Preliminary Design Review

November 5, 2019

Sample Acquisition:
Erik Benson

Launch Vehicle Structures:
David Torres

Payload Vehicle:
Michael Barton

Student Team Leader:
Ashby Scruggs

Launch Vehicle Recovery:
Gabriel Buss

Aerodynamics:
Ethan Johnson

Payload Integration:
Sean Clark

Underclassmen Representative:
Evan Waldron

Presentation Overview

- Launch Vehicle Leading Design
- Mission Performance Predictions
- Recovery Subsystem Design
- Preliminary Payload Design
- Preliminary Payload Retention Design
- Requirements Compliance Plan

Launch Vehicle Leading Design

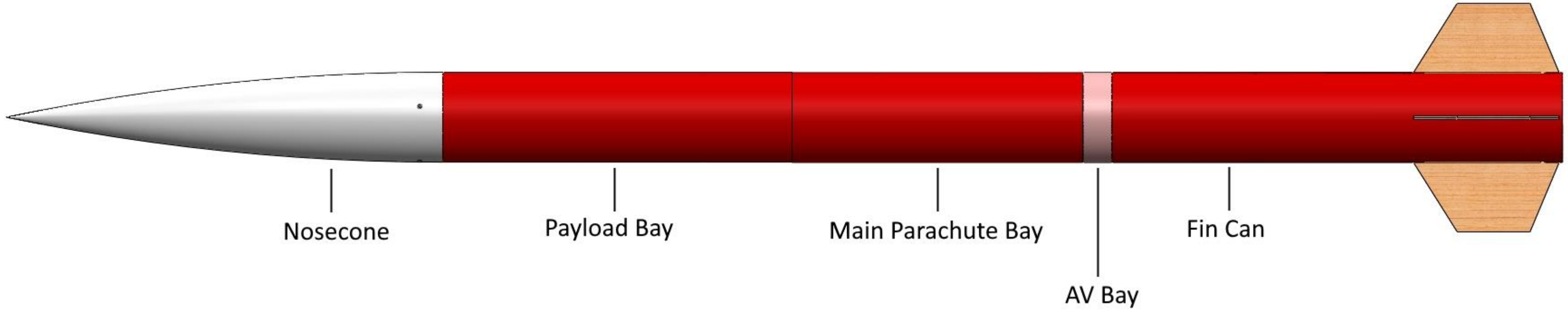
Material Selection

Structural Components

Alternative Designs

Launch Vehicle Dimensions

- Length: 107.5"
- Diameter: 6"
- Launch Weight: 44.70 lb
- Empty Weight: 40.61 lb



Material Selection

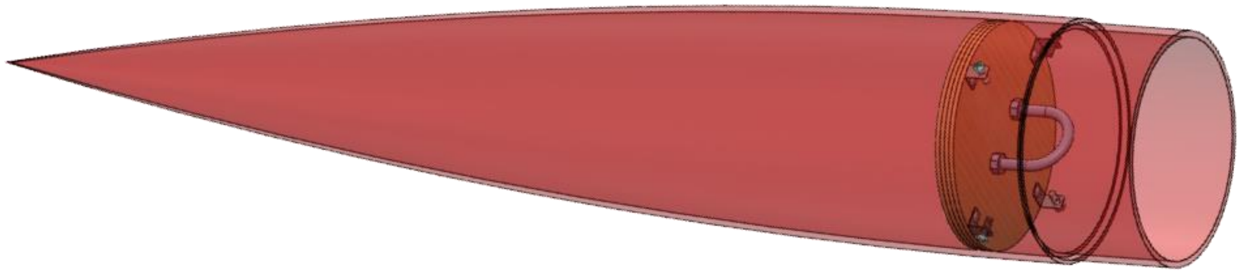
- G12 Fiberglass
  - Filament wound body tube
  - Heavy
  - Expensive
  - Durable
  - $2/inch more than Blue Tube 2.0
- Blue Tube 2.0
  - Reinforced paper based body tube
  - Light
  - Inexpesive relative to fiberglass
  - Suseptable to moisture damage

Selected Material – G12 Fiberglass

- Prioritizing Resistance to moisture
  - Integral to ensuring reusability of rocket
- Increase in durability is worth the increase in durability and cost
- RockSim simulations show launch vehicles ability to reach acceptable altitude with increased weight

Nosecone

- Von Karman (5.5:1)
  - Limited Commercial Availability
  - Expensive
  - Minimum drag for a given length and diameter
- Ogive (5:1)
  - Large Commercial Availability
  - Relatively Inexpensive
  - Similar drag characteristics to the Von Karman

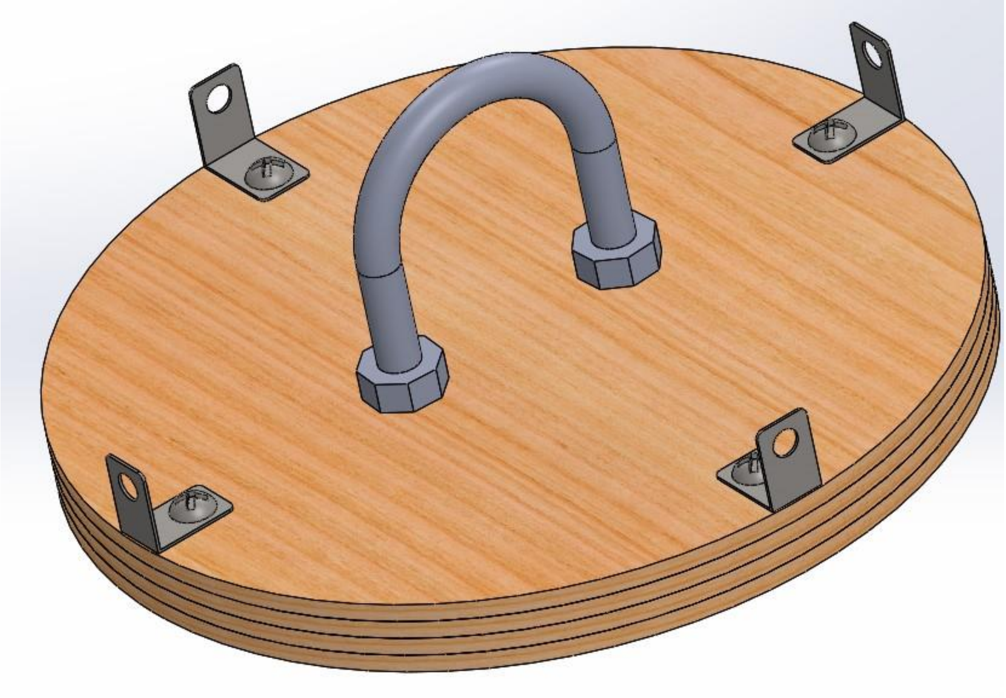


Nosecone Bulkhead

- Removable
  - Secured to nosecone via 4 bolts
  - Can easily be removed for the installation/removal of ballast
  - High stress concentrations at bolt locations
- Non-Removable
  - Secured with epoxy to the nosecone
  - Not designed to be removed
  - Stresses are distributed around the nosecone

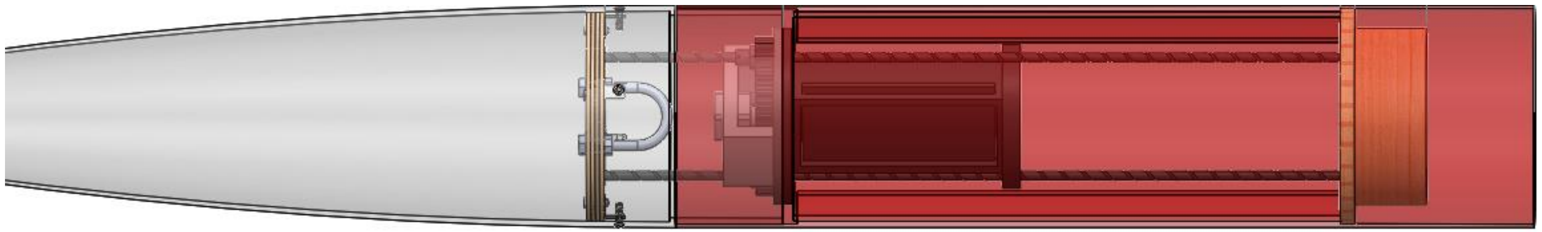
Removable Bulkheads

- A removable bulkhead provides the most benefit
- The ability to add and remove ballast is crucial
- Will be mounted via U-Bolts attached the bulkhead
- Will run FEA analysis on connections



