The Zenith Program

Preliminary Design Review

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Zenith Program Leads

Jedreck Acquissa

- **Role:** Recovery Systems Lead
- **Engineering Interests:** Fluid design and food manufacturing

Peyton C. Breland

- **Role:** Propulsion System Lead
- **Engineering Interests:** Fluid Design, Vehicle Design and Manufacturing

Dylan A. Gardner

- **Role:** Airframe Design Lead
- **Engineering Interests:** Fluid Processes, Heat Transfer, and Manufacturing

Mark A. Ioffredo

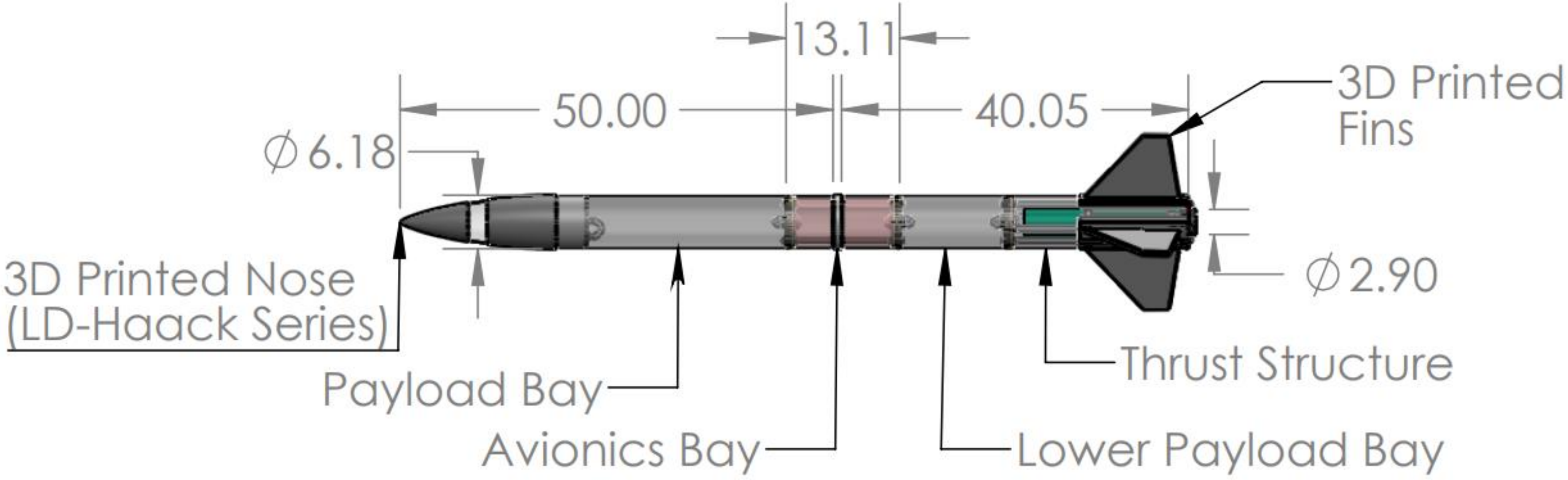
- **Role:** Avionics System Lead
- **Engineering Interests:** Fluid Design and Aerodynamics

Zachary L. Isriel

- **Role:** Program Director
- **Engineering Interests:** Human spaceflight, spacecraft R&D, commercial launch

Vehicle Design

Vehicle dimensions

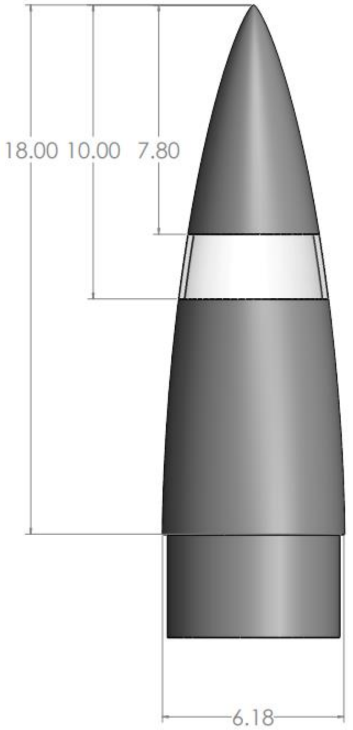


Total length- 91.05 inches

Mass – 34.3 lbs.

Nosecone and Camera Housing

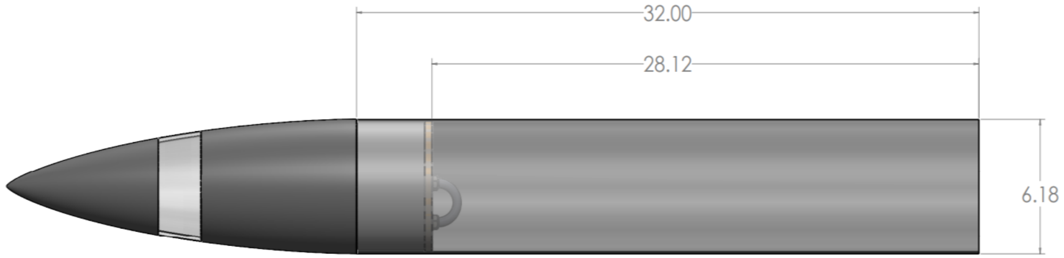
- Elliptical
  - Optimal for subsonic speed
  - Designed for low apogee flights
- Ogive
  - Sharp nose tip decreases drag
  - Tangency prevents wake separation
- LD – Haack Series
  - Mixture of Ogive and Elliptical
  - Slightly blunted nose tip
  - Higher volume nose tip while maintaining aerodynamic point



- Manufacturing method: 3D Printing
  - Optimal rebuild time
  - Custom geometry
- Nosecone Material: ABS Filament
  - Heat resistant
  - High strength
  - Light weight
- Camera Housing Material: Lexan
  - Heat resistant
  - Clear material desired for clear camera view

Upper Payload Bay

- Payload housing
  - Located in between the main parachute and nosecone shoulder
  - Payload rover exits the launch vehicle upon main parachute deployment



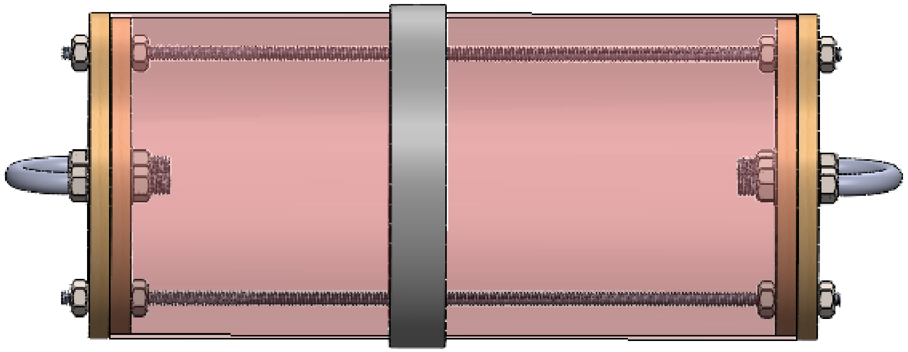
- Body tube material: Blue Tube 2.0
  - High strength
  - Abrasive resistant
  - Ease of custom manufacturing
    - Custom cut holes/sections for specific components

