NU HOPE

Northeastern University

High-altitude Object Protection Experiment

Agenda

- Overview of Launch Vehicle
  - Dimensions and Mass Statement
  - Motor Specification
  - Stability Analysis
- Recovery
  - Drogue and Main Descent
  - Predicted Altitude
  - Kinetic Energy
  - Lateral Drift
- Test Plans and Procedure
- Full Scale Flight Test
  - Launch Vehicle Verification
- Payload Protection System (PPS)
  - Design
  - Integration with Launch Vehicle

Overview of Launch Vehicle

Length	146 inches
Diameter	6.16 inches
Weight loaded	48.9 pounds
Body Tube Material	BlueTube
Number of Fins	4
Motor	*L2200G-18**
Number of Electronics Bays	2
Number of Altimeters	6 *(Booster 4, Payload 2)*
Number of Main Parachutes	2 *(Booster 72”, Payload 60”)*
Number of Drogue Parachutes	2 *(Booster 18”, Payload 15”)*

Overview of Launch Vehicle (cont.)

Thrust to Weight Ratio			10:3		
Rail Exit Velocity			91 ft/s		
	0 mph wind	5 mph wind	10 mph wind	15 mph wind	20 mph wind
Predicted altitude	5380 ft	5380 ft	5380 ft	5380 ft	5380 ft
Predicted drift-Payload Section	0.0 ft	608.9 ft	1217.8 ft	1826.7 ft	2435.6 ft
Predicted drift-Booster Stage	0.0 ft	589.2 ft	1178.5 ft	1767.7 ft	2357.0 ft

Center of Mass and Center of Pressure

Stability 3.45 cal

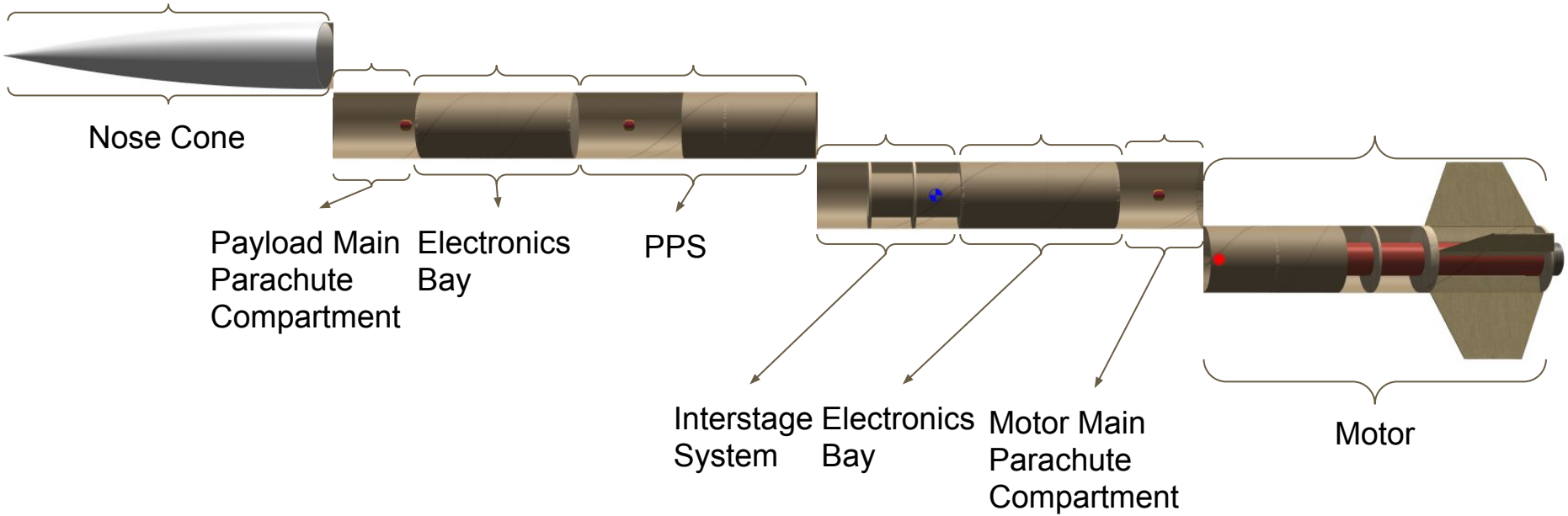
Center of mass 93.95 inches from nose cone

Center of Pressure 115.2 inches from nose cone

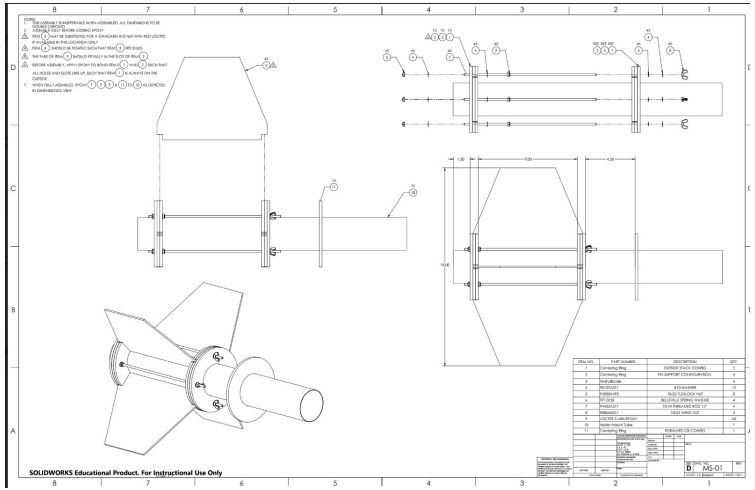
Launch Vehicle Sections and Systems

- Booster Stage
  - Motor Subsection
  - Aft Parachute Subsection
- Interstage System
  - Electronics bay
- Payload Section
  - PPS
  - Electronics bay
  - Nose Cone

