KNIGHTS EXPERIMENTAL ROCKETRY

KXR

at UCF

October 23rd, 2023
FAR10k Preliminary Design Review

Agenda

- Introduce Guests
- Introduction
- **Vehicle Design**
- **Payloads Design**
- **Propulsion Design**
- **Aerostructures Design**

Questions at the end of every section

Preliminary Design Purpose

- Communicate top-level designs to establish a viable concept
- Clear up misunderstandings between engineers and stakeholders
- Identify problems or concerns to overcome
- Establish baseline architecture
- Ensure the designs can satisfy requirements under allocated budget and schedule

Etiquette

- Maintain Professionalism
- Presenters: Say your name, be clear, concise, speak slowly
- 165 slides total, around 2.5 hours
- Brief Questions for breaks/intermissions
- Kind and constructive feedback (3 weeks of design)
- Speaker Queue by the door

Concept Definition: The Mission

- FAR51025 Contest
  - Point Based Competition
  - Mojave, California
  - May 31st
- DPF 2023
  - Dynamic Piston Liquid Bi-Propellant to ~5,000ft
- FAR 2022
  - 1st, 2nd, 3rd place
  - ~5,000ft solid motors with deployable payloads

Score Guide

FAR 51025 Scoring This will aid teams in how the scoring works for the competition.

Altitude: a point is awarded for every foot of altitude reached up to the target of the division entered. A point is deducted for every foot of altitude over the division target. Example, a rocket entered in the 10,000' division that reaches 9,500' would receive 9500 points and a rocket that reaches 10,500' would receive 9,500 points to their score. New Unlimited, team picks target altitude (different scoring metrix)

Motor type: Acknowledging the increased difficulty of experimental motor design, construction, and testing, additional points are added for their use in the rocket Changes for 2023: *experimenta*l solid motors an additional (10% of altitude reached) points added to the score, *experimental* hybrids an additional (20% of altitude reached) points and *experimental* liquids (30% of altitude reached) points. Commercial hybrids or liquids will receive 500 points.

2-stage rocket: An additional 1,000 points are given for teams competing in the 25,000' division that does so with a 2-stage rocket.

Water ballast nose cone: Many people use heavy materials for ballast to stabilize rocket flight. An additional 1,000 points are given to any team demonstrating the successful use of a nose cone containing 500 mL of water for ballast and safely releasing the water into the air at or near apogee.

Build video or photos: 500 points will be added to the team score for a 2 minute video of the team's build or 25 photographs and submitted Change for 2023: one week prior to arrival at the FAR facility.

Payload options, changes for 2023, points award for successful mission completion
1000-points: Remotely Radio-Controlled Rover. Changes for 2023: Rocket must deploy a rover that leaves the rocket and travels a minimum of 10-feet after touchdown with live video on the ground from the rover to the receiving station till. Rover can be deployed separately from the rocket in the air on a parachute or after landing.
3000-points: Autonomous rover: A rover that returns autonomously to FAR designated area with live video. New for 2023: 2,000 points if memory card used instead of live video.
1000-points: Remote Sensing. Changes for 2023: After landing, a remote video camera will record the landing surroundings in a 360-degree horizontal panorama for transmission to launch control.
1000-points: Reconnaissance. Glider deployment below 400' on rocket descent with live video transmission. New for 2023: 1,000 points for memory card video instead of live video if glider returns to FAR designated landing area for memory card retrieval.
2000-points: Reconnaissance Return. Release of drone below 400' altitude or after landing with live video during drone return to a FAR designated location by autonomous or remote control. New for 2023: 1,000 points if video memory card used instead of live video.
500-points: Remote Sensing. Rocket must transmit live video from liftoff to touch down. Live video must be seen by judges and or recorded by the ground launch area receiving station for later viewing.

500 additional points New changes for 2023: for a user defined scientific payload that is contained in a 0.5 to 3 U CubeSat, Pocket Cube (5cm*3) or CanSat form factor. Prior approval required.

New for 2023: points for on board video source recorded to a memory card during the flight must be received by judges or downloaded the day of the flight to rocketrycontest@gmail.com

Live video must be witnessed by a judge and recorded at the ground launch area receiving station. Ground station recording of live video can be done on memory card or cell phone video of screen.
Points are awarded for successful payload mission completion.

Challenge Selected	Points Possible
10,000 ft Altitude	10,000
SRAD Liquid Propulsion	3,000
Water Ballast	1,000
Build Video	500
Remotely Controlled Rover	1,000
Reconnaissance Return Drone	2,000
Remote Sensing Camera	500
Total Points	18,000
Max Possible Points	23,500

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Stakeholder Definition

The members of our team

- Cultivate a passion for science, technology, and space exploration
- Develop skills that prepare students for the professional industry

Friends of Amateur Rocketry Officials

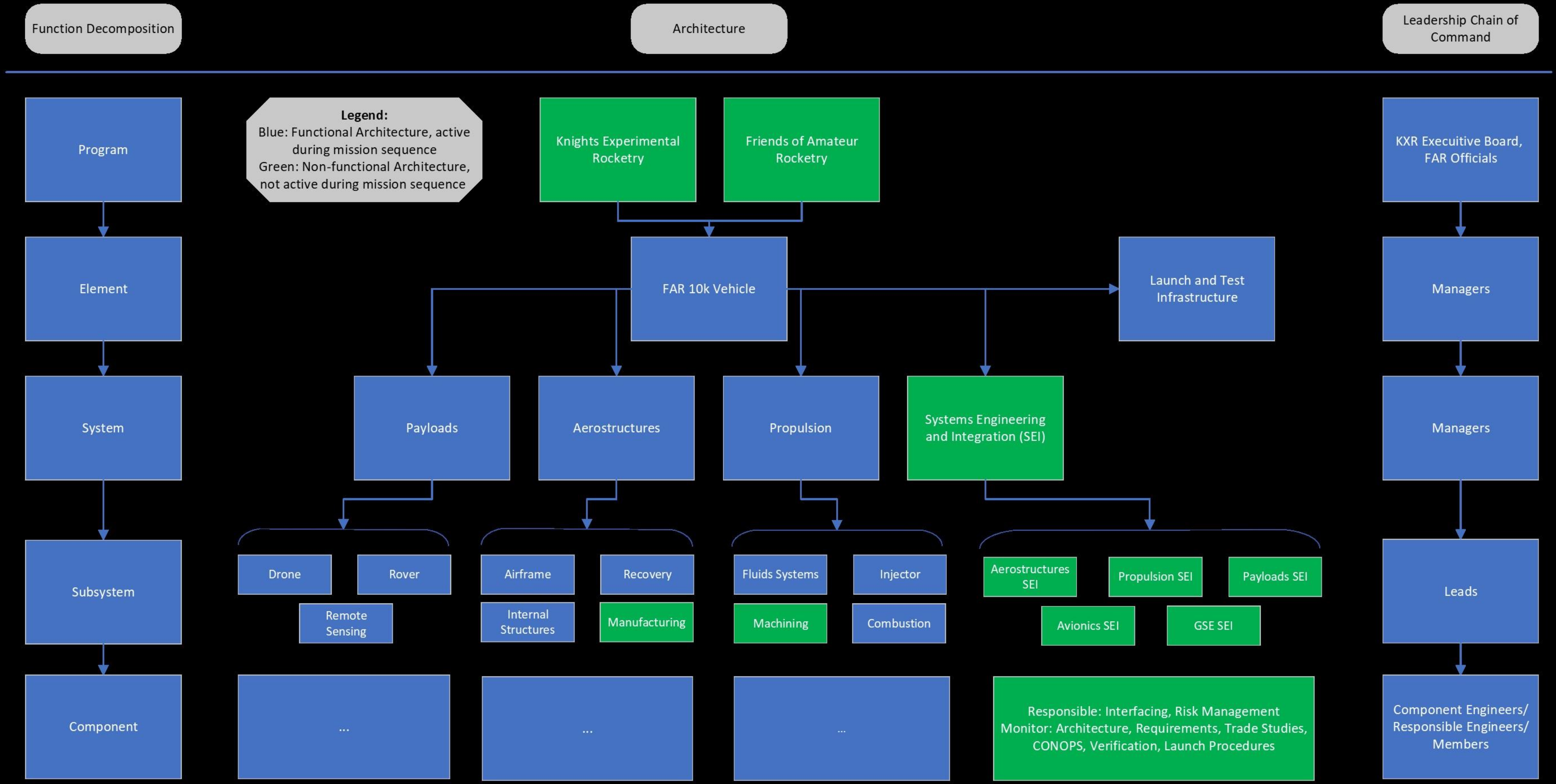
- Point scoring system and rules

KXR Executive Board

- Funding
- Outreach
- Misc. Support

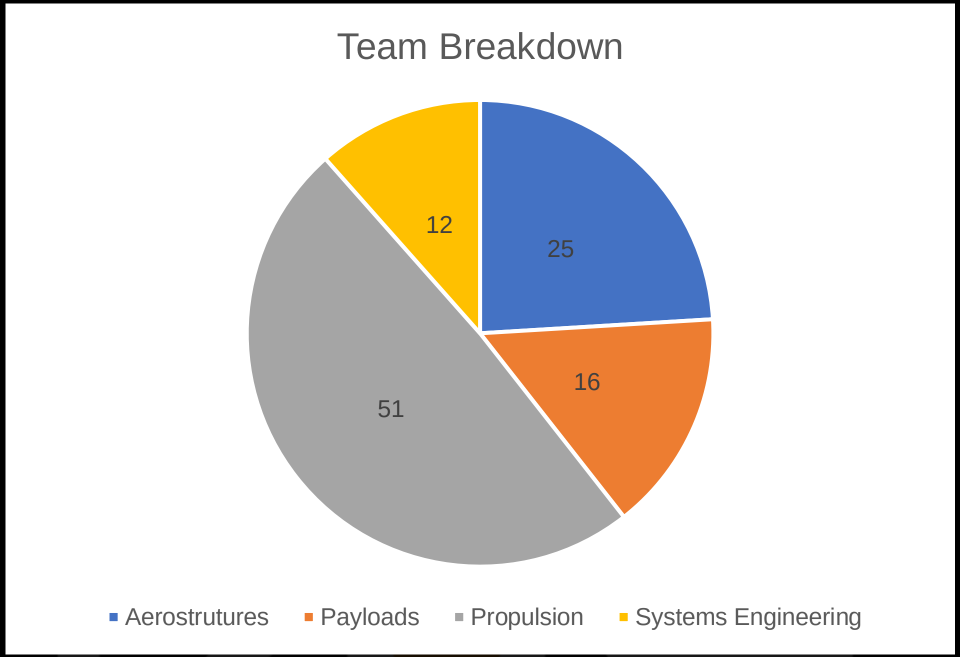
Technical Oversight

Organization Chart

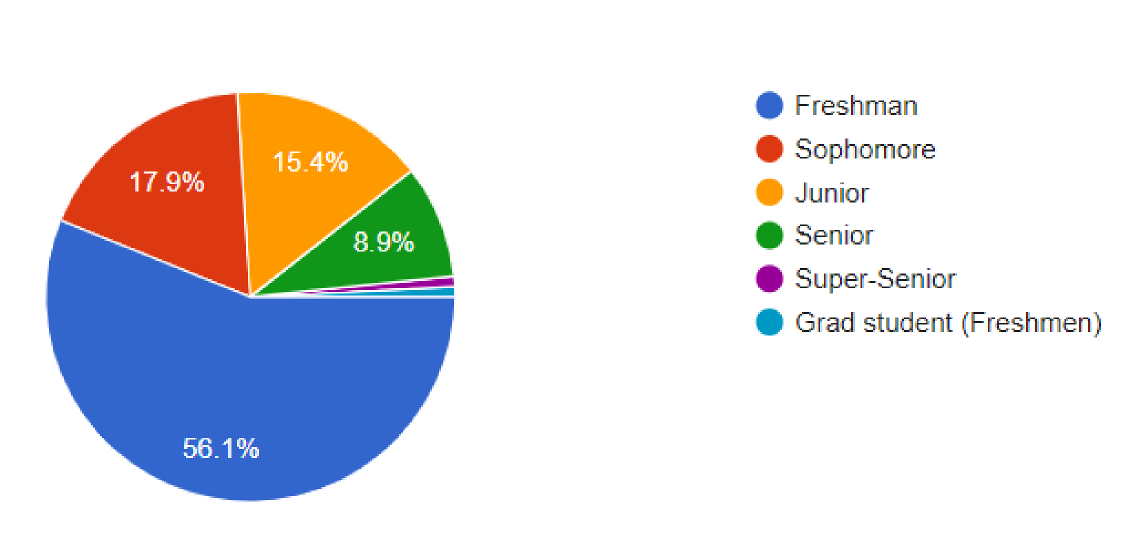


Team Demographics

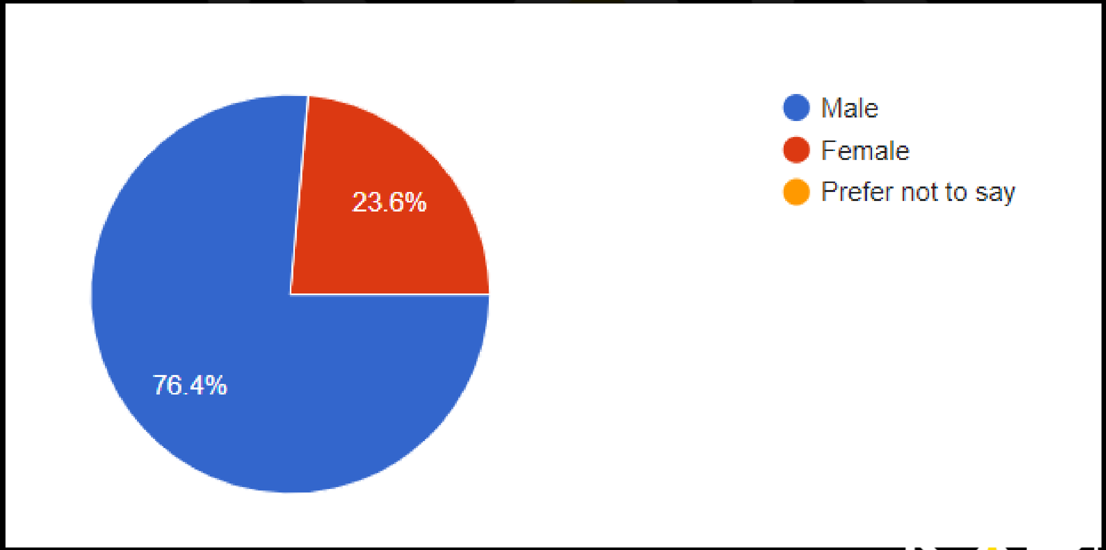
- Team: 96 students
- Managers: 4
- Leads: 20
- Component REs: ~50



Year in College



Gender



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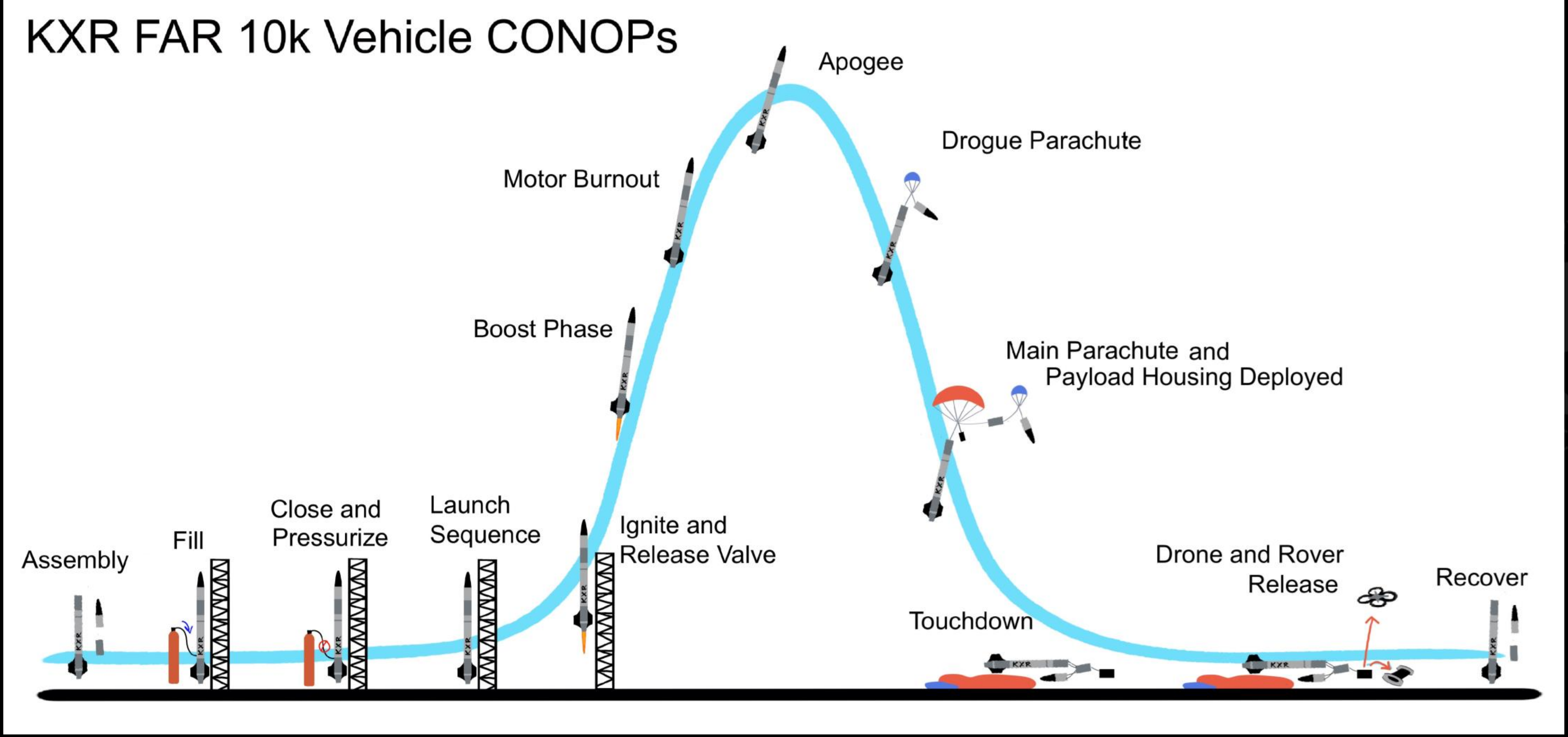
Vehicle Requirements and TPMs

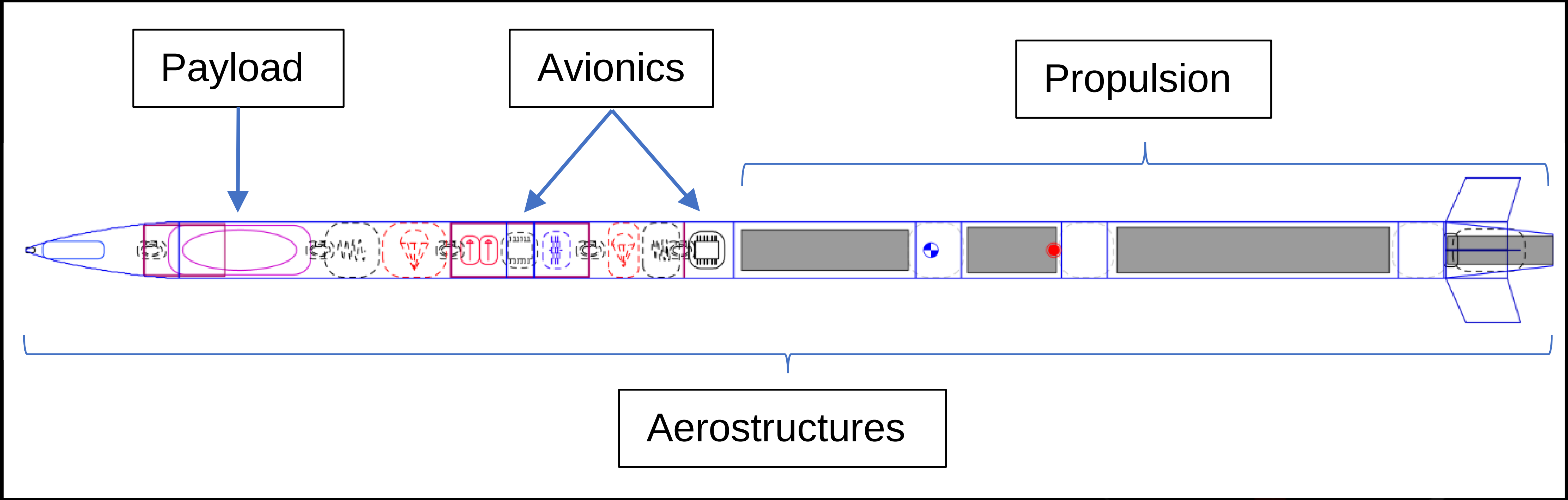
Requirement
The Vehicle **shall** launch to 10,000 feet.
The Vehicle **shall** be launched using liquid propulsion
The Vehicle **shall** withstand all flight loads
The Vehicle **shall** be stable during ascent duration.
The Vehicle **shall** be recovered in acceptable condition.
The Vehicle **shall** deploy rover and drone payloads on touchdown.
The Vehicle **shall** withstand ambient temperature of the desert environment.
The Vehicle **shall** interface between external ground support equipment (GSE) and FAR launch facility equipment

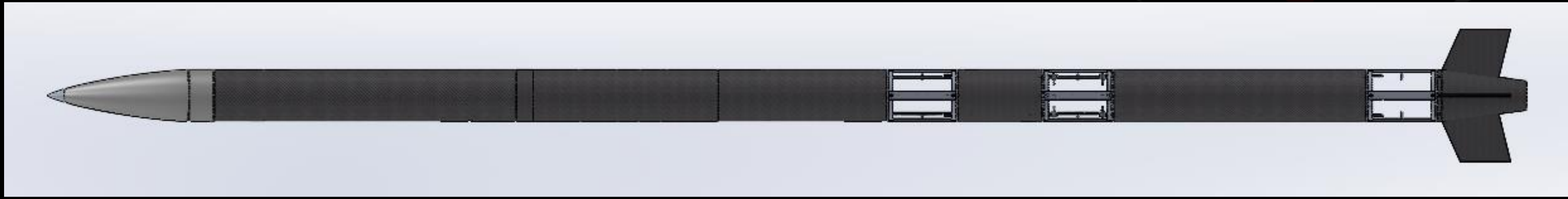
Performance Measures	
Altitude	10,000-16,148 ft
Impulse	16,534 Ns 3,710 lbfs
Velocity	Mach 1.08
Max Acceleration	5.89 g
Stability	2.18 cal
Mass	79.4 lb
Thrust to Weight	6.6
Length	14 ft
Diameter	6.2 in

Vehicle CONOPS



Vehicle Architecture





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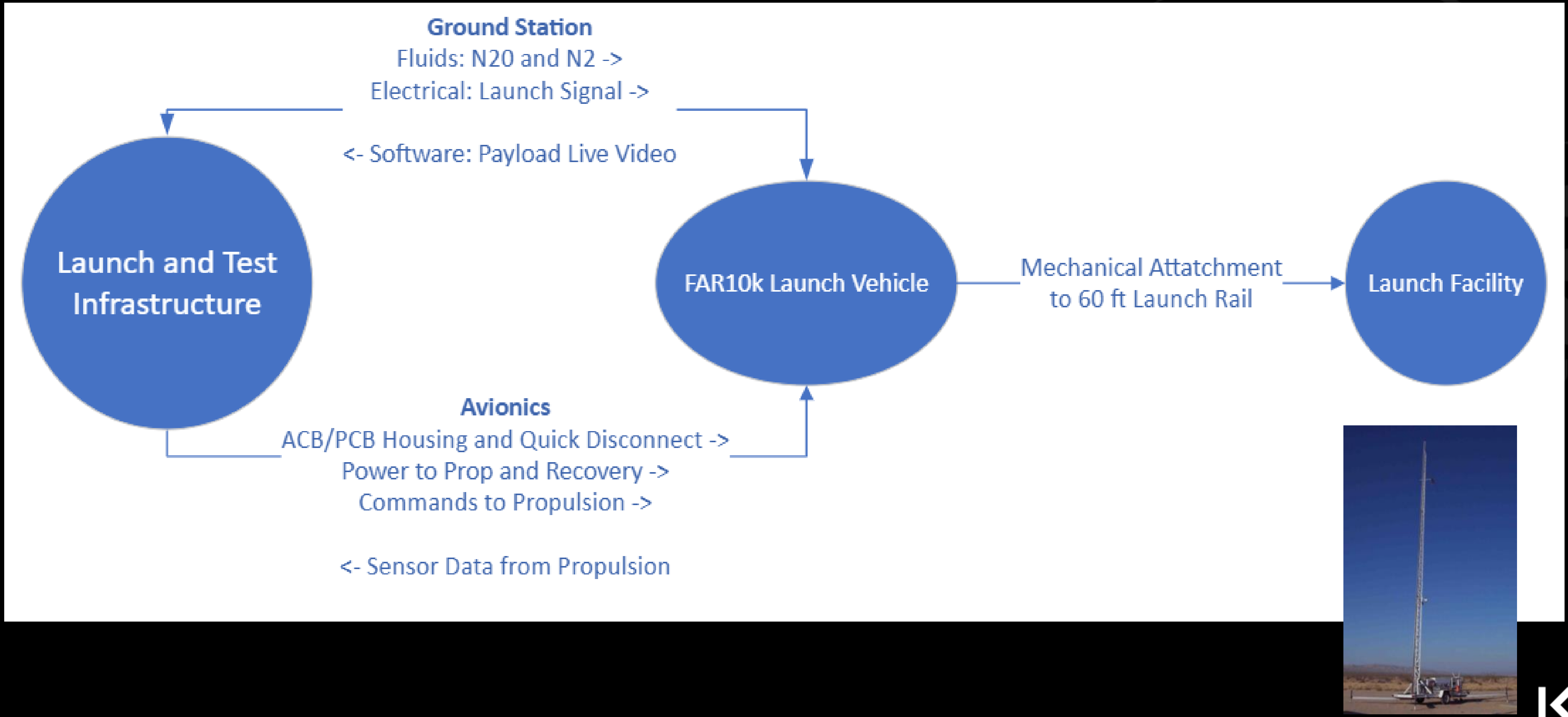
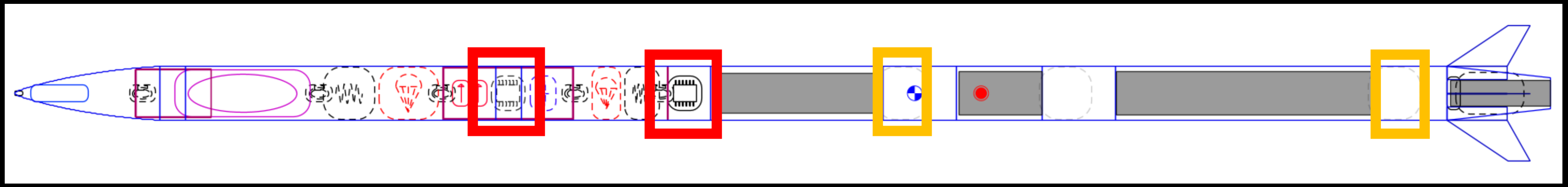
Vehicle Interface Diagram



Launch and Test Infrastructure Cont.

Avionics Control Board (ACB/ASS)	Propulsion Control Board (PCB^2)	Ground Station
Wired Power and Data Ports	Power to Sensors, Actuators	Fills Nitrogen and Nitrous Oxide
Wired connection to Cameras	Wired Commands to Actuators	Receives Live Telemetry and Video from ACB
Wireless Transmission of Live Video to Ground Station	Wired connection to GS	Receives Live Video from Drone/Rover
Wireless Transmission of Telemetry to Ground Station	Stores data locally	Sends wired commands to PCB^2 and ACB
Magnetic Power Connector	Magnetic Power Connector	



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Costs

Total Vehicle Budget: $13,000

Estimated System Breakdown

- Propulsion: $6,000
- Aerostructures: $4,500
- Payloads: $2,500

Sources of Funding

- UCF SG: $5,000
- KXR UCF: $5,000
- FSGC: $3,000

Schedule: 9 Months

PI-1: Concept Dev and Design September – December 3 months	Explore Concepts, Develop Team Structure, Create the final design Concept Exploration, Design Phase, PDR, SRR, and CDR, approve budget
PI-2: Procurement and Manufacturing December – March 3 months	Procure throughout winter break Manufacturing, Simulation Verification, Machining, Assembly, and travel
PI-3: Testing and Launch March – June 3.5 months	Begin Testing campaign, integration of systems, small changes and interation Travel to Mojave and Launch

Schedule: PI 1

PI-1: Concept Development and Design (August – December)

- Preplanning……………………………………………………………………(Aug. 1st –31st)
- Vehicle Concepts Design……………………………………………………...(Aug. 15th - 31st)
- Concept Development and Learning Phase……………………………….(Sprint 1,2)
- **System Requirements Review………………………………………….(Oct. 2nd)**
- Preliminary Design……………………………………………………...(Oct: Sprint 3,4,5,6)
- **Preliminary Design Review…………………………………………….(*Oct. 23th*)**
- Detailed Design…………………………………………………(Oct-Nov: Sprint 4,5,6)
- Sub-System/Component Requirements Review…...……………………..(Mid-Nov.)
- Critical Design Review……………………………………………………(End of Nov.)
- Begin Procurement………………………………………………………(Dec: Sprint 7)
- End of PI-1……………………………...……………………………………..(December)

More details in SEMP

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Verification Plans

1. System Verification Testing
2. Vehicle Dry Fit Test
3. Wet Dress Rehearsal
4. Launch Day Verification testing
5. Flight Demonstration

Questions?

- From Eboard and Industry Guests
- Pertaining to Vehicle Level only
- 7 minutes questions

KNIGHTS EXPERIMENTAL ROCKETRY

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October 23rd, 2023
Payload Preliminary Design Review
FAR10k Liquid Rocket

Payload Functional Requirements

System	Requirement	Requirement Type	Verification Method
Payloads	The Payloads System **shall** have a weight no more than [9] lbs	Performance	Inspection
Payloads	The Payloads System **shall** have a maximum length of [2.5] feet.	Performance	Inspection
Payloads	The Payloads System **shall** have a outer diameter less than [6] inches.	Performance	Inspection
Payloads	The Payloads System **shall** consist of [mechanical] and [electrical] subsystems.	Functional	Demonstration
Payloads	The Payloads System **shall** remain actively powered for [15] minutes	Performance	Test
Payloads	The Payloads System **shall** remain passively powered for [3] hours	Performance	Test
Payloads	The Payloads System **shall** have a mechanical interface with the Aerostructures system.	Interface	Demonstration
Payloads	The Payloads System **shall** impact the ground less than 30 ft/s	Performance	Analysis

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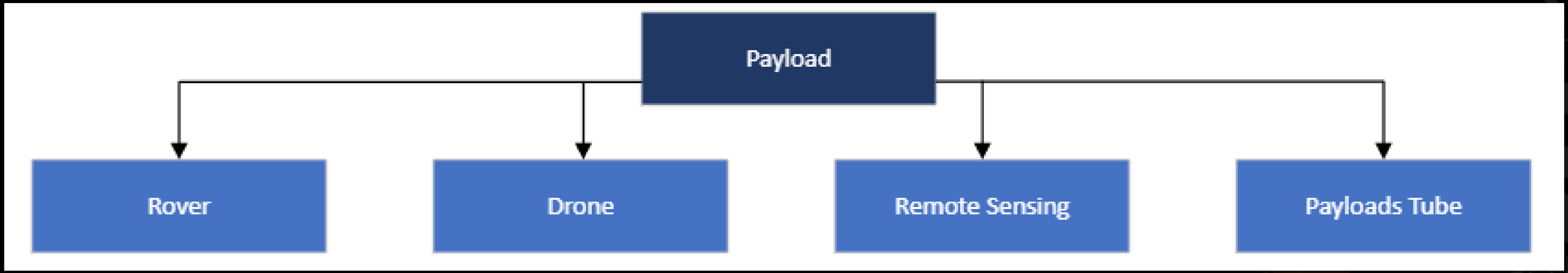
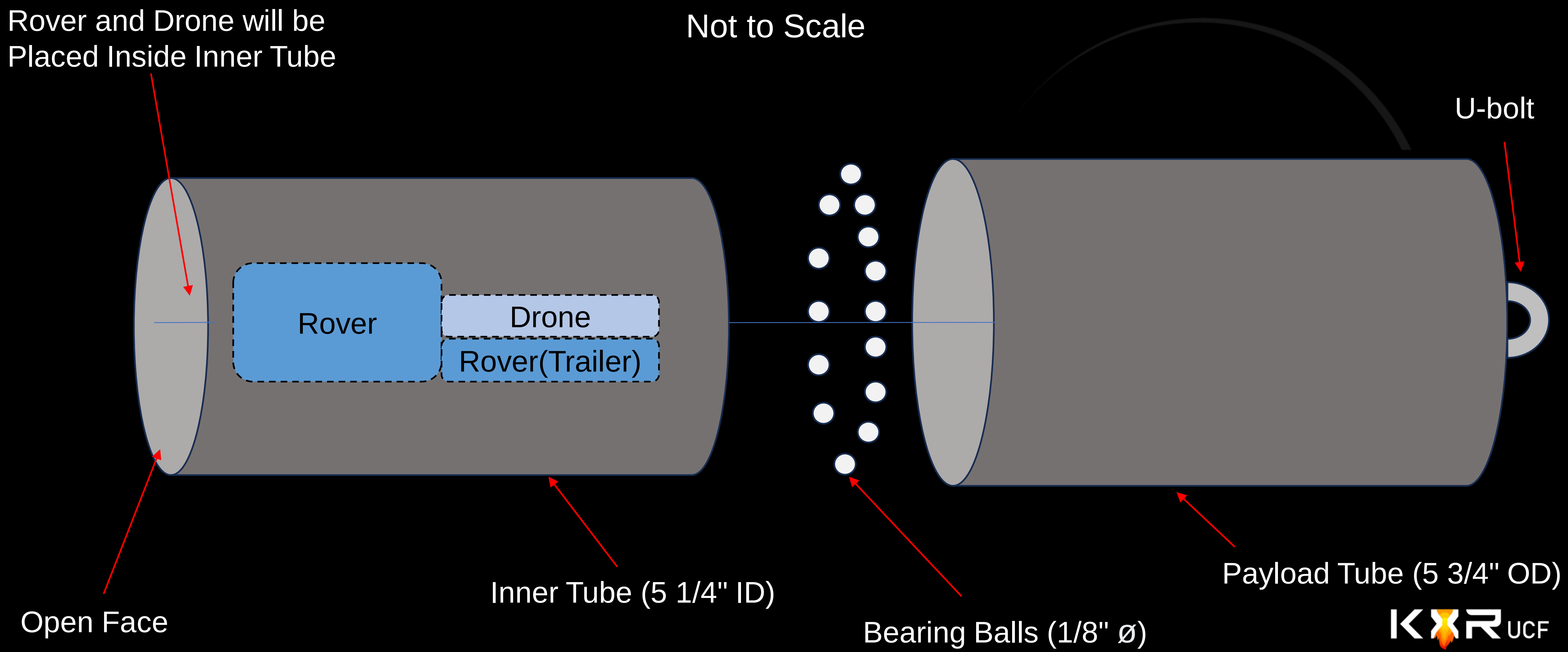
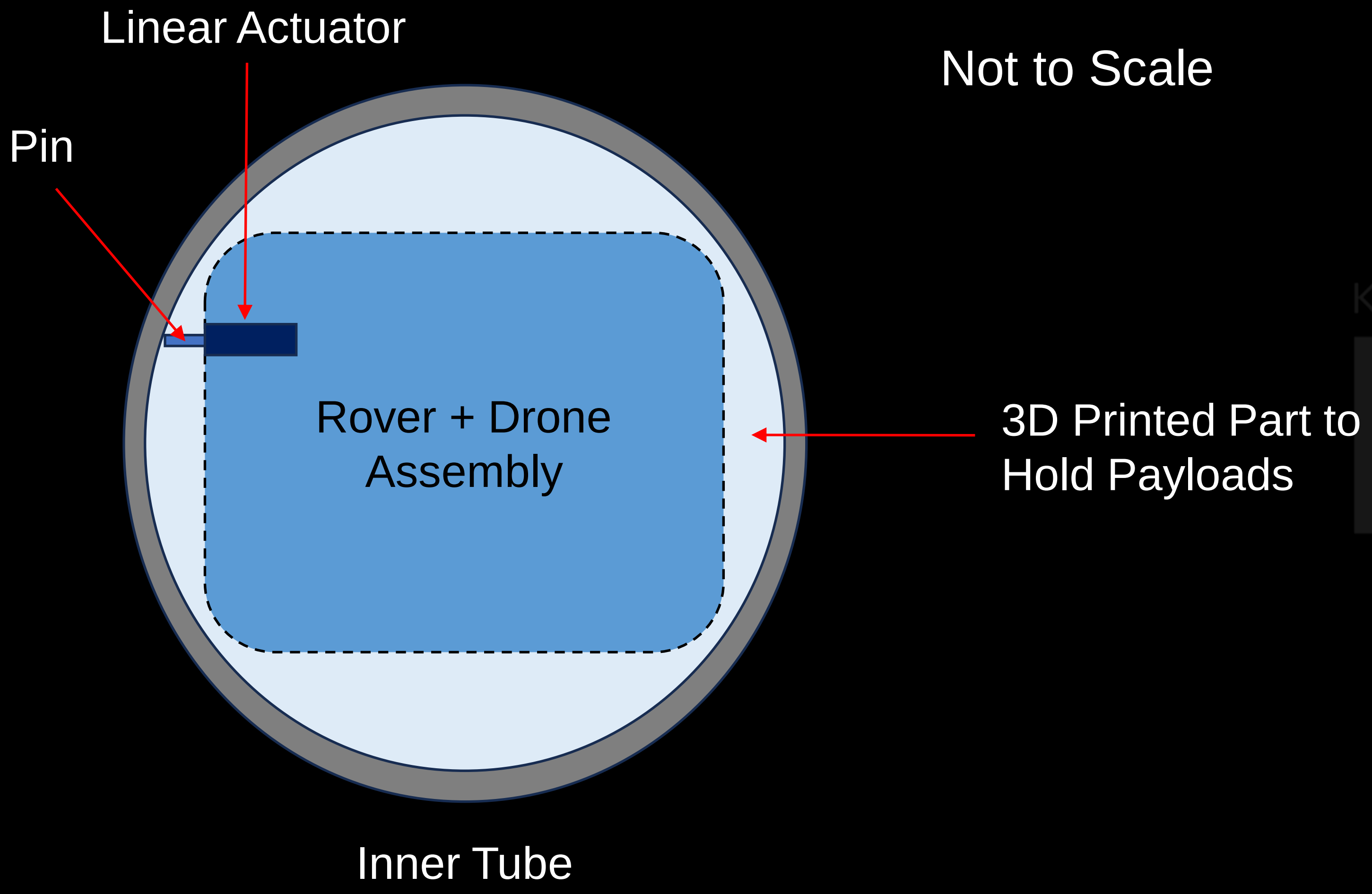
Payload Architecture



Payloads Tube Assembly



Payloads Tube Assembly



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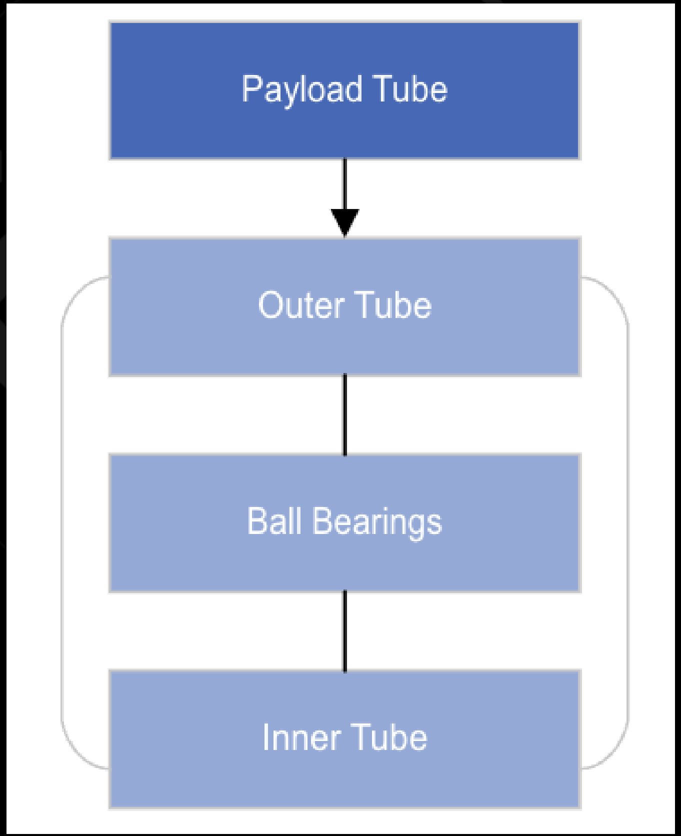
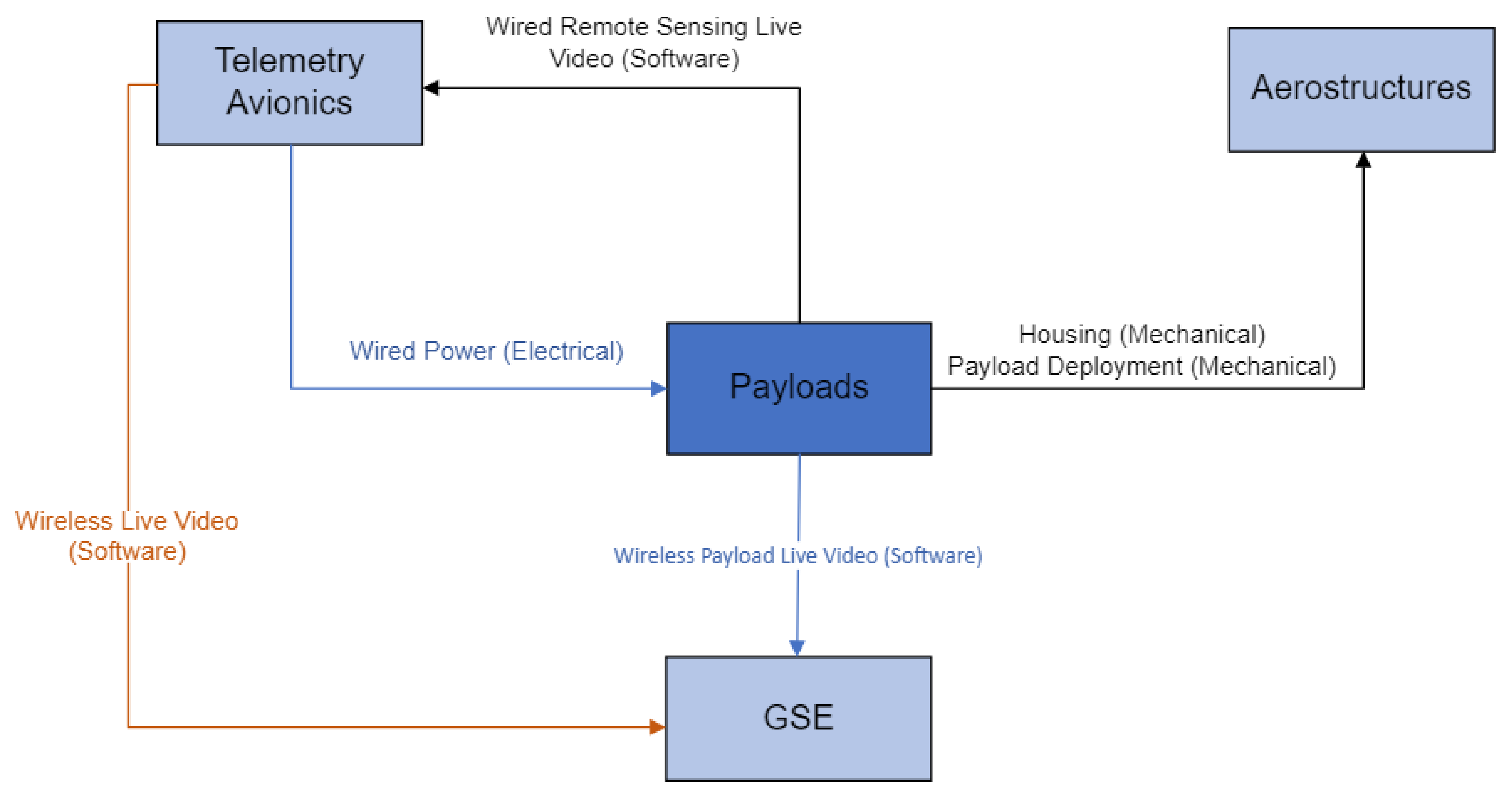
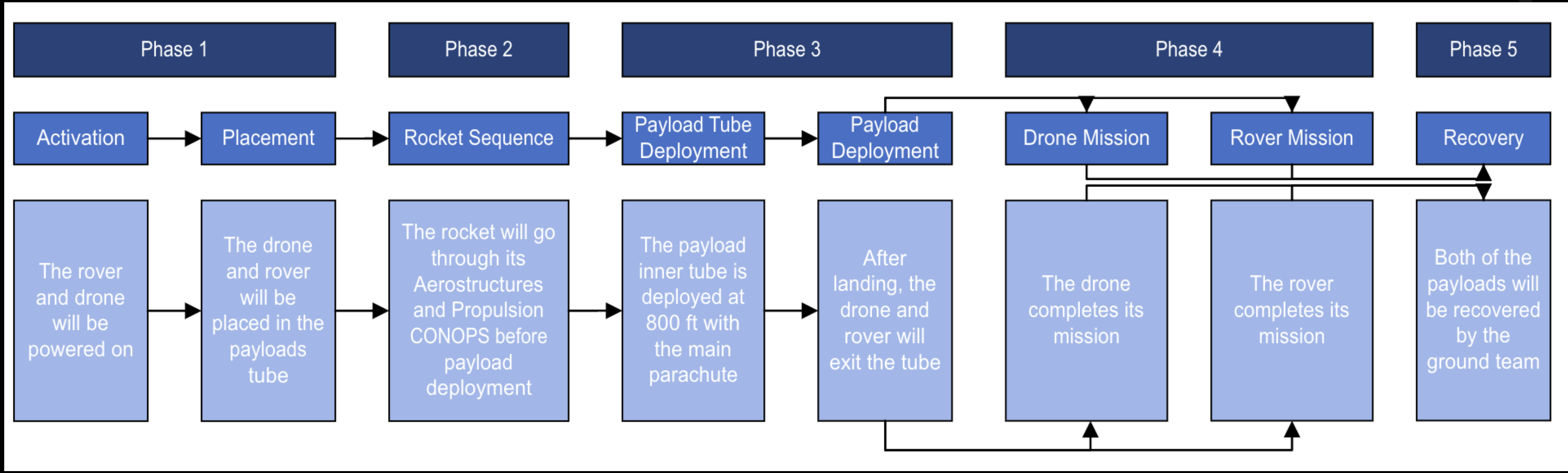
Payloads Tube Architecture



