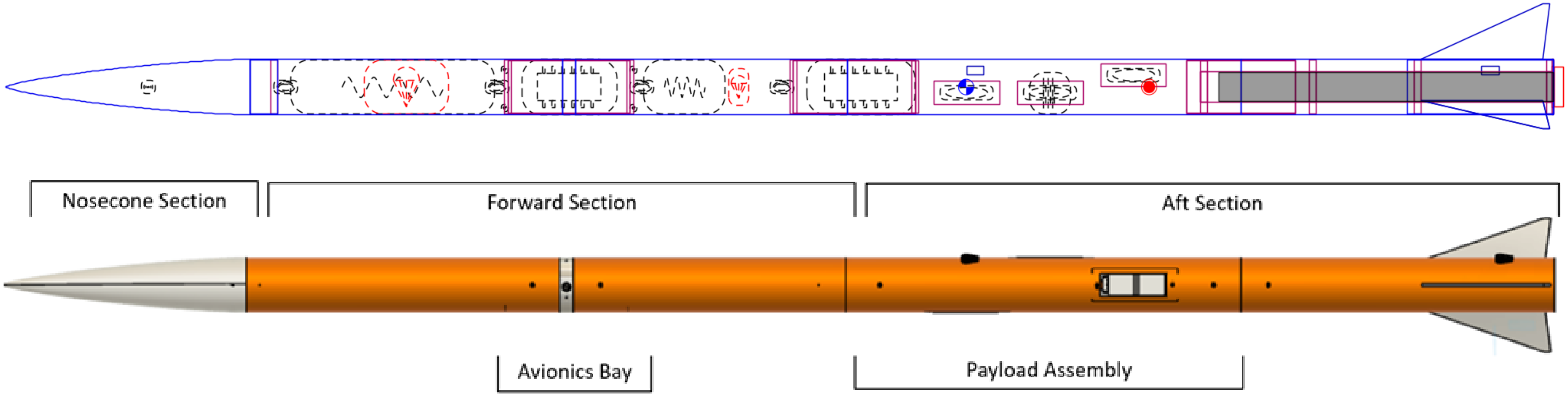
University of Florida

Critical Design Review

NASA Student Launch

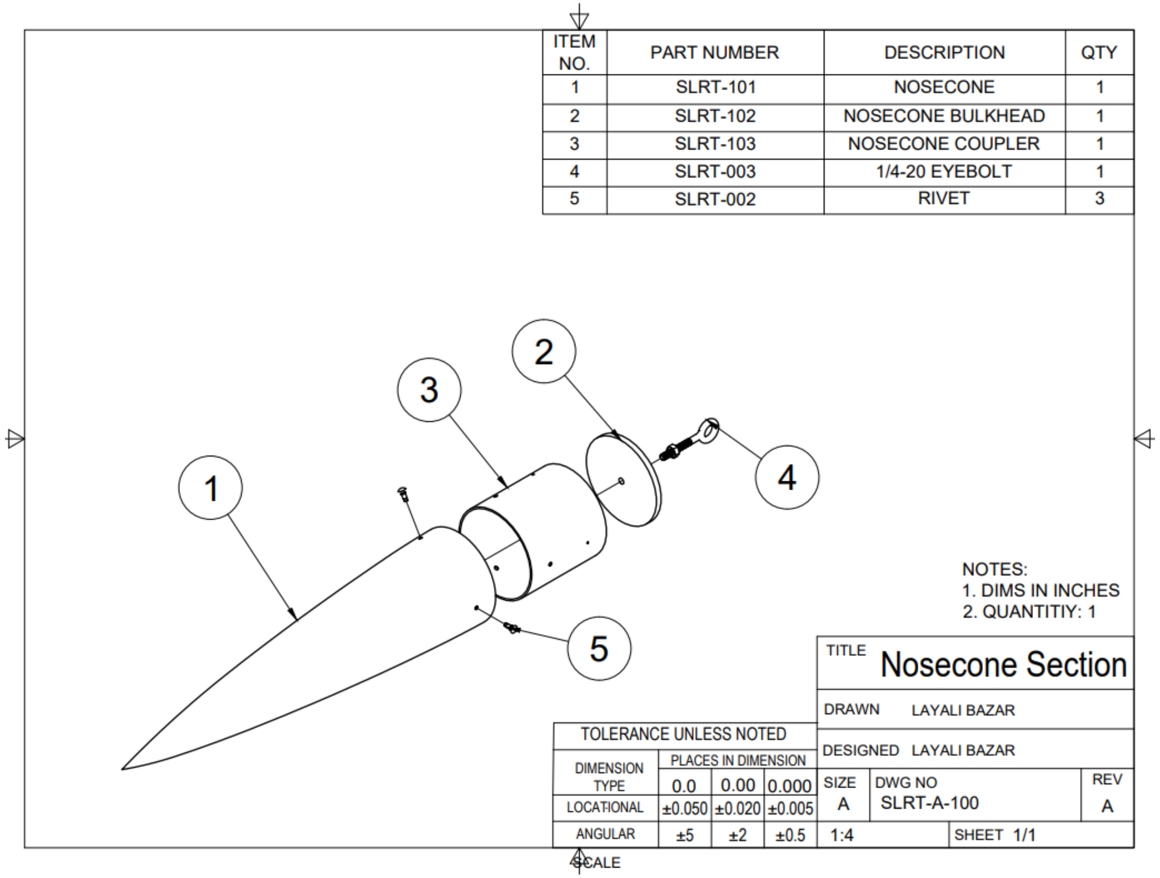
Vehicle Dimensions

Section	Length (in)	Mass (oz)
Nosecone	18.0	26.9
Forward	44.0	126.8
Aft	53.0	266.6
Total	**115.0**	**420.0**

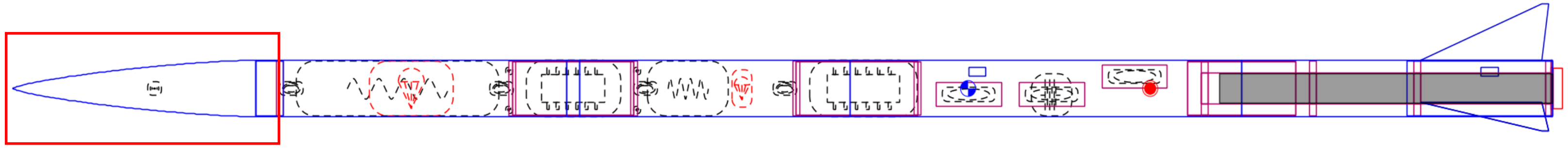


Final Design: Nosecone Section

- Nosecone Section
    - 4.02 in diameter G12 Fiberglass 4.5:1 Von Karman Nosecone
    - G12 Fiberglass Nosecone Shoulder
    - 3.8 in Type II PVC Nosecone Bulkhead
    - ¼-20 Steel Eyebolt
    - Steel hex nut
    - BIG RED BEE 900 GPS
    - Three 0.154 in Plastic Rivets

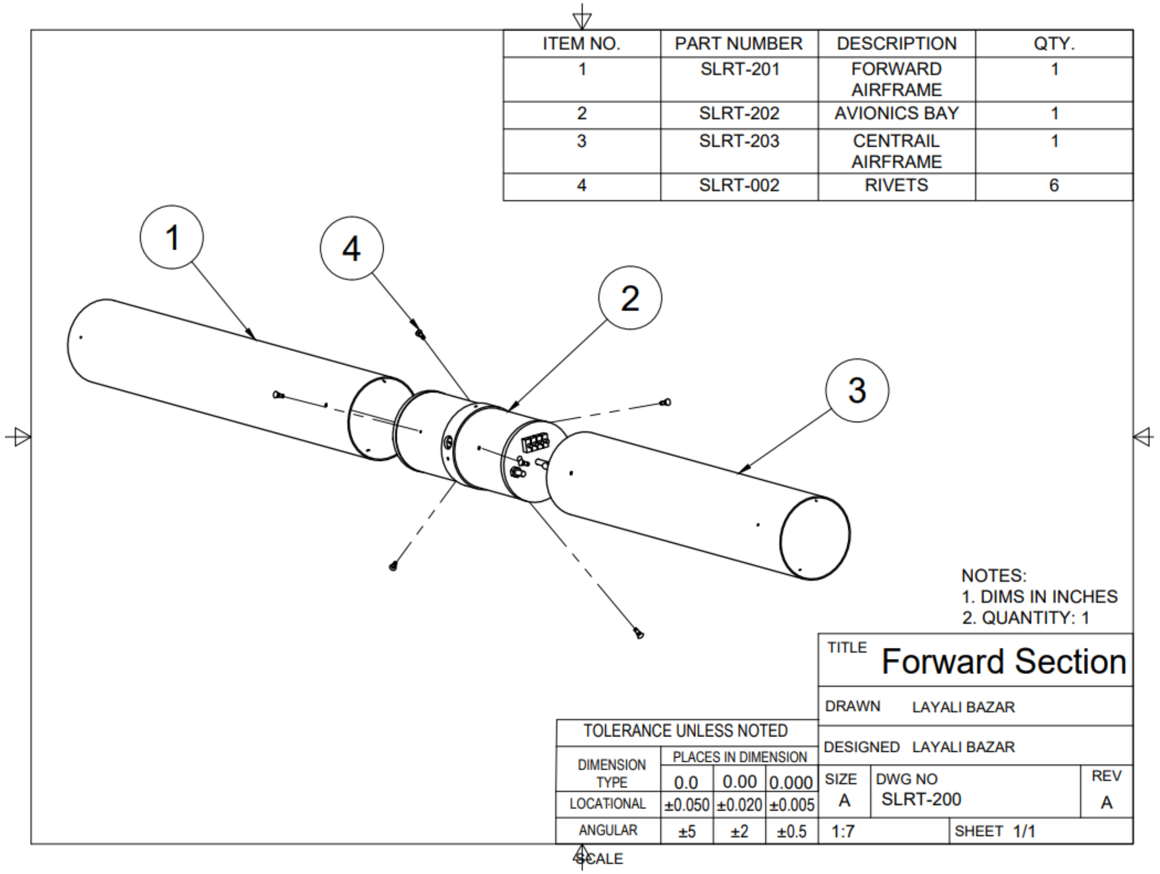


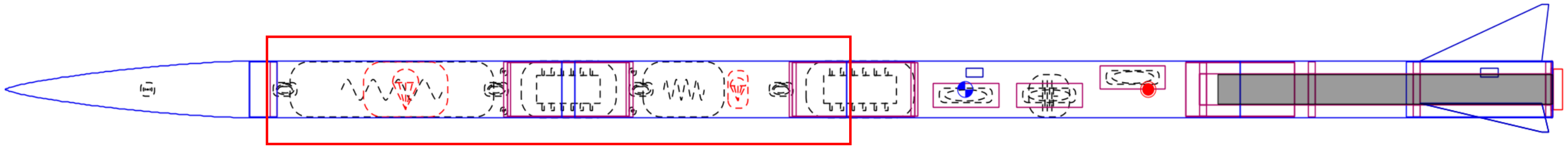
ITEM NO.	PART NUMBER	DESCRIPTION	QTY
1	SLRT-101	NOSECONE	1
2	SLRT-102	NOSECONE BULKHEAD	1
3	SLRT-103	NOSECONE COUPLER	1
4	SLRT-003	1/4-20 EYEBOLT	1
5	SLRT-002	RIVET	3



Final Design: Forward Section

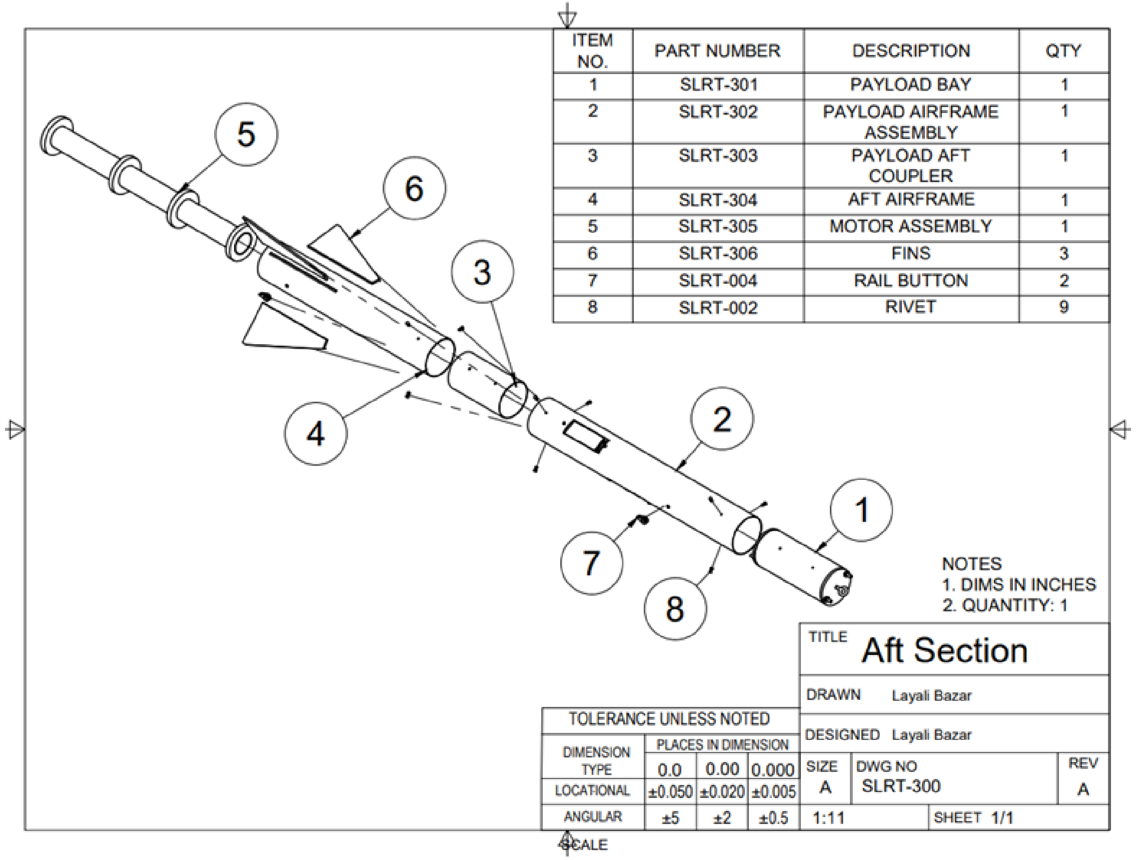
- Forward Section
  - 4.02 in G12 Fiberglass Forward Airframe
  - Avionics Bay
    - 3.898 in G12 Fiberglass Avionics Coupler
    - Two 3.8 in Type II PVC Avionics Bulkheads
    - 4.02 in G12 Fiberglass Switchband
  - 4.02 in G12 Fiberglass Central Airframe
  - Two Steel Eyebolts
  - Six 0.154 in Plastic Rivets



