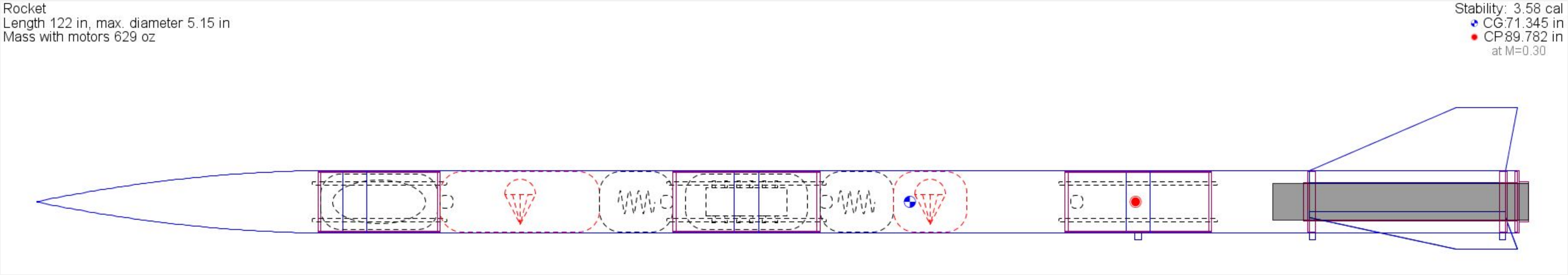
Project Walker
Preliminary Design Review

Vehicle Design Characteristics

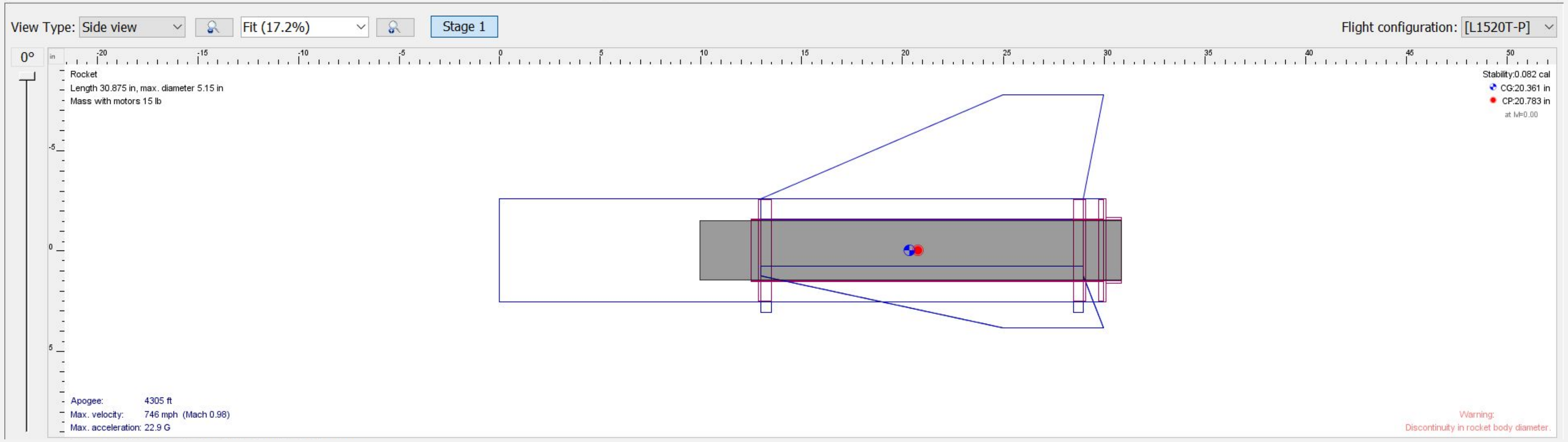
Vehicle Overview

- 122” long, 5.15” maximum diameter.
- 39.31 lbs. estimated weight.
- Designed to carry an autonomous rover as a payload to an altitude of 4,950 feet while maintaining safe values of aerodynamic stability, speed, and landing kinetic energy.
- Utilizes conventional dual deployment techniques.



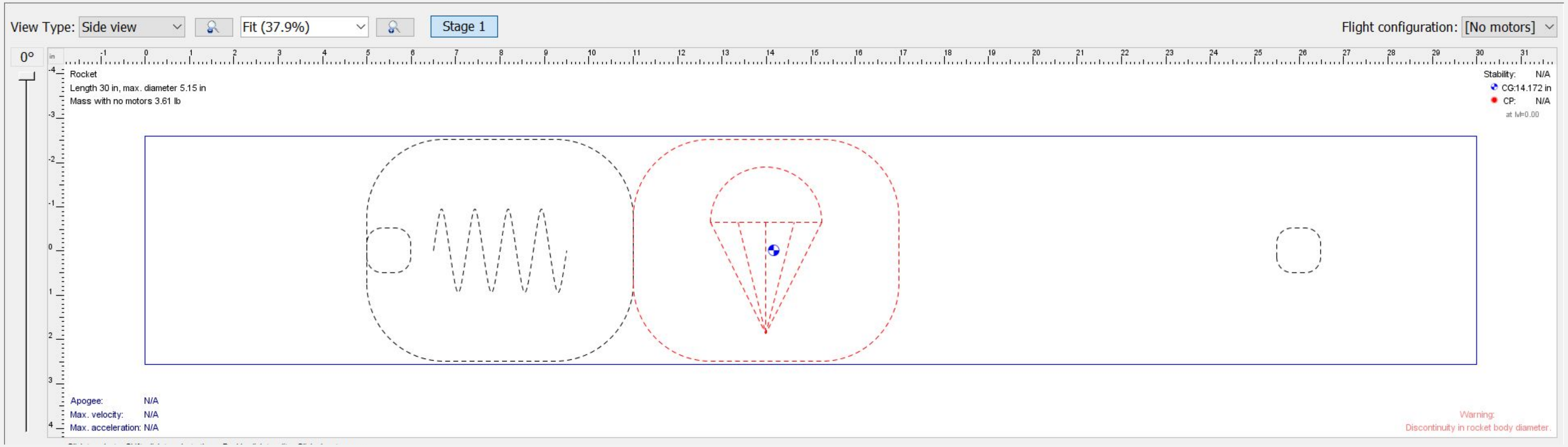
Lower Airframe

- 30.86” long, 5.15” maximum diameter.
- 14.7 lbs. estimated weight.
- Designed to interface with the mid airframe coupler tube at the top 5”, to house and retain the motor, to transfer thrust loads from the motor to the airframe, and to provide ample aerodynamic stability to meet project requirements.



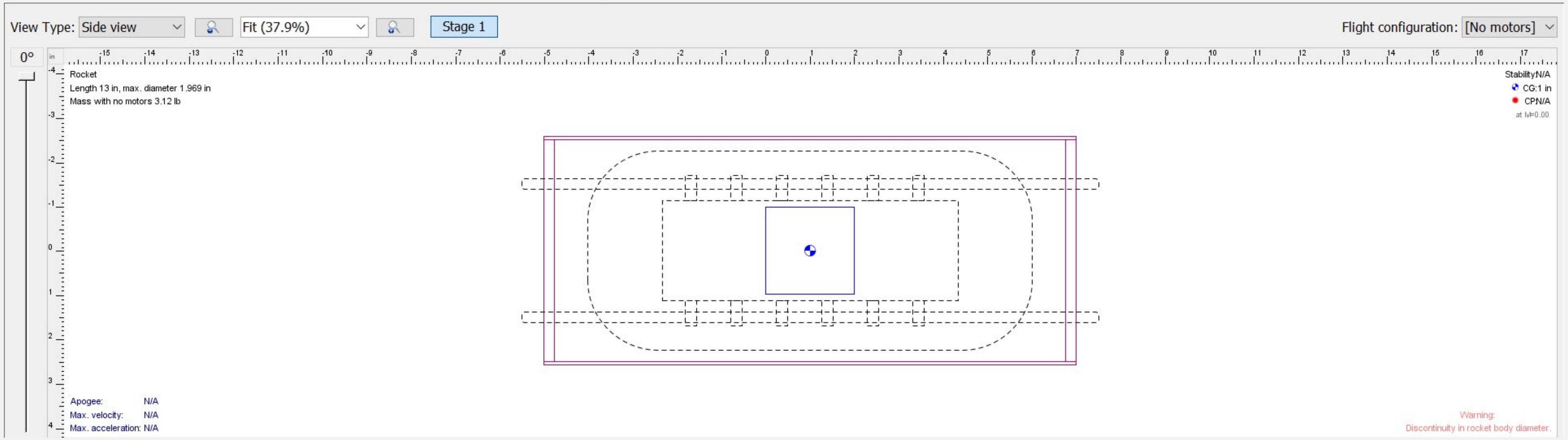
Mid Airframe

- 30” long, 5.15” maximum diameter.
- 3.61 lbs. estimated weight.
- Designed to hold drogue recovery gear and to interface with the avionics and lower airframe coupler tubes using 5” at each end.



