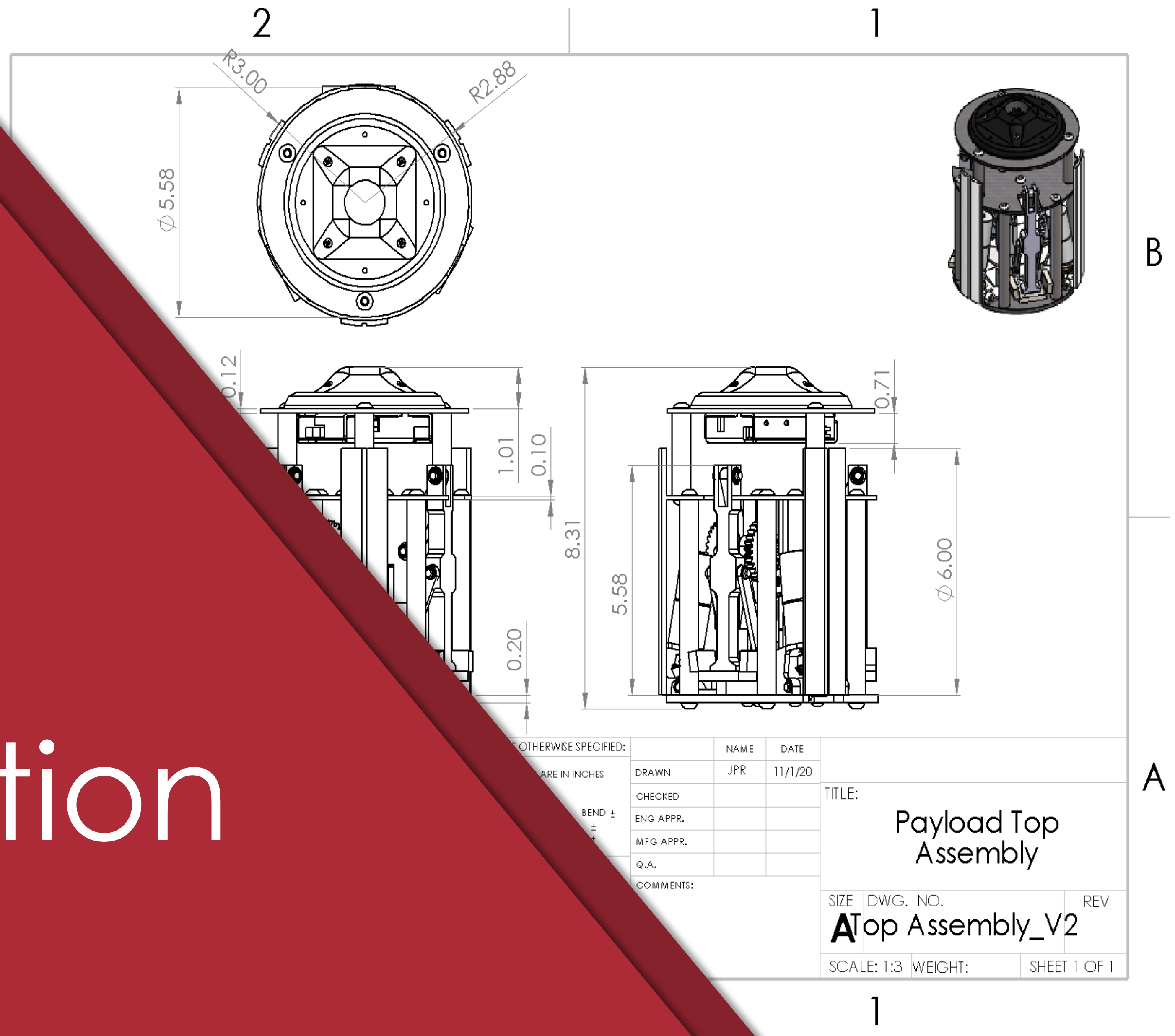
PDR Presentation

WPI HPRC

11/10/2020

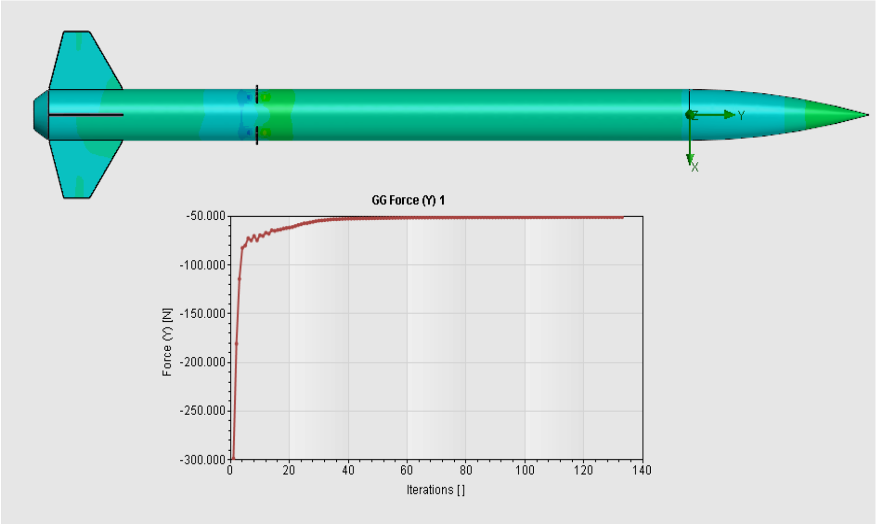


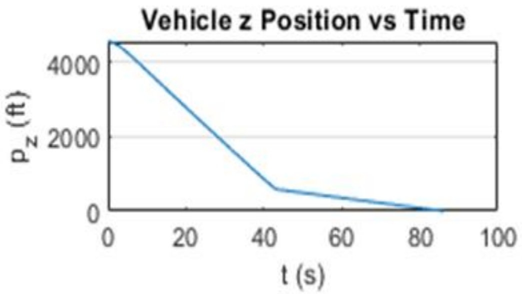
Nomenclature

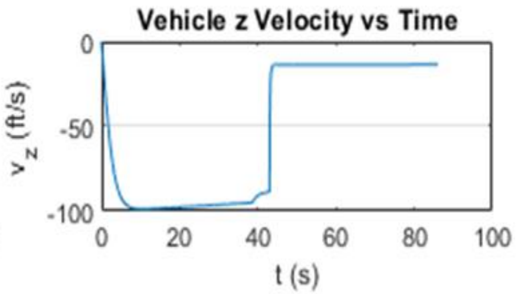
- 3D: Three Dimensional
- AARD: Advanced Retention Release Device
- ABS: Acrylonitrile Butadiene Styrene (FDM Filament)
- AGL: Above Ground Level
- AIAA: American Institution of Aeronautics and Astronautics
- APCP: Ammonium Perchlorate (Composite Solid Fuel)
- COVID-19: Coronavirus Disease 2019
- CMASS: Central Massachusetts Space Modeling Society
- CNC: Computer Numerical Control
- CTI: Cesaroni Technology Incorporated
- DOF: Degrees of Freedom
- E-Match: Electric Match
- EnP: Electronics and Programming
- FAA: Federal Aviation Administration
- FDM: Fused Deposition Modeling (3D Printing Technology)
- GPS: Global Positioning System
- HPR: High Power Rocketry
- HPRC: High Power Rocketry Club
- IDE: Integrated Development Environment (For Software Development)
- IMU: Inertial Measurement Unit
- LED: Light Emitting Diode
- LiPo: Lithium Polymer (Battery)
- LoRa: Long Range (Wireless Protocol)
- NAR: National Association of Rocketry
- NASA: National Aeronautics and Space Administration
- NFPA: National Fire Protection Association
- PC: Polycarbonate (FDM Filament)
- PLA: Polylactic Acid (FDM Filament)
- PPE: Personal Protective Equipment
- PWM: Pulse Width Modulation
- RSO: Range Safety Officer
- SGA: Student Government Association
- STEM: Science, Technology, Engineering, and Mathematics
- STM: ST Microelectronics
- TPU: Thermoplastic Polyurethane
- UAV: Unmanned Arial Vehicle
- USLI: University Student Launch Initiative
- WPI: Worcester Polytechnic Institute

Mission Performance Predictions

- Target apogee set to 4550 ft
  - Current calculated apogee is 4912 ft
  - Airbrake system capable of reducing apogee by ~400 ft
- Vehicle will descend in 86.1 seconds
  - Maximum landing KE is 64.0 ft*lbf
  - Payload descent time: 67.7 sec
- Vehicle will drift 2526 ft at 20 mph winds

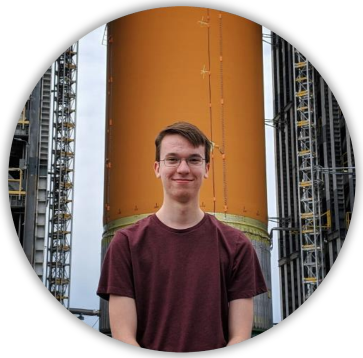






Officers

Captain
Kirsten Bowers



Rocket Lead
Troy Otter

Payload Lead
Thierry de Crespigny

Safety Officer
Michael Beskid

Treasurer
Kevin Schultz

Sponsorship Officer
Julia Sheats

Engagement Officer
Connor Walsh

Logistics Officer
Nikita Jagdish

Public Relations Officer
Chris Davenport

Documentation Officer
Max Schrader

Launch Vehicle

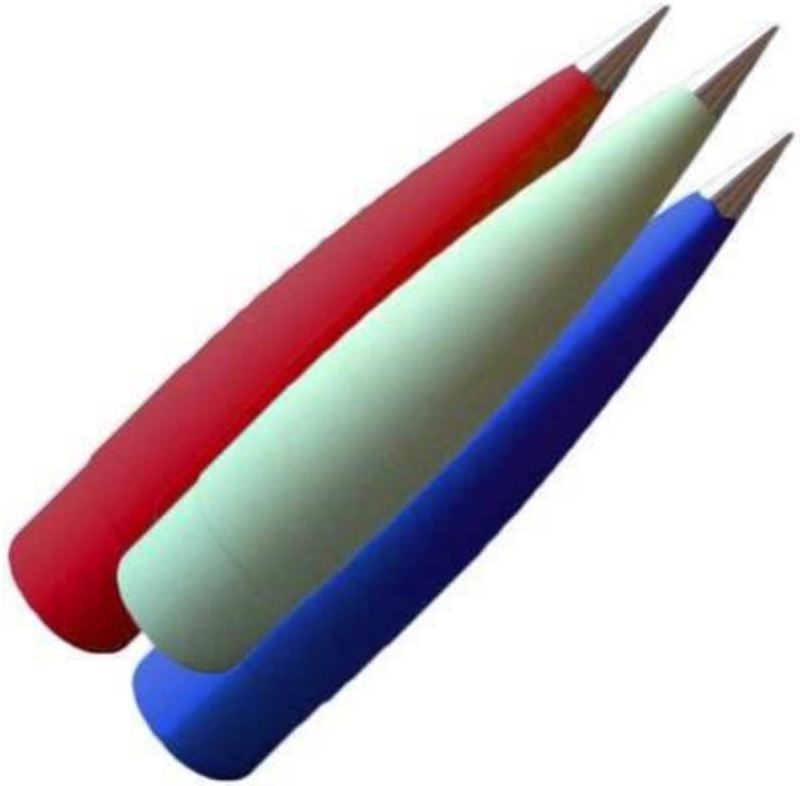
Launch Vehicle Overview

- Length: 108 in
- Diameter: 6.17 in
- Cg: 64.98 in
- Cp: 83.77 in
- Stability Margin: 3.05 cal
- Vehicle Wet Mass: 49.0 lb
- Rail Exit Velocity: 62.4 ft/s
- TWR: 8.41

Aerostructures

Nose Cone

- Durable
- Weighted
- Filament Wound Fiberglass
- Tangent Ogive (4:1)



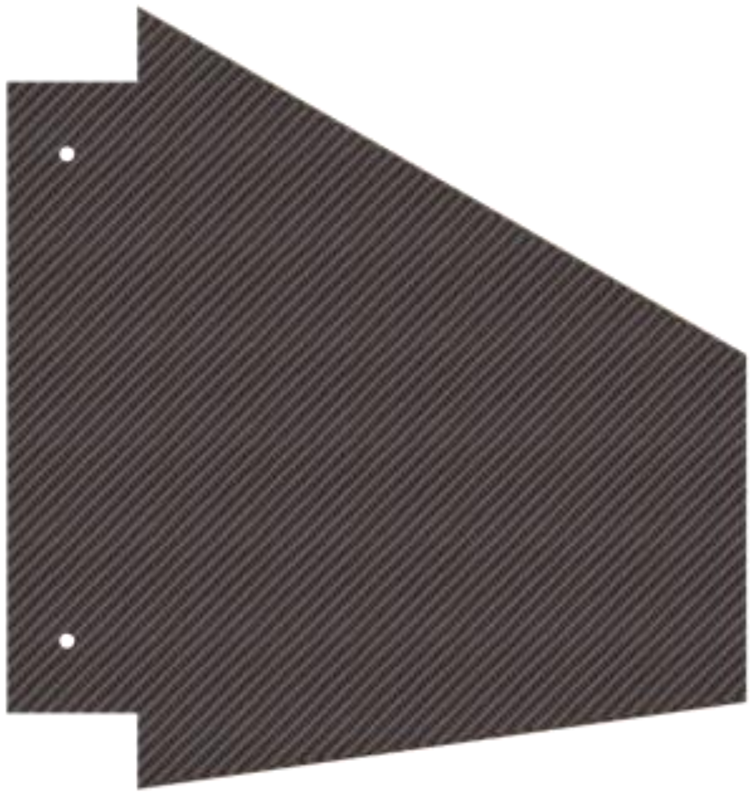
Airframe

- G12 Filament Wound Fiberglass from Madcow Rocketry
- Low Cost and Significant Strength
- Radio Transparent
- 6-inch Inner Diameter
- Attaching Assemblies Primarily with Bolts rather than Epoxy