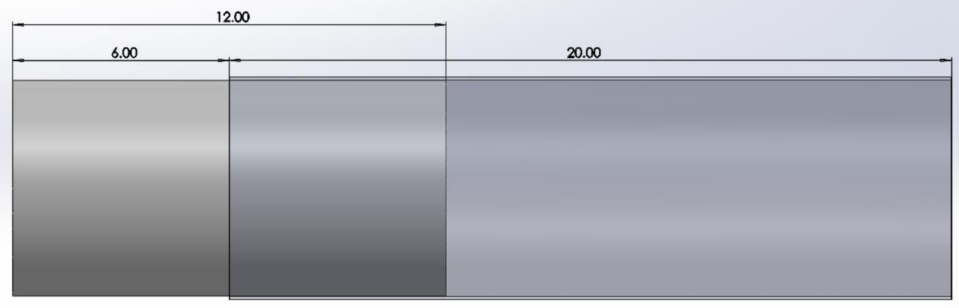
Payload Bay

- The payload bay will be located next to the nosecone
  - This will allow for a forward CG
  - This leads to a higher stability margin
- Separating the fincan and payload bay is also important
  - Separates the two heaviest sections of the rocket



Main Parachute Bay

- Located between payload and AV bay
  - Attached to payload with shear pins
  - Attached to AV bay with screws
- Main parachute will have a packing volume of 5"D and 7"L
  - Additional volume will house shock cords
- Estimated 10" of recovery material

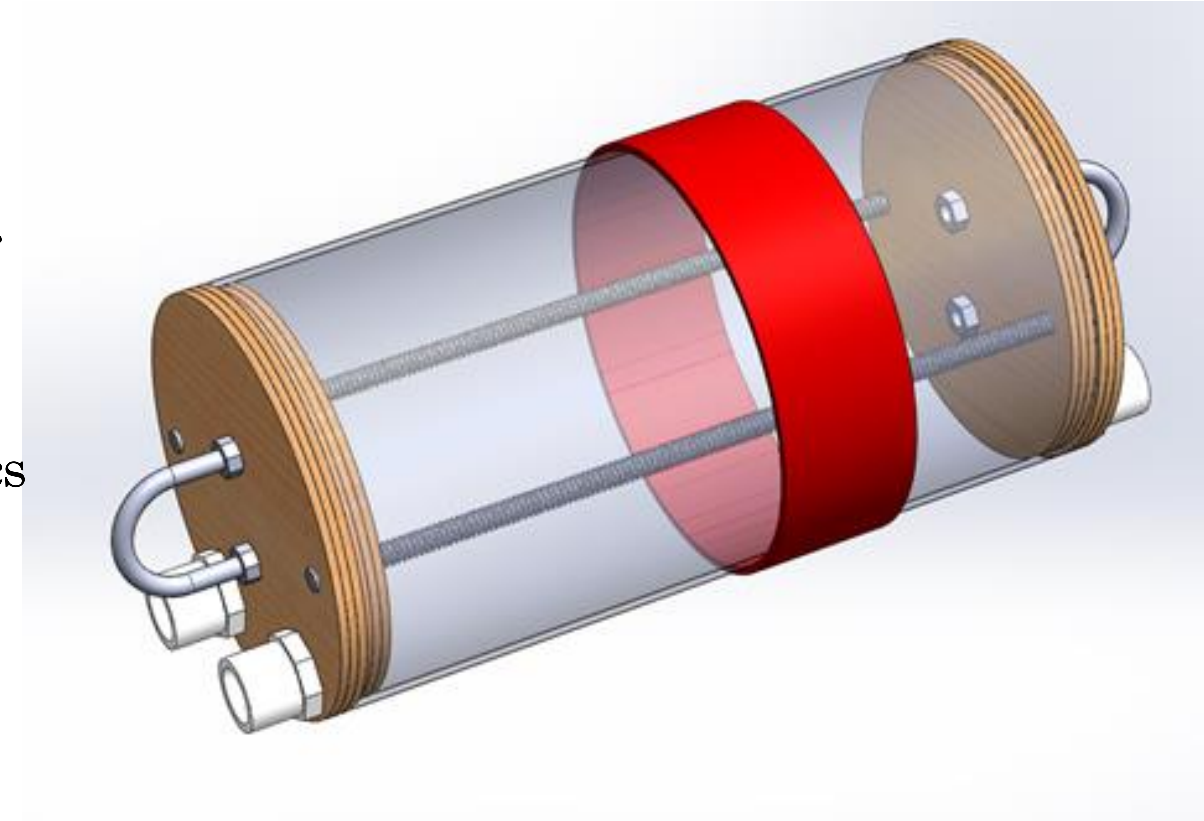


AV Bay

- Modular
  - Both bulkheads removable
    - Act as plugs to protect AV bay
    - U-Bolts and blast caps attached to both bulkheads
  - Consists of length of coupler
  - Parallel Construction
  - AV Sled is inaccessible while launch vehicle is mounted
- Integrated
  - One bulkhead fixed, and one removable
    - U-Bolts and blast caps attached to both bulkheads
  - Access hatch cut into side of airframe
    - Weakens integrity of airframe
    - Also allows access to AV sled

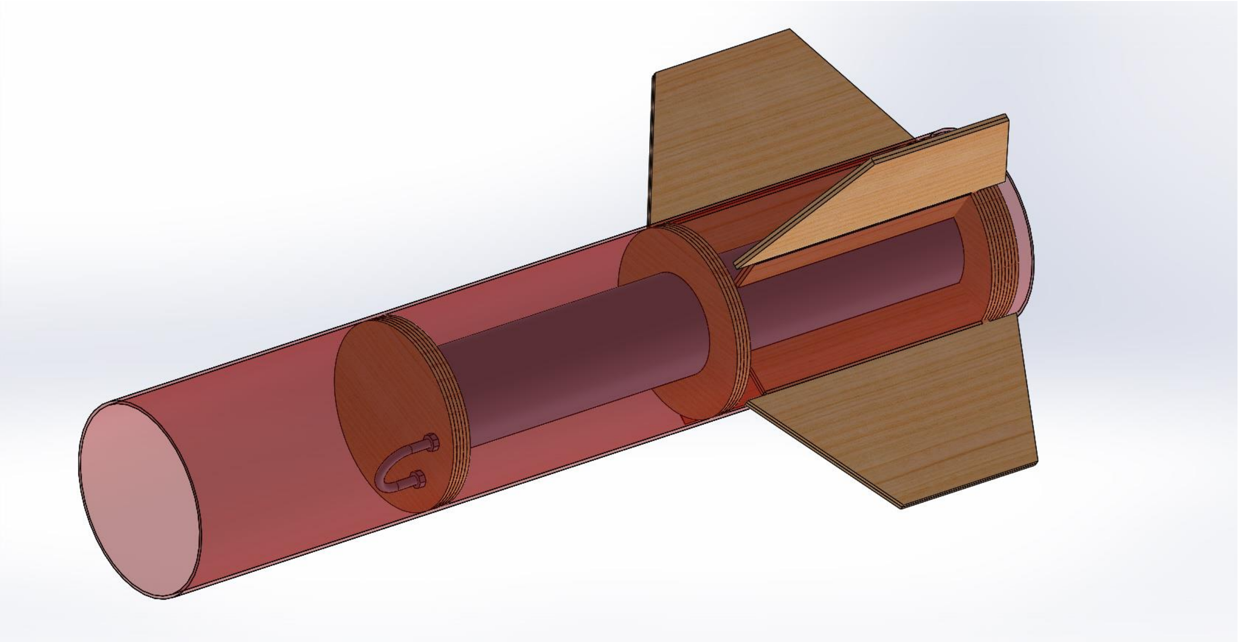
AV Bay Selection

- Modular
  - Blast caps are exposed
    - Allows for safer management of energetics
  - All wiring labels are visible
    - Prevents miswiring of energetics
  - Parallel construction during vehicle fabrication
    - Allows for faster overall construction time



Fin Can

- Motor tube is held in place by a bulkhead and three centering rings
- The motor retainer will be affixed to the aft centering ring
- Forward bulkhead has two centering rings on aft side
- Middle centering ring used for fin and motor tube alignment
- Drogue chute will be placed in forward most section.



