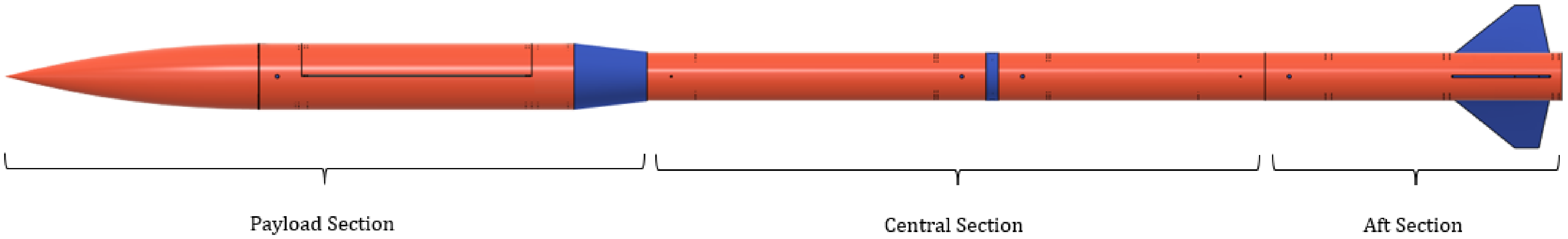
Project Avigator

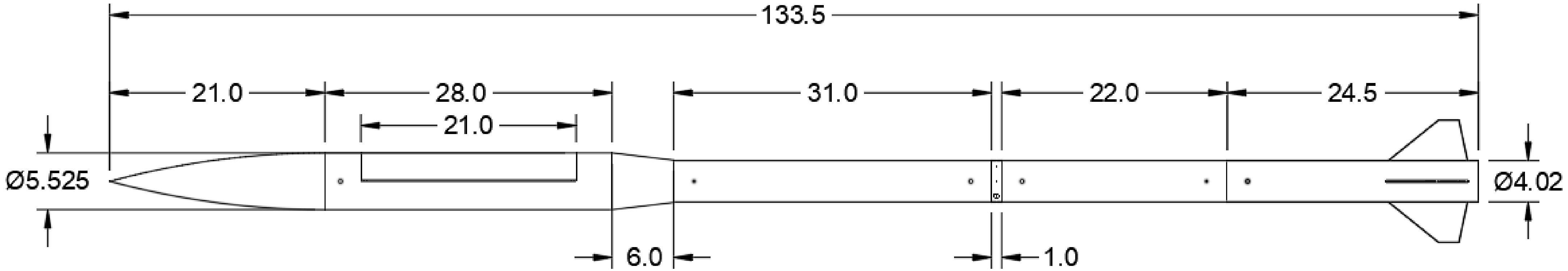
University of Florida

2024 Critical Design Review

Final Launch Vehicle Design

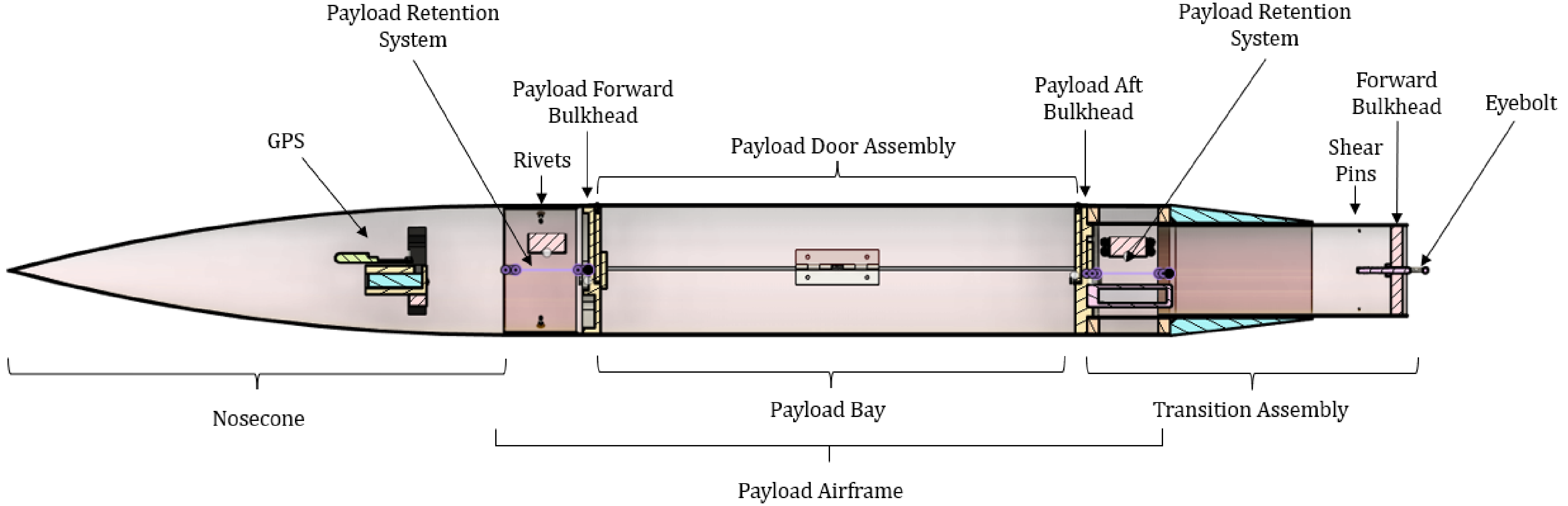
Launch Vehicle Dimensions





Section	Exterior Length (in)
Payload	55.0
Central	54.0
Aft	24.5
Total	**133.5**

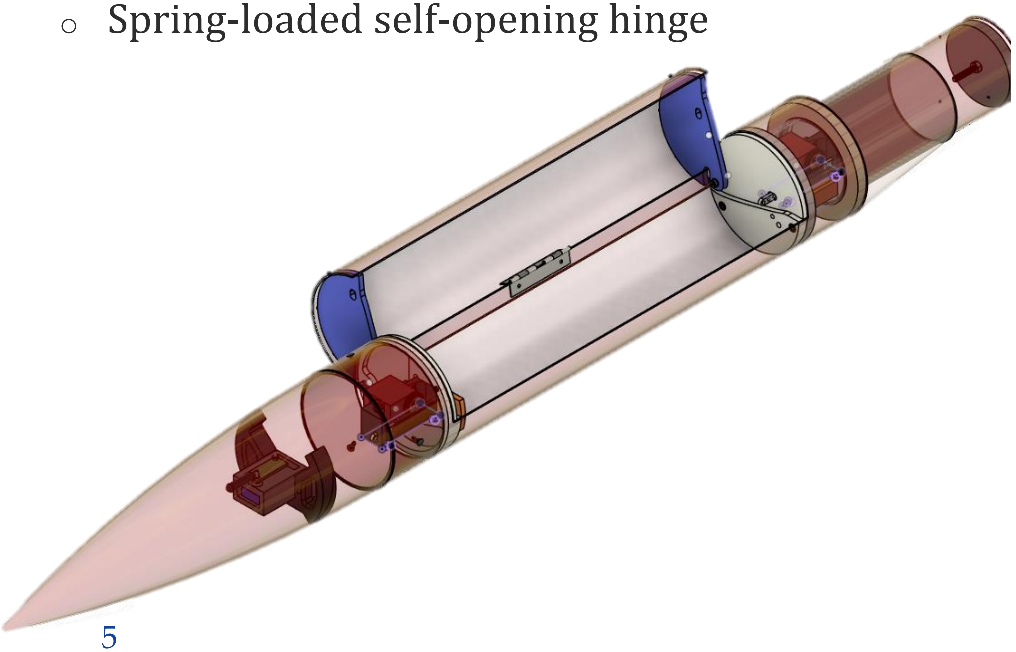
Payload Section

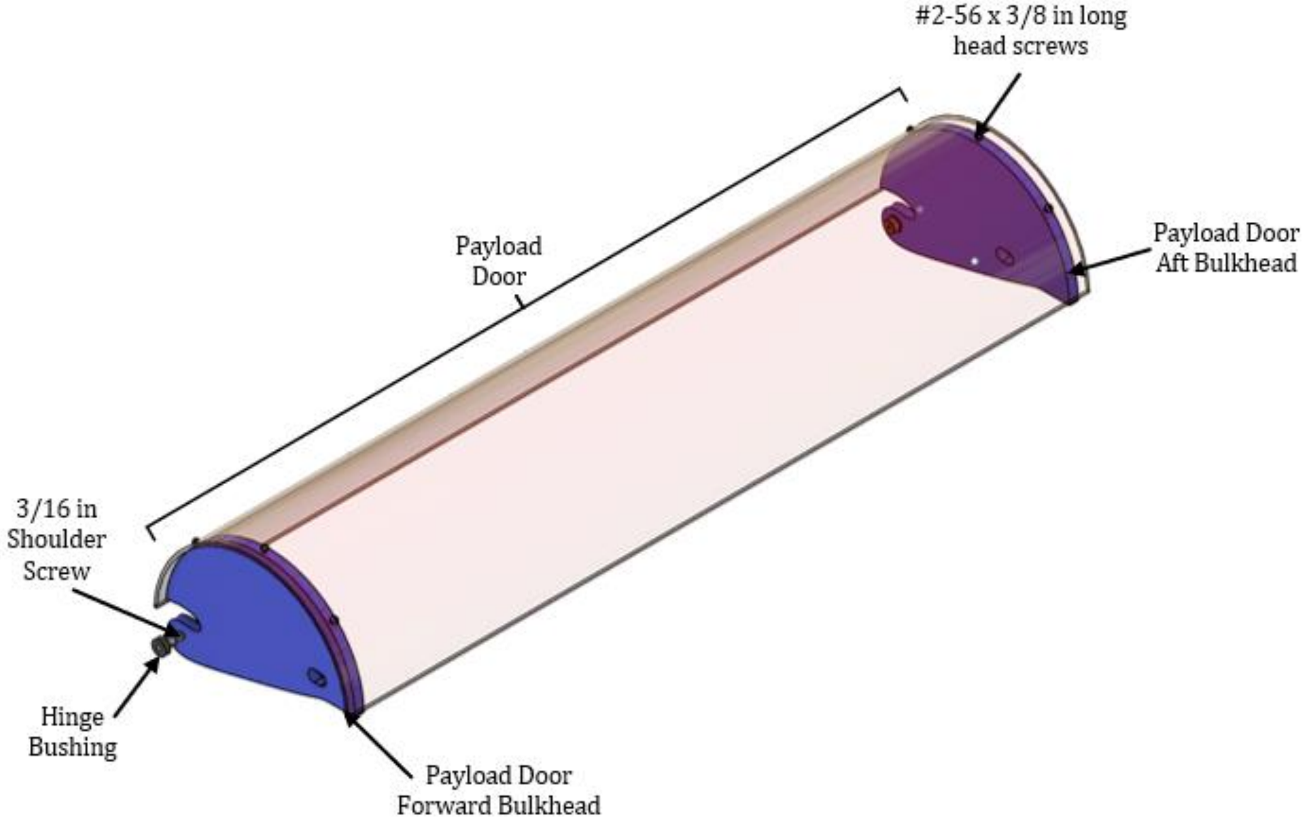


- 5.38 in poly-propylene plastic ogive shaped nosecone
  - GPS mount for Eggfinder Mini
  - Built-in nosecone shoulder
  - Three plastic rivets
- 5.525 in G12 fiberglass payload airframe
- Payload door assembly
  - Payload door made from payload airframe cutout
- 5.375 in diameter type II PVC payload forward and aft bulkhead
  - Rack and pinion mechanisms
  - Battery mount for 2000mAh battery
  - Two 1/4-20 head screws
- Transition assembly (5.525 in > 4.02 in)
- 3.755 in type II PVC forward bulkhead
  - 1/4-20 steel eyebolt and nut

Payload Section: Payload Door Assembly

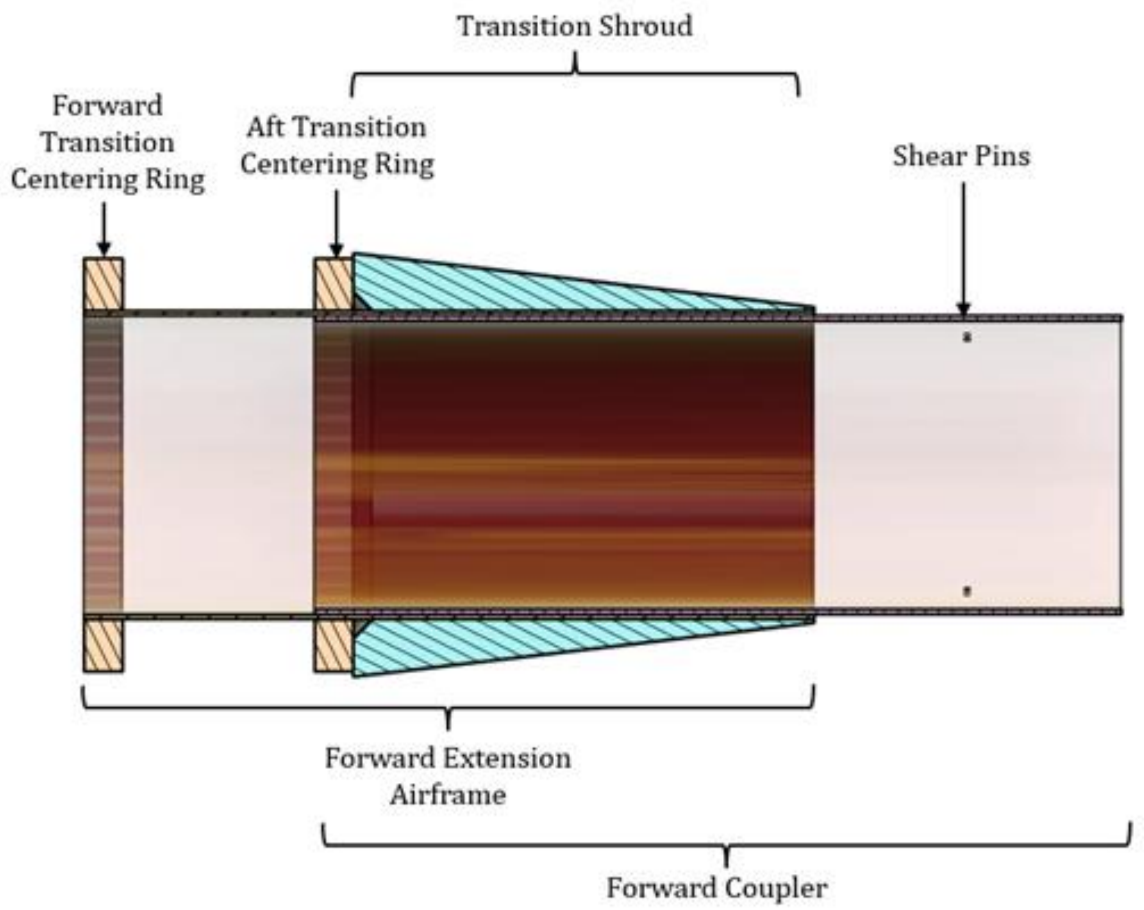
- Payload door assembly
  - 5.525 in G12 fiberglass payload door
  - Delrin plastic payload door bulkheads
  - Six #2-56, 3/8 in long head screws
  - Two 3/16 in shoulder screws
  - Spring-loaded self-opening hinge



