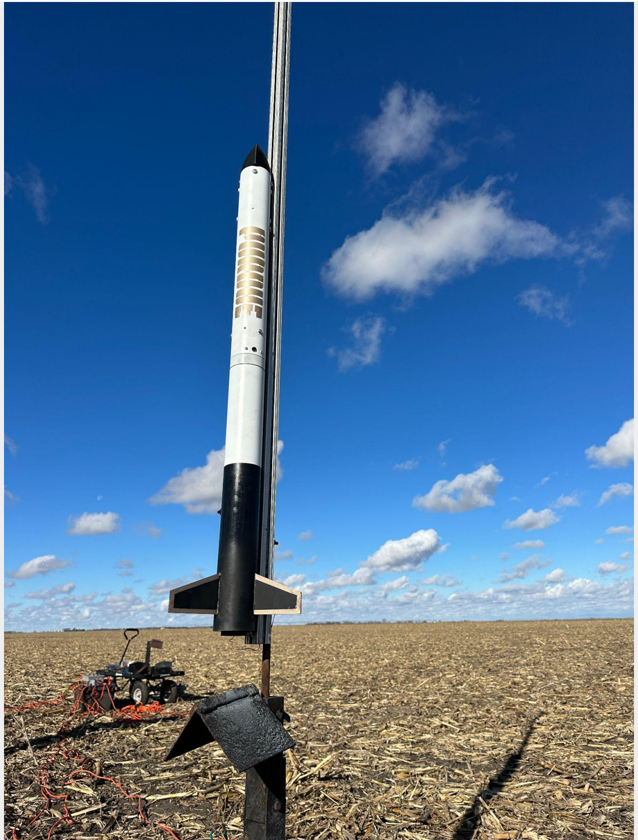
PSP™

Project Weber

Critical Design Review

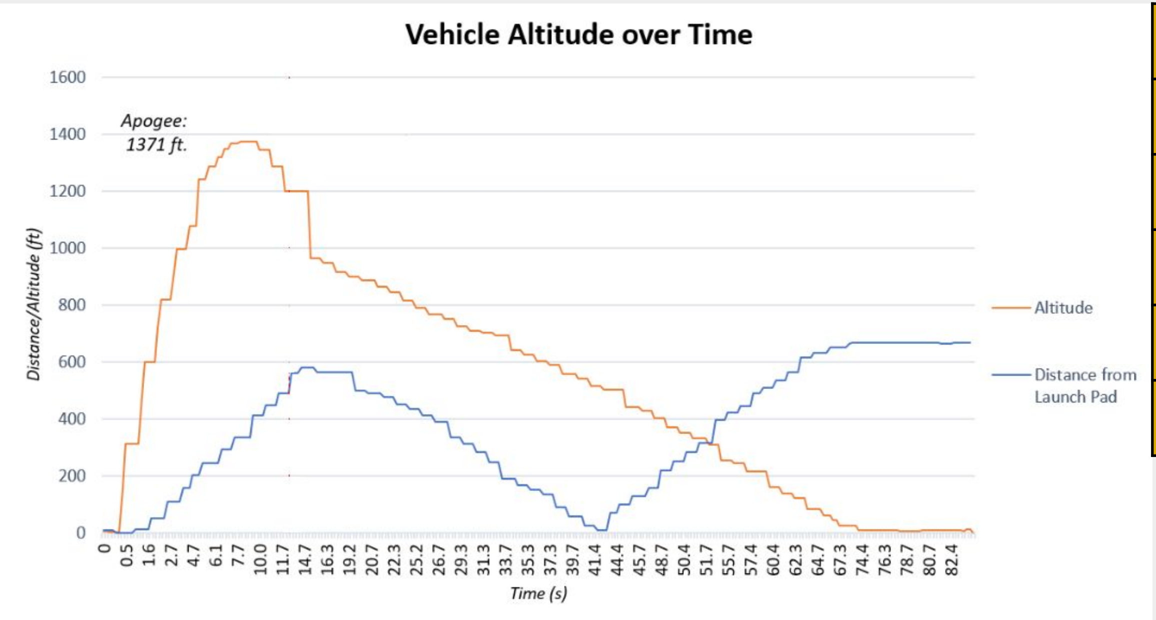
PSP-SL 2023

Subscale Flight



Launch Date	11/12/2021
Temperature	21°F
Weather	Sunny
Wind Speed	7.5 mph E
Location	Jordan Township, IN

Subscale Flight



Apogee	1371 ft
Maximum Velocity (ascent)	260.63 ft/s
Maximum Acceleration (ascent)	122.77 ft/s^2
Descent Time	66.4 sec
Landing Velocity	18.22 ft/sec
Drift Distance (total)	1236 ft

Construction

Launch Vehicle Dimensions

Vehicle Predicted Mass	49.3lbm
Vehicle Outer Diameter	6.17”
Vehicle Length	98”
Vehicle Independent Sections	3

Number of Fins	3
Booster Airframe Section Length	28”, 34” (w/coupler)
Avionics and Recovery Section Length	40”
Payload Section Length	30” , 36” (w/coupler)

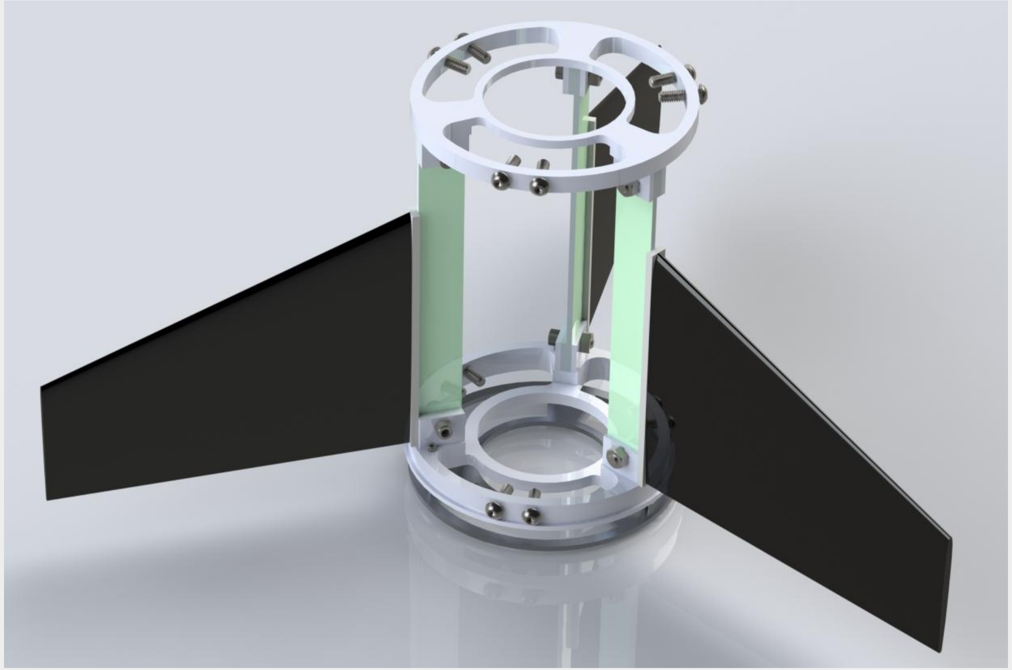
Booster Section Key Design Features

Motor Fin Support Structure

- Easily assembled and disassembled
- Machine toleranced aluminum 6061
- Keeps motor and fins secure and aligned

Fins

- Based on NACA 0006 airfoil
- Resin cast for consistency
- G10 Fiberglass insert for rigidity