Launch Vehicle Sections and Systems

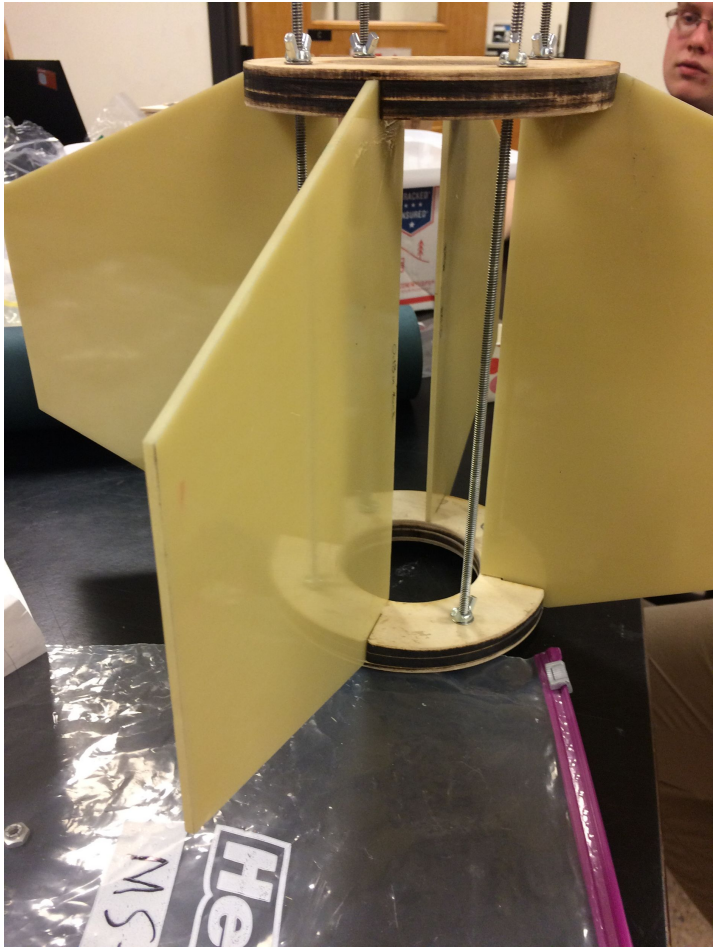


Motor and Aft-Parachute Subsections



Motor Subsection

- 4 G10 Fiberglass fins
- 3 Centering Rings
- Coupler tube with bulkhead attached to parachute

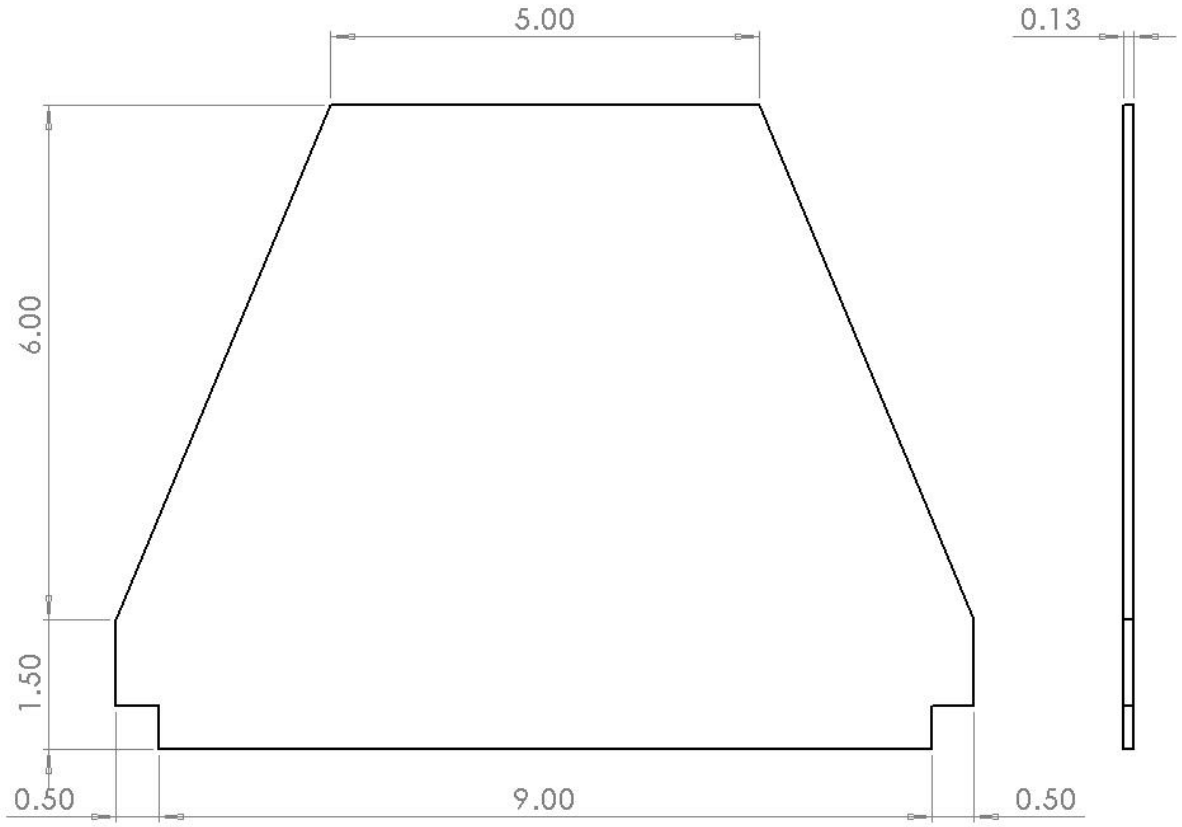


Motor Properties

Motor type	AeroTech L2200G-18
Loaded Mass	10.474 pounds
Burnout Mass	4.927 pounds
Total Impulse	5104 Ns
Maximum Thrust	3102 N
Average Thrust	2243
ISP	206.8 s
Burntime	2.27 s