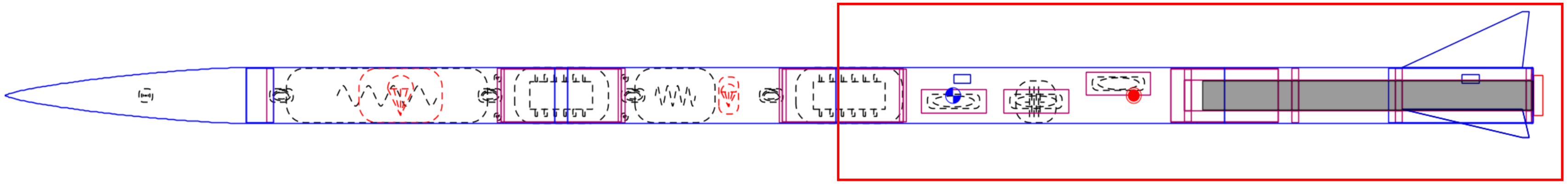


Final Design: Aft Section

- Aft Section
  - Payload Bay
    - 3.898 in G12 Fiberglass Coupler
    - Two 3.8 in Type II PVC Payload Bulkheads
  - 4.02 in G12 Fiberglass Payload Airframe
    - Three Payload Housings
    - Six 8-32 Screws
  - 3.898 in G12 Fiberglass Payload Aft Coupler
  - 4.02 in G12 Fiberglass Aft Airframe
  - Three 3/16 in thick G10 Fiberglass fins
  - Motor Assembly
    - Four 0.5 in thick Plywood Centering Rings
    - 2.24 in G12 Fiberglass Motor Tube
  - Two Delrin-Plastic Rail Buttons
  - Six 0.154 in Plastic Rivets



ITEM NO.	PART NUMBER	DESCRIPTION	QTY
1	SLRT-301	PAYLOAD BAY	1
2	SLRT-302	PAYLOAD AIRFRAME ASSEMBLY	1
3	SLRT-303	PAYLOAD AFT COUPLER	1
4	SLRT-304	AFT AIRFRAME	1
5	SLRT-305	MOTOR ASSEMBLY	1
6	SLRT-306	FINS	3
7	SLRT-004	RAIL BUTTON	2
8	SLRT-002	RIVET	9

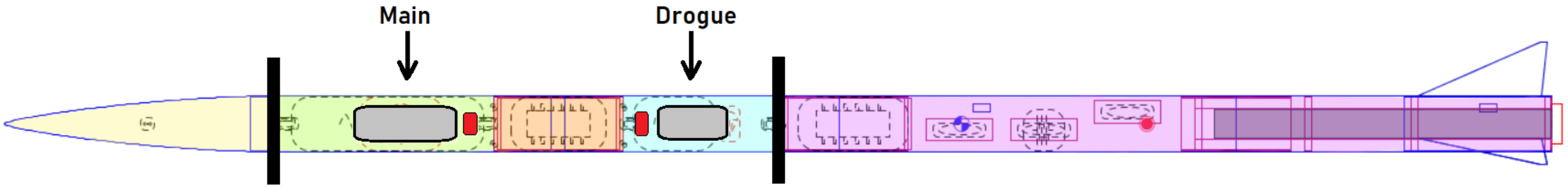


Separation Points

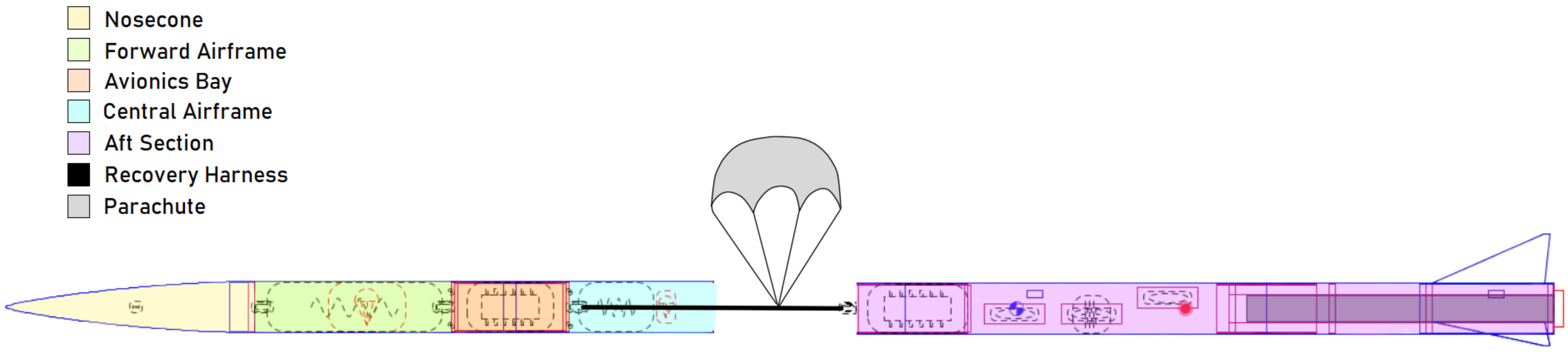
Component		Description
Main Ejection Charge	Primary	2.8 g at 600 ft AGL
	Secondary	3.5 g at 550 ft AGL
Drogue Ejection Charge	Primary	1.7 g at apogee
	Secondary	2.1 g at 1s after apogee

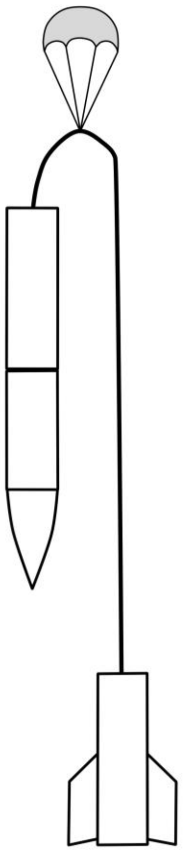
All ejection charges are black powder

- Nosecone
- Forward Airframe
- Avionics Bay
- Central Airframe
- Aft Section
- Separation Point
- Parachute
- Ejection Charge



First Separation Event

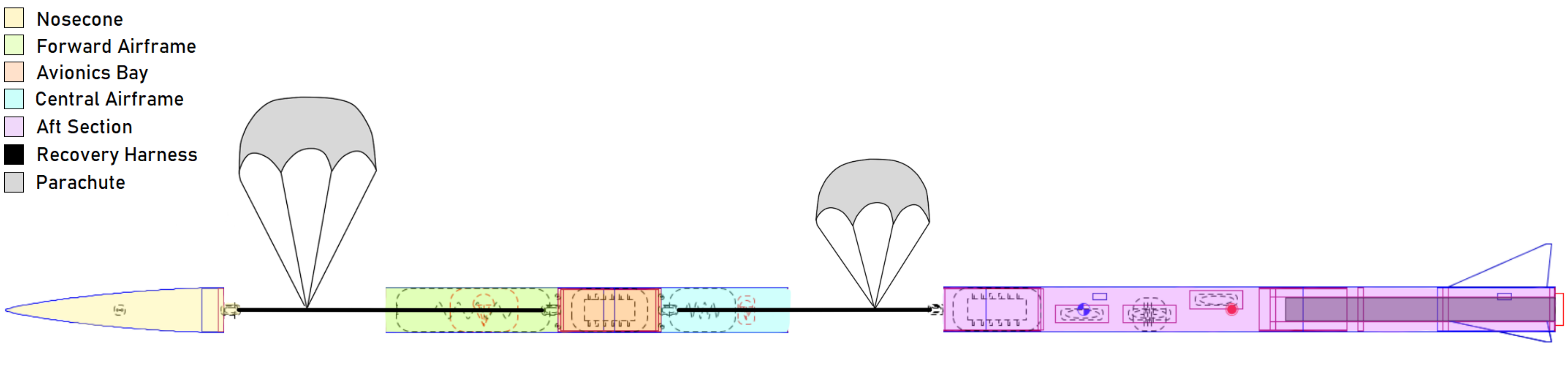




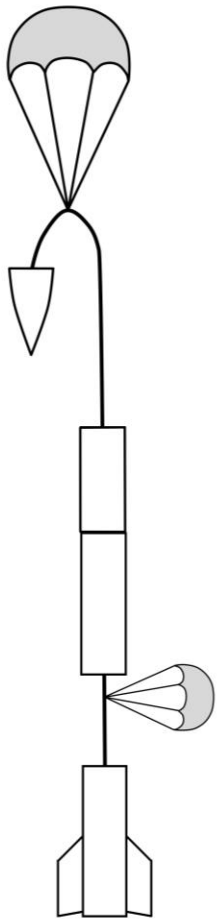
Drogue

Component Type	Component Name	C_D	Location	Descent Rate (ft/s)
Drogue Parachute	24" Rocketman Standard	0.97	Central Airframe	81.8
Aft Recovery Harness	7/16" Tubular Kevlar, 25 ft long	N/A	Central Airframe	N/A

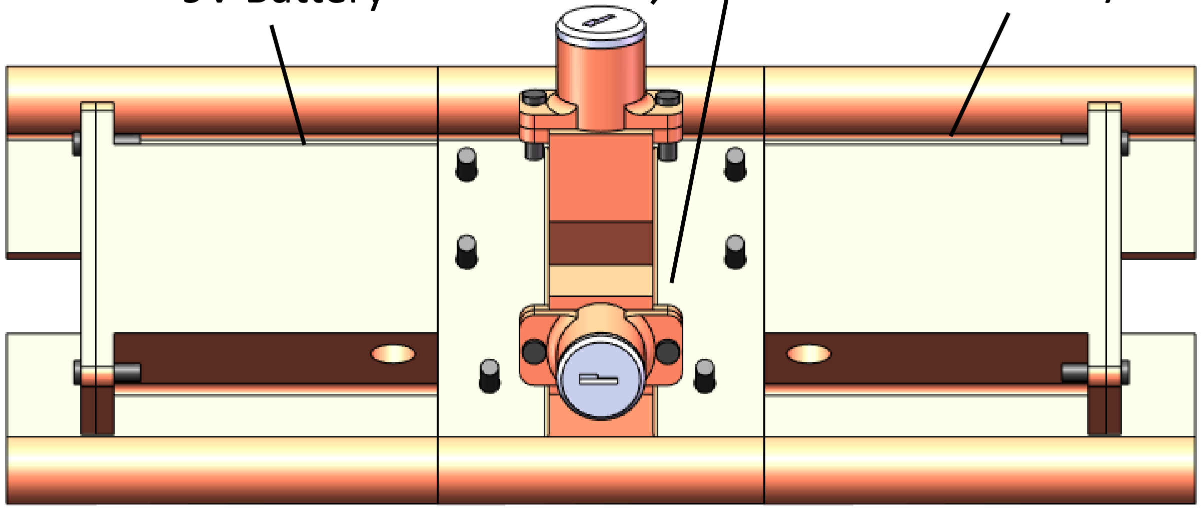
Second Separation Event

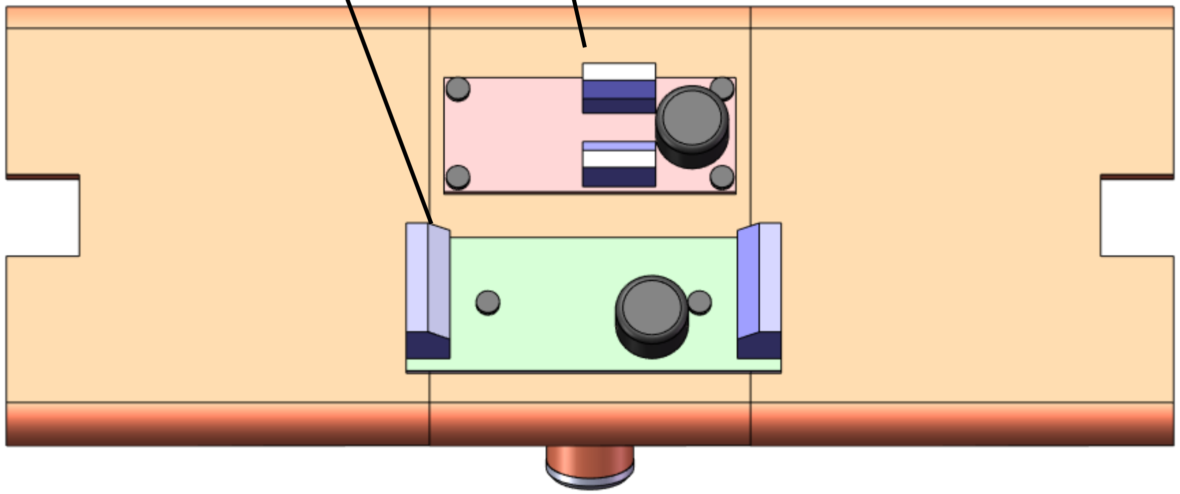


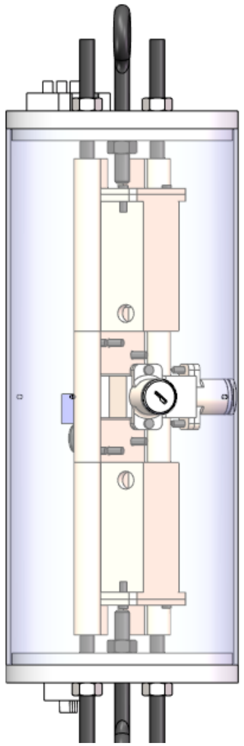
Component Type	Component Name	C_D	Location	Descent Rate (ft/s)
Main Parachute	72" Fruity Chute Iris Ultra	2.2	Forward Airframe	17.5
Forward Recovery Harness	7/16" Tubular Kevlar, 25 ft long	N/A	Forward Airframe	N/A



