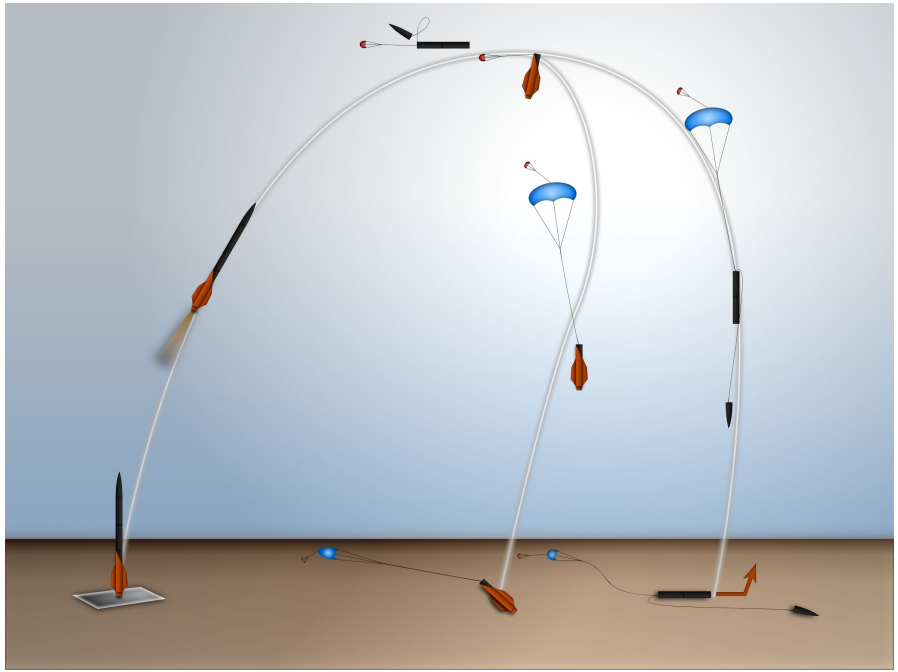
Oregon State University NASA USLI FRR

03/05/2018

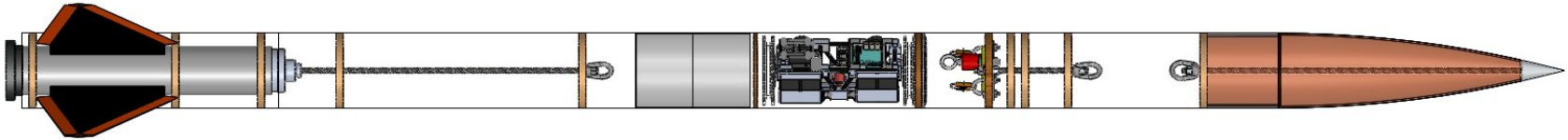
Mission Overview

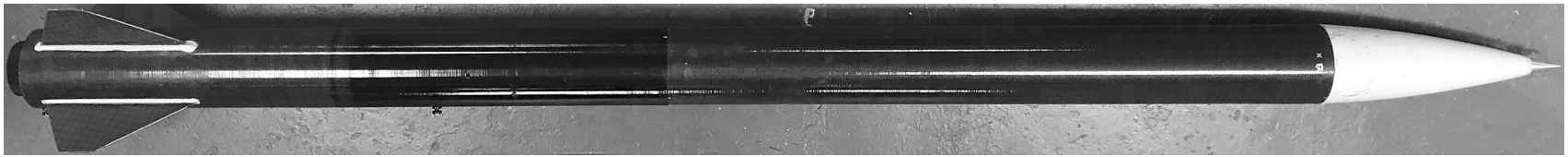


- Projected altitude of 4771 ft.
- 2 section separation at apogee
- Main deployment at 1000 ft.
- Autonomous rover ejection
- Solar panel deployment

Launch Vehicle Features

- Gross Weight: 39.425 lbs.
- Length: 104 in.
- Inner Diameter: 5.2 in.



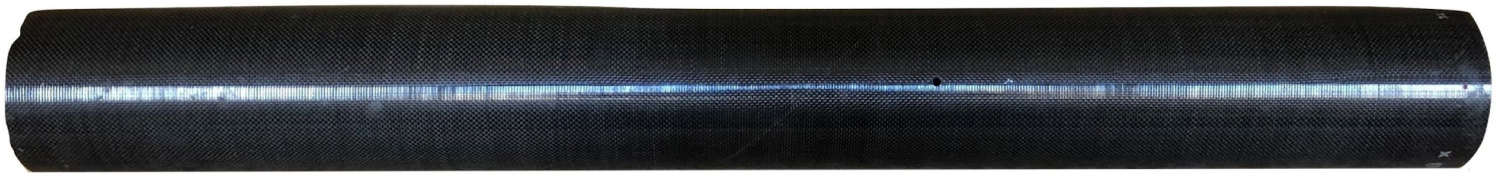


Airframe: Aft Section

- Material: Carbon fiber & fiberglass
- Length: 42.25 in.
- Inner Diameter: 5.2 in.
- Thickness: 0.0825 in.

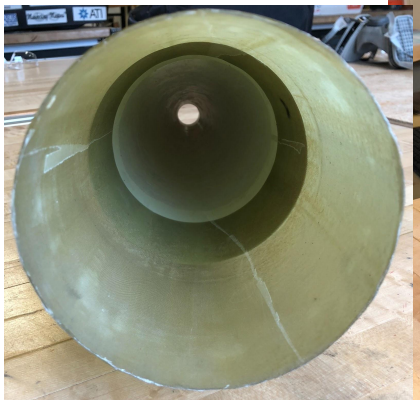
Airframe: Fore Section

- Material: Carbon fiber
- Length: 43.75 in.
- Inner Diameter: 5.2 in.
- Thickness: 0.0825 in.



Nose Cone

- Shape: 4:1 Ogive
- Overall Material: Fiberglass
- Tip Material: Aluminum
- Length: 16.5 in.
- Meshed nose cone and upper coupler
  - 5.5 in. coupler



Coupler

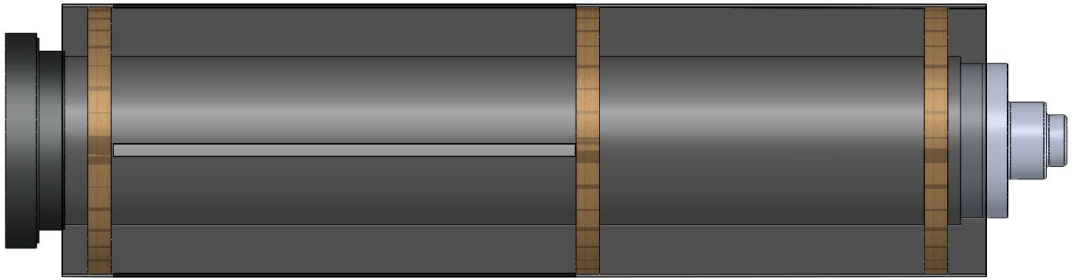
- Material: Carbon fiber
- Length: 8.875 in.
- Inner Diameter: 5.075 in.
- Thickness: 0.0715 in.
- Markings to line up coupler and tube

Fins

- Shape: Clipped Delta
- Material: Carbon fiber & Fiberglass

Motor Mounting

- 3 Centering Rings
- Motor Mount Tube
- Aft Retainer
- 4 Fins



Bulkheads

- Material: Plywood
- Outer Diameter: 5.2 in.
- Inner Diameter: 0.5 in.
- Thickness: 0.4605 in.

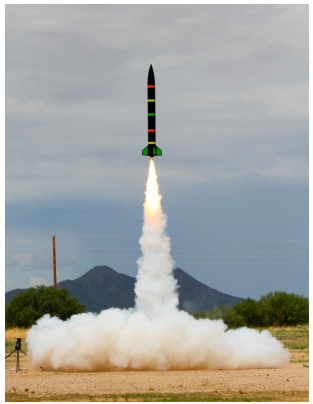
Attachment Hardware

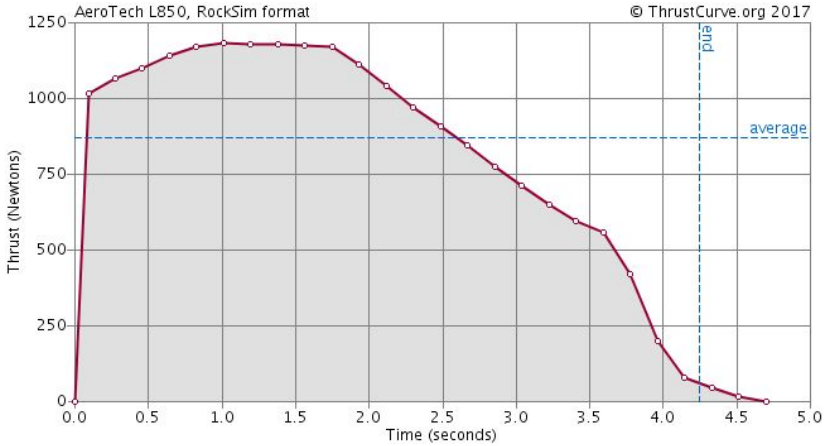
- Lock nut
- Eye nut
- Washer

- Standard System
- Ends of threaded rods
- Parachute quick links attach to eye

Motor Selection

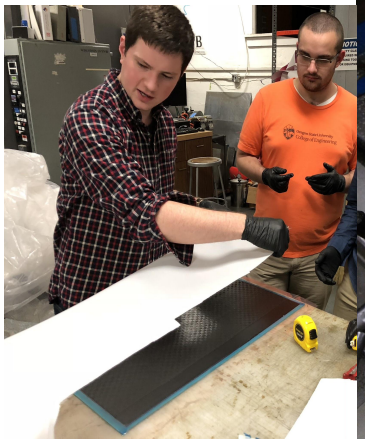
- Aerotech L850W Motor
- 75 mm Motor
- Total Impulse: 830.7 lb.-s
- Liftoff Thrust: 227.0 lb.