Mission Performance Predictions

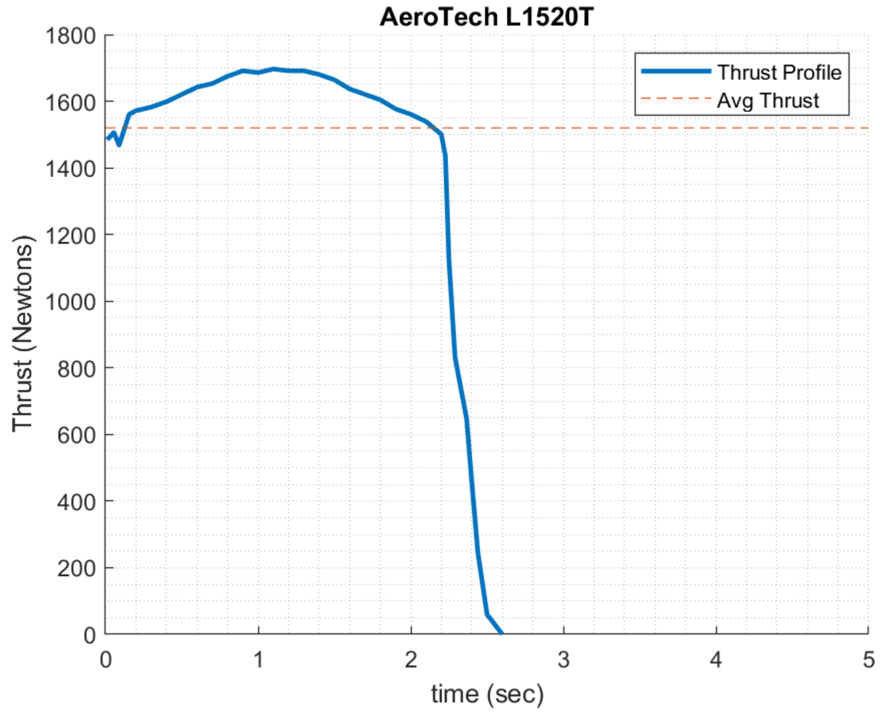
Motor Selection

Target Altitude

Flight Simulations

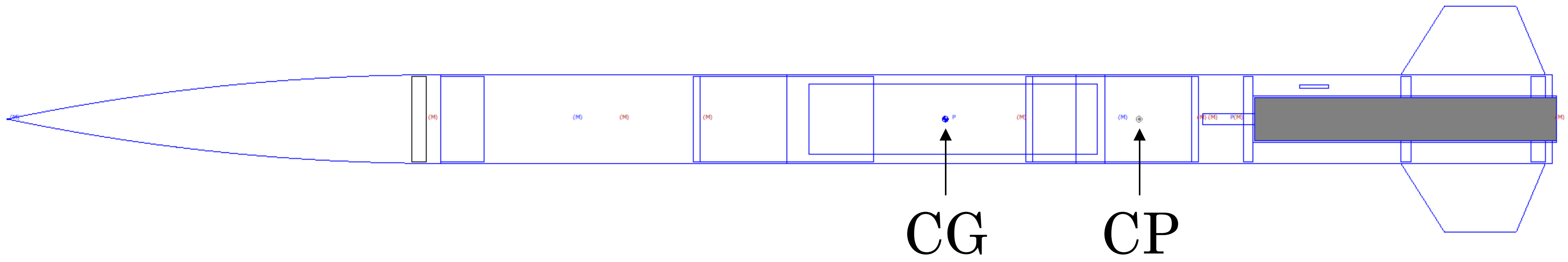
Preliminary Motor Selection

- RMS 75/3840 casing
- AeroTech L1520T
- Large initial force
- Powerful but short burn



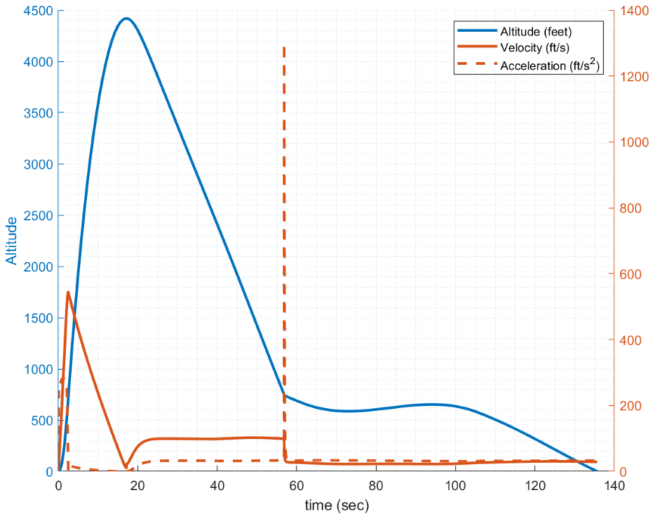
Flight Simulation Results

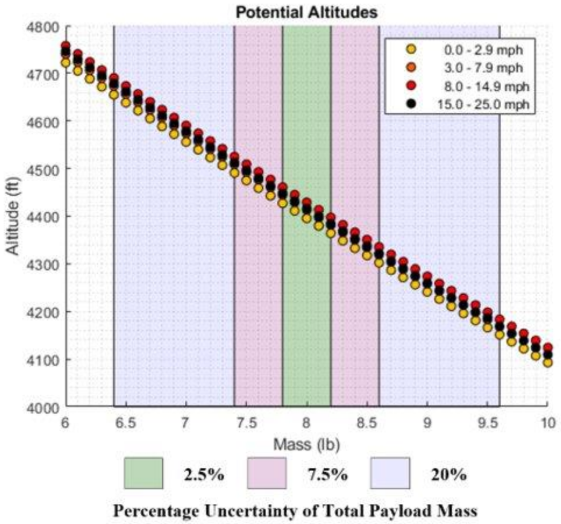
- Center of Pressure: 78.38 in
- Center of Gravity: 64.89 in
- Stability Margin: 2.19 calipers



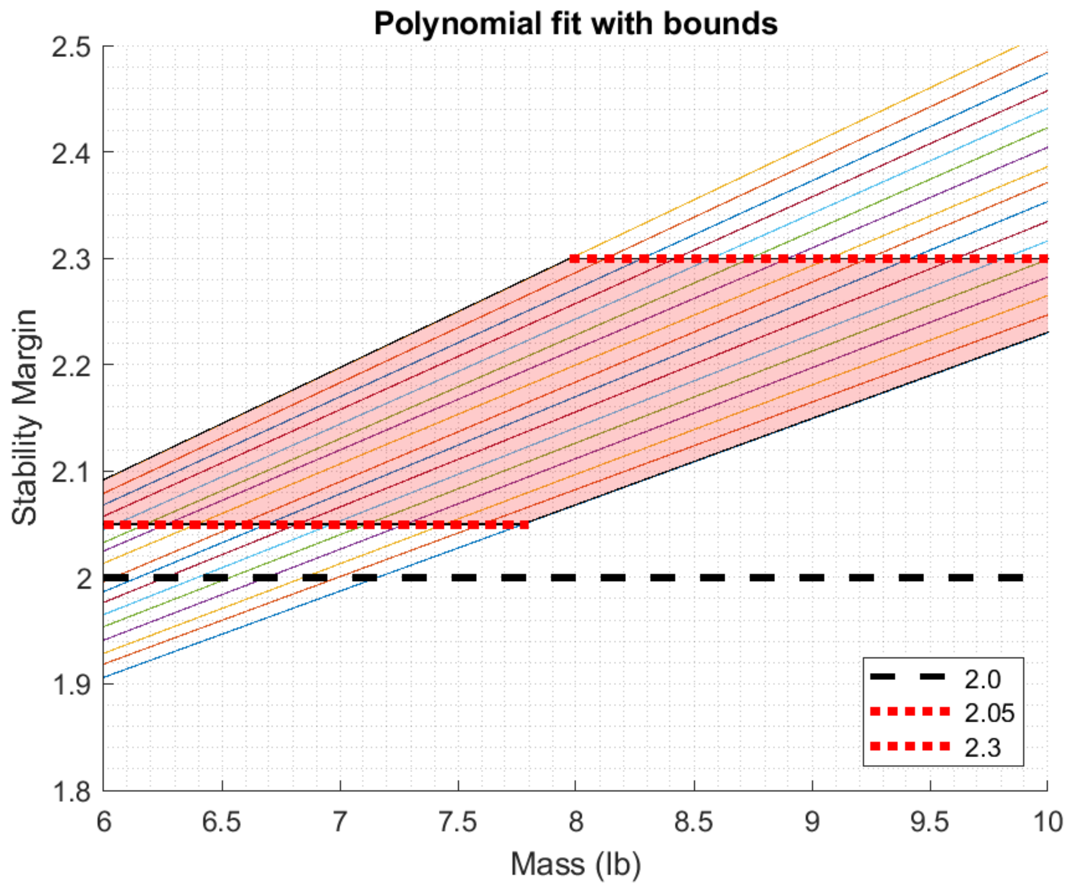
Flight Simulation Results

- Apogee: 4,420 ft
- Max Velocity: 544 ft/s
- Max Mach: 0.49
- Max Acceleration (accent): 284 ft/s^2
- Max Acceleration (chute): 1,300 ft/s^2
- Rail Exit Velocity: 73.48 ft/s
- Thrust-to-weight Ratio: 7.88