- 3 Airframe Sections
  - 22-inch Upper
  - 28-inch Middle
  - 29.95-inch Lower

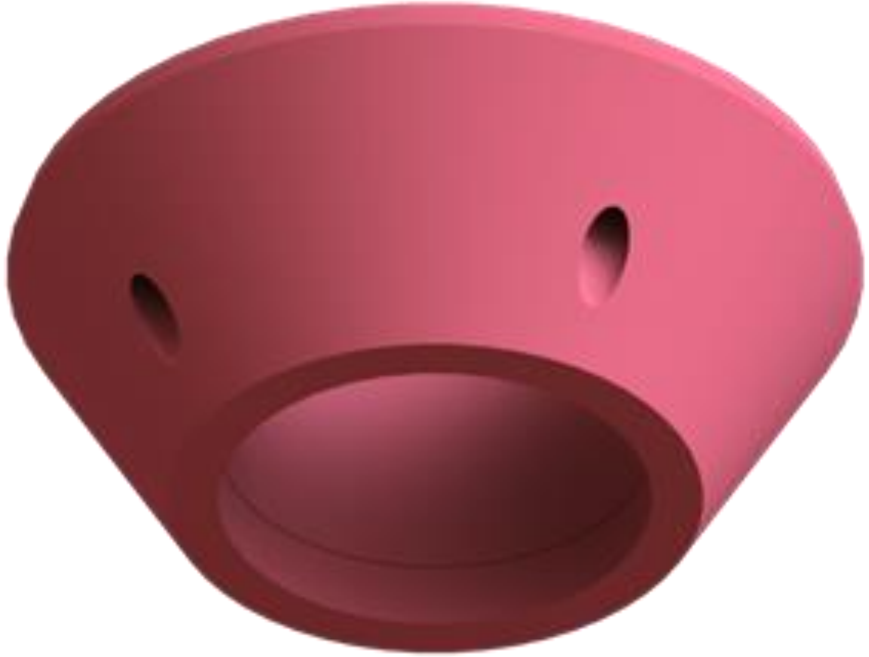
Fins

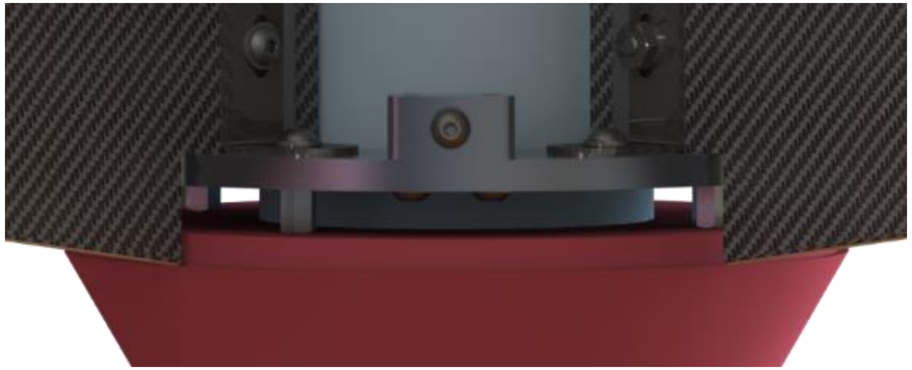
- Lightweight
- Manufacturability
- Carbon Fiber with Birch Core
- Trapezoidal Fin Shape
  - 10-inch Root Chord
  - 3.5-inch Tip Chord
  - 7-inch Height
- Rounded Edges



Tail Cone

- Lightweight and Durable
- MatterHackers NylonX Filament
- Conical Shape
- Mounted Through the Fin Ring on Threaded Standoffs

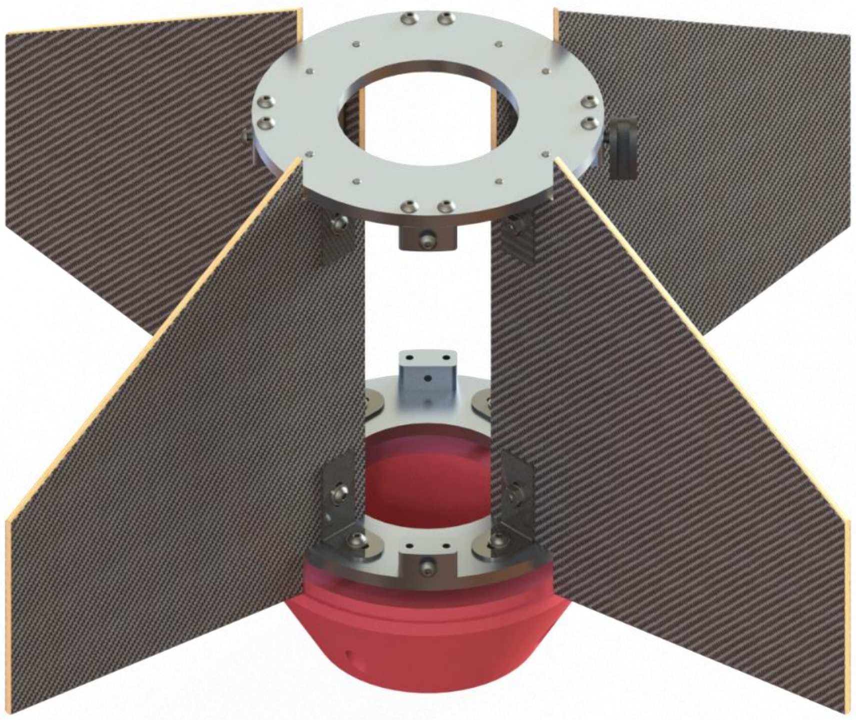




Propulsion Integration

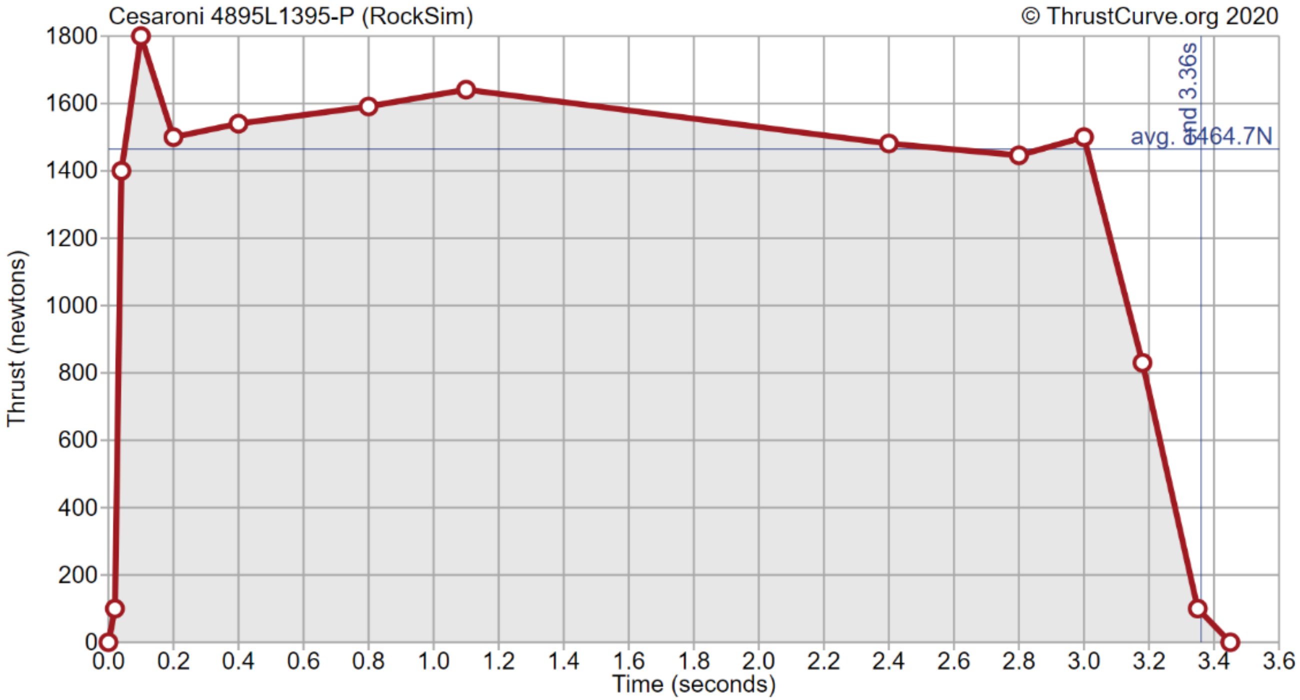
Fin Can

- Lightweight, modular, manufacturable
- Two 6061-T6 aluminum rings center the motor
- Right-angle brackets secure fins to rings
- Radial brackets secure rings to airframe



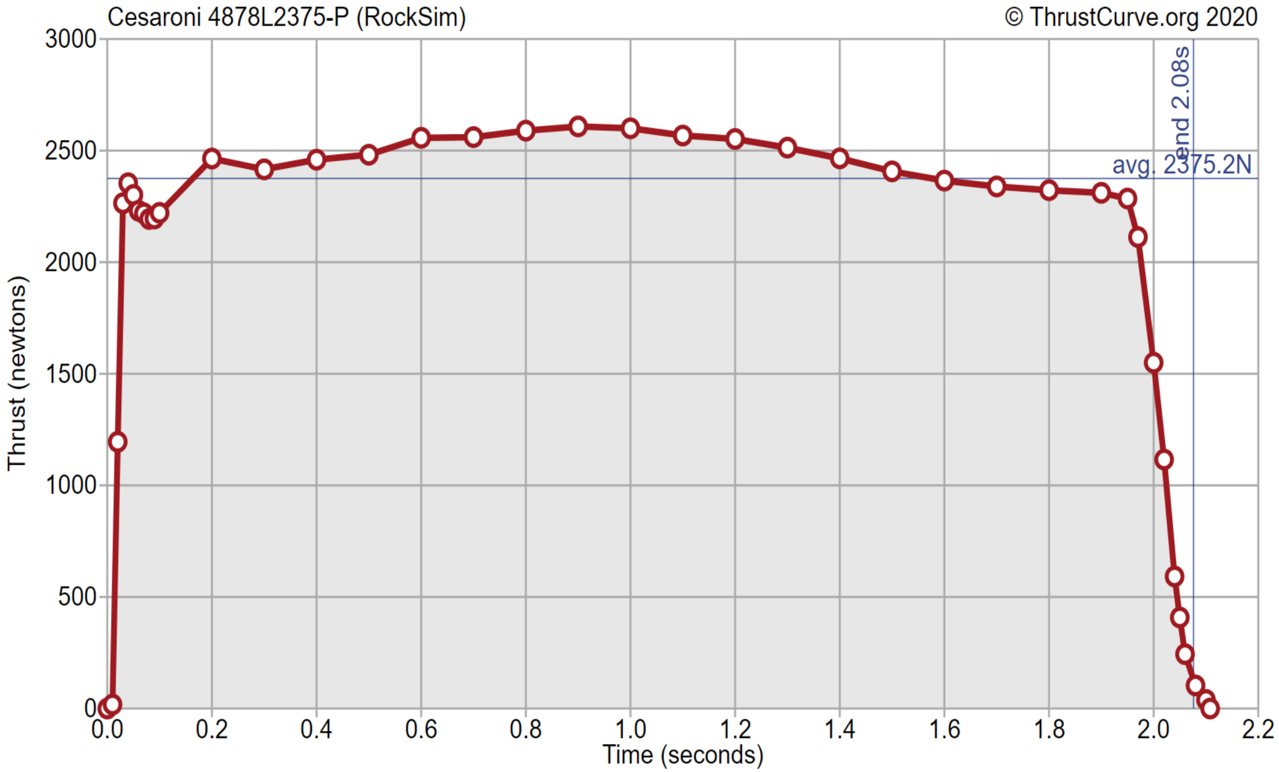
Primary Motor

- Motor: L1395
- Manufacturer: CTI
- Class: 91% L
- Avg. Thrust: 1418.86 N
- Thrust Duration: 3.45 s
- Total Impulse: 4895.40 Ns
- Weight: 4323 g



Secondary Motor

- Motor: L2375
- Manufacturer: CTI
- Class: 92% L
- Avg. Thrust: 2324.7 N
- Thrust Duration: 2.11 s
- Total Impulse: 4905.2 Ns
- Weight: 4161 g



Motor Retention

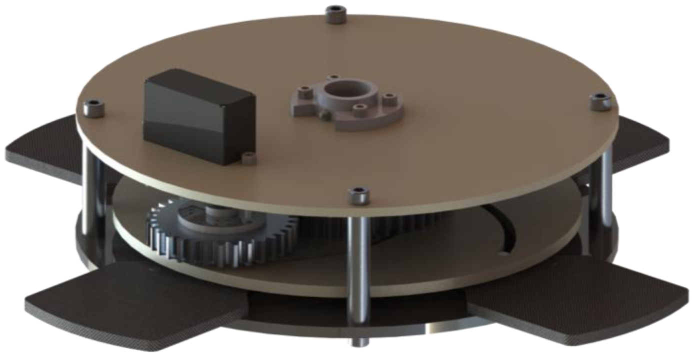
- Thrust plate centers the motor and retains its position in the airframe
- Solid bottom face separates motor heat emissions from electronics-bay above
- Radial brackets secure the thrust plate to the airframe
- Simple, multi-part assembly makes manufacturing process straightforward
- Takes advantage of threaded hole on the top face of motor

Mechanical Systems

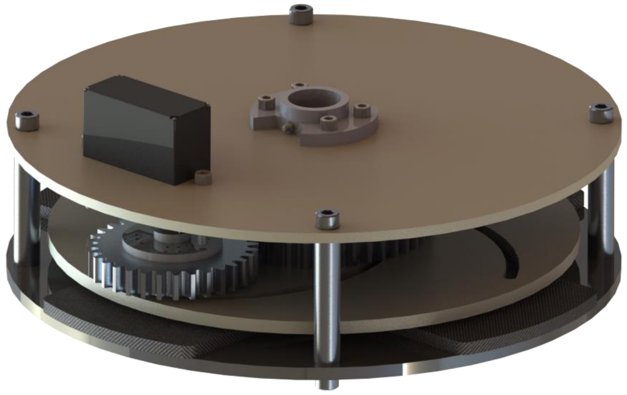
Purpose of the Airbrakes System

- The airbrakes will be deployed out of the lower airframe.
- The airbrakes can be deployed or retracted to vary surface area changing the amount of drag produced.
- This ability will allow for us to use simulation and launch day conditions data to reach our target apogee more precisely.

