
      - Height – 5in
      - Swept length – 2.5in
      - Sweep angle – 26.5in

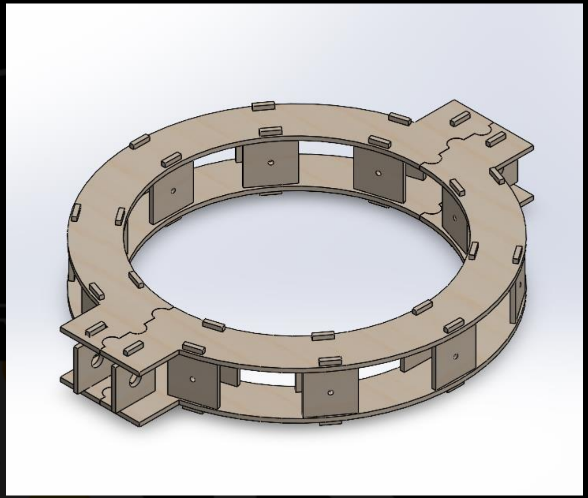


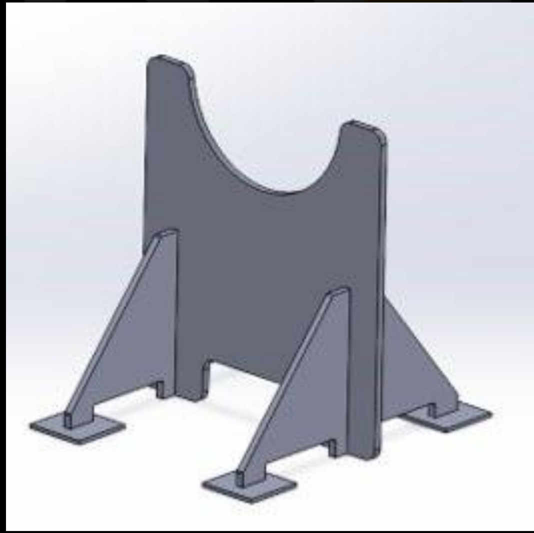


  - The airfoil will be NACA0006
  - The pre-preg will be cut to different lengths and shapes which will be stacked up to form the airfoil
    - This layering technique will be done for each side of the fin

Airframe Manufacturing Contd.

- Holes
  - We will be using the drilling collar to make our holes even spaced and the correct size
- Jigs
  - For drilling we have a drilling collar made from plywood
  - The drilling collar will double as our cutting collar
  - The rocket stands will be made from plywood and cut with the laser cutter in the TI Lab
- Rail Guides
  - 3D printed out of polycarbonate plastic





Manufacturing Process Plan (MPP)

Mix Epoxy/Resin for Layer 1	4	Epoxy/ Resin components are mixed to the proper ratio	Read the instructions on the Epoxy/Resin label to find the proper mixing ratios. Follow the instructions to a tee to ensure best results. Mix your Epoxy/Resin **ONE LAYER AT A TIME**. eg. mix epoxy for layer 1, lay fiberglass+epoxy for layer 1. Then mix and lay for layer 2, etc.	gloves, goggles,respirator, popsicle sticks, Epoxy/Resin, mixing cups	DO NOT MIX the resin and hardner until you are ready to lay. Be ready to work quickly from this point on, the Epoxy/Resin will cure quickly so be sure to have your fiberglass and mold ready to rock.
Seal Mold	5	Seal mold with layer of resin	Apply a layer of resin to the mold to seal any tiny pores or gaps in the material before laying fiberglass.	gloves, goggles, respirator, mixed Epoxy/Resin, paint brush	Especially necessary if chosen mold is wood.
Lay First Layer of Material	6	Material is oriented correct, no bubbles	Lay material on top of first resin coat, ensure it's laid in the correct direction, smooth out the material with gloved hands	1st layer of fiberglass, gloves	
Apply Epoxy/Resin Mix	7	Even layer coats entire surface of material	Use paint brushes to evenly coat the material with the resin mixture.	epoxy/resin mix, gloves, paint brushes	The exoxy/resin mix should be a specific amount proportional to the amount of material being covered. Use expocy calcultor to calculate amount of mix
Repeat steps 10-11	8		Repeat steps 10-11 until all layers are complete		

Steps 4 - 8 of Fiberglass Coupon for nose cone

Apply Carbon Fiber Prepreg	4	6 plys of carbon fiber prepreg must be applied	Apply each layer in the same direction	PrePreg Carbon Fiber, Scissors, Gloves	If carbon fiber bubbles or wrinkles, remove said ply and start again
Apply release film over carbon fiber	5	1 layer of release film must be evenly placed on carbon fiber surfaces	Must be even and wrinkle free	Release film, scissors	
Apply breather cloth over	6	Wrap liberal amount of breather cloth over composite surface	Must cover entirty of the mandrel	Breather cloth, scissors	
Vaccum Bag entire mandrel	7	Create an envelope bag with gum tape and insert test coupon	Bag must be totally sealed	Vacuum bag, vacuum sealent tape, scissors	
Insert Vacuum Connector	8	Place vacuum connector through bag	Bag must be totally sealed	Vacuum connector, Scissors	
Pull Vacuum in Autoclave	9	Pull 1 atmosphere of vacuum pressure	Ensure vacuum holds	Autoclave	
Cure tube in Autoclave	10	Run cure cycle	Cure for 1 hour at 250F	Autoclave	
Remove Vacuum supplies	11	Cut test coupon out of vacuum bag	Ensure all breather cloth and vacuum supplies are removed	Scissors	

