Cornell Rocketry PDR

Team Summary

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Presentation Outline

1. Changes made since proposal
2. Launch Vehicle Subsystem
3. Recovery Subsystem
4. Mission Performance Predictions
4. Payload Criteria
5. Project Plan

1.1 Changes Made Since Proposal - Launch Vehicle

- The payload and the R&T sections have been separated
- The drogue has been moved from below the nose cone to below the R&T bay
- The dimensions of the fins have changed
- The Hazard Detection Camera has been moved from the bottom of the sustainer section, to the top of the payload sled
- Overall length has increased from 95.5 inches to 110 inches and the weight of the rocket has increased from 32.7 lbs to 35.2 lbs

1.2 Changes Made Since Proposal - Recovery and Tracking

- Added reefing system to main parachute
- Designed cable cutter
- Nose cone ejected at 6,100 ft for better payload ejection mechanism design

2. Launch Vehicle Criteria

2.1 Mission Statement

2.2 Subsystem Overview

2.3 Material selection

2.4 Performance Characteristics

2.1 Mission Statement

Cornell Rocketry Team plans to develop a robust, streamlined, and cost effective inline two-stage rocket that will reach a desired apogee of 9,600 feet. Capabilities include a novel payload ejection system, the dispersion of ejectable methane units to collect scientific data, a custom recovery system made in house and a hazard detection camera to warn users on the ground of potential threats in real time. By demonstrating this technology, the team hopes that our efforts will contribute to the advancement of rocketry in both academic and commercial sectors.

2.2 Subsystem Overview

- Airframe subsystem
- R&T subsystem
- Payload subsystem
- Business subsystem

2.3 Material Selection- Airframe

- Blue Tube selected for airframe
  - Increased durability to withstand Mach .71 forces
- Fiberglass reinforcement
- Rocket lighter than rocket with same strength using phenolic tubing

2.3 Material Selection- Bulkheads

- Constructed from birch plywood reinforced with carbon fiber

- Primary bulkhead force is a bending force
  - Used property $M' = \sigma_0\rho$ plotted in CES Edupack for selection
  - Stress analysis in SolidWorks verified material choice

2.3 Material Selection- Fins

- Balsa wood core with three layers of carbon fiber reinforcement inserted into fin slots, secured with Proline High Temperature Epoxy
- Additional layer of carbon fiber secures fins to body

2.3 Material Selection- Nose Cone

- Constructed from filament wound fiberglass
    - o Superior strength to weight ratio than biaxial fiberglass
   - o Aluminum tip

2.6 Risk Analysis

- Extensive risk analysis completed on rocket
- Risk plot used to severity and probability of risk.
- Example of risks include:
  - Catastrophic failure during test launch
  - Not meeting major deadlines
  - Safety accidents during manufacturing
- Mitigation of Risks include extensive testing, adhering to strict schedules and following all proper safety procedures.

2.7 Testing

- Tension, Compression, Crush, Three Point Bending
- Ground Testing of electronics and recovery systems
- Drop Testing
- Half-scale and low power testing

# 2.9 Dimensional Drawing
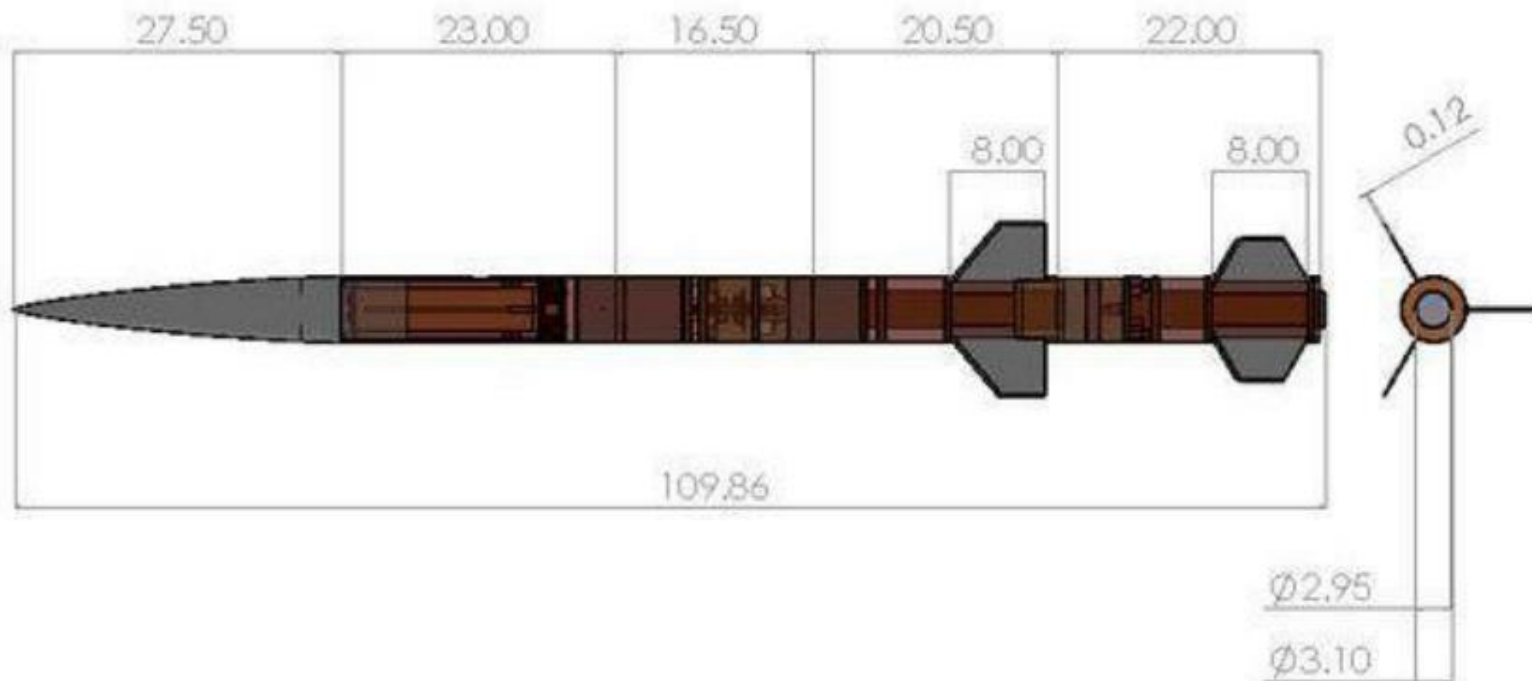
2.10 Electrical Schematics of Recovery System- 1st Stage

- Timer with 9V battery and key lock switch used to separate booster from sustainer stage