Payload Interface Diagram



Payload CONOPS



Payload Cost

Payload	Cost
Payloads Tube	$[200]
Rover	$[410]
Drone	$[500]
Remote Sensing	$[120]
GSE	$[400]
Buffer	$[300]
Total	**$[1930]**

Payload System Verification Plans

- Overall Payloads Tests (Demonstration)
- Finite Element Analysis (Analysis)
- Drop Tests (Demonstration)
- Torsional Rigidity Test (Demonstration)
- Ball Pin and Tuft Tests (Demonstration)
- Vibration and Shock Tests (Demonstration)
- Connectivity / Transmission Check (Inspection)

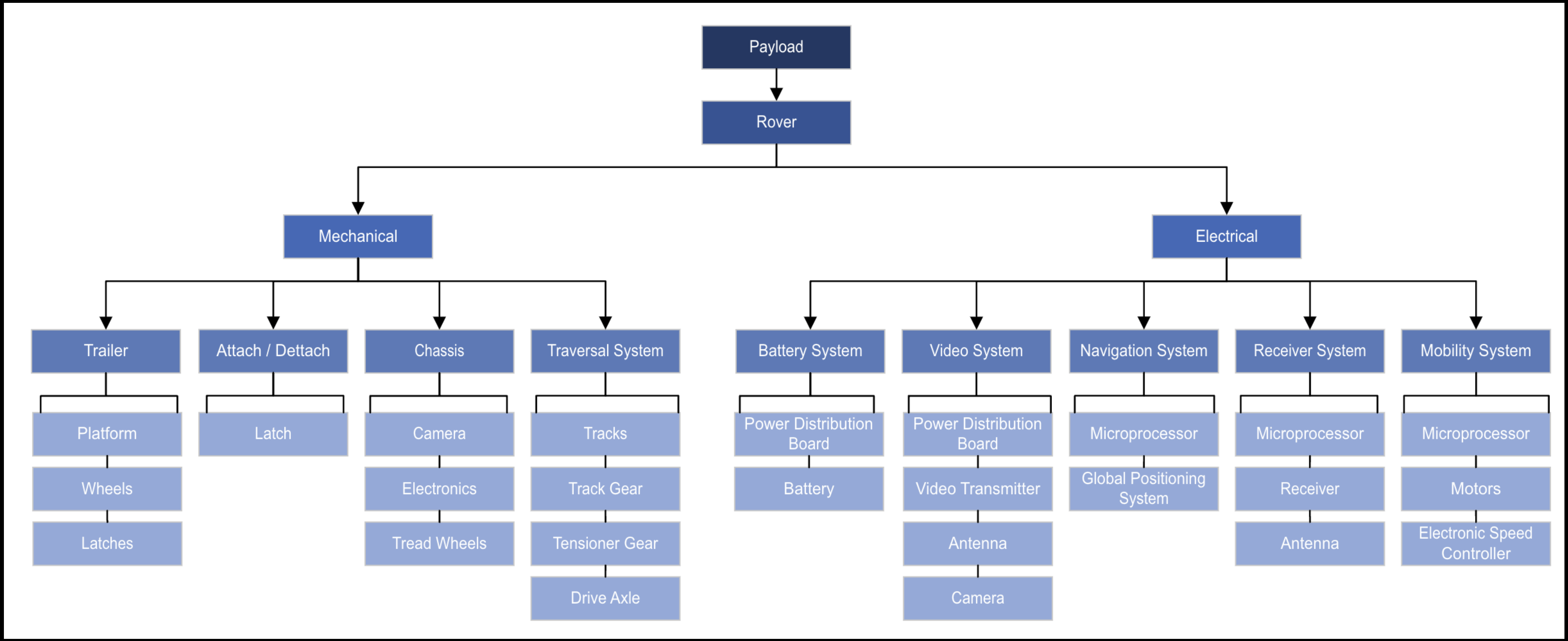
Payload System Risks

- Self-orienting mechanism
- Mechanical failure
- Tread slip/snap
- Battery Failure
  - Short circuit
  - Overheating
- Transmitter Interference
- Electric Failure
  - Latch Deployment

Rover Functional Requirements

System	Sub-System	Requirement	Type	Verification Method
Payloads	Rover	The Rover **shall** deploy from rocket at 800 ft with the main parachute	Interface	Test
Payloads	Rover	The Rover **shall** detach from payload tube on touchdown	Functional	Demonstration
Payloads	Rover	The Rover **shall** travel a minimum of 10 feet after landing	Performance	Demonstration
Payloads	Rover	The Rover **shall** be remote controlled	Functional	Demonstration
Payloads	Rover	The Rover **shall** have live video	Functional	Demonstration
Payloads	Rover	The Rover **shall** attach to the Drone	Functional	Demonstration
Payloads	Rover	The Rover **shall** detach from the Drone	Functional	Demonstration

Rover Component Breakdown (Architecture)



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Rover Subsystem

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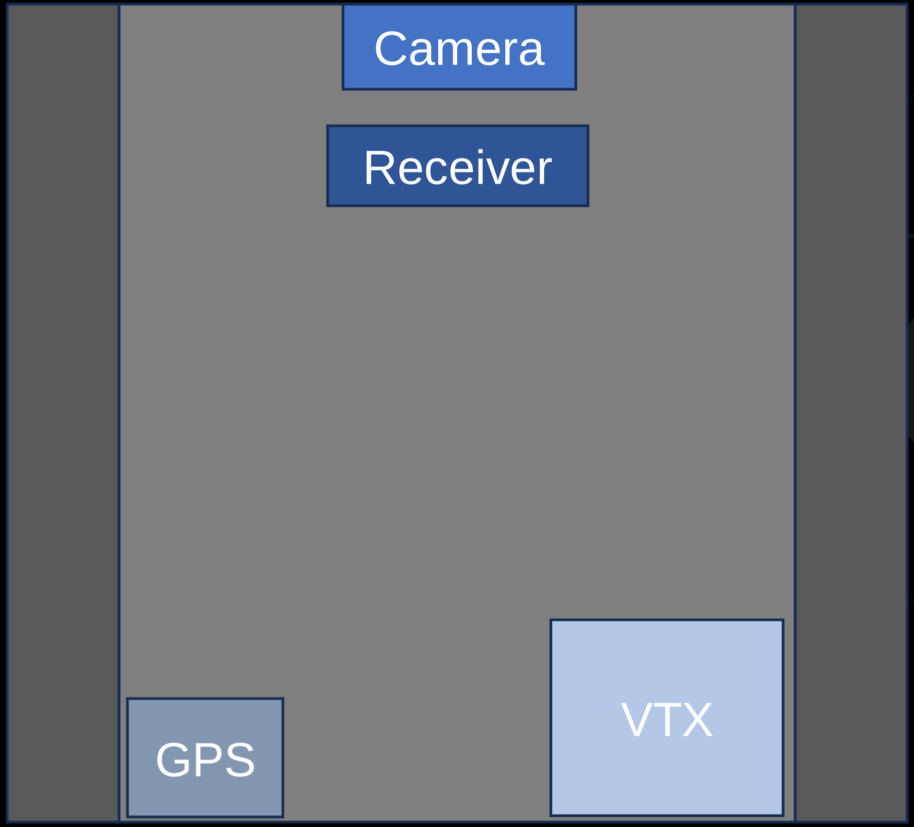
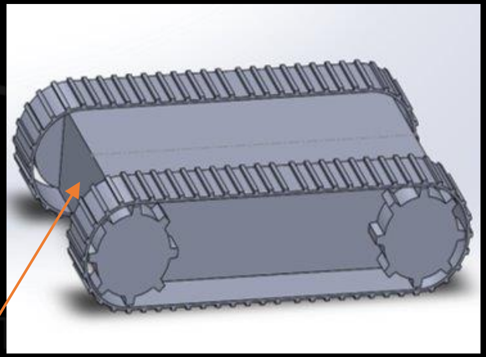
Front

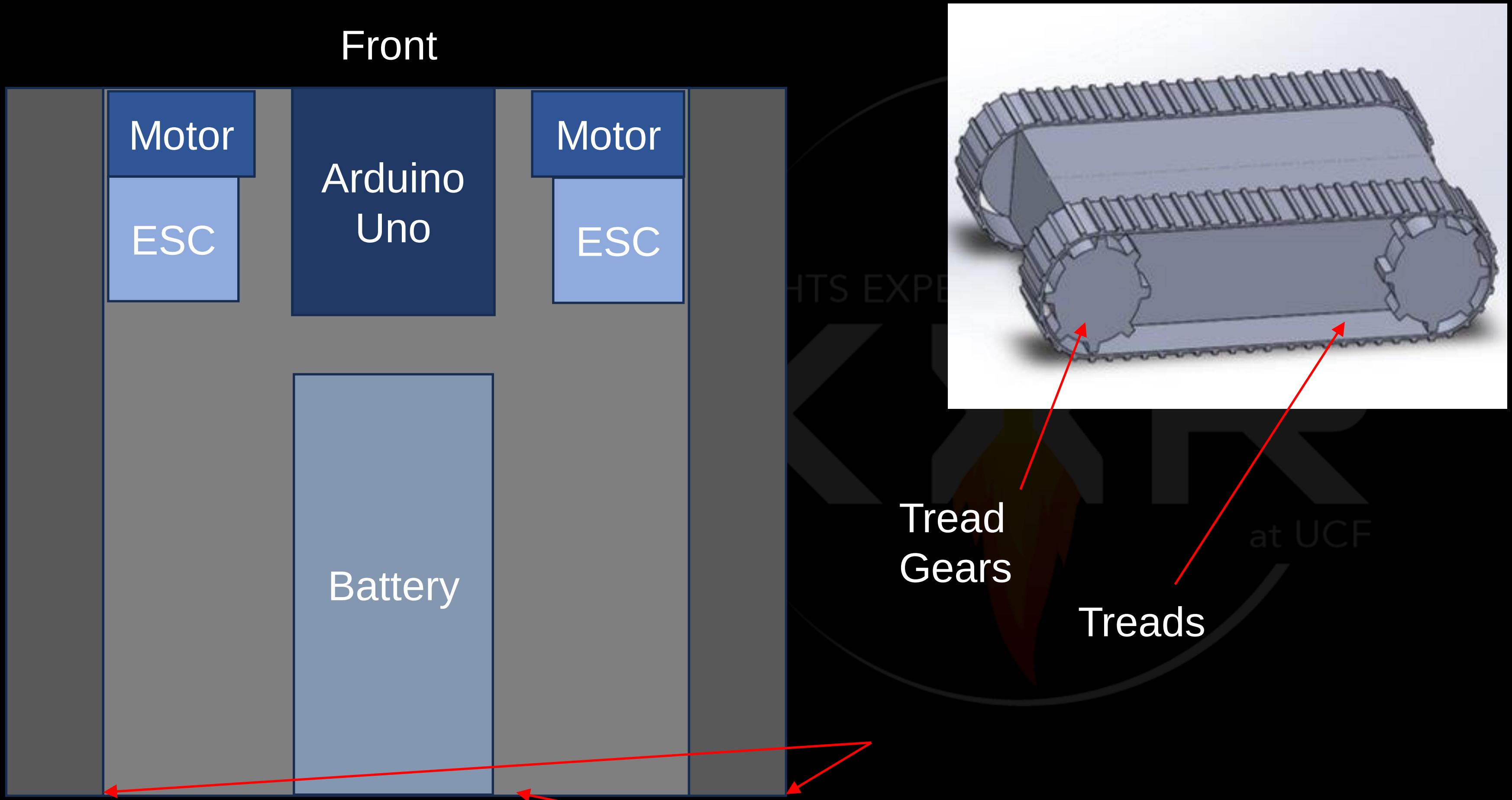


Top of Rover
(Top View)



Camera (front of rover)

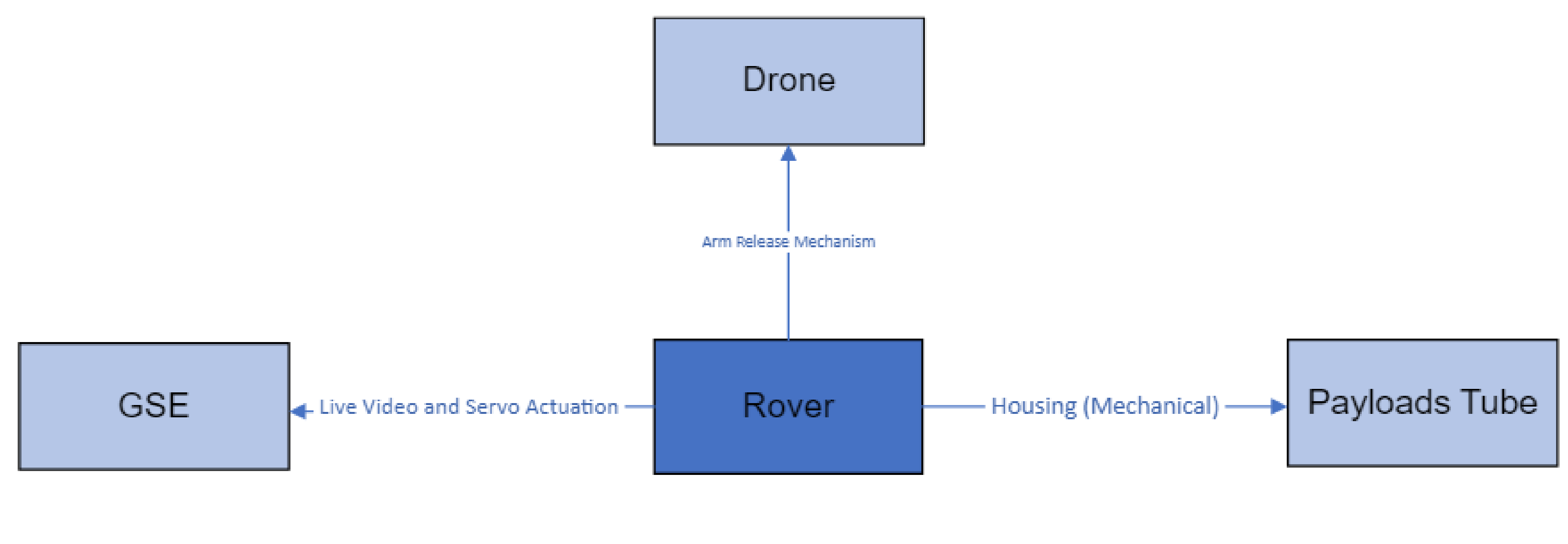
Rover Subsystem



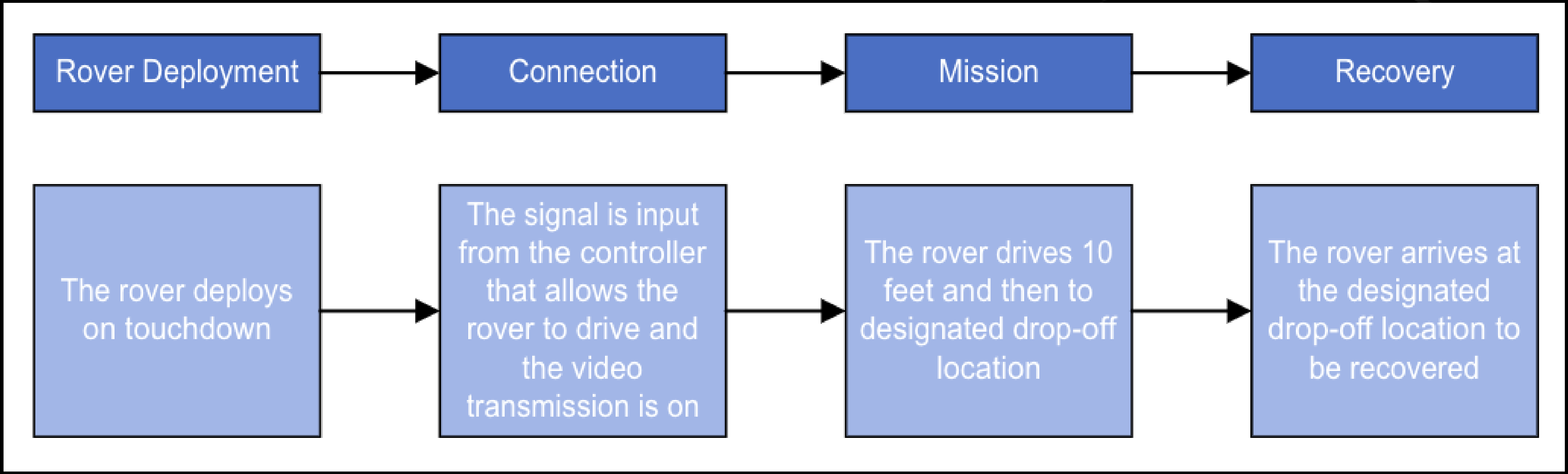
Rover TPMs

Measure	TPM Value	Units	Verification Method
Assembly Dimensions	18” x 4.64” x 2” (LxWxH)	in	Inspection
Weight	[1]	lbs	Inspection
Operating Time	[1.03 - 1.60]	hours	Analysis
Passive Power Draw	1405 - 2165	mA	Analysis

Rover Interface Diagram



Rover CONOPS



Mechanical Components

The Traversal System, or "Treads" provides propulsion to the rover, and consists of:

- Tank Tracks (SRAD)
  - Cables + Tread Piece Assembly
  - Treads are made of PVC
- Molded Plastic COTS Gears
- Metal Drive Axles from VEX robotics
- Fasteners & Nuts

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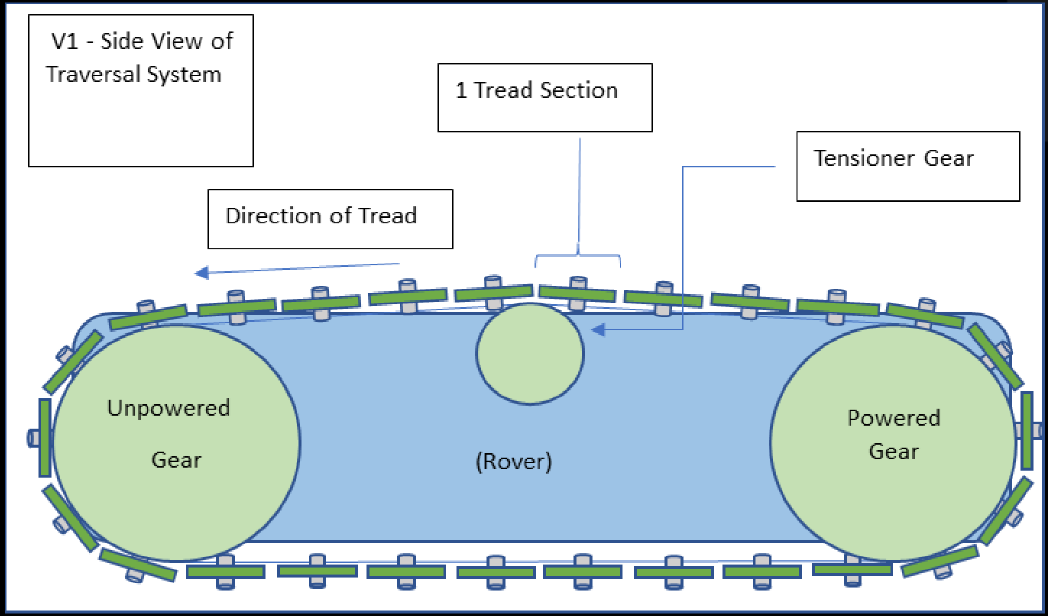
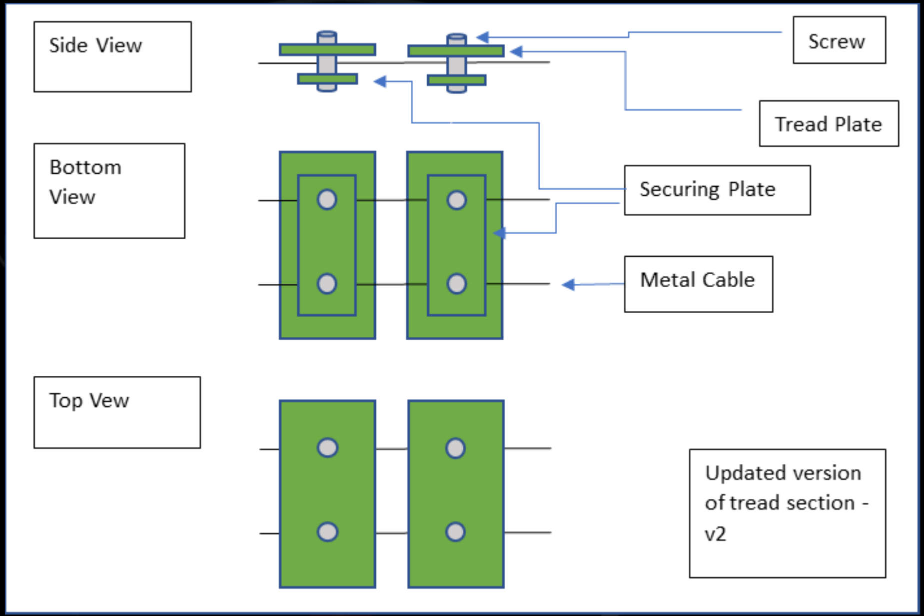
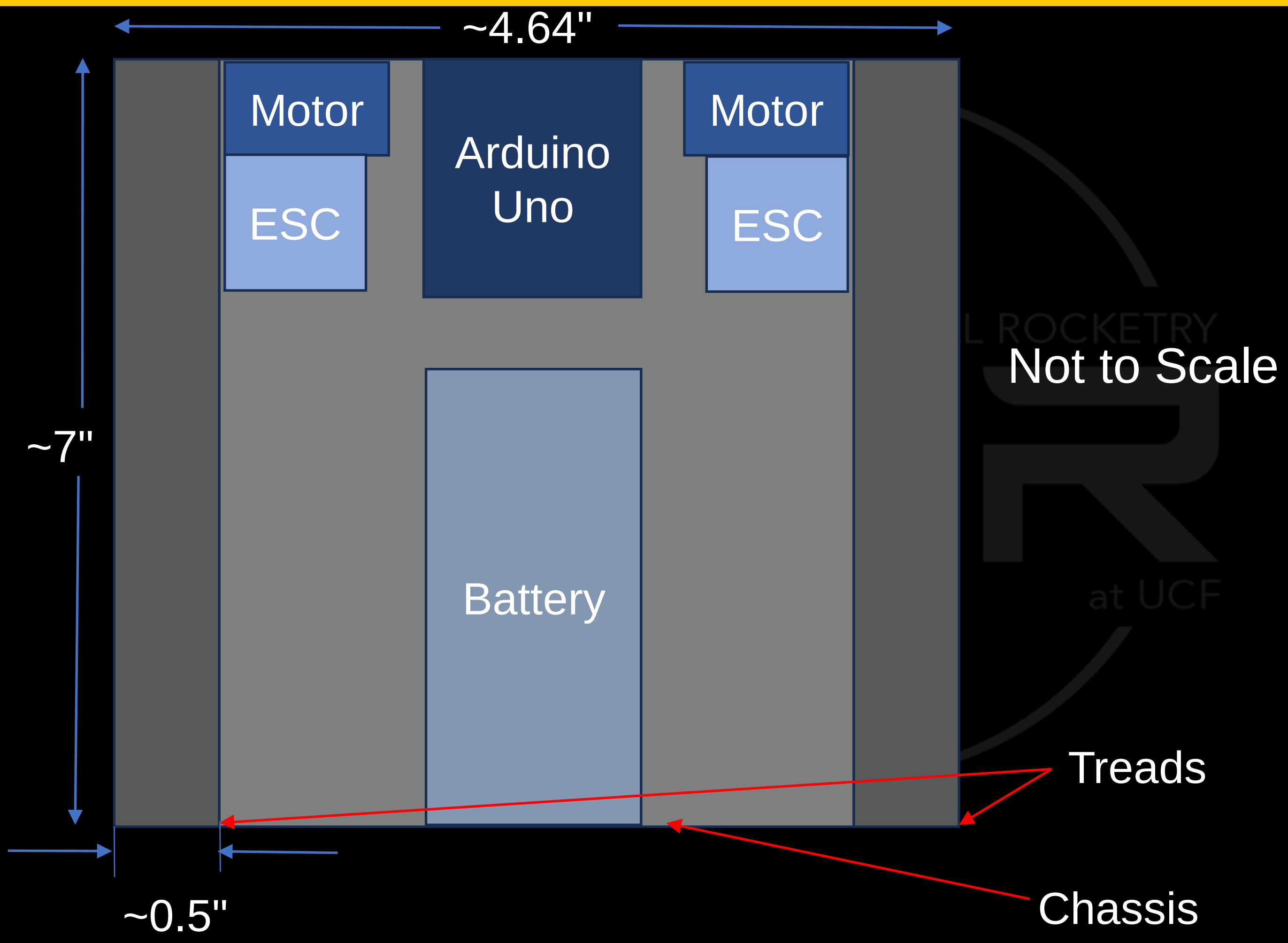




Mechanical Components

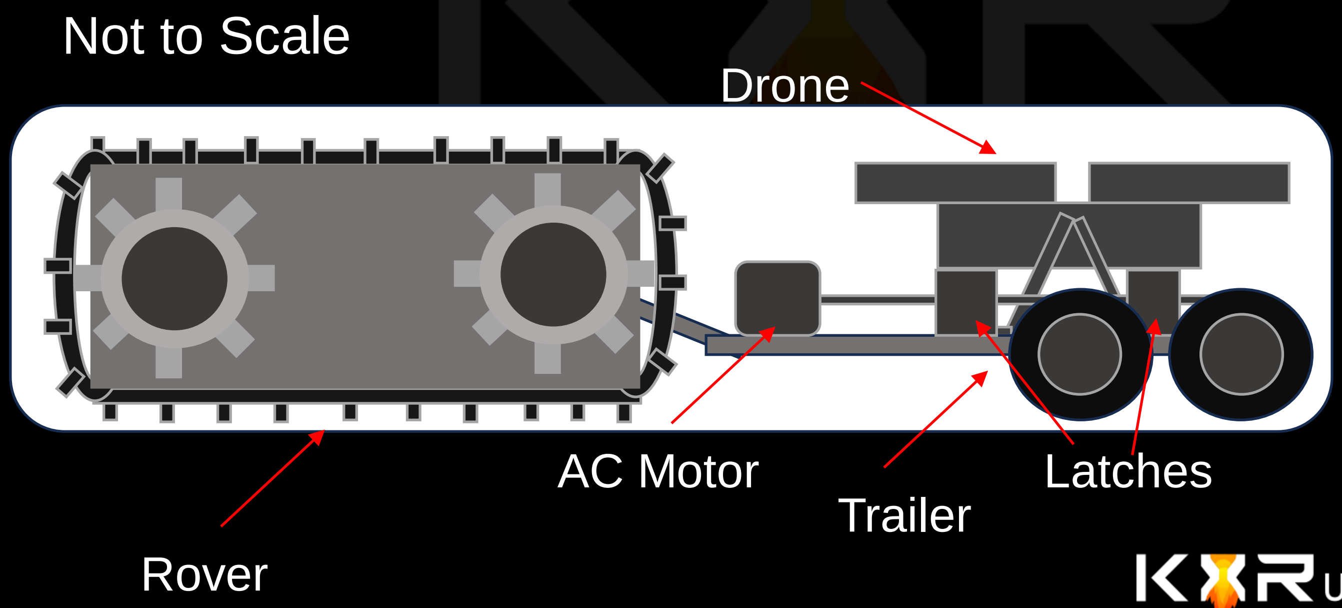
- Chassis
  - 7"x4.64"x2" (LxWxH)
    - Frame is made of Unistrut
    - Aluminum sheets are bolted on the top and bottom



Bottom of Rover

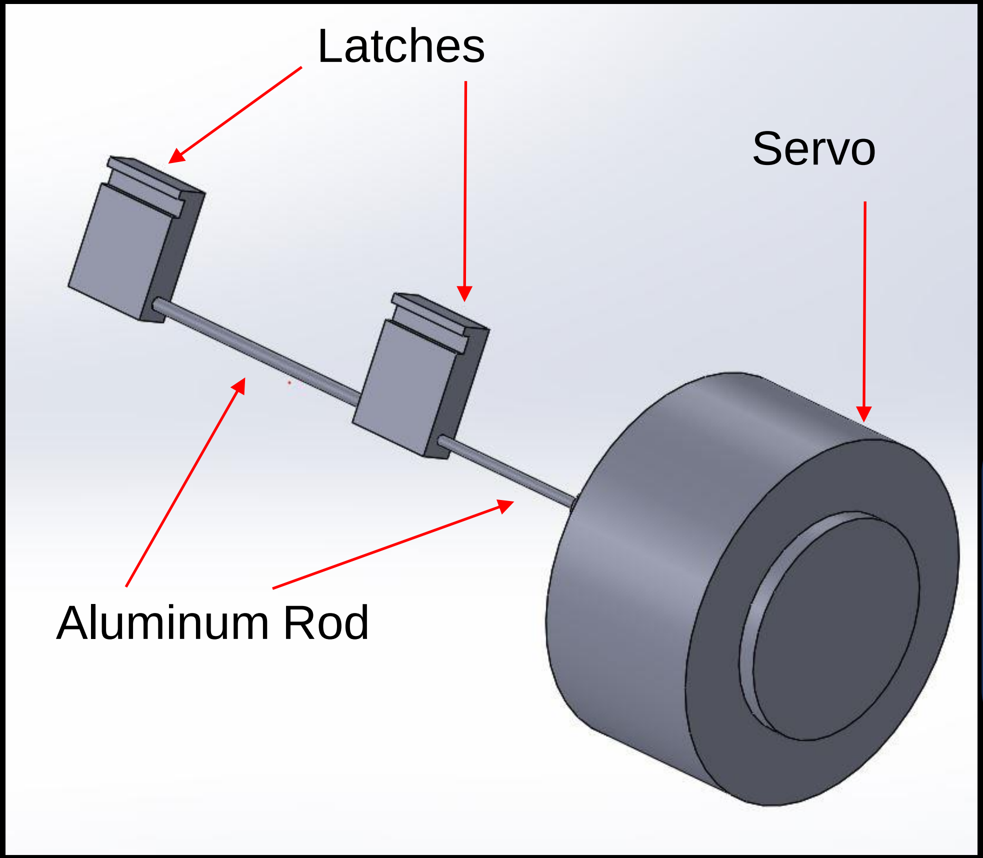
Mechanical Components

- Trailer
  - 11"x3.5"x1.25" (LxWxH)
  - Attached permanently to rover
  - Frame is made of Unistrut
  - Aluminum sheets are bolted on the top
  - COTS wheels
  - Used to drag and hold drone until drone deployment



Mechanical Components

- Attach/Detach Latch



- Attach/Detach Latch – Responsible for holding and releasing the drone from the trailer.
  - Servo
  - 3D Printed Latches
  - ¼" 12-inches Aluminum Rod

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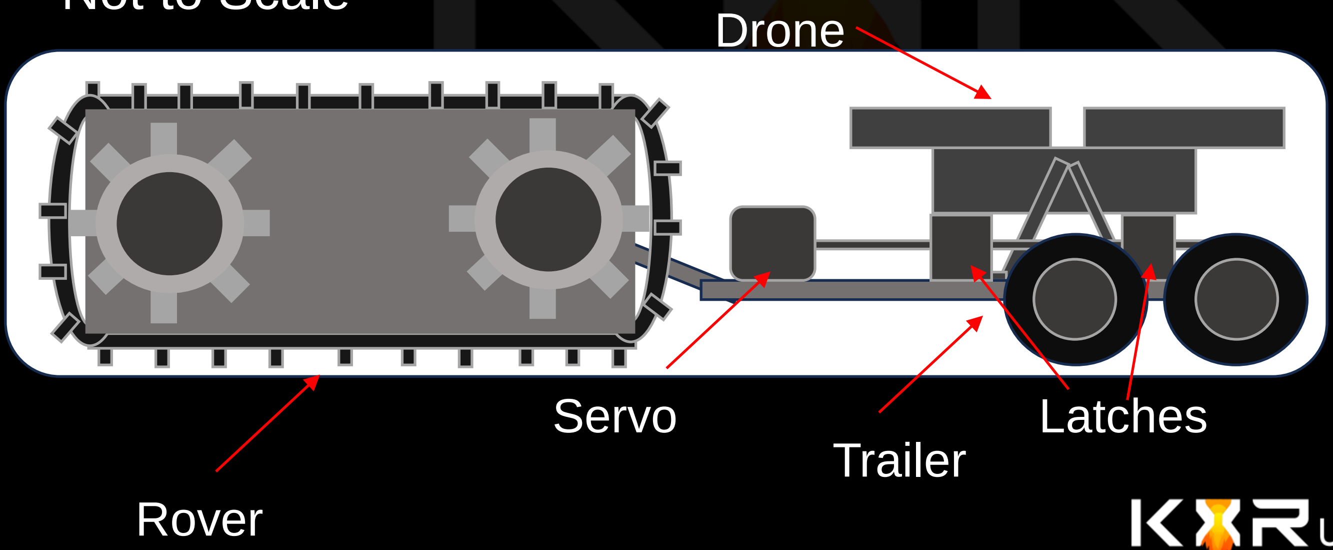
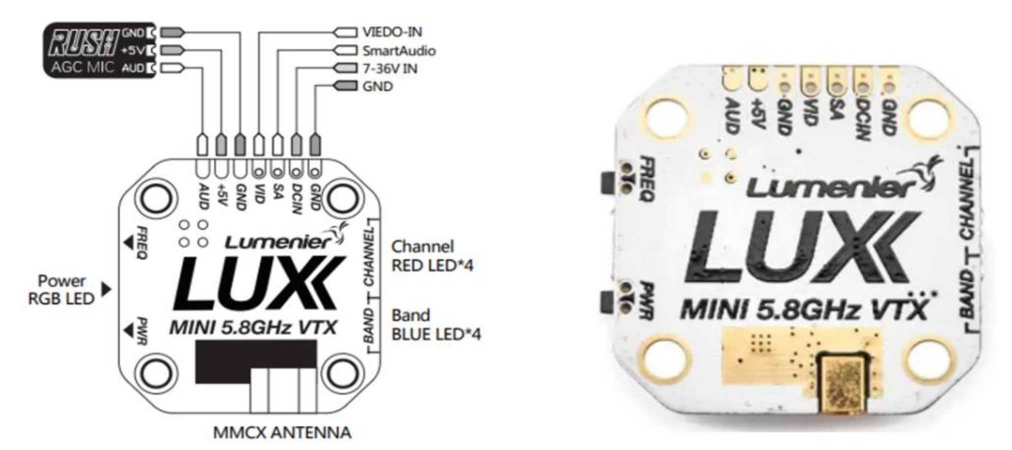


Electrical Components

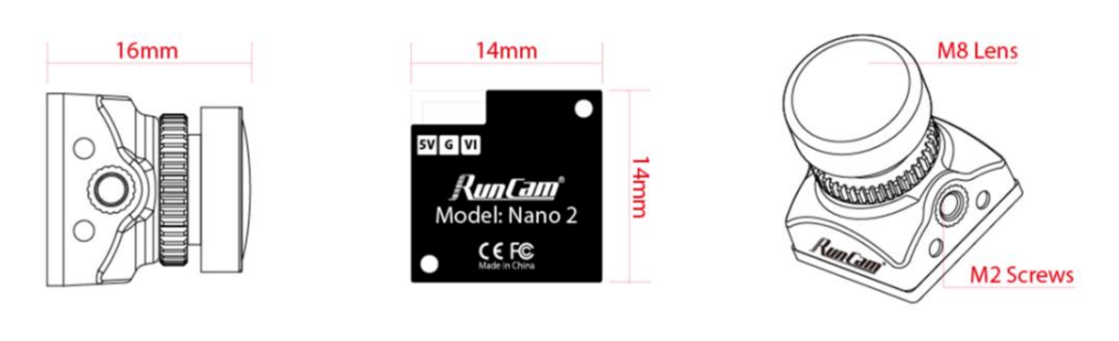
- Battery
  - Lumenier 2250mAh 4s 35C LiPo (14.8V Large Capacity)
    - Battery will be supplied with splitters and a power distribution board

Electrical Components

- Visual Transmitter
  - Lumenier LUX Mini VTX (380mA at 800mW. 5.8GHz)

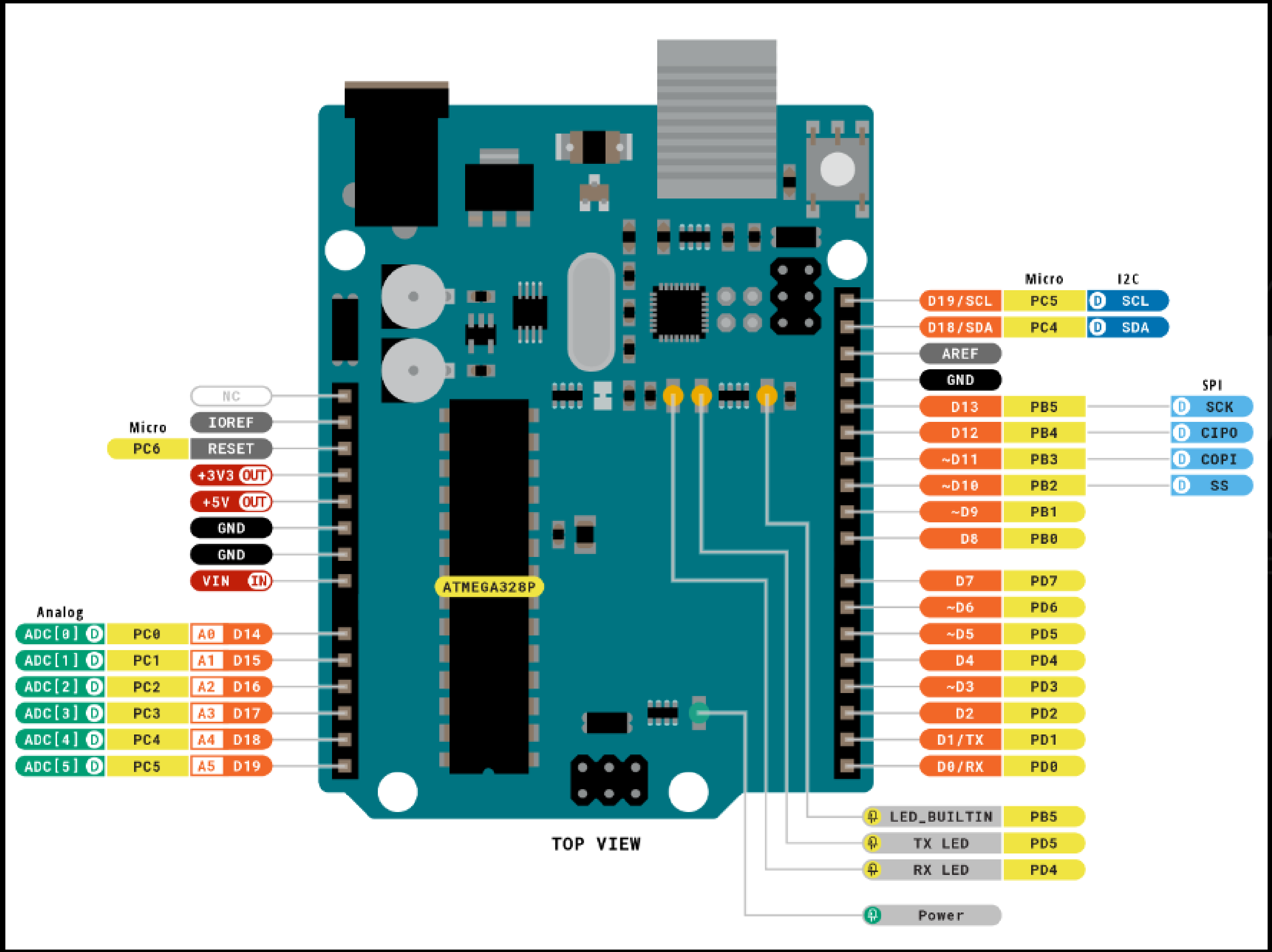


- Camera
  - Runcam Nano2: (Low Drain 155° FOV)



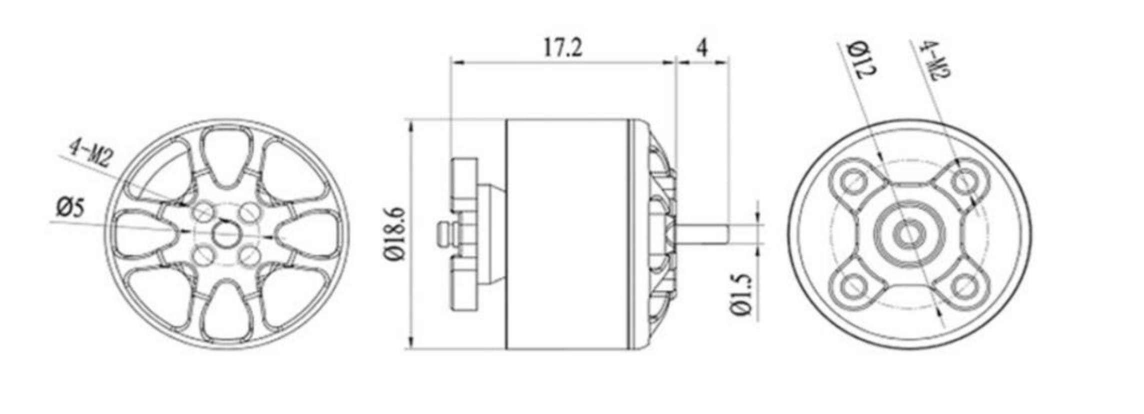
Electrical Components

- Microprocessor
  - Arduino UNO Rev 3 (Basic IO Pin Selection)
    - Note: The Arduino is not the centralized power source for rover electrical components.