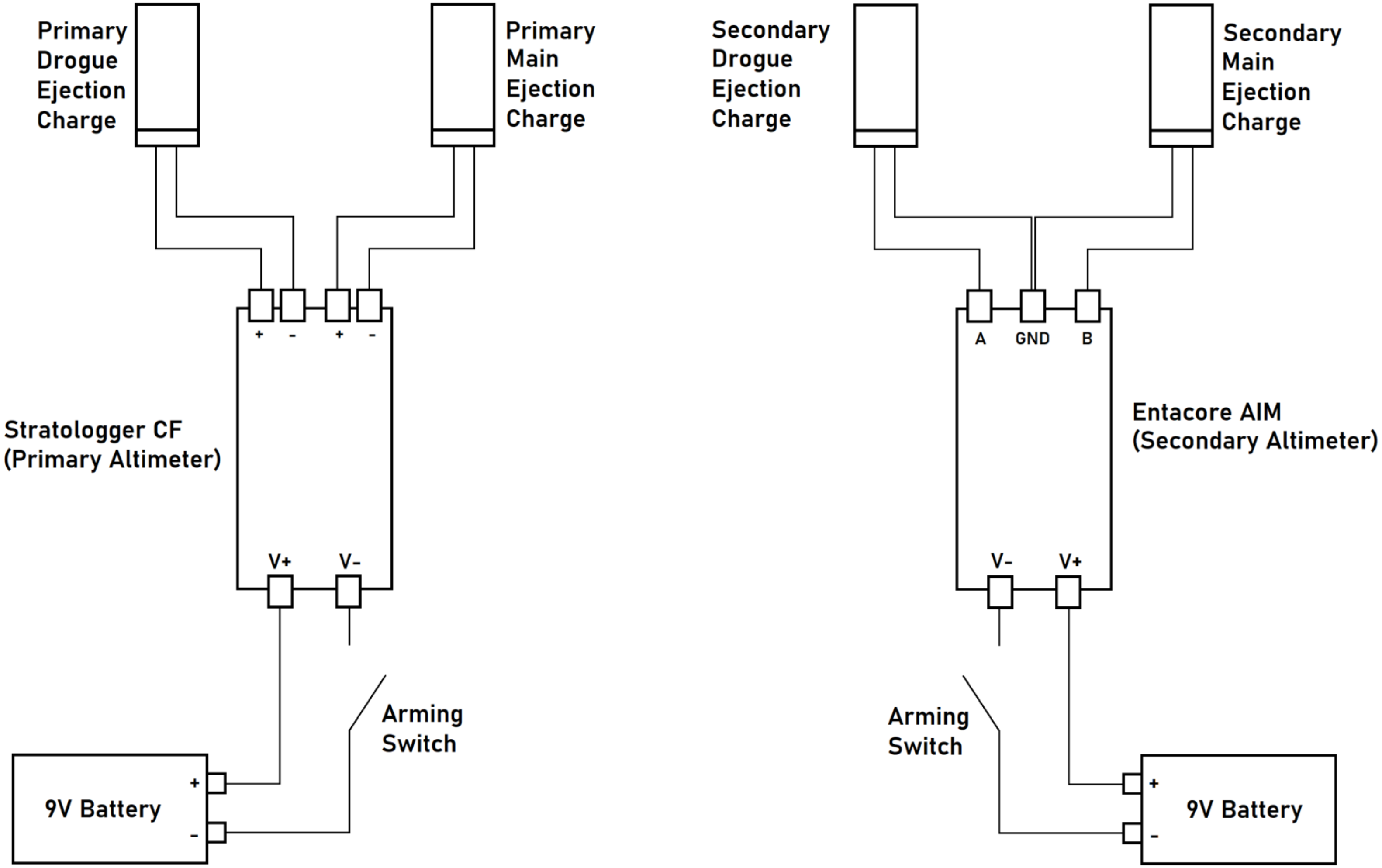
Avionics Bay





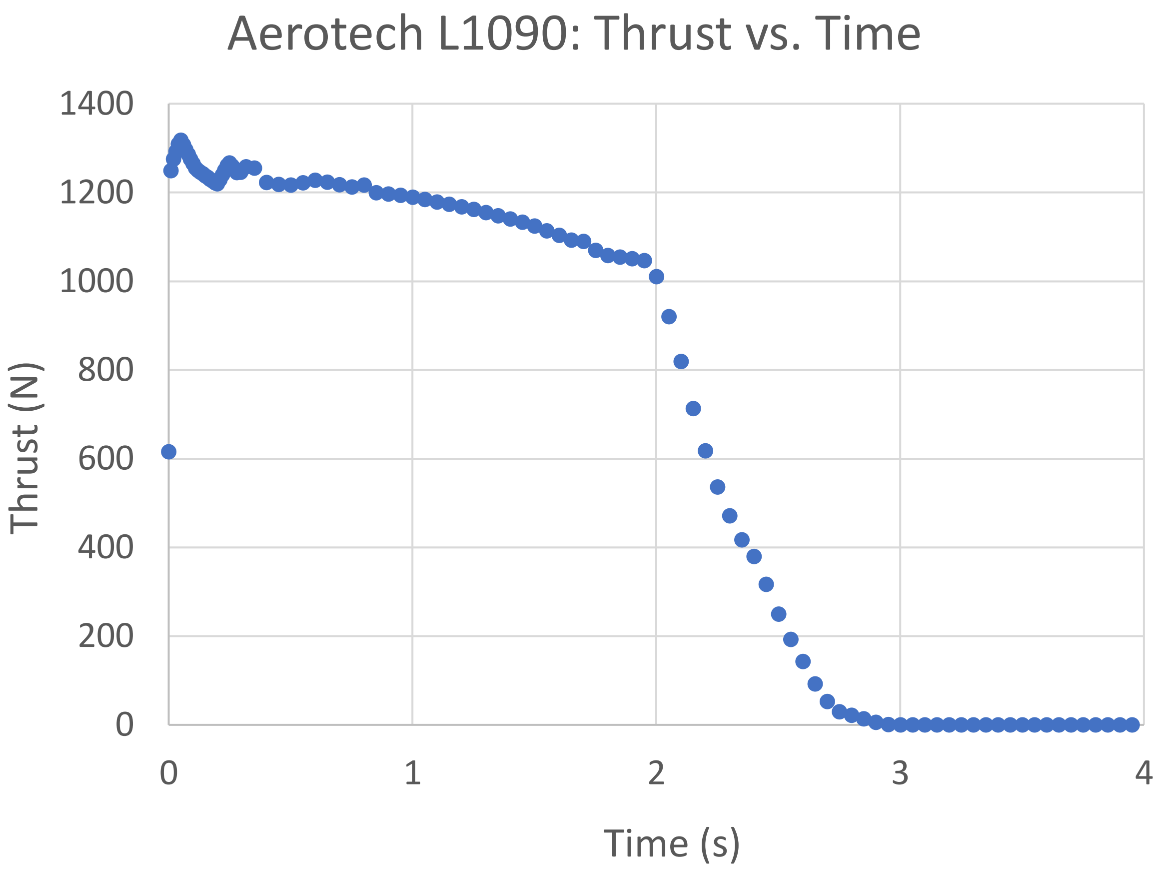


Altimeter Wiring



Motor Selection

- Motor: L1090W
- Impulse: 2671 N-s
- Maximum Thrust: 1487 N
- Propellant Mass: 1400 g
- Burn Time: 2.5 s
- Thrust to Weight Ratio: 8.53:1



Mission Performance Predictions

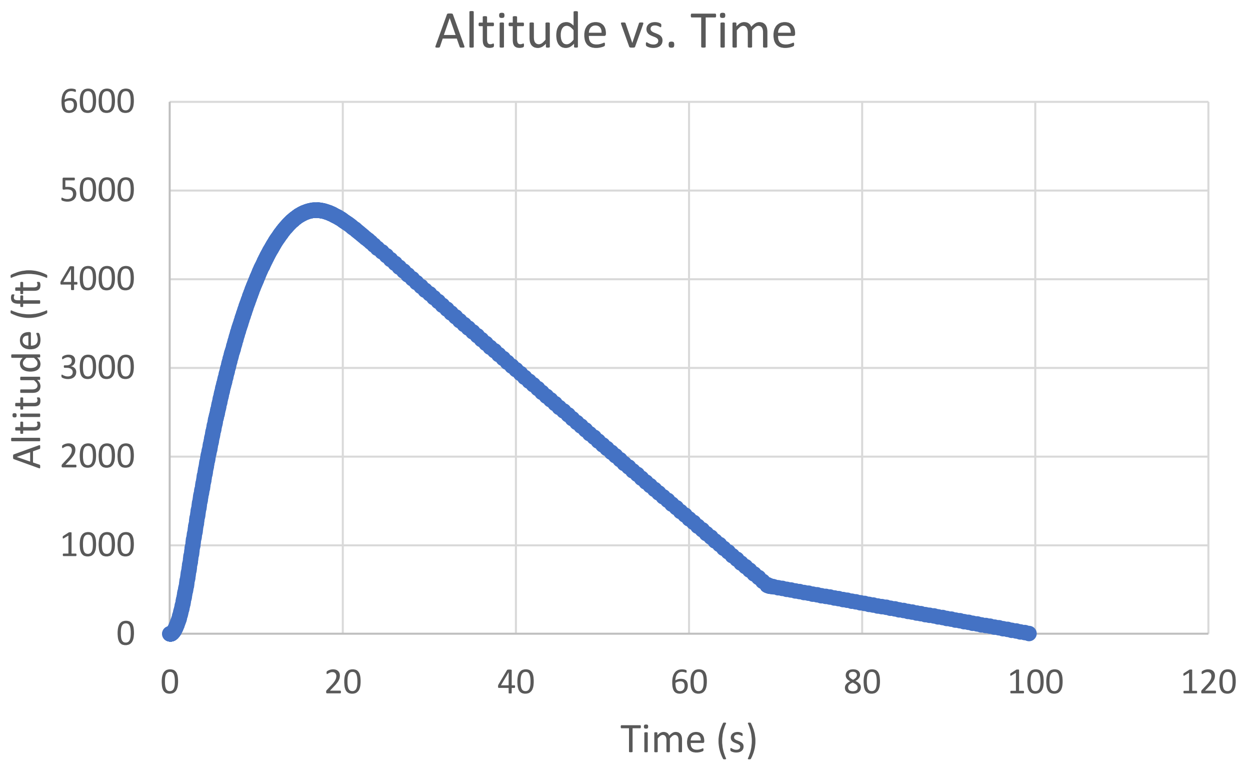
Mission Performance Predictions	
Apogee Altitude	4780 ft
Rail Exit Velocity	87 ft/s
Maximum Velocity	646 ft/s
Maximum Acceleration	332 ft/s^2
Launch Pad Static Stability	3.27 cal

Mission Performance Predictions: Simulation Conditions

Launch Conditions in Huntsille, AL	
Wind	5 mph
Launch Angle	10°
Launch Rod Length	144 in
Latitude	34.6 °N
Longitude	-86.7 °E
Altitude	800 ft
Temperature	80 °F
Pressure	1 atm

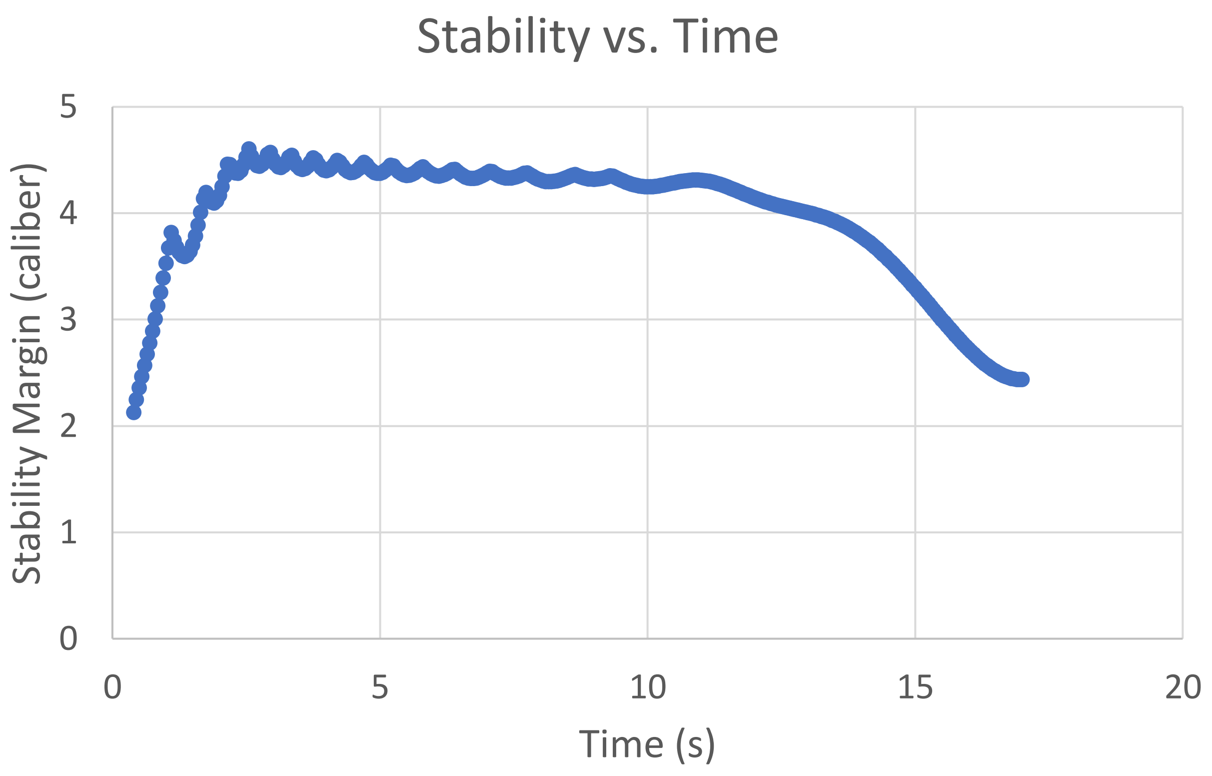
Mission Performance Predictions: Altitude

- Simulated Apogee: 4780 ft
- Target Apogee: 4600 ft



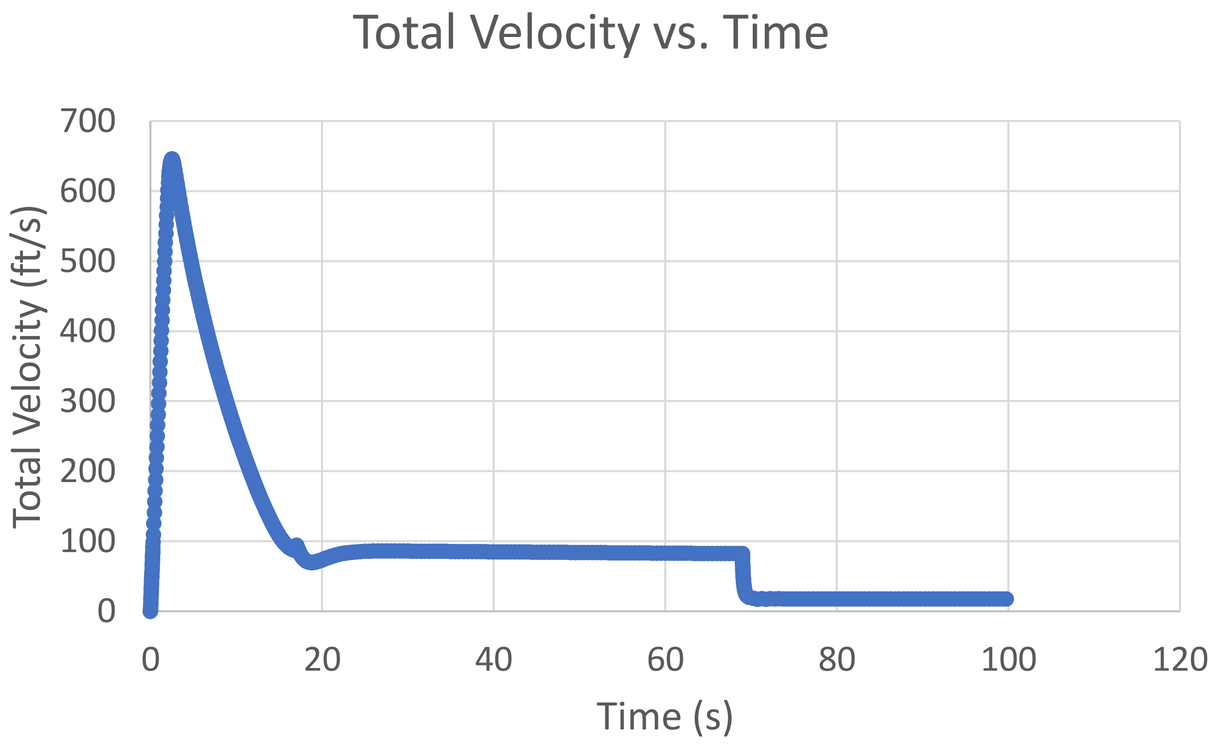
Mission Performance Predictions: Stability