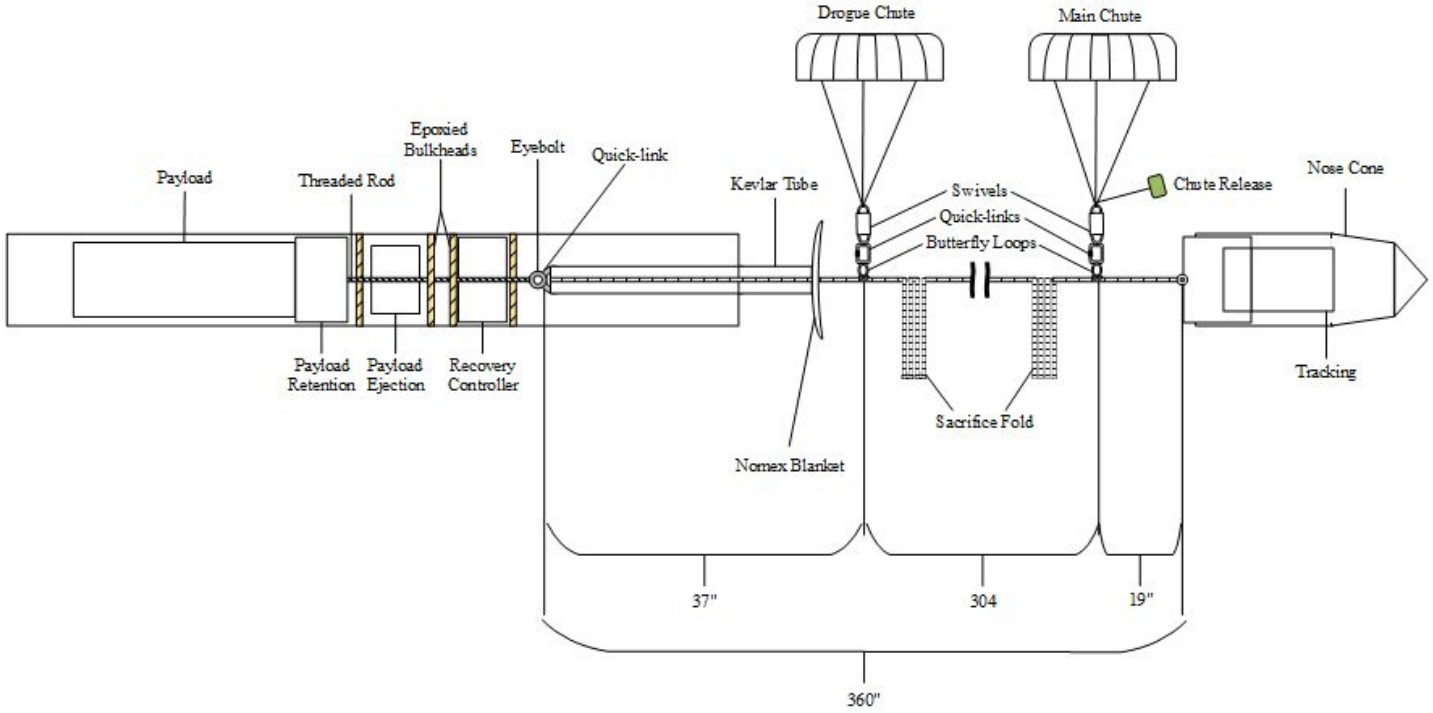


Manufacturing

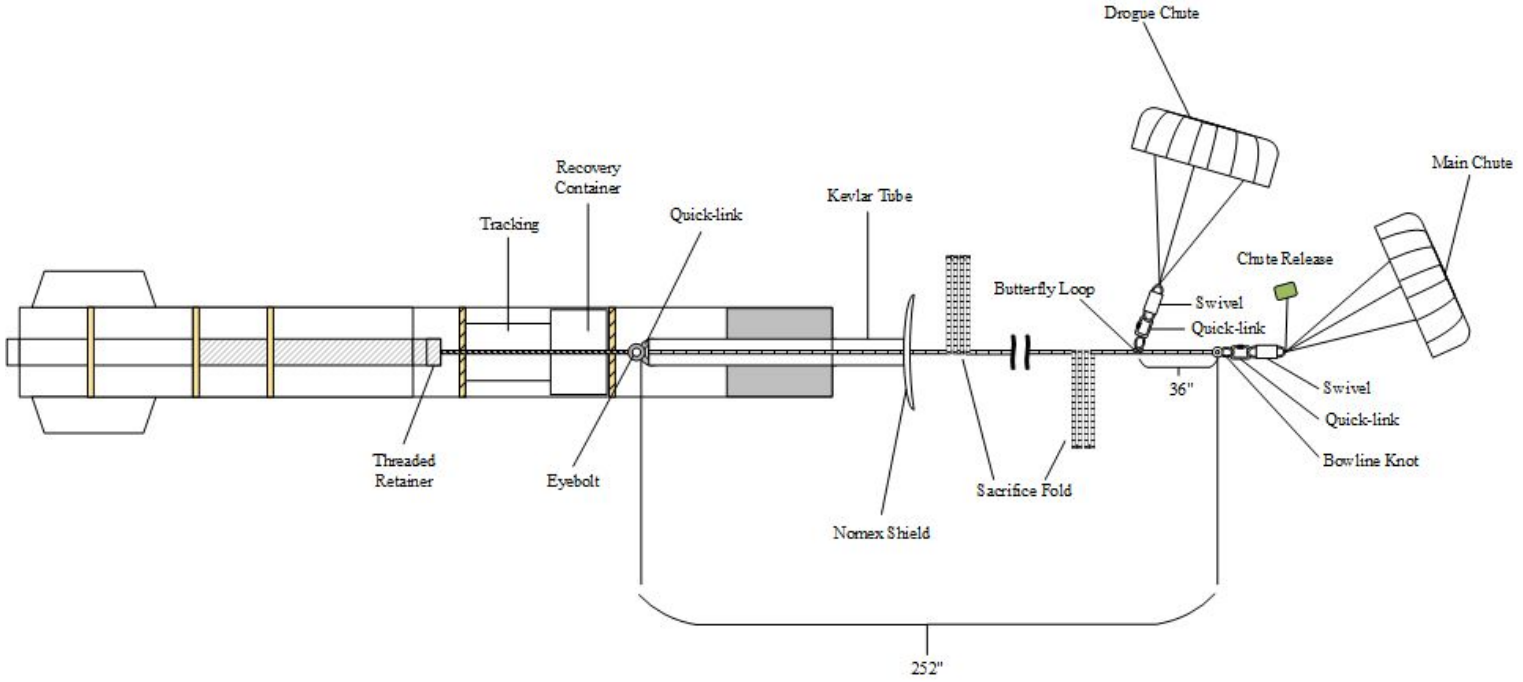
- Bulkheads
- Couplers
- Nose cone
- Fins



Fore Recovery System

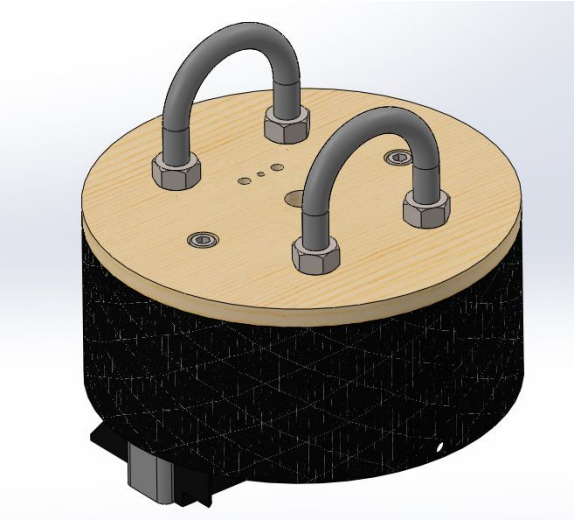


Aft Recovery System



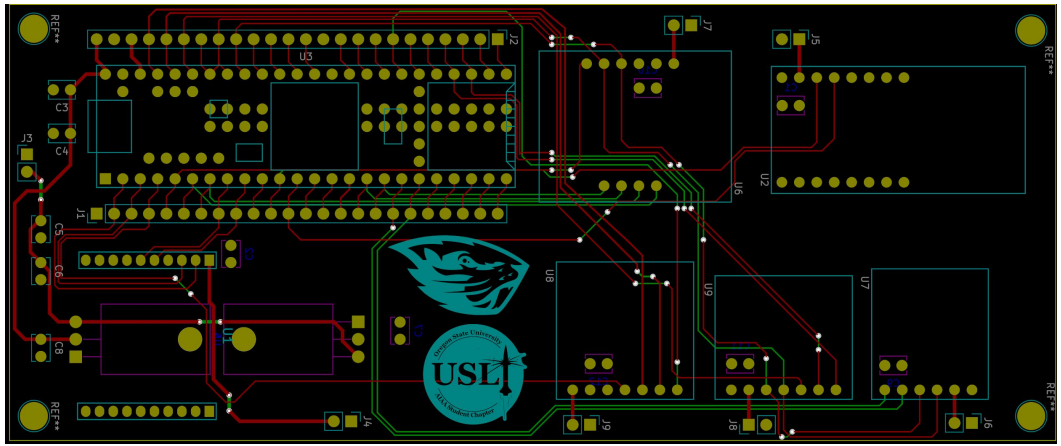
Electrical Isolation

- Copper tape applied to carbon fiber coupler housing
- 3-D printed backplate seals faraday cage



Avionics Boards

- Tracking unit and data logging combined into one system
- Includes GPS, IMU, and Barometer

