Preliminary Design Review

October 26th, 2022

Presentation Overview

- Launch Vehicle Leading Design
- Recovery System Leading Design
- Payload Leading Design
- Mission Performance Predictions
- Requirements Compliance Plan

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Launch Vehicle Leading Design

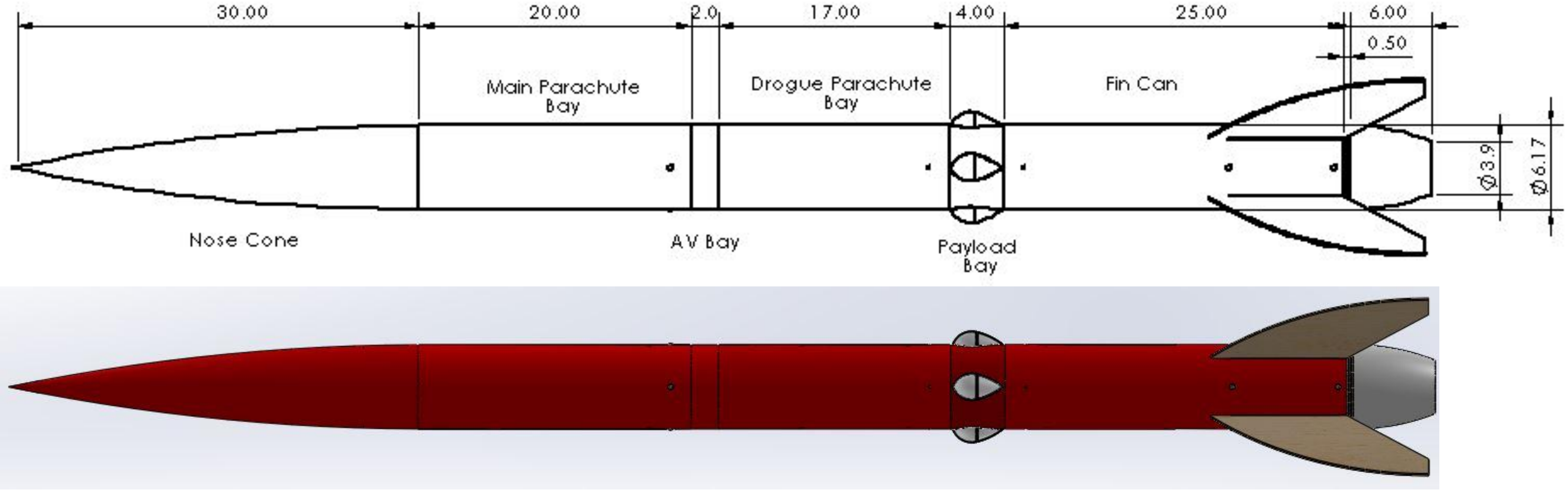
Material Selection

Airframe Sections

Fin Configuration

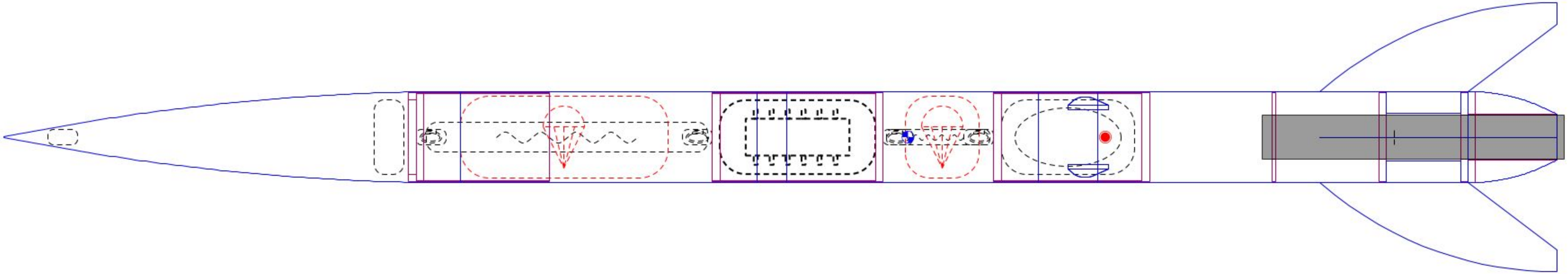
Launch Vehicle Dimensions

- Length: 104.5 in.
- Diameter: 6.17 in.
- Launch Weight: 43.22 lb.
- Comprised of 6 sections



Launch Vehicle Stability

- Center of Gravity: 61.2 in. from tip of nose cone
- Center of Pressure: 74.9 in. from tip of nose cone
- Static Stability: 2.15 cal.



Chosen Material: G12 Fiberglass

- Blue Tube 2.0
  - Vulcanized fiber-based
  - Abrasion resistant and durable material properties
  - Inexpensive
  - Lightweight
  - Prone to water damage without additional treatment
- G12 Fiberglass
  - Filament wound fiberglass
  - Highly durable and damage resistant
  - More expensive than blue tube
  - Heavier than other options
  - Water resistant

Note: Both materials provide adequate strength to withstand the forces of flight

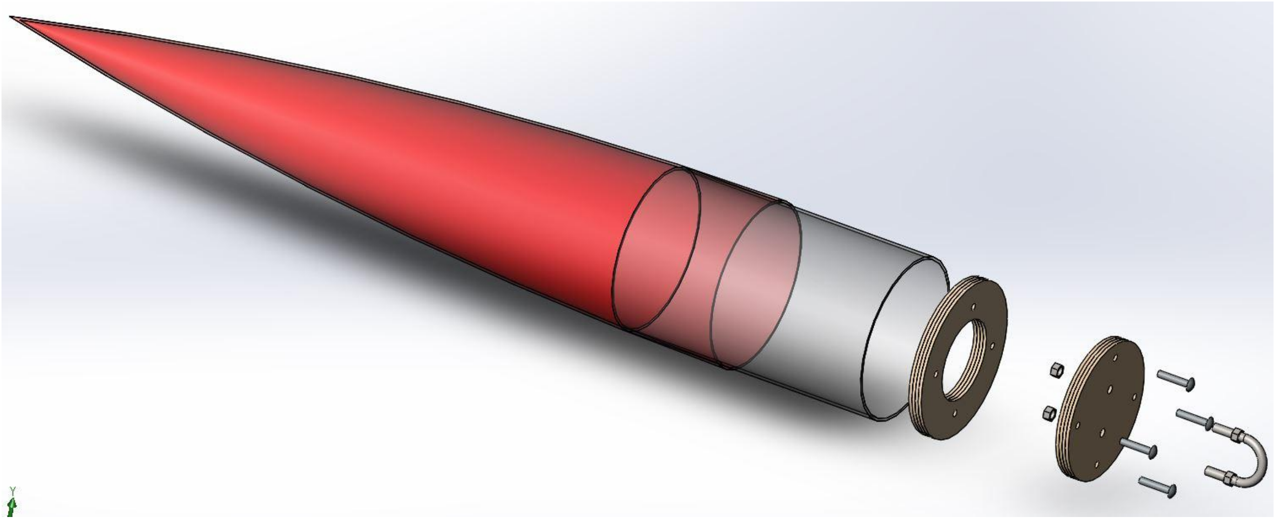
Chosen Nose Cone: 5:1 Ogive

- Conical
  - Simple design
  - Not optimal for subsonic speeds
- Elliptical Design
  - Optimal for subsonic speeds
  - Minimizes skin friction drag
  - Not commercially available

- Ogive
  - Many geometries available and sold by large retailers
  - 5:1 Ogive gives a desirable stability margin in RockSim simulations
  - Added length/weight improves stability