Fin Properties

- G10 Fiberglass
- Waterjet
- Isosceles Trapezoid
- ⅛ inch thick

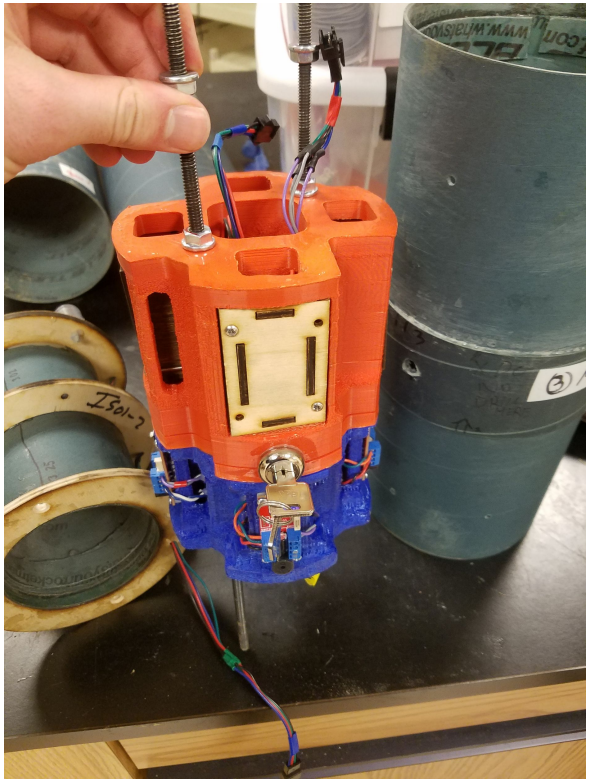


Motor Main Parachute Compartment

- Inside Aft-Parachute Subsection
- 72 inch diameter main parachute deploys
- Deploys at 500 ft
- 40 feet of ½ inch tubular kevlar

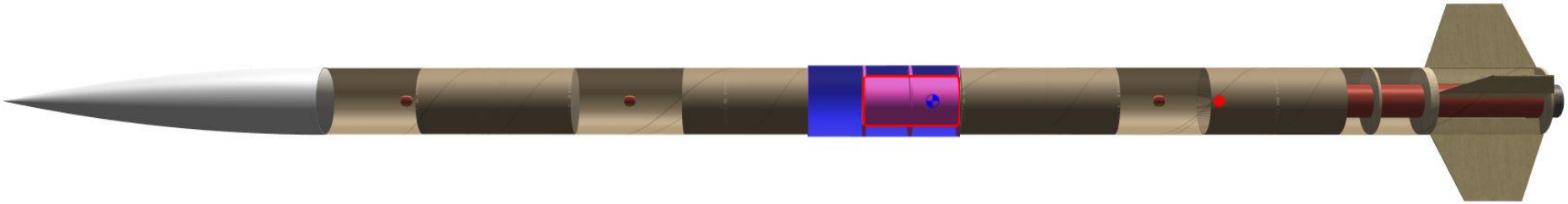
Aft/Interstage Parachutes Electronics bay

- Inside Aft-parachute Subsection
- Components
  - 4 x StratoLogger Altimeter
  - 2 x CT Components Keylock Switches
  - 4 x 9 Volt Batteries
    - Held in custom 9V battery holders
  - 1 x TeleGPS
- 3 - D Printed Housing
  - ABS 100% Infil
  - Threaded inserts to reinforce holes



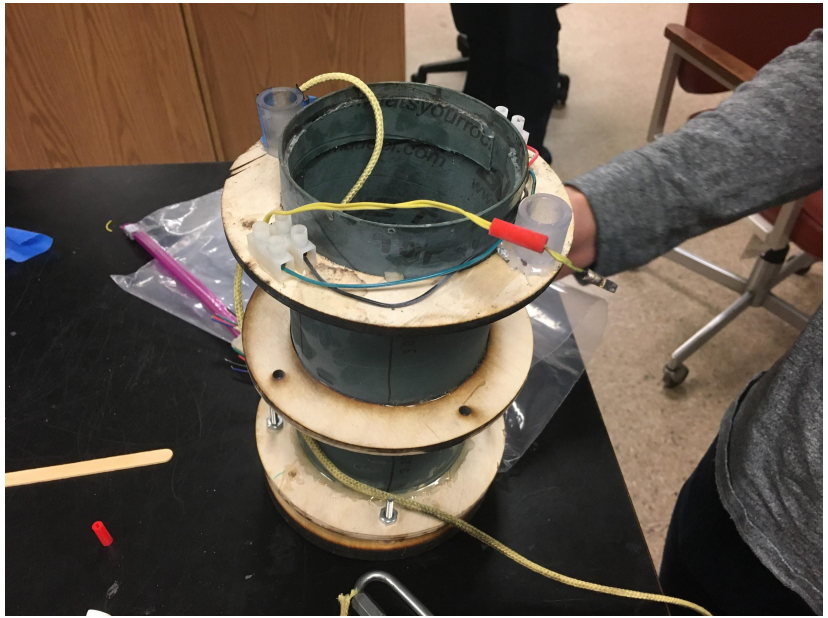
Interstage System

- Inside Aft-Parachute Section
- Features dual deploy parachute system
- Deploys drogues for both sections, 15 inch and 18 inch diameters
- Solves previous conflict of colliding drogue parachutes

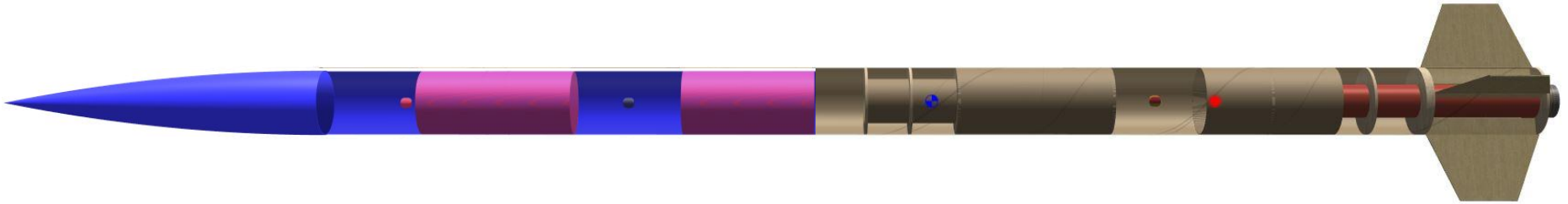


Interstage System (cont.)

