



The Zenith Program

Critical Design Review

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Gardner, Mark A. Ioffredo, Zachary L. Isriel

Zenith Program Leads



Jedreck Acquissa

- **Role:** Recovery Systems Lead
- **Engineering Interests:** Fluid Design and Food Manufacturing



Peyton C. Breland

- **Role:** Propulsion & Vehicle Design Lead
- **Engineering Interests:** Fluid Design, Flight Vehicle Design and Manufacturing



Dylan A. Gardner

- **Role:** STEM Engagement Lead
- **Engineering Interests:** Fluid design, Heat Transfer, and Manufacturing



Mark A. Ioffredo

- **Role:** Avionics System Lead
- **Engineering Interests:** Fluid Design and Aerodynamics



Zachary L. Isriel

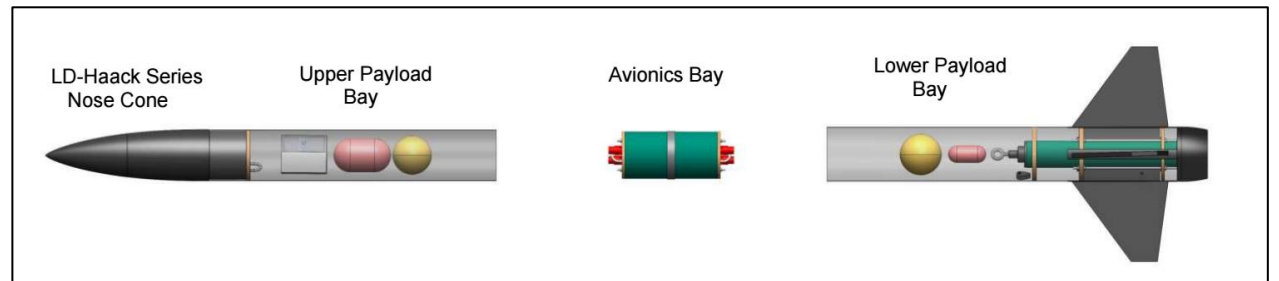
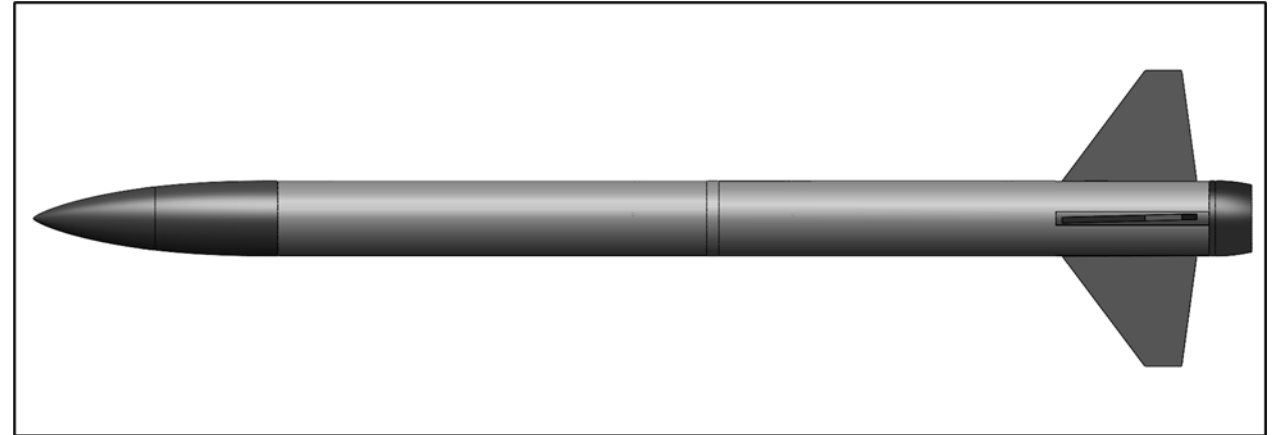
- **Role:** Program Director
- **Engineering Interests:** Human spaceflight, spacecraft R&D, commercial launch



Launch Vehicle Design

Launch Vehicle General Dimensions

- Full Scale Length: 99"
- Outer Airframe Diameter: 6.154"
- Weight: 38.30 lb
- Burnout Weight: 33.68 lb





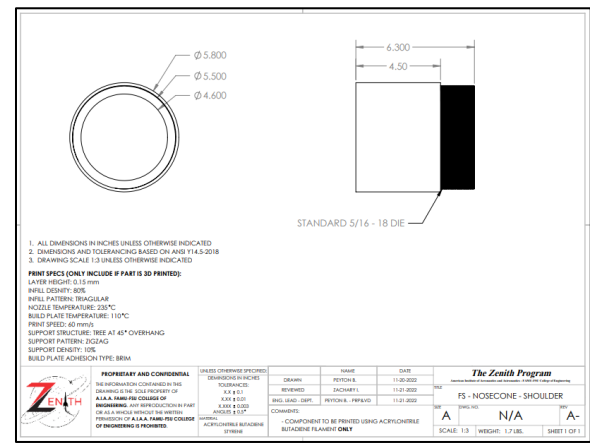
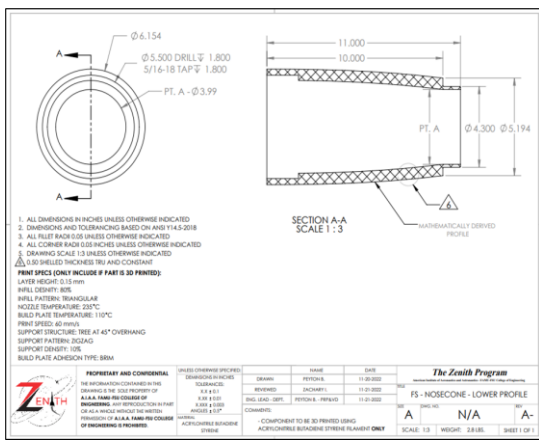
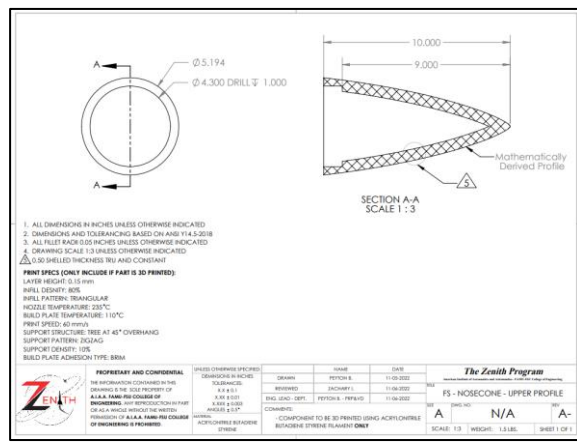
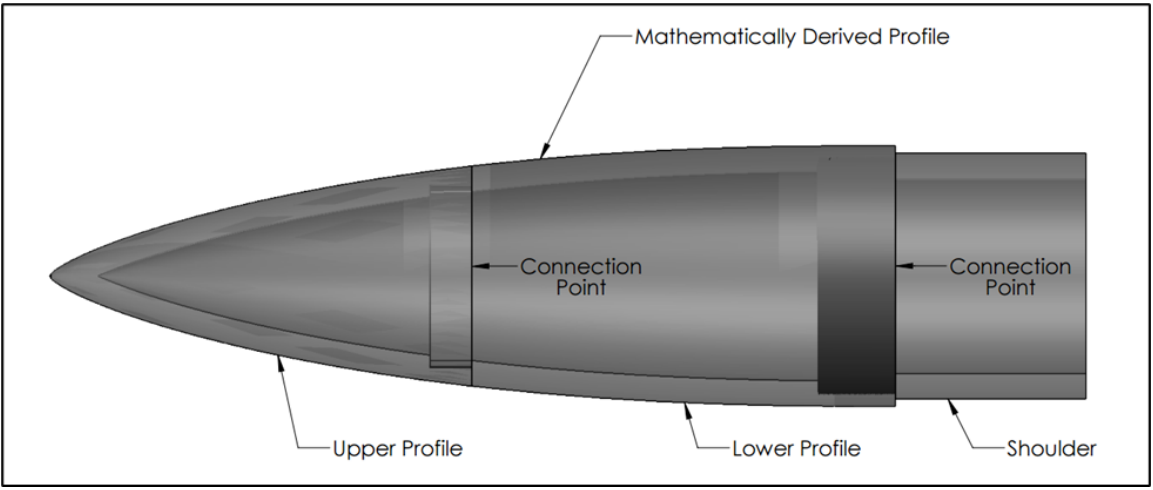
Material Selection

