PDR Presentation

Stony Brook University

NASA USLI 2019-2020

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SHAPING THE FUTURE OF AEROSPACE

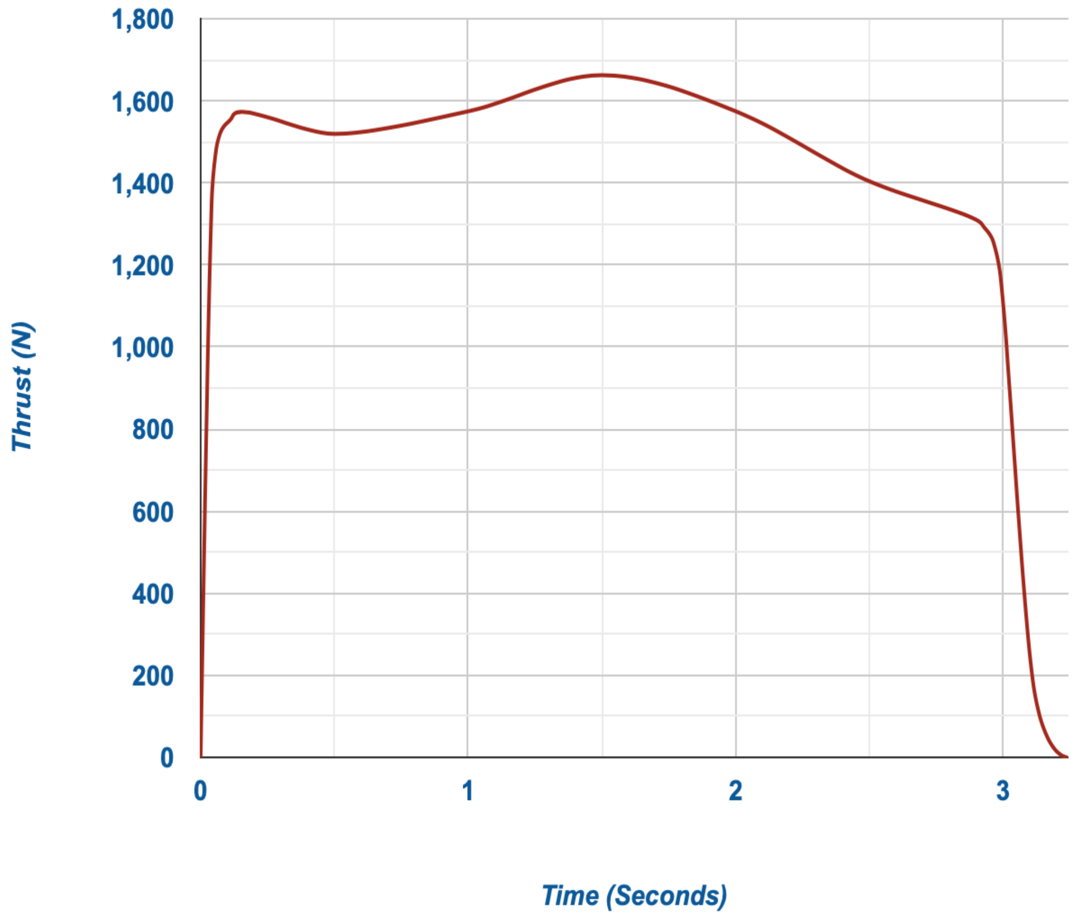
Agenda

i. **Launch Vehicle Design & Mission Performance Predictions**
ii. Launch Vehicle Trade Studies
iii. Launch Vehicle Subsystems
iv. Recovery Subsystem
v. Payload Design
vi. Requirements Compliance Plan

Launch Vehicle Design

Total Length (in)	Diameter (in)	Lift Off Weight (lb)	Airframe Material	Fin Material & Thickness	Coupler Lengths
104.6	6.17	49.3	G12 Fiberglass	3/16 (G10 Fiberglass)	6

Launch Vehicle Design: Motor Properties

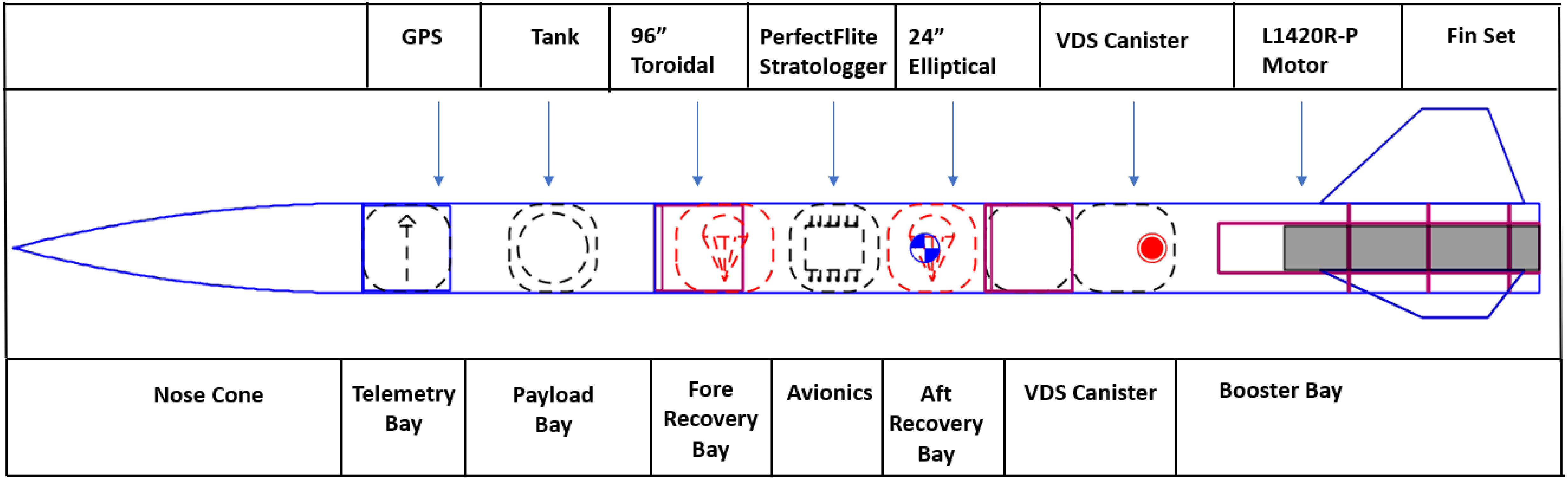


Motor Properties	
Brand	Aerotech L1420R-P
Max/Average Thrust	407.8/319.9
Total Impulse	1035
Mass Before/After Burn	10.05/4.47
Motor Retention Method	Screw On Retainer (Aeropack)

Launch Vehicle Design: Motor Comparison

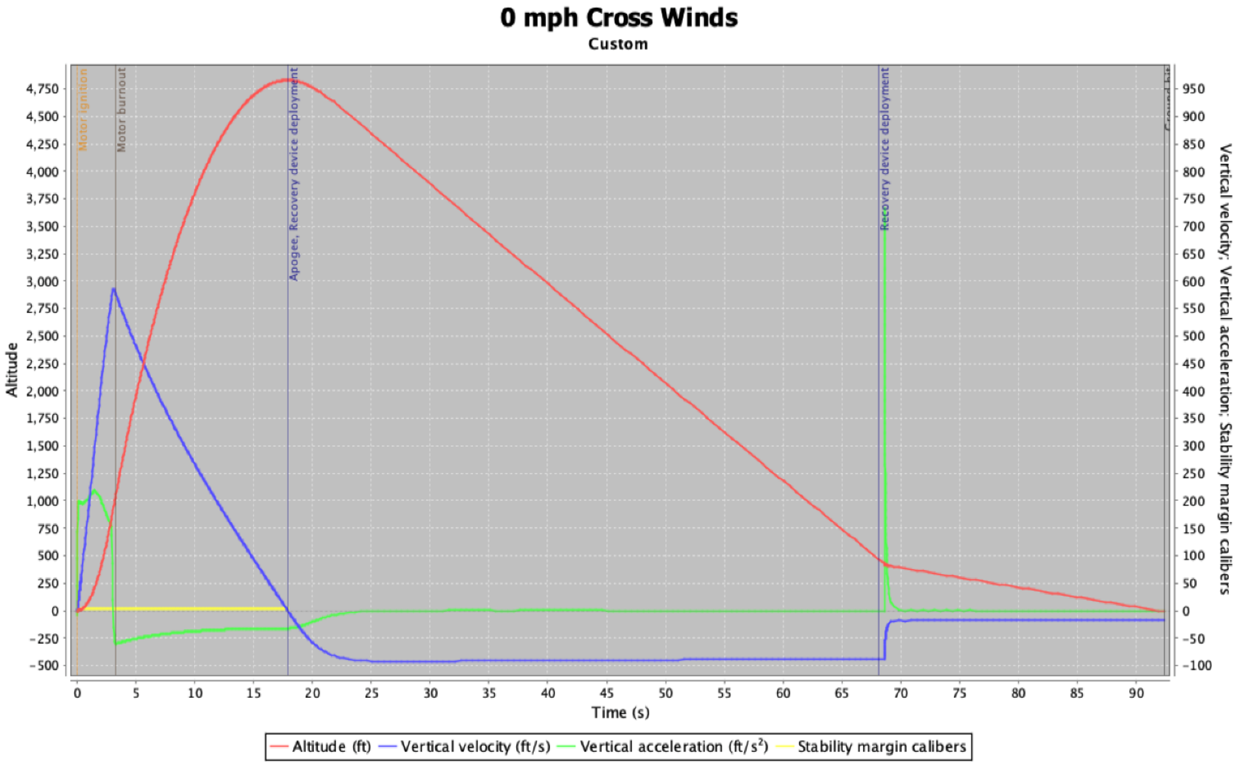
Motor	Manufacturer	Apogee (ft)	Max Velocity (ft/s)	Max Acceleration (ft/s^2)
L850W	Aerotech	3449	432	152
L1500T-P	Aerotech	3710	502	360
L1520T-P	Aerotech	3812	514	233
L1420R-P	Aerotech	4824	585	218
L1365M-P	Aerotech	4979	586	205
L2375-WT	CTI	5474	679	368
L2200G	Aerotech	5653	675	433

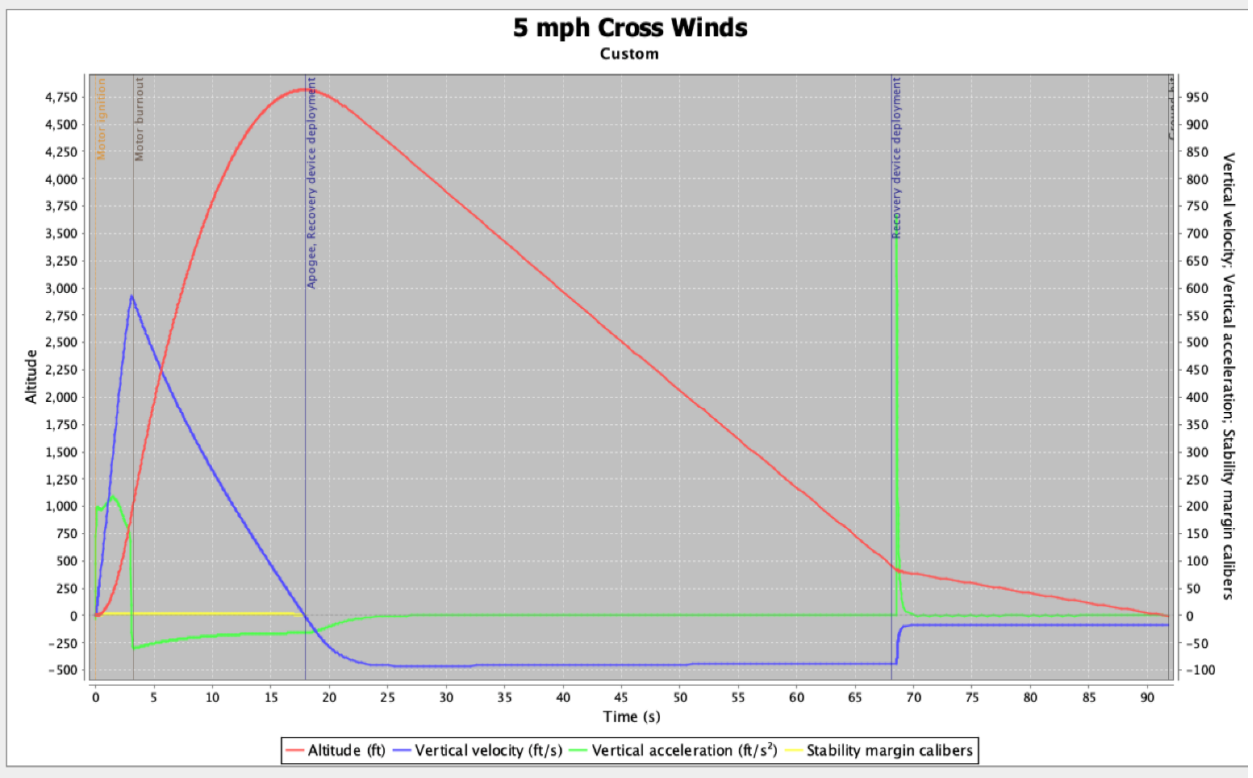
Launch Vehicle Design: Stability Analysis



CP (in from nose)	CG (in from nose)	Static Stability Margin (on pad)	Static Stability Margin (at rail exit)	Thrust-To-Weight Ratio	Rail Exit Velocity (ft/s)
78.073	62.497	2.52	2.625	6.49	58.7

Launch Vehicle Design: Ascent Analysis





Max Velocity (ft/s)	Max Mach Number	Max Acceleration (ft/s^2)	Target Apogee (ft)	Projected Apogee (ft)
585	0.53	218	4500	4824

Launch Vehicle Design: Airframe Size & Weights

Vehicle Component	Weight (lb)
Nose Cone and Telemetry Bay	5.26
Payload Bay	11.6
Avionics Bay	9.92
Booster Bay (Unloaded)	12.4
Total Vehicle (Unloaded)	39.2
Total Vehicle (Loaded)	49.3

Airframe Component	Length (inches)
Nose Cone	24
Payload Bay	20 (without coupler)
Avionics Bay	28.6
Booster Bay	32 (without coupler)
TOTAL Vehicle Length	104.6

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Launch Vehicle Design: Material Justification

Airframe

Design		G12 Fiberglass		Carbon Fiber		Phenolic Tubing	
Requirement	Weight	Rating	Score	Rating	Score	Rating	Score
Durability	1	8	8	9	9	3	3
Weight	2	4	8	9	18	8	16
Cost	3	8	24	2	6	9	27
Strength	4	6	24	6	24	2	8
Total		**64**		**57**		**54**	

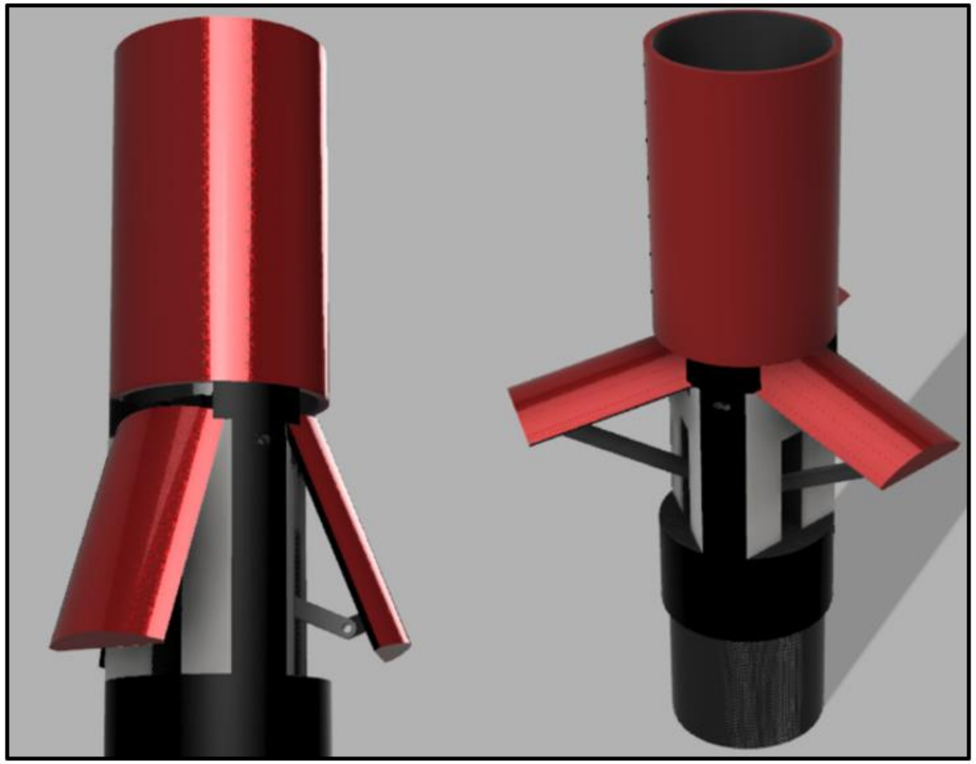
Nose Cone

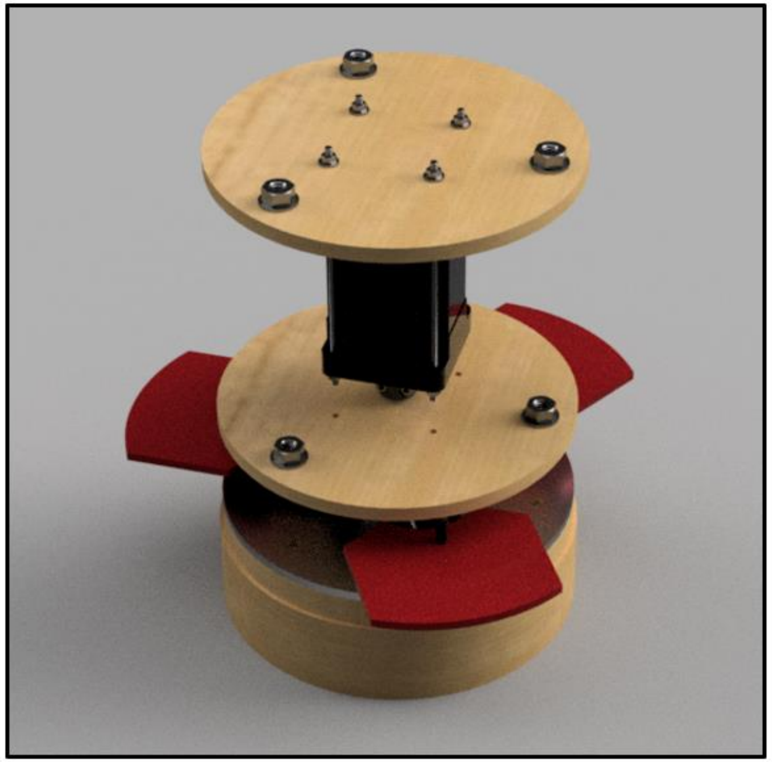
Design		G12 Fiberglass		Carbon Fiber		ABS Plastic	
Requirement	Weight	Rating	Score	Rating	Score	Rating	Score
Weight	1	4	4	8	8	5	5
Strength	3	6	18	8	24	2	6
Cost	2	6	12	2	4	8	16
RF-Transparency	4	6	24	2	8	4	16
Total		**58**		**44**		**43**	

