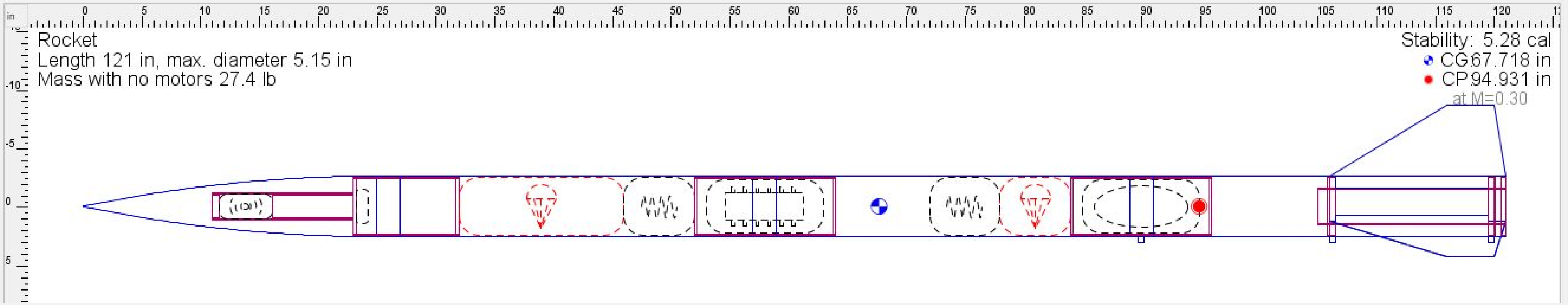
Project Grissom
Preliminary Design Review

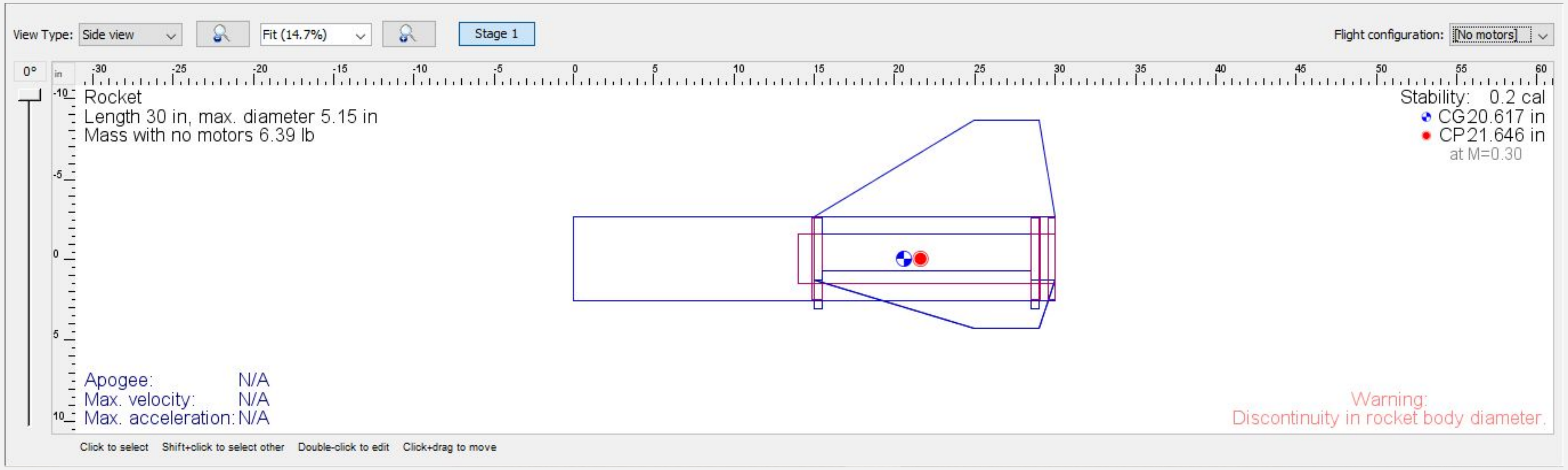
Vehicle Overview

- 121” long, 5.15” maximum diameter
- 27.4 lb estimated weight
- Designed to carry a camera payload to an altitude of one statute mile while maintaining ample aerodynamic stability and be recovered using conventional dual deployment techniques



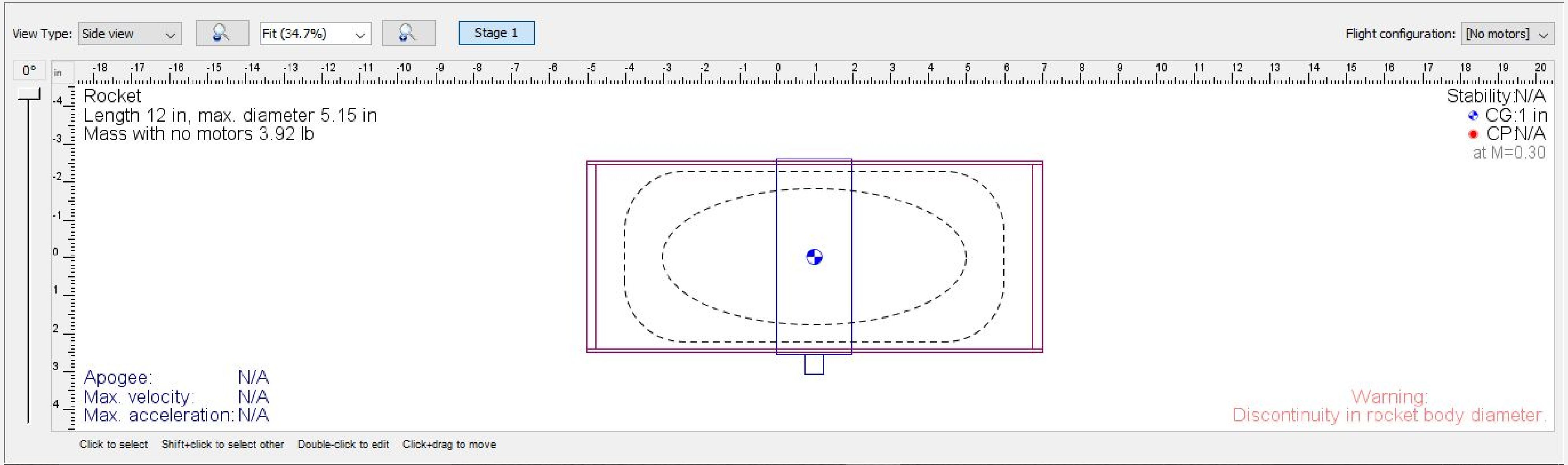
Lower Airframe

- 30” long, 5.15” maximum diameter
- 6.39 lb estimated mass
- Designed to interface with the payload bay coupler tube, house and retain motor, transfer thrust loads from the motor to the airframe, and provide ample aerodynamic stability



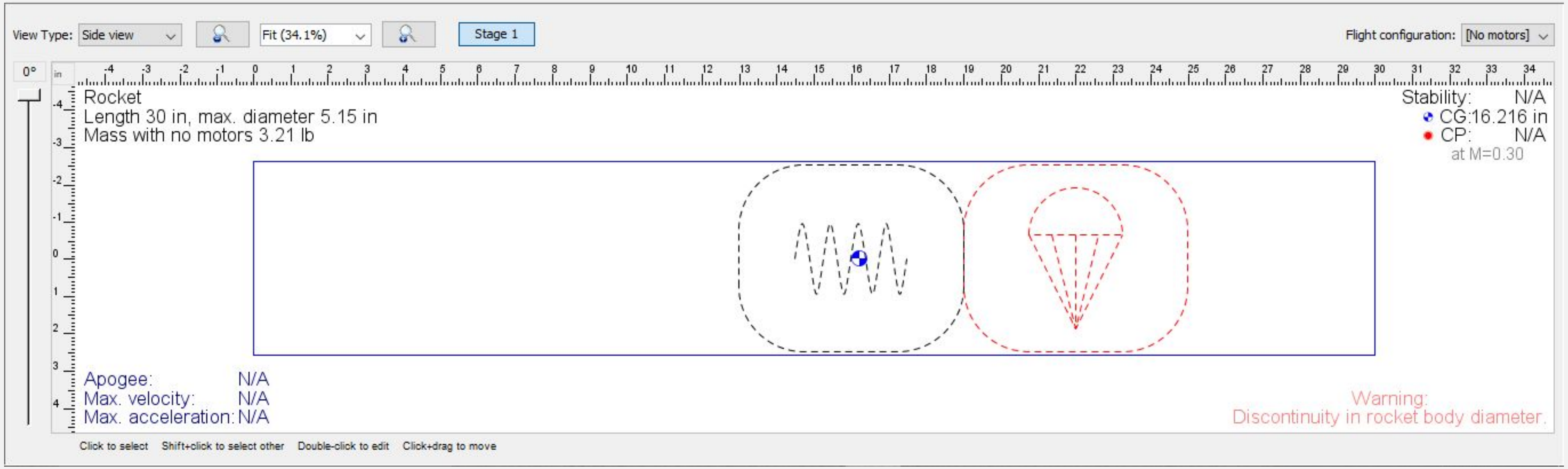
Payload Bay

- 12” long, 5.15” maximum diameter
- 3.91 lb estimated mass
- Designed to hold redundant camera payload systems and interface with the mid and lower airframe sections



