Project Avigator

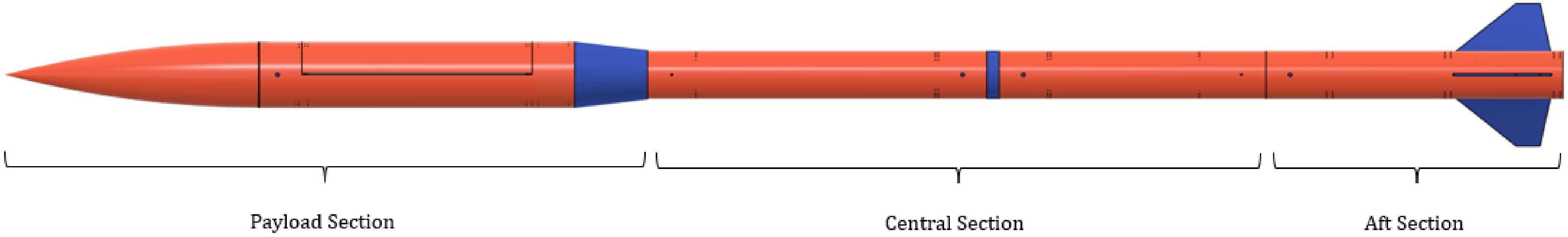
University of Florida

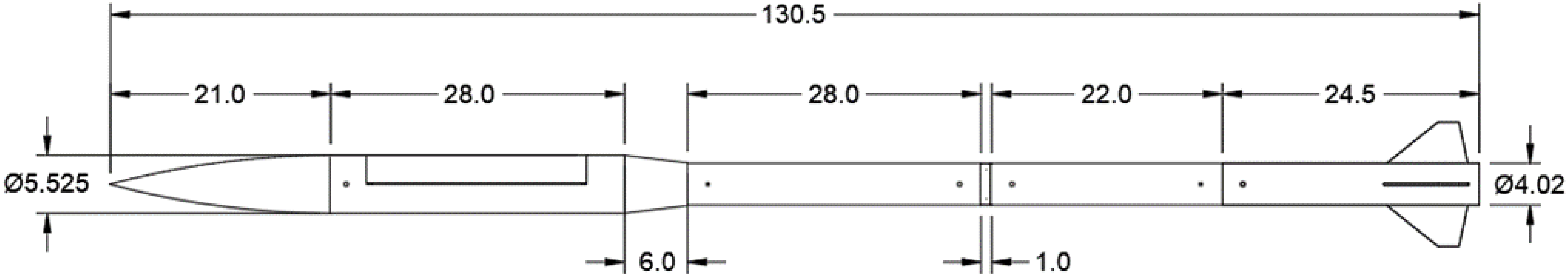
NASA University Student Launch Initiative

2024 Preliminary Design Review

Launch Vehicle Design

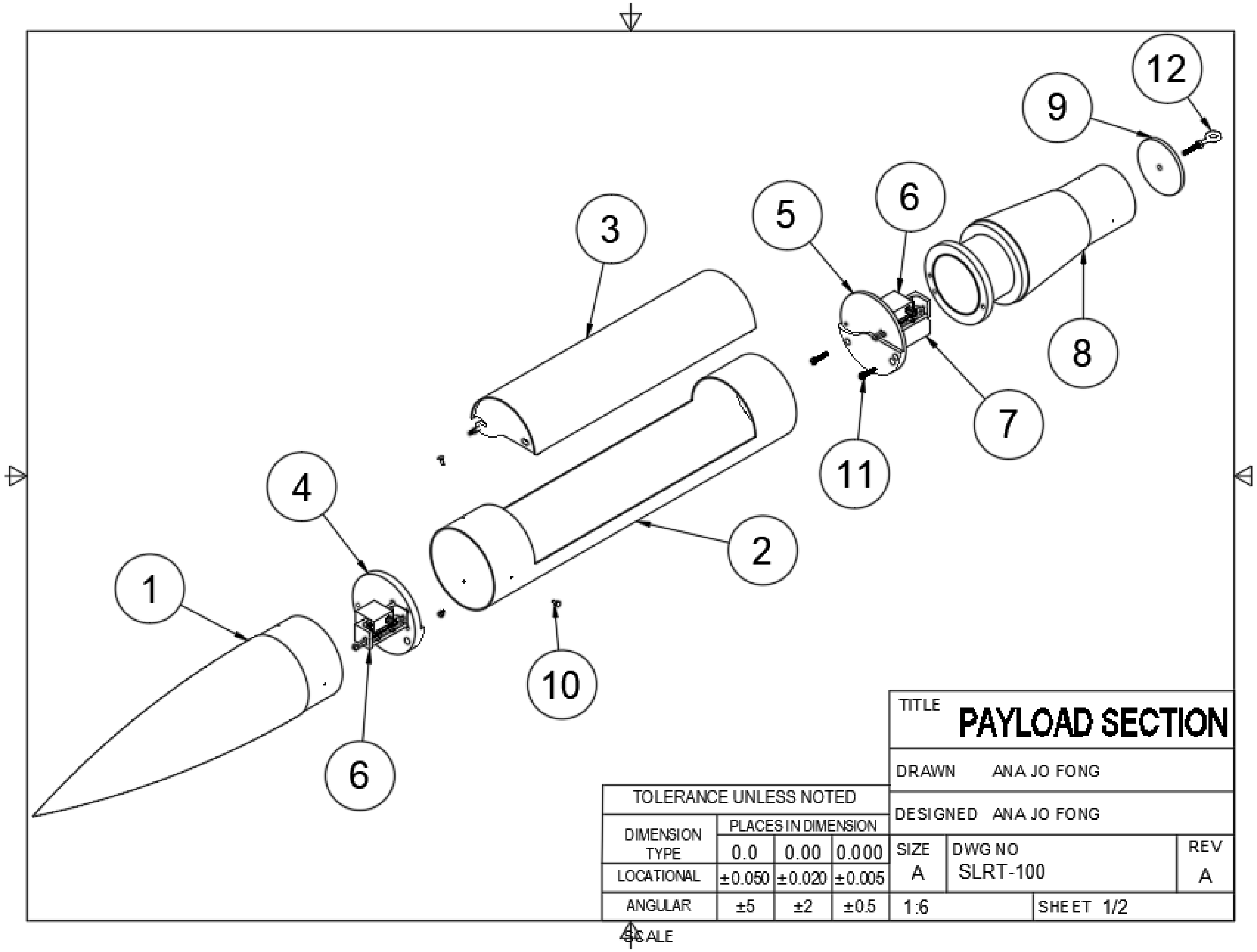
Leading Vehicle Design





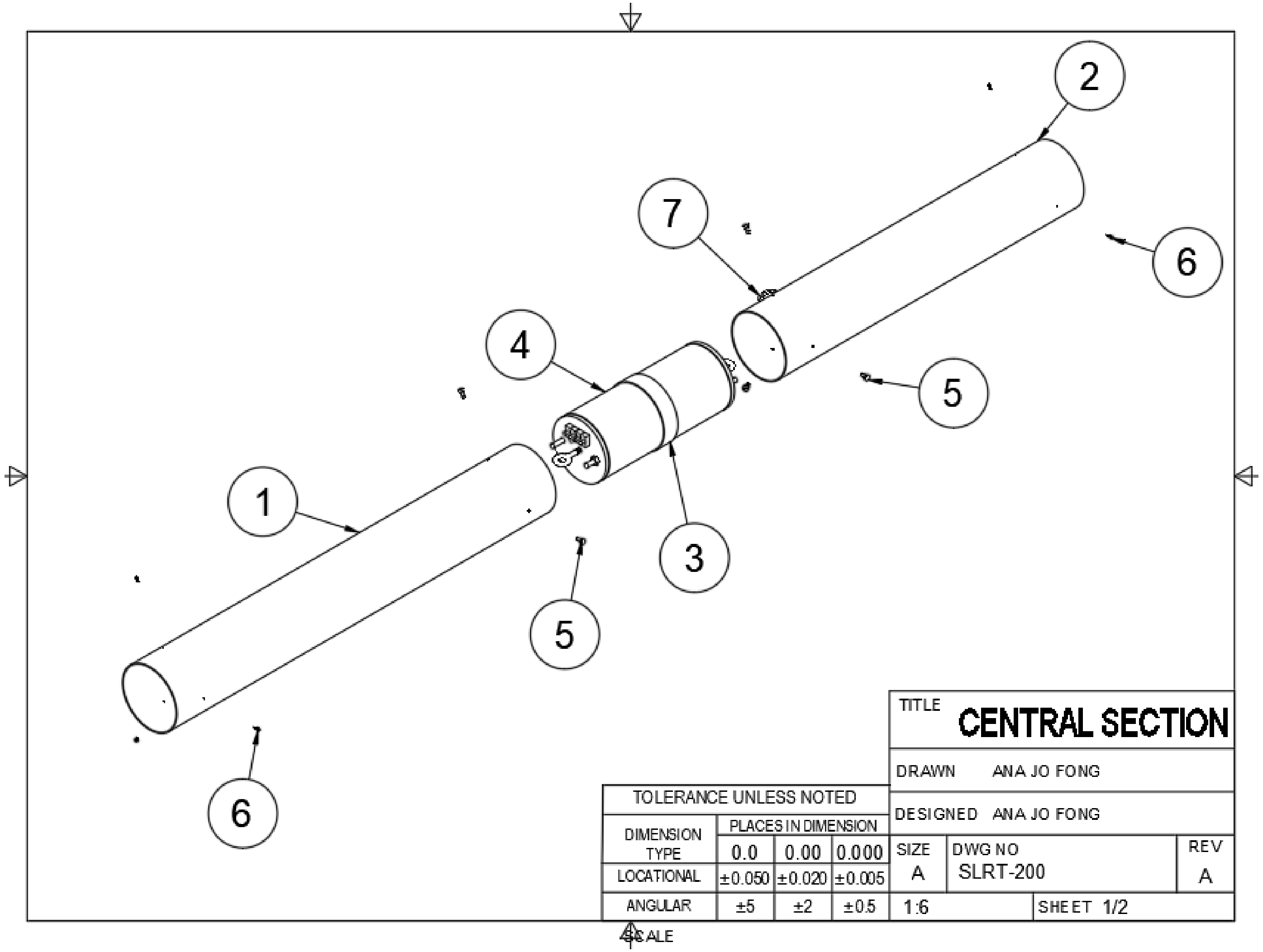
Section	Exterior Length (in)	Overall Mass (oz)
Payload	55.0	243.4
Central	51.0	119.7
Aft	24.5	222.6
Total	**130.5**	**385.7**