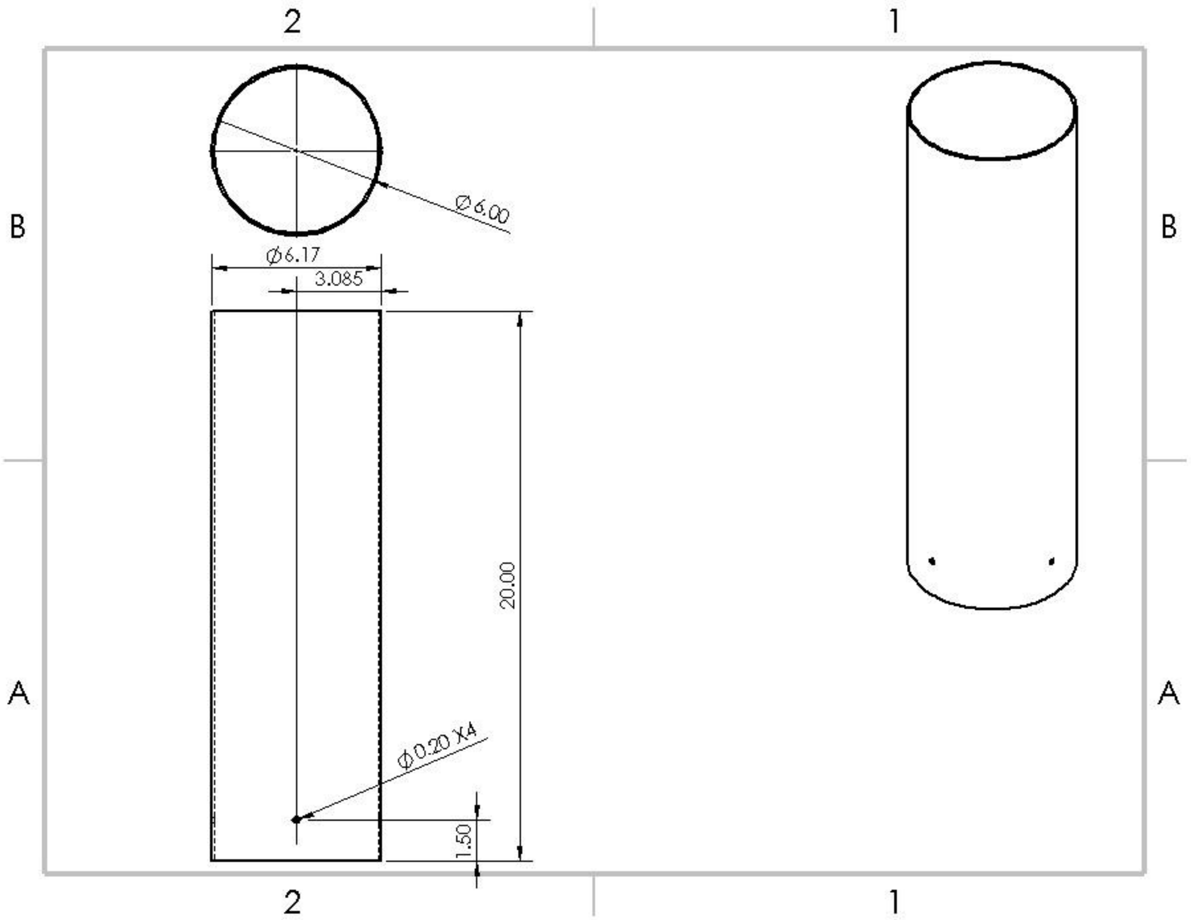
Chosen Nose Cone Bulkhead: Removable

- Removable Bulkhead
  - Permanent centering ring that bulkhead is bolted to
  - Allows for accessibility to adjust ballast on the forward side
  - More parts to manufacture, more failure points
  - 1 lb. of permanent ballast and 1 lb. of removable ballast



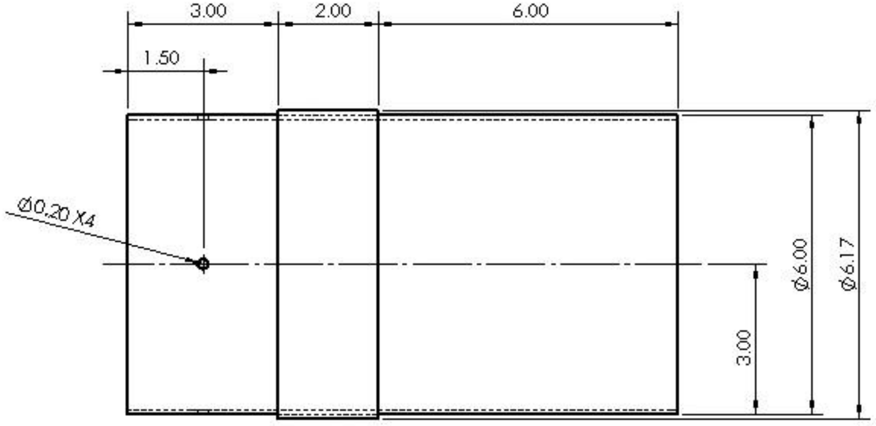
Main Parachute Bay

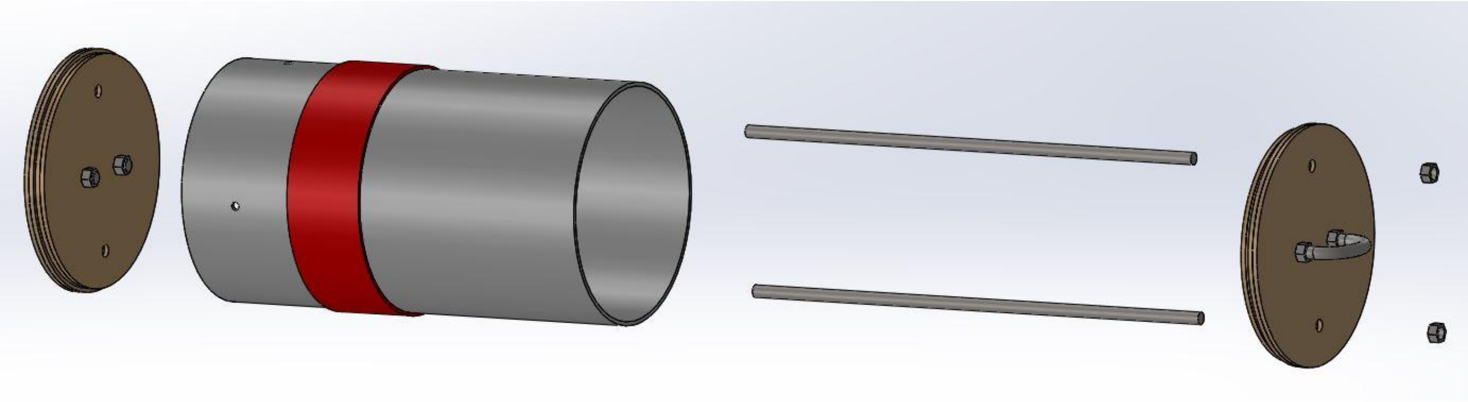
- Located between the nose cone and avionics bay
  - Shear pin connection to nose cone
  - Bolted connection to avionics bay
- 20 in. length