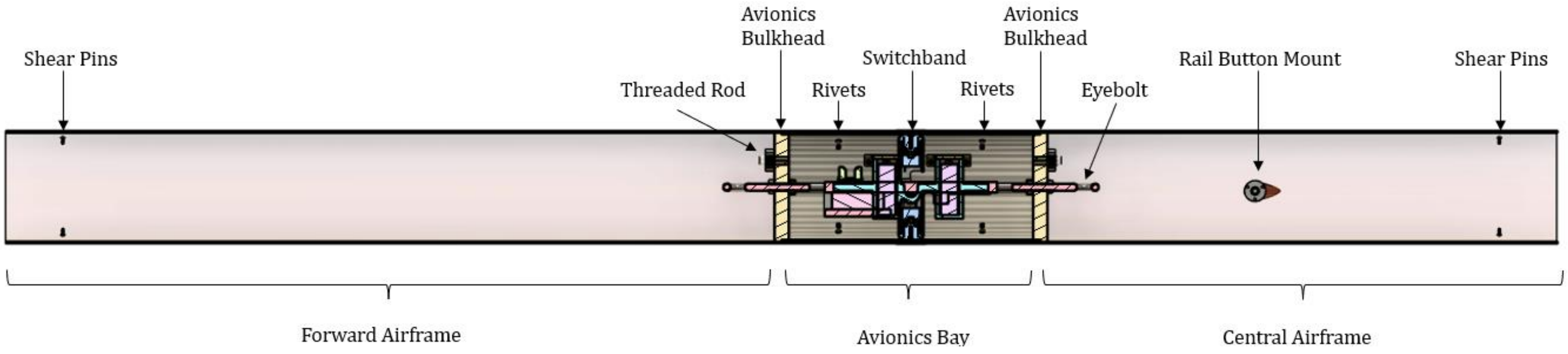


Payload Section: Transition Assembly

- Transition assembly
  - 3D printed PETG transition shroud (5.525 in > 4.02 in)
  - 4.02 in G12 fiberglass forward extension airframe
  - 3.898 in G12 fiberglass forward coupler
  - 5.375 in diameter type II PVC forward centering ring
  - 5.375 in diameter plywood aft centering ring



Central Section



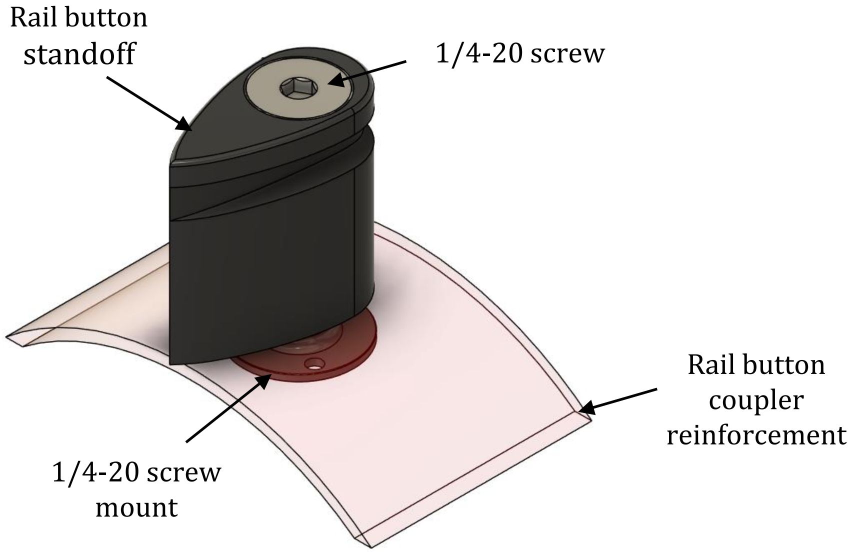
- 4.02 in G12 fiberglass forward airframe
  - Main parachute
- 4.02 in G12 fiberglass central airframe
  - Drogue parachute
- Rail button mount
- Six shear pins

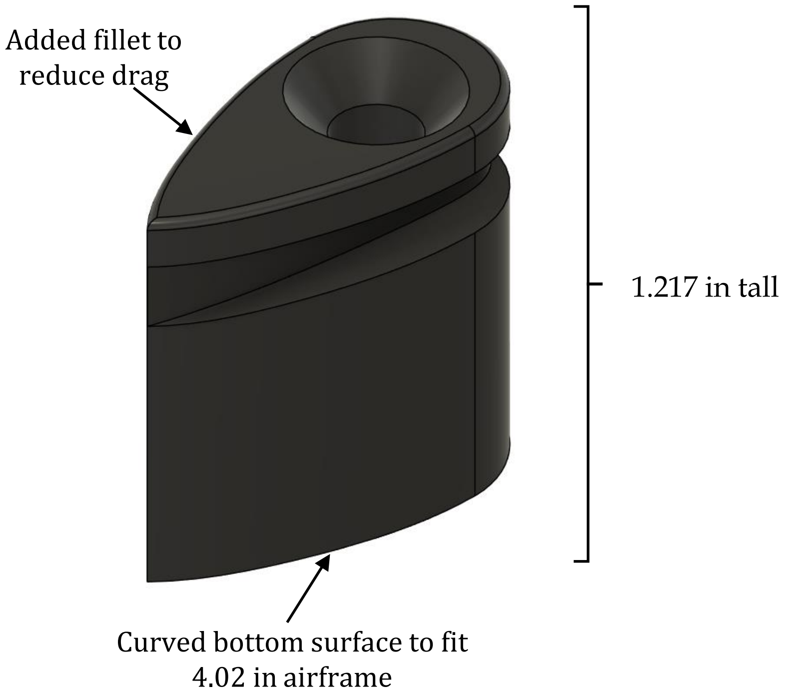
- 4.02 in G12 fiberglass avionics switchband
- Avionics bay
  - 3.898 in G12 fiberglass coupler
  - Two 3.9 in diameter type II PVC avionics bulkheads
  - Two 1/4-20 steel eyebolts and nuts
- Six plastic rivets

Central and Aft Section: Rail Button Mount

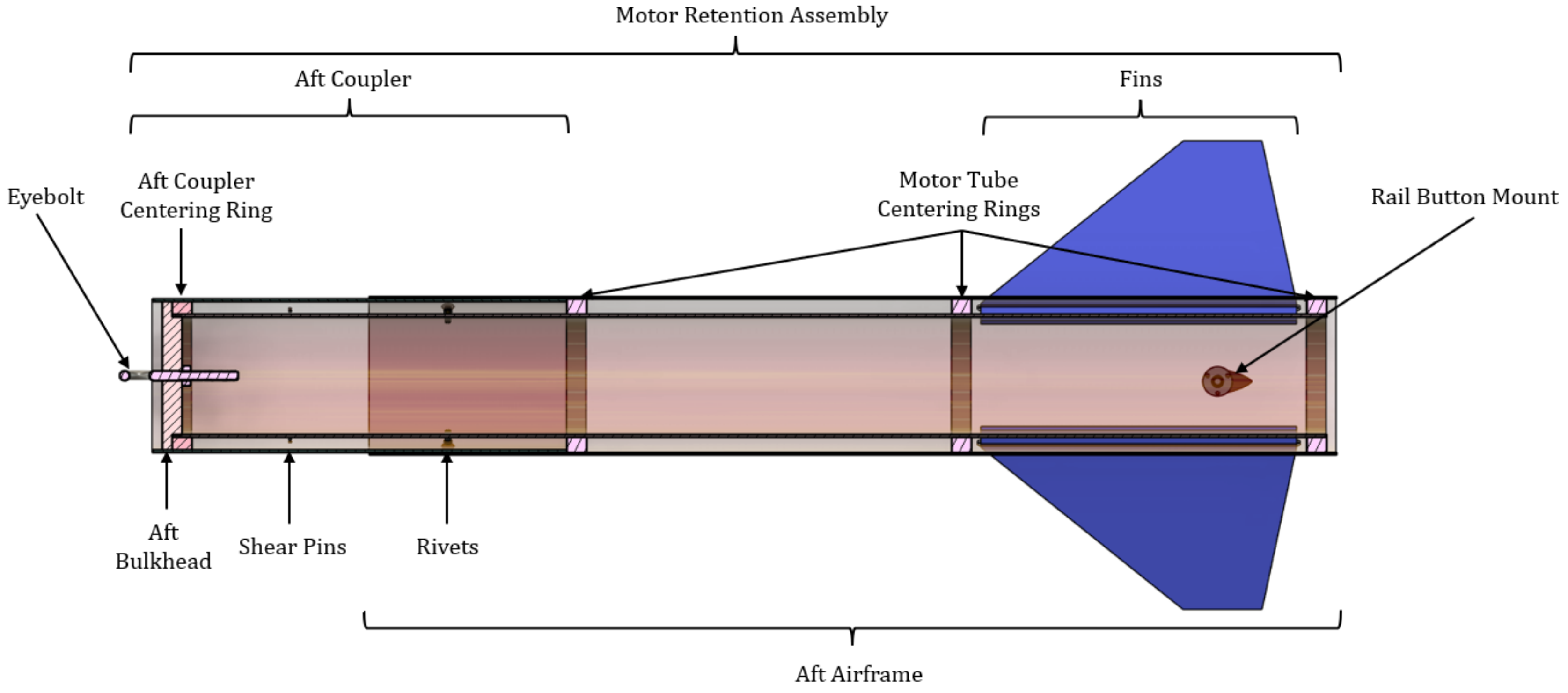
- Rail Button Mount
  - Delrin plastic rail button standoff
  - 1/4-20 x 1.5 in long screw
  - 1/4-20 screw mount
  - Rail button coupler reinforcement

- Delrin plastic rail button standoff
  - Manufactured using CNC mill
  - Large airfoiled shape
  - Fits 1515 rails



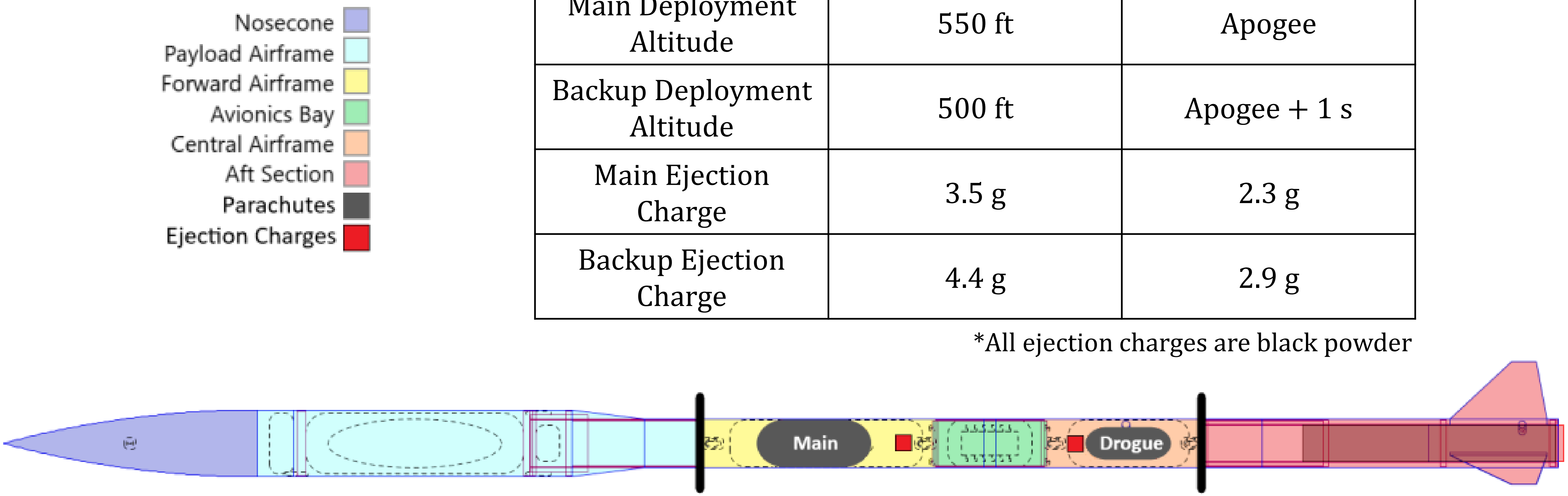


Aft Section



- 4.02 in G12 fiberglass aft airframe
- Motor retention assembly
  - 3.0 in G12 fiberglass airframe
  - Four plywood centering rings
    - One 3.755 in coupling to aft coupler
    - Three 3.9 in coupling to aft airframe
- 3.898 in G12 fiberglass coupler
  - Three plastic rivets
- 3.9 in diameter type II bulkhead
  - 1/4-20 steel eyebolts and nuts
- Three 0.198 in thick G10 fiberglass fins
- Rail button mount

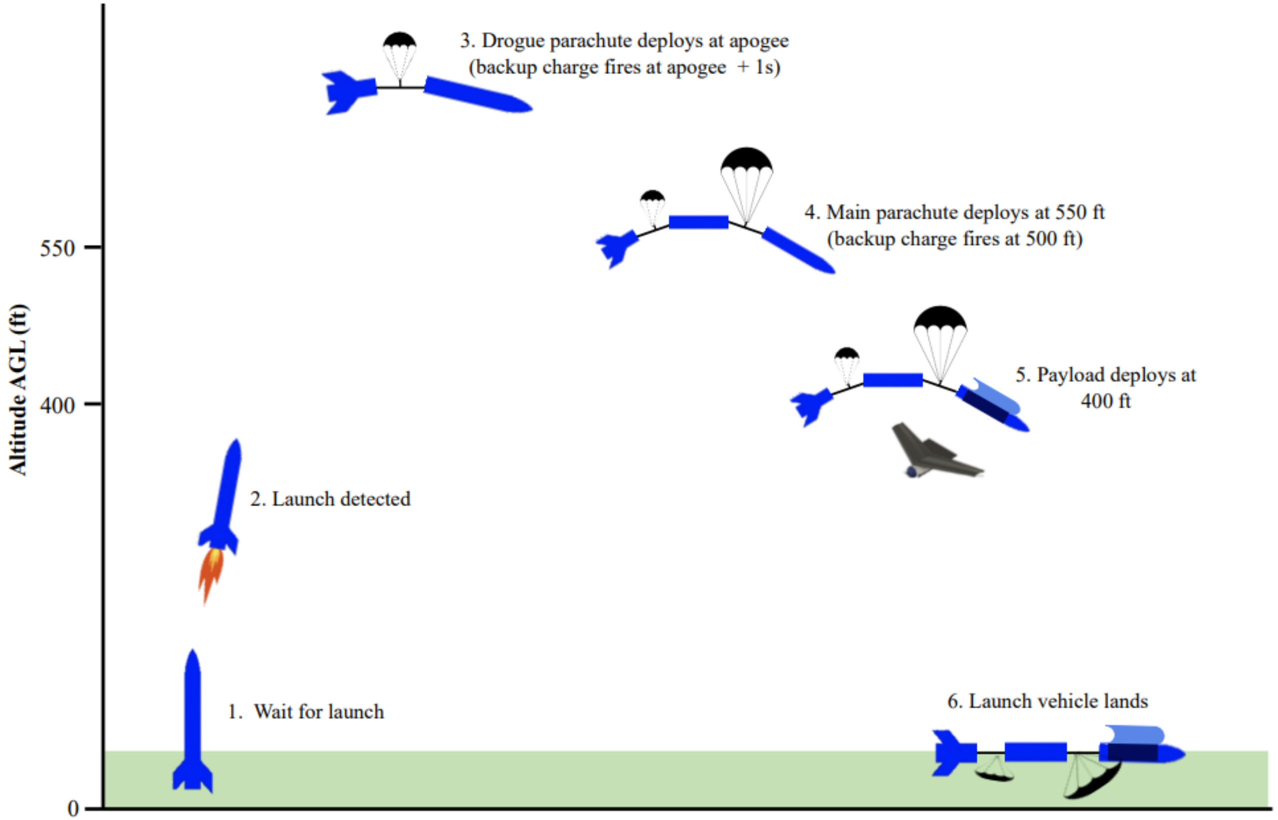
Separation Points

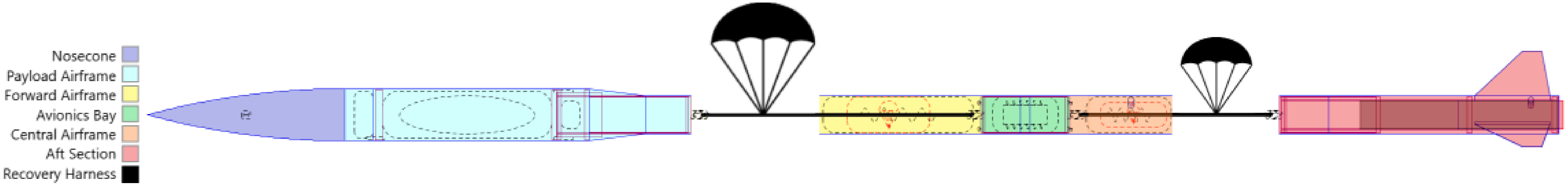


Component	Main Parachute	Drogue Parachute
Main Deployment Altitude	550 ft	Apogee
Backup Deployment Altitude	500 ft	Apogee + 1 s
Main Ejection Charge	3.5 g	2.3 g
Backup Ejection Charge	4.4 g	2.9 g