Payload Section



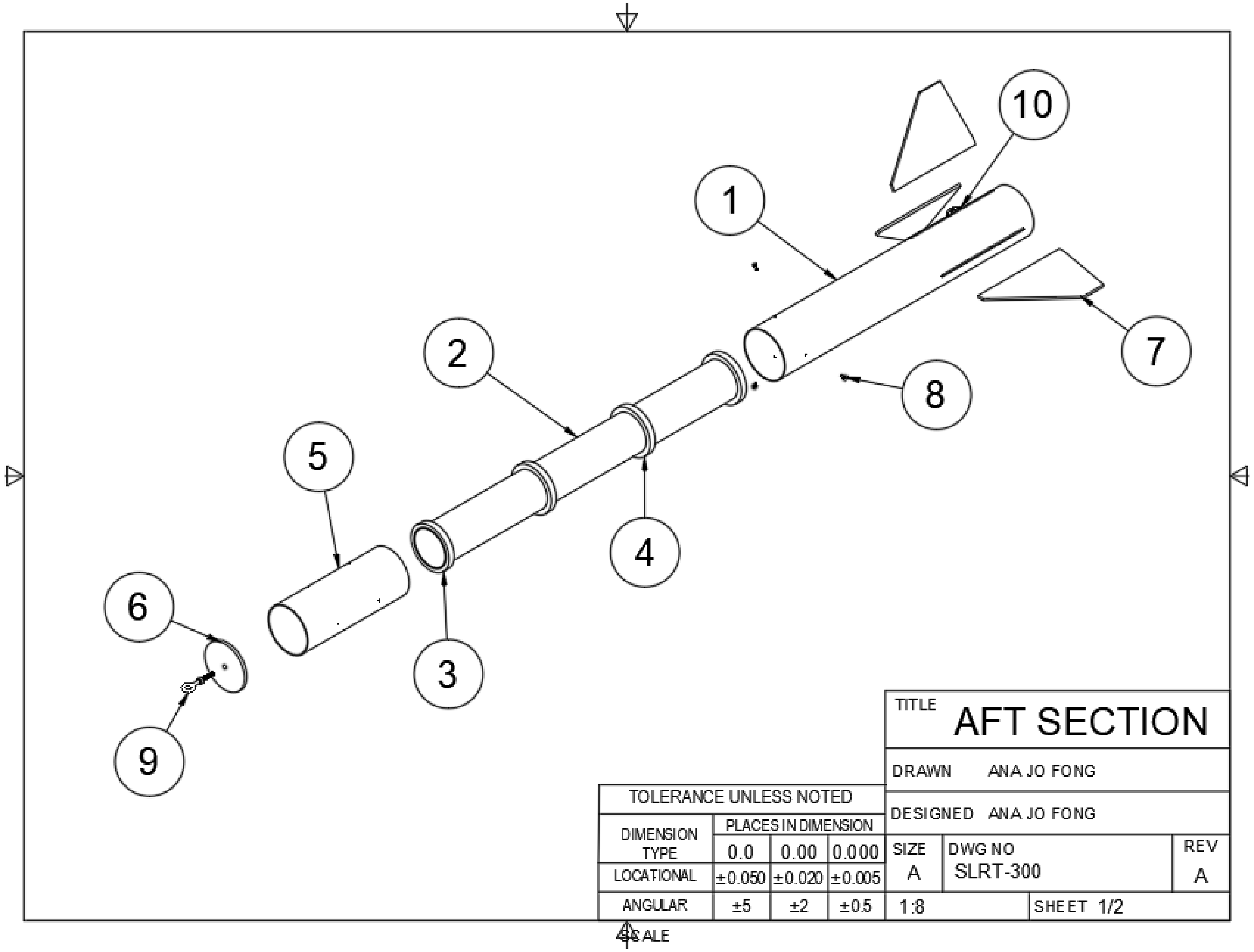
- Nosecone
  - GPS
- Payload Airframe
  - Payload Door
  - Forward Payload Bulkhead
    - Payload Retention System
  - Aft Payload Bulkhead
    - Payload Retention System
    - Battery Mount
- Transition Section
  - Centering Ring
  - Forward Coupler + Extension Airframe
  - Forward Bulkhead + Eyebolt

Central Section



- Forward Airframe
- Avionics Bay
- Switchband
- Central Airframe

Aft Section



- Aft Airframe
  - Motor Assembly
    - Motor Tube
    - Centering Ring
- Fin
- Aft Coupler
- Aft Bulkhead + Eyebolt

Launch Vehicle Material Selection

Component	Objectives	Alternative Materials	Selected Material
Nosecone	Cost, Compressive Strength, Mass	Poly-Propylene Plastic, G12 Fiberglass	Poly-Propylene Plastic
Airframe, Coupler	Compressive Strength, Density, Machinability, Cost	Blue Tube 2.0, G12 Fiberglas, Quantum Tube, Phenolic	G12 Fiberglass
Bulkhead	Tensile Strength, Machinability, Density, Cost	Plywood, Structural FRP Fiberglass, Type II PVC, Delrin Plastic	Type II PVC, Delrin Plastic
Centering Ring	Machinability, Shear Strength, Cost, Density	Plywood, Structural Fiberglass, Type II PVC, Phenolic	Plywood, Type II PVC
Transition Shroud	Compressive Strength, Thermal Resistivity, Water Resistance, Cost, Machinability	PETG, PLA, ABS	PETG
Fin	Flexural Strength, Impact Strength, Density, Cost	G10 Fiberglass, Plywood, Structural FRP Fiberglass	G10 Fiberglass

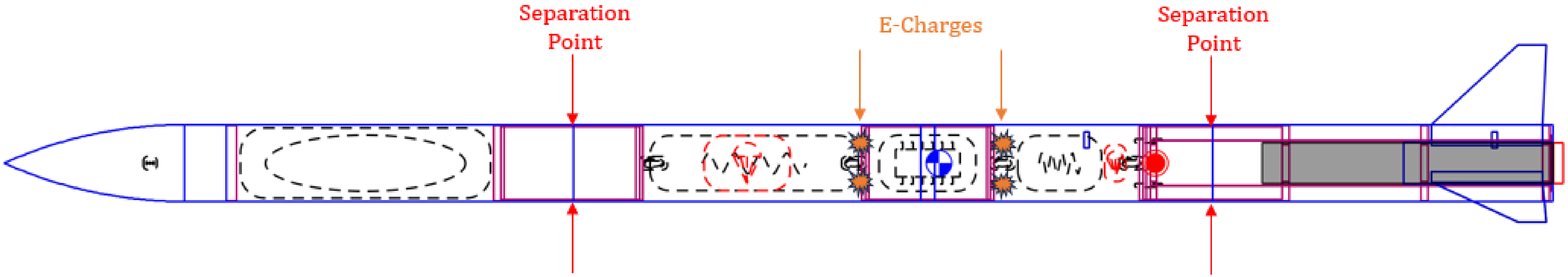
Alternative Design: Single Diameter Vehicle

Pros:

- Space for payload
- Relatively simple structure
- Aerodynamic

Cons:

- Extremely large airframe diameter
    - Heavy
    - Larger motor
- Expensive



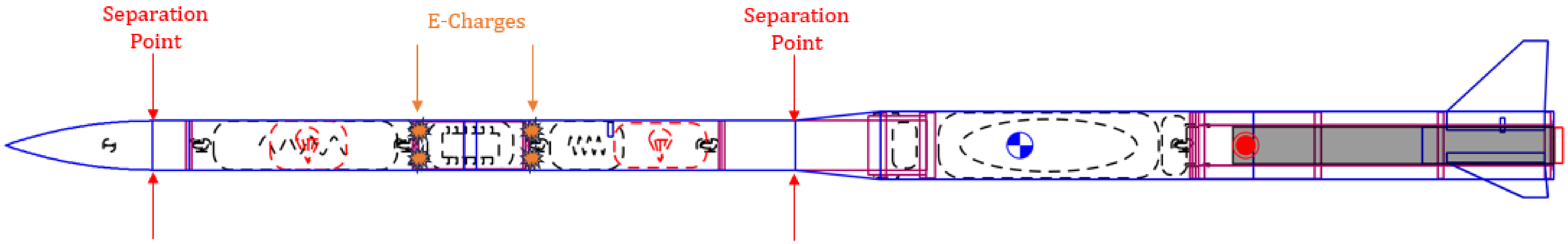
Alternative Design: Two-Diameter Vehicle with Large Aft

Pros:

- Structural integrity of payload section
- Cost efficient

Cons:

- Lower stability
- Payload experiences greater force due to proximity to motor
- Bottom heavy



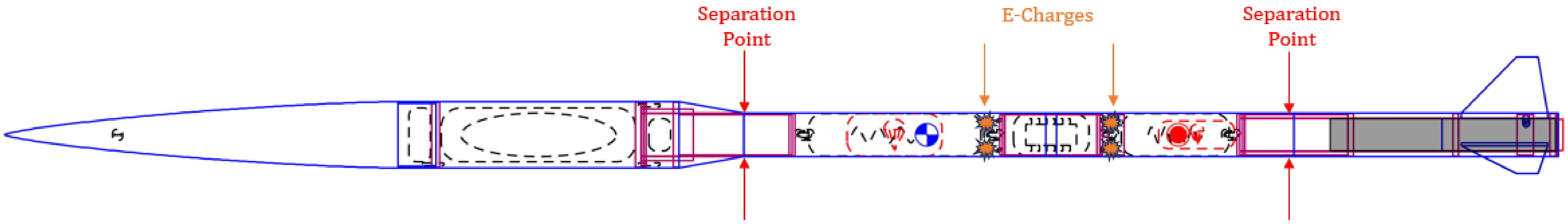
Alternative Design: Two-Diameter Vehicle with 6 in Forward

Pros:

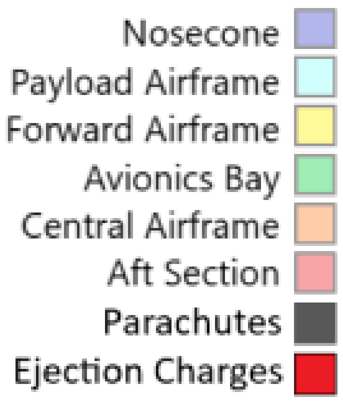
- More space for payload
- Initially thought that money could be saved on airframe

Cons:

- Higher costs due to nosecone
- Only commercially available nosecone is unnecessarily long
- Higher risk of flow separation at transition

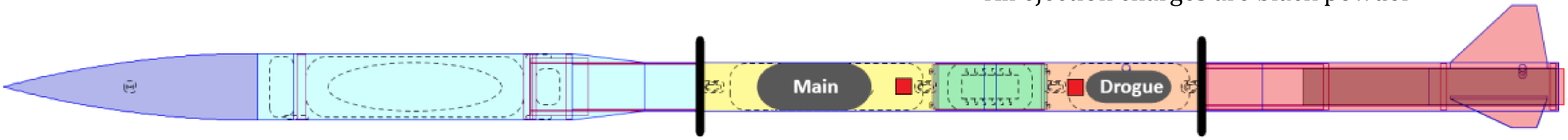


Separation Points



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

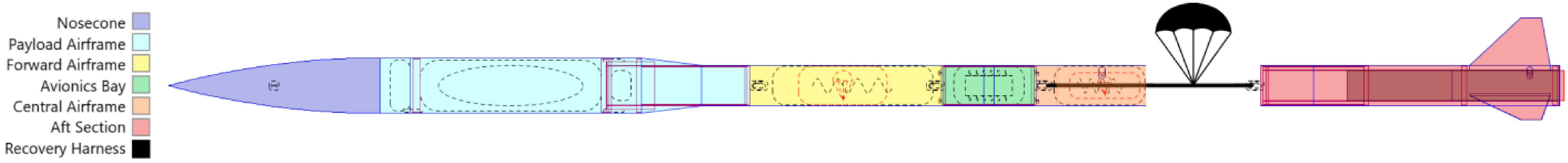
*All ejection charges are black powder



1st Separation Event

Component Type	Manufacturer	Model	Component Location
Drogue Parachute	b2 Rocketry	SkyAngle CERT-3 Drogue	Central Airframe
Recovery Harness	Onebadhawk	7/16-in, 25 ft long tubular Kevlar	Central Airframe