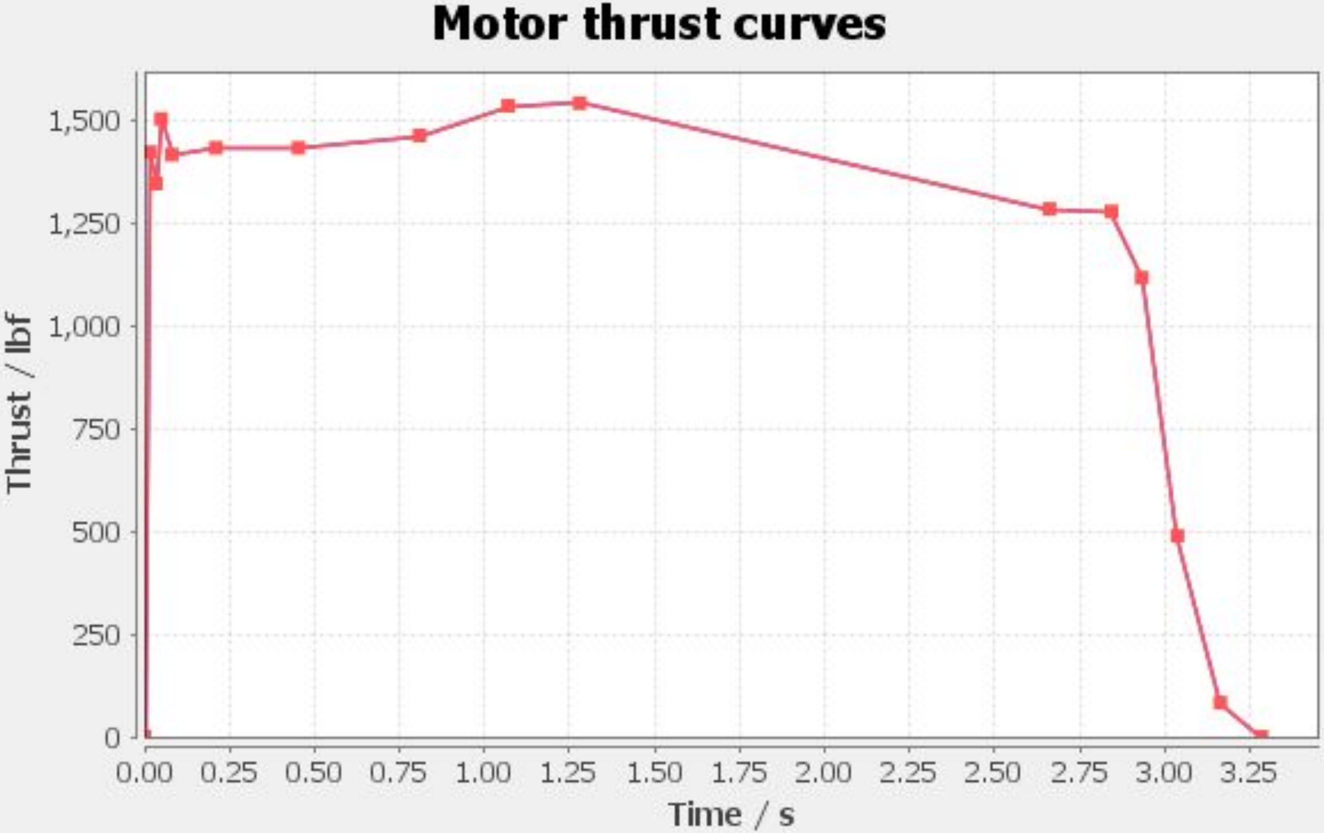


Payload Section Key Design Feature

Nose Cone Camera Bay:

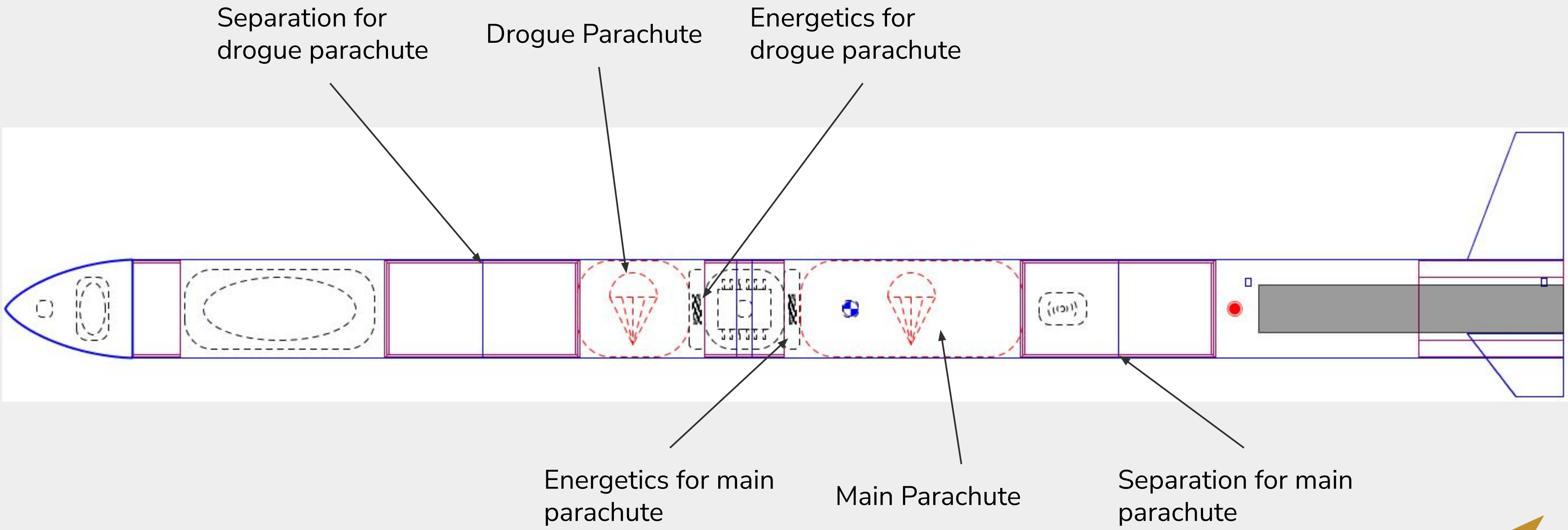
- 8” tall 6.17” diameter LV-Haack
- 3D printed PETG
- Aft facing cameras
- 3” shoulder