*All ejection charges are black powder

Recovery Concept of Operations





Kinetic Energy Predictions

Maximum Kinetic Energy (OpenRocket Simulations)		
Launch Vehicle Section	**Payload does deploy (ft-lbf)**	**Payload does not deploy (ft-lbf)**
Payload section with payload	N/A	**72.55**
Payload section without payload	39.78	N/A
Central section	22.06	26.25
Aft section	**52.71**	62.73

Maximum Kinetic Energy (ODE Solver MATLAB)		
Launch Vehicle Section	**Payload does deploy (ft-lbf)**	**Payload does not deploy (ft-lbf)**
Payload section with payload	N/A	**71.24**
Payload section without payload	39.26	N/A
Central section	21.77	25.78
Aft section	**52.03**	61.60

Recovery Components

Component Type	Component Name	Size/Length	Component Location
Drogue Parachute	SkyAngle CERT-3 Drogue	24 in	Central Airframe
Main Parachute	Iris Ultra Standard Parachute	84 in	Forward Airframe
Recovery Harnesses	Onebadhawk Tubular Kevlar	7/16-in, 25 ft long	Central & Forward Airframe
Main Altimeter	Stratologger CF	N/A	Avionics Bay
Backup Altimeter	MissileWorks RRC3	N/A	Avionics Bay
GPS	EggFinder Mini Transmitter	N/A	Nosecone

Scenario	Descent Rate
Under Drogue	88.9 ft/s
Under Main With Payload	18.0 ft/s
Under Main Without Payload	16.5 ft/s

Descent Time & Drift Predictions

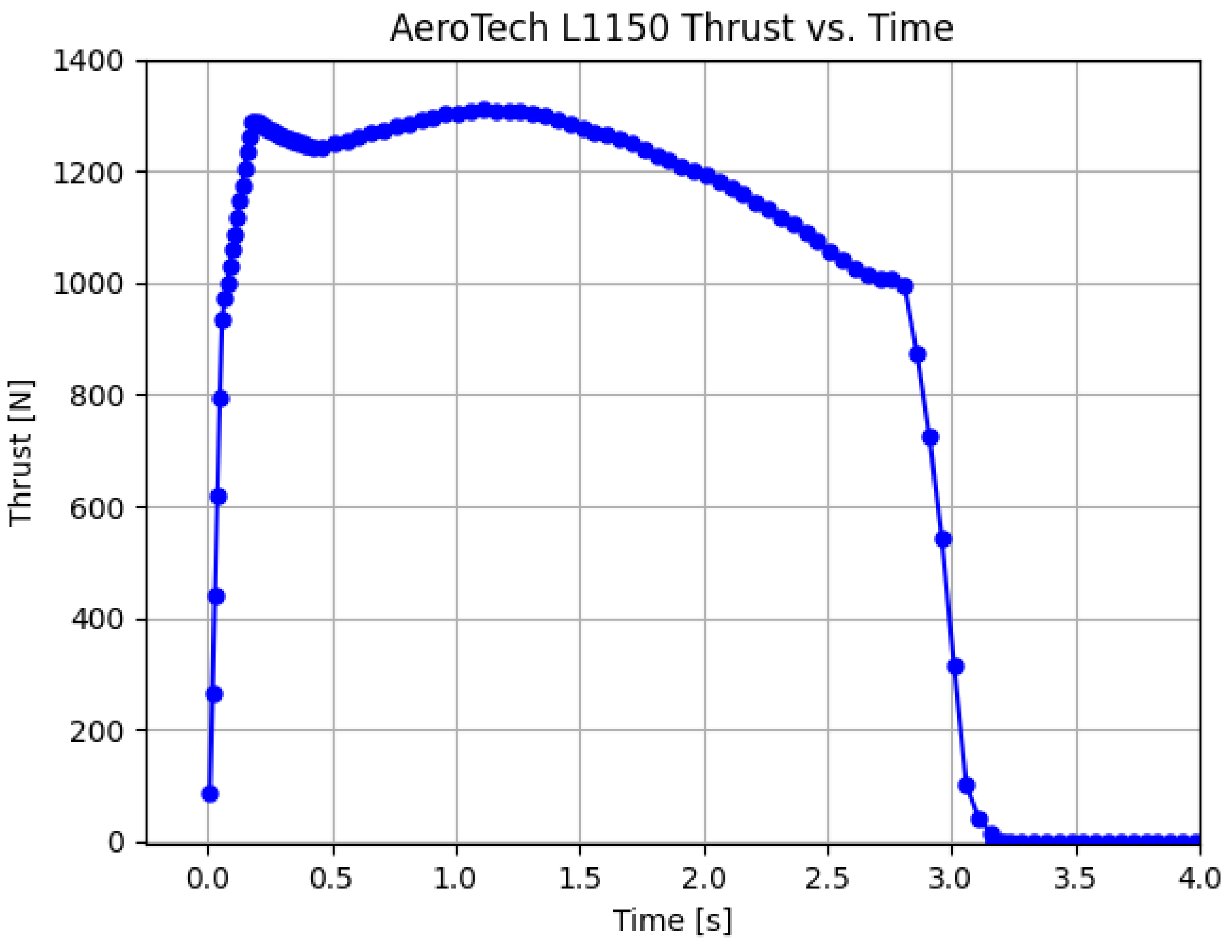
Descent Time		
Calculation Method	**Payload does deploy (s)**	**Payload does not deploy (s)**
Descent Time Calculations	**83.3**	81.3
OpenRocket Simulations	N/A	78.1
ODE Solver MATLAB	**83.3**	81.3

Total Drift (Descent Time Calculation)		
Wind Speed	**Payload does deploy (ft)**	**Payload does not deploy (ft)**
5 mph	611	596
10 mph	1222	1192
15 mph	1833	1788
20 mph	**2443**	2384

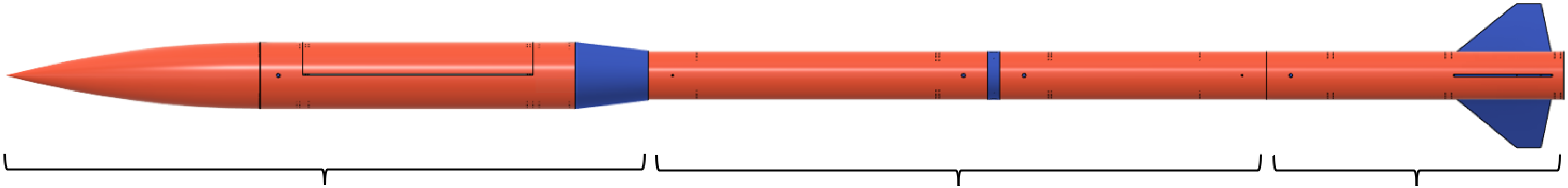
Total Drift (ODE Solver MATLAB)		
Wind Speed	**Payload does deploy (ft)**	**Payload does not deploy (ft)**
5 mph	611	596
10 mph	1221	1192
15 mph	1832	1788
20 mph	2442	2383

Selected Motor: AeroTech L1150

- Liftoff Thrust: **971 N**
- Maximum Thrust: **1346 N**
- Average Thrust: **1148 N**
- Total Impulse: **3517 N-s**
- Burn Time: **3.04 s**
- Thrust-to-Weight Ratio: **8.68:1**



Mass Statement



Payload Section
230.5 oz

Central Section
124.8 oz

Aft Section
246.0 oz (fully ballasted)
225.0 oz (non-ballasted)

- Mass margin: **3.6% (21 oz)**
- Dry mass (with ballast): **507.5 oz**
- Dry mass (without ballast): **528.5 oz**
- Total/Wet Mass (with ballast): **601.3 oz**

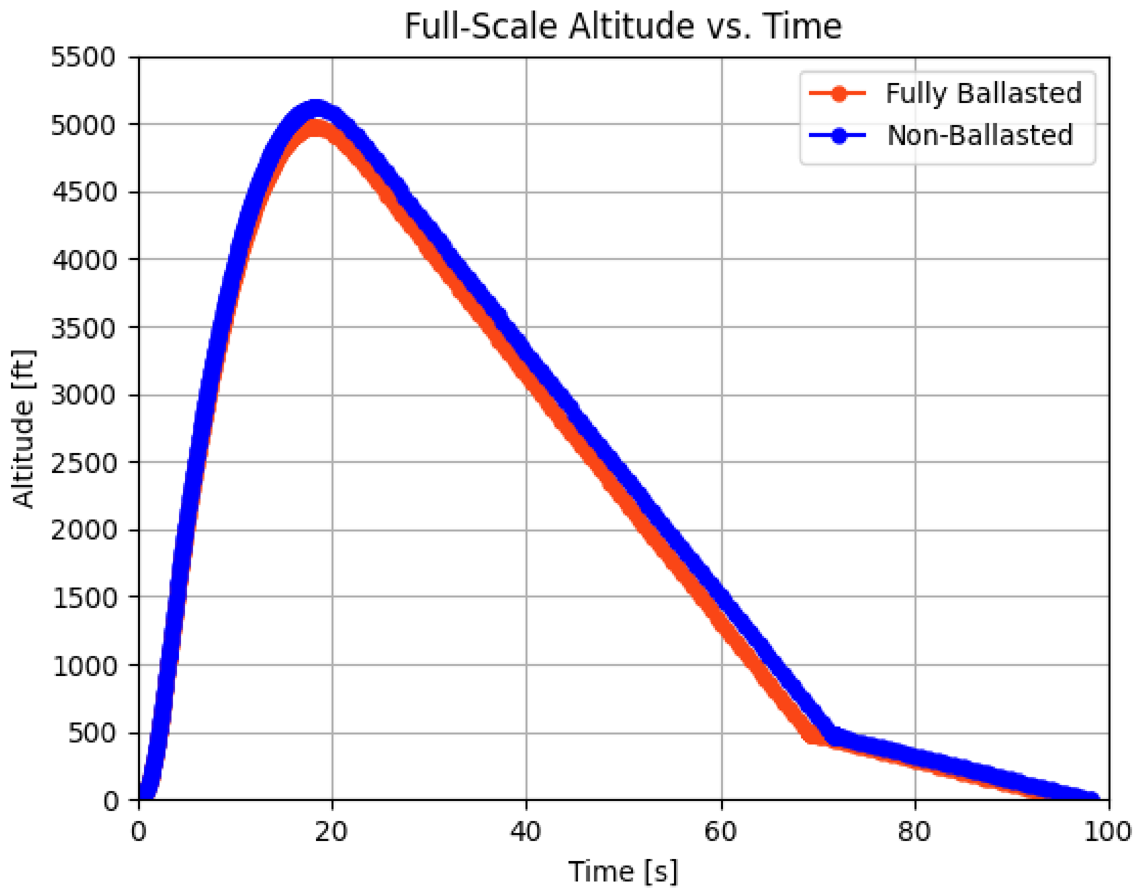
Mission Performance Predictions: Conditions

Launch Conditions in Huntsville, Alabama	
Wind	5 mph
Launch Angle	5°
Launch Rod Length	144 in
Latitude	34.6 °N
Longitude	86.7 °W
Altitude	800 ft
Temperature	80 °F
Pressure	1 atm

Launch Vehicle Simulation: Altitude Profile

- Apogee:
  5003 ft (fully ballasted)
  5115 ft (non-ballasted)

- Target Apogee: **5000 ft**

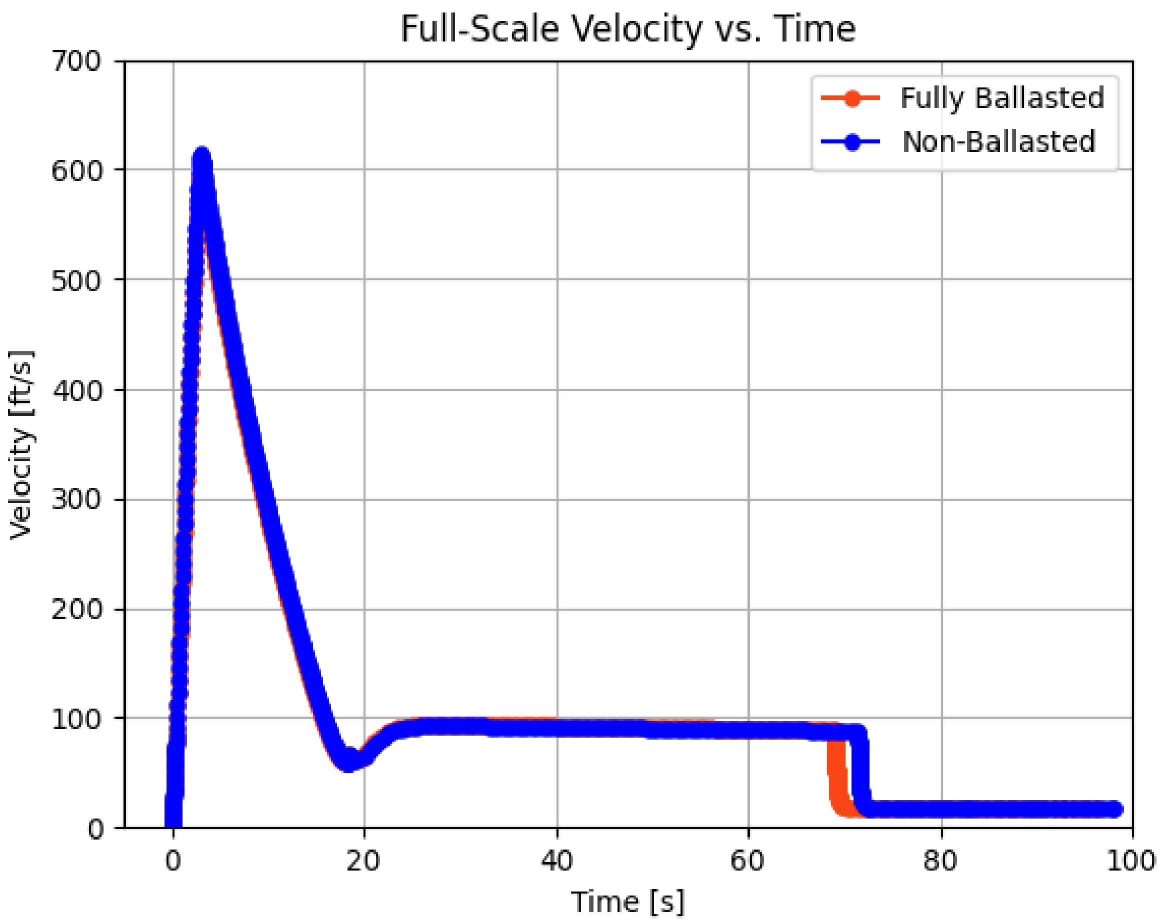


Launch Vehicle Simulation: Velocity Profile

- Velocity at Rail Exit:
  71.7 ft/s (fully ballasted)
  74.7 ft/s (non-ballasted)