- Key lock accessible from outside

- All systems redundant
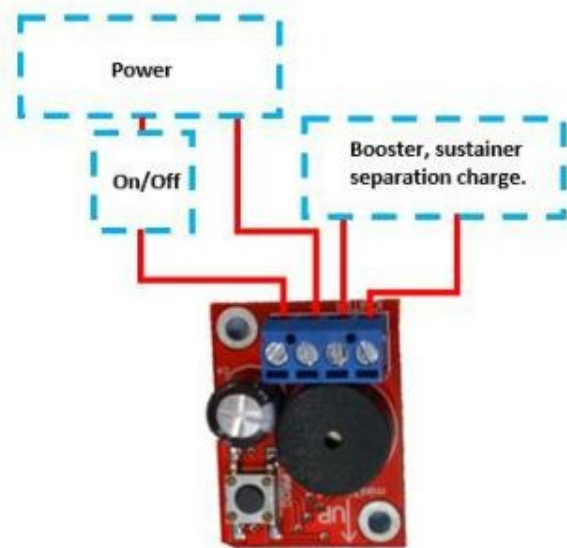
2.10 Electrical Schematics of Recovery System- 2nd Stage

- Two Raven 3 altimeters
  - Has 4 events
  - Minimum of three events needed to implement reefing systems
- All systems redundant
- Key lock accessible from outside
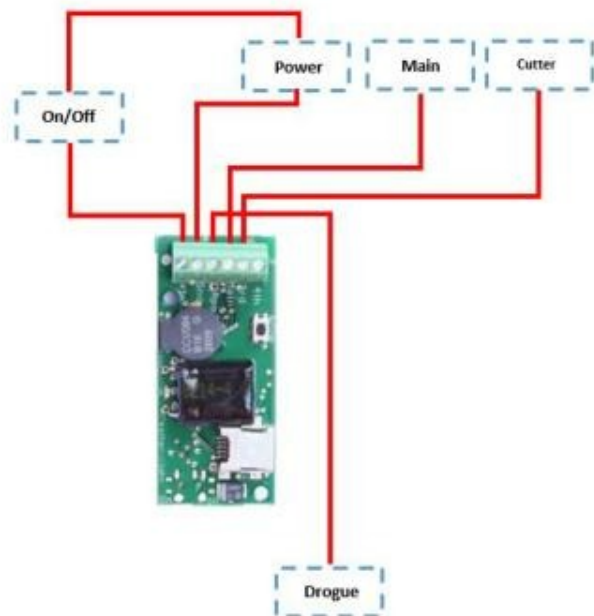
2.11 Mass Statement

Subsystem	Mass (lbs)
Airframe	23
Recovery and Tracking	6.6
Payload	5.6
Total	**35.2**

- Yields a 6.37:1 thrust to weight ratio
- Can increase weight by 9.7 lb and still launch safely
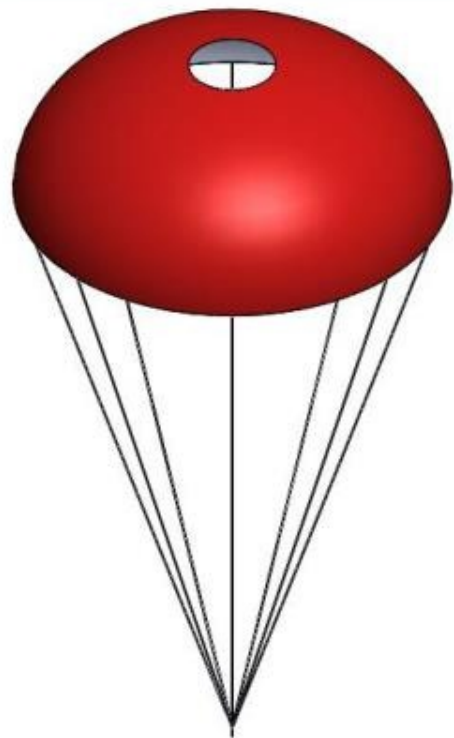
3. Recovery Subsystem