Avionics Bay

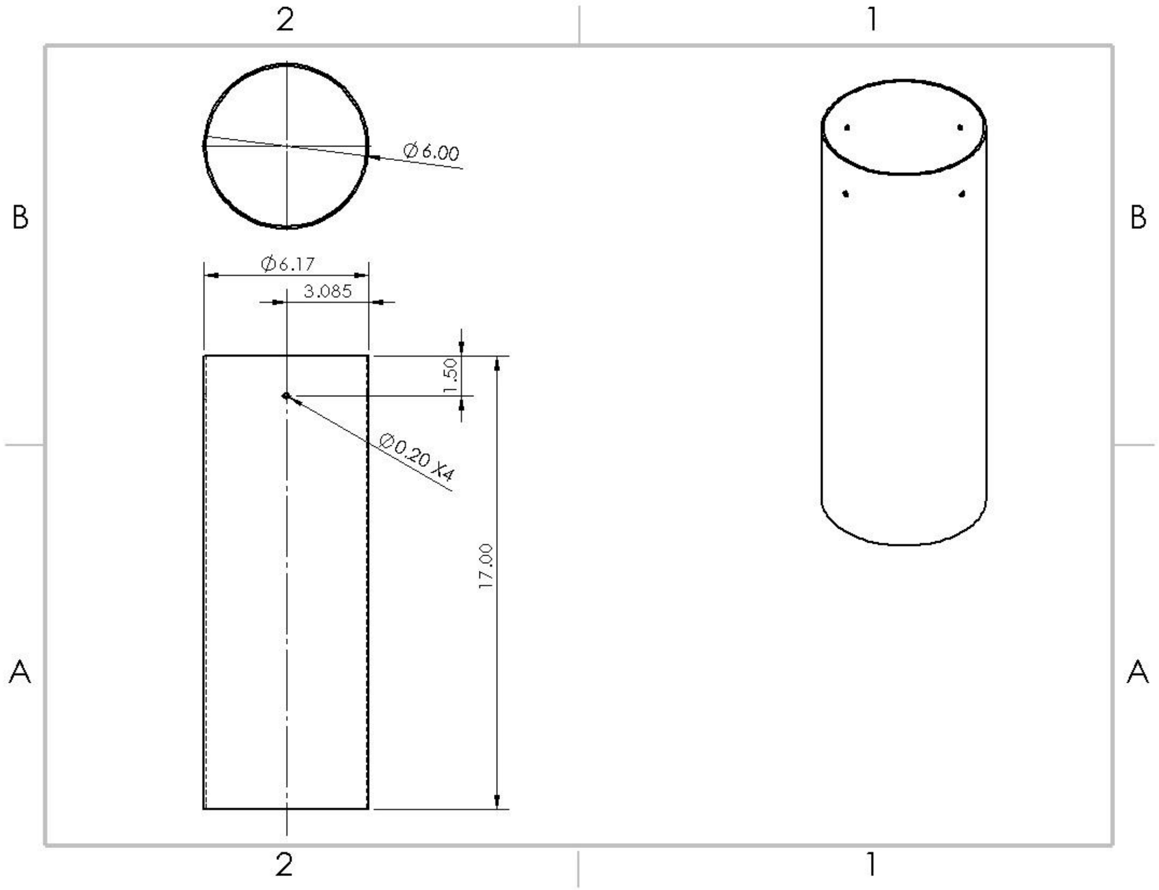
- Between the main parachute bay and drogue parachute bay
- Modular, 2 bulkhead design allows for accessibility to the avionics sled
- Easily accessible blast caps and U-bolts





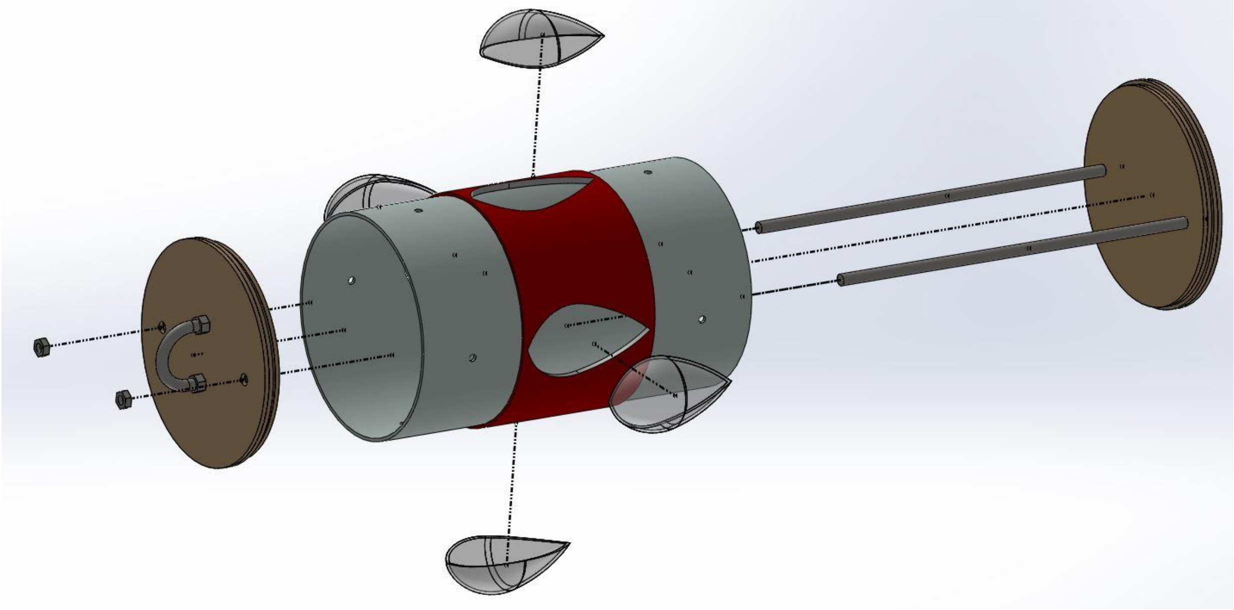
Drogue Parachute Bay

- Located between the nose cone and avionics bay
  - Shear pin connection to avionics bay
  - Bolted connection to payload bay
- 1 in. length



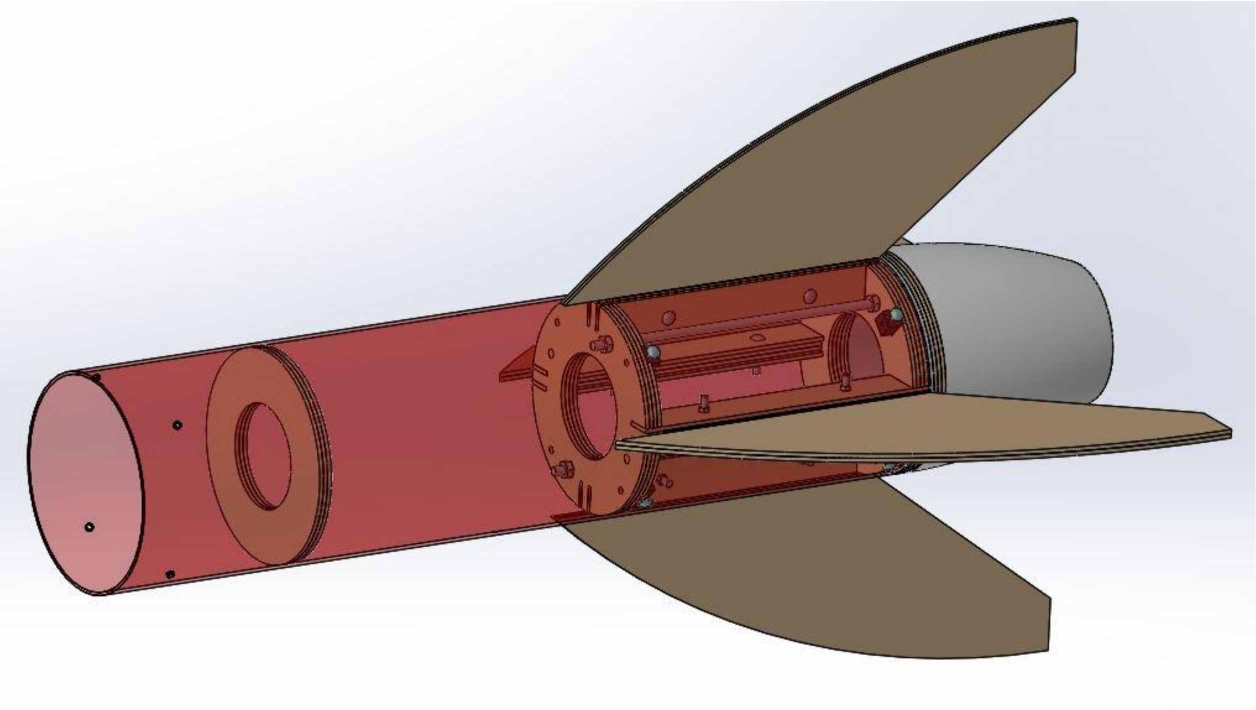
Payload Bay

- Between the avionics bay and the fin can
  - Shear pin connection to avionics bay
  - Bolted connection to the fin can
- Modular 2-bulkhead design functions similar to AV Bay.
  - Allows for payload electronics to be attached to a sled.
- 1 in. long, 4 in. airframe band