Airbrakes System



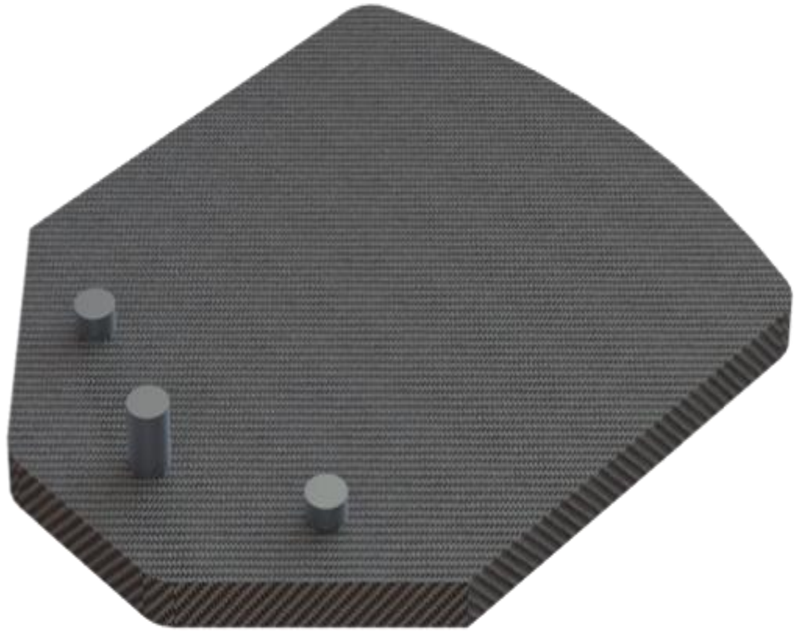
Airbrakes Open



Airbrakes Closed

Airbrake Fins

- 4 fins will be constructed out of a 1/8-inch carbon fiber plate that has been cut using a waterjet.
- 6061 Aluminum Guide pins of 1/8 " diameter of lengths .44" and .19 "
- Guide pins will be fit with epoxy to ensure a tight fit in the fins.



Airbrakes Actuation System

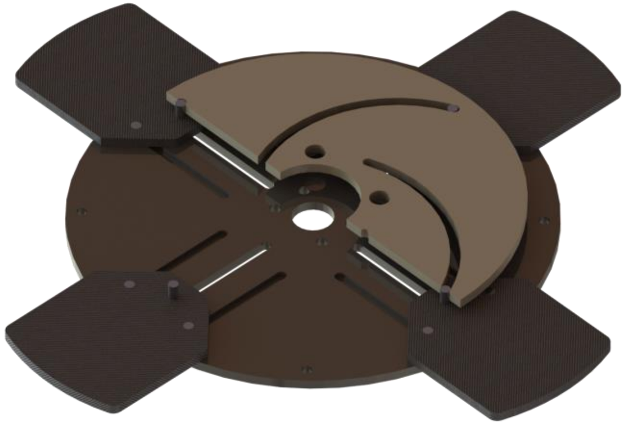
- The Actuation System consists of 2 plates.
- The guide plate which aligns and guides the fins straight out of tube.
- The actuator plate which when spun actuates the fin pins either deploying or retracting the fins.

Guide Plate (Delrin)

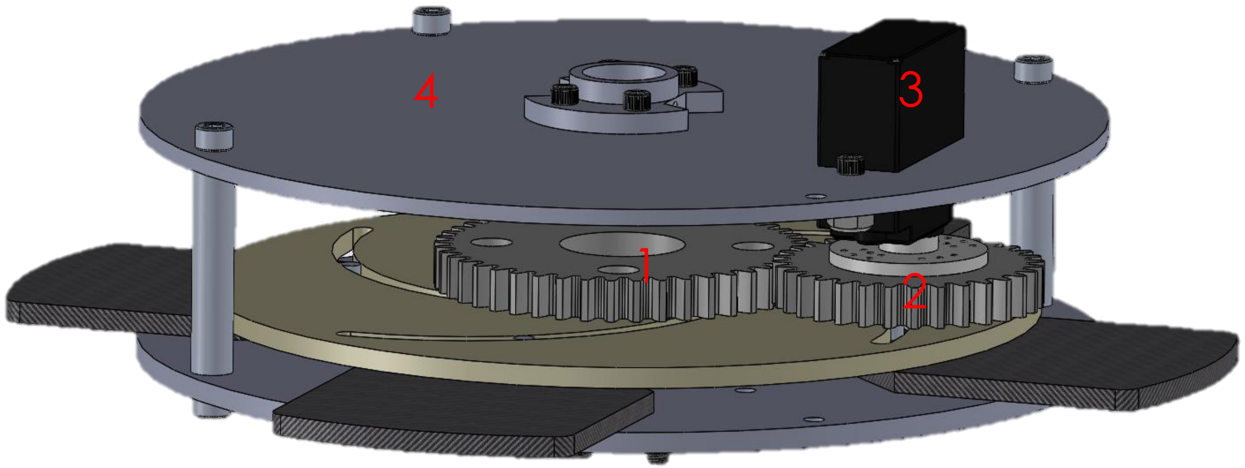
Actuator Plate (G10 Fiberglass)

Airbrakes Actuation System

- This combination of slots allows for equal deployment of the fins.
- The drag produced is easily varied by controlling the surface area exposed on the fins.



Airbrake Gear System



- Design Requirements:
  - Effective actuation of airbrakes via a servo
- Main Components:
  1. Drive Gear –Spur Gear connects directly to actuation plate via 4 pins
  2. Servo Gear- Spur Gear that meshes to the drive gear
  3. Servo - HI Tec Servo 7985MG, rated up to 10.3 in/lbs.
  4. Brace Plate – Fixes Servo in place during airbrake deployment
- Operation:
  - The servo spins in the opposite direction relative to the desired movement of the actuation plate.

Gearing Solutions

- Throughout our design process, we considered:
  - Bevel Gearing– Figure 1
  - Worm Gearing – Figure 2
  - Spur Gearing – Figure 3

Figure 1

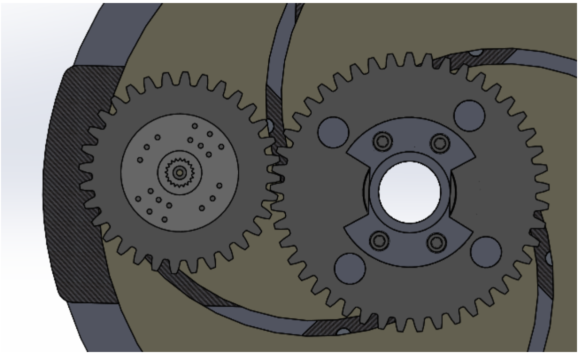
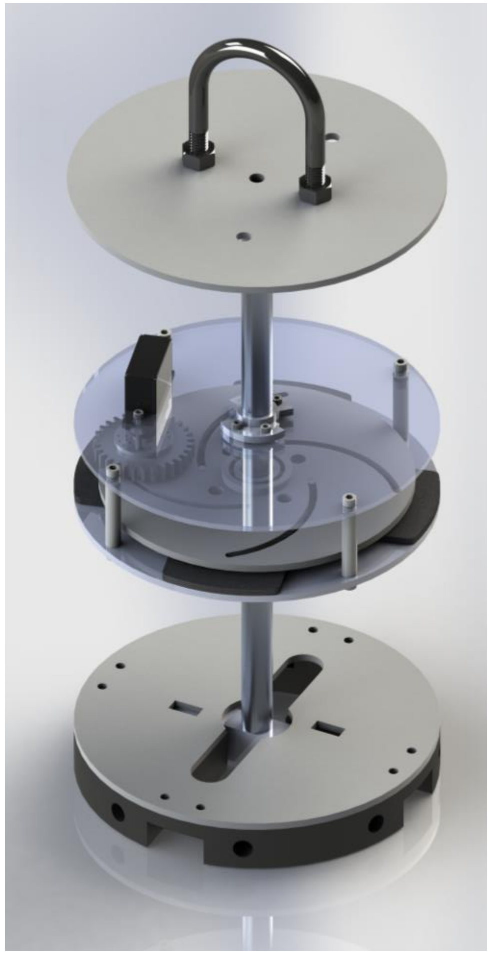


Figure 3

Figure 2

Airbrakes Avionics Bay Integration

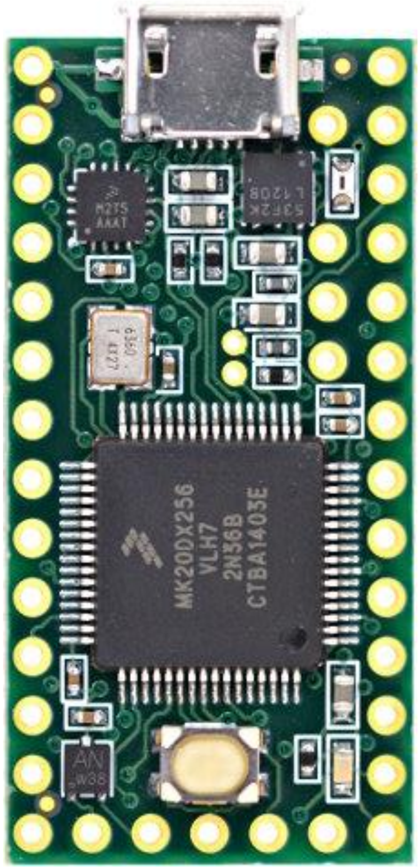
- The airbrake system will be attached to a spine made of 6061 Aluminum going through the center of its plates.
- Stationary plates will be attached to the spine using spine rings made of Nylon X
- The actuator plate will spin freely around the spine using a ball bearing.



Avionics

Avionics

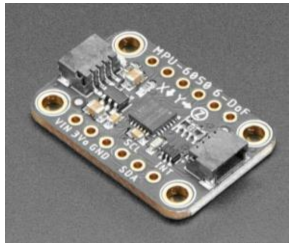
- The avionics subsystem will fulfill 3 primary functions
  - Data Logging
  - Telemetry and Tracking
  - Airbrake Control
- Runs on a Teensy 3.2 microcontroller using the Arduino environment.
- Final subsystem will use a single board solution incorporating the Teensy 3.2 microchip.

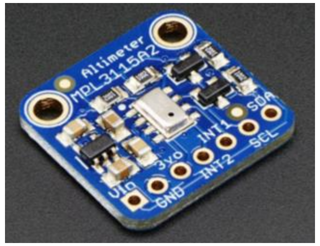


Avionics – Sensing and Data Logging

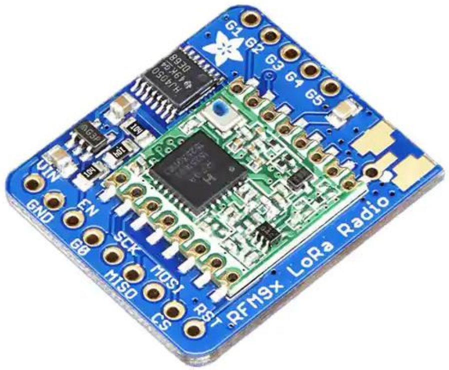
Our Avionics unit will collect data from these sensors:

- MPU 6050 Accelerometer
  - Triple axis accelerometer and gyroscope
- MPL3115A2 Barometer
  - 1.5 Pascal resolution pressure sensor
- MLX90393 Magnetometer
  - Triple axis magnetometer
- Storage device to log data, specific device TBD

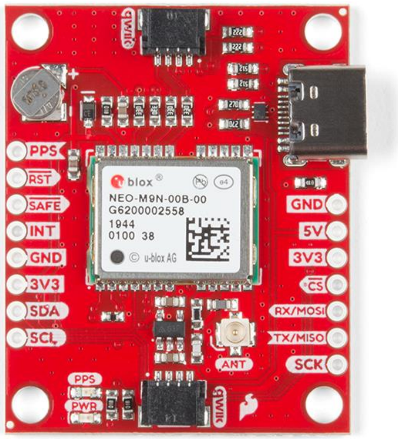




Avionics – Telemetry and Tracking



- Live telemetry
  - LoRa RFM-95W
  - 900 MHz radio version
  - Stores and transmits sensor data, position, and velocity



- GPS tracking
  - NEO-M9N, U.FL GPS
  - 10 mm GNSS antenna
  - 25Hz max update rate

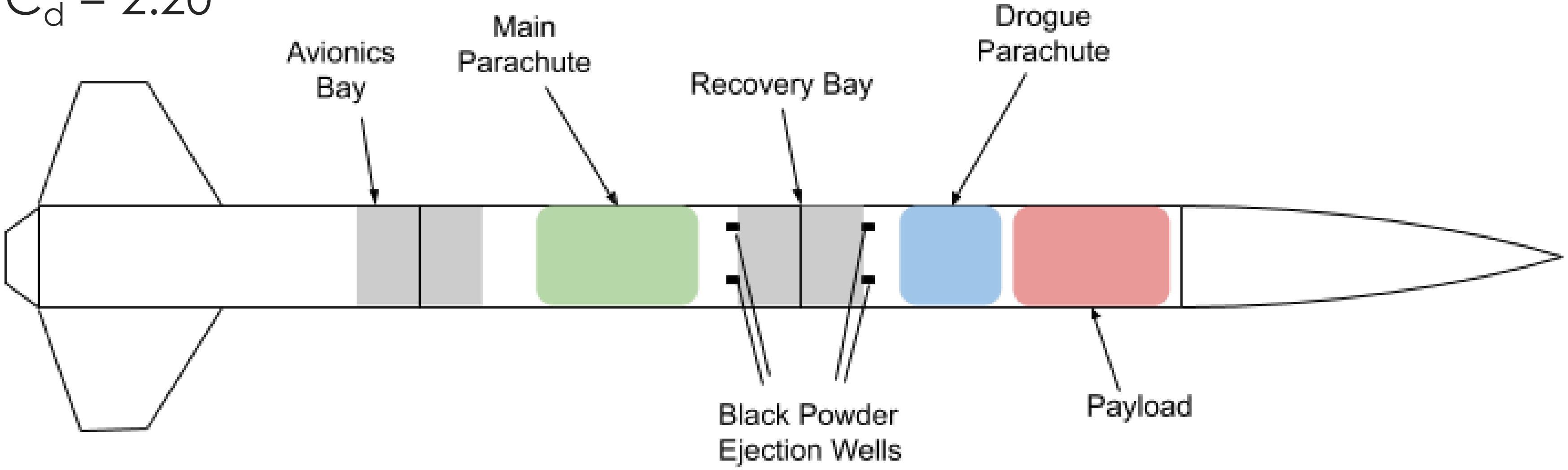
Avionics - Controls

- Multiple control algorithms are being considered.
  - Proportional Integral Derivative (PID)
  - Full State Feedback
- Before implementation, the control algorithm will be tested on a dynamical model of the vehicle.
  - The dynamical model will be written in either MATLAB or Simulink.
  - The final implementation will be in C++ within the main flight loop of the avionics board.