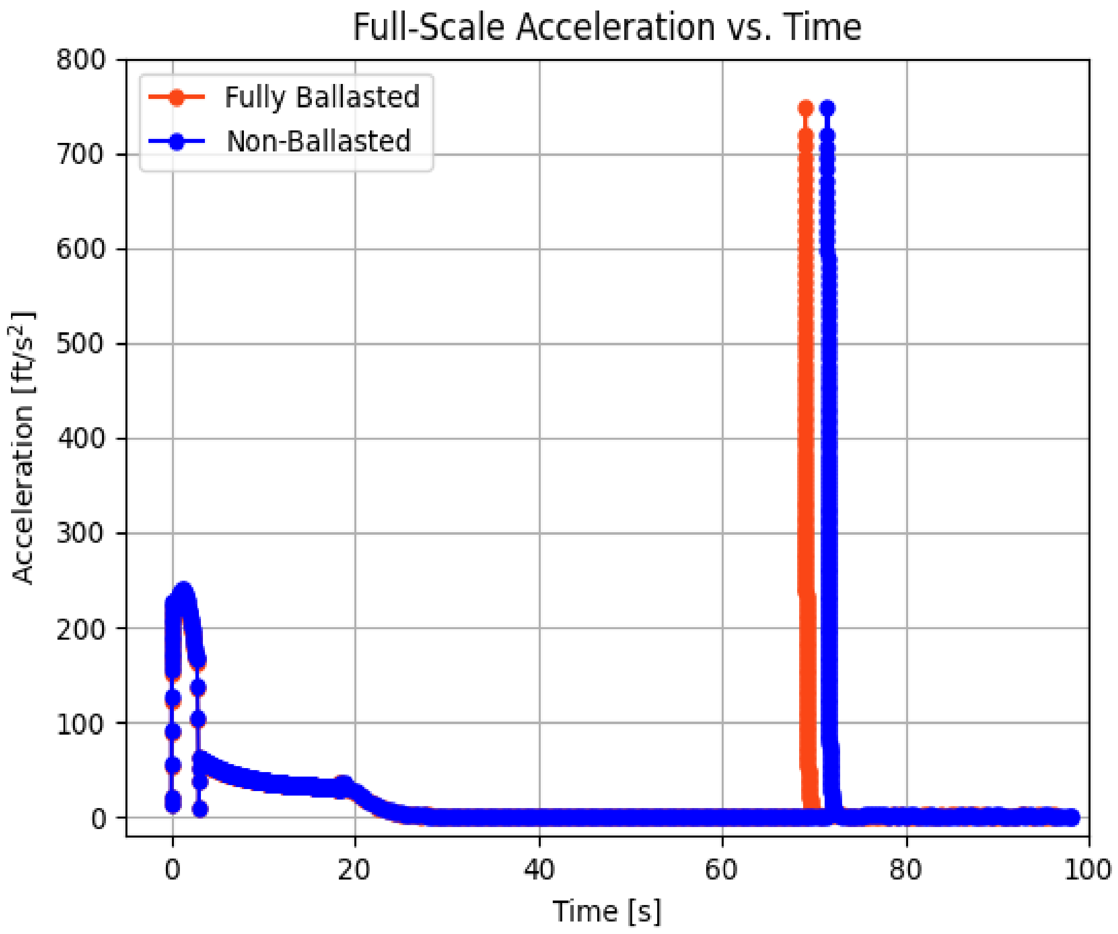
- Maximum Velocity:
  592 ft/s
  613 ft/s

- Maximum Mach Number:
  Mach 0.52
  Mach 0.54



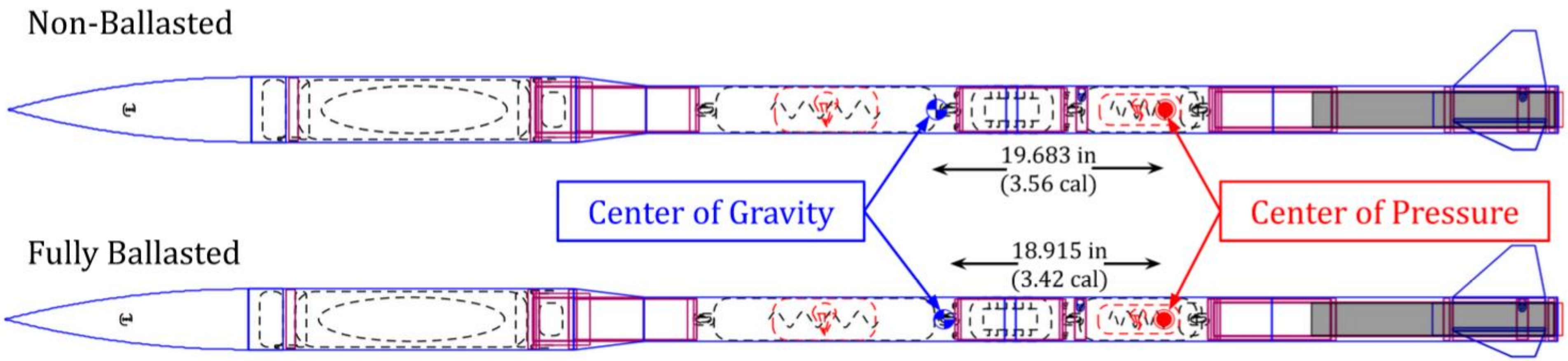
Launch Vehicle Simulation: Acceleration Profile

- Maximum Acceleration:
  - 230 ft/s^2 (fully ballasted)
  - 239 ft/s^2 (non-ballasted)



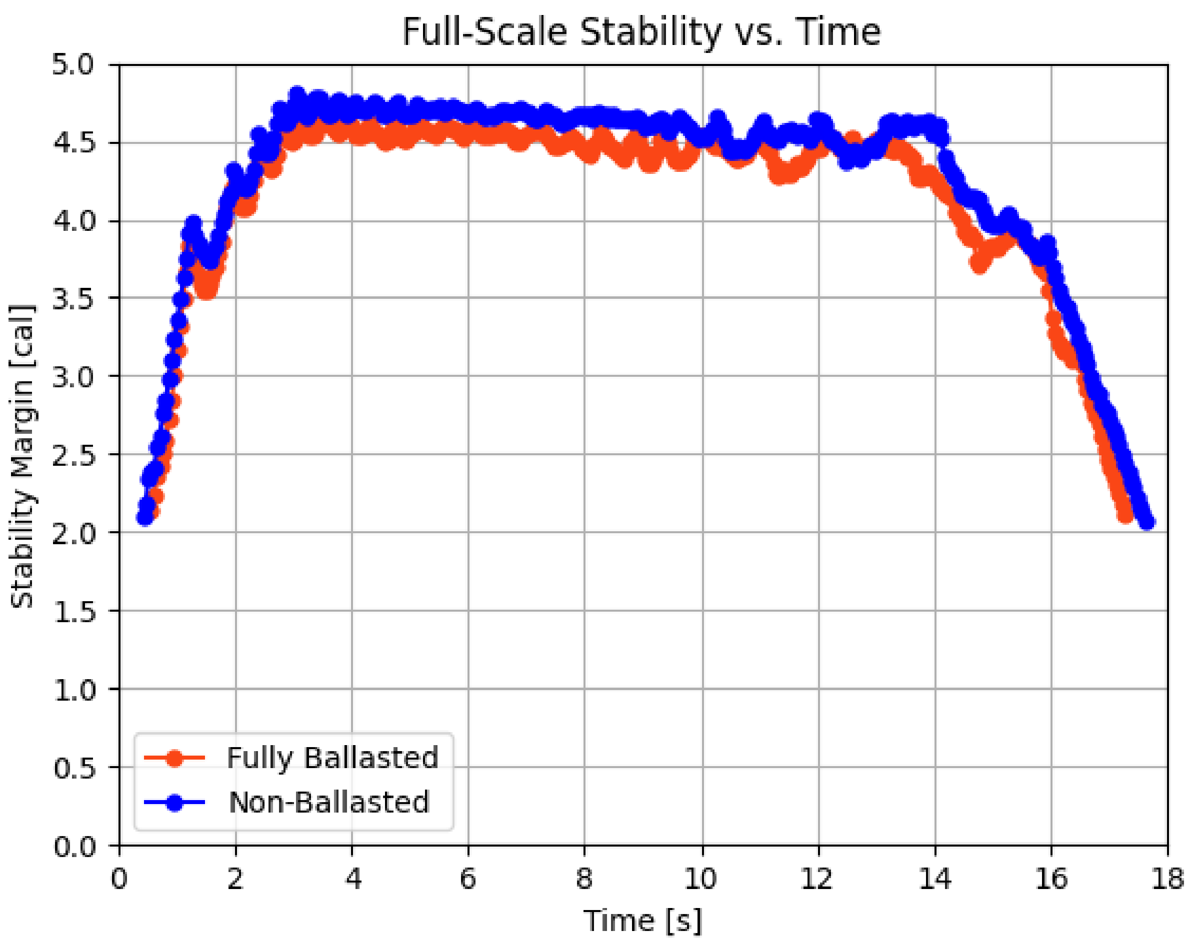
Launch Vehicle Stability

Parameter	Value **Non-Ballasted**	Value **Fully Ballasted**
x_{Cp} from nosecone tip	99.70 in	99.70 in
x_{Cg} from nosecone tip	80.02 in	80.79 in
Static Stability *Launch Pad*	3.56 cal	3.42 cal
Static Stability *Rail Exit*	3.70 cal	3.55 cal



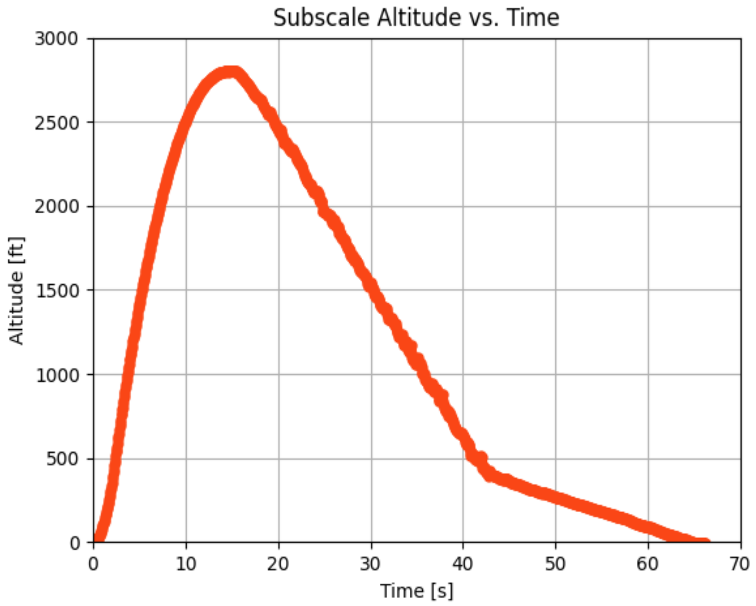
Launch Vehicle Stability

- Maximum Stability Margin:
  4.59 cal (fully ballasted)
  4.80 cal (non-ballasted)

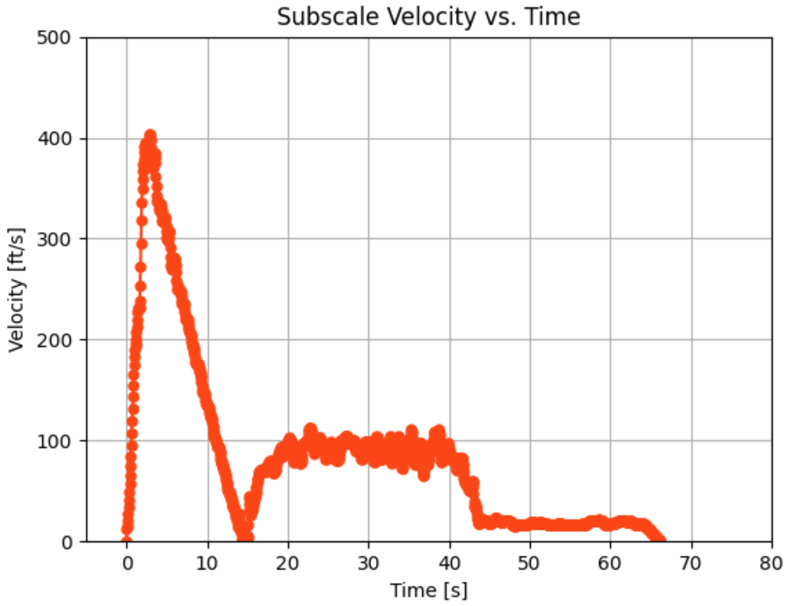


Subscale Flight Test

Subscale Flight Test Data



- Apogee: **2800 ft**



- Maximum Velocity: **403 ft/s**
  Mach 0.36
- Avg. Drogue Descent Rate: **91.0 ft/s**
- Avg. Main Descent Rate: **18.2 ft/s**

- Performed November 18th, 2023 near Plant City, FL
- Successful on first attempt
- Successful drogue and main deployment
- Successful recovery

Subscale Flight Test Data

Fully Deployed Main Parachute with the Parachute Protector and Recovery Harness

Nosecone with Payload Bay Door Still Intact

Forward Portion of the Central Section of the Launch Vehicle with the Avionics Bay Rivets Still Intact

Recovery Harness which Connects the Forward and Central Sections

Subscale Flight Test Data

Aft Portion of the Central Section

Drogue Parachute and Parachute Protector Harnessed to the Aft Section

Recovery Harness and Ballasts Attached to the Aft Section

Aft Section of the Launch Vehicle with the Conditions of the Fins

Staged Recovery System Testing

- Completed recovery system electronics tests:
  - Passed: Altimeter Functionality Test (LV-A-1)
    - Determined that the altimeters used can properly activate and reads different altitudes.
    - Determined that the altimeters used can detect drogue and main separation altitudes.

Drogue Detection

Main Detection

Staged Recovery System Testing

- Transmitter Connectivity Demonstration (LV-R-4)
  - Passed: Determined that the GPS was able to connect to the satellites and ground station.
- GPS Functionality Demonstration (LV-R-1)
  - Passed: Determined that the GPS Activates, displays coordinates, and displays different coordinates when moved. The locations used for this test are shown below.

	Location 1	Location 2	Proper position change?
Position 1	29.64714 -82.34951	29.64576 -82.35114	Yes
Position 2	29.647143 -82.34951	29.64832 -82.34950	Yes
Position 3	29.647143 -82.34951	29.38554 82.20425	Yes
Position 4	29.647143 -82.34951	29.64859 -82.3495	Yes
Position 5	29.647143 -82.34951	29.64857 -82.34711	Yes

Staged Recovery System Testing

- Subscale Main Parachute Ejection Demonstration (LV-R-11):

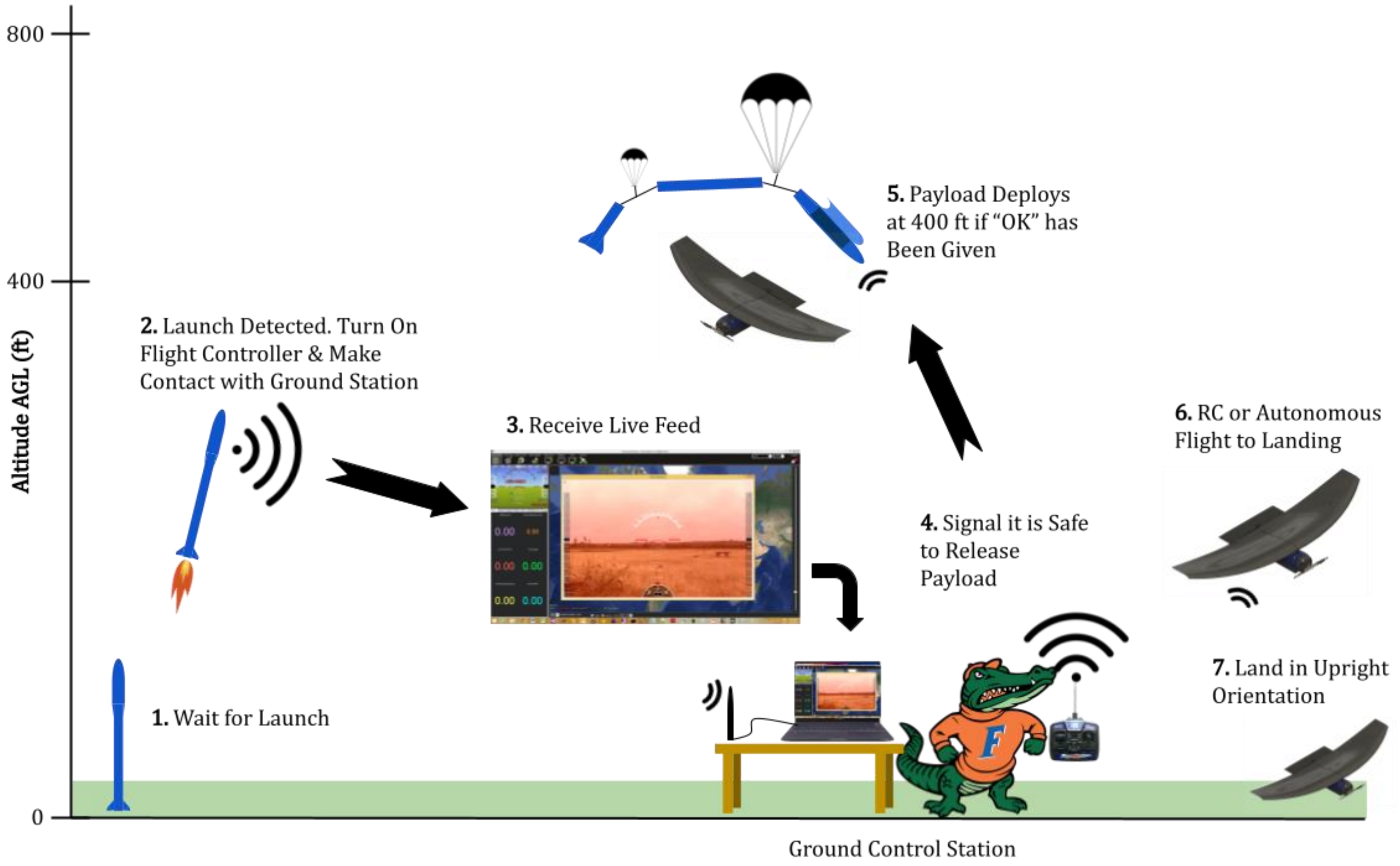
Trial	Primary Charge (g)	Secondary Charge (g)	Success?
1	1.375	1.719	No
2	1.405	1.756	No
3	1.8	2.25	No
4	2.2	2.75	Yes