Static Stability Analysis



Method	Result	Comparison
Barrowman	2.17	$\%_{\mathrm{diff}} = 0.917\%$
RockSim	2.19	

Recovery Subsystem Design

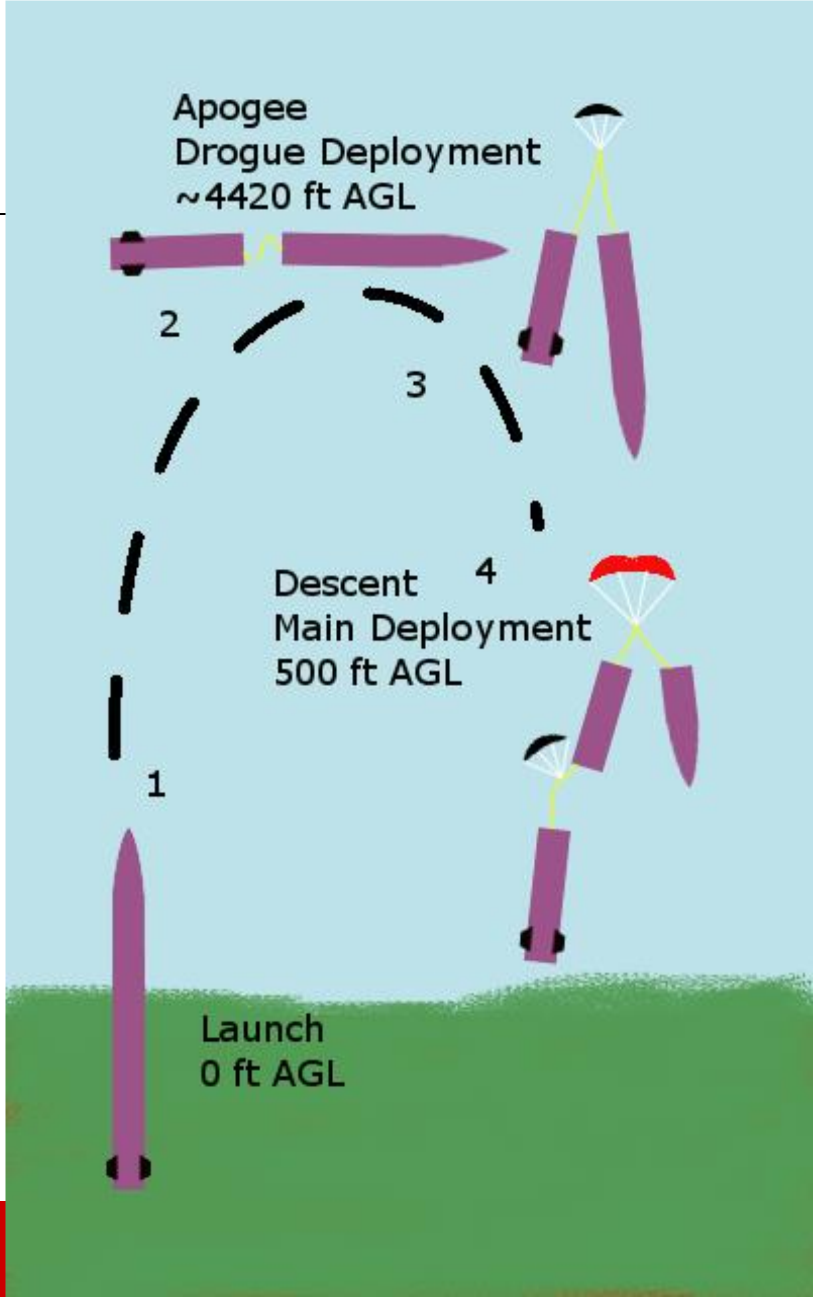
Component Selection

Recovery Events

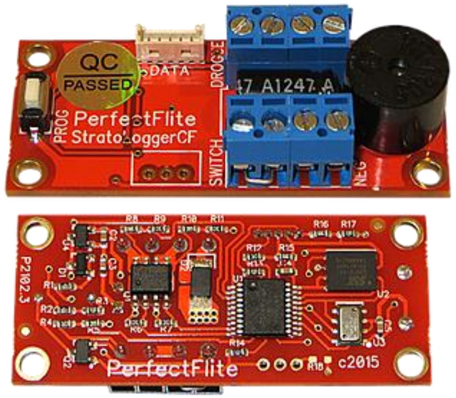
Performance Predictions

Recovery Overview

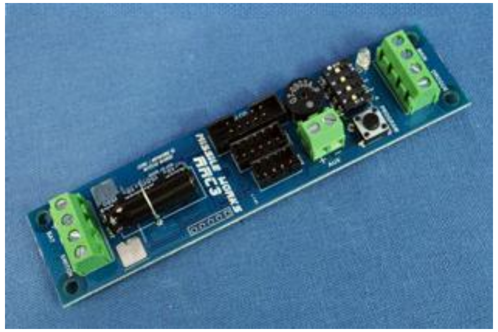
- Drogue deployment at apogee, declared as 4420 ft AGL. Secondary charge at apogee + 1 sec
- Main deployment at 500 ft AGL. Secondary charge at 450 ft



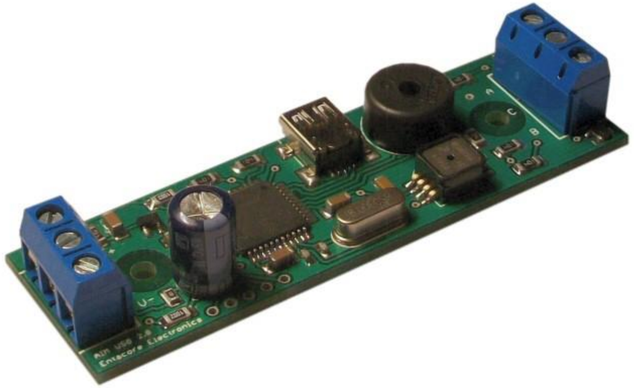
Altimeter Alternatives



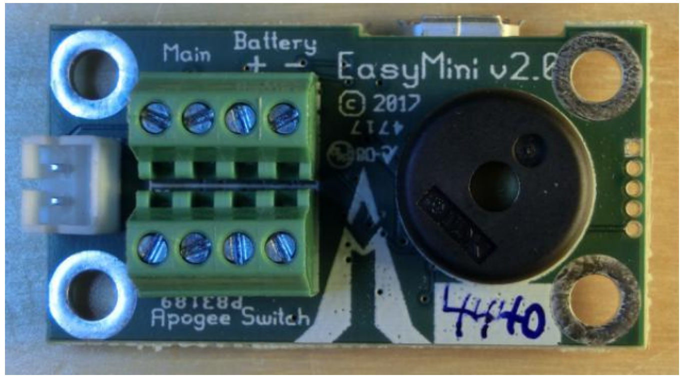
PerfectFlite StratoLoggerCF



Missile Works RRC3 Sport



Entacore AIM USB 3.0

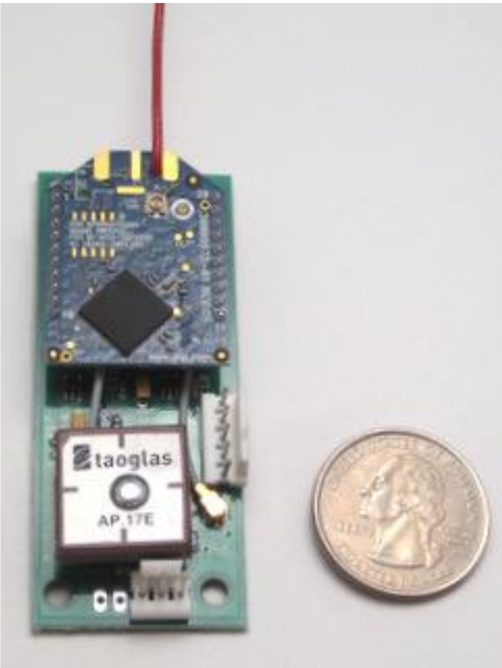


AtlusMetrum EasyMini

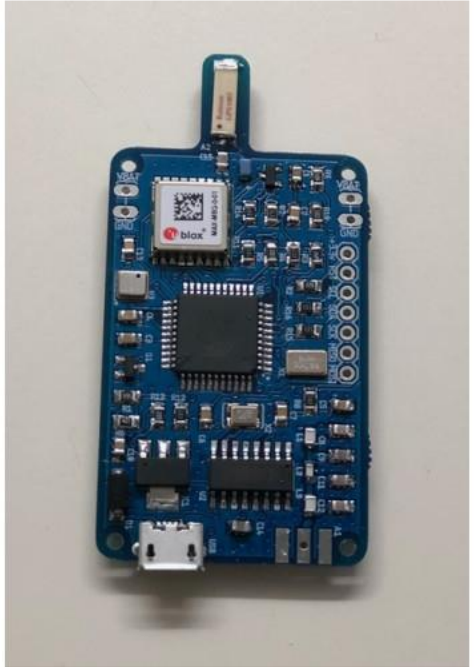
Altimeter Comparisons

Altimeter	RRC3 Sport	Entacore AIM	StratoLoggerCF	EasyMini
Main Deployment Variability	300 to 3000 ft increments of 100 ft	100 to 9999 ft increments of 1 ft	100 to 9999 ft increments of 1 ft	Any
Delay after apogee	0 to 30 sec, increments of 1	Yes	0 to 5 sec	Yes
Max Altitude	40,000 ft MSL	38,615 ft MSL	100000 ft MSL	100000 ft MSL
Minimum Apogee	100 to 300 ft	N/A	100 AGL	N/A
Altitude 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, temperature, voltage	Altitude, velocity, acceleration, temperature, voltage
Additional Comments		Shared Ground Pin, no switch pins		Reported Quiet Speaker