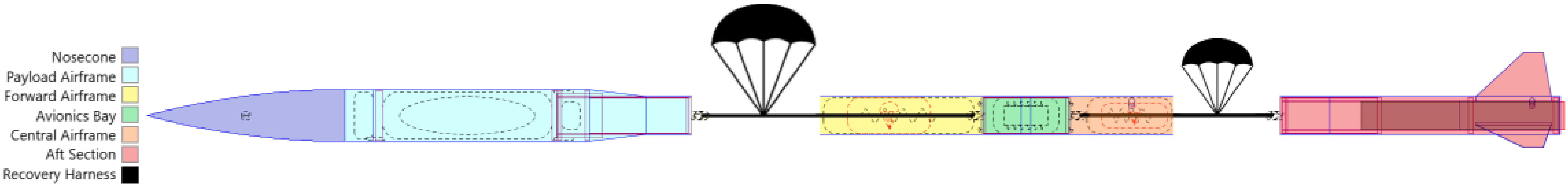
Descent Rate
88.6 ft/s



2nd Separation Event

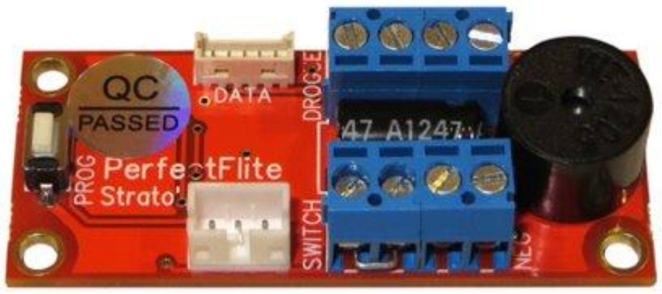
Component Type	Manufacturer	Model	Component Location
Main Parachute	Fruity Chutes	Iris Ultra 84 in Standard Parachute	Forward Airframe
Recovery Harness	Onebadhawk	7/16-in, 25 ft long tubular Kevlar	Forward Airframe

Scenario	Descent Rate
With Payload	17.6 ft/s
Without Payload	16.4 ft/s

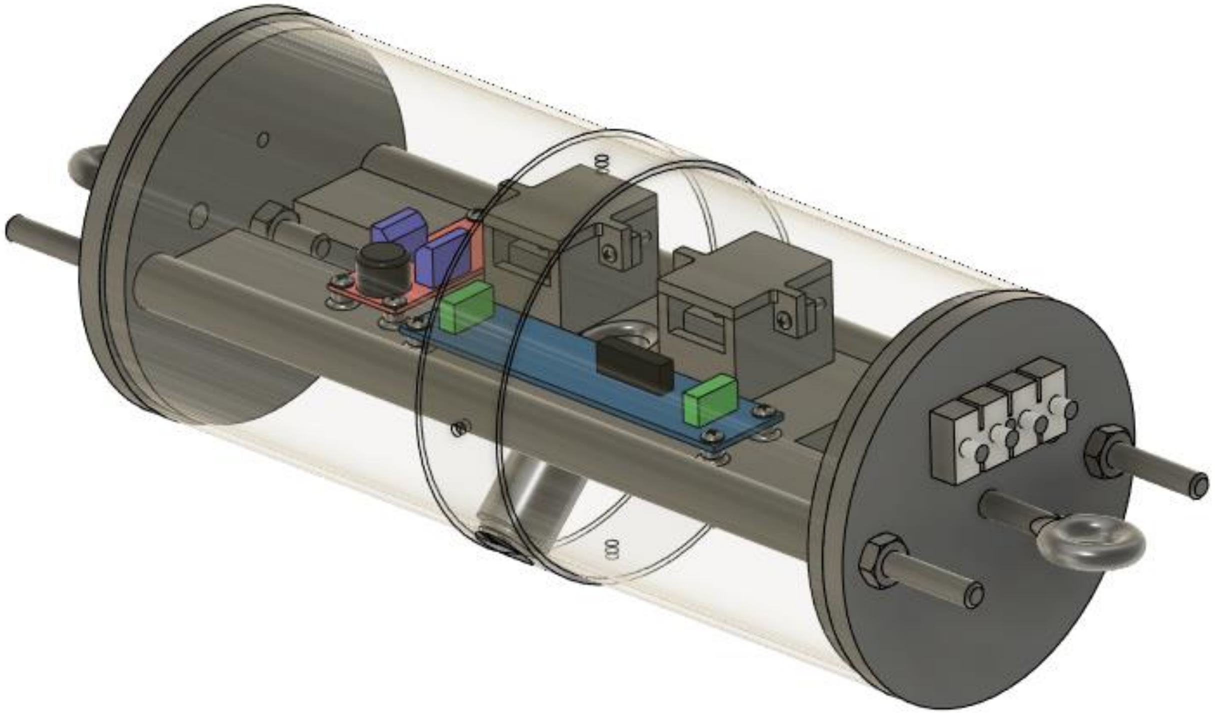


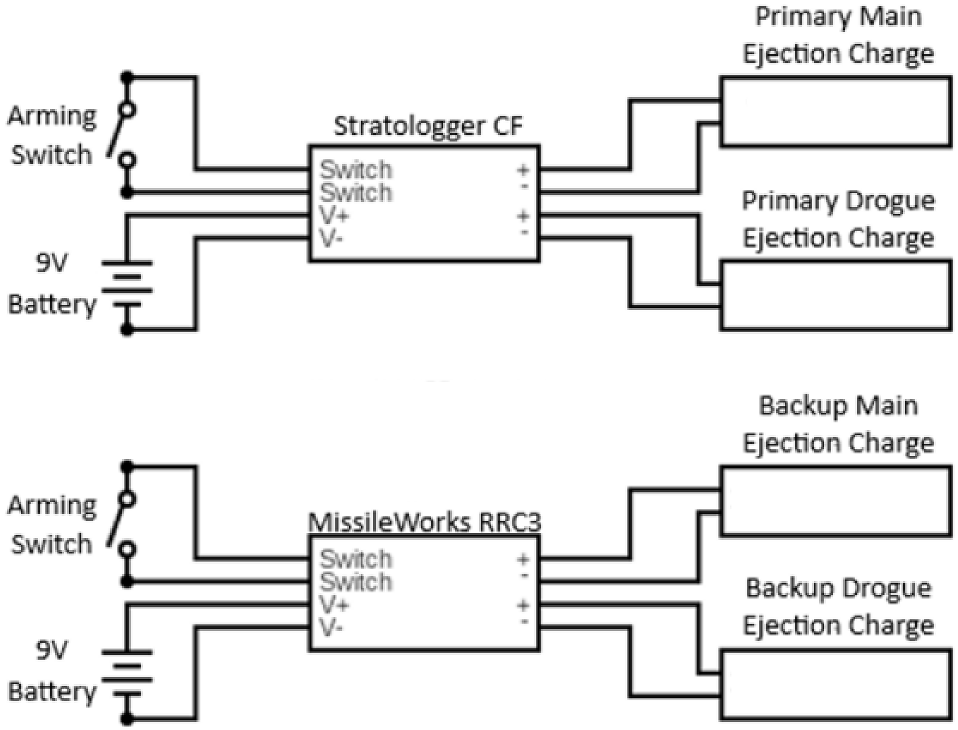
Recovery Components

Component Type	Component Name	Component Location
Main Altimeter	Stratologger CF	Avionics Bay
Backup Altimeter	MissileWorks RRC3	Avionics Bay
GPS	EggFinder Mini Transmitter	Nosecone



Avionics Bay & Wiring Diagram





Descent Calculations

Descent Time		
Calculation Method	**Payload does deploy (s)**	**Payload does not deploy (s)**
Descent Time Calculations	84.5	82.7
OpenRocket Simulations	N/A	84.8
ODE Solver MATLAB	85.5	83.2

Total Drift (Descent Time Calculation)		
Wind Speed	**Payload does deploy (ft)**	**Payload does not deploy (ft)**
5 mph	615	600
10 mph	1230	1213
15 mph	1845	1819
20 mph	2477	2426

Total Drift (ODE Solver MATLAB)		
Wind Speed	**Payload does deploy (ft)**	**Payload does not deploy (ft)**
5 mph	627	610
10 mph	1254	1220
15 mph	1881	1829
20 mph	**2508**	2439

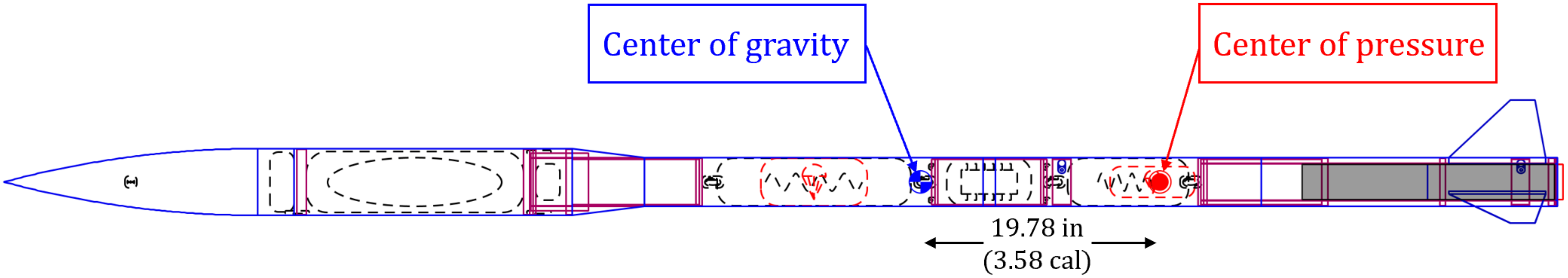
Kinetic Energy Calculations

Maximum Kinetic Energy (OpenRocket Simulation)		
Launch Vehicle Section	**Payload does deploy (ft-lbf)**	**Payload does not deploy (ft-lbf)**
Payload section with payload	N/A	**74.91**
Payload section without payload	**42.43**	N/A
Central section	21.11	24.87
Aft section	40.63	47.86

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	**70.54**
Payload section without payload	**39.09**	N/A
Central section	19.45	23.42
Aft section	37.42	45.07

Static Stability

- Static stability on launch rail: 3.58 calibers
- Center of gravity: 77.14” from tip of nosecone
- Center of pressure: 96.92” from tip of nosecone



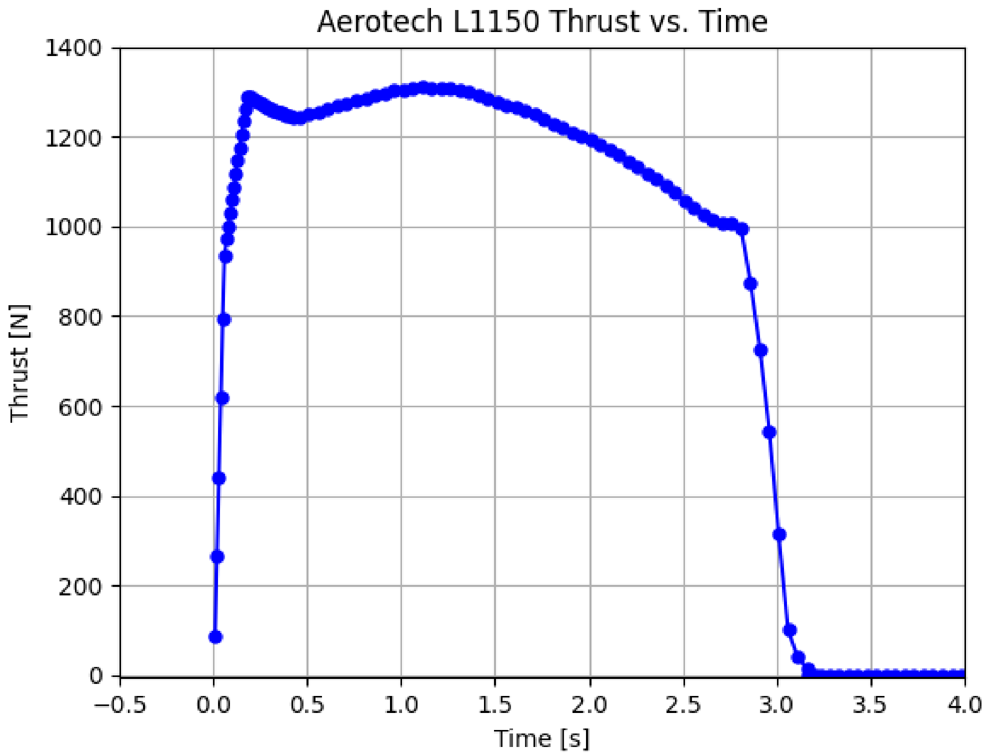
Preliminary Motor Selection

Motor			L1150			L875		
Objective	Weighting Factor	Parameter	Mag.	Score	Value	Mag.	Score	Value
Cost	0.50	USD	289.99	10.00	5.00	448.99	6.46	3.23
Maximum Mach Number	0.25	-	0.54	9.63	2.41	0.52	10.00	2.50
Apogee Range	0.15	ft	460	8.72	1.31	401	10.00	1.50
Sustainability	0.10	Reloadability	Reloadable	10.00	1.00	Non-reloadable	0.00	0.00
Overall Value					9.72			7.23
Motor			**L1256**			**L1520**		
Objective	Weighting Factor	Parameter	Mag.	Score	Value	Mag.	Score	Value
Cost	0.50	USD	289.99	10.00	5.00	289.99	10.00	5.00
Maximum Mach Number	0.25	-	0.58	8.97	2.24	0.60	8.67	2.17
Apogee Range	0.15	ft	465	8.62	1.29	423	9.48	1.42
Sustainability	0.10	Reloadability	Reloadable	10.00	1.00	Reloadable	10.00	1.00
Overall value					9.54			9.59