- Previous experiences have shown the feasibility and reliability of the system

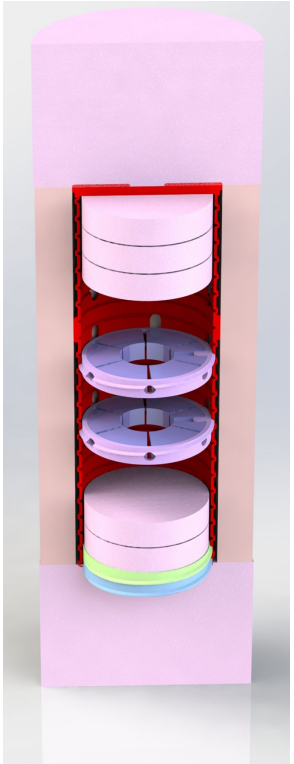


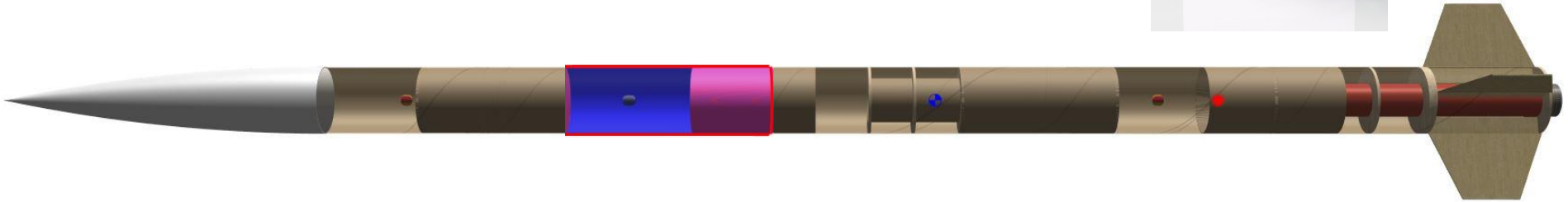
Payload Section



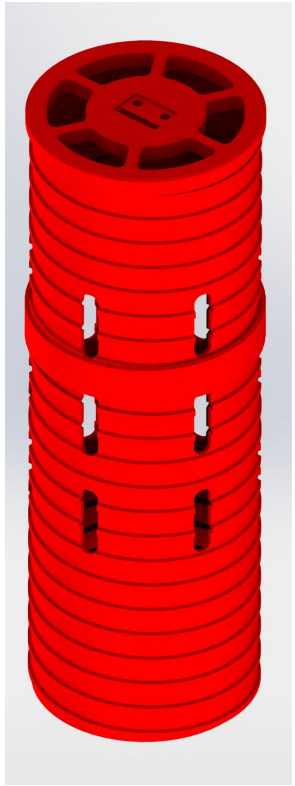
Payload Protection System, Canister

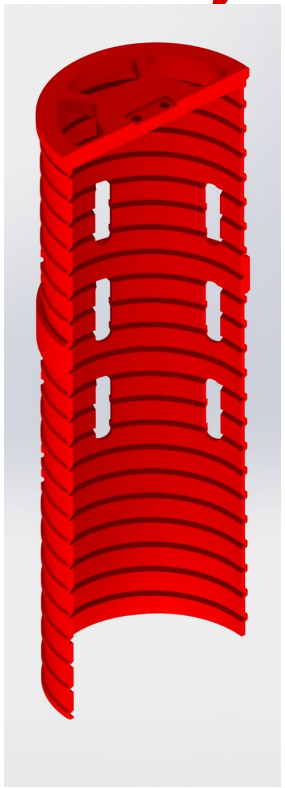
- 3D printed canister using PLA
  - Printed in two sections due to print height limit
- Adjustable threaded disks contain payloads of varying heights
- Horizontal straps and foam contain narrow or varying diameter payloads
- Adaptable to multiple simultaneous payload objects

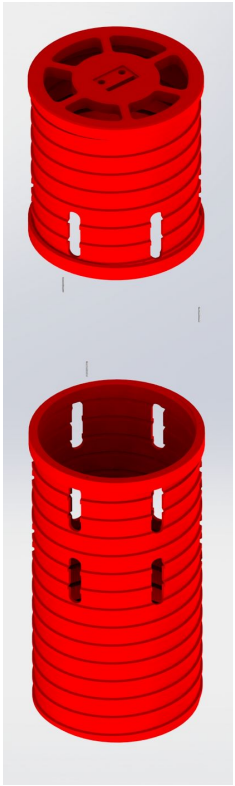


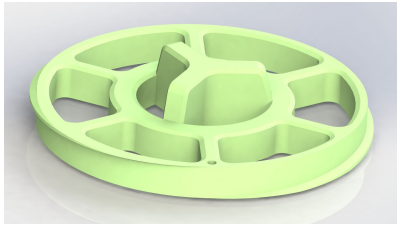


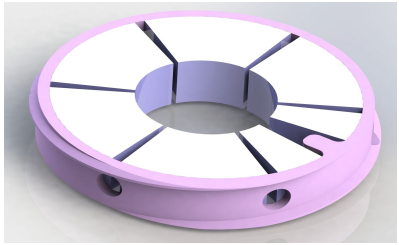
Payload Protection System, Subcomponents