Electrical Components

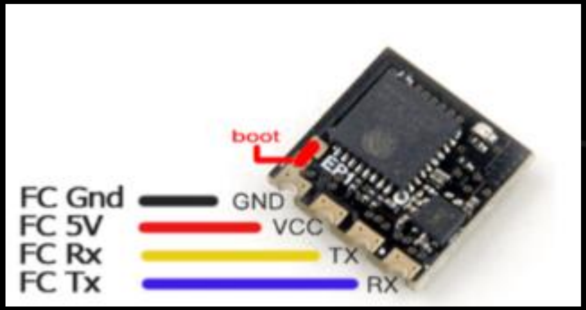
- Motors
  - Arthur 3650k Brushless DC: 1.1A (Smaller than traditional 1408)



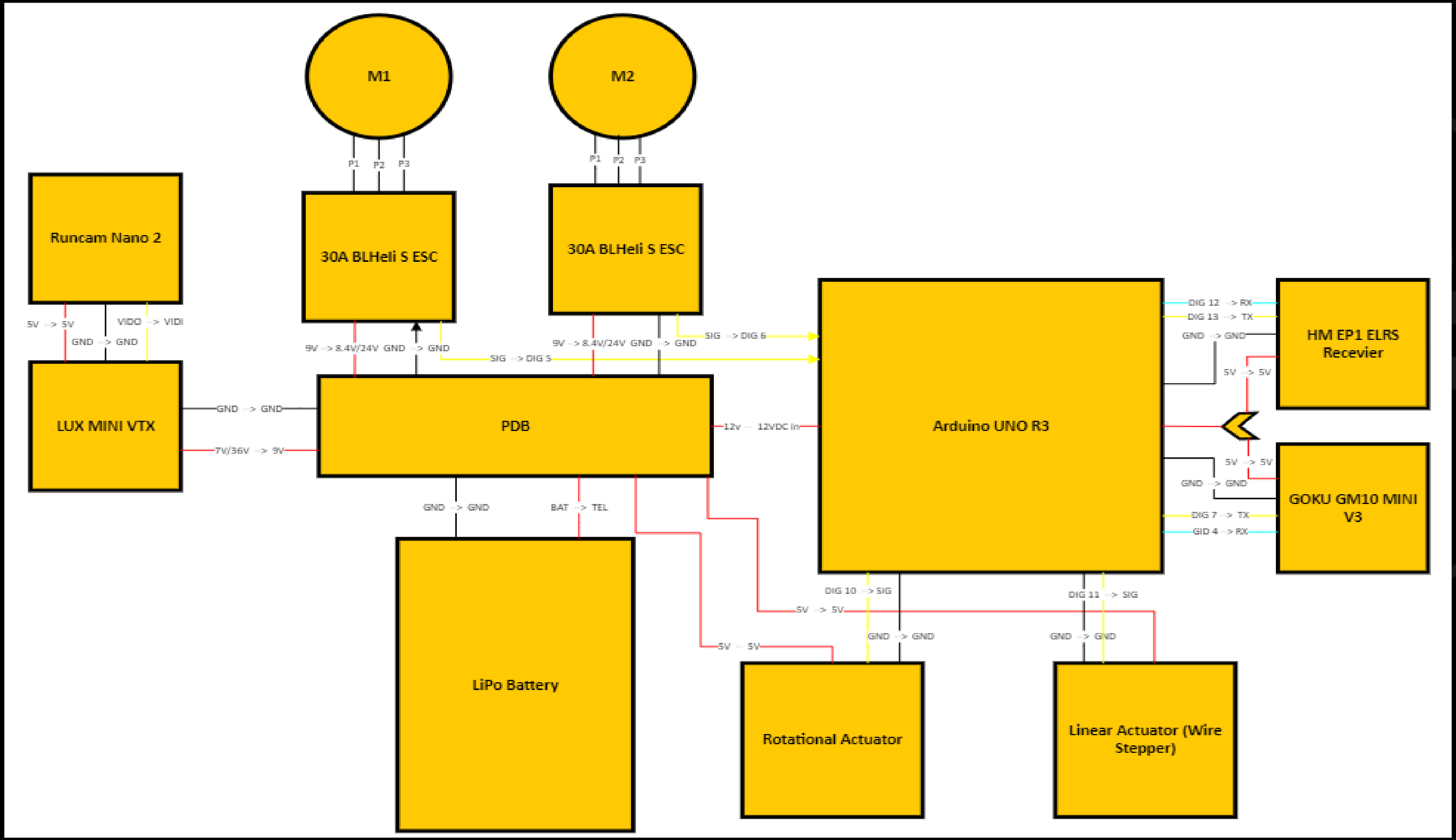
- Electronic Speed Controller
  - Lumenier 30A BLHeli_S

Electrical Components

- GPS
  - GOKU GM10 Mini V3 (32 Satellite Channels lightweight)
- Receiver
  - Happy Model EP1 RX ELRS: (Low Drain ELRS Module)



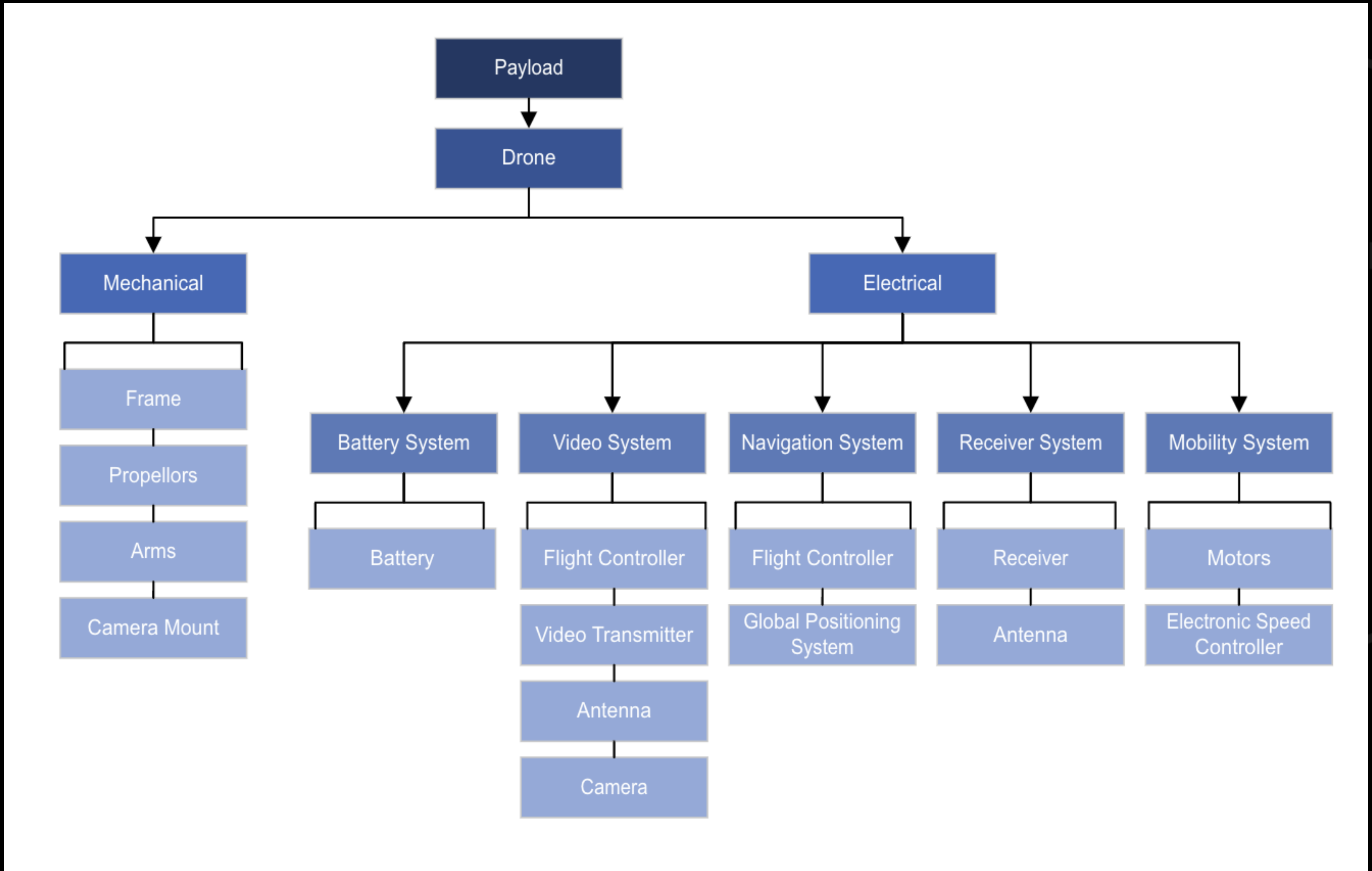
Rover Wiring Diagram



Drone Functional Requirements

System	Sub-System	Requirement	Type	Verification Method
Payloads	Drone	The Drone **shall** deploy from rocket at 800 ft with the main parachute	Performance	Test
Payloads	Drone	The Drone Shall detach from the rover trailer after exiting payload tube	Functional	Demonstration
Payloads	Drone	The Drone **shall** be remote controlled	Functional	Demonstration
Payloads	Drone	The Drone **shall** have a video recording the landing surroundings	Functional	Demonstration
Payloads	Drone	The Drone **shall** attach to the Rover	Functional	Demonstration
Payloads	Drone	The Drone **shall** detach from the Rover	Functional	Demonstration
Payloads	Drone	The Drone **shall** return to designated drop off area	Performance	Demonstration

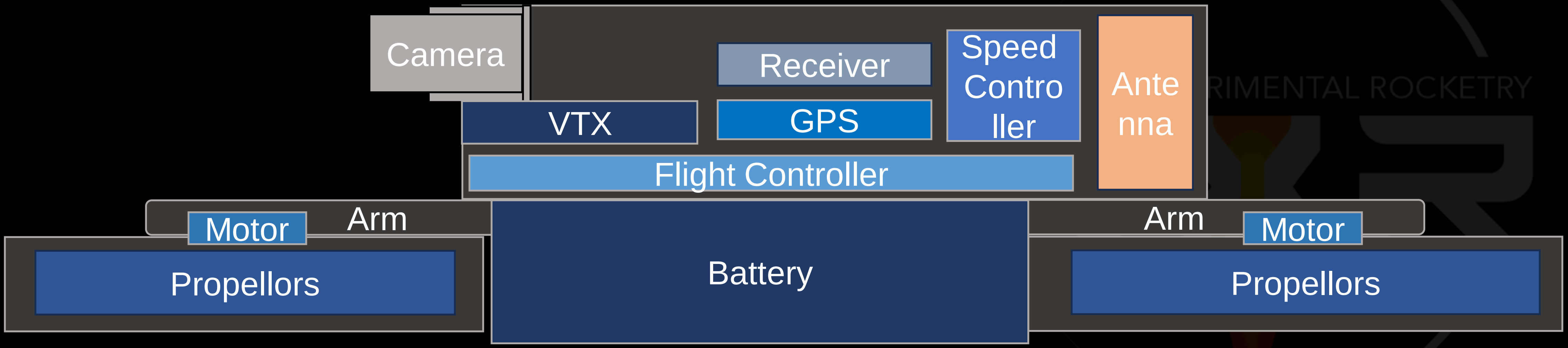
Drone Component Breakdown (Architecture)



Drone Subsystem

Side View

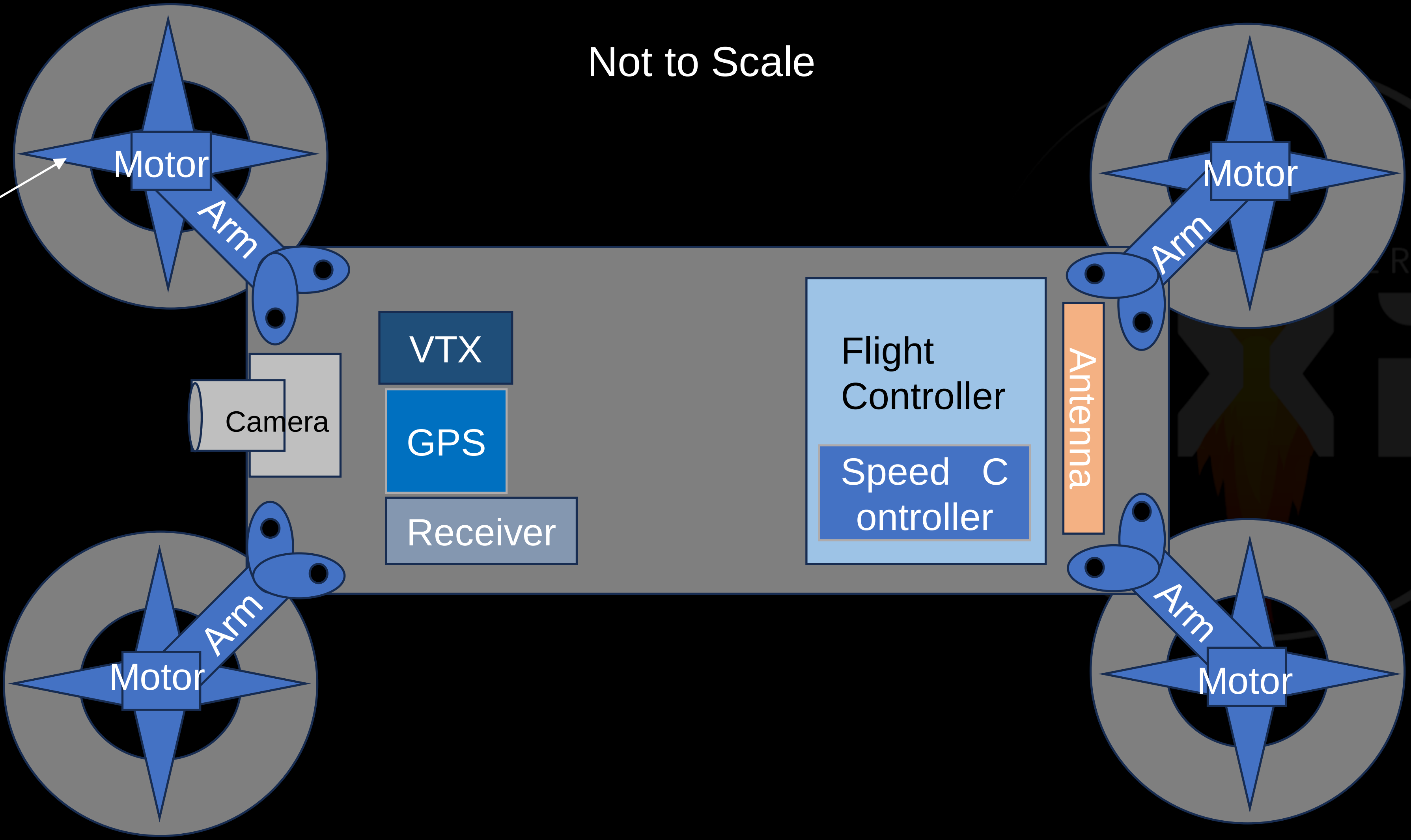
Not to Scale



Drone Subsystem

Top View

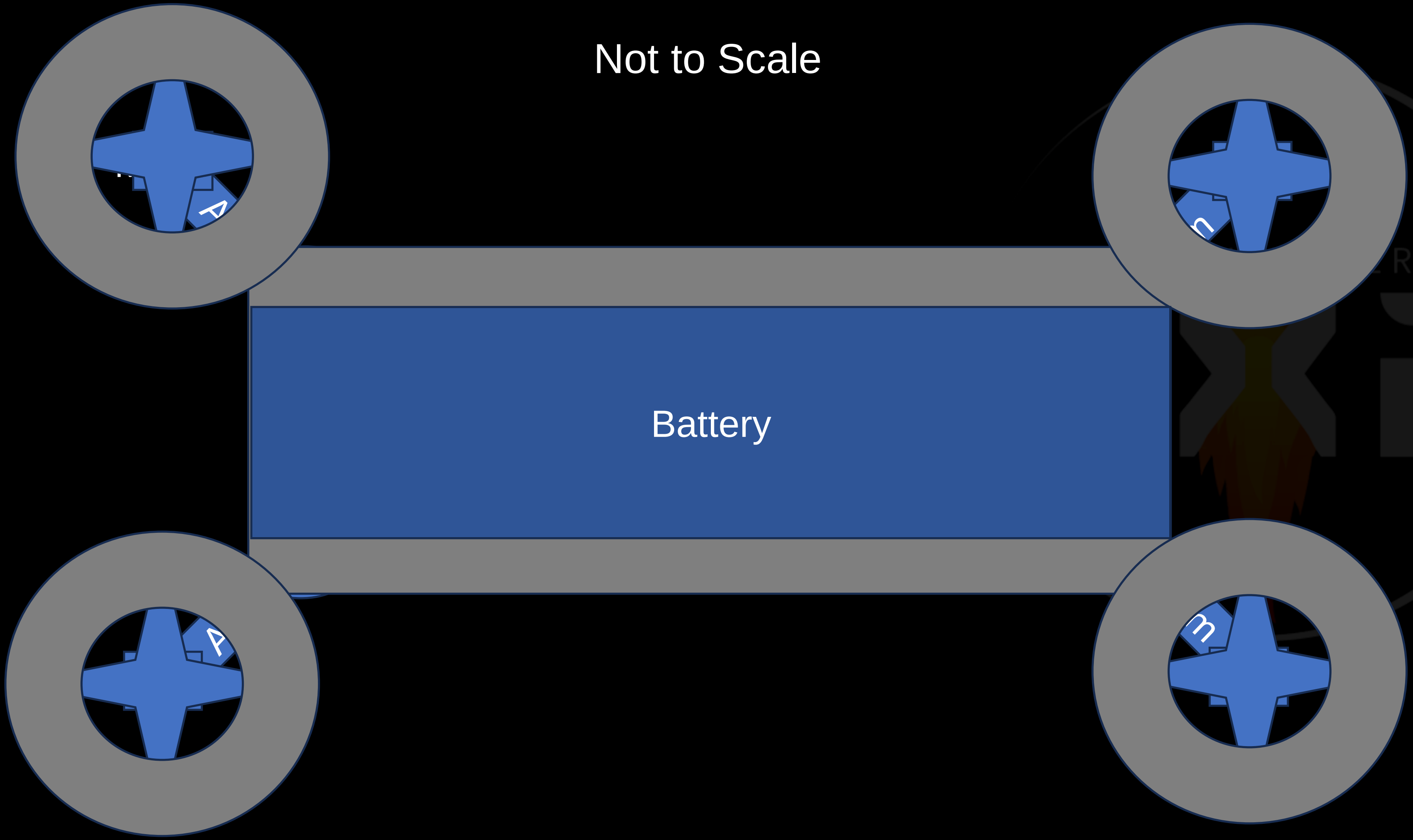
Not to Scale



Drone Subsystem

Bottom View

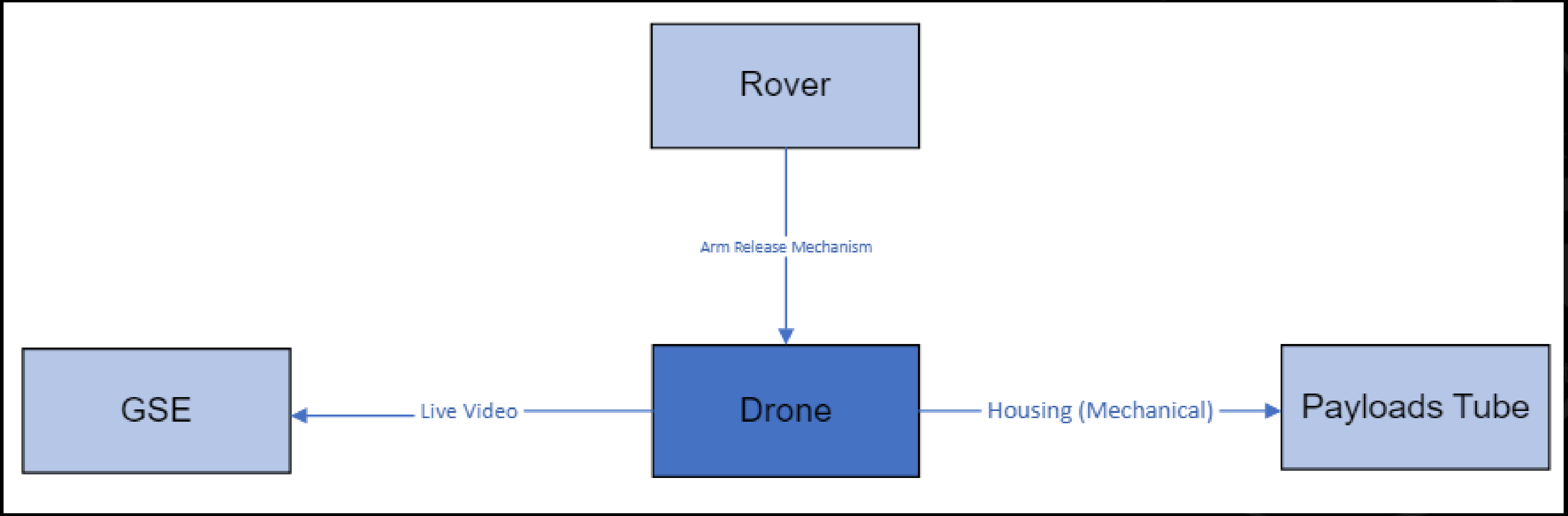
Not to Scale



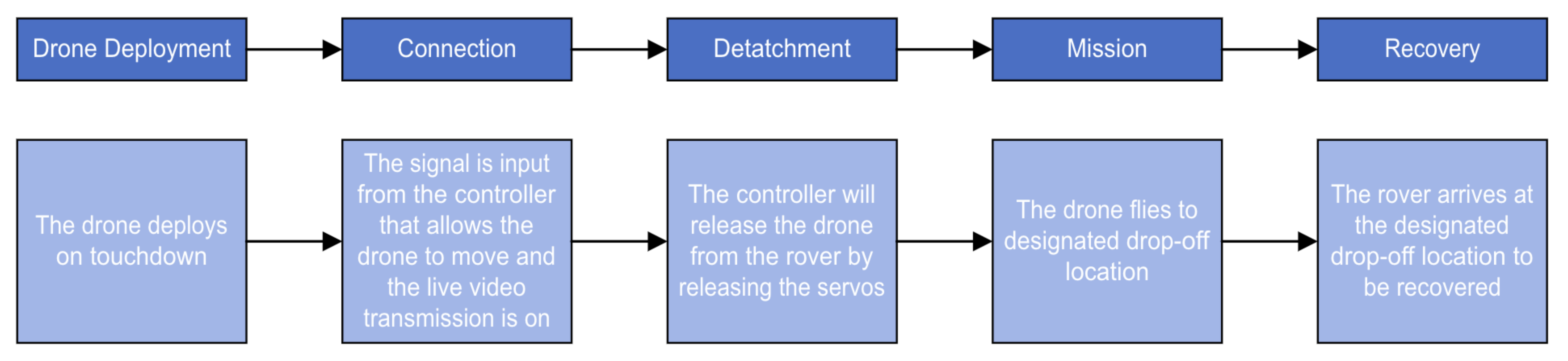
Drone TPMs

Measure	TPM Value	Units	Verification Method
Assembly Dimensions	9.5 x 4.65 x 2 (LxWxH)	in	Inspection
Weight w/o Electronics	[0.44]	lbs	Inspection
With w/ Electronics	[0.88]	lbs	Inspection
Active Operating Time	[0.32 - 0.33]	hours	Analysis
Passive Power Draw	[4300 – 5125]	mA	Analysis

Drone Interface Diagram



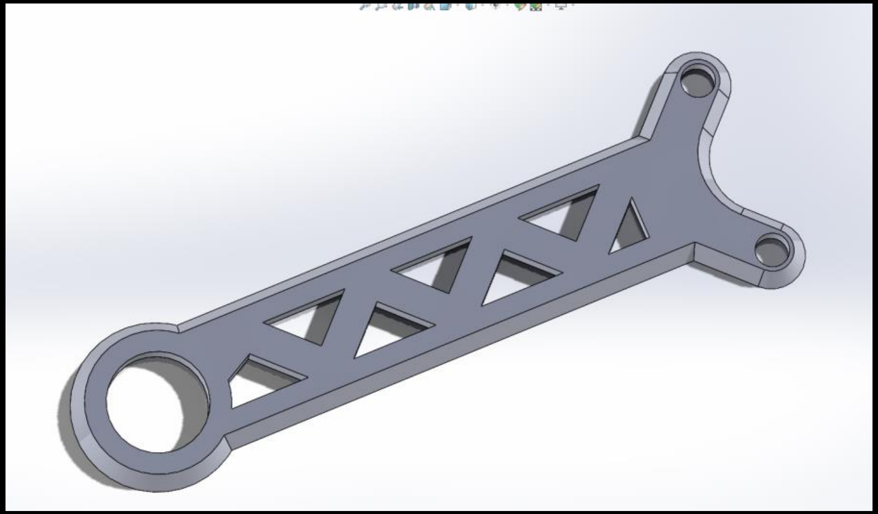
Drone CONOPS



KXR UCF

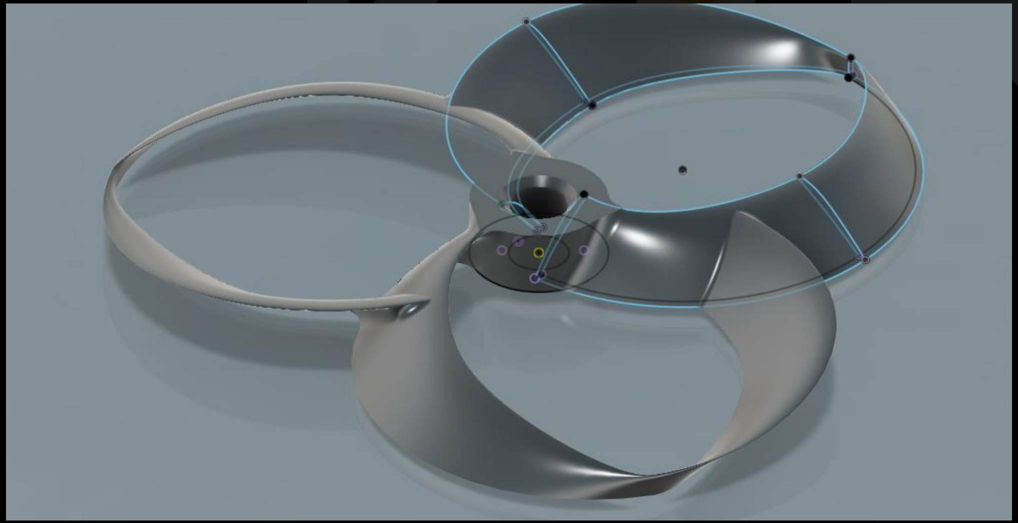
Mechanical Components

- Arms:
  - There will be four arms attached to the airframe.
  - Made of carbon fiber
  - 3D Printed



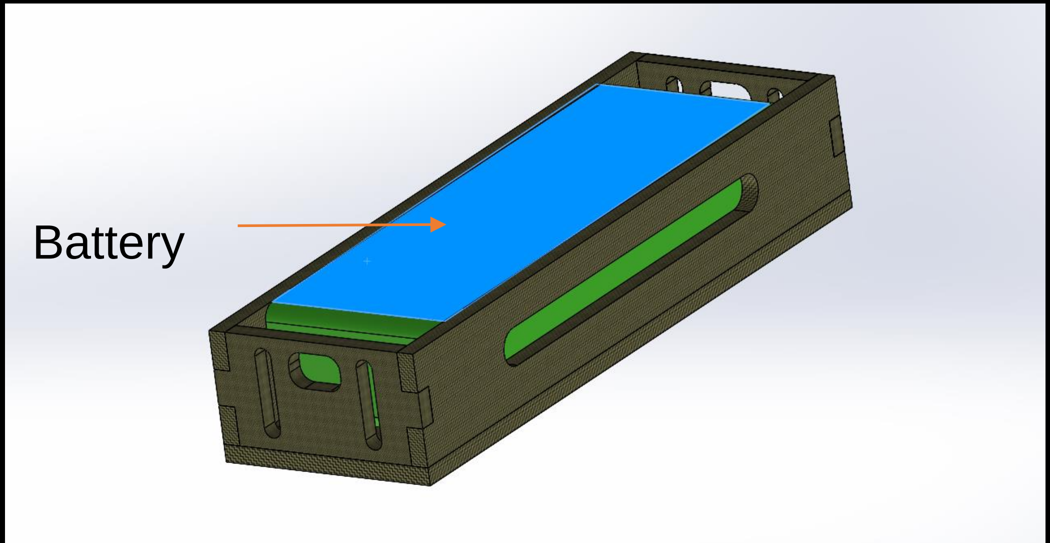
Propellers:

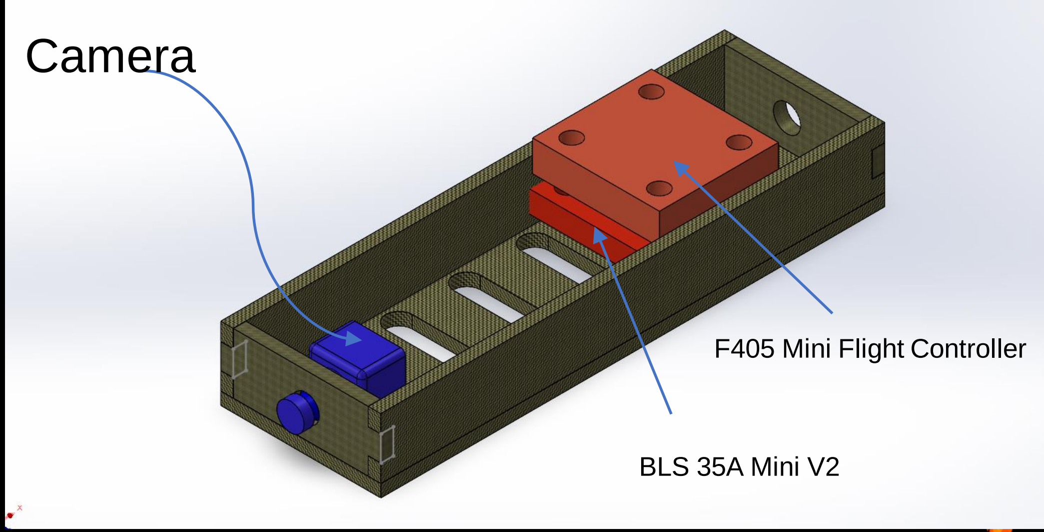
- We decided for toroidal type propellers in due to studies we found showing that they had an increased level of efficiency compared to standard propellers.
- Resin printed



Mechanical Components

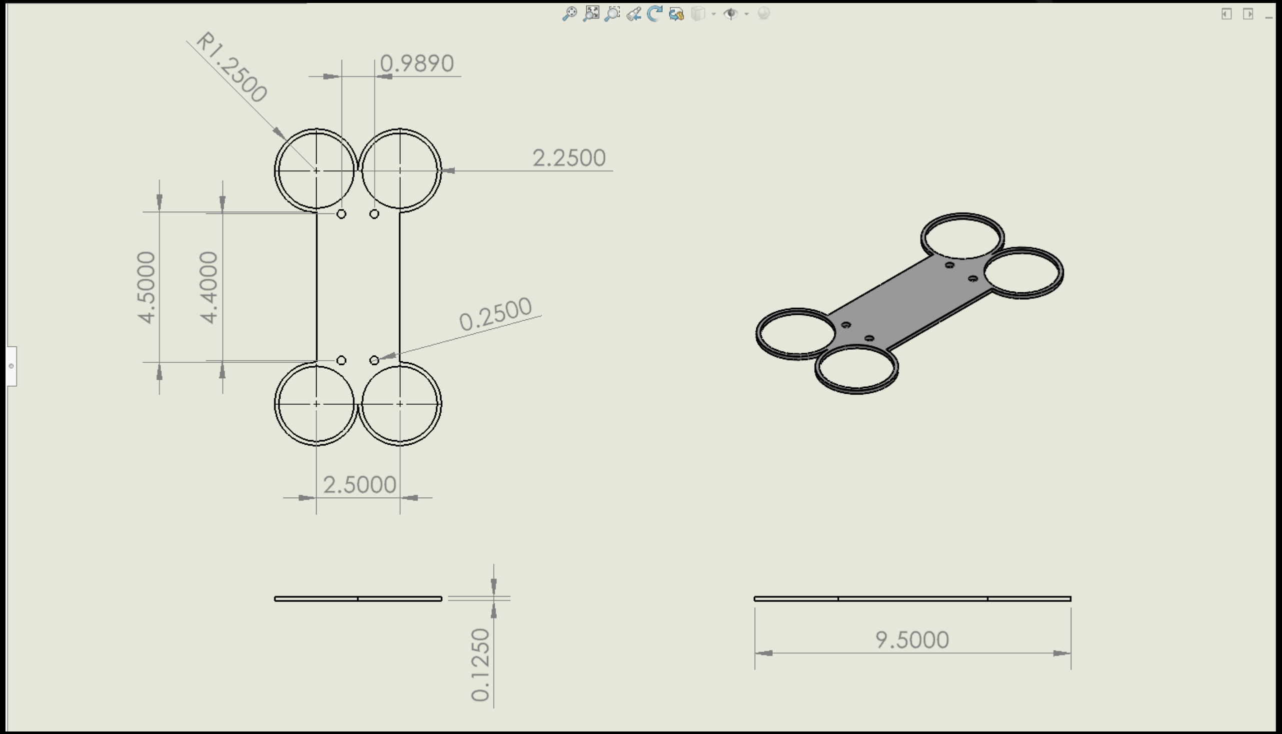
- Electrical Housing:
  - Houses all electronics
  - Perforations in housing for airflow
  - Electronics will be stacked
  - Made from printed carbon fiber





Mechanical Components

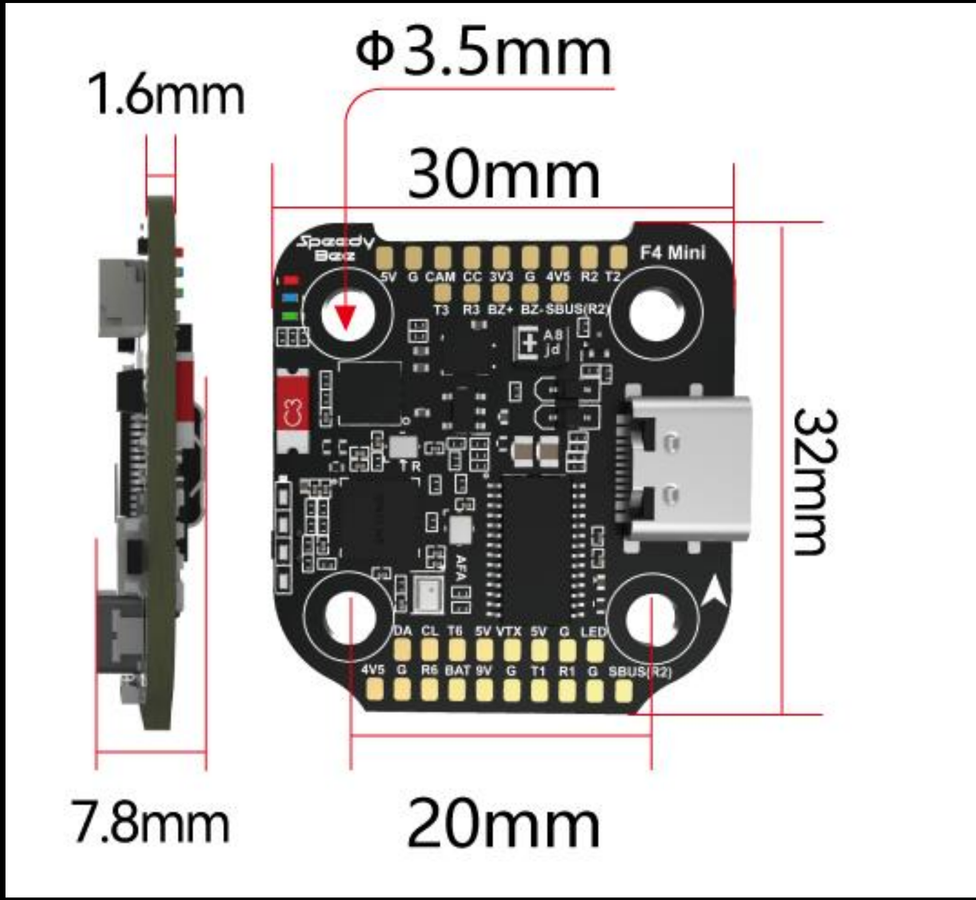
- Drone Airframe:
  - The dimensions were chosen due to size constraints.
  - Made of printed carbon fiber



KXR UCF

Electrical Components

- Flight Controller
  - SpeedyBee F405 Mini 20x20 (Compact centralized stack)
    - Note: Battery and operations are centralized through the flight controller

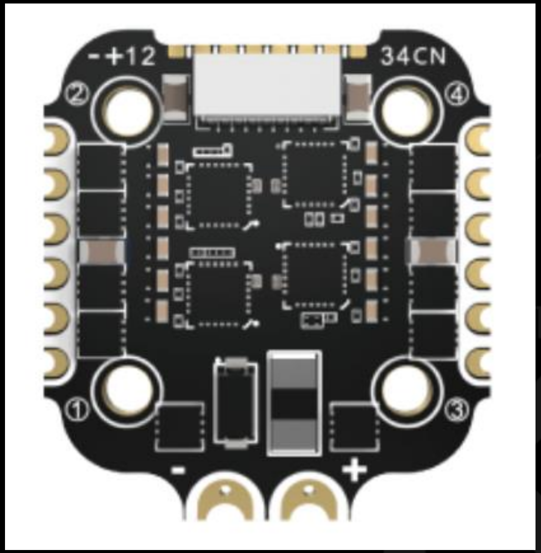


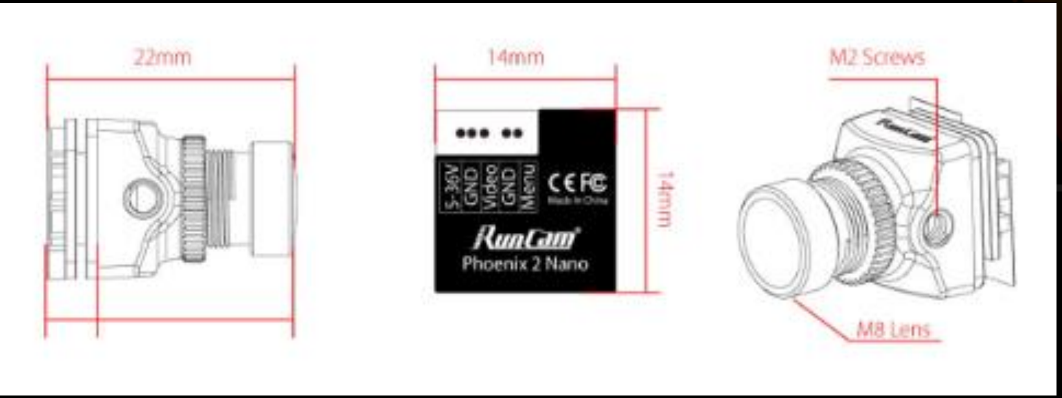
Electrical Components

- Battery
  - Lumenier 1800mAh 3s 35C (High Capacity Lightweight)
    - Battery is scalable to mission requirements

Electrical Components

- Electronic Speed Controller
  - SpeedyBee F405 Mini BLS (Stackable 4 in 1 ESC)
- Camera
  - RunCam Pheonix 2 Nano (Highest Quality 155° FOV)

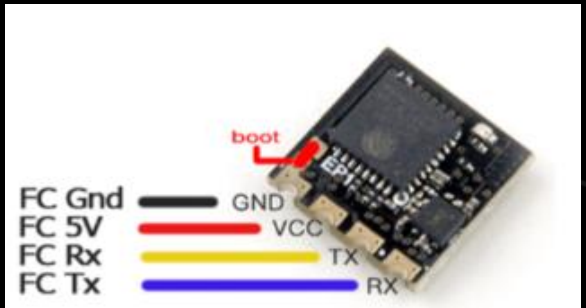




Electrical Components

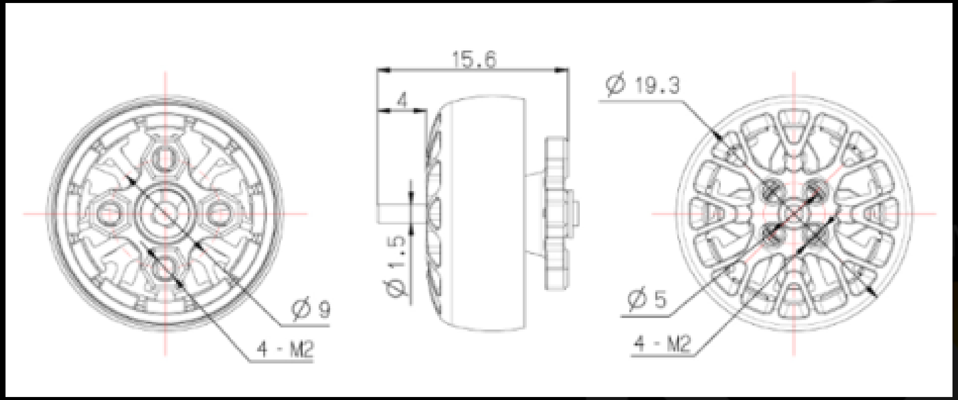
- Visual Transmitter
  - Rush Tank II (380mA at 800mW, 6s capable)