Preliminary Motor Selection

- Selected motor: Aerotech L1150

Aerotech L1150 Motor Specifications	
Propellant mass	1902 g
Maximum thrust	1346 N
Total impulse	3517 N-s
Burn time	3.1 s
Thrust to weight ratio	7.06:1



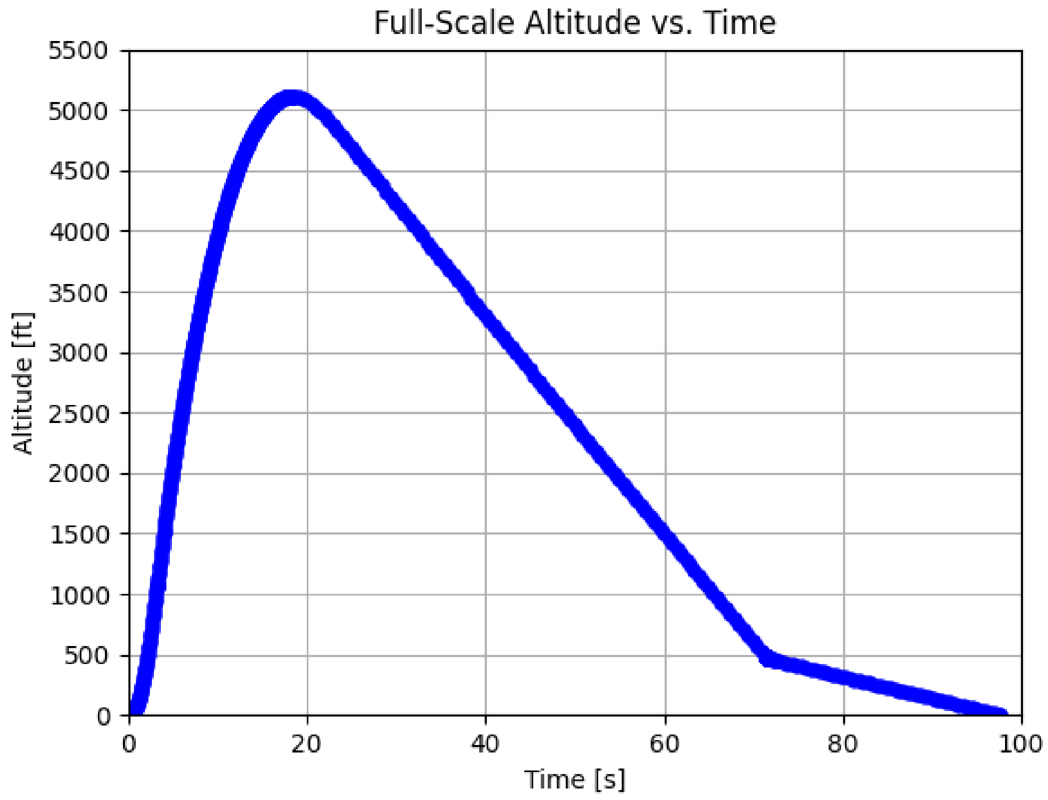
Mission Performance Predictions

The proceeding OpenRocket simulations employed the following launch conditions and do not account for the deployment of the payload.

Launch Conditions in Huntsville, Alabama	
Wind	5 mph
Launch Angle	5°
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

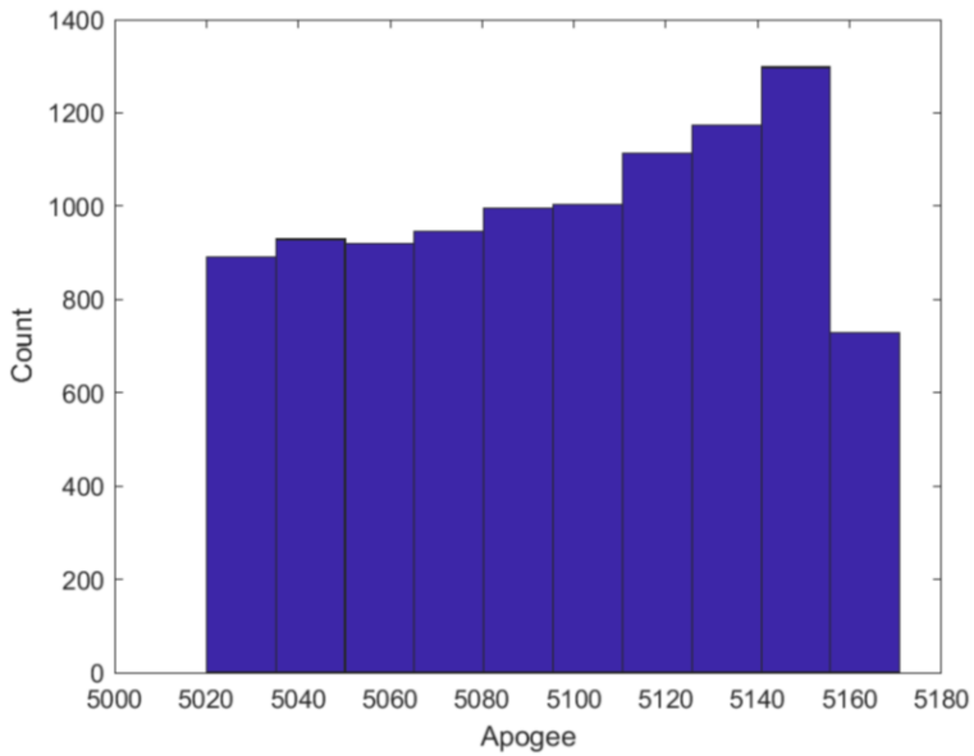
- Target apogee altitude: 5000 ft
  - Determined from a Monte Carlo sensitivity analysis
- OpenRocket simulated apogee altitude: 5063 ft



Mission Performance Predictions

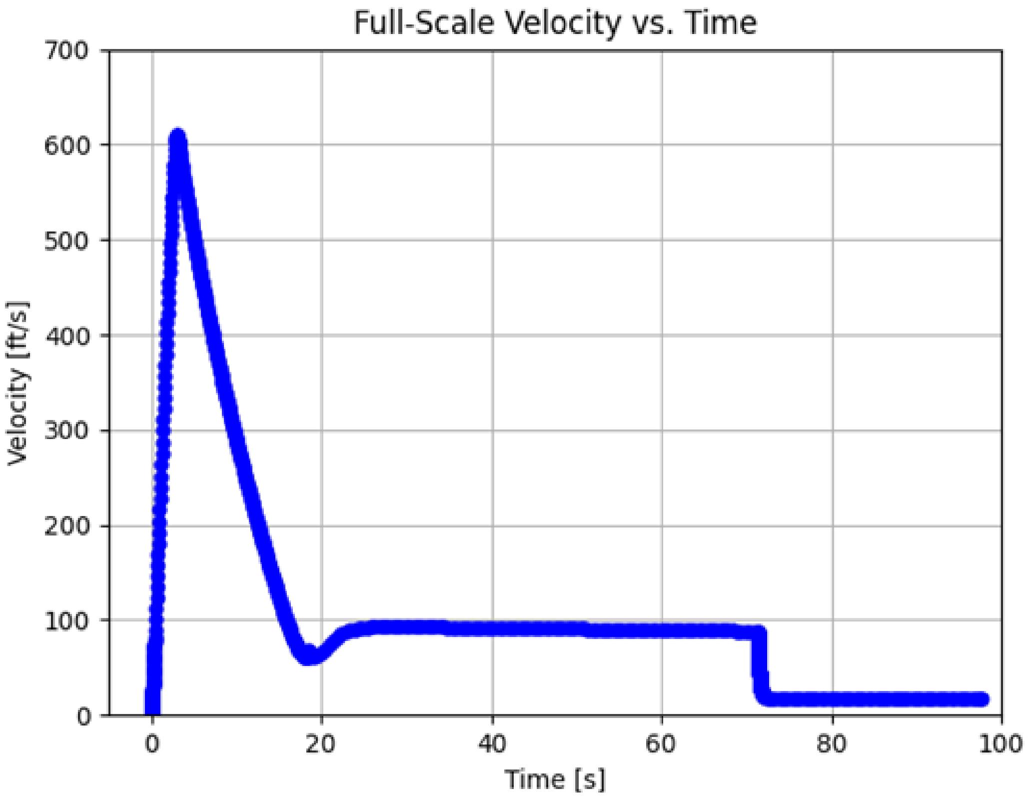
10,0000 simulations were performed for each launch angle-wind condition pairing to determine the most probable altitude.