- Payload Housing Material:
  - ABS - 3D Printed
    - Ease of manufacturing specific geometry
    - High strength
    - Quick rebuild time
    - Cost efficient

Avionics Bay

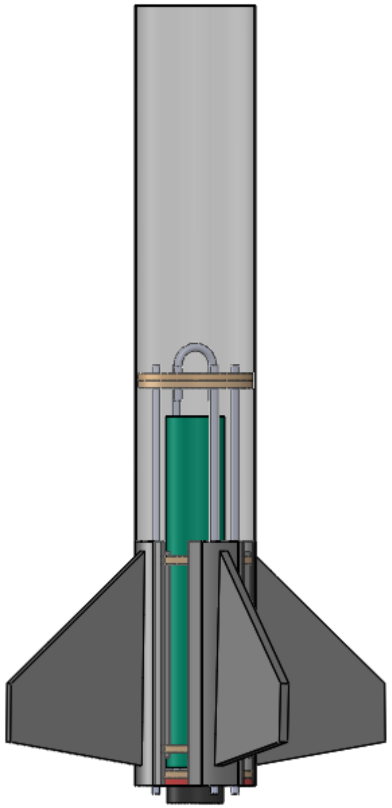
- Contains
  - Flight computer
  - Backup altimeter
  - Power System

- Avionics sled
  - Plywood bulkheads reinforced with threaded rods
  - ABS printed
    - High strength material
    - Ease of manufacturing to hold avionics components in a specific needed configurations



Lower Payload Bay

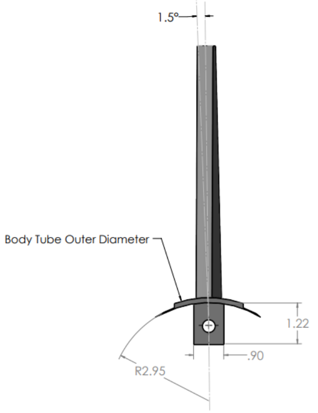
- Drogue recovery system
  - Located above U-Bolt/Bulkhead configuration
- Thrust Structure
  - Threaded rods
    - Motor stability
    - Holds fins into place
  - Plywood Centering Rings
    - Center the motor
    - Provide fin attachments

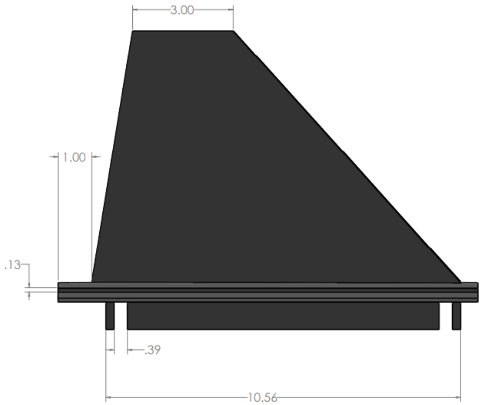


- Thrust distribution
  - Thrust Plate
    - Connected to aft centering ring
    - Distributes loads to the airframe
    - Motor retainer connection
      - Alternative: Tail cone

Fin Configuration

- Fin Type: Clipped Delta
  - Optimized using OpenRocket
  - Wider surface area to reduce wing loads
  - Canted 1.5 degrees
    - Spin stabilization





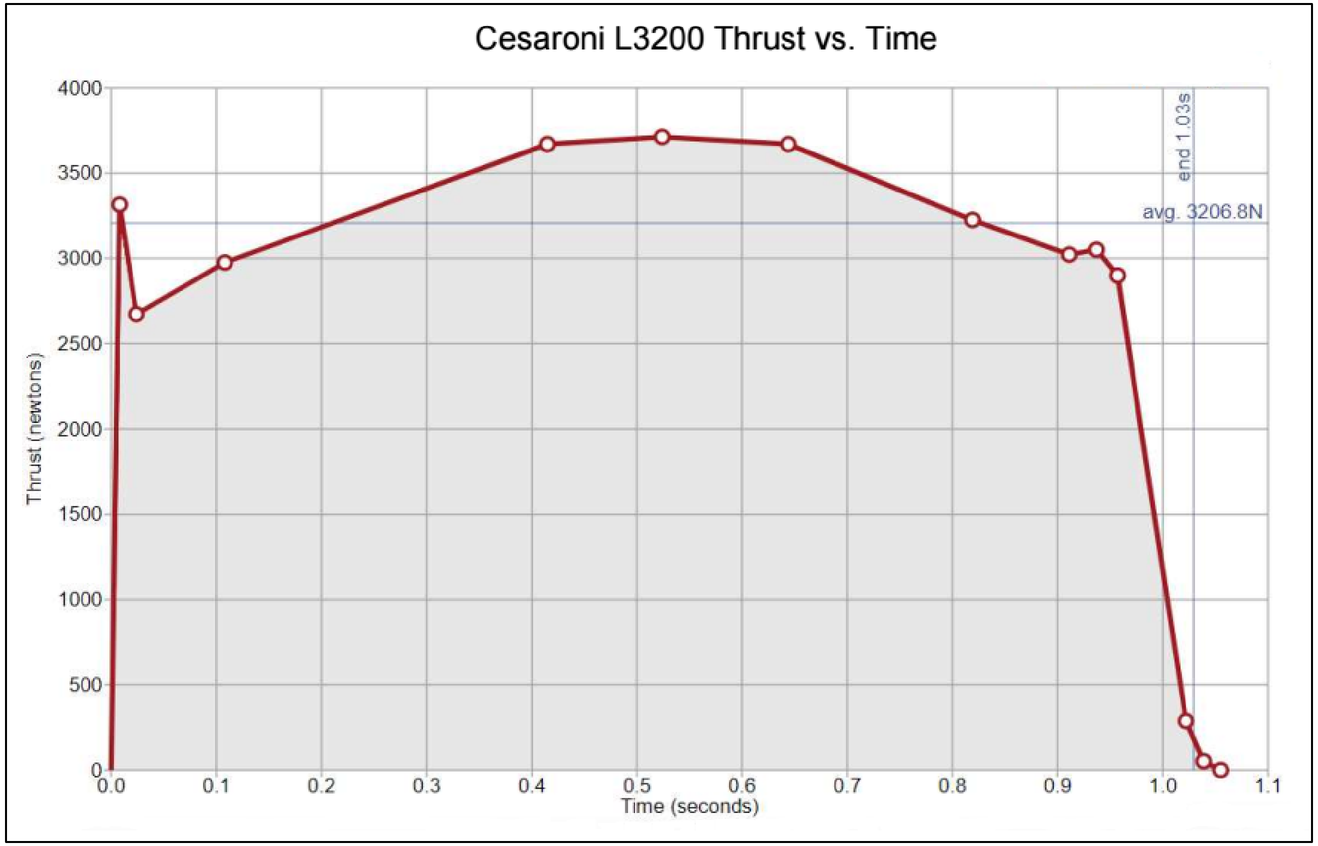
- Fin Material: ABS – 3D Printed
  - Ease of manufacturing specific geometry
  - High strength
  - Heat resistant
  - Quick rebuild time
  - Cost efficient