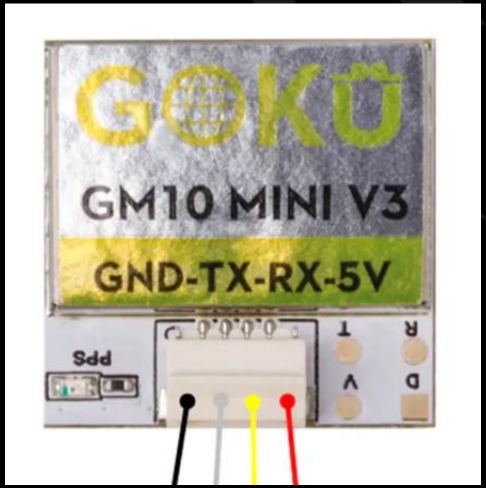
- Receiver
  - Happy Model EP1 RX ELRS: (Low Drain ELRS Module)



Electrical Components

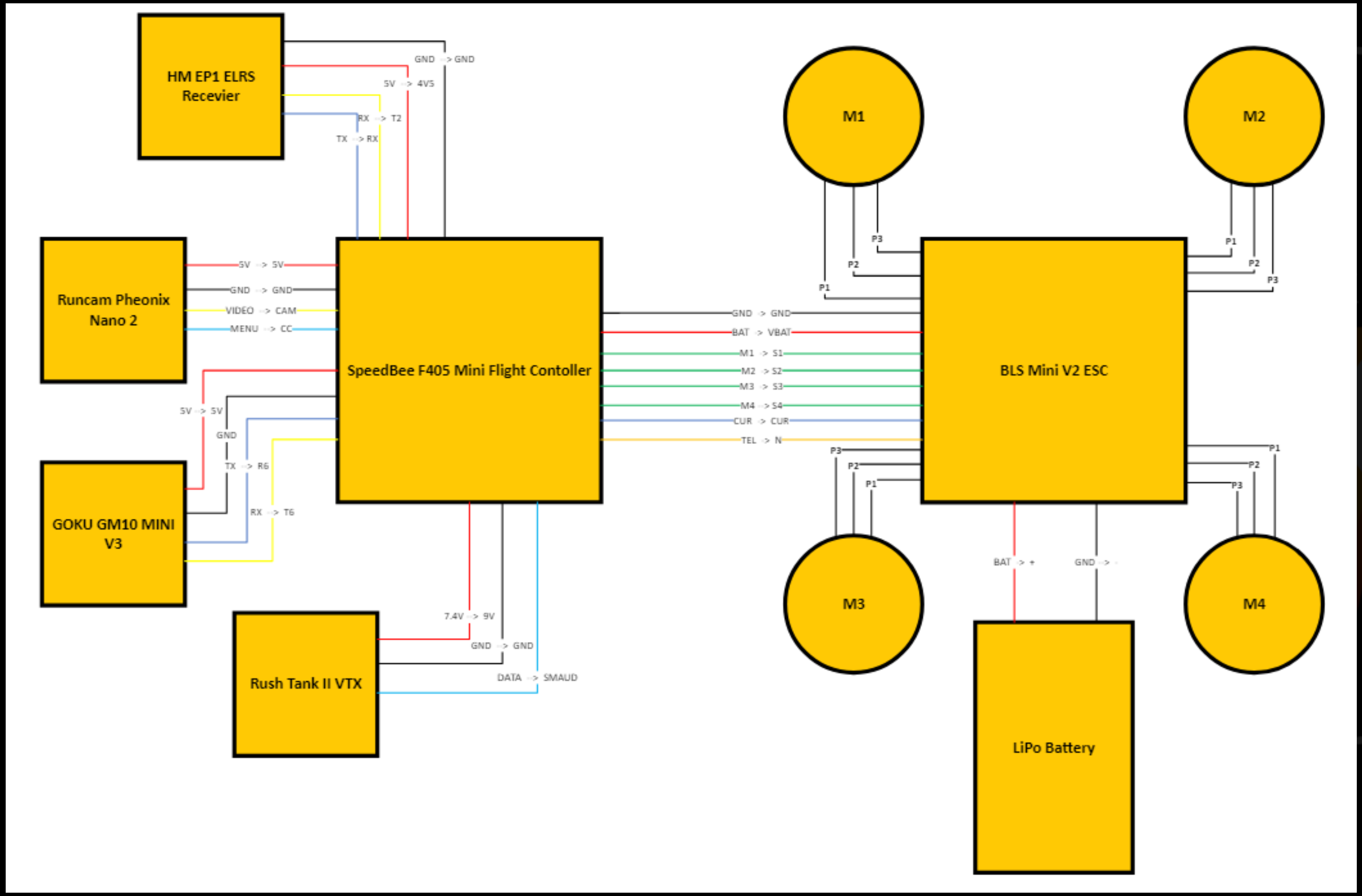
- Motors
  - SpeedyBee 4500KV (Lightweight 1404 Motors)
- GPS
  - GOKU GM10 Mini V3 (32 Satellite Channels, lightweight)





KXR UCF

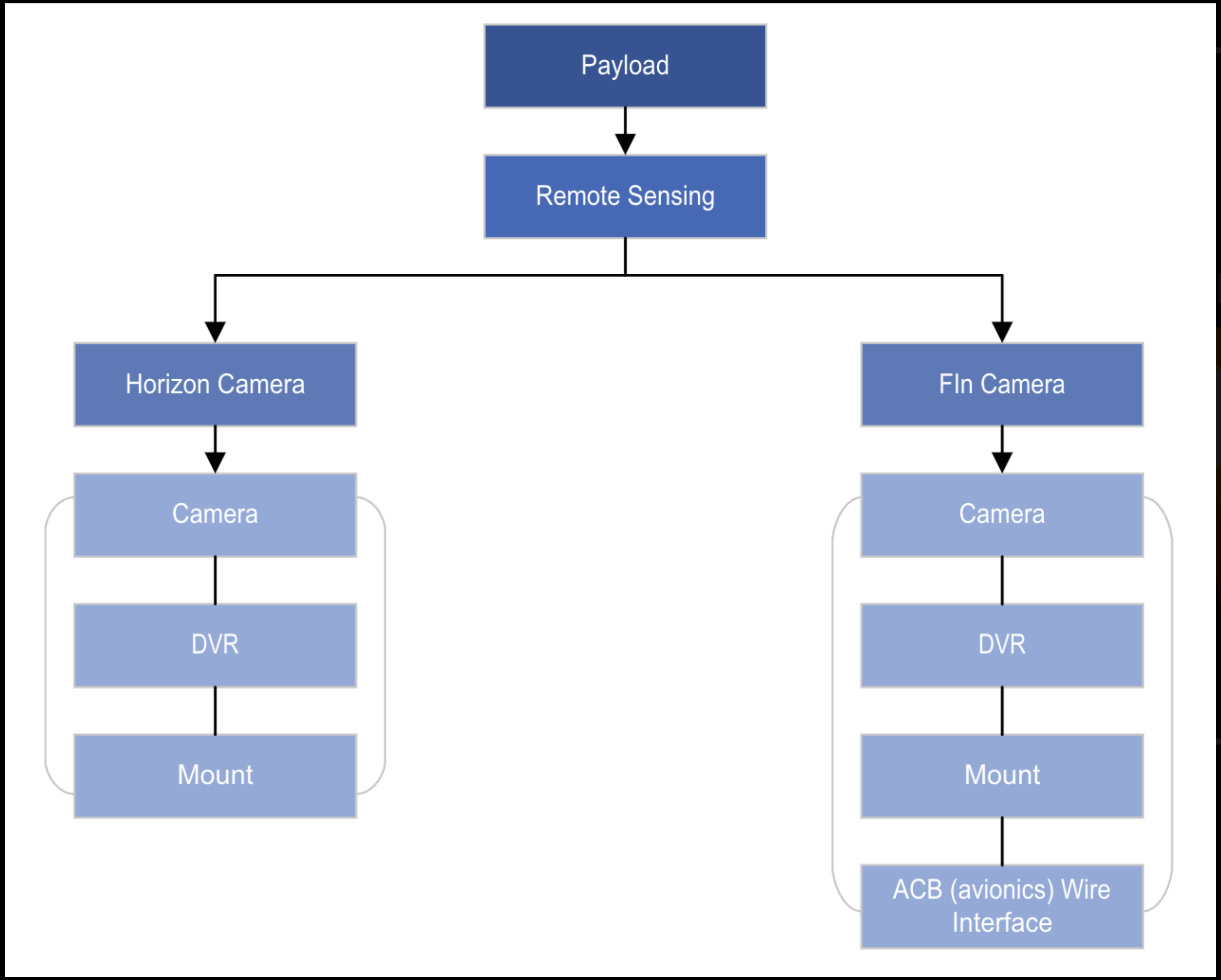
Drone Wiring Diagram



Remote Sensing Functional Requirements

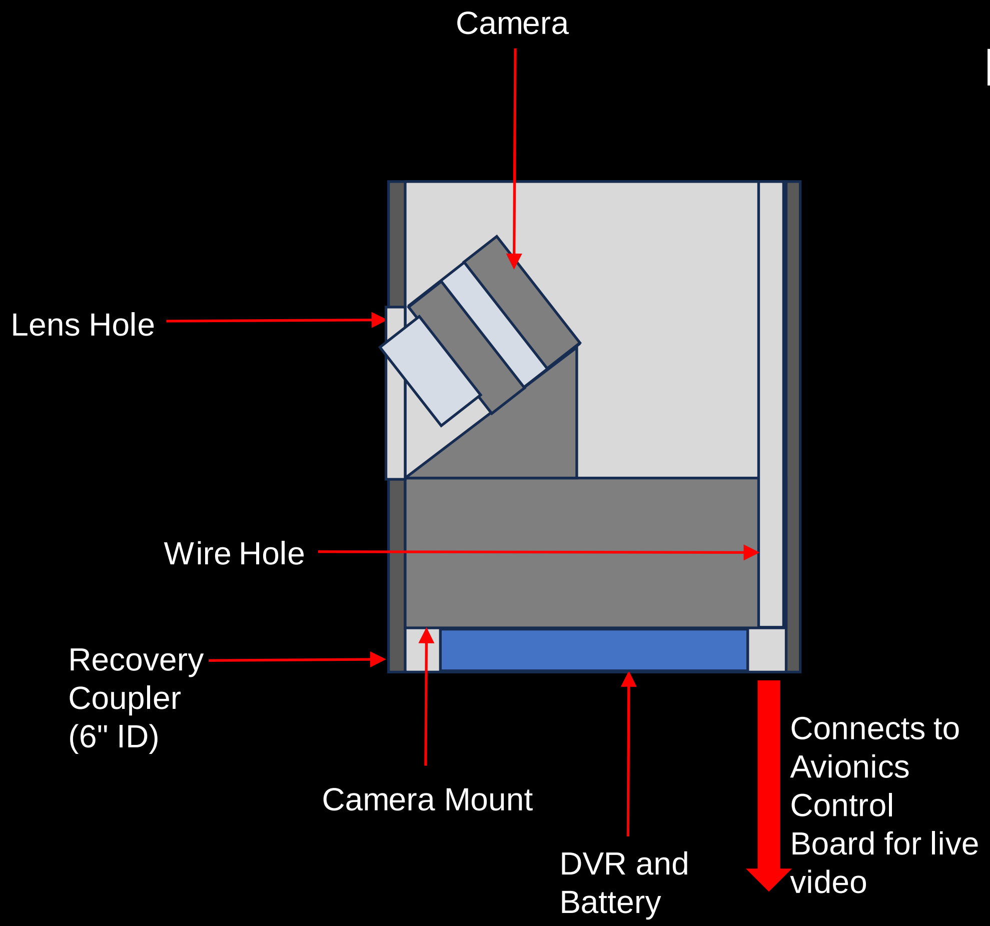
System	Sub-System	Requirement	Type	Verification Method
Payloads	Remote Sensing	The Horizon Camera **shall** operate throughout flight	Performance	Demonstration
Payloads	Remote Sensing	The Fin Camera **shall** operate throughout flight	Performance	Demonstration
Payloads	Remote Sensing	The Horizon Camera **shall** save video locally	Performance	Demonstration
Payloads	Remote Sensing	The Fin Camera **shall** have live video sent to GSE and save locally	Functional	Demonstration

Remote Sensing (Architecture)

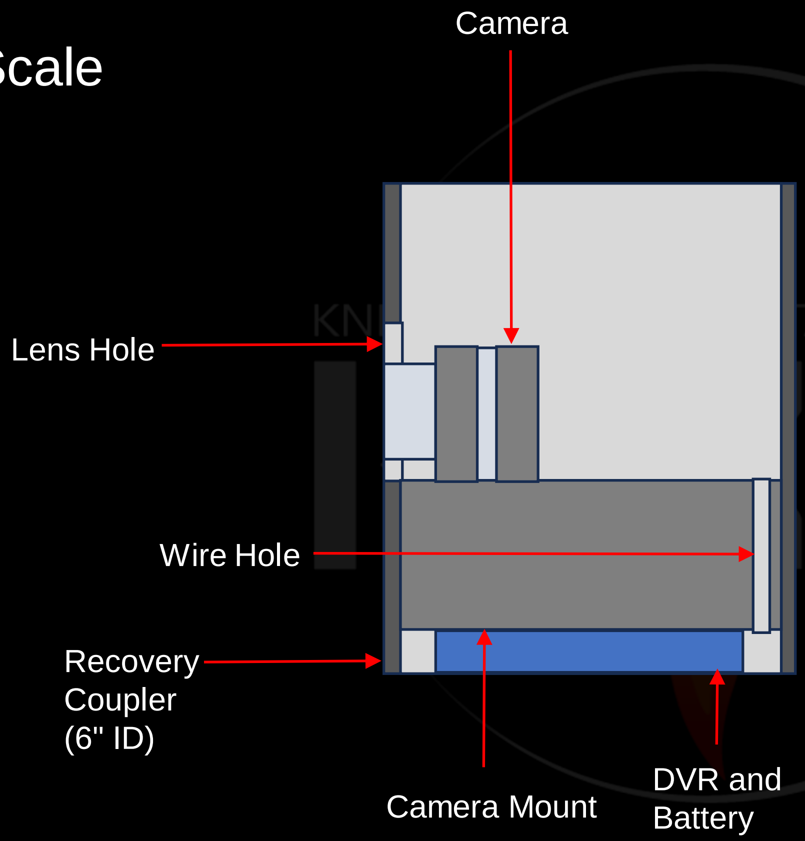


Remote Sensing Subsystem

Not to Scale



Fin Camera



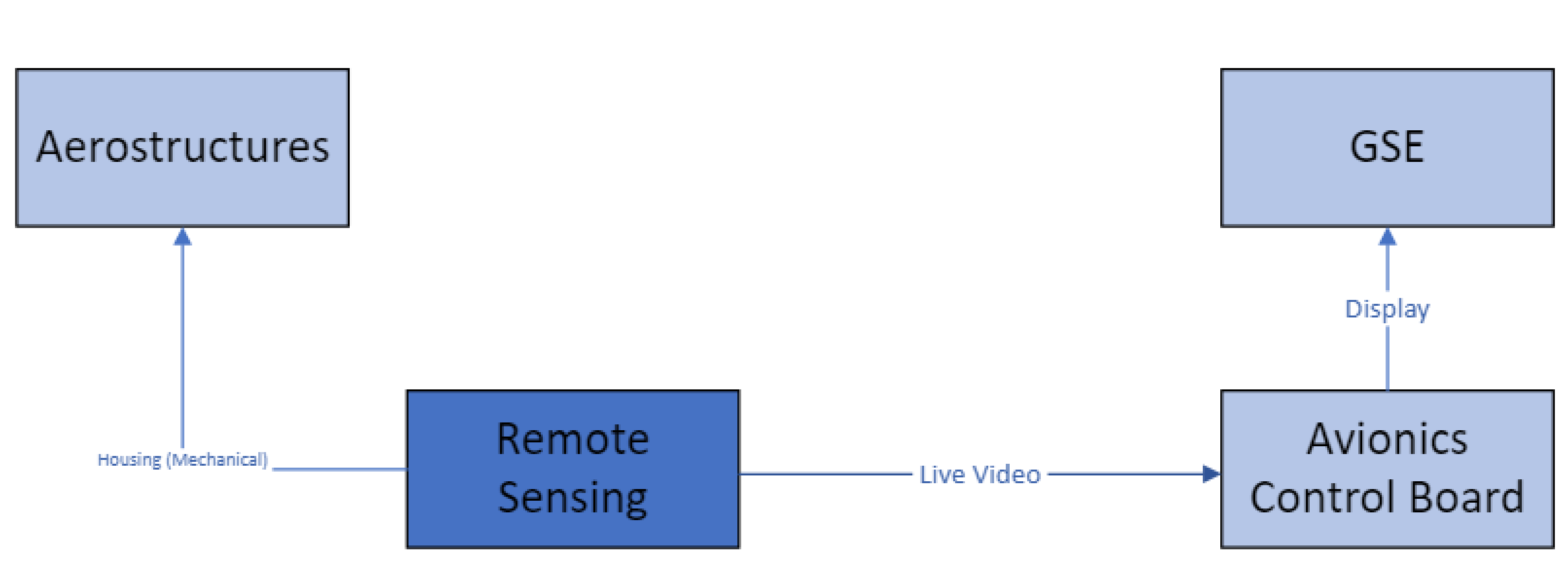
Horizon Camera

Remote Sensing TPMs

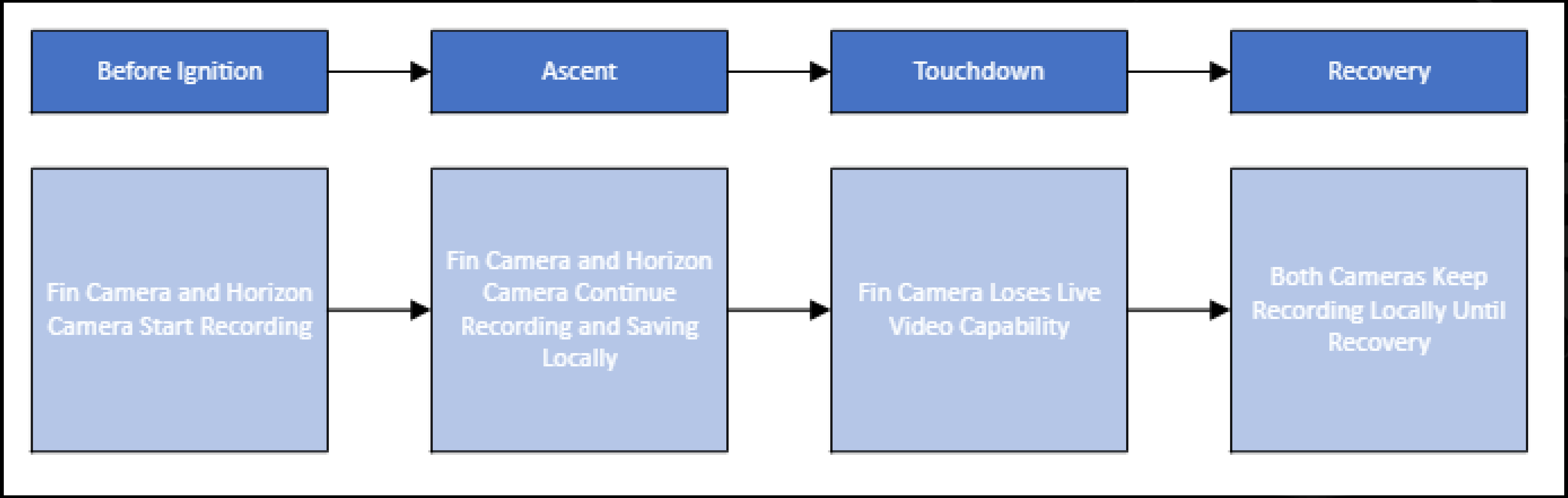
Measure	TPM Value	Units	Verification Method
Weight of System	[1 - 2]	oz	Inspection
Diameter	6	in	Inspection
Height	2	in	Inspection
Video Storage	3	hours	Inspection
Power	5	V	Analysis
Operational Time	[4]	hours	Analysis

KXR UCF

Remote Sensing Interface Diagram

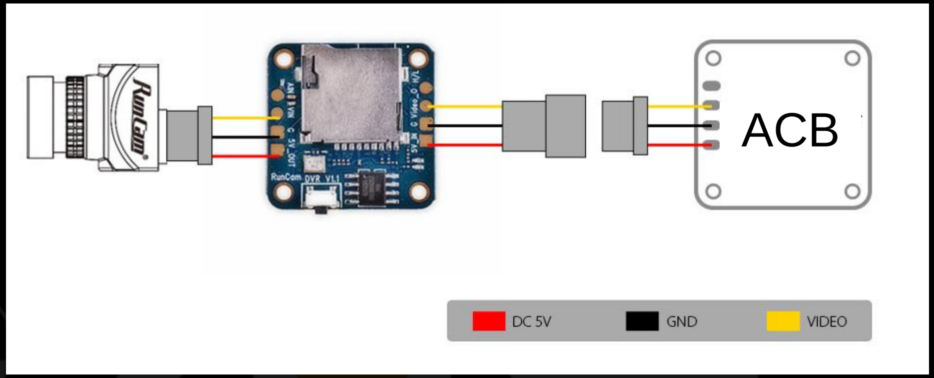


Remote Sensing CONOPS



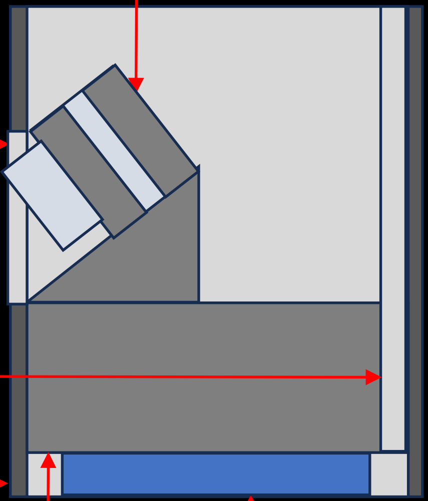
Fin Camera Components

Phoenix 2
RunCam



Camera

Lens Hole



Wire Hole

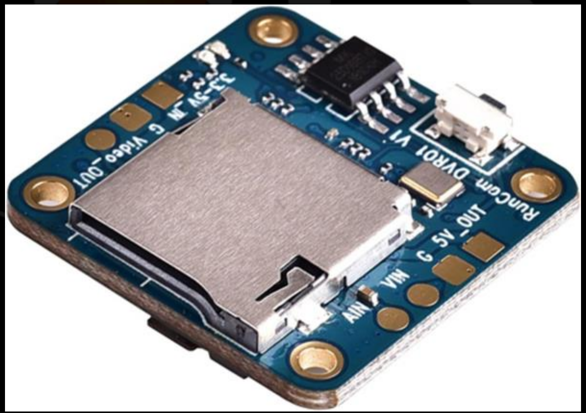
Recovery
Coupler
(6" ID)

Camera Mount

DVR and
Battery

Connects to
Avionics
Control
Board (ACB)
for live video

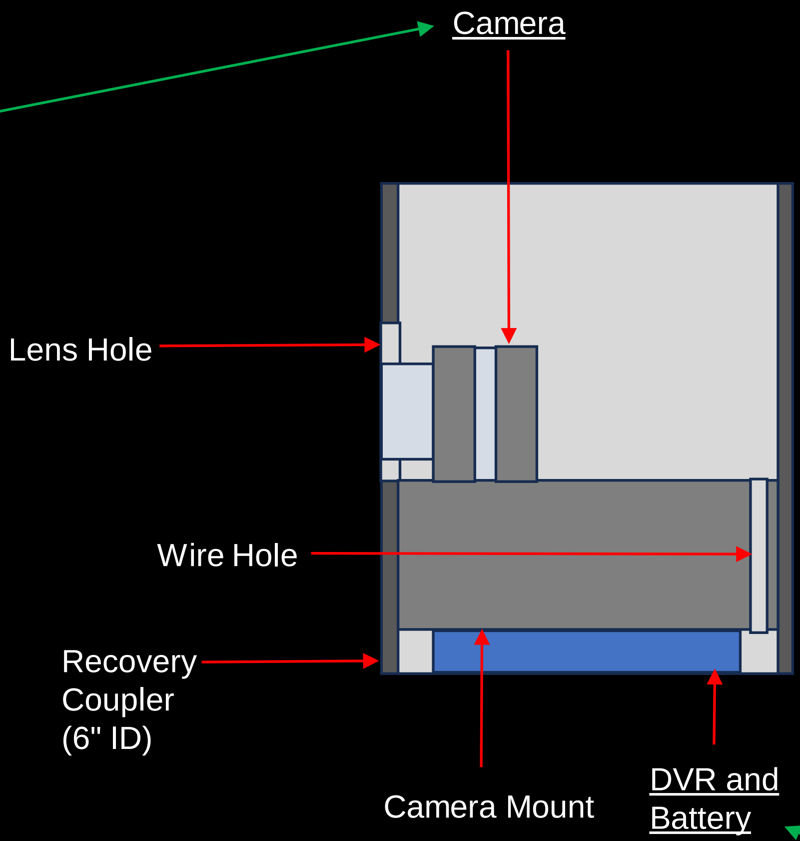
Fin Camera



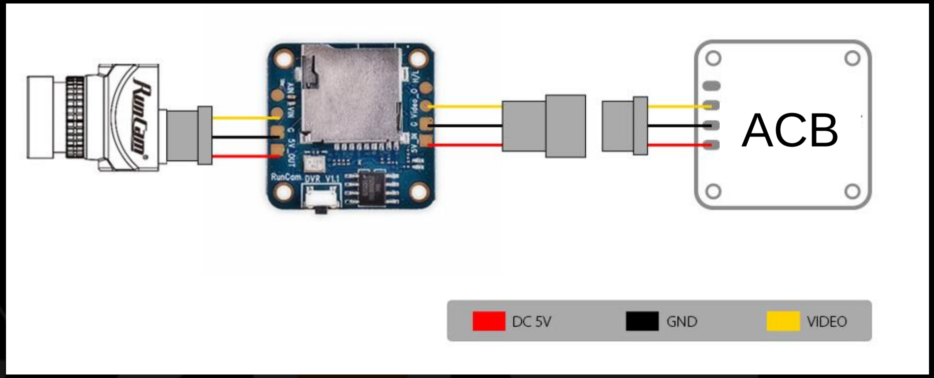
Digital Video Recorder

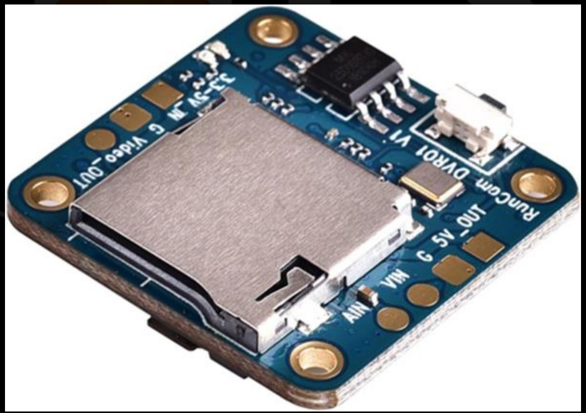
Horizon Camera Components

Phoenix 2
RunCam



Horizon Camera





Digital Video Recorder

Questions?

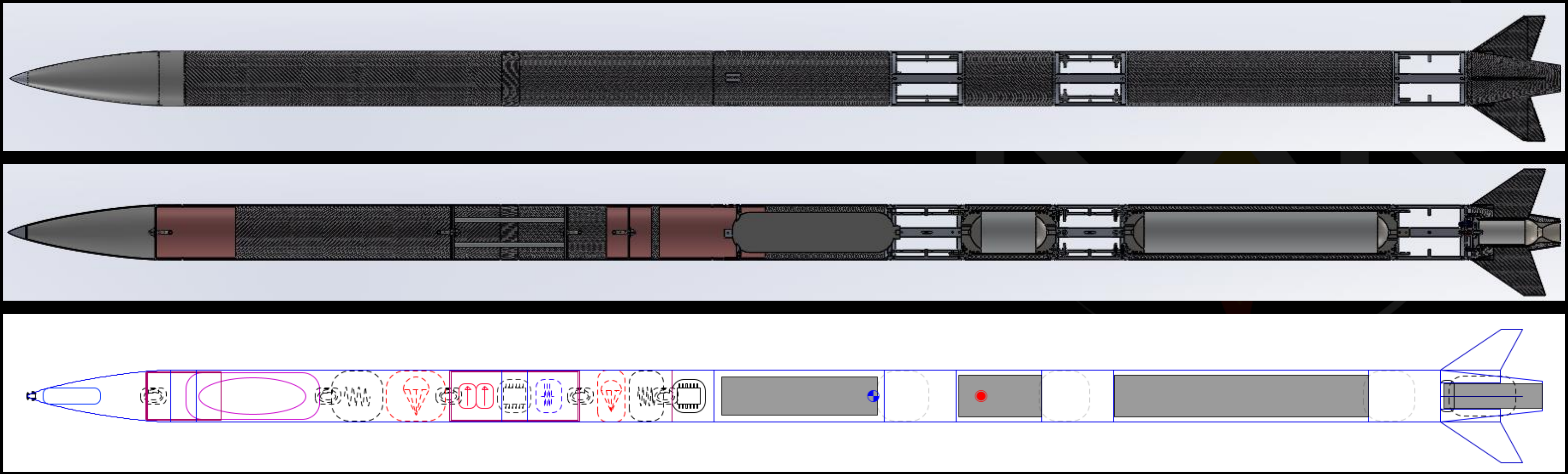
Thank You for Listening!

KNIGHTS EXPERIMENTAL ROCKETRY
KXR
at UCF

Aerostructures PDR
FAR10k Liquid Rocket

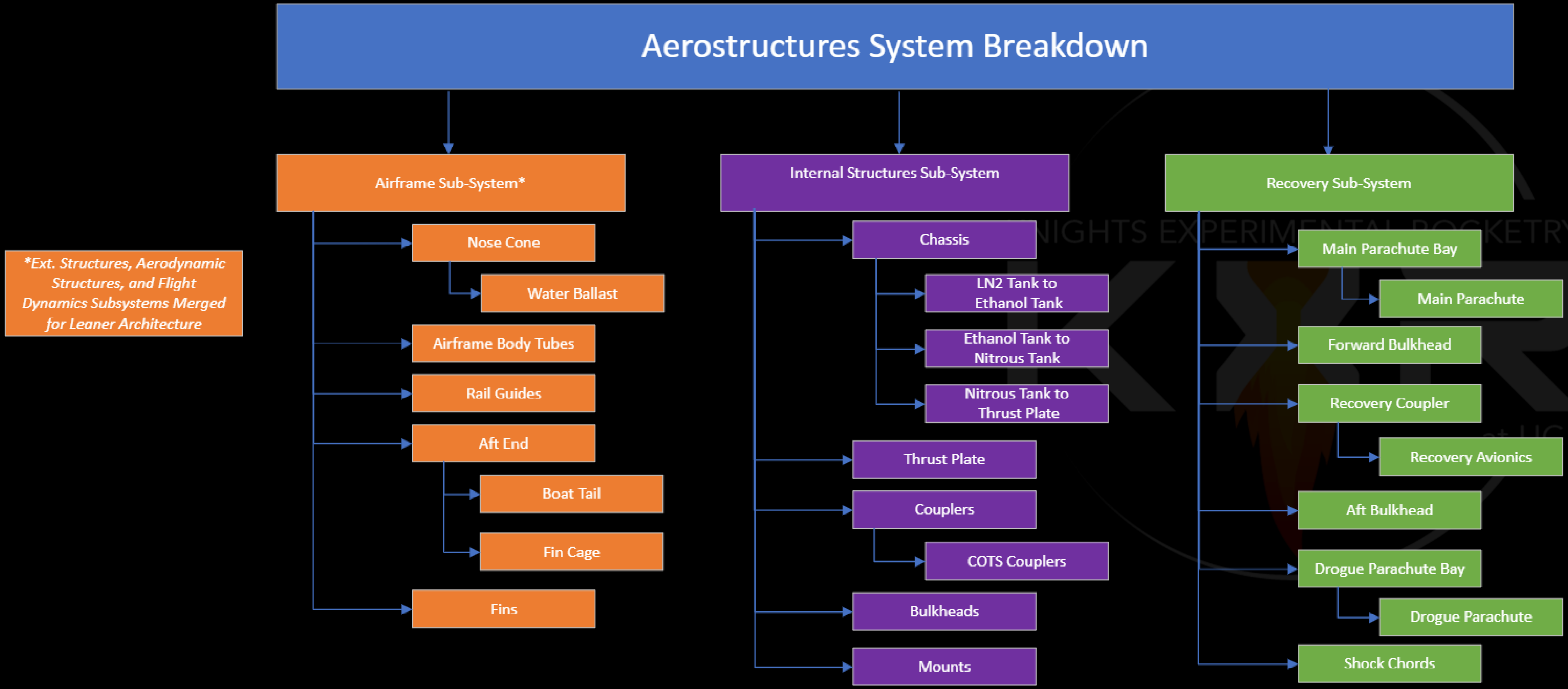
Aerostructures System

Encompasses and integrates all systems
Designed to withstand all aspects of flight
Shall be recovered in a condition that can relaunch

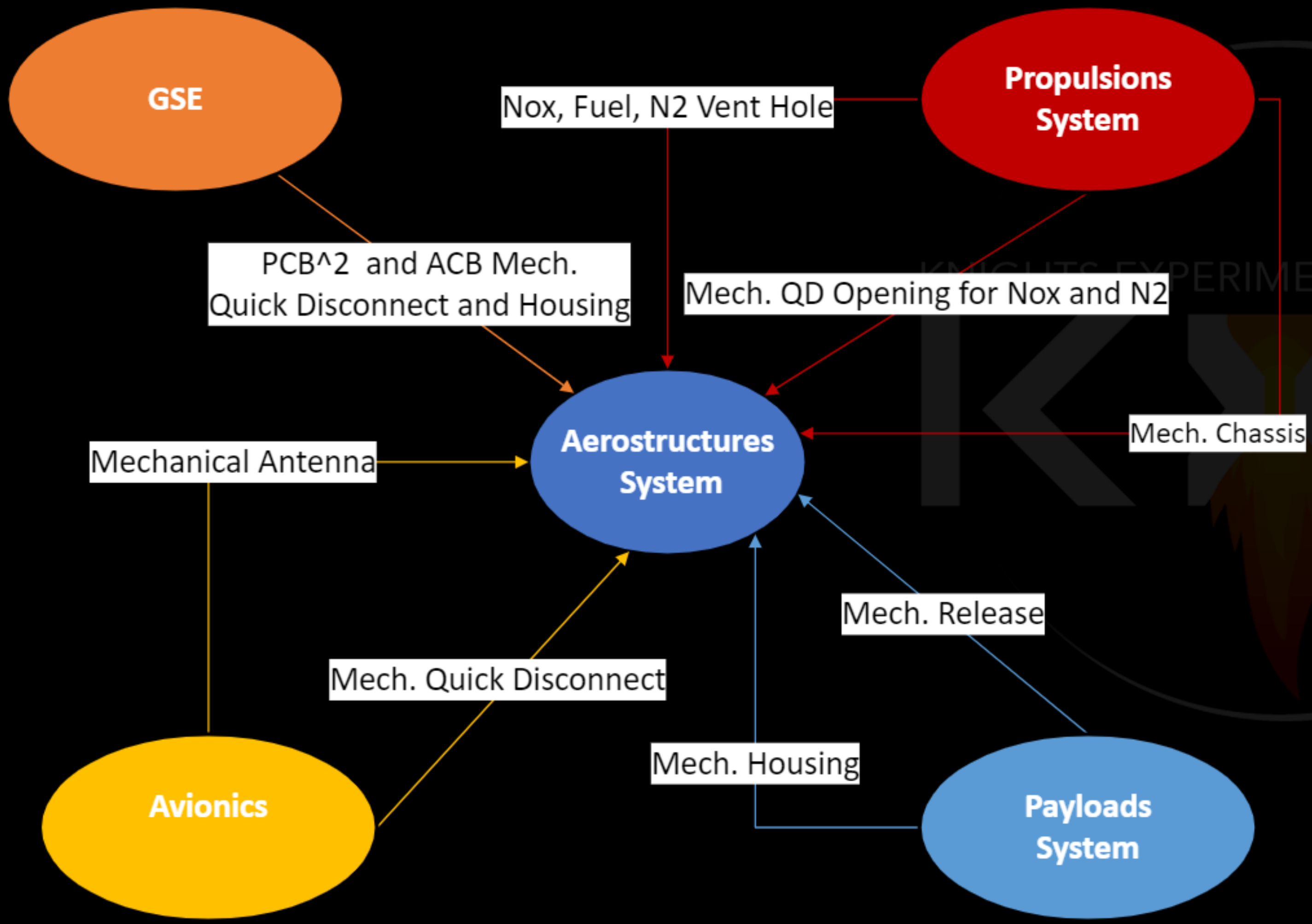


PDR CAD and Open Rocket

Aerostructures Architecture



Aerostructures Interface Diagram



Aerostructures Functional Requirements

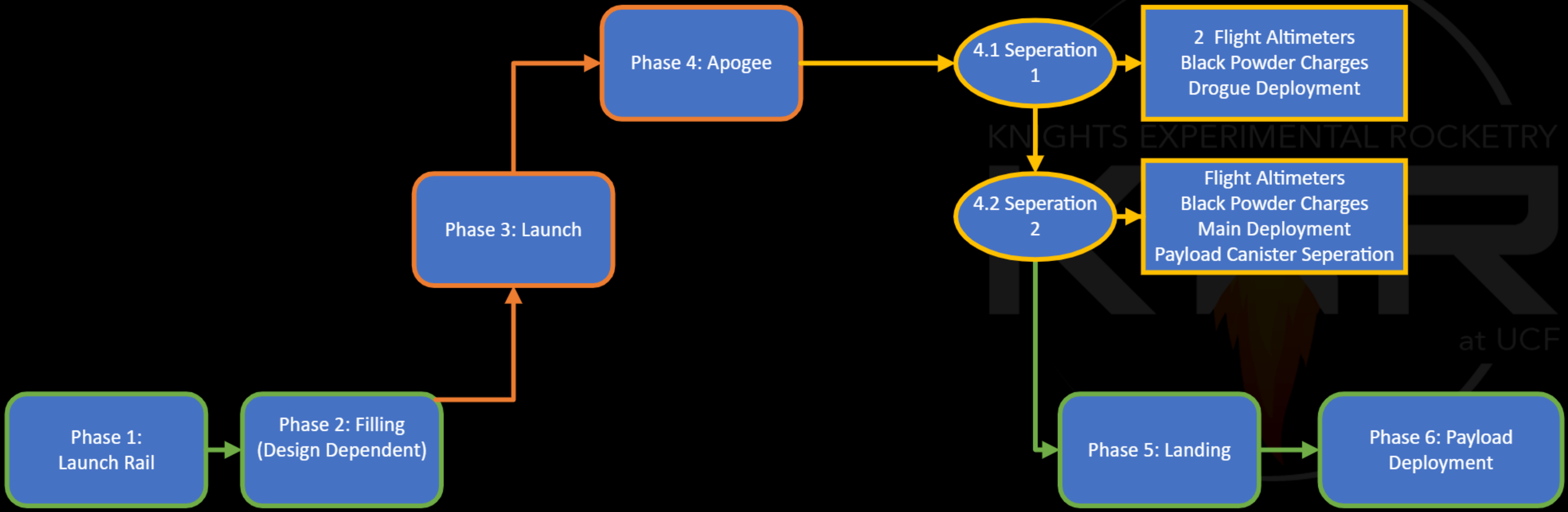
Requirement		Requirement Type		Verification Method
The Aerostructures System **shall** consist of recovery, [water ballast] subsystems.		Functional		[Inspection]
The Aerostructures System **shall** resist aerodynamic loads during the vehicle's mission.		Functional		[Analysis]
The Aerostructures System **shall** have a dual deploy recovery system.		Functional		[Inspection]
The Aerostructures system **shall** withstand a load of [6] G's		Performance		[Analysis]
The Aerostructures system **shall** have an internal diameter of 6 in		Performance		[Inspection]
The Aerostructures system **shall** have a max length of 15 ft		Performance		[Inspection]
The Aerostructures system **shall** resist a snatch force of [680 lbs.]		Performance		[Test/Analysis]

KXR UCF

Aerostructures System Verification Plans

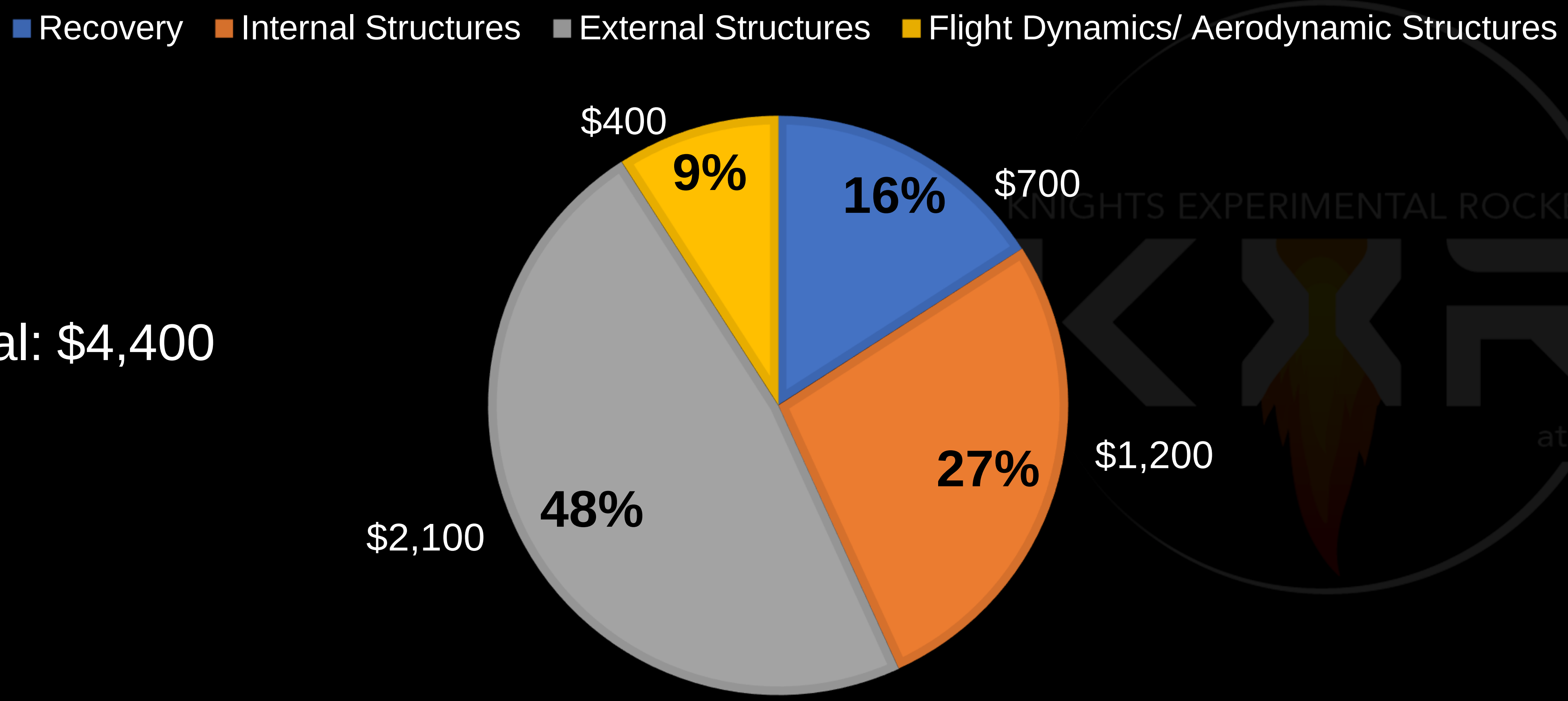
- Visual/Digital Inspection of System Interfaces (CAD)
- FEA and ANSYS Component Load Analysis (Analysis)
- Test Article (Test)
- Dry Fitting Components (Demonstration)
- Confirmation of Dimensions and Mass (Inspection)
- Dual Deploy Recovery System Test (Test)
- Launch