Recovery

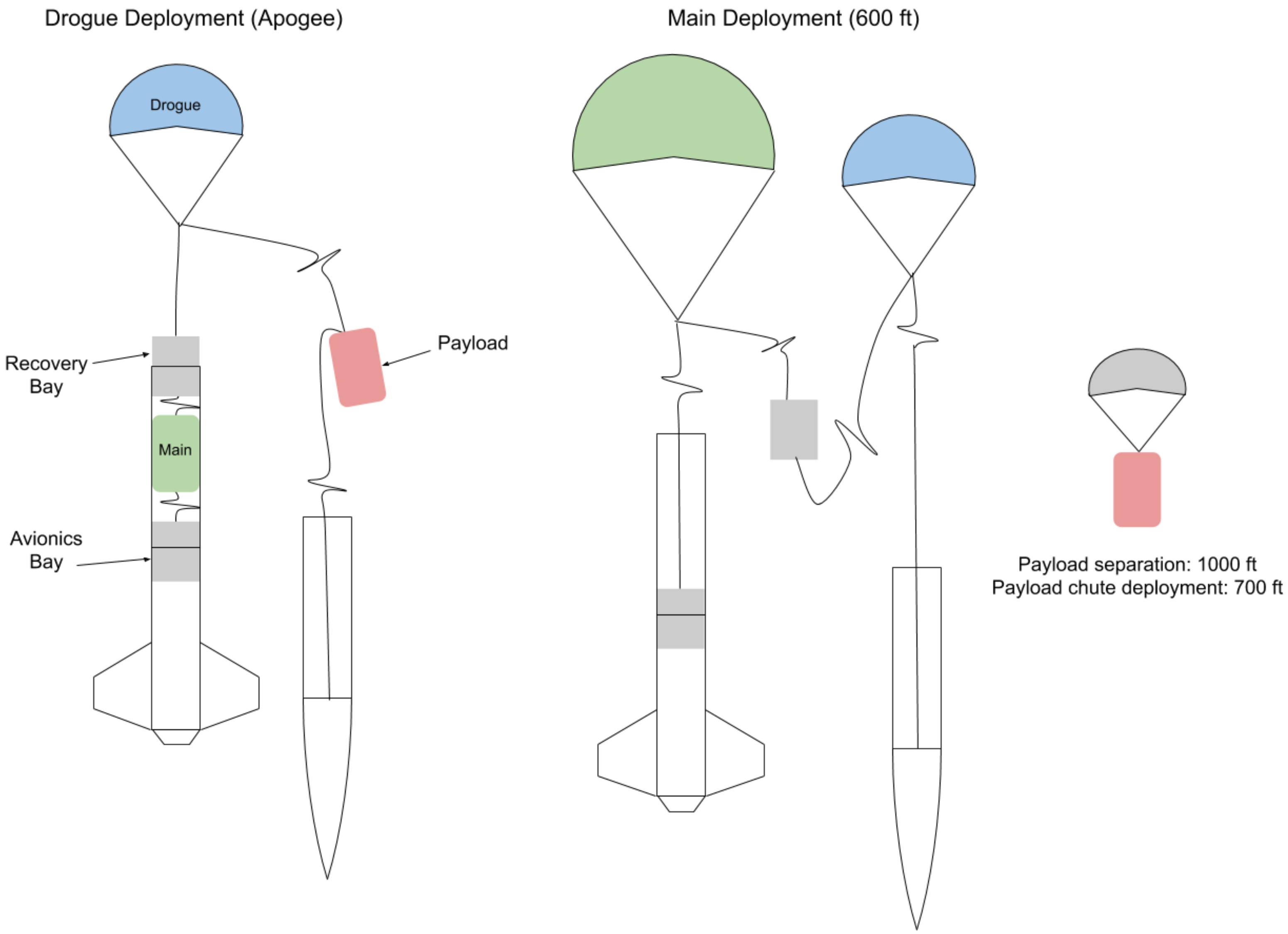
Recovery System

- Drogue parachute
  - 32 in diameter, $C_d = 0.75$
- Main parachute
  - 120 in diameter, $C_d = 2.20$



Recovery Events

- Drogue deployment at apogee
  - Altimeter will send signal for black powder to ignite and eject drogue
  - Tension in shock cord will pull payload out of airframe
- Main deployment at 600 ft
  - Altimeter will send signal for black powder to ignite and eject the main
  - Reefing ring will lengthen opening time to reduce load

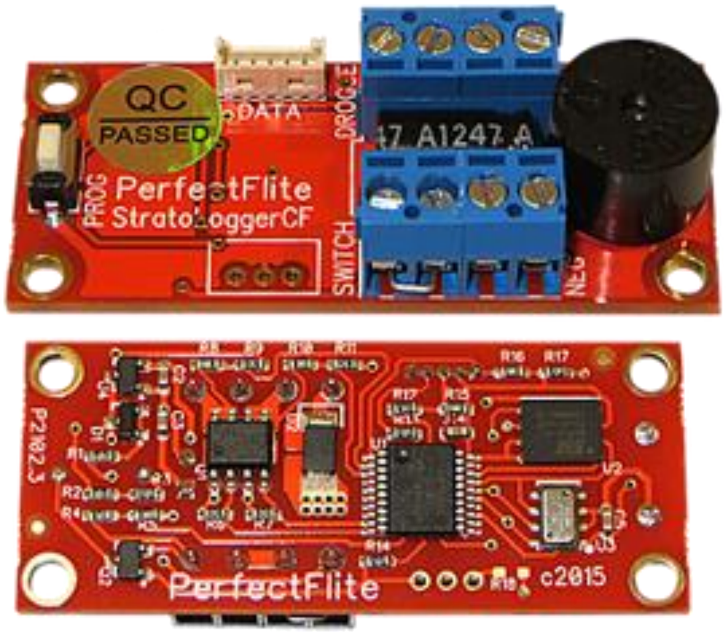

Drogue Deployment (Apogee)
Main Deployment (600 ft)
Drogue
Recovery Bay
Main
Avionics Bay
Payload
Payload separation: 1000 ft
Payload chute deployment: 700 ft

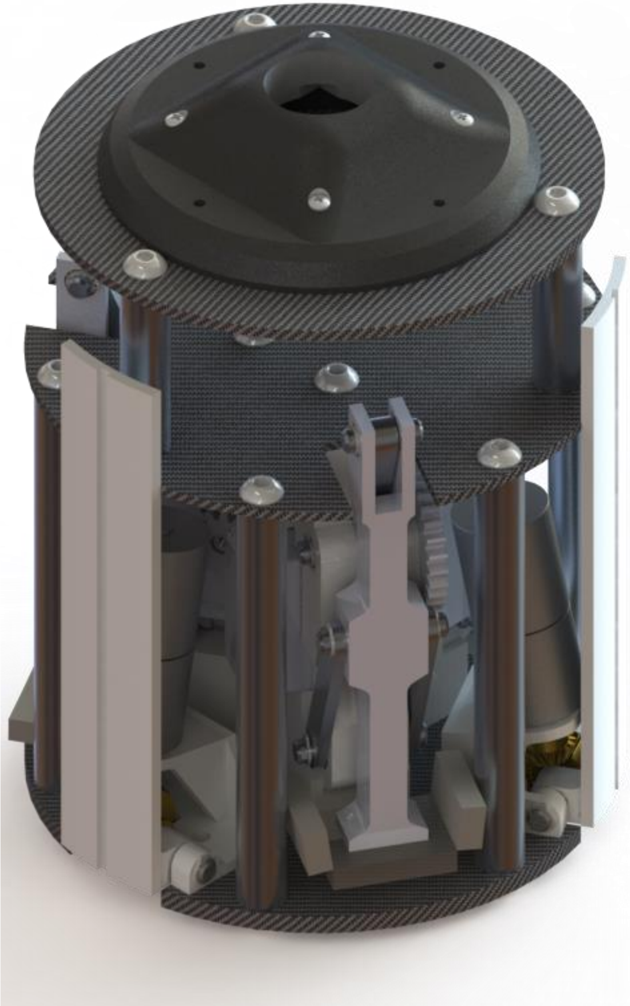
Recovery Bay

- Housed between the middle and upper airframes
- Fiberglass bulkheads take very small loads
- U-bolts are connected directly to the central spine with adapters
- Adapters and spine take most of the deployment loads
- Electronics sled houses the altimeters, batteries, and switches
- Switches accessible through the switch band

Recovery Electronics

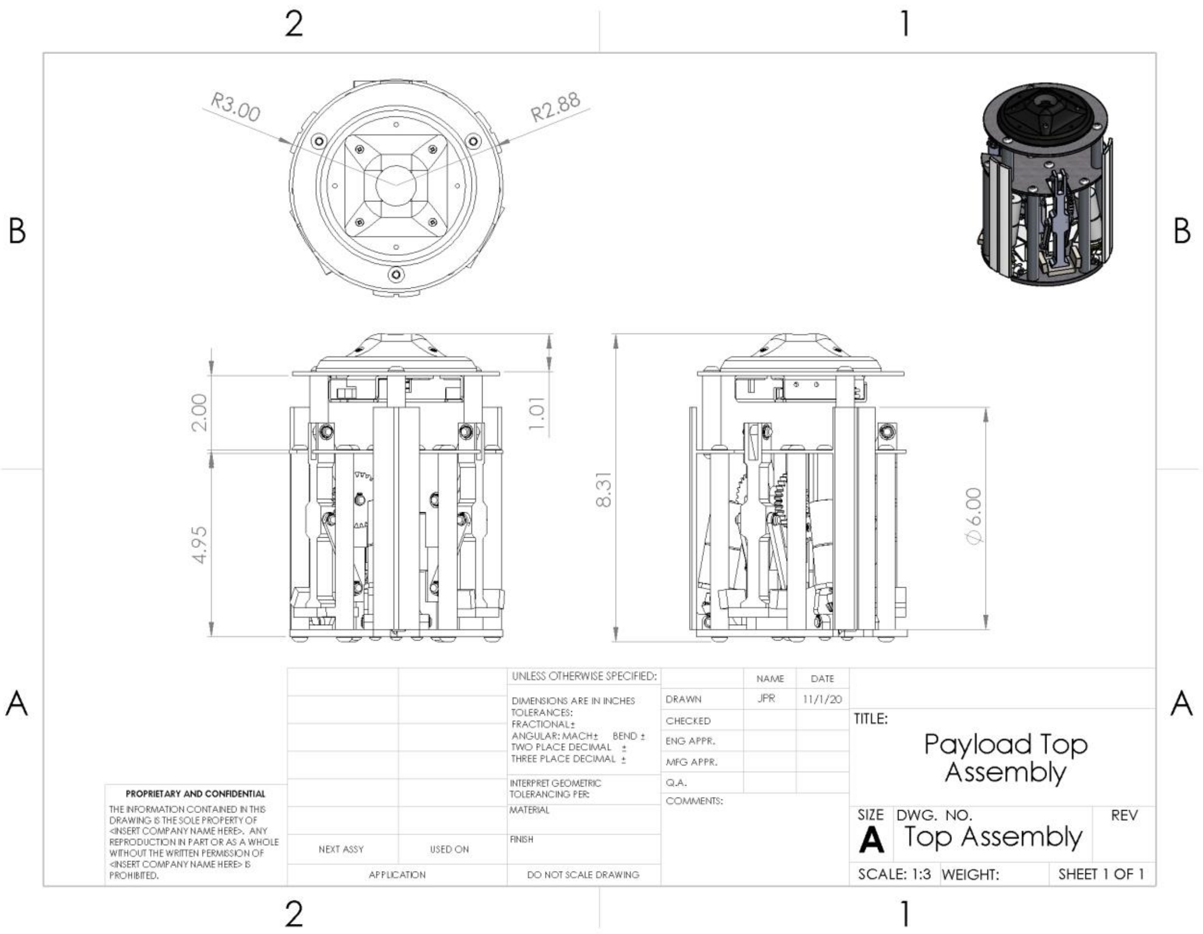
- StratoLogger Altimeters
  - Accurate and cost-effective
  - Designed for dual event deployment
- Lithium Polymer (LiPo) Batteries
  - Compact
  - More reliable than 9V batteries
  - Resistant to cold
- Apogee Rotary Switches
  - Externally wired
  - Easy to switch on/off