Launch Vehicle Design: Nose Cone Justification

Design		Tangent Ogive		Conical		Von Karman	
Requirement	Weight	Rating	Score	Rating	Score	Rating	Score
Volume	5	7	35	5	25	6	30
Drag Coefficient	3	6	18	5	15	7	21
Availability	2	7	14	6	12	6	12
Total		67		52		63	

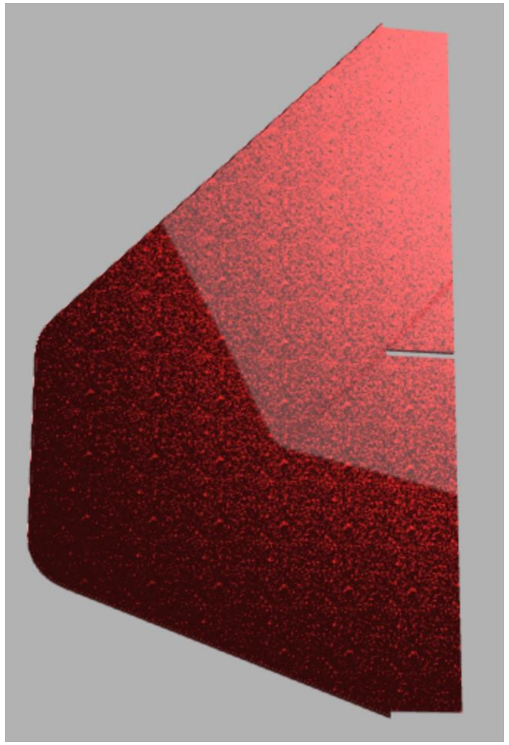
Launch Vehicle Design: VDS Justification





Design		Pistons		CAM		Gears	
Requirement	Weight	Rating	Score	Rating	Score	Rating	Score
Weight	2	5	10	6	12	5	10
Complexity	4	6	24	3	12	5	20
Manufacturability	4	6	24	4	16	5	20
Total		**58**		**40**		**50**	

Launch Vehicle Design: Fin Shape Justification



Design		Elliptical		Trapezoidal		Delta		Cropped Delta	
Requirement	Weight	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Cost	3	2	6	8	24	8	24	8	24
Apogee	2	8	16	4	8	10	20	6	12
Safety Factor	5	4	20	10	50	6	30	8	40
Total		**42**		**82**		**74**		**76**	

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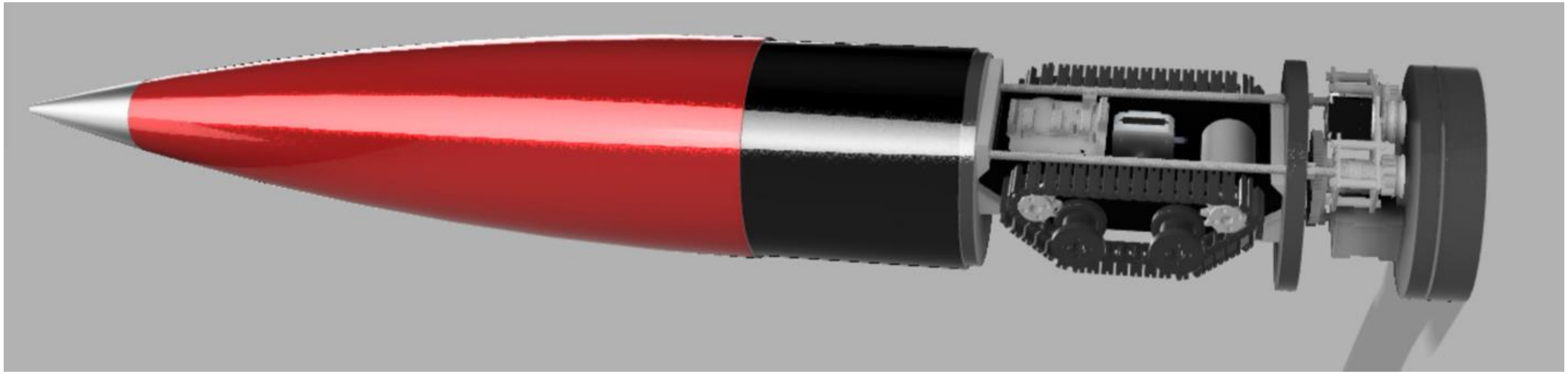
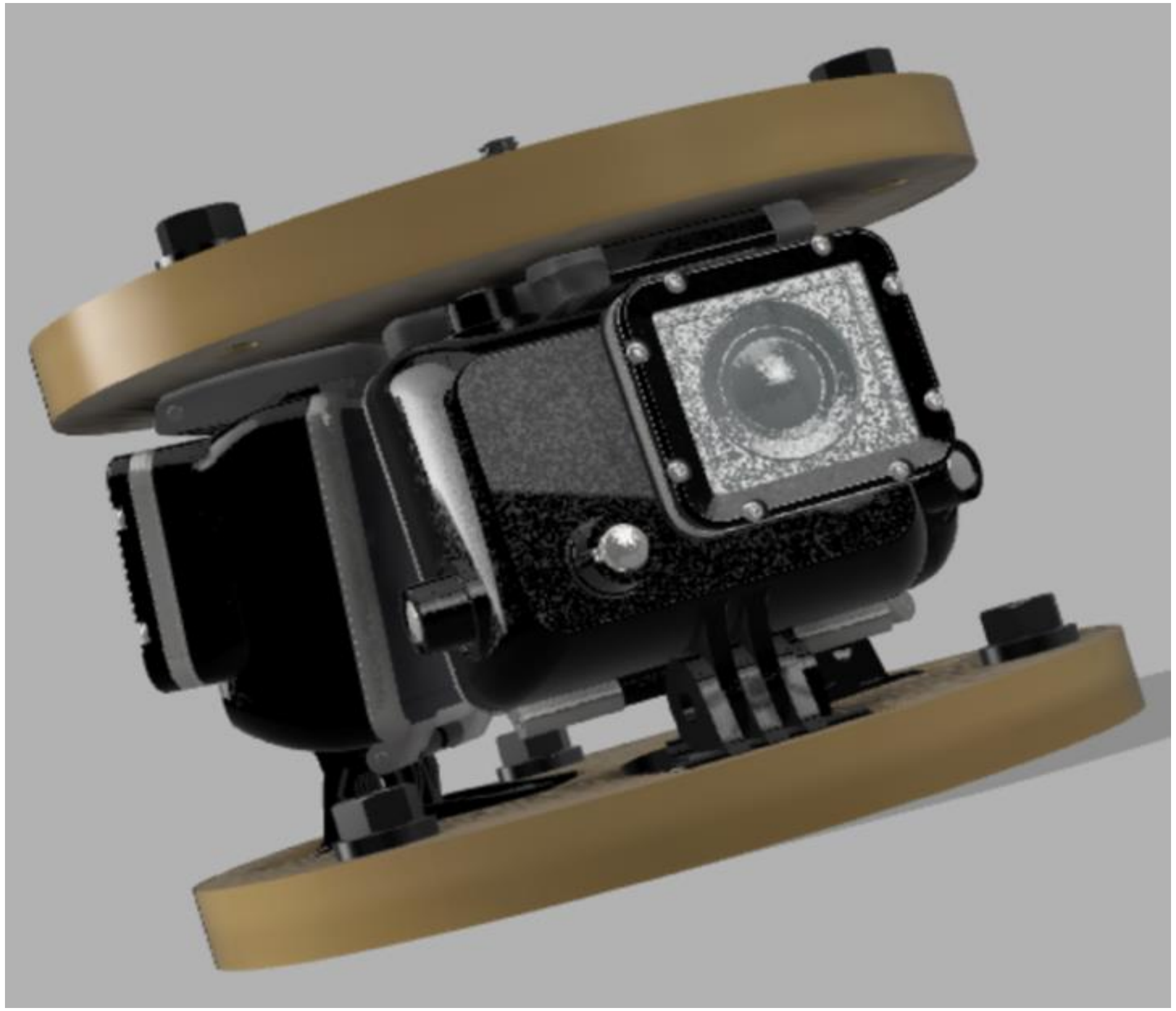
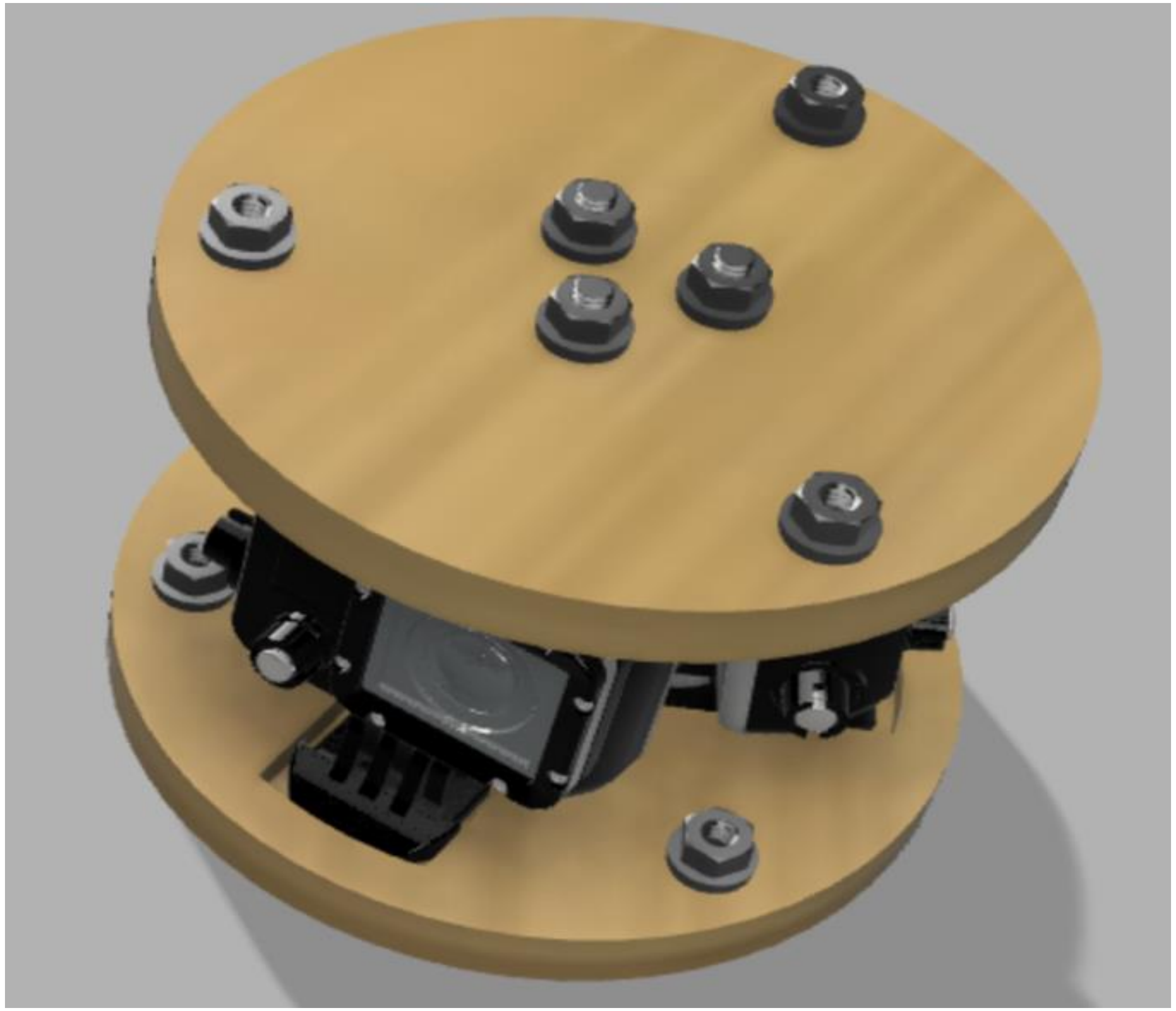
Launch Vehicle Subsystems: Nose Cone + Payload