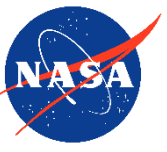
- 3-Printed Components: Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA)
- Airframe: Blue Tube
- Bulkheads and Centering Rings: Baltic Birch Plywood
- Payload Bay Roof Enclosure : LEXAN



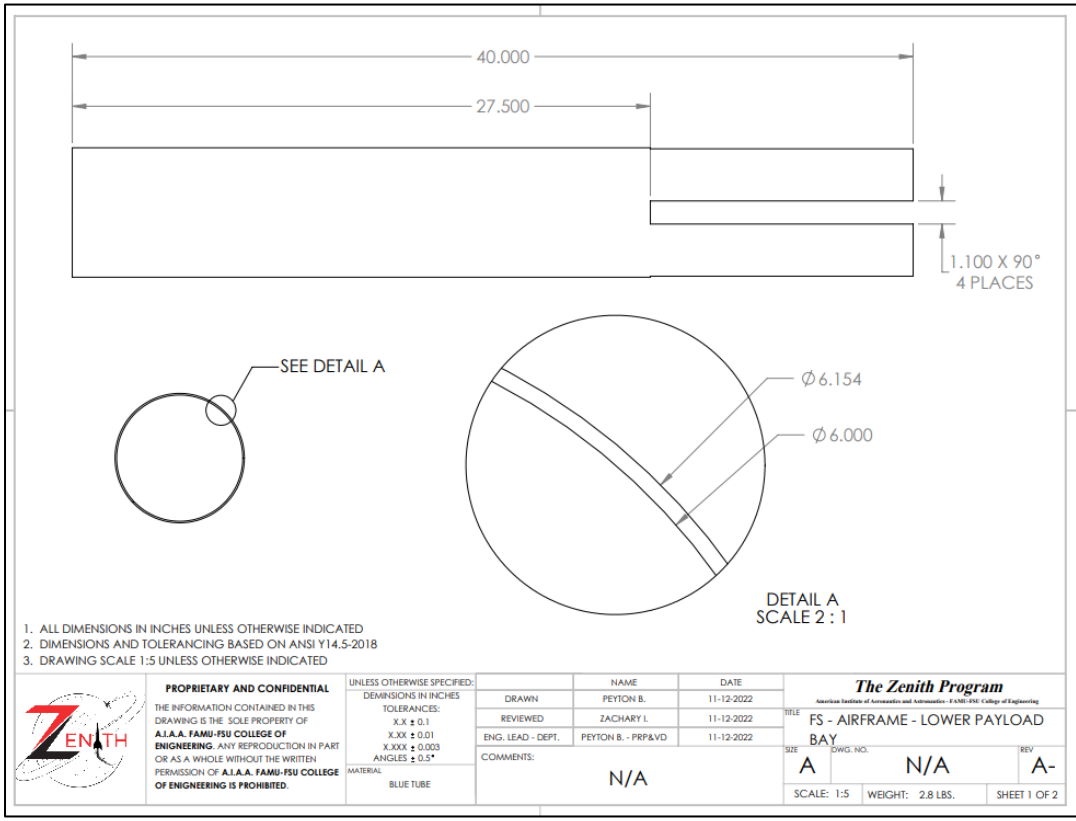
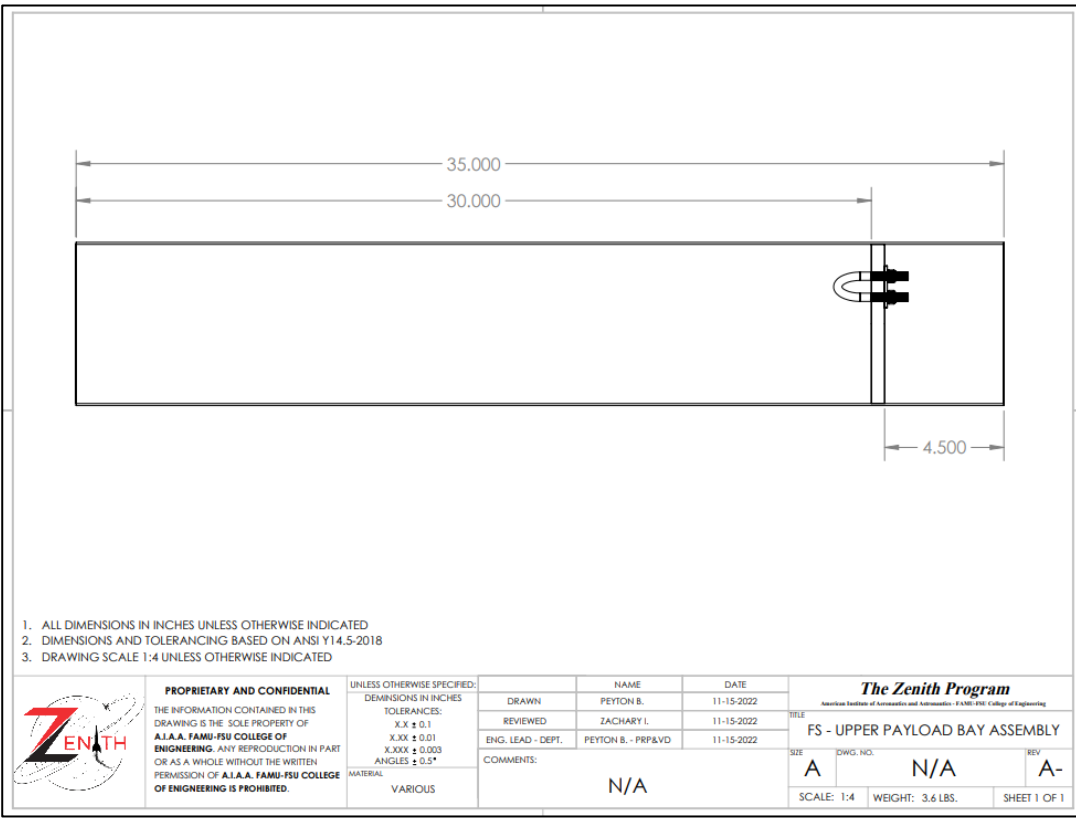
Nosecone Design

- LD-Haack Series
 - Mathematically Derived Profile
- 3-D Printed from ABS in 3 separate sections for ease of printing