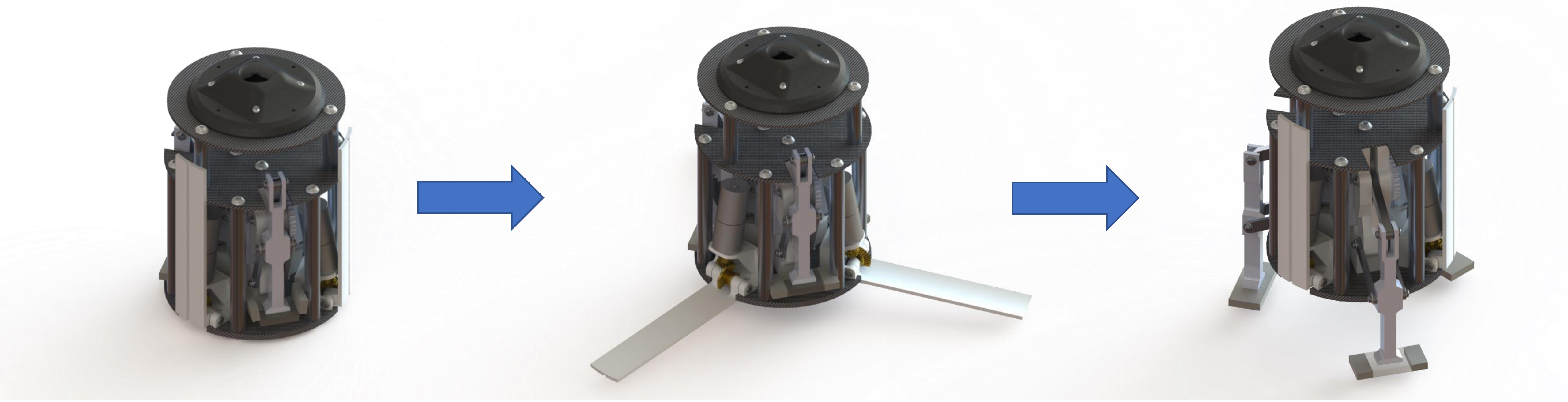


Payload

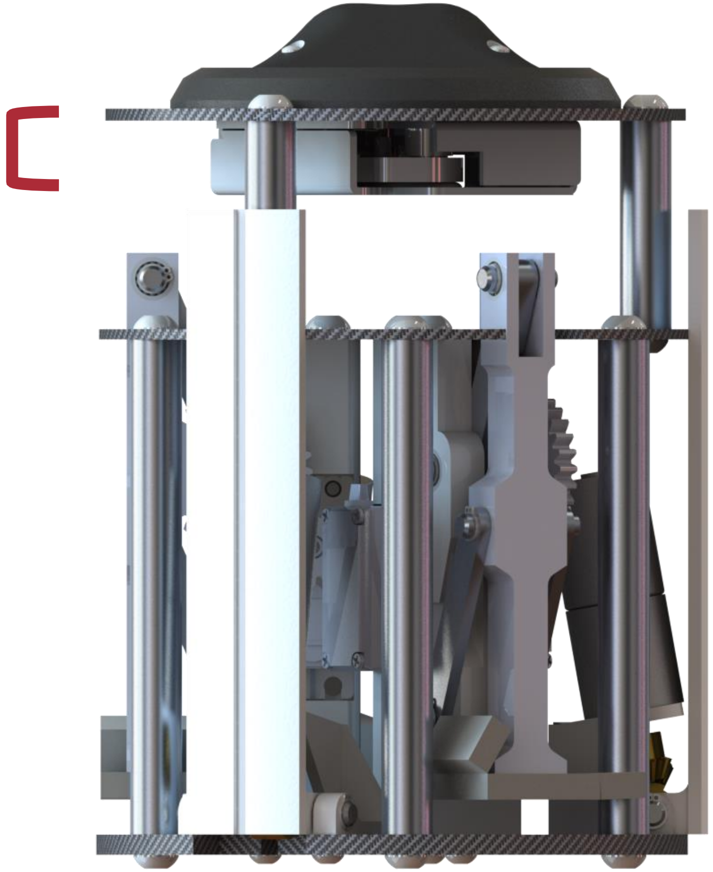
Payload Overview



Concept of Operations

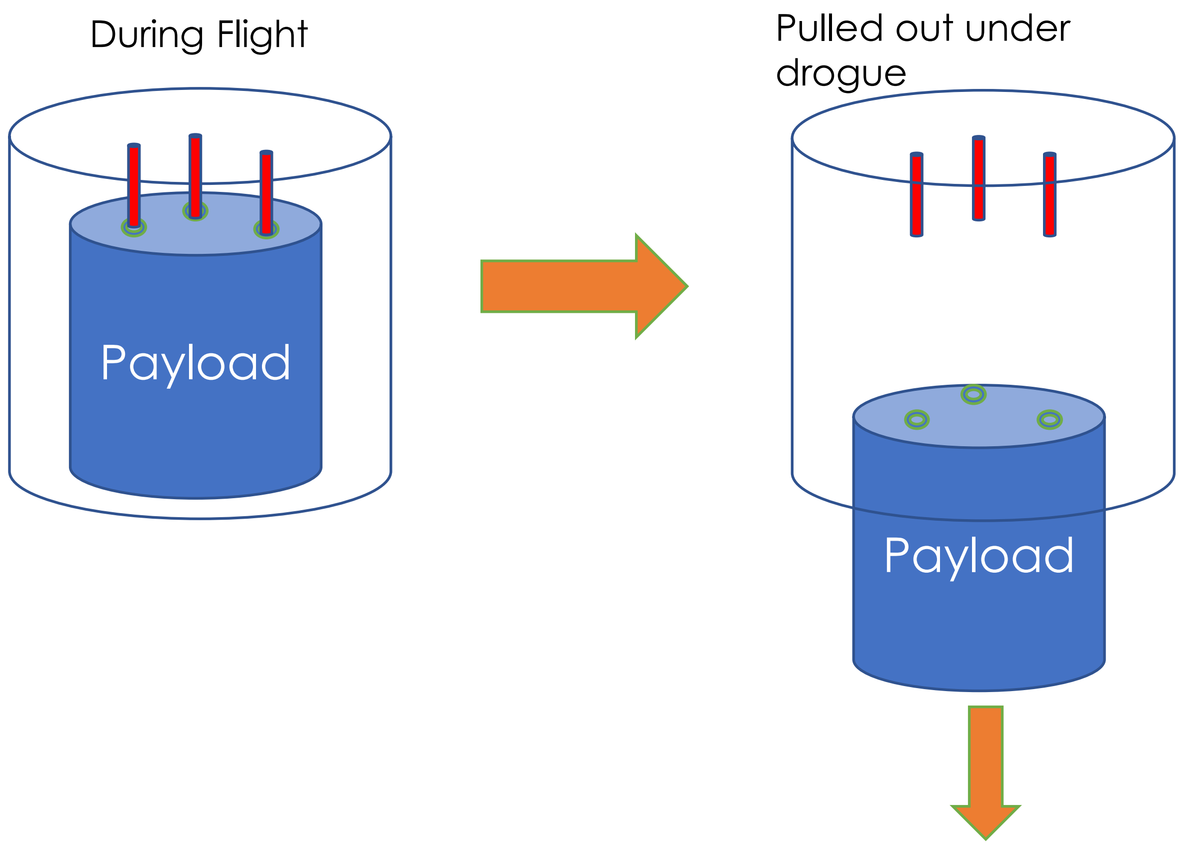


Payload Retention



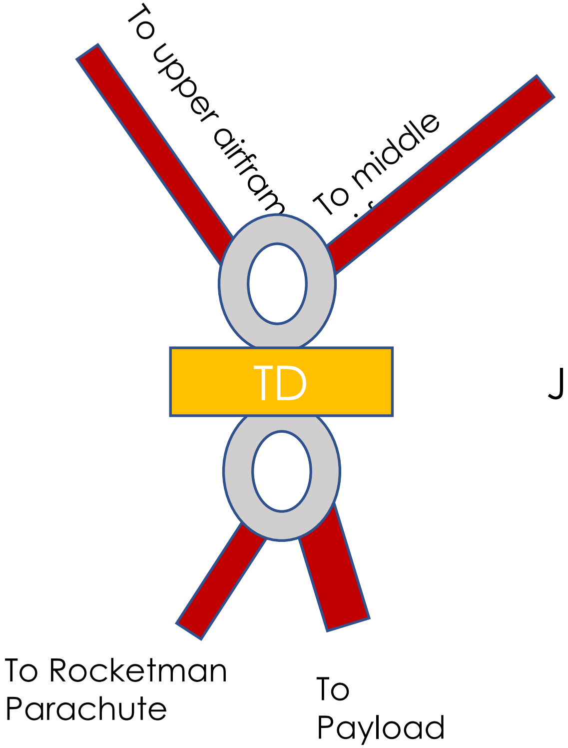
Alignment Pins

- Deployment From Body Tube
- Slides under drogue
- Restricts movement during flight