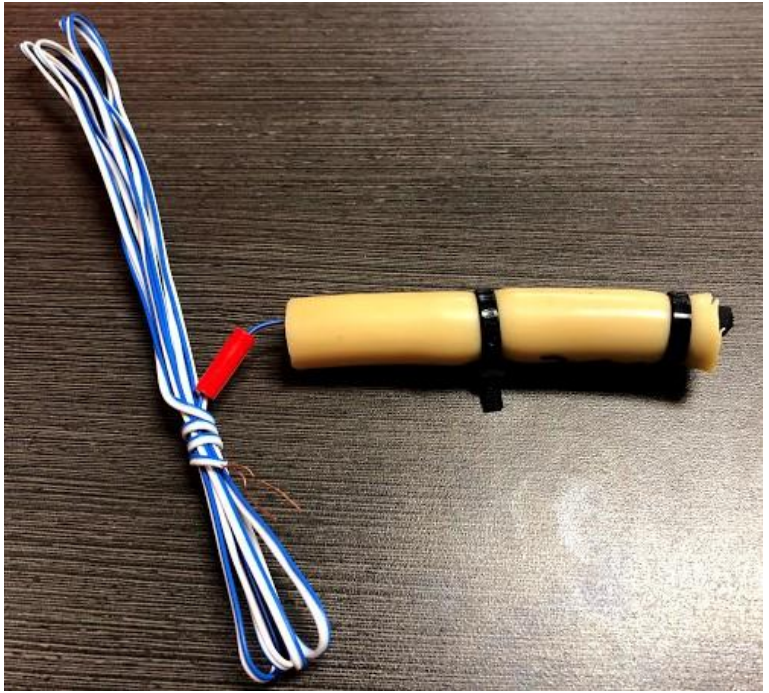


Altimeters and Controllers

- **Primary Altimeters:** MissileWorks RRC3
- **Secondary Altimeters:** PerfectFlite StratoLogger CF
- **Main Deployment:** Jolly Logic Chute Release

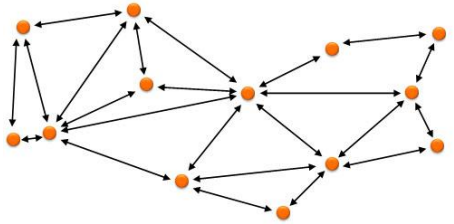
Ejection Charges

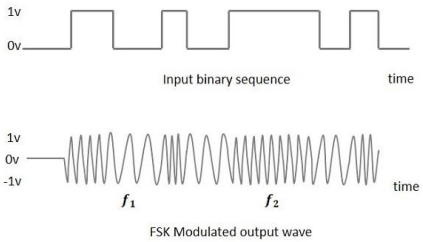
- Black powder ejection testing results:
  - Aft: 5.5 g
  - Fore: 4.5 g



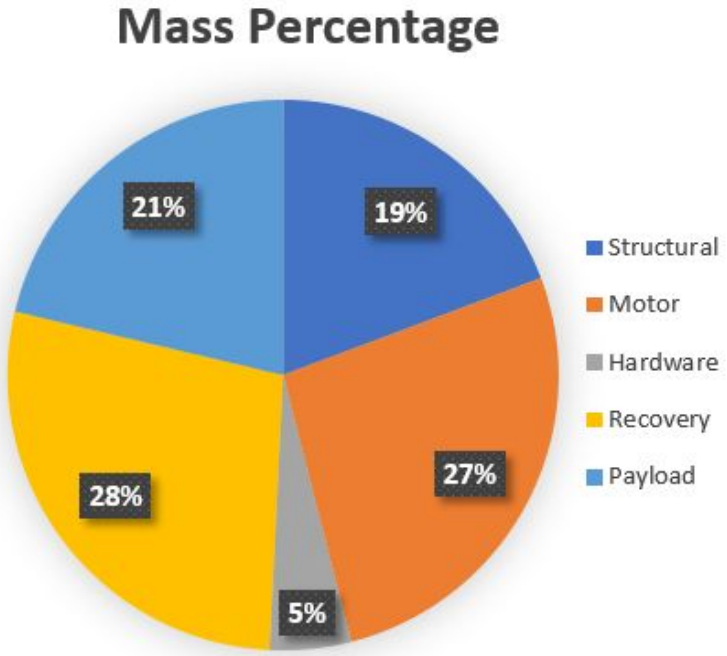
Rocket-Locating Transmitters

- Frequency: 902 - 928 MHz
- Power: 250 mW (software selectable)
- Range: Tested at 1.5 miles line of sight
- Transmission Protocols/Specifications
  - FHSS used across all 64 channels in band
  - GFSK digital modulation scheme
  - Digimesh reliable data transfer protocol





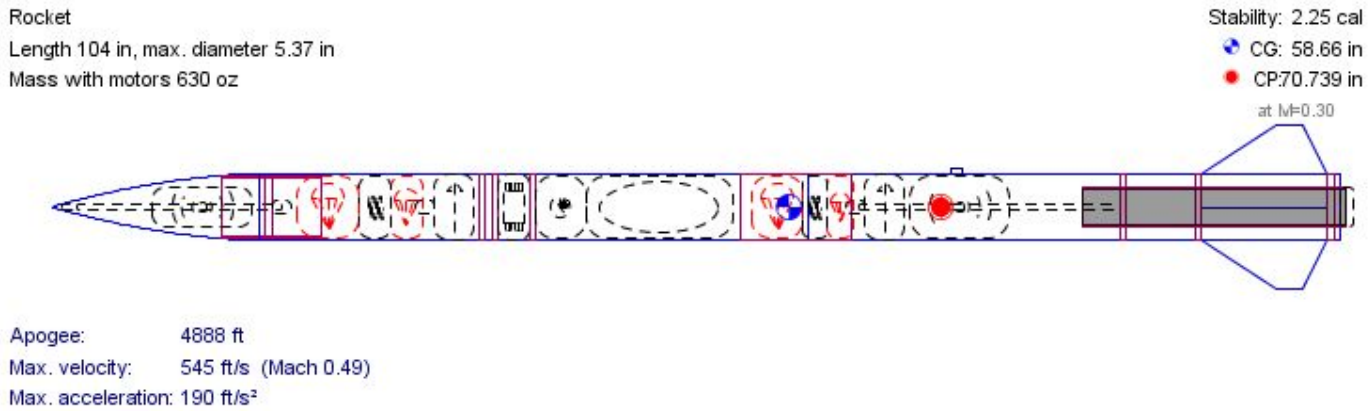
Component Weights



Section	Mass (lbf.)
Structural	7.60
Motor	10.54
Hardware	1.88
Recovery	11.00
Payload	8.39
Total	39.43

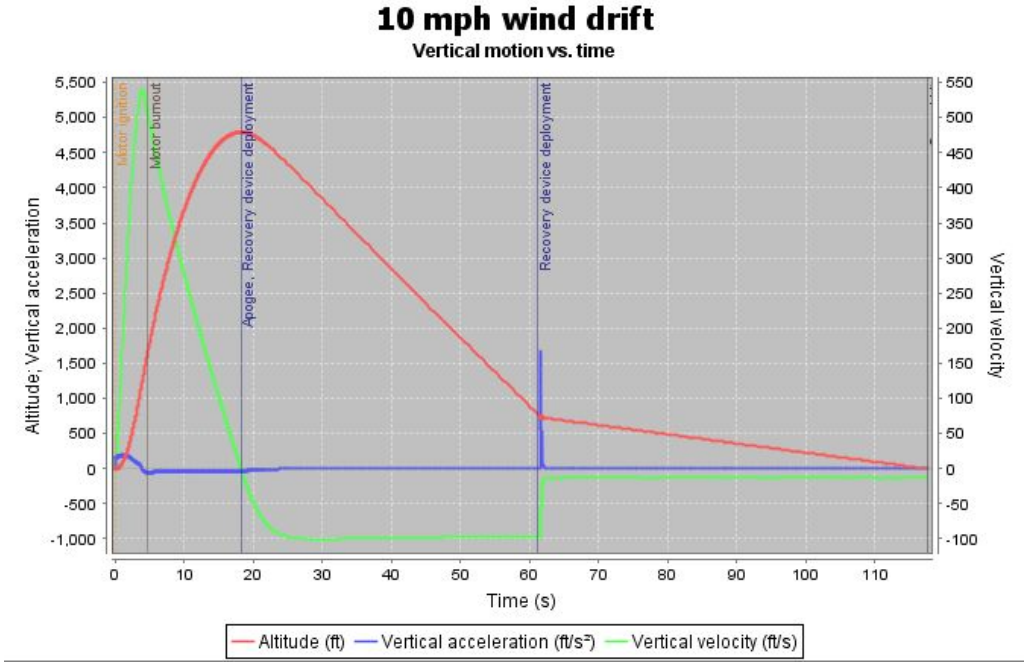
Launch Vehicle Stability

- Stability: 2.25 calibers
- CG: 58.66 in. aft of the tip
- CP: 70.74 in. aft of the tip



Flight Profile

- Velocity off the rod: 62.5 ft./s
- Thrust to weight ratio: 5.638
- Maximum velocity: 545 ft./s



Projected Altitude

- The projected altitude is below 5280 ft.

Wind Velocity	OpenRocket
0 mph	4875 ft.
5 mph	4838 ft.
10 mph	4771 ft.
15 mph	4708 ft.
20 mph	4649 ft.

Parachute Sizes and Decent Rates

- Simulations include tumbling
- Actual descent velocities are slower than predicted

Velocity (ft./s)						
Section	Main (ft.)	Drouge (ft.)	Tumbling	Drogue	Main	Landing
Fore	8	2	122.95	77.00	14.43	14.07
Aft	7	1.5	113.43	86.36	15.50	15.16

Drift Calculations

- Calculated using descent time and assuming constant wind velocity

Simulation	Cross Wind Velocity (ft./s)						
Section	Program	Decent Time (s)	0	5	10	15	20
Fore	MATLAB	116.30	0	581	1,163	1,744	2,326
	OpenRocket	100.5	0	503	1,005	1,508	2,010
Aft	MATLAB	107.59	0	538	1,076	1,614	2,152
	OpenRocket	100.5	0	503	1,005	1,508	2,010

Kinetic Energy

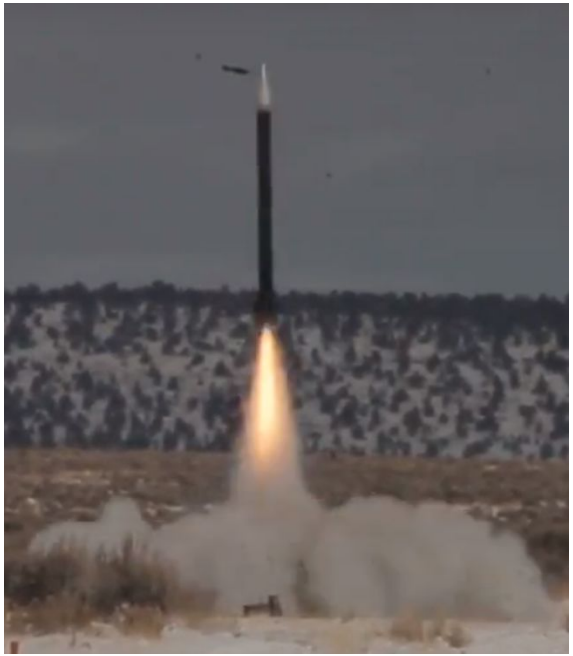
- All sections land within KE limitations