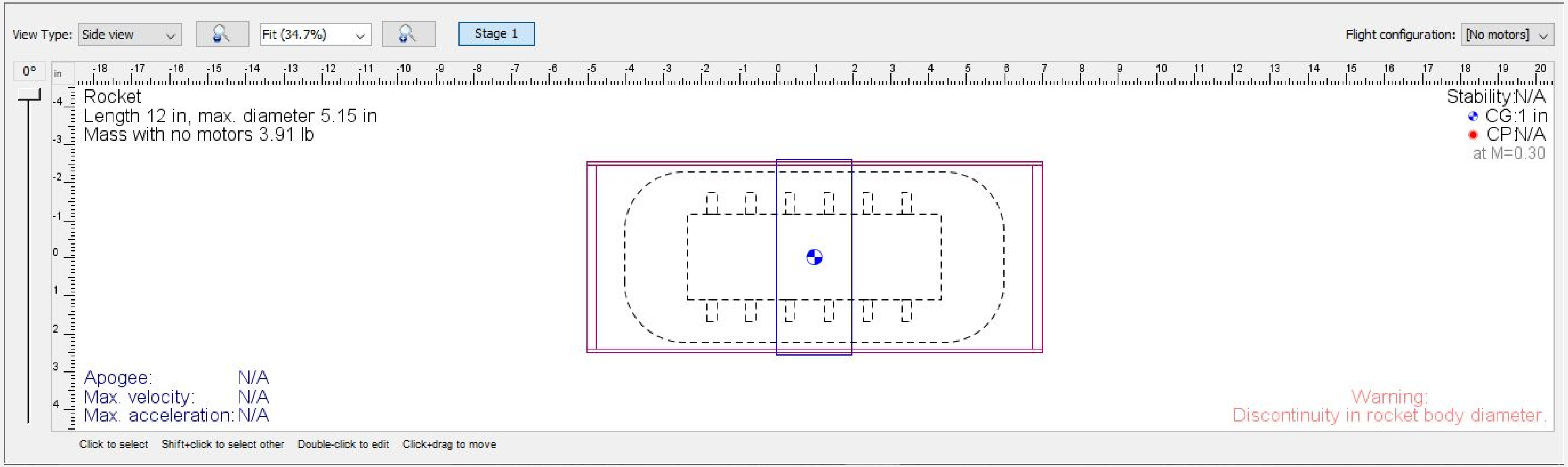
Mid Airframe

- 30” long, 5.15” maximum diameter
- 3.21 lb estimated mass
- Designed to hold drogue recovery gear, interface with the avionics and payload bay coupler tubes, and prevent a negative CG shift



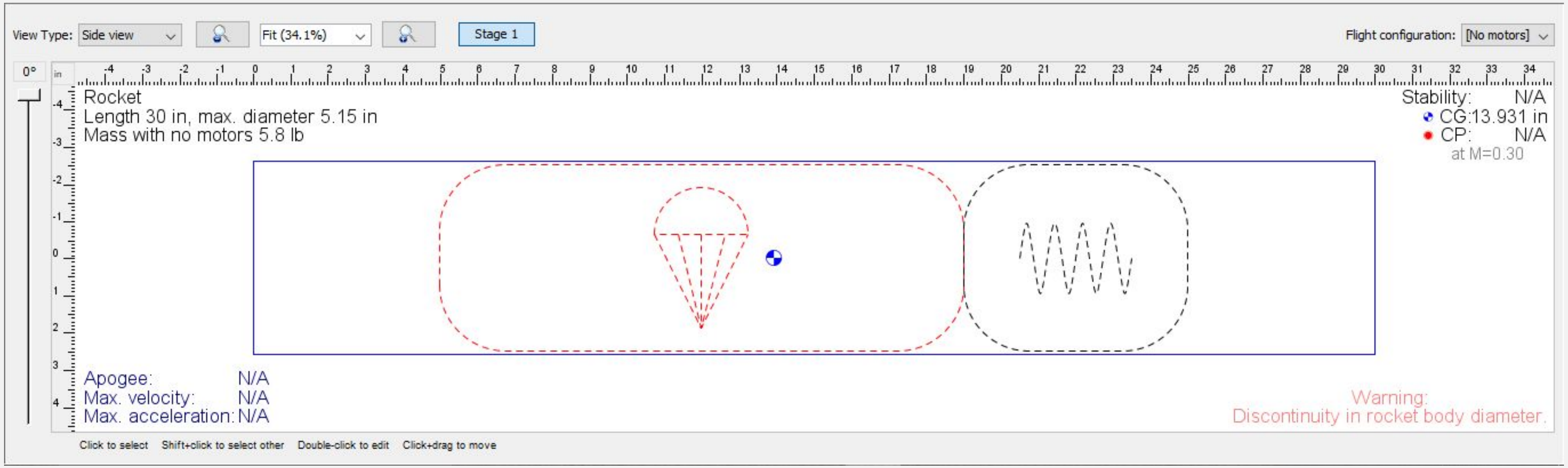
Avionics Bay

- 12” long, 5.15” maximum diameter
- 3.91 lb estimated mass
- Designed to hold redundant avionics systems and interface with the upper and mid airframe sections



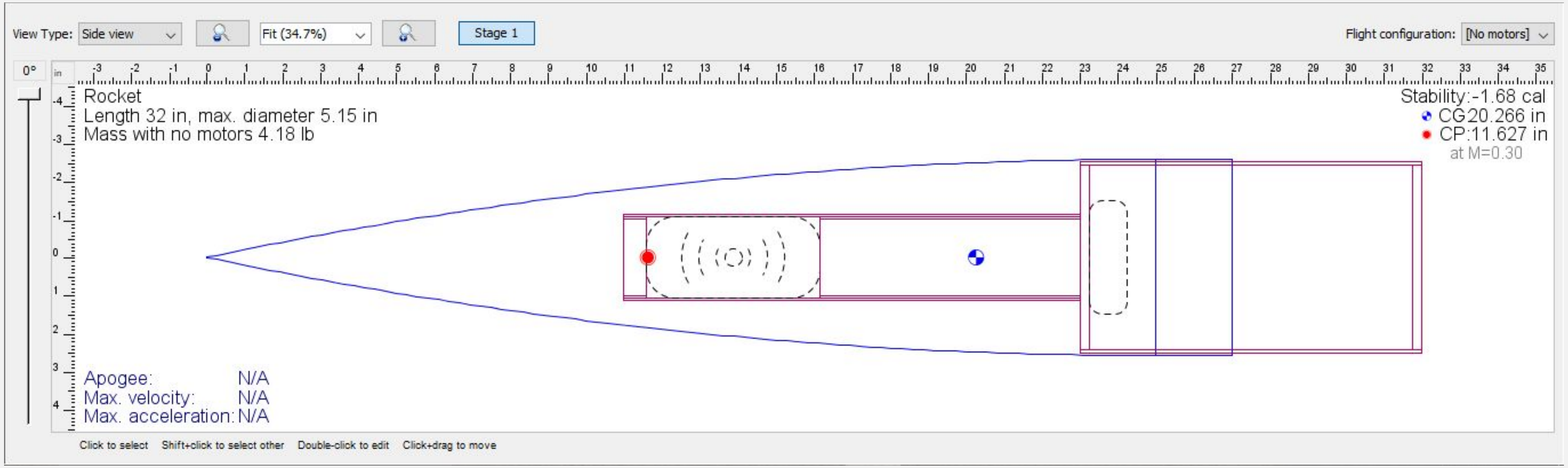
Upper Airframe

- 30” long, 5.15 maximum diameter
- 5.8 lb estimated weight
- Designed to hold main recovery gear, interface with the nosecone and avionics bay coupler tubes, and prevent a negative CG shift



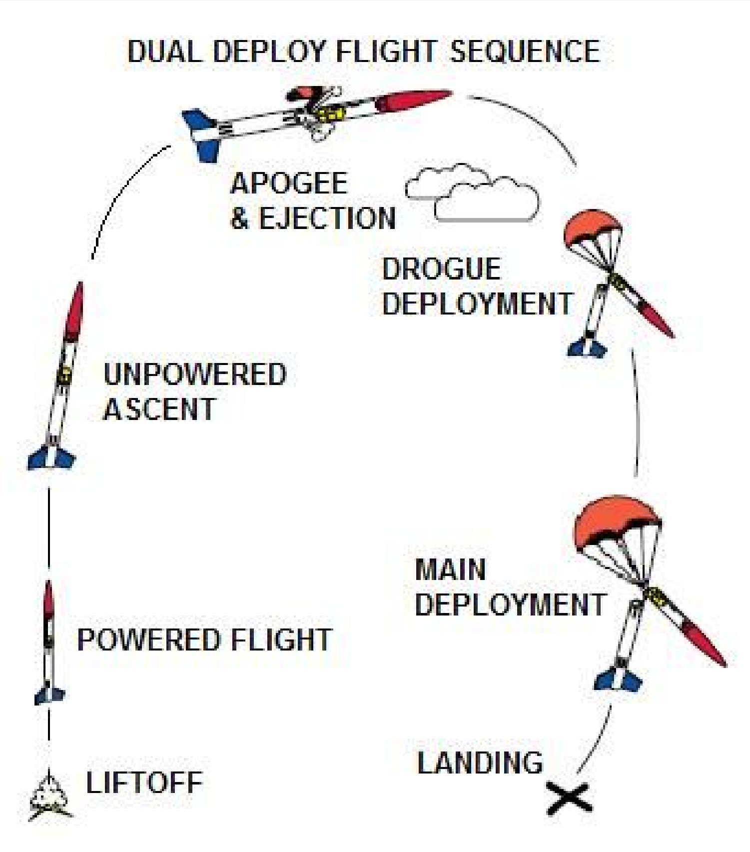
Nosecone

- 32" long, 5.15" maximum diameter
- 4.19 lb estimated weight
- Designed to reduce drag, increase interior volume for future payloads or electronics, and interface with upper payload tube