- Fin Flutter Speed

Max Vehicle Speed:	538 ft/s
Fin Flutter Speed:	1837 ft/s
Percent Flutter Speed Achieved:	29%
Factor of Safety:	**3.44**

Motor Selection – Cesaroni L3200

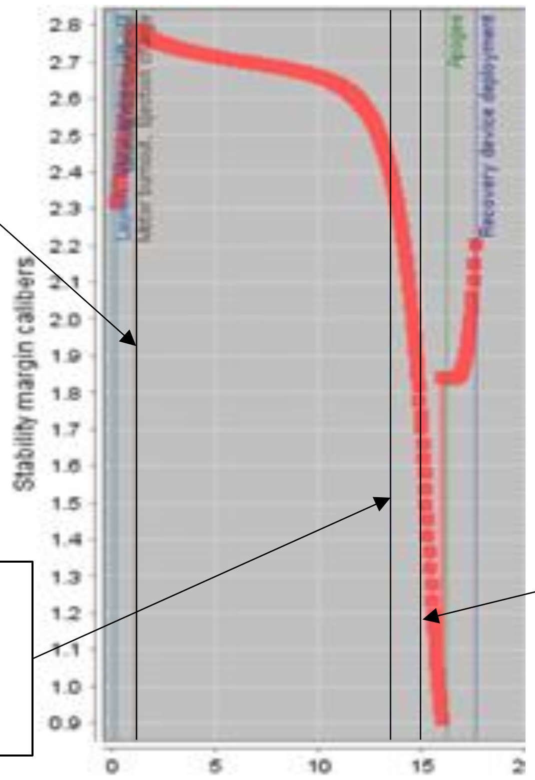
- Cesaroni Technology - L3200
  - Total Impulse: 3,300.3 Ns
  - Initial Thrust: 3,283.6 N
  - Max Thrust: 3,723.0 N
  - Burn Time: 1.0 s
  - Weight: 3,264 g



Stability Margin – Cesaroni L3200

- Off-pad numbers (OpenRocket):
  - **Stability:** 2.26 cal
  - **CG:** 59.232 inches from the nose tip
  - **CP:** 73.205 inches from the nose tip
  - Distance between CG and CP: 13.973 inches

Stability vs. flight time plot



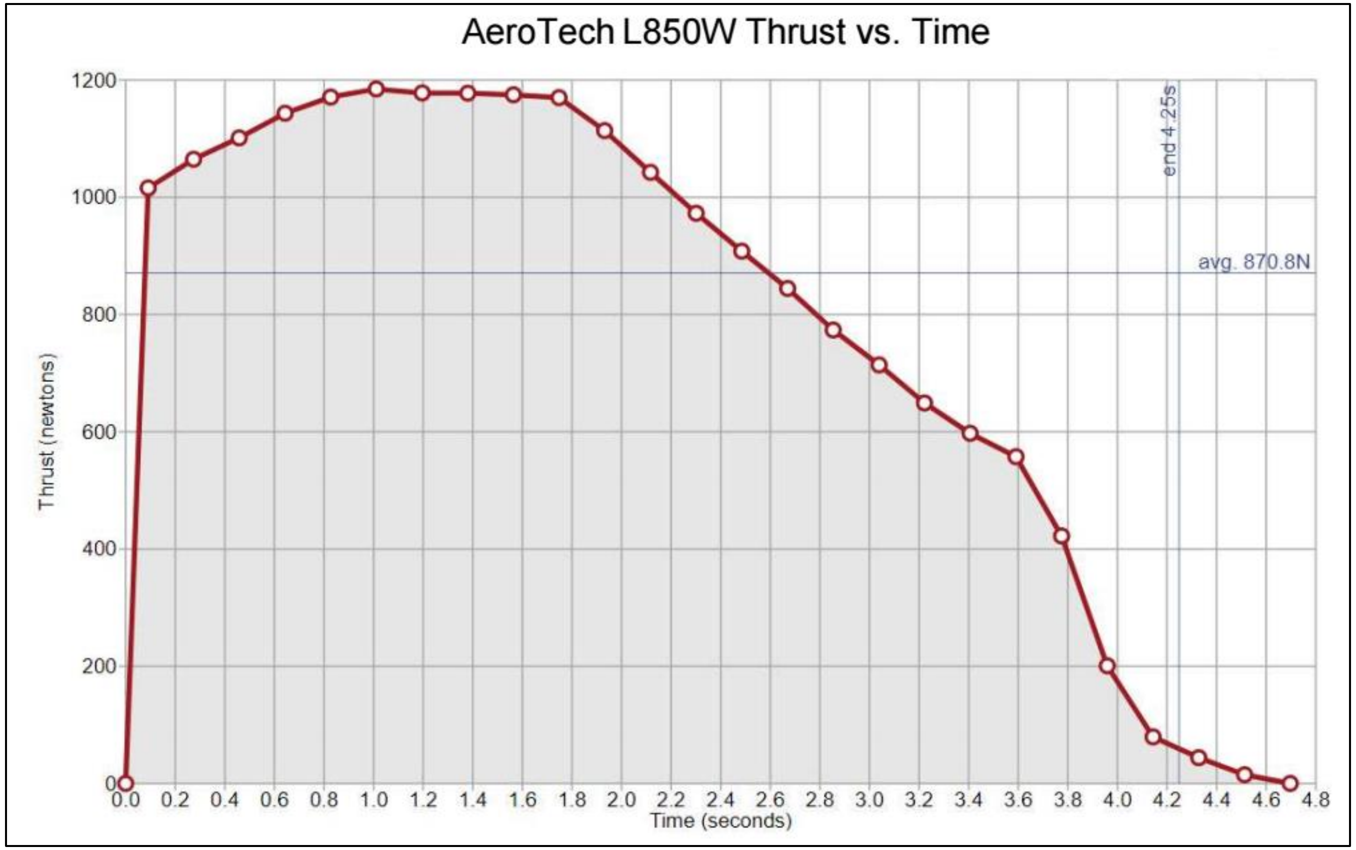
t = 1s
Motor burnout

t = 14s
Stability falls below 2 cal

t = 15s
Apogee

Leading Motor Selection – AeroTech L850W

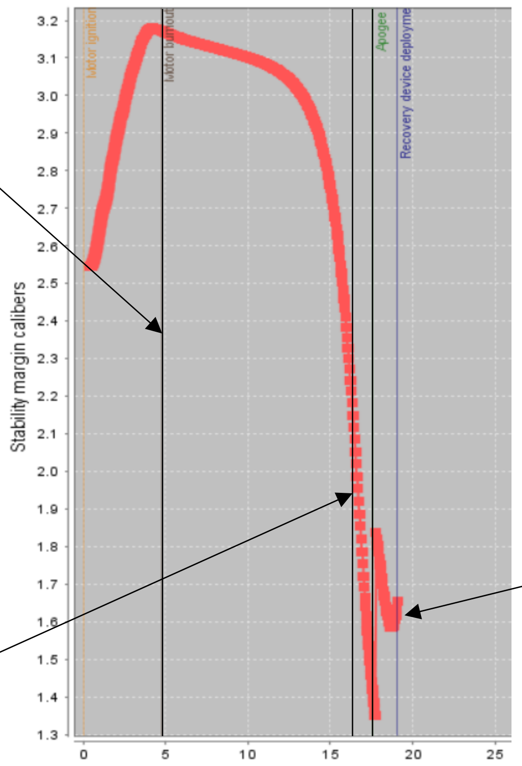
- AeroTech L850W
  - Total Impulse: 3,646.2 Ns
  - Initial Thrust: 1,000.9 N
  - Max Thrust: 1,866.2 N
  - Burn Time: 4.4 s
  - Weight: 3,742 g