3.1 Parachute Design
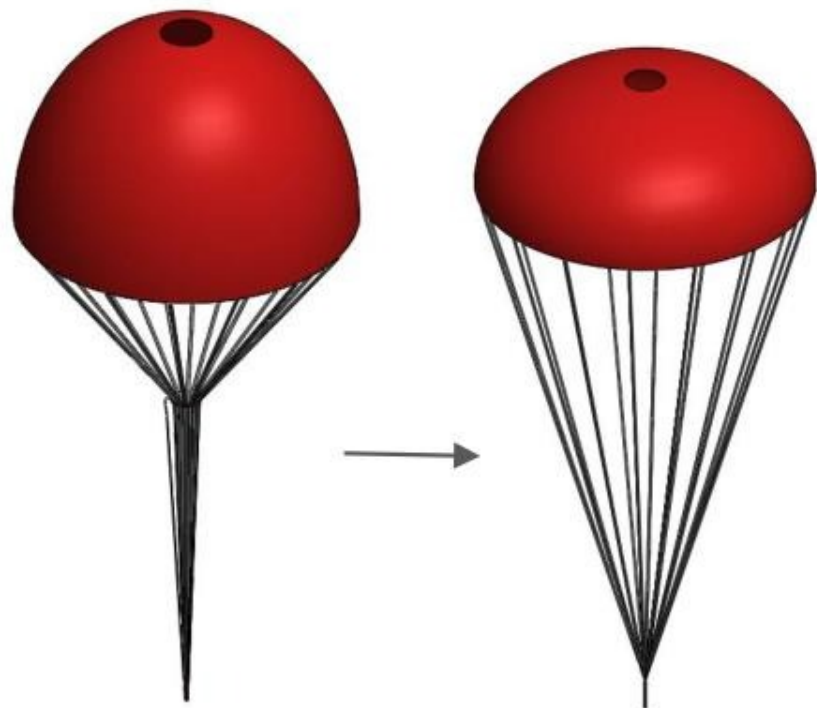
3.2 Main Parachute

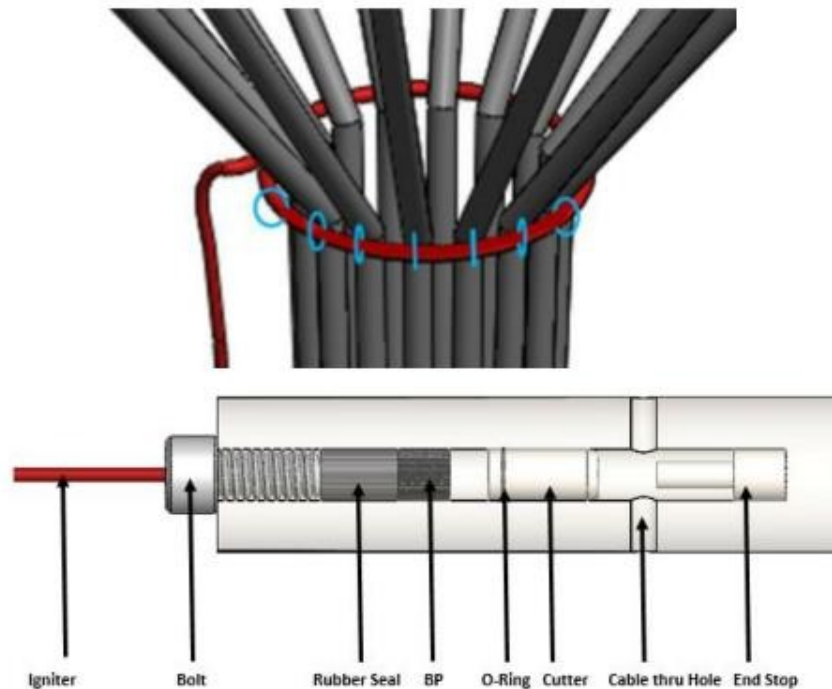3.3 R&T Bay

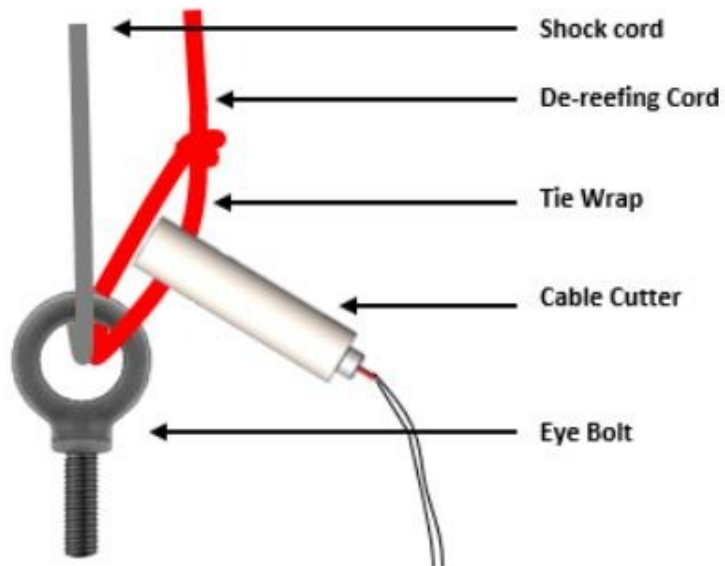3.4 Forces on Rocket

3.1 Parachute Design

- Parachute Type: semi-ellipsoid
- Coefficient of Drag: 1.25
- Shroud lines proportional to diameter of parachute
- Spill hole located at center of each parachute for stabilization
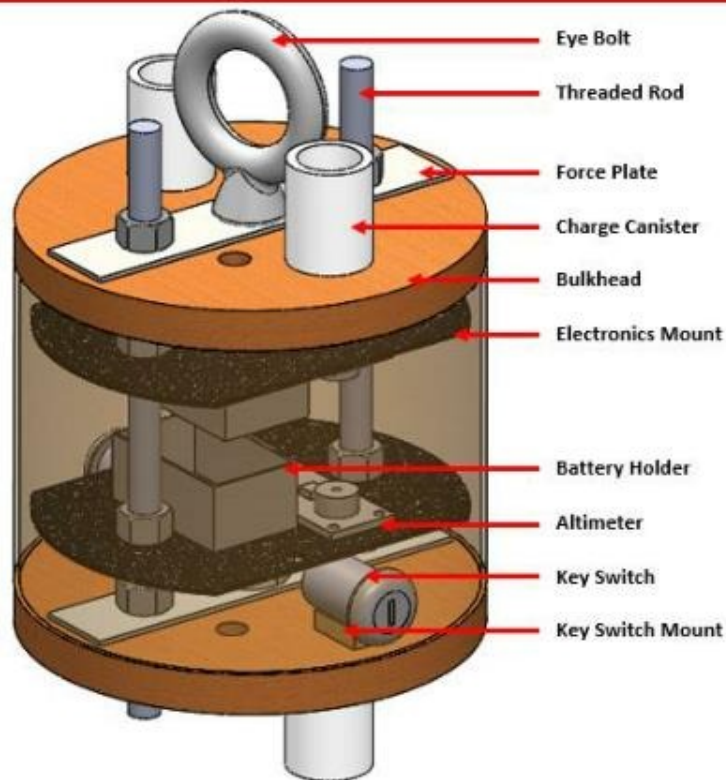
3.2 Main Parachute

- 120 inch diameter main parachute
- Deployed at 900 ft
- Main Parachute uses reefing mechanism
  - Will allow parachute to open more smoothly
  - Less force applied to components on rockets
- Cable cutter built in-house

3.2 Main Parachute

Shock cord

De-reefing Cord

Tie Wrap

Cable Cutter

Eye Bolt

Igniter   Bolt   Rubber Seal   BP   O-Ring   Cutter   Cable thru Hole   End Stop

3.3 R&T Bay

Eye Bolt
Threaded Rod
Force Plate
Charge Canister
Bulkhead
Electronics Mount
Battery Holder
Altimeter
Key Switch
Key Switch Mount

- Designed to be lightweight
- Carbon fiber electronic mounts
- Removable Carbon Fiber disks allows addition of more electronics
- Individual carbon fiber plates allows multiple people to work on different electronic components simultaneously
- R&T bay can be completely assembled outside of rocket for easier launch preparation

3.4 Forces on Rocket
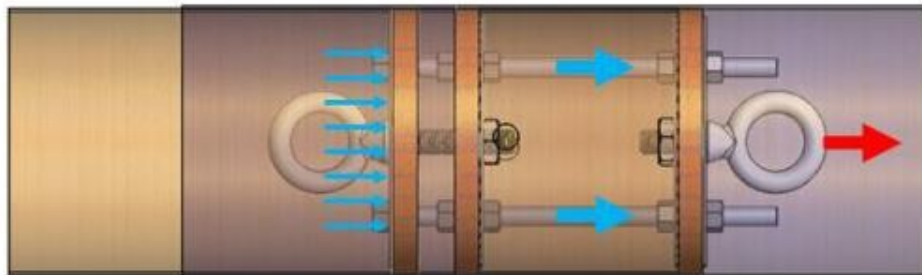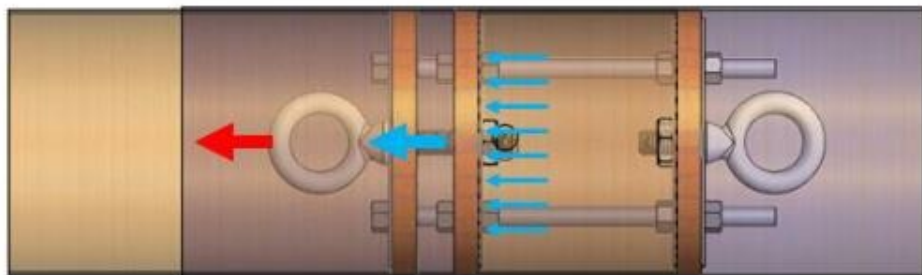
- Forces exerted on rocket as seen in diagrams