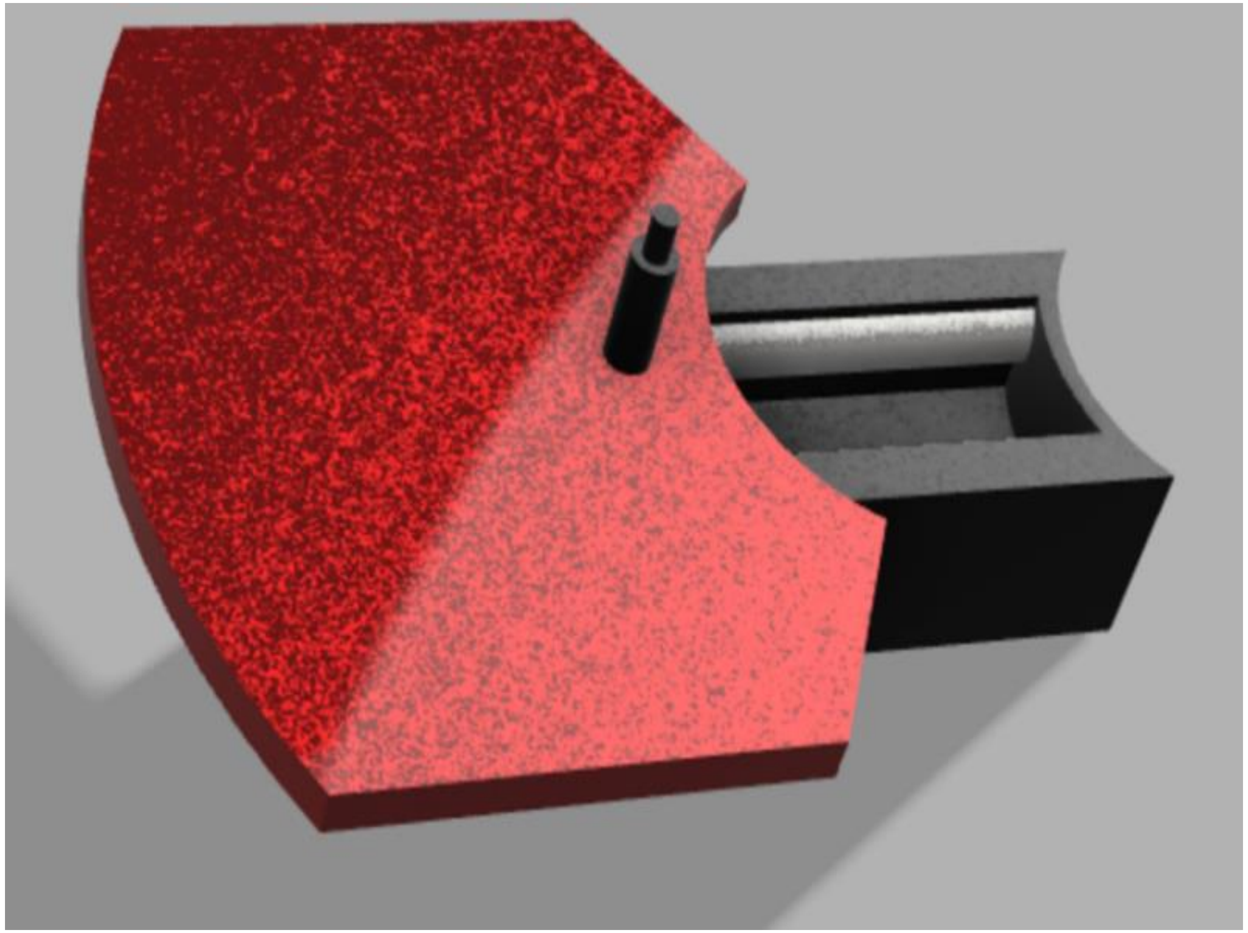


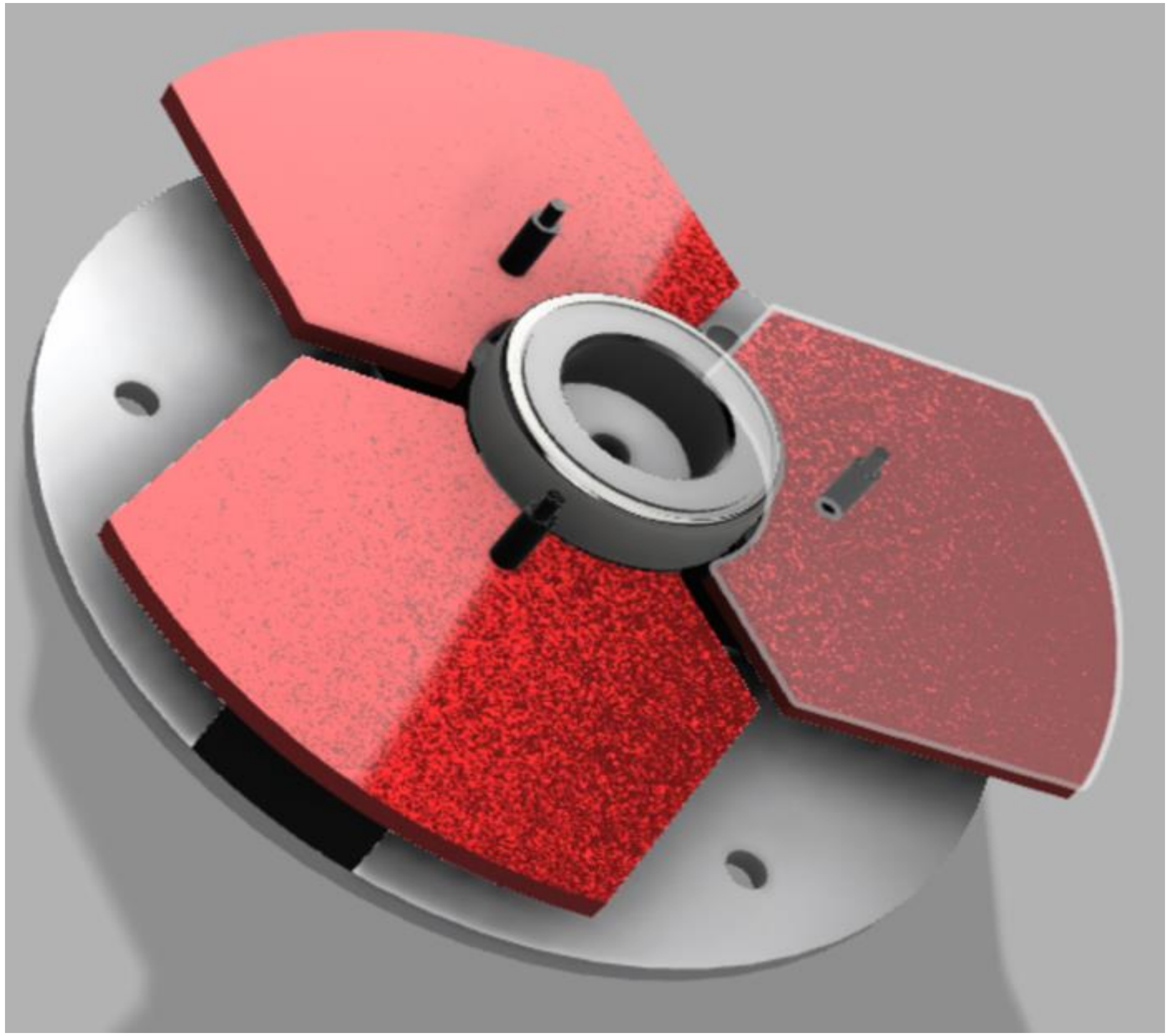
Launch Vehicle Subsystems: Camera Bay



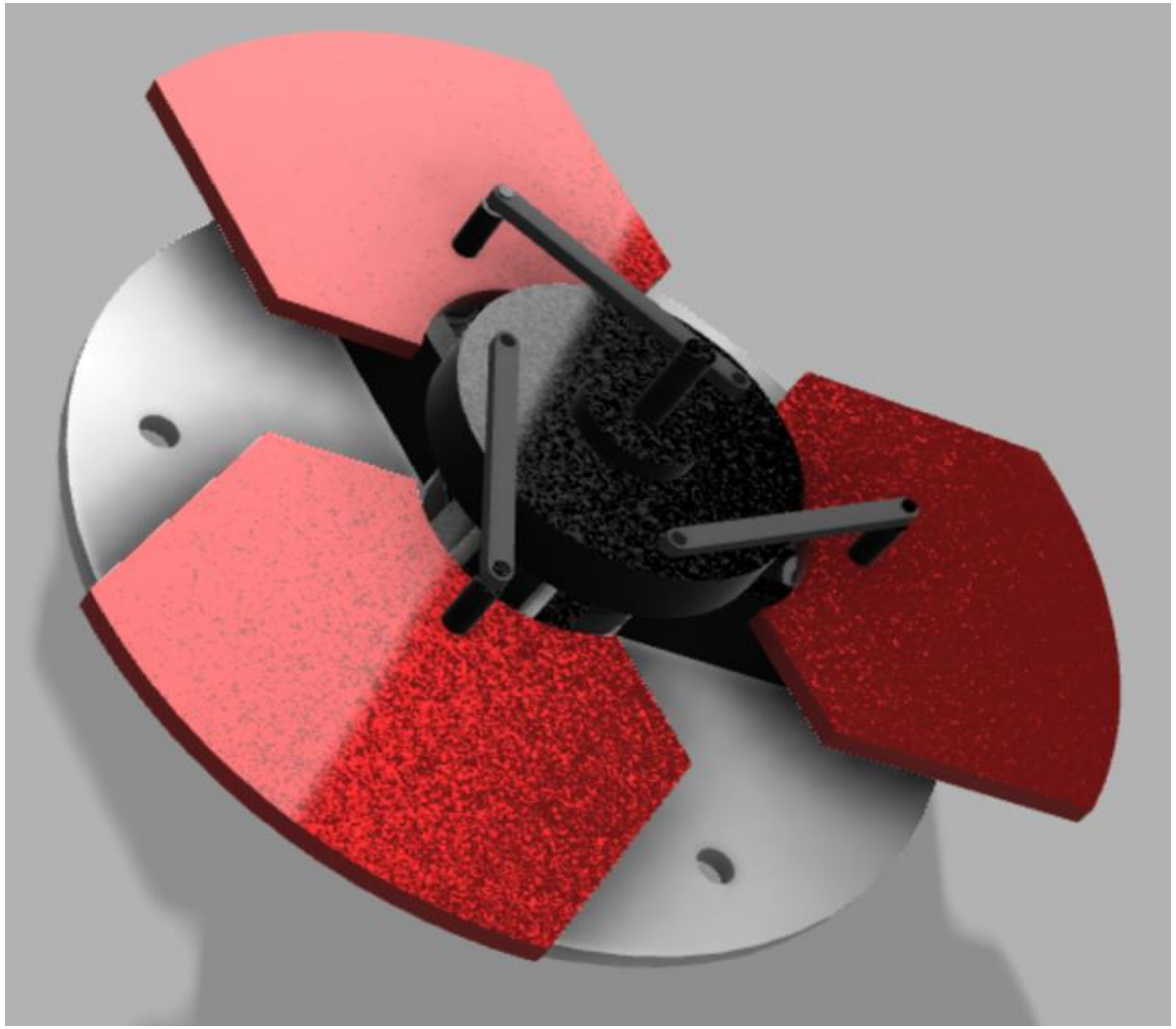


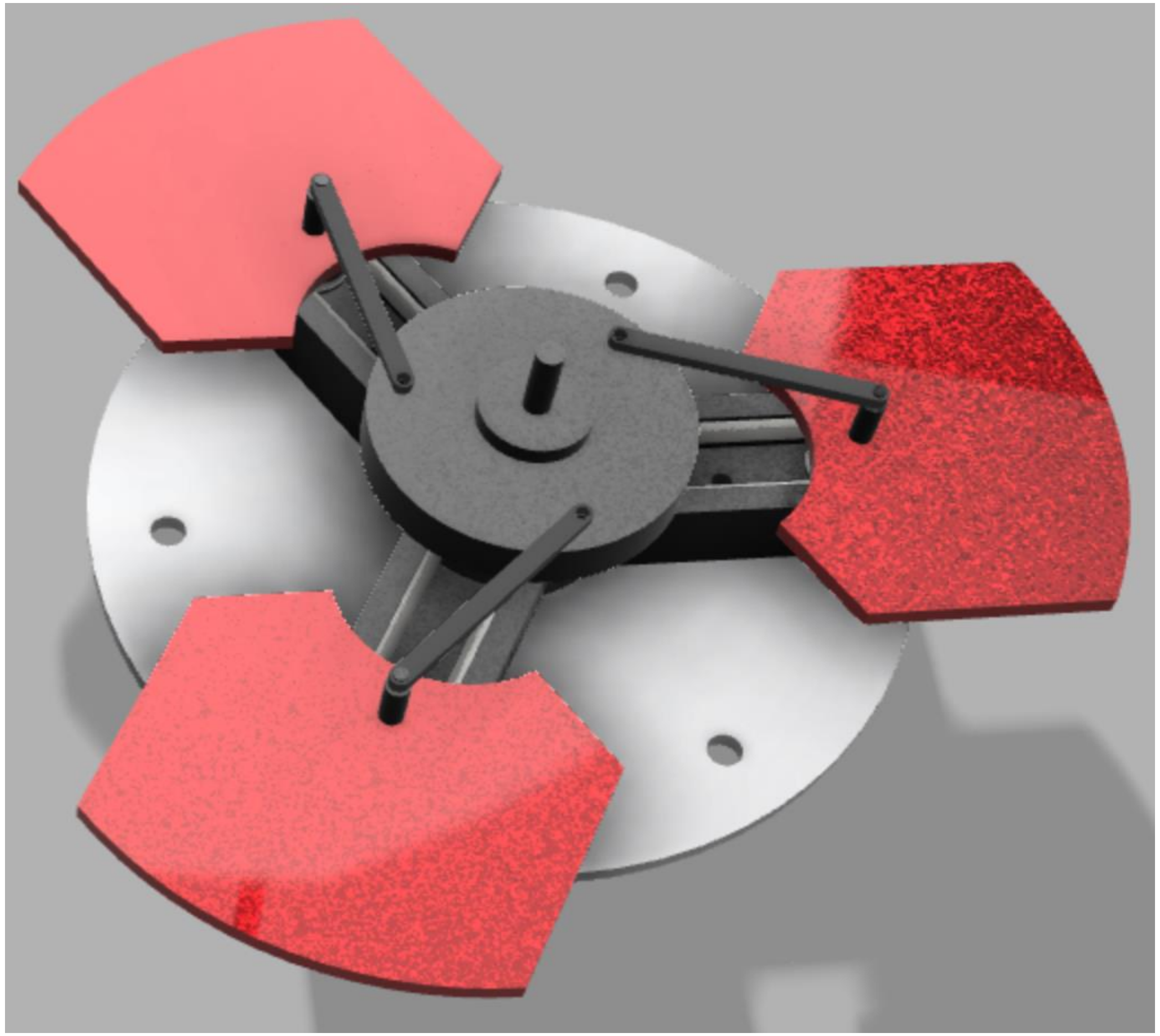
Launch Vehicle Subsystems: BEDS



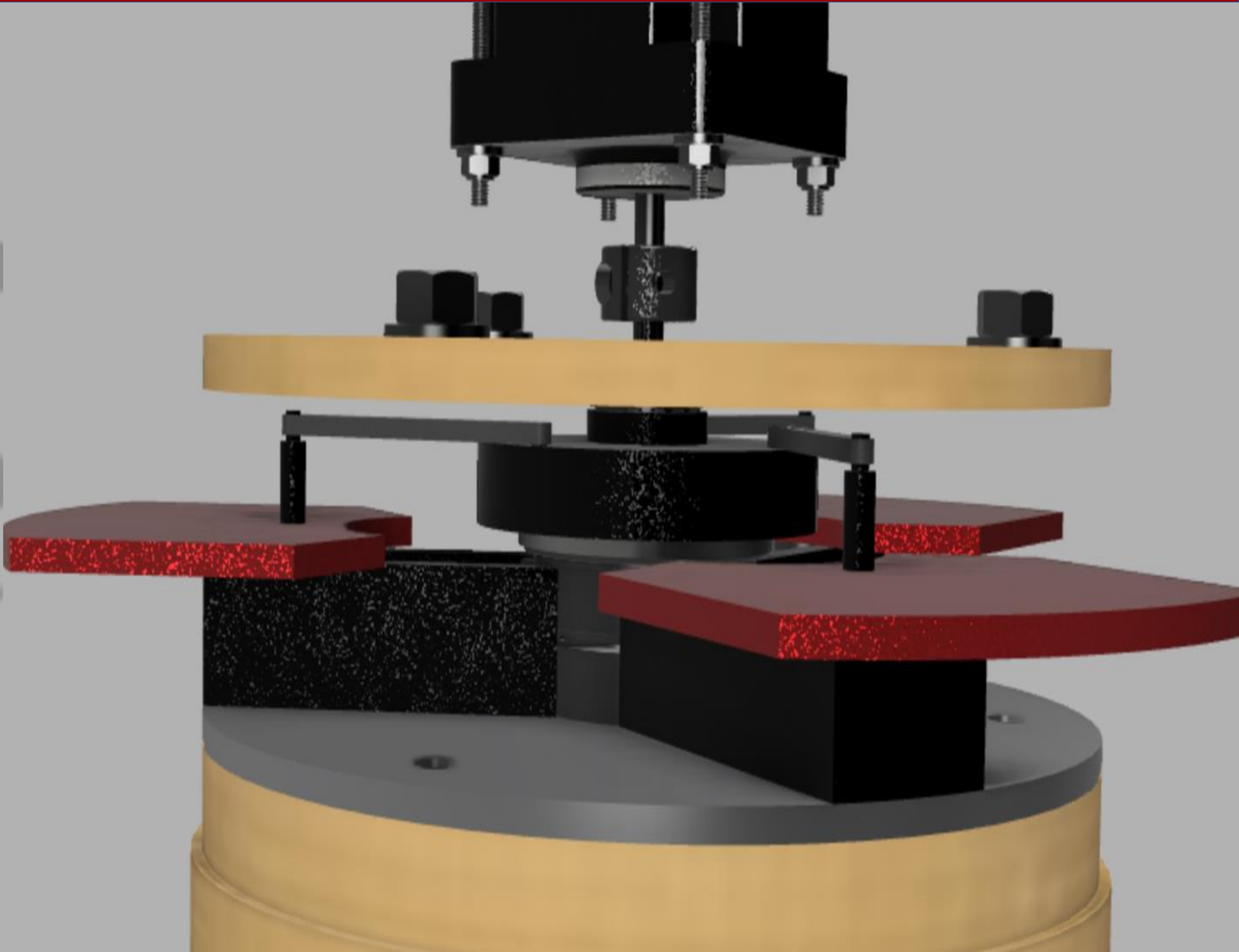


Launch Vehicle Subsystems: BEDS

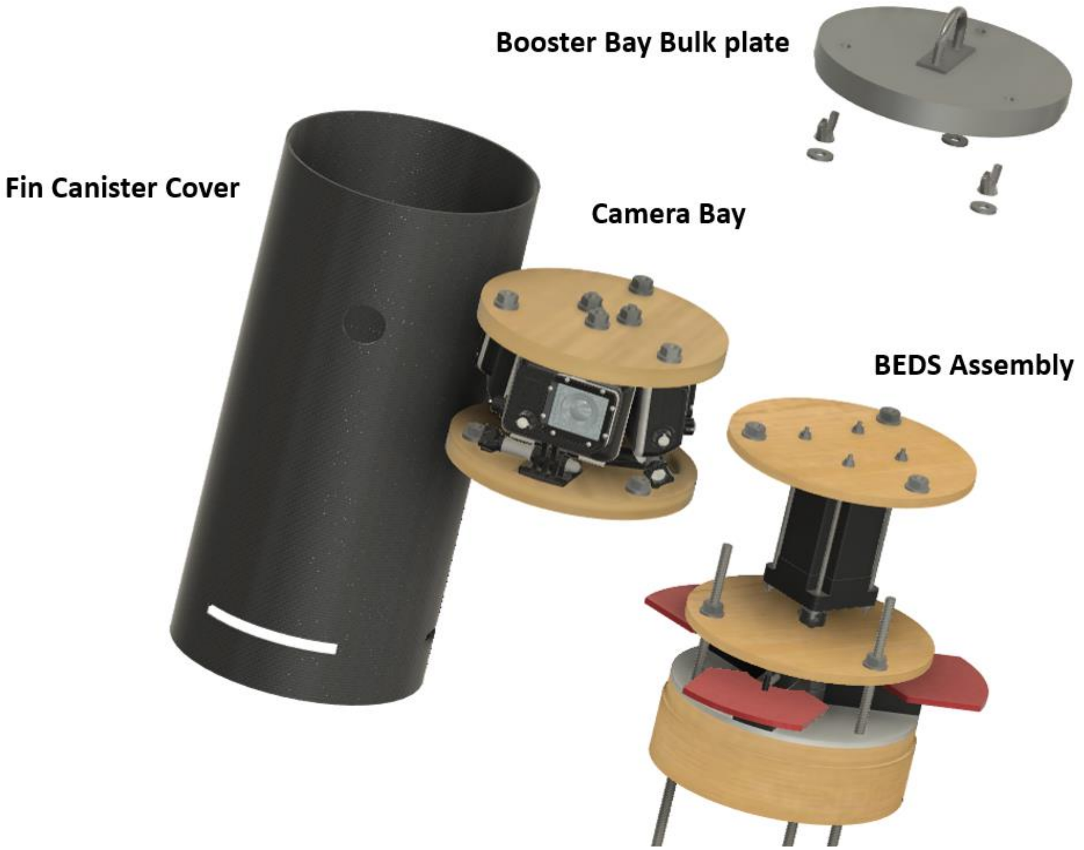




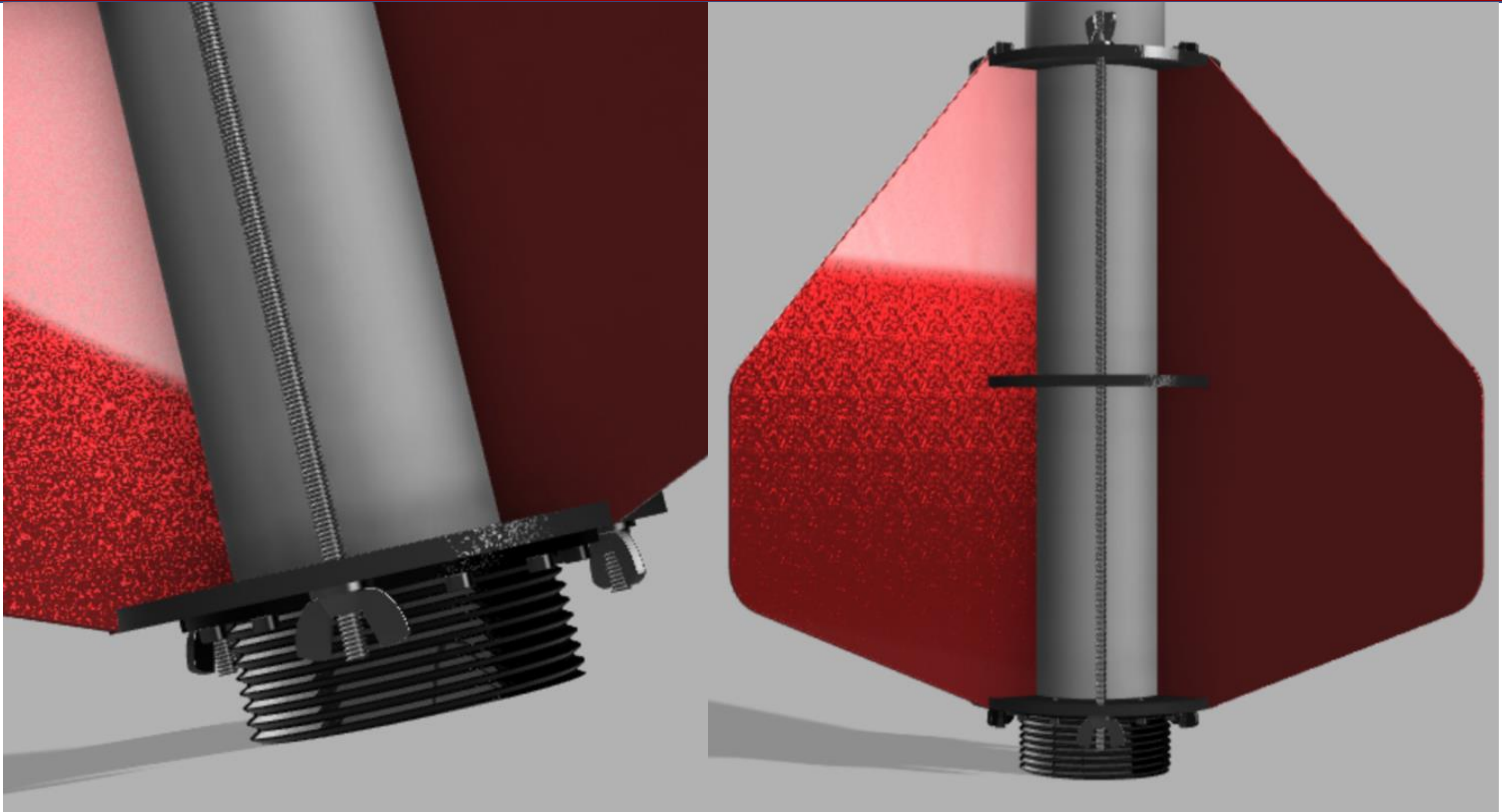
Launch Vehicle Subsystems: BEDS



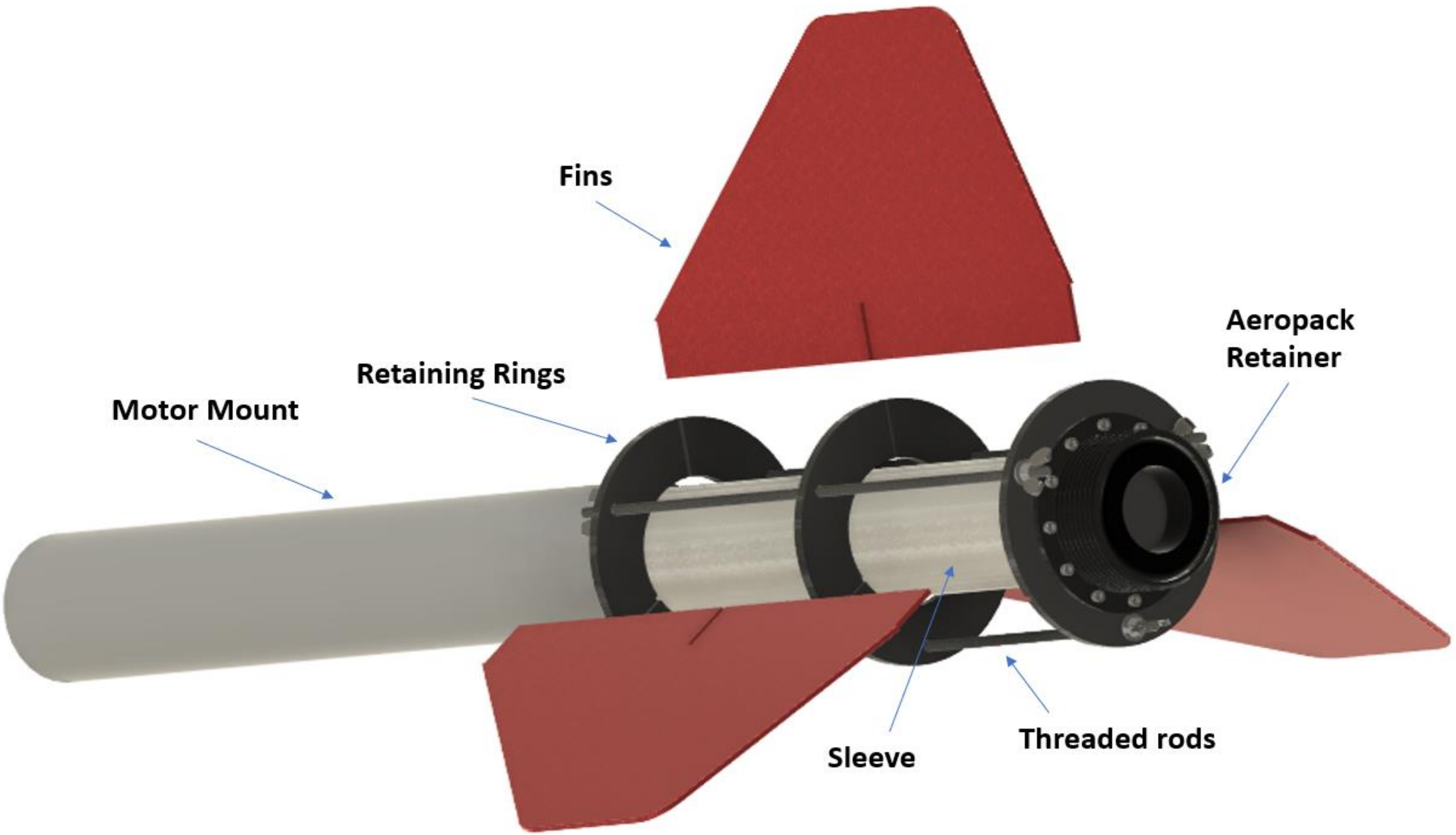
Launch Vehicle Subsystems: BEDS Canister