Monte Carlo Simulation: Altitude					
Launch Angle	Wind Condition	Probability Weight	Predicted Average Altitude (ft)		
			Unballasted	Ballasted	Average
5 deg	0 mph	5%	5320	4740	5030
5 deg	5 mph	20%	5307	4720	5014
5 deg	10 mph	60%	5287	4701	4994
10 deg	15 mph	10%	5102	4676	4889
10 deg	20 mph	5%	5076	4605	4841
				Most Probable Altitude	**5000 ft**



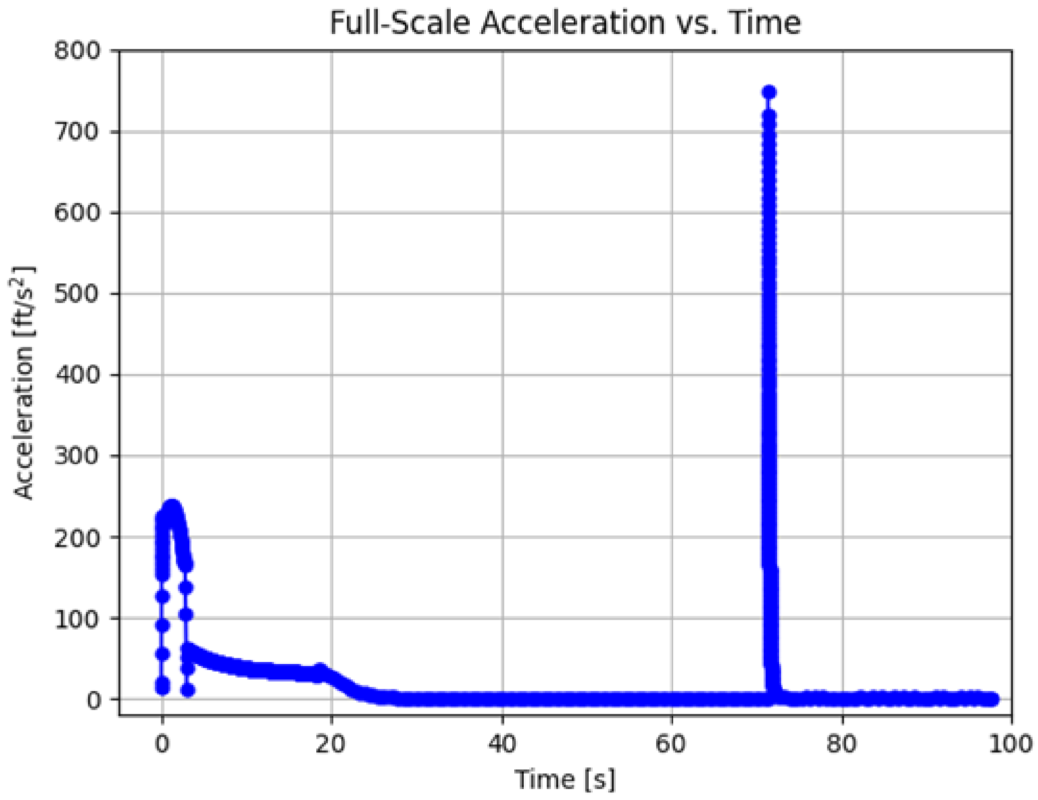
Mission Performance Predictions

- Velocity upon launch rail clearance: 73.9 ft/s
- Maximum velocity: 607 ft/s (Mach 0.54)
- Ground-hit velocity: 17.6 ft/s
- Drogue parachute deployment: 18.38 s
- Main parachute deployment: 70.87 s



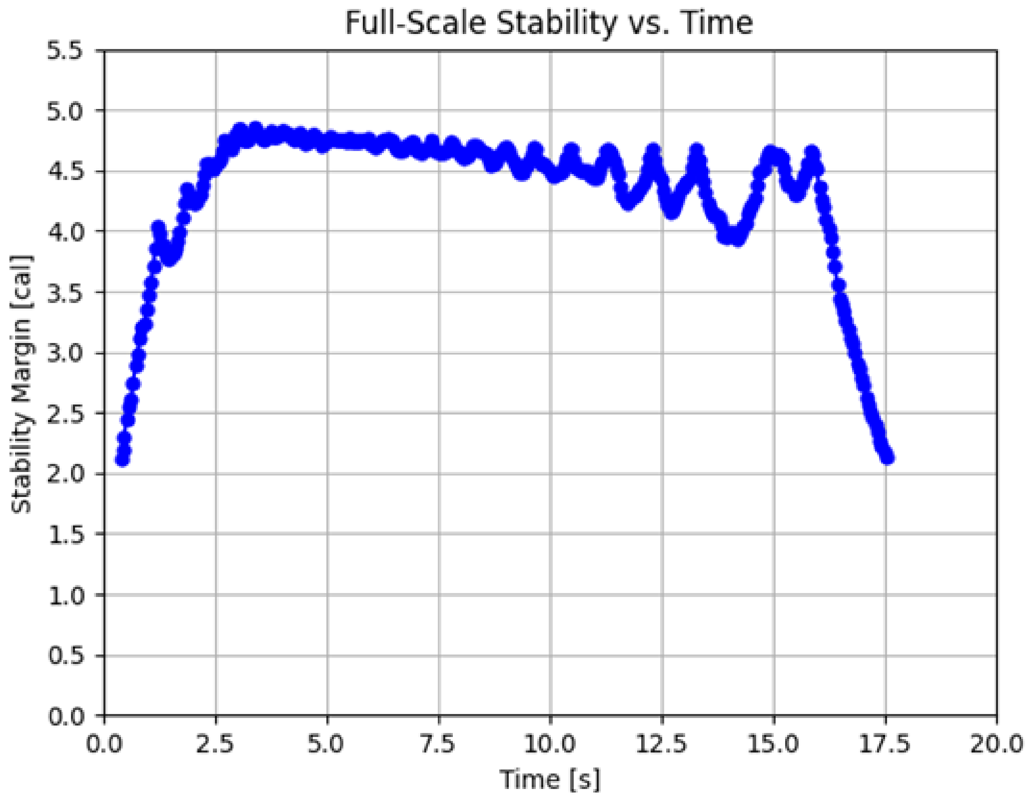
Mission Performance Predictions

- Maximum acceleration: 238 ft/s^2
- First spike: maximum motor thrust
- Second spike: deployment of main parachute



Mission Performance Predictions

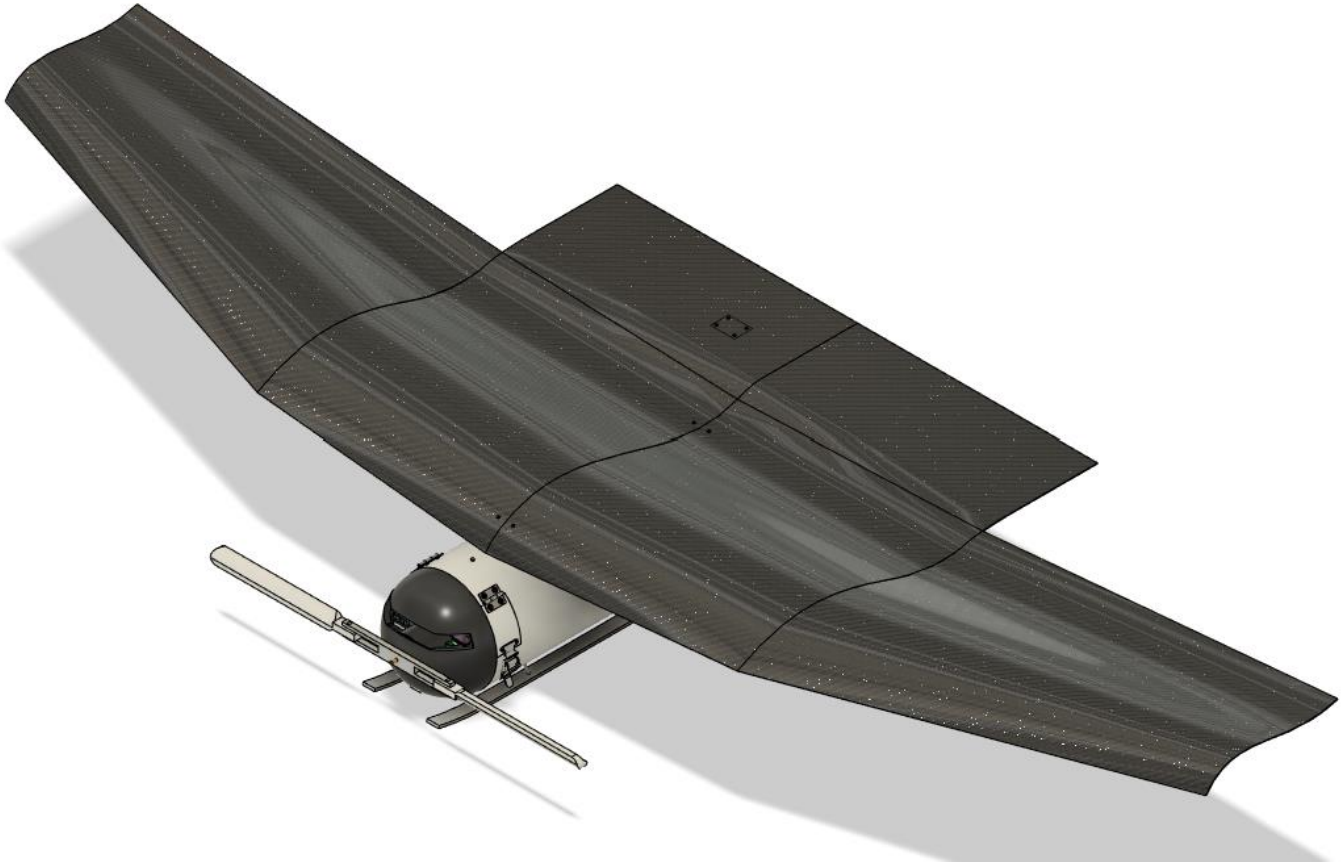
- Static stability on launch rail: 3.58 calibers
- Static stability upon rail exit: 3.61 calibers
- Maximum static stability: 4.86 calibers



Payload Design

Preliminary Payload Design

- Fixed-wing Craft
- Rollable carbon fiber wing
- Radio Controlled deployment and flight
- Lands on skis
- Single Propeller to generate thrust
- STEMnauts represented as LEGO minifigures
  - Located in the cockpit
- Elevators and rudders control pitch and yaw



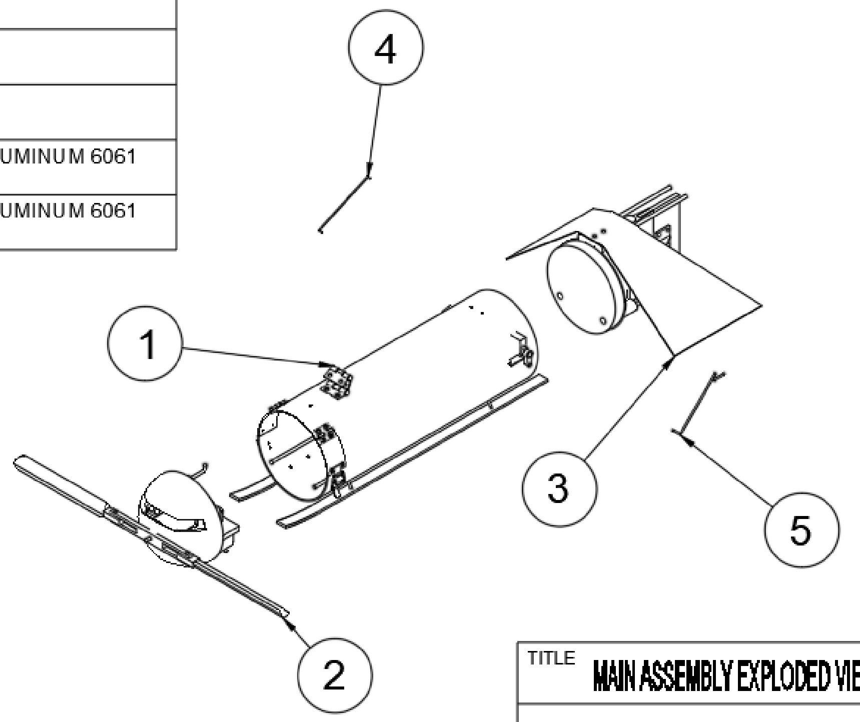
Payload Mechanical

<u>Three Assemblies:</u>

1. Cabin
   - Fiberglass
   - Houses electronics sled
   - Skis attached
   - STEMnaut ingress method
2. Cockpit
   - STEMnauts stored
   - Folding propeller & motor
   - FPV Camera
3. Empennage
   - Rudder and elevator
   - Control rods
   - Diagonal stabilizers