- Subscale Drogue Parachute Ejection Demonstration (LV-R-12):

Trial	Primary Charge (g)	Secondary Charge (g)	Success?
1	1.250	1.563	No
2	1.455	1.819	No
3	1.555	1.944	No
4	1.730	2.163	No
5	1.850	2.313	Yes

Final Payload Design

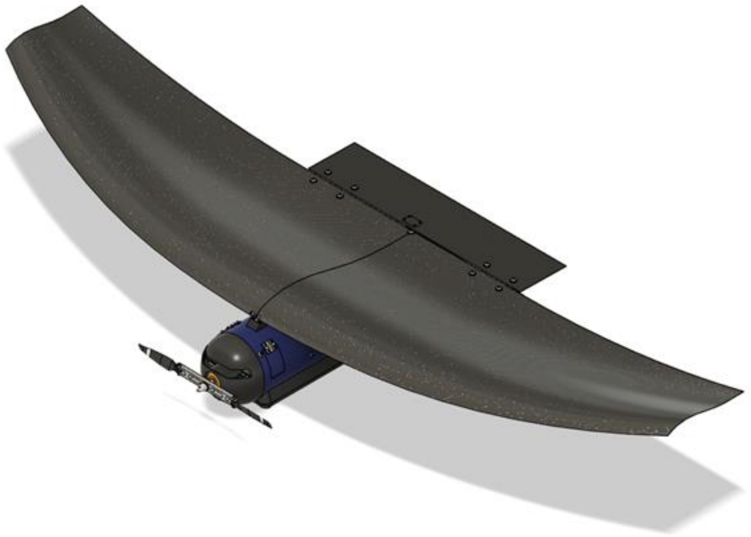
Payload Concept of Operations

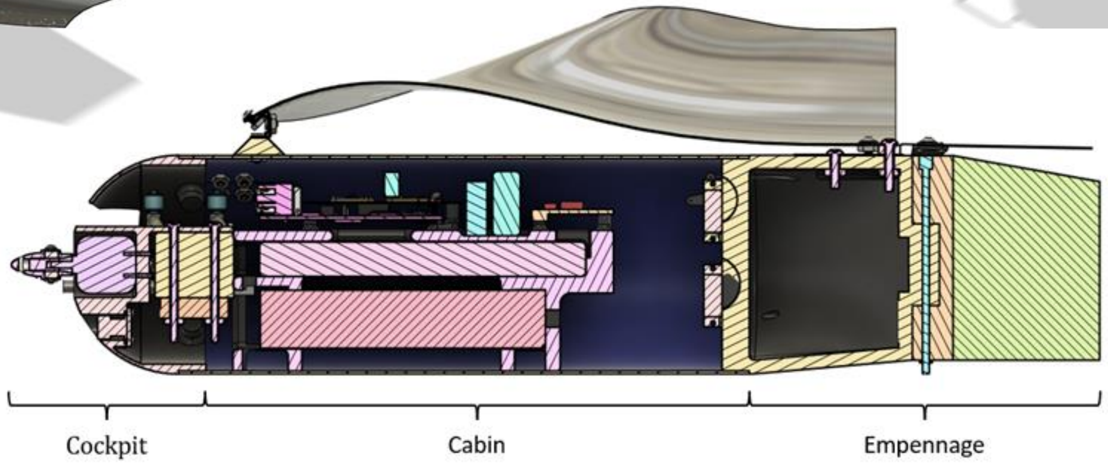


Payload Mechanical Design

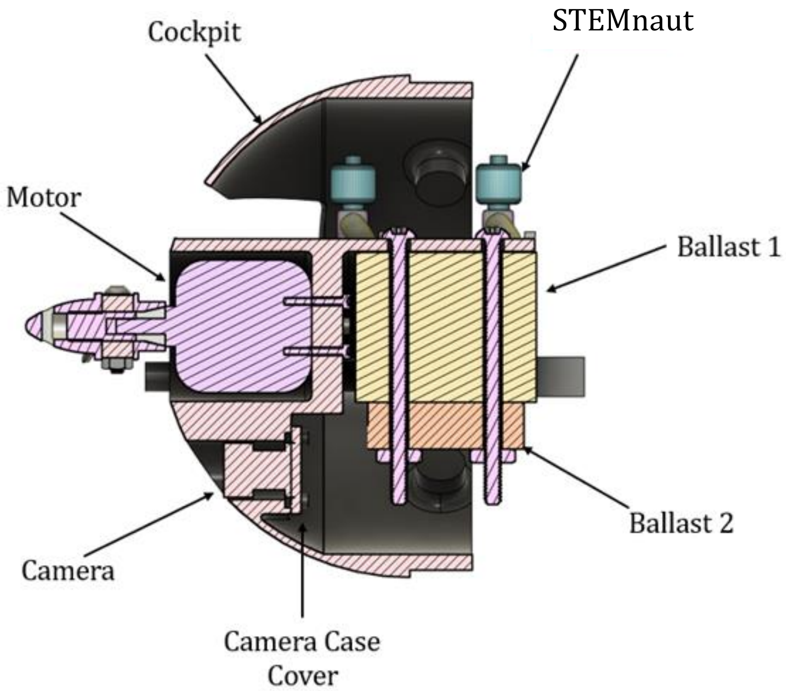
Design Concept: Folding Carbon Fiber Wing Aircraft

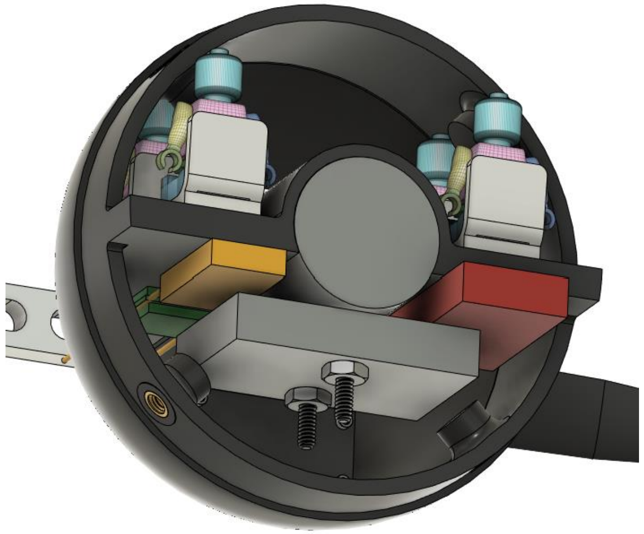
- Fuselage into 3 sub-assemblies: cockpit, cabin, and empennage
- Wing and elevator mounted to top of fuselage





Cockpit Design



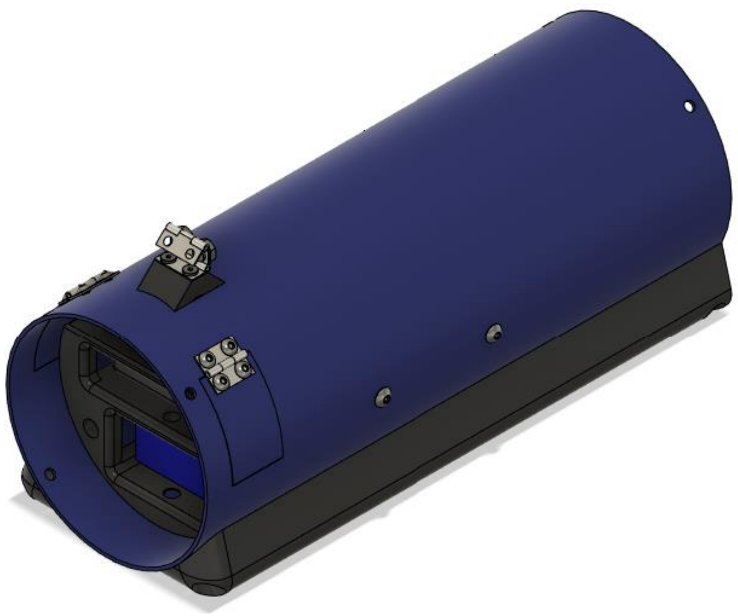


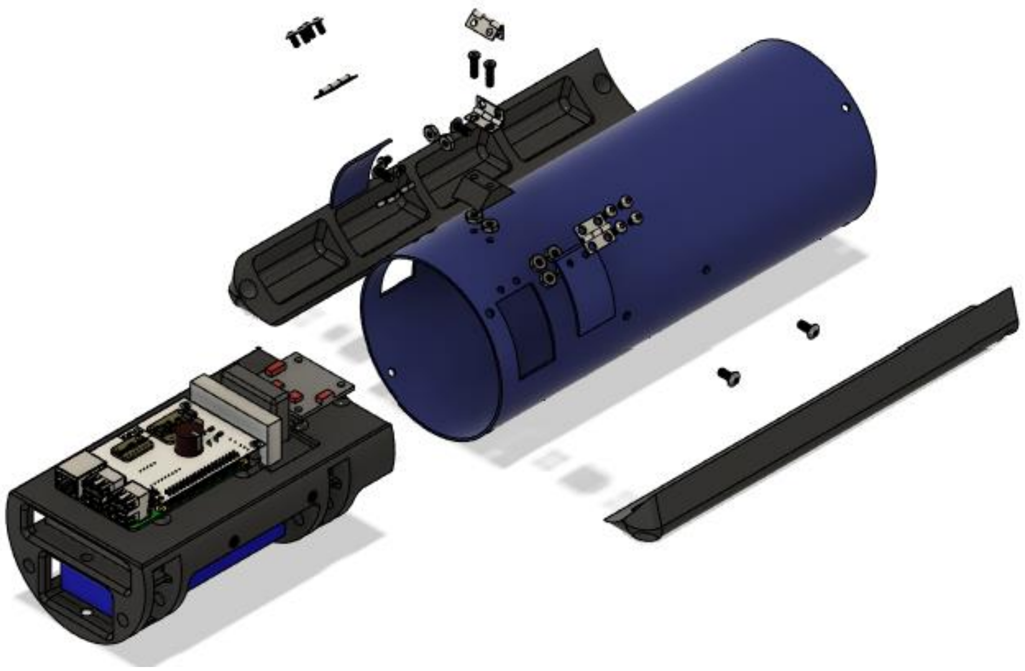
Cockpit
- 3D Printed
- PETG
- Heat-set inserts to attach to cabin
- Features folding propellor

STEMnauts
- LEGO Minifigure
- Seats glued to middle platform

Ballast
- Two ballast, one cylindrical, one rectangular
- Secured by through bolts
- Payload transmitters and receivers

Cabin Design





Central Fuselage
- Bluetube
- Protective housing for electronics
- Doors for entry and exit

Landing Skis
- 3D printed
- PETG
- Attached to central fuselage with epoxy

Electronics Sled
- 3D printed
- PETG
- Mounting for payload electronics
- Fastened to central fuselage with heat-set inserts and screws