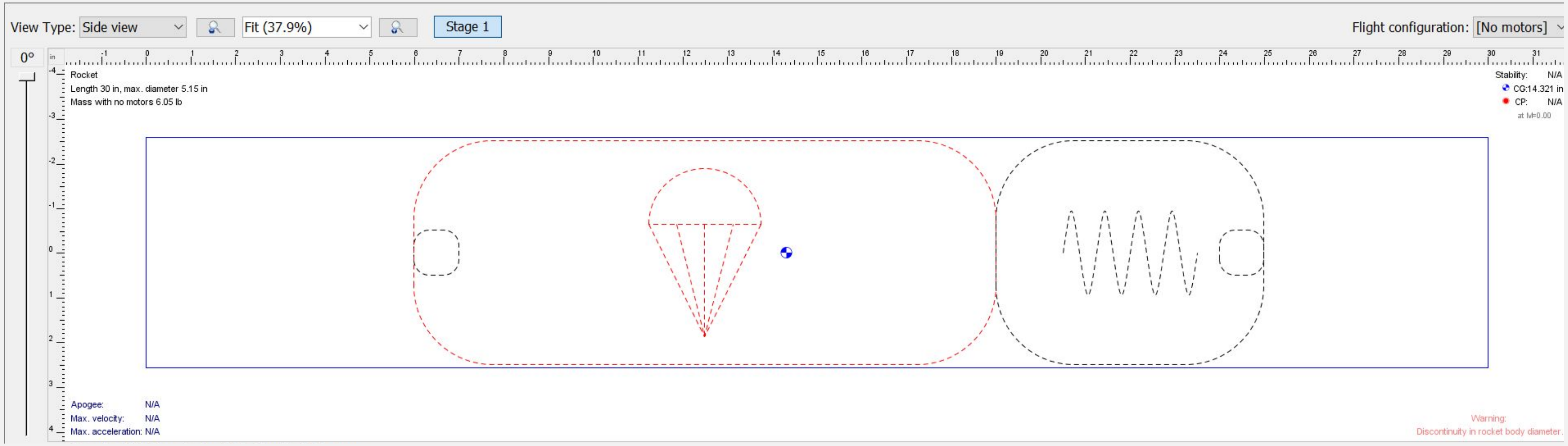
Avionics Bay

- 12” long, 5.15” outer diameter at the 2” long switch band and 5” outer diameter at the coupler
- 3.91 lbs. estimated weight.
- Designed to hold redundant avionics systems and interface with the upper and mid airframe sections using 5” at either end of the coupler.



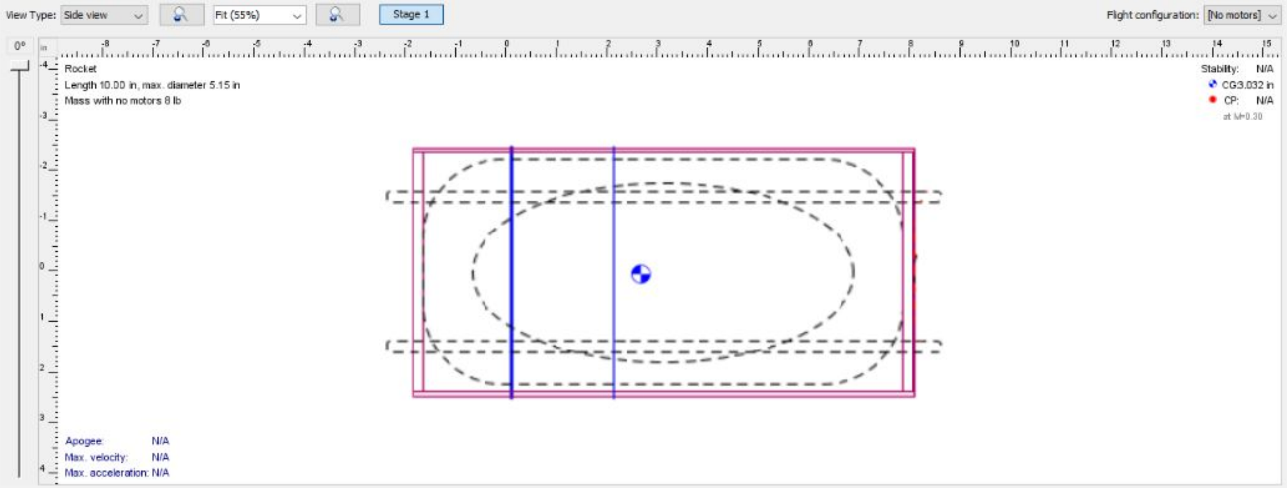
Upper Airframe

- 30” long, 5.15” maximum diameter.
- 6.05 lbs. estimated weight.
- Designed to hold main recovery gear and to interface with the payload and avionics bay coupler tubes using 6” at the fore end and 5” at the aft end.



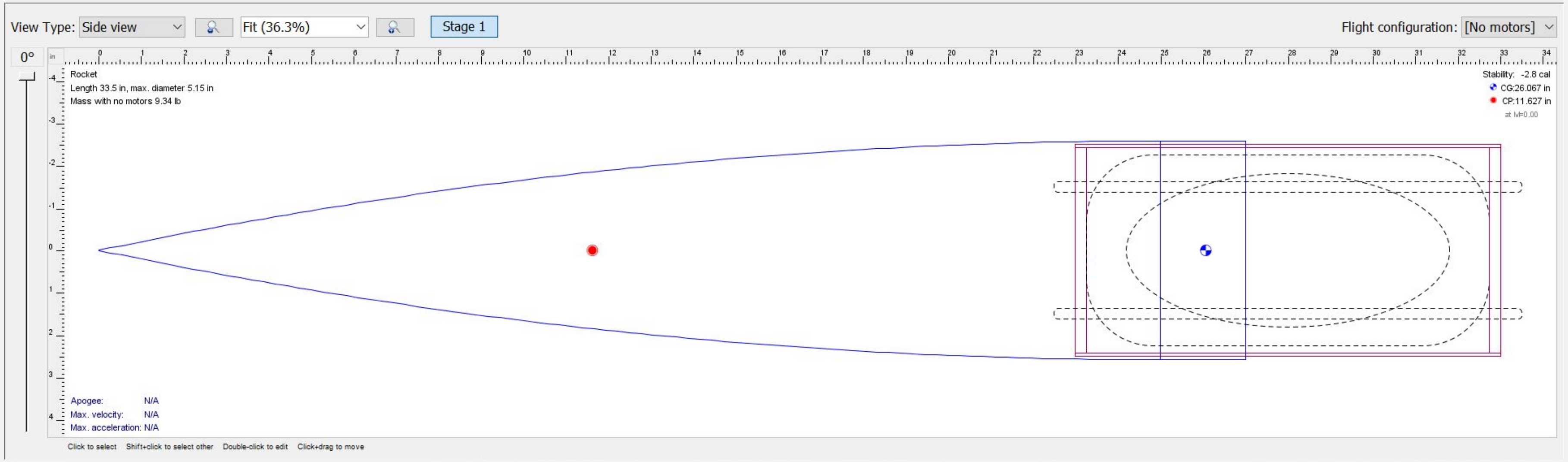
Payload Bay

- 10” long, 5.15” outer diameter at the 2” long switch band (located 2” from fore side) and 5” outer diameter at the coupler
- 8 lbs. estimated weight.
- Designed to hold the payload retention system, the payload deployment system, and the rover payload and to interfaces with nose cone for 2” and upper airframe for 6”



