Preliminary Design Review

North Carolina State University

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Presentation Overview

- Launch Vehicle Leading Design
- Recovery System Leading Design
- Payload Leading Design
- Mission Performance Predictions
- Requirements Compliance Plan

Launch Vehicle Leading Design

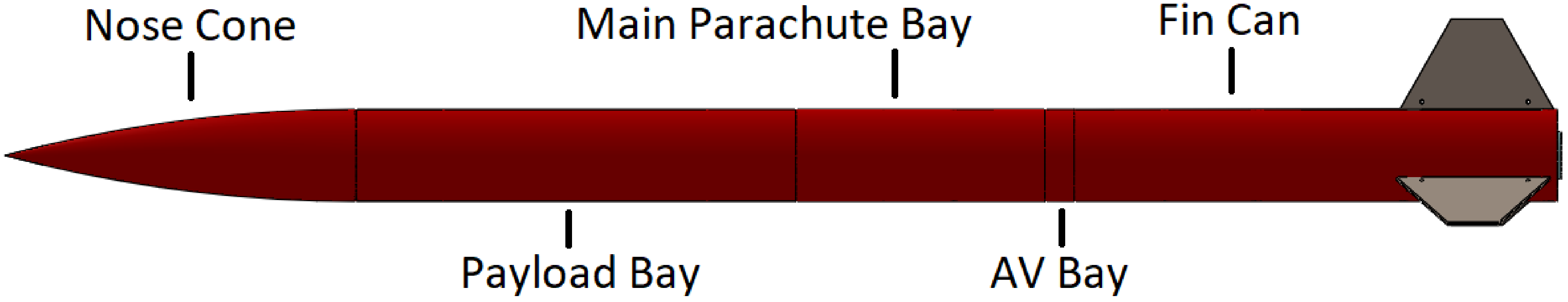
Material Selection

Airframe Sections

Fin Configuration

Launch Vehicle Dimensions

- Length: 106.25"
- Diameter: 6"
- Launch Weight: 45.4 lb
- Empty Weight: 41.3 lb



Material Selection

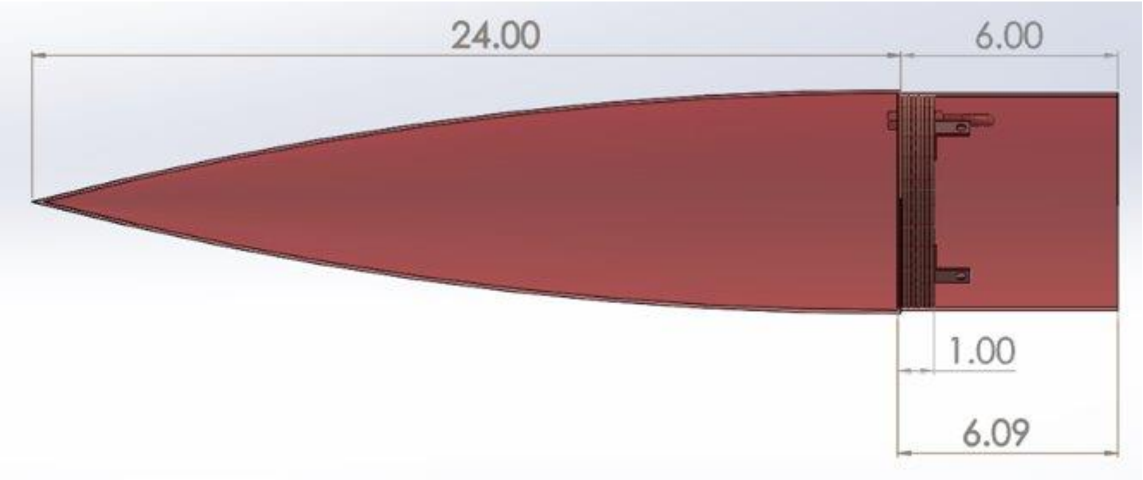
- Blue Tube 2.0
  - Vulcanized fiber-based airframe
  - Abrasion resistant and durable
  - Inexpensive compared to fiberglass
  - Lightweight
  - Prone to moisture damage without treatment
- G12 Fiberglass
  - More durable and damage resistant than Blue Tube
  - $29 more per foot than Blue Tube
  - Heavier than Blue Tube
  - Moisture resistant

Chosen Material- G12 Fiberglass

- Moisture resistance is important for reusability of launch vehicle
- Increase in strength and durability is worth the extra weight and cost
- RockSim simulations have the launch vehicle reach an acceptable apogee even with increased weight

Chosen Nose Cone: 4:1 Ogive

- Conical
  - Simple design
  - Not ideal for subsonic speeds
- Elliptical Design
  - Optimal design for full scale
  - Minimizes friction drag
  - No commercially available options
- Ogive
  - Many geometries available
  - Commercially available in dimensions for subscale and full scale
  - 4:1 Ogive gives desired stability margin

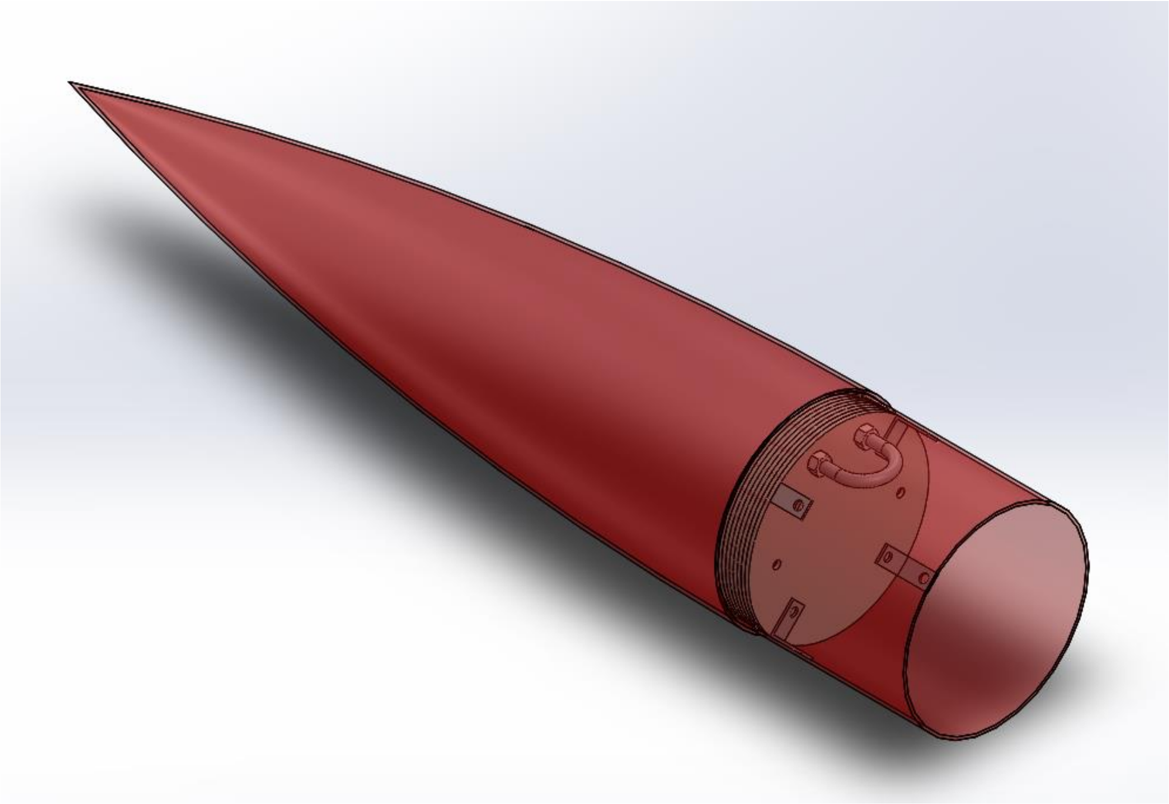


Nose Cone Bulkhead

- Fixed
  - Additional strength and stress distribution from epoxy bond
  - Simple, one-time installation
  - Difficult to remove should changes need to be made
- Removable
  - Stress is concentrated on bolted connections
  - Allows easy installation of ballast on forward side
  - Gives additional space on forward side for payload integration electronics

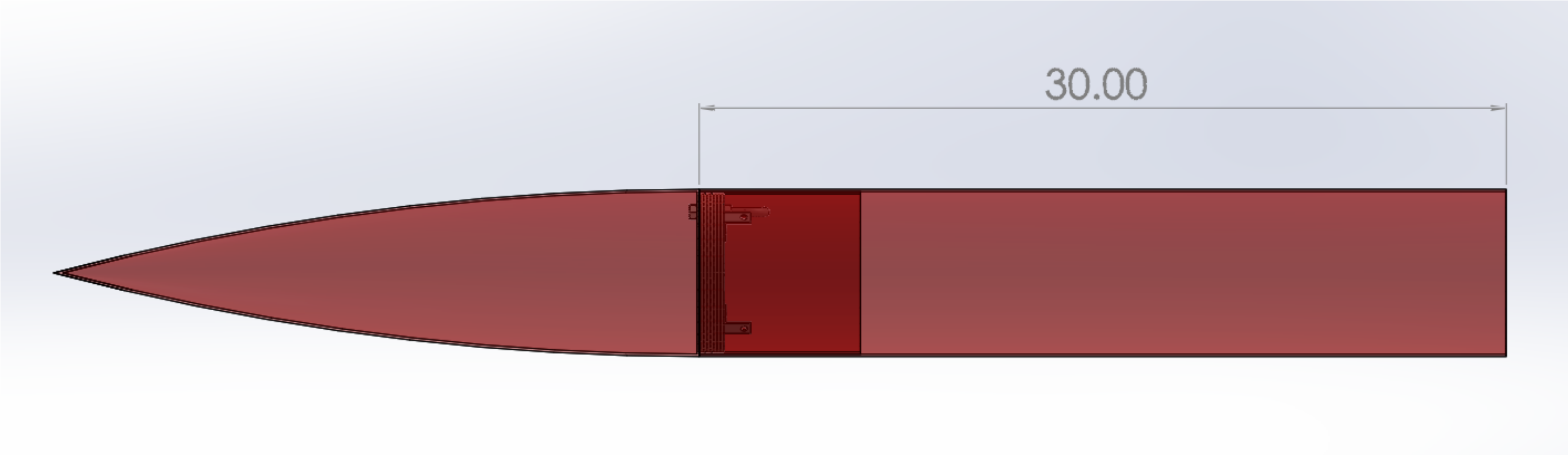
Removable Bulkhead

- A removable bulkhead is the best option for this launch vehicle design
- Gives the option to add ballast as needed
- Payload integration requires the additional space to store electronics
- L-brackets will be used to mount bulkhead to nose cone