Empennage Design

Aft Fuselage

- 3D printed
- PETG
- Mounting for servos

Diagonal Stabalizers

- Carbon fiber
- Improve stability

Rudder Slot

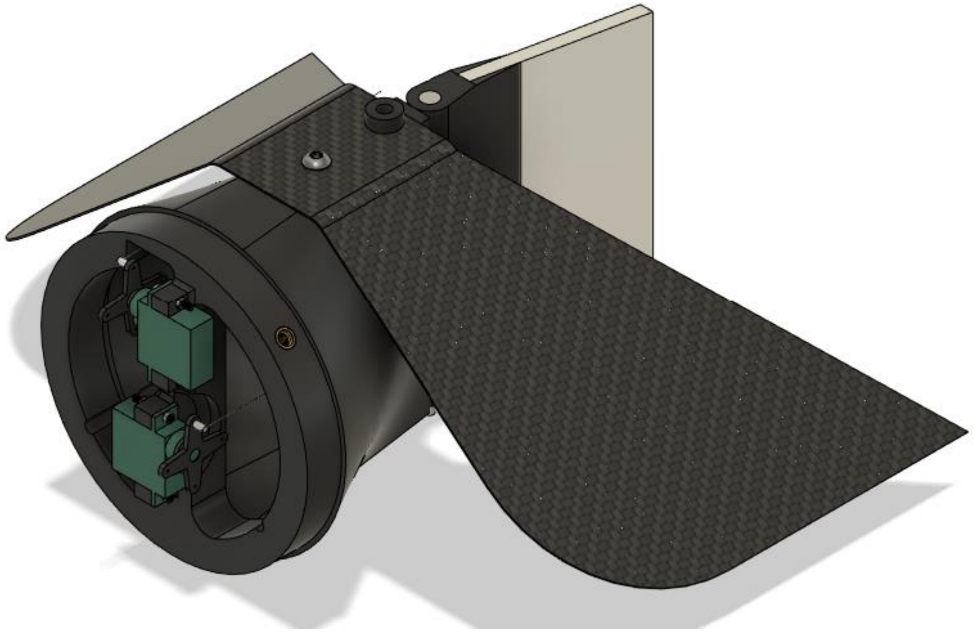
- 3D printed
- Integral control horn

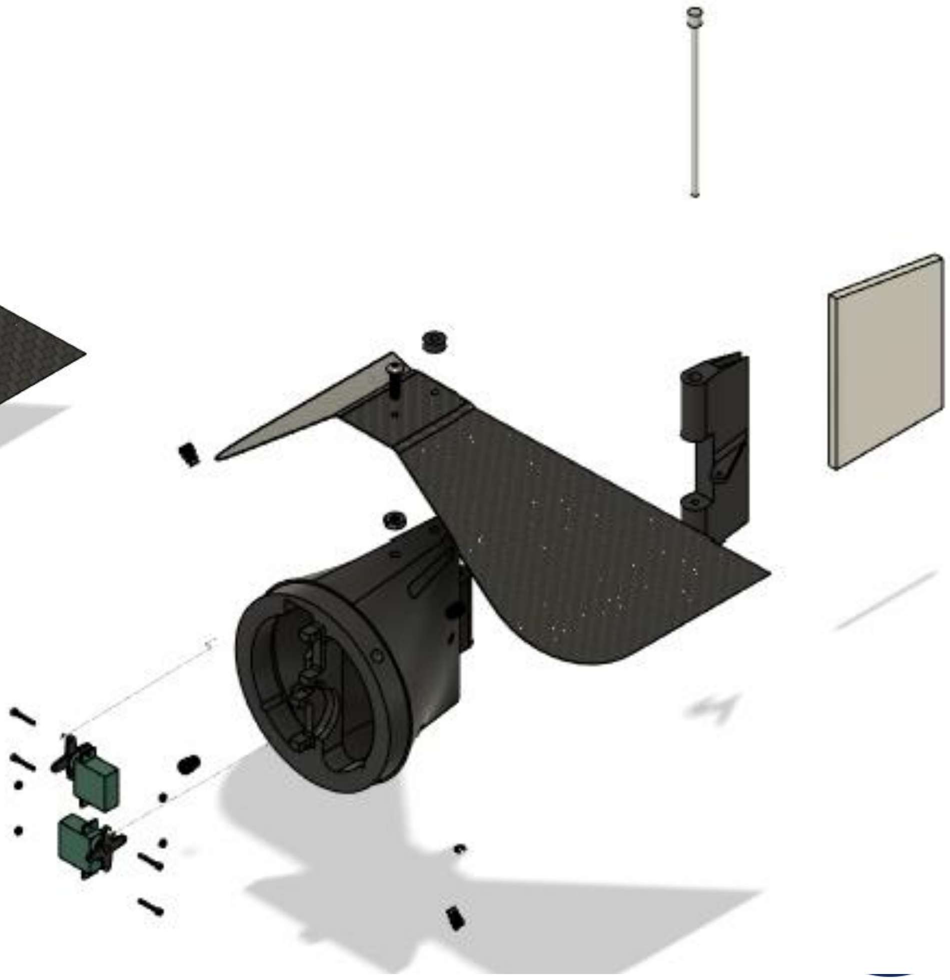
Rudder

- Foam board

Rudder Pin

- Aluminum
- Held in place with c-clip





Wing and Elevator Mounting

Front Wing Stand Off

- 3D printed
- PETG
- Paired with hinges to allow wing to flex

Rear Wing Stand Off

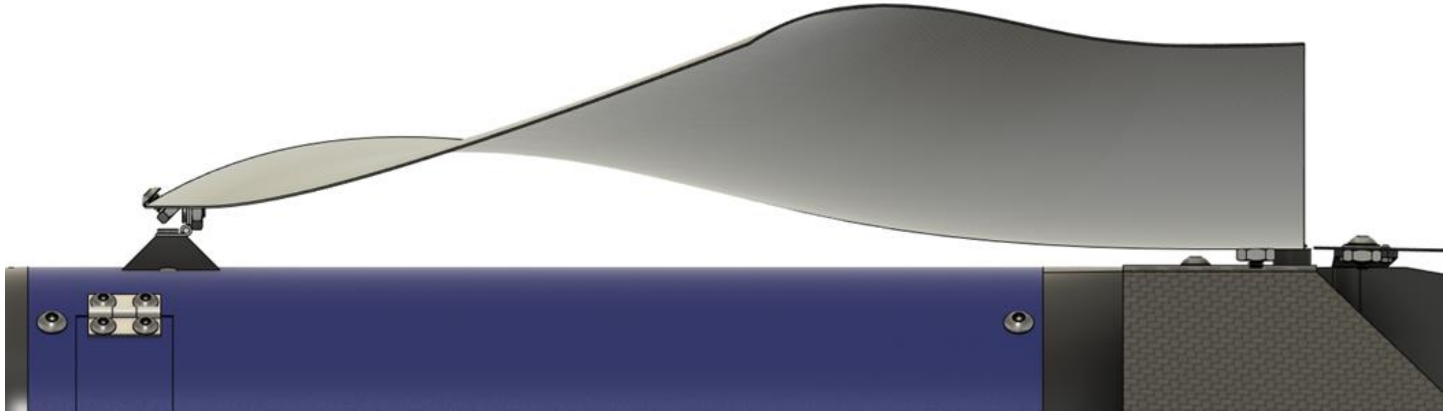
- 3D printed
- PETG
- Allows wing to roll

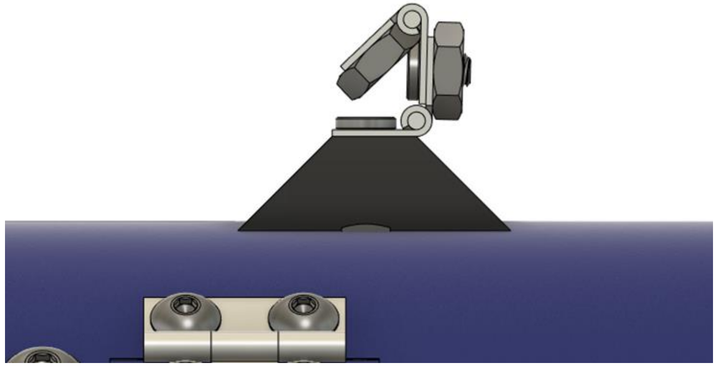
Hinges

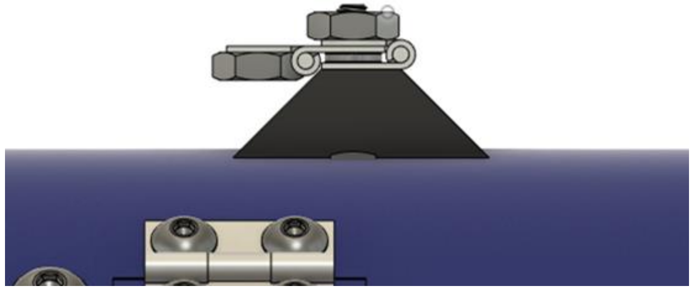
- Aluminum
- 2 in front to allow for folding

Elevator

- Attached to back of wing by fabric hinge
- Carbon Fiber







Foil Design And Stability Analysis

Airfoil Parameters

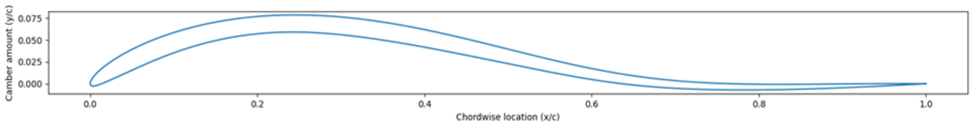
Parameter	Value
Camber	6.88%
Camber Position	24.63%
Zero Lift Angle of Attack	-1.438 deg
For Two Degree Angle of Attack	
Section Coefficient of Lift	0.395
Section Coefficient of Drag	0.022
Lift-to-Drag Ratio	17.677
Pitching Moment Coefficient	0.022

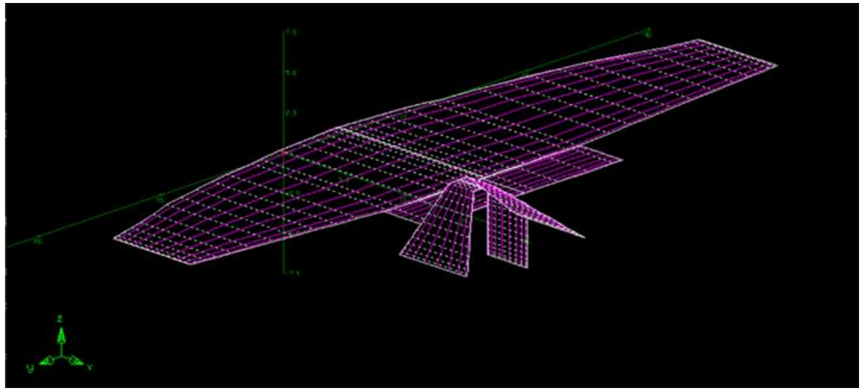
Wing Parameters

Parameter	Value
Root Chord	12 in
Tip Chord	5.5 in
Taper Ratio	0.417
Sweep	10.8 deg
Planform Area	516.2 in^2
Polyhedral Angle	3 deg
Polyhedral Position (from root)	8.0 in

Stability Parameters

Coefficient	Value (rad^{-1})
C_{m_α}	-0.4818
C_{l_β}	-0.0818
C_{n_β}	0.0152





Payload Dimensions

Fuselage

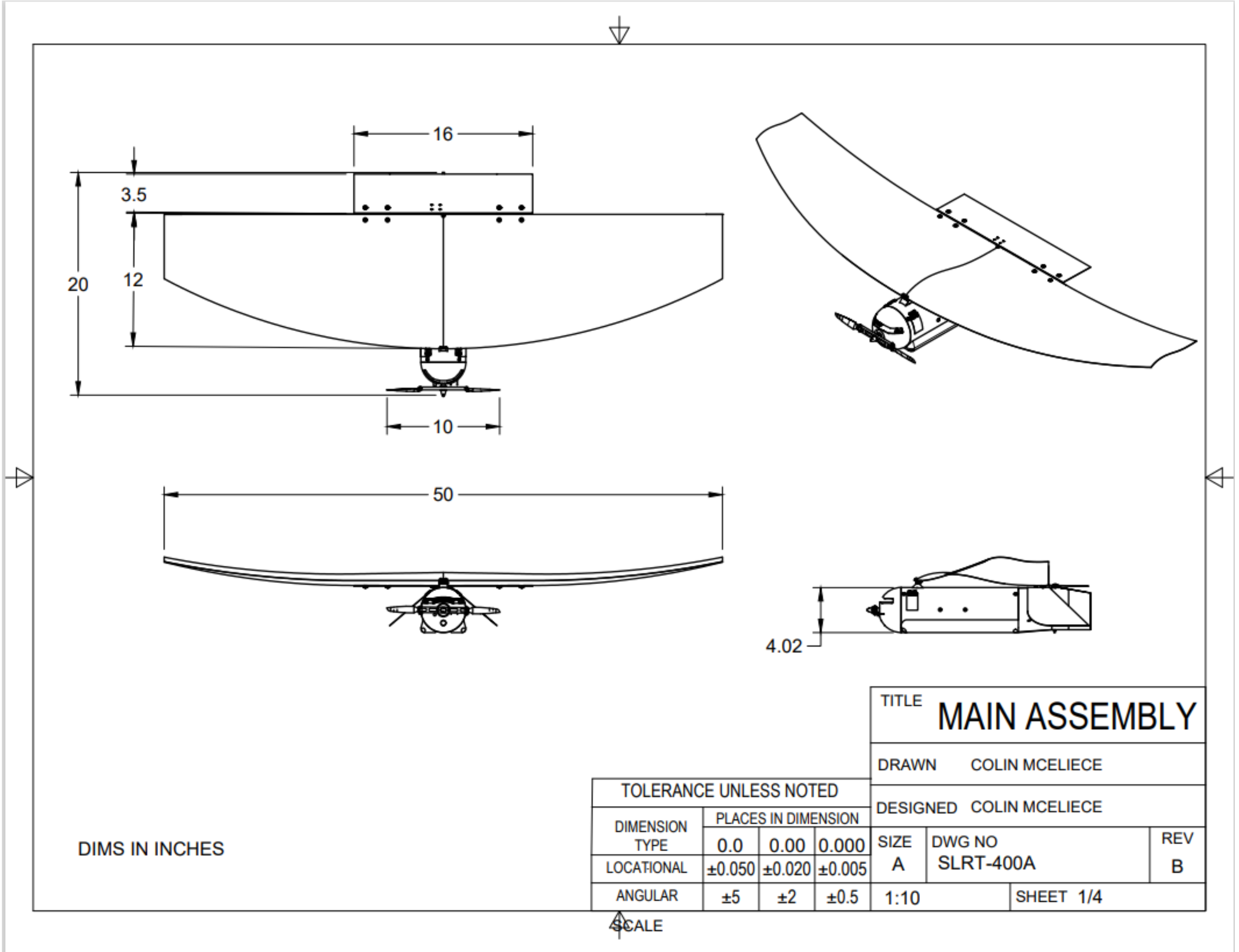
- 20 in length
- 4 in diameter

Wing and Propeller

- 50 in wingspan
- 12 in chord length
- 10 in propeller

Elevator and Rudder

- 16x3.5 in elevator
- 3x4 in rudder



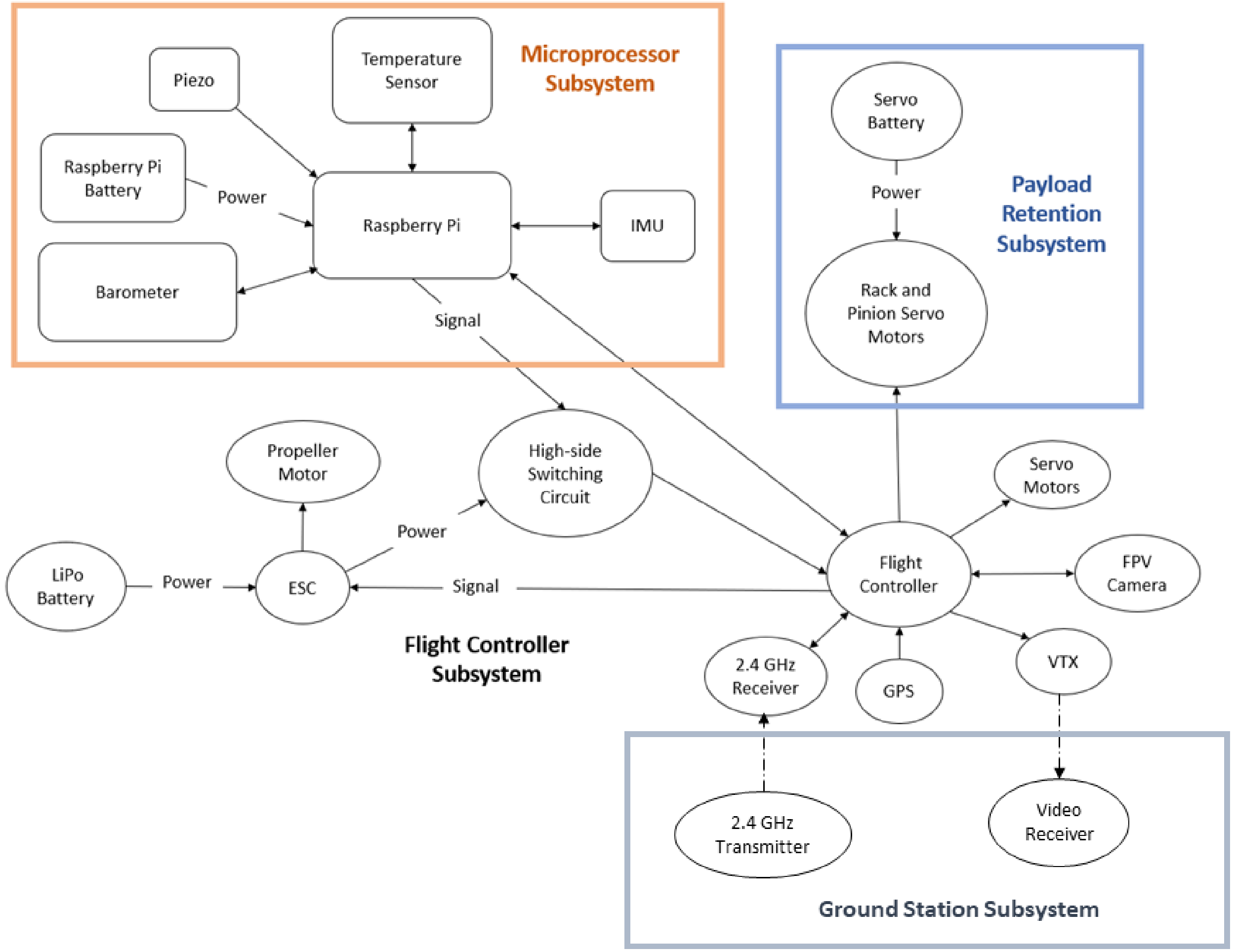
Payload Electrical Design

Microprocessor Subsystem
- Detects STEMnaut survivability parameters
- Turns on Flight Controller Subsystem
- Temperature Safety