Nose Cone

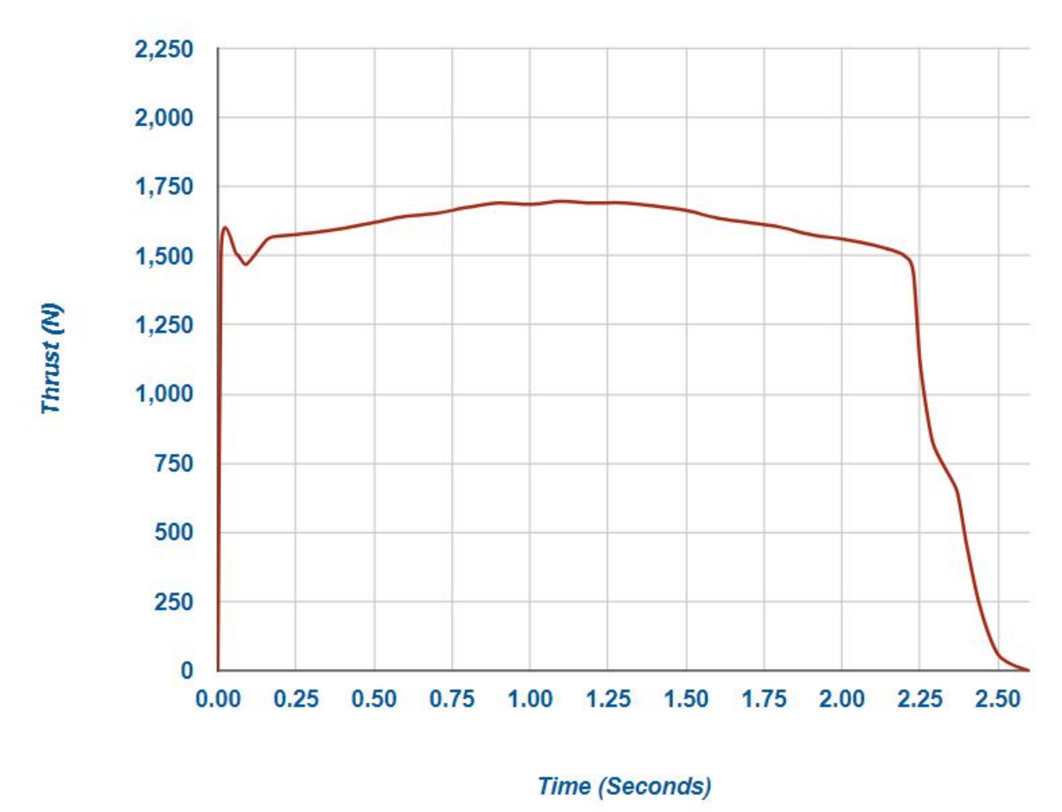
- 25” long with 5.15” maximum diameter at base and an extended 2” to interface with the payload coupler
- Weight with the cone, coupler, bulk plates, and switch band is 2.84 pounds; cone alone is 1.43 pounds.
- Designed to reduce drag, to feature an increased interior volume for future payloads or electronics, and to interface with upper payload coupler.



Current Motor Choice

- Aerotech Rocketry L1520 Blue:
  - Total impulse: 841.55 lbf-s.
  - Max thrust: 381.42 lbf.
  - Average thrust: 323.67 lbf.
  - Liftoff thrust: 355.2 lbf.
  - Burn time: 2.6 seconds.
  - Propellant mass: 4.08 lb.

- Hardware:
  - Dimensions: 2.95” dia x 20.91” length.
  - Loaded mass: 8.04 lb.
  - Empty weight: 3.96 lbs.



Thrust/Weight and Exit Velocity

- The thrust-to-weight ratio that the vehicle achieves is ~8.99:1.
    - Liftoff Thrust: 355.2 lbs.
    - Liftoff weight: 39.5 lbs.

- Maximum Acceleration is ~287 ft/sec^2.

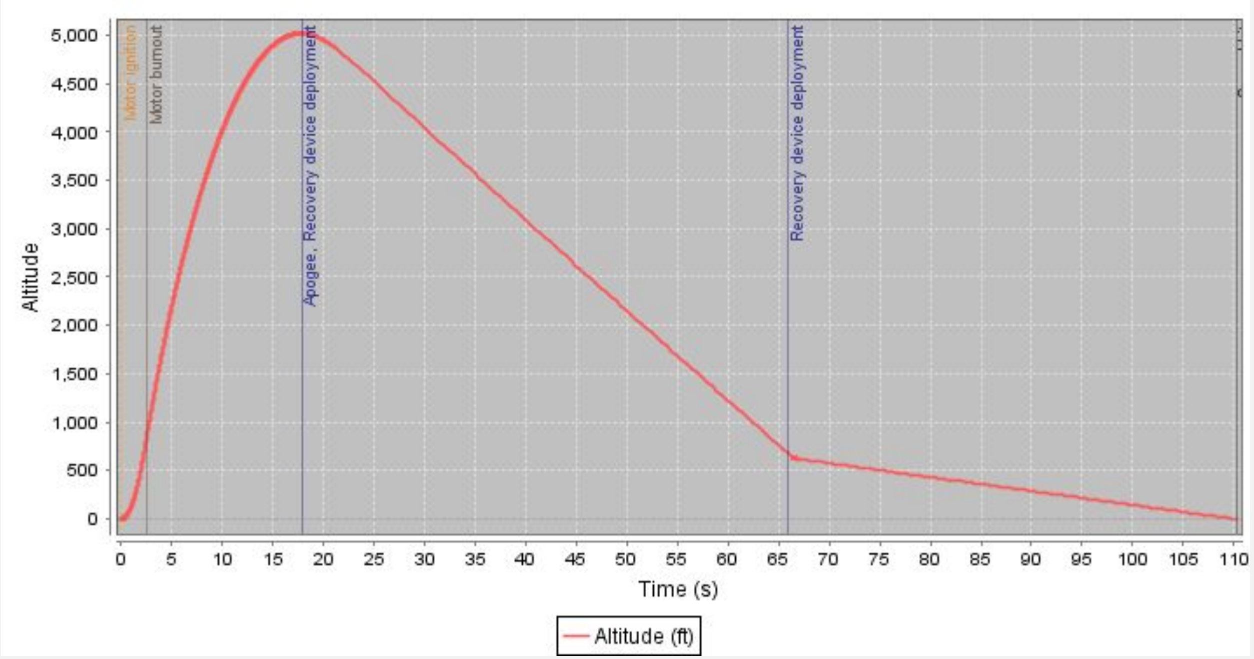
- Maximum Velocity is ~ 620 ft/sec.

- Rail exit velocity is 79.4 ft/sec.

Altitude Predictions

- Simulated in OpenRocket 15.03.
  - Maximum altitude: 5,023’ AGL.
  - Chosen altitude for competition: 4,950’ AGL

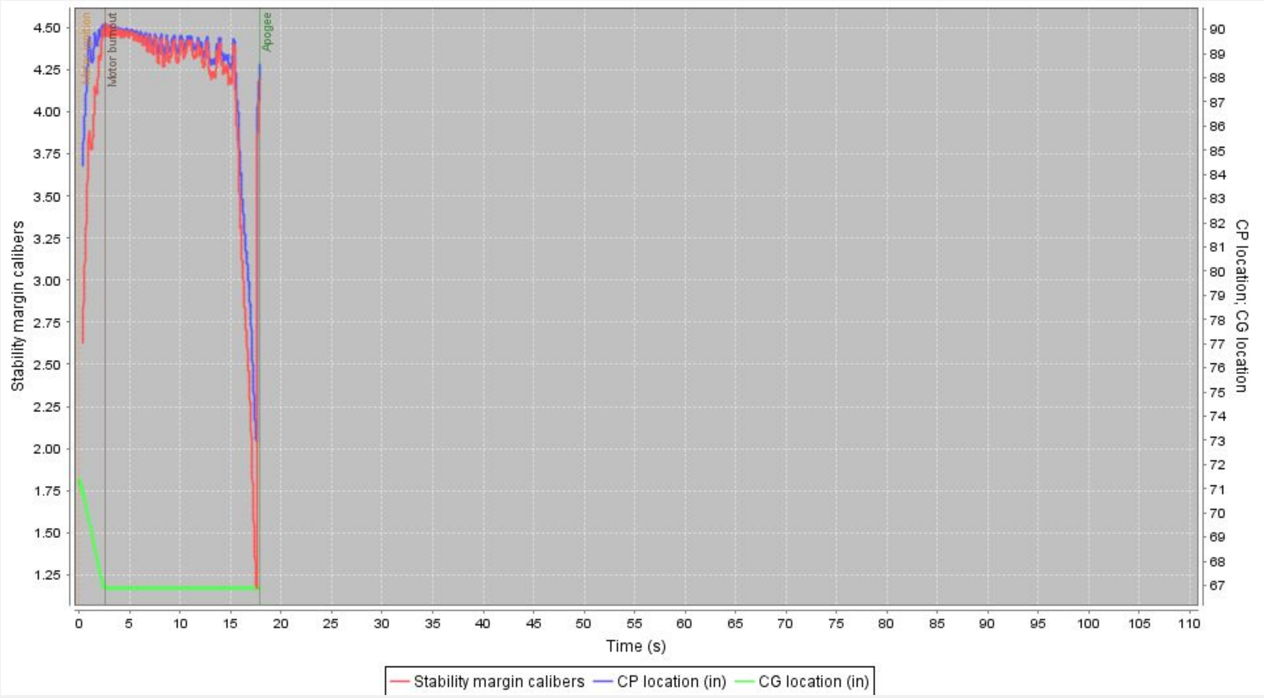
- Simulation settings:
  - Calculation: Extended Barrowman.
  - Simulation: 6-DOF Runge-Kutta 4.
  - Geodetic: Spherical approximation.
  - Time step: 0.02 seconds.