- Stability Margin at Rail: 3.27 cal
- Stability Margin at Rail Exit: 2.13 cal
- Maximum Stability Margin: 4.39 cal



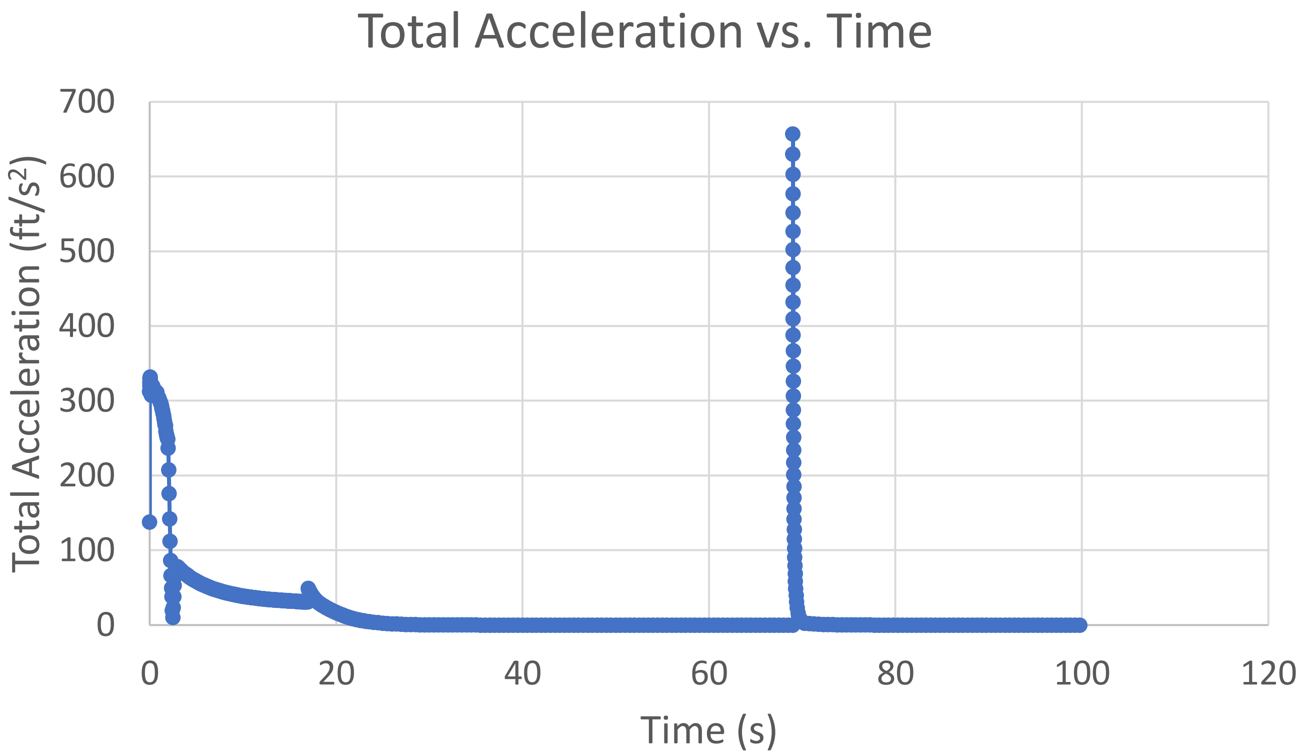
Mission Performance Predictions: Velocity

- Velocity at Rail Exit: 87 ft/s
- Maximum Velocity: 646 ft/s
- Maximum Mach Number: 0.57



Mission Performance Predictions: Acceleration

- Maximum Acceleration: 332 ft/s^2



Descent Time

Excel Calculations:

$$descent\ time = \frac{apogee - main\ deployment\ height}{drogue\ descent\ rate} + \frac{main\ deployment\ height}{main\ descent\ rate}$$

OpenRocket Simulation:

$$descent\ time = flight\ time - time\ to\ apogee$$

MATLAB Simulation:

$$\begin{cases} 0 = \frac{1}{2}\rho v^2 S_{drogue} C_{D,drogue} - mg, & h_{main} < h \leq h_{apogee} \\ 0 = \frac{1}{2}\rho v^2 S_{main} C_{D,main} - mg, & h_{main} \leq h \leq h_{apogee} \end{cases}$$

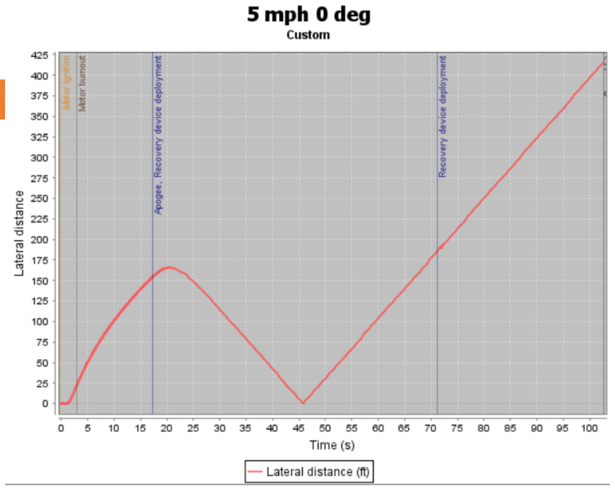
Descent Time Results		
Excel Calculations	Time under drogue	51.1 s
	Time under main	34.3 s
	Descent time	**85.4 s**
OpenRocket Simulation	Flight time	99.8 s
	Time to apogee	16.9 s
	Descent time	**82.9 s**
MATLAB Simulation	Descent time	**84.1 s**

Descent Rates from OpenRocket	
Drogue Parachute	81.8 ft/s
Main Parachute	17.5 ft/s

Drift Calculations

Excel Calculations and MATLAB Simulation: $drift = descent\ time * wind\ speed$

OpenRocket Simulation: $drift = peak\ lateral\ distance + total\ lateral\ distance$



Drift Calculation Results						
Wind Speed		**0 mph**	**5 mph**	**10 mph**	**15 mph**	**20 mph**
Excel Calculations	Drift under drogue	0 ft	375 ft	749 ft	1124 ft	1499 ft
	Drift under main	0 ft	251 ft	503 ft	754 ft	1006 ft
	Drift	**0 ft**	**626 ft**	**1252 ft**	**1878 ft**	**2505 ft**
OpenRocket Simulation	Peak lateral distance	8 ft	166 ft	294 ft	337 ft	355 ft
	Total lateral distance	7 ft	416 ft	868 ft	1421 ft	2028 ft
	Drift	**15 ft**	**582 ft**	**1162 ft**	**1758 ft**	**2383 ft**
MATLAB Simulation	Drift	**0 ft**	**616 ft**	**1233 ft**	**1849 ft**	**2466 ft**

Kinetic Energy At Ground Hit

$$kinetic\ energy = \frac{1}{2} * m_{section} * main\ descent\ rate^2$$

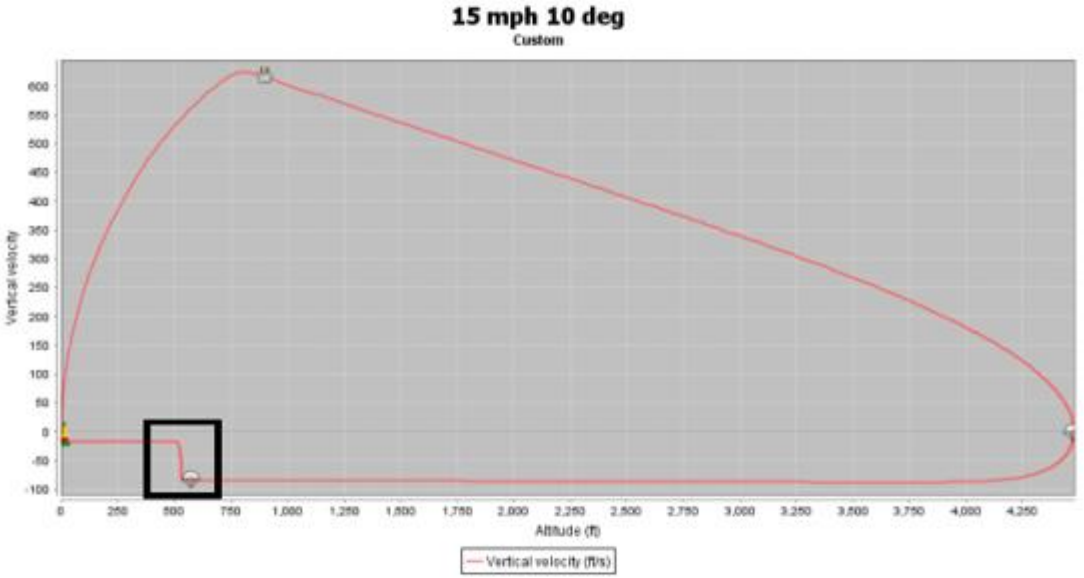
Kinetic Energy at Ground Hit			
Section	Nosecone	Central	Aft
Excel Calculations (ft-lbs)	8.0	37.7	64.5
MATLAB (ft-lbs)	8.2	38.6	66.1

Kinetic Energy at Main Deployment		
Section	Central, Forward and Nosecone	Aft
Excel Calculations (ft-lbs)	999.1	1409.2
MATLAB (ft-lbs)	1019.2	1438.1

Force During Main Parachute Deployment

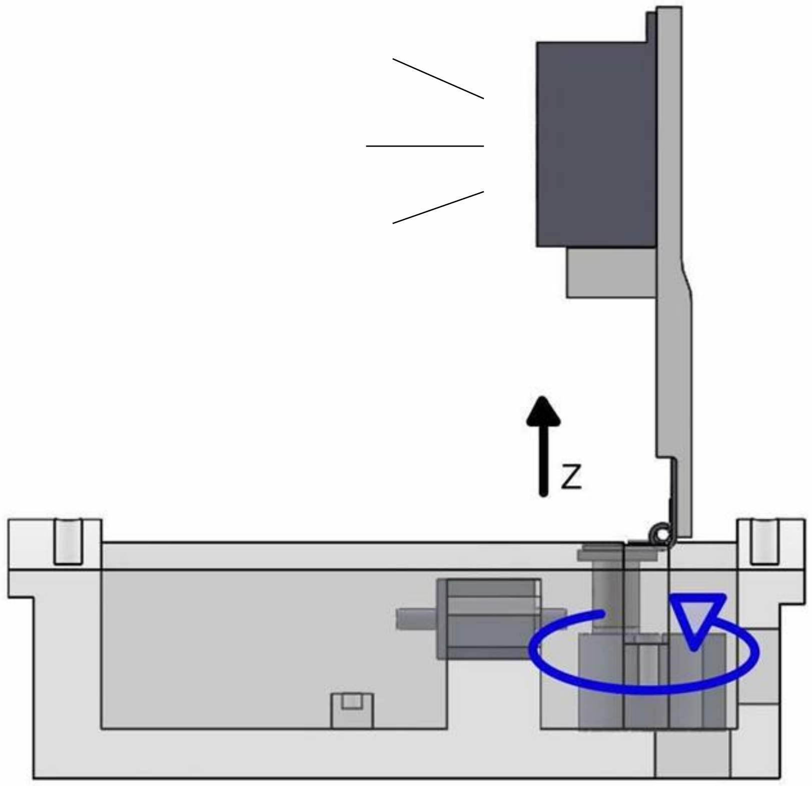
$$Load = \frac{\Delta KE}{d}$$

Predicted Deployment Load	
KE of Aft Section Under Drogue (OpenRocket)	1409.2 ft-lbs
KE of Aft Section Under Main (OpenRocket)	64.5 ft-lbs
ΔKE (OpenRocket)	1344.7 ft-lbs
d	75 ft
Load (OpenRocket)	**287 oz (17.9 lb)**
KE of Aft Section Under Drogue (MATLAB)	1438.1 ft-lbs
KE of Aft Section Under Main (MATLAB)	66.1 ft-lbs
ΔKE (MATLAB)	1372.0 ft-lbs
Load (OpenRocket)	**293 oz (18.3 lb)**