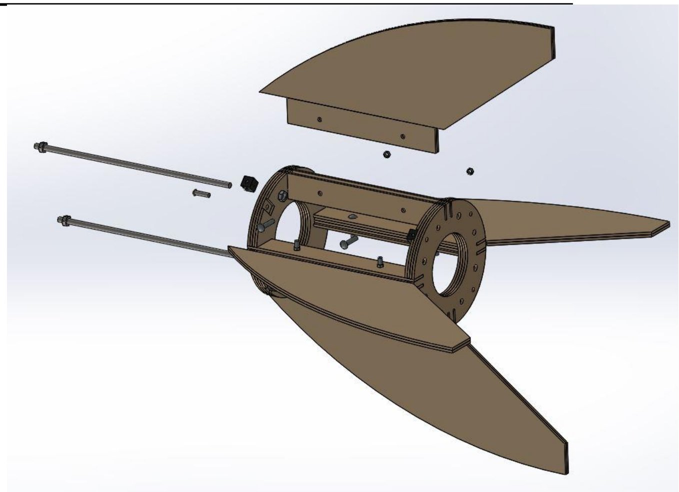
Fin Can

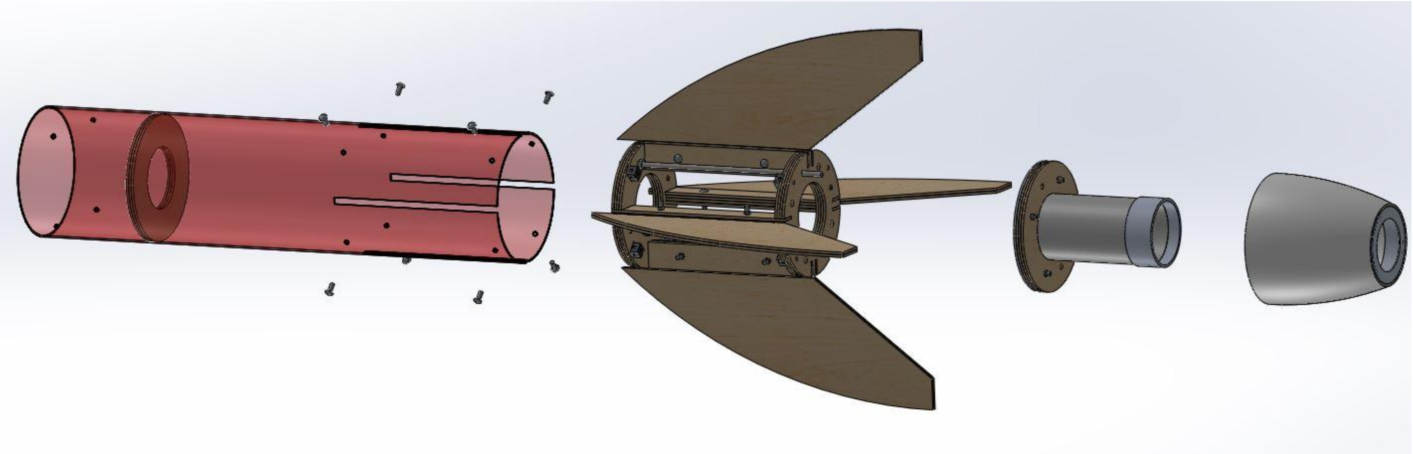
- Removable Fin System
  - Allows for easy repairs
- Overall length 31 in. including tailcone
- 6 in. Ogive tail cone used to reduce turbulent airflow



Removable Fin System

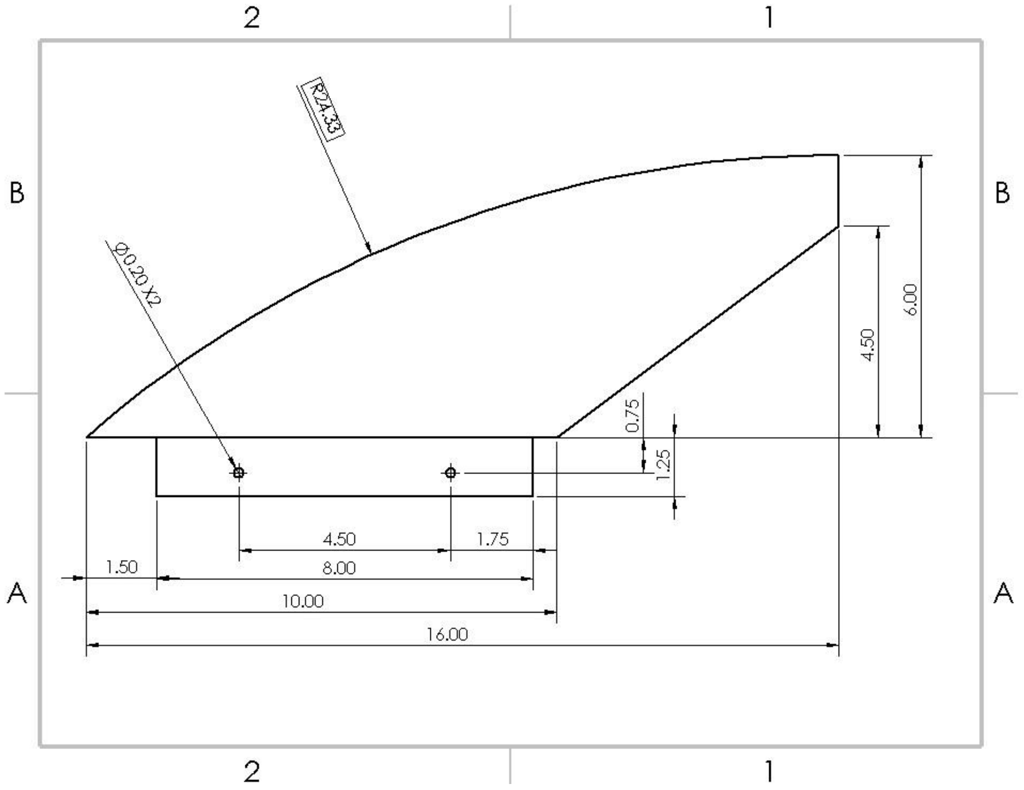
- Fins are bolted to runners that span the centering rings
- Threaded rods support assembly and attach the thrust plate
- Thrust plate ensures motor force is directly transferred to the airframe





Four Fin Configuration

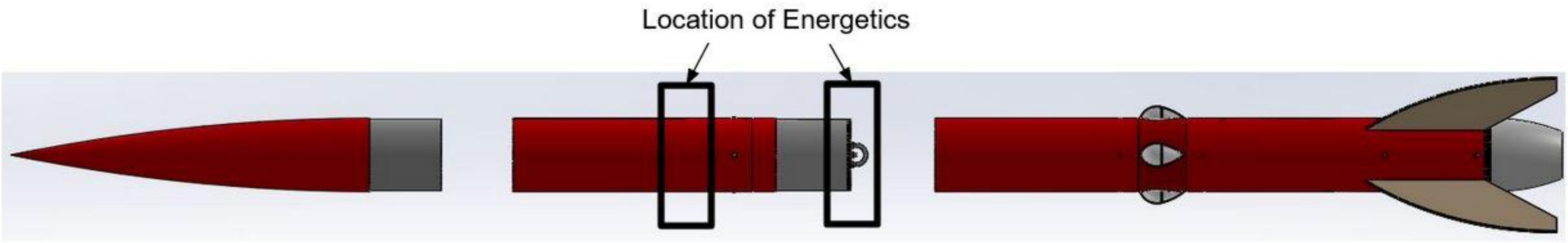
- Justification for Fin Configuration:
  - Symmetry for camera housings
  - Additional fin improves stability margin
- Leading-edge sweep reduces drag, pushes CP aftwards, and increases stability efficiency