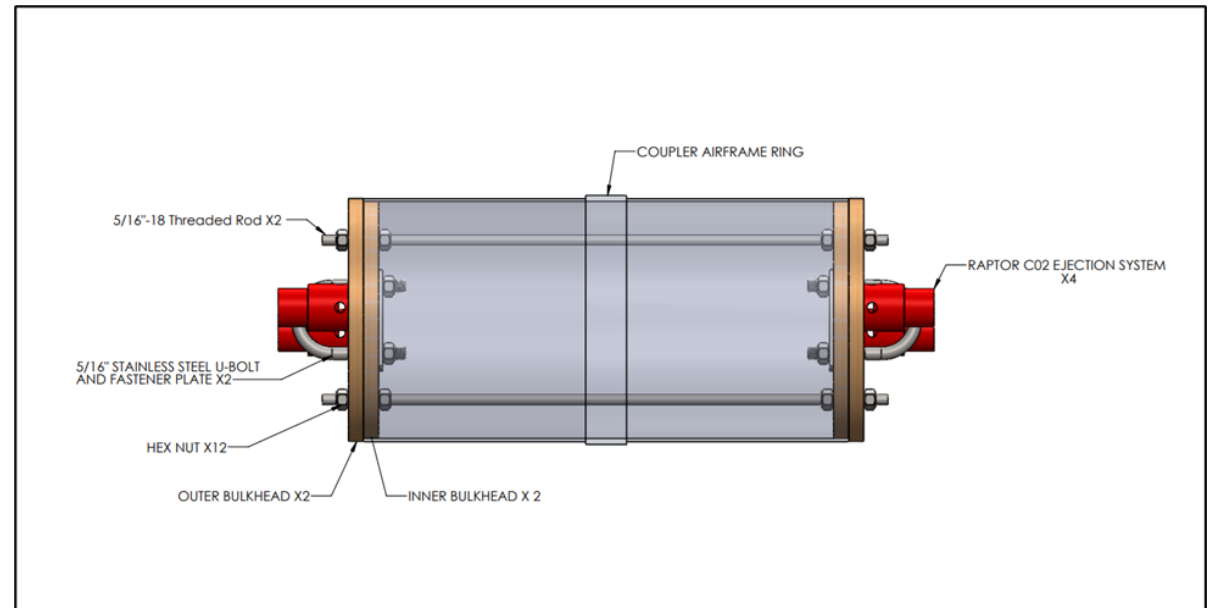


Upper & Lower Payload Bays



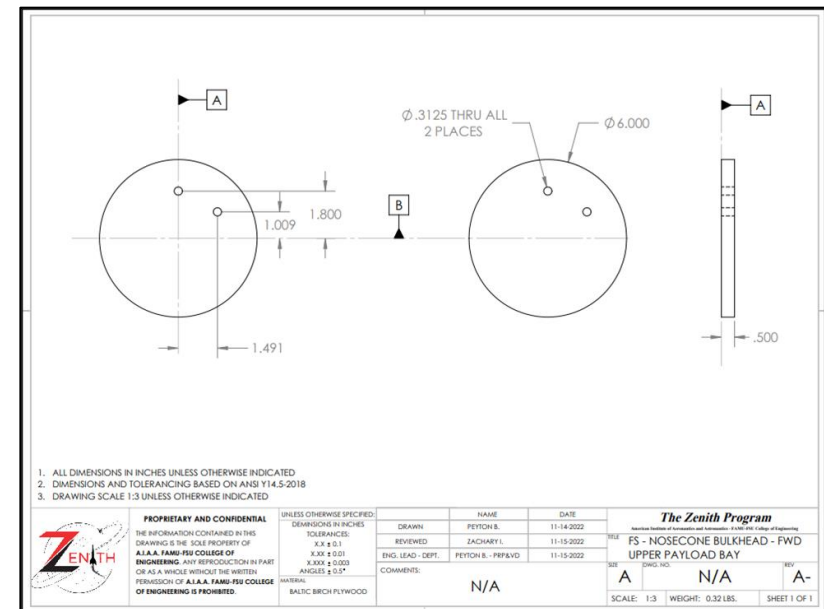
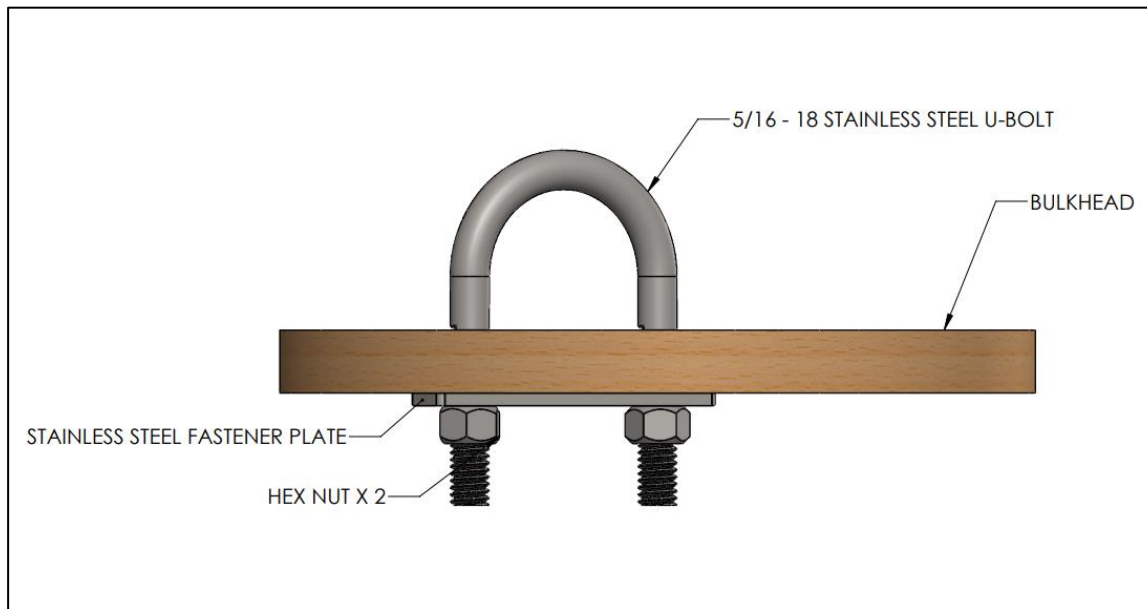
Avionics Bay

- Between UPB and LPB
- Sled and bulkheads held together by 5/16"-18 UNC threaded rods
- Two CO2 Ejection charges on each side
 - CO2 Cartridges sits inside of bay



Centering Rings, Bulkheads, & U-bolts

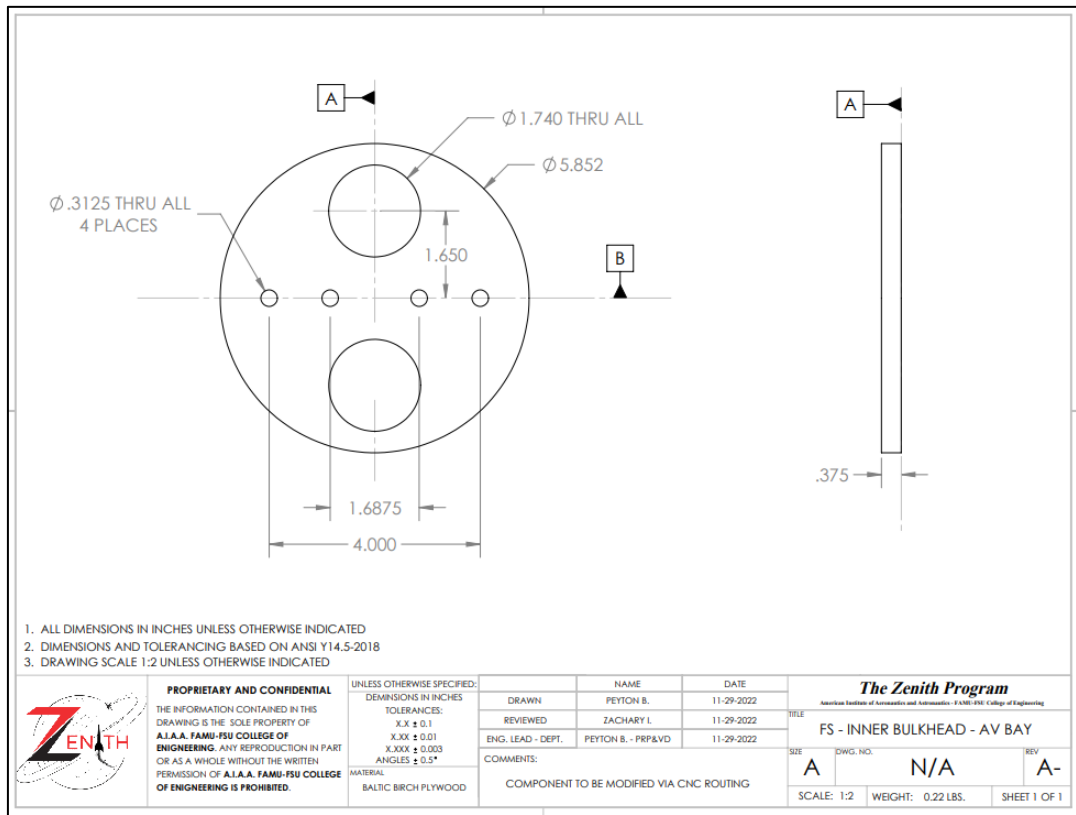
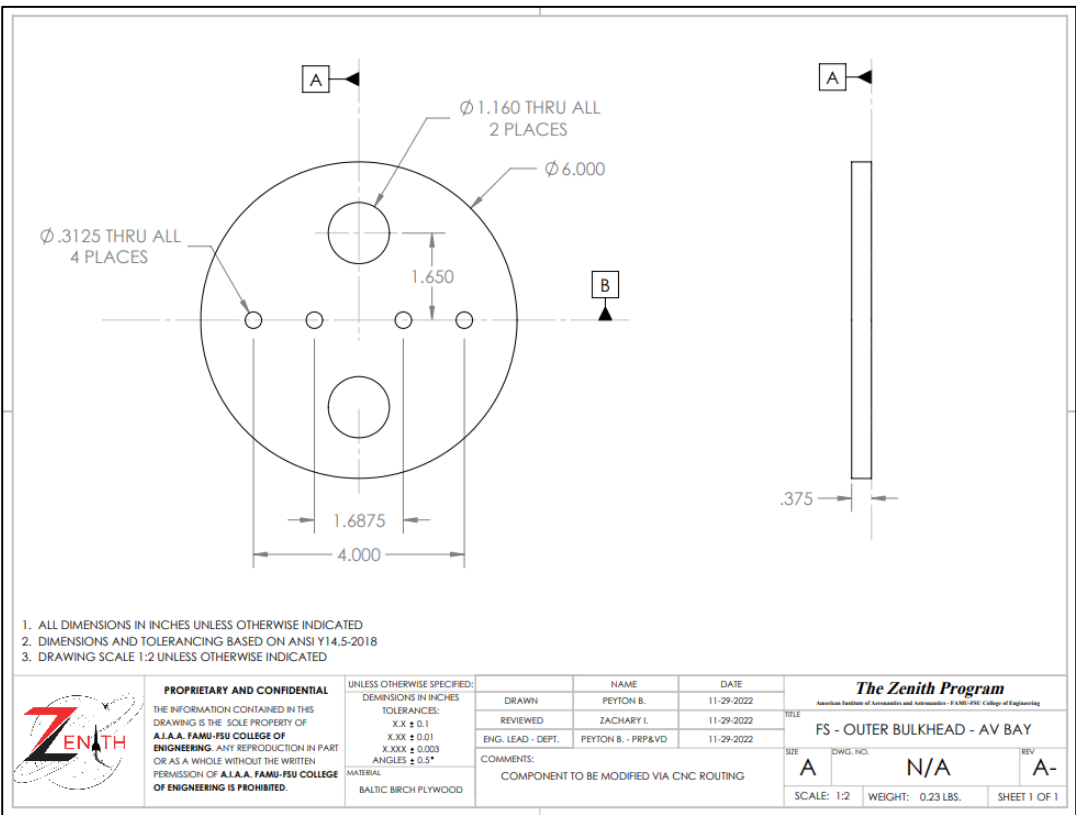
➤ Nose Cone Bulkhead