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 lb 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 XLarge parachute
    - 24” diameter
    - 4x 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
  - 4x 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: 3.8125lbs

Fireproofing

- Nomex heat shield
  - Protects parachute from ejection gases
  - 18”x18” 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: 260

- CO_2 : 225

	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 black powder type
- Mass Estimated- how many grams needed for smooth ejection
- $C*D^2*L$= Grams
  - D: Diameter of airframe => 5.15 in
  - L: Length of recovery => 30 in
  - 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

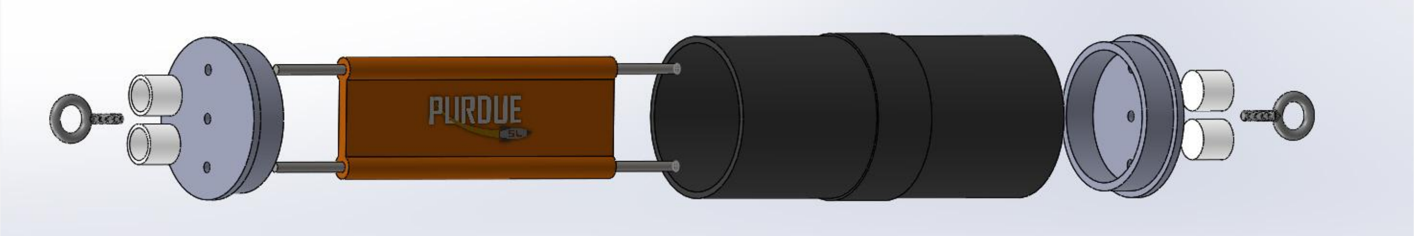
Weight/Importance:
15: Must have
10: Good to have
5: Nice to have

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

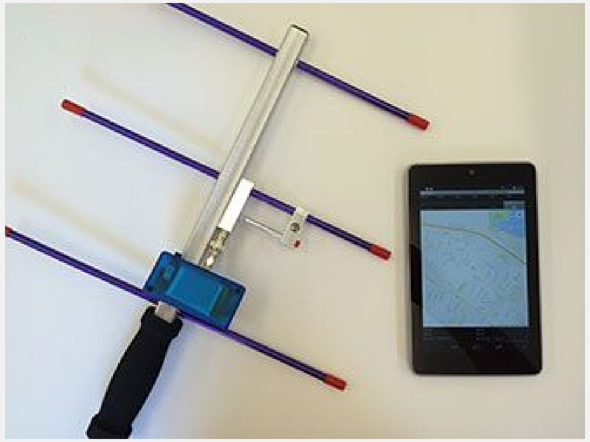
Avionics

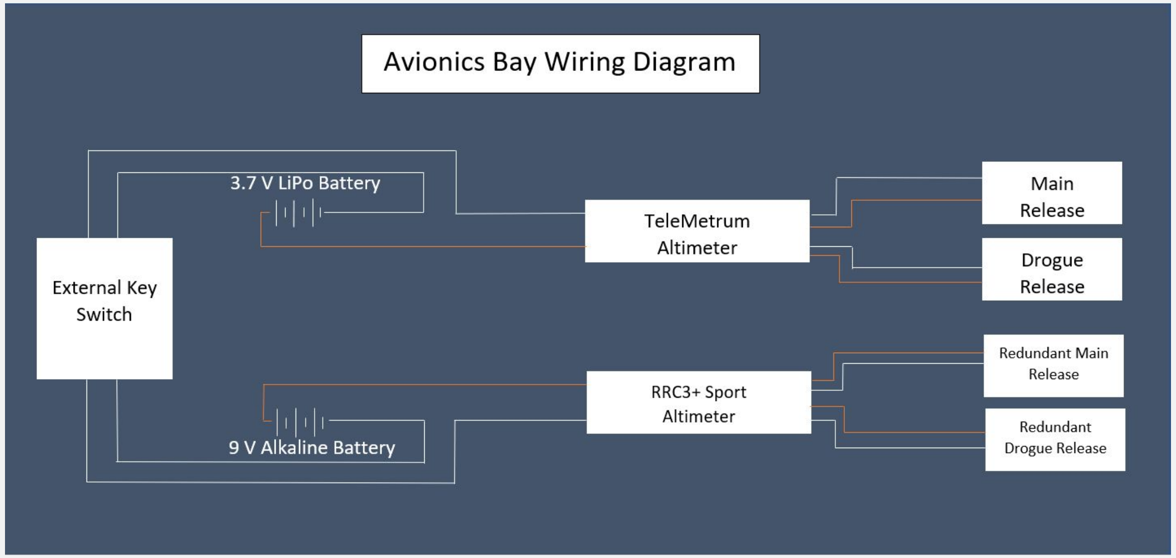
- The Avionics Bay consists of:
  - 2 Altimeters
    - TeleMetrum
    - RRC3+ Sport
  - 2 Batteries
    - 3.7V LiPo
    - 9V
  - 1 3D Printed Sled
  - Eye Bolts
  - Steel Threaded Rods
  - 4Fg Black Powder
  - Capsules to hold Black Powder
  - External Key Switch



Avionics

- The overall weight of the Avionics bay is around half of a pound (~0.54 lb)
- 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 a key switch on the side of the rocket
- Then both altimeters will be powered on
- Then at apogee the drogue shoot will be released
- Then closer to the ground the main parachute will be released.
- The redundancy for the drogue will have a time delay of 2 seconds and for main it will be 200 ft lower.