Final Motor Choice

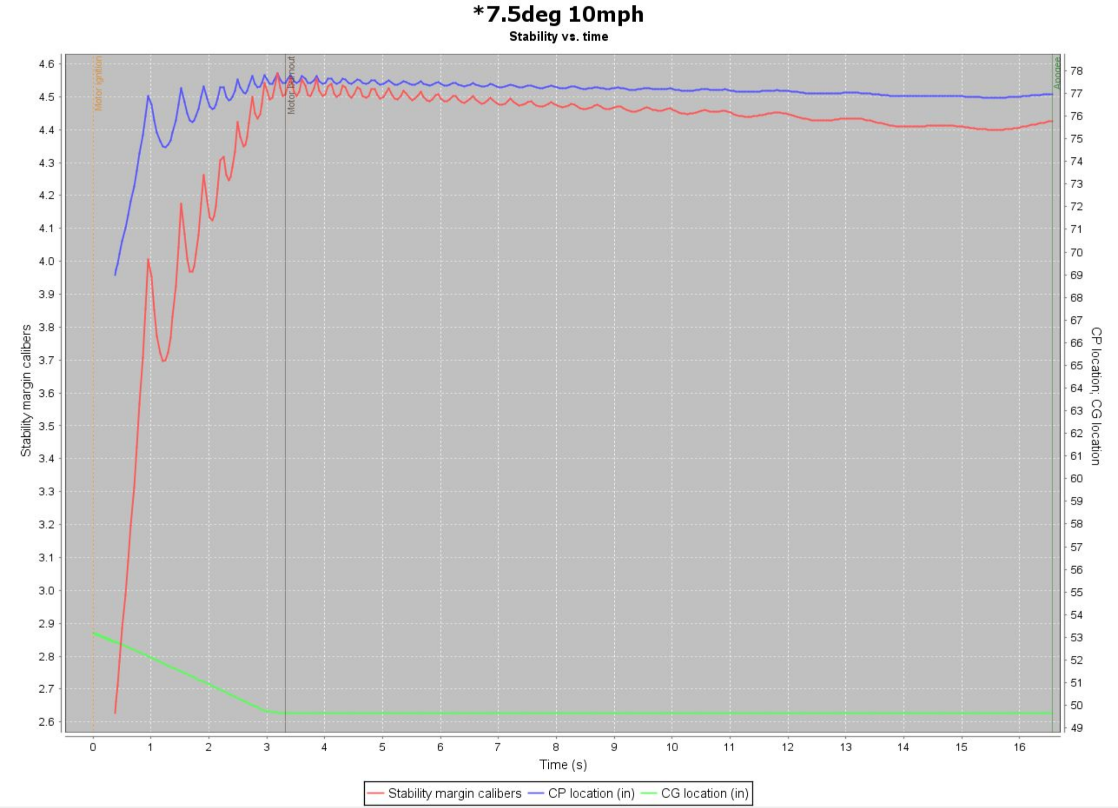


Cesaroni L1350-CS-P	
Impulse	4280 Ns
Avg Thrust	303 lbf
Max Thrust	346 lbf
Burn Time	3.17 sec
Thrust to Weight	6.14
Rail Exit Velocity	66.2 ft/s

Points of Separation, Energetic Materials



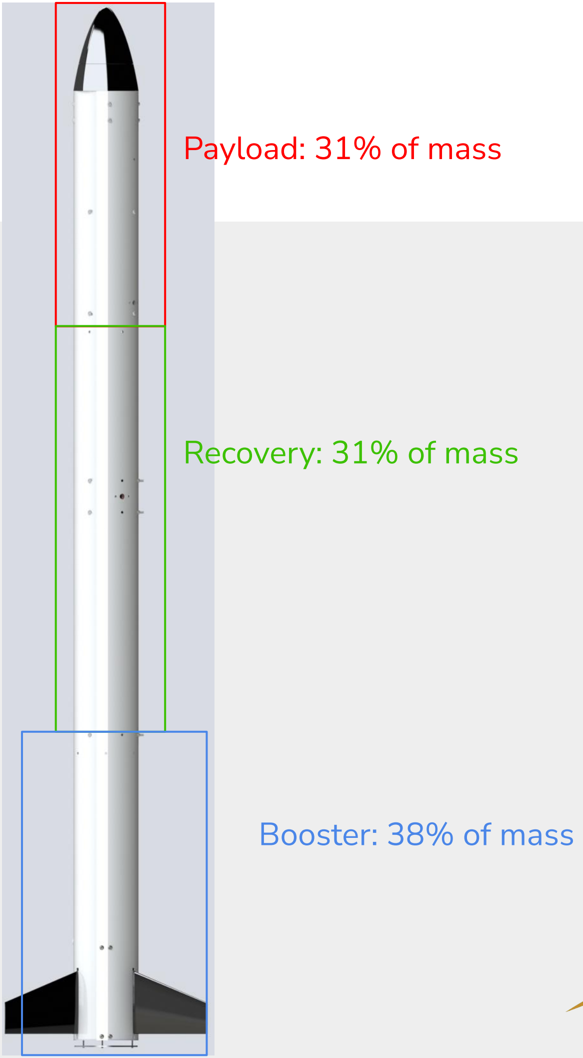
Vehicle Stability Margin



Center of Gravity (from nose)	53.18”
Center of Pressure (from nose)	77.35”
Worst Case Scenario off Rail Stability (20mph 10deg)	2.1 cal

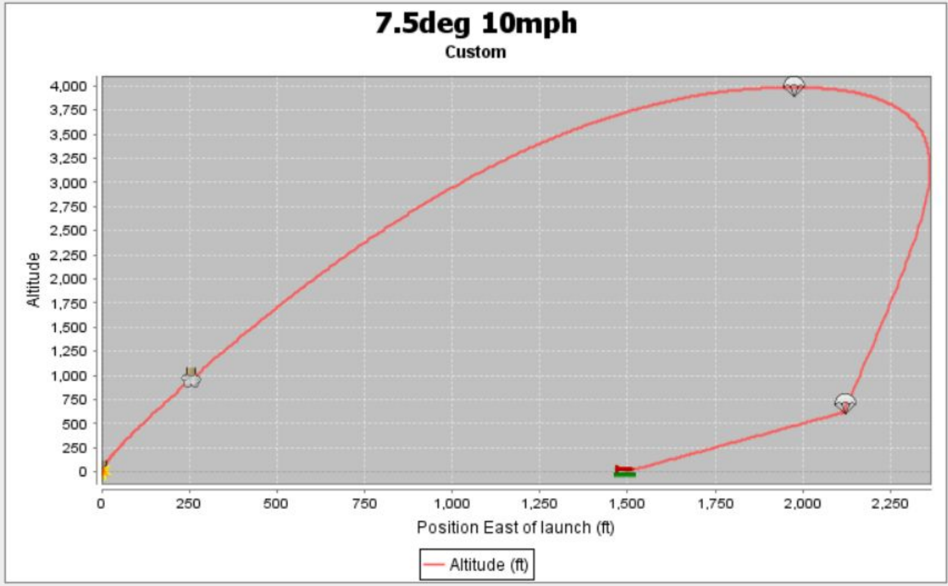
Mass Margin

Component(s)	Mass (lbm)
Camera Bay	1.2
Nosecone Ballast	1.25
Payload	6.3
Drogue Parachute + Shock Cord	.565
Avionics	2.93
Avionics Ballast	2
Main Parachute + Shock Cord	2.84
Motor Fin Support Structure	1.1
Fins	2.8
Motor	7.87
Estimated Total	**49.3**