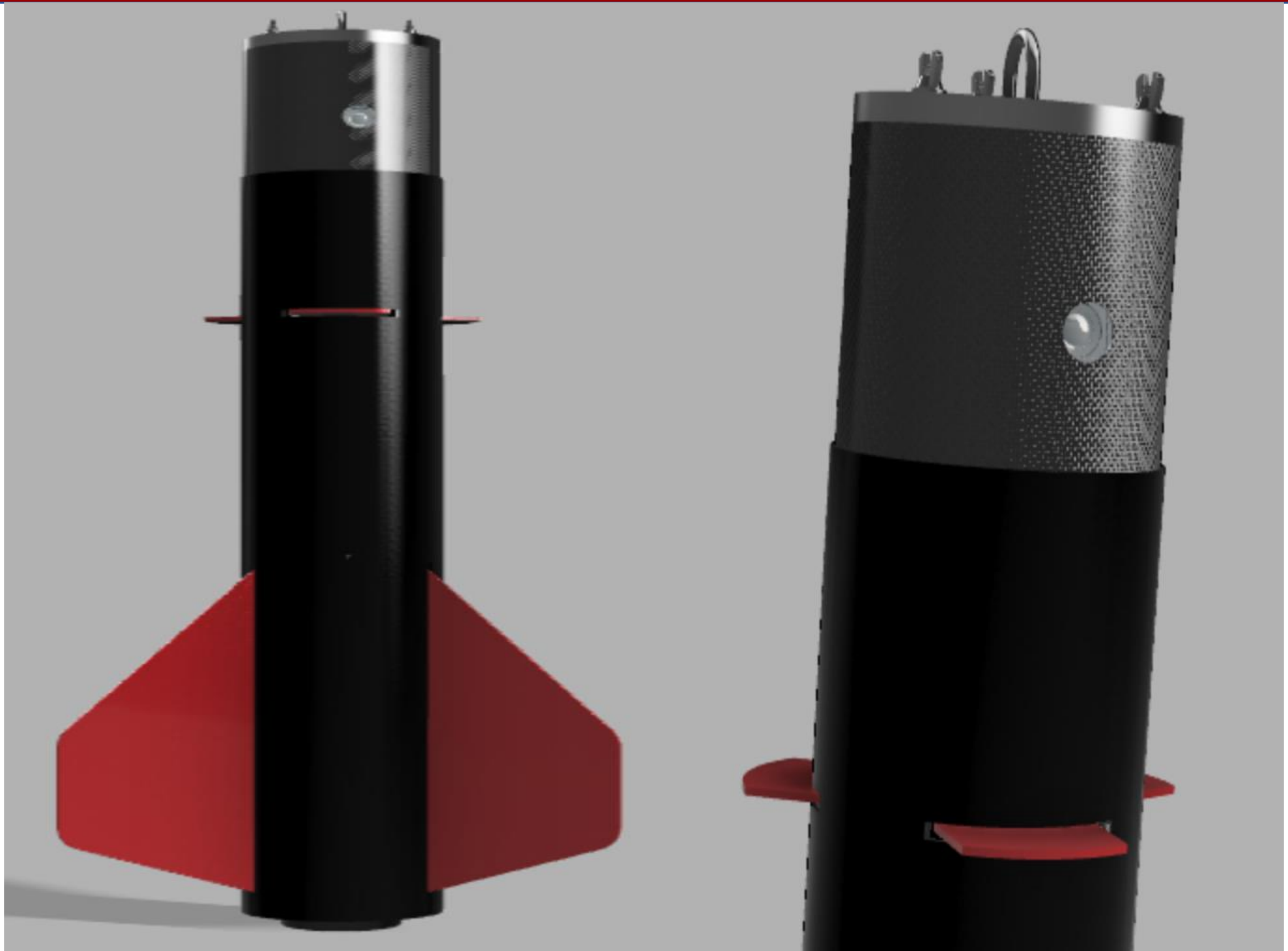
Launch Vehicle Subsystems: Booster Bay



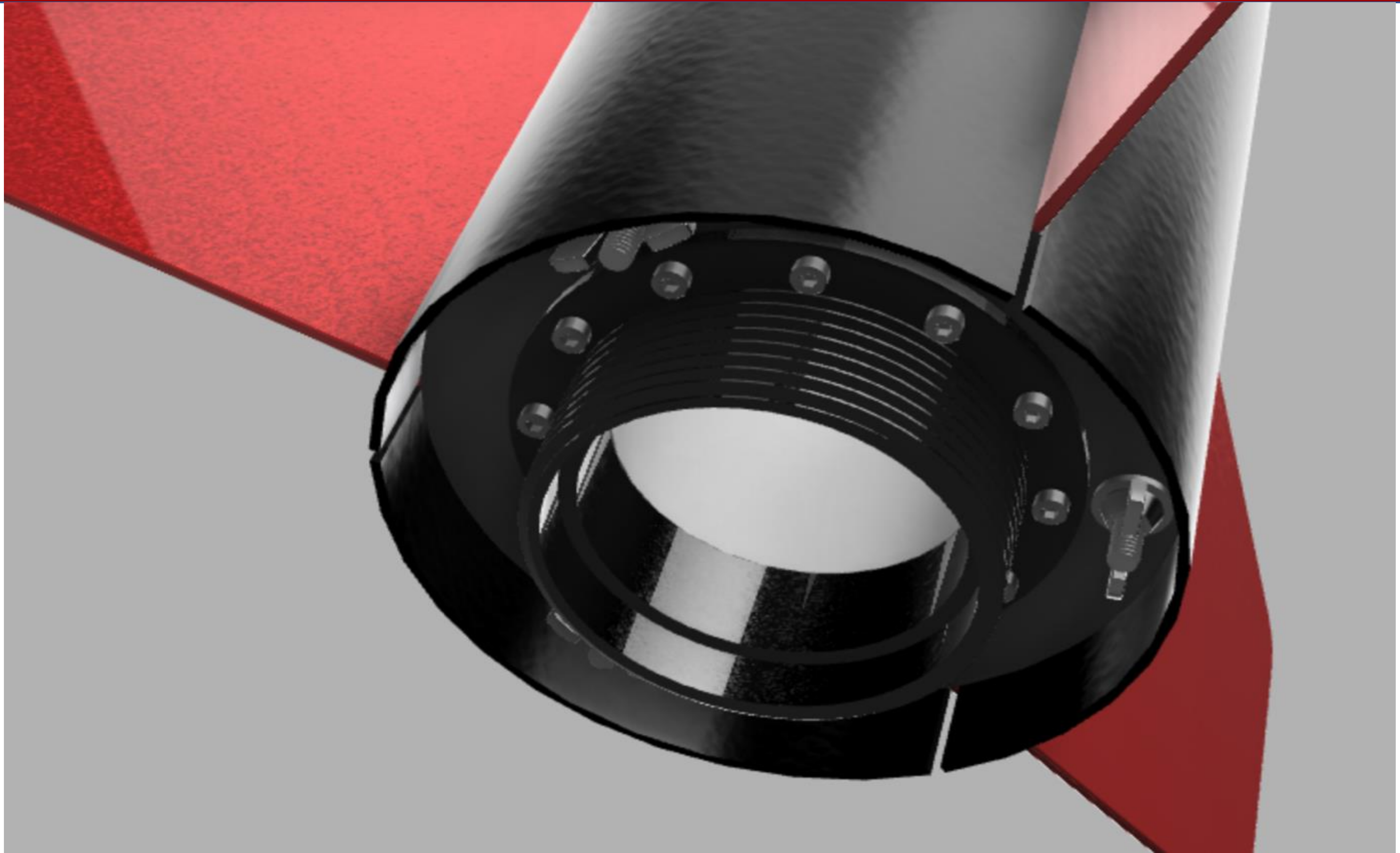
Launch Vehicle Subsystems: Booster Bay



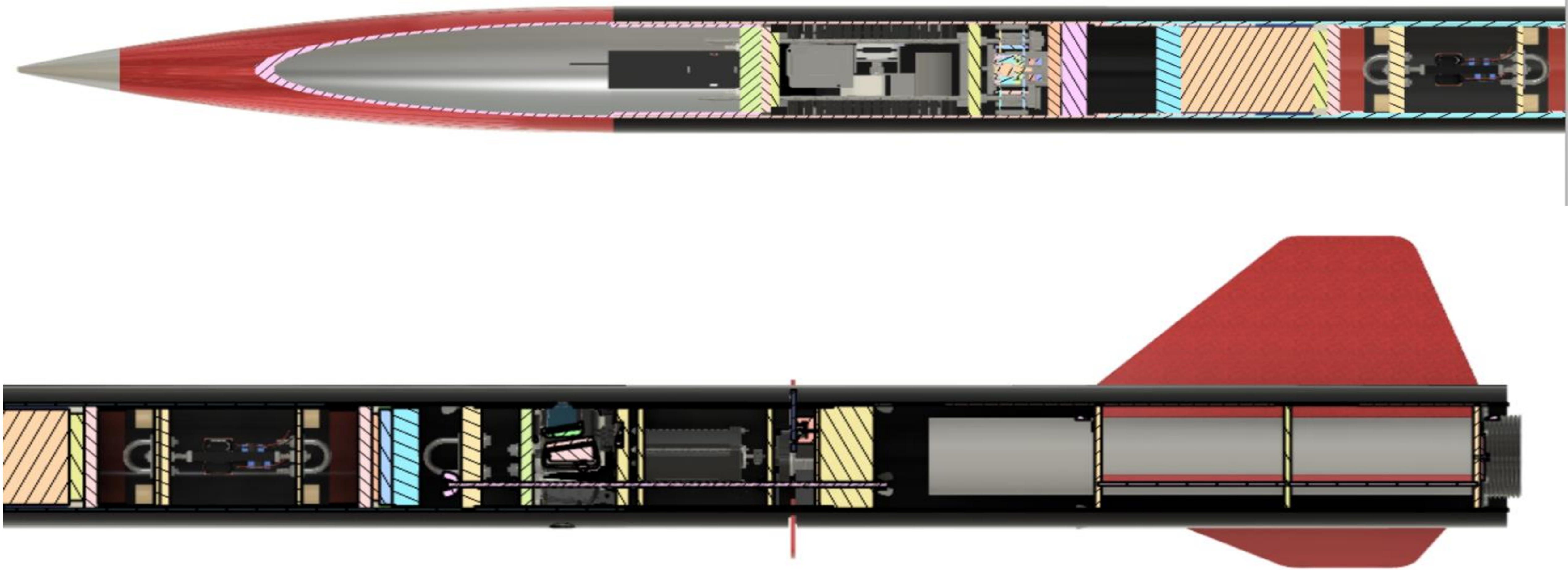
Launch Vehicle Subsystems: Booster Bay



Launch Vehicle Subsystems: Booster Bay



Launch Vehicle Subsystems: Total Assembly



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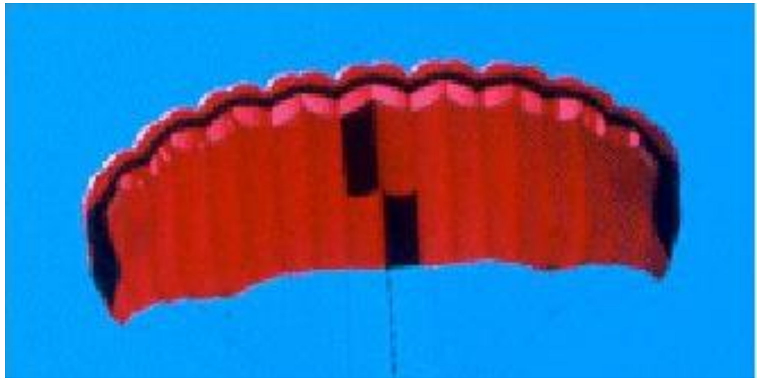
Recovery Subsystem: Parachute Design

Main Parachute: Iris Ultra 96’’ Standard Parachute

- Annular/Toroidal Design
- Diameter of 96''
- Rated to Support 50lbf at 20fps
- Cd = 2.2
- Deployment at 600 ft AGL

Drogue Parachute: 24’’ Elliptical Parachute

- Diameter of 24''
- Deployment at 4500 ft AGL

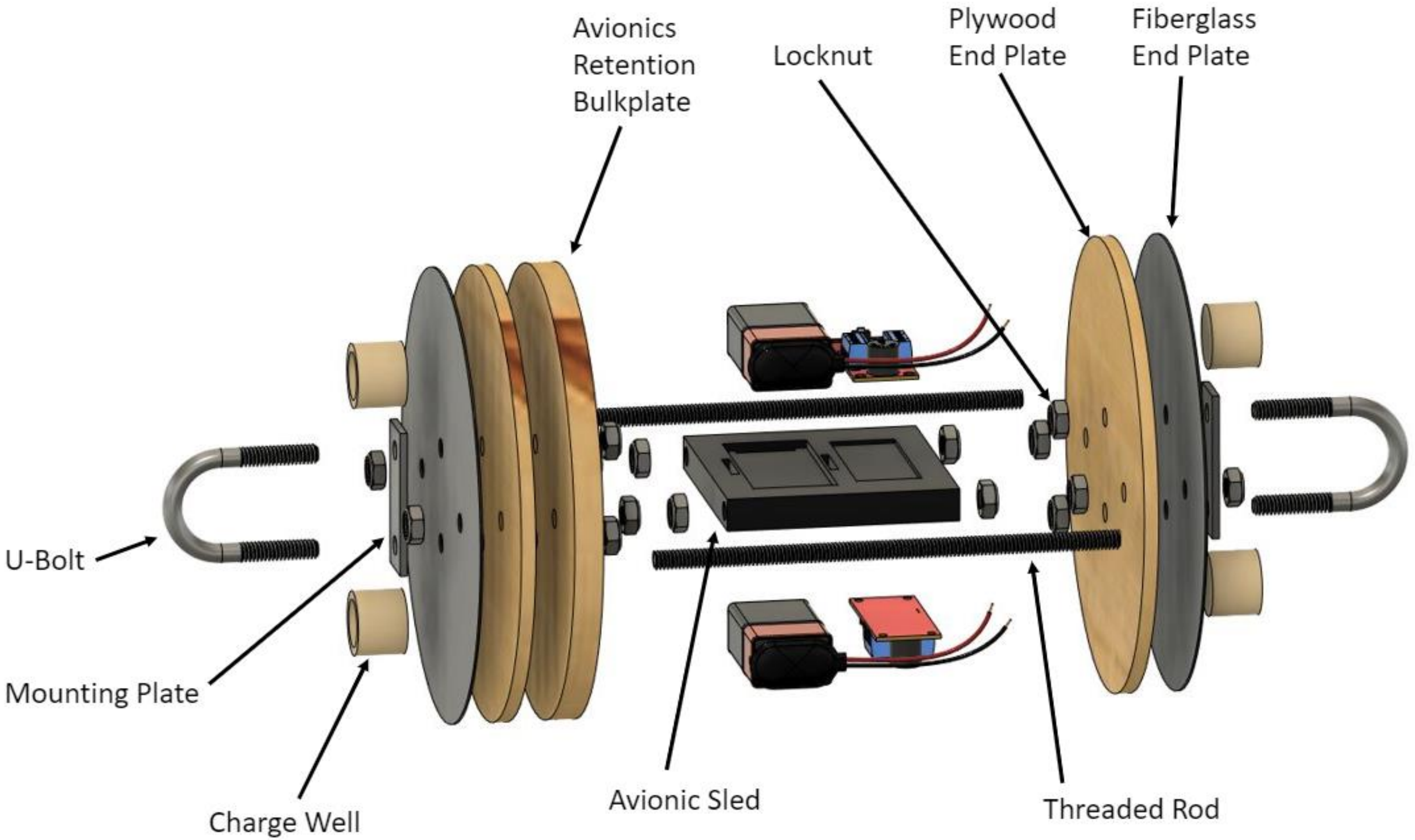


Recovery Subsystem: Parachute Design

Wind Speed (mph)	Wind Speed (ft/s)	Drift(ft)
20	29.33	2173.4
15	22	1630.2
10	14.67	1087.0
5	7.33	543.2
0	0	0