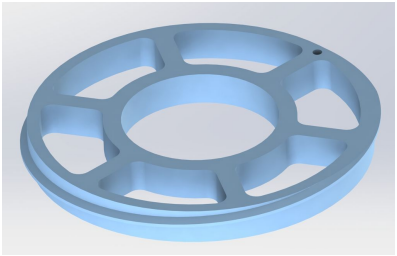




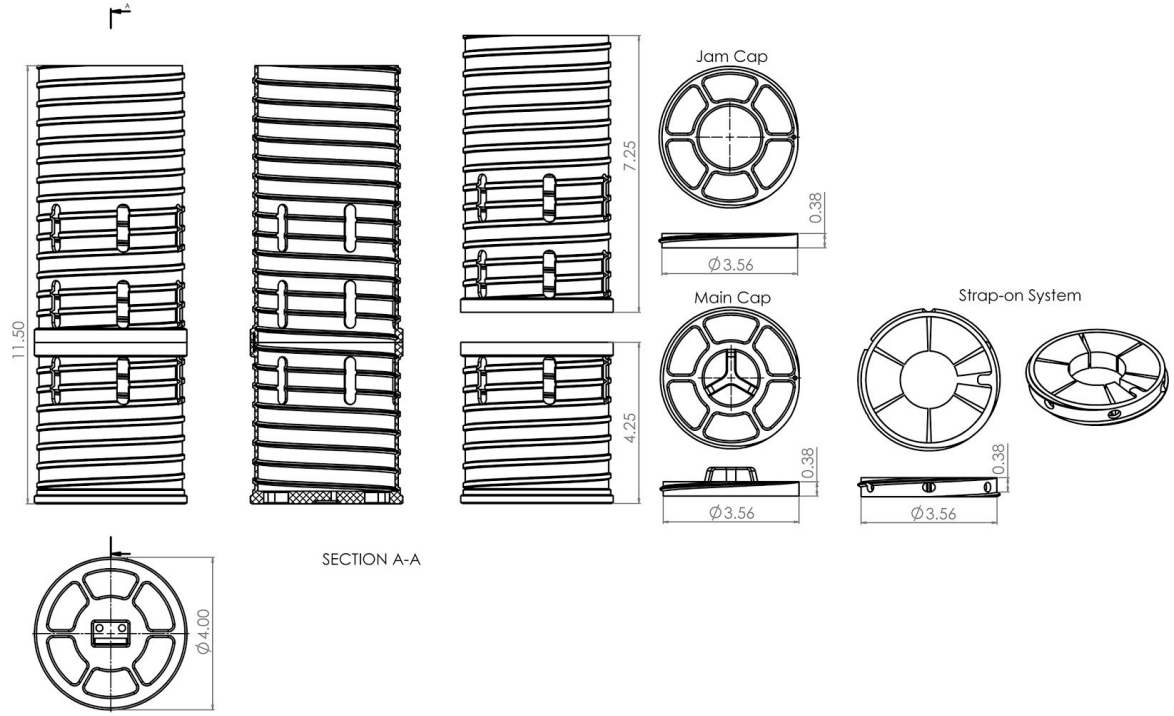






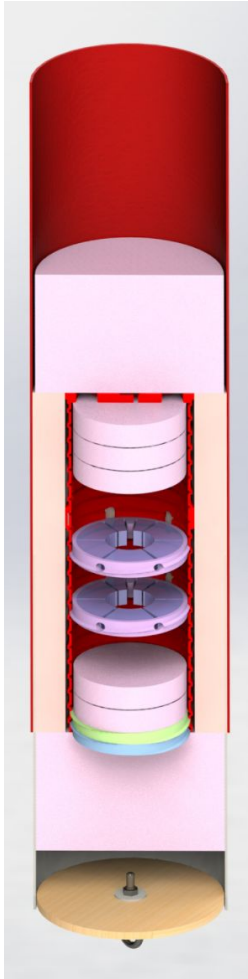


Payload Protection System, Subcomponents



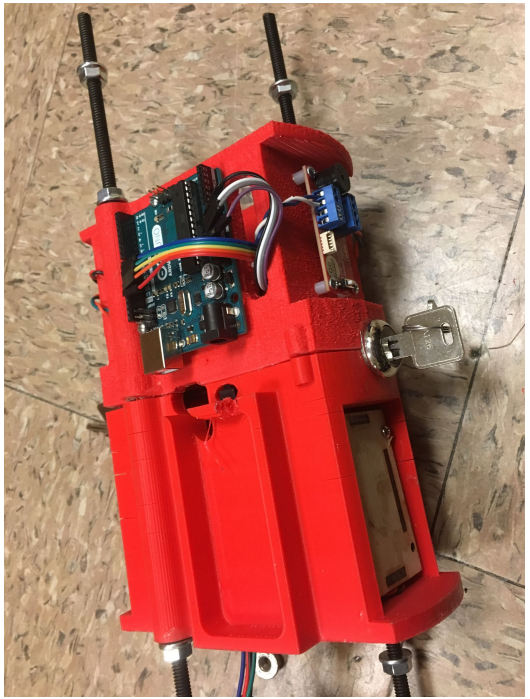
Payload Integration

- PPS is inside the body tube of the Payload Section.
- Above the Payload System
  - Payload electronics bay - closes in the top of top of the PPS
- Below the Payload System
  - Interstage - permanently connected to the body tube surrounding the PPS through epoxy



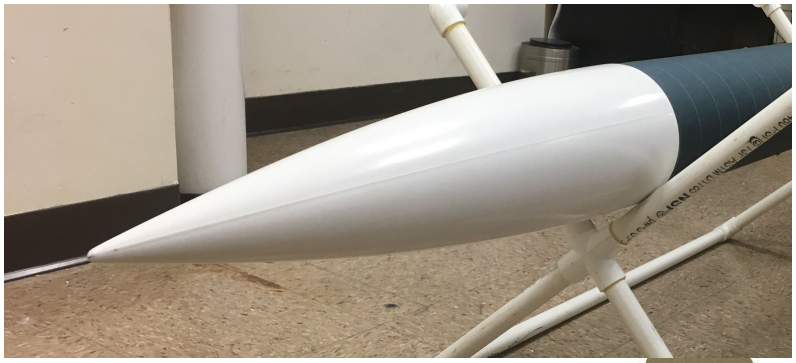
Payload Electronics Bay

- Teensy 3.6 microcontroller
- Two StratoLogger altimeters
- Adafruit Ultimate GPS module
- Xbee XSC Pro 900Mhz module
- LIS 331 3-axis accelerometer