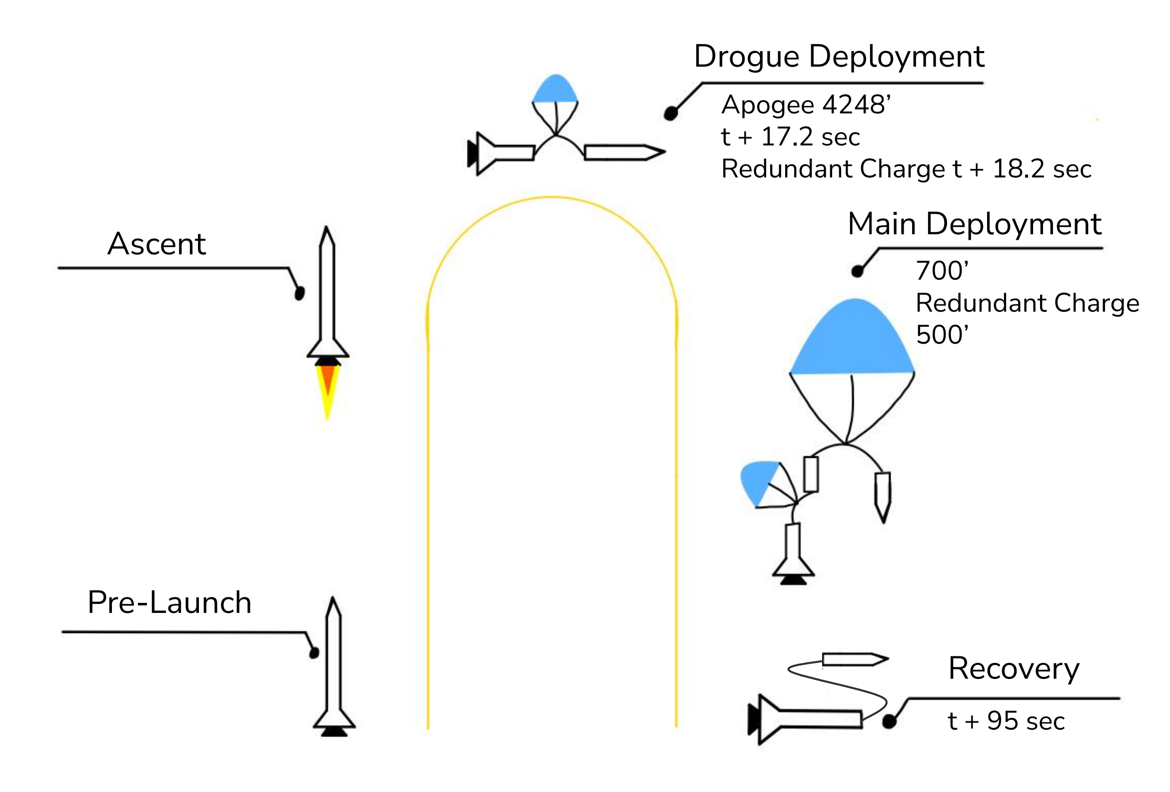
Drift Distance from Apogee

Launch Angle (deg)	Wind Speed (mph)	Drift Distance (ft)
5	0	269
5	5	133
7.5	10	482
7.5	15	883
10	20	1205



Avionics and Recovery

Vehicle Trajectory Overview



Primary Altimeter

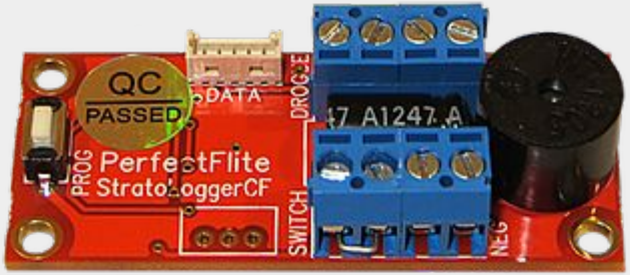
Altus Metrum TeleMetrum

- Uses a 3.7V LiPo battery
- Has live GPS/telemetry capability
- Doubles as primary vehicle locator
- Reliable in past launches

Redundant Altimeter

PerfectFlite StratoLoggerCF

- Uses a 9V alkaline battery
- Sized for relatively short avionics bay
- Reliable in past launches



Drogue Parachute

18” Fruity Chutes Classic Elliptical

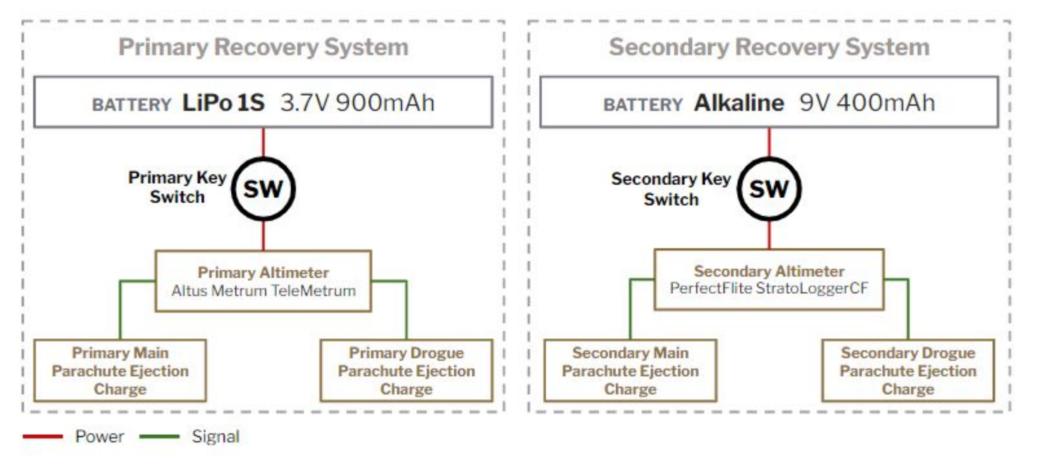
- **CD:** 1.55
- **Materials:** 1.1oz rip-stop, 220lb nylon shroud lines, 1000lb swivel
- High drag coefficient, compact and lightweight
- Allows for better descent time

Main Parachute

144” Rocketman High-Performance CD 2.2

- **CD:** 2.2
- **Materials:** 1.1oz rip-stop, 250lb nylon shroud lines, 3000lb swivel
- Perfectly sized such that it allows vehicle to satisfy landing kinetic energy and descent time requirements
- High drag coefficient, compact and lightweight
- Reliable in past launches

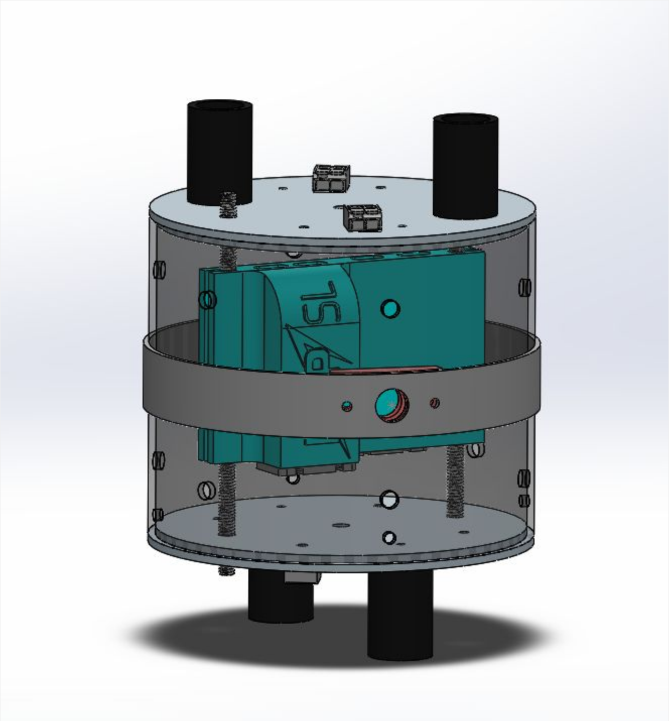
Wiring Diagram



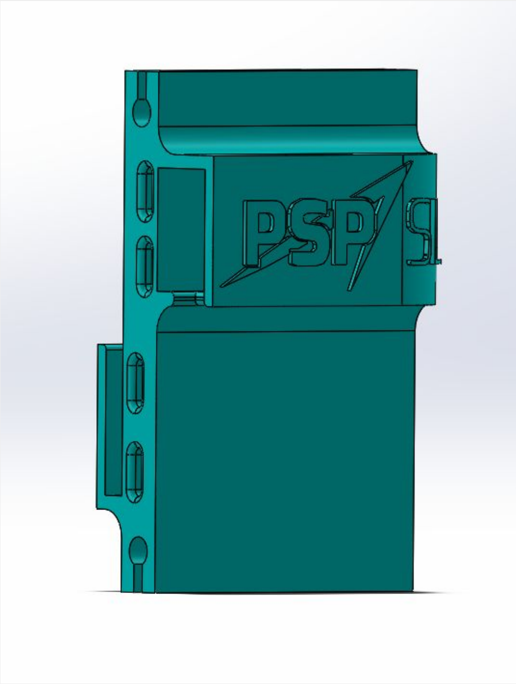
Ejection Charges

Ejection Charge Type	FFFFg Black Powder
Ejection Charge Locations	Forward and Aft Avionics Bay Bulkheads
Primary Drogue	2g
Redundant Drogue	3g
Primary Main	4g
Redundant Main	5g