Steps 4 – 11 of Carbon Fiber prepreg coupons for tubes and tail cone

- All the test coupon MPPs are finished, except for the fins' coupon, which is still being fleshed out. These MMPs include:
  - Body tube test coupon
  - Tail Cone test coupon
  - Nose Cone test coupon
  - Fin test coupon

Machine Costs and Printing Times

- Nose Cone
  - Mold: 5 days to 3D print*
  - Water Ballast: a few hours to 3D print*
  - Nose Cone Tip: 2-3 hours to machine, the material is free. Total cost is < $100.
- Tail Cone
  - Mold will take 4 days to 3D print*
- Chassis
  - 10 hours to machine
  - Material cost $150
  - Total cost to manufacture is $500
- Thrust Plate
  - 3.5 hours to machine
  - Will cost $158

*only cost is for filament, between $30-40

Manufacturing Schedule

- Largely dependent on when materials arrive
  - Best case Jan. – Apr., worst case Jan. – May.

1 – 5 Jan:
Make test coupons and send out to lab for testing

8 – 12 Jan:
Review test data
Prepare to make first tube (finalize body tube MPP, repair mandrel)

Jan. 14:
Drawings finished for machined parts (all except nose cone tip)

Jan 15 – Feb 16:
Submit drawings to machine shop.
Make pre-preg body tubes.

Feb 19 – Mar 1:
Finalize molds + start printing them
Start fins

Mar 4 – 8:
Finish fins

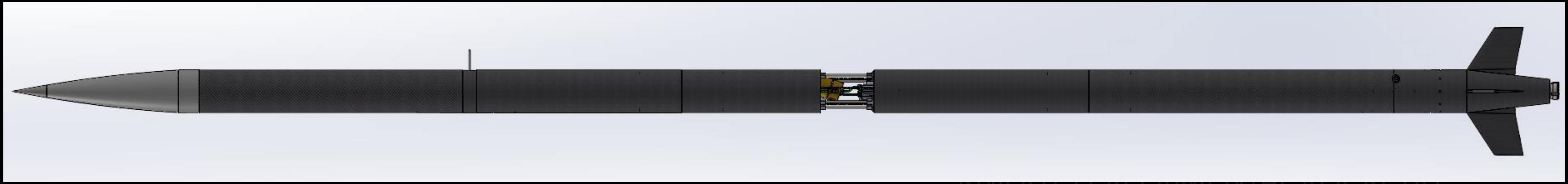
Mar 11 – 15:
Make tail cone

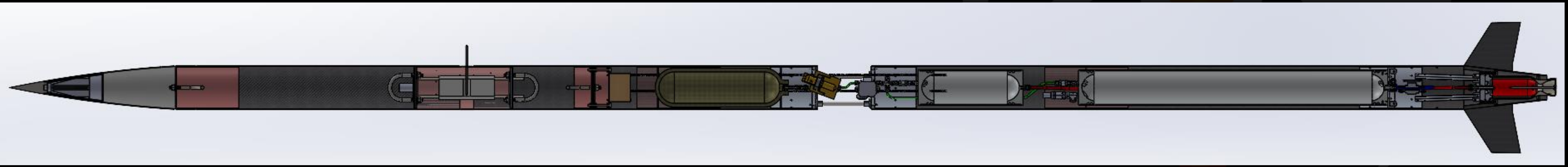
Mar 18 – 22: spring break
Start nose cone (if possible)

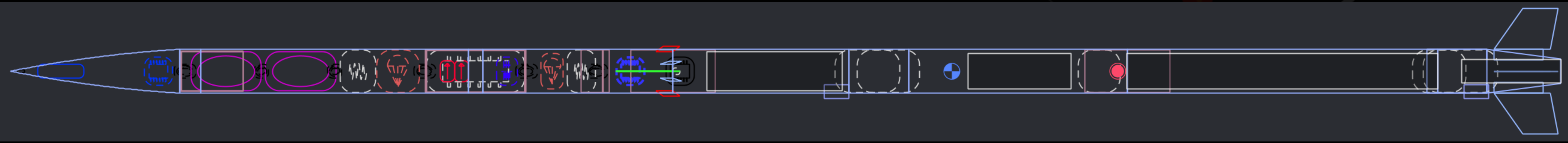
Mar 25 – 29:
Finish nose cone
Print water ballast
Machine nose cone tip

Month of April:
Post-processing, assembly

Questions?







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