Stability Margin – AeroTech L850W

- Off-pad numbers (OpenRocket):
  - **Stability:** 2.54 cal
  - **CG:** 62.705 inches from the nose tip
  - **CP:** 78.429 inches from the nose tip
  - Distance between CG and CP: 15.724 inches

Stability vs. flight time plot

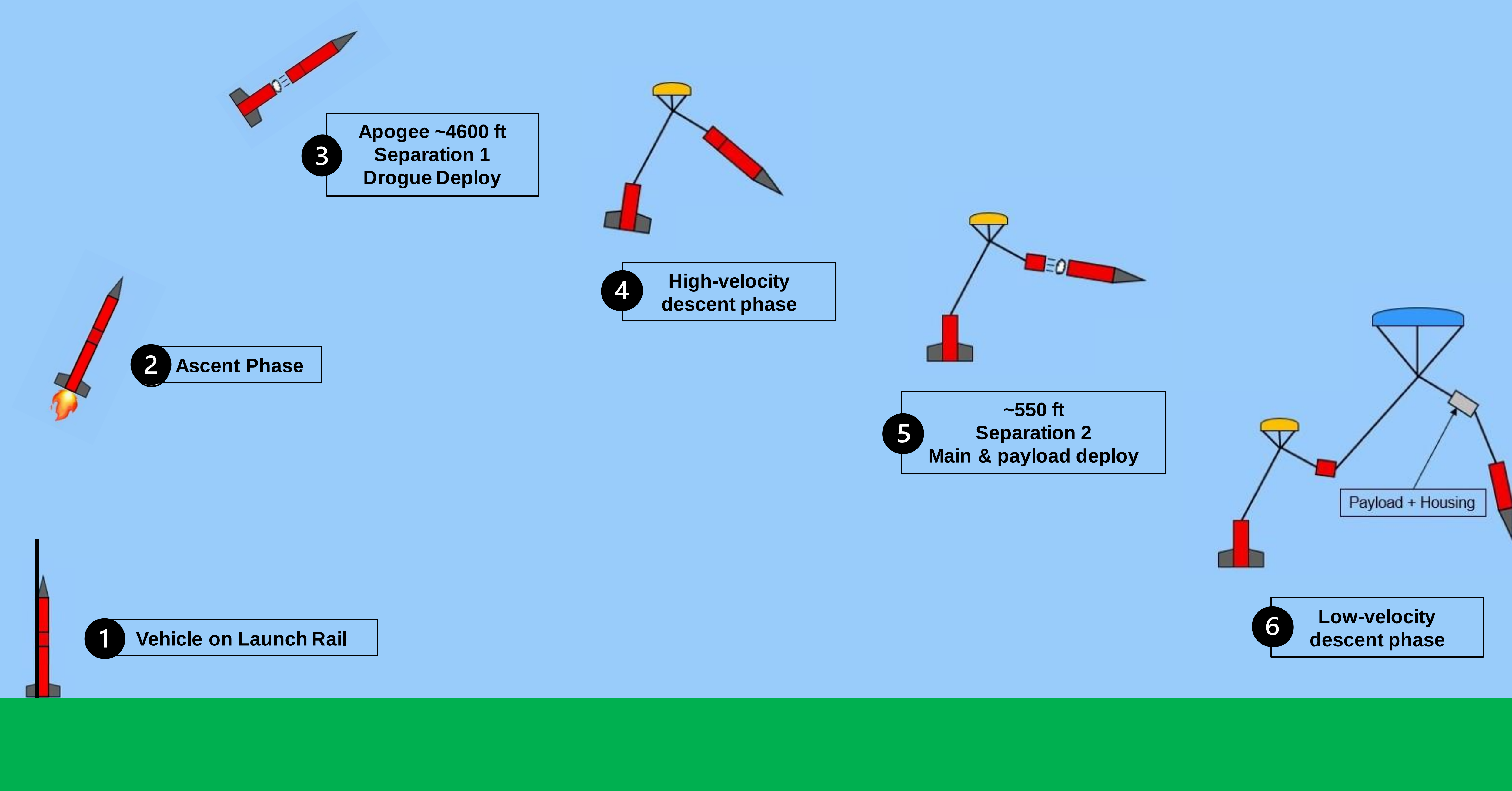


Motor Alternatives

Motor	Manufacturer	Total Impulse (Ns)	Initial Thrust (N)	Max Thrust (N)	Burn Time (s)	Weight (g)
L3200	Cesaroni Technology	3,300.3	3,283.6	3,723.0	1.0	3,264
L850W	AeroTech	3,646.2	1,000.9	1,866.2	4.4	3,742
L820	Cesaroni Technology	2945.6	690.6	984.8	3.59	3420.0

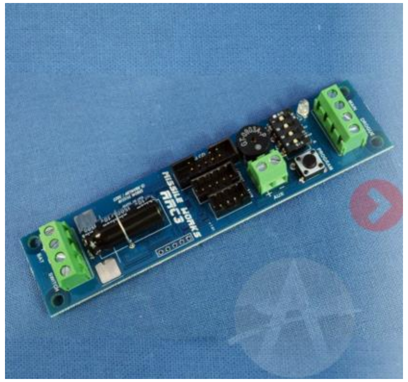
Recovery Subsystem

Flight Profile Overview



Altimeter Comparison

- Missile Works: RRC3



- Altus Metrum: EasyMini v2.0

- Entacore: AIM 3

- Altus Metrum: TeleMega v4.0

Altimeter Comparison (cont.)

	EasyMini v2.0	TeleMega v4.0	AIM 3	RRC3
Manufacturer	Altus Metrum	Altus Metrum	Entacore	Missile Works
Dimensions (weight)	1.5"L x 0.8"W x 0.6"H (6.52 g)	3.25"L x 1.25"W x 0.625"H (24.95 g)	2.56"L x 0.98"W x 0.59"H (12.81 g)	3.92"L x 0.925"W (17.01 g)
Logged Data	Altitude, Velocity, Total flight time, and Temperature	Altitude, Velocity, Accelereation, Time (total flight, burn, and ground to apogee), and Temperature	Altitude, Velocity	Altitude, Velocity, Time to Apogee
Measurement Units	Imperial / Metric	Imperial / Metric	Imperial / Metric	Imperial
Max Altitude (ft)	100,000	100,000	38,615	40,000
Sampling Rate (Hz)	100 (ascent), 10 (descent)	100 (ascent), 10 (descent)	10	20
Minimum Altitude for arming (ft)	N/A	N/A	N/A	300
# of Flights Stored	Varies (10 min)	Varies (40 min)	Varies (30 min)	15 (28 min each)
# of Pyro Channels	2	6	2	3
Battery (V)	3.7 - 12	3.7 - 12	3.7 - 14	3.7 - 10
Price ($ USD)	96.93	484.62	121.15	96.50
Additional Info	Consists of a barometric pressure sensor only	Built-in GPS/telemetry unit. Downloadable data via USB cable and AltOS software. Extra accessories required for ground station. Requires HAM license.	Consists of a barometric pressure sensor only	Consists of a barometric pressure sensor only. Telemetry and other advanced functions are optional add-ons.