Overall Avionics Bay Design



Key Details	
Coupler Length	5”
Overall Weight	~3 lbm
Switch Type	Keylock
Altimeter/Battery Retention	Altimeter Sled/Battery Guard
Ejection Charge Retention	4 Black Powder Canisters



Attachment Hardware

Drogue Shock Cord

- ⅜" tubular Kevlar
- 30' long

Main Shock Cord

- ⅜" tubular Kevlar
- 60' long

Harness/Airframe Interfaces

- ¼" stainless steel quick links through looped tether ends
- ¼" stainless steel eye bolts through bulkheads

Kinetic Energy

Vehicle Section	Kinetic Energy Under the Drogue Parachute (ft-lbf)	Landing Kinetic Energy Under the Main Parachute (ft-lbf)
Payload (Upper)	3017.1	52.2
Recovery (Middle)	-	52.4
Booster (Lower)	5804.1	48.0
Total	8821.3	152.7

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Mission Performance Predictions

Parameter	Value	Pass/Fail
Predicted Apogee	4177’	N/A
Ascent Time	17.4 sec	N/A
Drogue Descent Velocity	112.2 ft/sec	N/A
Landing Velocity	14.8 ft/sec	N/A
Descent Time	70.2 sec	Pass
Drift Distance	312’	Pass
Rail Exit Velocity	70.9 ft/sec	Pass
Landing Kinetic Energy of the Heaviest Section	57.7 ft-lbf	Pass

Notes: This simulation was run with a launch rail angle of 7.5° from vertical and the horizontal wind speed set to 10mph. The vehicle was launched against the wind.

Avionics and Recovery Testing

Test ID	Req. ID	Test	Test Articles	Status
VT.A.1	S.A.14, S.A.13.1, S.A.13.2 S.A.14.1, S.A.14.3	Altimeter Continuity and Battery Drain Test	StratoLoggerCF Altimeter, Telemetrum Altimeter, 9V Battery, 3.7V LiPo Battery	Complete
VT.A.2	S.A.13, S.A.13.3	Altimeter Ejection Vacuum Test	StratoLogger CF Altimeter, Telemetrum Altimeter	Incomplete
VT.A.3	S.A.6, S.A.7, S.A.8	Black Powder Ejection Test	Drogue and Main Ejection Systems	Incomplete
VT.A.4	S.A.17	Independent Section Tracker GPS Test	TeleMetrum Altimeter GPS and EggFinder Trackers	Incomplete
VT.A.5	S.A.5	Parachute Drop Test	Drogue and Main Parachutes	In Progress

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Black Powder Ejection Test

Objective: The black powder ejection setup will separate the airframe at indicated points.

Success Criteria: Both black powder canisters must separate fully at the correct airframe sections, not damage any vehicle components, and fully eject each parachutes.

Methodology: Ignite both black powder dual deploy ejection systems with the full vehicle on the ground and record airframe separation.

Results: This test has not yet been conducted.

Independent Section GPS Tracker Test

Objective: GPS trackers wimaintain connection to the Avionics Ground Control Station (AGCS) throughout duration of the flight.

Success Criteria: All GPS trackers must maintain connection to the AGCS for the duration of each trial.

Methodology: Connect trackers within booster coupler and 3D printed sled

Results: This test has not yet been conducted.

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Altimeter Continuity and Battery Drain Test

Objective: Altimeter systems fulfill the requirements that they function continuously across all likely flight temperatures and durations.

Success Criteria: Both altimeters must maintain continuity and receive adequate power from their respective batteries for 3 hours powered on, and the voltages of both batteries must remain the same after 18 hours powered off.

Operation: Connect altimeters to batteries and e-matches and periodically check continuity and voltage in two temperature environments.

Status: Both altimeter systems passed the continuity test for cold and warm weather conditions and battery drain test.

Altimeter Ejection Vacuum Test

Objective: Altimeters will ignite both ejection charges at the specified time.

Success Criteria: Both altimeters must ignite the drogue parachute e-matches at apogee (or 2s after apogee) and the main parachute e-matches at the correct altitudes during descent.

Operation: Altimeters experience a simulated flight in a team derived vacuum chamber.

Status: This test has not yet been conducted.

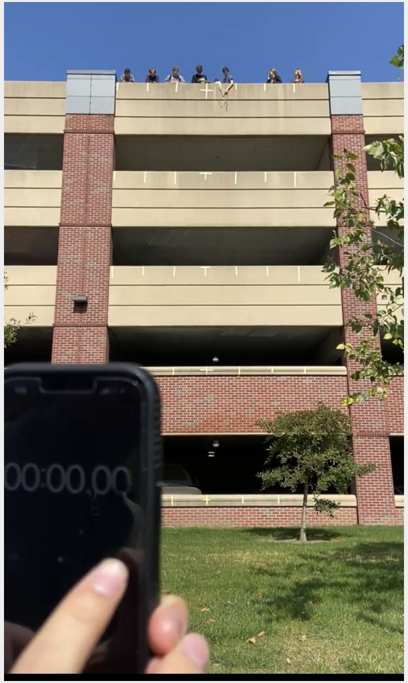
Parachute Drop Test

Objective: Parachutes will open consistently within an appropriate distance range and time frame to allow for full deployment after ejection.

Success Criteria: Both parachutes must fully deploy.

Methodology: Record video and time for a weighted drogue and main parachute to free fall from the top of a parking garage.

Results: This test has not been conducted for the main and drogue parachute.