PARTS LIST

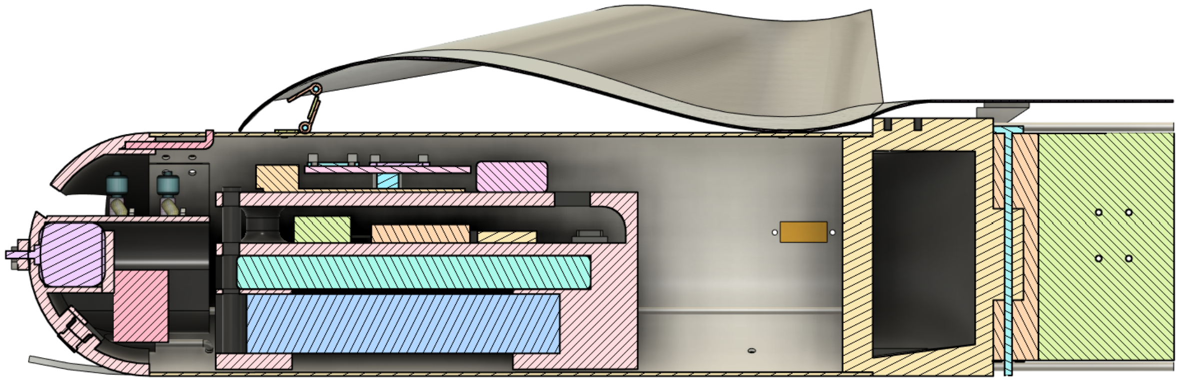
ITEM	QTY	PART NUMBER	MATERIAL
1	1	CABIN ASSEMBLY	
2	1	COCKPIT ASSEMBLY	
3	1	EMPANNEGE ASSEMBLY	
4	1	ELEVATOR CONTROL ROD	ALUMINUM 6061
5	1	RUDDER CONTROL ROD	ALUMINUM 6061



TOLERANCE UNLESS NOTED			
DIMENSION TYPE	PLACES IN DIMENSION		
	0.0	0.00	0.000
LOCATIONAL	±0.050	±0.020	±0.005
ANGULAR	±5	±2	±0.5

TITLE MAIN ASSEMBLY EXPLODED VIEW
DRAWN COLIN MCELIECE
DESIGNED COLIN MCELIECE
SIZE A
DWG NO SLRT-400B
REV A
SCALE 1:5
SHEET 1/1

Payload Mechanical



Section View of Payload

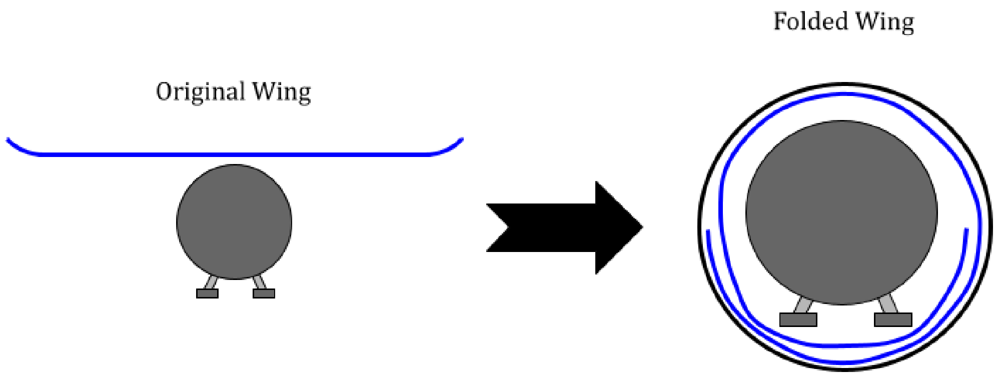
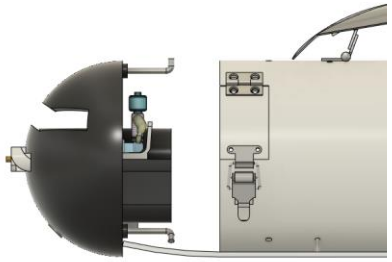
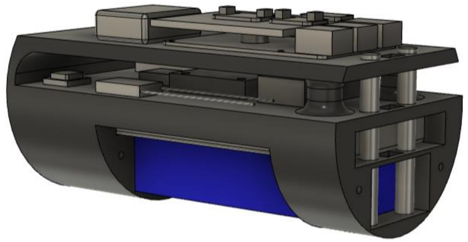


Diagram of Rolled Wing



Removed Cockpit



Electronics Sled

Folding Prop

Stability

Static stability analysis performed along three aircraft axes

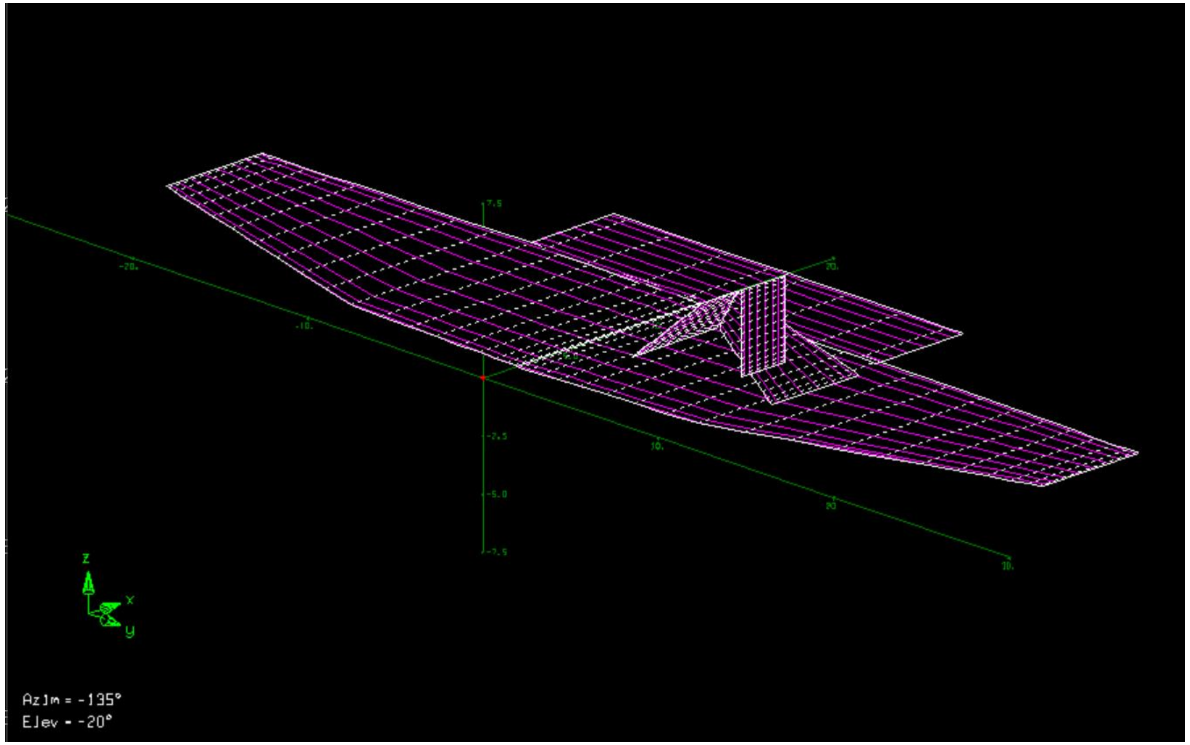
- Longitudinal
- Lateral
- Directional

$$C_{m_\alpha} = C_{m_{\alpha_w}} + C_{m_{\alpha_t}} < 0$$

$$C_{l_\beta} = C_{l_{\beta_\Gamma}} + C_{l_{\beta_{position}}} + C_{l_{\beta_\Lambda}} + C_{l_{\beta_v}} < 0$$

$$C_{n_\beta} = C_{n_{\beta_f}} + C_{n_{\beta_\Lambda}} + C_{n_{\beta_v}} > 0$$

Coefficient	Value
C_{m_α}	-0.016610
C_{l_β}	-0.001166
C_{n_β}	0.000345



Athena Vortex Lattice (AVL) Geometry

Payload Electrical

Microprocessor Subsystem

- Sensor Suite
- Detects STEMnaut survivability parameters
- Turns on Flight Controller Subsystem

Flight Controller Subsystem

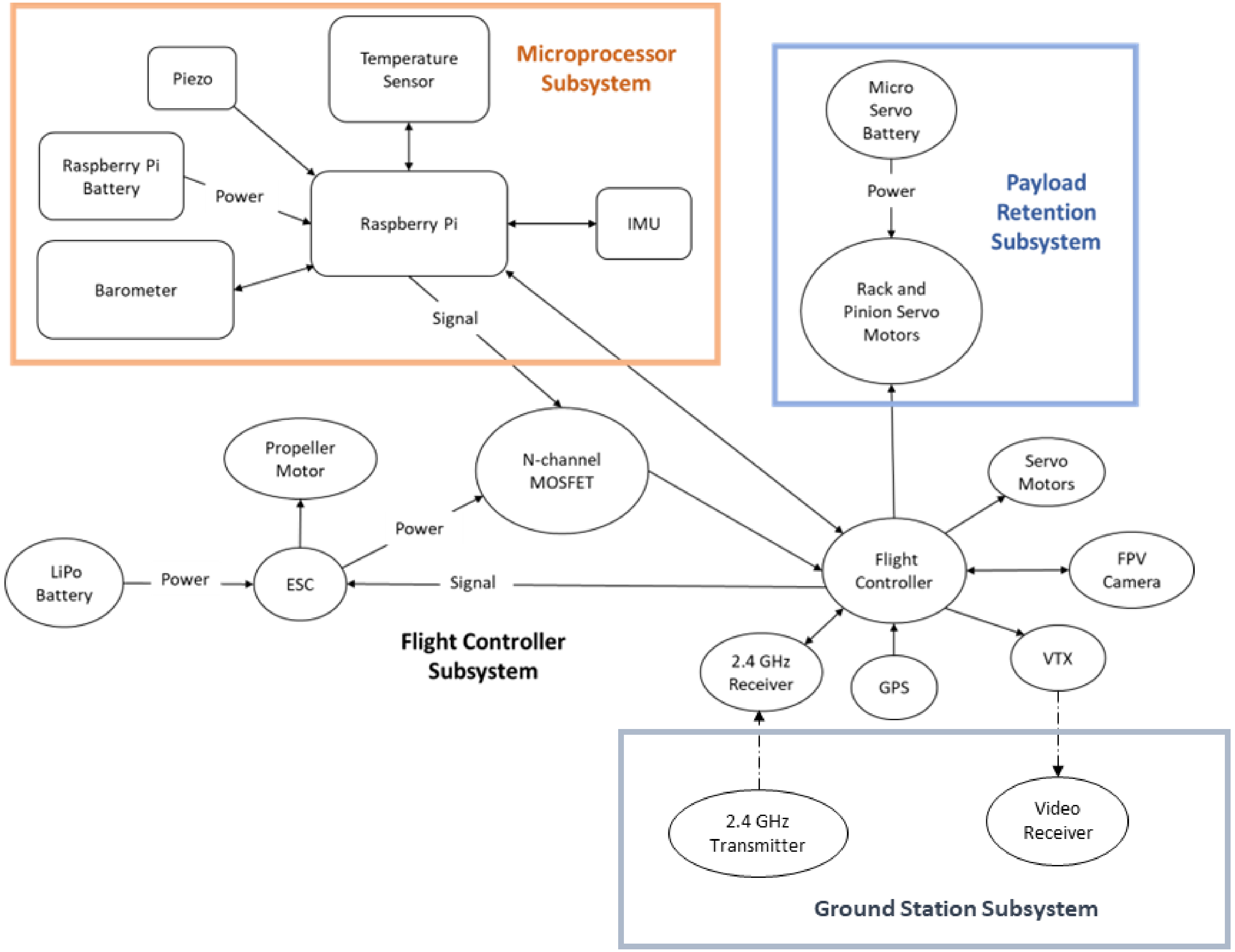
- Manages Flight
- Signals Deployment
- Transmits Video (5.8 GHz)
- Receives Radio Commands (2.4 GHz)