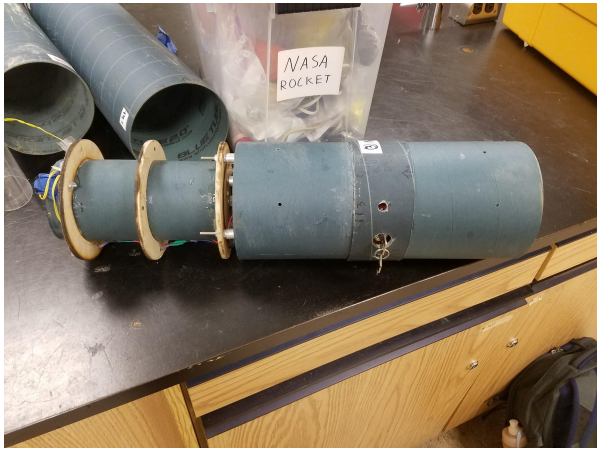


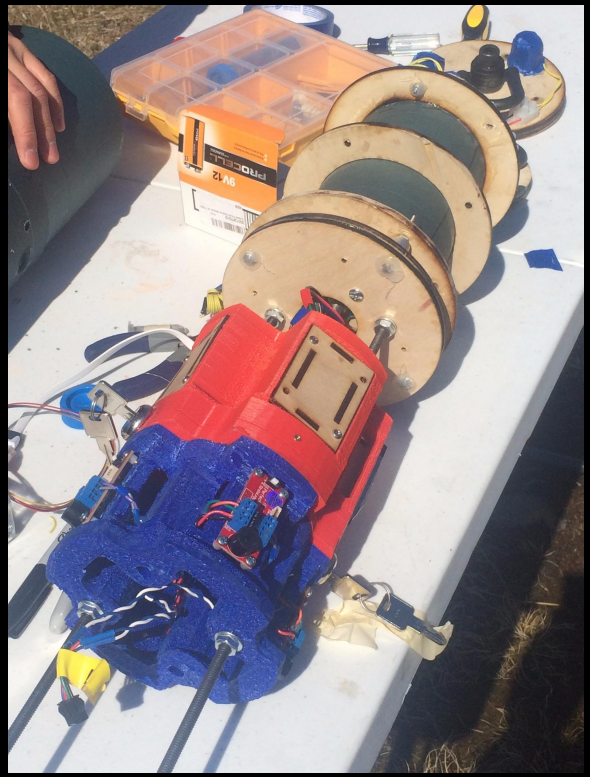
Nose Cone Subsection and Payload Main Parachute Compartment

- 24 inches nose cone composed of Fiberglass
- Detaches to deploy 60 inch main parachute
- Attached to ⅜ inch forged eye bolt on the nose cone and a ½ inch hoist ring on the PPS
- Connected with 35 ft of ½ tubular kevlar



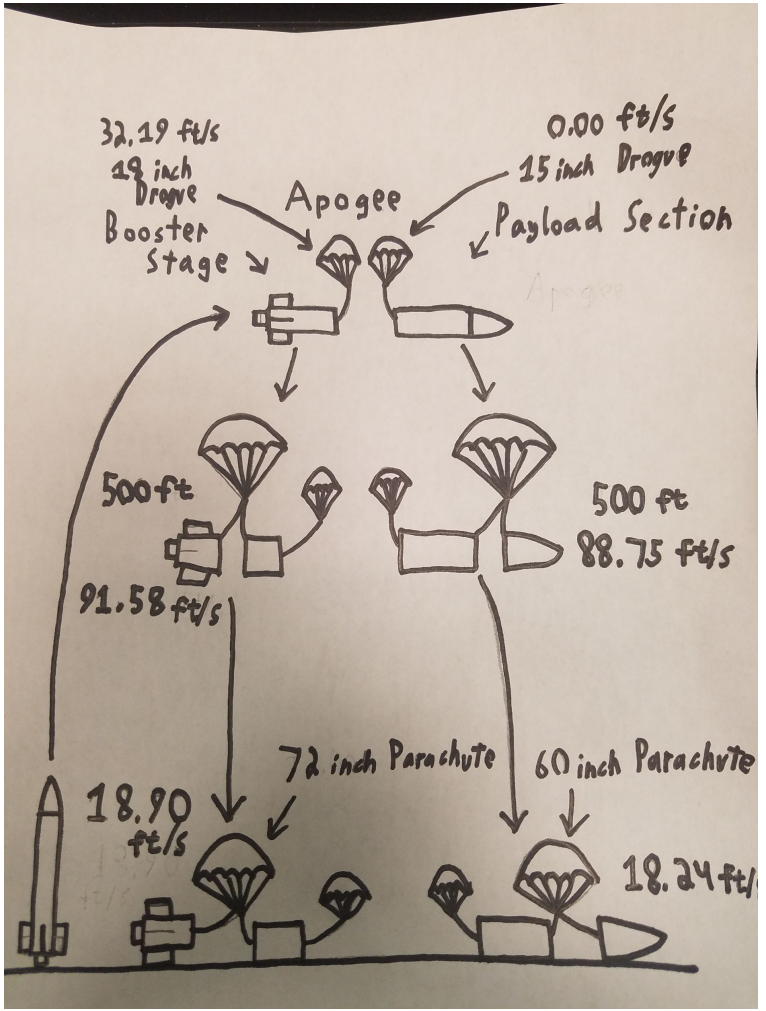
Recovery Systems





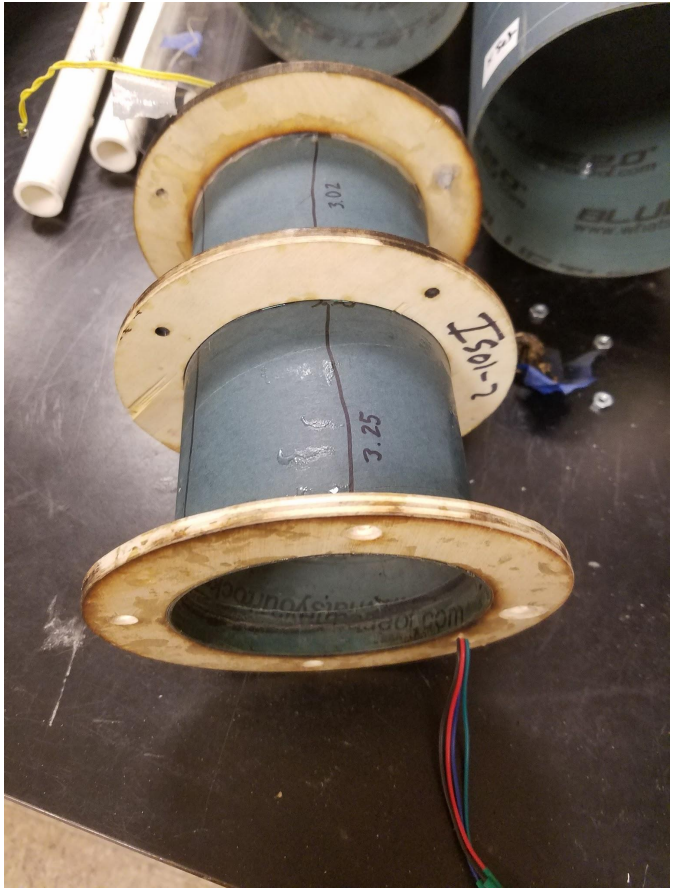
Launch Procedure

- Apogee of 5380 ft
- 2 instances of separation
  - Apogee
    - Drogues deployed at 5380 ft and 5173 ft
  - 500 ft separation for deployment for both main parachutes
- Checklists