Parachute Drop Test experimental setup

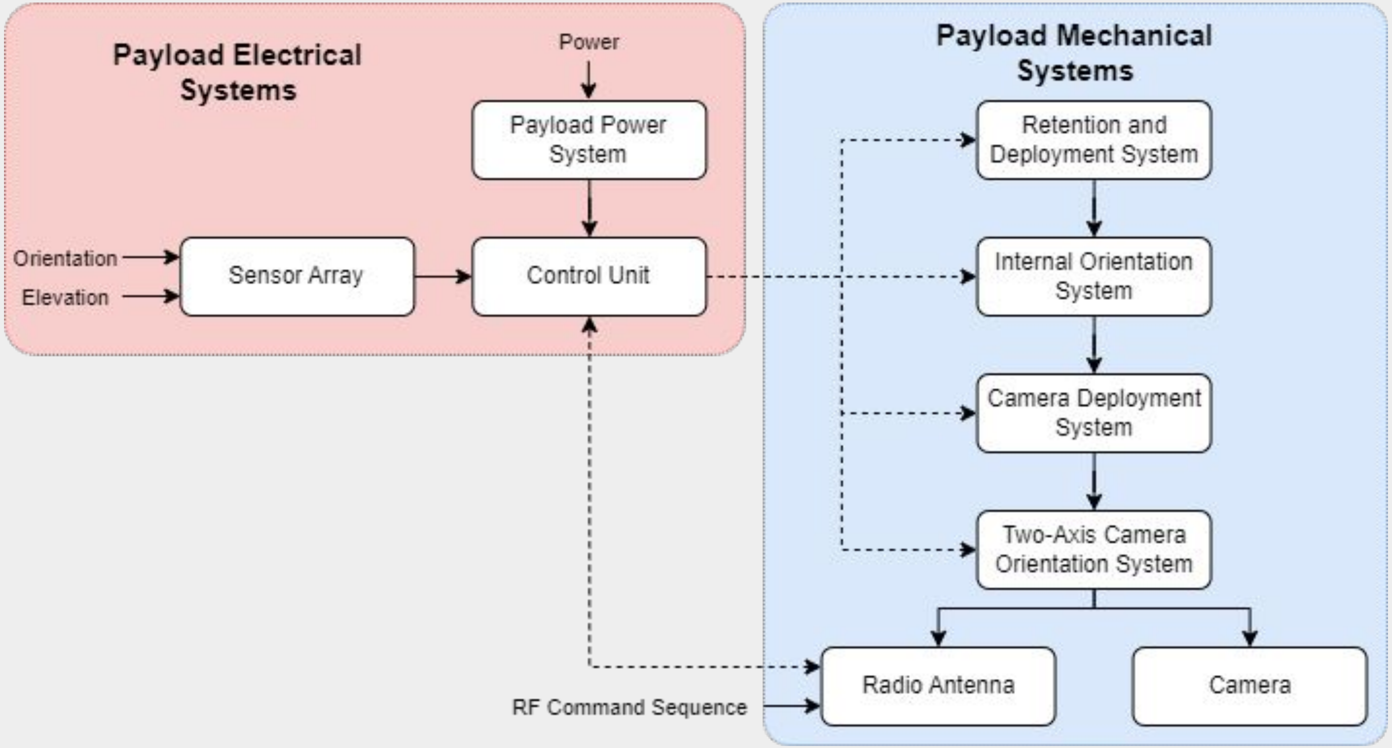
Payload

System Overview

- Payload System General Mission:
  - Extend an autonomous camera system out of the vehicle through an opening in the airframe and complete commands received by NASA transmitters

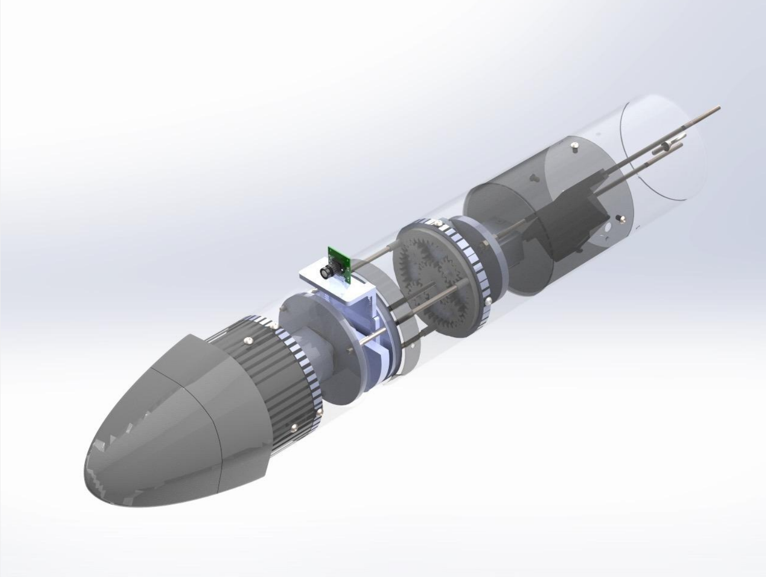
- Subsystem Overview:
  - Mechanical subsystems: Internal Orientation System (IOS), Retention and Deployment (R&D), Camera Deployment System (CDS), Two Axis Camera Orientation System (TACOS)
  - Electrical Subsystems: Autonomous Payload Interface (API), electronic hardware

System Diagram



Mechanical Subsystems Overview

- Comprised of:
    - Internal Orientation System (IOS)
    - Retention and Deployment subsystem (R&D)
    - Camera Deployment System (CDS)
    - Two Axis Camera Orientation System (TACOS)
- Each designed to actuate individually to successfully deploy the camera above the airframe.
- Open configuration (shown)
- Closed configuration (flight ready)



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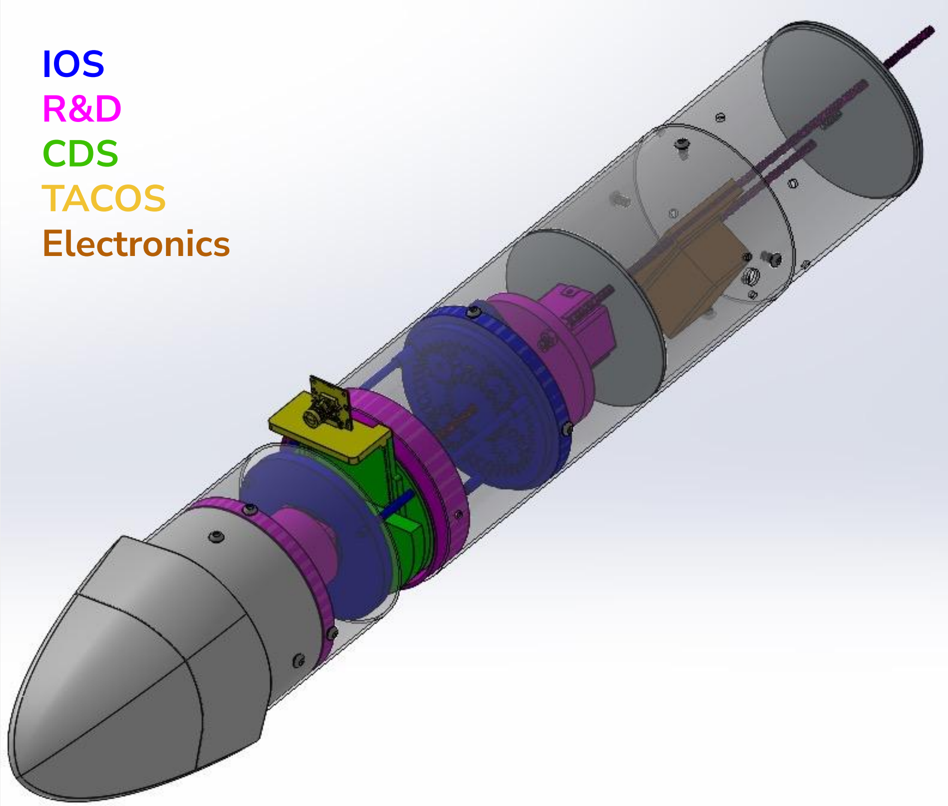
Payload Deployment Operations

1. IOS spins CDS to be aligned with vertical axis

2. R&D creates a gap in the airframe with a lead screw

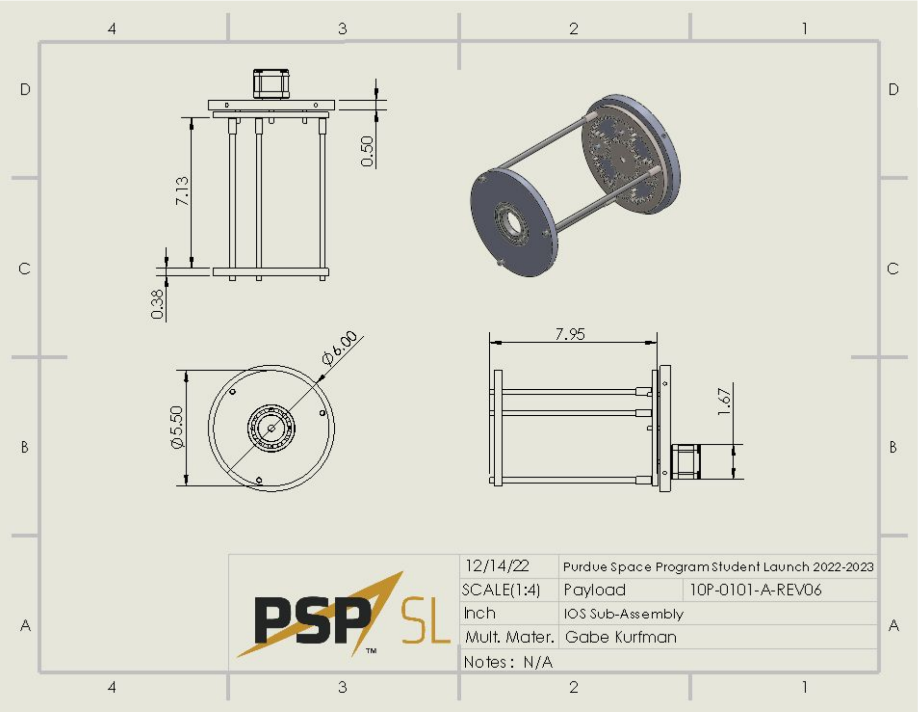
3. CDS raises the camera with a rack and pinion mechanism