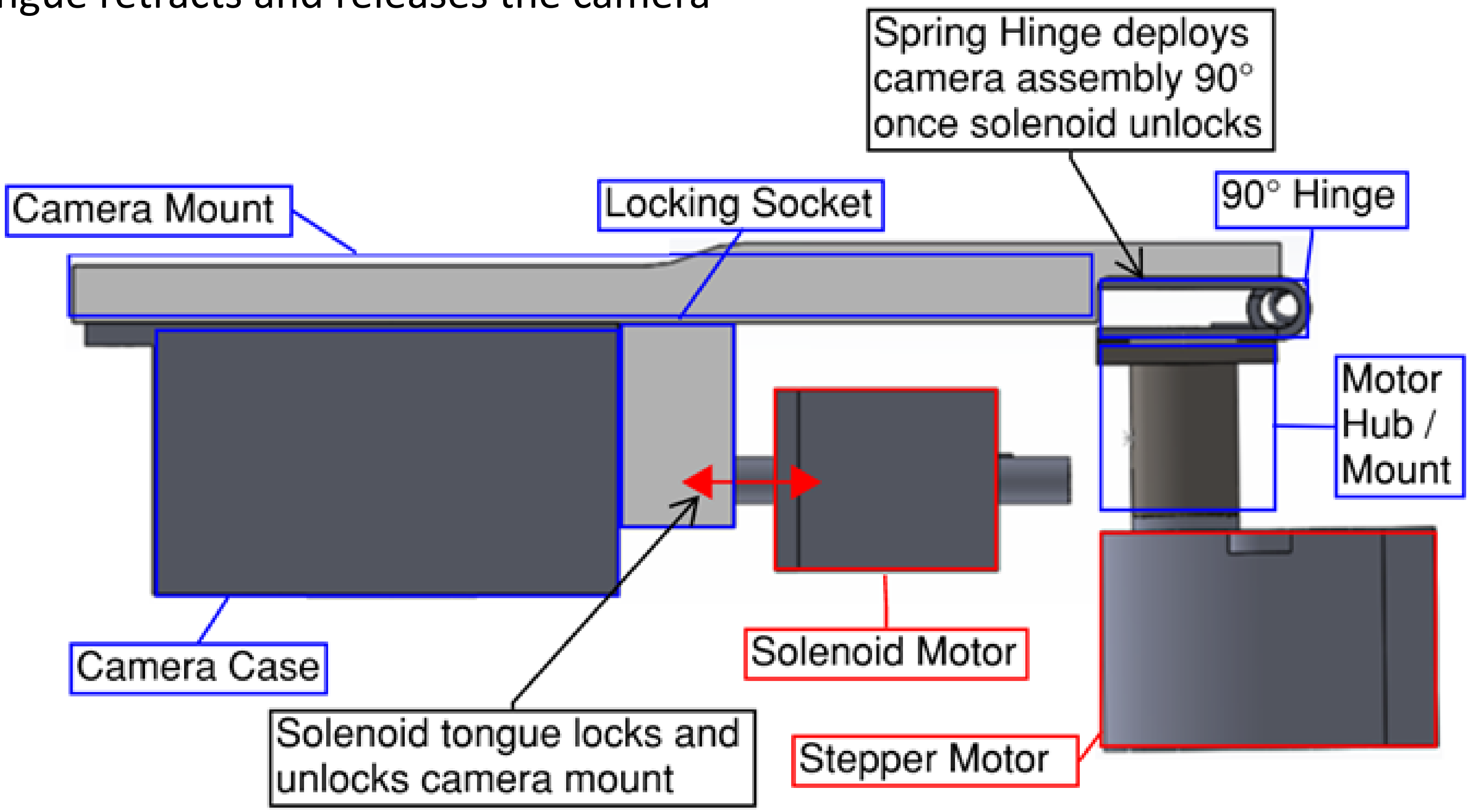
Payload Design Overview

- Three payload systems align with three fins
- One system rotates out on a spring-hinge 90°
- It can rotate about the z-axis using a stepper motor
- IMU detects landing and orientation
- SDR Dongle receives, and Raspberry Pi decodes APRS



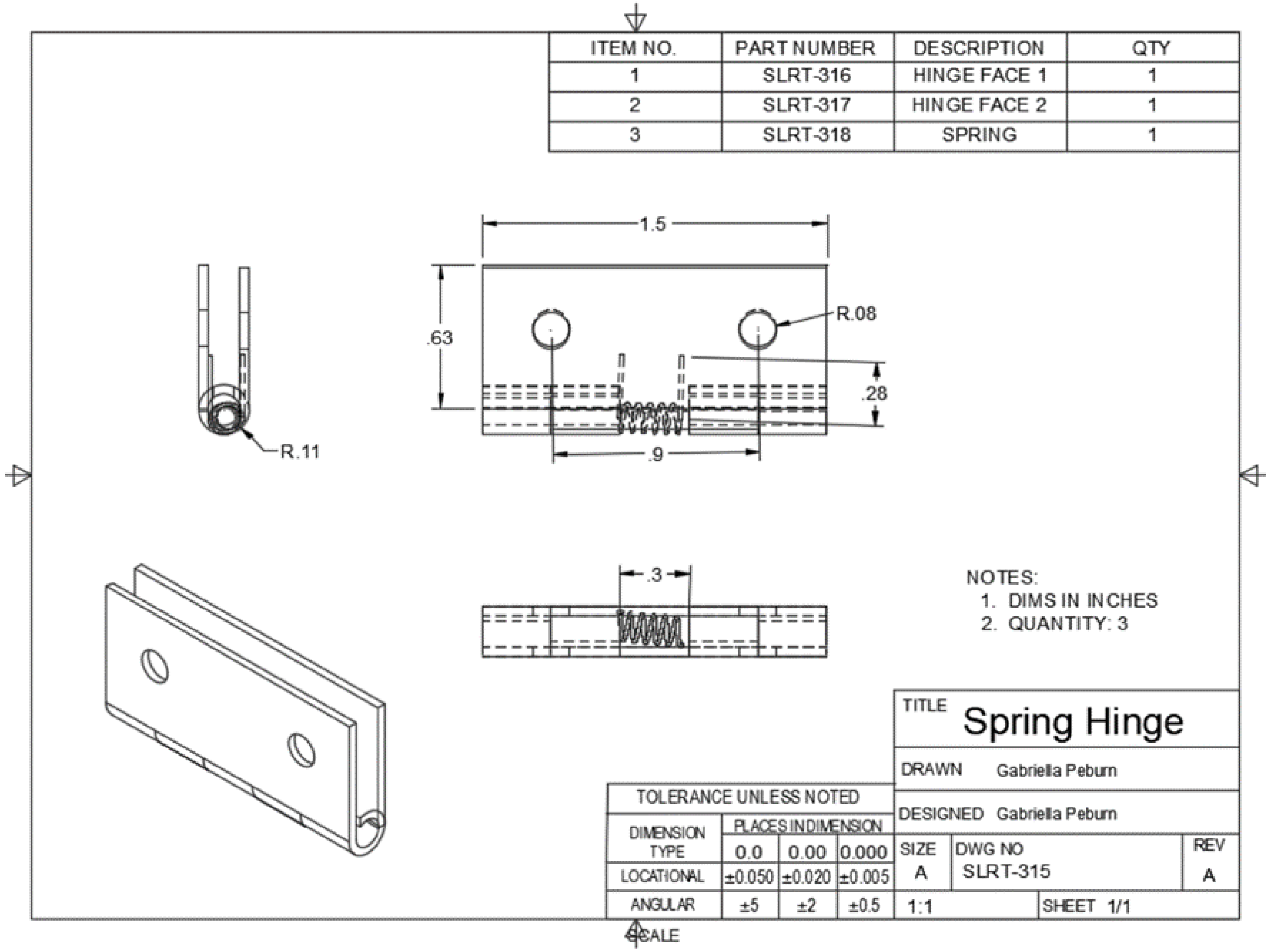
Payload Mechanical Overview

- Camera system rotates out 90° on a spring-loaded hinge when the solenoid tongue retracts and releases the camera mount



Payload Mechanical Overview

- The spring-loaded hinge is secured closer to the forward end of the airframe
- Direction of the airflow will always push the hinge closed
- Protects launch vehicle from aerodynamic effects of mechanical failure

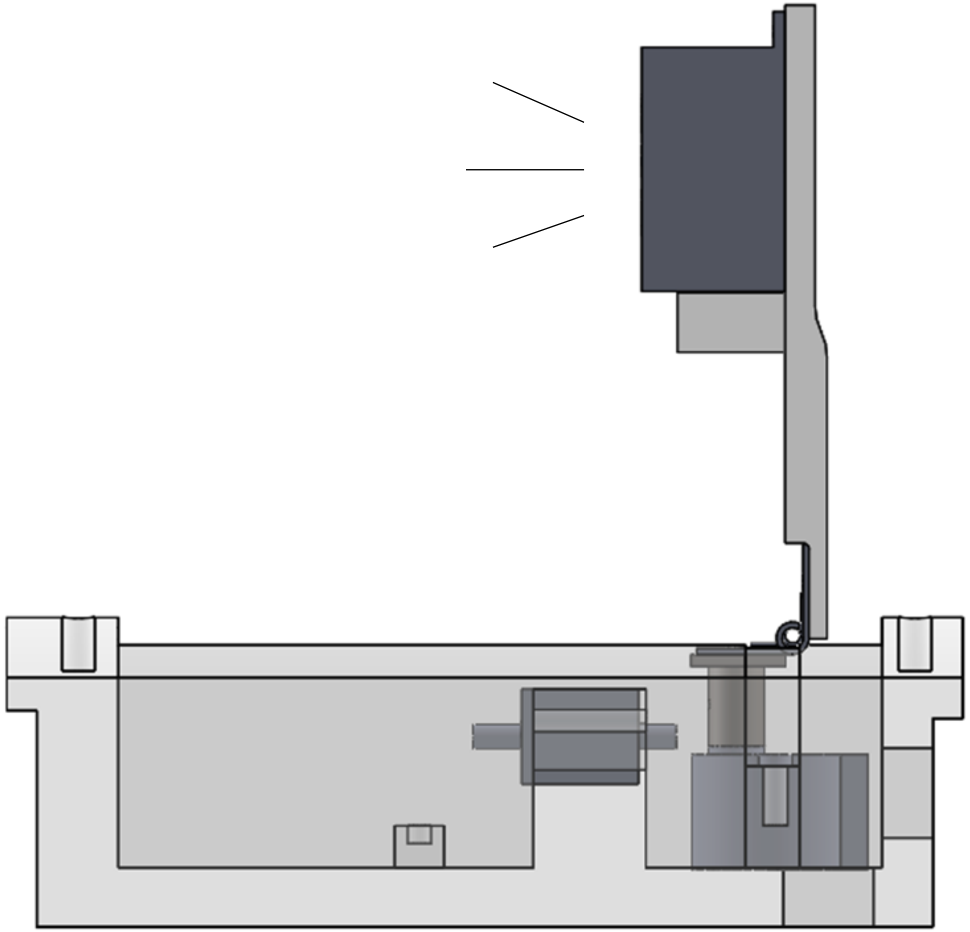


Payload Mechanical System

- When the solenoid is retracted, the camera mount system will rotate up so the spring-loaded hinge will spring to its naturally released state

- The spring-loaded hinge is fastened to a motor hub. The torque is transmitted through one M6 threaded insert and set screw.

- The spring mount is secured to a stepper motor that rotates the camera system about the z-axis.

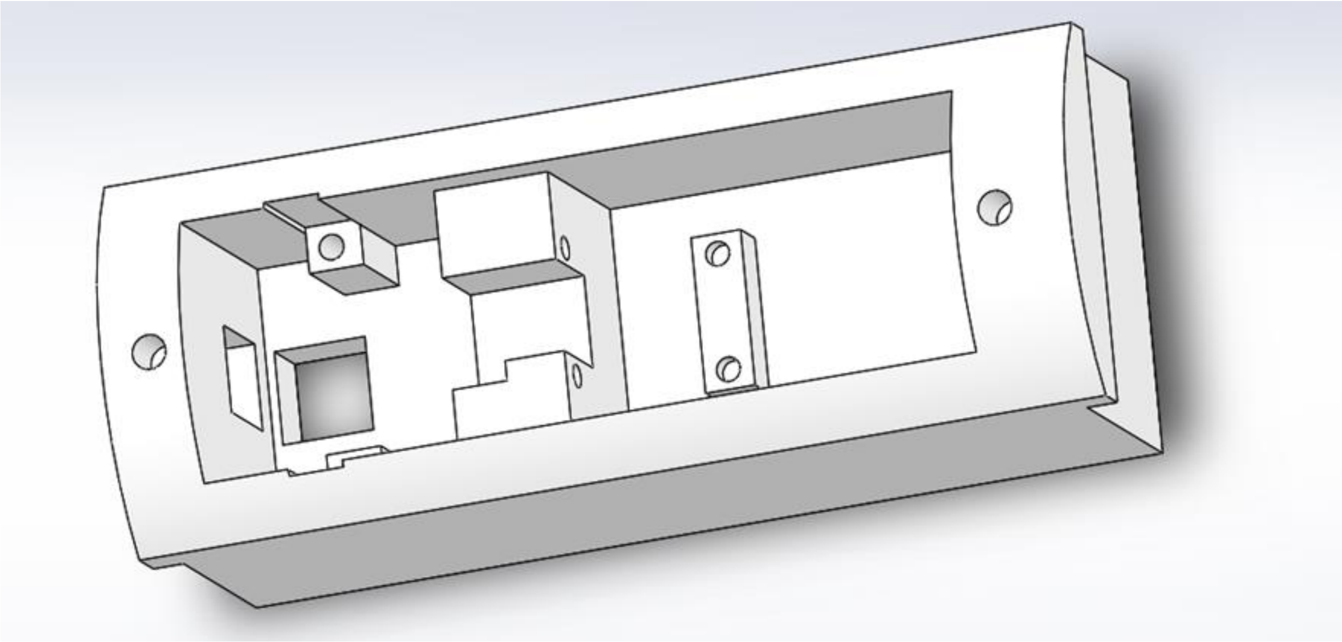


Payload Housing Retention System

- Each of the three camera systems has its own housing secured with 8-32 fasteners

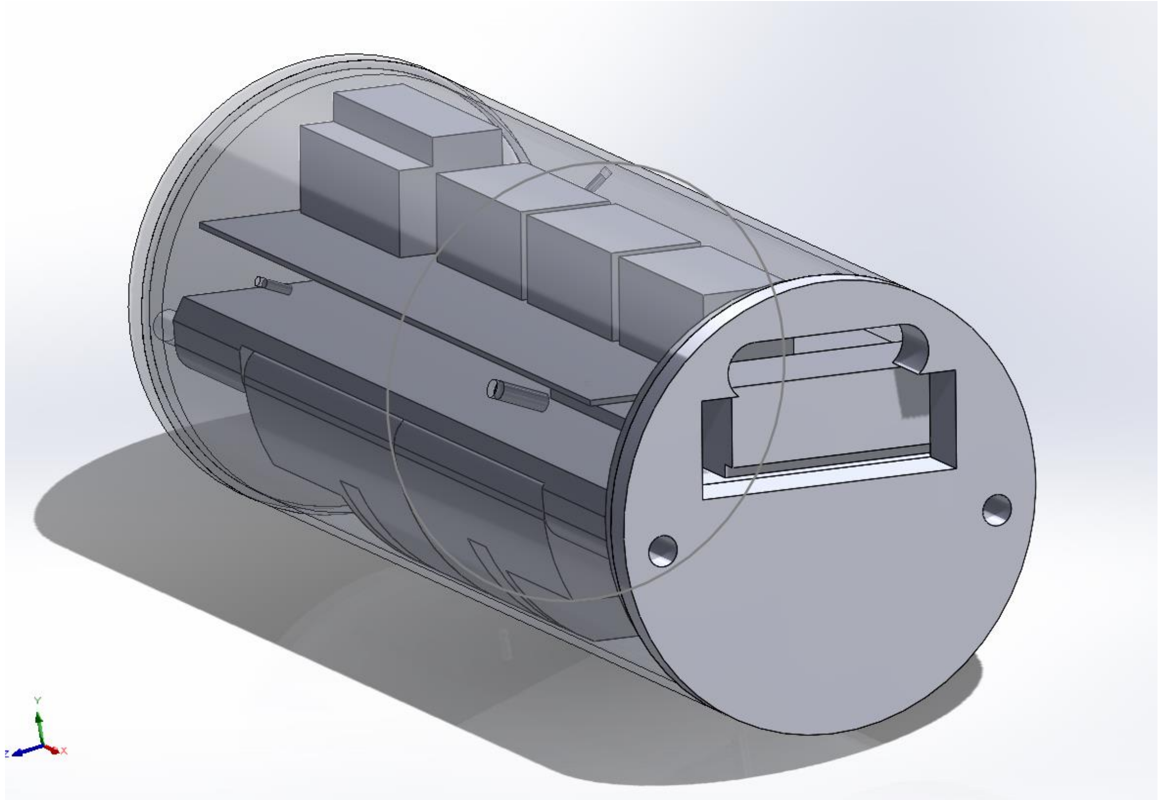
- Secures the motors and components
- Protects the launch vehicle from mechanical failure