Stability Margins

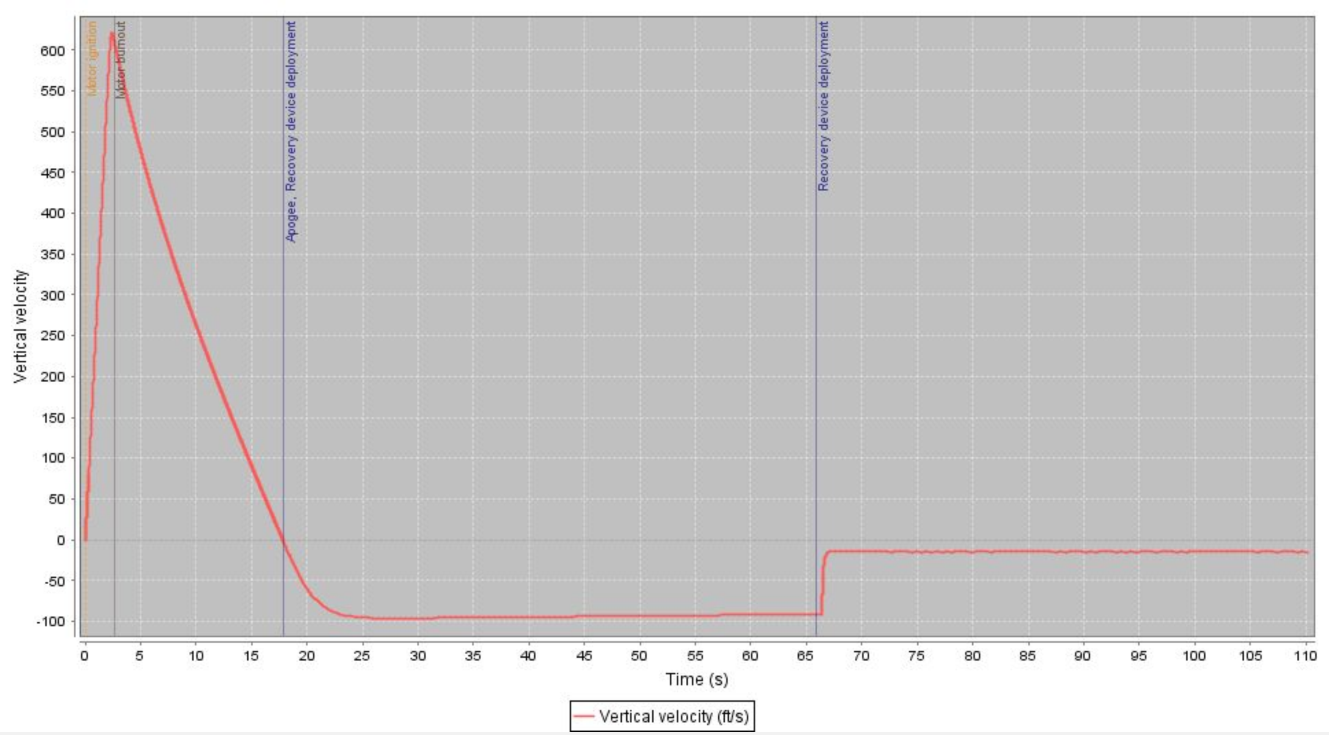
- Static:
  - Stability margin: 3.58 calibers.
  - CP location: 89.782” from datum.
  - CG location: 71.345” from datum.

- At takeoff:
  - Stability margin: 2.71 calibers.



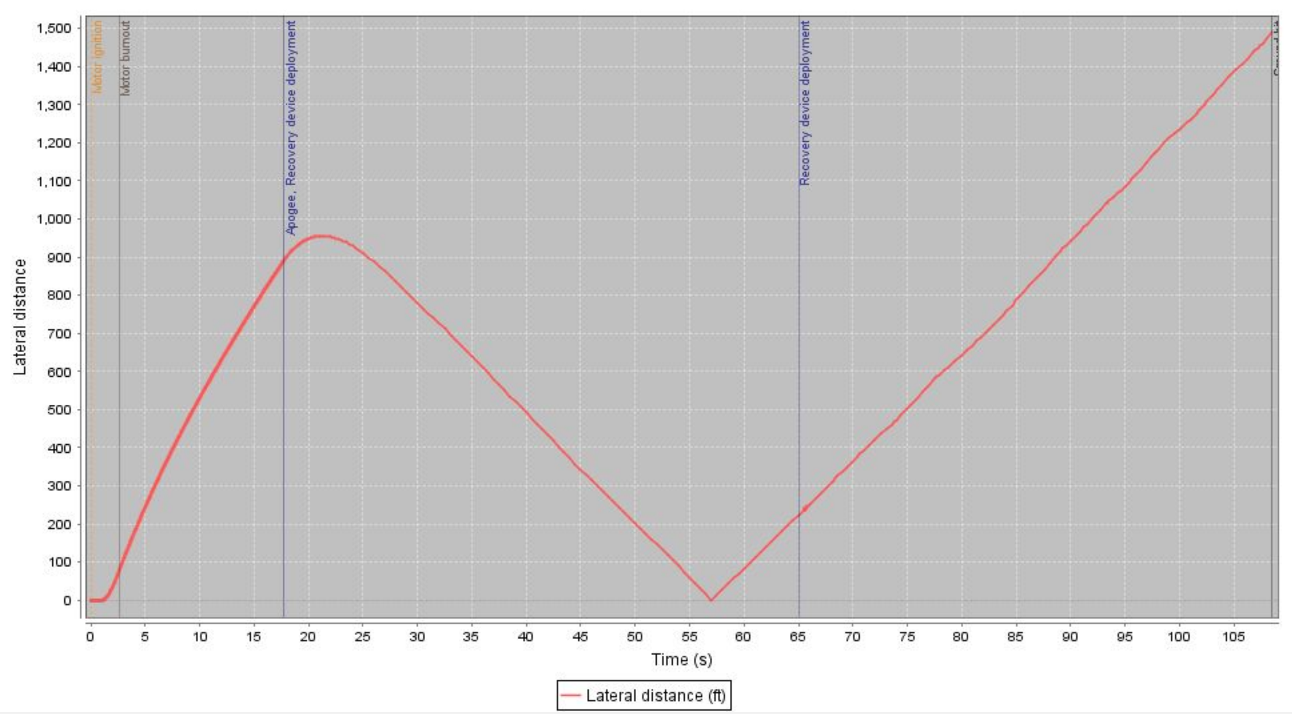
Landing Energy

- Landing velocity: 13.7 ft/s.
- Total landing energy: 103.31 ft/lbs.
- Lower section energy: 48.74 ft/lbs.
- Mid section energy: 21.93 ft/lbs.
- Upper section energy: 31.62 ft/lbs.



Drift Calculations

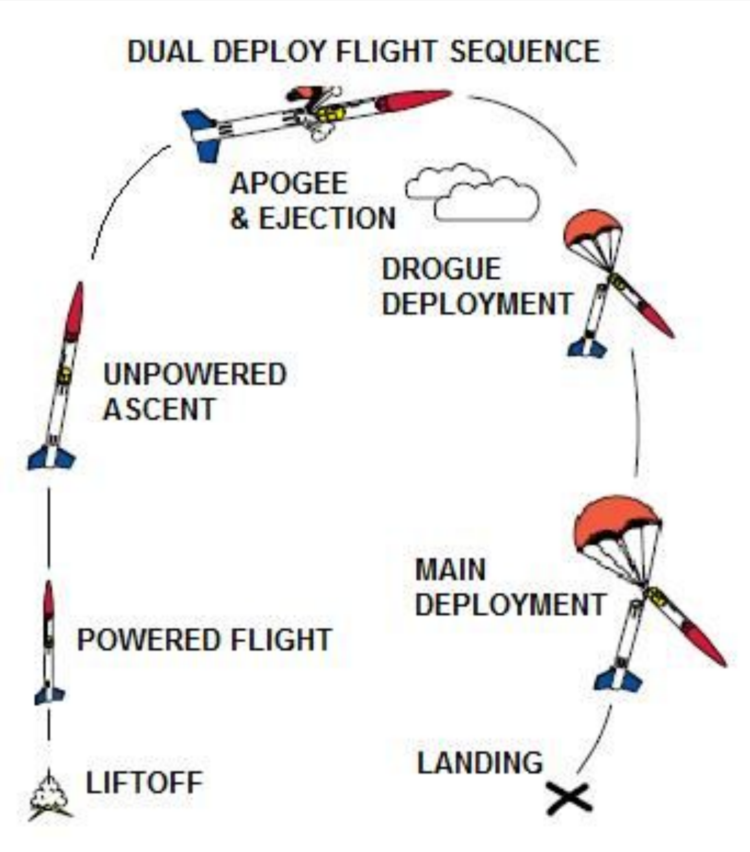
- Maximum drift distance of 1489.27’.
- Wind Speed: 20 MPH.
- Standard Deviation: 10%.
- Turbulence Intensity: 2.0 MPH.



Recovery System Information

Recovery Overview

- Standard dual deployment configuration:
    - 24” drogue parachute at apogee.
    - 100” main parachute at 700’ AGL.
    - Kevlar Shock cord.
    - Nomex heat shields.
    - ¼” SS connection points.