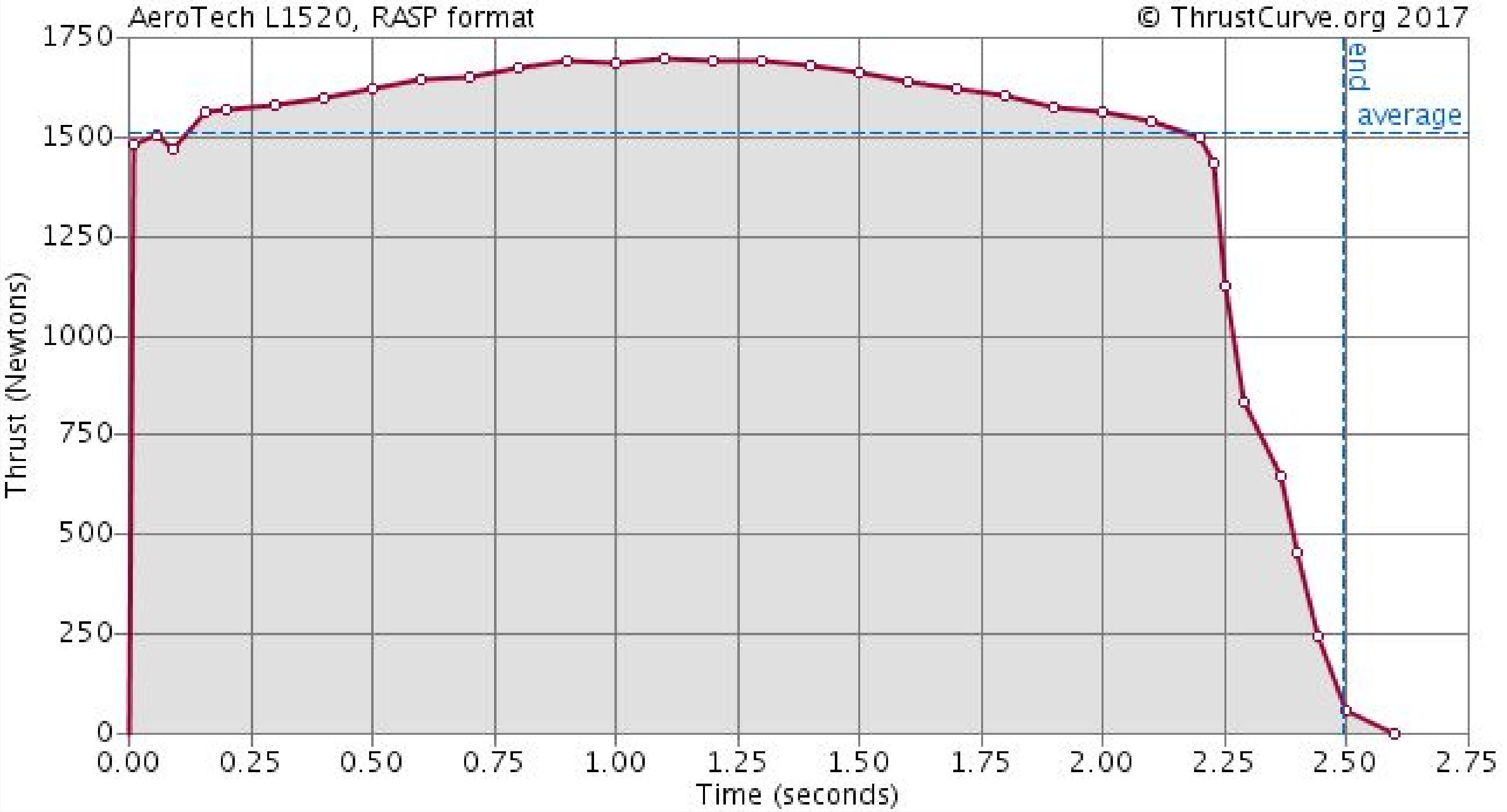




Current Motor Choice

- Aerotech Rocketry L1520 Blue
  - Total impulse: 3,715 n/s
  - Max thrust: 1,765 newtons
  - Average thrust: 1,567 newtons
  - Liftoff thrust: 1,513 newtons
  - Burn time: 2.4 seconds
  - Propellant mass: 1854 grams

- Hardware: 75/3840 casing
  - Dimensions: 3” dia x 20.39” length
  - Loaded mass: 3,651 grams
  - Empty weight: 1,797 grams



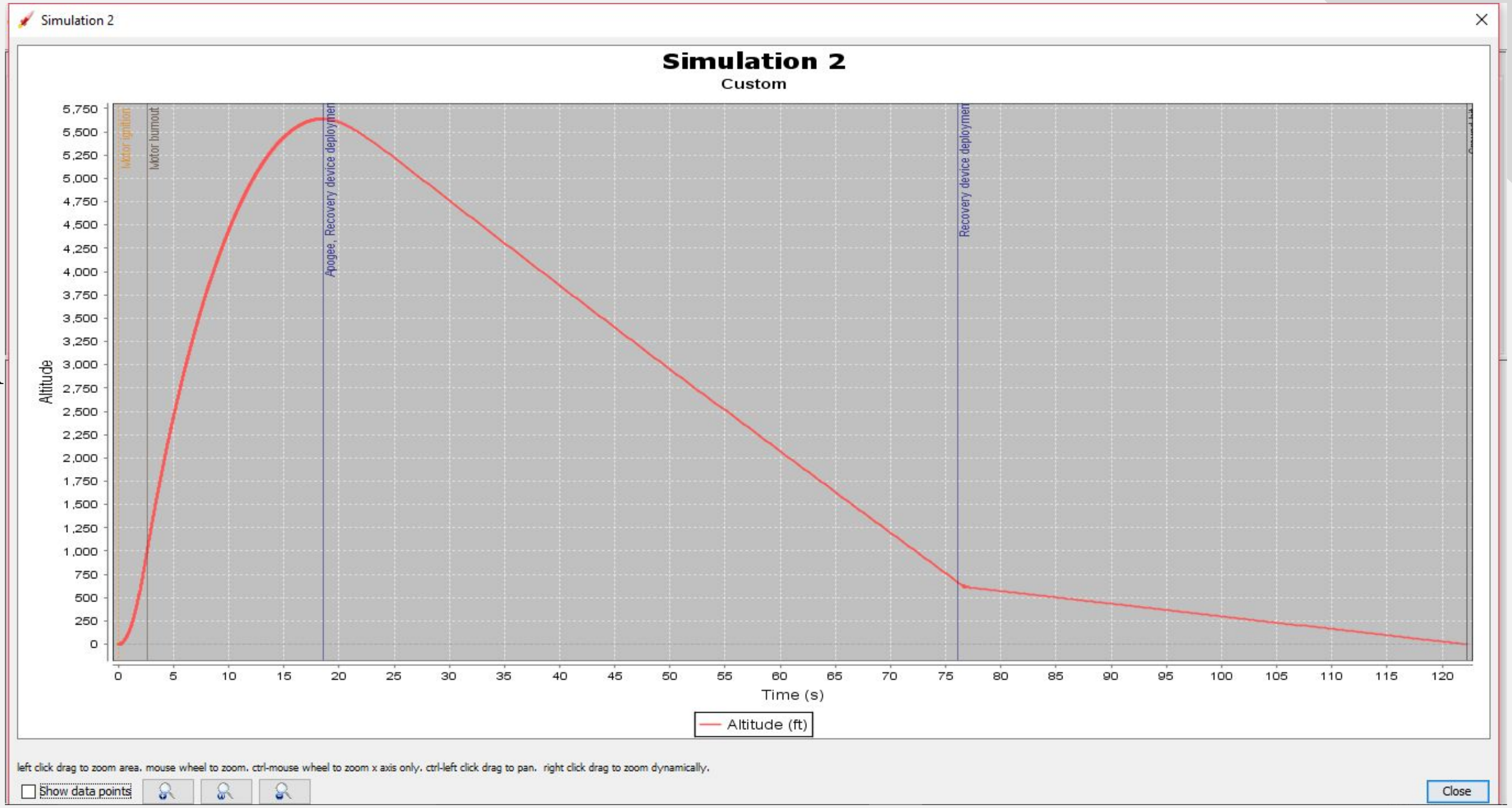
Thrust:Weight and Exit Velocity

- The thrust:weight ratio that we achieve is ~9.9:1
  - Liftoff Thrust: 340.1 lbs
  - Liftoff weight: 35.4 lbs
- Maximum Acceleration is ~323 ft/sec^2
- Maximum Velocity is ~ 692.27 ft/sec
- We will also have an exit velocity of 83.45 ft/sec

Altitude Predictions

- Simulated in OpenRocket 15.03
  - Maximum altitude: 5,638’ AGL

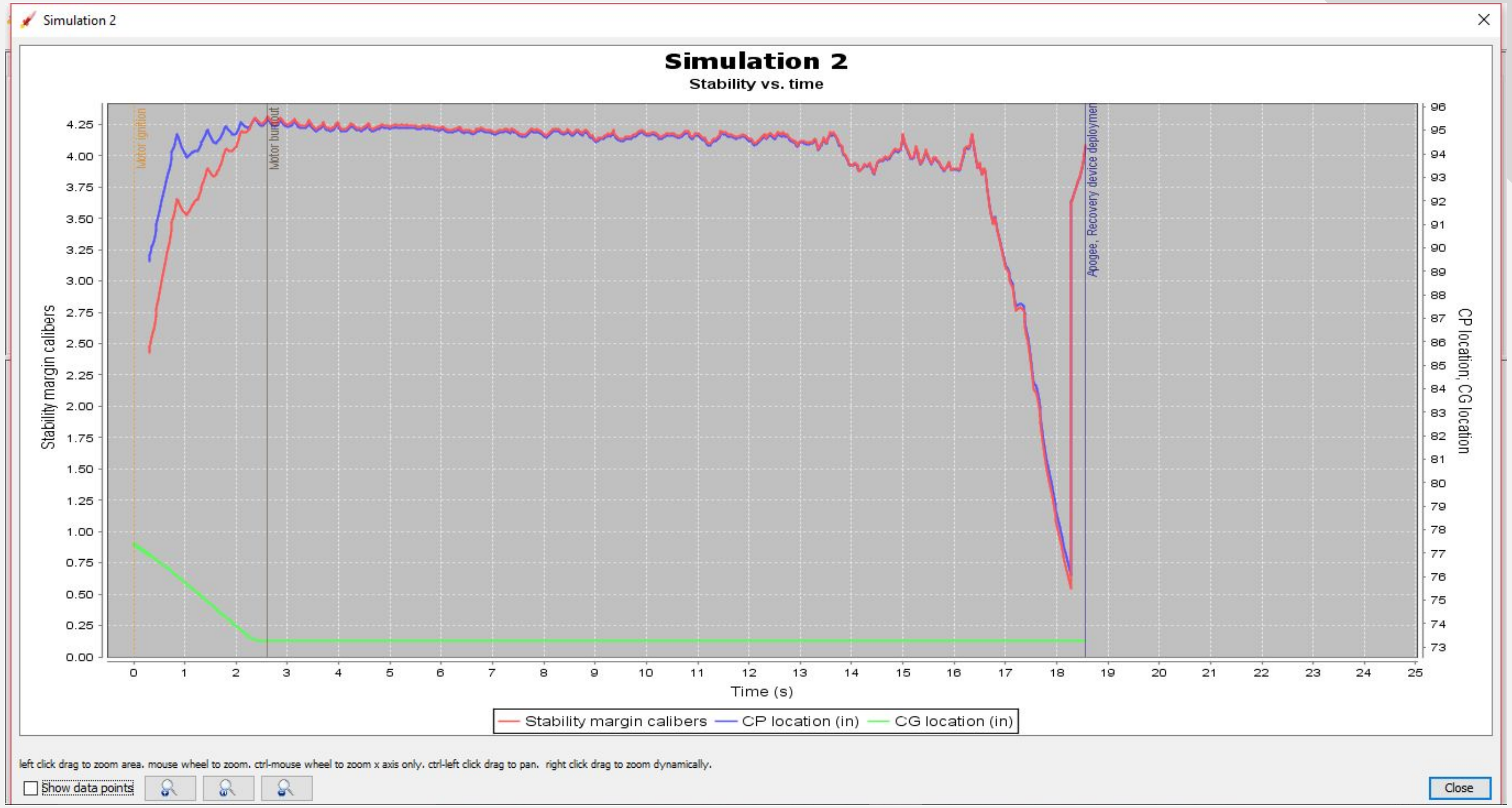
- Simulation settings:
  - Calculation: Extended Barrowman
  - Simulation: 6-DOF Runge-Kutta 4
  - Geodedic: spherical approximation
  - Time step: 0.02 seconds