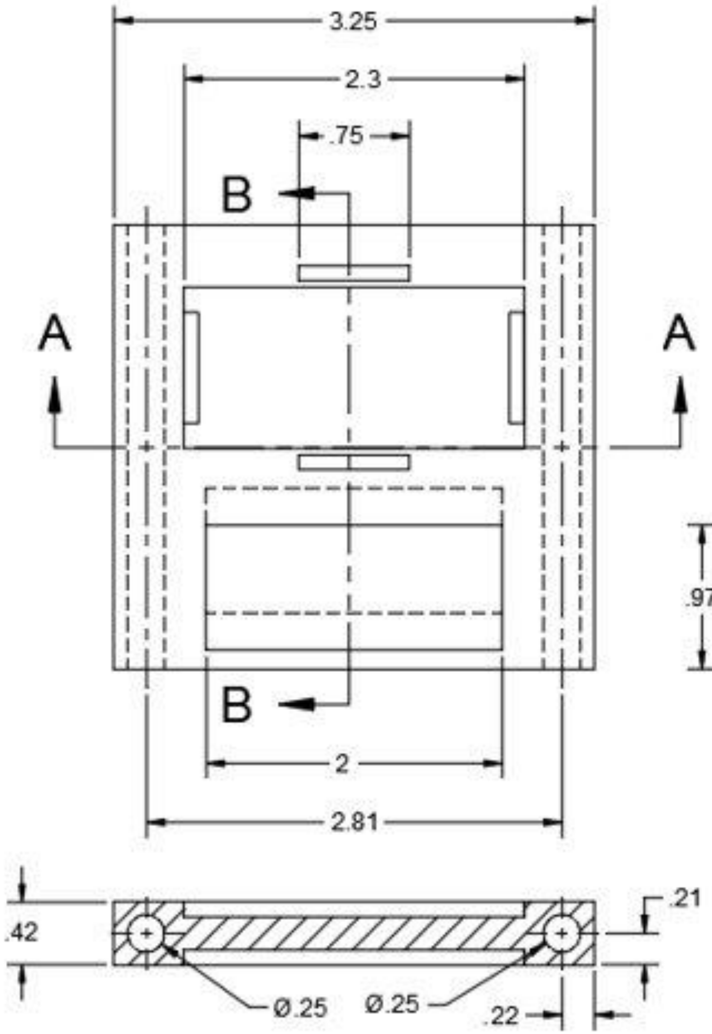
Distance of Drift based on Wind Speed

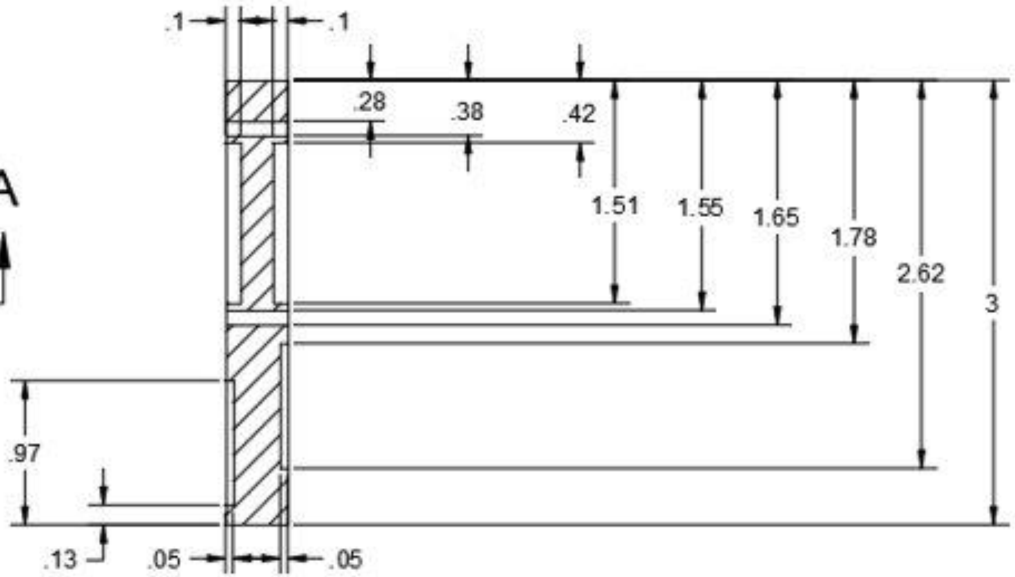
Recovery Subsystem: Avionics Bay



Recovery Subsystem: Avionics Bay Sled

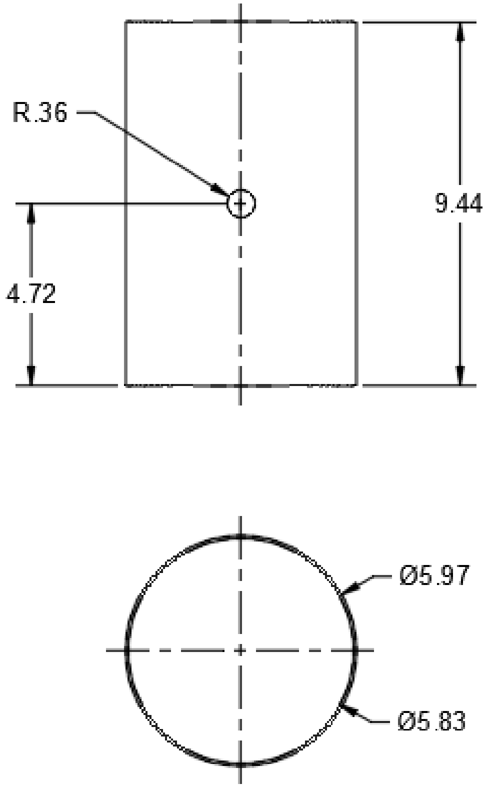
- Indentations in sled help constrain electronics.
- ABS plastic avionic sled is machinable, strong, easily fabricated, and flexible.
- Slots allow for the use of cable ties for battery security.





Recovery Subsystem: Avionics Bay Tube

- Blue tubing is light, durable, and flexible.
- Hole in the top of the tube allows for the attachment of the avionics bay arming switch.
- Recessed design reduces section length.

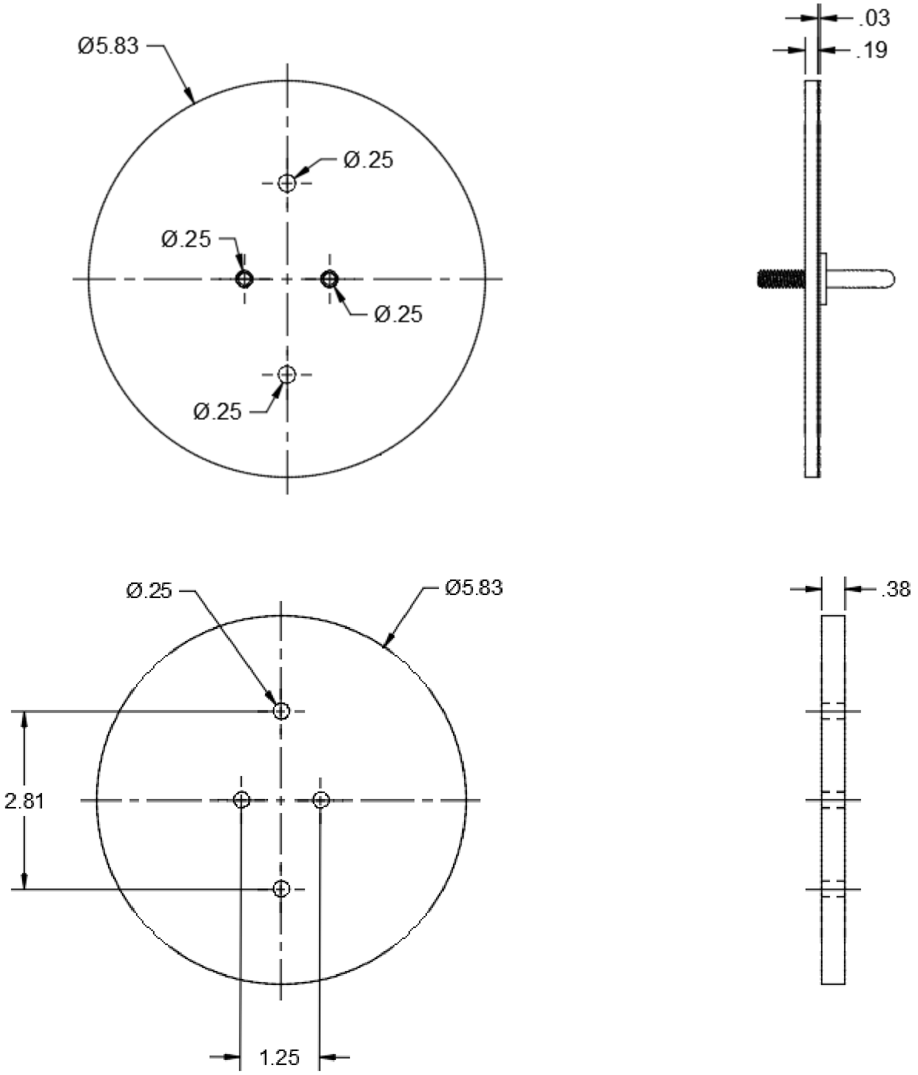


Recovery Subsystem: End Plates & Bulkplates

- Retention bulk plate is epoxied to the avionic tube to ensure that avionics bay is stable, but removable.

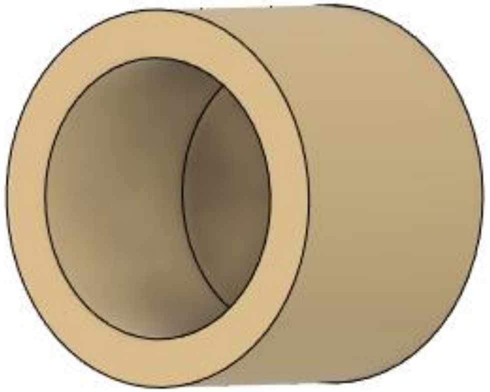
- Fiberglass outer plate protects inner avionics bay from hot ejection gases.

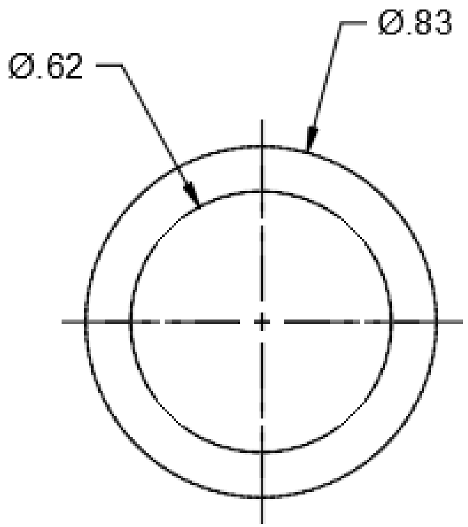
- Use of plywood inner plate increases system strength while minimizing weight.

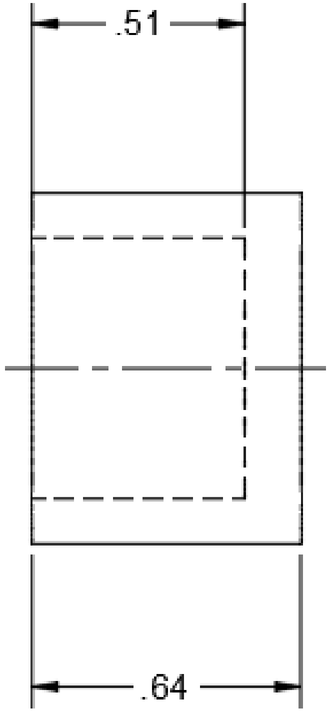


Recovery Subsystem: Avionics Bay Charge Wells

- PVC charge wells support 2 grams of black powder.
- Requires 0.18g of black powder for drogue deployment and 0.4056g for main chute deployment.
- Lighter than aluminum wells.

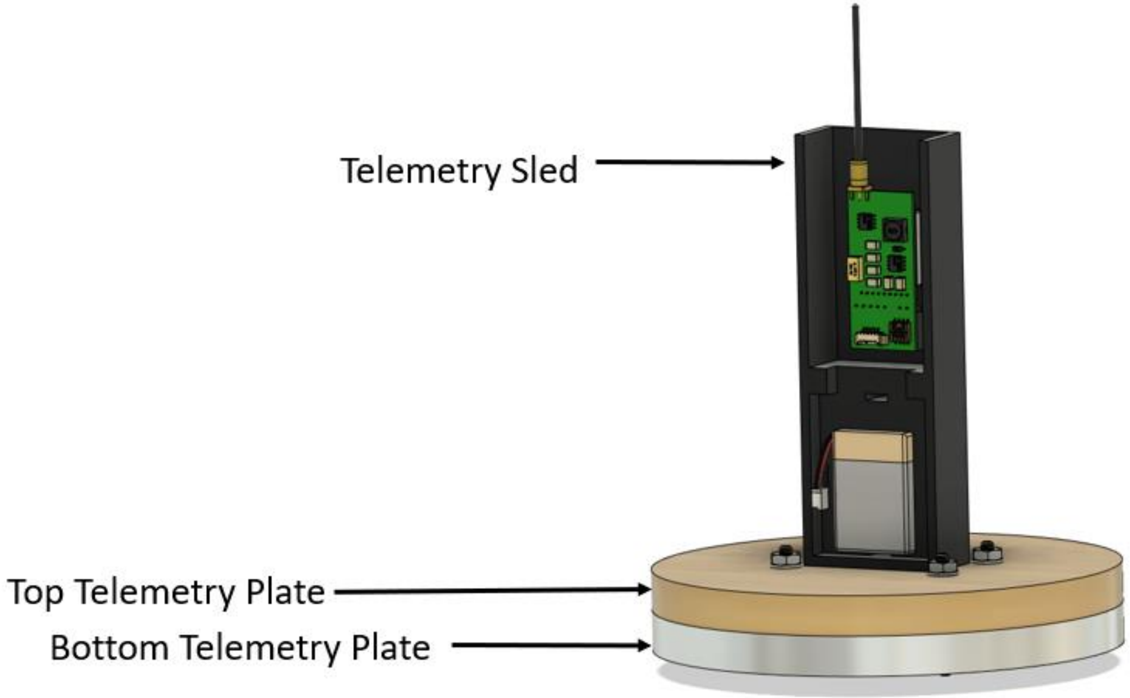






Recovery Subsystem: Telemetry Bay

- Sled slots through the top telemetry plate.
- Sled base attached to bottom plate.
- Sparing use of aluminum to reduce weight.
- Aluminum nuts and threaded rods are lighter and non-magnetic.

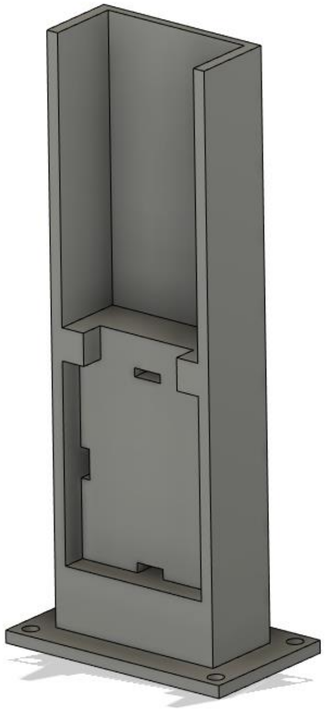


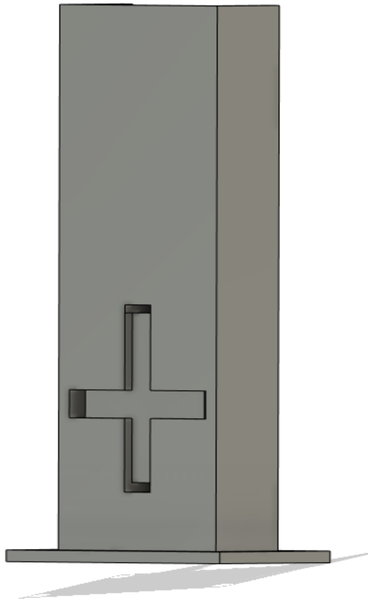
Recovery Subsystem: Telemetry Sled

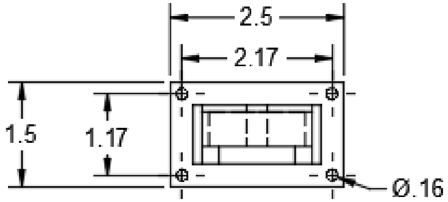
- ABS plastic telemetry sled is machinable, strong,
  easily fabricated, and flexible.

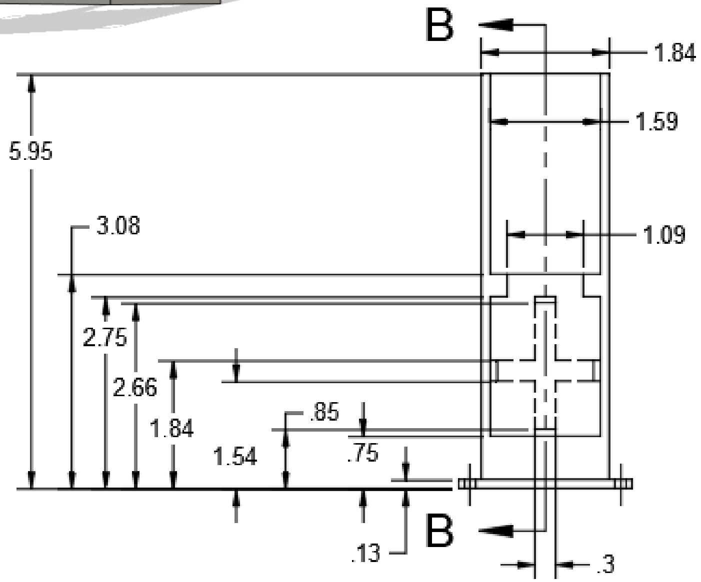
- Separate transmitter and battery compartments constrain movement.

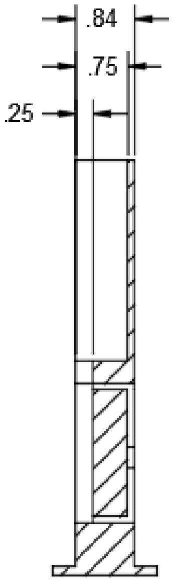
- Slots cut through to implement cable ties.





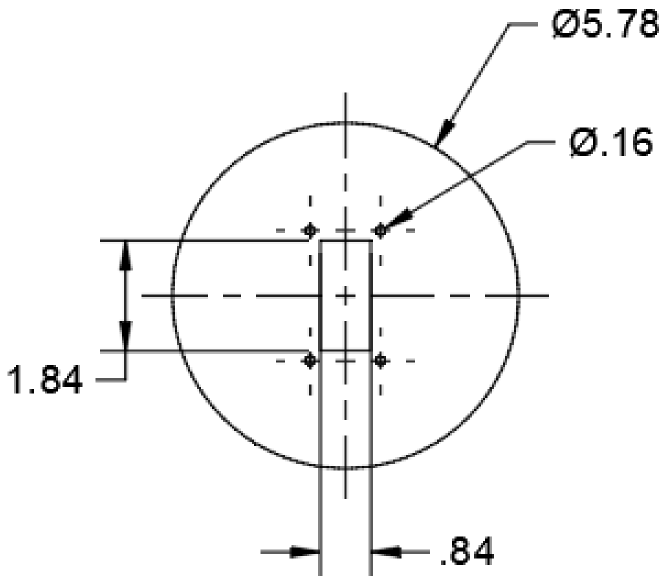


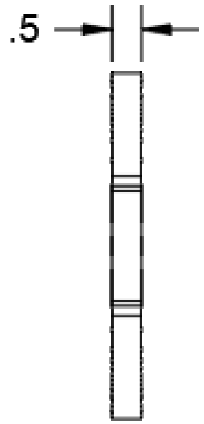


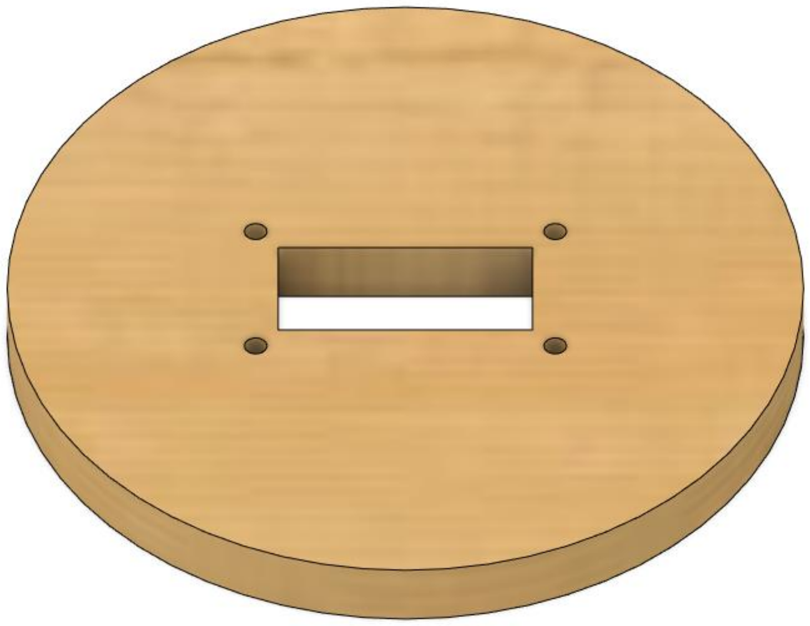


Recovery Subsystem: Telemetry Bay Top Plate

- Top plate is made of MIL-P-6070 plywood and epoxied to the nosecone.