Aerostructures CONOPS



Aerostructures System Cost

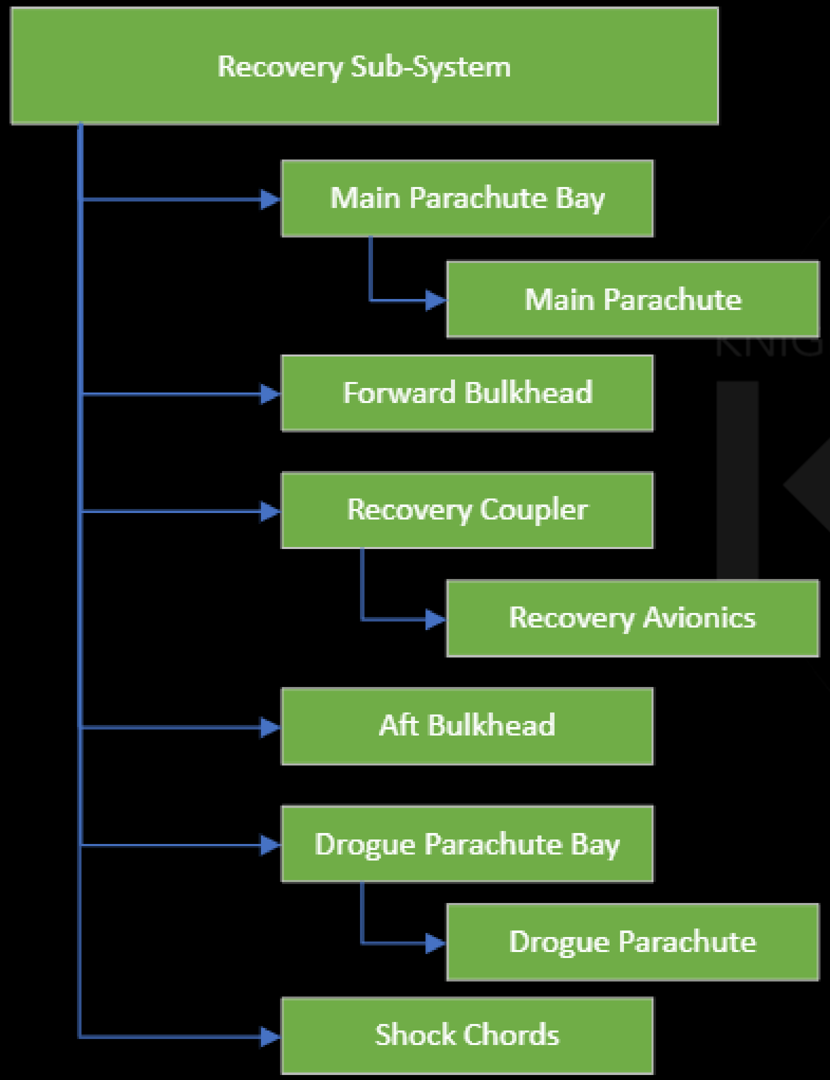
Total: $4,400



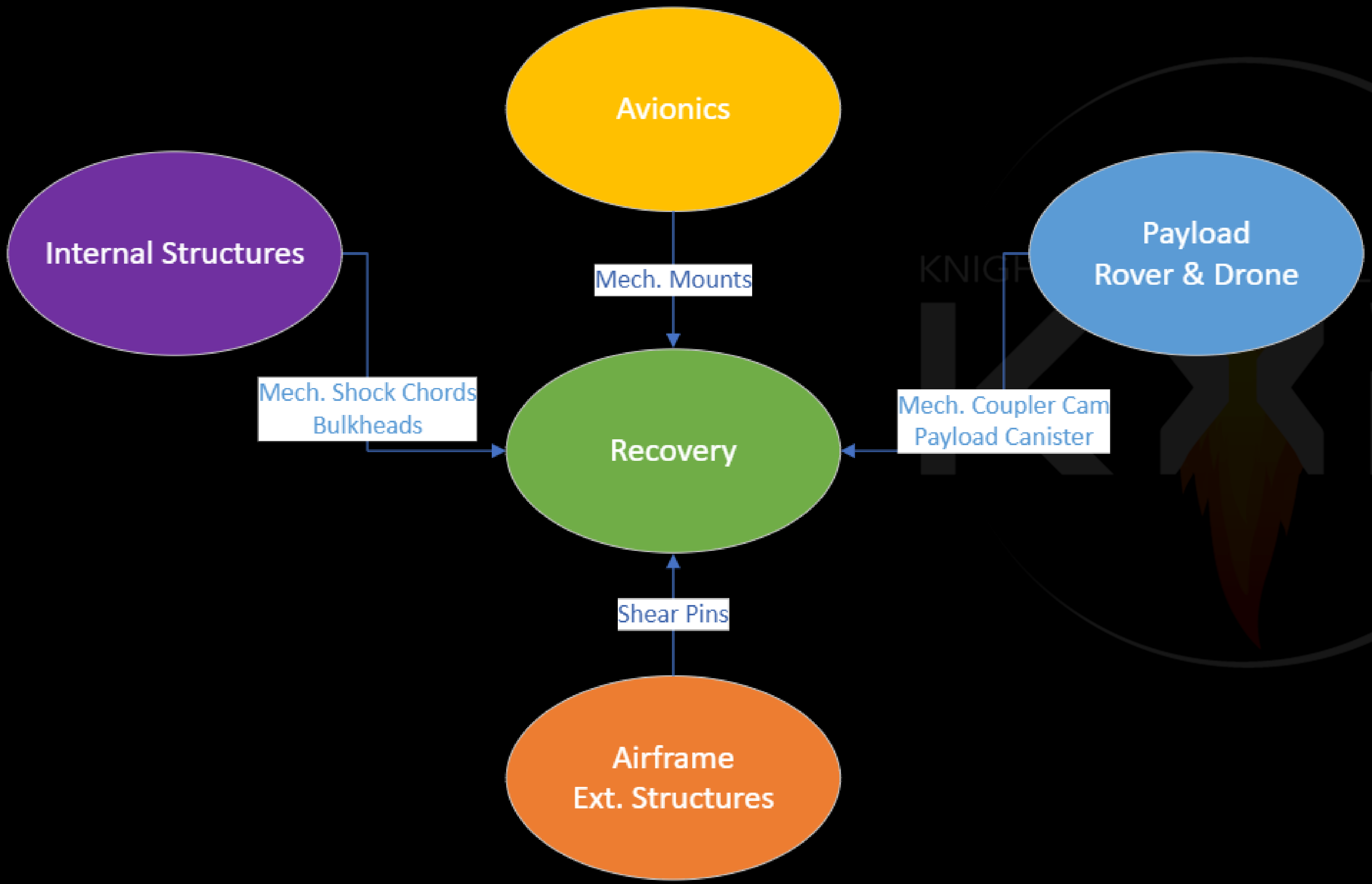
Aerostructures System Risk

- Failure to Recover
- Structural Failure During Flight
- Manufacturing Failure / Timeline
- Launch Site Conditions

Recovery Component Breakdown



Recovery Interface Diagram



Recovery Functional Requirements & TPM's

Measure	TPM Value	Unit s	Verification Method
Compressive Loads	1100	lbs.	Demonstration
Tension loads	679	Lbs .	Demonstration
Size of Recovery compartment	[TBD]	ft^3	Inspection
Packing Length of Chutes	DC: 3"D x 5"L MC: 4"D x 11"L	in	Inspection
Descent Rate	D: [50] M: [20]	Ft/s	Test

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 **shall** create a safe controlled descent for the vehicle	Functional	Demonstration

Drogue + Main Chute

6 ft Drogue will deploy at apogee (delayed deployment if first altimeter fails)

- Compartment: L = 3.232 in; D = 6.043 in
- center of the rocket

12ft Main will deploy at 800 ft

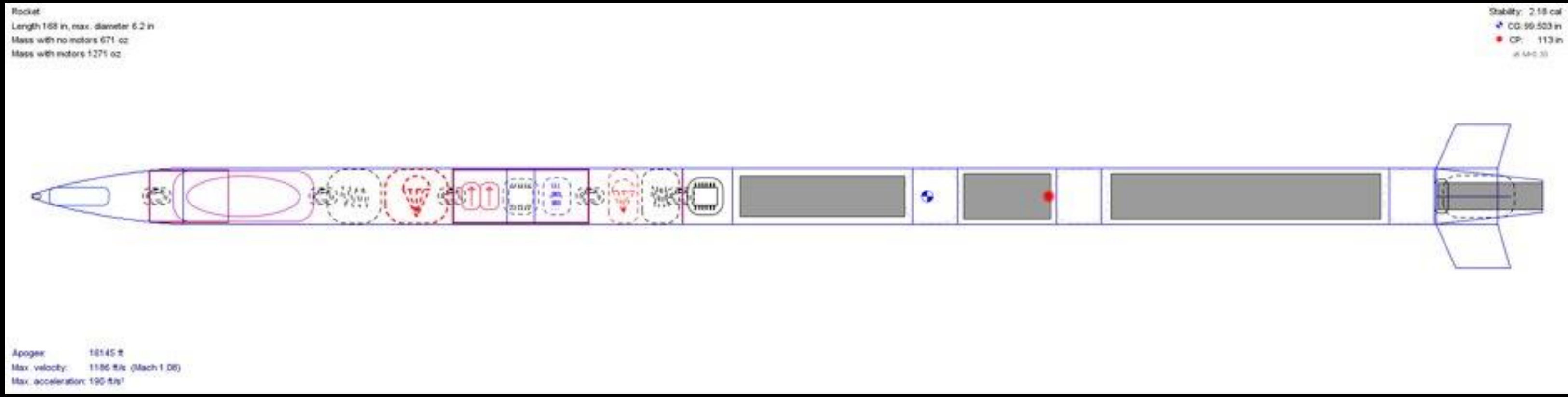
- Compartment: L = 6.917 in; D = 6 in
- forward section of the rocket

6ft Standard Parachute... Price: $60.50 / Colors may vary
Weight of parachute: 6.0oz
Packing Volume: 3.0"D x 5.0L"= 35.34"^3
Descent Rate:
15ft/sec: 6.5lbs
17ft/sec: 8.0lbs
20ft/sec: 11.5lbs
25ft/sec: 17.0lbs

Add to Cart

12ft Standard Parachute... Price: $155.00 / Colors may vary
Weight of parachute: 17oz
Packing Volume: 4.0"D x 11.0L"= 138.23"^3
Descent Rate:
15ft/sec: 24.0lbs
17ft/sec: 33.0lbs
20ft/sec: 43.0lbs
25ft/sec: 67.0lbs

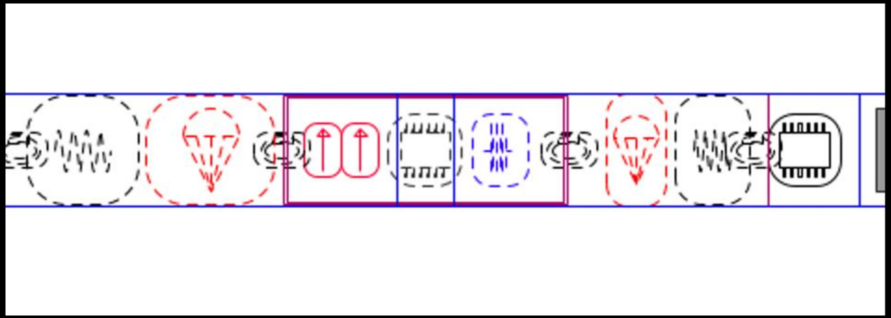
Add to Cart

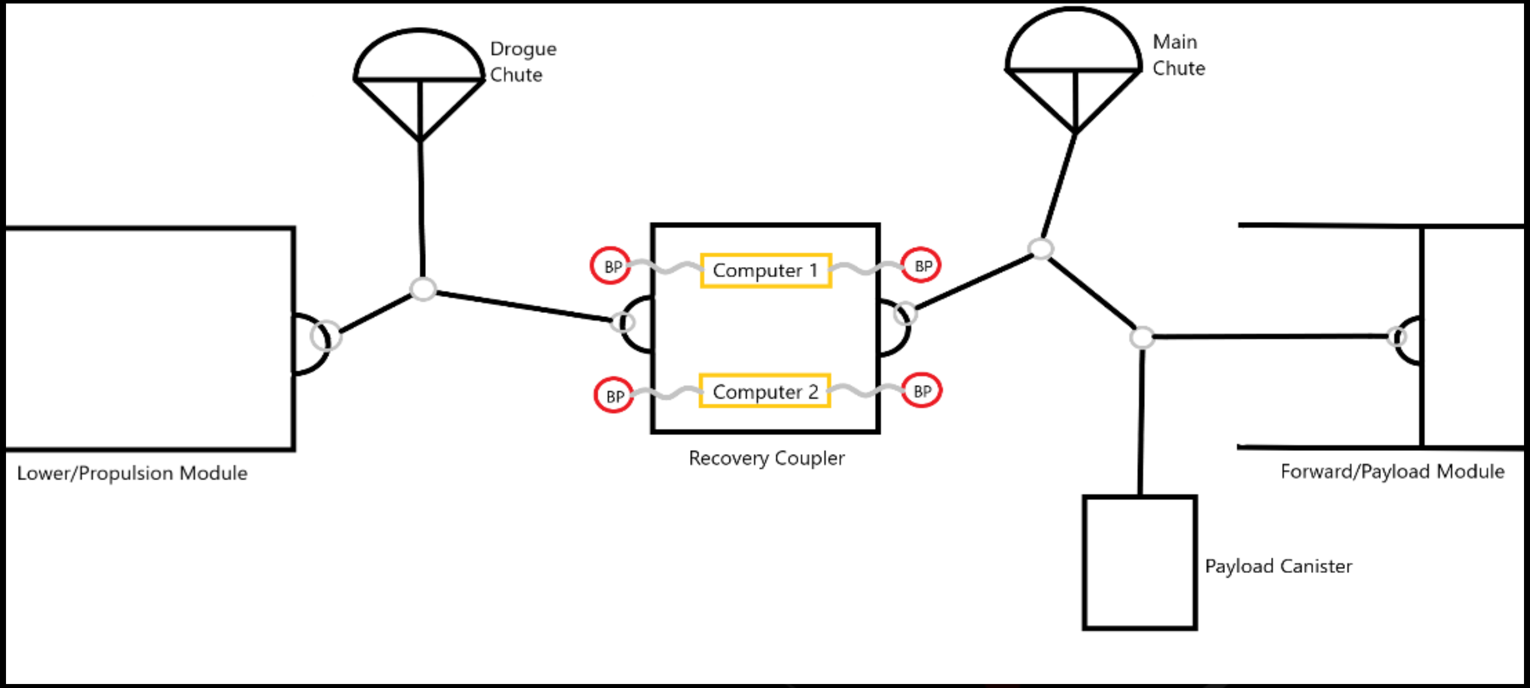


Sized for Specific Descent Rates

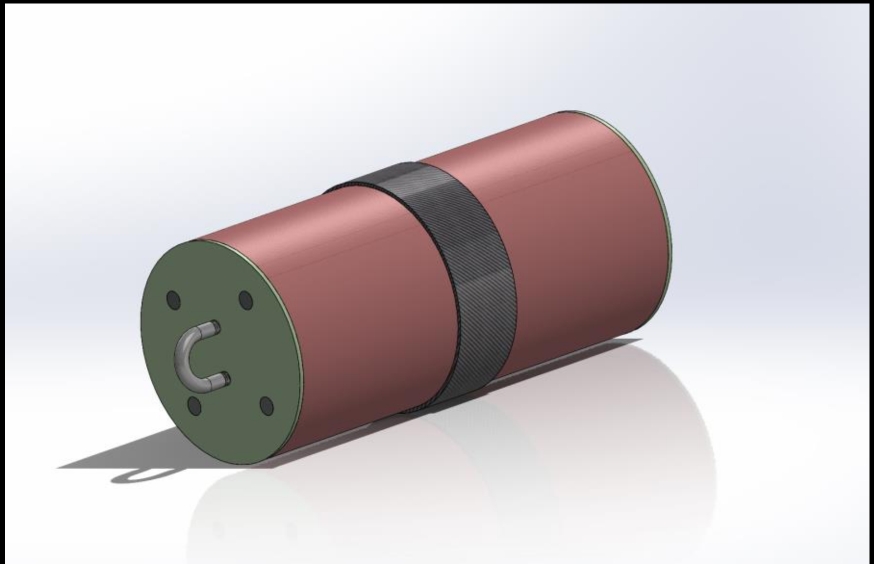
Shock Cords

- Connects Body Tube Segments during recovery
- Pulls out Payload during deployment



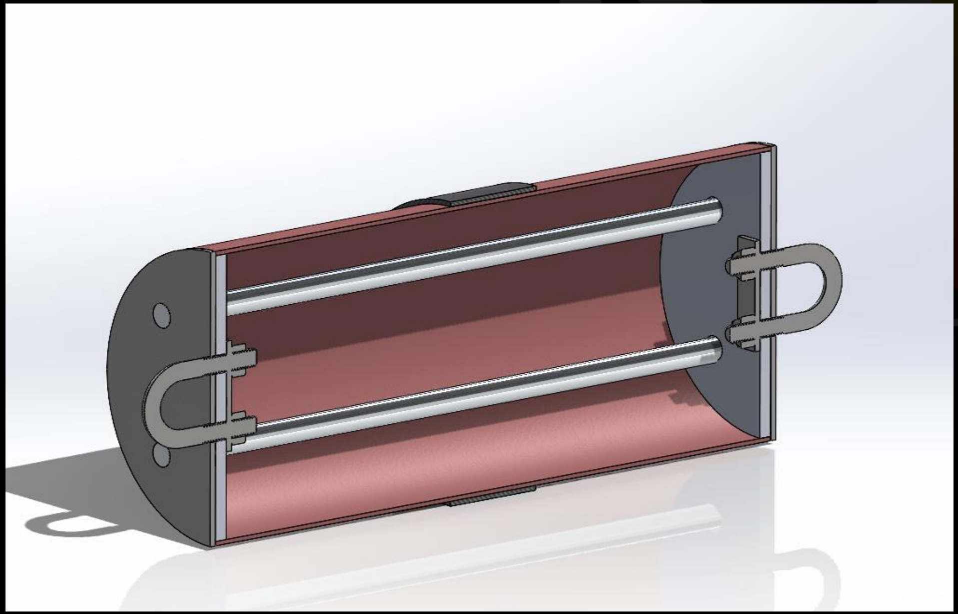


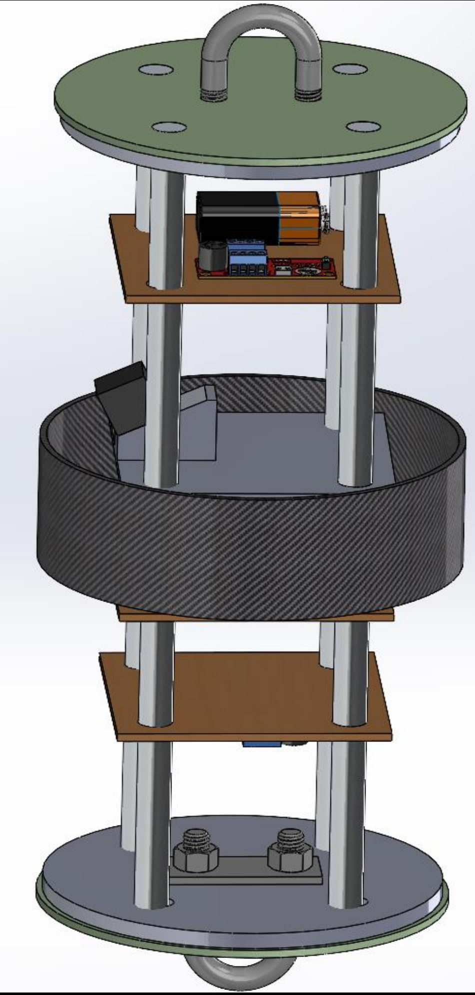
Recovery Coupler



To withstand the high forces experienced during launch and recovery, the coupler will be assembled from:

- Four ¼ inch rods, 1 caliber connection on each end
- COTS 6 x14 inch G12 Fiberglass Tube
- 2 Bulkheads
- Carbon Fiber Switch band

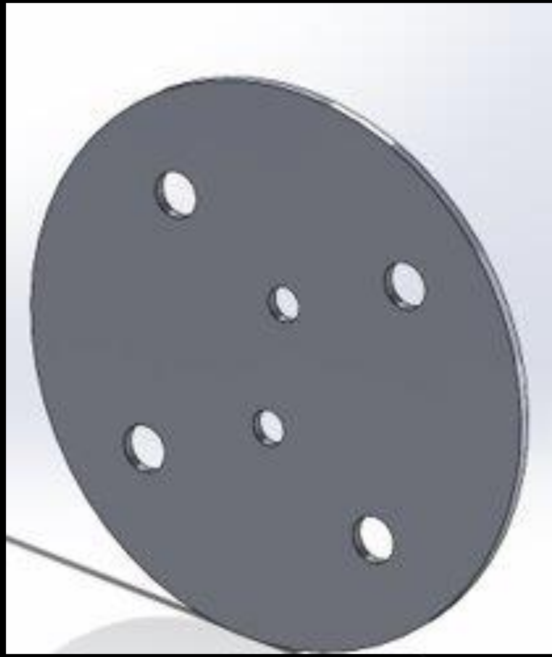


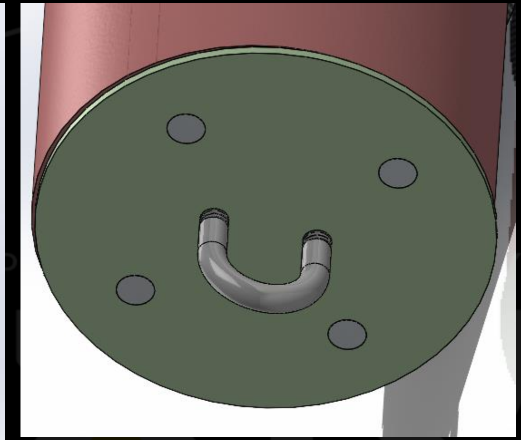


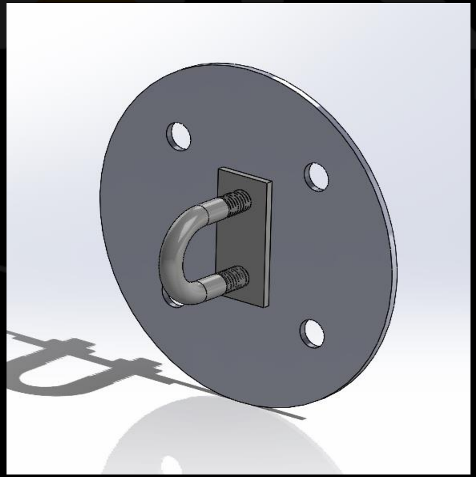
Telemetry to facilitate communication during the recovery stage will be housed within the recovery coupler.

Recovery Bulkheads

- Bulkheads
  - Made from G10 fiberglass
  - U-bolts (bought from McMaster) Black Oxidized Steel
  - Withstand snatch force: 679lbs of force
  - Black Powder charges on the bulkhead





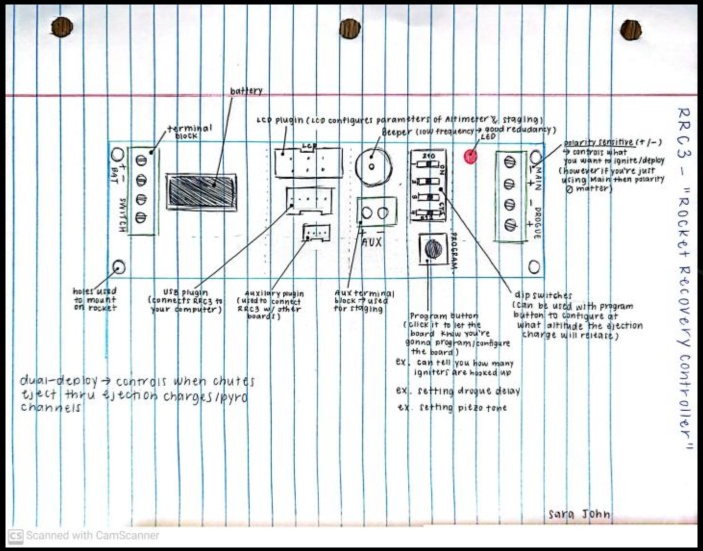


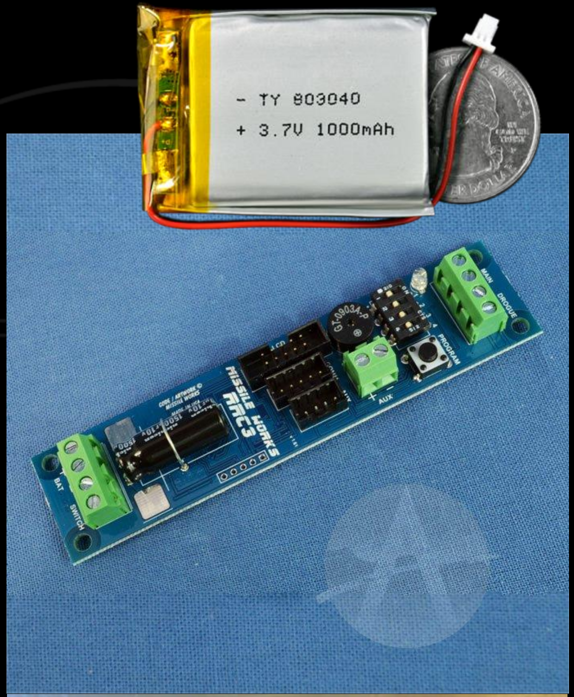
KXR UCF

Recovery Avionics (Altimeters)

Fully dual redundant avionics system with independent batteries

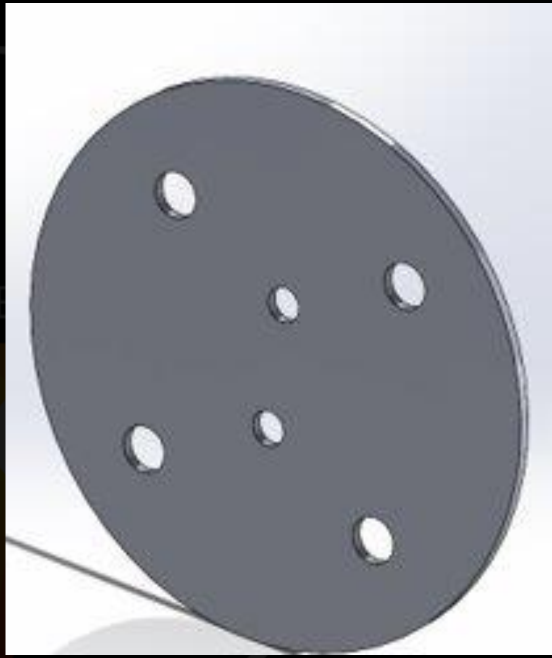
- Missile Works RRC3 - $80
  - Length 3.92"
  - Width 0.925"
  - Weight ~0.6oz (17 g)
- AltusMetrum EasyMini - $80
  - Length 1.5"
  - Width 0.8"
  - Weight ~0.23 oz (6.52 g)
- Batteries: 2x 850MAH LiPO Battery
  - $10 each

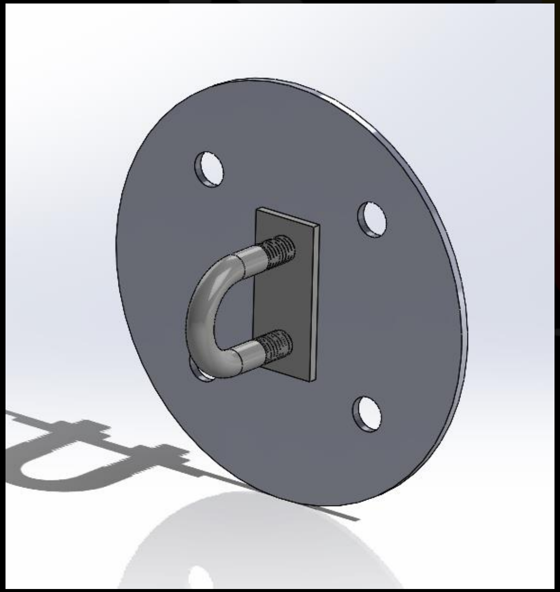




Recovery System Manufacturing

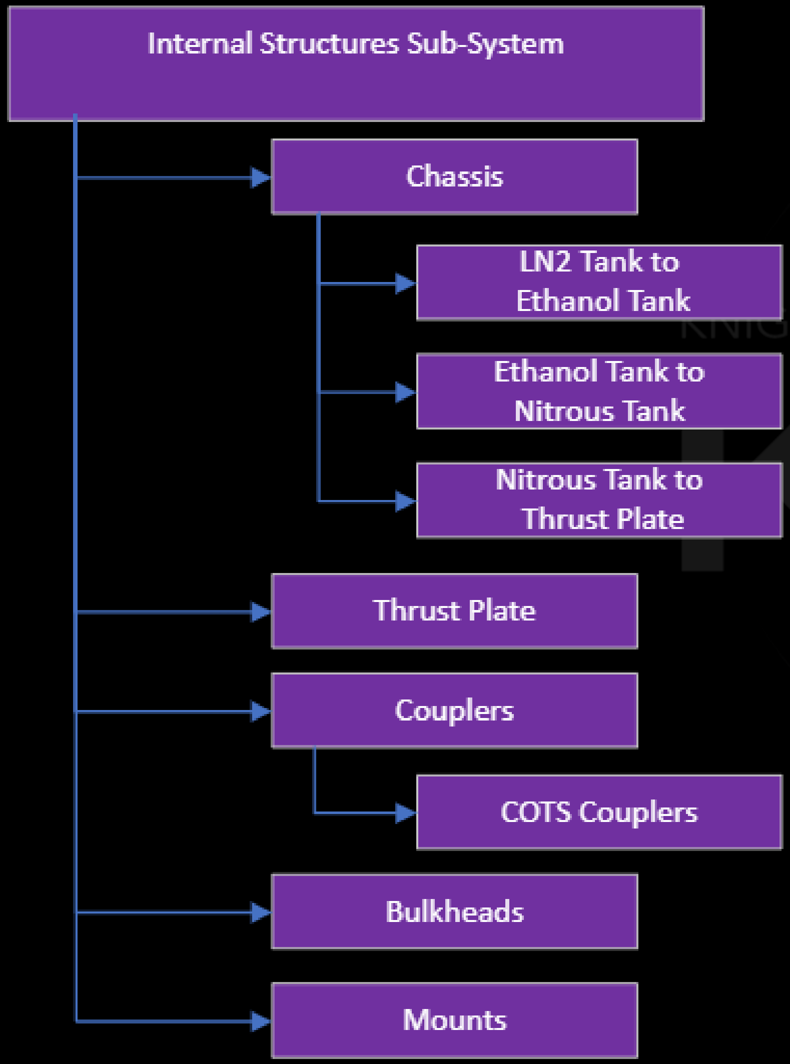
- Bulkheads
  - Made from G10 fiberglass
  - Bulkheads will be designed through CAD. The drawing file will be sent to a fabrication center and produced from there
  - U-bolts will be bought from McMaster



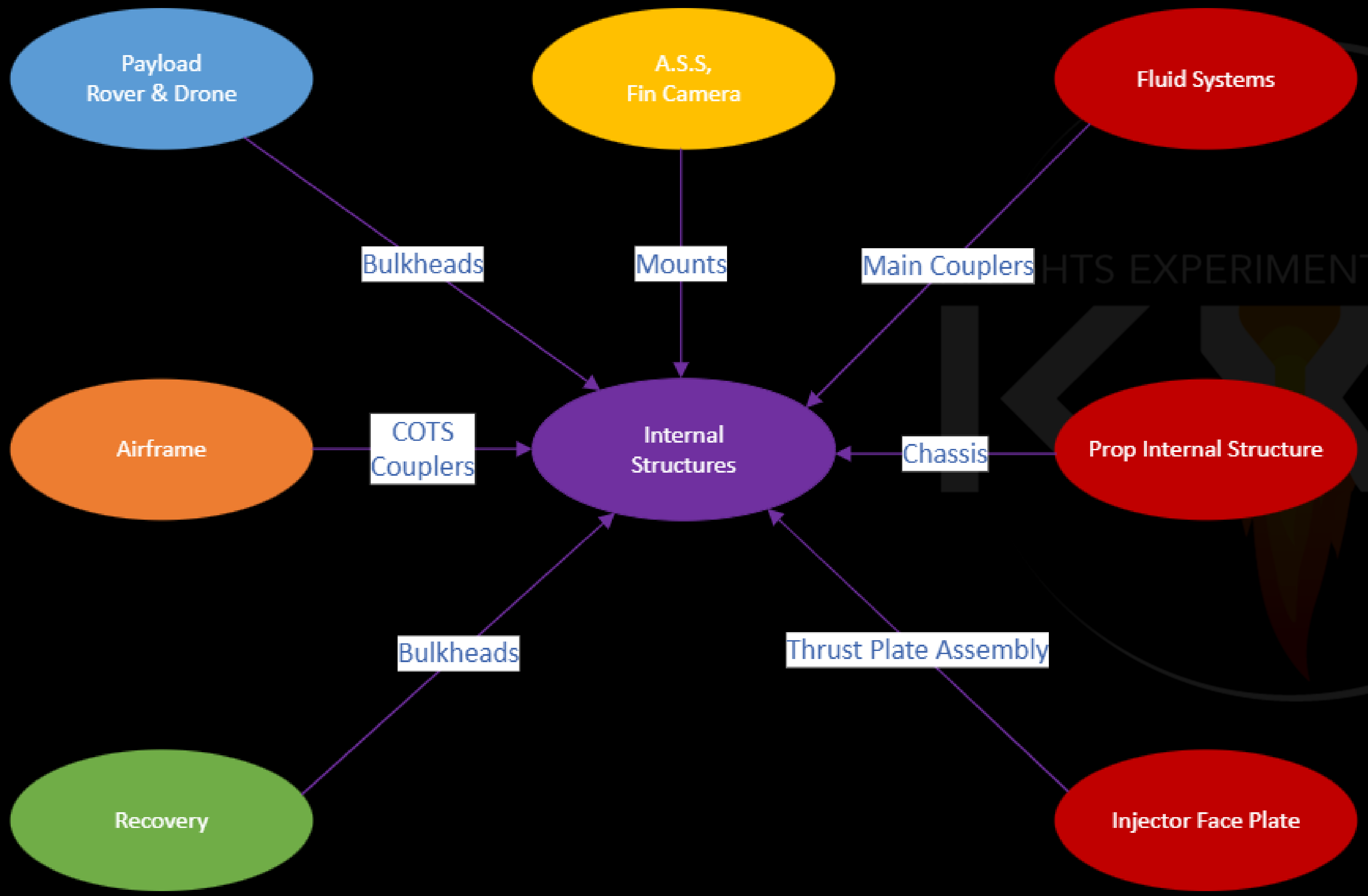


Internal Structures Subsystem

Internal Structures Component Breakdown



Internal Structures Interface Diagram



Internal Structures Functional Requirements &TPM's

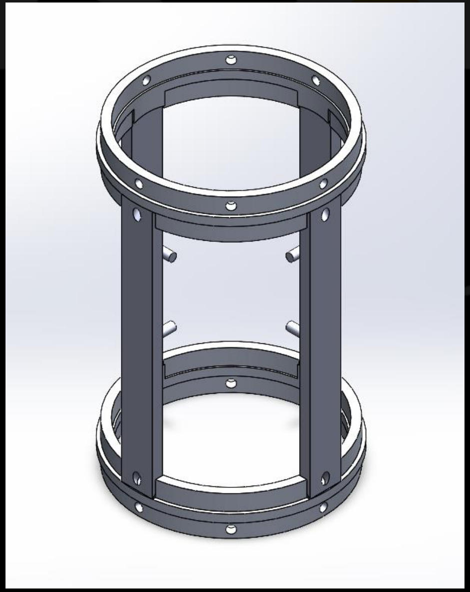
Measure	TPM Value	Units	Verification Method
Compression Loads	1100	lbs.	Analysis
Snatch Force	679	lbs.	Analysis
Ground Impact	[TBD]	lbs.	TBD
Shear Force	[TBD]	lbs.	Analysis
Bending Loads	[TBD]	lbs.	Analysis
Torsional Loads	[TBD]	lbs.	Analysis

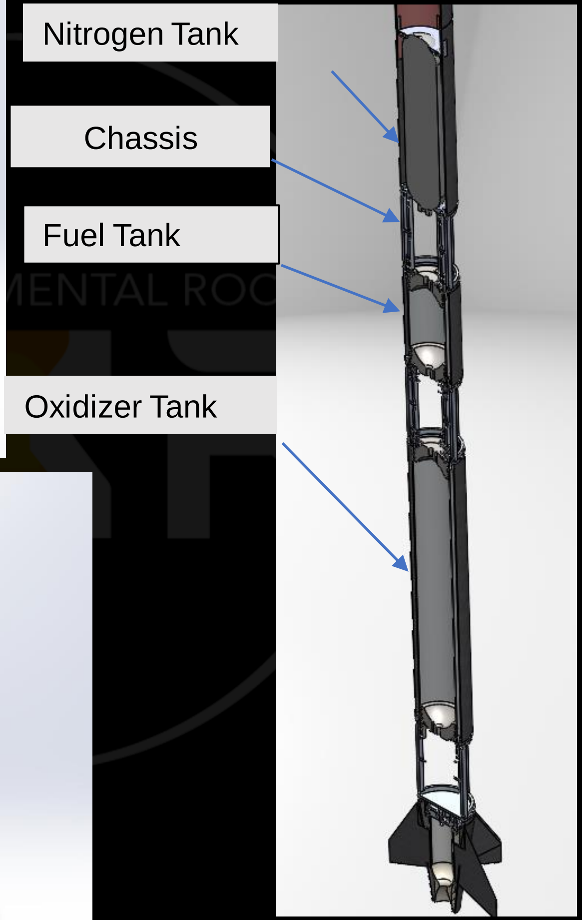
Requirement	Requirement Type	Verification Method
The Internal Structures-System **will** support and protect the **Propulsion** and **Payload** systems	Functional	Analysis
The internal Structures Sub-System **will** withstand the loads and vibrations acting on the rocket	Functional	Analysis
The Internal Structures **will** allow easy access to the internal components of the vehicle	Functional	Analysis
The Internal Structures **will** allow separation between motor, payload and recovery section of the vehicle.	Functional	Inspection

Chassis

- Chassis will be composed of three sets of aluminum couplers connected by struts and attached to fluid system bulkheads and connections
- Will take on loads during flight such as snatch force, compressive loads, bending, and shear
- Connections with fluid systems will allow the tanks to handle the compressive loads and also act as centering rings
- Allows easy access to propellent Valves
- Material Cost Breakdown:

Item	Description	Cost	Total
6061 Aluminum	1.500" Thick 8.000" Dia. X Precision Ground Blanks	$114..04	$570.20
6061 Aluminum	0.375" x 1" Aluminum Rectangle Bar 6061-T6511-Extruded	$4.50	$54.00

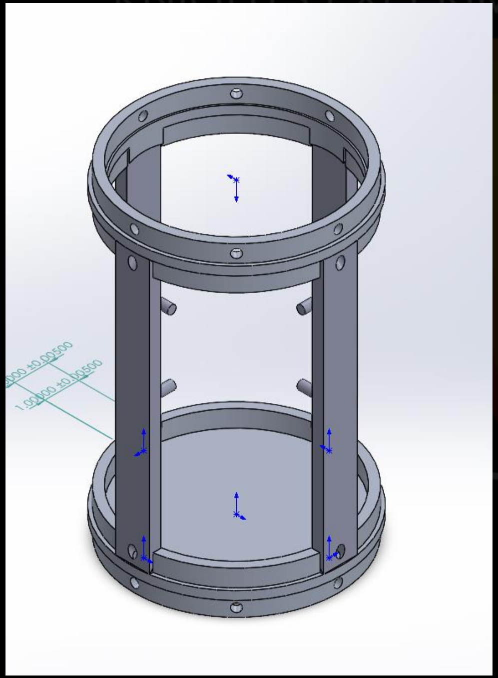


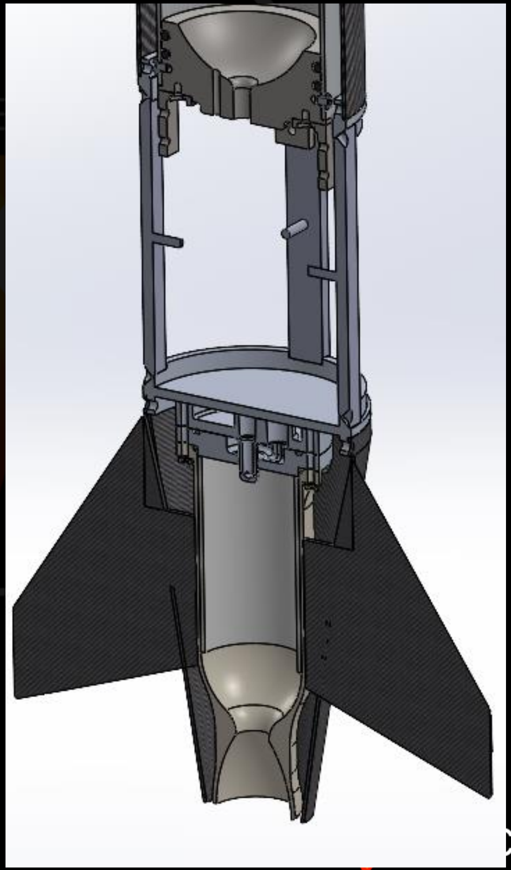


Thrust Plate Assembly

- Thrust Plate will take on the forces experienced during launch and redistribute loads to the airframe.
- Struts will interface with the chassis, tanks. As well as the injector.
- Material Cost Breakdown:

Item	Description	Cost	Total
6061 Aluminum	1.500" Thick 8.000" Dia. X Precision Ground Blanks	$114.04	$114.04