Section	Weight (lb.)	Main Size (ft.)	Drogue Size (ft.)	Main Velocity (ft./s)	Drogue Velocity (ft./s)	Landing Velocity (ft./s)	Drogue Kinetic Energy (ft.-lbf.)	Landing Kinetic Energy (ft.-lbf.)
Nose Cone	4.31	8	2	14.43	77.00	14.07	397.1	13.28
Payload	15.50						1,336	44.66
Aft	16.01	7	1.5	15.50	84.16	15.16	1,765	57.19

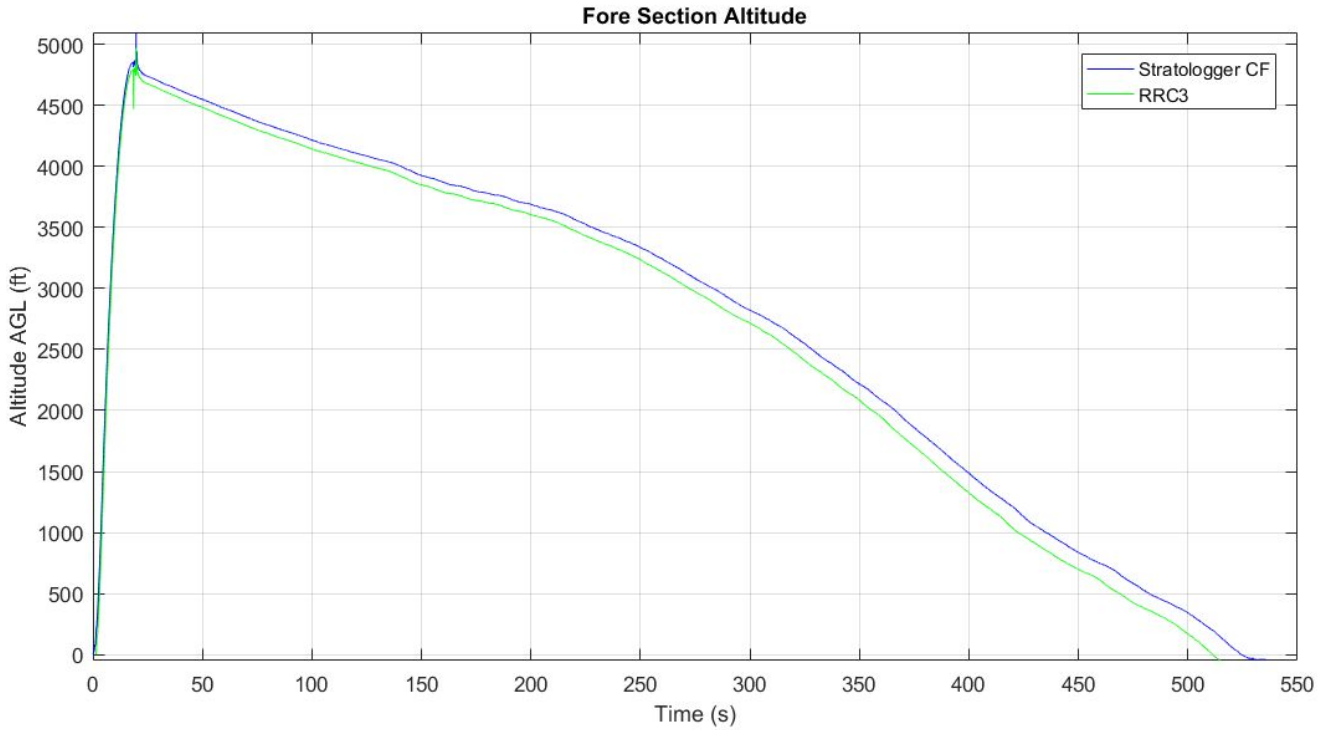
Full Scale Flight

Full Scale Flight

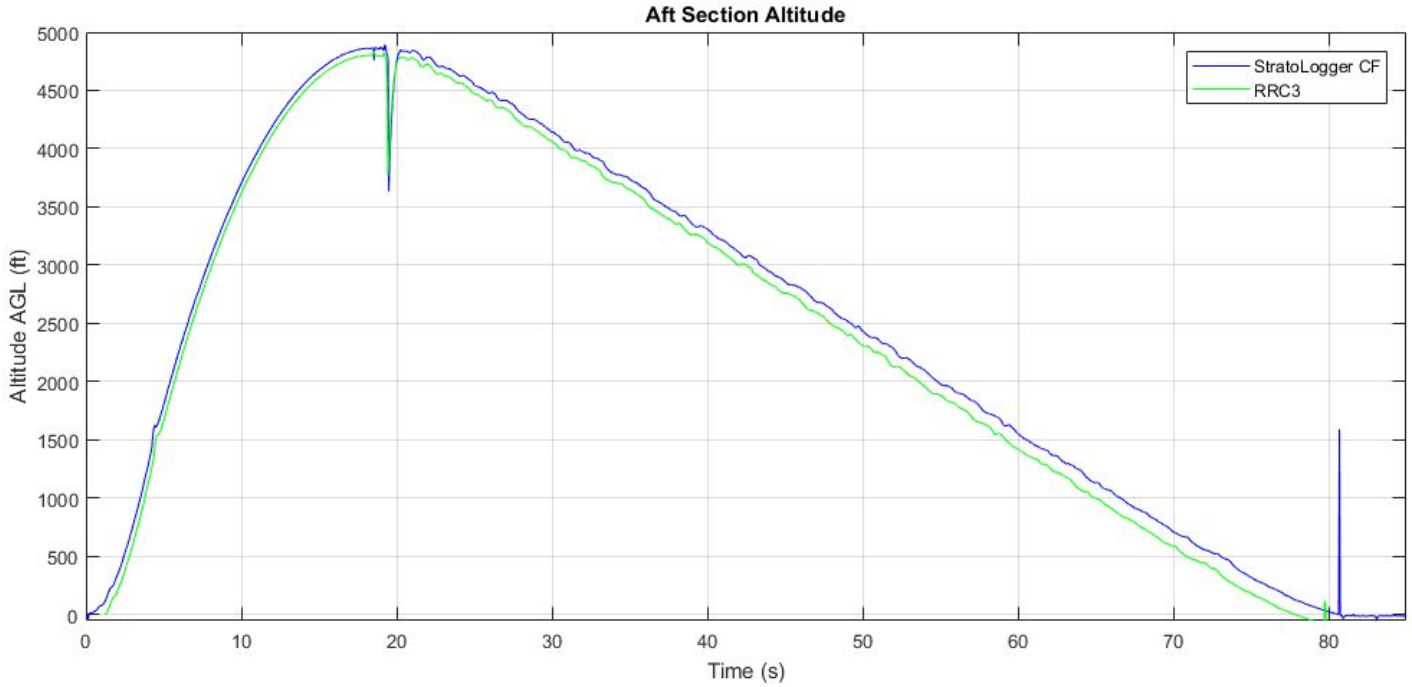
- Wind Speed: 17 mph
- Temperature: 24°F
- Altitude: 4826 ft.
  - One main deployed at apogee
  - Other main did not fully deploy
  - Fore section of the rocket was dragged for half a mile through the snow



Full Scale Flight

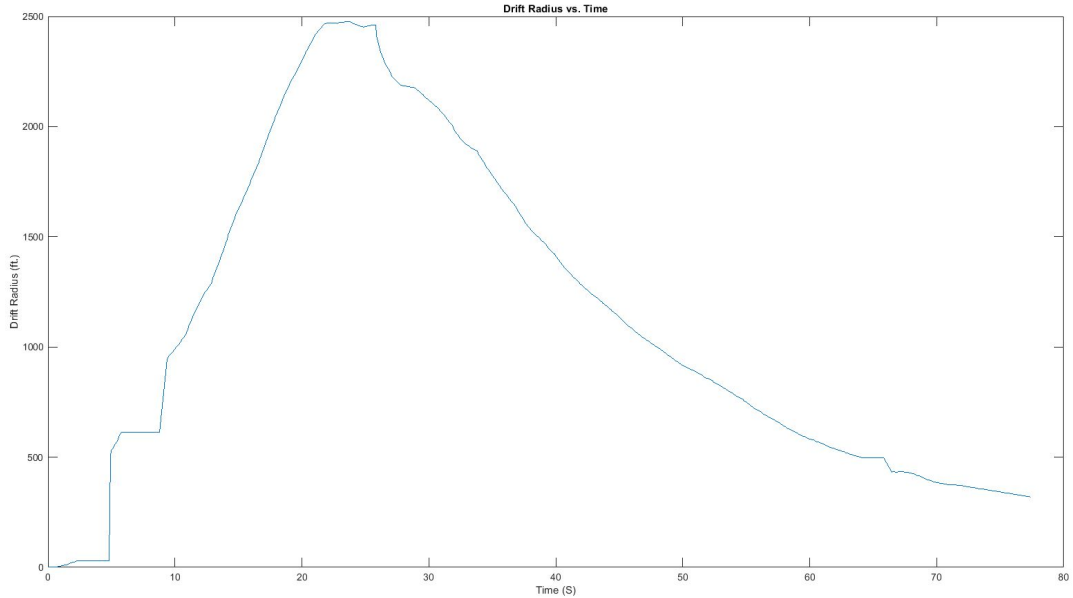


Full Scale Flight



Full Scale Flight

- Full Scale Drift Radius for Aft Section



Full Scale Flight

- Apogee Altitude: 4845 ft.
- Apogee Time: 19.20 s
- Max Velocity: 521 ft./s
- Motor Burn: 3.30 s

Full Scale Flight

- Fore Section Hit Velocity: 12.5 ft./s
- Aft Section Hit Velocity: 16.2 ft./s
- Both drouges were tangled around bridle lines