- Top image: Main

- Bottom image: Drogue

- R&T Bay Retainer ring transmits forces through coupler tubes to airframe

3.4 Forces on Rocket

	Length	K	Mass c	Mass r	Snatch Force
Booster Main	6 ft (72 in)	6.265E6	1.00 lb	3.57 lb	232.918 lbf
2nd Stage Main	36 ft (432 in)	3.759E7	6.91 lb	5.87 lb	1149.99 lbf
2nd Stage Drogue	20 ft (240 in)	2.088E7	8.67 lb	12.69 lb	1091.87 lbf
Nose Cone Main	4 ft (48 in)	4.177E6	0.54 lb	1.34 lb	131.889 lbf

Calculated snatch force on rocket from parachute deployment.

4. Mission Performance Predictions

4.1 Motor Characteristics

4.2 Altitude Simulation
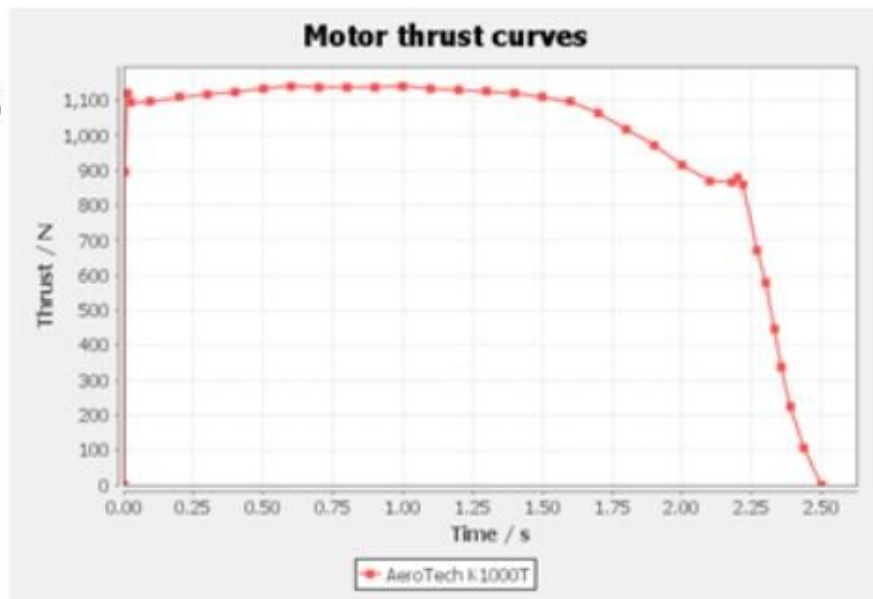
4.3 Velocity Simulation

4.4 CP and CG Estimates

4.5 Kinetic Energy Estimates

4.6 Drift for Each Section

4.1 Motor Characteristics

- First stage: Aerotech K1000T-P motor
  - ○ Average thrust: 1012 N
  - ○ Total impulse: 2497 N*s
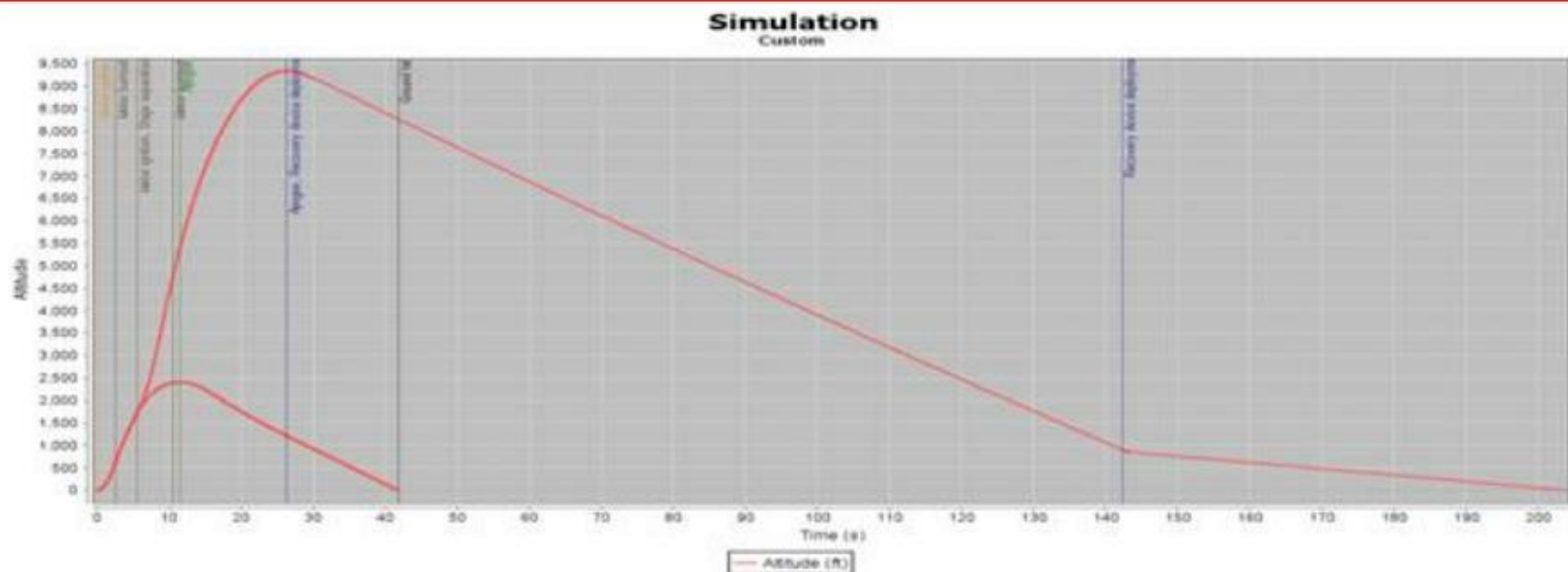 - ○ Thrust to weight: 6.46