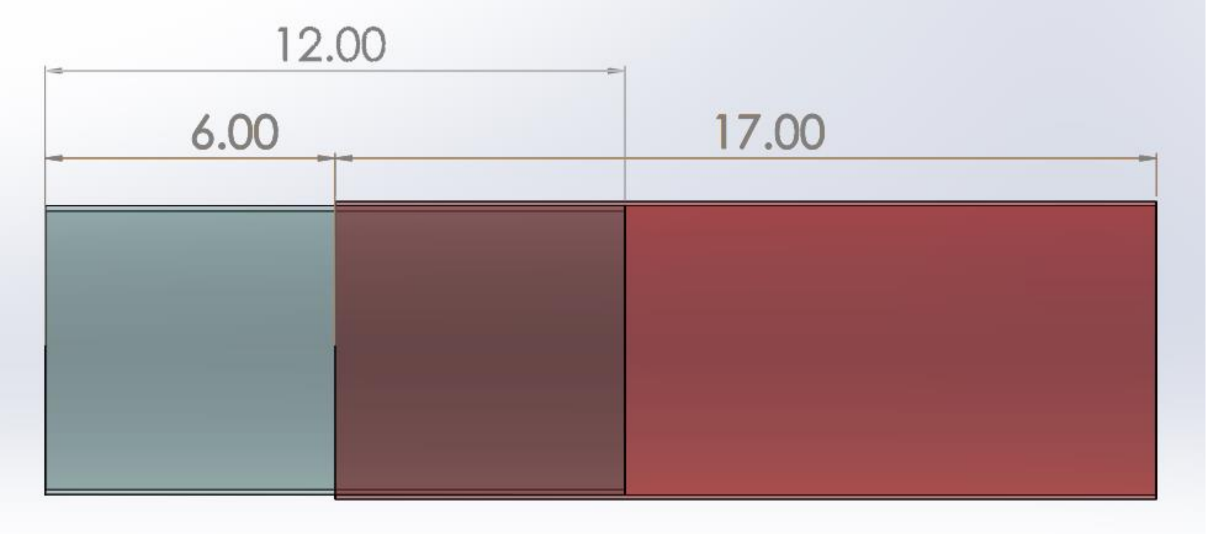
Payload Bay

- Located between nose cone and main parachute bay
- Forward location shifts CG forward for better stability
- Shear pins through body hold payload in place



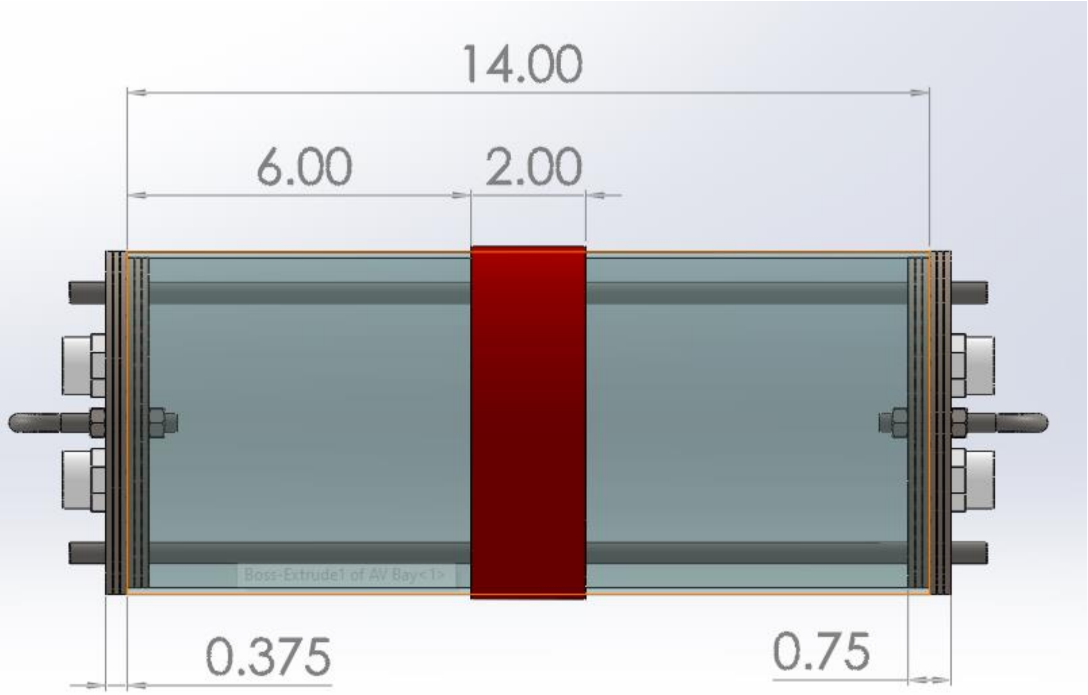
Main Parachute Bay

- Located between payload bay and AV Bay
  - Shear pin connection to payload bay
  - Bolted connection to AV bay
- Main parachute packing volume: 5" D, 7" L
- Recovery material takes up 10" of main parachute bay length



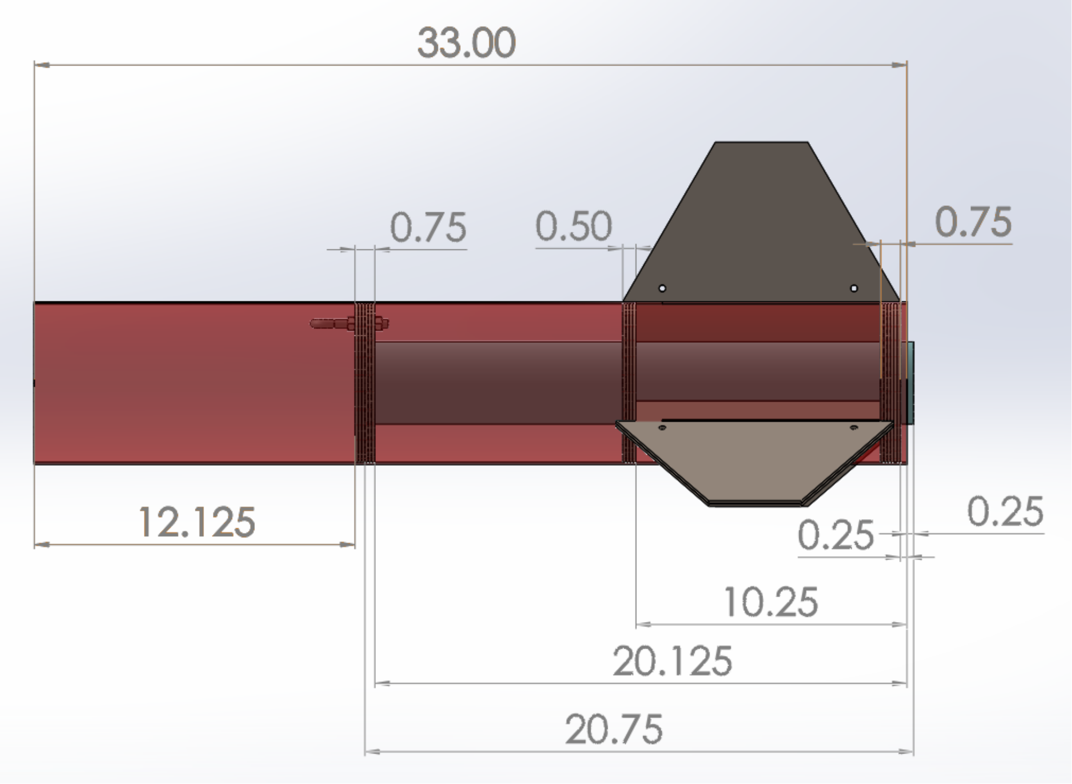
AV Bay

- Modular design allows for easily accessible AV sled
- Allows simultaneous assembly alongside launch vehicle
- Easy access to blast caps and U-bolts



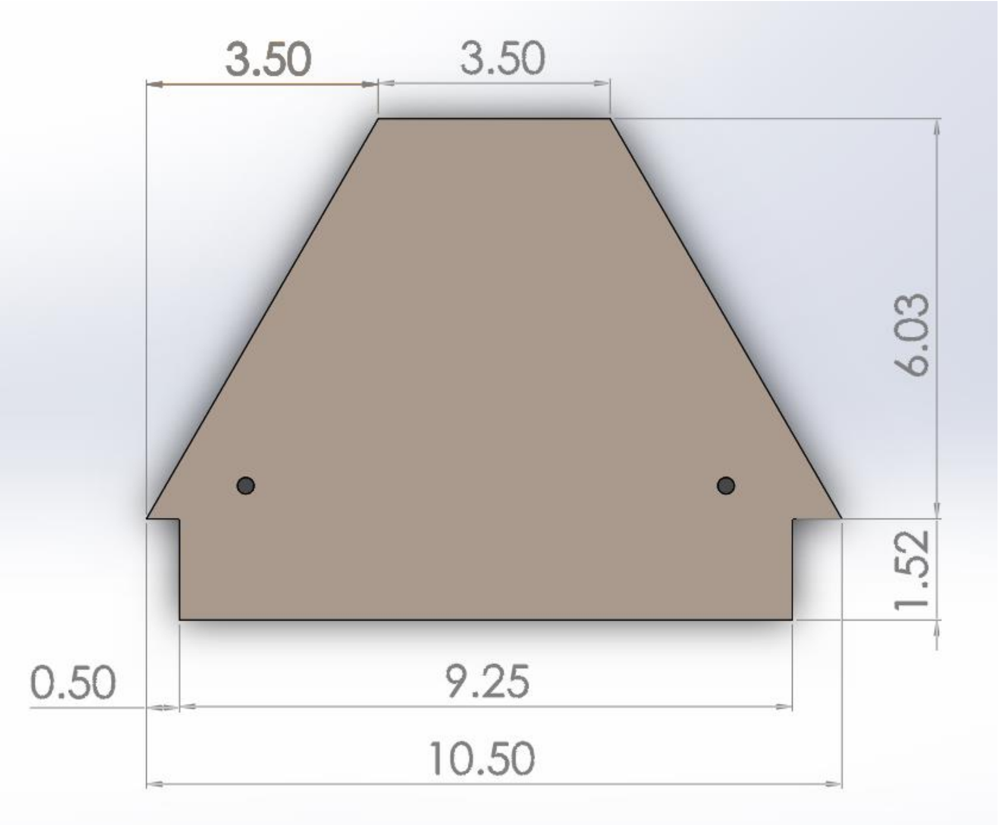
Fin Can

- Centering rings and engine block are used to align and secure motor tube
- Middle centering ring is additionally used to align and support fins
- 12.125" space forward of engine block is used to store drogue parachute



Three-Fin Configuration

- Primarily chosen for weight and drag reduction, as well as lower chance of weathercocking
- Leading-edge sweep reduces drag, pushes CP aft, increasing stability
- Trailing-edge sweep reduces drag, protects fins from damage on landing