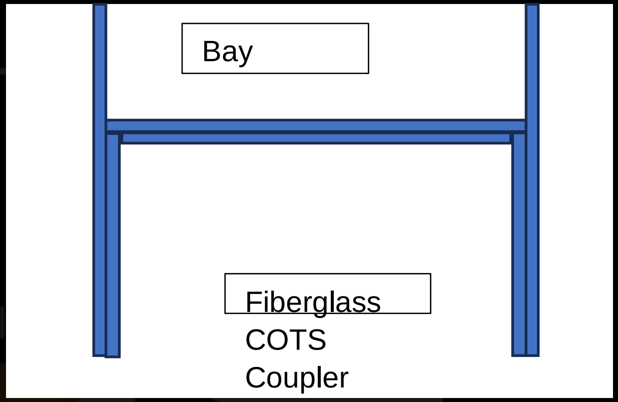


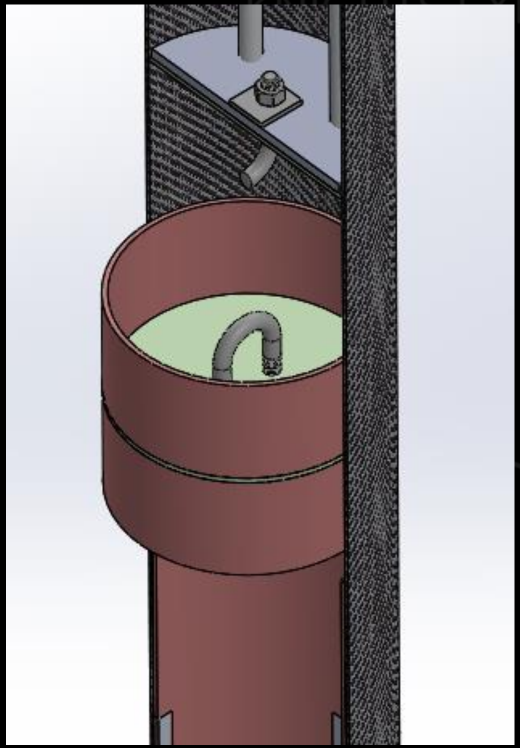


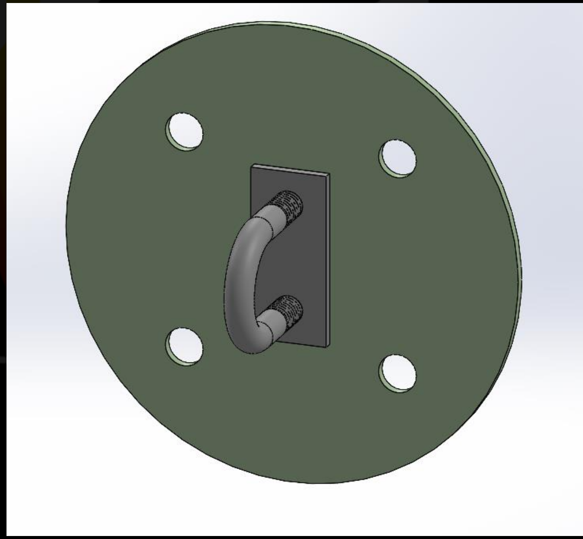
Bulkheads/Main Couplers

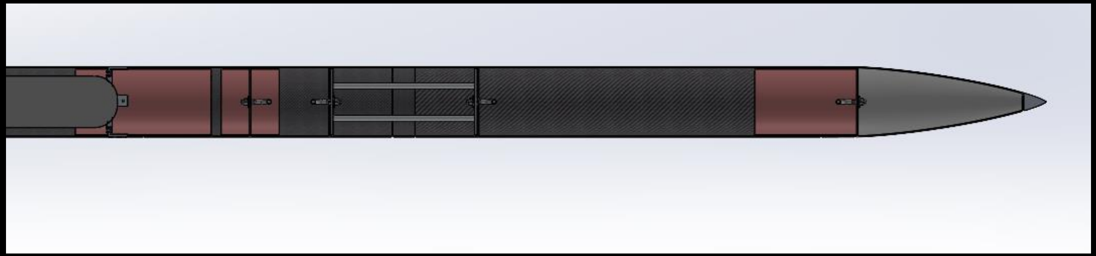
- G12 fiberglass couplers will join the propulsion section of the airframe with the rest of the aerostructure.
- G10 Bulkheads will be used to protect different sections of the airframe, such as the propulsion system, recovery, and payloads sections
- Material Cost Breakdown:

Item	Description	Cost	Total
G12 Fiberglass Coupler Tube	6" Fiberglass Coupler	$60.00	$120.00
G10 Fiberglass Plates	6" Fiberglass round plate	$13.01	$26.02









Internal Structures Manufacturing

- Bulkheads
  - Material: G10 Fiberglass
  - Manufactured with CNC machine, post-processing as necessary

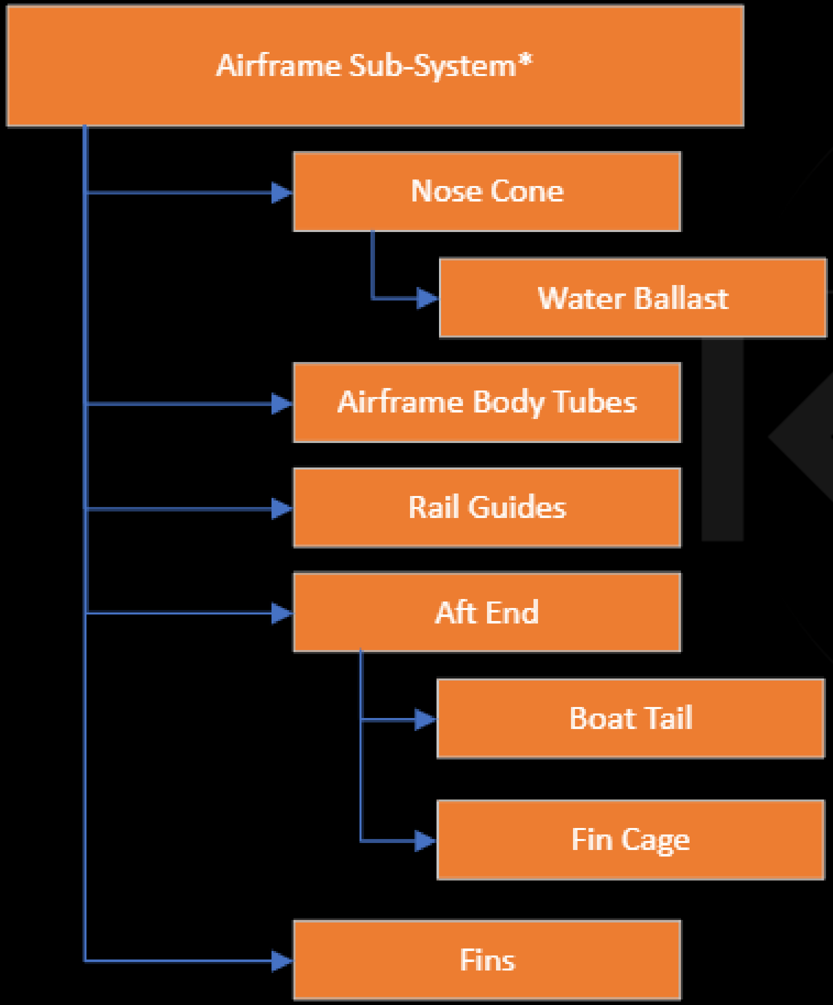
- Thrust Plate
  - Machined out of 6061 aluminum

- Chassis
  - Top and bottom plates: machined out of 6061 aluminum
  - Struts: machined out 6061 aluminum

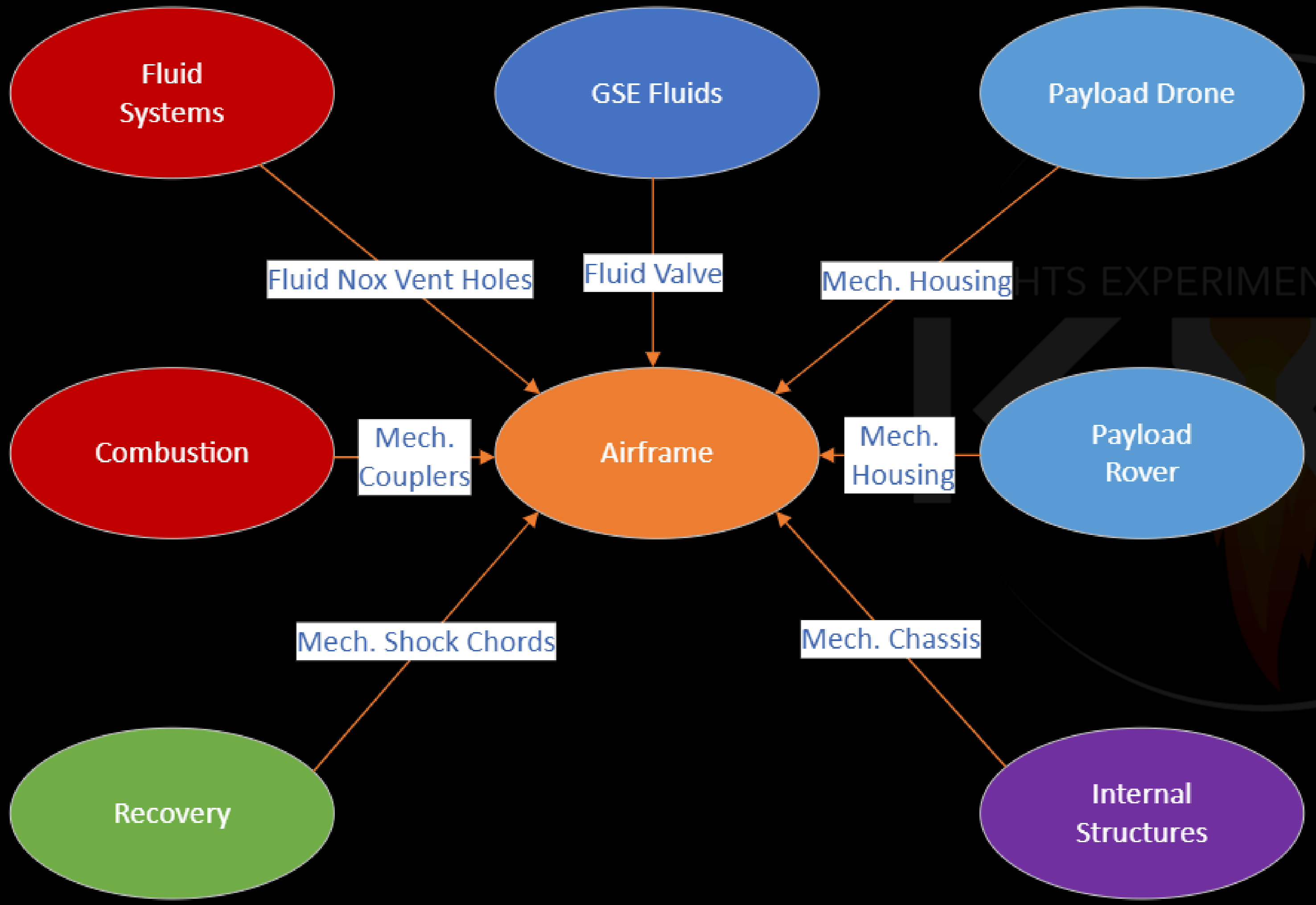
- Main Couplers
  - Commercial of the shelf fiberglass couplers

Airframe Component Breakdown

**Ext. Structures, Aerodynamic Structures, and Flight Dynamics Subsystems Merged for Leaner Architecture*



Airframe Interface Diagram



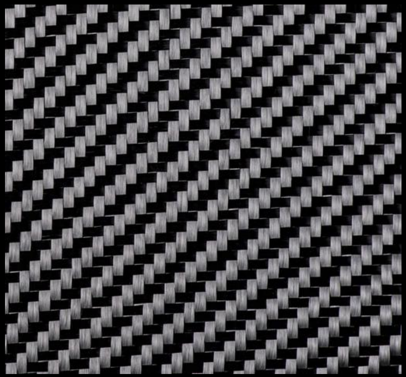
Airframe Functional Requirements & TPM's

Measure	TPM Value	Units	Verification Method
Compressive Loads	1100	lbs.	[Sim/Test]
Tension Loads (Snatch)	679	lbs.	[Analysis]
Bending Moment	[TBD]	ft-lb	[TBD]
Vibrations	[TBD]	[TBD]	[TBD]
Temps	[TBD]	[TBD]	[TBD]
Ground Impact	[TBD]	[TBD]	[TBD]

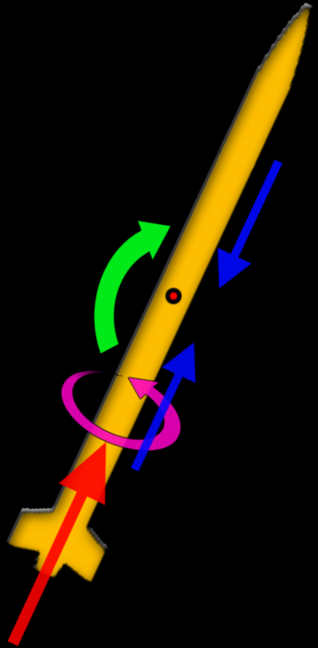
Requirement		Requirement Type		Verification Method
The Airframe Sub-system **will** be optimized for transonic speeds		Functional		Analysis
The Airframe Sub-system **will** provide stability in flight		Functional		Analysis
The Airframe Sub-system **will** withstand flight loads		Functional		Analysis

External Structures Lay-Up

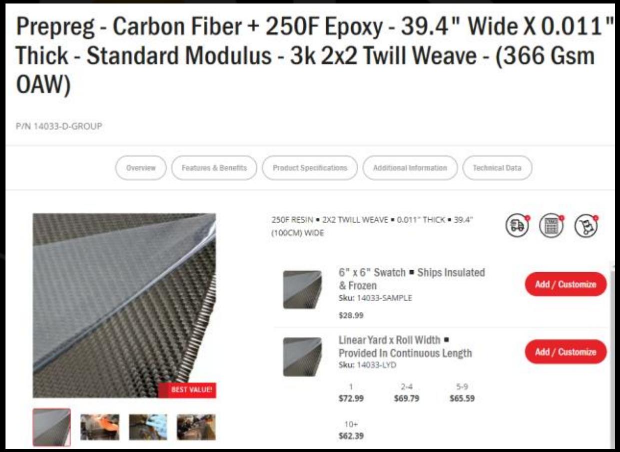
- Using 3K 2x2 twill weave pre-preg carbon fiber
- Preliminary Stack up is 6 plies, using rolling technique
- Designing for about 1100.0 lbs. of compressive load on the airframe (G-loading & Drag Force) (See force calculator) (Bending force to be determined)



3k 2x2 Twill Weave



Thrust
Compressive Force
Bending Force
Shear / Torsional Force

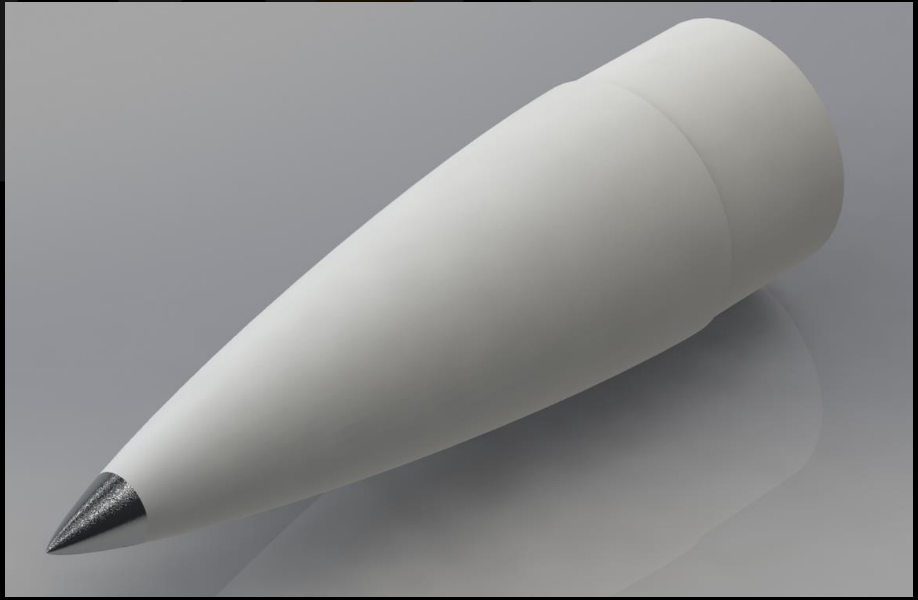


Nose Cone

- Von Karman Nose Cone
  - Well suited for trans-sonic regime
- Wet-Lay Fiberglass on 3-D Printed Mandrel
  - Using a combination of 6-inch and 2-inch dry fiber-glass sleeves and wet-laying with epoxy
  - ~ 5 ply lay up
- Aluminum Tip

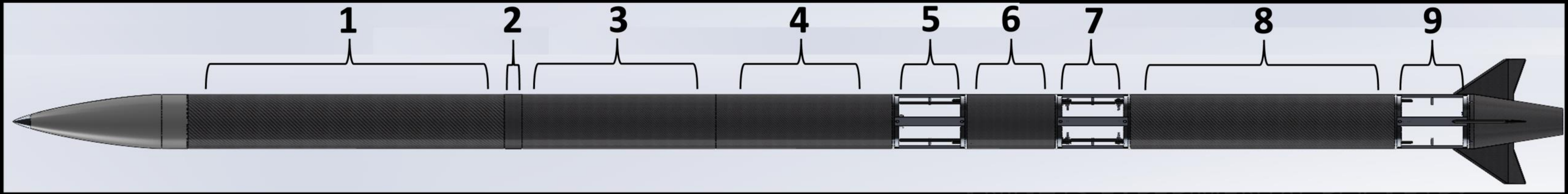
$$\theta(x) = \arccos\left(1 - \frac{2x}{L}\right)$$

$$y(\theta, C) = \frac{R}{\sqrt{\pi}}\sqrt{\theta - \frac{\sin(2\theta)}{2} + C\sin^3(\theta)}$$



Item	Item Desc.	Cost	Qty.	Total Cost
Composite	6 in. FG Sleeves	7.34	7	51.38
Composite	2 in. FG Sleeves	2.73	7	19.11
Epoxy	AdTech 820 Hardener	135 / gal	1	135.00
Epoxy	AdTech 820 Resin	357 / 5gal	1	357.28
Aluminum	Al. Tip Stock	62.50	1	62.50
Total	-	-	-	**625.27**

Body Tubes / Design



1 Payload Body Tube

2 Switch Ring

3 Lower Recovery Tube

4 Nitrogen Tank Tube

5 Nitrogen Mount

6 Fuel Tank Tube

7 Fuel Mount

8 Oxidizer Tank Tube

9 Combustion Chamber Tube

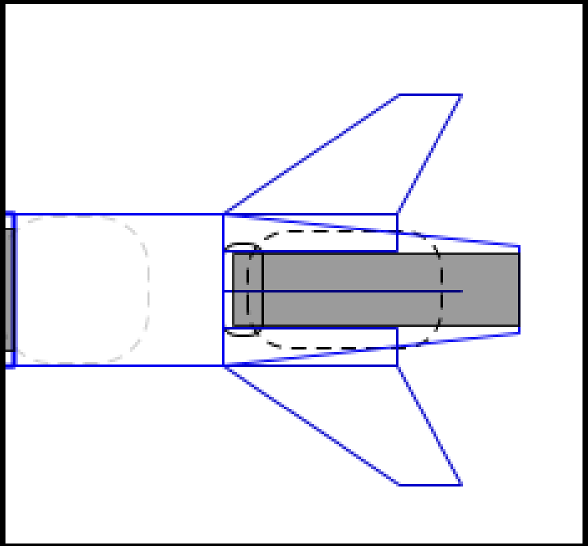
- Layup: 6 Plies, Pre-Preg, 3k 2x2 Twill

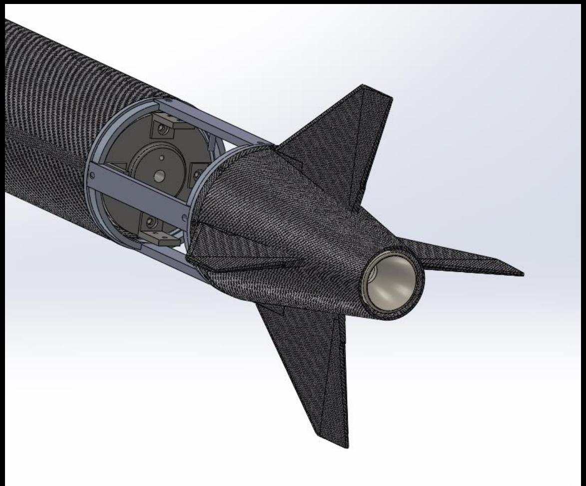
Item	Description	Cost	Quantity	Total
Pre-Preg Carbon Fiber	2x2 Twill; sold by yard	($157 for shipping + $62.39 per yard)	20 yards	$1405 (Prelim)

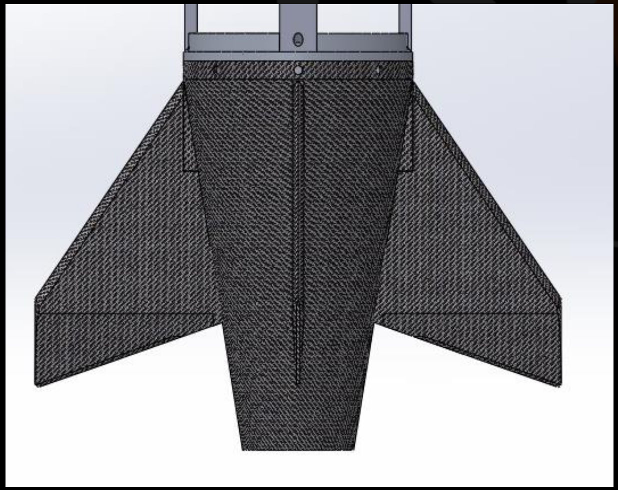
Boat Tail

- Boat Tail geometry is an aerodynamic taper to the airframe.
- Lowest drag coefficient out of all three possible geometries.
  - The boat tail decreases our drag coefficient by 0.088.

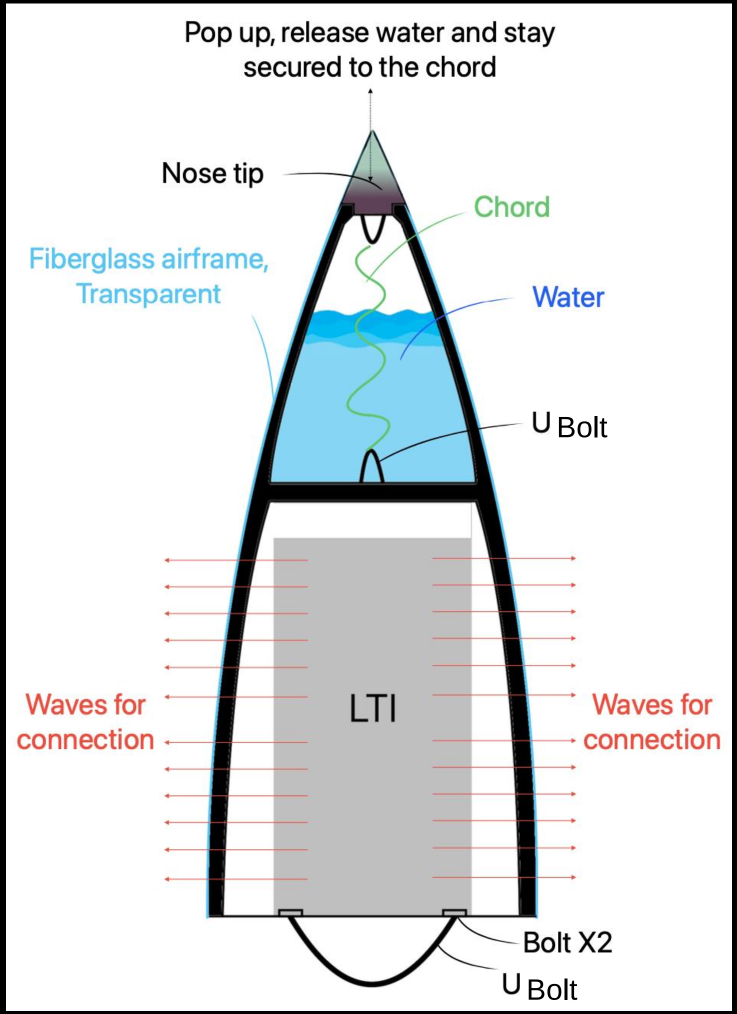
Boat Tail	0.000 (0%)	0.042 (10%)	0.021 (5%)	**0.063 (14%)**	<-- Boat Tail Drag Coefficient
Transition	0.080 (18%)	0.044 (10%)	0.006 (1%)	**0.130 (29%)**	<-- Tail Cone Drag Coefficient
Transition	0.000 (0%)	0.132 (29%)	0.019 (4%)	**0.151 (33%)**	<-- Flat End Drag Coefficient







Water ballast



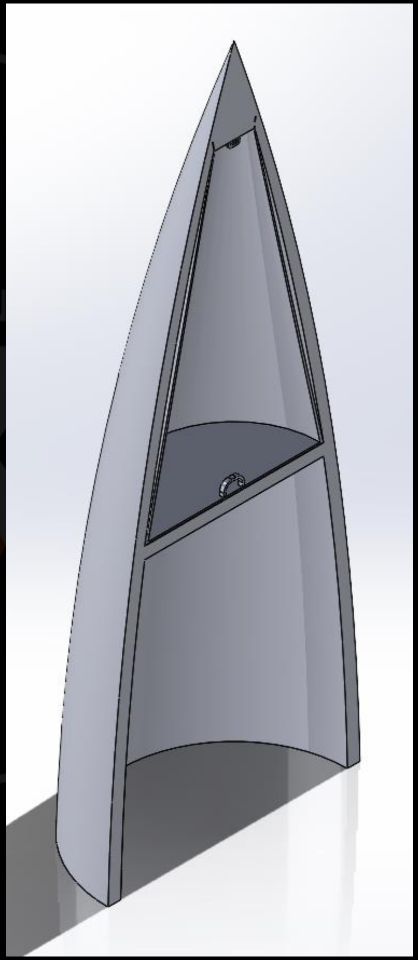
Function/ Performance:

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

Characteristics – TPM values:

- 500ml of water

Item	Full Item Description	Cost	Quantity	Total	Link (not hyperlink)
G10 plate	Fiberglass Plate	21	1	21	Eplastics
U-bolt	U-bolt	2.5	1	2.5	Home Depot
Water	H2O	1	500 mL	1	Publix
Aluminum (3'' diameter by 6"length)	Aluminum to be cnc'd for the nose cone tip	48.07	1	48.07	Online Metals
Nylon Paracord	Ties tip to fiberglass bulkhead	3.99	1	3.99	Amazon
Total money expenditure: $ 76.56					



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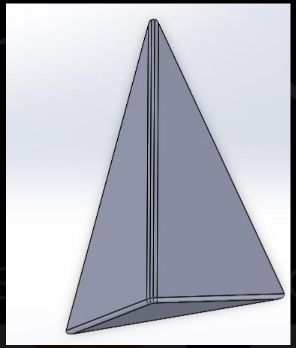
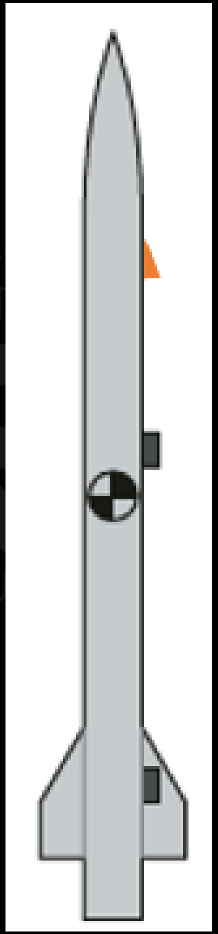
Rail Guides Component Breakdown

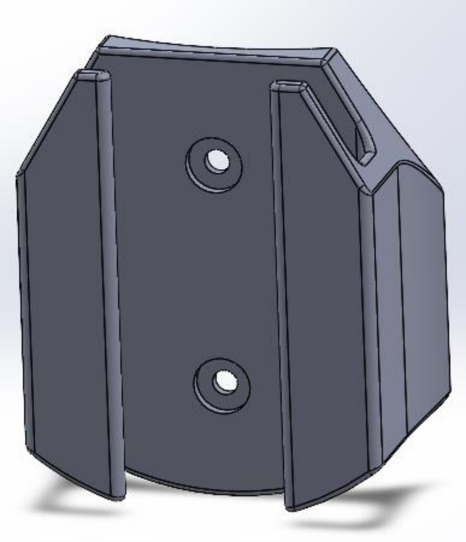
Function/ Performance:

- 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
- Potential addition of upstream geometry to reduce drag

- Characteristics – TPM values:
- 200lbs of Friction and shear resisted in flanges







Item	Full Item Description	Cost	Quantity	Total	Link (not hyperlink)
Launch Lugs	Custom molded medium density Polyethylene launch lugs	$150	2	$300	Custom Rubber Corps
Wedge (Optional)	Custom molded medium density Polyethylene triangular wedge	$120	1	$400	Custom Rubber Corps
Bolts	M5 cross countersunk head screws (package)	$14	1	$14	McMaster-Carr

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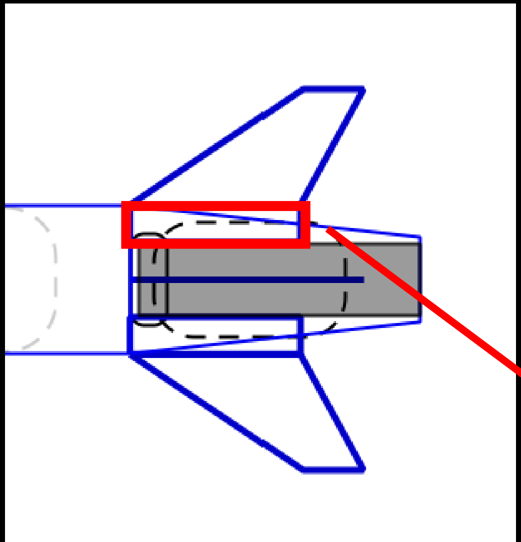
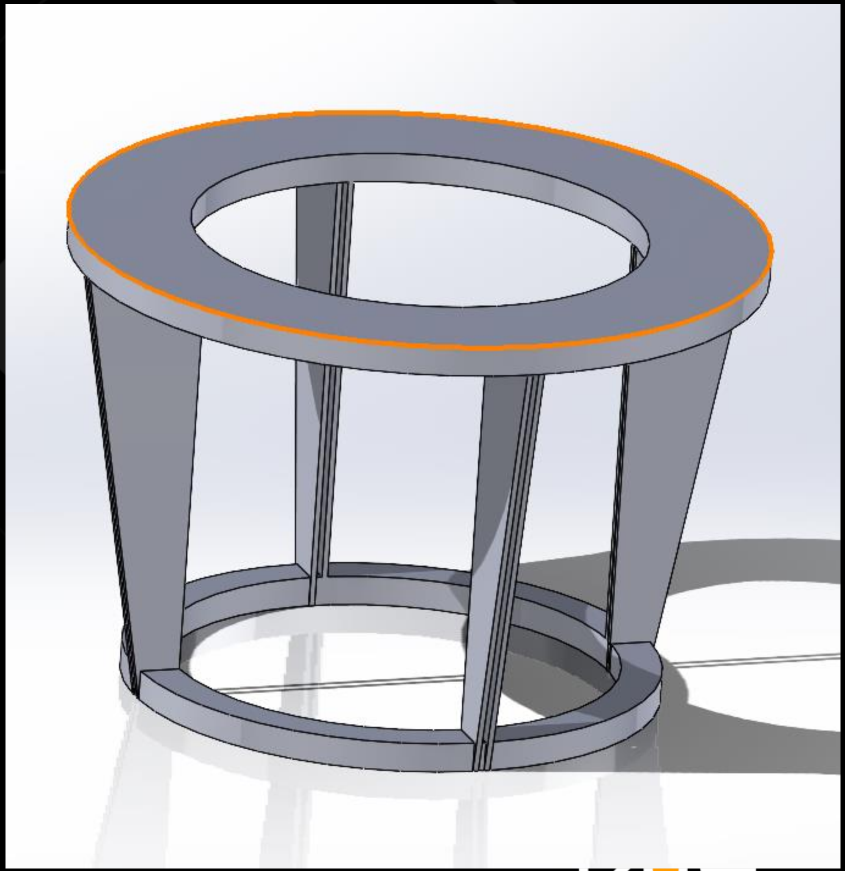
Fin Cage Component Breakdown

- The fin cage will allow fins to be inserted and held in place to the airframe.
- It will be inside the tail cone, around the combustion chamber of the rocket.
- G10 CNC plates

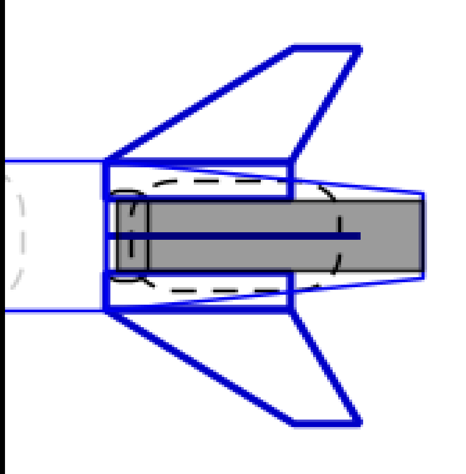


Fin tabs are Inserted into Fin cage



Fins

Segment	Unit (inches)
Tip chord	2.5
Height	4.8
Root Chord	7
Thickness	0.3



Function/ Performance:

- Shall resist all loads experienced in flight.
- The fins shall provide passive stability to the vehicle.
- The fins shall withstand a fin flutter load of [lb.].
- Fins should minimize the aerodynamic forces acting on the vehicle.

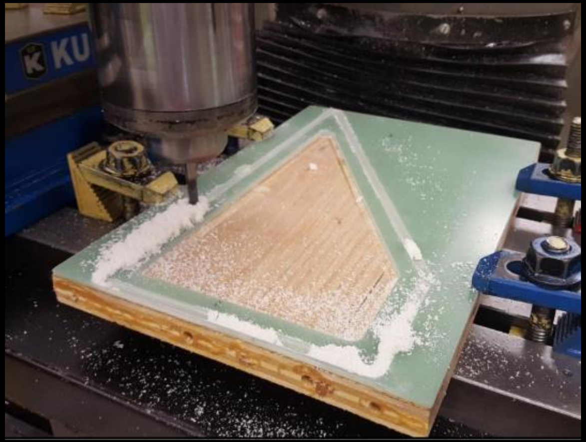
Characteristics – TPM values:

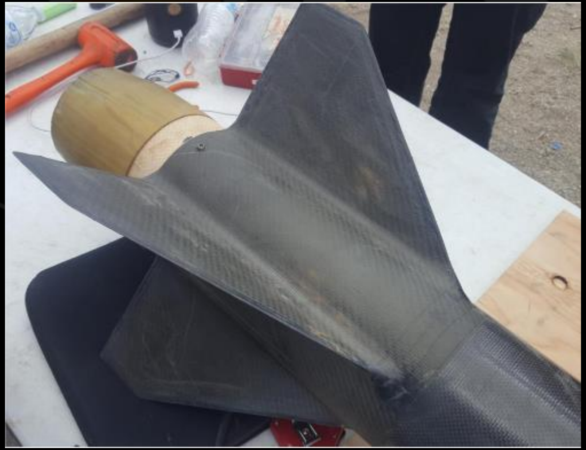
- Pressure Cd [0.0035] Coefficient of pressure
- Friction Drag [291.886] Newtons
- Max lift coefficient [18.37] Normal force Coefficient

Item	Full Item Description	Cost	Quantity	Total	Link (not hyperlink)
G10 plate	Fiberglass Plate FR4	21	4	84	Eplastics
Prepreg	Prepreg 3K, 2x2 Twill Weave Carbon – 1yd roll	199.95	1?	199.95?	FiberGlast
Aluminum plate	3/16 X 3 0.66lb 6ft 6061-T6511 Aluminum Flat plate	48	1?	48?	MetalsDepot

Fins Layup

- Using 3k 2x2 twill CF (6 plies tip to tip) laid on G10 fiberglass or 6061 aluminum
- Exploring Current Materials
  - Aluminum
  - G10
  - Aramid?
- Need to consider flutter & vibrations





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
  - Cure tube in autoclave and post-process as necessary
- Nose Cone
  - 3D-printed and sanded
  - Wet-lay fiberglass over the 3D-printed mold
  - Post-process nose cone as necessary
  - Tip made from aluminum cut out with a CNC
- Water Ballast
  - Bulkheads made from G10 plates laser cut with a CNC machine and a drill press
- Rail Guides
  - Machine rail mount

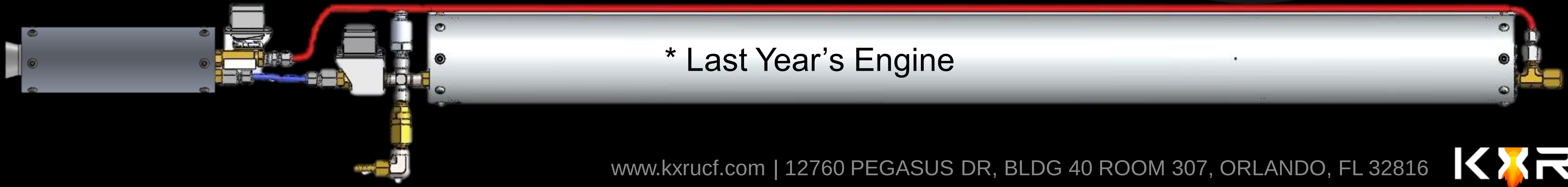
Airframe Manufacturing contd.

- Boat Tail
  - The part will be designed in CAD and then 3D printed. The 3D print will be used as a mold for carbon fiber wet lay. *potentially carbon fiber prepreg but more research would need to be done
- Fin Cage
  - Will be done like last year’s cage. The material will be G10 fiberglass and the parts will be made on a CNC machine and then assembled.
- Fins*
  - Made from G10 plates
  - Plates covered with prepreg
  - Sanded down to optimal airfoil cross section design
  - Sand edges to be rounded
  - *other option: use aluminum instead of G10

Questions?