Drogue Parachute Alternatives

Parachute	Drag Coefficient	Projected Area (ft^2)	Descent Speed (ft/s)	Descent Time from Apogee to Main Deployment (s)	Wind Drift from Apogee to Main Deployment at 20 MPH (ft)
Fruity Chute 15" Classic Elliptical	1.5	1.1781	121.3116	33.3851	979.297
Fruity Chute 18" Classic Elliptical	1.5	1.6965	101.0919	40.0626	1175.168
Fruity Chute 24" Classic Elliptical	1.5	3.0159	75.8202	53.4159	1566.865
Fruity Chute 30" Classic Elliptical	1.5	4.7124	60.6558	66.7702	1958.593

Main Parachute Alternatives

Parachute	Drag Coefficient	Projected Area (ft^2)	Descent Speed (ft/s)	Descent Time from Main Deployment to Ground (s)	Wind Drift from Main Deployment to Ground at 20 MPH (ft)	Kinetic Energy of Heaviest Recovered Section (ft-lb)
Fruity Chute 60" Iris Ultra Standard	2.2	19.0267	24.9256	22.0657	647.259	83.5662
Fruity Chute 72" Iris Ultra Standard	2.2	27.3985	20.7713	26.4788	776.712	58.0319
Fruity Chute 84" Iris Ultra Standard	2.2	37.2924	17.8040	30.8919	906.164	42.6357
Fruity Chute 96" Iris Ultra Standard	2.2	48.7084	15.5785	35.3051	1035.615	32.6430

Parachute Selection

Drogue:

Fruity Chute 24" Classic Elliptical

Main:

Fruity Chutes 72" Iris Ultra Standard

Wind Drift and Descent Time

- Maximum Wind Drift
  - 2343.733 ft
- Descent Time
  - 79.9 s
- Yearly Avg. wind speeds in Huntsville, AL: 5-12 mph

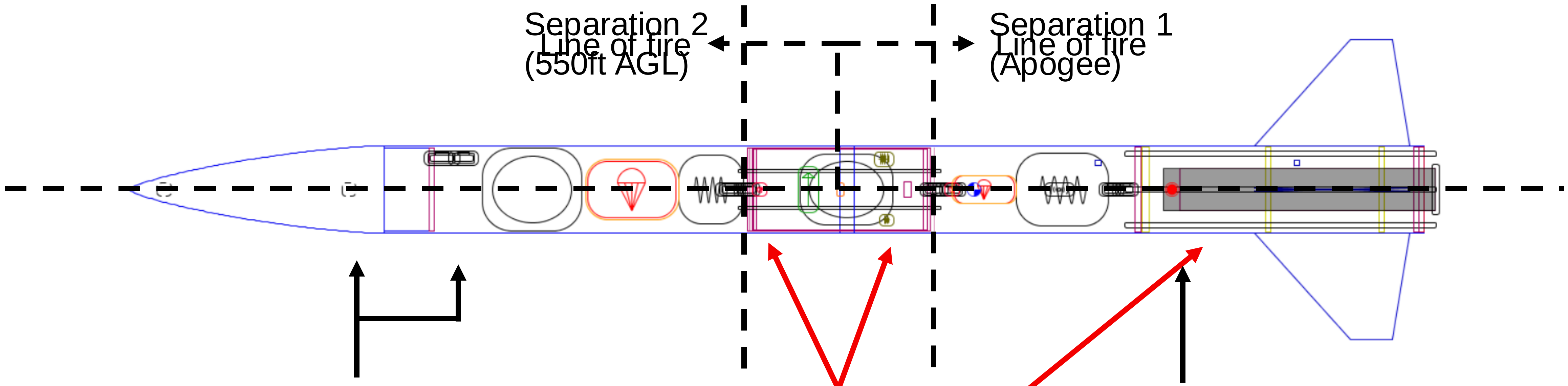
Wind Speed (mph)	Apogee (ft)	Descent Time (s)	Wind Drift (ft)
0	4600	79.9	0
5	4600	79.9	585.9333
10	4600	79.9	1171.867
15	4600	79.9	1757.8
20	4600	79.9	2343.733

Kinetic Energy

Section	mass (g)	mass (lbm)	mass (slug)	Descent Velocity (ft/s)	Kinetic Energy (ft-lb)
Nosecone + upper payload bay	3321.6	7.3229	0.2276	20.77	49.093
Nosecone + upper payload bay + payload	4910.6	10.8260	0.3365	20.77	72.578
Payload	1589	3.5031	0.1089	20.77	23.485
AV bay	1547	3.4106	0.1060	20.77	22.865
Fin can	3925.9	8.6551	0.2690	20.77	58.024