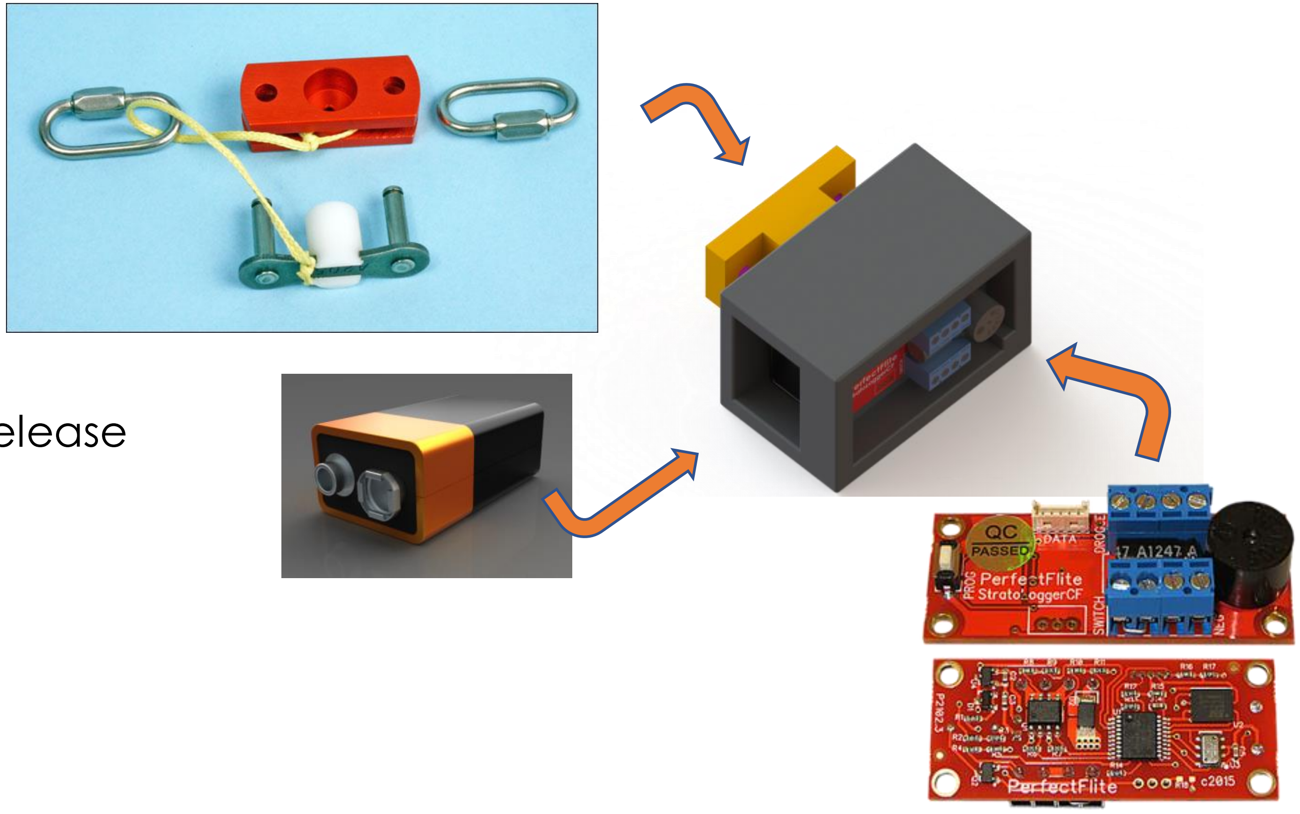


Tender Descender Payload Release

- Tender Descender Package

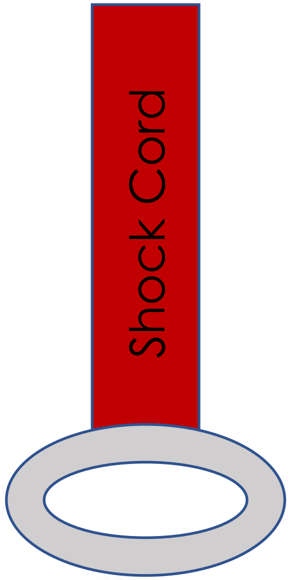


Jolly Logic Chute Release

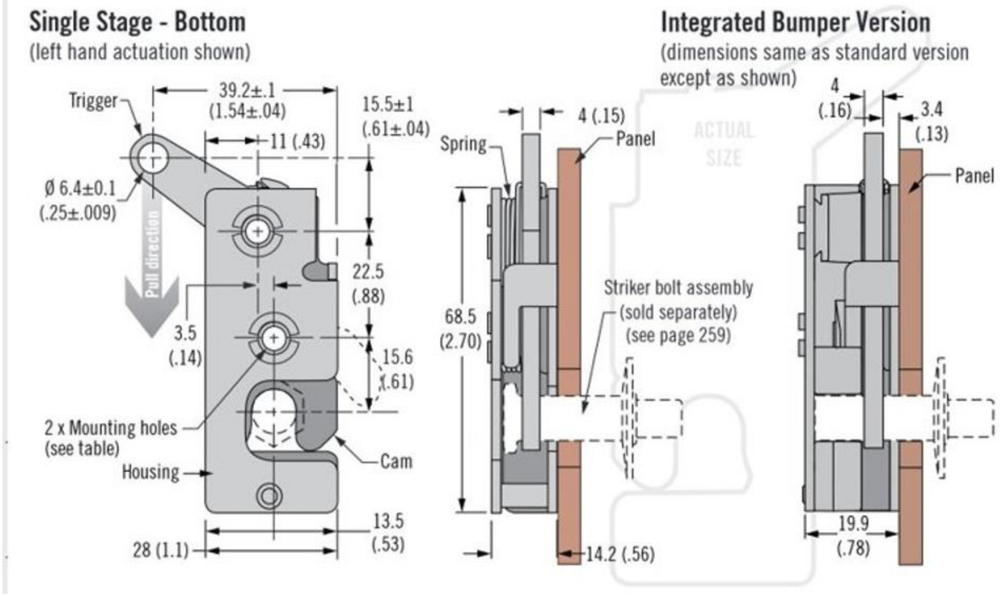


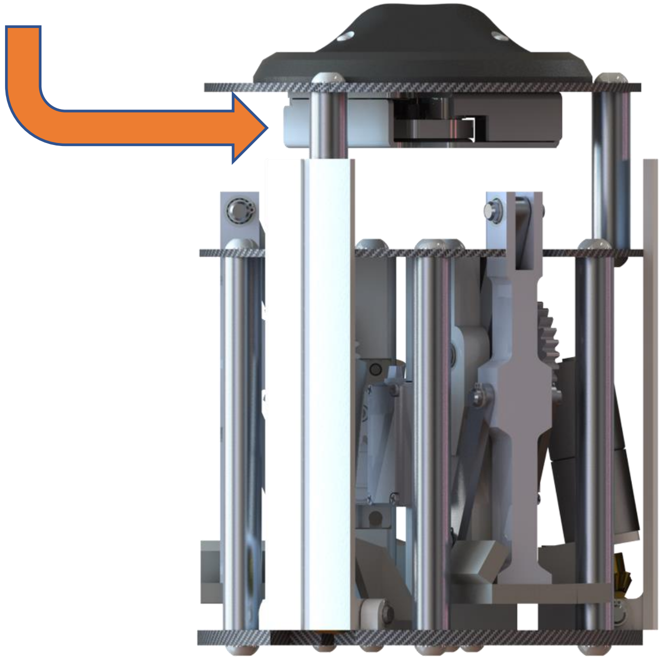
Retaining the Shock Cord

To parachute & Tender Descender



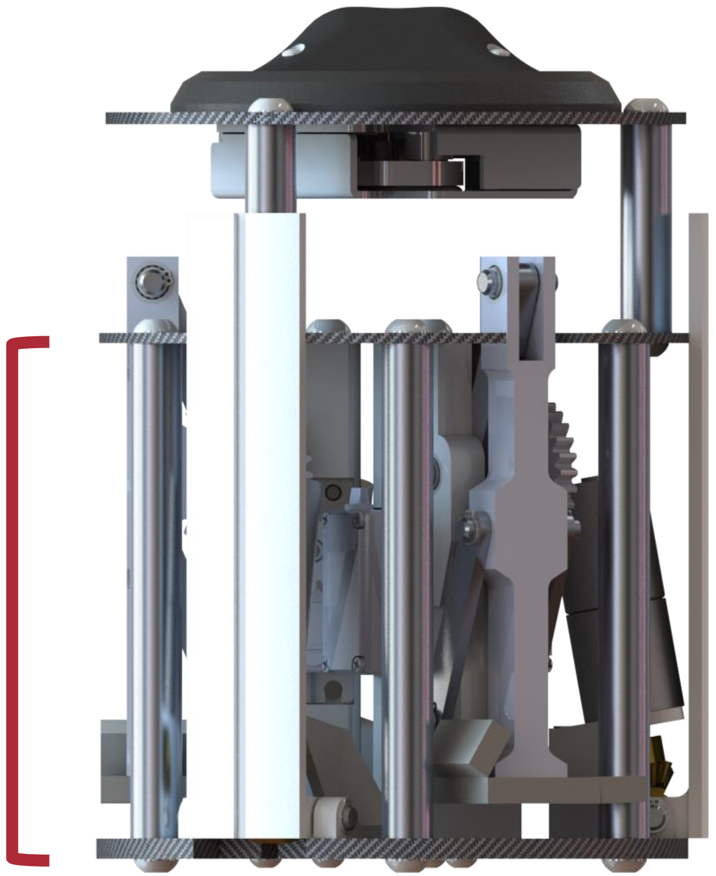
- Rotary Latch Mechanism
- *R4-EM-R21-161 by Southco* holds shock cord to payload
- Electronically Actuated





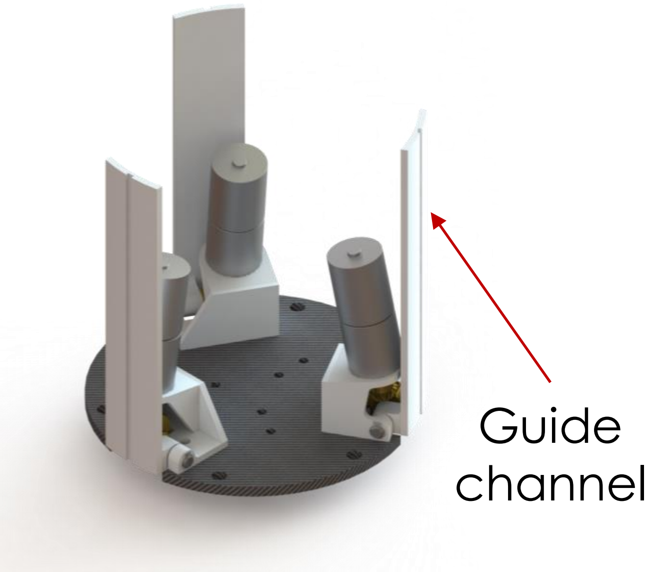
R4-EM-R21-161

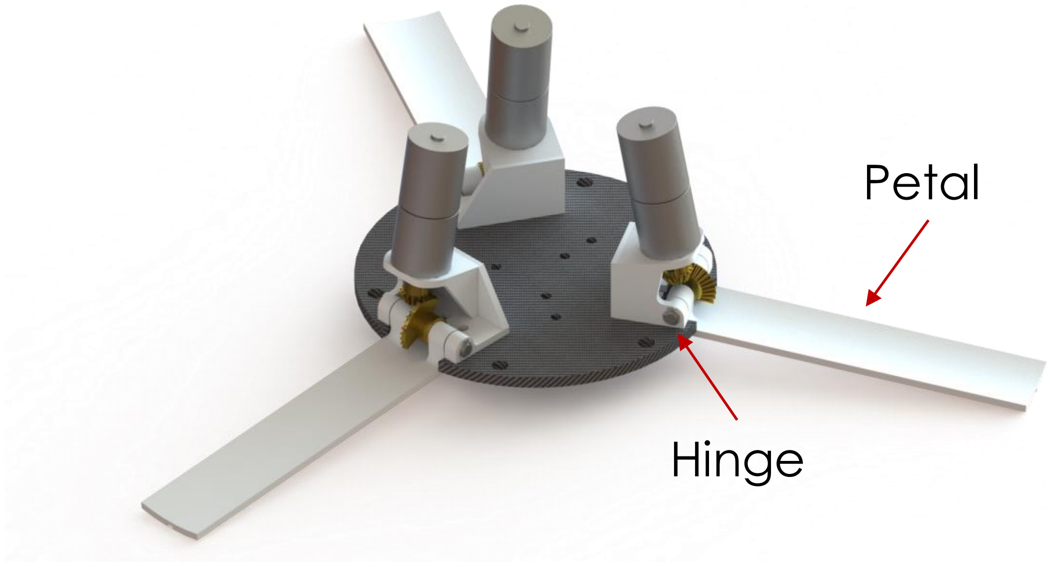
Self-Righting



Petals

- Three petals
- 6" x 1-¼" x ⅛" curved sections
- 3D Printed NylonX



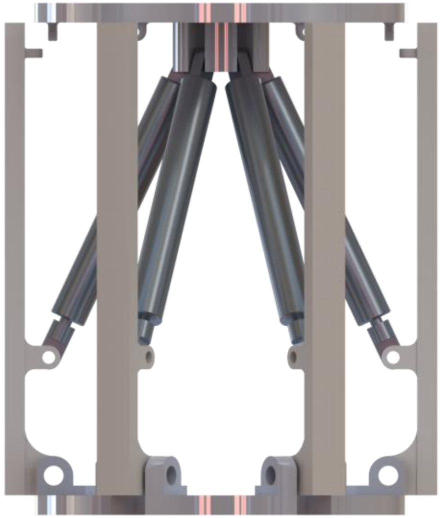


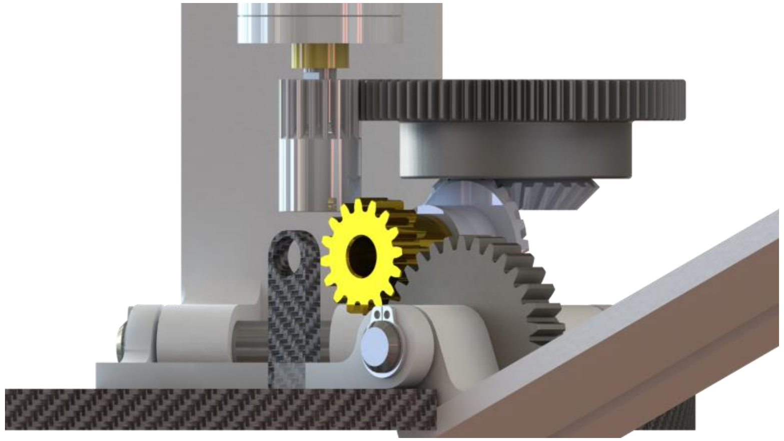
Selected Drive: Gearmotor

- 25D 499:1 ActoBotics gearmotor
- 2:1 bevel drive to transmit torque to petal
- Required torque increases with mass and height of the center of mass
  - Current estimates show ~30in-lb needed
- Consolidated hinge and motor mount

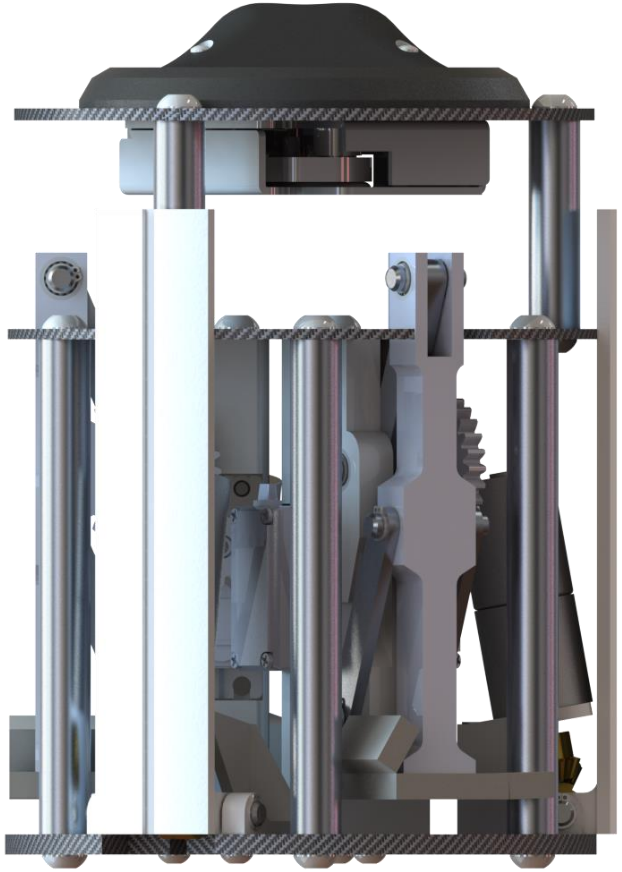
Drive Selection

Design	Complexity	Force	Cost	Size	Score
Gearmotor	3	5	3	4	77
Torsion Spring	5	1	5	5	51
Gas Springs	3	3	2	1	44
Linear Actuators	3	3	1	2	43
Multigear Drive	1	4	2	2	34
Weight	40	30	5	25	100