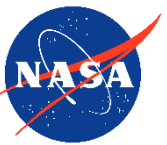




Centering Rings, Bulkheads, & U-bolts

➤ Avionics Bay Bulkheads





Centering Rings, Bulkheads, & U-bolts

➤ Centering Rings and Bulkheads material: Baltic Birch Plywood

1. ALL DIMENSIONS IN INCHES UNLESS OTHERWISE INDICATED
 2. DIMENSIONS AND TOLERANCING BASED ON ANSI Y14.5-2018
 3. DRAWING SCALE 1:2 UNLESS OTHERWISE INDICATED

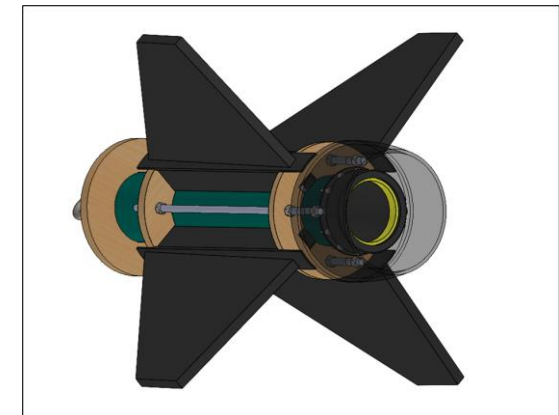
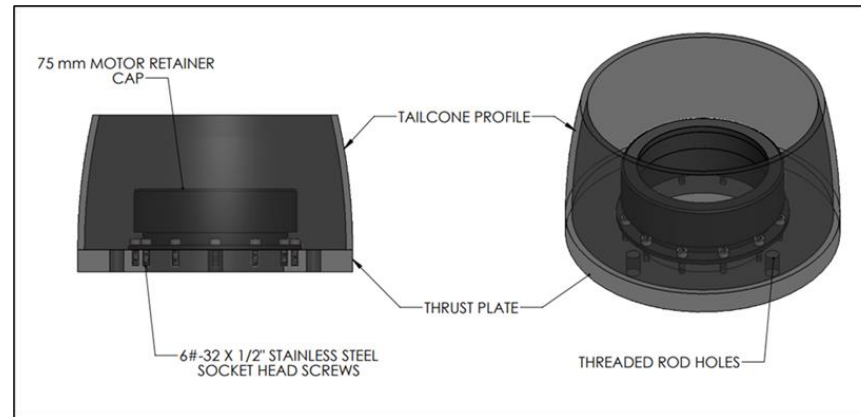
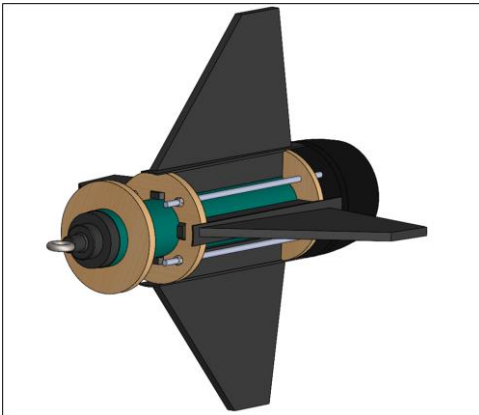
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		DIMENSIONS IN INCHES	DRAWN	PEYTON B.		11-21-2022	A
		TOLERANCES:	REVIEWED	ZACHARY L.		11-21-2022	N/A
		X.XX ± 0.1 X.XXX ± 0.01 X.XXX ± 0.003 ANGLES ± 0.5°	ENG. LEAD - DEPT.	PEYTON B. - PRP&VD		11-21-2022	A-
MATERIAL	COMMENTS:	N/A		SCALE: 1:2	WEIGHT: 0.24 LBS.	SHEET 1 OF 1	

1. ALL DIMENSIONS IN INCHES UNLESS OTHERWISE INDICATED
 2. DIMENSIONS AND TOLERANCING BASED ON ANSI Y14.5-2018
 3. DRAWING SCALE 1:2 UNLESS OTHERWISE INDICATED

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		DIMENSIONS IN INCHES	DRAWN	PEYTON B.		11-21-2022	A
		TOLERANCES:	REVIEWED	ZACHARY L.		11-21-2022	N/A
		X.XX ± 0.1 X.XXX ± 0.01 X.XXX ± 0.003 ANGLES ± 0.5°	ENG. LEAD - DEPT.	PEYTON B. - PRP&VD		11-21-2022	A-
MATERIAL	COMMENTS:	N/A		SCALE: 1:2	WEIGHT: 0.22 LBS.	SHEET 1 OF 1	

Fin Can

- Front 2 centering rings are epoxied in place
- Aft centering ring (in front of tail cone) is removeable
 - Held in place by threaded rods
- 3D Printed ABS tail cone insulated with fiber glass

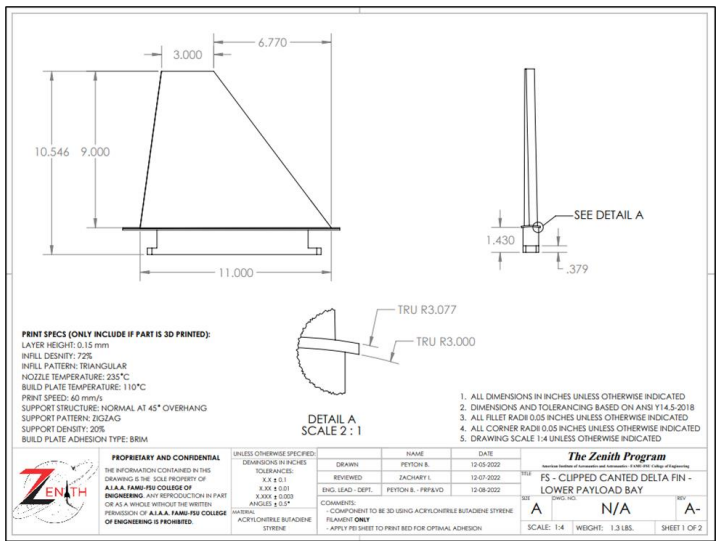
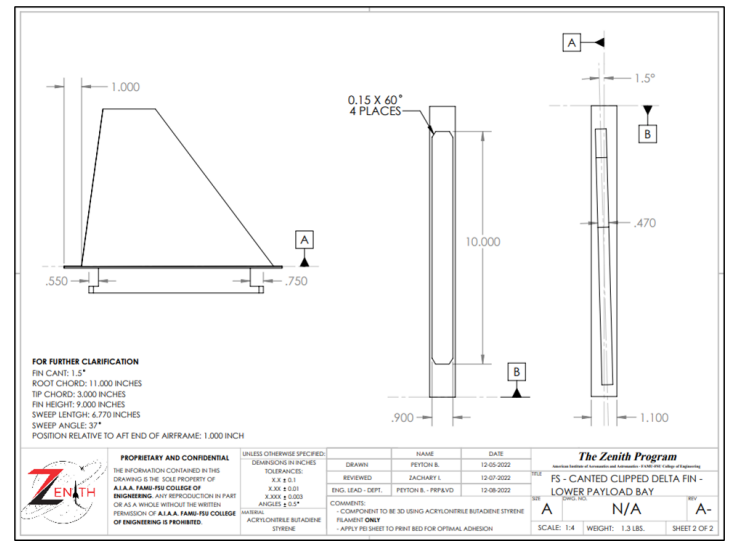