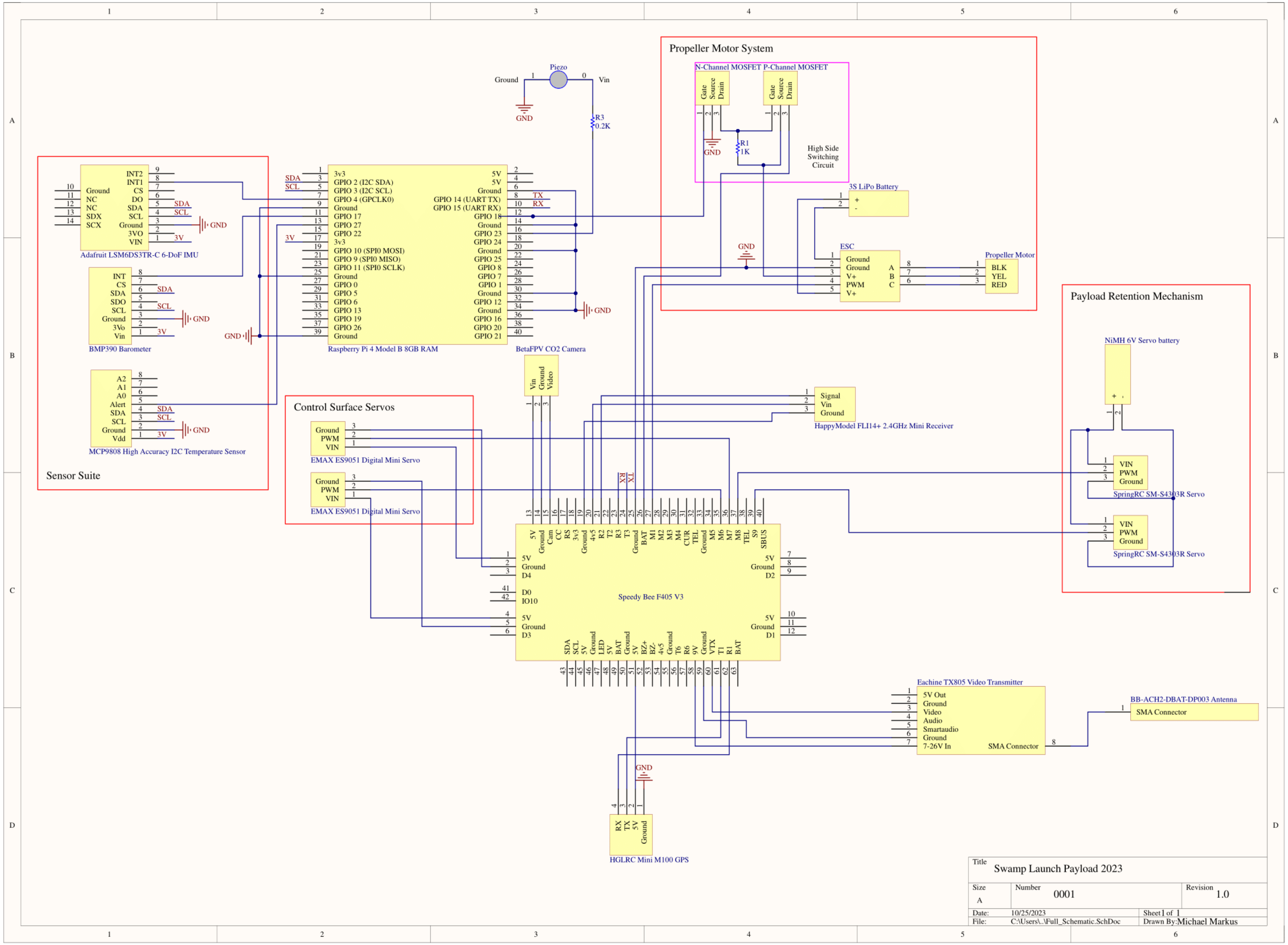
Payload Retention Subsystem

- Retains & Deploys payload

Ground Station

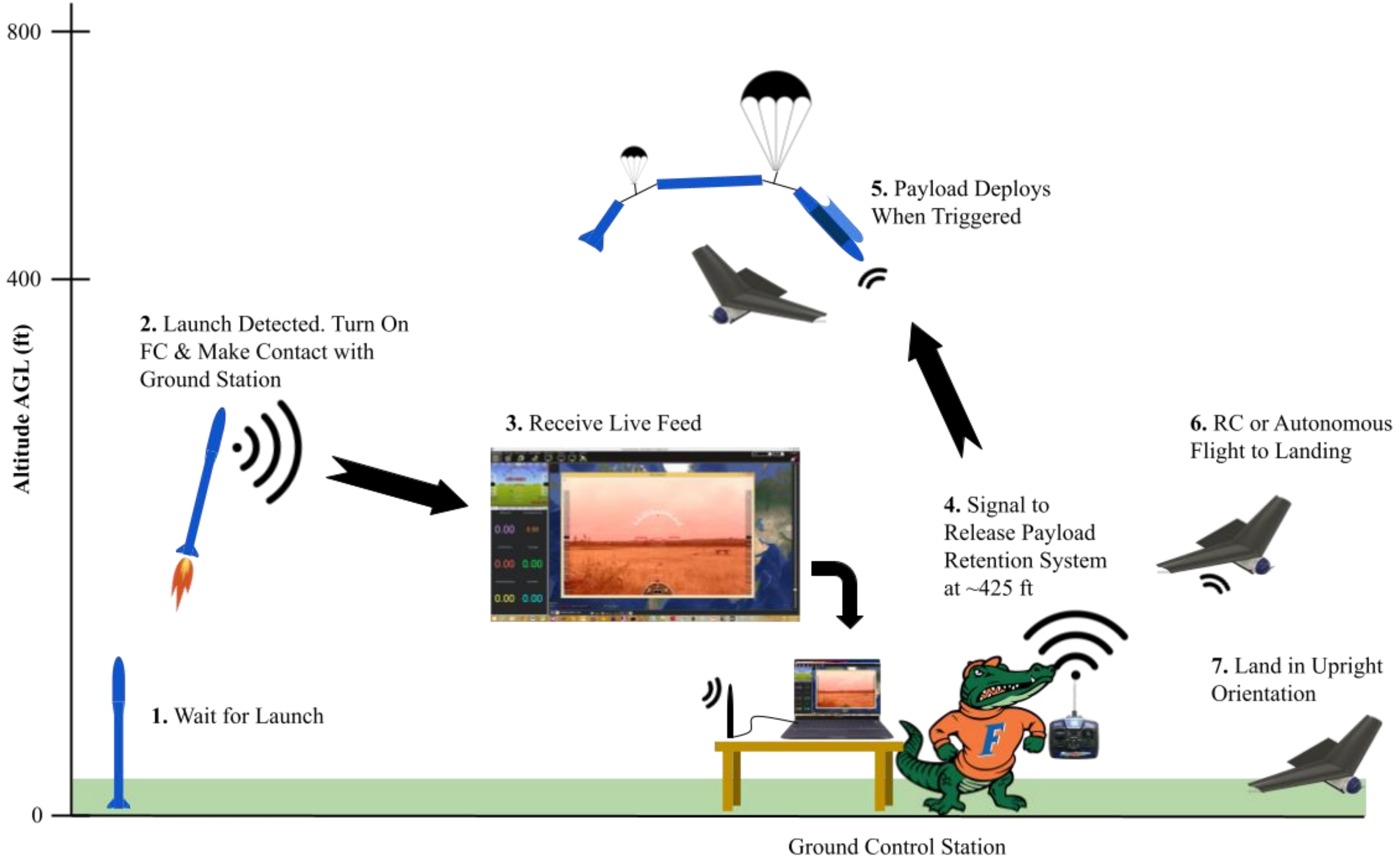
- Sends commands to payload
- Receives video from payload





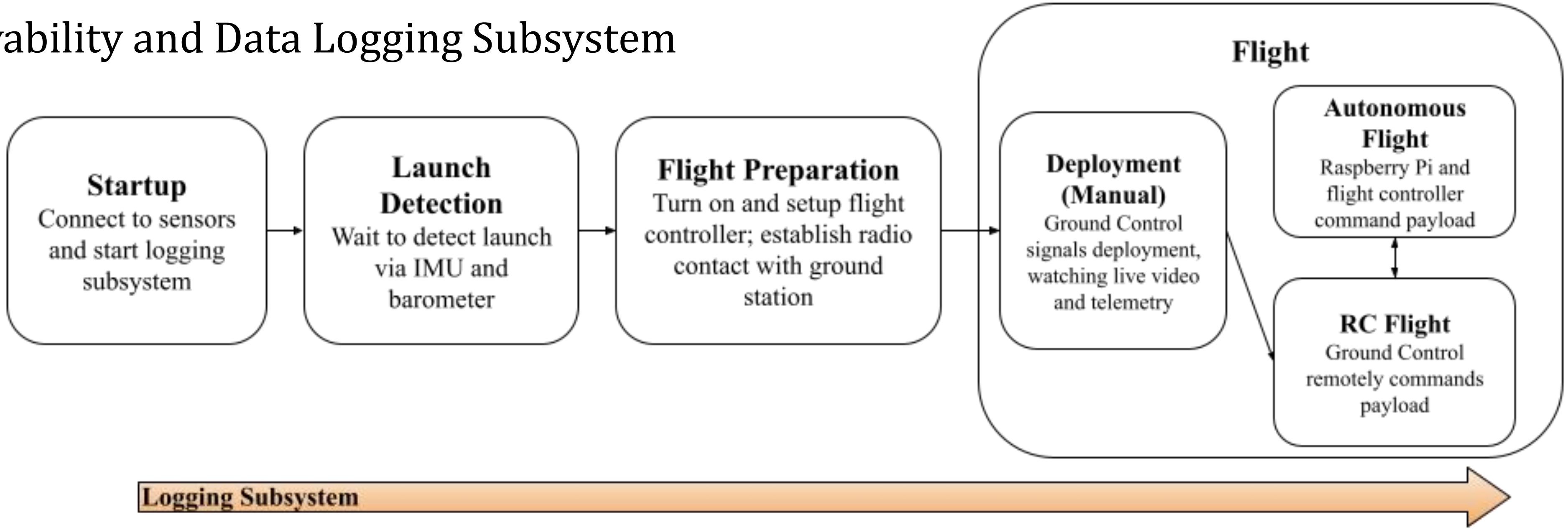
Propeller Motor System
N-Channel MOSFET
P-Channel MOSFET
Gate Source Drain
High Side Switching Circuit
R1 1K
GND
3S LiPo Battery
+
-
ESC
Ground
Ground
V+
PWM
V+
A
B
C
Propeller Motor
BLK
YEL
RED
Piezo
Ground
Vin
R3 0.2K
GND
Adafruit LSM6DS3TR-C 6-DoF IMU
INT2
INT1
CS
DO
SDA
SCL
Ground
3VO
VIN
NC
SDX
SCX
SDA
SCL
GND
3V
BMP390 Barometer
INT
CS
SDA
SDO
SCL
Ground
3Vo
Vin
MCP9808 High Accuracy I2C Temperature Sensor
A2
A1
A0
Alert
SDA
SCL
Ground
Vdd
Sensor Suite
Raspberry Pi 4 Model B 8GB RAM
3v3
GPIO 2 (I2C SDA)
GPIO 3 (I2C SCL)
GPIO 4 (GPCLK0)
Ground
GPIO 17
GPIO 27
GPIO 22
3v3
GPIO 10 (SPI0 MOSI)
GPIO 9 (SPI0 MISO)
GPIO 11 (SPI0 SCLK)
Ground
GPIO 0
GPIO 5
GPIO 6
GPIO 13
GPIO 19
GPIO 26
Ground
5V
5V
Ground
GPIO 14 (UART TX)
GPIO 15 (UART RX)
GPIO 18
Ground
GPIO 23
GPIO 24
Ground
GPIO 25
GPIO 8
GPIO 7
GPIO 1
Ground
GPIO 12
Ground
GPIO 16
GPIO 20
GPIO 21
TX
RX
BetaFPV CO2 Camera
Vin
Ground
Video
HappyModel FLI14+ 2.4GHz Mini Receiver
Signal
Vin
Ground
Control Surface Servos
EMAX ES9051 Digital Mini Servo
Ground
PWM
VIN
Payload Retention Mechanism
NiMH 6V Servo battery
SpringRC SM-S4303R Servo
VIN
PWM
Ground
Speedy Bee F405 V3
5V
Ground
Cam
CC
RS
3v3
4v5
R2
T2
R3
T3
BAT
M1
M2
M3
M4
CUR
TEL
M5
M6
M7
M8
S9
SBUS
D4
D0
IO10
D3
D2
D1
SDA
SCL
LED
BZ+
BZ-
T6
R6
9V
VTX
T1
R1
Eachine TX805 Video Transmitter
5V Out
Ground
Video
Audio
Smartaudio
Ground
7-26V In
SMA Connector
BB-ACH2-DBAT-DP003 Antenna
SMA Connector
HGLRC Mini M100 GPS
RX
TX
5V
Ground
Title
Swamp Launch Payload 2023
Size
A
Number
0001
Revision
1.0
Date: 10/25/2023
File: C:\Users\..\Full_Schematic.SchDoc
Sheet1 of 1
Drawn By: Michael Markus