Recovery Subsystem Leading Design

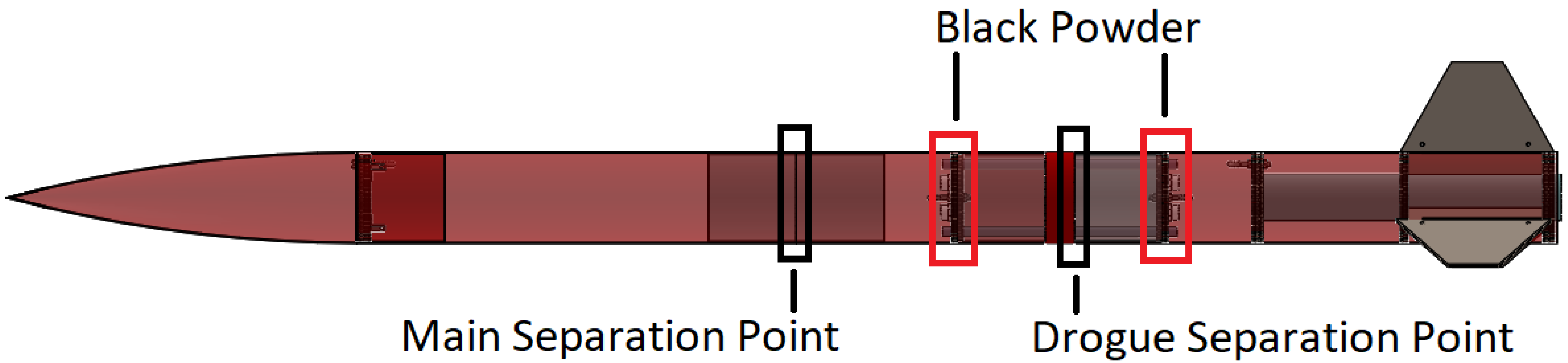
Component Selection

Recovery Events

Performance Predictions

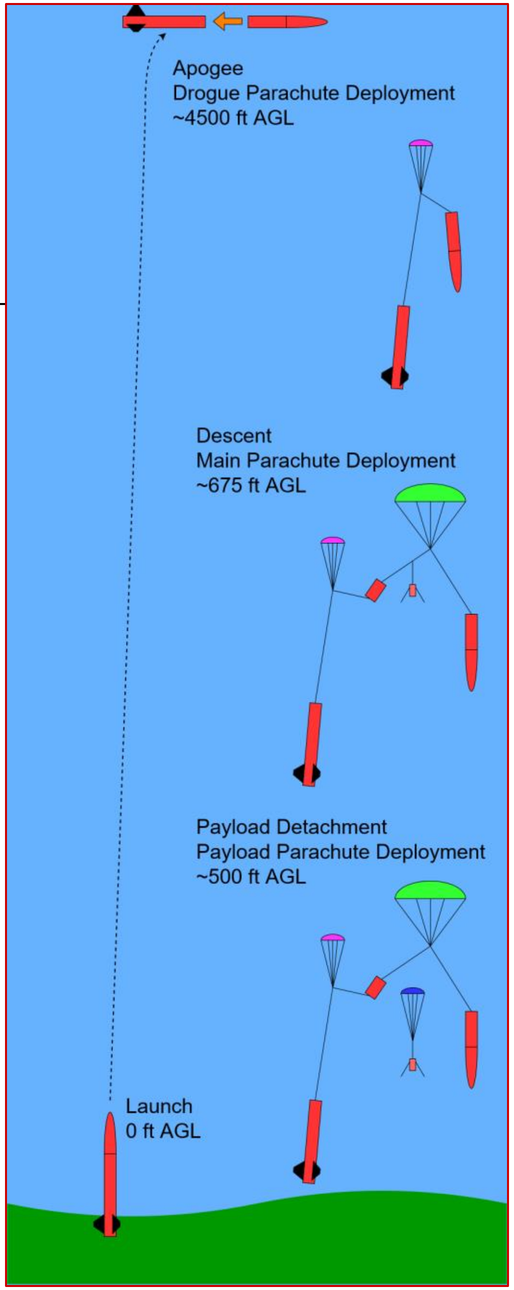
Recovery System Locations

- Drogue parachute stored in fin can
- Main parachute stored in main parachute bay
- Modular AV can

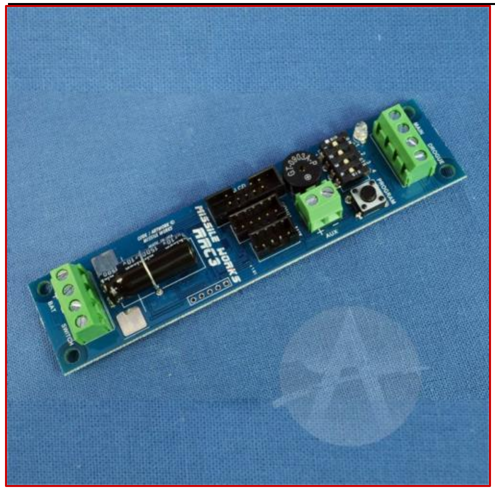


Recovery Overview

- Drogue parachute deployment at apogee
  - Secondary at apogee + 1 sec
- Main parachute deployment at 675 ft
  - Secondary charge at 650 ft
- Payload jettison at 500 ft
- Objective: Safe recovery of all launch vehicle and payload sections

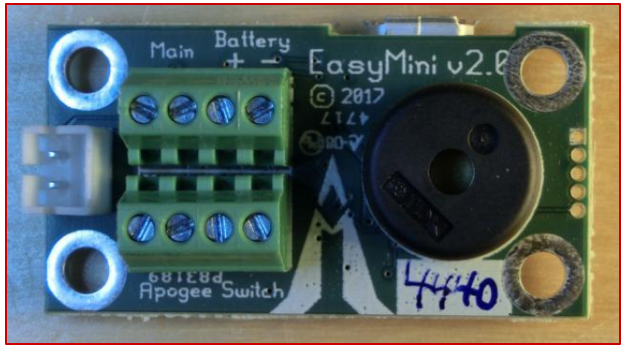


Altimeter Alternatives



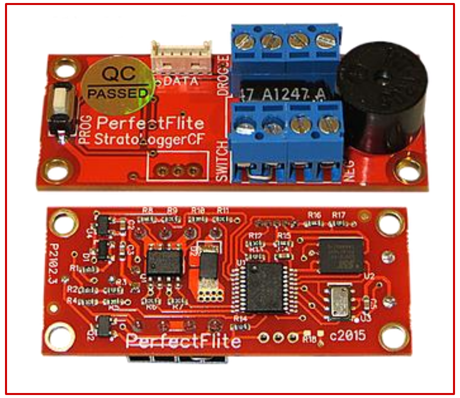
Missile Works RRC3

Entacore AIM USB 3.0



Altus Metrum EasyMini

PerfectFlite StratoLogger CF

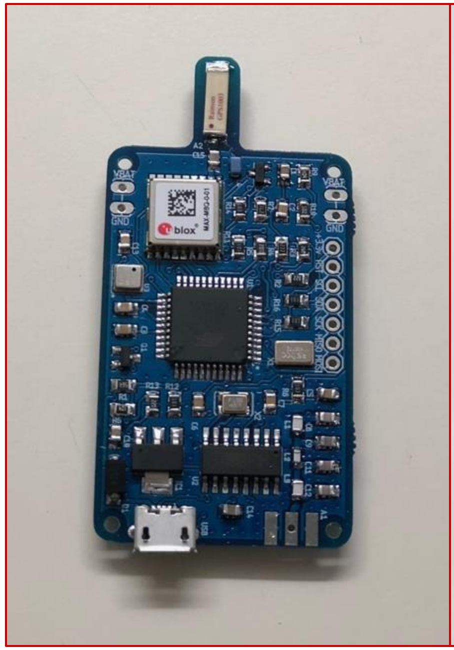


Altimeter Comparison

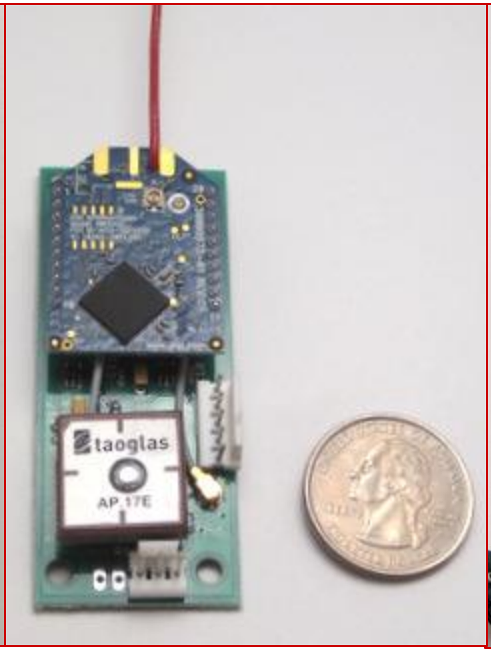
Altimeter	RRC3	Entacore AIM	StratoLogger CF	EasyMini
Main Deployment Variability	300 to 3000 ft; Increments of 100 ft	100 to 999 ft; Increments of 1 ft	100 to 9999 ft; Increments of 1 ft	Any
Delay After Apogee	0 to 30 sec; Increments of 1 sec	Available	0 to 5 sec; Increments of 1 sec	Available
Minimum Apogee	100 to 300 ft	N/A	100 ft	N/A
Altitude Logging Resolution	1 ft	1 ft	1 ft	1 ft
Dimensions	3.92” L x 0.925” W	2.75” L x 0.984” W	2” L x 0.84” W	1.5” L x 0.8” W
Data Logged	Altitude, velocity, temperature, voltage	Altitude, velocity, temperature, voltage, continuity	Altitude, voltage, temperature, voltage	Altitude, velocity, acceleration, temperature, voltage

- Selection considerations
  - Form factor
  - Ease of wiring
  - Reliability
  - Adaptability