- One central housing contains the radio



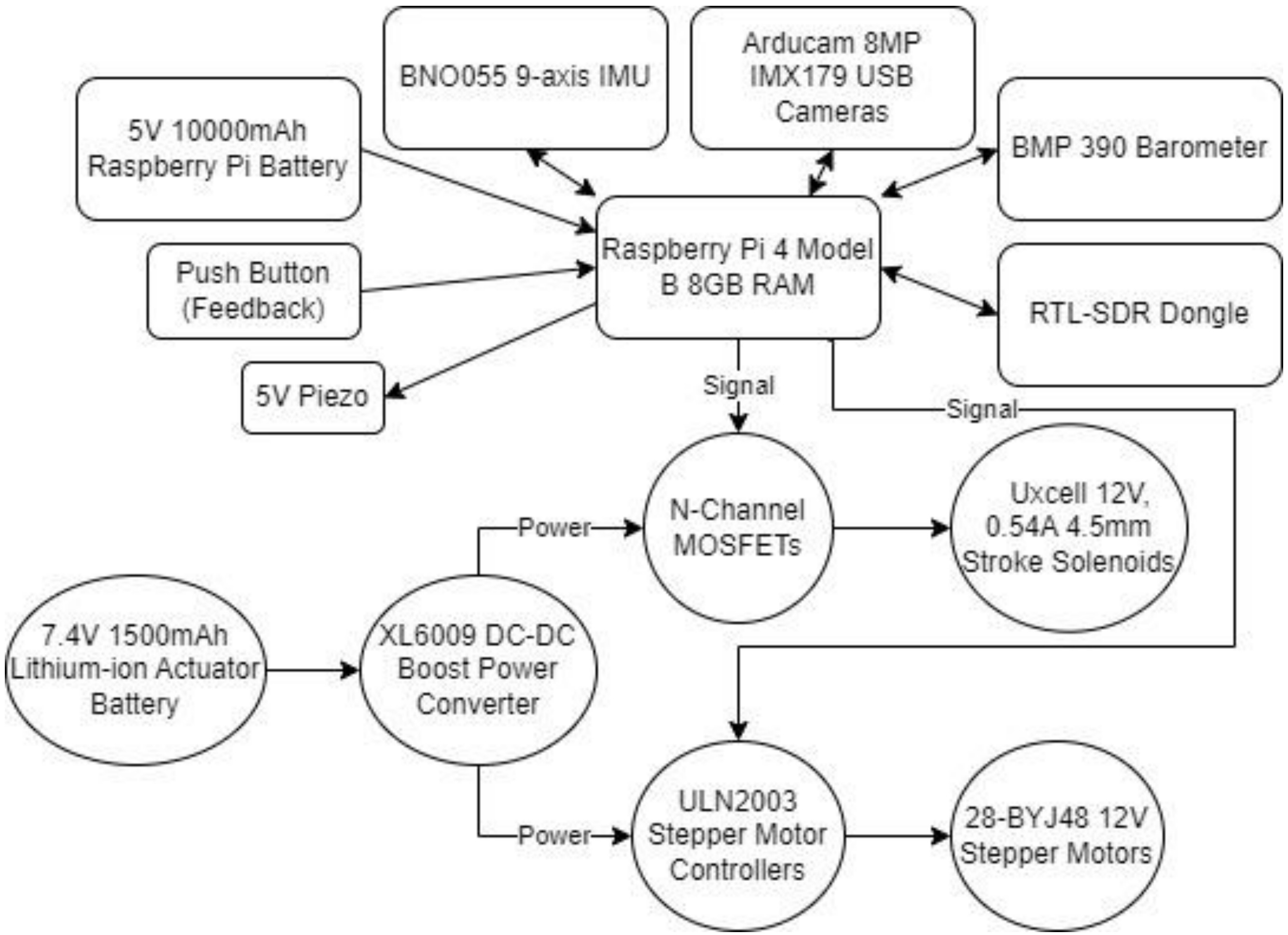
Payload Electronics Retention System

- The electronics are contained in the payload aft coupler
- Fitted on a 3D printed sled and secured with threaded inserts
- The batteries have their own 3D printed housing fastened to the threaded rod



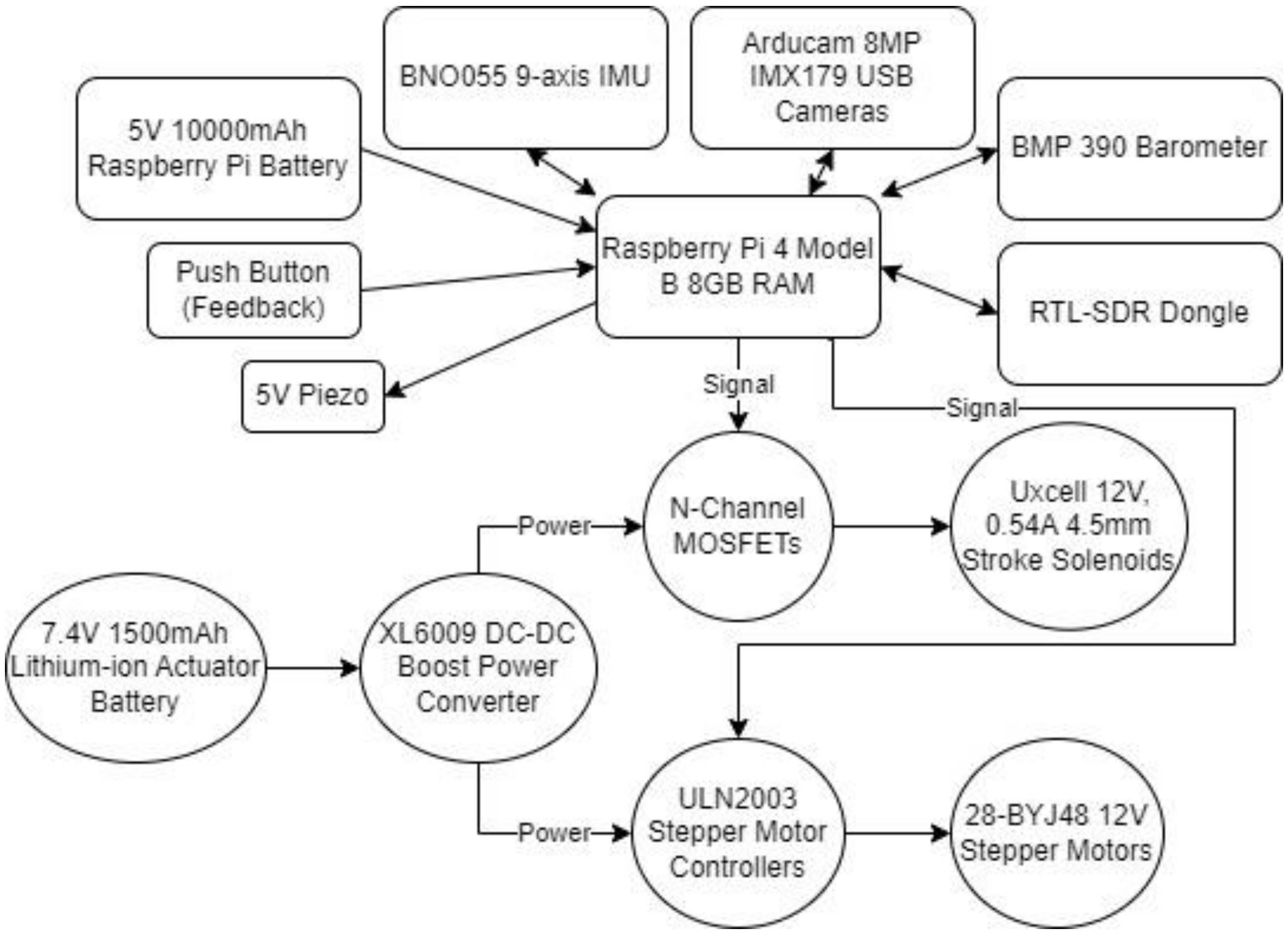
Payload Electronics (Core & Inputs)

- Microprocessor
  - Raspberry Pi 4 8GB RAM
- Input
  - BNO055 IMU – 9-axis
  - BMP390 Barometer – 0.25m
  - USB Cameras – 8MP, 150 FOV
  - RTL-SDR Dongle (USB)
  - Push Buttons



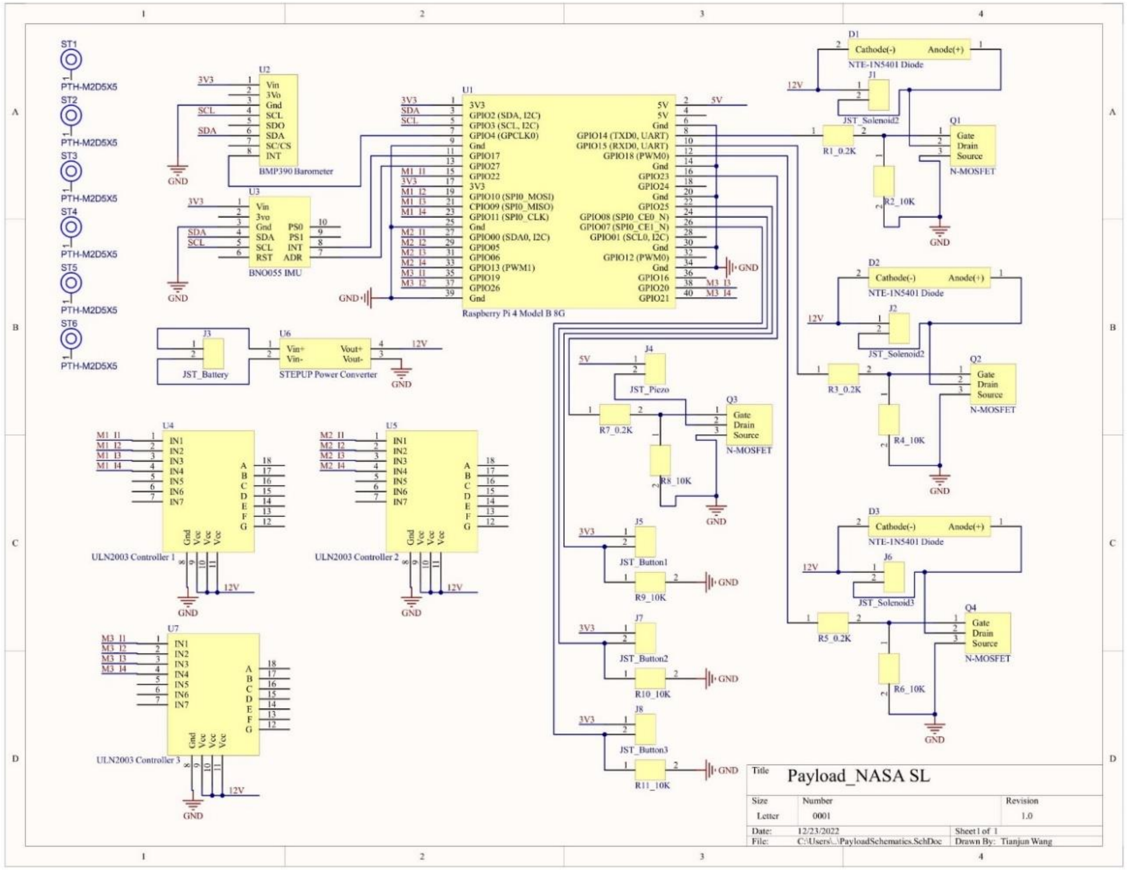
Payload Electronics (Outputs & Power)

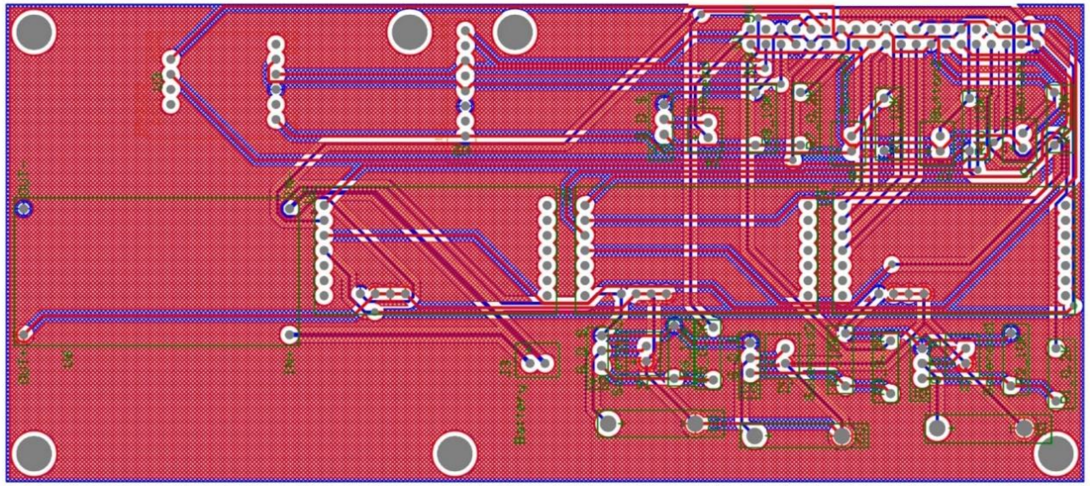
- Output
  - Piezo
    - 5V Direct Current
  - Actuator Subsystem
    - 4.5mm Stroke Solenoids
    - N-Channel MOSFETs
    - 28-BYJ48 12V Stepper Motors
    - ULN2003 Controllers
- Power Supply
  - 5V 10000mAh Power Bank
  - 7.4V 1500mAh Li-ion Battery
  - XL6009 DC-DC Converter