1st Separation

- Launch vehicle reaches Apogee 5380
- Booster stage and Payload section separate and drogues deployed at apogee
- One deploys instantly, other has delay of 1 second controlled by the stratologger
    - Tested thrice, once in full scale and twice in subscale



Drogue parachutes

- Payload section
  - 15 inch diameter, 88.7 ft/s
  - Secured by ½ inch diameter Kevlar shock cord
  - Secured to bulkhead by ¼ inch eyebolt
- Booster stage
  - 18 inch, 91.6 ft/s
  - Secured by ½ inch diameter Kevlar shock cord
  - Secured to bulkhead by ¼ inch eyebolt

2nd Separations

- Payload Section splits at 500 ft.
  - Main parachute deploys
  - Splits between Nose Cone and Payload Subsections
- Booster Stage splits at 500 ft.
  - Main parachute deploys
  - Splits between Motor and Aft-Parachute Subsections

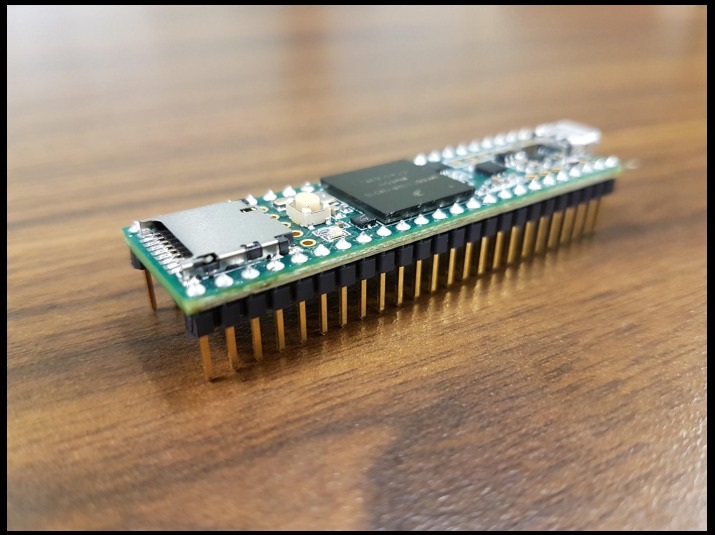
Main Parachutes

- Booster Stage
  - 72 inch diameter, 18.9 ft/s
  - Impact energies of 72.57 ft-lbf and 74.051 ft-lbf for interstage/aft parachute subsystem and motor section
  - Secured by ½ inch diameter Kevlar shock cord
  - Secured to both bulkheads via hoist rings

Main Parachutes

- Payload Section
  - 60 inch diameter, 18.2 ft/s
  - Impact energies of 12.686 ft-lbf and 74.346 ft-lbf for Nose Cone and PPS Sections
  - Secured by ½ inch diameter Kevlar shock cord
  - Secured to the nosecone bulkhead via eyebolt and the PPS Subsection bulkhead via hoist ring

Electronics and Telemetry

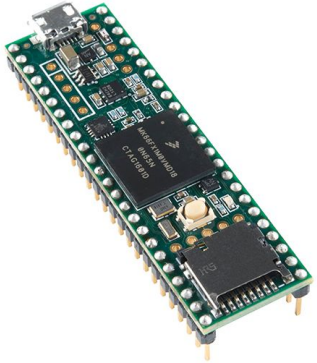


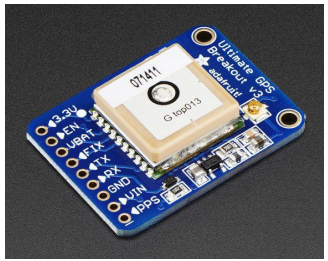
Booster Stage Electronics Bay

- 4 StratoLoggers
- 4 9V batteries
  - One for each StratoLogger
- Tunnels for wiring
- Two threaded rods
- TeleGPS
- Faraday Cages (around StratoLoggers)

Payload Section Electronics Bay

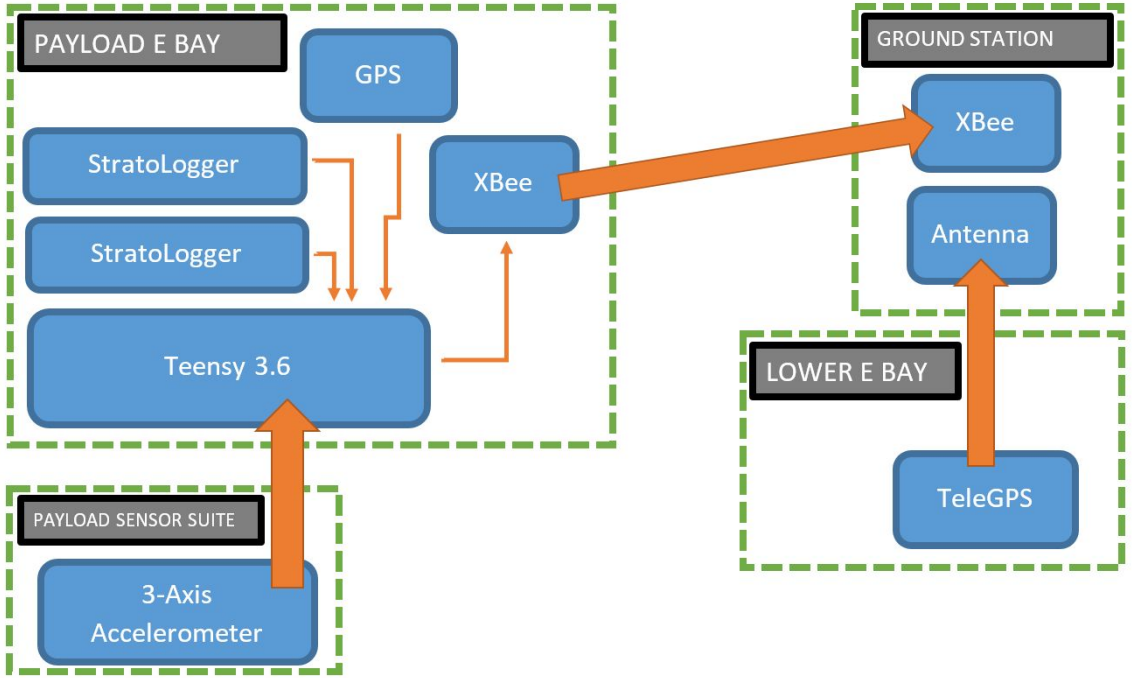
- 2 StratoLoggers
- 2 9V batteries
- Teensy 3.6
- Adafruit Ultimate GPS module
- Xbee XSC Pro 900Mhz module
- Pulse W1063 antenna
- 7.4 Lipo battery
- Faraday Cages (around StratoLoggers)
- LIS331 - 3-axis Accelerometer
    - Accelerometer is mounted on the payload canister and attached to electronics bay via ribbon cable