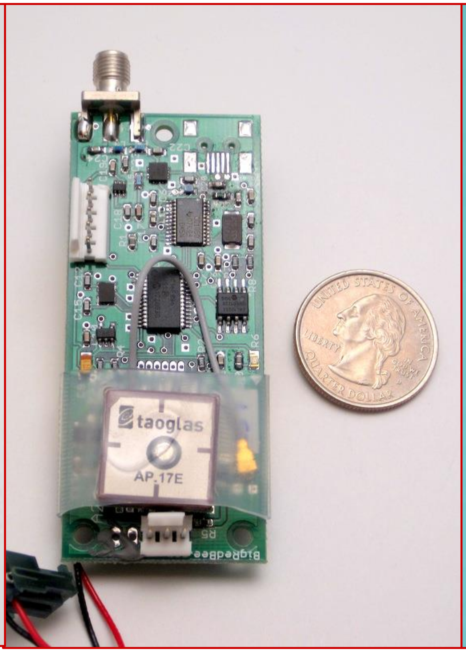
Tracking Alternatives



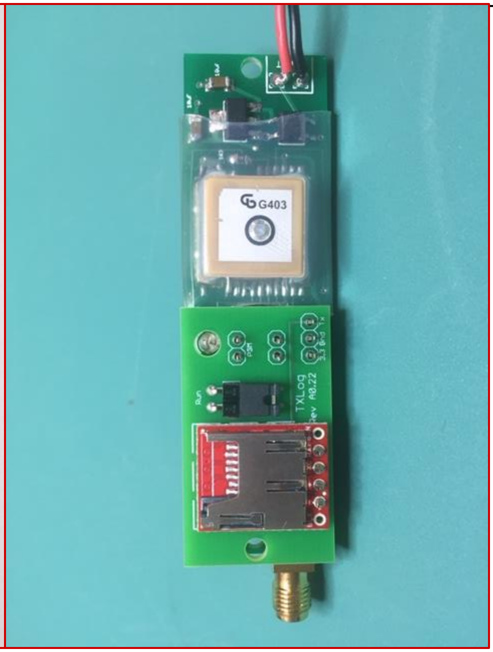
LightAPRS+W



BigRedBee 900

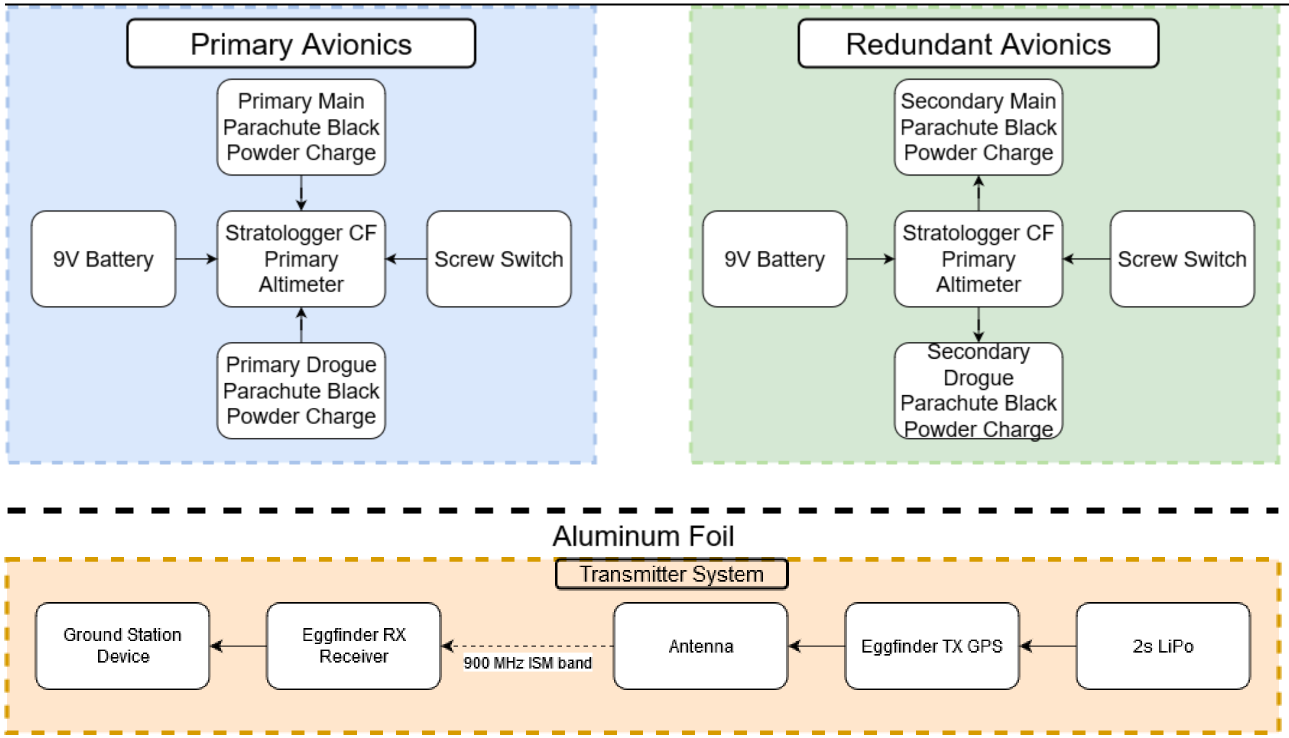


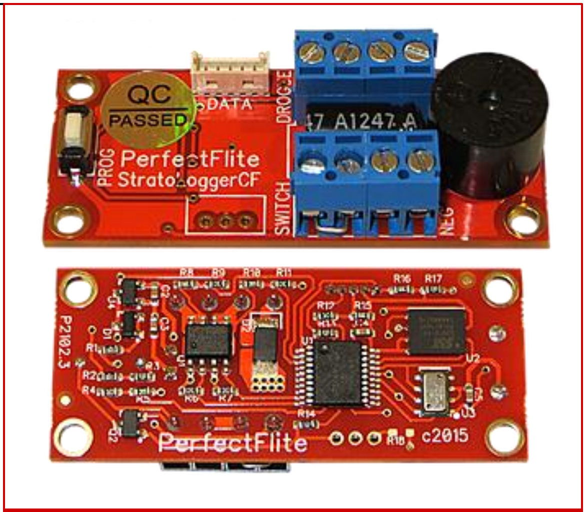
BigRedBee BeeLine

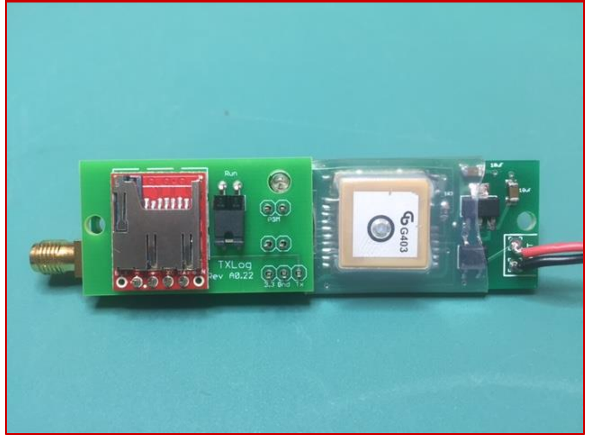


Eggfinder TX

Leading Avionics Alternatives







- Two StratoLogger CF Altimeters
- Eggfinder GPS TX/RX Tracker
- Redundant primary and secondary avionics systems

Parachute Alternatives - Drogue

Parachute	Drag Coefficient	Descent Velocity	Scent Time from Apogee to Main Deployment	Wind Drift from Apogee to Main Deployment (20 mph
Fruity Chutes 12 inch Classic Elliptical	1.34	181.3 ft/s	20.8 s	610.1 ft
Fruity Chutes 15 inch Classic Elliptical	1.37	143.3 ft/s	26.3 s	771.5 ft
Fruity Chutes 18 inch Classic Elliptical	1.43	117.0 ft/s	32.2 s	944.6 ft
Fruity Chutes 24 inch Classic Elliptical	1.47	86.4 ft/s	43.7 s	1281.9 ft
Fruity Chutes 24 inch Compact Elliptical	1.41	88.5 ft/s	42.7 s	1252.5 ft

Drogue Parachute Comparison

Parachute Alternatives - Main

Parachute	Drag Coefficient	Landing Velocity	Maximum Section Kinetic Energy	Descent Time from Main Deployment	Wind Drift Under Main (20 mph)
Fruity Chutes 96 inch Iris UltraCompact	2.09	18.1 ft/s	68.3 ft-lbf	38.6 s	1132.3 ft
Fruity Chutes 120 inch Iris Ultra Standard	2.11	14.5 ft/s	43.3 ft-lbf	48.4 s	1419.7 ft

Main Parachute Comparison – Payload Attached

Parachute	Drag Coefficient	Landing Velocity	Maximum Section Kinetic Energy	Descent Time from Main Deployment	Wind Drift Under Main (20 mph)
Fruity Chutes 84 inch Iris UltraCompact	2.13	17.9 ft/s	66.5 ft-lbf	37.7 s	1105.9 ft
Fruity Chutes 84 inch Iris Ultra Standard	2.13	17.9 ft/s	66.5 ft-lbf	37.7 s	1105.9 ft
Rocketman 144 inch Pro-X	0.82	16.8 ft/s	58.8ft-lbf	40.1 s	1176.2 ft
Fruity Chutes 120 inch Iris UltraCompact	2.11	12.6 ft/s	33.1 ft-lbf	52.5 s	1569.3 ft

Main Parachute Comparison – Payload Detached

Parachute Alternatives - Payload

Parachute	Drag Coefficient	Landing Velocity	Maximum Section Kinetic Energy	Wind Drift from Apogee (20 mph)
Fruity Chutes 36 inch Classic Elliptical	1.43	28.5 ft/s	123.1 ft-lbf	2062.8 ft
Fruity Chutes 48 inch Classic Elliptical	1.44	21.3 ft/s	68.7 ft-lbf	2167.4 ft
Fruity Chutes 60 inch Iris UltraCompact	2.16	13.9 ft/s	29.3 ft-lbf	2386.9 ft

Payload Parachute Comparison

Leading Parachute Alternatives

- Main
  - Fruity Chutes 120 inch Iris UltraCompact
    - Able to accomidate successful or failed payload deployment
    - Deployment bag
- Drogue
  - Fruity Chutes 18 inch Classic Elliptical
    - Descent rate under 130 ft/s
    - Facilitates higher main deployment altitude
    - Nomex sheet protection
- Payload
  - Fruity Chutes 48 inch Classic Elliptical
    - Furled, streamer-like initial descent
    - Balance of kinetic energy and wind drift

Wind Drift and Descent Time

- Downrange movement due to field wind conditions
  - Descent time, apogee, drift
  - Descent Time: 84.7 s
  - Wind Drift (20 mph): 2484.5 ft

Speed	Apogee	Descent Time	Drift Distance
0 mph	4473 ft	84.7 s	0 ft
5 mph	4473 ft	84.7 s	621.1 ft
10 mph	4473 ft	84.7 s	1242.3 ft
15 mph	4473 ft	84.7 s	1863.4 ft
20 mph	4473 ft	84.7 s	2484.5 ft

Kinetic Energy at Landing

Section	Mass	Descent Velocity (Payload attached)	Descent Velocity	Kinetic Energy (Payload attached)	Kinetic Energy
Nosecone	0.225315 slugs	14.5 ft/s	12.6 ft/s	23.6 ft-lbf	18.0 ft-lbf
Nosecone w/ Payload	0.528335 slugs	14.5 ft/s	N/A	55.2 ft-lbf	N/A
Payload	0.30304 slugs	14.5 ft/s	N/A	31.7 ft-lbf	N/A
Midsection	0.334088 slugs	14.5 ft/s	12.6 ft/s	34.9 ft-lbf	26.6 ft-lbf
Fin can	0.414601 slugs	14.5 ft/s	12.6 ft/s	43.3 ft-lbf	33.1 ft-lbf

- Consider three cases
  - Payload successfully deployed
  - Payload exits payload bay but remains attached to recovery harness
  - Payload fails to exit payload bay
- Worst case scenario: Payload remains in payload bay
  - Nosecone w/ Payload mass: 0.528 slugs
  - Maximum section kinetic energy: 55.2 ft-lbf

Opening Shock

- Confirm that the airframe and recovery harness can withstand opening shock
  - Full launch vehicle load at main parachute deployment: 458 lbf
  - Kevlar shock cord rated for 6600 lbf
  - FS of ~14

Section	Mass	Opening Shock
Forward Section	0.528355 slugs	158 lbf
Midsection and Fin Can	0.748689 slugs	225 lbf

Mission Performance Predictions

Target Apogee

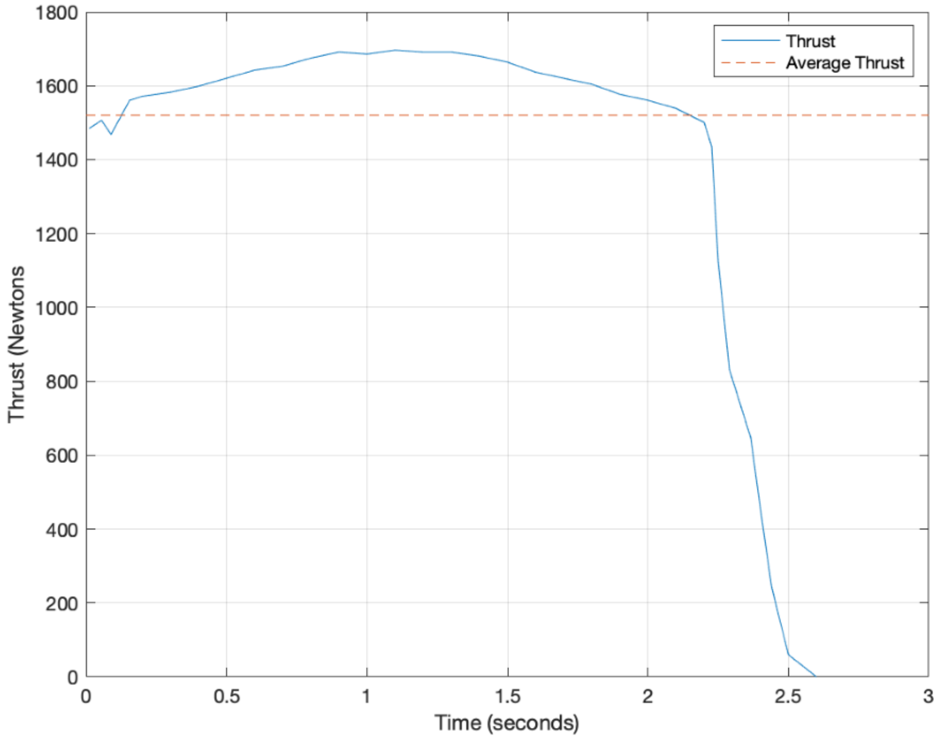
Stability Margin

Motor Alternatives

Motor	Total Impulse (lbf-s)	Initial Thrust (N)	Max Thrust (lbf)	Burn time (s)	Weight (oz)
L850W	819.74	1000.9	419.56	4.4	132
L1256WS	850.94	1352.4	339.14	3.0	132.49
L1390G	887.81	1416.5	370.80	2.6	136.83
L1520T	835.41	1545.4	396.88	2.4	128.79