Stability Margins

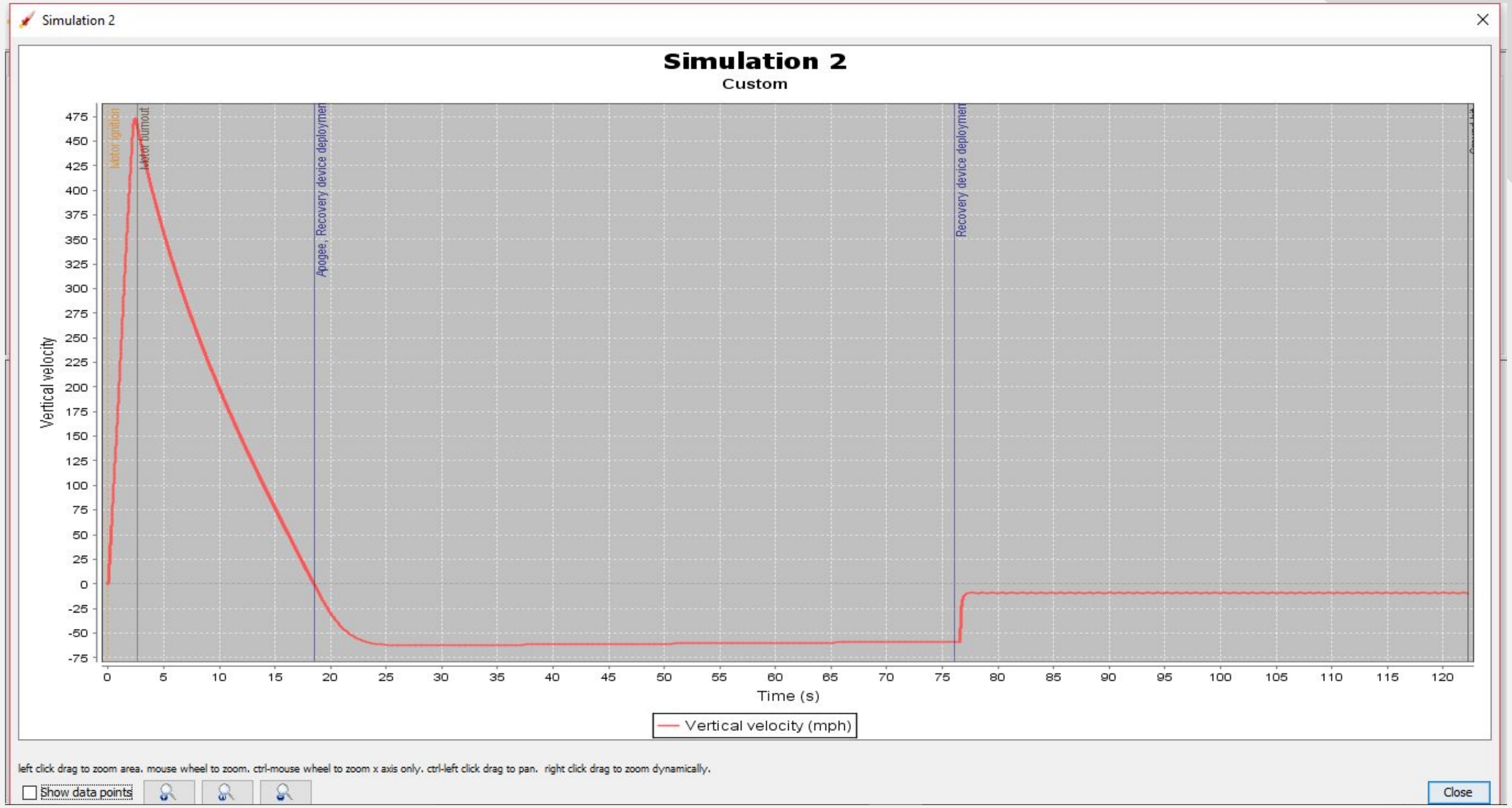
- Static:
    - Stability margin: 3.38 calibers
    - CP location: 94.9” from datum
    - CG location: 77.4” from datum

- At takeoff:
    - Stability margin: 2.5 calibers
    - CP location: 89.8” from datum
    - CG location: 77.4” from datum



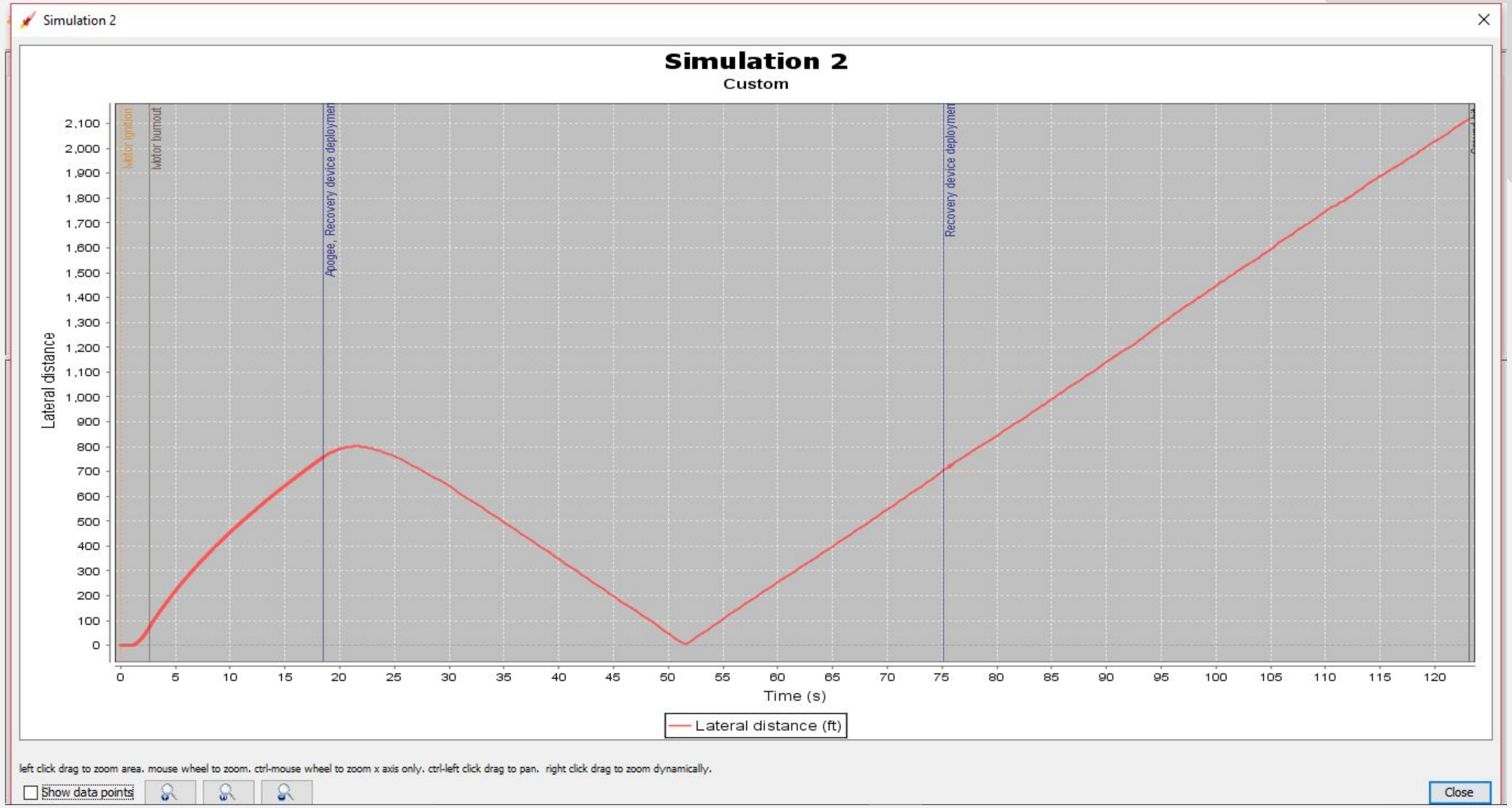
Landing Energy

- Landing velocity: 8.5 MPH
- Total landing energy: 76.081 ft/lbs
- Lower section energy: 42.509 ft/lbs
- Mid section energy: 23.425 ft/lbs
- Nosecone Energy: 10.096 ft/lbs