Fin Design

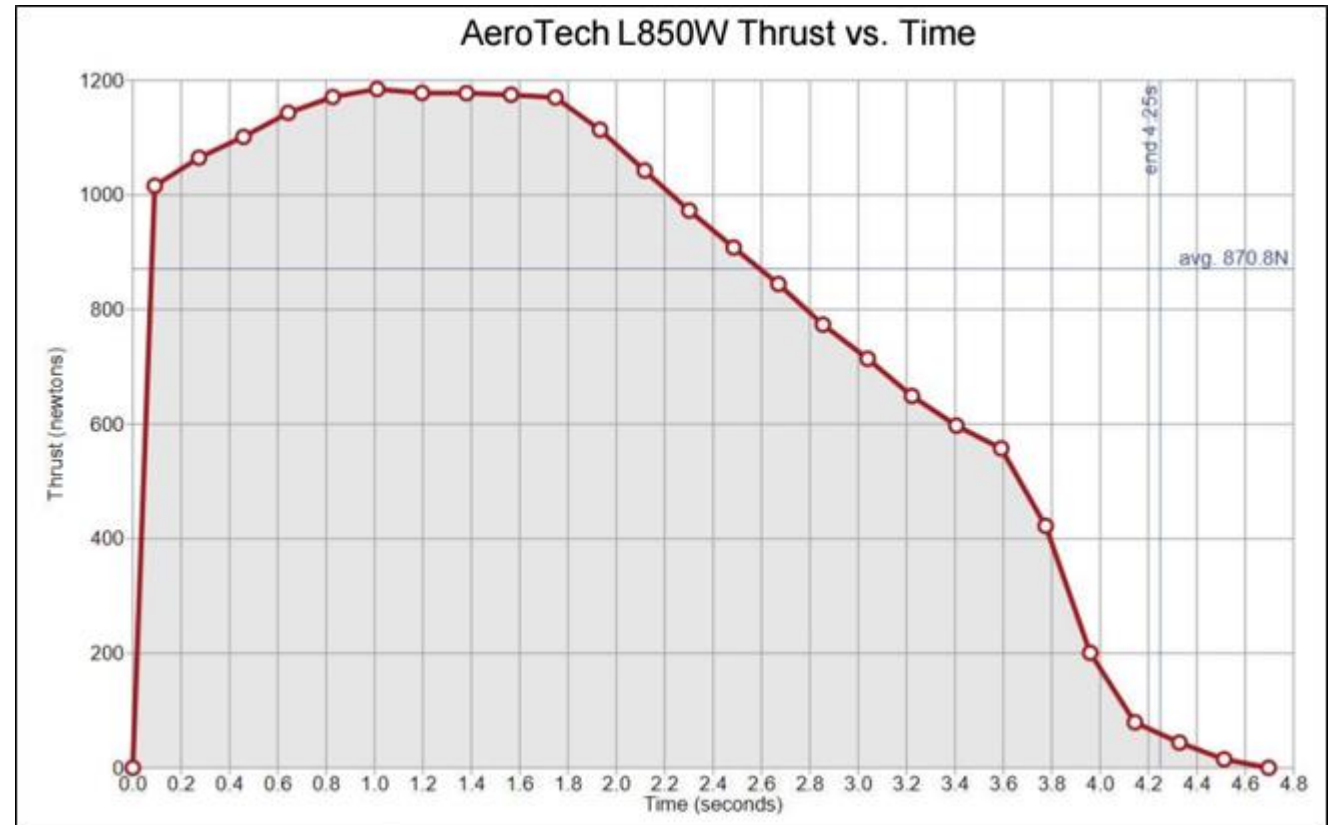
- Clipped Delta Geometry
- Each fin canted 1.5° to allow spin stabilization

➤ Material: 3-D printed ABS



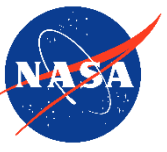
Motor Selection

- AeroTech L850W
- Motor Specifications
 - Total Impulse: 3,646.2 Ns
 - Initial Thrust: 1,000.9 N
 - Max Thrust: 1,866.2 N
 - Burn Time: 4.4 s
 - Weight: 3,742 g

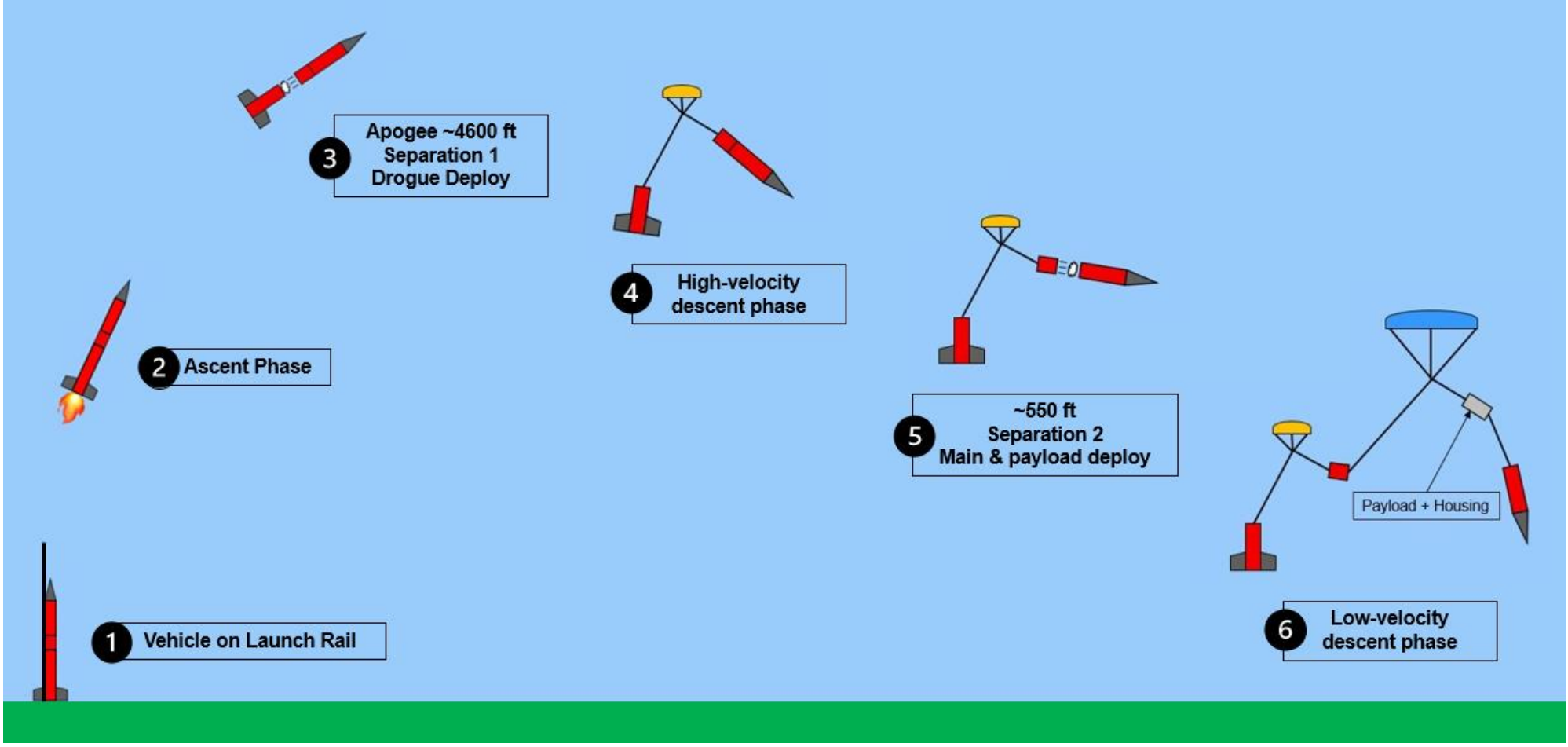




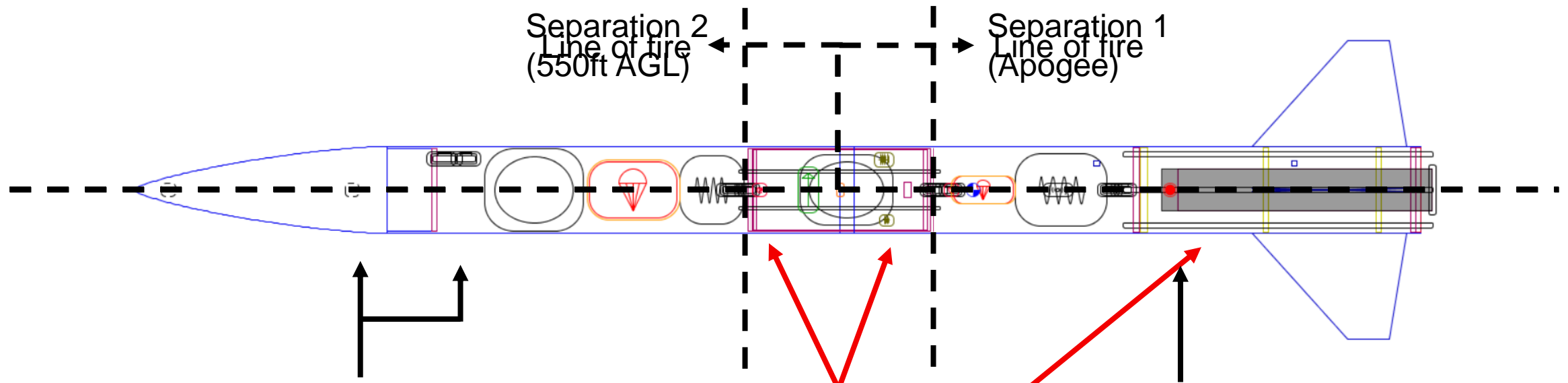
Recovery System



Recovery Overview



Separation & Energetic Locations



Event: Main Chute and Rover Deploy to Apogee ~~CO2 Ejection Charge #1~~ ~~CO2 Ejection Charge #2~~ Main Chute Deploy