Leading Motor Selection

- AeroTech L1520T
- Short burn time
- High Max and Average Thrust
- RMS 75/3840 Casing

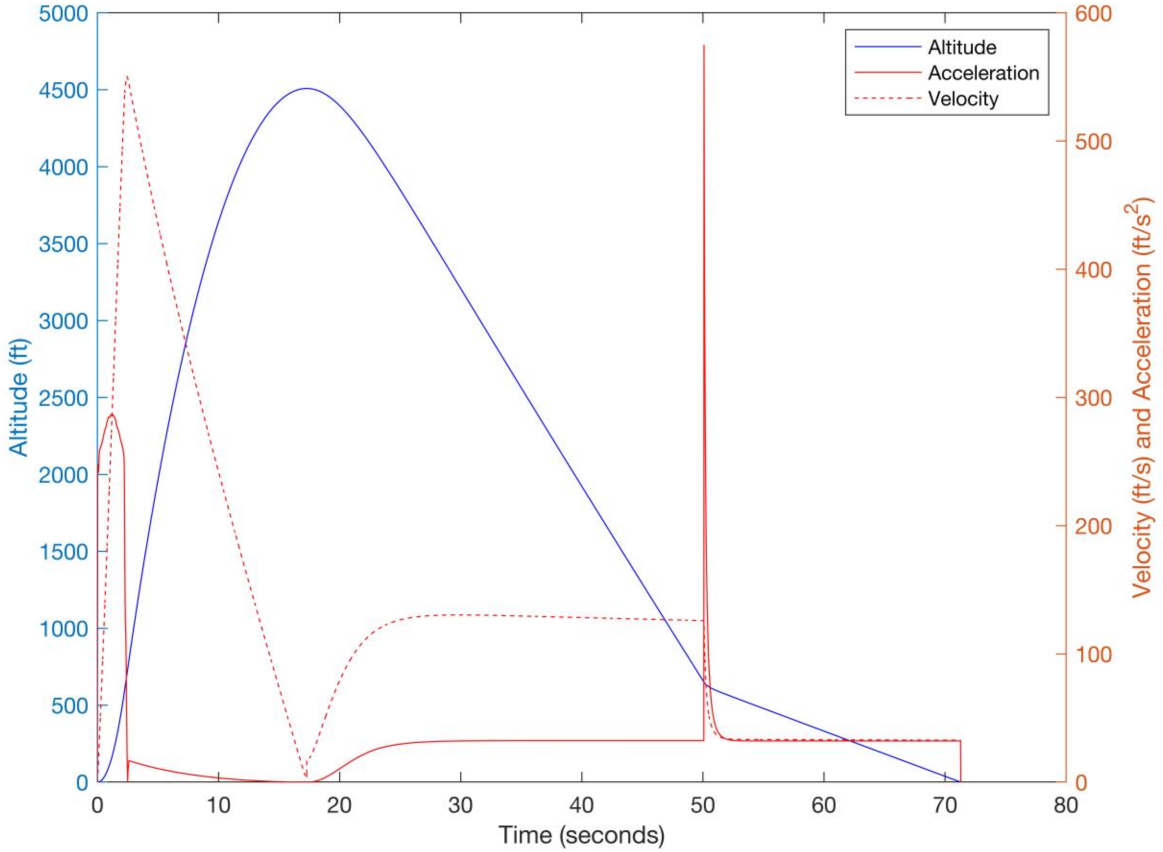


Target Altitude

<u>4473 feet</u>

<u>Based on</u>

- 3 - 14.9 MPH winds
- 5° cant of the launch rail
- 144" launch rail



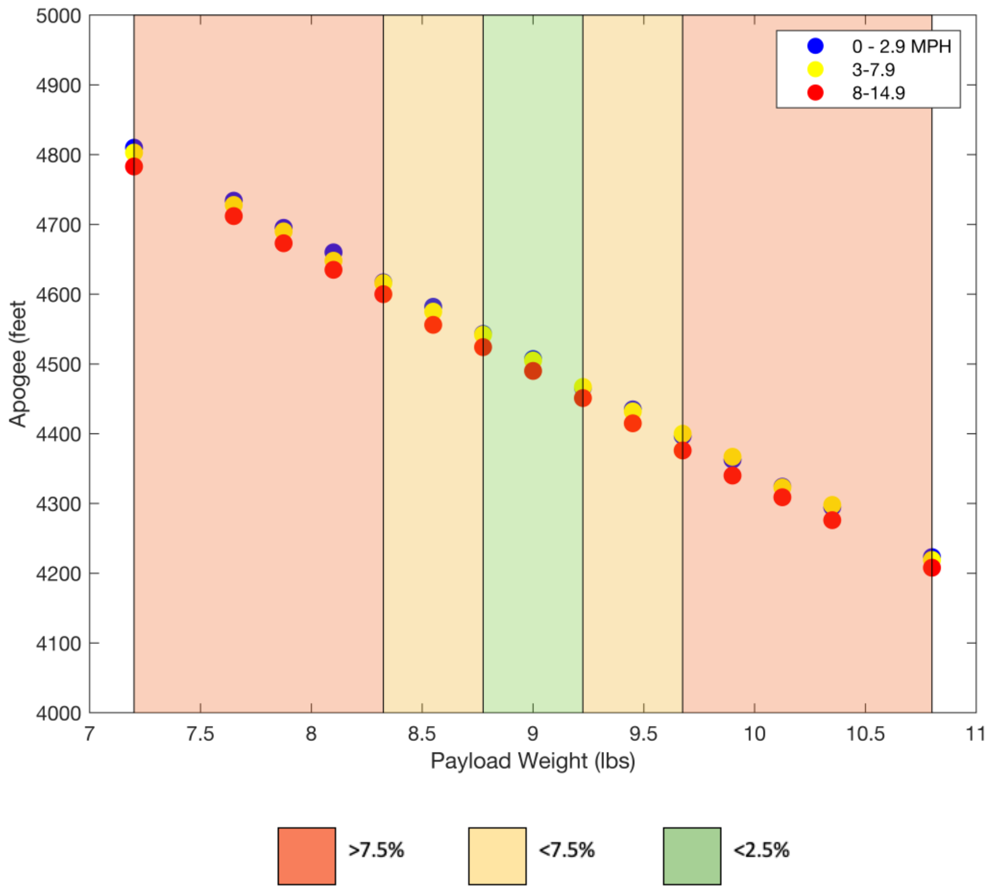
Other Key Flight Characteristics

- Velocity at Launch Rail Departure: 73.75 ft/s
- Peak Velocity: 548.66 ft/s
- Peak Mach: 0.488 Mach
- Peak Acceleration: 542.56 ft/s^2
- Thrust to Weight Ratio: 7.94

Apogee Uncertainty

Uncertainty

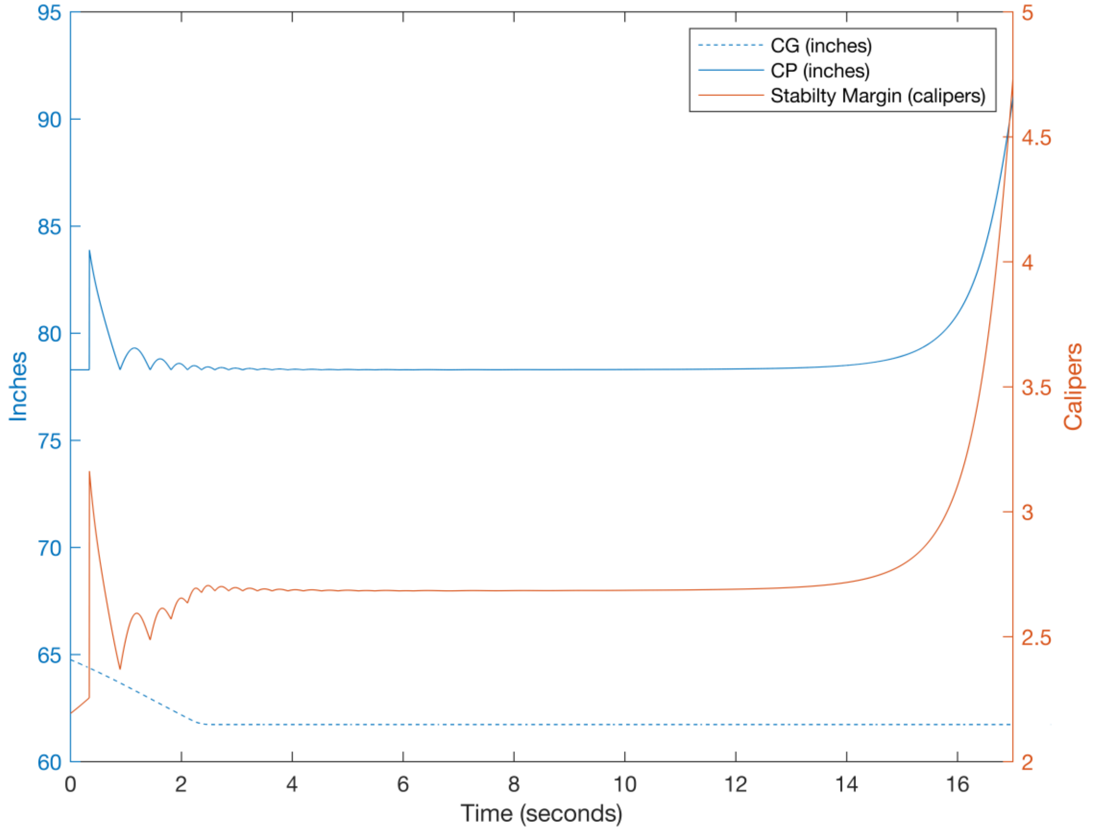
- Wind Speed
- Payload Weight



Static Stability Margin of Launch Vehicle

- Initial: 2.2
- At departure of Launch Rail: 2.38

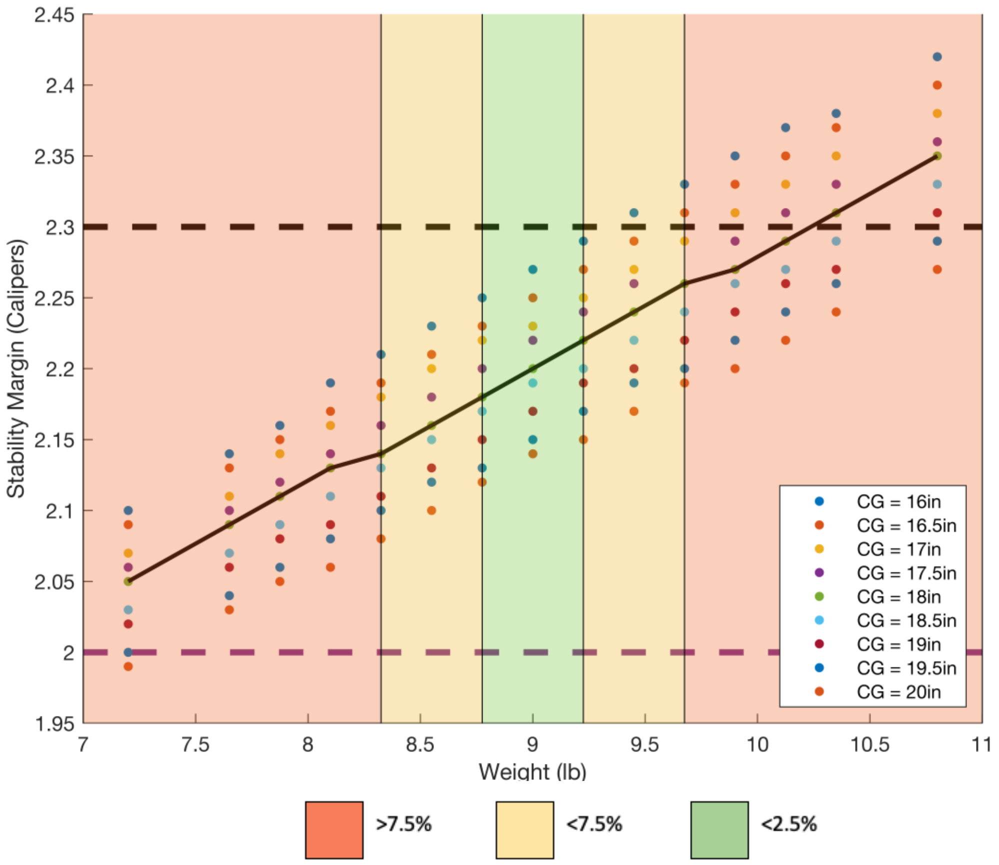
Computational Method	Static Margin (Calipers)
Barrowman's Method	2.29
RockSim	2.2