Root Failure Causes

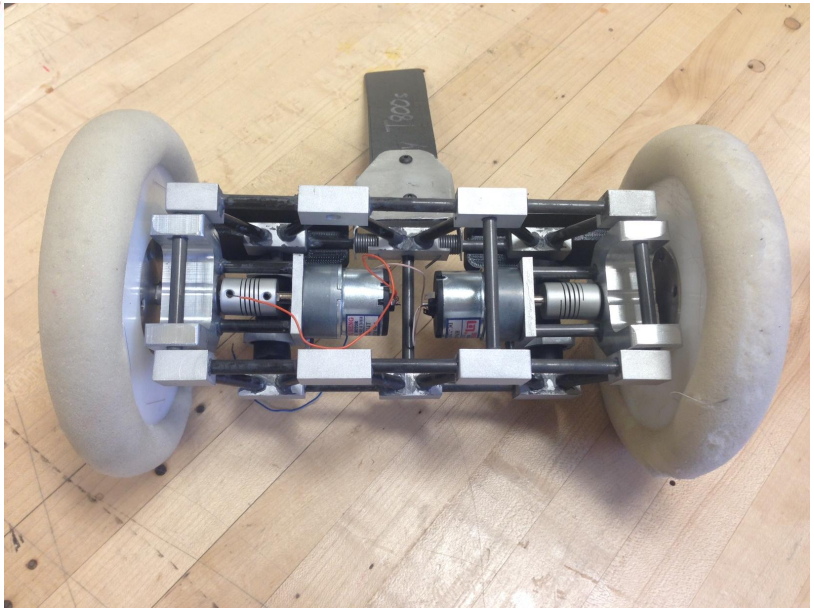
- Main Deployment at Apogee
  - Jolly Logic rubber band failure
  - Due to extreme conditions
  - To be replaced with a Kevlar cord
- Reefed Main
  - Nomex blanket slid up the main chute
  - Blanket will be secured to the ma harness with Kevlar cord

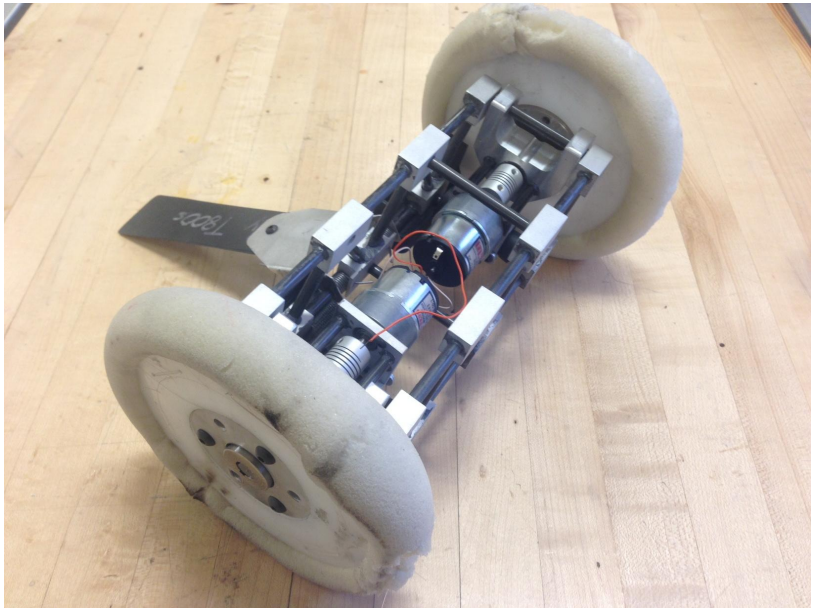
Repairs Needed

- Damage to be addressed
  - End of carbon fiber tube smashed
  - Nose cone coupler damage
  - Nose cone threaded rod bent

Full Scale Results

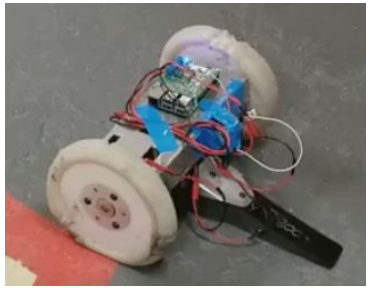
Payload: Rover

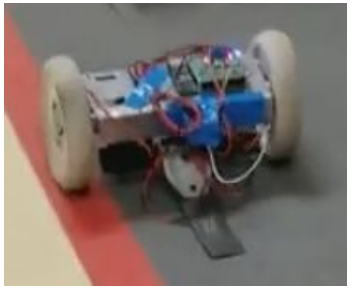


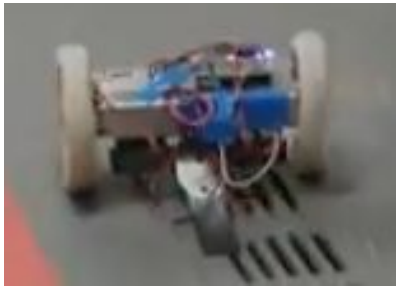


Payload: Rover

- Rover weight: 4.53 lbs.
- Rover length: 10.875 in.
- Rover diameter: 4.8 in.

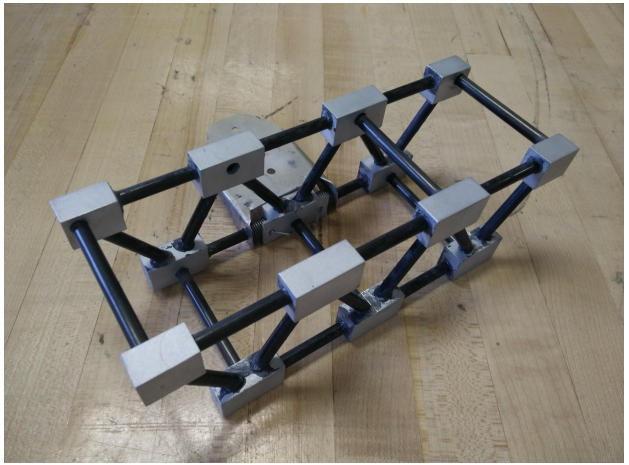


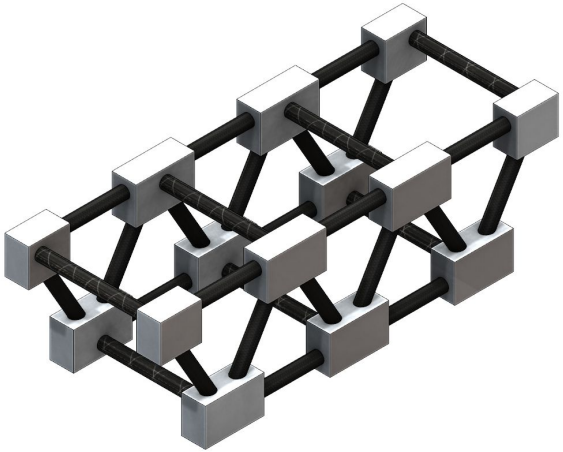




Payload: Chassis

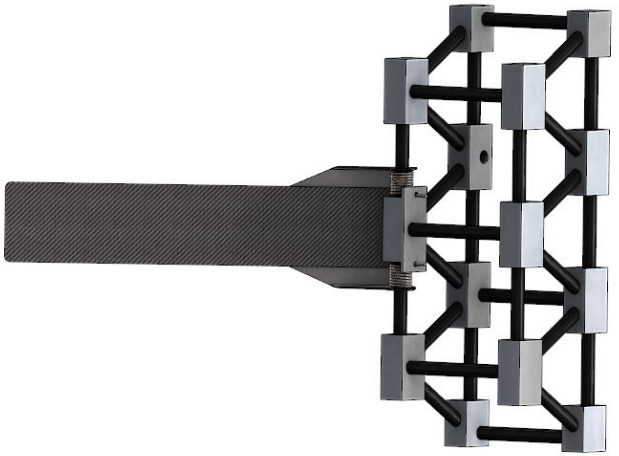
- Carbon fiber and aluminum truss frame
- Permanently bonded with epoxy
- Protects internal components





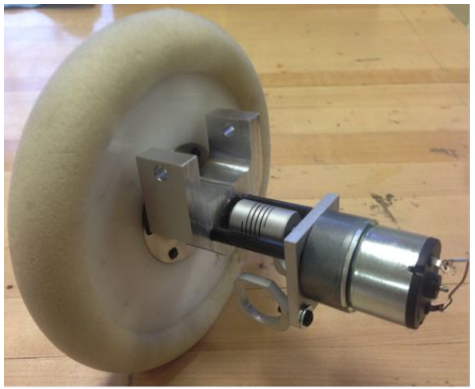
Payload: Stabilizer

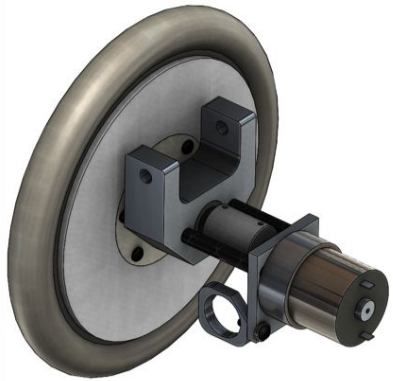
- Spring-loaded aluminum
- Flexible carbon fiber plate
- Initially contained within airframe, springs out to 7.5 in.



Payload: Drivetrain

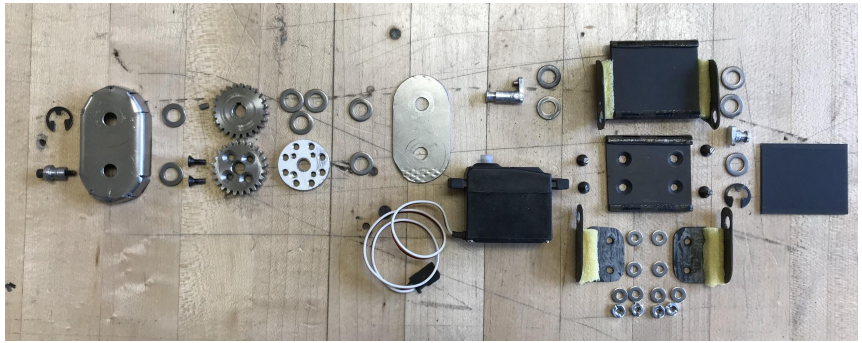
- Max Speed: 7.14 ft./s
- Max Climb Angle: 30°
- Compressive Strength: Withstand 150 lb.
- Ground Clearance: 1.05 in.