Recovery Subsystem Leading Design

Recovery Locations

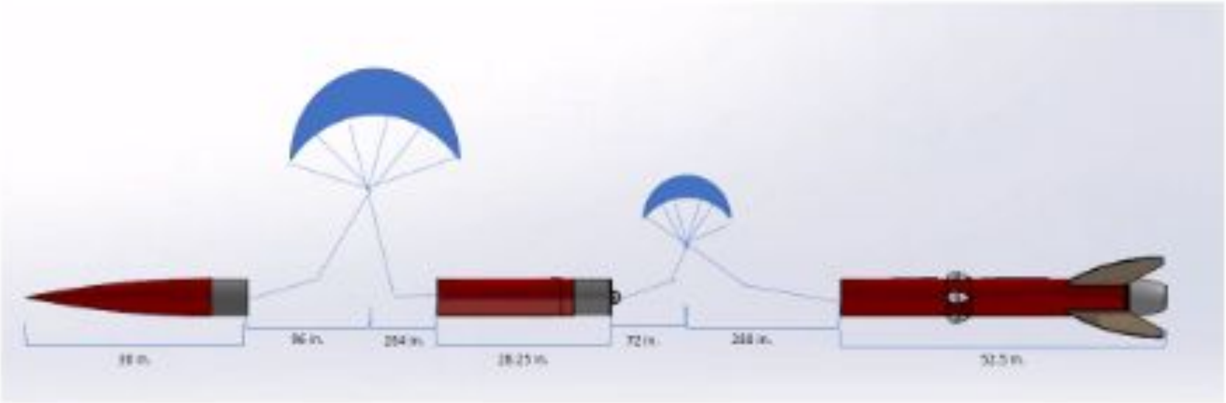
- Drogue Parachute is found in the drogue parachute bay
- Main Parachute is found in the Main parachute bay
- Avionics bay is where all recovery electronics are



Launch Vehicle Separation Points

Recovery Overview

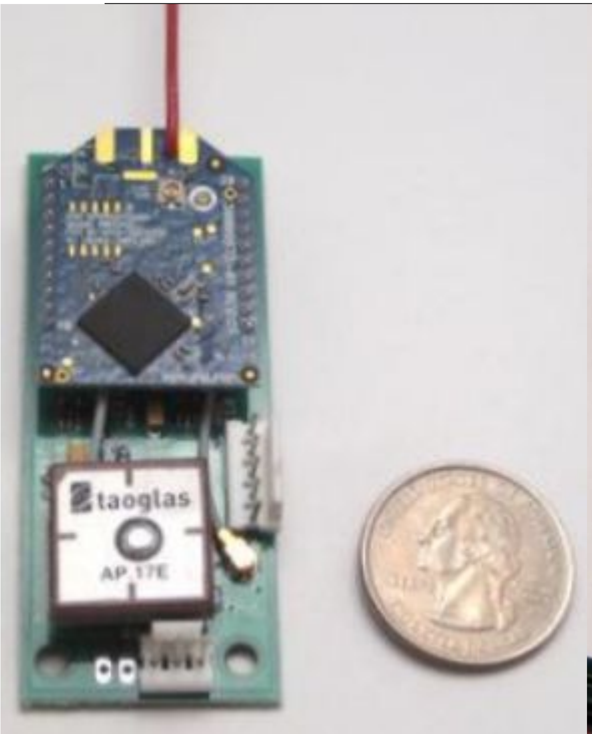
- Drogue deploys at Apogee
  - Secondary is approximately 1 sec after apogee
- Main deploys at 550 ft.
  - Secondary charge at 500 ft.
- Objective is the safe recovery of all parts of the launch vehicle and payload



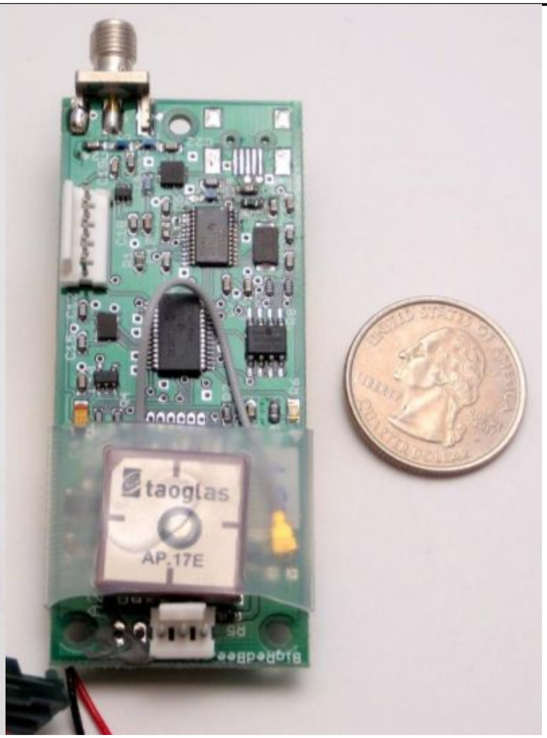
Altimeter Comparison

Altimeter	Deployment Variability	Altitude Recording Resolution	Dimensions	Data Recorded	Price	Owned by Club
RRC3	300 to 3000 ft 100 ft Increments	1 ft	3.92" x .925"	Altitude, Velocity, Temperature	$96.50	Yes
Entacore AIM	100 to 100,000 ft 1 ft increments	1 ft	2.75" x .984"	Altitude, Velocity, Temperature	$121.15	Yes
Stratologger CF	100 to 9999 ft 1 ft Increments	1 ft	2" x .84"	Altitude, Voltage, Temperature	$69.95	Yes
EasyMini	100 to 100,000 ft 100 ft increment on ascent 10 ft increment on descent	1 ft	1.5" x .8"	Altitude, Velocity, Acceleration, Temperature, Voltage	$96.93	No