Stability Margin Uncertainty

Uncertainty

- Payload Weight
- Payload CG



Payload Leading Design

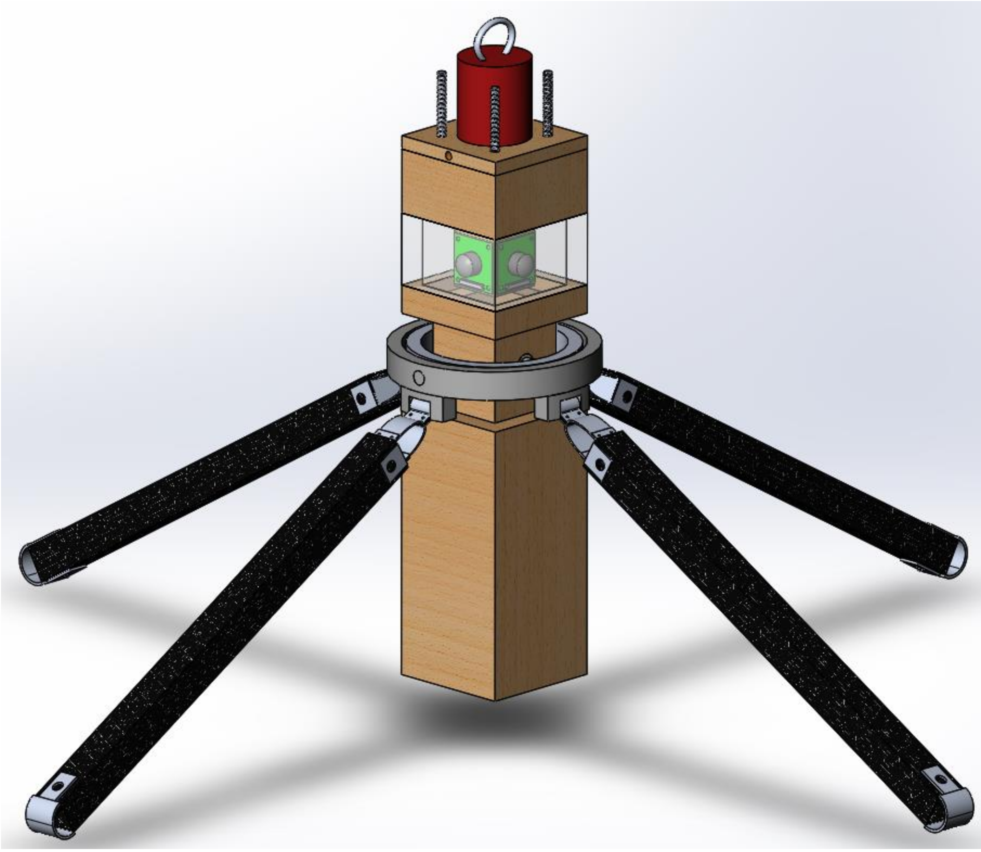
Planetary Lander

Deployment and Integration

Imaging System

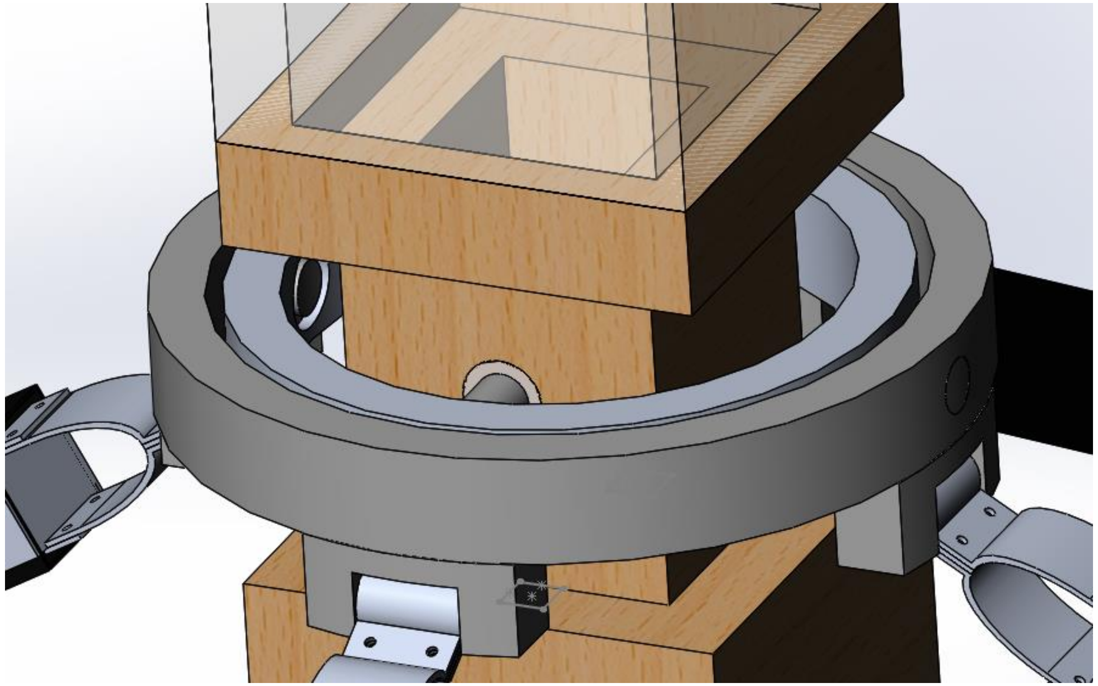
LOPSIDED

- Lander for Observation of Planetary Surface Inclination, Details, and Environment Data
- Main Objectives:
  - House the Planetary Observation System (POS)
  - Land and take initial orientation measurement
  - Re-orient within 5° of vertical using levelling system
  - Record new orientation measurement



Leading Levelling and Chassis Design

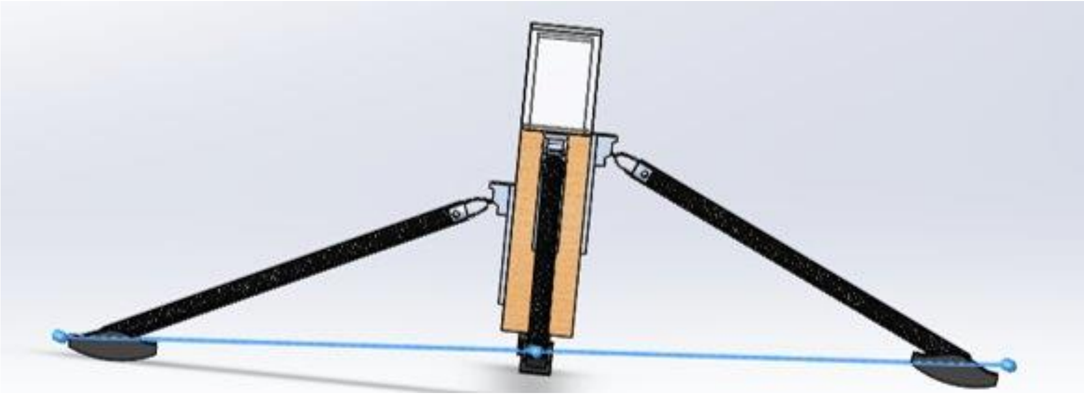
- 2-axis (both horizontal) gyroscopic levelling system driven by the force due to gravity
  - CG will be beneath the two axes
    - A ballast will be placed at the bottom of the chassis to achieve this
- The chassis will feature a cutout to increase the rings' range of tilt to ~ 15° off neutral



Alternative Leveling and Chassis Designs

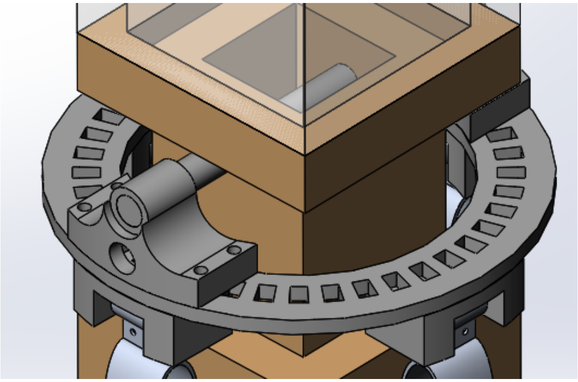
Varying Leg Attachment Height

- Cons:
  - ~4° minimum range
  - Occupies too much internal volume



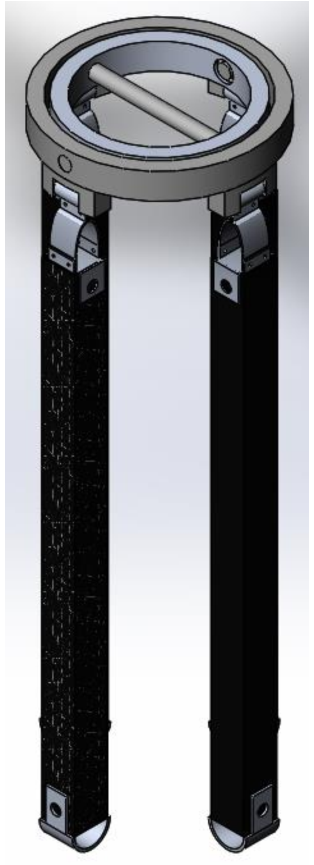
2-Axis Chassis Rotation (Vertical and Horizontal)

- Pros:
  - ~15° minimum range
- Cons:
  - Difficult to actuate



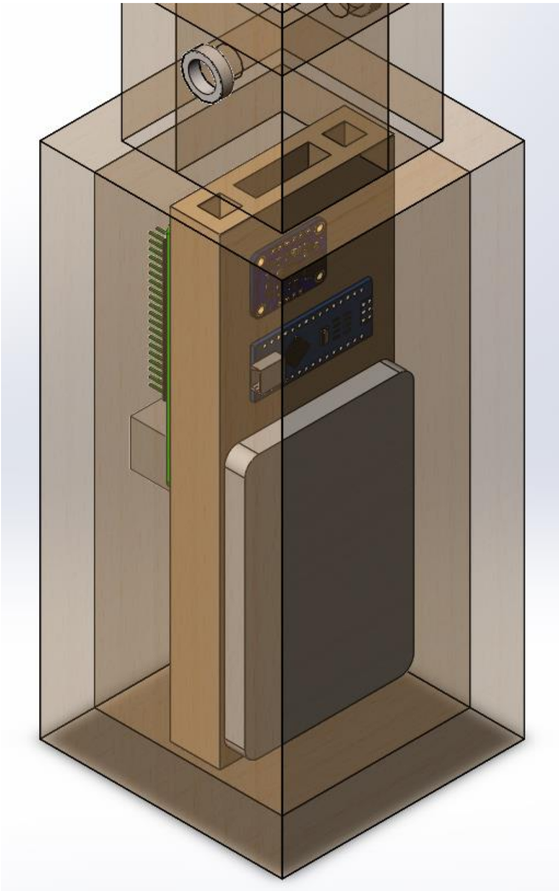
Support and Levelling System

- Rods will connect to the rings via ball bearings
- Leg rotation driven by torsional springs, stopped by set screw
- Materials: Aluminum and carbon fiber