FAR 10k Propulsion PDR

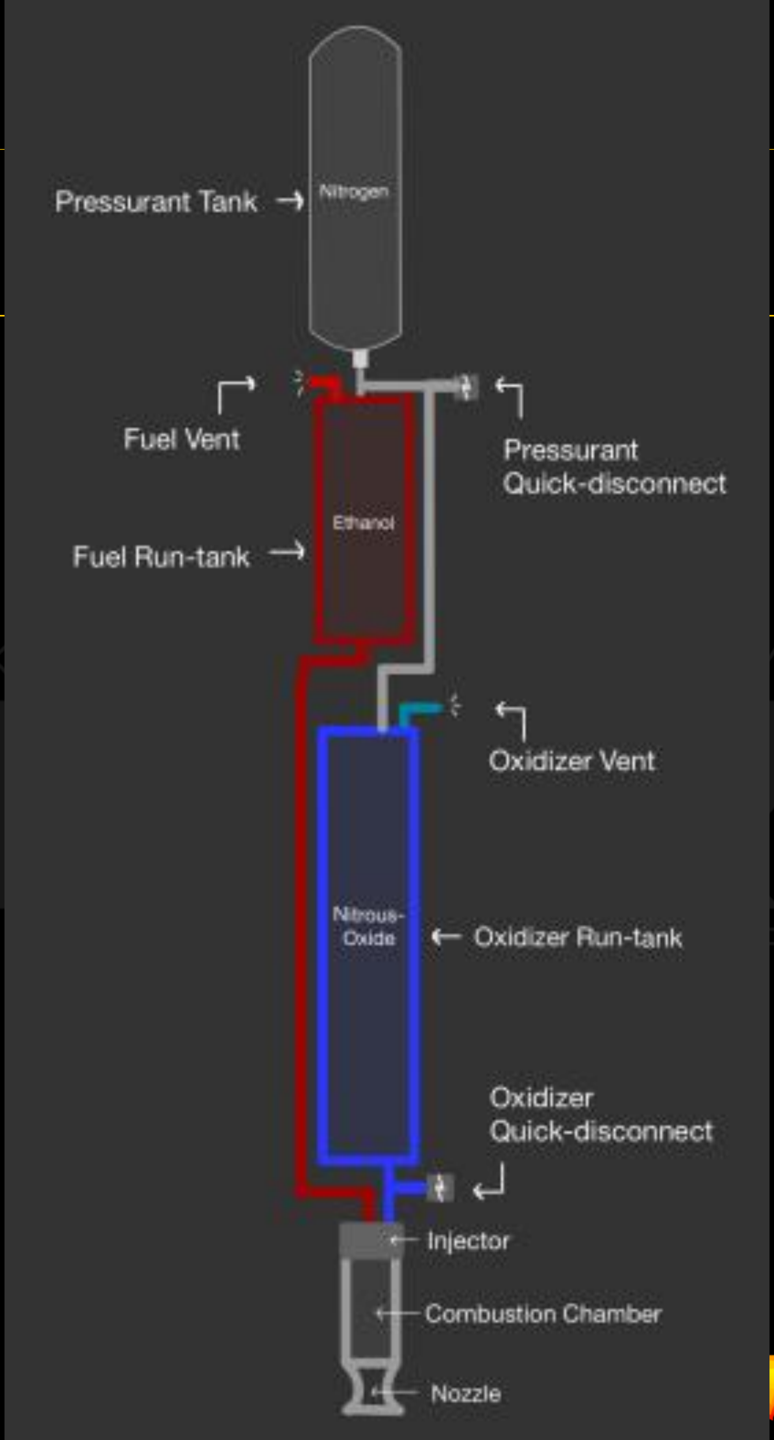
Propulsion System



Propulsion Architecture

- Fuel: Ethanol
- Oxidizer: Liquid Nitrous Oxide
- Total Propulsion System Height ~ 8.5 feet
- Total Propulsion System Weight ~ 45 lbs dry & 68 lbs wet

- Target Apogee: 10,000 ft
- Target Thrust: 2,362 N ≈ 531 lbf



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Propulsion System Requirements

Functional Requirement	Verification Method
The Propulsion System shall create thrust.	Demonstration
The Propulsion System shall contain an oxidizer, fuel, and pressurant.	Demonstration
The Propulsion System shall indicate tank capacities.	Demonstration
The Propulsion System shall be reusable.	Demonstration
The Propulsion System should cost less than $6,000.	Inspection
Performance Requirement	
The Propulsion System shall have a wet mass of less than 50 lbs.	Inspection
The Propulsion System shall have a total length of less than 9 feet.	Inspection
The Propulsion System shall have an Oxidizer to Fuel Ratio of 3:1.	Test
The Propulsion System shall have a Burn Time of 7 seconds.	Test
The Propulsion System shall have a total Impulse of 3710 lbfs.	Analysis
The Propulsion System shall have a total Mass Flow Rate of 2.5 lb/s.	Test

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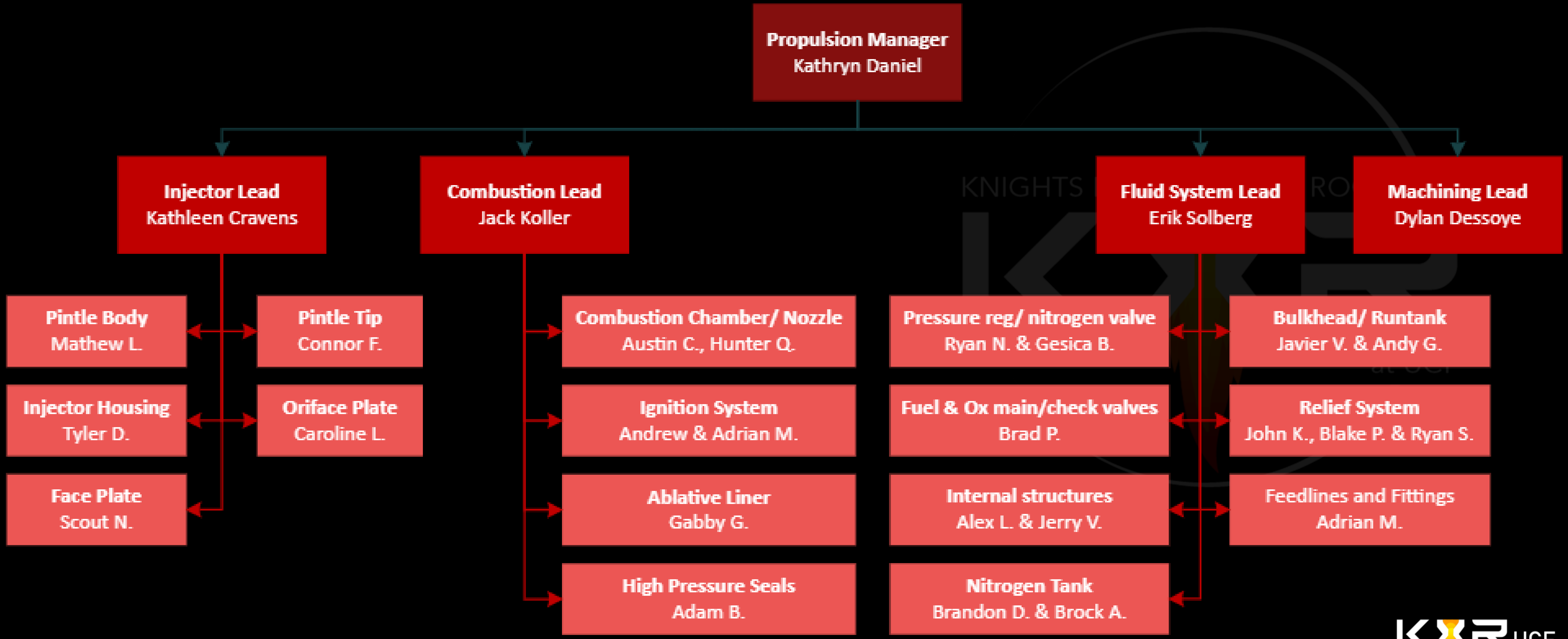
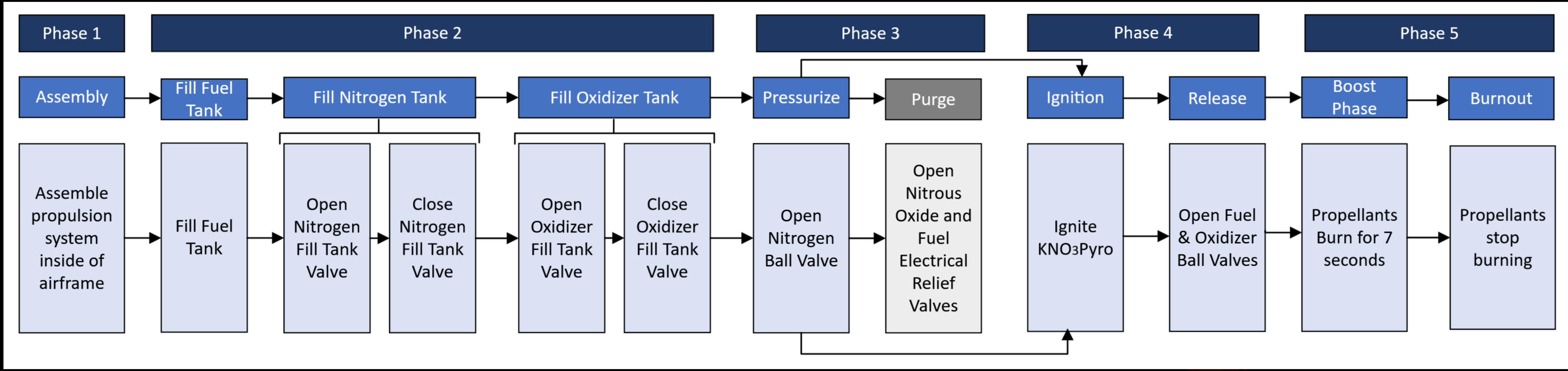
Propulsion Org Chart



Propulsion CONOPS



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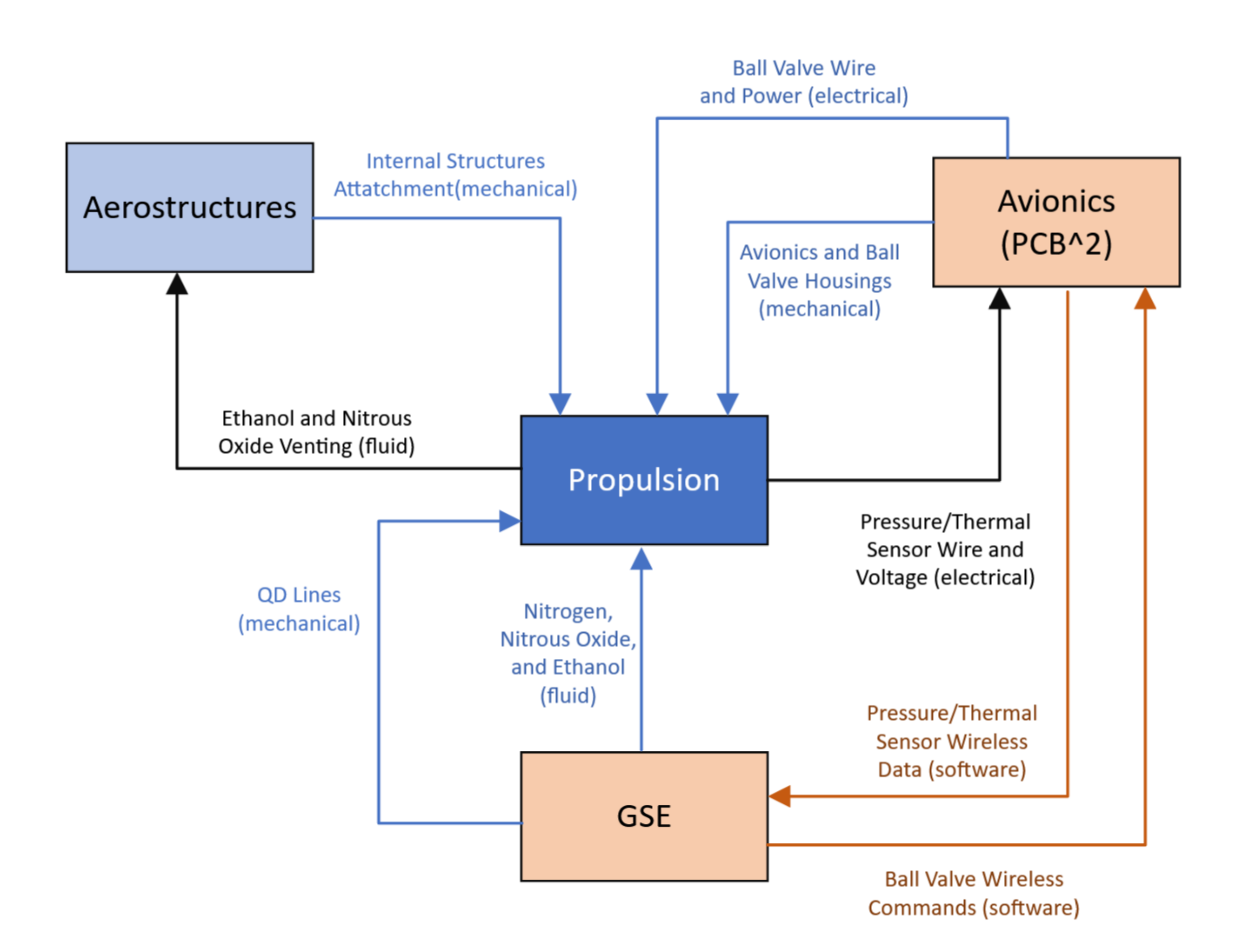
Propulsion Interface Diagram

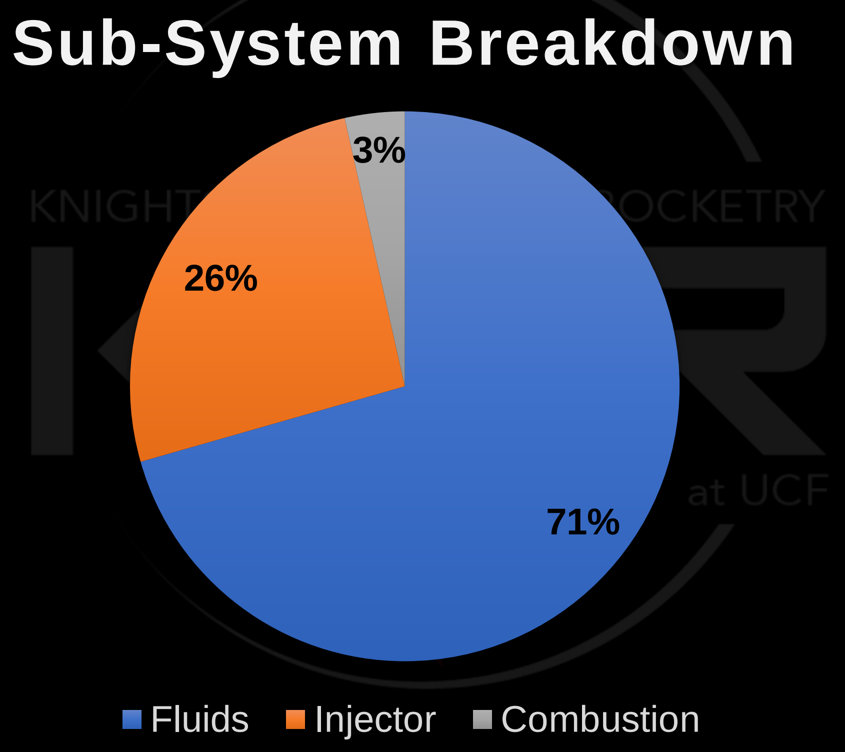


Propulsion System Verification Plans

- Finite Element Analysis of Components
  - Flange Stress, thrust plate
- Computational Fluid Dynamics Simulations of Components
  - Injector
- Inspection of Machined/COTS Components
- Dry Fit Demonstration
- Injector Water Flow Test
- Hydrostatic Test
- Cold Flow Test
- Static Fire Tests
- Launch

Propulsion Cost

- Fluids Subsystem Cost ~ $2600
- Combustion Cost ~ $130
- Injector Cost ~ $950
- Total ~ $3680



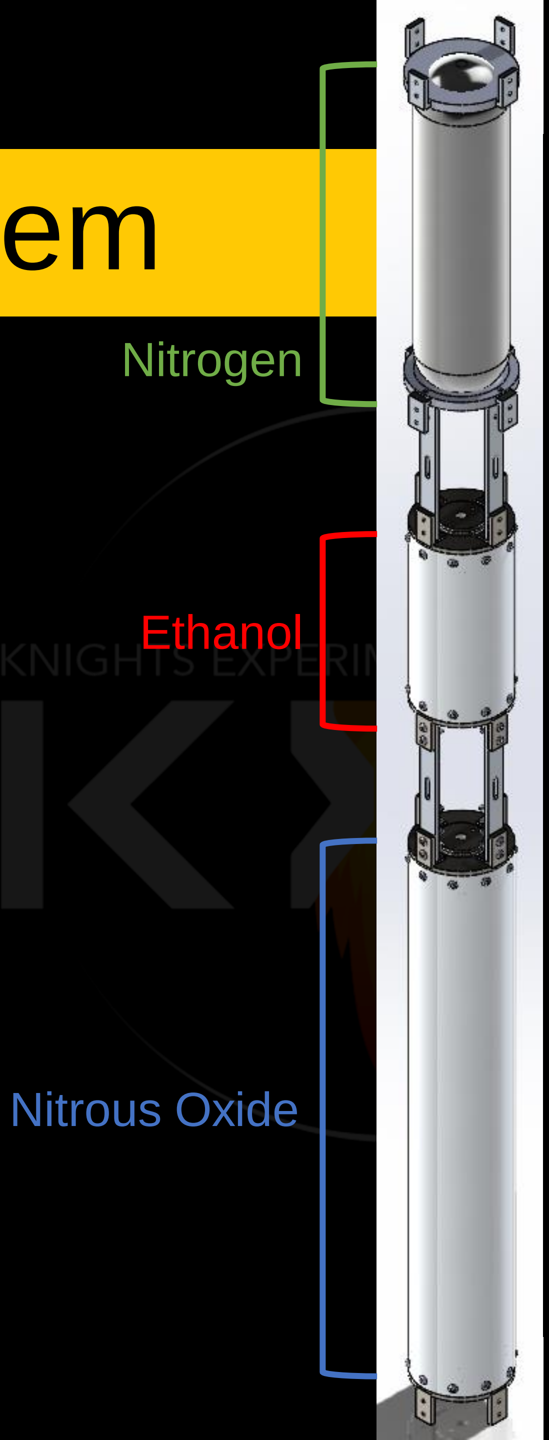
Propulsion System Risk

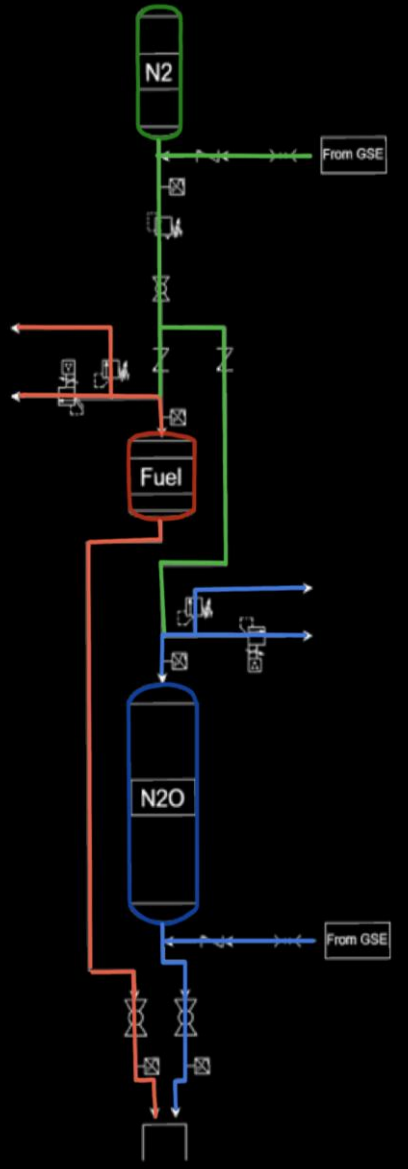
- Propellant Leaks
- Propellant valve timing error
- Nitrogen Valve freeze
- Low initial thrust
- Pressure Regulator Failure
- Ignitor Blowout/ Failure

KNIGHTS EXPERIMENTAL ROCKETRY at UCF

Fluids Subsystem

- Regulated Pressure Fed
  - Constant pressure feeding the propellants
  - Minimal performance loss over time
  - Less propellant mass
  - Nitrogen supply a part of the propulsion system
- Considered Blowdown Fed
  - Propellants lose pressure over time
  - Performance loss over time
  - More propellant mass, larger tanks





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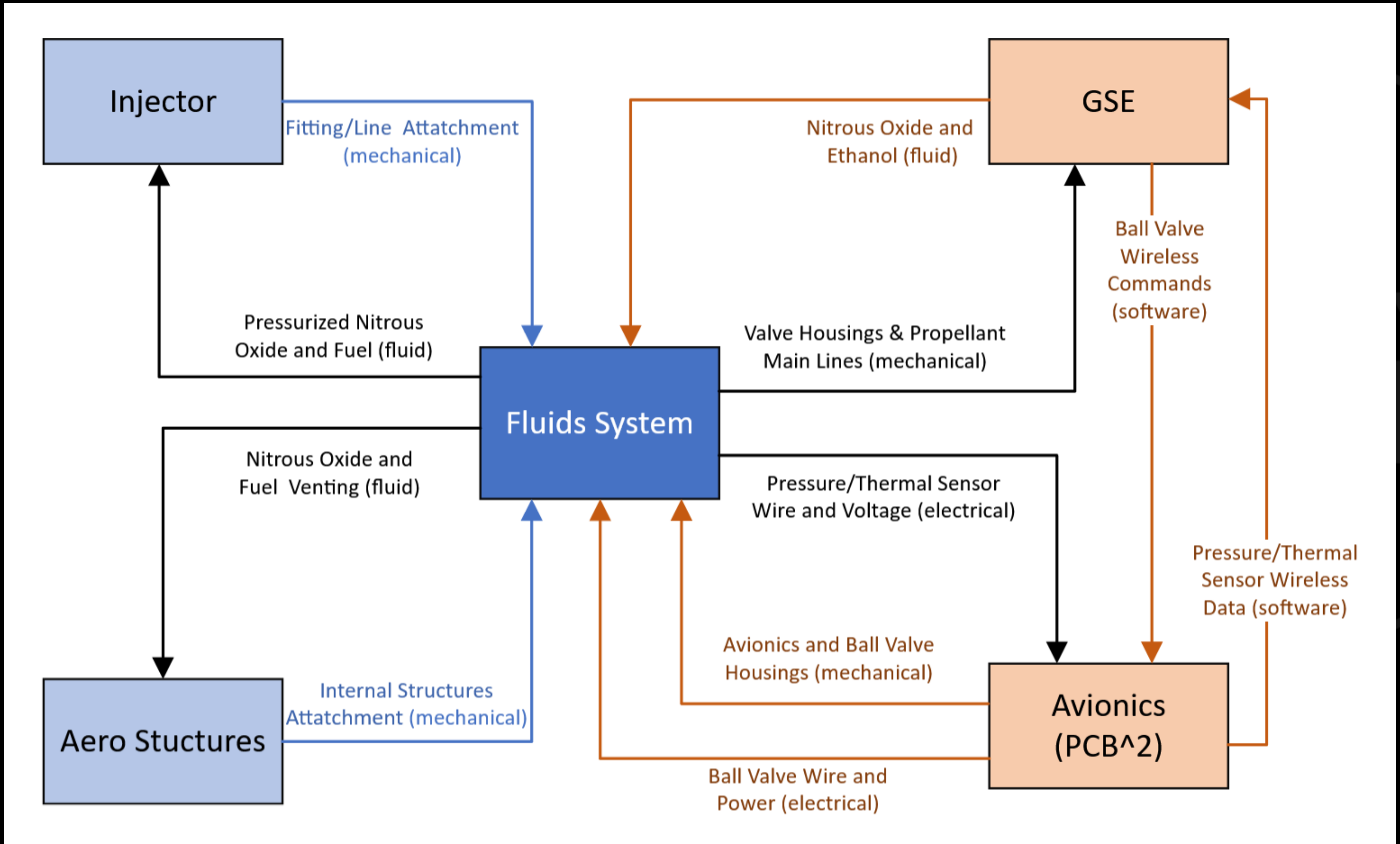
Fluids Requirements and TPMs

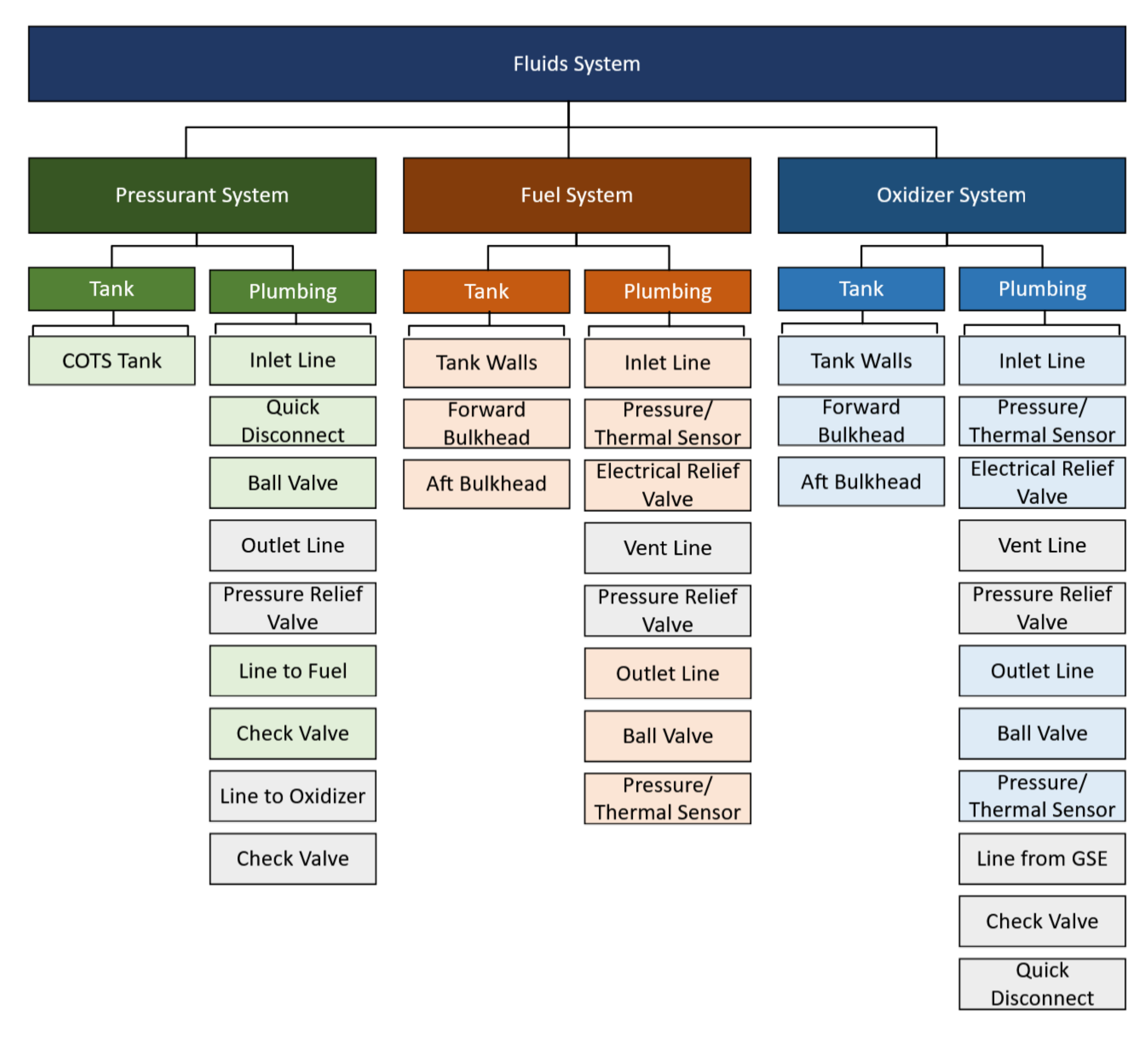
Functional Requirement	Verification Method
The Fluids Subsystem shall restrict/enable fluid flow throughout the propulsion system.	Demonstration
The Fluids Subsystem shall report Fuel tank pressure.	Demonstration
The Fluids Subsystem shall report Fuel tank fill volume.	Demonstration
The Fluids Subsystem shall report Oxidixer tank pressure.	Demonstration
The Fluids Subsystem shall report Oxidizer tank fill volume.	Demonstration
The Fluids Subsystem shall report Nitrogen tank pressure.	Demonstration
The Fluids Subsystem shall report Nitrogen tank fill volume.	Demonstration

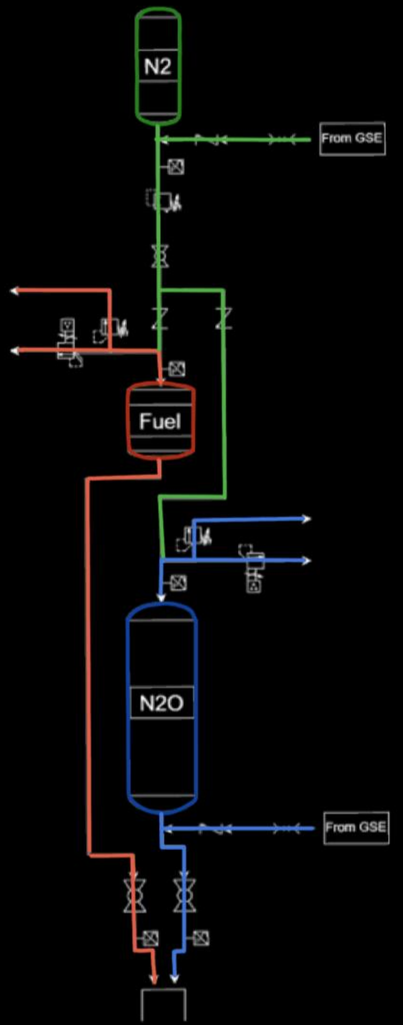
Operating Pressure	800	psi	Test
Total Delivered Propellant Mass Flow	2.5	lb/s	Test
Delivered Fuel Mass Flow	0.625	lb/s	Test
Delivered Oxidizer Mass Flow	1.875	lb/s	Test
Ethanol Weight	4.375	lb	Test
Nitrous Oxide Weight	13.125	lb	Test
Nitrogen Weight	1.4	lb	Test

Fluids Interface Diagram



Fluids Component Breakdown





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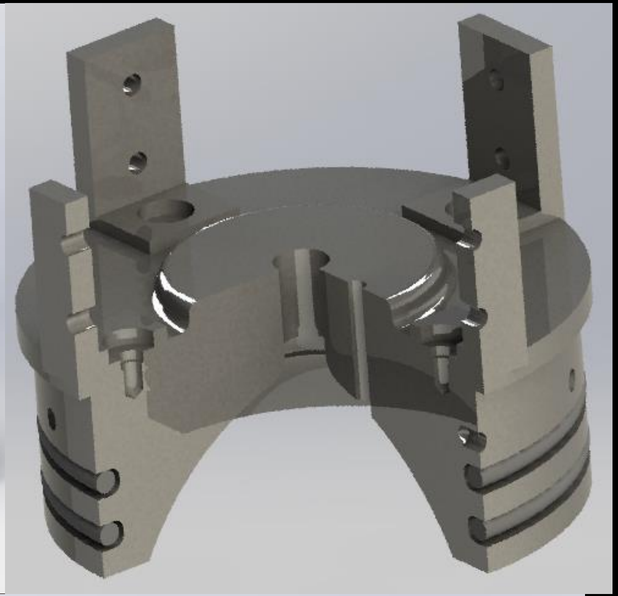
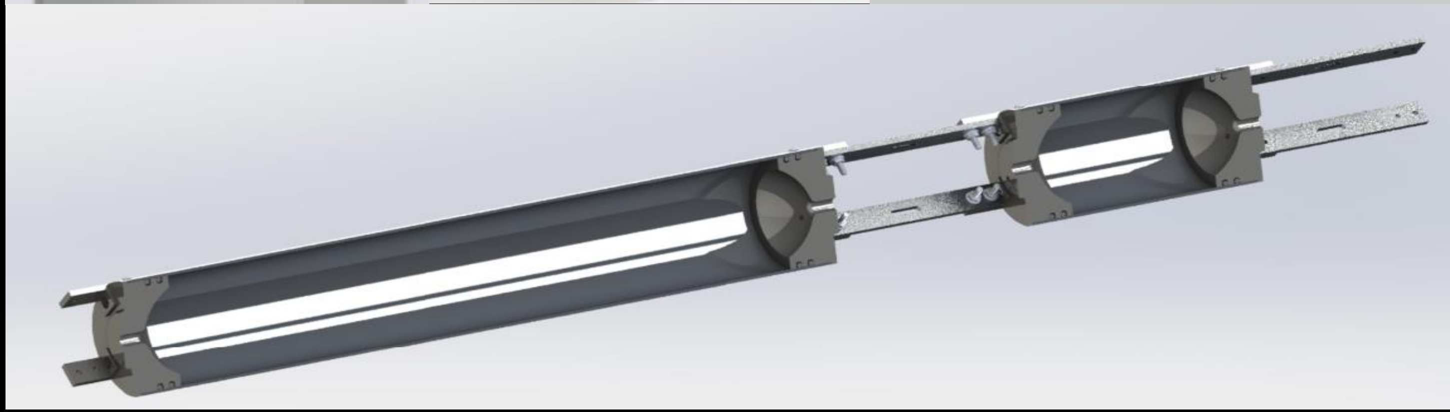
Propellant Tanks

Estimated components

- 4 struts per bulkhead
- 2 bulkheads per tank
- 2 tanks total

- Machined in-house (UCF Machine Shop)
- Stock Lead times: TBD
- O-ring Calculations: In-progress
- Estimated stock material costs:
  - Tank Rounds: $93.41
  - Bulkheads: $179.48
  - Total: $272.89





Propellant Tanks

- Utilized equations shown to calculate Force on Bulkhead, Bolt Shear, and No. of bolts required
- Assumed SF = 2
- 20% N_2O & 10% Ethanol tank volume dedicated to ullage (Required for pressure-fed system)
- MEOP 800 psi (CC 750psi MEOP + SF)
- Total Weight of Fuel and Oxidizer tanks subassemblies (Dry): ~20 ± 2lbs
- Stock material: 6061 Aluminum Alloy

Initial Conditions:	Value
Total Mass Flow (lb/s)	2.5
O/F	3
Burn Time (s)	7

Oxidizer	Value
Mass Flow (lb/s)	1.875
Mass (lb)	13.125
Volume (in^3)	482.502
Volume with Ullage	579.002
Height of Tank (in)	32.674

Fuel	Value
Mass Flow (lb/s)	0.625
Mass (lb)	4.375
Volume (in^3)	156.457
Volume with Ullage	172.103
Height of Tank (in)	9.712

Force of Bulkhead

$$F_{bulk} = \left(\frac{\pi}{4}(D_i)^2 \times MEOP\right)$$

Minimum Number of Bolts

$$n_{bolts} = \frac{F_{bulk}}{F_{bolt}^{max}}$$

Bolt Shear

$$\sigma_{bolt\ shear} = \frac{\left(\frac{\pi}{4}(D_i)^2 \times MEOP\right)}{\left(\frac{\pi}{4}(d_{bolt})^2 \times n\right)}$$

MEOP (psi)	Tank ID (in)	Tank wall thickness (in)	Target SF	Estimated Hoop Stress (psi)	Max Shear Stress of Aluminum (psi)	SF calculated
800	4.75	0.125	2	15200	30000	1.973684211

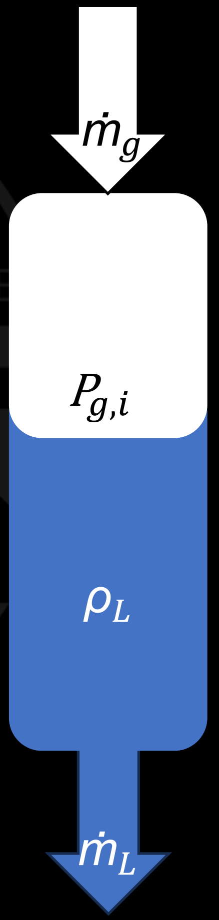
Ultimate Stress of Bolt (psi)	Max Bolt Force (LB)	Min # of bolts	Reccommended # of bolts	Bolt Shear (psi)	Safety Factor Bolt Shear
72000	3534.291735	4.011111111	10	28880	2

Sizing Nitrogen Tank

- Related the volumetric flow rates of the pressurant entering and the propellant leaving to derive this equation
  - $\dot{m}_g = \frac{\dot{m}_L P_{g,i}}{\rho_{L,i} R_g T_{g,i}}$
  - $m_g = \dot{m}_g * Burn\ Time$
  - $V_g = \frac{m_g R_g T_g}{P_g}$
  - Nitrogen tank operating = 3500 psi
  - Nitrogen tank volume > 0.622 Gallons
  - Still investigating how isentropic expansion and Joule-Thomson affects our nitrogen supply

Propellant	Tank Operating Pressure (psi)	Density of Propellant (lb/ft^3)	Specific Gas Constant (N2)	Nitrogen Temperature (K)
Ethanol	800	773.990	296.8	310
Nitrous Oxide	800	752.926	296.8	310

Propellant	Nitrogen Mass Flow Rate (lb/s)	Nitrogen Weight Required (lb)	Nitrogen Volume Required (Gallons)
Ethanol	0.048	0.339	0.152
Nitrous Oxide	0.149	1.045	0.470
Total	0.198	1.384	0.622



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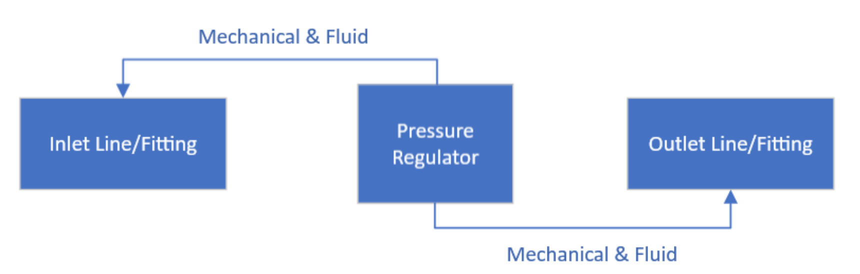
Nitrogen Tank

- Aluminum tank overlayed with carbon fiber
- Commercial off the Shelf (COTS)
- Cost of $191.53
- Total Volume of 3.0 L ~ 0.8 Gallons
- Weight of 2.1kg ~ 4.6 lb
- 4500 psi Maximum Operating Pressure
- Straight Port with M18*1.5
- Clamping bulkhead system for propulsion system interface
- Nitrogen is easier to obtain than helium

Pressure Regulator

- Spring-loaded high-flow pressure regulator
- Debris or freeze up could cause leakage
- Must be mounted vertically due to length being longer than internal chassis diameter
- Cost: $655
- Rated to – 60 F
- Cv 0.8
- Weight 2.75 lb Length: 6.5 in Diameter: 3 in
- Inlet Pressure: 3500 psi Outlet Pressure: 800 psi
- Inlet NPT fitting of ¼ " Outlet NPT fitting of ½ "

Functional and Performance Requirements	Verification Methods
Regulator shall create an inlet pressure of 3,500 psi	Analysis
Regulator shall create an outlet pressure of 800 psi	Analysis
Regulator shall be able to withstand a temperature of -60F	Demonstration
Coefficient of flow shall be 0.8	Analysis
Seal material shall be able to withstand -60 degrees Fahrenheit	Analysis
Regulator shall handle a mass flow rate of .22 lb/s of nitrogen	Analysis




Aqua Environment 873

Nitrogen Tank Valve/Check Valves

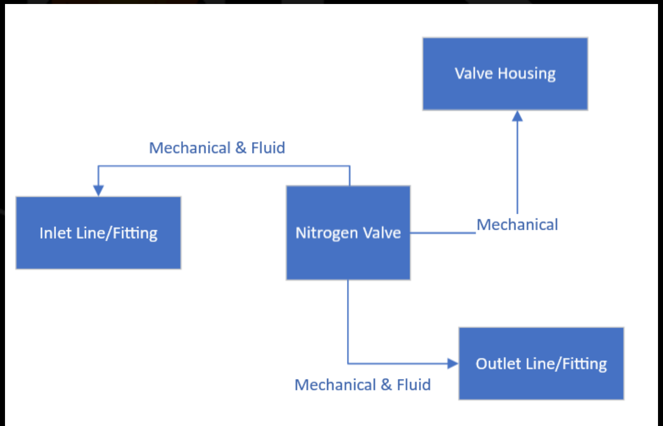
- **Nitrogen Tank Valve**
  - Servo-actuated ball valve after pressure regulator
  - Chose servo-actuated due to lower risk and cost factors
  - Cost: ~$120-$150
  - Fitting size: 1/4"

- **Nitrogen Check Valves**
  - 3x check valves: one for each propellant feed line to prevent upstream propellant mixing and one for filling
  - Still in talks with various suppliers for check valves
  - NPT fitting of 1/4"

Generant

Check valve

Ball Valve



KXR UCF

RE Brad Potier (Sorry I can't be here)

Fuel and Oxidizer Main/Check Valve

- **Progress** Given specified orifice diameters from the fitting's component group selected configurable ball valves and Check valves that minimized pressure drop. Decided on Servo actuated ball valves as last year system found it reliable
- **To Do** Make Servo ball valve interface assemblies and size the servos to actuate the valves
- **Cost** 32$ for servos and 330$ valves

line	Valve type	Valve Description	CV	Delta P (Pa)	Delta P (Psi)	link
Ethanol	Check valve	Inline Yor lok fitting 1/4" Tubing	0.75	1.81876E-07	2.63789E-11	Mcmaster
NOX	Check valve	Inline Yor lok fitting 1/2" Tubing	3.3	8.84906E-08	1.28345E-11	Mcmaster
Ethanol	Ball valve	lockable lever 1/4" tubing	1.3	6.05356E-08	8.77996E-12	Mcmaster
NOX	Ball valve	lockable lever 1/2" tubing	9.3	1.11419E-08	1.616E-12	Mcmaster
Ethanol	Check valve	Poppet 1/4" tubing	0.47	4.63129E-07	6.71713E-11	Swage
NOX	Check valve	Poppet 1/2" tubing	1.68	3.41434E-07	4.95209E-11	Swage
Ethanol	Ball valve	3 piece lever 1/4" Tubing	1.2	7.10452E-08	1.03043E-11	Swage
NOX	Ball valve	3 piece lever 3/8" Tubing	7.5	1.71318E-08	2.48476E-12	Swage

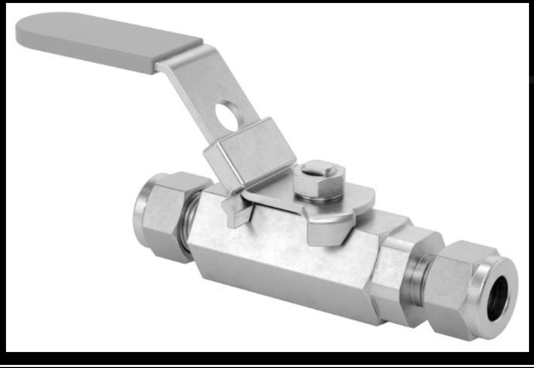
$$\Delta P = G \cdot \frac{Q_l^2}{C_V^2}$$

Fuel

Mdot(kg/s)	rho(kg/m^3)	SG
0.283	785.2	0.787563

Oxidizer

Mdot(kg/s)	rho(kg/m^3)	SG
0.85	752	0.754263



Mcmaster Compression fitting Stainless Steel ball valve MOP 2000 PSI

Mcmaster Compression fitting Brass check valve MOP 3000 & 2200 psi (¼ & ½")

Servos

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Relief Valves

For Each Propellant Tank:

- 1 x Active Relief Valve (Primary)
  - $88.00
  - 0.125 in orifice, 1/8”
  - Allows controlled venting
  - Allows venting to atmospheric
- 1 x Passive Relief Valve (Redundant)
  - $79.58
  - 0.11 in orifice, 1/4”
  - Allows tanks to vent without additional control

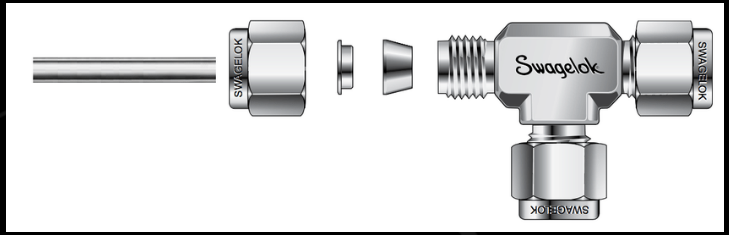
Relief calculations still in progress

Aqua 1607 Relief Valve
Passive

Swagelok B-41S2 Ball Valve
Active

Feedlines & Fittings

- Fittings
  - Mostly compression fittings for ease of assembly
  - NPT used on some components
  - Cost ~ $400



- Feedlines
  - $\frac{1}{4}$" for pressure and relief system
  - $\frac{1}{2}$" for oxidizer feedline
  - $\frac{1}{4}$" for fuel feedline

mass flow (lb/s)	gamma	Pressure (psi)	R	kelvin	Diameter (in)
0.139	1.4	800	191.609	310	0.005401
0.139	1.4	4000	191.609	310	0.05

mass flow (lb/s)	gamma	tempature (kelvin)	pressure (psi)	R J/(kg(k))	diameter	Columr
1.8748	1.31	310	800	188.91	0.3750	0

$$\dot{m} = \rho v A$$

$$\dot{m} = \frac{A p_t}{\sqrt{T_t}} \sqrt{\frac{\gamma}{R}} M \left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{\gamma+1}{2(\gamma-1)}}$$

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Internal Structures

- **Expected max. compressive force of about 1650lbs** and **max. snatch force of 679lbs (SFs of 1.5):**
  - **Mitigate Forces on Pressure Vessels**
    - Bulkheads are joined by vertical inter-tank struts.
    - **Inter-tank struts contain a slot for a sliding interface with chassis struts.**
    - **As a result of this design: expect most forces to act upon the thrust plate assembly.**

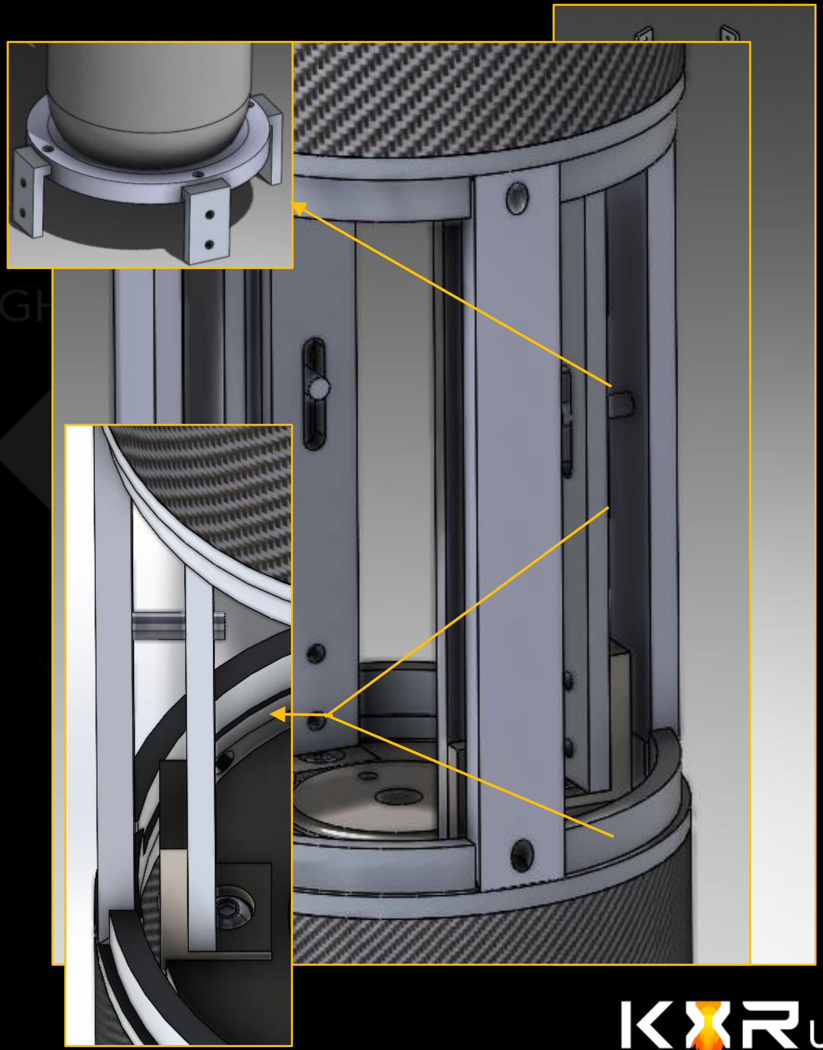
- **With considerations toward static-fire testing and maintenance:**
  - Couplers for airframe are to be jointed halves.
  - Sliding interfaces within struts can be used in test stand.

- Knitro's unique fastening interface:
  - Disc-tank faces filleted, identical l-brackets as bulkhead
  - Expected Cost of 4 L-brackets and 0.3in thick 6061-T6 discs (machined in-house): \$16.49+142.92; **\$159.41**

- **Estimated Cost of Propulsion's Internal Structures: \$305.28**

  (Sum of Propellant tank structural components and Knitro's structural component costs.)