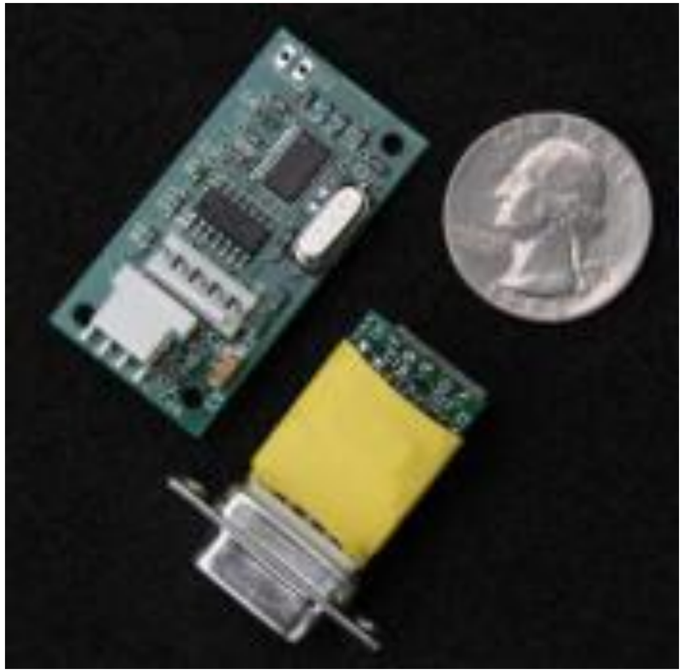
Tracking System Alternatives



BigRedBee BRB900

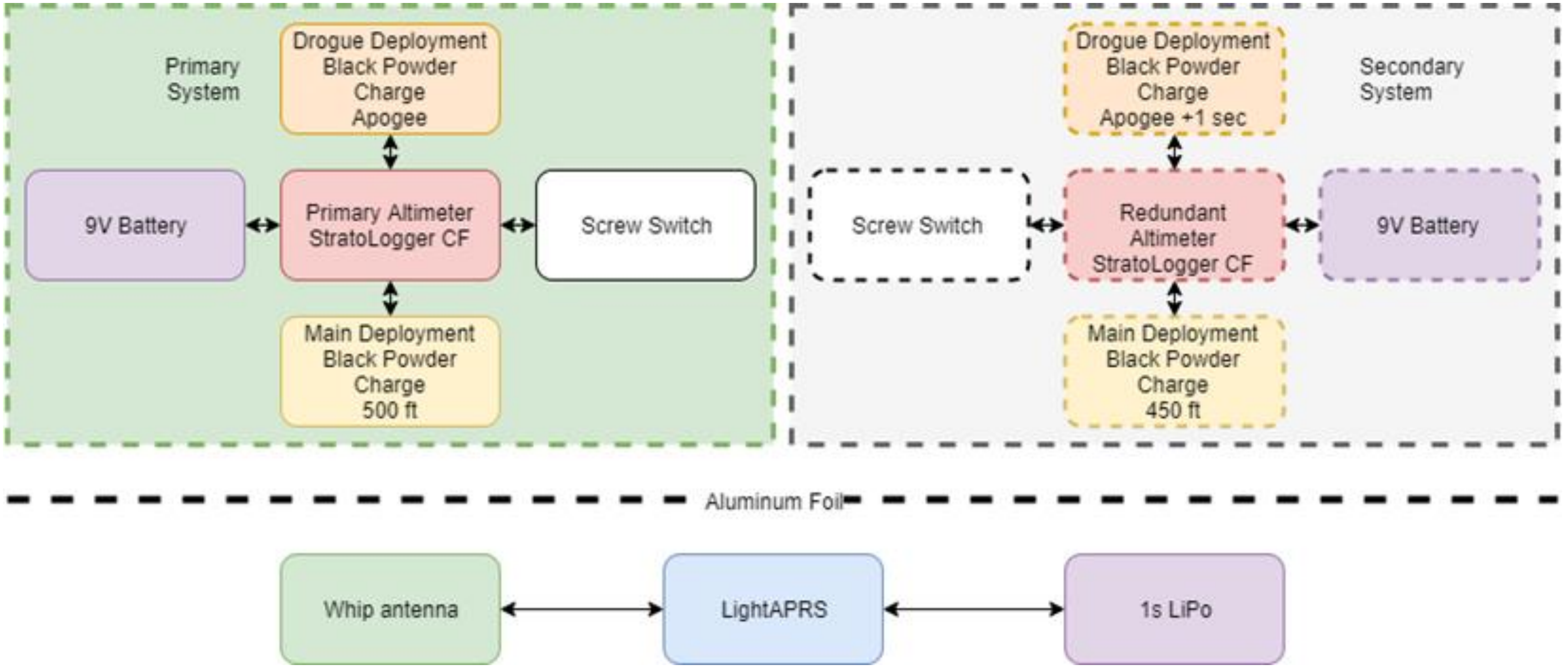


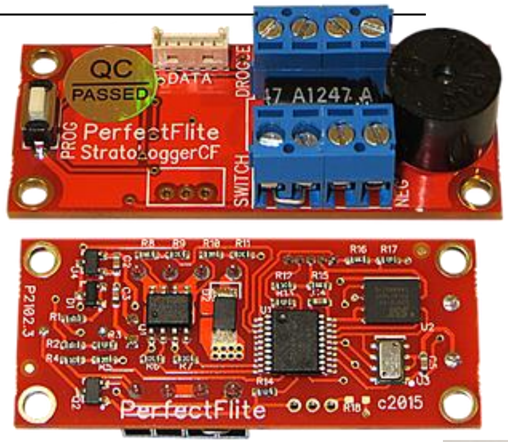
QRP Labs LightAPRS



BigRedBee BeeLine

Leading Avionics Design





- Two StratoLoggerCF altimeters
- LightAPRS Tracking
- Separate Primary and Secondary Systems ensure redundancy

Parachute Alternatives

Drogue Comparisons

Parachute	Descent Velocity	Descent Time from Apogee to Main Deployment	Wind Drift from Apogee to Main Deploy (20 mph)
Fruity Chutes 15 inch Classic Elliptical	138.7 ft/s	28.3 s	829.8 ft
Fruity Chutes 18 inch Classic Elliptical	113.3 ft/s	34.6 s	1016.3 ft
Fruity Chutes 24 inch Classic Elliptical	83.7 ft/s	46.9 s	1376.1 ft
Fruity Chutes 24 inch Compact Elliptical	85.6 ft/s	45.8 s	1344.5 ft

Main Comparisons

Parachute	Descent Velocity	Maximum Section Kinetic Energy	Descent Time from Main Deployment	Wind Drift Under Main (20 mph)
Fruity Chutes 120-inch Iris UltraCompact	14. ft/s	53.1 ft-lbf	35.7 s	1047.9 ft
Fruity Chutes 120-inch Iris Ultra Standard	14. ft/s	52.9 ft-lbf	35.8 s	1050.5 ft
Sky Angle CERT 3 XXL	13.6 ft/s	50.3 ft-lbf	36.7 s	1077.1 ft
168-inch Rocketman Pro-X	15.8 ft/s	67.9 ft-lbf	31.6 s	927.3 ft

Leading Parachute Selection

- Main:
  - 120” Iris UltraCompact
    - High C_D allows for efficient packing
    - Less susceptible to changes in mass (lower KE)
    - Deployed using piston ejection
- Drogue:
  - 24” Compact Elliptical
    - Descent Rate less than 100 ft/s
    - Favorable Drift performance
    - Protected by Nomex sheet