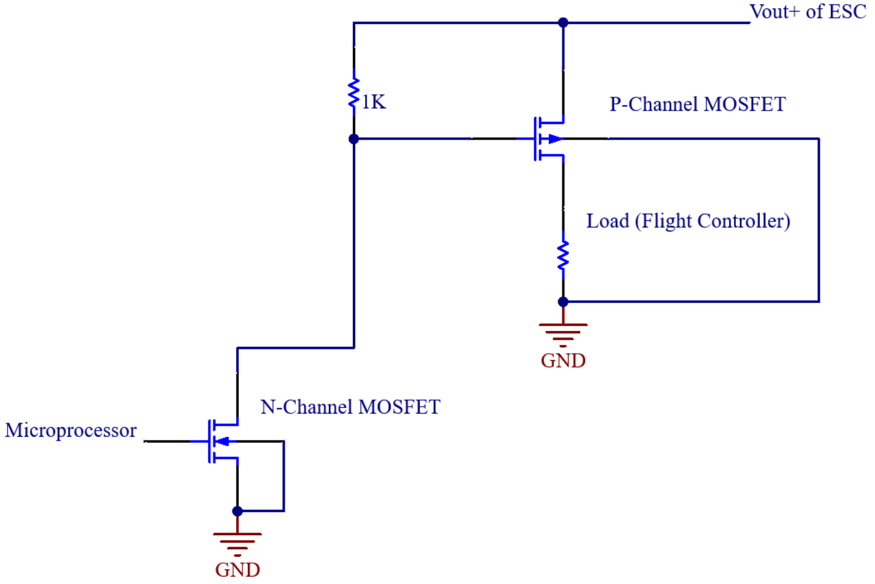
Flight Controller Subsystem
- Controls Deployment & Flight
- Transmits Video (5.733 GHz)
- Receives Radio Commands (2.4 GHz ISM Band, Frequency Hopping)

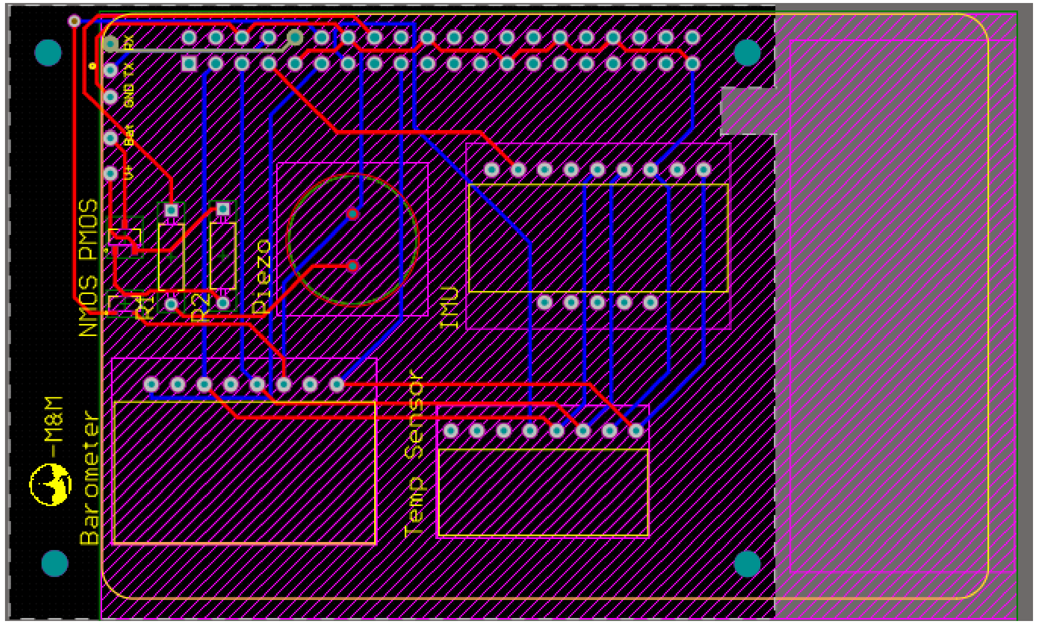
Payload Retention Subsystem
- Retains & Deploys payload

Ground Station
- Sends commands to payload
- Receives video from payload



High Side Switching Circuit & PCB





High Side Switching Circuit

- Composed of an N and P channel MOSFET and resistor
- High Output from Raspberry Pi GPIO pin allows power to be supplied to the Flight Controller

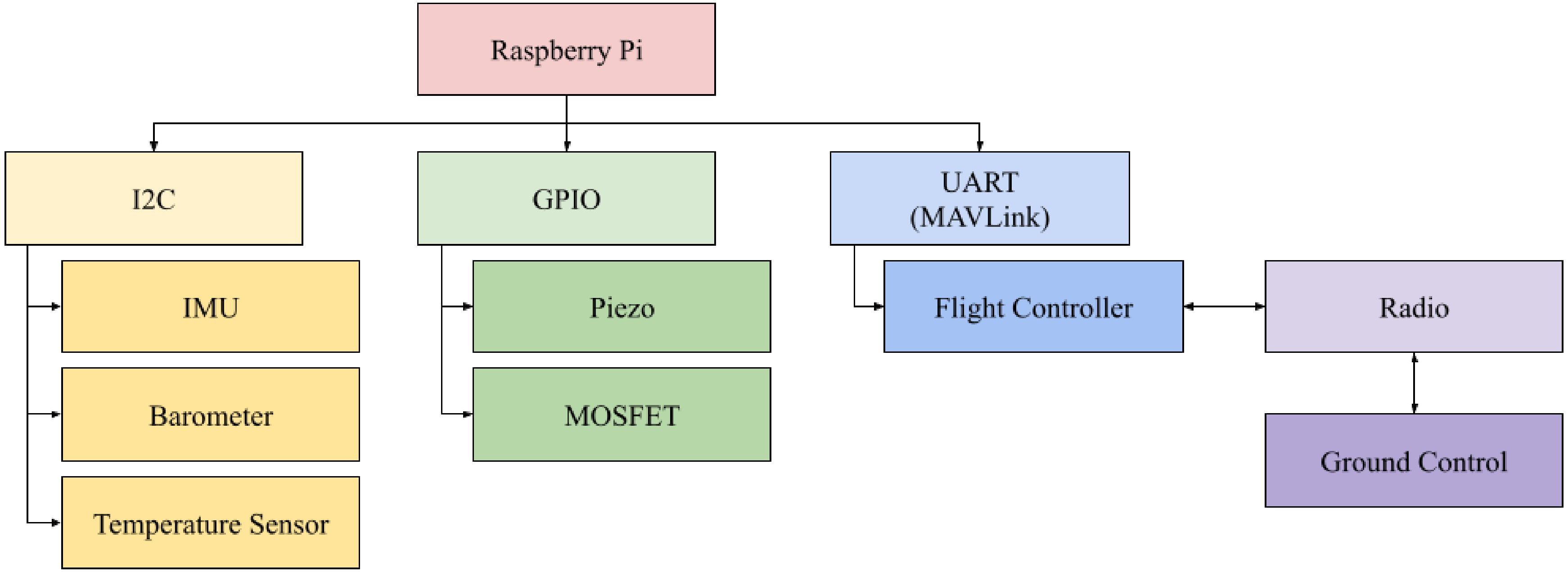
PCB

- Designed to mount on top of the Raspberry Pi
- Contains sensors, piezo, high side switching circuit, UART connections between Raspberry Pi and Flight controller, and ground

Payload Software Design

Three Systems

- **Raspberry Pi:** Main computer, running custom code
- **Flight Controller:** ArduPilot Plane firmware
- **Ground Station:** Mission Planner and FPV Display



Raspberry Pi Software

Four States:

Startup

- Turns on and configures sensor suite
- Piezo signals any issues and state changes
- 10 minute window to lock payload in retention system
- Starts logging data
    - Logs acceleration, altitude, and temperature data
    - Checks STEMnaut survivability through g-forces

Launch Detection

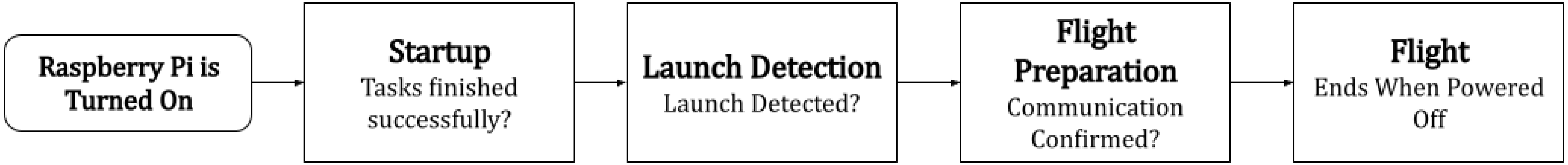
- Loop that checks sensor data for launch conditions

Flight Preparation

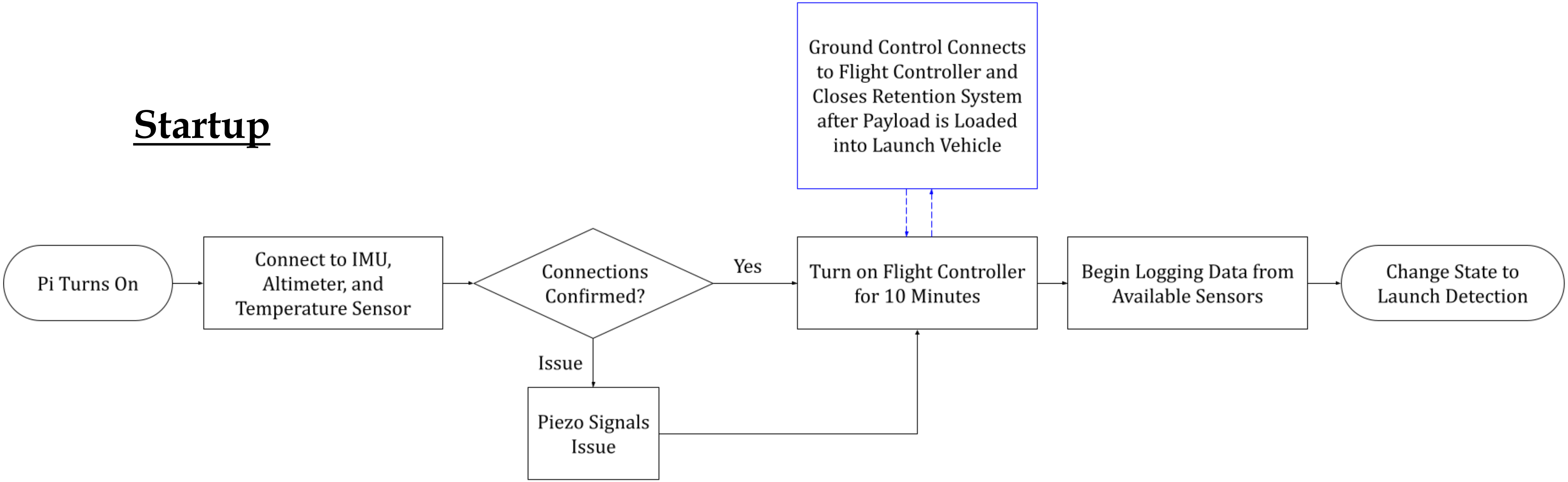
- Turns on flight controller
- Establishes connections between Raspberry Pi, flight controller, and ground station

Flight

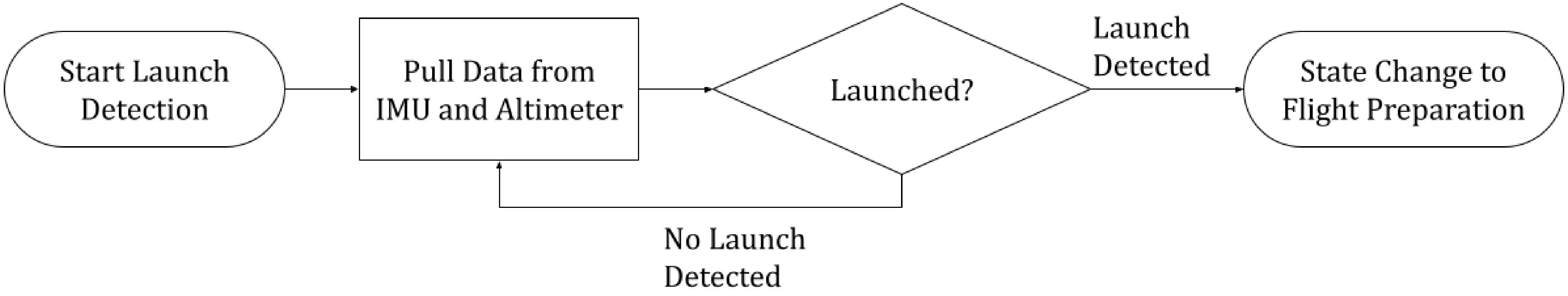
- Ground station arms payload to signal release if deemed safe
- Payload autonomously deploys at 400 ft only if armed and no issues are detected
- RC controlled flight with autopilot backup