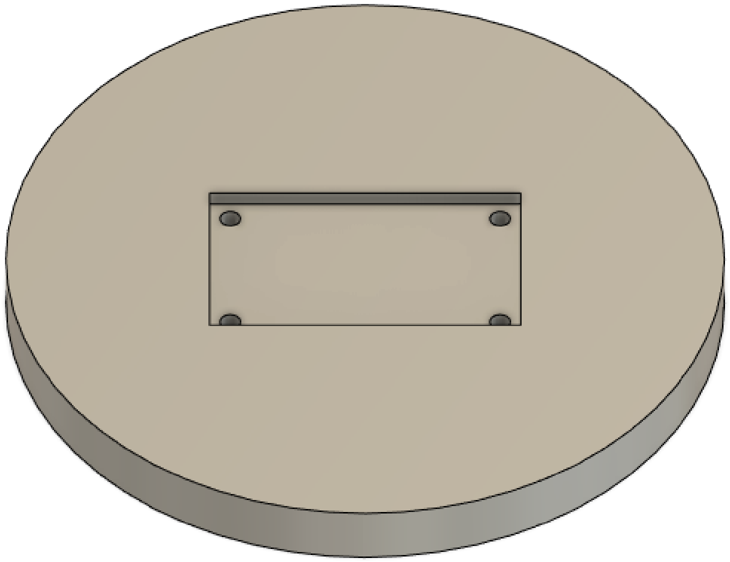


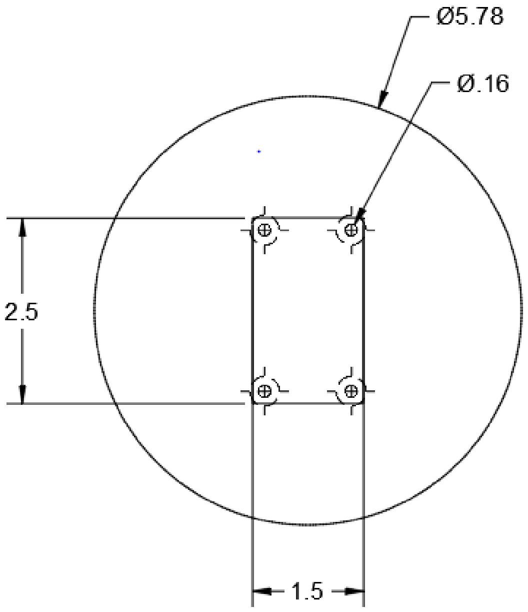


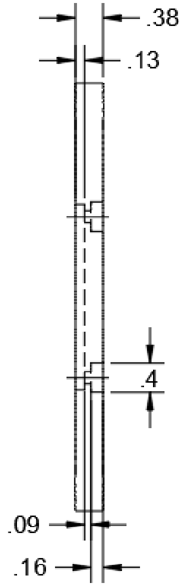
Recovery Subsystem: Telemetry Bay Bottom Plate

- Bottom plate is made of aluminum to interface with payload bay.

- Nuts on the bottom surface are counterbored to not interfere with payload bay.





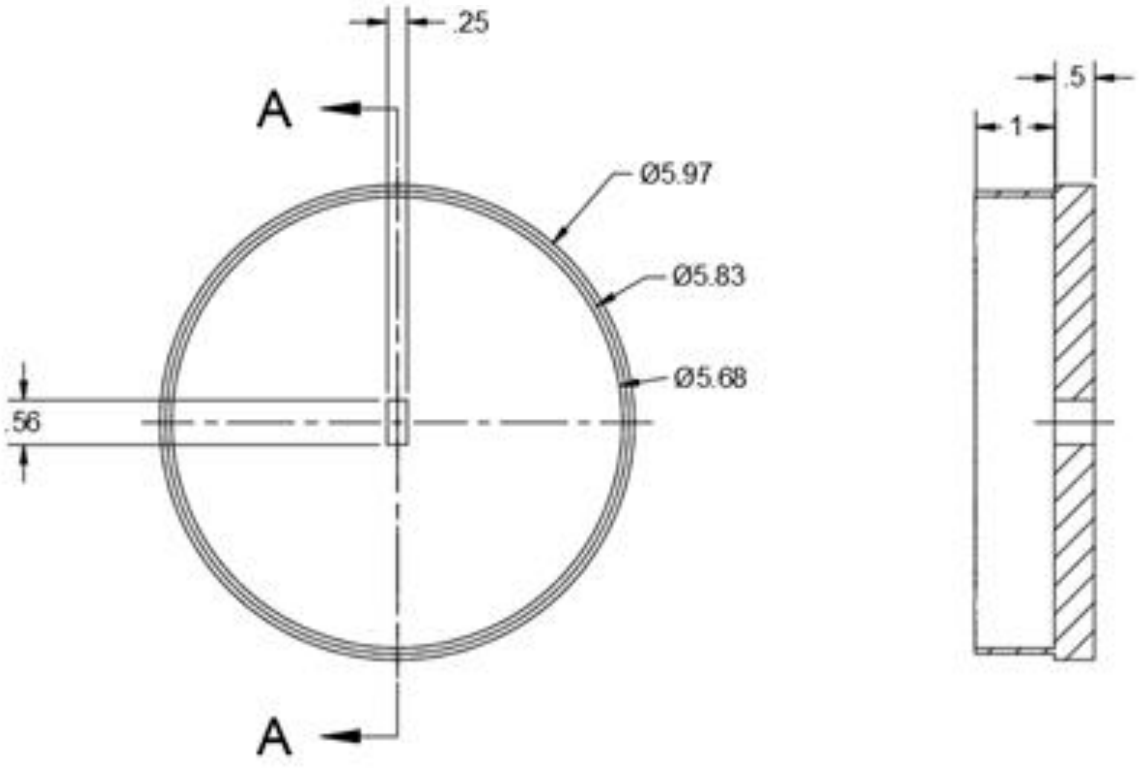


Ejection and Deployment: Recovery Harness & Mounts

- U-bolt spreads force out over a large area, unlike eyebolts.
- U-bolt is made of Zinc-Plated Steel to resist corrosion.
- Kevlar shock cord ensures tethering does not suffer burns from ignition gases.

Recovery Subsystem: Ejection Pistons

- Pistons are made of MIL-P-6070 Plywood.
- Inner diameter transition tight fit allows for assembly and disassembly of system.
- Outer diameter close running fit allows moderate speed of piston movement.
- Hole machined through for passage of the shock cord.



Recovery Subsystem: Parachute Protection

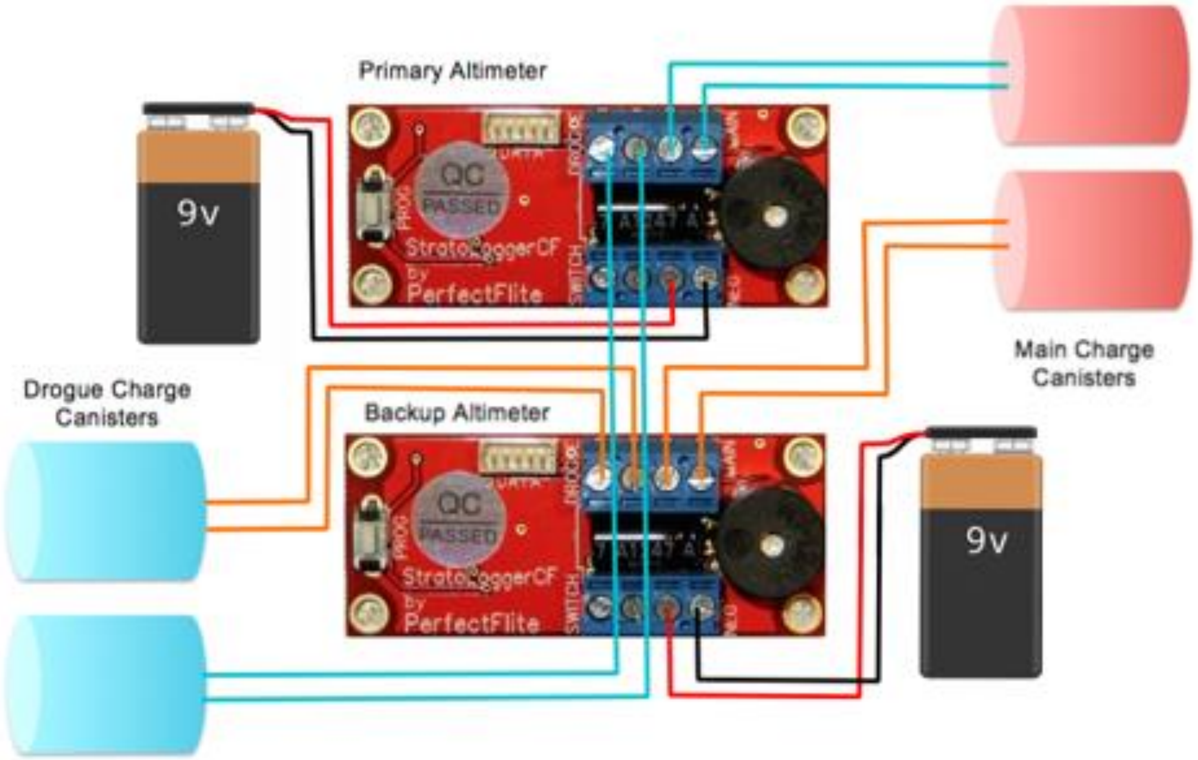
- Nomex blanket protects nylon parachutes from hot ejection gases.
- Does not lengthen parachute bays as much as deployment bags, saving space.

Recovery Subsystem: Shear Pins

- Used to keep parachute bays connected to other airframe sections.
- Ignition gases produce a force to break pins and deploy parachute.
- 4 pins that can withstand a total of 84.44 lbf.

Recovery Subsystem: Avionics Circuit

- Circuit is fully redundant with independent power sources for each altimeter.
- Independent of other electrical systems.



Recovery Subsystem: Altimeters, GPS, Arming Switch

- PerfectFlite StratoLoggerCF Altimeter
  - 0.1% accuracy
  - Stores 16 flights of 18 minutes each
  - Brownout protection
  - Resistant to false trigger by strong winds (100+ mph)
  - 9,999 ft AGL range
  - Dual Deployment
  - Runs for weeks on 9V battery

- BRB900 GPS Telemetry System
  - 6 mile range
  - Battery add-on prevents overcharge.
  - Receiver/Transmitter pairing
  - Does not require HAM license

- Rotary Switch Arming Device
  - Does not require a specific key
  - Can be operated by screwdriver, fingernail, etc.
  - Will not activate avionics due to flight forces

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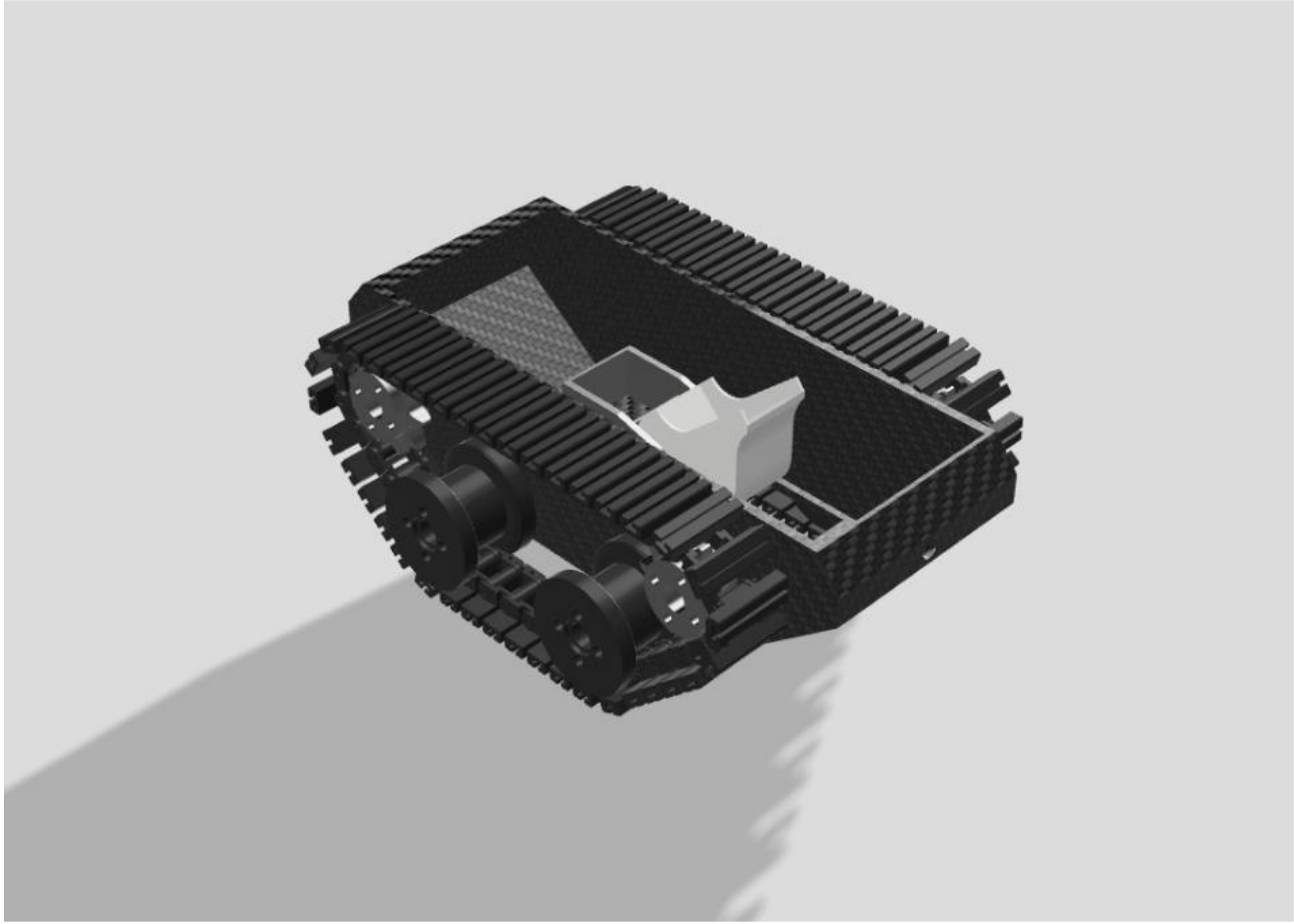
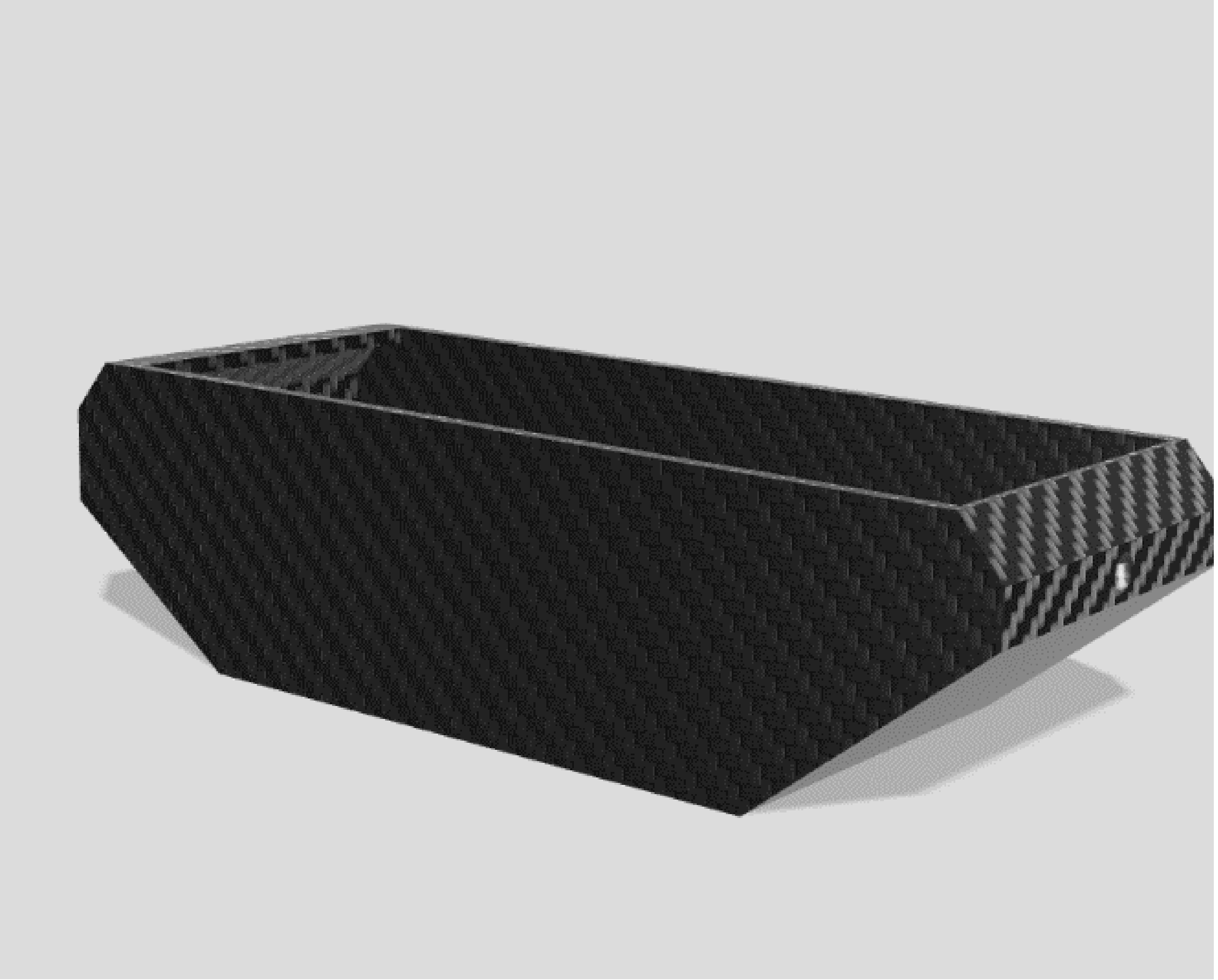
Payload Design: Overview

- Octagonal Prism Chassis Design
- Tank drive with separate motors controlling each track.
- Sample collection scoop located near the center of the chassis.
- Scoop path deposits collected sample into storage container.
- Remotely controlled.