Shock Cord

- Kevlar tether:
  - ½" thickness.
  - 7,200 lbs. breaking strength.
  - Fireproof.
  - 3 sewn loops:
    - One on each end for bulkhead attachment.
    - One ⅓ the length from the top for parachute attachment.
  - Estimated weight: 0.4 lbs.

Drogue Parachute

- Skyangle Cert-3 Drogue parachute:
  - 24” diameter.
  - Four ⅝” shroud lines rated at 2,250 lbs.
  - 0 porosity 1.9 ounce ripstop nylon.
  - Drag coefficient of 1.16.
  - Surface area of 6.3 square feet.
  - Rated for 1.0-2.2 lbs.
  - Estimated weight: 0.375 lbs.

Main Parachute

- Skyangle Cert-3 XLarge parachute:
  - 100” diameter.
  - Four ⅝” shroud lines rated at 2,250 lbs.
  - 0 porosity 1.9 ounce ripstop nylon.
  - Drag coefficient of 2.59.
  - Surface area of 89 square feet.
  - Rated for 32.6-70.6 lbs.
  - Estimated weight: 3.8125 lbs.

Fireproofing

- Nomex heat shield:
  - Protects parachute from ejection gases.
  - 18x18” square.
  - Slides directly over shock cord.
  - Burrito wrap parachute.
  - Estimated weight: 0.5 lbs.

Ejection Charges

- Used weighted decision matrix:
  - Black powder (FFFFg) or CO_2
- Primary criteria:
  - Volume, simplicity, reliability, and weight.
- Secondary/tertiary criteria:
  - Style and cleanliness.

		METRIC HOW WILL MEASURE IF THE CRITERION WAS ADDRESSED?					
CRITERIA	Weight/Importance	Overall Estimated Volume	Time to Develop	Reviews	Residue Remaining	Total Weight	Team ranking
Volume	15	X					
Simplicity	15		X				
Reliability	15			X			
Cleanliness	10				X		
Weight	15					X	
Coolness	5						X
	Units	cm^3	hours	1-5	1-5	g	1-5

Ejection Charges

- Estimated/calculated values for criteria:
  - Applied to weighted decision matrix.
- Black powder score: 245.
- CO_2 score: 195.

	Overall Estimated Volume	Time to Develop	Reviews	Residue Remaining	Total Weight	Team ranking
Black Powder	20.88	5 hours	4	3	3	4
CO2	83.9	12 hours	4	5	1	5

BENCHMARKING (Unweighted)			BENCHMARKING (Weighted)	
Black Powder	CO2		Black Powder	CO2
2	1		30	15
4	2		60	30
4	4		60	60
3	5		30	50
3	1		45	15
4	5		20	25
		WEIGHTED TOTAL -->	245	195

Ejection Charges

- Ejection canister caps to contain black powder.
- FFFFg is the chosen black powder type.
- Calculation for how many grams needed for smooth ejection:

  $C*D^2*L$= Grams:
  - D: Diameter of airframe => 5.15 inches.
  - L: Length of recovery => 30 inches.
  - C: Constant Conversion from 10 PSI => 0.00399.
  - Yielded: 3.22 +/- 0.15 g per capsule.

Avionics

- Missile Works RRC2, Missile Works RRC3+ Sport, Eggtimer TRS, and the Altus Metrum TeleMetrum.
- We compared the four altimeters based on set criteria with specific weights.
- Primary criteria:
  - Cost, altitude, efficiency, reliability, and extras.
- Secondary criteria:
  - Battery/voltage and size.
- Tertiary criteria:
  - Operating system.
- TeleMetrum is the primary altimeter.
- RRC3+ Sport is secondary altimeter.

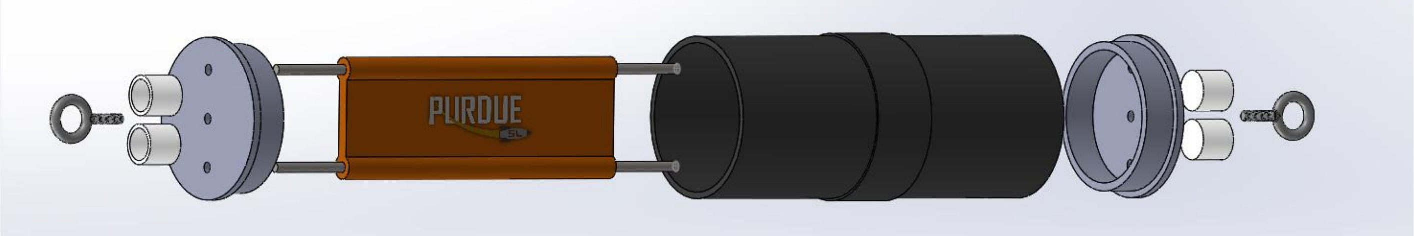
Weight/Importance:
15: Must have
10: Good to have
5: Nice to have

CRITERIA	Weight/Importance	METRIC HOW WILL MEASURE IF THE CRITERION WAS ADDRESSED? Price	Voltage	Maximum height	Ratio of Max. height to Cost	Area	Computer Type	Reviews	Weight	GPS / Telemetry
Cost	15	X								
Battery / Voltage	10		X							
Altitude	15			X						
Efficiency	15				X					
Size	10					X				
Operating System	5						X			
Reliability	15							X		
Extras	15								X	X
	Units	Dollars	Volt	ft	ratio	in^3	Type	Stars	g	yes/no

	Price	GPS Price	Total Price	Mininmum Voltage	Maximum Voltage	Maximum height	Ratio of Max. height to Cost	Area	Barometer or accelerometer	Computer Type	Reviews	Weight	GPS / Telemetry
RRC2	45	150	45	3.5	10	40,000	444.44	1.0545	Barometer	Wind pnly	4	10g	0
RRC3+ Sport	90	150	90	3.5	10	40,000	242.497	1.813	Barometer	Wind only	5	17g	1
Eggtimer TRS	140	0	140	4.5	30	30,000	400	1.95	Barometer	Only Wind	4	25g	2
TeleMetrum	300	0	300	3.7	5	100,000	333.33	0.555	Barometric	Wind, Mac, Linux	4	18.4g	2

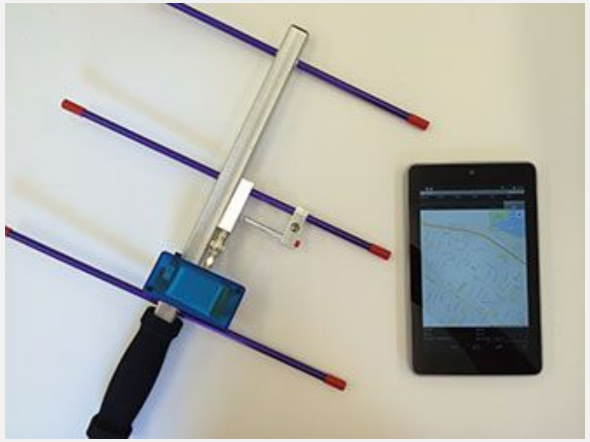
Avionics

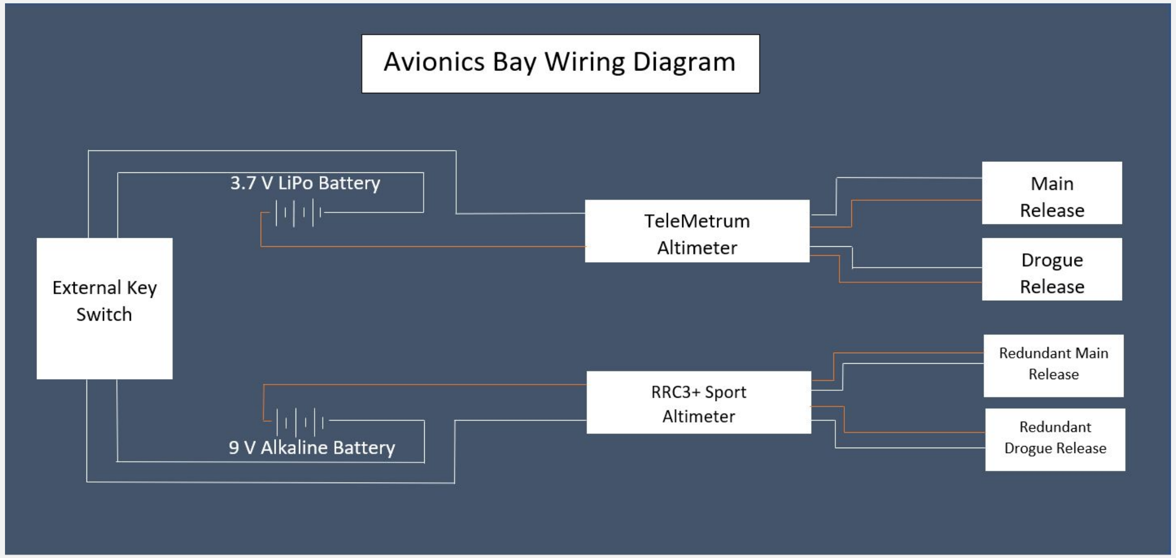
- The avionics bay consists of:
  - 2 altimeters:
    - TeleMetrum.
    - RRC3+ Sport.
  - 2 batteries:
    - 3.7V LiPo.
    - 9V.
  - 1 3D-printed sled.
  - Eye bolts.
  - Steel threaded rods.
  - 4Fg black powder.
  - Capsules to hold black powder.
  - External key switches.