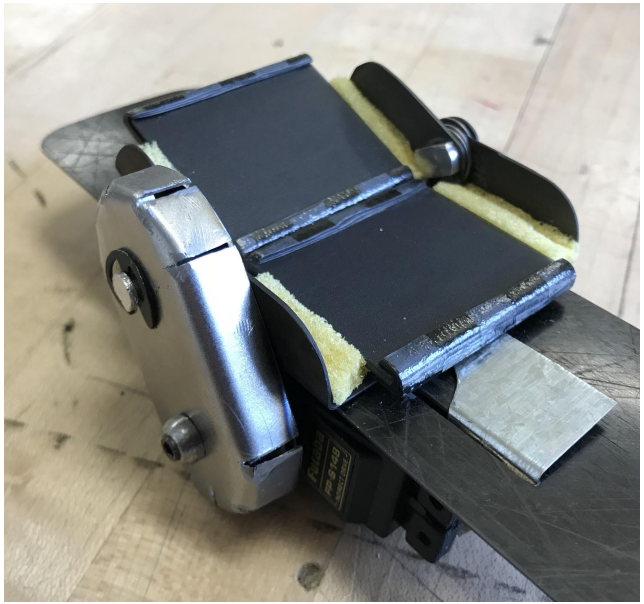




Payload: Solar Panel

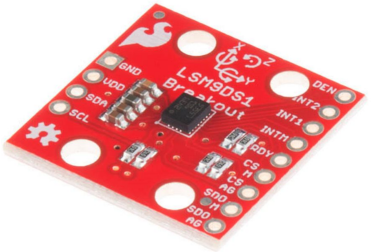
- Carbon fiber structure
- Aluminum axles
- Steel gears, couplers, fasteners
- Polyimide foam padding



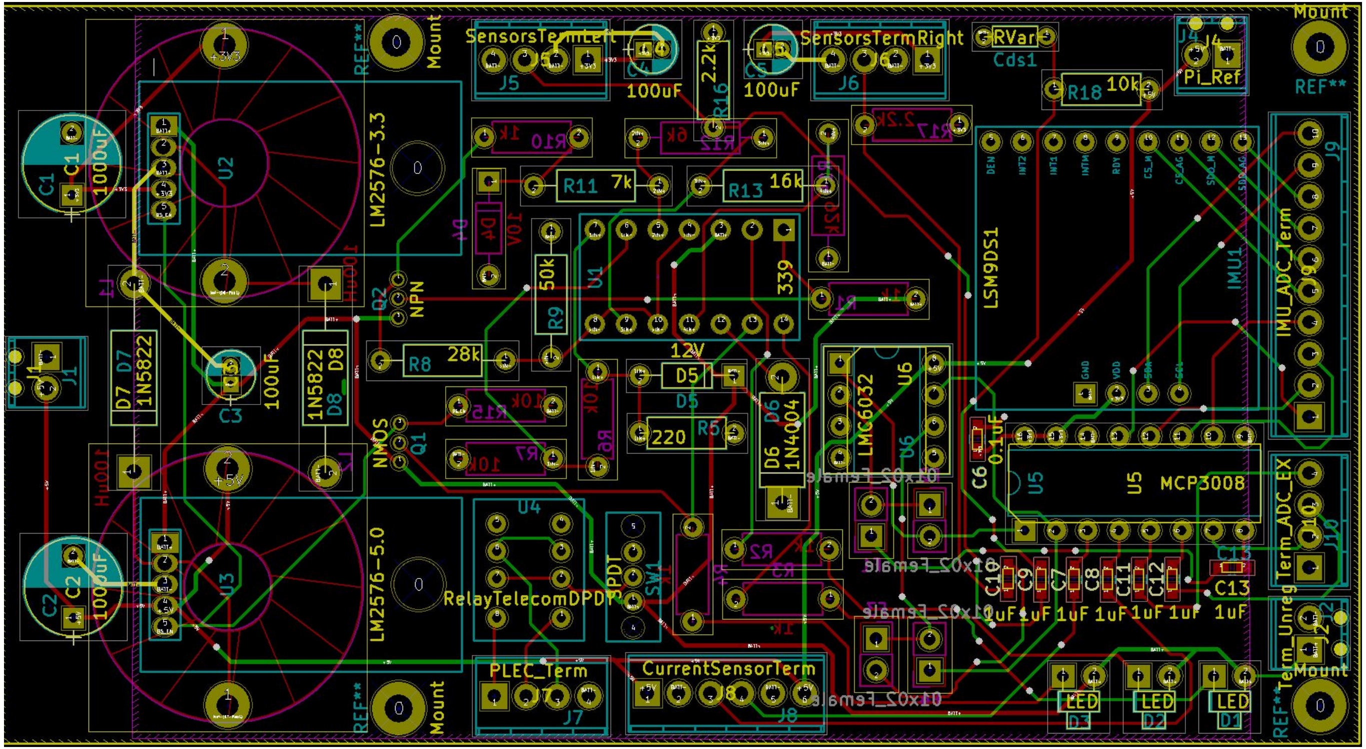


Payload: Sensors

- Object detection sensors (Sonar)
- Inertial localization (IMU)
- Launch vehicle proximity sensors (Mics)
- Light detection sensor

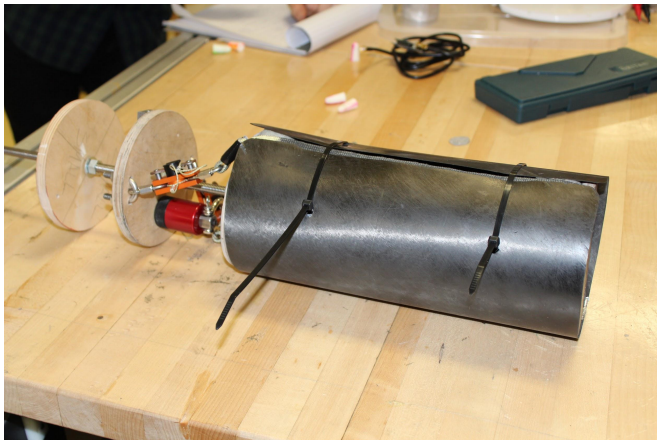


Payload: PCB


SensorsTermLeft
J5
C4
100uF
2.2k
R16
C5
100uF
SensorsTermRight
J6
RVar
Cds1
J4
Pi_Ref
Mount
REF**
R18
10k
C1
1000uF
U2
LM2576-3.3
R10
1k
R11
7k
R13
16k
R12
6k
R17
2.2K
D4
10V
50k
R9
U1
339
LSM9DS1
IMU1
IMU_ADC_Term
J9
D7
1N5822
J1
C3
100uF
1N5822
D8
Q2
NPN
R8
28k
12V
D5
D6
1N4004
U6
LMC6032
R1
R15
10k
R5
220
Q1
NMOS
R7
10k
C6
0.1uF
U5
MCP3008
Term_ADC_EX
J10
C2
1000uF
U3
LM2576-5.0
U4
RelayTelecomDPDT
SPDT
SW1
R2
R3
C10
C9
C7
C8
C11
C12
C13
1uF
Term_Unreg
J2
PLEC_Term
J7
CurrentSensorTerm
J8
LED
D3
D2
D1

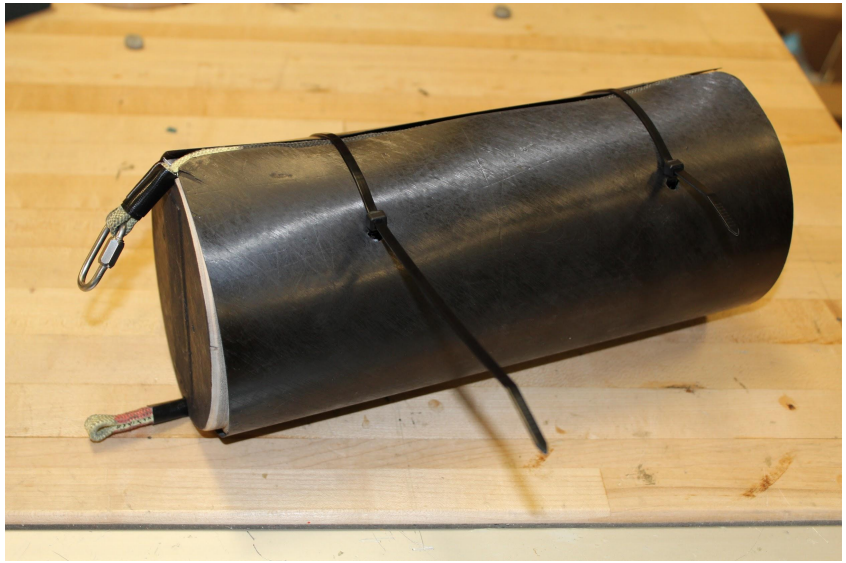
Ejection Structures

- ~0.1 oz. (3 g) black powder charge used for payload ejection
- ARRD and two Tender Descenders attach by quick link to kevlar harness. Payload flown but not ejected during full scale test
- Payload wrap unfurls when not retained



Ejection Structures

- Wheel compression assists with airframe fit and pressure seal for ejection charges
- Zip ties utilized in assembly process and removed while integrating to launch vehicle
- Carbon fiber wrap has finite life, may need to be manufactured again prior to competition



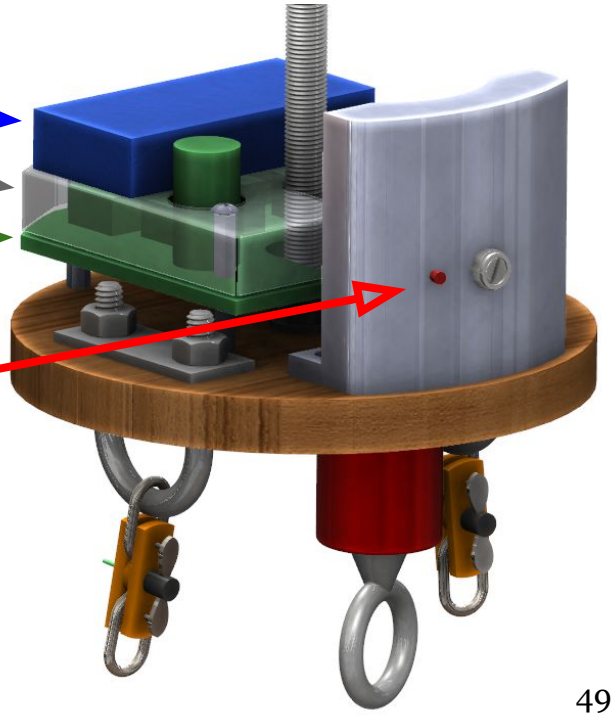
Payload Ejection Testing

- Charge sizing tests resulted in 25% success rate for payload ejection at 20° landing angle
- Further testing necessary with integrated electronics and final charge size
- Process is shown to be safe