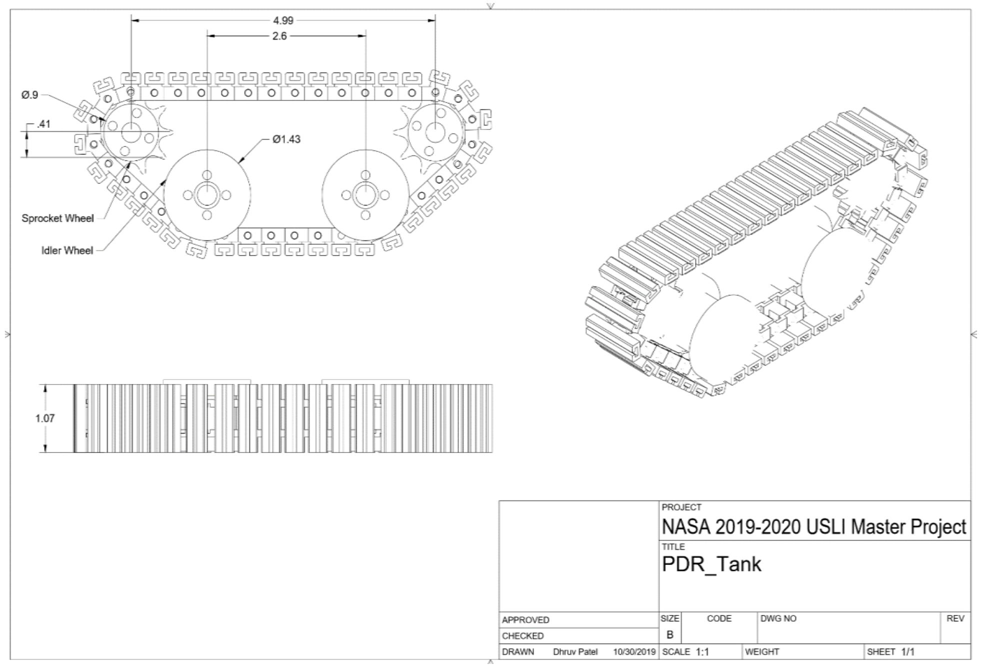
Payload Design: Chassis

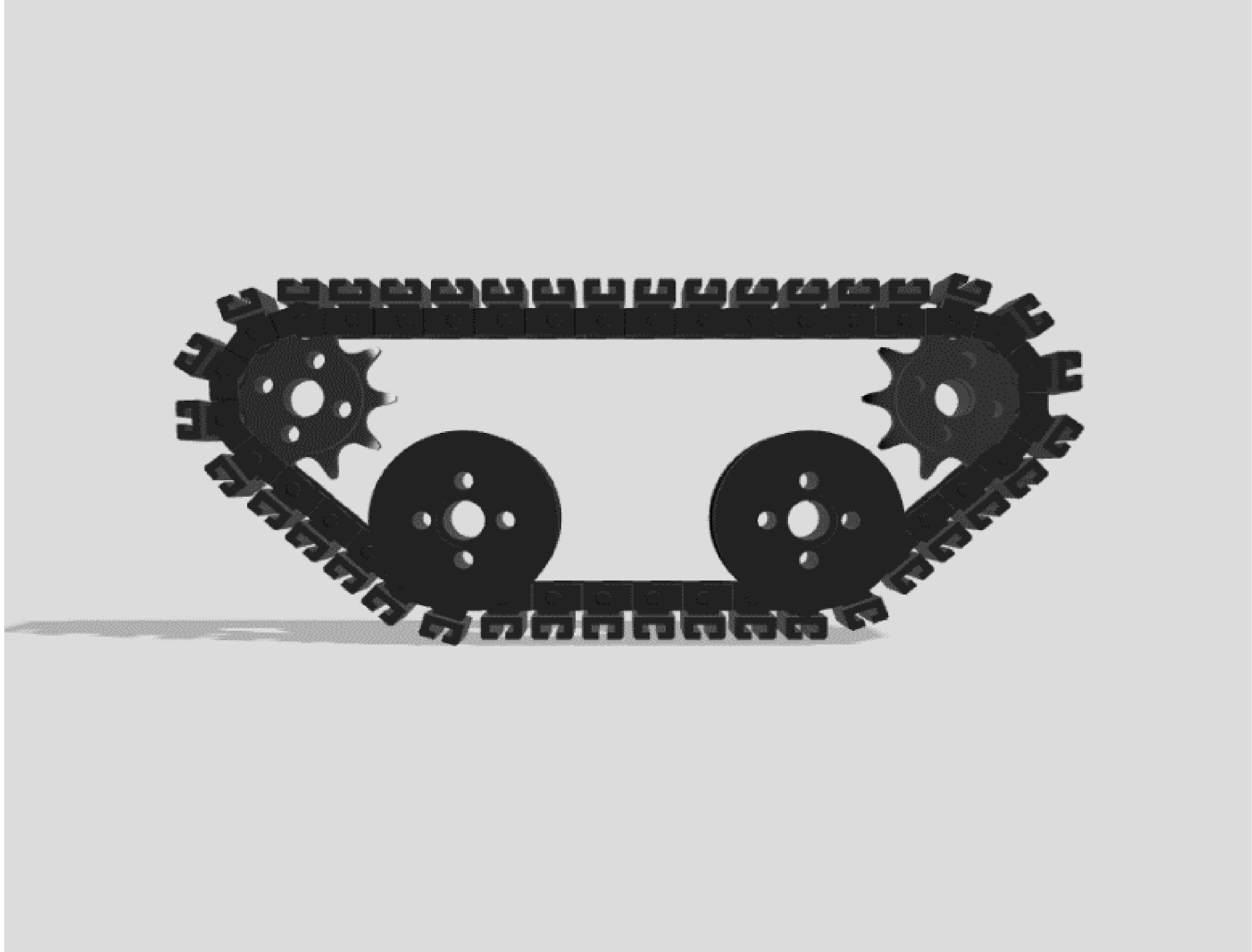
- Slanted front and rear plates allow for increased ground clearance.
- Low chance of rover getting trapped in uneven terrain.
- Higher volume to surface area than rectangular chassis.
- Carbon Fiber body.
- Light weight and high strength to weight ratio.



Payload Design: Drive

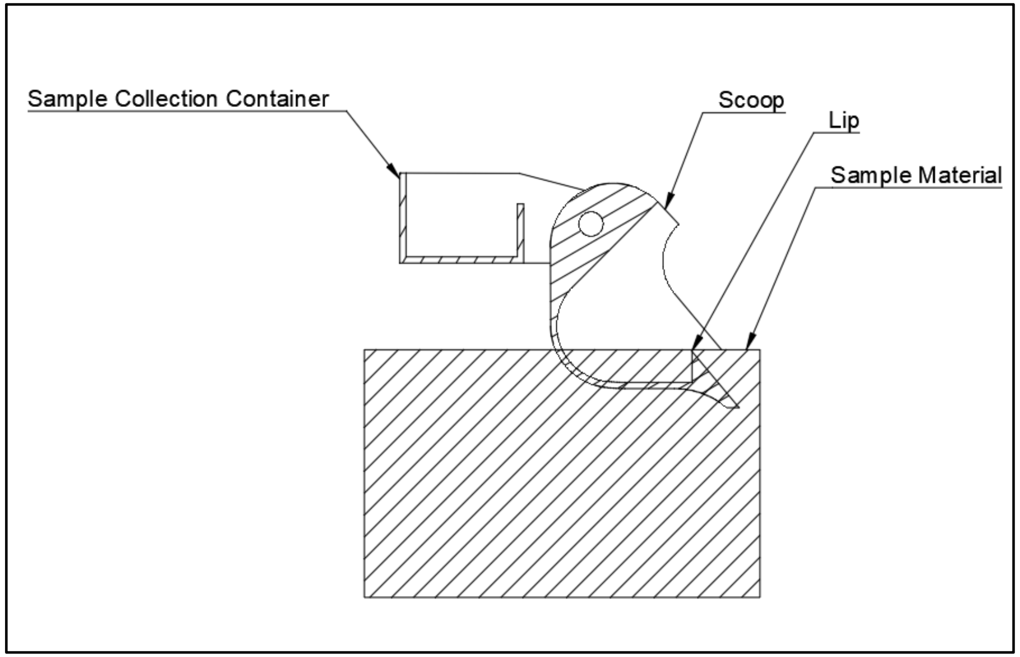
- Tank Drive with treads.
- Good for rough terrain.
- Zero turn radius.
- Space efficient due to direct drivetrain
- Two sprocket wheels with two idler wheels
- Track link material is acetal with rubber inserts .
- Rubber inserts provide additional traction.

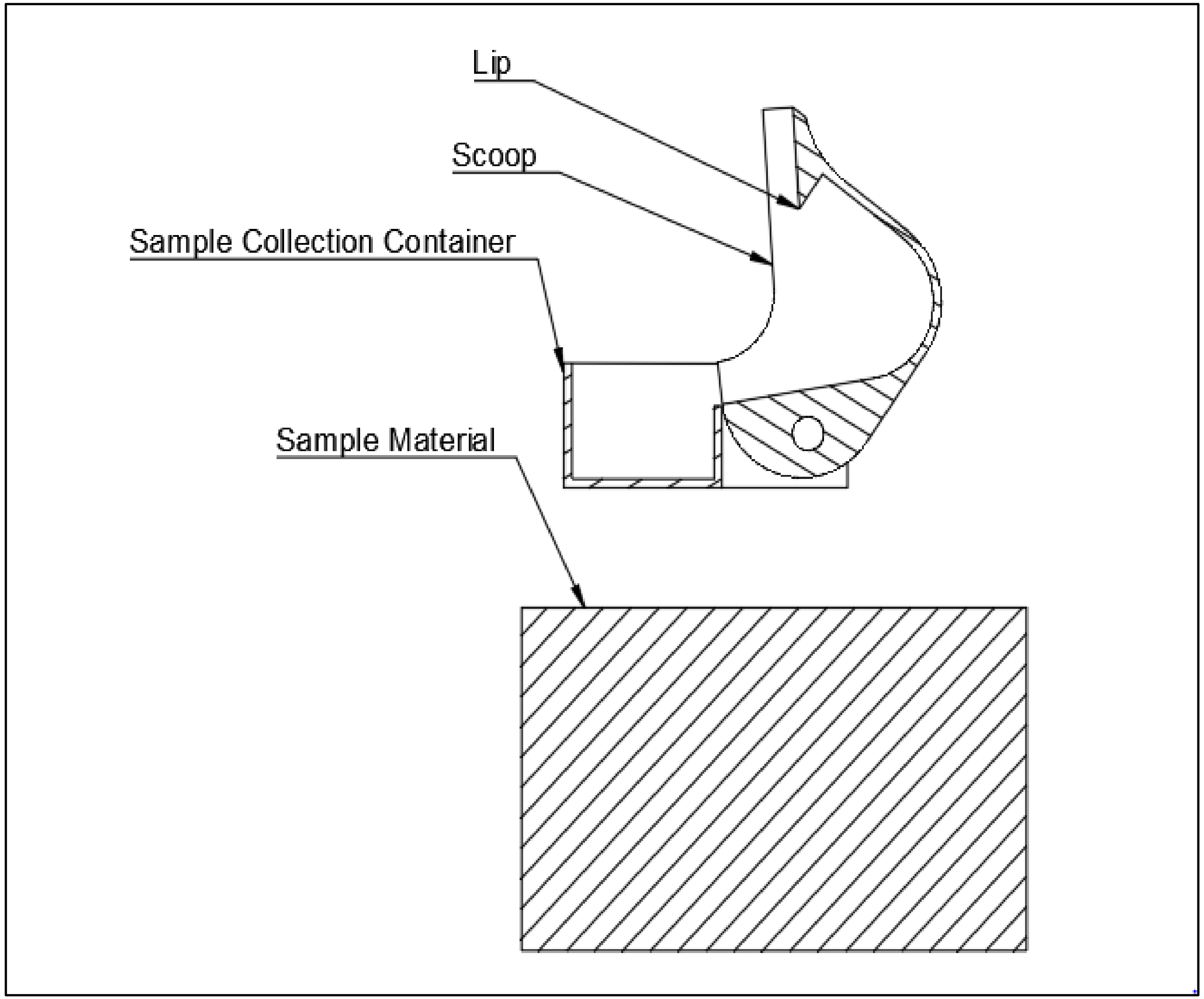




Payload Design: Sample Collection Scoop

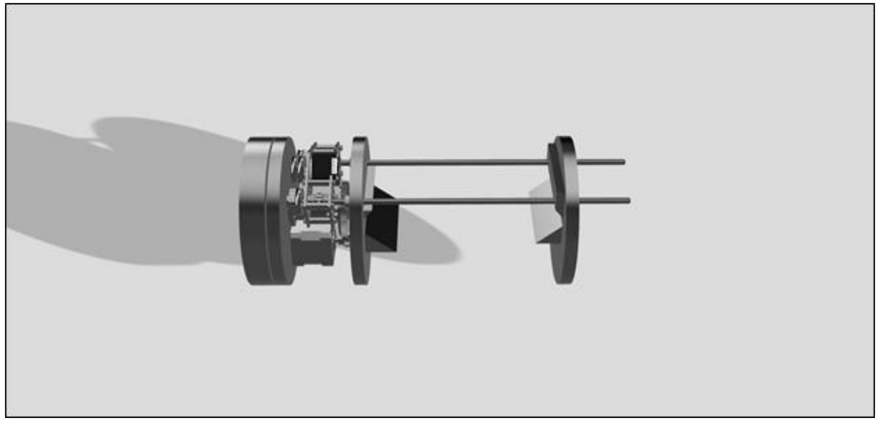
- Scoop is attached directly to the motor
- The scoop geometry prevents collected material from falling by incorporating a lip.
- Rotating the scoop backward will transfer the collected sample to the sample container.
- The scoop material is ABS which is easily 3d printed and lightweight.

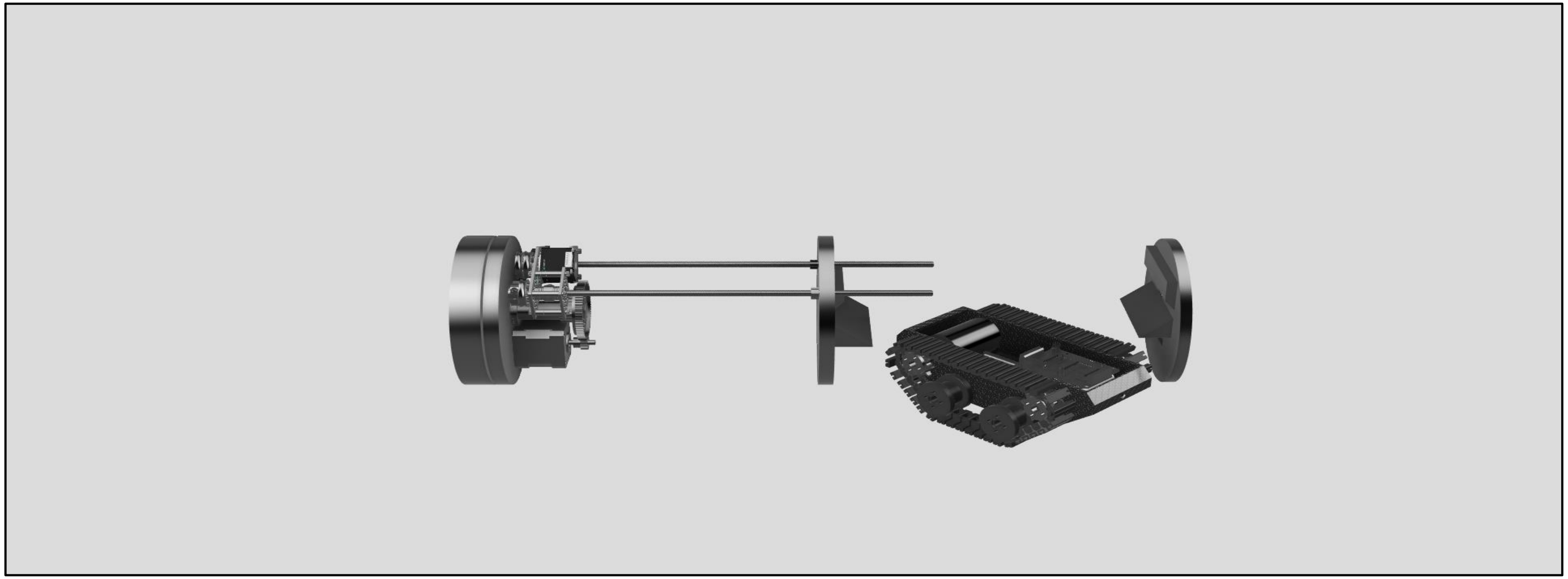




Payload Design: TEARS Overview

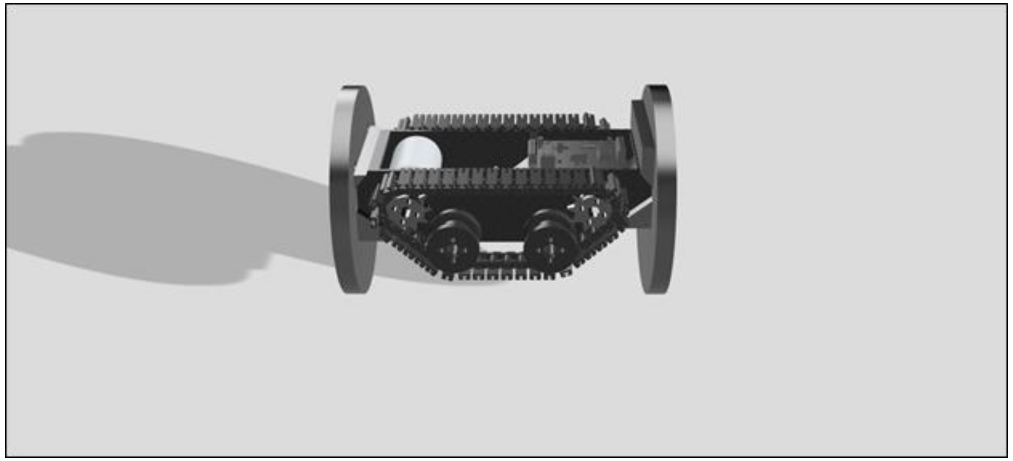
- Two plate retention mechanism
- Dual lead screw linear actuation
- Remote controlled reorientation and exiting
- Front retention mount integrated with the nose cone