4. TACOS move and adjust camera controlled by API.



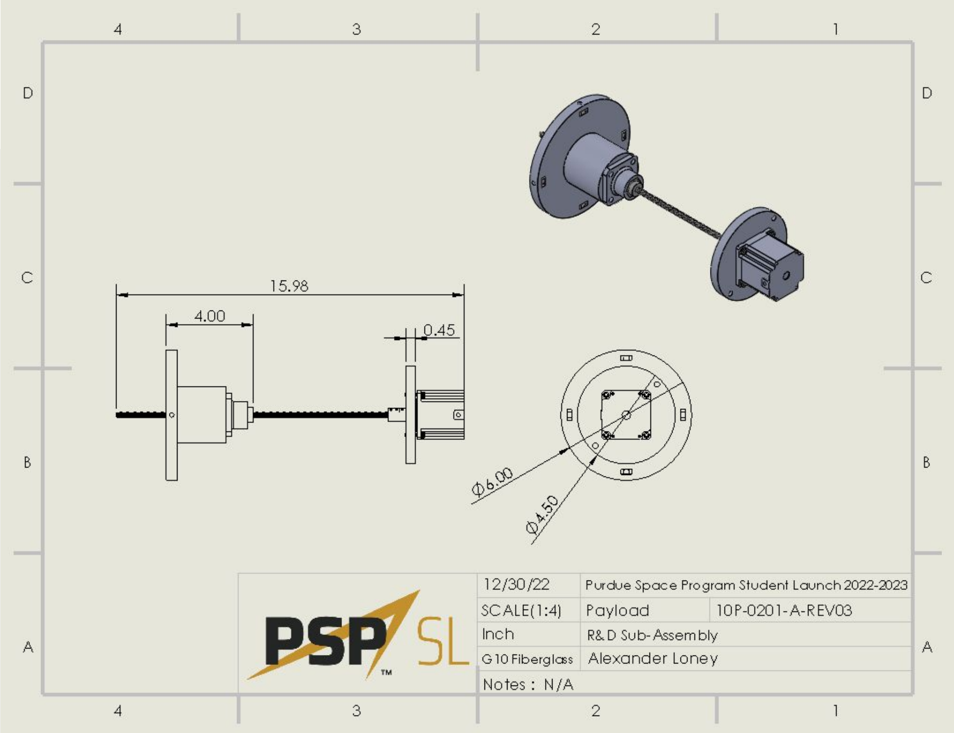
IOS

- NEMA 17 non-captive stepper motor
- 3D printed PLA with the exception of the linear rods and ball bearing
- Operational in closed configuration
- 360 degree rotation about the central vehicle axis.



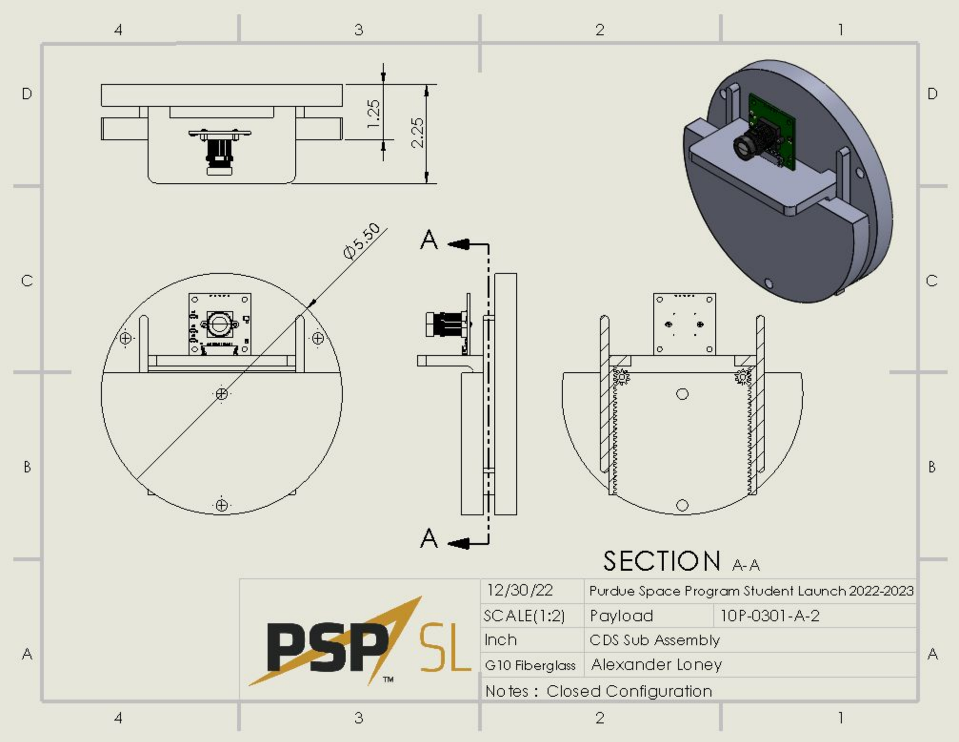
R&D

- Nema 23 stepper motor
- Applies 1.5 Nm of torque to keep the airframe in closed configuration during flight.
- Extends the airframe 1.75” away (2.27” including support ring).
- Main structural support from rotating components to the fixed airframe.



CDS & TACOS

- 3 Nema 10 stepper motors
- 1 Servo Motor
- Lower torque needed to raise the camera and adjust for commands.
- Redesigned rack and pinion design.
- Camera extension length of 3.85” above the airframe.