Payload Ejection Controller

- Battery (Blue)
- Faraday cage (Transparent)
- PCB (Green)

- Arming Switch & LED
  - Flush with outside of L.V.
  - Screwdriver needed to arm



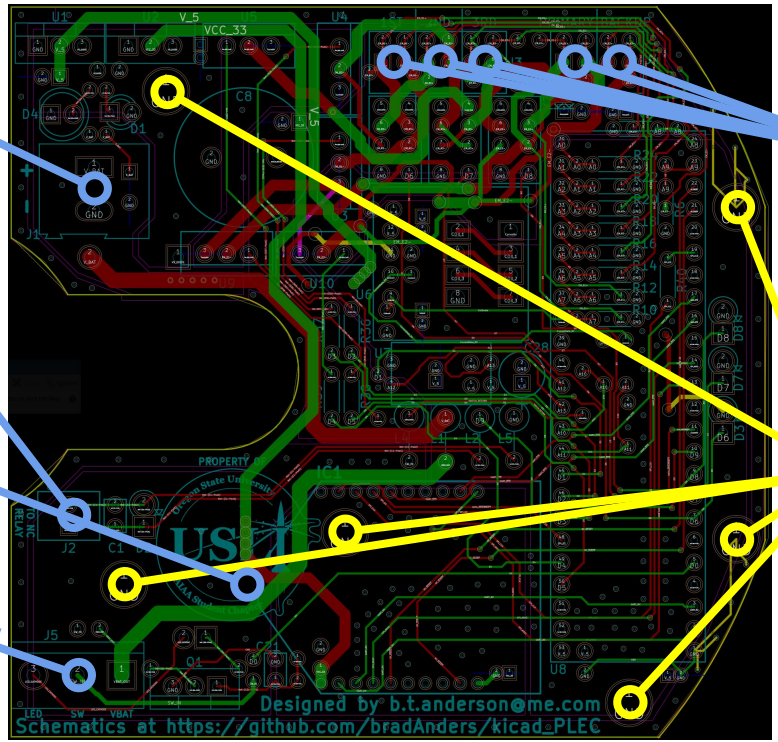
Payload Ejection Controller

To Battery

To Rover Relay

To RF Antenna

To Arming Switch and LED



To Five E-Matches

Five 4-40 Clearance Grounded Holes to Fasten Faraday Cage

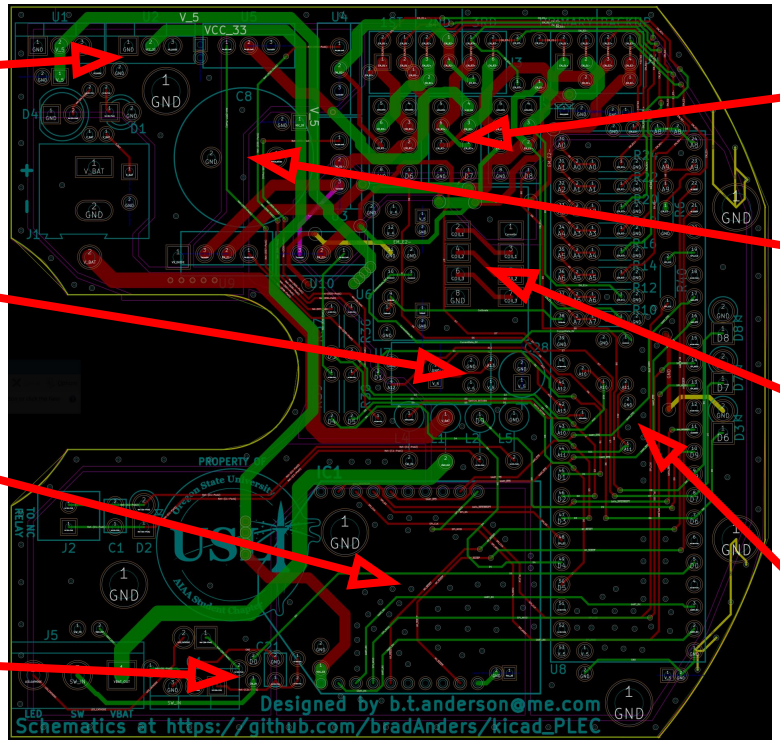
Payload Ejection Controller

Power Regulators

Pressure Sensor

Radio Transceiver

LED PWM Circuit



Power Relays

Discharge Cap

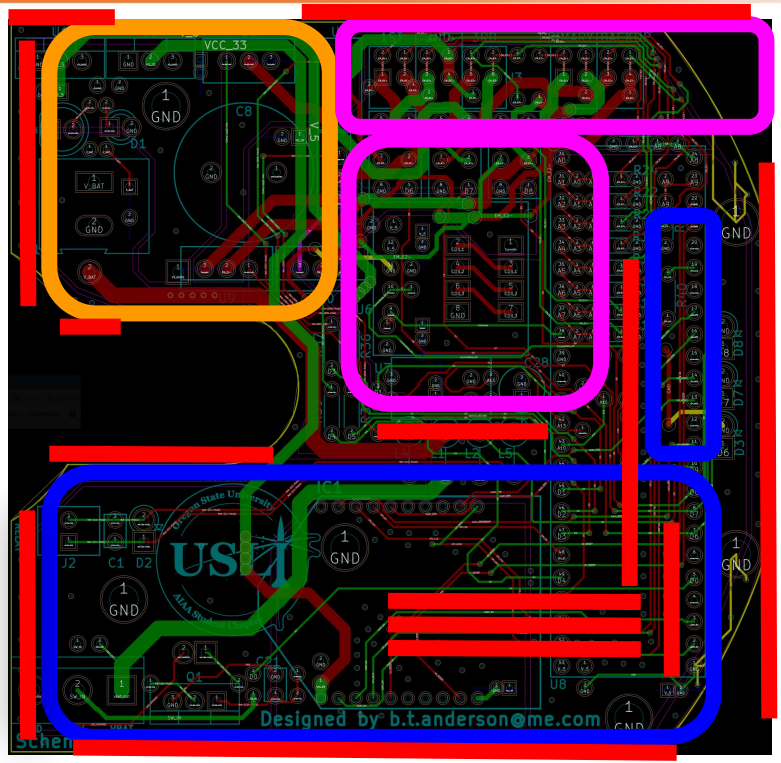
Current Sensor

Teensy and 13 ADC Pins

Payload Ejection Controller

DC/Power Signals

HF/Digital Signals

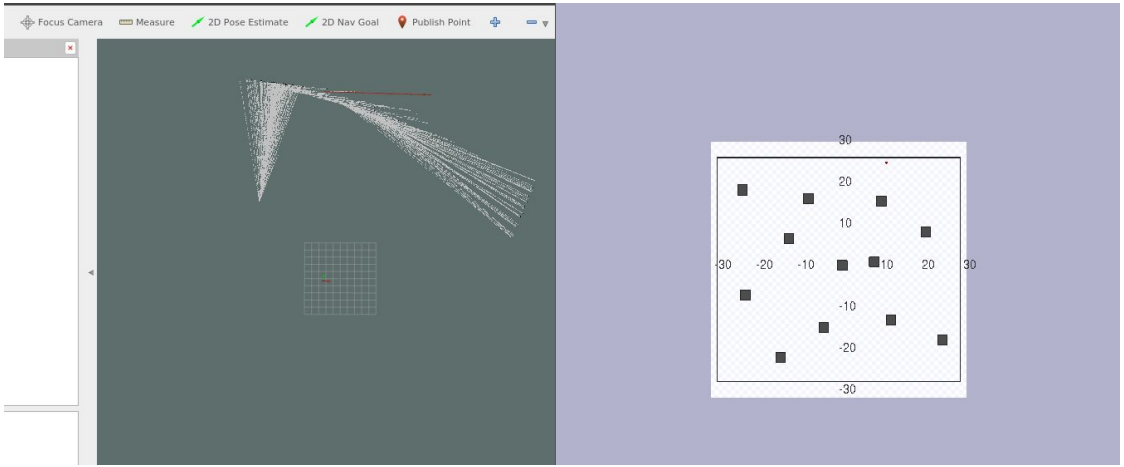


Analog Signals

Ferrite/Via EMI Isolation

Rover Algorithm

- ROS (Robot Operating System) implementation
- SLAM (Simultaneous Localization and Mapping)
- Object avoidance
- Direct drive



Test Procedures

- Major tests include:
  - Separation ejection testing
  - Launch vehicle assembly testing
  - Payload ejection testing
  - Payload performance testing:
    - Hill climb
    - Maximum velocity
    - Obstacle detection
    - Solar deployment

Test Plans: Separation Ejection

- Passing Conditions:
  - Success: Separation of sections and parachute ejection from packing; tether fully extended
  - Types of Failures: Strength, Ejection, and Partial Separation
- Test Procedure:
  - Attach charges to bulkhead
  - Attach pressure sensor
  - Close body tubes/insert shear pins
  - Perform safety protocols
- Test Materials Required:
  - Black powder
  - Pressure sensor
  - Ejection interface
  - Initiate test
  - Record results test
  - Record pressure data
  - Repeat as necessary

Test Plans: Separation Ejection

- Status - *Complete*
  - 9 ejection tests were done before full scale
  - 5 aft and fore sections achieved full separation

Test Plans: Launch Vehicle

- Passing Conditions:
  - Total weight < 45 lb.
  - Time required < 2.5 hr.
- Test Materials Required:
  - Precise scale
  - Timer
  - Measuring tape
- Test Procedures:
  - Measure interior space
  - Start timer
  - Assemble the launch vehicle
  - Stop timer
  - Place vehicle on scale
  - Count components