  (12 Struts, 12 L Brackets, 2 discs)



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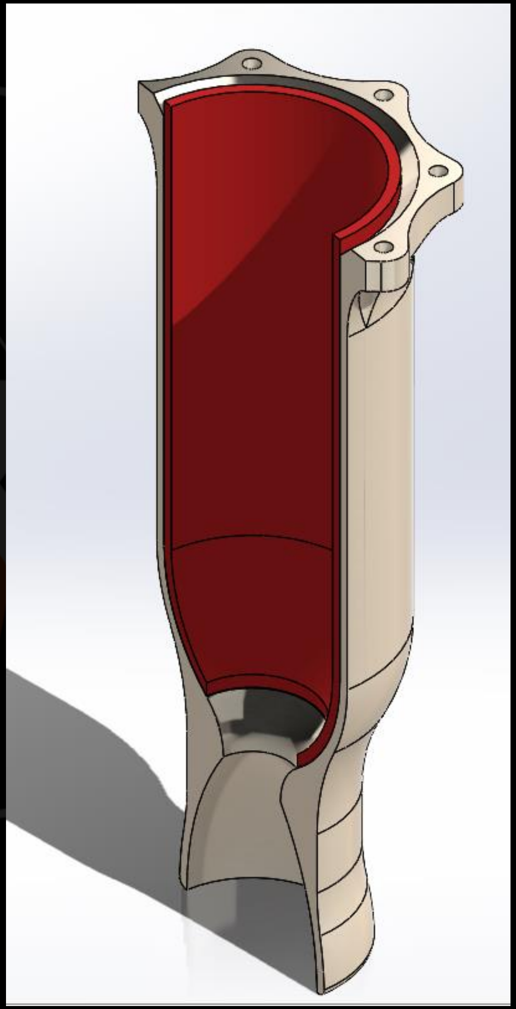
Fluid Systems Manufacturing

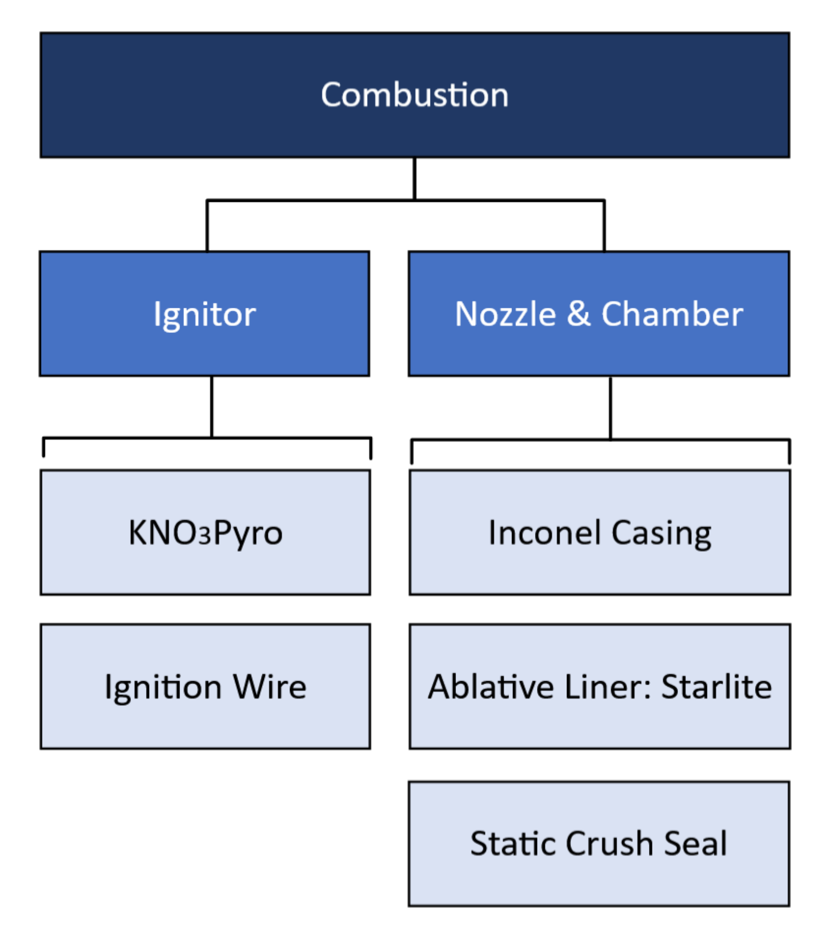
- Bulkheads
  - Machined entirely out of billet aluminum 6061-T6
  - Helicoils for threads
- Tank Walls
  - Prebought aluminum 6061-T6 tube stock
    - May need to turn ends depending on tube stocks "roundness"
  - Drill holes for bulkheads to bolt to
- Feed Lines
  - Lines will be bent by our team
  - Swagelok fittings and flares will be done by our team

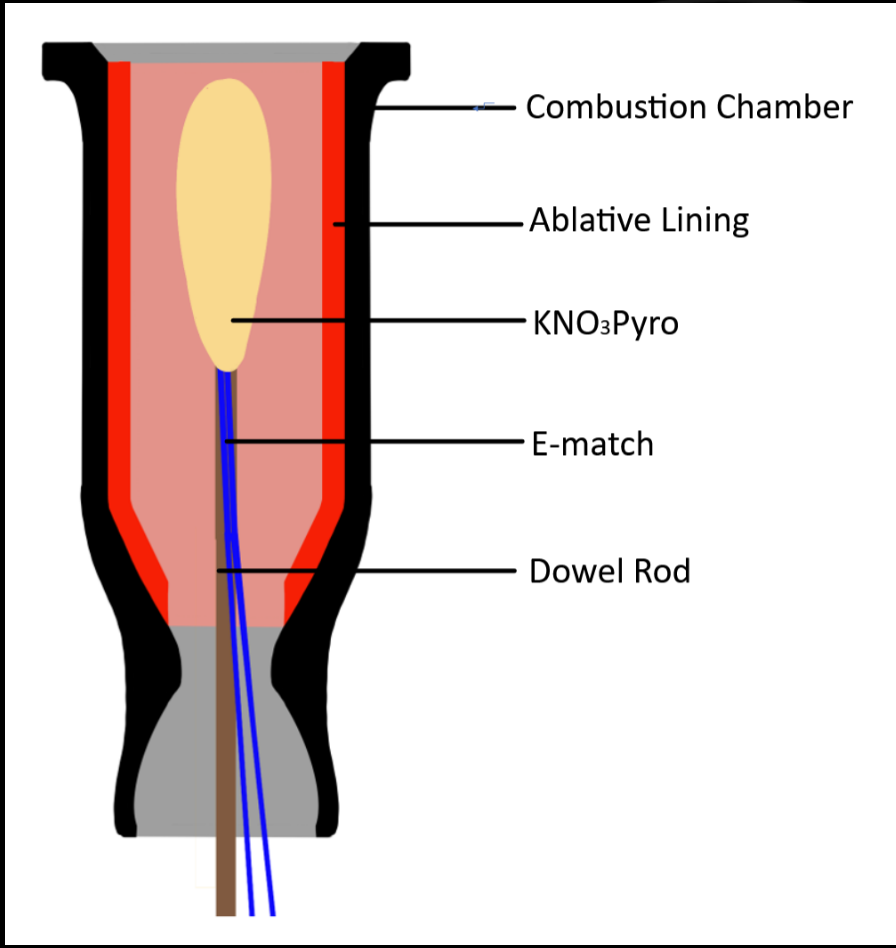
Combustion Subsystem

- Single piece combustion chamber and nozzle
- Ablative liner
- Chamber Pressure: 500 psi
- O/F Ratio: 3
- Total Mass Flow Rate: 2.5 lbm/s
- Expansion Ratio: 5.28
  - Assumed ambient condition of 13 psi



Combustion Component Breakdown



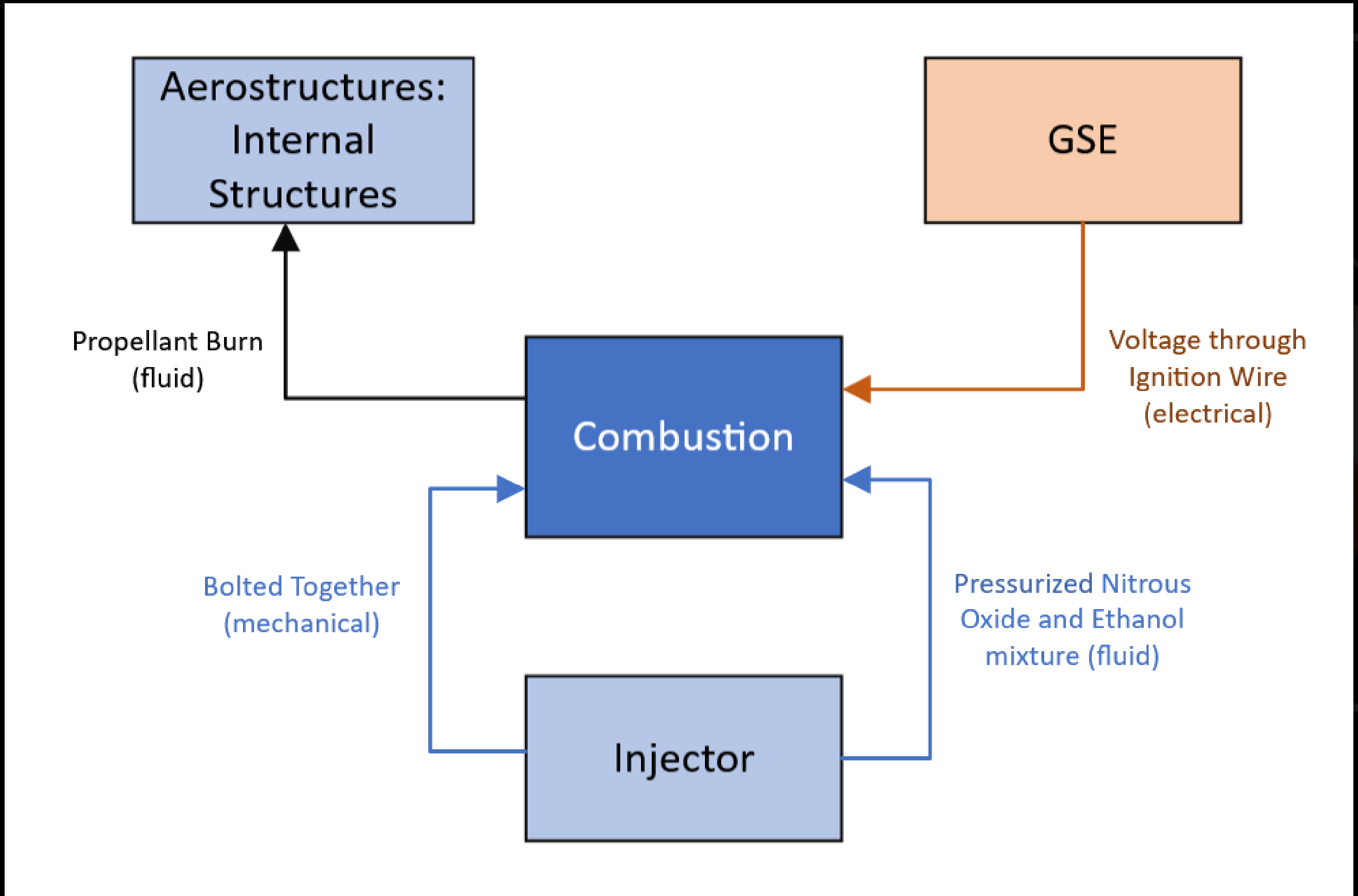


Combustion System Requirements

Functional Requirement	Verification Method
The Combustion Subsystem shall ignite the propellants.	Demonstration
The Combustion chamber shall withstand ignition temperatures.	Demonstration
The Combustion chamber shall withstand burn temperatures.	Demonstration
The Combustion chamber shall withstand burn pressure.	Analysis
The Combustion chamber shall seal all pressure.	Demonstration

Technical Performance Measure	Value	Units	Verification Method
Maximum Chamber Pressure	500	psi	Analysis & Test
Maximum Chamber Temperature	2600	K	Analysis
Burn Time	7	sec	Test

Combustion Interface Diagram



Combustion Chamber and Nozzle

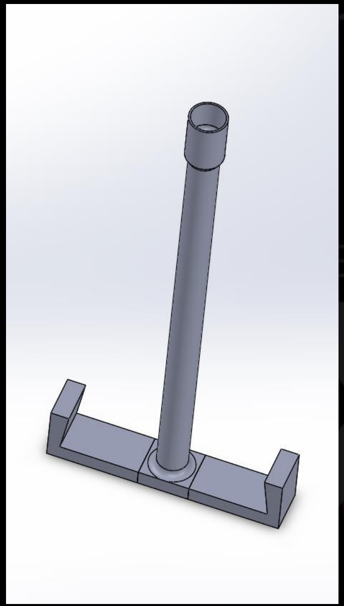
- Initial values found with CEA
- Design verified with RPA

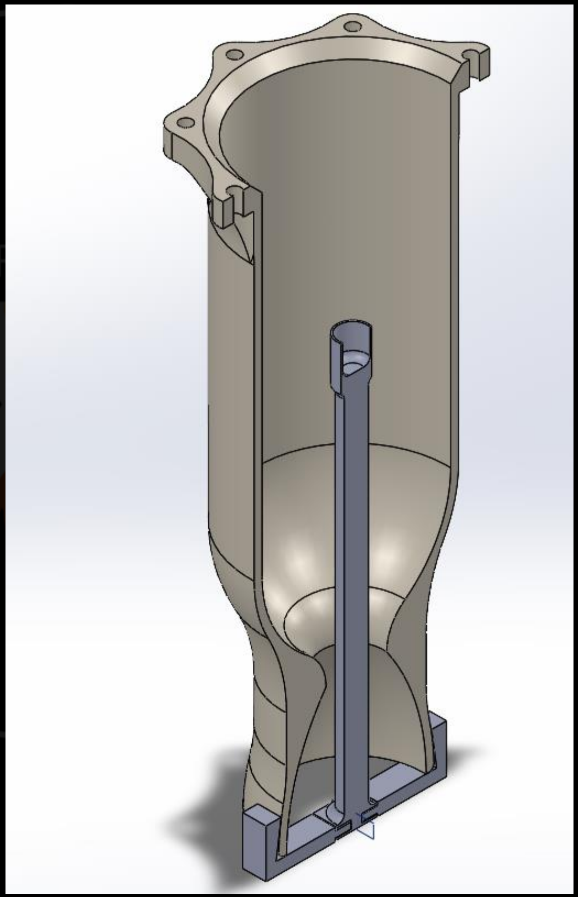
- Estimated Specific Impulse
  - 212 seconds
- Estimated Thrust
  - 531 lbf peak
- 1/8" chamber wall thickness
- 9.5" overall length

```
Thrust and mass flow rates
-------------------------------------------
   Chamber thrust (opt):  531.46974    lbf
 Specific impulse (vac):  233.23215      s
   Chamber thrust (vac):  583.08037    lbf
 Specific impulse (opt):  212.58789      s
   Total mass flow rate:    2.50000  lbm/s
Oxidizer mass flow rate:    1.87500  lbm/s
    Fuel mass flow rate:    0.62500  lbm/s

Geometry of thrust chamber with parabolic nozzle
-------------------------------------------
    Dc =    3.00  in       b =   40.00 deg
    R2 =    1.81  in      R1 =    0.72  in
    L* =   58.00  in
    Lc =    6.96  in    Lcyl =    4.83  in
    Dt =    0.97  in
    Rn =    0.18  in      Tn =   19.38 deg
    Le =    2.00  in      Te =   15.28 deg
    De =    2.22  in
 Ae/At =    5.28
 Le/Dt =    2.07
Le/c15  =   84.71 % (relative to length of cone nozzle with Te=15 deg)

  Mass =  -13.44 lbm

  Divergence efficiency:    0.98852
        Drag efficiency:    0.96478
     Thrust coefficient:    1.59416  (vac)
```

Rocket Ignition

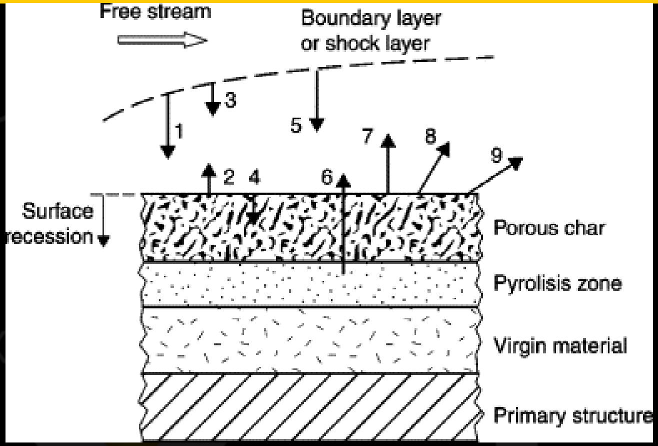
- Ignitor (2 Part System)
  - Rocket Candy
    - 65% Potassium Nitrate (oxidizer)
    - 35% Sugar (fuel)
  - 9v Initiator (e-match)
    - 3 for Redundancy
- Why this combination?
  - Lowest Production Cost (est. $3.45 per batch)
  - Relatively Safe and Reliable
- Risk of blowout before ignition





Ablative Liner

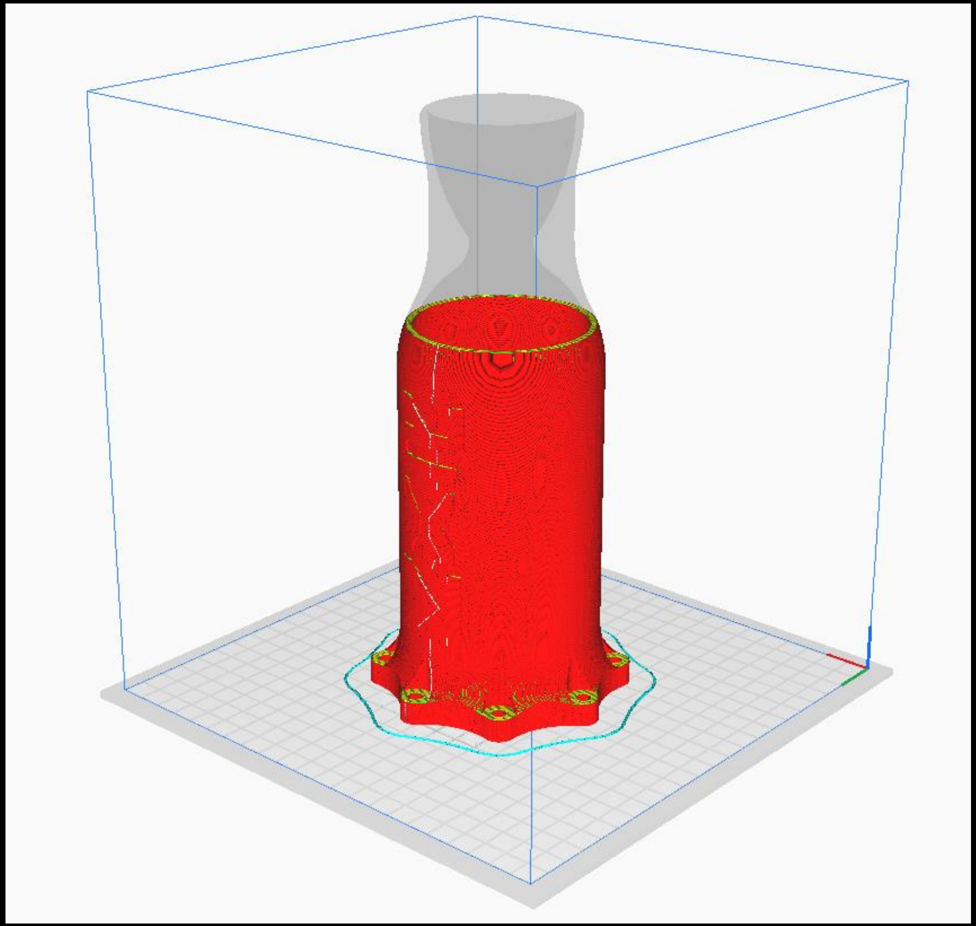
- Peak chamber temperatures of 2600K
- Minimal thickness to prevent chamber wall erosion over engine lifetime (1/8")
- Starlite
  - Great insulation and heat dispersion
  - Ease of manufacturing (cornstarch, flour, sugar, baking soda, borax)
- Phenolic Garolite (RCS liner) shall be used if Starlite deemed impractical
- Tapered up until the engine throat



Hot Side: 823 K = 1022 F
Cold Side: 329 K = 133 F

Combustion Manufacturing

- Combustion Chamber
  - DMLS Inconel 718
  - Printed axially for ease of post machining
  - Post machining needed for internal geometries
- Ablative Liner
  - SRAD mold for Starlite
    - 3D Printed ABS filament
  - Needs to be dried for rigidity



Preliminary combustion chamber cad in Cura slicer to show print orientation

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Injector Subsystem

- Pintle Injector
  - Chosen over impinging due to performance predictability and ease of manufacturing
  - Discrete radial elements, continuous axial element
- Stacked plate design to interface with combustion chamber flange
- Estimated 750 psi inlet pressure from propellant tanks

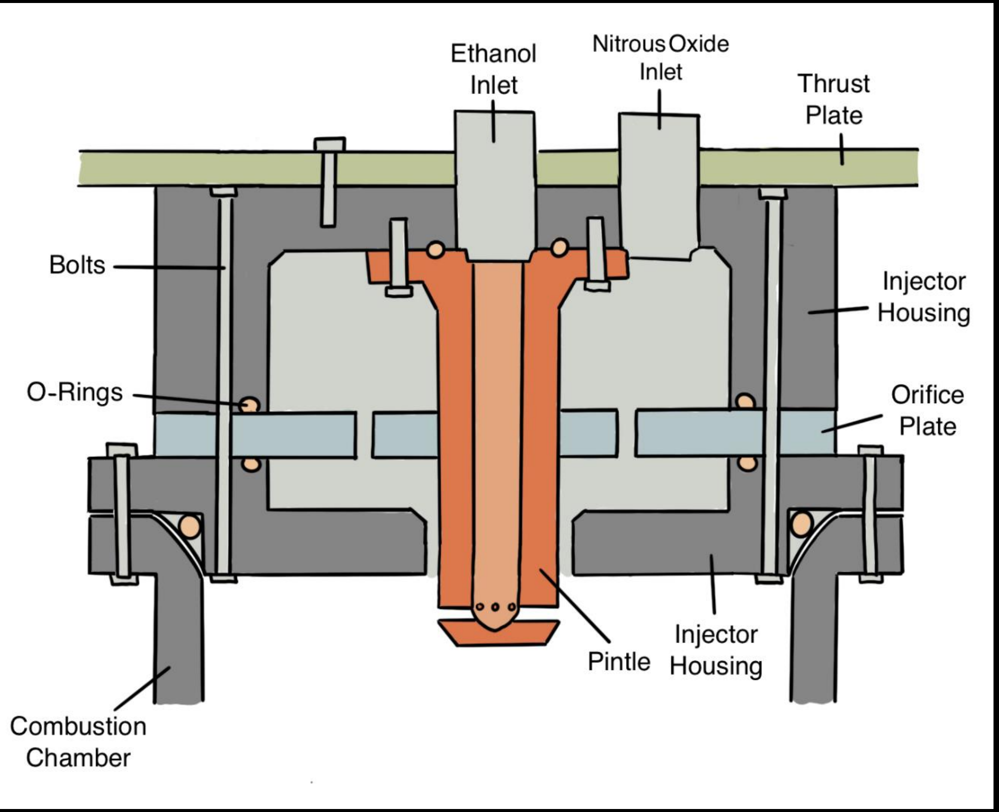
Injector Requirements and TPMs

Requirement	Verification Method
The Injector shall be able to withstand ignition temperatures.	Test
The Injector shall be able to withstand burn temperatures.	Test
The Injector should be able to produce a combustion efficiency (C*) of at least 90 to 95%.	Analysis
The Injector should maintain an equivalence ratio of 3:1.	Analysis
The Injector shall be able to withstand pressurization stress.	Test

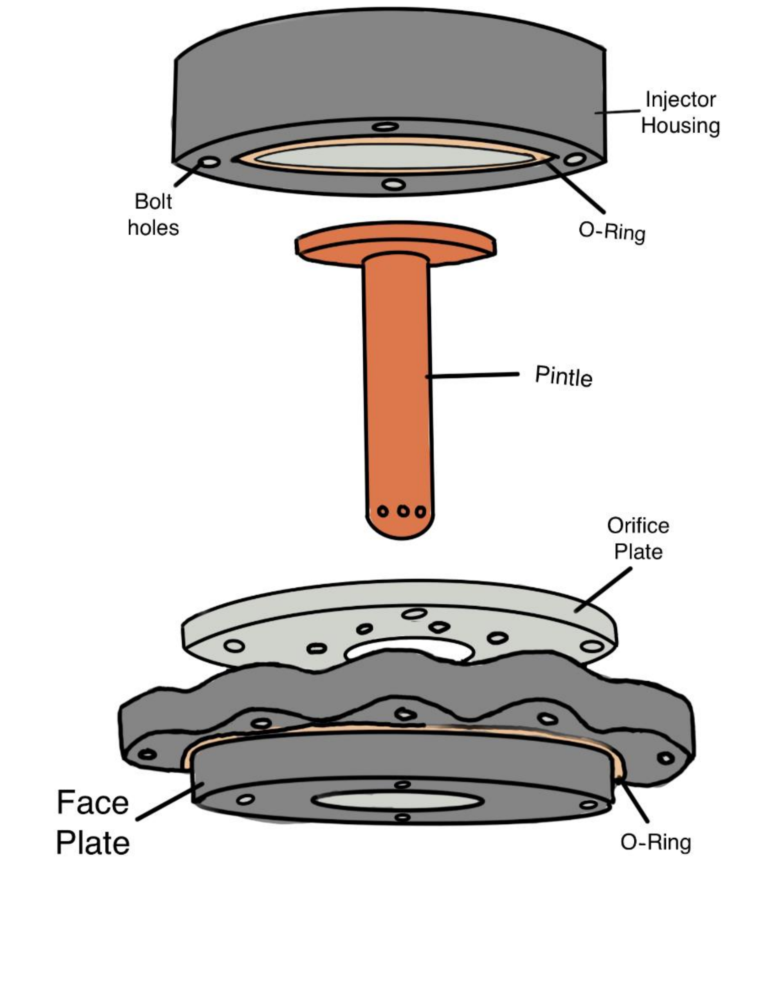
Technical Performance Measure	Value	Units	Verification Method
Maximum Ignition Temperature	2600	K	Analysis
Ethanol Mass Flow Rate	0.625	lb/s	Test
Nitrous Oxide Mass Flow Rate	1.875	lb/s	Test
Minimum Pressure Drop from Inlet and Combustion Chamber	20	%	Test
Maximum Stress from Pressurization	7500	psi	Analysis

UCF

Injector Component Breakdown



- Injector
  - Pintle
  - Injector Housing
  - Orifice Plate
  - Face Plate



Injector – Fluid Design

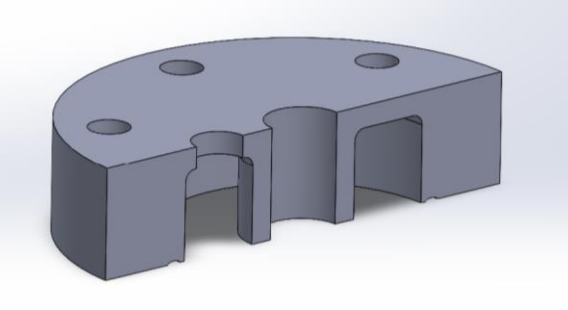
- Radial (discrete) fuel orifices
  - 8 x 0.047” diameter
- Axial (continuous) oxidizer orifice
  - 1 x 0.546” diameter
  - 0.5” pintle OD
- Cd values and nitrous density are unpredictable
- Pintle geometry may change to achieve a higher blockage factor
- Minimum expected combustion efficiency of 90% C*

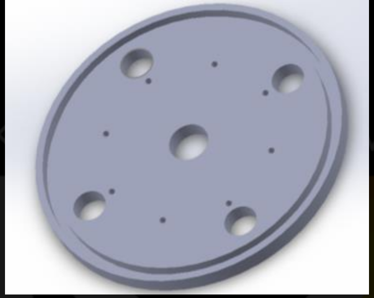
Radial Sizing (solve for diameter)	Value
mdot (lbm/s)	0.625
rho (lb/ft^3)	48.4
inlet pressure (psi)	750
Δp (psi)	250
Δp (lb/ft^2)	36000
Cd	0.65
number of orifices	8
total orifice area (in^2)	0.013071105
orifice diameter (in)	0.045610645
orifice diameter (1/64 of an in)	2.919081253
V (ft/s)	142.2606733

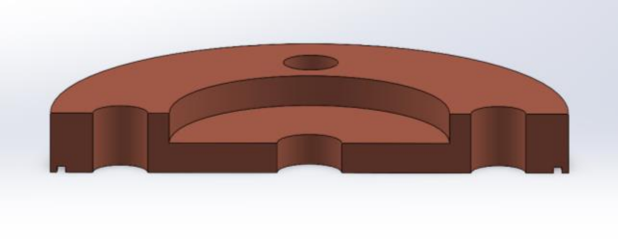
Axial Sizing (solve for diameter)	Value
mdot (lbm/s)	1.875
rho (lb/ft^3)	44
pintle diameter (in)	0.5
inlet pressure (psi)	750
Δp (psi)	250
Cd (estimated)	0.7
total orifice area (in^2)	0.038189608
orifice diameter (in)	0.546465479
V (ft/s)	160.6815032
total momentum ratio	0.295119373
blockage factor	0.232293105
spray Angle (deg, from vertical)	39.45448811

Housing, Orifice Plate, and Face Plate

- Injector Housing
  - Design Considerations: Annulus Volume, Wall Thickness, Pressure Transducer, Flange Bolt Integration, Inlet Valve
  - Points of Failure: Wall Thickness, Seals
- Orifice Plate
  - Design Considerations: Plate Thickness, Orifice Diameter
  - Depressurizes to better control spray angle, distributes Oxidizer evenly
- Face Plate
  - Design Considerations: Plate thickness, Orifice Diameter
  - Points of Failure: Seals, Section facing combustion chamber.
  - Directs flow towards the central orifice where it enters the combustion chamber







Technical Specifications	Measure	Verification
Injector Outer Diameter	4.25 inches	Inspection
Oxidizer Orifice Diameter	0.532''	Inspection
Face Plate Thickness (Thinnest)	0.25''	Inspection
Orifice Plate Thickness (Thinnest)	0.25''	Inspection

Requirements	Verification
Injector Housing shall intake 750 psi of oxidizer and evenly distribute it through an annulus	Test
Injector housing shall minimize head loss	Test
Orifice plate shall depressurize 250 psi and evenly distribute oxidizer	Test

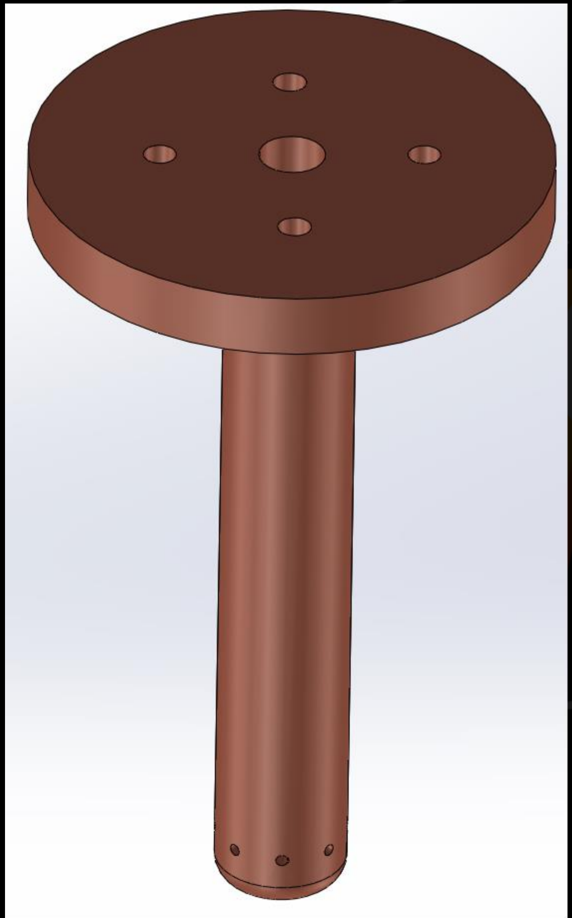
KXR UCF

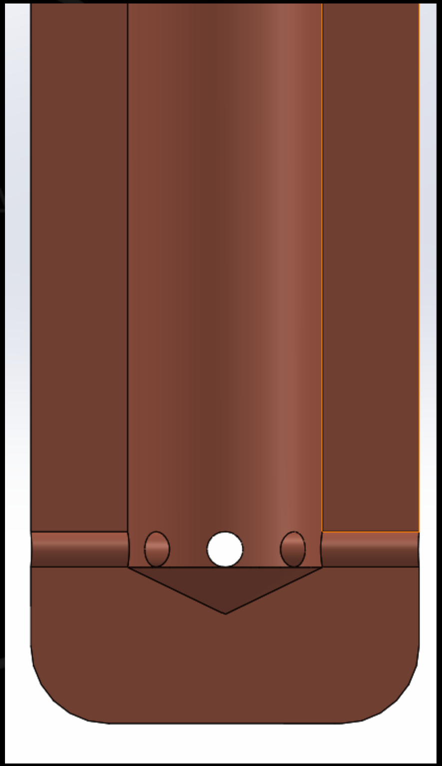
Pintle

- Pintle
  - Fuel cavity depth maximized to achieve pintle tip cooling
- Design Considerations
  - Thermal Load and Threading

Requirement	Verification
The Pintle Tip shall be able to withstand temperatures of 2600 K for 7 seconds	Test
The Pintle Body shall achieve a 0.625lbs mass flow for the fuel.	Analysis

Technical Specifications	Measure	Verification
Pintle Outer Diameter	0.5 Inches	Inspection
Pintle Inner Diameter	0.25 Inches	Inspection
Orifice Diameter	3/64 Inch	Inspection
Number of Orifices	8	Inspection

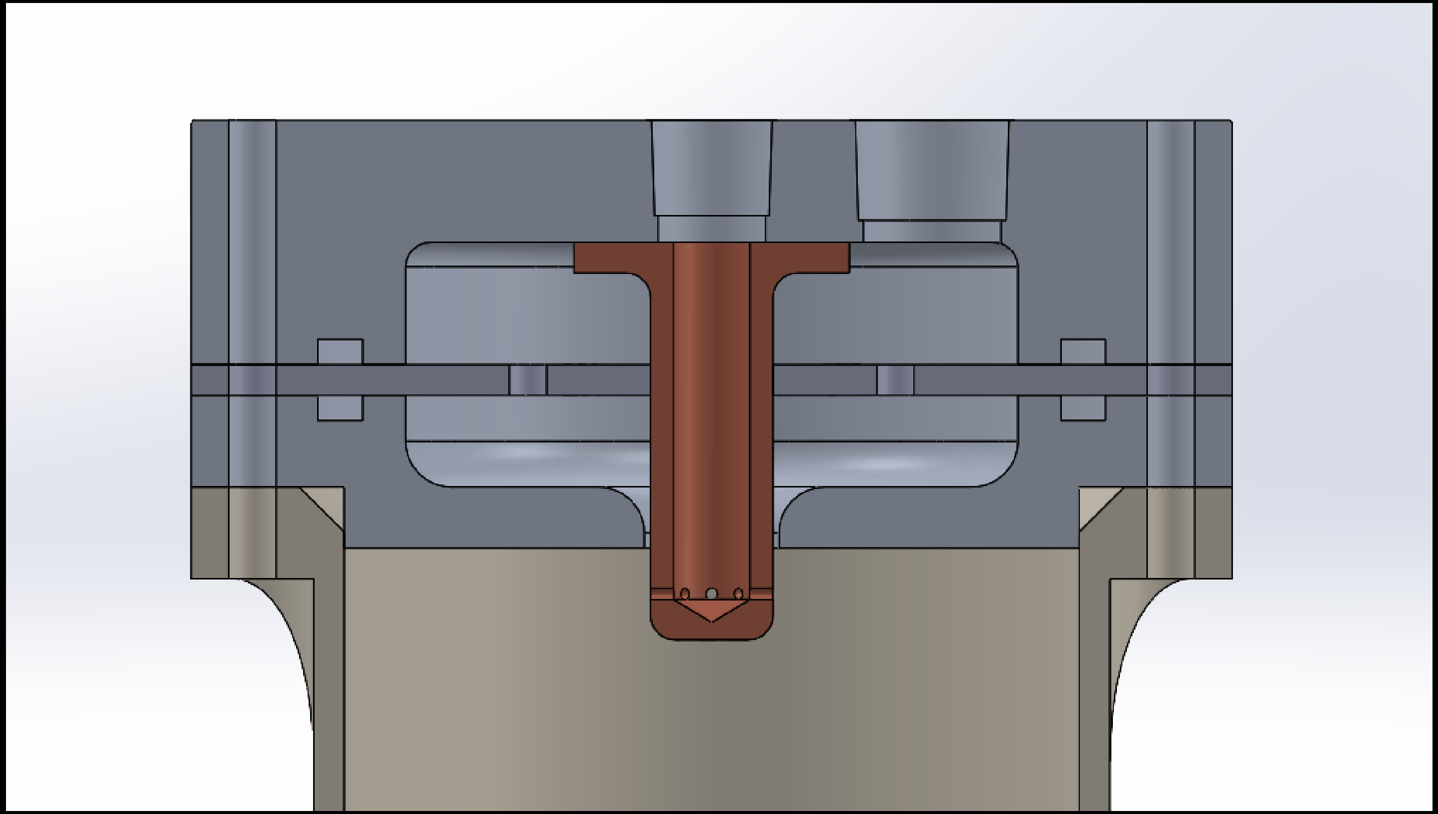




KXR UCF

Injector Manufacturing

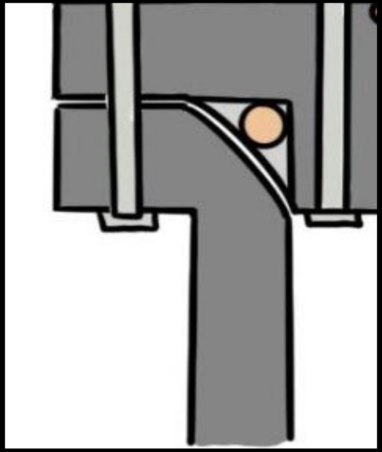
- Injector body
  - Aluminum 6061-T6
- Pintle
  - Copper
- Orifice Plate
  - 0.25" aluminum 6061-T6 sheet metal
  - Laser cut and post machined if needed
- Face plate
  - Copper or Aluminum

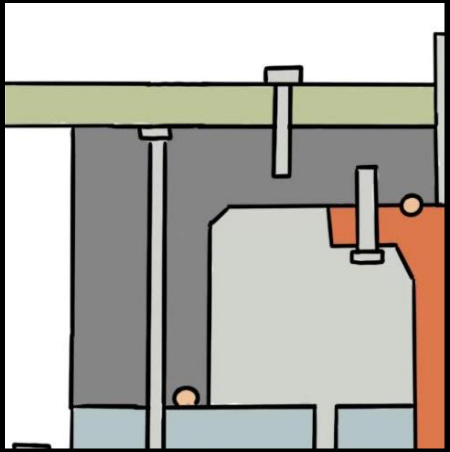


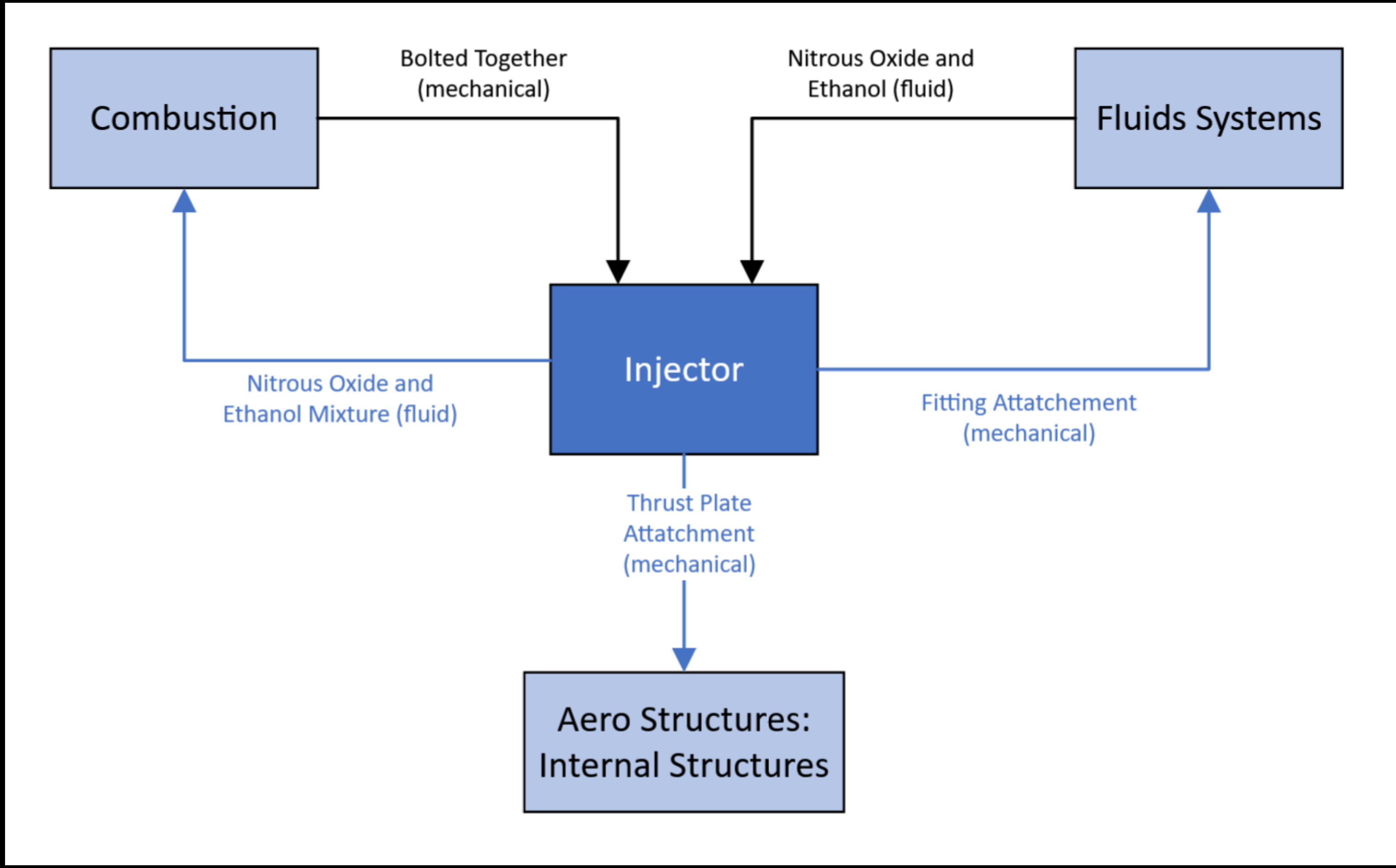
Integration Plan

Combustion Integration: nitrile crush glands will fit into combustion chamber chamfers, pressure sealing the chamber and injector.

Aerostructures Integration: bolts will attach the injector housing to the thrust plate.







Propulsion System Questions?