Performance Parameters

- Winds effects on Apogee, Descent Time, and Drift
  - Descent Time: 82 sec
  - Max Drift: 2392 ft

Wind Speed	Apogee	Descent Time	Drift Distance
0 mph	4425 ft AGL	82 s	0 ft
5 mph	4425 ft AGL	82 s	598 ft
10 mph	4425 ft AGL	82 s	1196 ft
15 mph	4425 ft AGL	82 s	1794 ft
20 mph	4425 ft AGL	82 s	2392 ft

Performance Parameters

- Kinetic Energy at Landing
  - Mass of Heaviest Section: .5426 slugs
  - Max KE: 53.1 ft-lbs

Section	Mass	Main Velocity	Kinetic Energy at Landing
Nosecone	.5426 slugs	14.0 ft/s	53.1 ft-lbs
Midsection	.3588 slugs	14.0 ft/s	35.1 ft-lbs
Fin can	.2953 slugs	14.0 ft/s	28.9 ft-lbs

Preliminary Payload Design

Rover Design

Sample Collection Design

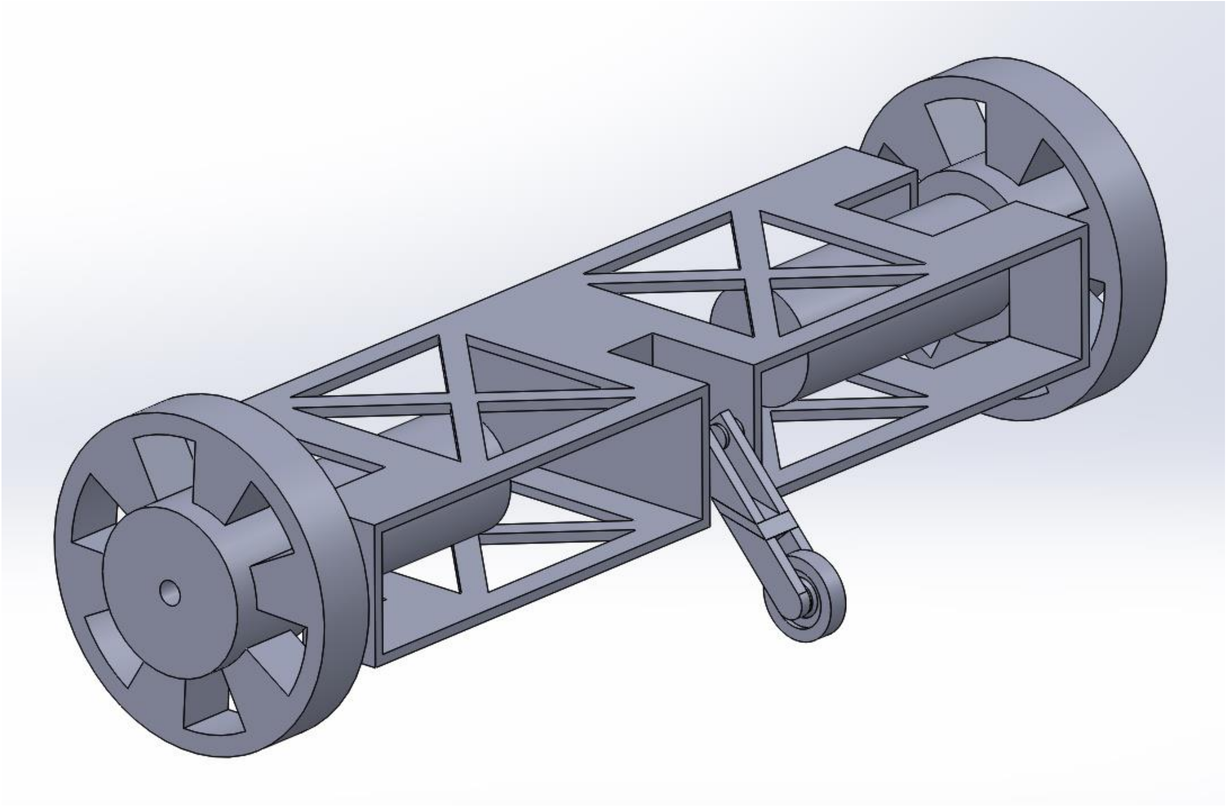
Alternative Designs

Preliminary Payload Design

- Designation: BURRITO

  Bilateral Uptake Rover for Regolith Ice Transport Operations

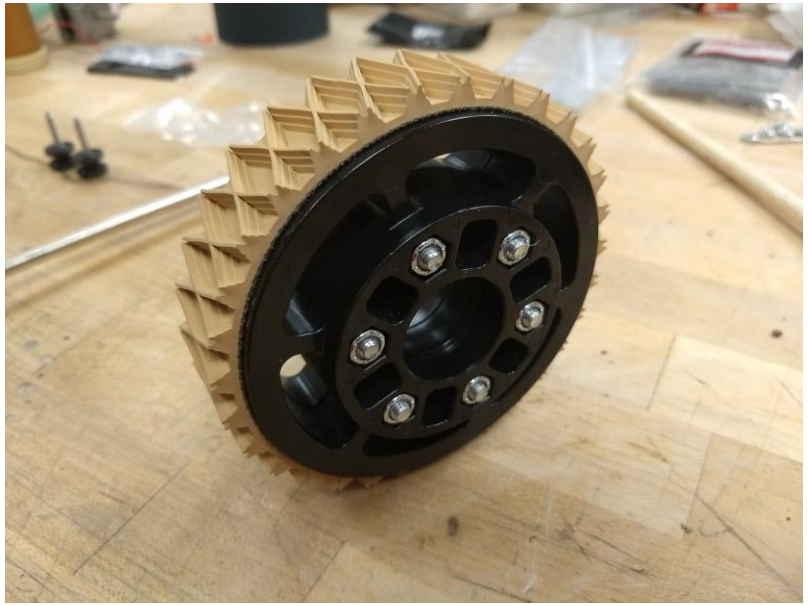
- Function
  - Drive toward recovery site following deployment.
  - Allow SICCU system to collect simulated ice.
  - Drive 10 linear feet away from recovery site.



Rover Traction Design

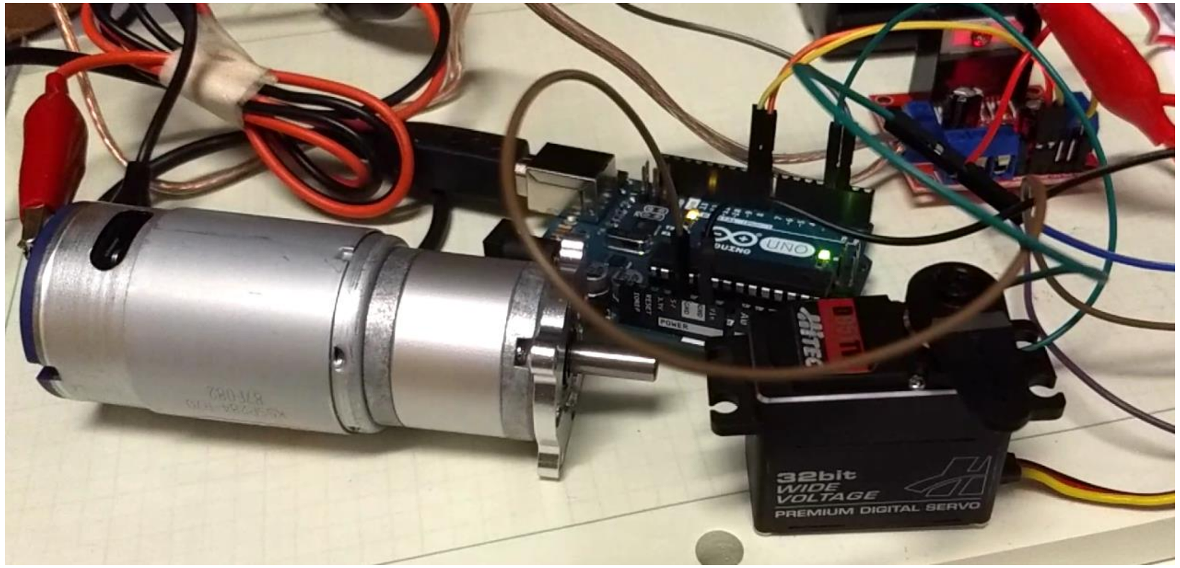
- Fixed Radius Wheels
  - Pros: high traction, lightweight
  - Cons: chassis could get stuck
- Tank Treads
  - Pros: high traction, all-terrain
  - Cons: heavy, less space for other components
- Mecanum Wheels
  - Pros: can make payload deployment easier
  - Cons: complex moving parts, low traction