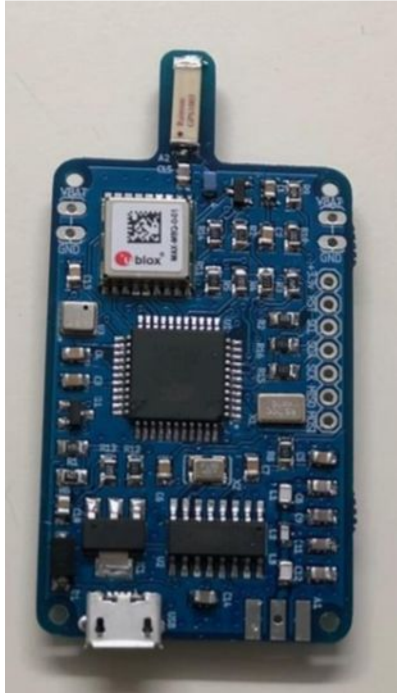
Tracker Alternatives



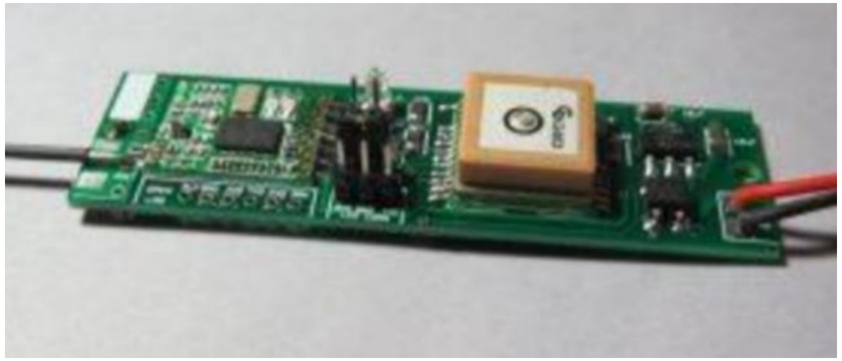
BigRedBee 900



BigRedBee Beeline



LightAPRS+W

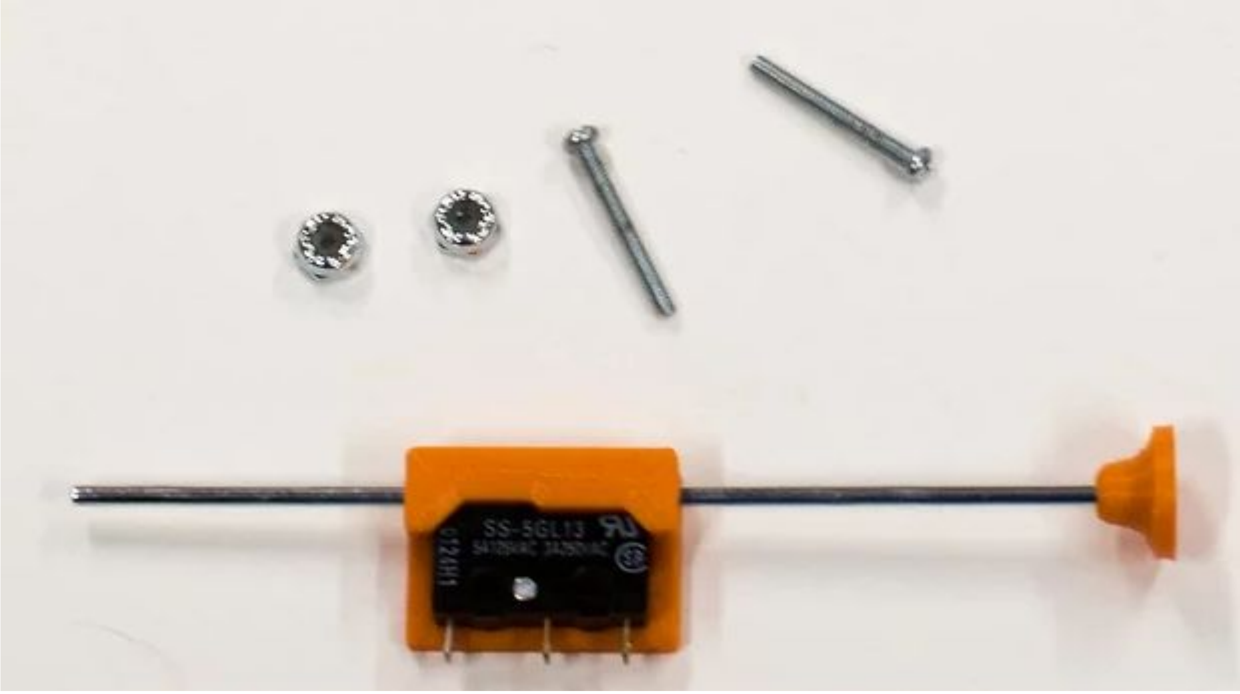


Eggfinder GPS

Altimeter Arming Switches

Pull-Pin Switches

Mechanical arming switches that can be locked in the "ON" position



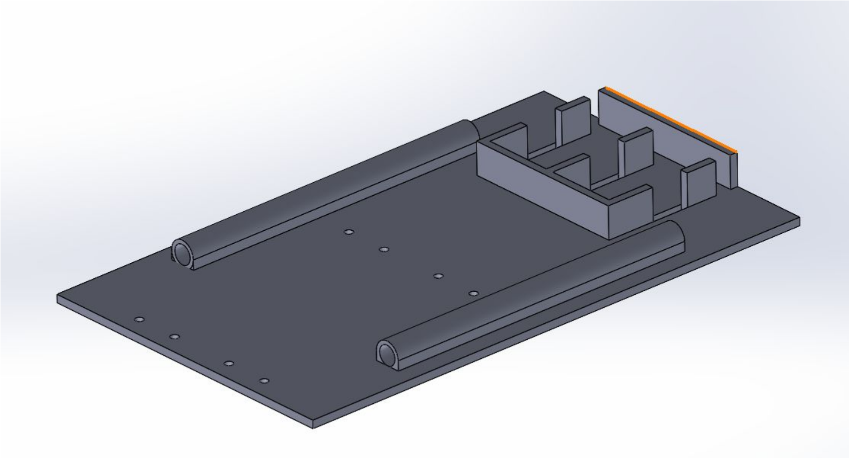
Drogue Parachute Alternatives

Parachute	Drag Coefficient	Descent Velocity	Descent time from Apogee to Main Deployment	Wind Drift (20 mph) From Apogee To Main Deployment	Does the Club Own It?
Fruity Chutes 12” Classic Elliptical	1.34	172.91 ft/s	22.84	670 ft	No
Fruity Chutes 15” Classic Elliptical	1.37	136.69 ft/s	28.89 seconds	847 ft	No
Fruity Chutes 18” Classic Elliptical	1.43	111.6 ft/s	35.39 seconds	1038 ft	Yes
Fruity Chutes 24” Classic Elliptical	1.47	82.43 ft/s	47.92 seconds	1406 ft	Yes
Fruity Chutes 24” Compact Elliptical	1.41	84.37 ft/s	46.81 seconds	1373 ft	Yes