Drift Calculations

- Maximum drift distance of 2,100’
- Windspeed: 20 MPH
- Standard Deviation: 10%
- Turbulence Intensity: 2.0 MPH



Safety Officer Info

- The Safety Officer for the Purdue SL Team participating in the 2018 competition will be Michael Repella

- 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

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

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 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

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 personnel protective equipment and material safety data sheets

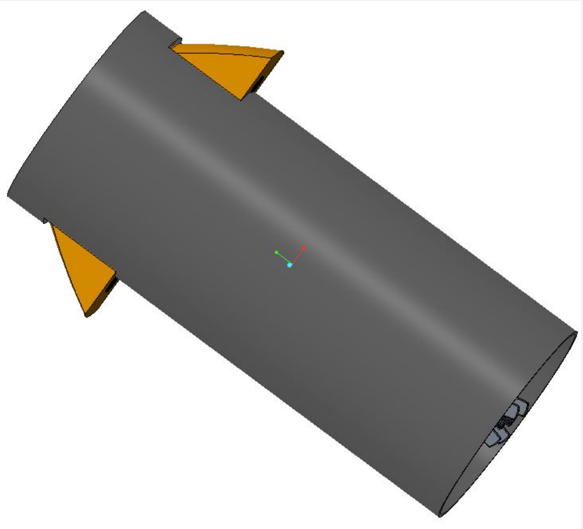
Team Safety Statement

- 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 Grissom or the NASA SL program

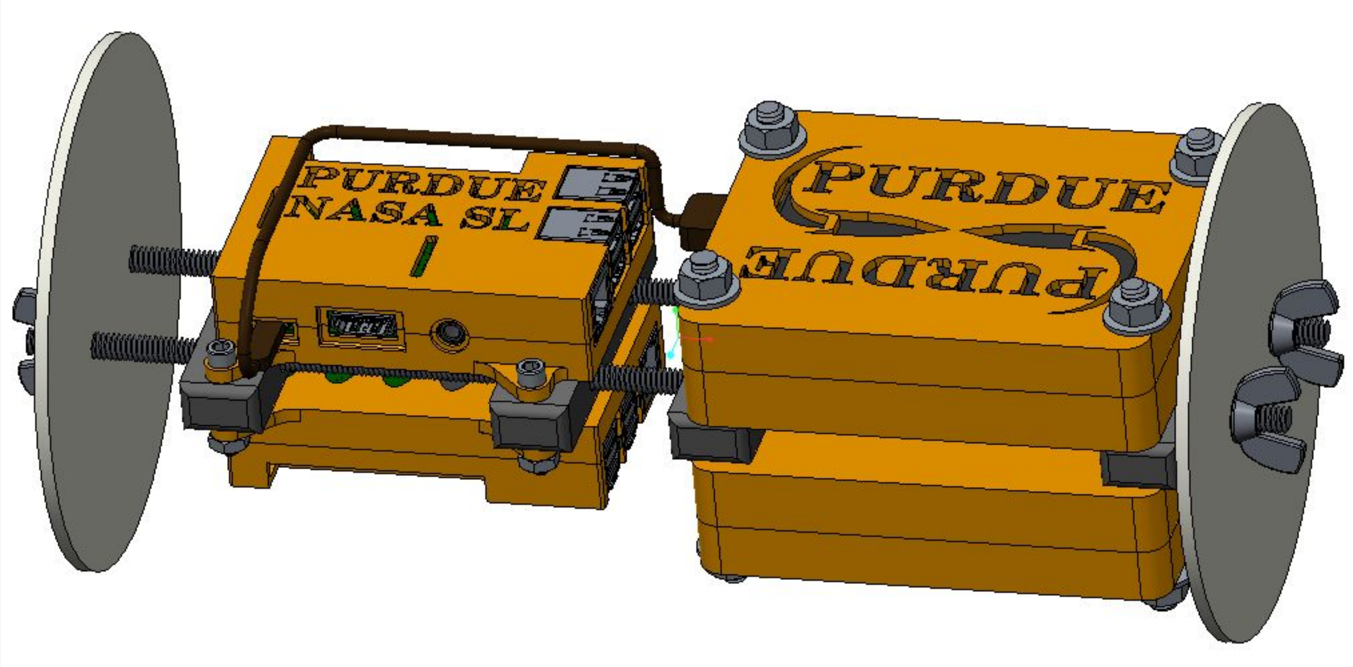
Payload Design

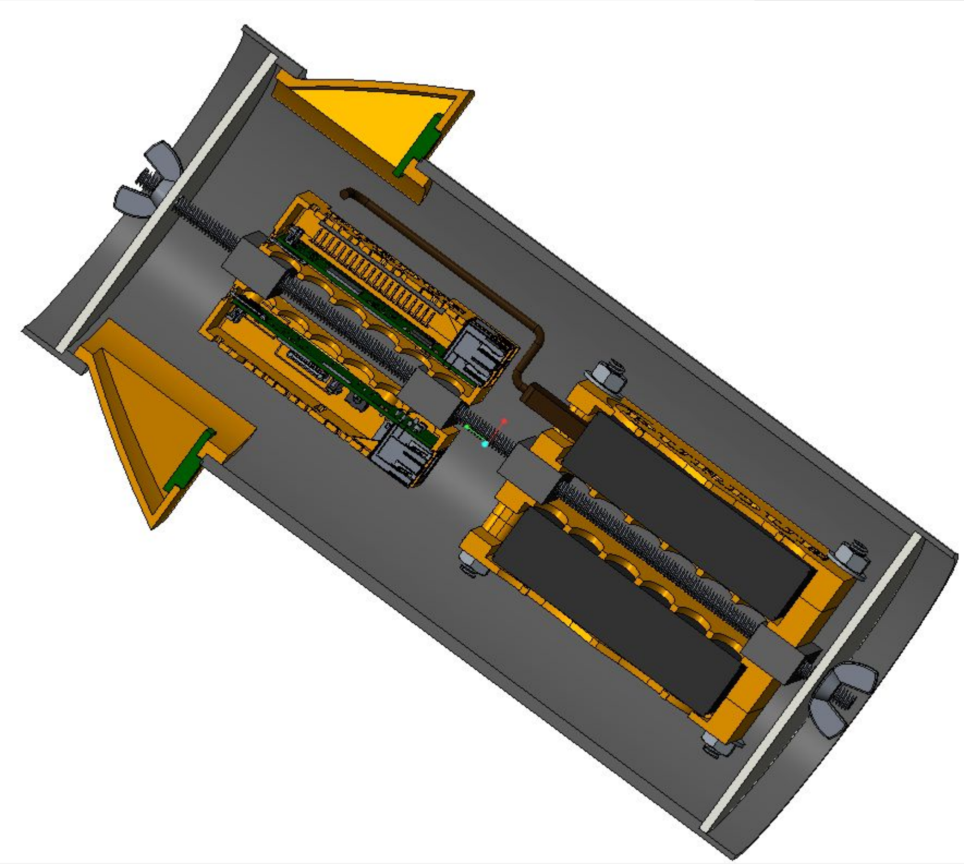
- Mission
  - Identify ground targets
  - Distinguish targets by color
- Requirements
  - Less than 2 lbs
  - Dimensions
    - 12” long & 4.815” diameter
  - 2 hours of autonomous operation
  - Independent from avionics bay
  - Processing must be done in real time on board the launch vehicle
  - Full redundancy system

- Key components
  - 2 x on board computer
  - 2 x video camera
  - 2 x Power supply