- Leading Design
  - Fixed radius wheels with plaction treads
  - 4.25 in. diameter to maximize clearance

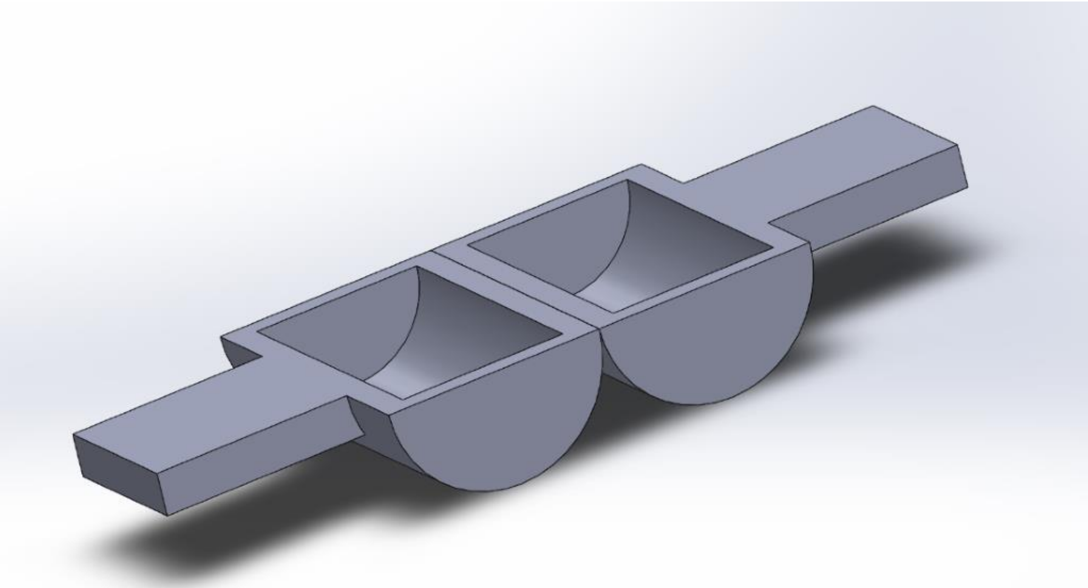


Rover Controls Design

- Microcontroller
  - Arduino Uno programmed in a variant of C.
  - Access to libraries that make components easy to command.
- Electronic Speed Controller
  - Takes commands from Arduino and controls DC motors
- Radio Receiver
  - Can send signals to the Arduino to be turned into actions
- Current Prototyping
  - Successfully demonstrated command of a DC motor and servo



Sample Collection Leading Design



- Collection Method: Two Scoop
- Scoop Material: Schedule 40 PVC
- Scoop Side Inserts: Acrylic
- Scoop Power Delivery: Servos

Preliminary Payload Integration Design

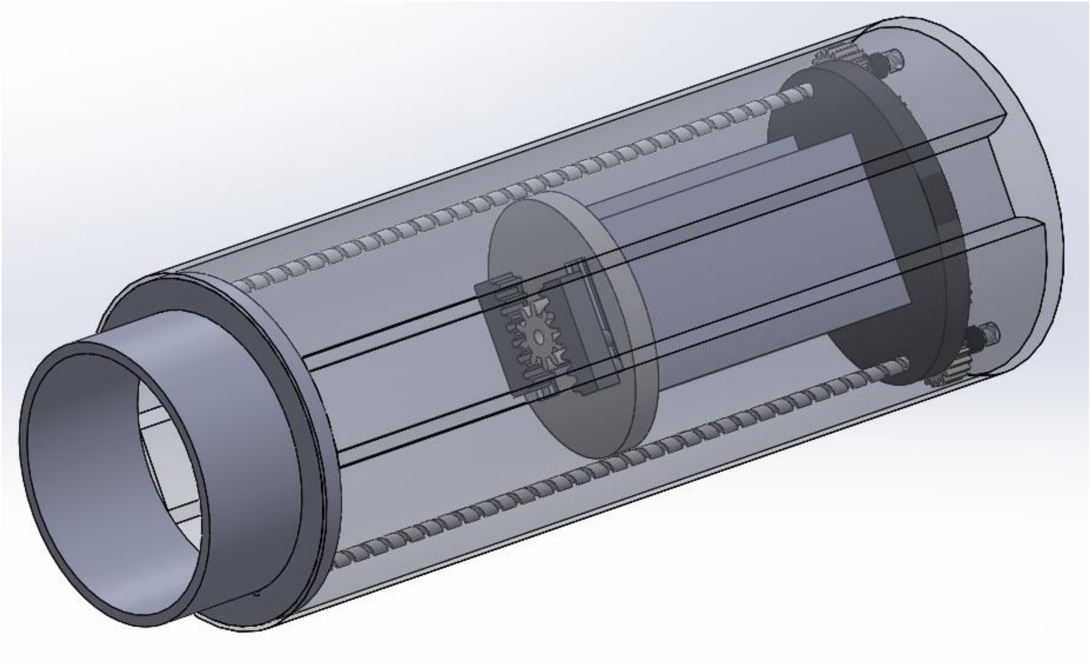
Retention System Design

Deployment System Design

Alternative Designs

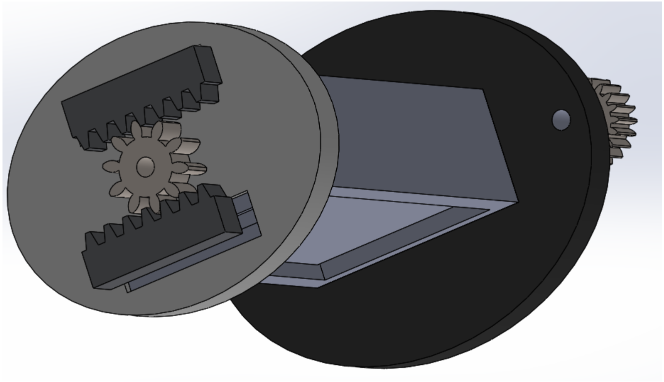
Payload Integration Design

- Retention system
- Actuation System
- Controls



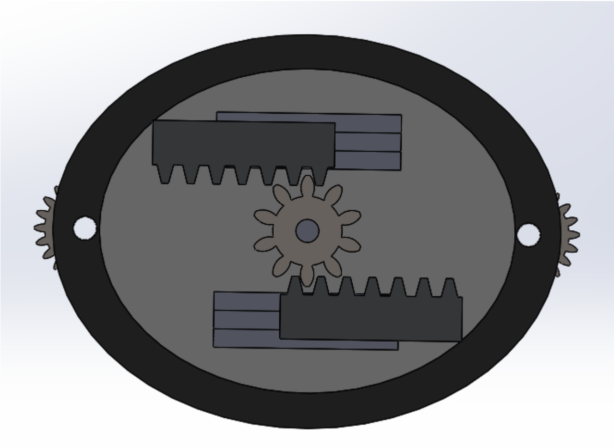
Retention System

- Gear Rack
  - ~0.426lbs
  - Relatively small surface area
- Southco R4-EM
  - 0.625lbs
  - Relatively large surface area
  - Rated for 1522lbf

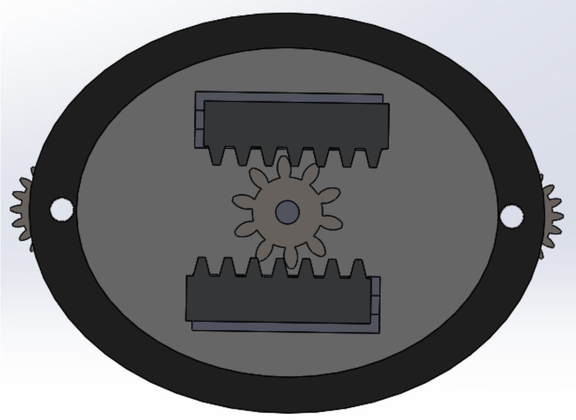


Retention System

- Gear Rack
  - Metal gear and gear rack
  - Minimum safety factor 1.5
    - Rated >= 360lbf