Motor thrust curves

4.1 Motor Characteristics

- Second stage: Aerotech K560W motor

  - Ignited 3 seconds after first stage burn out

  - Average thrust: 551 N

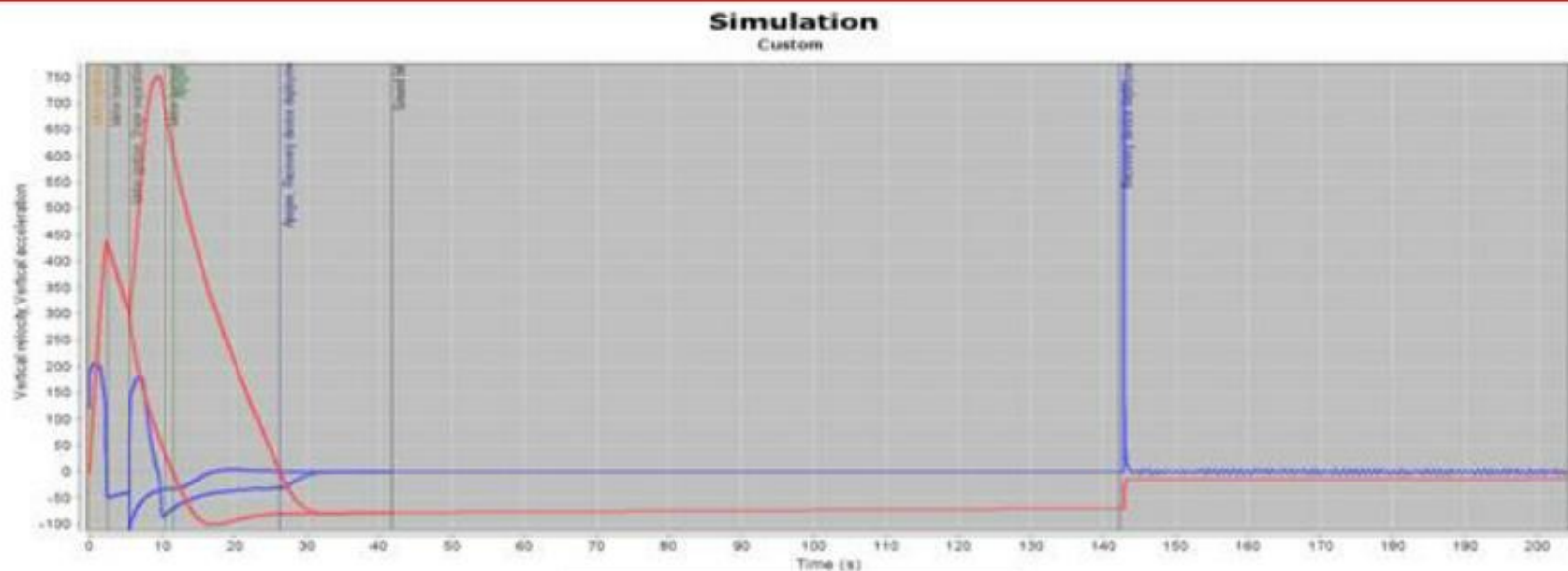 - Total impulse: 2467 N*s

  - Thrust to weight: 4.84

Motor thrust curves
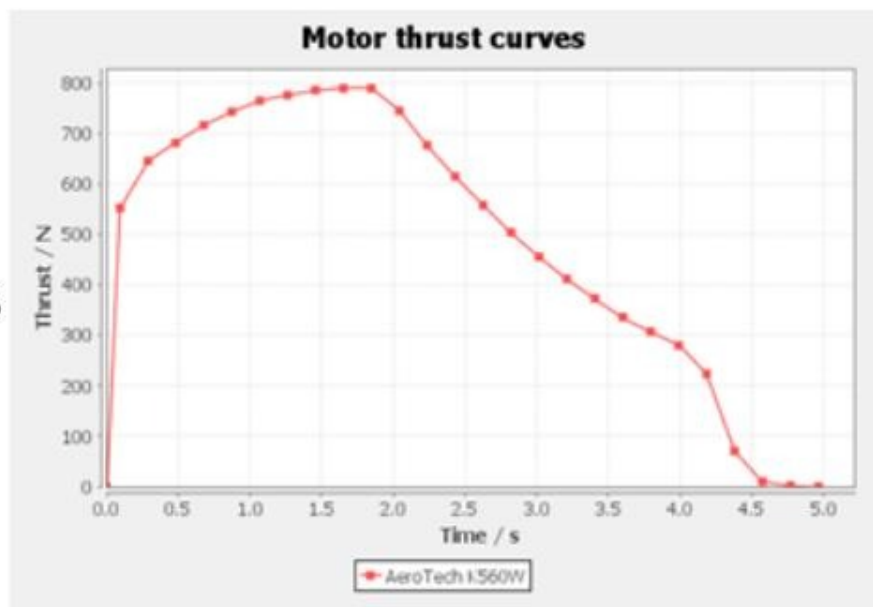
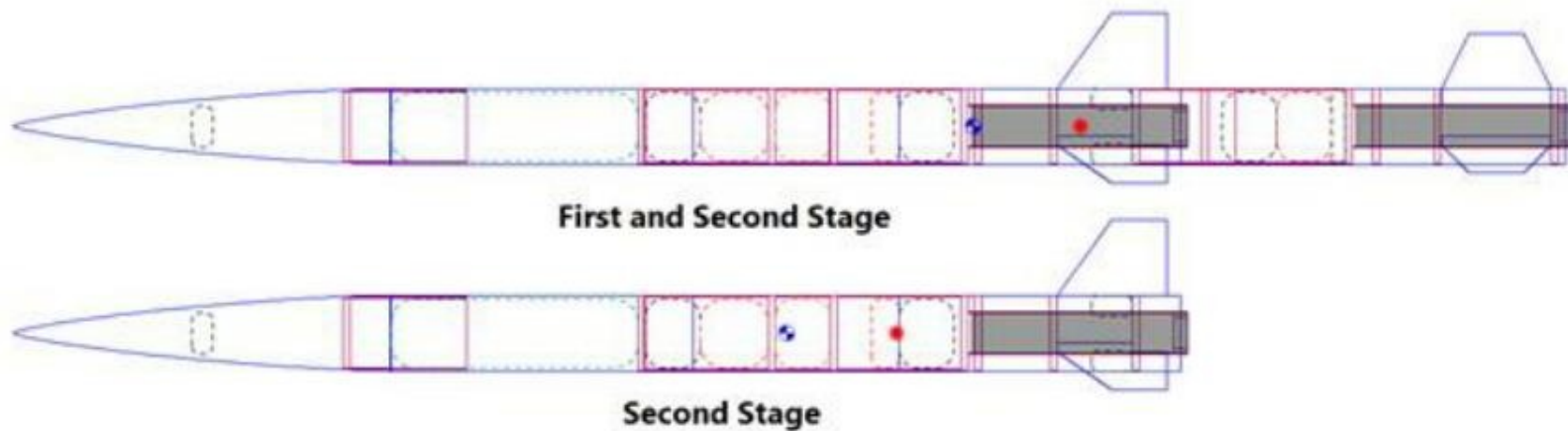# 4.2 Altitude Simulation