Telemetry

- The Adafruit GPS gets position data → Teensy 3.6
  - Position and accelerometer data → SD card
- Teensy 3.6 → XBee
- XBee → XBee Explorer Dongle at Ground Station
  - Pulse W1063 transmitting and receiving antenna
- Data stored and read out on Computer
  - Python code at ground station parses data
- TeleGPS gets position data → Ground Station
  - TeleGPS onboard transmitter, 3-element Yagi receiving antenna
- Data stored and read out on Computer



Launch Vehicle Requirements Verification

- Reach apogee of 5280 ft
  - Subscale and fullscale launches have shown actual apogee close to predicted apogee, and predicted apogee with L2200 will be tested
- Successfully deploy all parachutes
  - All parachutes have deployed multiple times
- Slow sections to insure that kinetic energies are below 75 ft-lbf
  - Calculations from predicted and actual values put kinetic energy under 75 ft-lbf
- Drift less than the 2500 ft maximum
  - Drift has been consistently less than 2500 ft
    - Even when the winds were 19.6 ft/s on a subscale launch

Payload Requirements Verification

- Successfully deploy all parachutes
  - Multiple tests have shown successful deployment of all parachutes
- Minimize impact forces
  - PPS has been tested separately
- Protect an unspecified fragile object
  - There is a design to adapt to many objects
- Send data back to ground station
  - A telemetry system has been designed as well as GPS components

Testing!

Payload Tests

- Dampening test- testing effectiveness of exterior dampening system
- Paracord drop test- testing force upon main parachute deployment
- Foam dampening test- tested different types of foam in drop of payload
- Wiring test- tests connections in electronics bay
- Subscale launch- launched subscale vehicle
- Max Force test- tests maximum force on payload
- Switch test- ensure electronics bay keys turn on all electronics

Launch Vehicle Tests

- Full Scale test- test launch to full apogee
- Tracking test- ensure gps tracking works
- Parachute/structure test- ensure parachutes deploy at correct altitude and vehicle is reuseable
- Launch delay test- ensure StratoLoggers can record for 90 minutes

Launch Vehicle Tests (Continued)

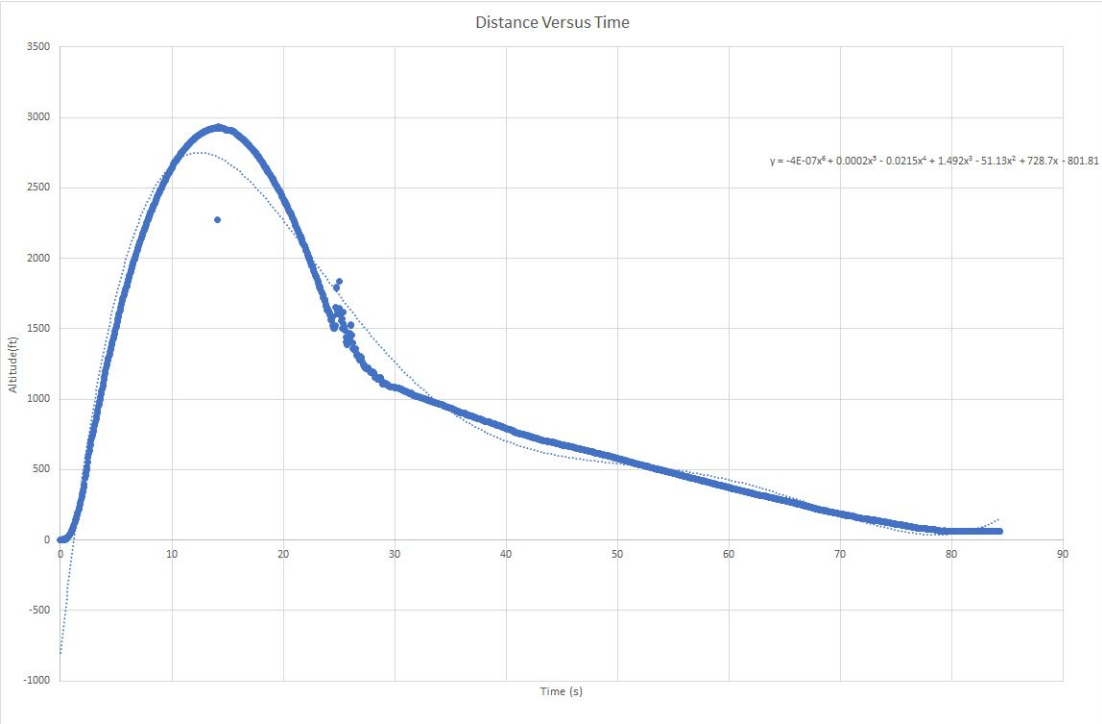
- Assembly test- ensure assembly time less than 4 hours
- Firing test- ensure motor can be lit by 12V DC current
- Acceleration test- affirm velocity at end of rail
- Kinetic energy test- ensure impact energies less than 75 ft-lb
- Interference test- ensure GPS not affected by other electronics

Launch Vehicle Tests (cont.)

- Ejection test- ensure charges will separate sections and deploy parachutes
- Parachute Deployment Test- ensure parachutes deploy

Full Scale Launch Video

Full Scale Test Flight Results



- Data from Stratologgers of the full scale flight
- Motor drogue released late
  - Roughly 200 ft delay
- All other tested functions performed according to expectation

Updates

- Project Update
- Payload Update
- Launch Vehicle Update

Questions?