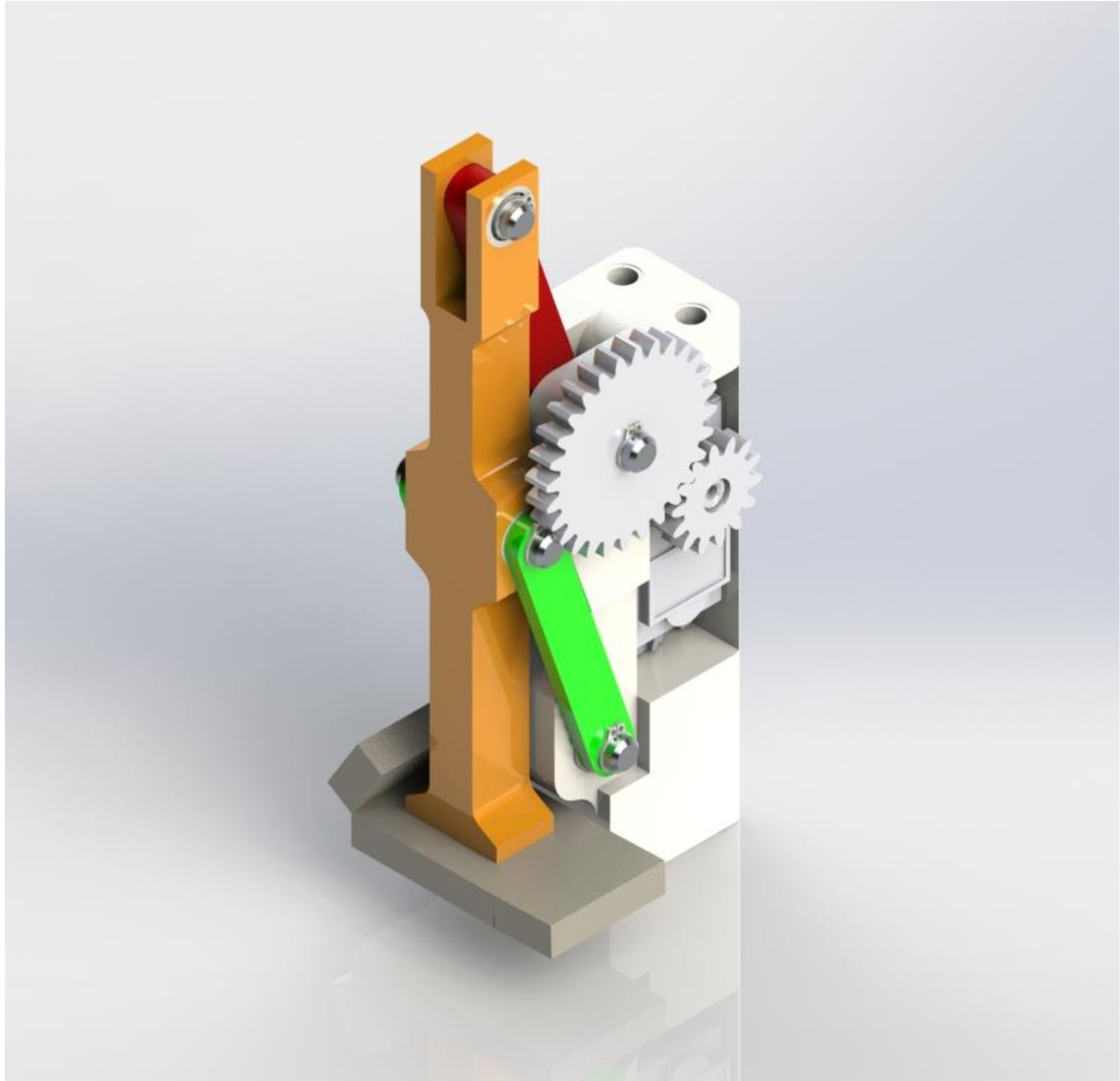


Stabilization System



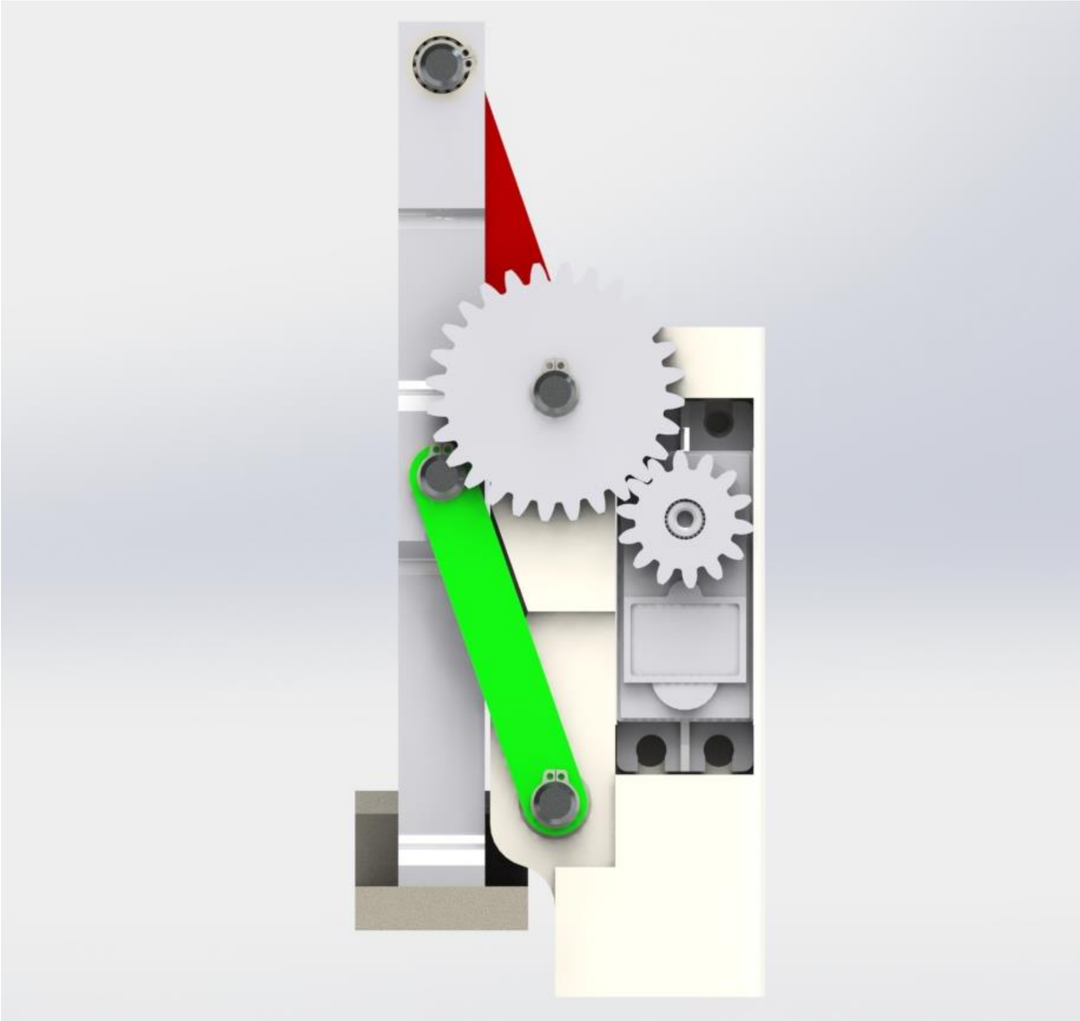
Fourbar Linkage

- Parallel Configuration
- Specifications
  - 3x equally spaced
  - Support 5 lb. per foot
  - Weighs 0.45 lb.
  - 3D printed NylonX filament
  - Bolts into structural plates



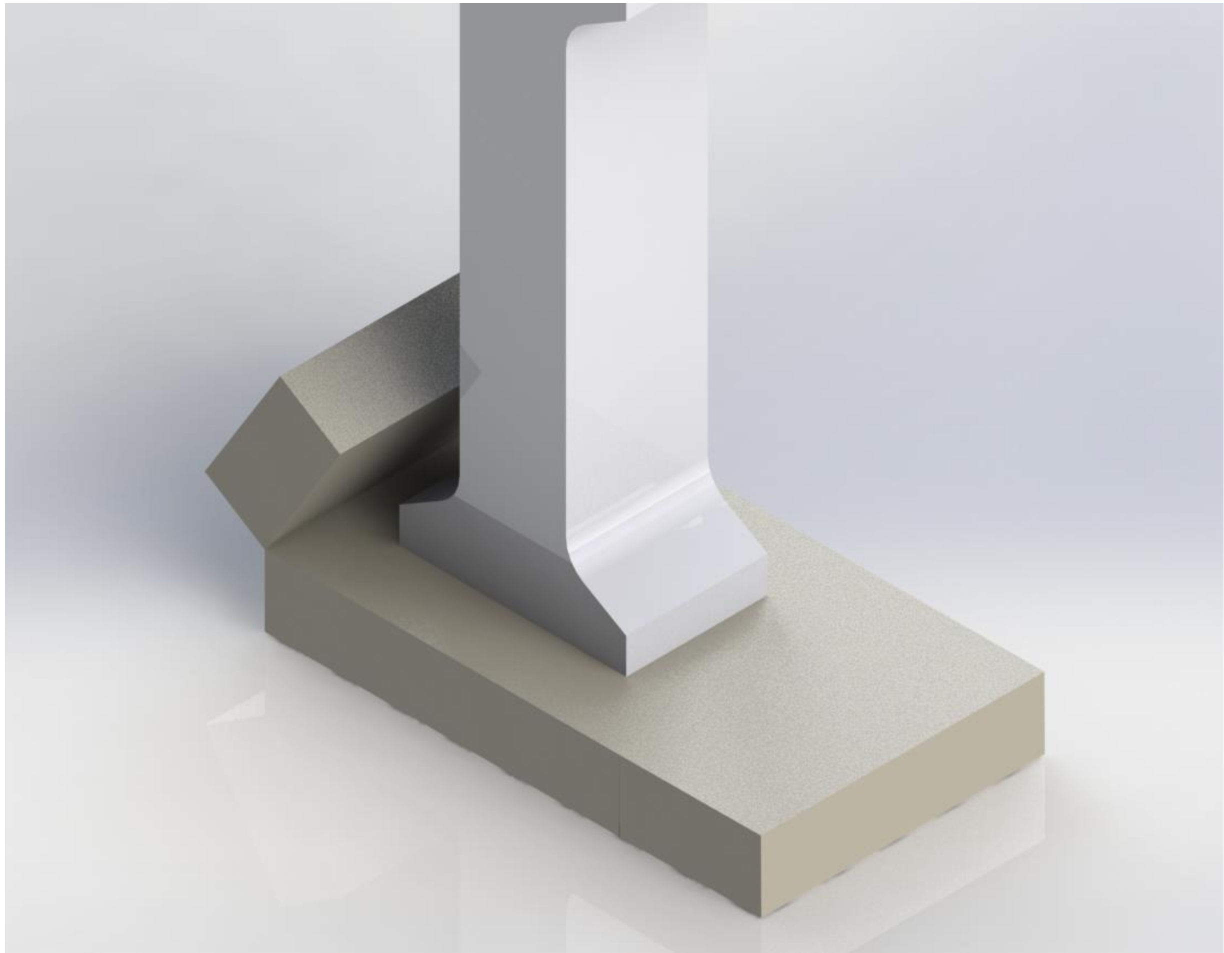
Power Transmission

- goBILDA Dual-mode servo
  - Continuous Rotation modifiable
  - 5.16 in-lbf at 29% I_{stall}
  - Lightweight
- 2:1 torque ratio
  - DELRIN gears
  - 14T – 28T

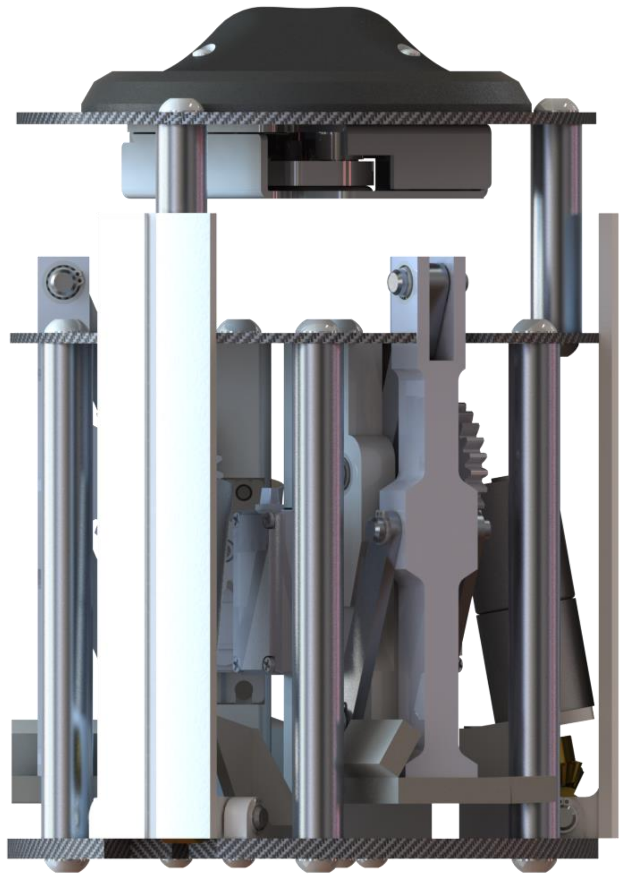


Foot

- Custom sandwich composite
  - Two Polyethylene foam layers
  - One Polyurethane foam layer
  - Foldable for compact storage
- 3D Printed "Traction Bottom"
  - NinjaTech Cheetah flexible filament

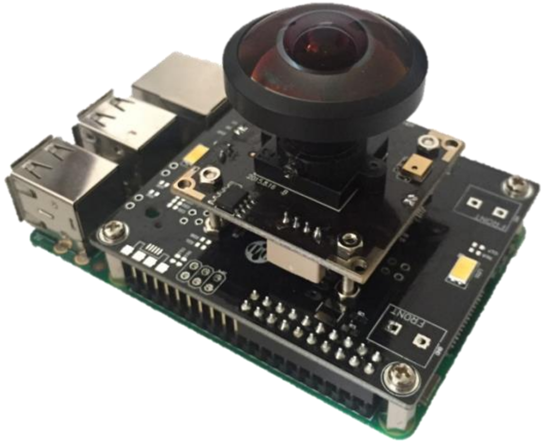


Photography



Photography

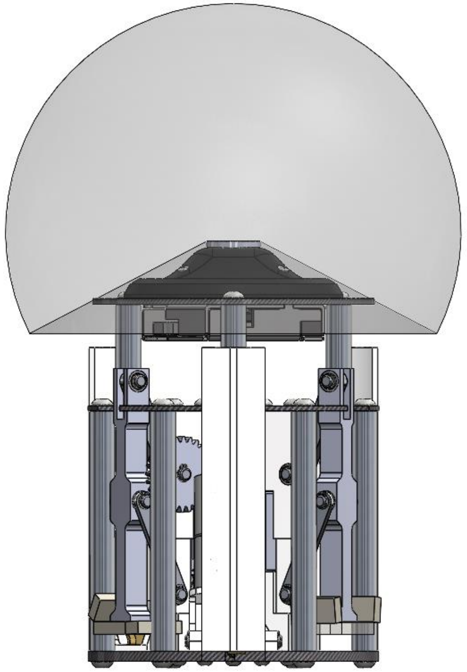
- Raspberry PI 3B+/Zero W
  - Process images taken by camera into full panoramic view
  - Transmit to ground station over GSM () receiver



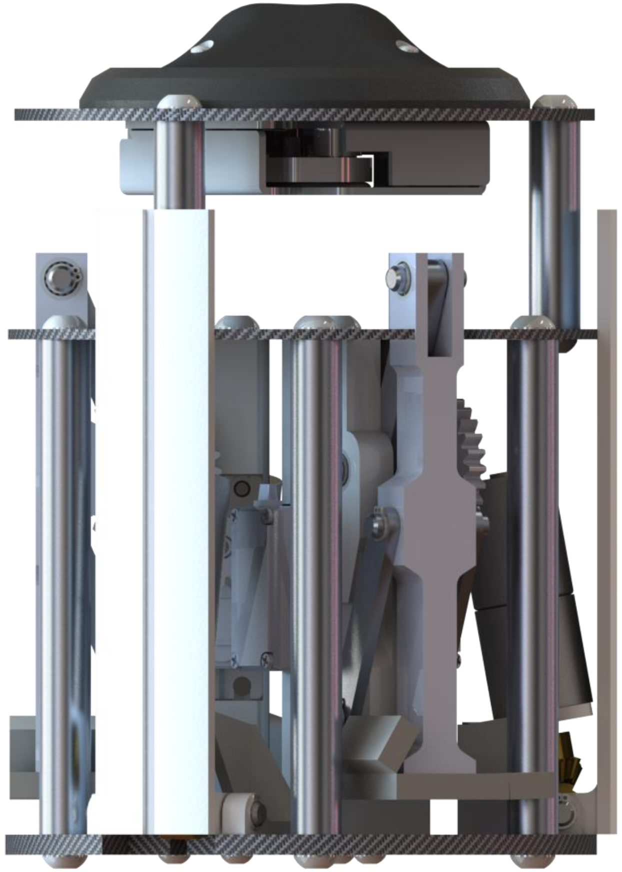
- PICAM360
  - 8 MP sensor
  - Offers a 360-degree horizontal field of view with a 235-degree vertical field of view

Photography contd.