- Projected apogee: 9,600 ft
- Time to apogee: 29.6 s

4.3 Rocket Vertical and Horizontal Velocities

- Rail exit velocity: 64 ft/s
- Max velocity: 758 ft/s
- Max acceleration: 206 ft/s

4.4 CP and CG Estimates

First and Second Stage

Second Stage

	CG (in)	CP (in)	Static Stability Margin (Calibers)
Before Separation	68.8	78.0	1.66
After Separation	56.7	66.3	1.74

4.5 Kinetic Energy Estimates

	Kinetic Energy at Landing
Booster Section	34.0789 ft-lbf
Sustainer Section	35.0019 ft-lbf
R&T Section	19.9333 ft-lbf
Payload Section	22.6227 ft-lbf
Nosecone	23.3366 ft-lbf

- All of these fall below the required 75 ft-lbf KE with a safety factor of 2.14

4.6 Drift for Each Section

- Drift of components calculated using custom MATLAB Script

	0 mph	5 mph	10 mph	15 mph	20 mph
1st stage	0 ft	343.9332 ft	687.8682 ft	1031.8 ft	1375.7318 ft
2nd stage	0 ft	1636 ft ft	3273.1674 ft	4909.74 ft	6546.3126 ft
NoseCone	0 ft	1731.1 ft	3462.3679 ft	5193.54 ft	6924.7121 ft

4. Payload Criteria

4.1 Hazard Detection Camera

4.2 Payload Ejection Mechanism

4.3 Ejectable Methane Units

4.4 Dual Inline Staging

4.1 Hazard Detection Camera

- Detect three categories of objects during descent:
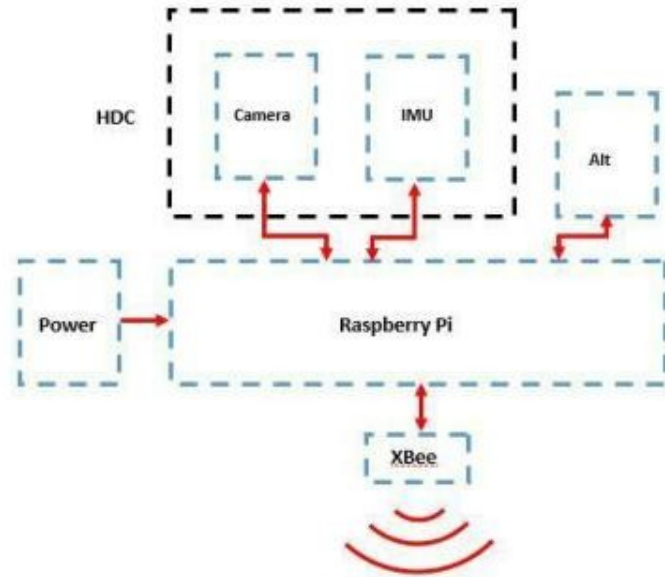 - Objects > 5 ft², objects < 5 ft², circular objects
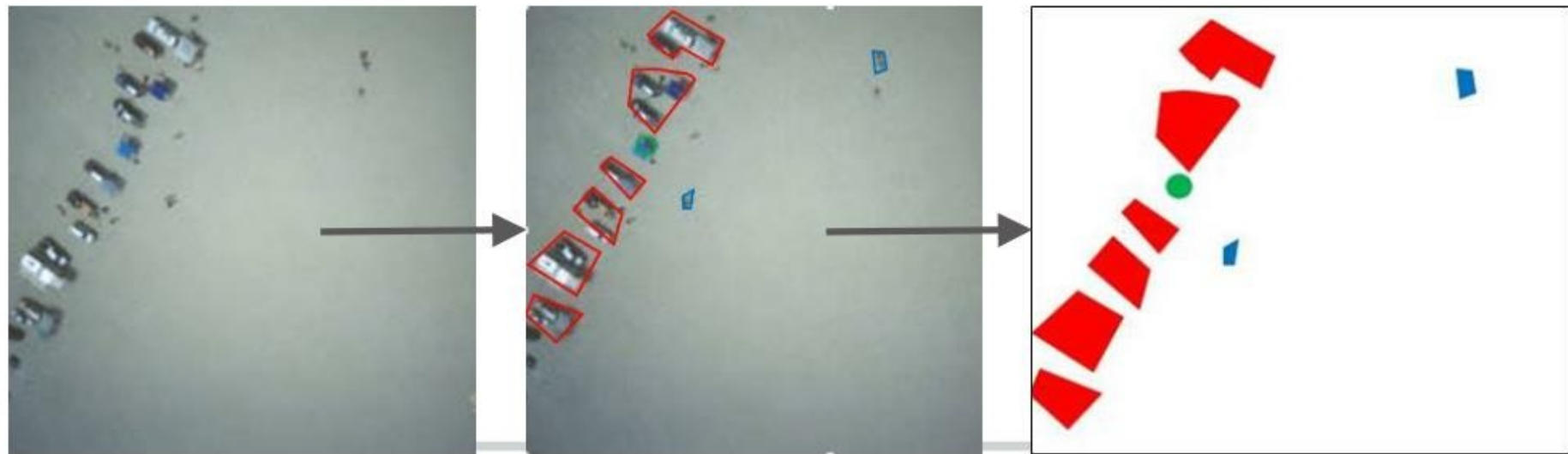
4.1 Hazard Detection Camera