- Mass of largest section: 4910.6 g
- Maximum Kinetic energy: 72.58 ft-lb

Separation & Energetic Locations



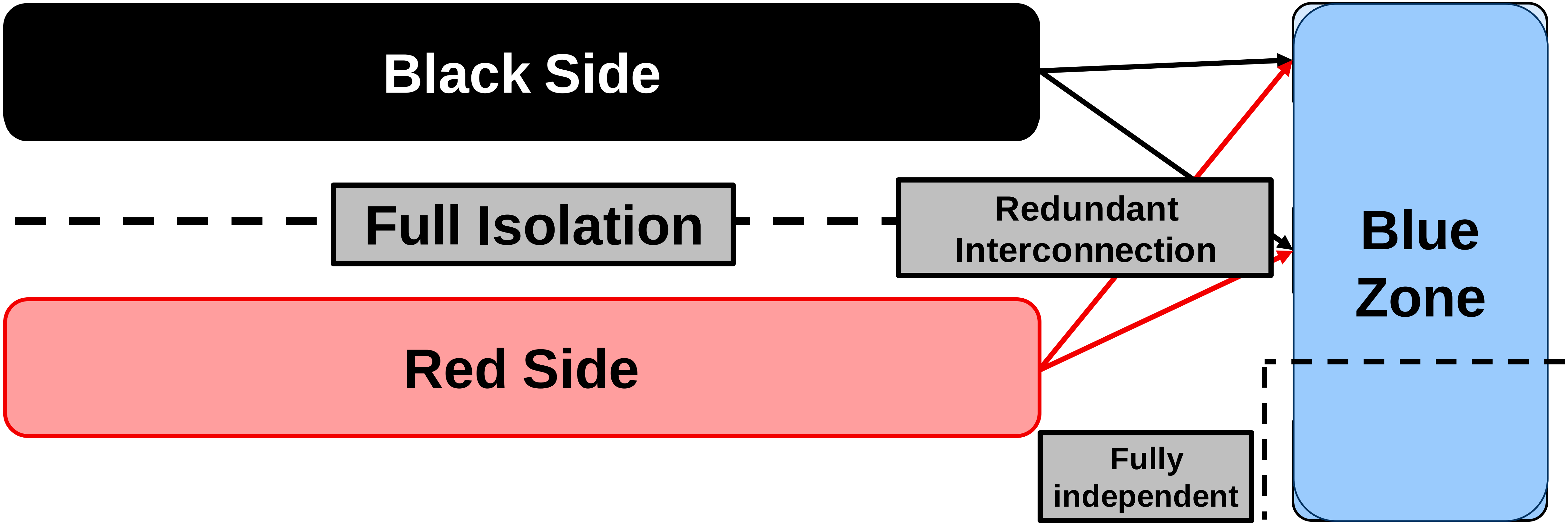
Event: Main Chute and Rover Deploy

Energetic: CO2 Ejection Charges #3,4

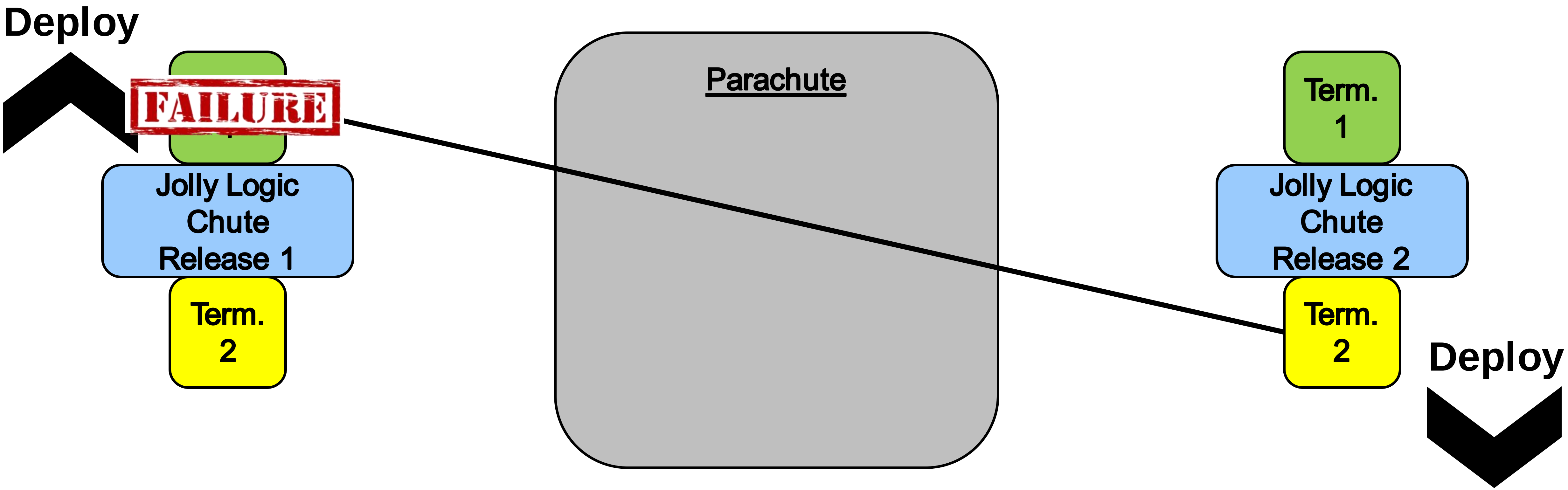
Energetic: AeroTech Motor

Event: Drogue Chute Deploy

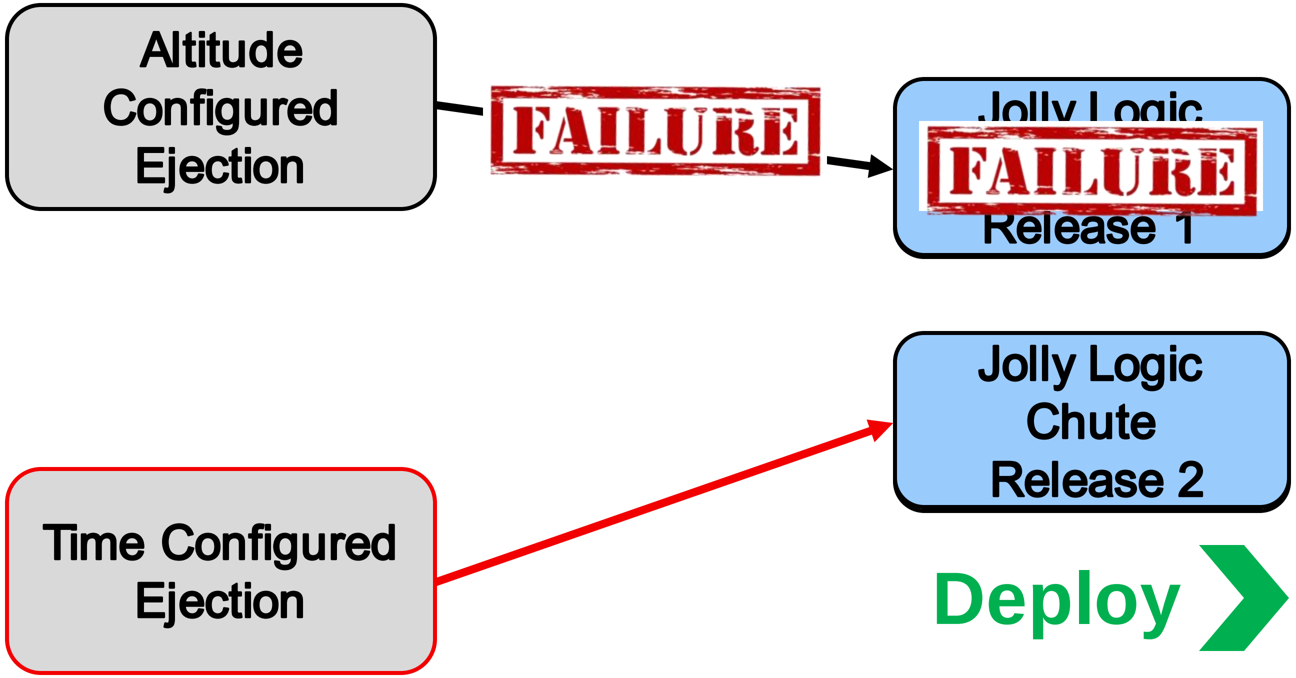
Avionics Redundancy



Deployment Redundancy - Hardware



Deployment Redundancy - Commands



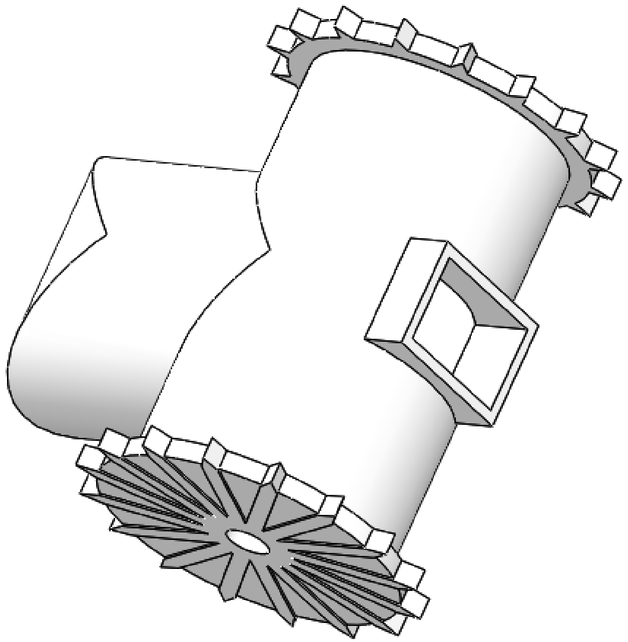
Jolly 2 triggers independent deploy of tether side 2