Payload Electronics

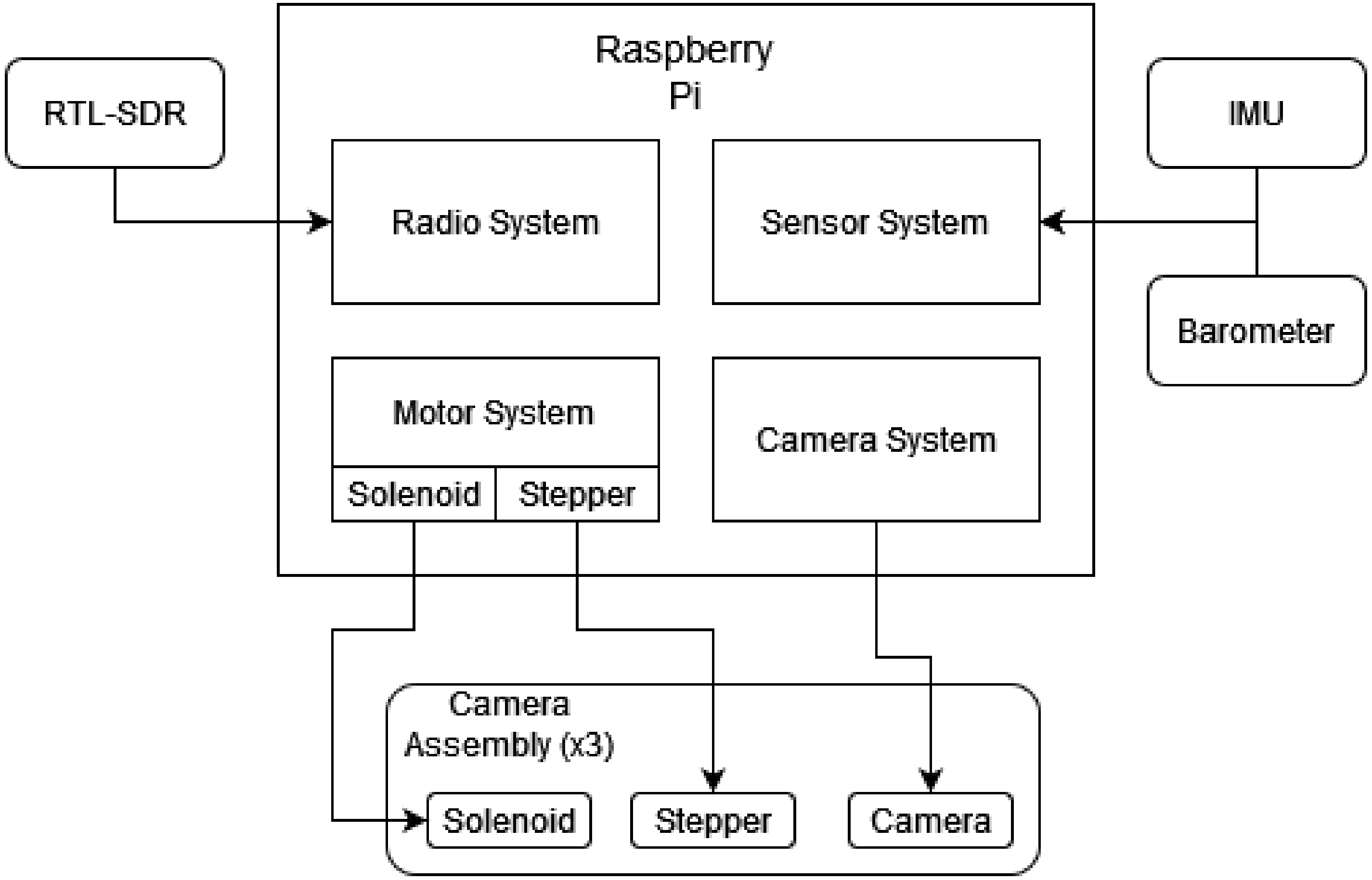
- Interface
  - USB Ports
    - Cameras & SDR Radio Dongle
  - I2C Communication Pins
    - IMU & Barometers
  - GPIO-Input
    - Push Buttons
  - GPIO-Output
    - Piezo & Actuators
- PCB Placement
  - Space Constraints





Payload Software Overview

- Four Subsystems
- Inputs
  - IMU
  - Barometer
  - RTL-SDR Radio Dongle
- Outputs
  - Solenoid Motor
  - Stepper Motor
  - Camera



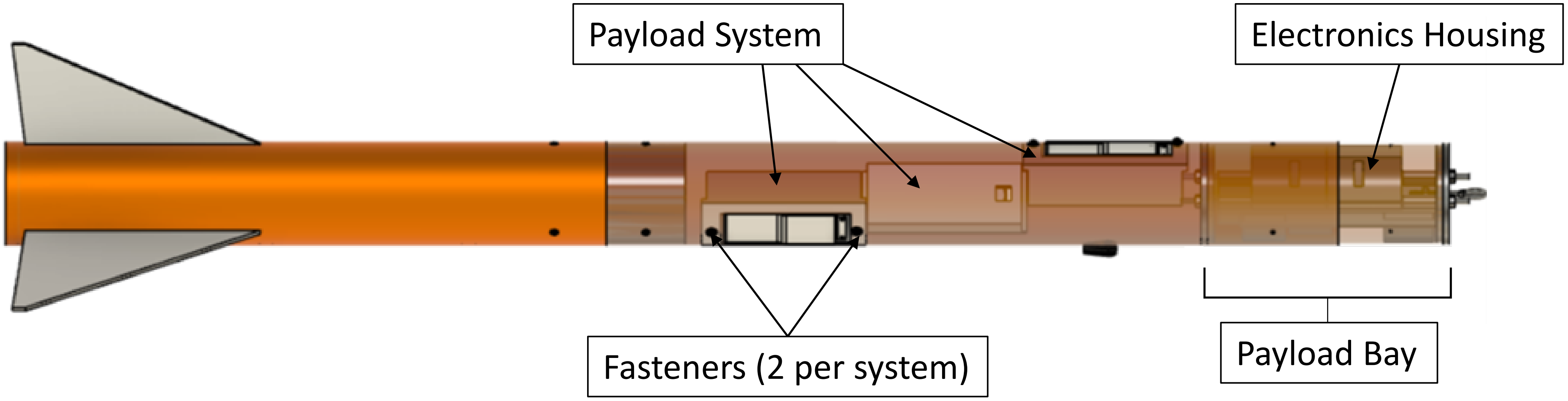
Payload Software Inputs

- Sensor System
  - Collect and Store Acceleration Data
  - State Tracking
  - Final Orientation

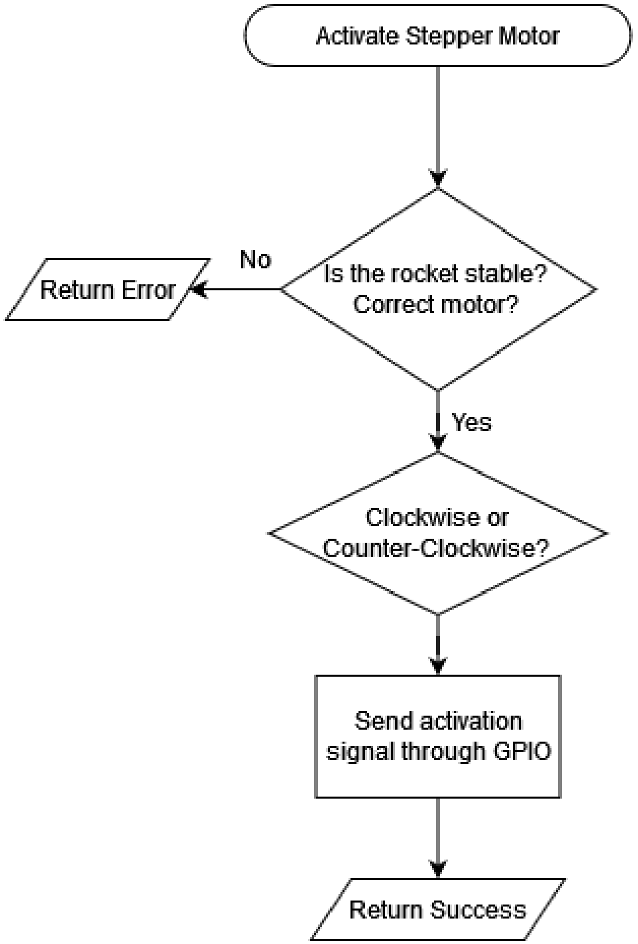
- Radio System
  - Receive Radio Messages
  - Decode APRS
  - Output Command Sequence

```
FW0175>APRS:@302224z2827.57N/08043.23W_089/000g004t073r000p000P000b10188h69eMB50
Weather Report, WEATHER Station (blue), Generic, (obsolete. Digis should use APNxxx instead)
N 28 27.5700, W 080 43.2300
wind 0.0 mph, direction 89, gust 4, temperature 73, rain 0.00 in last hour, rain 0.00 in last 24 hours,
 rain 0.00 since midnight, barometer 30.09, humidity 69, "eMB50"
```

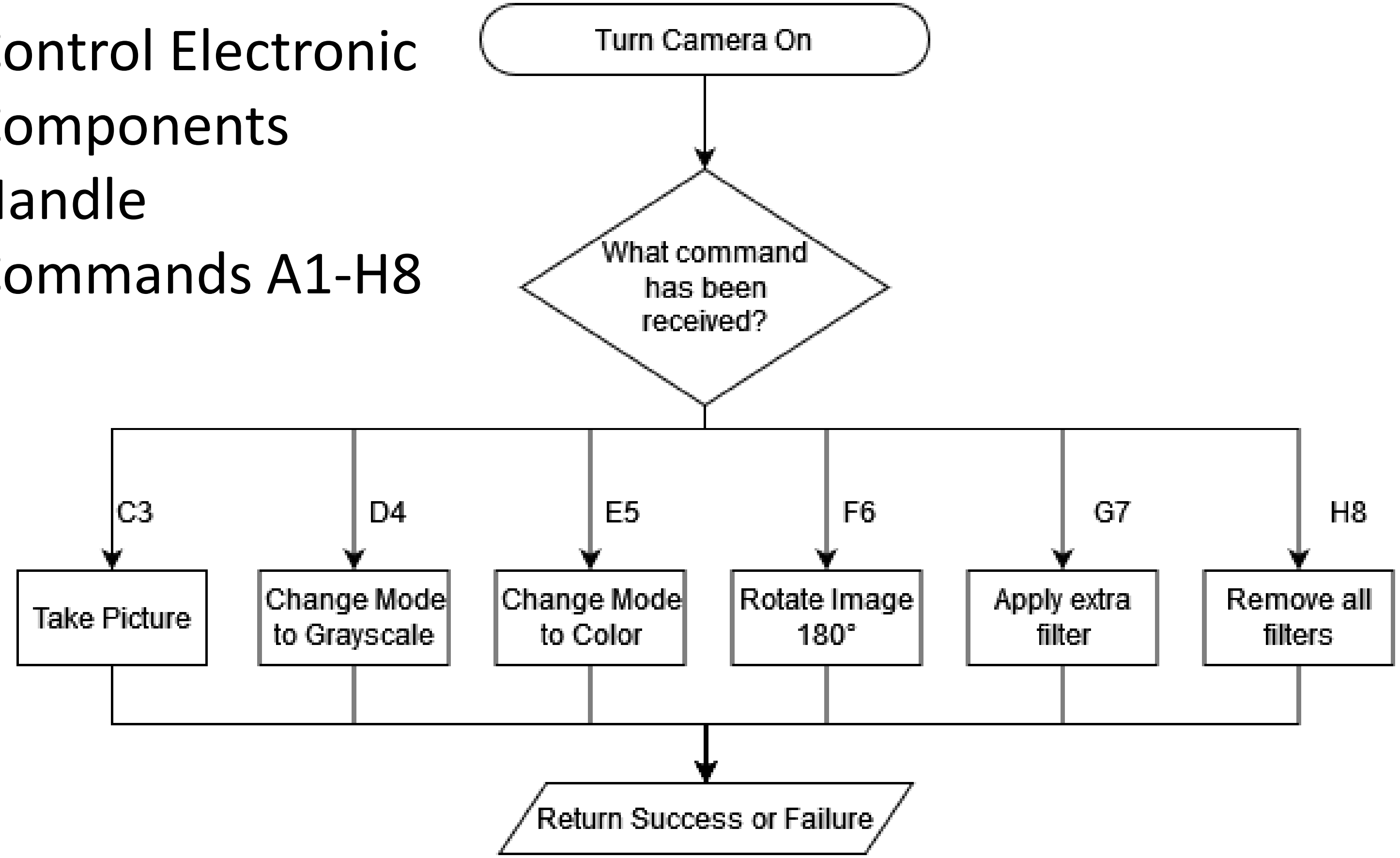
Payload Integration



Payload Software Outputs



- Control Electronic Components
- Handle Commands A1-H8



Test Plans and Procedures

Test Name	Objective	Procedure
Airframe Material Compression Test	Measure compressive strength of airframe material.	Use Instron UTM to experimentally determine maximum compressive strength of a section of airframe.
Altimeter Accuracy Test	Measure the accuracy of the altimeter in detecting a change in altitude.	Move altimeter to several known altitudes and record altimeter reading.
Parachute Deployment Time Test	Measure the time for the parachute to open upon deployment when folded in different ways.	Drop folded and weighted parachute from a height to simulate vehicle recovery conditions.
Radio Reception Test	Receive and record an APRS transmission with the SDR dongle and the Raspberry Pi. Determine the effective range.	Transmit radio instructions to payload receiver and determine if instructions were received.
Payload Acceleration Resilience Demonstration	Determine ability of payload to operate after exposure to significant acceleration.	Subject payload to G-forces similar to those experienced during launch and verify that payload still functions.
…	…	…

Launch Vehicle Testing Categories:

- Material Strength
- Material Properties
- System Properties
- Avionics
- Recovery
- Launches

Payload Testing Categories:

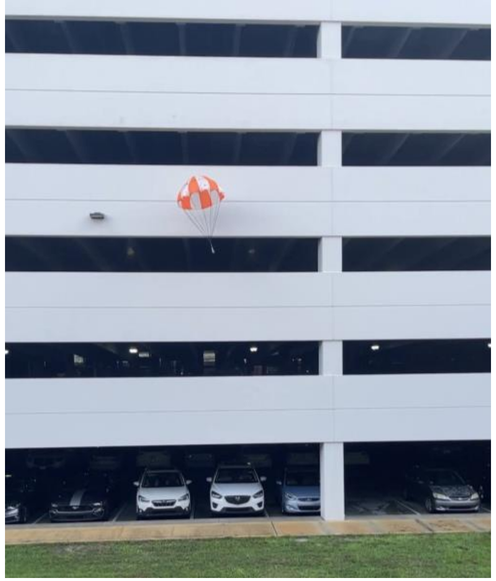
- Component Function
- System Integration
- Durability
- System Function
- Launches