- Will begin looking for hazards at 1600 ft
- Camera module mounted on payload ejection sled
- Will only turn on if nosecone separates from rocket
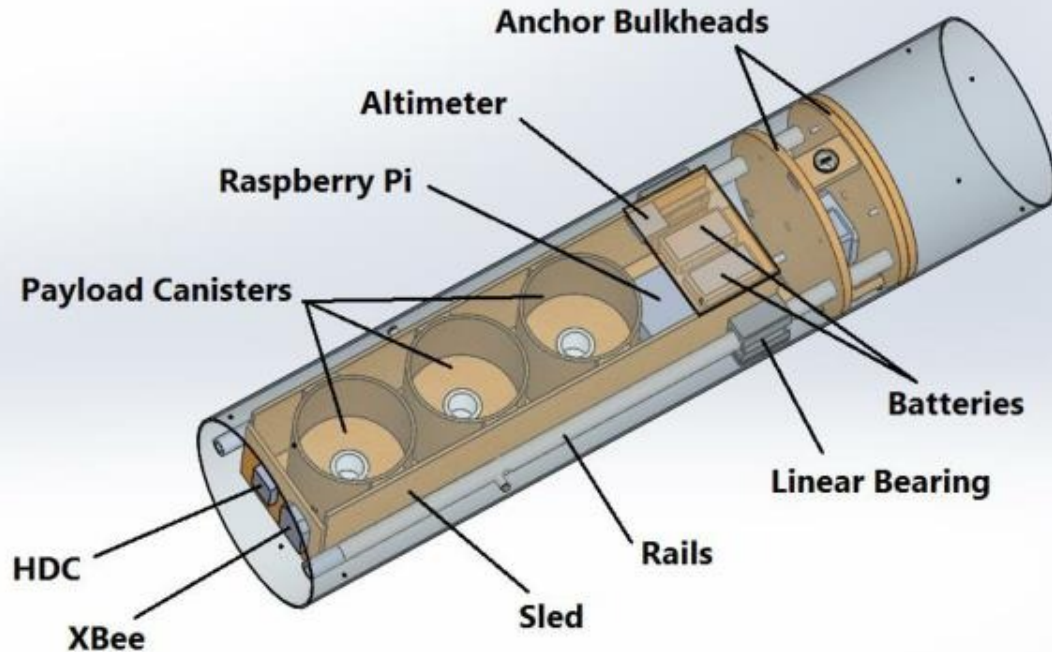- Will test full capabilities in half-scale test
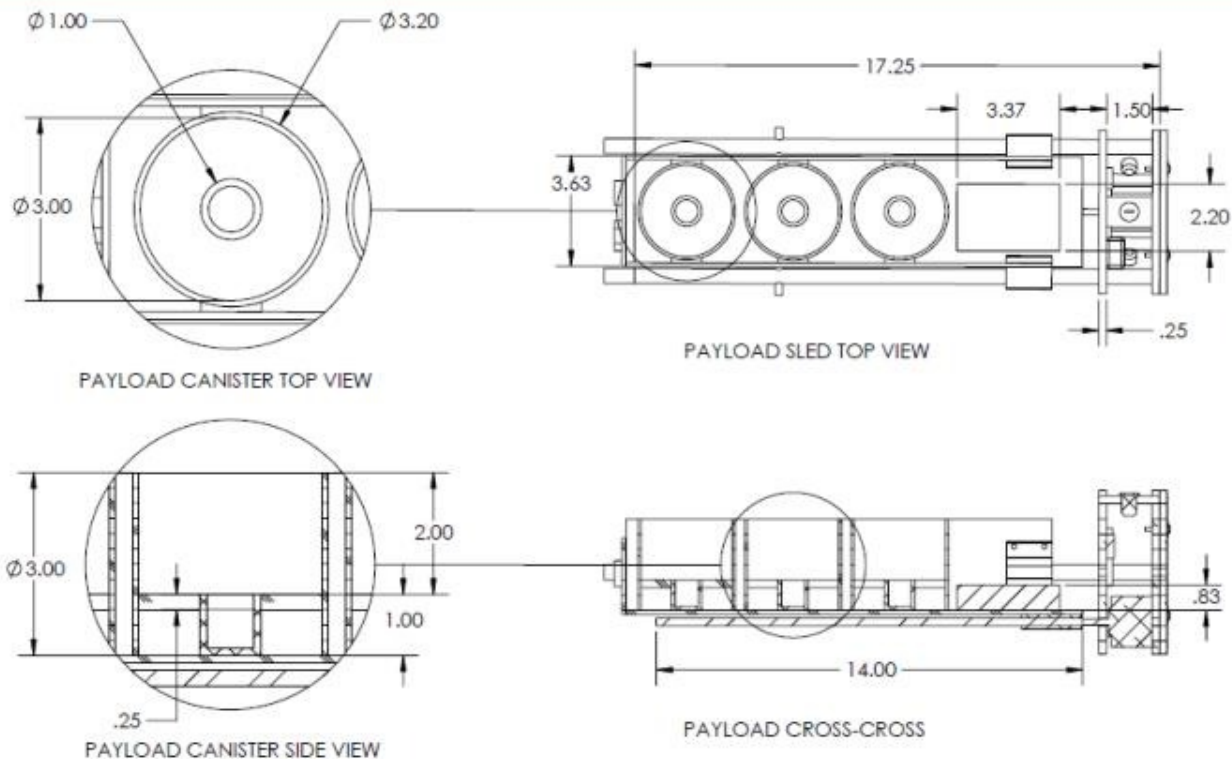
4.1 Hazard Detection Camera

- Raspberry pi processor used for edge detection
- OpenCV vision software will be used

4.2 Payload Ejection Mechanism

4.2 Payload Ejection Mechanism

PAYLOAD CANISTER TOP VIEW

PAYLOAD SLED TOP VIEW

PAYLOAD CANISTER SIDE VIEW

PAYLOAD CROSS-CROSS

4.2 Payload Ejection Mechanism

- Houses three Ejectable Methane sensing Units (EMUs) to be ejected at 1500 ft, 1000 ft and 500 ft