Avionics

- The overall weight of the avionics bay ~ 0.54 lbs.
- We will use the TeleDongle in combination with the Arrow 3-element Yagi as our form of communication with the launch vehicle.
- Altimeters turned on externally by key switches on the side of the rocket, then both altimeters will be powered on.
- At apogee the drogue chute will be released, then at 700’ AGL the main parachute will be released.
- The redundant ejection charge for the drogue will have a time delay of 1 second and for the main parachute it will be at 650’ AGL.





Safety

Safety Officer Information

- The Safety Officer for the Purdue SL Team participating in the 2019 competition will be Jory Lyons.

- Some of the Safety Officer's most important duties are as follows:
  - Enforcing all safety plans and procedures set by the team.
  - Enforcing all laws and regulations set for the team by authorities and governing bodies.
  - Ensuring that all team members are properly trained and supervised to be carrying out their current task.

NAR/TRA Personnel Procedures

- Victor Barlow is the NAR mentor currently working with the team.
- This NAR mentor will:
  - Be on location whenever the rocket is being launched to serve as Range Safety Officer.
  - Work with the Safety Officer to ensure that all team members follow the NAR High Power Rocket Safety Code during all launches.
  - Prepare motors and ejection charges during full-scale flights as needed, even though other team members have certification for such tasks.

Hazard Recognition/Avoidance

- Prior to the first construction meeting, the team will hold a short briefing on basic launch vehicle construction safety, in which all team members will be instructed on fundamental safety procedures (e.g. wearing protective eyewear during construction), as well as how to use lab equipment and recognize any potential hazards associated with it.

- Briefings will be carried out before major events and launches.

Project Risks

- The seriousness of a risk will be evaluated by two criteria: the likelihood of an event to occur and the impact of the event should it happen or fail to be prevented.

- By cross-examining the likelihood of an event with the impact it would have if it occurred, the total numerical risk is determined using the displayed table.

- Using this table, one can use charts of possible events to conduct analyses of preliminary personnel hazards, preliminary failure mode and effects, and environmental concerns.

Category	Negligible	Minor	Moderate	Major	Disastrous
Remote	1	2	3	4	5
Unlikely	2	4	6	8	10
Possible	3	6	9	12	15
Likely	4	8	12	16	20
Very Likely	5	10	15	20	25

Green: Very low risk
Yellow: Low risk
Orange: Medium risk
Red: High risk
Dark red: Very high risk

Safety Considerations

- Risks above 'medium' must be signed off by the team lead, safety officer, or other commanding officer.
- Failures to the program must be addressed ahead of time to insure continued individual and team safety and success.
- For the protection of individuals and the team, PPE must always be worn and verified by team members for working on a task.
- Safety tables are to include hazards, likelihood, severity, risk, mitigation, and verification (and risk after mitigation).
  - These tables will help demonstrate the collective understanding of all components needed to complete the project, and how risk/delays impact the project.

Safety Checklists

- Three checklists were created for team members to use to ensure safe procedures are followed before, during, and after launch.

- Pre-launch checklist: Includes general safety procedures, checks for safe rocket construction, ensures proper use of the launch pad, and gives proper procedures for launching.

- Launch checklist: Ensures team members are behaving safely during the launch and gives instruction on how to safely handle a misfire.

- Post-launch checklist: Ensures the rocket and launch pad are properly tended to after the launch.

Plan for Compliance with Laws

- The project team will follow regulations listed in NFPA 1127 and CFR 27 Part 55.
- All launches will be conducted in an area with an active FAA waiver that extends the projected altitude of the launch vehicle.
- All team members present at launch will closely follow the NAR High Power Rocket Safety Code and the team safety agreement, which both encourage lawful rocketry.

Hazardous Materials Plan

- Hazardous materials will be stored off-site, within the Zucrow Labs research facilities adjacent to the Purdue University Airport.

- Certain members of the team currently hold a Low Explosives User Permit, and these are the members who will handle the acquisition, transportation, and storage of the hazardous materials involved in this project.

- All team members will be given a briefing on the plan to properly handle hazardous materials by the safety officer, which will emphasize use of personal protective equipment and material safety data sheets.

Team Safety Statement

- All team members must sign a printed safety statement.

- This statement is an affirmation by team members that they will comply with all relevant laws and regulations and the NAR High Power Rocketry Safety Code and will obey all instructions given by the Safety Officer and Range Safety Officer, whether verbally or through team safety documents.

- The statement ensures members realize any violation of these agreements can completely halt a rocket launch and may result in that team member being unable to participate in Project Walker or the NASA SL program.

Payload

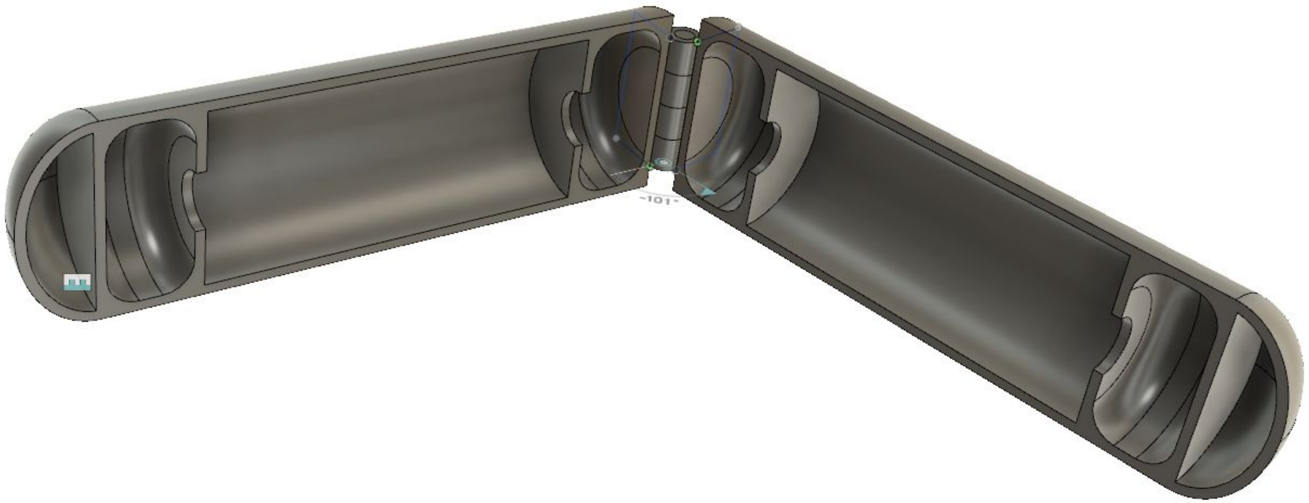
Payload Design

- Mission
  - Deploy an autonomous rover.
    - Drives 10 feet from rocket.
    - Collects and stores 10 mL soil sample.

- Requirements
  - Less than 8 lbs.
  - Dimensions:
    - 12” long & 4.815” diameter.
  - 3 hours of battery life.
  - Rover can autonomously navigate and avoid obstacles.
  - Rover must stay inside of payload bay until landing.

- Key components
  - 2 x wheel.
  - 2 x LIDAR sensors.
  - 1 x Anker PowerCore power supply.
  - 1 x Arduino unit.
  - 1 x soil collection apparatus.