Staged Recovery System Testing

Subscale Drogue Parachute Ejection Testing
- Initial failure to eject parachute, charge size increased
- Primary charge successful at 1.15 g black powder
- 1.45 g secondary charge also successful

Subscale Main Parachute Ejection Testing
- Primary charge successful at 1.39 g black powder
- 1.74 g secondary charge also successful

Staged Recovery System Testing

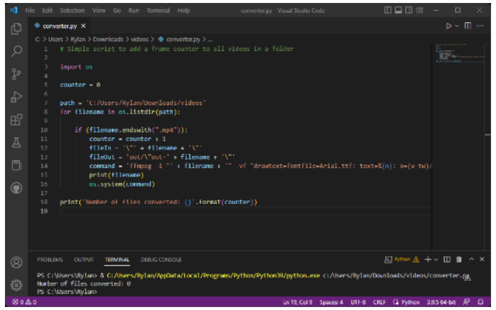


Parachute Drag Test

- Performed prior to subscale launch
- Calculated coefficient of drag of each parachute

Parachute Preparation Test

- Performed prior to subscale launch
- Measured packed dimensions of parachutes



Parachute Deployment Time Test

- Performed prior to subscale launch
- Determined time for parachutes to open

Parachute Unfolding Demonstration

- Performed on-site of subscale launch
- Ensure folding method was reliable

Altimeter Accuracy Test

- Performed prior to subscale launch
- Verified accuracy of altimeters

Avionics Battery Life Test

- Performed prior to subscale launch
- Measured battery life of avionics system

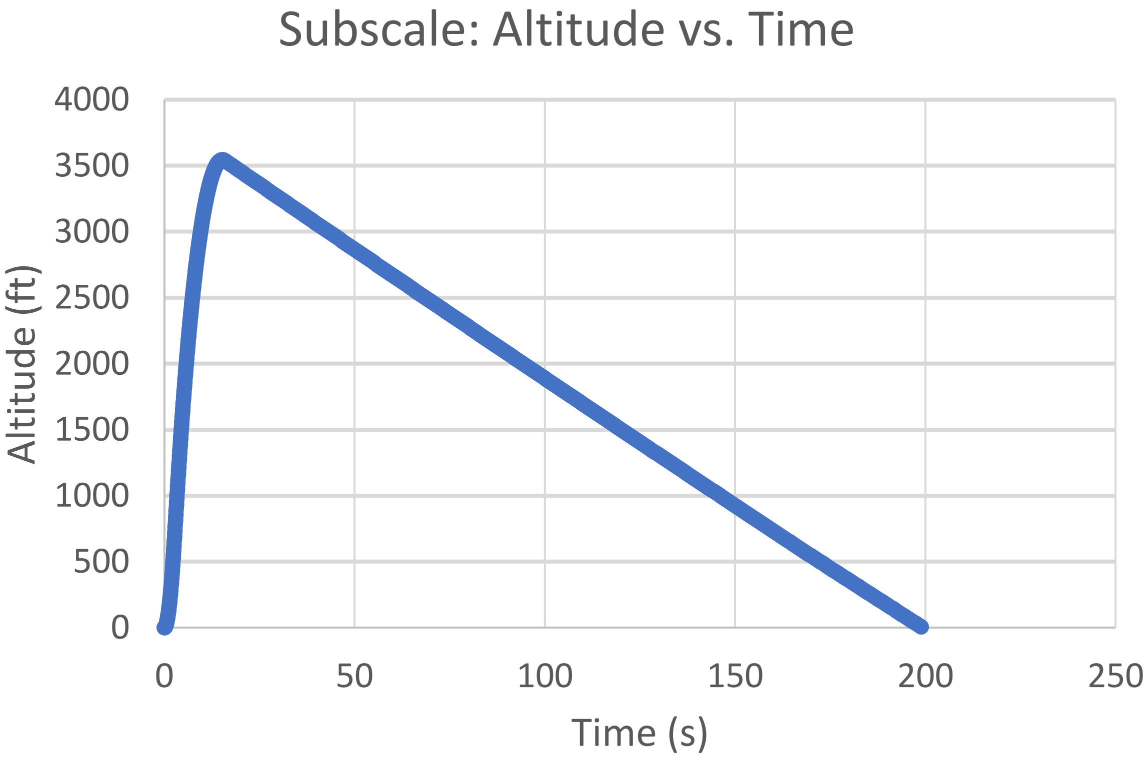
Subscale Flight Test

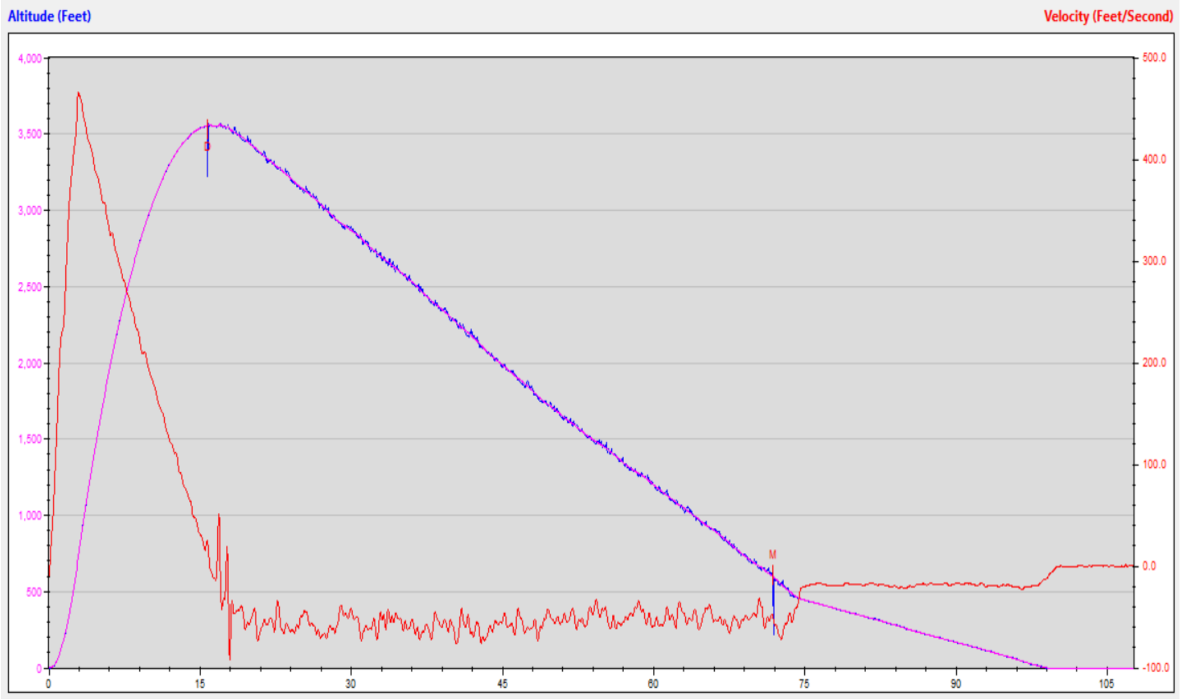
Launch Vehicle Recoverable and Reusable

Staged Recovery System Successful

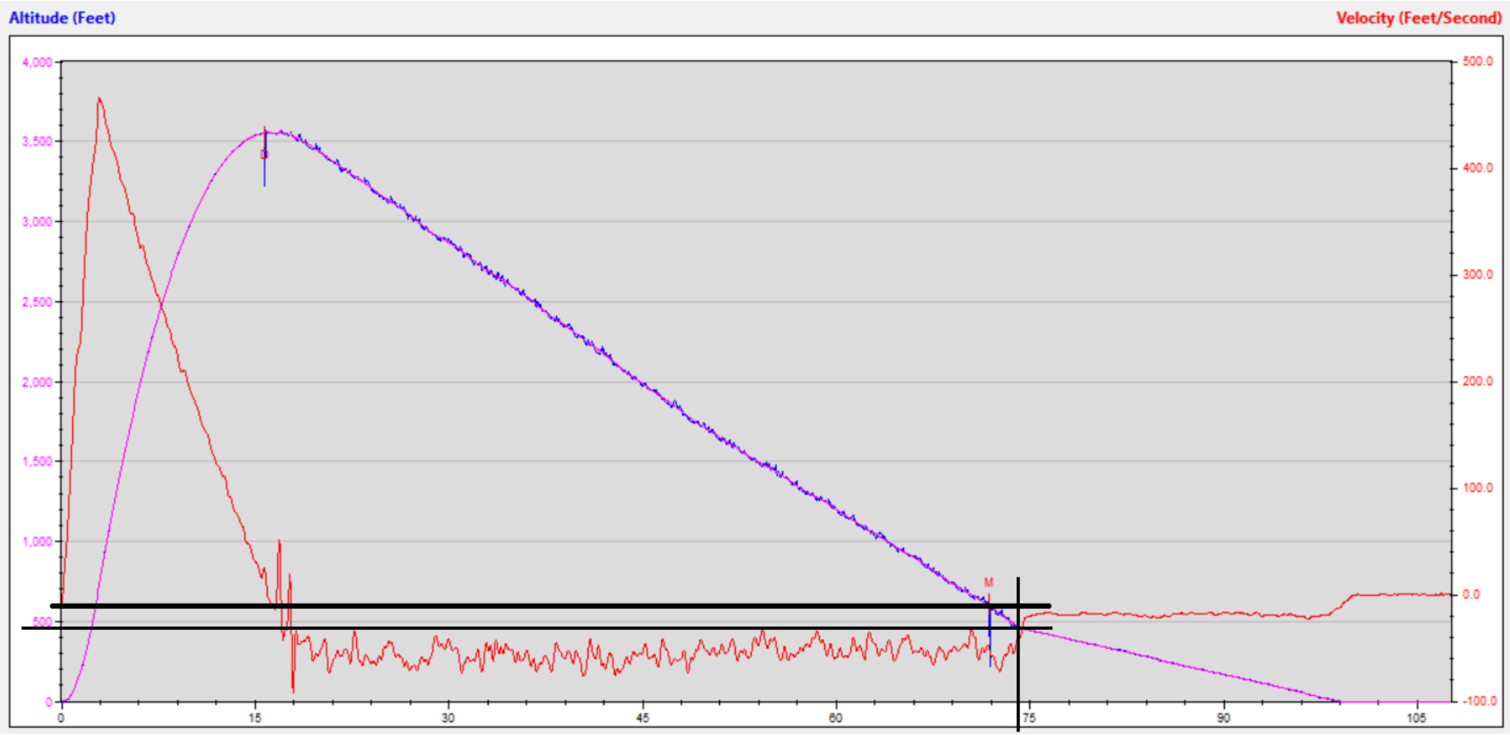
- Performed December 3rd, 2022, at SEARS in Sampson, AL
- Vehicle scaled 75% overall
- Payload scaled 60%—camera housing flown, ballast added for electronics
- No damage—vehicle and parachutes reusable

Subscale Flight Test Data





Subscale Flight Test



Average Descent Rates	
Drogue	55 ft/s
Main	19 ft/s

- Slowed to main descent rate ~460 ft AGL
- Apogee: 3,557 ft
- Successful drogue deployment
- Suspected failure of primary main charge to eject parachute, secondary charge successful

Requirements Compliance Plan – General and Safety

General

Requirement	Compliance Plan	Verification
Work Completed by Team	All work will be done by team and will be done specifically for this year's competition.	Ongoing
Project Plan Maintained	A project plan will be maintained, including milestones, budget/funding plans, checklists, risks, mitigations.	Ongoing
Educational Engagement	Team will directly engage a minimum of 250 participants.	~100/250 participants engaged.
Team Mentor	A team mentor will be identified.	Mr. Jimmy Yawn will be the team mentor.
…	…	…

Safety

Requirement	Compliance Plan	Verification
Checklists	Checklists will be included in the FRR report.	FRR report not yet submitted.
Safety Officer	A Safety Officer will be identified.	Luka Bjellos will be the Safety Officer.
…	…	…

Requirements Compliance Plan – Launch Vehicle

NASA

Requirement	Compliance Plan	Verification
Launch Vehicle Reusable	Recovery system will ensure no damage to launch vehicle during landing.	Partial; successful subscale demonstration launch.
Number of Independent Sections	Launch vehicle will have fewer than 4 independent sections.	Verified; design includes 3 independent sections.
Preparation Time	Preparation rehearsals will be performed.	Unverified.
Pressure Vessels	No pressure vessels will be included in the launch vehicle.	Verified.
Ballast	Ballast will not exceed 10% of unballasted launch vehicle weight.	Unverified.
…	…	…

Team-Derived

Requirement	Compliance Plan	Verification
Payload Airframe Strength	Perform compression test on model of payload airframe section to ensure sufficient strength.	Partial; successful subscale launch.
…	…	…

Requirements Compliance Plan – Recovery

NASA

Requirement	Compliance Plan	Verification
Ground Ejection Test	Ejection testing will be performed for all launch vehicles.	Partial; subscale ejection testing complete.
Avionics Interference	Shielding and interference testing will ensure no interference occurs.	Unverified.
…	…	…

Team-Derived

Requirement	Compliance Plan	Verification
Parachute Opening Time	A parachute deployment time test will be performed to ensure parachutes will open quickly enough to slow the launch vehicle to a safe descent rate.	Verified; test has been completed.
…	…	…

Requirements Compliance Plan – Payload

NASA

Requirement	Compliance Plan	Verification
RAFCO Reception	Radio reception testing will be performed.	Unverified.
Initiation After Landing	Landing detection functionality will be included in payload design and tested.	Unverified.
UAS Guidelines	No UAS (unmanned aircraft system) will be included in payload.	Verified.
…	…	…

Team-Derived

Requirement	Compliance Plan	Verification
Camera Angle	Landing conditions will be simulated and angle from vertical of camera will be measured.	Unverified.
Acceleration Resistance	Payload will be subjected to acceleration similar to launch. Functionality afterward will be verified.	Unverified.
Landing Detection	Landing conditions will be simulated, and landing detection verified.	Unverified.
…	…	…

Safety Plan

Final assembly and launch procedures:

- Avionics and recovery
- Payload preparation
  - Camera system preparation
  - Payload bay preparation
- Ejection charge preparation
- Launch vehicle assembly
- Motor preparation
- Launch pad procedure
- Igniter installation
- Launch procedure
- Troubleshooting
- Post-flight inspection

- Safety Officers continue to oversee manufacturing and testing

University of Florida

Thank you!