Red side triggers independent charge

Payload

Payload

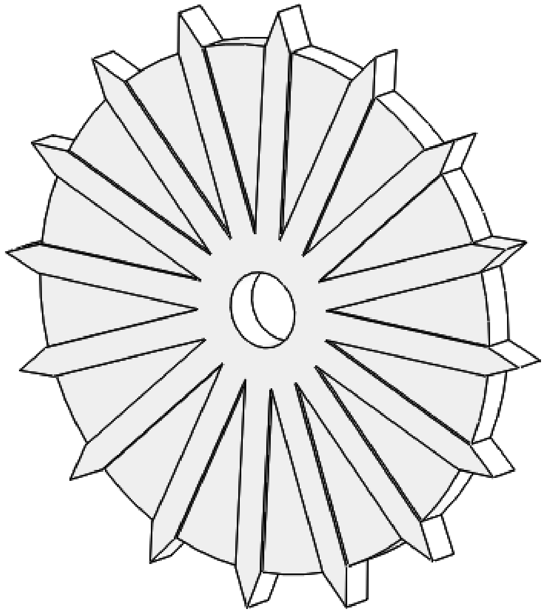
- Dual Wheeled Scout Rover
  - Coaxial wheel design
  - 3D printed
  - Front camera for data collection
- 4 main systems
  - Traction
  - Drivetrain
  - Stability
  - Hardware



Traction

- Spiked wheel
  - Prevents slip
  - 3d printed

- Round Wheel
  - Be purchased instead of 3D printed
  - Can slip



Drivetrain

- Two brushed DC motors
  - Independent wheel control
  - Allows for turning

- One Brushed DC motor
  - Contain a mechanical differential
  - Only powers the wheels in the same direction

Stability

- Tether
  - Attaches the rover to the launch vehicle
  - Can add in returning the rover to the vehicle

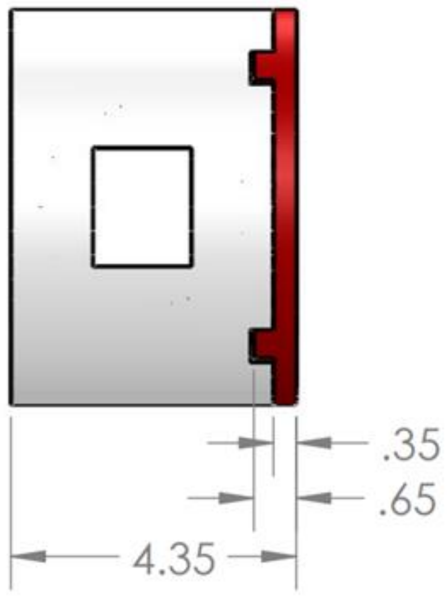
- Extendable outrigger
  - Springs out after deployment
  - Provides a skid to prevent rolling