Parachutes & Recovery Harness

Drogue:

Fruity Chutes 24" Classic
Elliptical



Main:

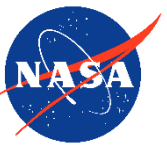
Fruity Chutes 84" Iris Ultra
Standard



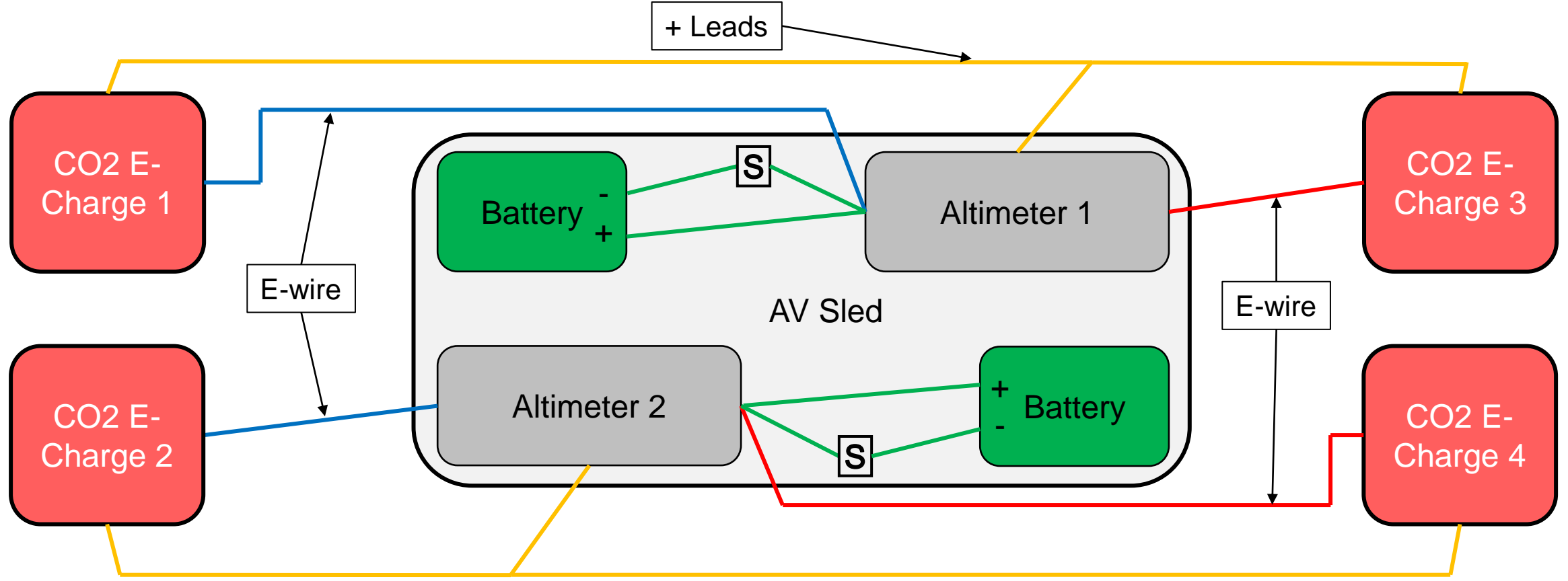
Shock Cord:

9/16-inch Nylon webbed
3000 lbf



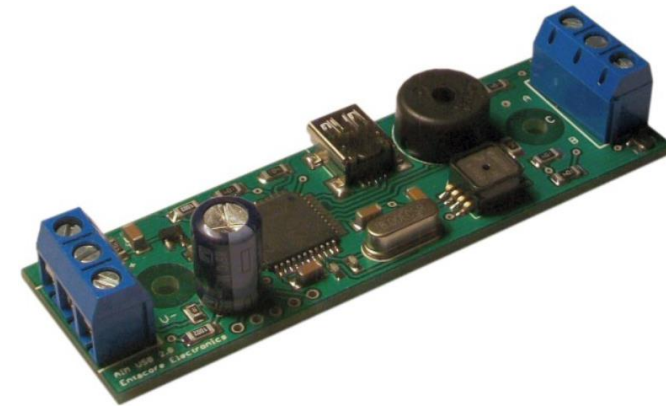


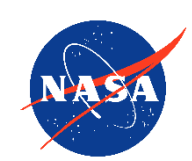
Recovery Avionics



Altimeters

- Primary: Altus Metrum TeleMega v4
 - Drogue: Apogee + 1.5s
 - Main: 550 ft AGL
- Secondary: Entacore AIM 4 USB
 - Drogue: Apogee + 2 sec
 - Main: 550 ft + 2 sec
 - Pyro events for AIM coded to seconds after liftoff based upon simulation data, as backup for TeleMega barometer-based events





GPS Trackers/Locators

Altus Metrum TeleMega v4

- Transmitter Operating Frequency: 433 MHz
- Transmitter Operating Power: 10-40 mW
- Live Telemetry downlink via additional ground station kit
- GPS Tracker

Apple AirTag

- Bluetooth for proximity locating
- Apple-designed U1 chip for ultra wideband and precision tracking
 - Two transmitting frequencies: 6.24 GHz and 8.2368 GHz
- Built-in speaker for sonic locating
- Accelerometer sensor

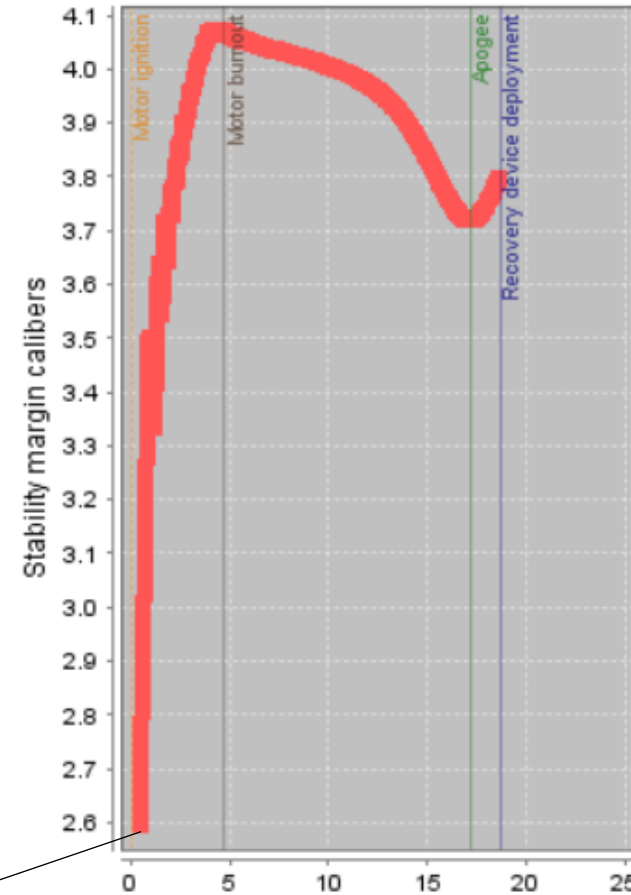


Mission Performance Predictions

Predicted Launch Values

- Static Stability Margin: 2.6 calibers
- Thrust to Weight ratio: 5.05
- Rail Exit Velocity: 64.5 ft/s
- Max Velocity: 544 ft/s
- Max Acceleration: 196.1 ft/s²