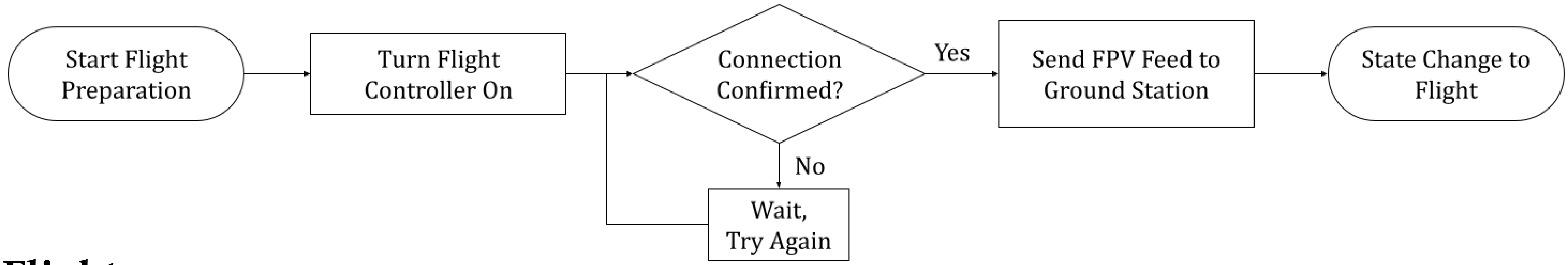
Startup



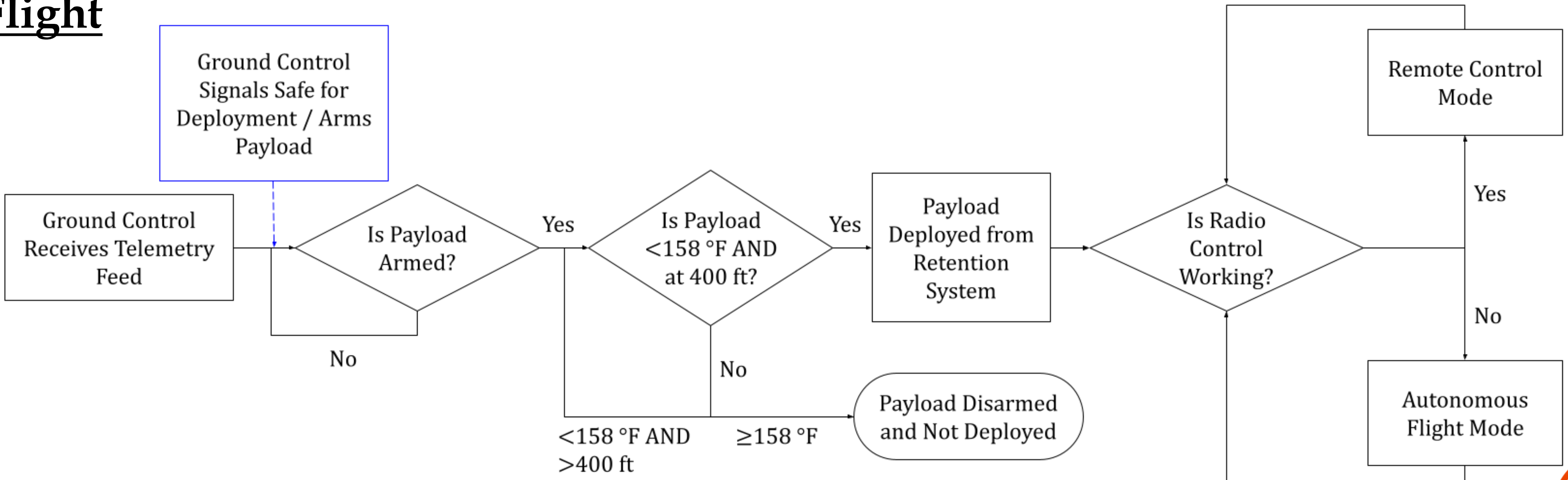
Launch Detection



Flight Preparation

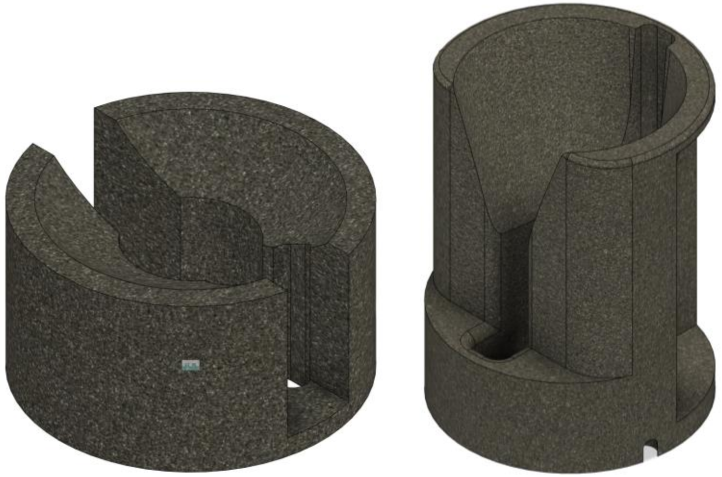


Flight

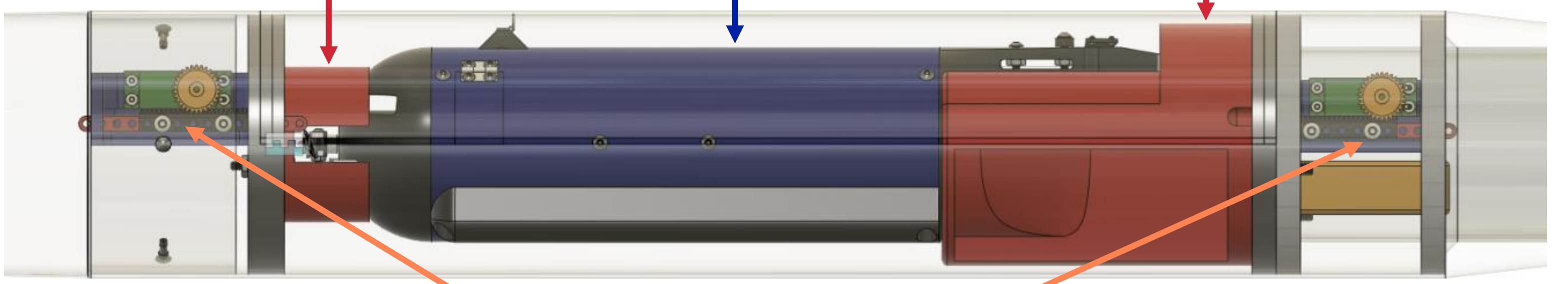


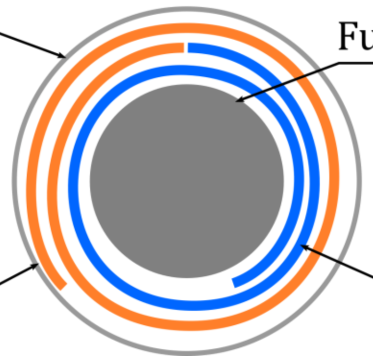
Payload Integration

- Sabots installed to the forward and aft end of the payload.
  - Made from two-part expanded foam.
  - Prevents payload from moving within the bay.
  - Secured to payload bulkheads with a short length of 1/4 in Kevlar recovery harness and eyebolt.



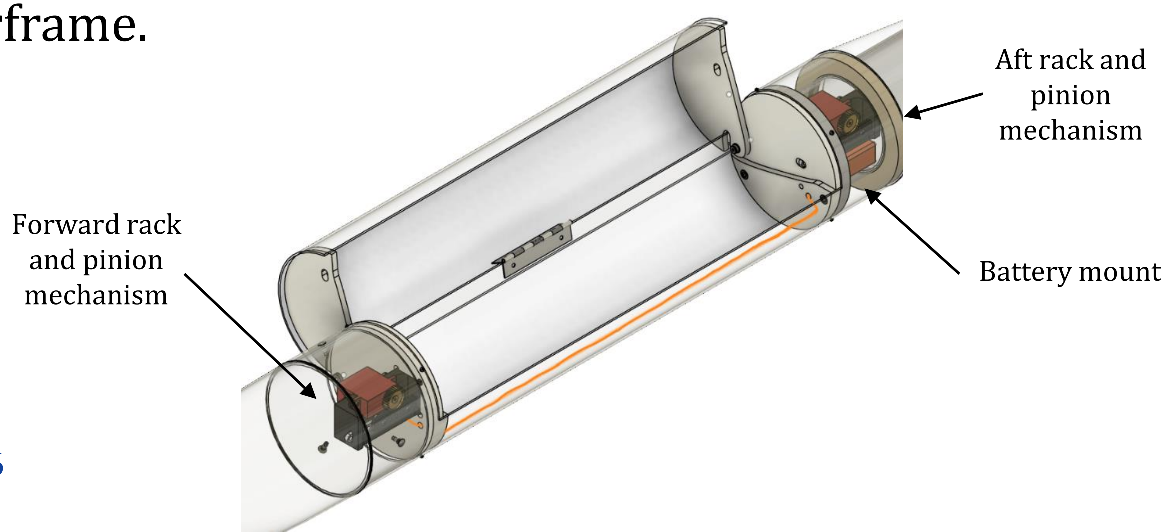
Forward sabot Aft sabot



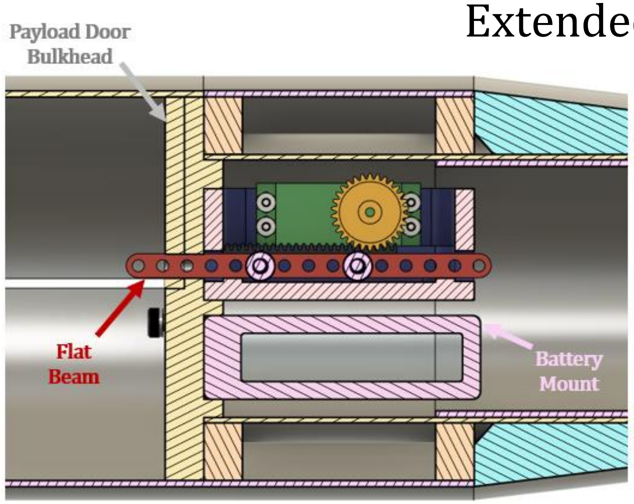


Payload Retention System

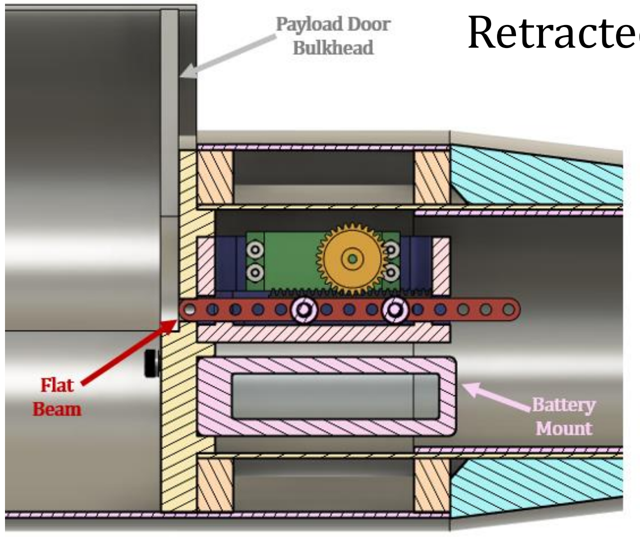
- Rack and pinion mechanisms (one in the forward end and the other in the aft end).
  - UHMW polyethylene servo mount
  - MOD 0.8 pinion gear and gear rack
  - 1102 series flat beam
  - Miuzei 20kg servo motor
  - Six 6-32 fasteners
- 2000mAh battery will power both mechanisms with wires (shown in orange) running through the side of the payload airframe.



Extended position

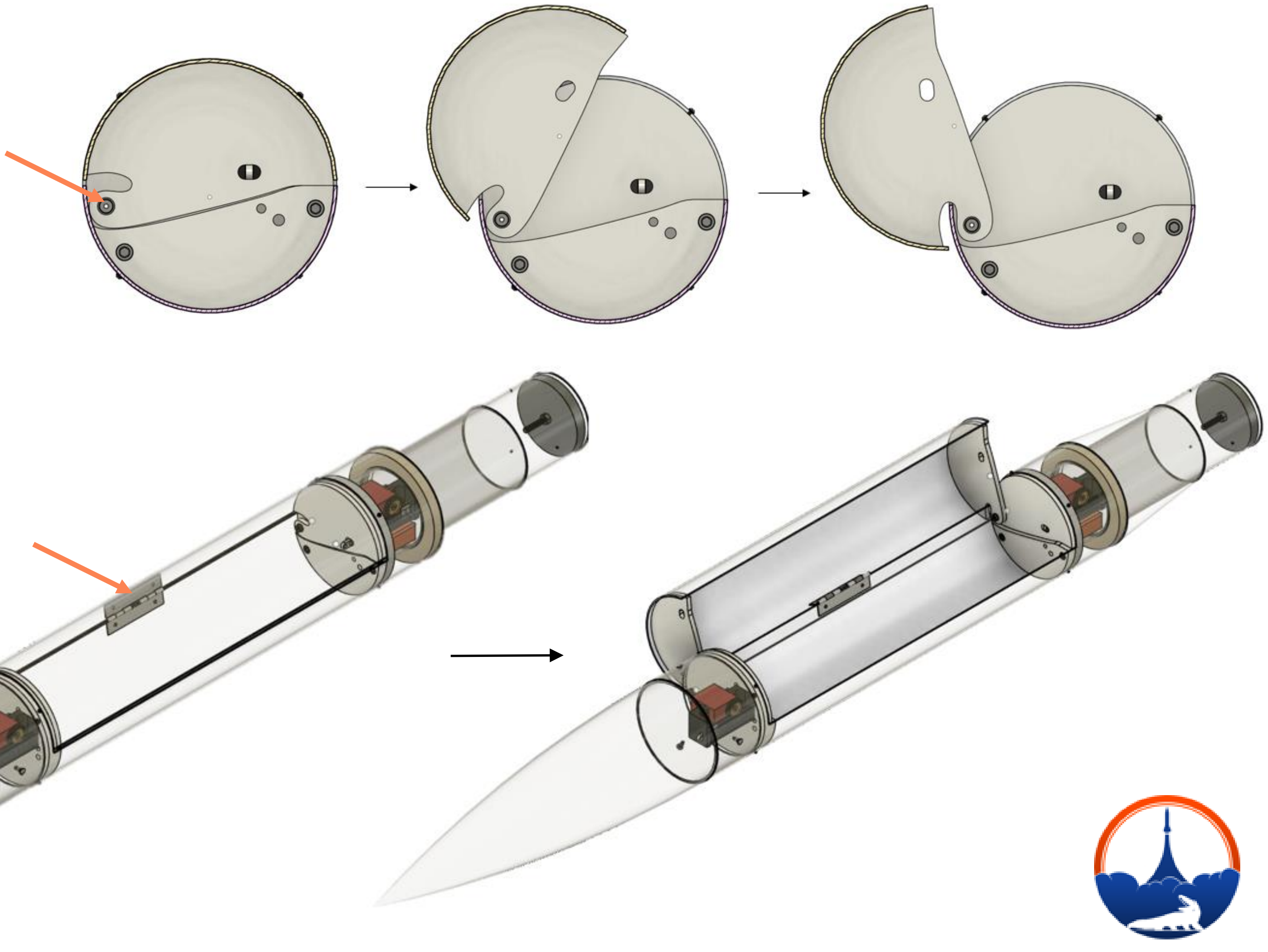


Retracted position



Payload Door Hinge

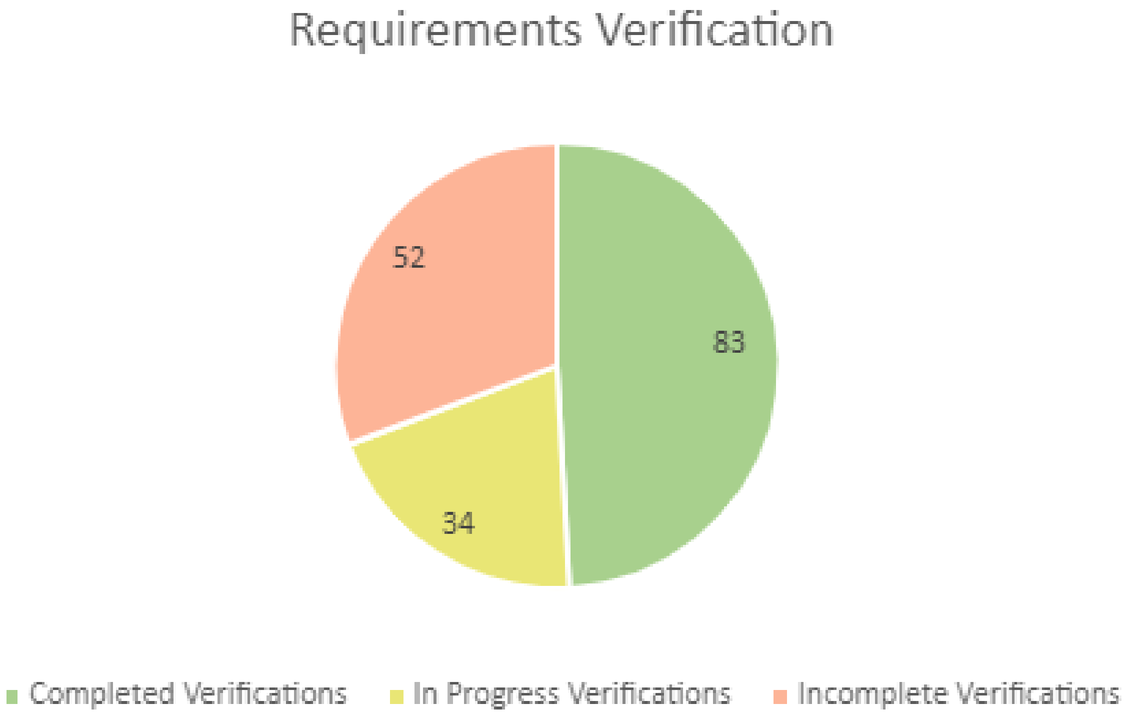
- Payload door bulkheads:
  - Extended arm joint that pivots about a shoulder screw.
  - Cutout above the curved joint for clearance with the airframe.
- Self-opening spring hinge:
  - Bottom door leaf epoxied to the payload airframe.
  - Top door leaf spring forces against the payload door.



Requirements Verification

Requirements Verification

- The team has developed a total of 51 requirements, which break down into three subsections.
  - Launch Vehicle Requirements
  - Recovery Requirements
  - Payload Requirements
- As progression continues in the project, the team derived requirements are updated to reflect design changes.
- Total requirements: 169
  - Team derived: 51
  - NASA: 118



Test Plans and Procedures

- The team has developed a list of unique tests separated into two tables, launch vehicle tests and payload tests.
  - Subscale tests are separated into a unique table. These tests are derived from the launch vehicle tests.

- The tables list each test’s ID, name, objective, used materials, methodology, tested variable, and success criteria.

Test ID	Test Name	Objective	Materials Used	Methodology	Variables Tested	Success Criteria
P-MS-1	Wing Material Flexural Strength Test	Ensure the wings can withstand appropriate bending forces.	Intron UTM, carbon fiber sample	Secure the fiberglass into the Instron UTM and simulate axial and lateral compression until failure or 30 kN is reached. Record data and determine maximum allowable compression.	Flexural strength	Material survives applied load with a factor of safety of at least 1.5.
P-SP-1	Wing Coefficient of Lift Analysis	Simulate flight conditions to determine the coefficient of lift of the wings.	SolidWorks	Use SolidWorks simulations to calculate the coefficient of drag of the wings in flight conditions.	Coefficient of lift	Coefficient of lift is calculated
P-	Skis Impulse	Ensure the Skis will	Skis material	Secure a strain gauge onto the fin	Impulse	Material survives applied load with a

- As the project progresses, the team will continue to complete all developed test to verify the integrity of the launch vehicle and payload.

Project Avigator

University of Florida

Thank you!