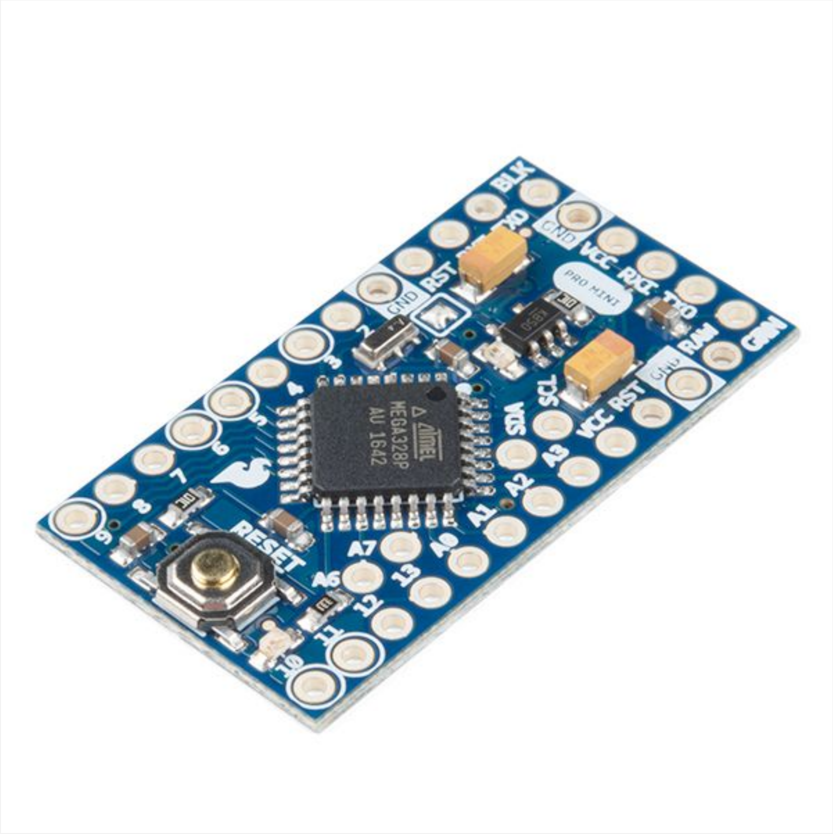
Payload/Vehicle Interface



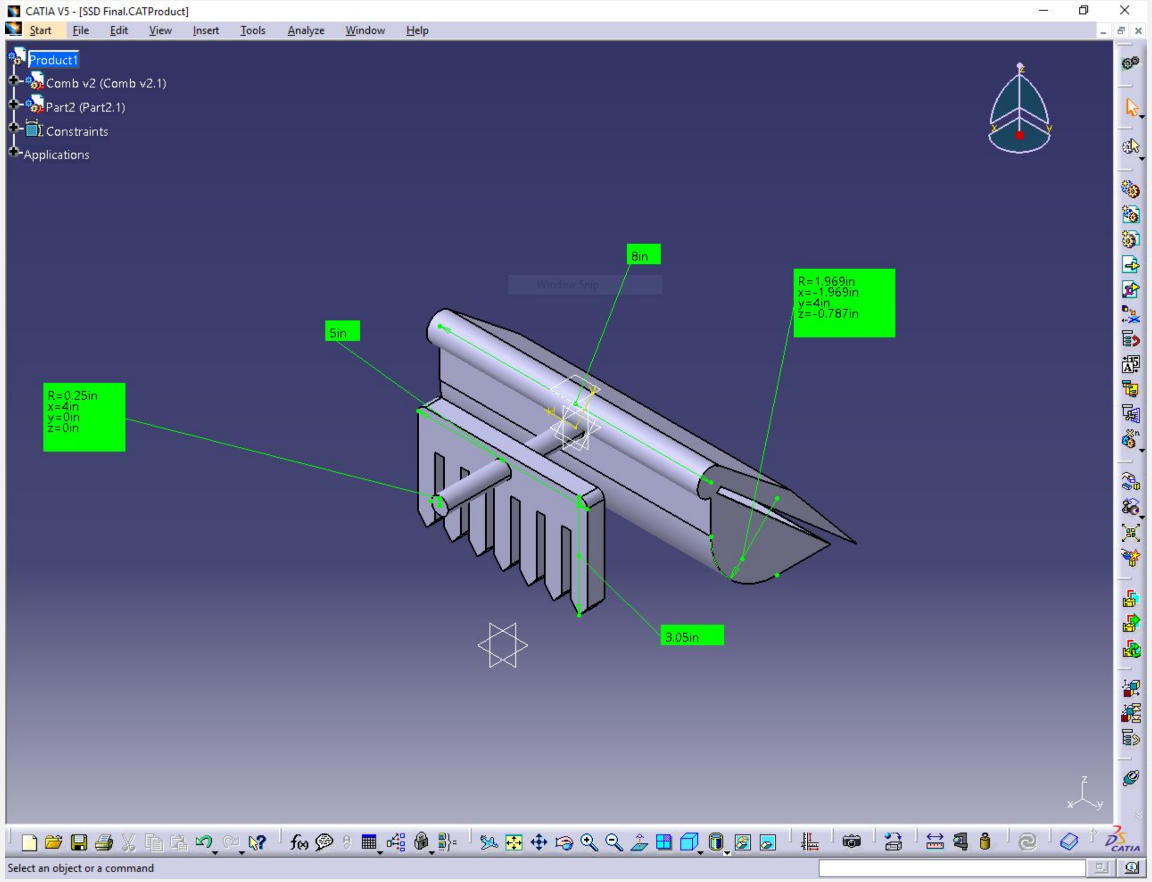
- Hinged capsule.
  - 3D printed.
  - Spring loaded hinge to stay open.
  - Rounded front face.
  - Rover held in by wheels.
- Black powder ejection.
- Shear pins to hold capsule during flight.
- Located near nose of rocket.

On Board Computer

- Arduino Pro Mini 328 - 5V/16MHz:
  - Cost: $9.95.
- I/O Pins:
  - 14 Digital input/output.
  - 8 Analog.
  - 6 PWM.
- Mass: < 2g.
- Dimensions:
  - 1.3x0.7”.
- Processing Performance:
  - ATmega 328 @ 16 MHz.



Soil Sampling System



Power Supply

- Requirements:
  - Less than $30 per battery.
  - Less than one pound.
  - Less than four inches wide.

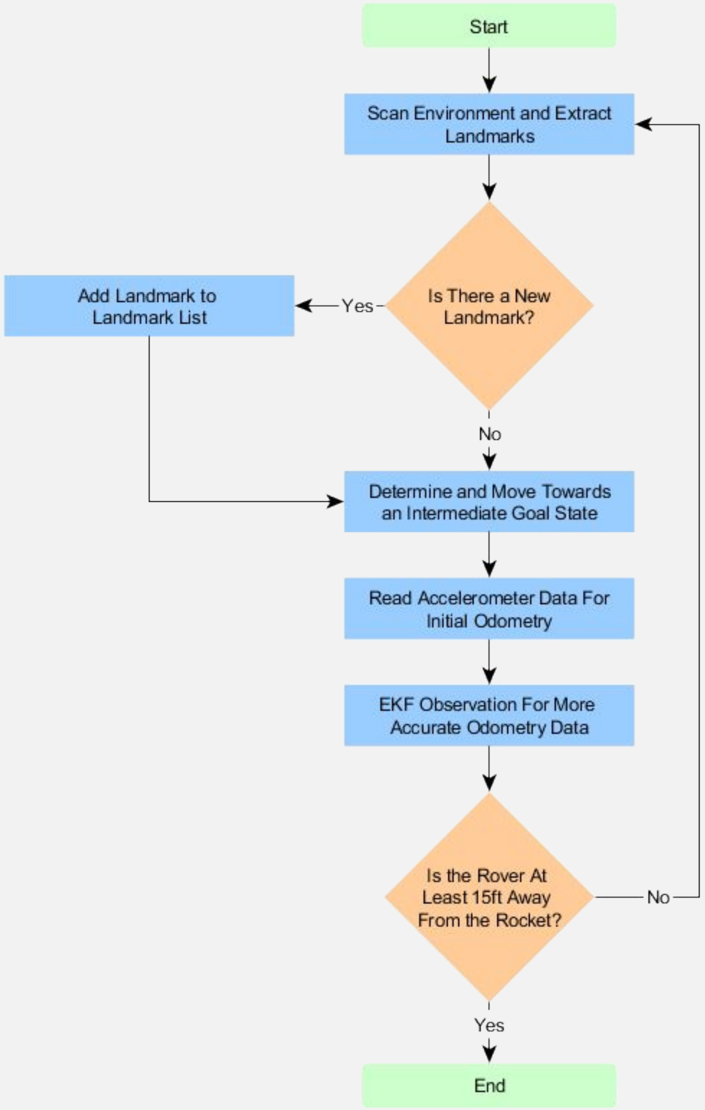
- Leading Choice: Anker PowerCore 10,000mAh:
  - Allows for even weight distribution.
  - Meets all requirements.
  - Provides significant power for dimensions and cost.

https://www.anker.com/products/variant/PowerCore-10000mAh/A1263011

1	Battery (Supplier/Link)	mAh	L (in)	W (in)	T(in)	m(lb)	Price ($)	Amps (A)	Volts (V)
2	RAVPower Portable Charger with 2 ports (Amazon)	20100	6.81	3.19	0.87	0.84	49.99	2.4 per	5
3	RAVPower Portable Charger with 1 port (Amazon)	6700	3.54	1.57	0.98	0.26	13.99	2.4	N/A
4	Anker PowerCore Charger with 1 port (Amazon)	10000	3.6	2.3	0.9	0.4	25.99	2.4	5
5	Anker PowerCore 2-in-1 Portable/Wall Charger (Amazon)	5000	3.6	2.8	1.2	0.42	25.99	2.1	5
6	ROMOSS USB for Raspberry Pi (Adafruit)	10000	5.4	2.4	0.8	0.64	39.95	2	5 each

Software

- Software Development:
  - Arduino IDE.
- Coding Language:
  - C/C++.
- Algorithms:
  - Object detection:
    - Landmark extraction.
    - Landmark avoidance.
  - State estimation:
    - Position relative to rocket.