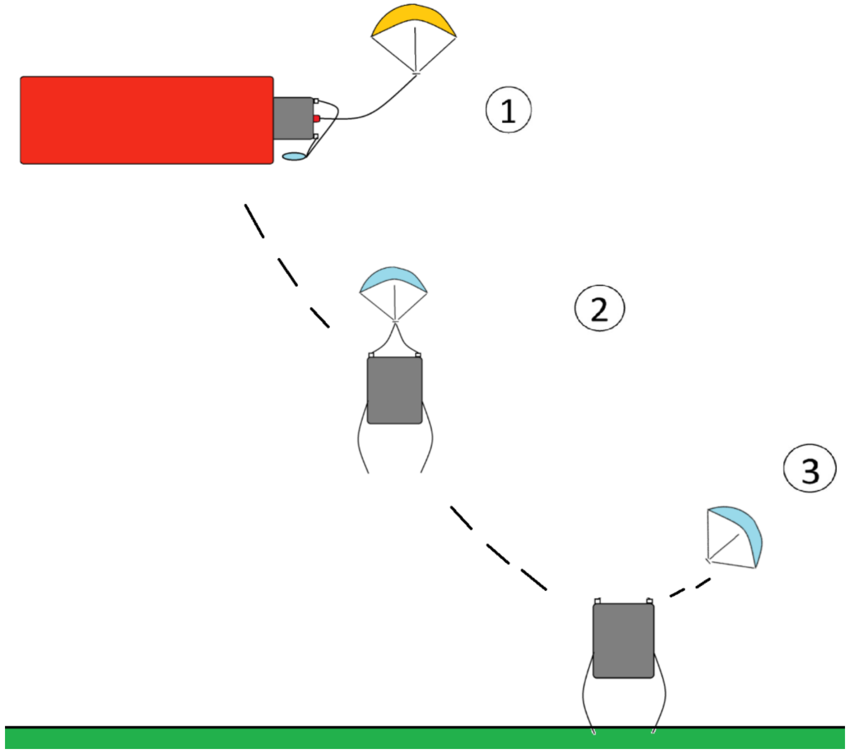
Electronics Section

- Lower Third Section of Chassis
- Contain LOPSIDED and POS electronics
- Contain ballast to lower CG
- All mounted on a sled for easy access



Payload Deployment and Integration

- Main Objectives:
  - Retain LOPSIDED throughout main-vehicle launch until deployment.
  - Release LOPSIDED while avoiding impacts that cause damages to electronics or leveling components.
  - Release parachute post-landing to avoid parachute pull on LOPSIDED or covering of POS.

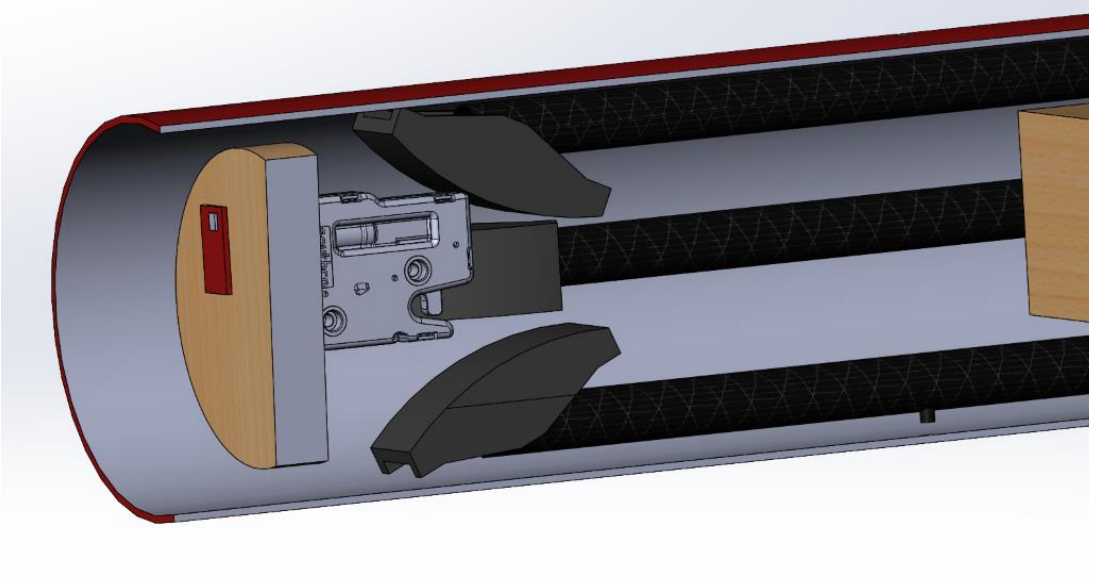


Retention Alternative Designs

Design	Components	Pros	Cons
Electronic Integration	• Rotary Latch • Shear Pins (x4) • Altimeter Electronics	• Lightweight • Simple • Reliable • Small	• Electronics dependence
Mechanical Integration	• Rollers • Rails (x4) • Rail locks	• Robust • Mechanical	• Heavy • Limits space

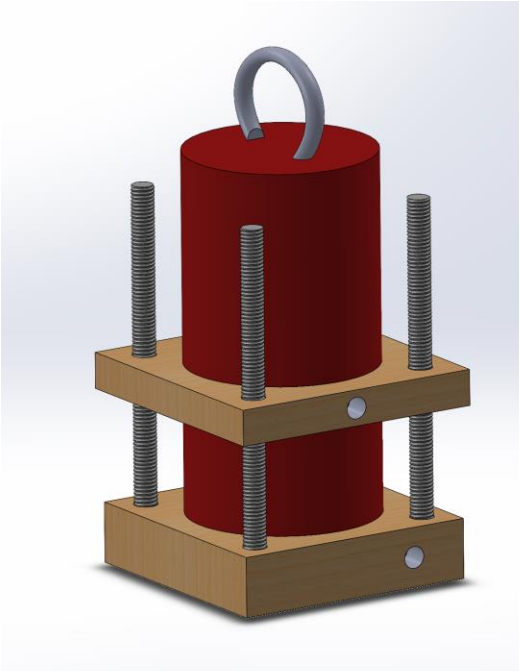
Electronic Integration Design

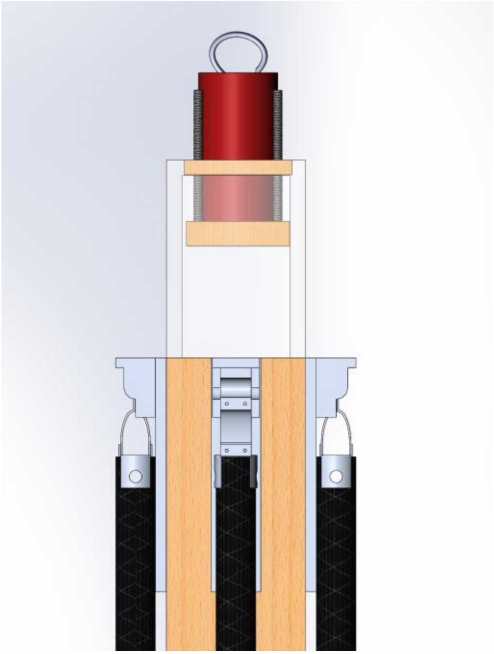
- Altimeter: StratoLogger CF
- Shear Pins
- Rotary Latch: R4-EM series
  - Holding Force: 1522lbf



Releasing LOPSIDED from Main Parachute

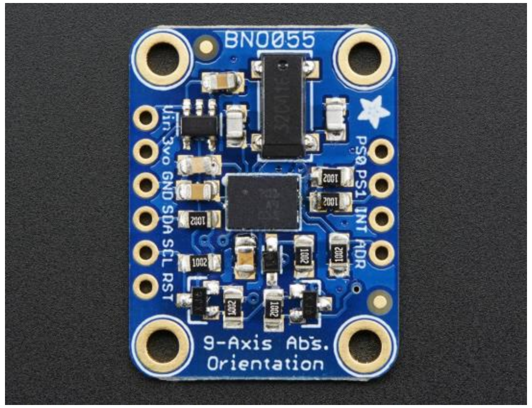
- The Advanced Retention Release Device (ARRD) activated at 500 ft AGL.
- ARRD separates LOPSIDED from the main parachute.
- Altimeter sends electric signal through e-match to ignite the ARRD's black powder.
- ARRD is attached to LOPSIDED using a housing with four lead screws and a wooden platform at the bottom.

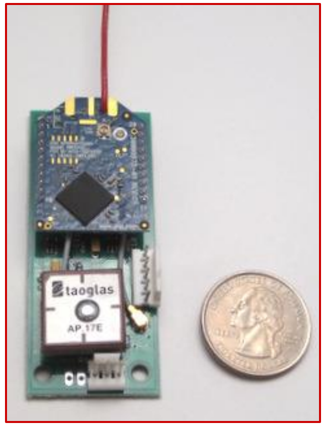


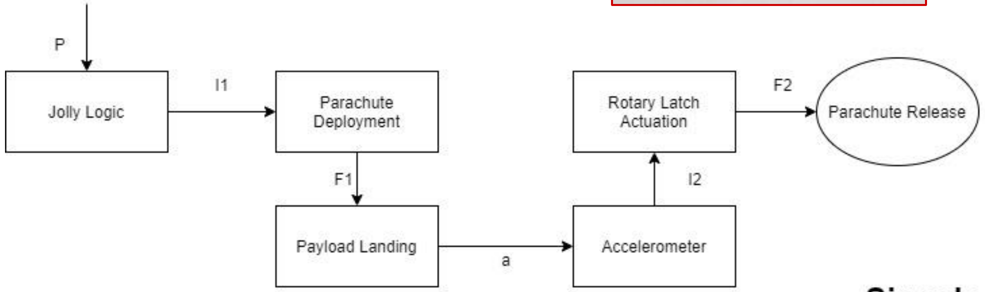


Electronics

- Power Source: 9V Batteries
- Altimeter: StratoLogger CF
- Tracker: BRB900
    - Frequency: 900MHz
    - Power: 250mW
- Acceleration Sensor:
    - Adafruit BNO05
    - 9 DOF
- Jolly Logic Chute Release





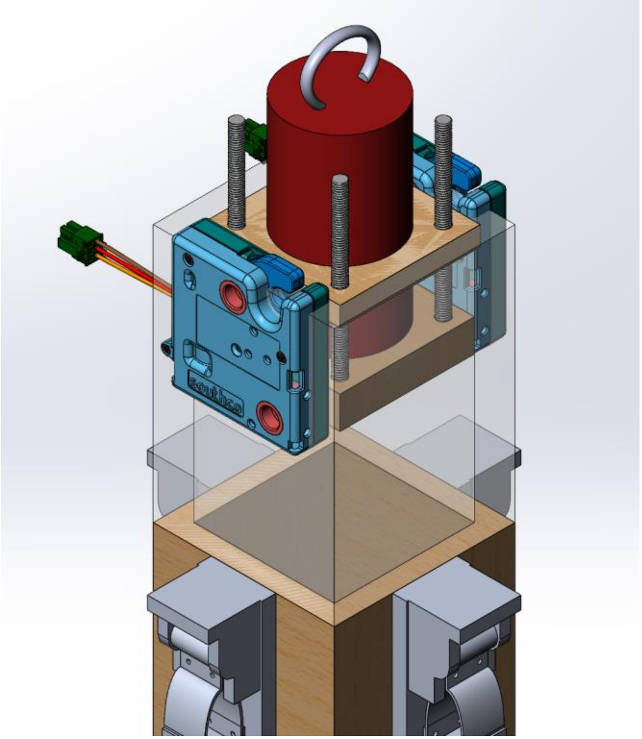


Signals

I1	-Current from Jolly Logic
I2	-Current from Accelerometer
F1	-Pulling Force from Parachute
F2	-Pulling Force from Latch
P	-Pressure
a	-Payload Acceleration