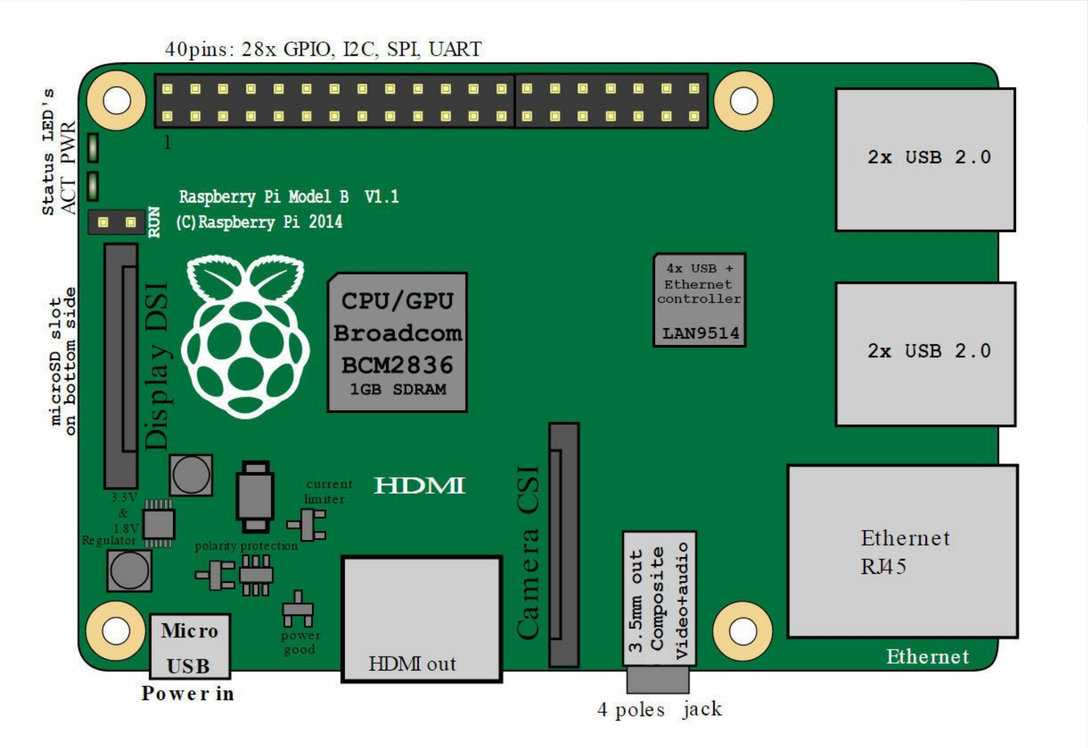
Payload/Vehicle Interface





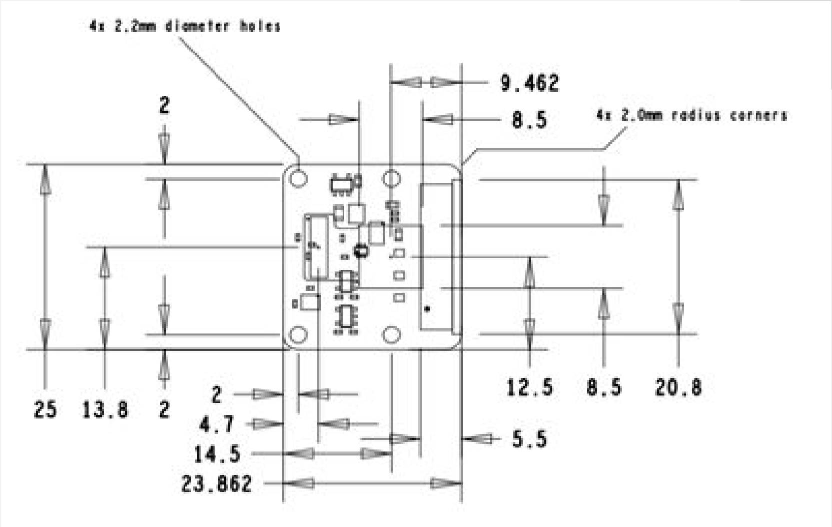
On Board Computer

- Raspberry Pi Model 3B
  - Cost: $35
- Operating Requirements:
  - 4.75 - 5.25 Volts
  - 5 Amps
- Mass: 0.042 kg
- Dimensions:
  - 85.6mm x 56.4mm x 17.0 mm
- Processing Performance
  - 1 GB SDRAM
  - Quad Cortex A52 @ 1.2Ghz



Camera

- Raspberry Pi Camera Module V2
  - Cost: $25.99
- Resolution
  - 8 MP (3280x2464)
- Frame Rate
  - 1080p @ 30 fps
  - 720p @ 60 fps
- Port: CSI
- 79 degree field of view
- Mass: 0.0031 kg
- Dimensions
  - 0.98” x 0.94” x 0.35”



Power Supply

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

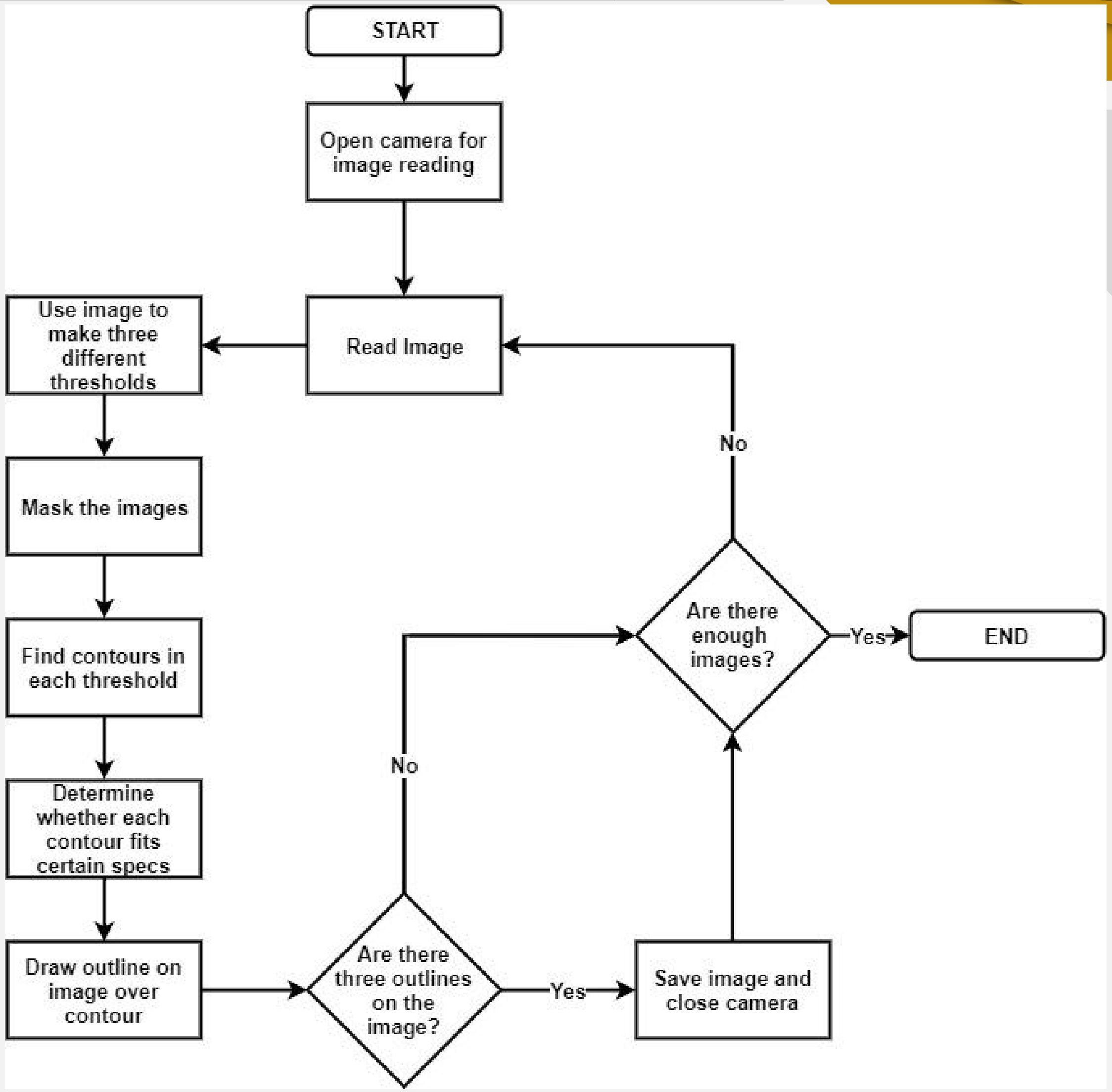
- Leading Choice: Anker PowerCore 10,000mAh
    - Allows for even weight distribution
    - Meets all requirements
    - Provides significant power for dimensions and cost

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

- Operating system
  - Raspbian
- Video processing program
  - OpenCV
- Coding Language:
  - Python 3
- Algorithms
  - Feature detection
    - Arcs lengths
    - Number of sides
  - Color distinction
    - RGB/HSV
    - L*a*b values



General Reqs. Verification Plan

- Members will:
  - Ensure each subteam knows their respective tasks, plans, and procedures and how they pertain to the project
  - 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
    - Design, construction, and and launch familiarization