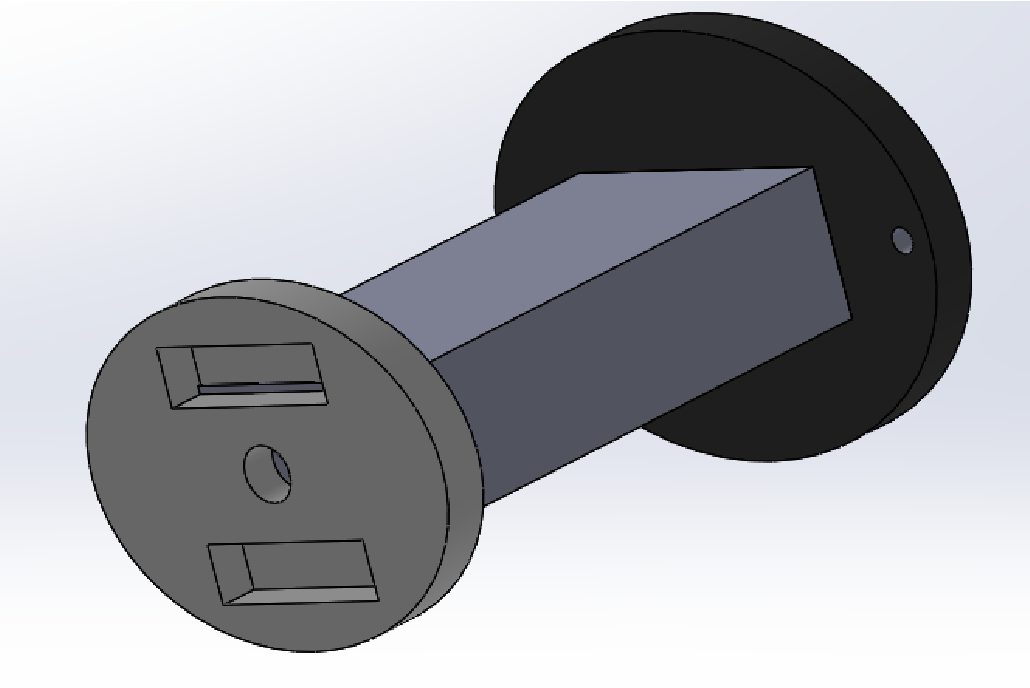


- Sequence
  - Rover fully extended and free of payload bay
  - Locking motor engages
  - Gear racks pulled to central position



Actuation System

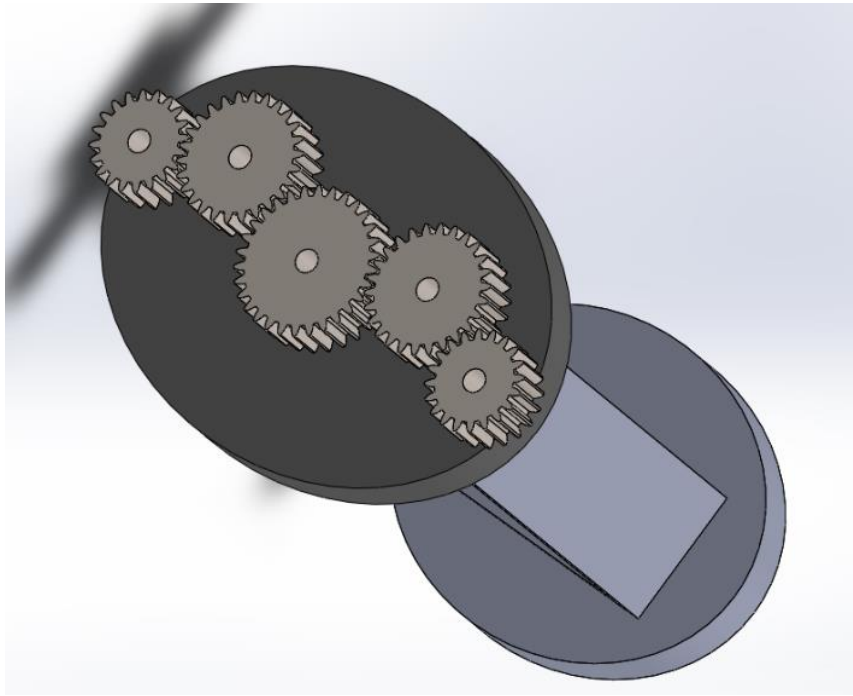
- Main plate (black)
  - Holds power transmission and motor
- Electronics Bay
  - Houses electronics
  - 6 inches in length to clear coupler section
- Pusher Plate
  - Holds locking mechanism
  - Interfaces with the rover



Power Transmission

Gear Driven

- Five gear power transmission
  - More reliable than belt driven
  - Oval main plate geometry
  - Gear box will be enclosed preventing any loose particles from jamming teeth
  - Improved gear ratio from three gear system, optimizing torque output

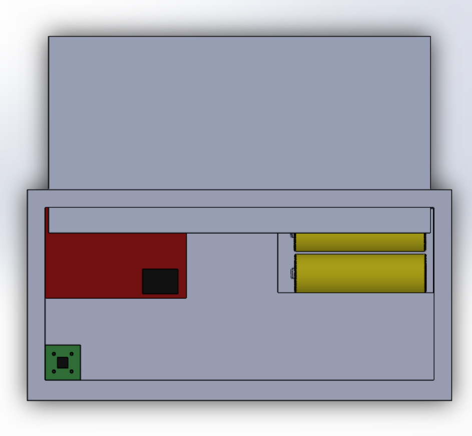


Controls

Feedback

- Instruments
  - Accelerometer
    - Sensitive in +/- 40 gees
  - RF Transceiver
    - Requests confirmation from team
    - Acts as redundancy for landing detection.
  - Micro Controller
    - Arduino

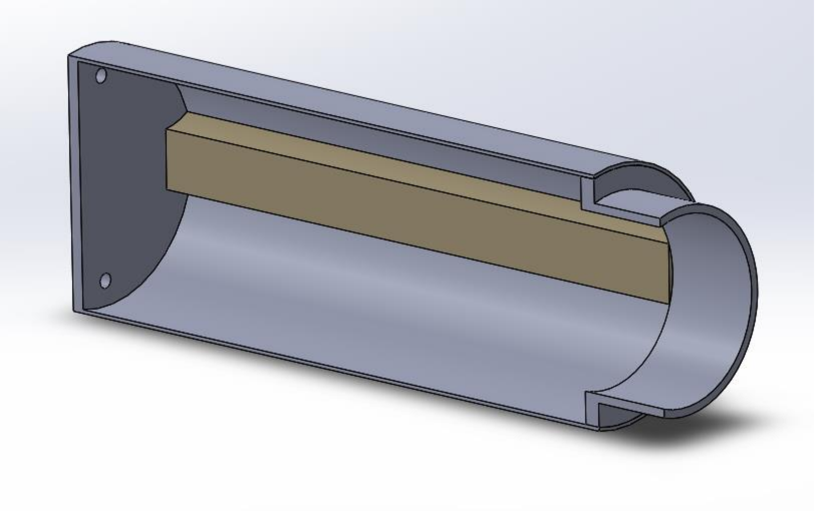
- Housing



- Components need to fit within 5.9”x3” area
- Foam padding to absorb vibrations

Additional Support

- Radial Supports
  - Extend axially along payload bay
  - Restrict radial movement
  - Assist in guiding rover out of payload bay
- Aft Centering Ring
  - Extends available room
  - Prevents cantilever effects on latching mechanism.



Requirement Compliance Plan

NASA SL Requirements

Team Derived Requirements

NASA SL Requirements

- Onboard electrical components will be tested to verify functionality for at least two hours (NASA 2.7)
- Qualification flights will be performed to verify functionality of all launch vehicle and payload systems (NASA 2.18)
- Ground ejection tests will be performed for the drogue and main parachutes prior to each flight (NASA 3.2)
- The payload will be tested to verify it can traverse the terrain expected at the launch field (NASA 4.3.4)
- A payload retention test will be performed to verify functionality of the payload retention system during all expected flight loads (NASA 4.3.7.2)

Team Derived Requirements - Vehicle

- The launch vehicle shall have a static stability margin between 2.0 and 2.3 upon rail exit
  - A minimum static stability margin of 2.0 is required by NASA SL requirement 2.14
  - A maximum of 2.3 prevents undesirable weathervaning in high wind conditions
- The launch vehicle airframe shall be water resistant
  - The team's home launch field in Bayboro, NC has several large irrigation ditches the launch vehicle is prone to landing in
  - The leading choice for airframe material is G12 Fiberglass

Team Derived Requirements - Recovery

- The launch vehicle shall use U-Bolts for all shock cord attachments
  - No single point of failure
- Drogue descent velocity shall be less than 100 feet per second
  - Reduces the shock caused by main parachute deployment

Team Derived Requirements - Payload

- The payload shall have a combined weight of no more than 9 pounds
  - Meets kinetic energy limits in NASA SL requirement 3.3
  - Meets apogee target of 4420 ft
- The sample collection system shall collect at least 15 mL of simulated lunar ice
  - Ensures the minimum of 10 mL is collected per NASA SL requirement 4.3.3

Questions?