- Successful image capture



Electrical



Hardware

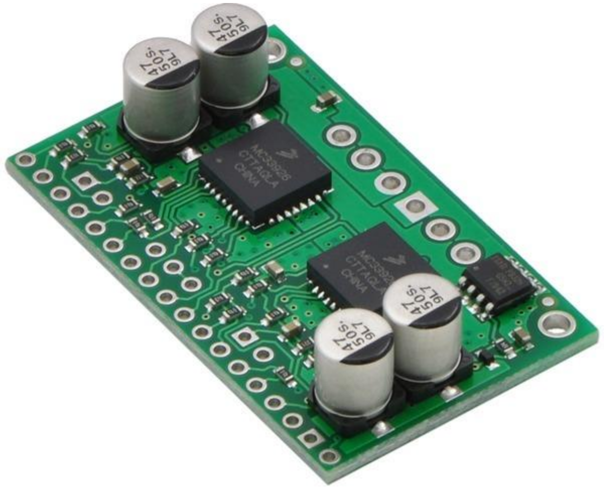
- Power management
  - DC motors
  - Servo motors
- Control/signal processing
  - Microcontrollers/microprocessors
  - Sensors

Power Management

- 12V 2.5Ah LiPo battery

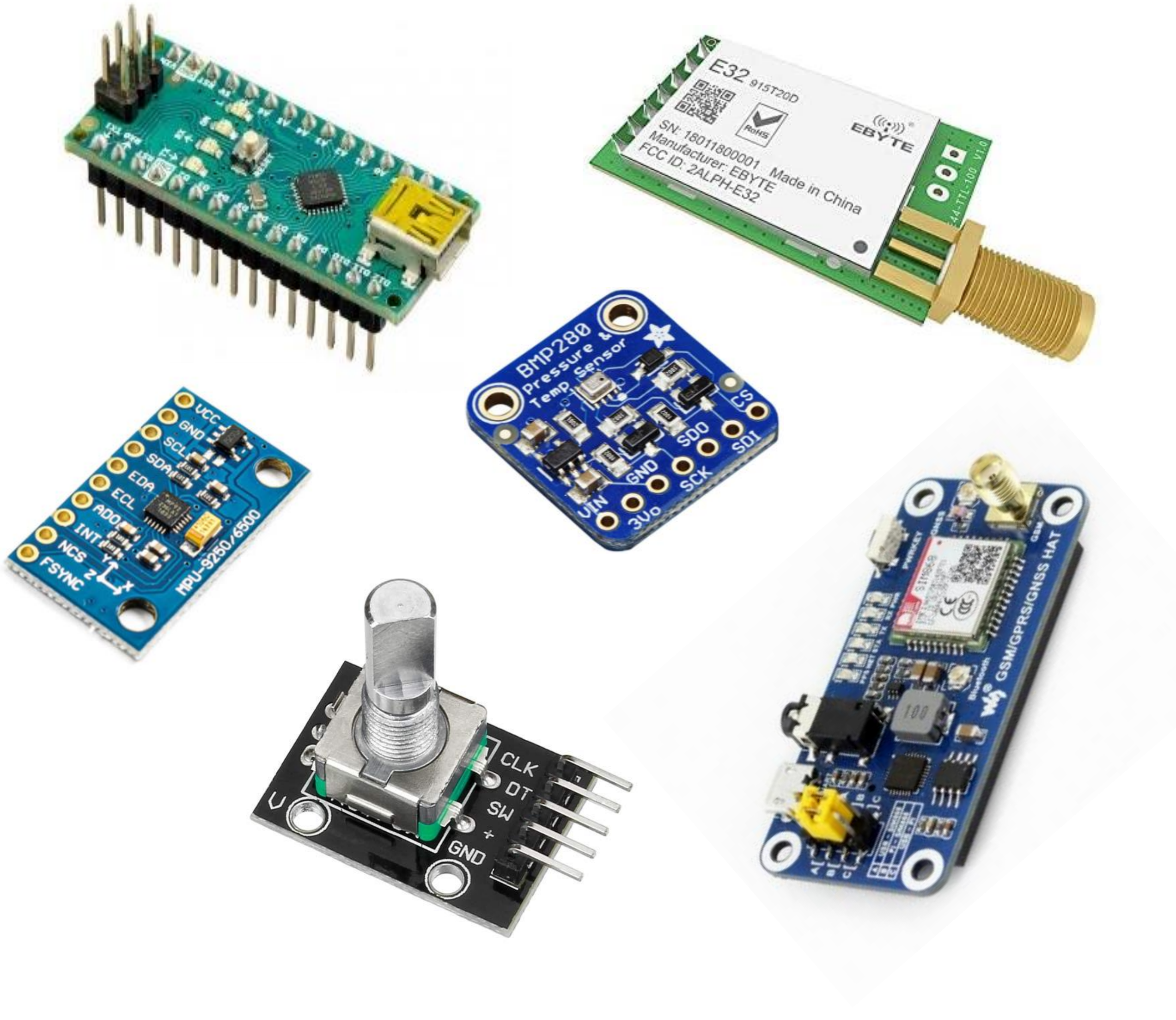
- 3 Battery Eliminator Circuits (BECs)

- 4 DC motor controllers

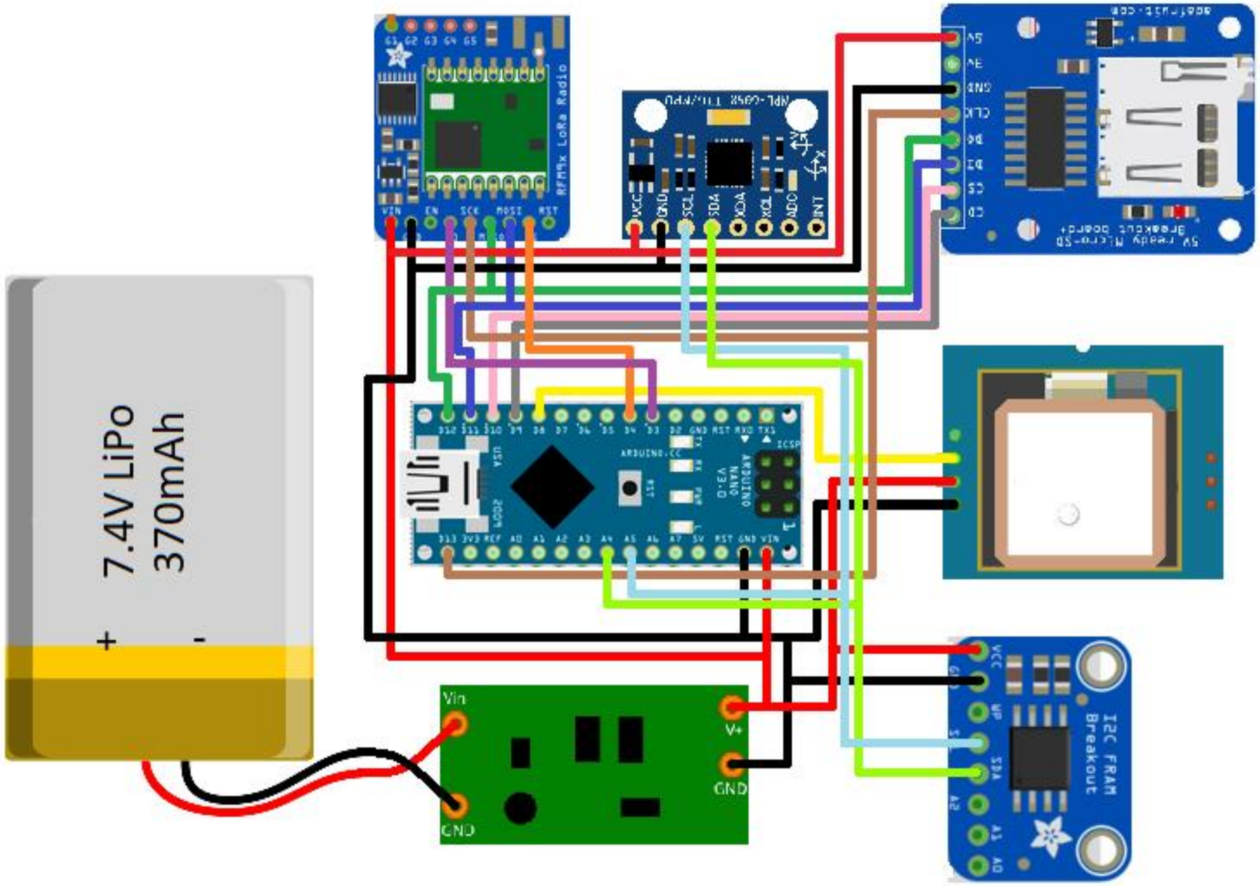


Sensor system

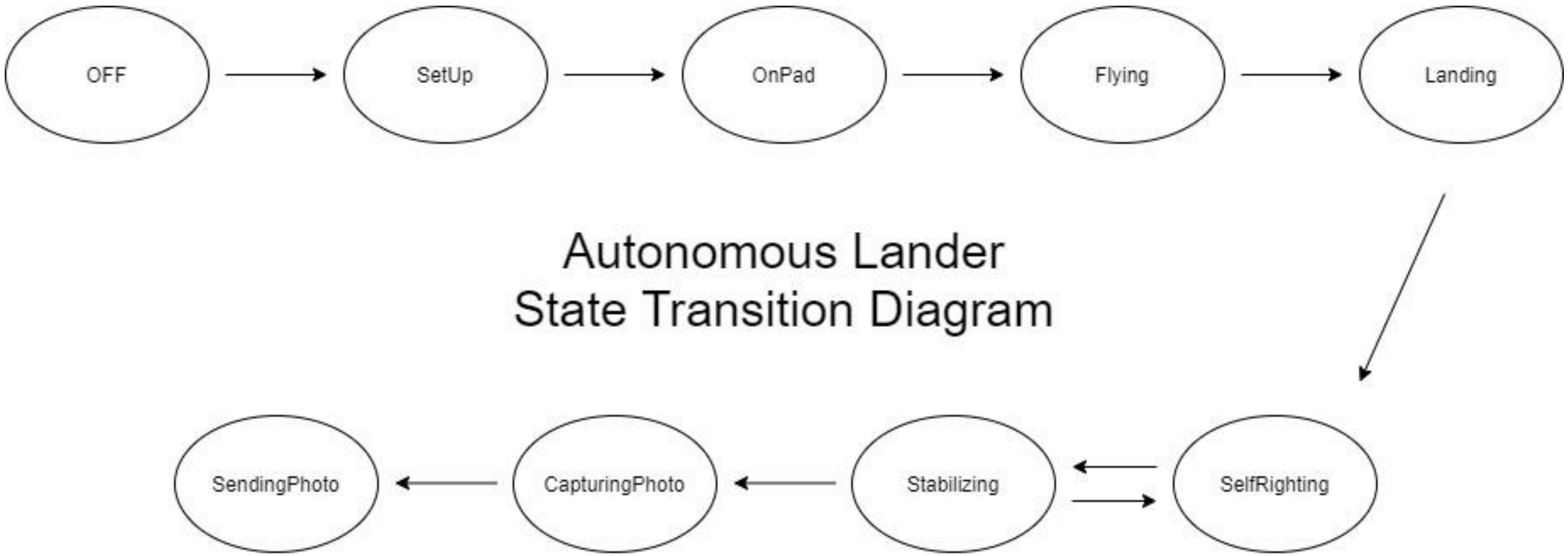
- Arduino (ATmega32P)
- LoRa transceiver
- Barometer (altitude)
- IMU 3-axis for:
  - Inertial acceleration
  - Angular rate
  - Magnetic field strength
- GPS
- Rotary encoders



Diagram



Software


OFF
SetUp
OnPad
Flying
Landing
Autonomous Lander
State Transition Diagram
SendingPhoto
CapturingPhoto
Stabilizing
SelfRighting

Team Operations

Safety

General Safety

- Safety is the highest priority of WPI HPRC and is the first consideration in all planning and decision-making
- WPI HPRC will comply with the NAR High Power Rocket Safety Code, FAA regulations, and all relevant local laws
- All team members will be trained in proper safety practices and will follow all instructions from the team safety officer, other safety personnel, and the RSO at launch events
- Team members must complete several requirements before they are permitted to work on rocket and payload fabrication or attend launch events
  - Attend a mandatory safety briefing conducted by the team safety officer
  - Sign the WPI HPRC Member Safety Agreement
  - Obtain proper authorization from WPI for each lab/workspace used

Hazard Analyses

- WPI HPRC maintains hazard analysis tables to identify potential risks to the successful completion of the project
- Hazards are categorized by Project Risks, Personnel Hazards, Failure Modes and Effects, and Environmental Concerns
- Each hazard is classified by its probability to occur and the severity of the impact on the project
- A mitigation plan is provided for each hazard identified to minimize risk to the project

Project Risk	Severity			
Probability	I - Irrecoverable	II - Significant	III - Minor	IV – Negligible
A – Probable	AI	AII	AIII	AIV
B – May Occur	BI	BII	BIII	BIV
C - Unlikely	CI	CII	CIII	CIV
D – Highly Unlikely	DI	DII	DIII	DIV

Table 3 Project Risk Assessment Matrix

Project plan

Requirements Verification Plan

- WPI HPRC will abide by all NASA and derived requirements
  - Requirements will be verified as outlined in each verification plan
- The executive board which consists of the Captain, Rocket Lead and Payload Lead will oversee this throughout design and construction

Budget/Funding

Overall Current Budget	
Components	
Budget Given by AIAA	+ $2,654.85
Funds Moved from Logistics Budget	+ $2,366.90
Expenses Thus Far	- $549.51
TinkerBox Funding (up to $3,000)	+ $535.65
Sponsorship	+ $1,000
Total in Component Budget as of PDR	$6,007.89
Logistics	
Budget Given by AIAA	+ $4,733.80
Funds Taken from Logistics Budget for Components	- $2,366.90
Total in Logistic Budget as of PDR	$2,366.90
Total in Account	$8,374.79

PDR Presentation Nov 10th

Subscale Construction (continued)

Subscale Launch Nov 21st

Revision Based on Subscale and Ordering

Winter Vacation/CDR Writing

CDR Due Jan 4th

Questions?