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

Payload Reqs. Verification Plan

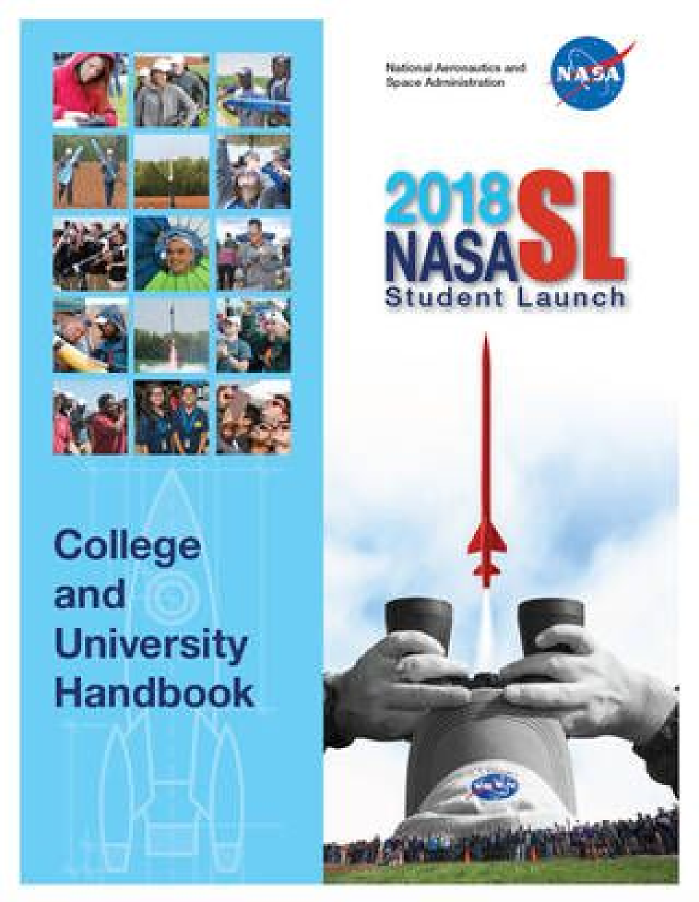
- Have a functioning camera on all flights to determine feasibility of capturing clear images under flight conditions
- Arrange tarps of different color values on the field at all test launches
  - Plan A: Payload design will be mounted permanently to launch vehicle body
    - Simple design, less components for potential failure
  - Plan B: If image clarity is an issue, opt for a deployable payload at apogee
    - More complex system
    - Aerodynamic forces are minimal and higher probability of capturing clear images

Safety Reqs. Verification Plan

- The requirements of the safety team are verified by how well team members follow safe rocketry procedures and how safe the launch is overall
- In order to ensure all 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 they may not be aware of

Vehicle Derived Reqs.

- Vehicle team will be operating under the requirements presented in the 2018 USLI College and University Handbook

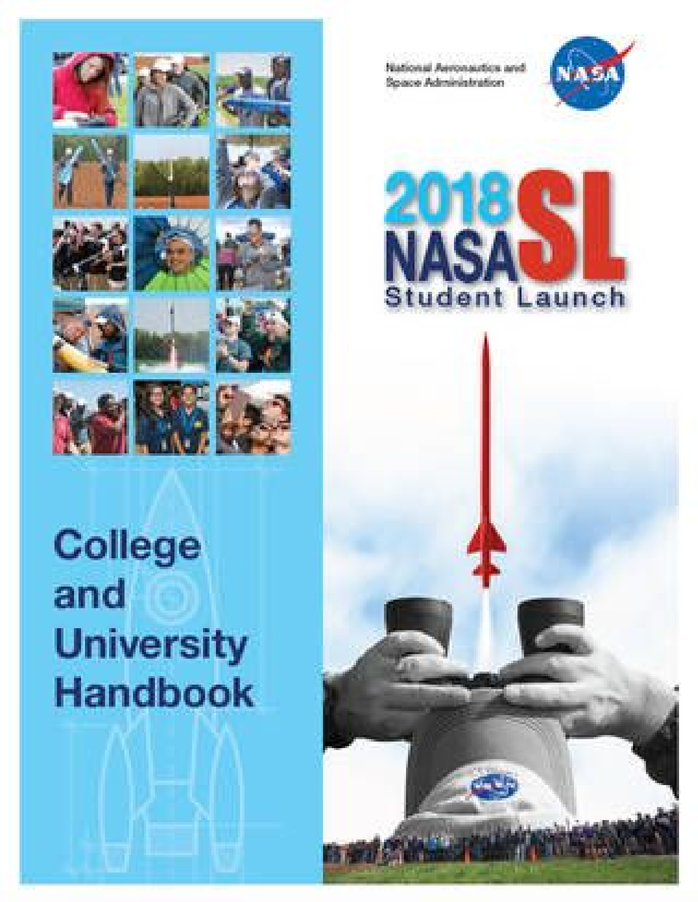


Payload Derived Reqs.

- Payload identifies target based on color
- Payload identifies target based on shape
- Latency threshold less than 100 ms/loop iteration.
- Sum of the payload components must not exceed two lbs.
- Battery supply powers system must operate for three hours.

Recovery Derived Reqs.

- Recovery team will be operating under the requirements presented in the 2018 USLI College and University Handbook



General Derived Reqs.

- 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 sub scale flight and recovery on a sub scale motor while carrying a functional payload system.
- Have a successful full scale test flight and recovery on a full scale motor while carrying a functional redundant payload system.

General Derived Reqs. Cont

- 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 2018 USLI College and University Handbook.
- Fulfill and exceed all educational engagement requirements presented to us by NASA within the 2018 USLI College and University 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.
- Successful finish of the competition in Huntsville, Alabama.

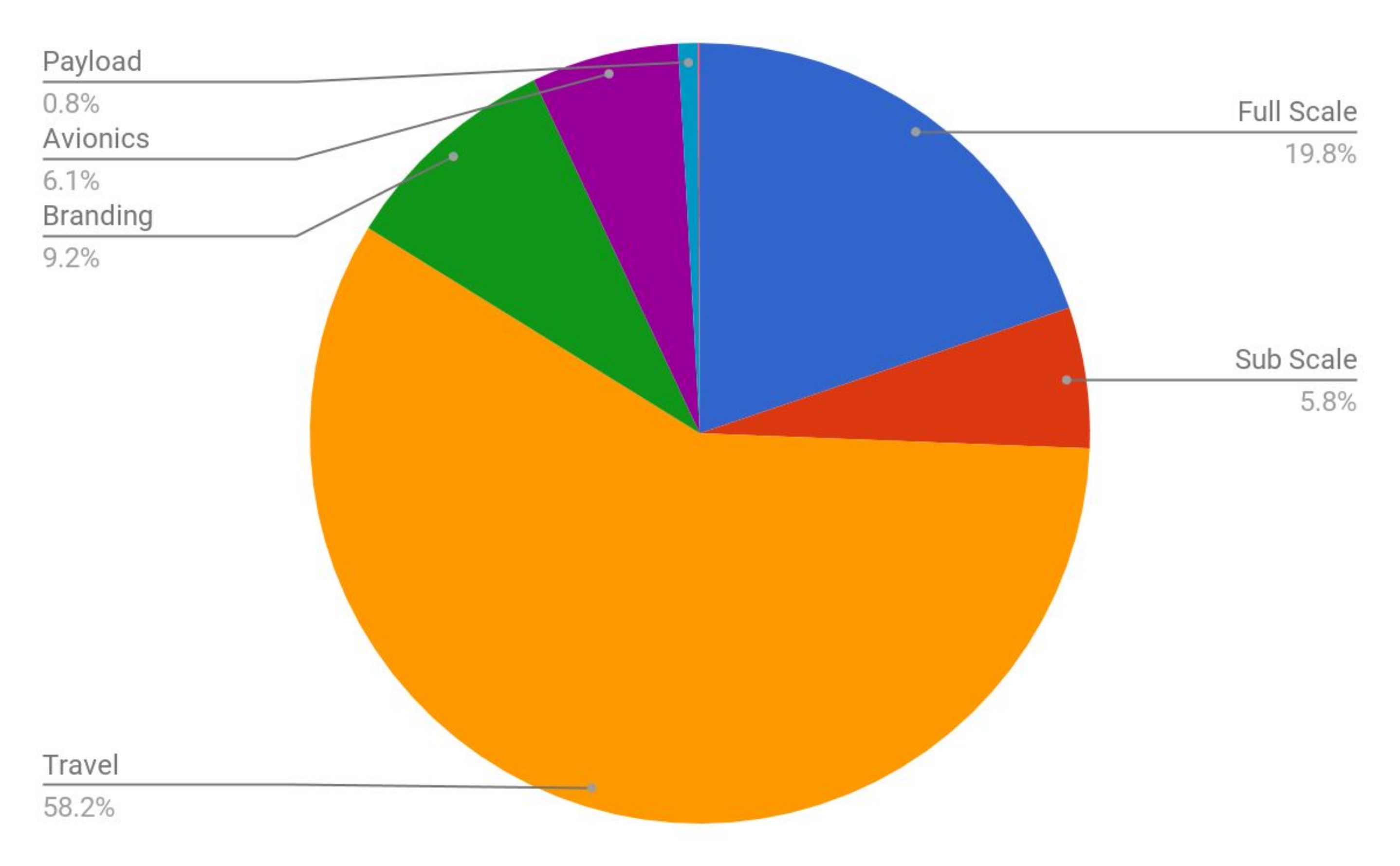
Safety Derived Reqs.

- The safety team would like to achieve and create the following:
  - Full compliance with local, state, and federal laws and a positive reputation as a team which prioritizes lawful rocketry
  - Team-wide knowledge of how to work safely with high-power rockets
  - Fully-functional hazard analysis and contingency plans to both prevent and react optimally to any emergency situations.
  - An organized set of procedures which can be followed to enforce safe construction and launch practices and to be prepared for any emergency

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

- Imagination Station Mini-makers Faire
  - Taught coding using Tynker, a program that teaches basic logic and animation.
- Burnett Creek Elementary School
  - Gave a presentation on the basics of spaceflight and rockets to 3rd graders.
- Space Day
  - Assisted with the teaching of space topics such as mars exploration and innovation.
  - Had Mark Polansky (astronaut) talk and present to the kids.

Question and Answer Session