Post-Landing Parachute Release

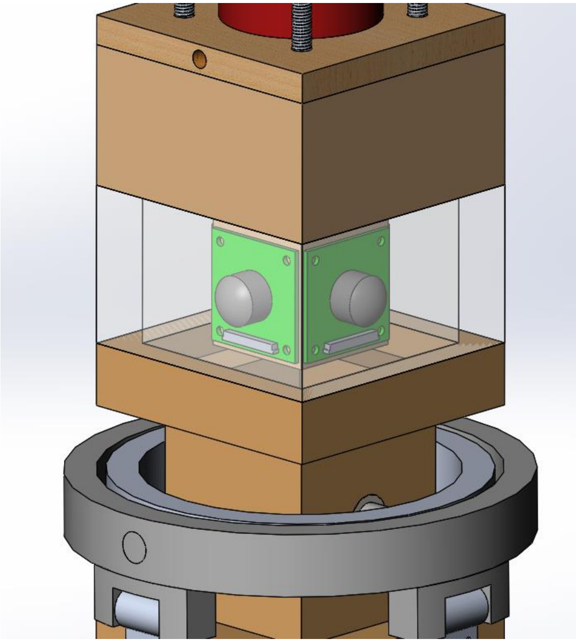
- Actuators: Electronic Rotary Latch
  - R4-EM 5&7 rated for high loads
  - Dimensions: 2.73inx2.73inx0.82in
  - Holding Force: 993lbf
  - Activated using accelerometer

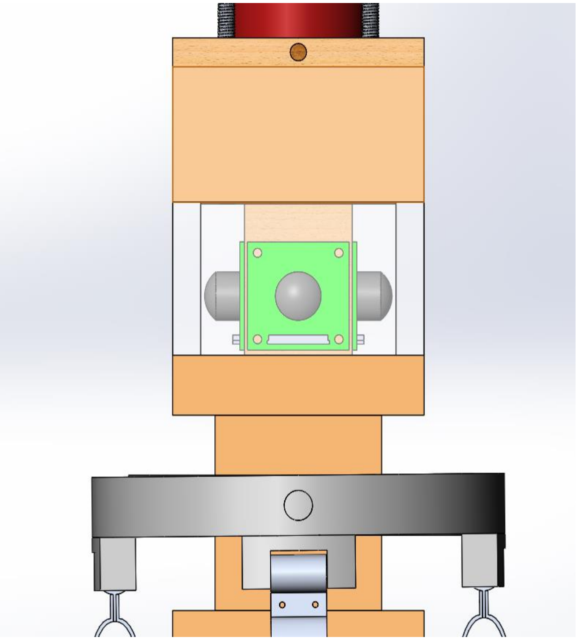


- Alternative: Electromagnetic lock
  - 3510LM Cabinet Lock
  - Holding Force: 250lbf
  - Dimensions: 1.65inx1.65inx0.79in
  - Power Supply: 12VAC/VDC

Planetary Observation System (POS)

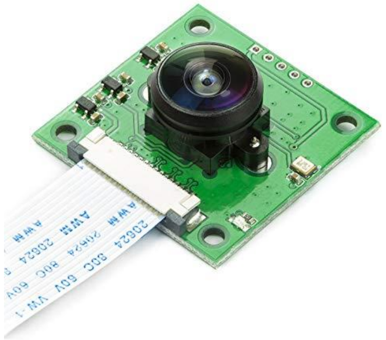
- Payload must capture a 360° panoramic photograph of the landing site and transmit it back to the team
- Main Objectives:
  - After self-leveling is completed, initiate photo capture
  - Process images to generate 360-degree panoramas
  - Transmit images back to team ground station

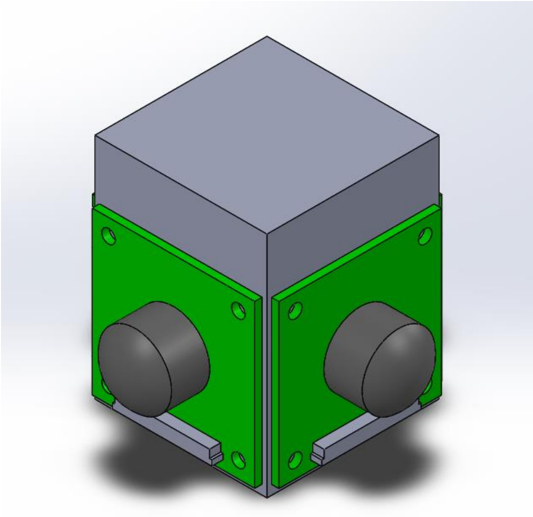


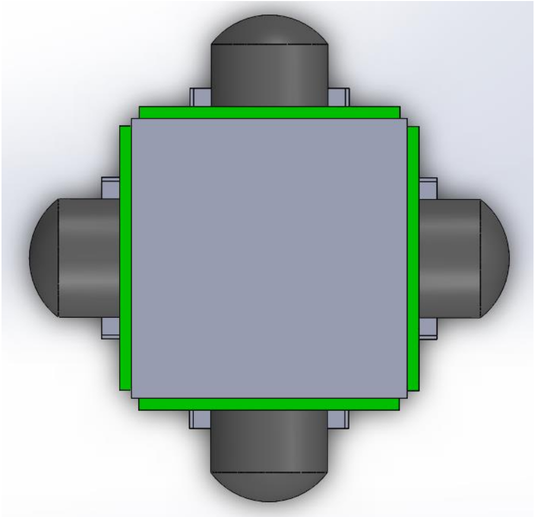


Leading Imaging Design (Cameras)

- Four Arducam Fisheye Raspberry Pi cameras
  - Horizontal field of view (HFOV) = 194°
- Two cameras facing opposite directions can capture a full 360° view
- Four cameras = two 360° images, offset by 90°
  - Provides redundancy if:
    - One camera fails
    - Two opposite facing cameras fail







Alternate Designs

Single 360° Camera

- Pros
  - Simple hardware integration
  - Robust
- Cons
  - High weight
  - Difficult software integration

Single Camera, Actuated

- Pros
  - Camera designed to work with Raspberry Pi
  - Communication with only one camera
- Cons
  - Moving parts add complication
  - Difficult integration with leveling system

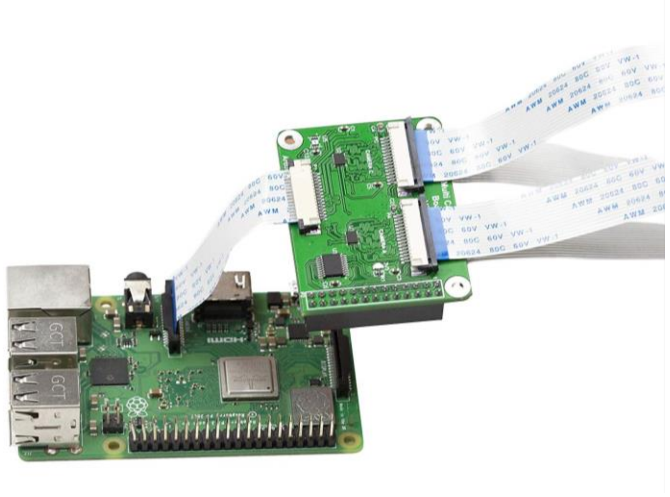
Two 180° Cameras

- Pros
  - Cameras designed to work with Raspberry Pi
  - Simple hardware integration
- Cons
  - Need to interface with multiple cameras
  - Alignment is important

The two 180° camera design was modified to the leading four 180° camera design

POS Computer

- Raspberry Pi 3B+
  - Raspbian OS
- Arducam Multi-Camera Adapter board
  - Allows multiple camera modules to interface with one board
- Python scripts will be used for:
  - Initiating image capture after leveling is complete
  - Image processing
  - Initiating data transmission



Additional POS Electronics

- Adafruit Triple-Axis Accelerometer
  - Used to detect LOPSIDED landing and payload leveling
- 433 MHz Transmitter
  - Used to transmit images to ground station
- 5V, 2500 mAh battery pack

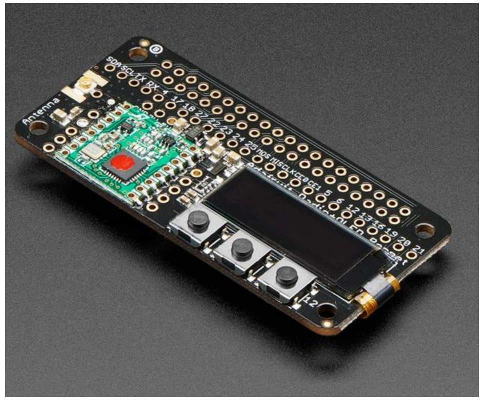
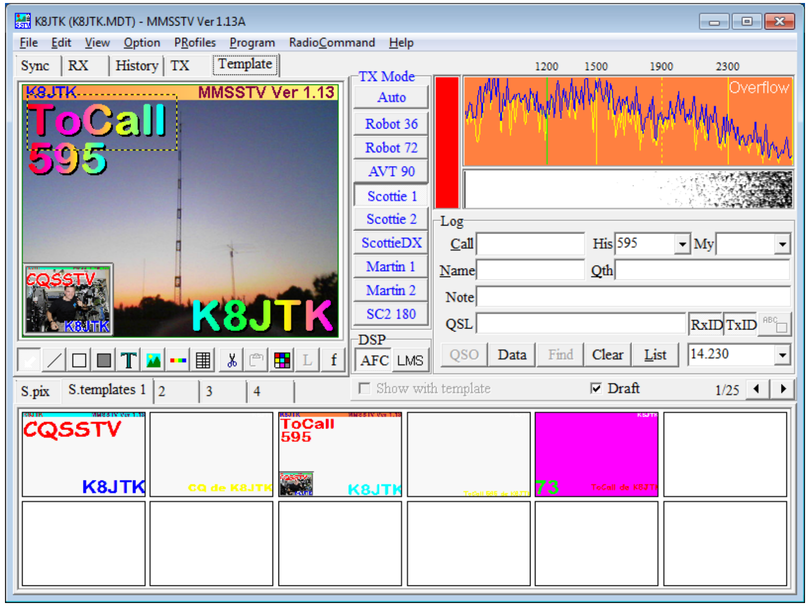


Image Transmission

- Slow-Scan Television (SSTV)
  - Transmission method that utilizes voice radio frequencies to send static images
  - Images are converted to audio (WAV) files, transmitted, and decoded using computer software
- Pros
  - Large transmission range
  - Low power
- Cons
  - Low bandwidth
  - Limited image resolution



Requirements Compliance

Team-Derived Requirements

Compliance Plan

Team-Derived Requirements

- Developed for Launch Vehicle, Recovery, and Payload
- Designed to increase safety and probability of mission success
- Examples:
  - TDR 2.2: All critical components of the launch vehicle SHALL be designed with a minimum factor of safety of 1.5.
  - TDR 3.10: The recovery system SHALL be capable of recovering the launch vehicle within NASA Handbook requirements should the LOPSIDED-POS fail to separate from the launch vehicle.
  - TDR 4.11: LOPSIDED SHALL have a center of gravity beneath its pivoting axes.

Requirements Compliance Plan

- Each requirement has its own needs
- Requirements verified by analysis done by CDR
- Test plans supplied with CDR, verified by FRR
- Inspection/Demonstration requirements verified by FRR
  - Most require full scale to be built and/or launched

Questions?