NOTE : The values shown in this table are simulated with 10 mph wind speeds



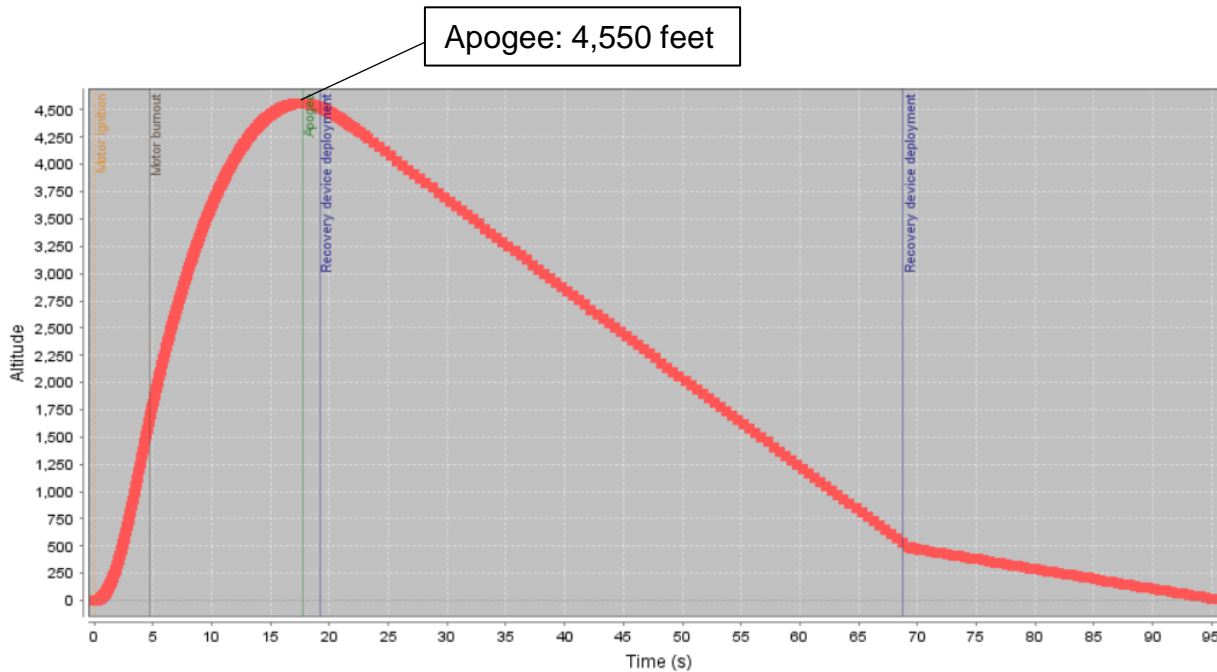
Static Stability Margin: 2.6 Calibers

Apogee

- Predicted to be 4,600 ft
- Hand calculated apogee: 4,431 ft

➤ Simulated via OpenRocket

- Various wind conditions ranging from: 0-20 MPH
- Various launch angles ranging from: 5-10°
- 144" Launch rail length

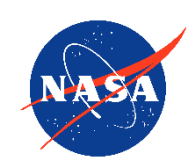




Fin Flutter Calculations

Max Vehicle Speed:	544 ft/s
Fin Flutter Speed:	1837 ft/s
Percent Flutter Speed Achieved:	29%
Factor of Safety:	3.44





Wind Drift and Descent Time

- Maximum Wind Drift
 - 2367.2 ft
- Descent Time
 - 80.7 s
- Yearly Avg. wind speeds in Huntsville, AL: 5-12 mph

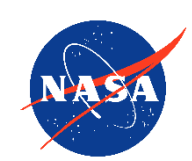
Wind Speed (mph)	Apogee (ft)	Descent Time (s)	Wind Drift (ft)
0	4600	80.7	0
5	4600	80.7	591.8
10	4600	80.7	1183.6
15	4600	80.7	1775.4
20	4600	80.7	2367.2



Landing Kinetic Energy

Section	mass (g)	mass (lbm)	mass (slug)	Descent Velocity (ft/s)	Kinetic Energy (ft-lb)
Nosecone + UPB	4720	10.4058	0.3234	18.6	55.946
Nosecone + UPB + payload	6120	13.4923	0.4194	18.6	72.540
Payload	1400	3.0865	0.0959	18.6	16.594
AV bay	2056	4.5327	0.1409	18.6	24.370
LPB + Fin can	6235	13.7458	0.4272	18.6	73.903

- Mass of largest section: 6235 g
- Maximum Kinetic Energy: 73.9 ft-lb



Main Parachute Opening Shock Force

- Nylon webbed harness rated at 3000 lbf
- Max loading: 97.68 lbf
 - Combination of the bottom half sections of the launch vehicle tethered to the main parachute
- Factor of Safety ~ 30

Section	Mass (slug)	Opening Shock (lbf)
Nosecone + UPB (slug)	0.3235	55.4881
Payload (slug)	0.0960	16.4583
AV Bay (slug)	0.1409	24.1703
LPB + Fin Can (slug)	0.4286	73.5100



Subscale Launch Results

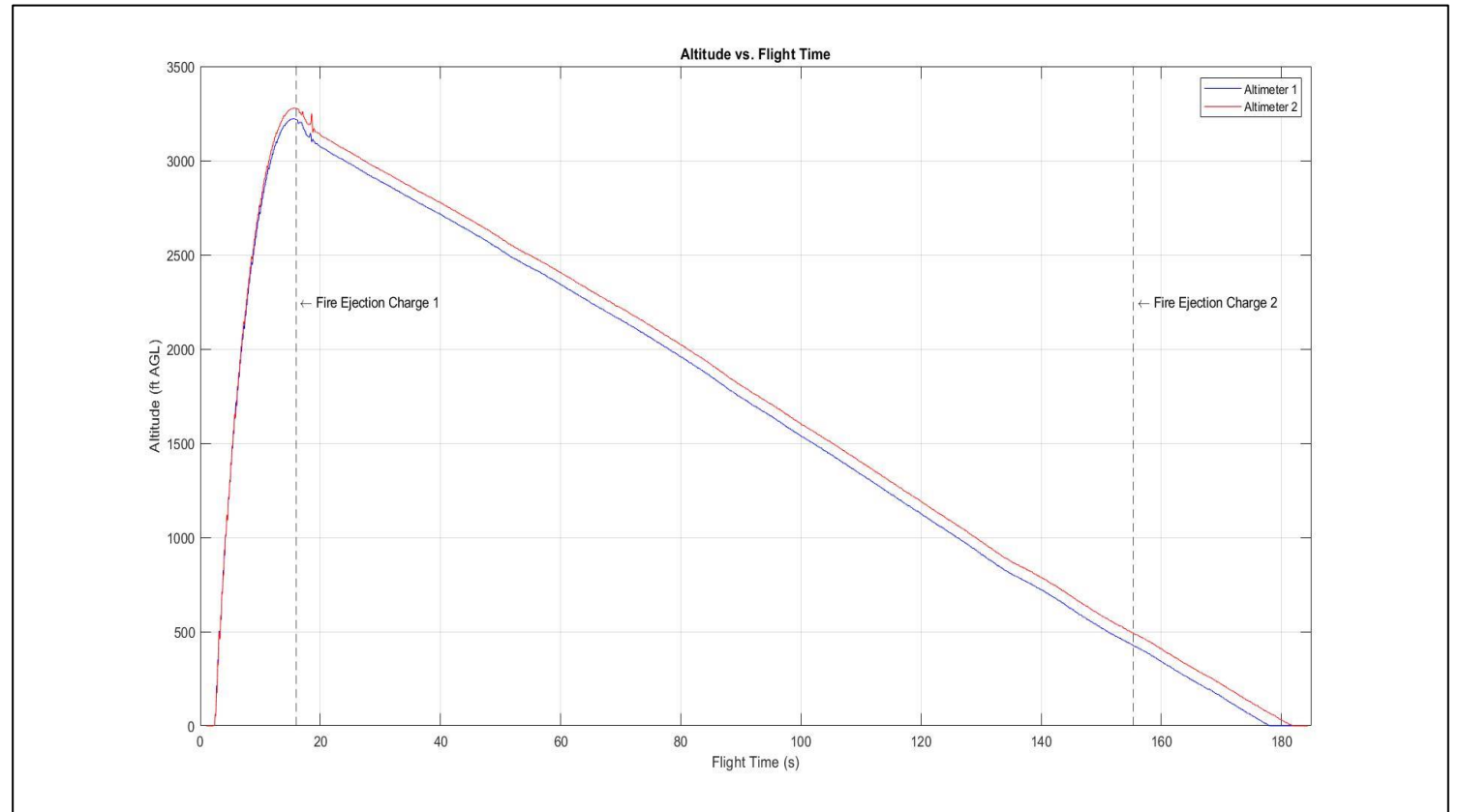
Launch Day Conditions

- Date: Saturday, December 17th, 2022
- Location: Palm Bay, FL
- Weather:
 - Temperature: 74 °F
 - Wind: 9 MPH (N → NE)
 - Mostly clear skies