Payload Software



Payload Software

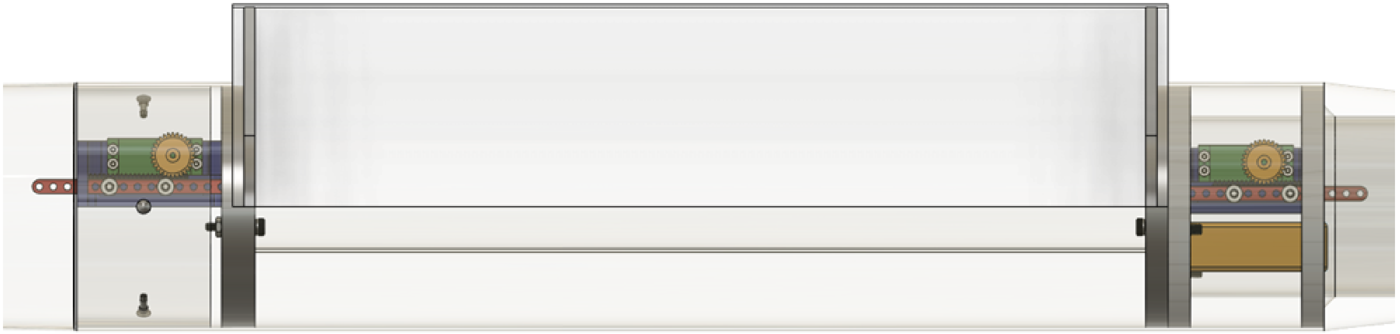
- Main Computer: Raspberry Pi
- Ground Station: Laptop Running Mission Planner
- 4 States:
  - Startup
  - Launch Detection
  - Flight Preparation
  - Flight
- Survivability and Data Logging Subsystem

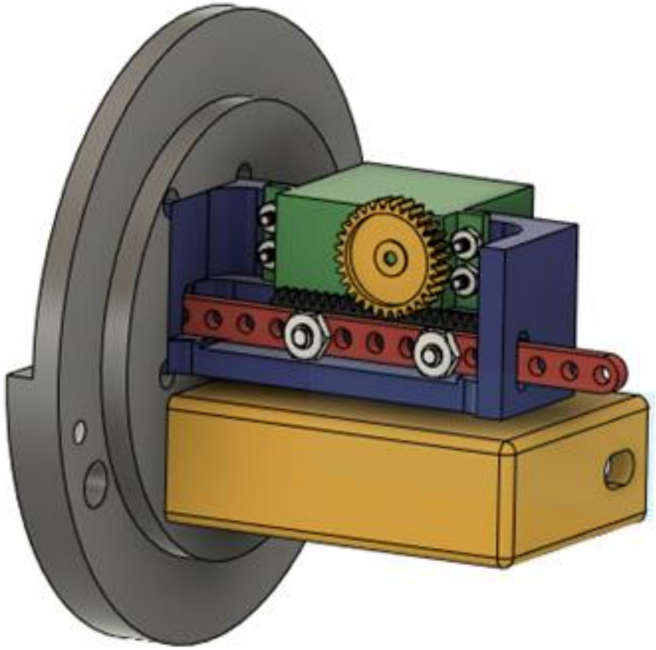


Payload Retention System

Closed payload door

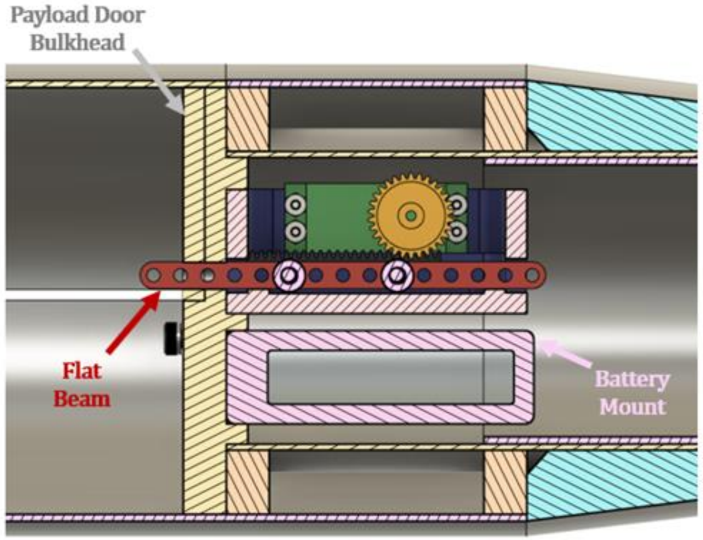
Opened payload door

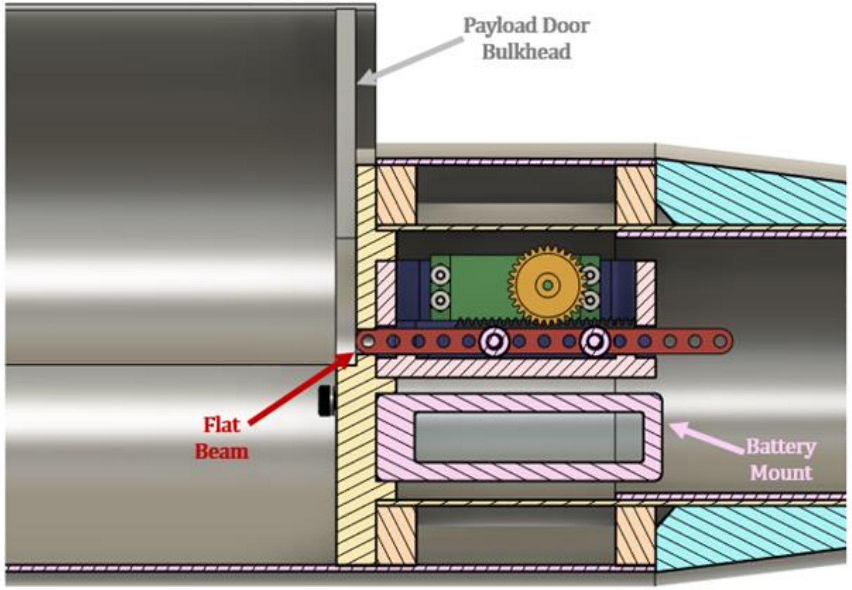




Payload Retention System

- Rack and pinion mechanism:
  - Servo motor, gear pinion, gear rack, flat beam.
- Extended flat beam interfaces with payload door bulkheads, keeping the retention system closed.
- Retracted flat beam releases the payload door bulkheads, allowing the payload door to open.





Requirements Compliance Plan

Requirements Compliance Plan

- NASA Requirements
  - Design
- Team-Derived Requirements
  - Launch Vehicle
  - Recovery
  - Payload
- Verification
  - Simulation
  - Testing
    - Launch vehicle
    - Recovery
    - Payload

6.1.1 Vehicle Team Derived Requirements

Requirement ID	Description	Justification
	Mechanical	
1.1	The airframe must withstand at least 1346 N of compressive force.	As stated in 3.3.2.3, the maximum thrust, and thus compressive force that the airframe will experience is 1346 N.
1.2	The transition must not cause flow separation.	Flow separation at the transition will result in turbulence, excess drag, and loss of stability on the launch vehicle.
1.3	The transition shroud must not fail from bending moments during flight.	If the transition shroud fails during flight, flow along the launch vehicle will separate, resulting in excess drag.
1.4	The rail buttons must guide the rocket off the launch tower without breaking, catching, or otherwise impacting the flight of the launch vehicle.	If the rail buttons fail during launch, the launch vehicle may not fly as intended.
1.6	The fins must withstand the forces experienced when impacting the ground without snapping, buckling, cracking, or breaking in any way.	If any failure occurs in the fins, the rocket is considered nonreusable and therefore the launch is a failure.
1.7	The epoxy must withstand at least 1346 N of force.	As calculated by OpenRocket simulations, the maximum thrust force and thus the maximum load applied to the epoxy is 1346 N. See 3.3.2.3.
1.8	The bulkheads must protect nearby electronics from the explosion used for parachute ejection.	If the explosion from the parachute ejections damages the electronics on board, a variety of systems on the launch vehicle could fail as a result. See 5.3.1 and 5.3.2
1.9	The epoxy in the aft and forward bulkheads cannot fail	If the bulkheads get dislodged from

Safety

- Risk Analysis tables were developed to address possible failures and concerns for the project
  - Separated into Personnel Hazards, Environmental Hazards, Project Risks and Failure Modes & Effects Analysis
  - Sections were analyzed for Impact & Likelihood on a linear sliding scale from 1-10 to measure a Risk Priority Number (RPN) as a product of the two
    - FMEA section scores generated from team as a whole and included Detectability as a factor
    - Project Risks section used a simplified scale of low, medium, or high risk (1-3)
- Prior to launch, launch safety checklist will be implemented to ensure proper and safe assembly and launch

5.4.1 Effects of Environment on Launch Vehicle

Hazard	Cause	Effect	I	L	Score	Mitigation
Drift or change in trajectory	Excessive Wind	1. Unretrievable 2. Unpredictable flight path leading to further hazardous flying conditions	8	2	16	Align the launch rail at an angle into the wind and abort the launch if the wind reaches a hazardous speed (20mph).
Precipitation soaks launch vehicle electronics	Extreme humidity or rain at launch site	1. Electronic disruption and energetics leakage 2. Potential failure of electronics systems	7	4	28	Provide canopy at prep site. Store electronics in water-tight containers until assembly.
Launch vehicle propulsion systems soaked	Extreme humidity or rain at launch site	Incomplete and unpredictable motor ignition and propulsion	8	2	16	Provide canopy at prep site. Motor stored in water protected areas until integrated in vehicle.
Brittle adhesive at epoxy joints	Excessively low humidity and high temperature	Loosened or cracked fins	6	3	18	Manufacture with an extended curing duration. Provide cooling to fin joints prior to launch if necessary. Provide shaded canopy at prep site
Overheating of electrical components	Excessively high temperature	Payload electronics malfunction or fail, wing and rudder motors do not function correctly resulting in uncontrolled flight	8	2	16	Provide canopy at prep site. Store electrical components away from high heat sources until assembly.

Project Avigator

University of Florida

Thank you!