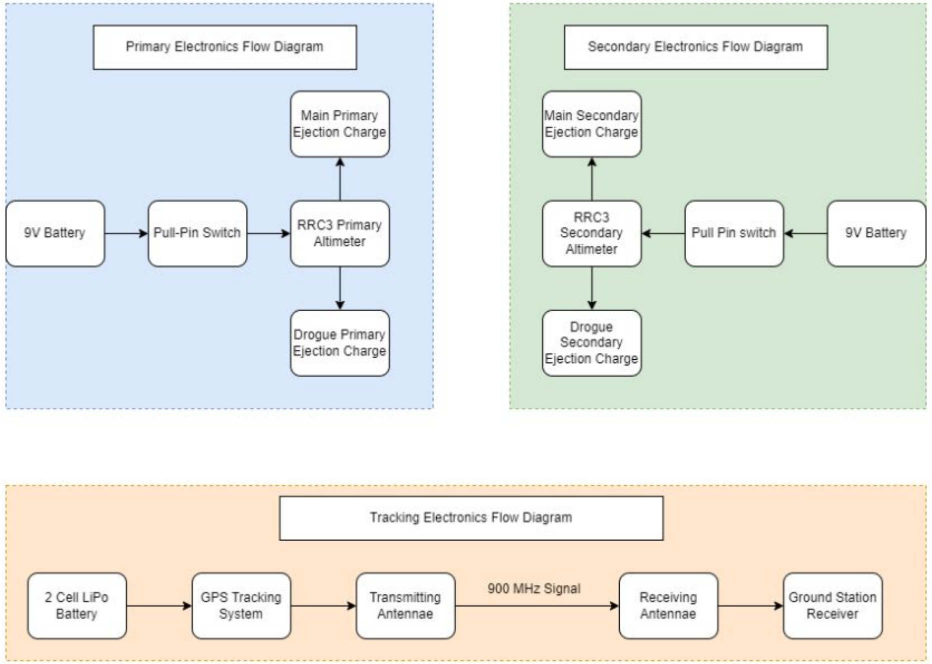
Main Parachute Alternatives

Parachute	Drag Coefficient	Landing Velocity	Impact Kinetic Energy	Descent time from Main Deployment	Wind Drift (20 mph) From Main Deployment	Does the Club Own It?
Fruity Chutes 72” Iris UltraCompact	2.033	23.38 ft/s	173.04 ft-lbf	23.51 seconds	690 ft	No
Fruity Chutes 84” Iris UltraCompact	2.134	19.56 ft/s	121.1 ft-lbf	28.11 seconds	825 ft	No
Fruity Chutes 84” Iris Ultra Standard	2.131	19.58 ft/s	121.27 ft-lbf	28.09 seconds	824 ft	Yes
Fruity Chutes 96” Iris UltraCompact	2.087	17.31 ft/s	94.8 ft-lbf	31.77 seconds	932 ft	No
Fruity Chutes 120” Iris UltraCompact	2.105	13.79 ft/s	60.16 ft-lbf	39.88 seconds	1170 ft	Yes
Fruity Chutes 144” Iris UltraCompact	2.118	11.46 ft/s	41.52 ft-lbf	48.01 seconds	1408 ft	No
Rocketman 120” Pro-X	.855	21.64 ft/s	148.19 ft-lbf	25.41 seconds	745 ft	Yes

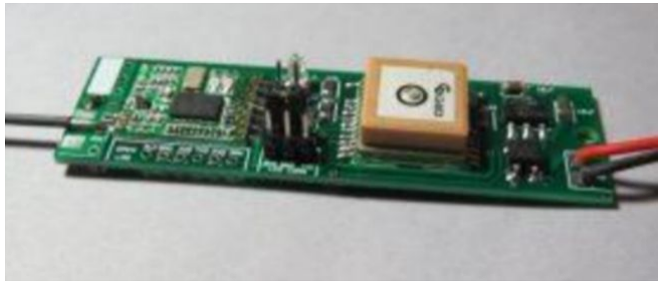
Leading Avionics Design



AV Sled Model

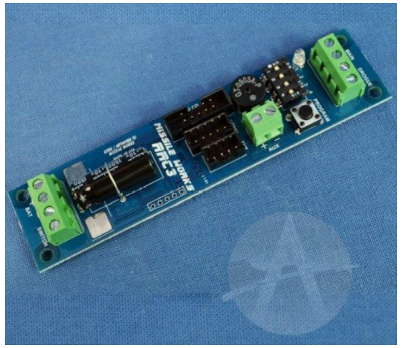


AV Bay Electronics Diagram



Eggfinder GPS

MissileWorks RRC3 "Sport" Altimeter



Leading Parachute Configuration

- Drogue
  - Fruity Chutes 18 in. Compact Elliptical
  - Nomex Sheet Protected
- Main
  - Fruity Chutes 120 in. Iris UltraCompact
  - Nomex Sheet Protected
  - Allows landing kinetic energy to be below 65 ft-lbf

Fruity Chute Iris UltraCompact

Wind Drift and Descent Time

Calculated based on constant wind down range.

Maximum Wind Drift

- 2208 ft

Descent Time

- 75.7

$$t = \frac{h_a - h_m}{v_d} + \frac{h_m}{v_m}$$

Wind Velocity	Drift Distance
0 mph	0
5 mph	552
10 mph	1104
15 mph	1656
20 mph	2208

Kinetic Energy

Section	Mass of Section	Descent Velocity Necessary to be Awarded Points	Descent Velocity Necessary to be Awarded Bonus Points
Nose Cone	.207 slugs	26.92 ft/s	25.06 ft/s
Main Parachute Bay and Avionics Bay	.220 slugs	26.11 ft/s	24.31 ft/s
Drogue Parachute Bay, Payload Bay, and Fin Can	.632 slugs	15.4 ft/s	14.34 ft/s

Section	Mass of Section	Velocity Under Main Parachute	Impact Energy
Nose Cone	.207 slugs	6.11 ft/s	4.247 ft-lbf
Main Parachute Bay And Avionics Bay	.220 slugs	9.16 ft/s	9.230 ft-lbf
Drogue Parachute Bay, Payload Bay, and Fin Can	.6332 slugs	13.79 ft/s	60.206 ft-lbf

Opening Shock

Shock force generated from opening the main parachute: 316.63 ft-lbf

Kevlar Rated at: 6600 ft-lbf

Factor of Safety: 20.8

Section	Mass of Section	Opening Shock
Nose Cone	.207 slugs	56.488 ft-lbf
Main Parachute Bay And Avionics Bay	.220 slugs	60.036 ft-lbf
Drogue Parachute Bay, Payload Bay, and Fin Can	.6332 slugs	172.741 ft-lbf
Total	1.161 slugs	316.633 ft-lbf