- Features sled on rails which will begin motorized extension at 6100 ft

- Will fully protrude full 12" from rocket prior to 1600 ft

- Will fully retract by 100 ft to avoid damage

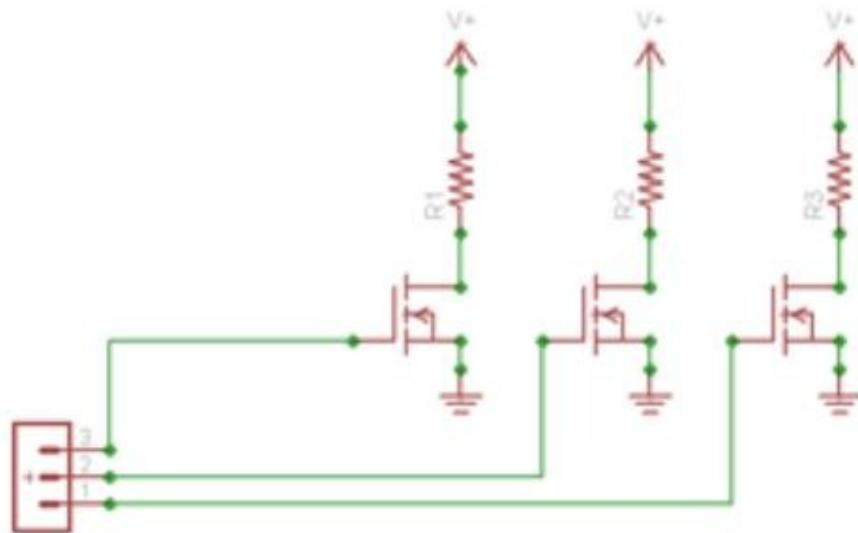# 4.3 Payload Ejection Mechanism
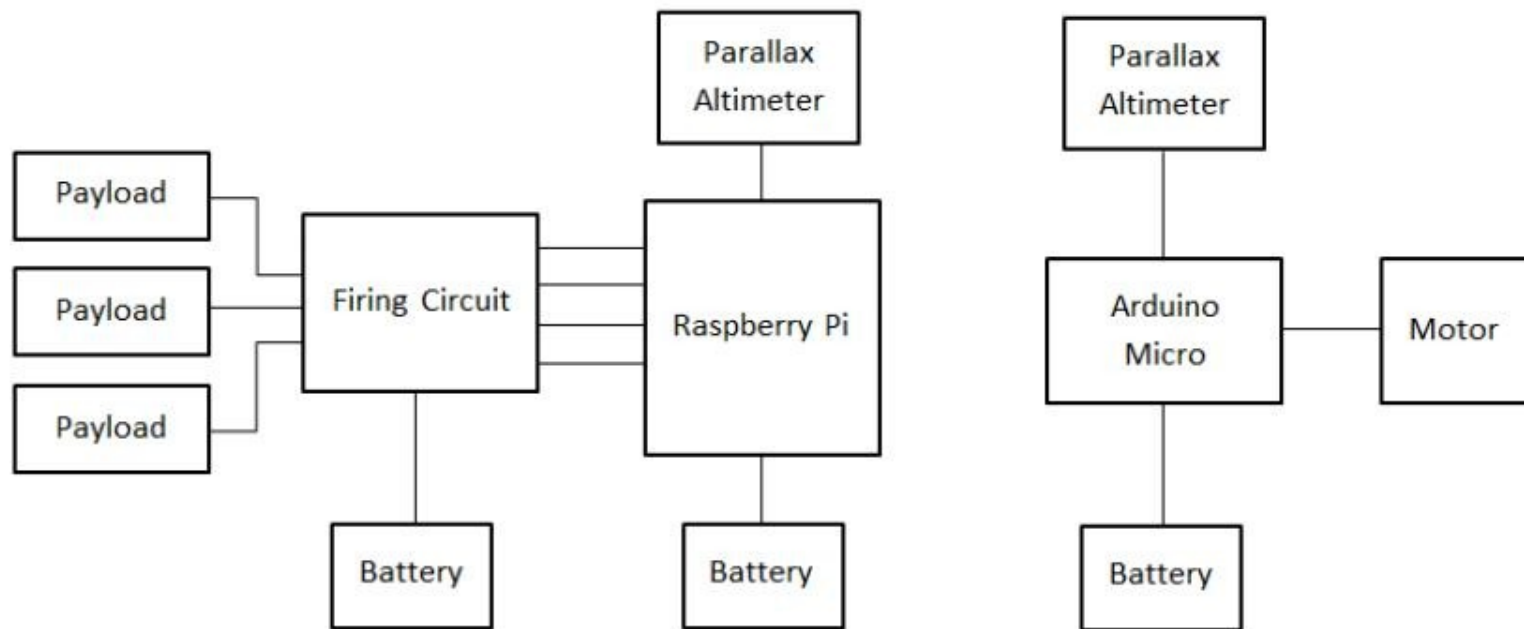
4.2 Payload Ejection Mechanism

- Parallax altimeter will determine when to eject EMUs
  - Will fire using pyrotechnic charge, threaded into phenolic canisters
  - Altimeter interfaces with Raspberry Pi to ignite E-match with transistor circuit.

4.3 Payload Ejection Mechanism

- Firing Circuit Schematic

4.3 Ejectable Methane Units

- Payload ejection mechanism will deploy the EMUs at three different heights
- The payloads' descent will be slowed with tri-wing configuration
- Wings made of nylon and spring wire
- Terminal velocity: 7 ft/s

4.3 Ejectable Methane Units

- Payload units 3D printed from ABS plastic
- Paired with offset stand to give wings clearance from base
- When leg and wings contracted, largest dimension: 2.8"

4.3 Ejectable Methane Units

- Will collect atmospheric methane concentrations on ground
- Will send methane concentrations and GPS coordinates to ground station with XBee
- Achieves actuation with the use of a double jointed arm and nitinol wire

4.4 Dual Inline Staging

- Two stage, inline motor design
  - Eliminates hazards involved with simultaneous ignition errors associated with parallel motors
  - Lower thrust to weight ratio
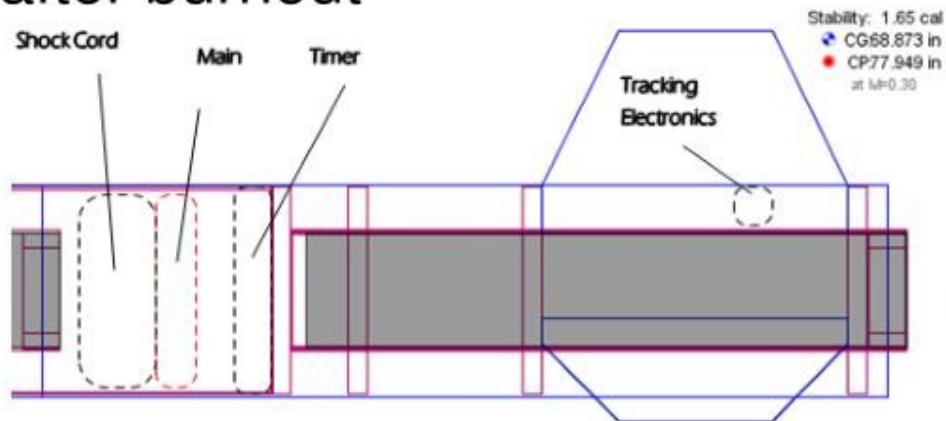 - Danger of misaligned rocket during ignition

4.4 Dual Inline Staging

- Ignition of second stage
  - Stager series to avoid premature ignition
  - PerfectFlite MiniTimer4 series staging device and
    - Arms only if 0.3 second upward acceleration prior to deceleration
  - RockeTiltometer for redundancy
    - Only fires within specified angle range

4.4 Dual Inline Staging

- 1st stage burns for 2.5 s
- Timer blows black powder charge, separating booster
- Main deploys
- Second stage ignites 3s after burnout
  - ~100ft between stages

Shock Cord

Main

Timer

Tracking Electronics

Stability: 1.65 cal
CG 68.873 in
CP 77.949 in
at M=0.30

Funding Plan

- Majority of funding from Cornell University
- Finishing a new sponsorship packet and plan to send it out in mid January
- Actively searching for more funds and ways to cut down on costs to save for travel for more teammates

Educational Engagement

- Previously taught concepts and physics behind rocketry with middle school students
- Team up with URRG to hold an event at the Science Center
- Create more connections with school and Boy Scouts in the area