Test Plans: Launch Vehicle

- Status - *Complete*
  - Full scale integration occurred February 27th
  - Integration in 2.33 hr.
  - Additional testing will be done to bring this time down

Test Plans: Payload Ejection

- Passing Conditions:
  - Rover clears airframe
  - Avoid entanglement
  - Successful 5 ft. travel
- Test Materials Required:
  - Test apparatus
  - Payload ejection housing
  - Rover payload
  - E-matches
  - Black powder
- Test Procedures:
  - Secure airframe
  - Place black powder charge
  - Insert dummy payload
  - Secure the payload housing
  - Activate charges
  - Retrieve rover

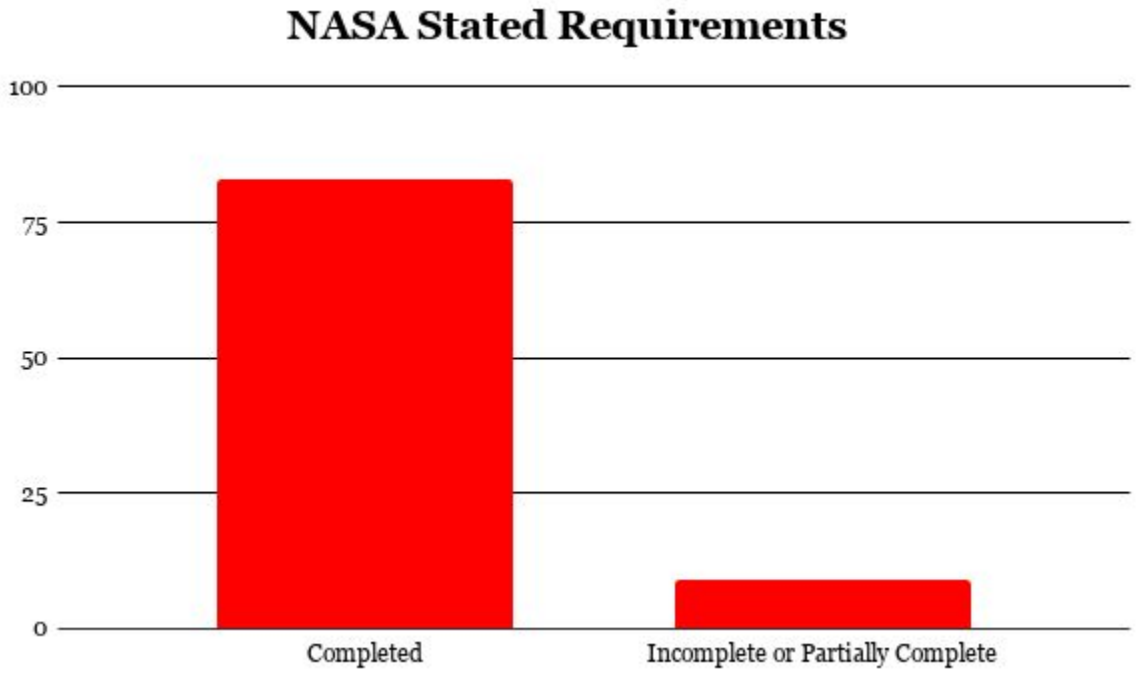
Test Plans: Payload Ejection

- Status - *Complete*
  - Complete ejection testing
  - Ejection of over 30 ft. from tube at 20° angle

Test Plans: Payload

- Hill Climb:
  - Complete: Rover climbed 30° hill with ease
- Maximum Velocity:
  - Complete: Rover traveled at maximum velocity of 7.14 ft./s
- Object Detection:
  - Complete: Sensors have a 100% object detection rate
- Solar Deployment:
  - Incomplete: Test incomplete and scheduled for March 12th

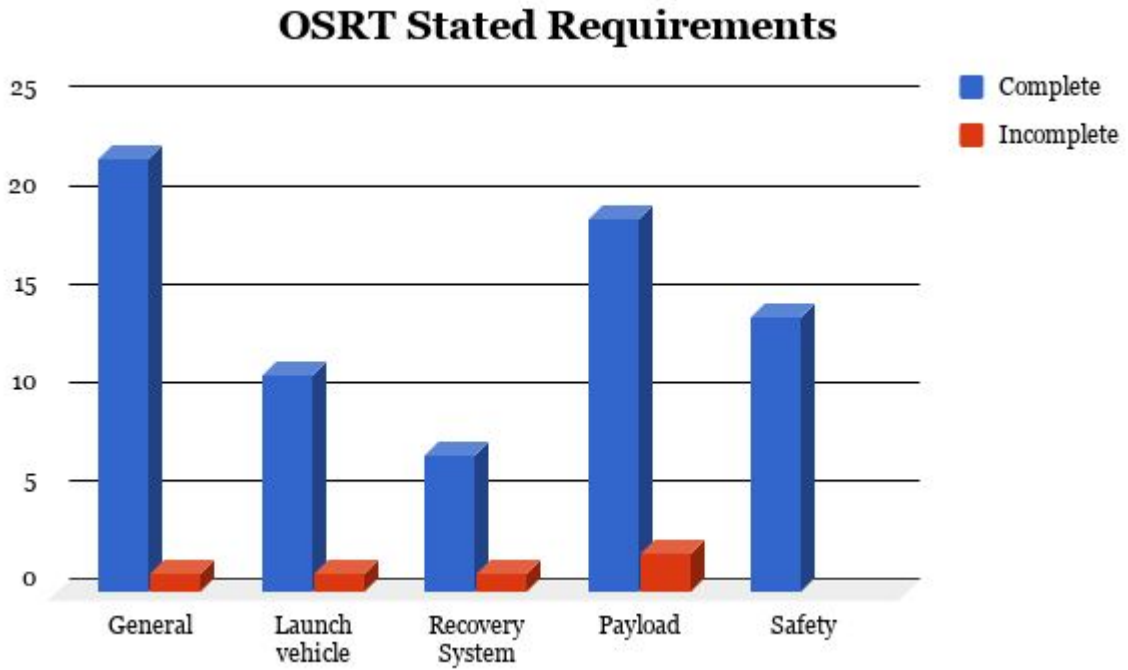
Requirement Verification



Requirement Verification

- Incomplete Requirements:
  - Recoverable and reusable
  - Not successfully launched and recovered
  - Recovery system did not function as designed
  - Current vehicle not in final flight configuration
  - Tracking not fully functional
- Mitigation Plan: Relaunch March 24, 2018

Requirement Verification



Requirement Verification

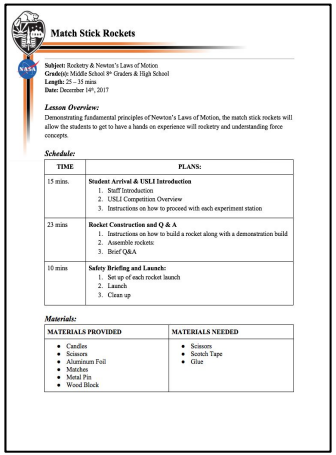
- Incomplete Requirements:
  - Tracking properly implemented
  - Rover navigational algorithms implemented
  - Launch vehicle localization not implemented
  - Number of L1 certified members insufficient
- Mitigation Plan: Relaunch March 24 with sufficient time to perform certification launches and rover testing

Educational Outreach

- Seven Outreach Events Completed
  - Silver Crest Middle School - 19 students
    - Model rocket launch
  - Philomath Middle School - 21 students
    - Model rocket launch
  - Sprague High School - 191 students
    - Aerodynamics, matchstick rockets, & electromagnetism
  - Walker Middle School - 191 students
    - Electromagnetism & mousetrap cars
  - Yamhill Carlton Aerospace Program - 28 students
    - Campus and facilities tour

Educational Outreach

- Seven Outreach Events Completed
  - STEM Night Santiam Christian School - about 400 students
    - Indirect outreach night
  - Guy Lee Elementary School - about 80 students
    - Rocketry and Space
- Over 900 Students Reached!



Match Stick Rockets

Subject: Rocketry & Newton's Laws of Motion
Grade(s): Middle School 8th Graders & High School
Length: 25 – 35 mins
Date: December 14th, 2017

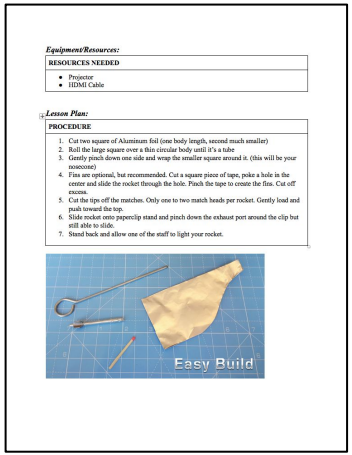
Lesson Overview:
Demonstrating fundamental principles of Newton's Laws of Motion, the match stick rockets will allow the students to get to have a hands on experience will rocketry and understanding force concepts.

Schedule:

TIME	PLANS:
15 mins.	**Student Arrival & USLI Introduction** 1. Staff Introduction 2. USLI Competition Overview 3. Instructions on how to proceed with each experiment station
23 mins	**Rocket Construction and Q & A** 1. Instructions on how to build a rocket along with a demonstration build 2. Assemble rockets 3. Brief Q&A
10 mins	**Safety Briefing and Launch:** 1. Set up of each rocket launch 2. Launch 3. Clean up

Materials:

MATERIALS PROVIDED	MATERIALS NEEDED
• Candles • Scissors • Aluminum Foil • Matches • Metal Pin • Wood Block	• Scissors • Scotch Tape • Glue



Equipment/Resources:

RESOURCES NEEDED
• Projector • HDMI Cable

Lesson Plan:

PROCEDURE
1. Cut two square of Aluminum foil (one body length, second much smaller) 2. Roll the large square over a thin circular body until it's a tube 3. Gently pinch down one side and wrap the smaller square around it. (this will be your nosecone) 4. Fins are optional, but recommended. Cut a square piece of tape, poke a hole in the center and slide the rocket through the hole. Pinch the tape to create the fins. Cut off excess. 5. Cut the tips off the matches. Only one to two match heads per rocket. Gently load and push toward the top. 6. Slide rocket onto papercilp stand and pinch down the exhaust port around the clip but still able to slide. 7. Stand back and allow one of the staff to light your rocket.

Questions?

Rocket Launch