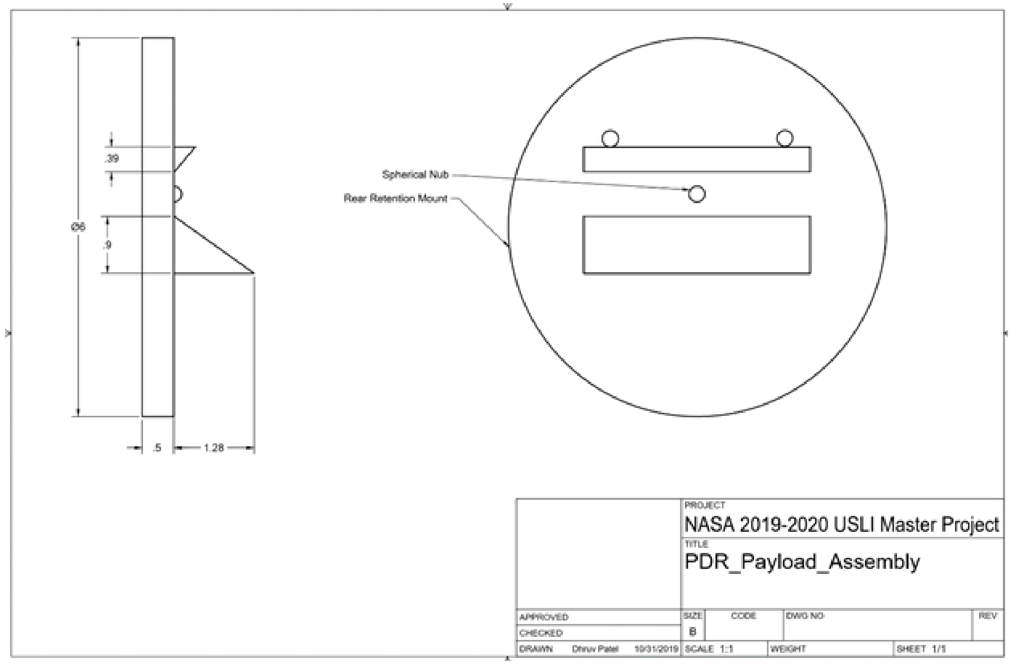




Payload Design: Retention

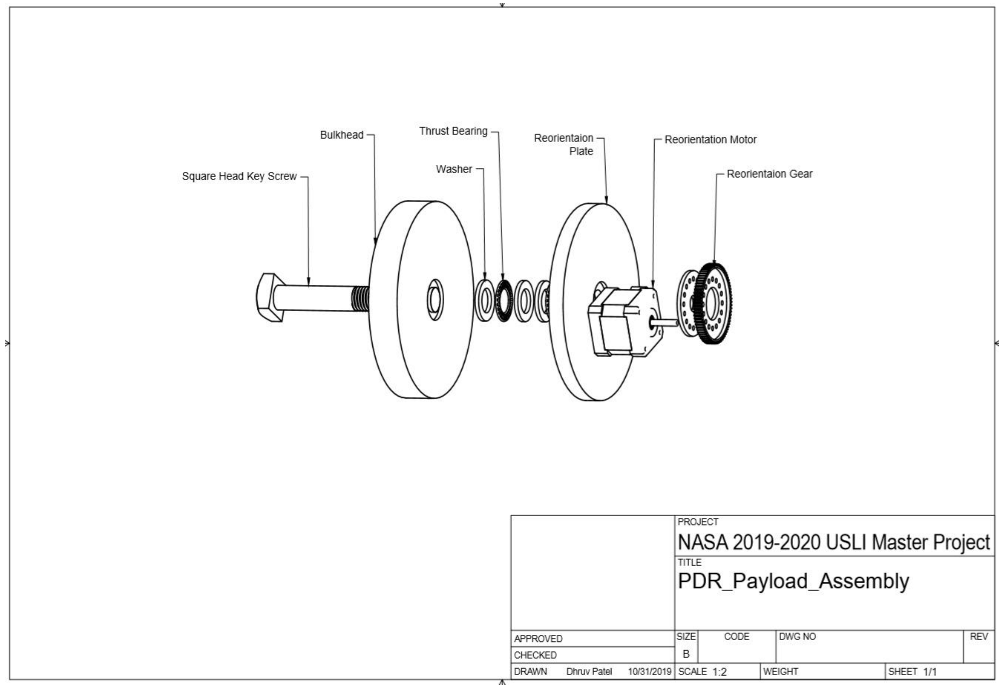
- Geometrically constrained retention mechanism.
- Retention mount with a negative profile of the front and rear end of payload chassis.
- Spherical nubs in the center of the retention mount attach to matching hole in payload chassis, preventing lateral movement.
- Retention mounts will be fiberglass due to its high strength to weight ratio and low cost.

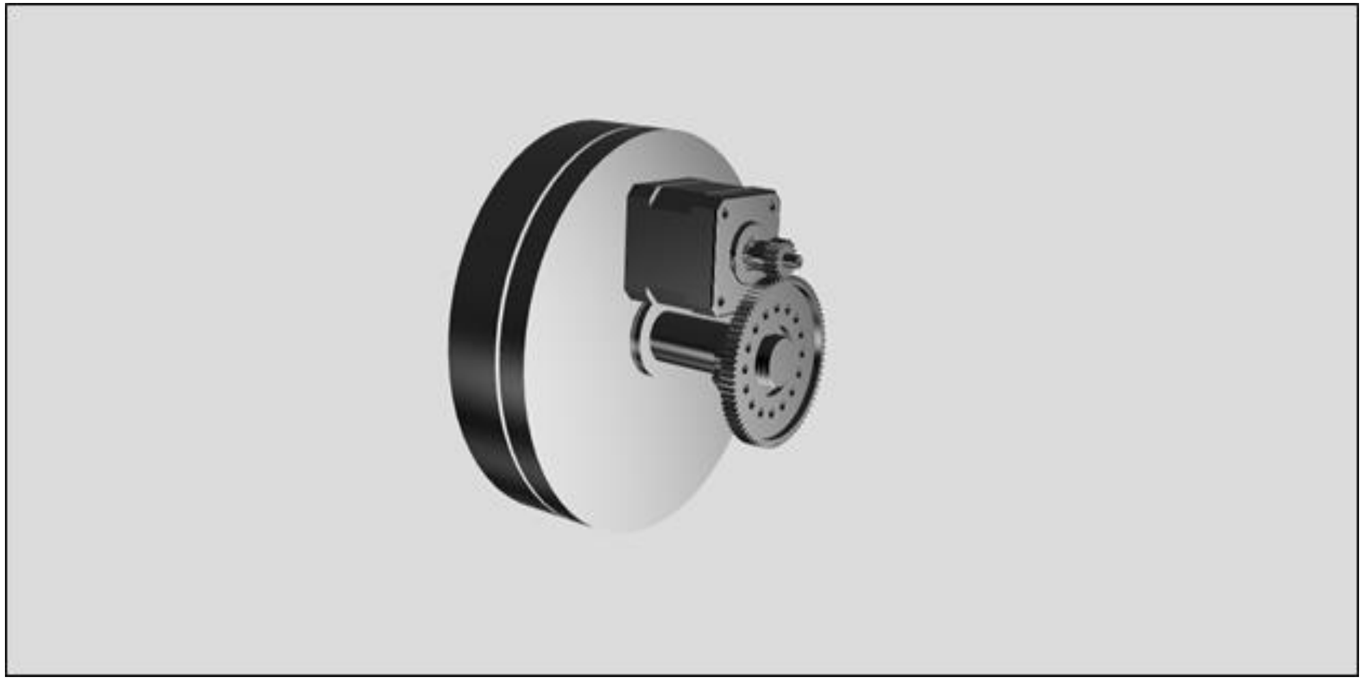




Payload Design: Reorientation

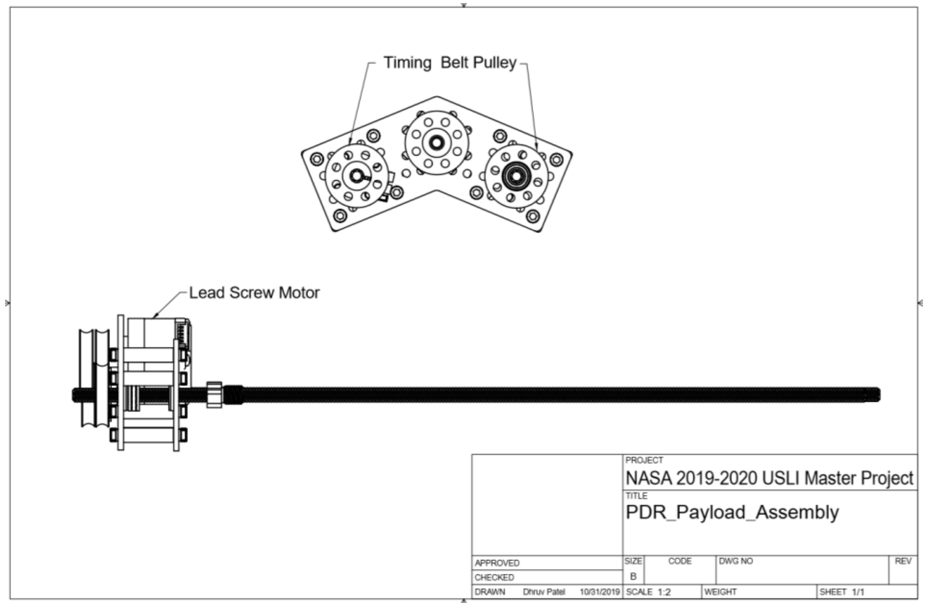
- Square head screw attaches through bulkhead and reorientation plate and prevents rotation
- Thrust bearings allow for axial rotation
- Motor mounted on reorientation plate rotates around fixed gear

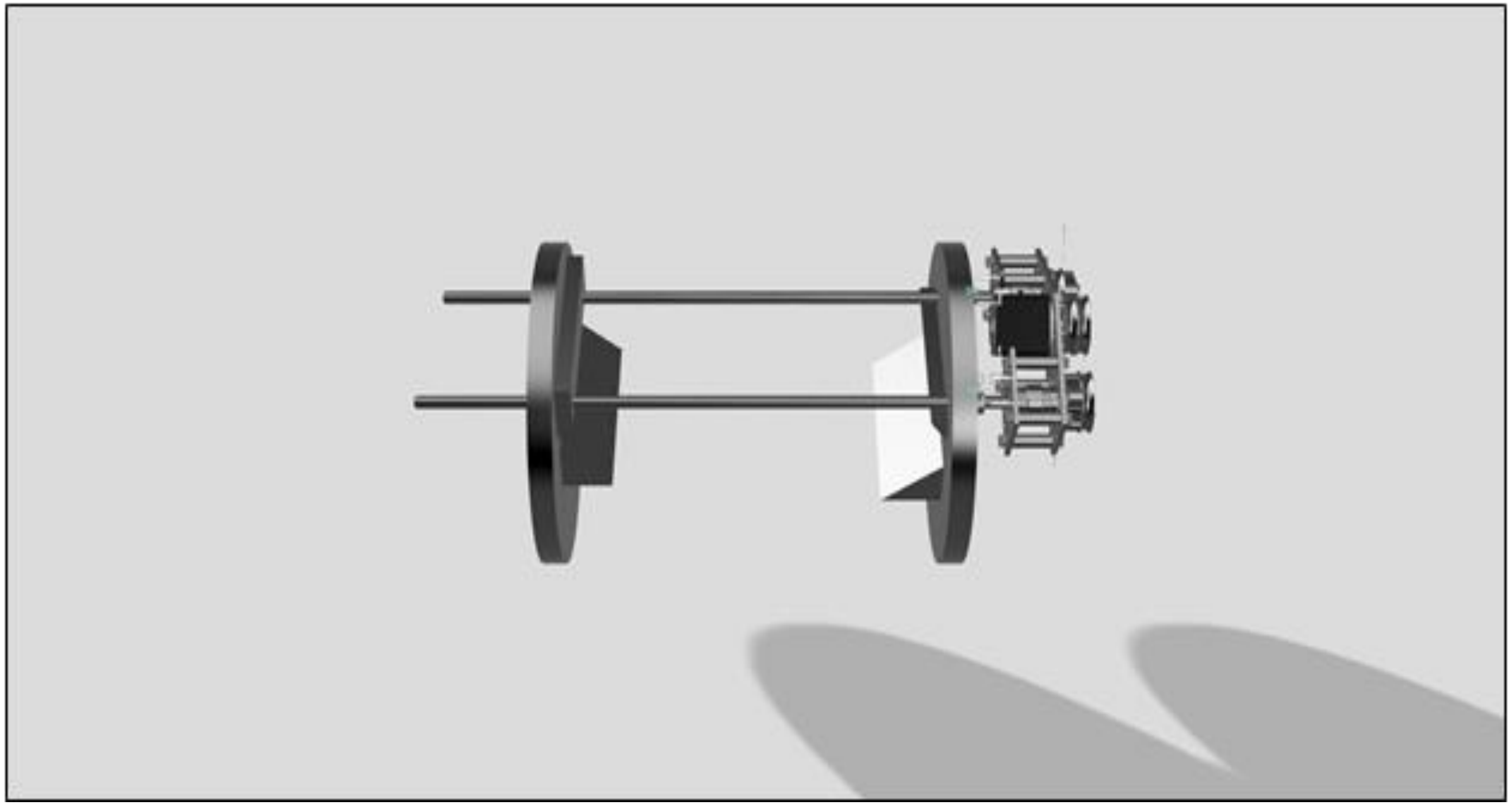




Payload Design: Exiting

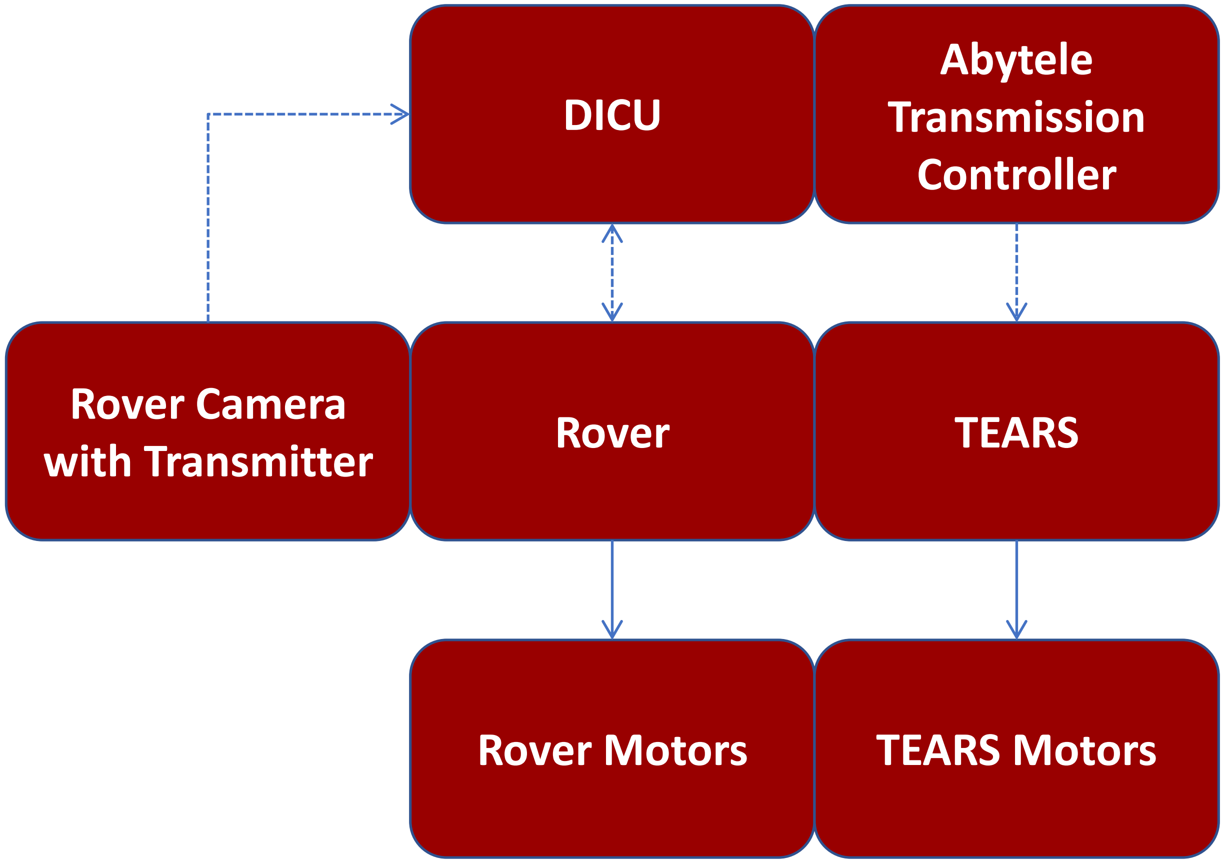
- Dual lead screw linear actuator
- Direct payload-nosecone attachment
- Torque amplification via gear power transmission
- One motor actuation to ensure both leadscrews rotate in unison
- Steel screws to ensure rigidity





Payload Design: Electronics

- Rover video fed into 3.5” DICU display via FPV Transmitter
- Rover data fed into 7” DICU display via XBee
- DICU input controls rover motors through XBee
- Rover XBee provides transmissions to the Raspberry Pi Zero W which in turn is connected to a motor controller to control motors.
- TEARS will receive communications through the Abytele Receiver
- Receiver will send bursts of 3.3 volts to the Raspberry Pi Zero W whenever the Transmission controller specifies, it then tells the motor controller to drive the motors when voltage bursts occur



Requirement Compliance Plan

Description	Verification Method	Verification Plan
The launch vehicle will not surpass a weight of 50 lbs.	Inspection	The weight of the rocket affects our motor selection and maximum height above ground level (AGL). Lightweight materials will be chosen, and a strict mass budget will be enforced for all subsystems.
The vehicle will reach the target apogee of 4,500 ft with the payload and active VDS.	Testing Demonstration	Simulations will be produced in OpenRocket and hand calculations will be conducted to verify the flight profile. A full-scale launch with the payload and VDS prior to the competition will be completed.
The launch vehicle will reach the target apogee within 250 ft.	Testing	A subscale launch that is closely modeled after the full-scale launch will be used to verify the apogee during flight. A tolerance of ±250 ft is specified.
The vehicle will withstand the launch, flight and landing forces.	Testing Analysis	FEA and CFD simulations along with testing will ensure that the airframe and fins do not rupture during flight.

Requirement Compliance Plan

Description	Verification Method	Verification Plan
The telemetry bay will not interfere with payload deployment.	Inspection	The Recovery team will work closely with the Payload team in order to ensure their designs work in conjunction with one another.
The electronic tracking equipment will not have its signals blocked by sections of the rocket.	Inspection Testing	The telemetry bay will not be surrounded in metal or be housed in a section of airframe or nosecone that is made of carbon fiber or is painted with metallic paint, which would block RF signals of the GPS transmitter. Ground tests and test flights will also verify the transmission of RF signals to the ground receiver.
The electronic tracking equipment will send data to a ground receiver, which will not receive interference from other electronics tracking equipment on other rockets.	Inspection Testing	The tracking system will be connected or coded in such a way that the receiver in use by the SBU team only receives data from the proper GPS tracking device.
The parachutes will not only be deployed by the expansion of hot gases alone but will be assisted by a mechanical ejection mechanism as well.	Inspection Testing	Parachute deployment will be assisted by pistons that will push the parachutes out of their respective bays. Ground testing and flight tests will ensure the system works.
The parachutes will not be adversely affected by hot ejection gases.	Inspection	The parachutes will be protected by an object or device as nylon parachutes are susceptible to burning or melting.

Requirement	Verification Method	Verification Plan
The rover must be reoriented to drive orientation before full deployment.	Demonstration	The reorientation system will be activated prior to full deployment of the rover.
The exiting and reorientation system, and the rover will be remotely controlled.	Demonstration	RF transmitters and receivers with appropriate range requirements will be used to control TEARS and the rover.
The rover must have the ability to traverse difficult terrain.	Testing	The tank tread design will be driven on various terrains under wet and dry conditions.
The sample collection unit must have the ability to perform collection multiple times	Demonstration	The sample collection scoop will have a generated path that allows transfer of collected sample to a storage container so that collection can happen again if necessary.
The payload batteries must be able to provide power to all electronics for a minimum of 45 mins.	Testing	Different batteries will be put through timed test under launch ready configuration set up to ensure the battery will last tat load
The payload must fit within a 6 inch diameter.	Demonstration	Electronics and batteries will be sized to optimize space within the rover.