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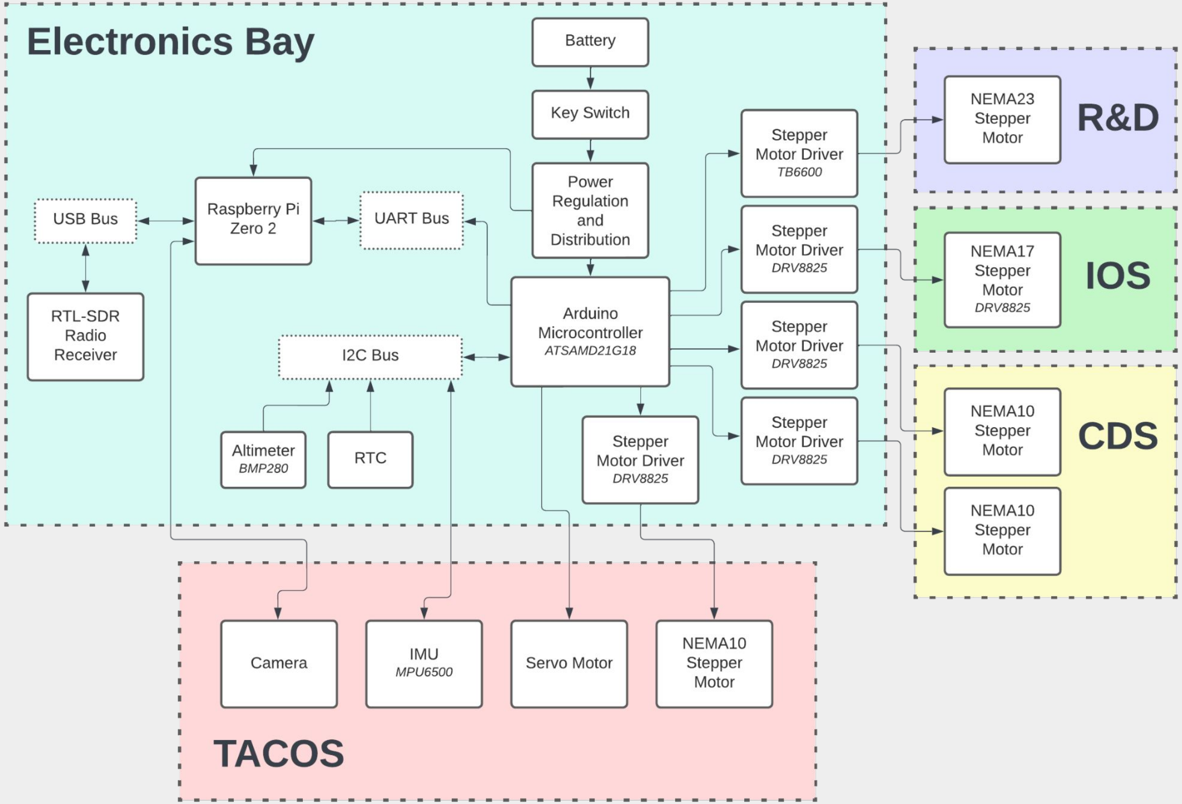
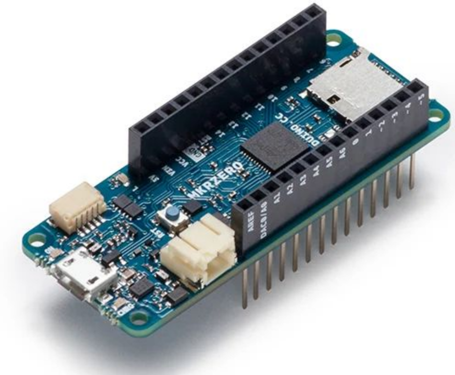
Payload Electronics Block Diagram

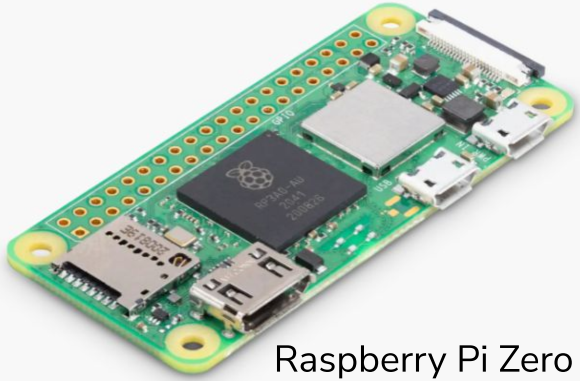


Payload Electronics

- Electronics will utilize an Arduino MKR Zero as the primary microcontroller.
- A Raspberry Pi Zero is used for interfacing with the camera and radio receiver.
- The team is using familiar components for other aspects of the electronics.
  - BMP280 Pressure Sensor
  - MPU6500 IMU
  - DRV8825 Stepper Motor Driver



Arduino MKR Zero



Raspberry Pi Zero

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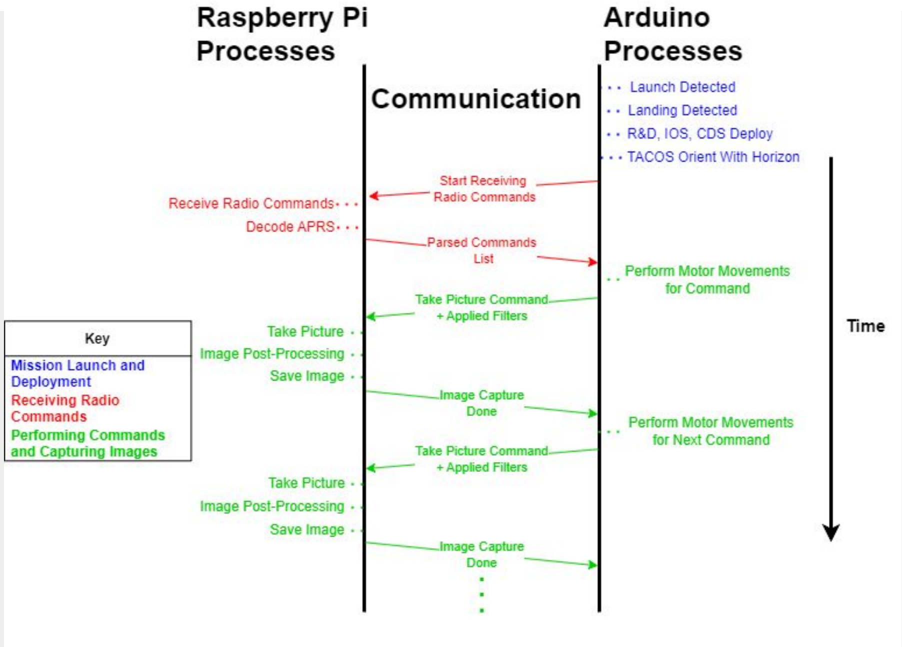
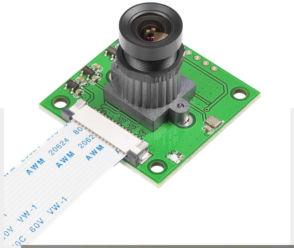
Payload Software Overview

- Arduino interfaces with mechanical components and the Raspberry Pi.
- Order of Operations
    a. Arduino Detects Launch/Landing.
    b. Arduino Deploys system.
    c. Arduino tells Raspberry Pi to Receive Radio Commands from NASA.
    d. Raspberry Decodes Commands and Sends them to the Arduino.
    e. Arduino Performs Motor Movements and Tells Raspberry Pi when to take a Picture.
    f. Raspberry Pi Captures an Image and Saves it to its SD Card.



Camera and Imaging



ArduCAM OV5647

- Payload camera is interfaced to Raspberry Pi Zero.
- Arduino MKR Zero sends commands to Rasbperry Pi to take a picture and perform image processing.
    - Image focusing is done manually, will be fine tuned before launch
    - Finished image is saved on Raspberry Pi SD Card.
    - Timestamp, callsign, and commands done to obtain the image are put on each image.

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Radio Receiver

- The team is using an RTL-SDR module.
    - Can be configured to receive a wide range of frequencies.
- Interfaced with the Raspberry Pi Zero via USB.
    - Raspberry Pi will decode the APRS messages and communicate them to the Arduino.
- Antenna will be connected and contained inside the Payload coupler.

Notable Payload Test Plans

VT.P.1: APRS Decoding Test

Ensure the payload can receive and decode APRS radio messages

VT.P.2: R&D Loading Test

Ensure compliance with flight loading FoS of 1.33

VT.P.8: Camera Imaging Test

Ensure the camera and Raspberry Pi are able to capture and process images

R&VP

R&VP

PROJECT REQUIREMENTS (NASA Requirements, Team Requirements)							Verification Type(s)					
Label	ID	Mission Critical	Status	Originator	Requirement Summary	Req's Subordinate To	PR	A	D	I	T	Verification ID's or Prerequisites
G	2.6	☑	In Progress	NASA	The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.		☐	☐	☑	☐	☐	
G	2.7	☑	Incomplete	NASA	The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.		☑	☐	☐	☐	☐	S.P.6, S.P.7
G	2.8	☑	Incomplete	NASA	The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated launch services provider.		☐	☐	☑	☐	☐	
G	2.9	☑	Incomplete	NASA	The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).		☐	☐	☑	☐	☐	
G	2.10	☑	Complete	NASA	The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).		☐	☐	☑	☑	☐	