Derived Requirements and Verification Plans

General Derived Requirements I

- Create and maintain a functioning website and social media profile with regular project updates, documents, and milestones that highlight our progress as it relates to the scope of the project.
- Not spend any money out of pocket using personal funds without a means of being fully reimbursed through Purdue SEDS or some other school related organization.
- Have a successful subscale flight and recovery on a subscale motor while simulating a payload system.
- Have a successful full scale test flight and recovery on a full scale motor while carrying a fully functional payload system.
- Successfully design, build, and test a working on-board payload capable of meeting the requirements derived by the team and presented to us by NASA within the 2019 NASA Student Launch Handbook.

General Derived Requirements II

- Fulfill and exceed all educational engagement requirements presented to us by NASA within the 2019 NASA Student Launch Handbook.
- Have a functioning and attractive rocket booth that highlights the work done by our team, including a functional payload on display for viewers to see and a full scale rocket for spectators to interact with.
- No disqualification by any means whatsoever.
- No breaches of safety by any means whatsoever.
- Successful completion of the competition in Huntsville, Alabama.

Vehicle Derived Requirements I

- The vehicle will deliver the payload to an apogee altitude of 4,950 +/- 100 feet above ground level (AGL).
- The vehicle will feature a retainment system which is able to maintain the condition of the payload during flight so that it remains in good condition to be fully operational for the next flight.
- Upon reaching the ground, the vehicle will expel the payload such that it may operate autonomously without physical contact with the launch vehicle.
- The vehicle will carry at least two commercially available, barometric altimeters for recording the official altitude.
- Each altimeter will be armed by a separate, dedicated power supply.
- The launch vehicle will not horizontally drift more than 2000 feet from where it launches.

Vehicle Derived Requirements II

- The launch vehicle must be able to maintain full functionality when launched on a day with at least 20 mph wind speeds.
- The launch vehicle will achieve its objective using three sections in a dual-deployment recovery configuration.
- The launch vehicle will be proven to be airworthy via the construction and fully-successful operation of a 0.45x scale model by 12/09/2018.
- The full-scale rocket will be launched and recovered in a test flight by 03/03/2019, configured in the same configuration that will be used on the final launch day.
    - If the Student Launch office determines that a re-flight is necessary, then another flight of the full-scale vehicle will be successfully conducted before March 28th, 2018.

Recovery Derived Requirements

- The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at an altitude of 700 feet.
- If the drogue parachute does not immediately deploy at apogee, the secondary altimeter will detect this and eject the parachute at one second after reaching apogee.
- If the main parachute does not immediately deploy once the vehicle reaches 700 feet AGL, the secondary altimeter will detect this and eject the parachute at 650 feet AGL.
- The recovery system will contain two redundant, commercially available altimeters with separate power systems.
- Recovery area will be limited to a 2000 foot radius from the launch pads.
- The recovery system electronics will be properly shielded from interference and will be placed at a suitable distance from any transmitting devices stored in the payload bay or any e-matches.

Payload Derived Requirements

- Successfully deploy the rover.
- Rover moves at least 20 feet from the nearest rocket component.
- Soil collection system effectively loosens the soil such that the hopper can collect and contain a 10mL soil sample.
- Sum of the payload components must not exceed six pounds.
- Battery supply power system must operate for at least three hours.
- The LIDAR sensor used on the payload will be able to detect objects within at least a 25-foot radius from the payload.

Safety Derived Requirements

- Remain in full compliance with local, state, and federal laws and maintain a positive reputation as a team which prioritizes lawful rocketry.
- Create team-wide knowledge of how to work safely with high-power rockets.
- Maintain fully-functional hazard analysis and contingency plans to both prevent and react optimally to any emergency situations.
- Organize a set of procedures which can be followed to enforce safe construction and launch practices and to be prepared for any emergency.
- Help create other derived requirements and help prove why they are necessary to help justify why the requirement exists, and how it will be verified or attempted with.

General Reqs. Verification Plan

- Ensure each subteam knows their respective tasks, plans, and procedures and how they pertain to the project.
- Encourage team members to become familiar with tasks, plans, and procedures of other subteams and how they relate to the project as well as their own subteam.
- Gain experience in multiple disciplines and more knowledge of the vehicle by having all members attend build and launch days.

Vehicle Reqs. Verification Plan

- Ground test electronics to ensure complete circuits without shorts or opens.
    - Will use light bulbs as a continuity check rather than energetics.

- Ground test ejection charges to ensure proper pressurization.
    - Must completely deploy recovery gear.

- Successfully complete one sub scale flight with an active payload.

- Successfully complete one full scale flight with an active payload.

Recovery Reqs. Verification Plan

- Ground test electronics:
  - Ignite charges, pressurize airframe enough to break shear pins, and fully deploy recovery gear.

- Drop test parachutes:
  - Determine inflation time and altitude loss between deployment and inflation.

- Full scale flight test using exact same recovery gear and setup as will be used in the final flight in Huntsville.

Payload Reqs. Verification Plan

- Ground test of individual components:
  - Successful payload deployment.
  - The rover successfully traveling a distance of at least 20 feet away from the closest component.
  - Successful soil collection.

- All three components work together as intended on a final ground test.

- Full scale flight:
  - The payload survives no damage during rocket flight.
  - All three components successfully complete their tasks.

Safety Reqs. Verification Plan

- The requirements of the safety team are verified by how well team members follow safe rocketry procedures as well as how safe the launch is overall.

- In order to ensure all students working on this project understand the safe practices which are relevant to it, all team members must sign a team safety statement.

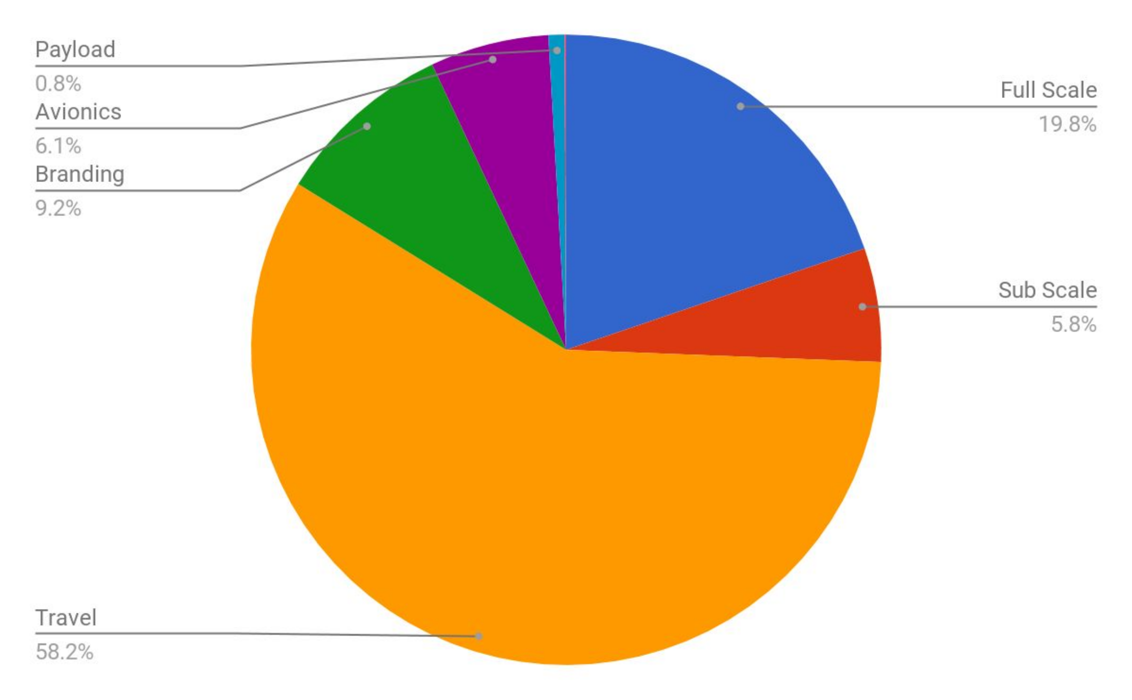
- Documents created by the safety team for this project and relevant safety resources will be discussed by the safety officer in front of the project team to inform them on safety procedures and any dangers associated with high-power rocketry of which they may not be aware.

Funding and Educational Engagement

Budget

Total estimated project cost: ~$10,500.

- Full Scale: $2067
- Sub Scale: $609
- Travel: $6080
- Branding: $960
- Avionics: $685
- Payload: $86
- Social: $8



Educational Engagement

Outreach Events:

- Purdue Space Day
  - Assisted with the teaching of space topics such as launch vehicle construction and propulsion.
  - Lead groups of students in working on space-themed projects and activities.
  - Astronaut Charlie Walker (right) interacted with and presented to the kids.

- Future plans

Question and Answer Session