Flight Result: Partial Success

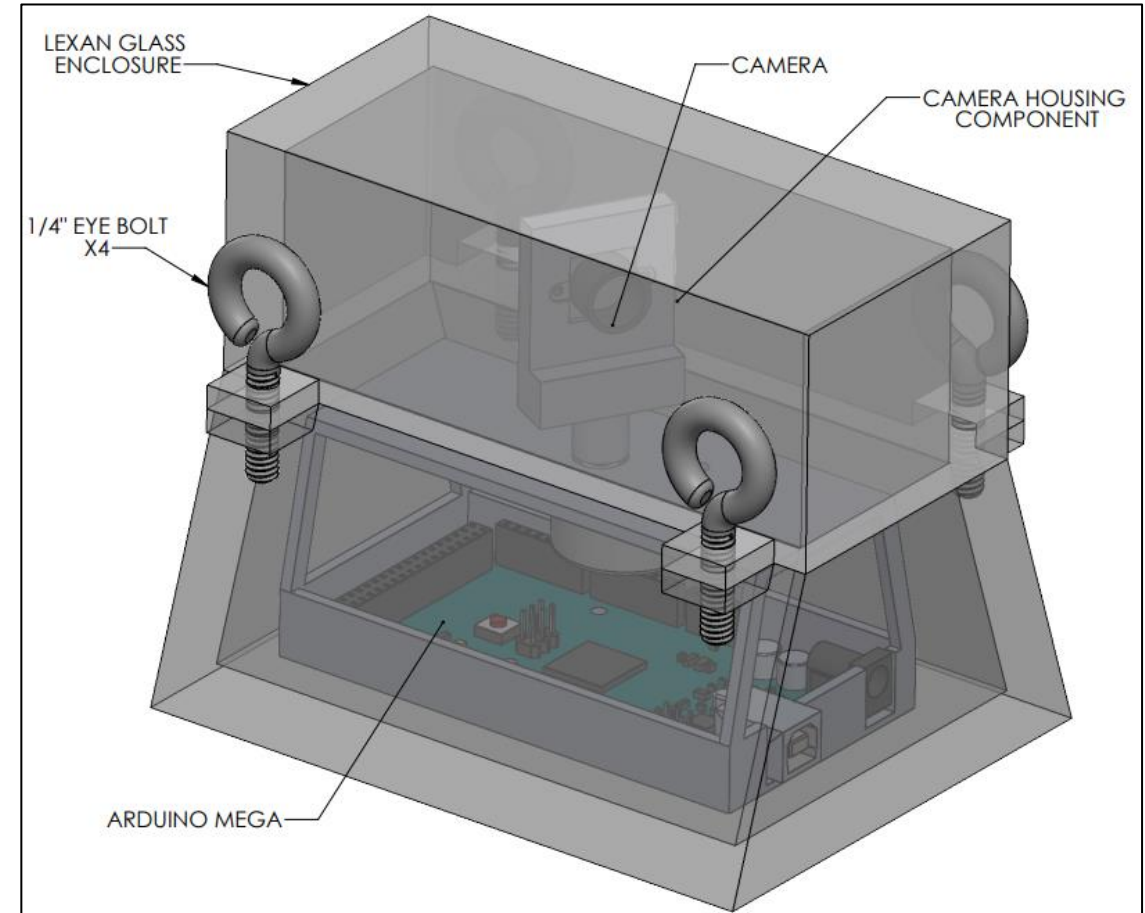
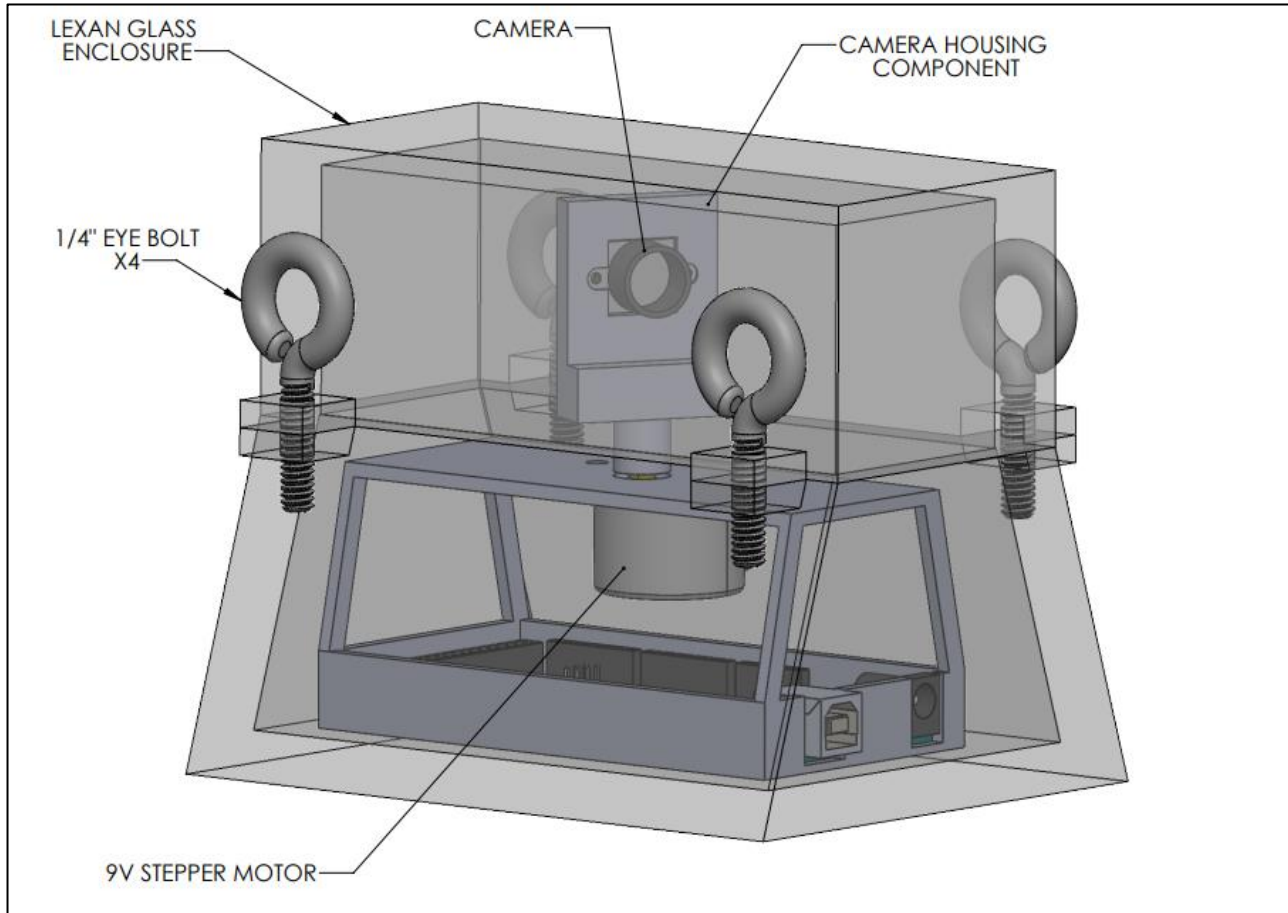
- Achieved Altitude: 3,279 ft
- Vehicle recovered safely on pavement w/ only a minor scratch on one of the fins





Payload

Revised Payload Design





Requirements Verification



Status of Requirements Verification

- Fabrication shop manager appointed to ensure team derived safety requirements are met
- Pre-flight simulations implemented for mission critical structures or flight metrics to avoid part failure or vehicle underperformance
- Pre-flight testing regime developed as result of partial failure in sub-scale flight to physically test all loads vehicle will experience in flight. Avionics verification measures under development.
- Assembly, Pre-Flight, Terminal Count & Launch, and Post-Flight operation checklists created and implemented for future test flights to ensure adherence to NASA vehicle performance requirements and team derived safety requirements



Testing Plan

Test	NET Date	Planned Date	NLT Date
Fin Can Drop (Shear Pin Testing)	1/16/23	Week of 1/23/23	2/6/23
Separation Test (Resized Shear Pins and Charges)	1/23/23	Following can drop	2/6/23
ABS Material Testing (contingent on HPMI availability)	1/16/23	HPMI dependent	*3/6/23 (FRR)
Payload receiver and RAFCO testing	1/23/23	Week of 1/30/23	2/6/23
Full-Scale Flight	2/11/23	2/18/23	2/25/23



THANK YOU!