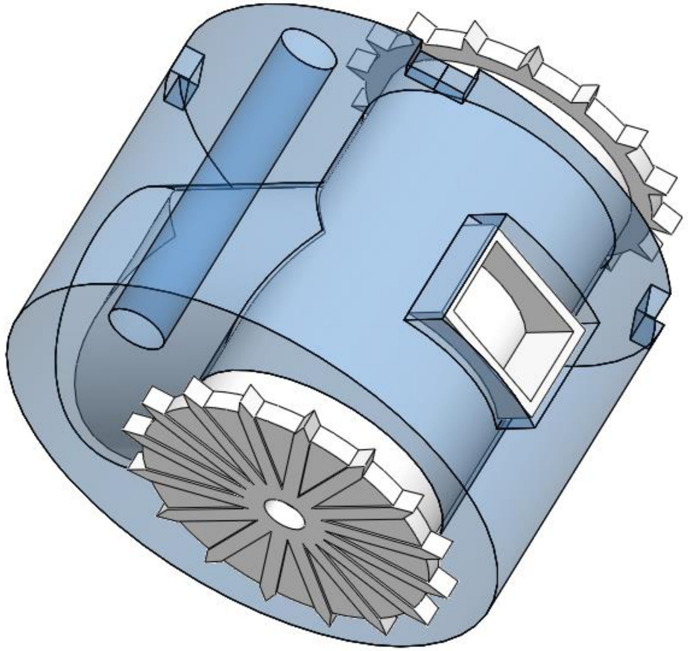
Hardware

- Raspberry Pi
    - Increased complexity
    - Can make its own decisions

- Arduino Mega
    - Team experience
    - Runs faster

Integration



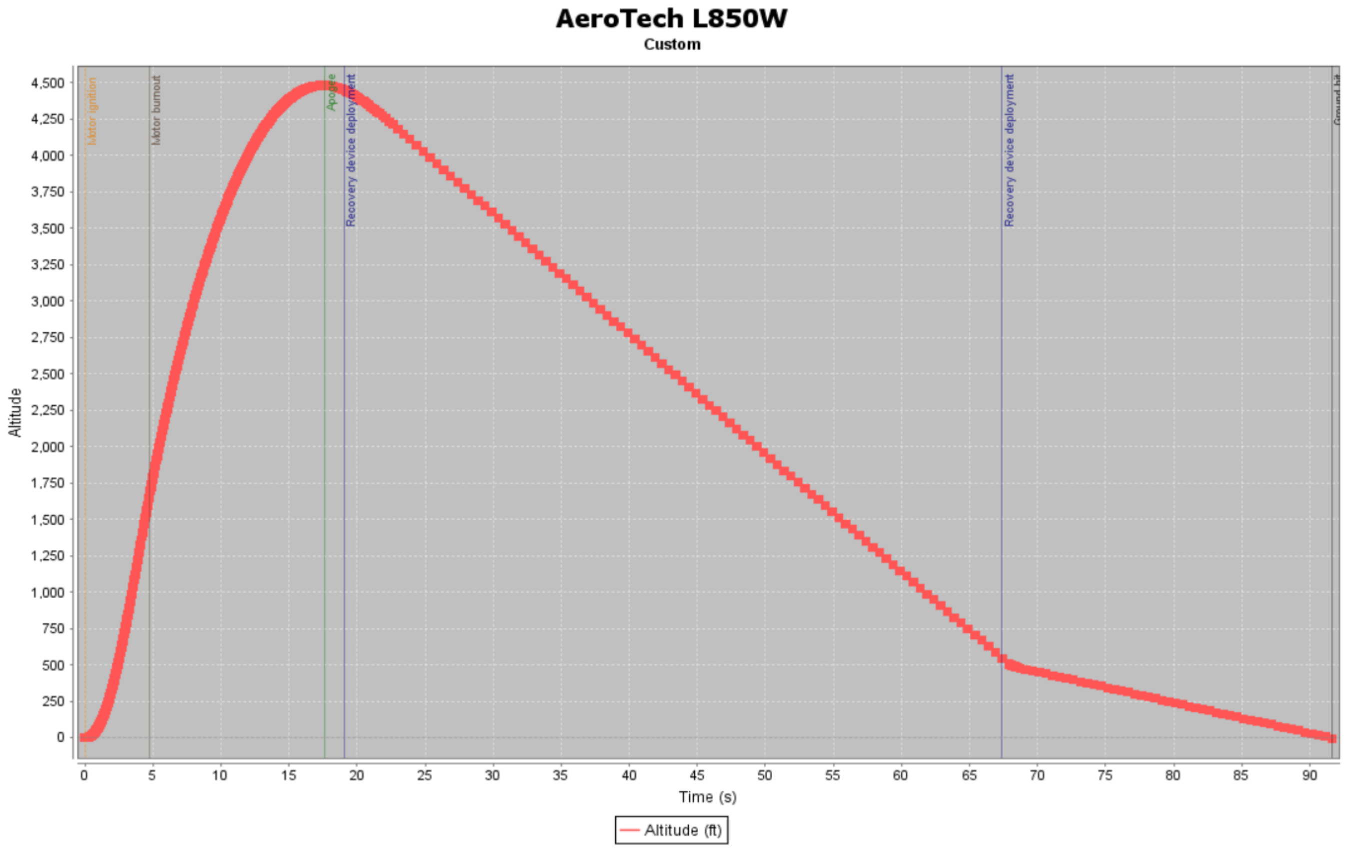


- Rover Deployment
  - Spring System
  - Extended Housing
  - Gear system

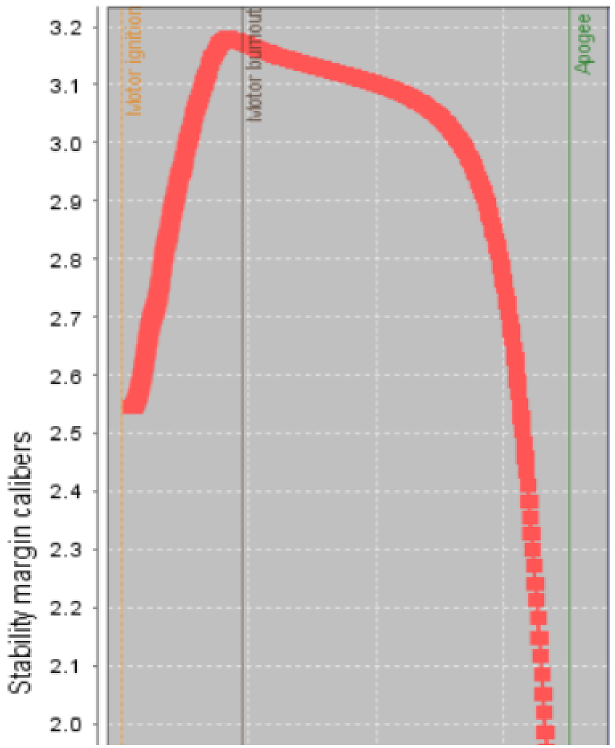
Mission Performance Predictions

Apogee

- **Target:** 4,600 feet
- Validation Methods
  - OpenRocket solver
  - MATLAB script
- Accuracy Check
  - Model sub-scale vehicle in OpenRocket
  - Compare actual flight data against OR data



Stability Margins



Vehicle	
Max Vehicle Stability	3.2 cal
Min Vehicle Stability	2.55 cal
Stability Decay (>2 cal) at	16 s
Apogee at	17.5 s

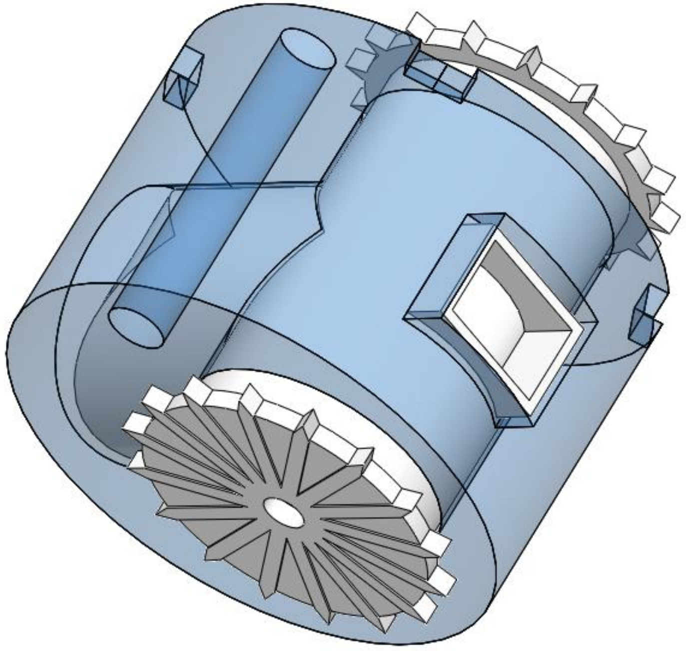
Fins	
Max Vehicle Speed	538 ft/s
Fin Flutter Speed	1837 ft/s
Percent Flutter Speed Achieved	29%
Factor of Safety	3.44

Flight Profile Velocities/Energies

Rail Exit Velocity	64 ft/s
Max Velocity	538 ft/s
Max Mach #	.478 ft/s
Ground Impact Velocity	20.77 ft/s
Max Kinetic Energy	72.58 ft-lb

Performance Unknowns

- Rover housing deployment from body tube
- Rover housing opening mechanism
- Rover traction and stability in rough terrain



Requirements Compliance

NASA requirements

- Vehicle simulations verify adherence to guidelines for:
    - Rail exit velocity greater than 52 ft/s
    - Thrust to weight above 25:1
    - Apogee > 4000 ft and < 6000ft
    - Max velocity < M1
- Avionics unit will use redundant altimeters
    - Primary: TeleMega v4 flight computer
    - Backup: Entacore AIM-3 Dual Deployment altimeter
    - Jolly logics: independent on-board altimeters for main chute deployment
- Avionics bay is the only coupler
    - Manufacturer ensures avionics bay is 2x vehicle diameter

NASA requirements

- Apogee event timeframe verification
  - Subscale test flight to ensure drogue deploy before Apo + 2s
  - Ground tests of ejection charges to ensure section separation
- Main chute deploy follows same verification
- Wind drift
  - Harder to judge based on small-scale flight
  - Predictions and calculations only so good
  - Preliminary investigation suggests worst case vehicle remains within recovery area

Requirement Verification Strategy

	Requirement	Verification
1	Vehicle/Payload Design Requirements	Validation of designs by technical leads and project director. Ensure purchased parts mirrors design exactly or as close as possible.
2	Vehicle/Payload Performance Requirements	Extensive pre-flight simulation. Ground test all sub-systems. Sub-scale technology demonstrator. Payload demonstration flight.
3	Team Requirements	Project director ensures STEM engagement goal met and that all team members comply with NASA requirements.

Q&A Session