Main Deployment Opening Shock

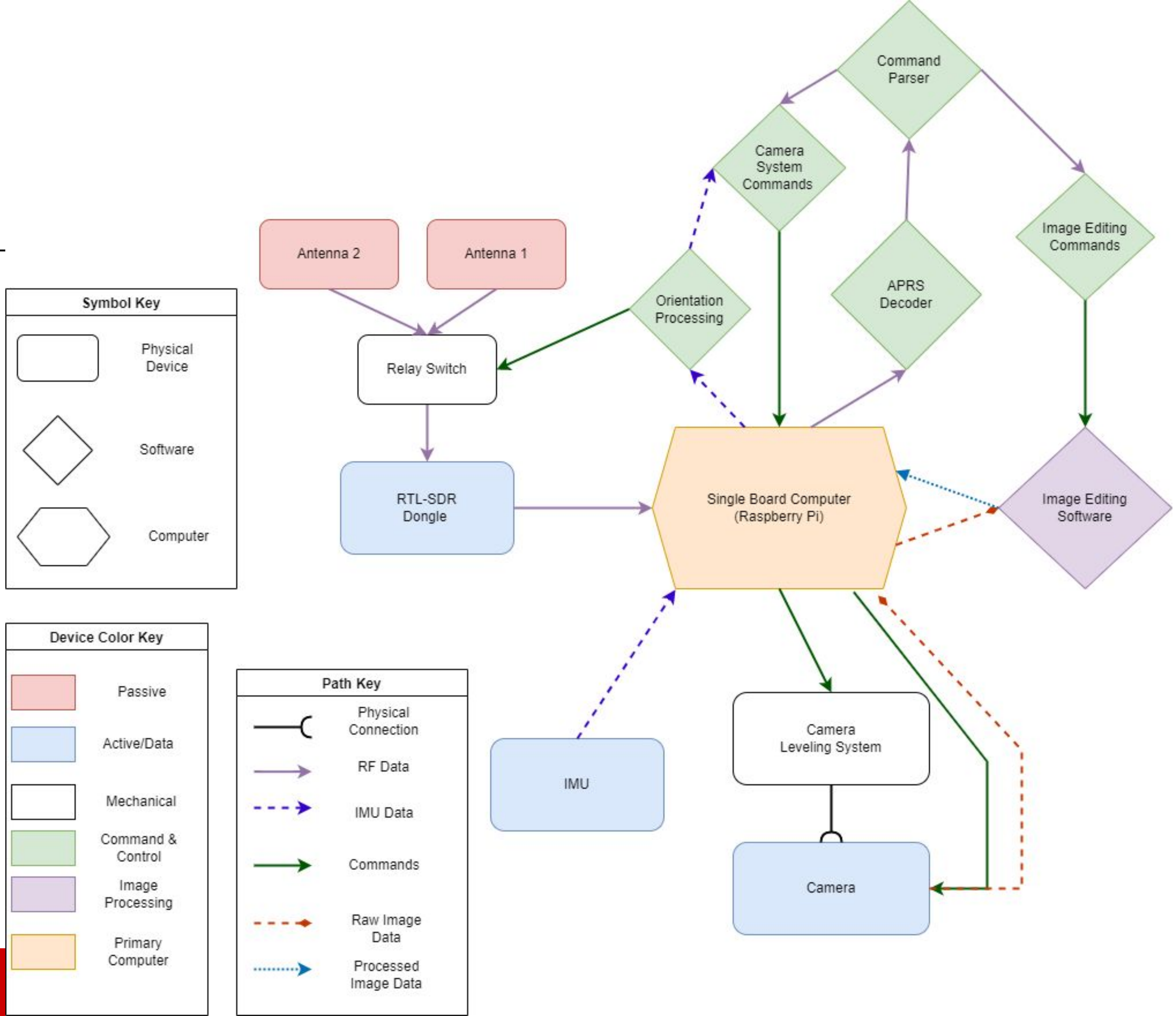
Leading Payload Design

System Overview
RAFCO subsystem
Camera subsystem

Payload Objective and Requirements

- Camera capable of rotating 360° around axis normal to the ground, with a clear view of the launch field
- On-board image editing including timestamping, filters, and color removal
- Receive RF commands transmitted over APRS (Automatic Packet Reporting System) on the 2-meter radio band, between 144.90 MHz and 145.10 MHz
- System performs commands within 30 sec

Payload System Overview



Payload System Components

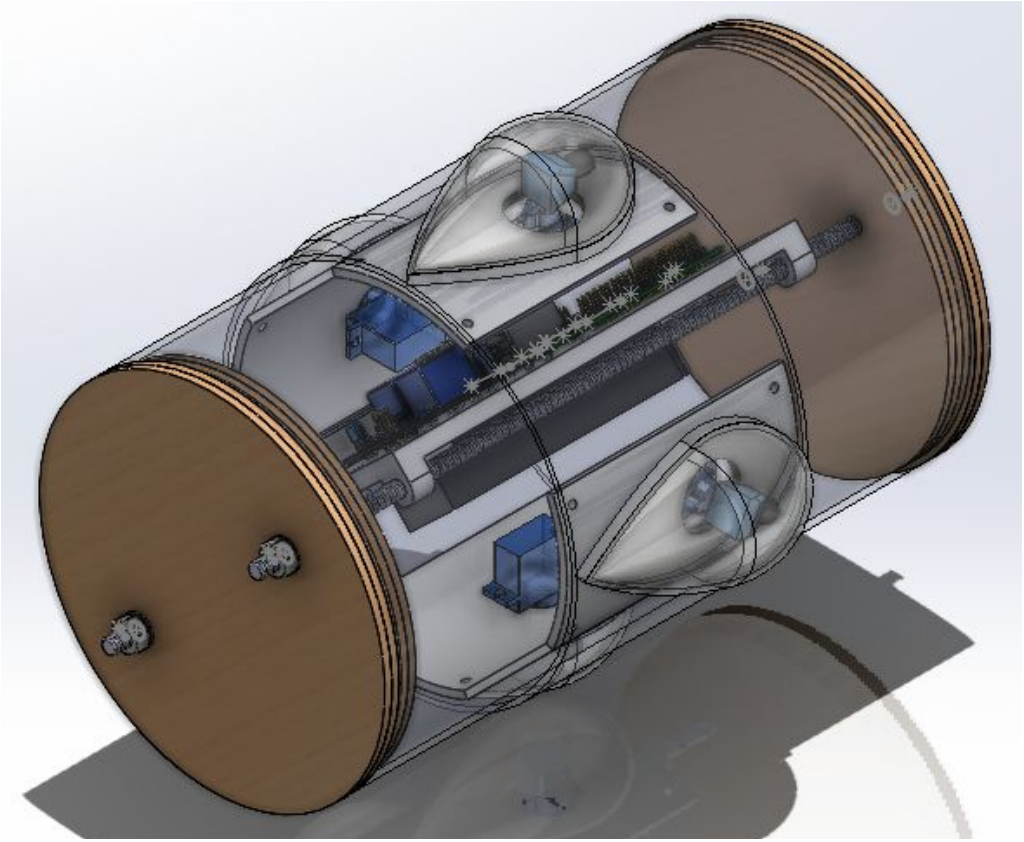
- Two major subsystems:
  - RAFCO (radio frequency commands) system
  - Camera system
- Each of these subsystems consists of electronic hardware and software designed to support their final purpose
- These subsystems both interface with or exist as software on a Raspberry Pi, the main payload computer

Payload System Design Philosophy

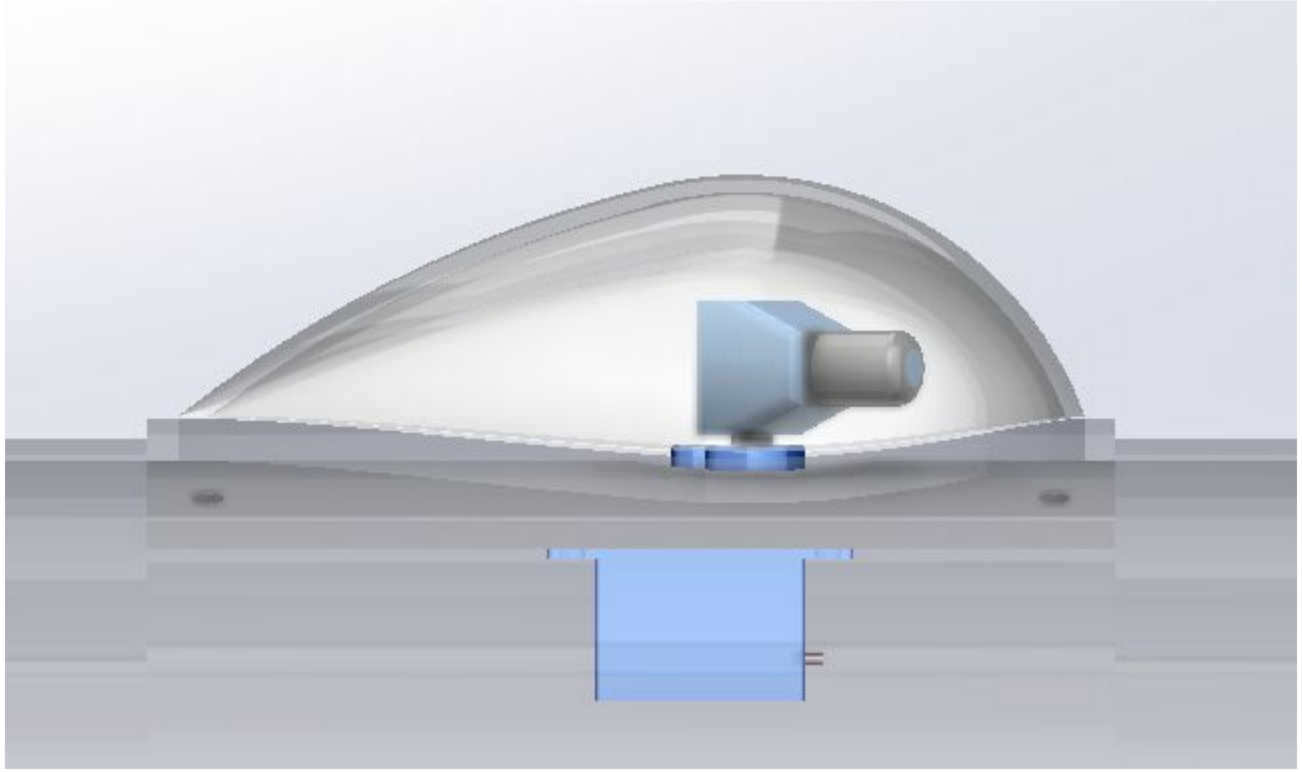
- The primary design philosophy behind this payload design is to accomplish the design challenge with the least amount of complications possible

- This emphasizes reliability, ease of construction, and simplicity of operation

Camera Subsystem Overview



The payload bay with camera components.



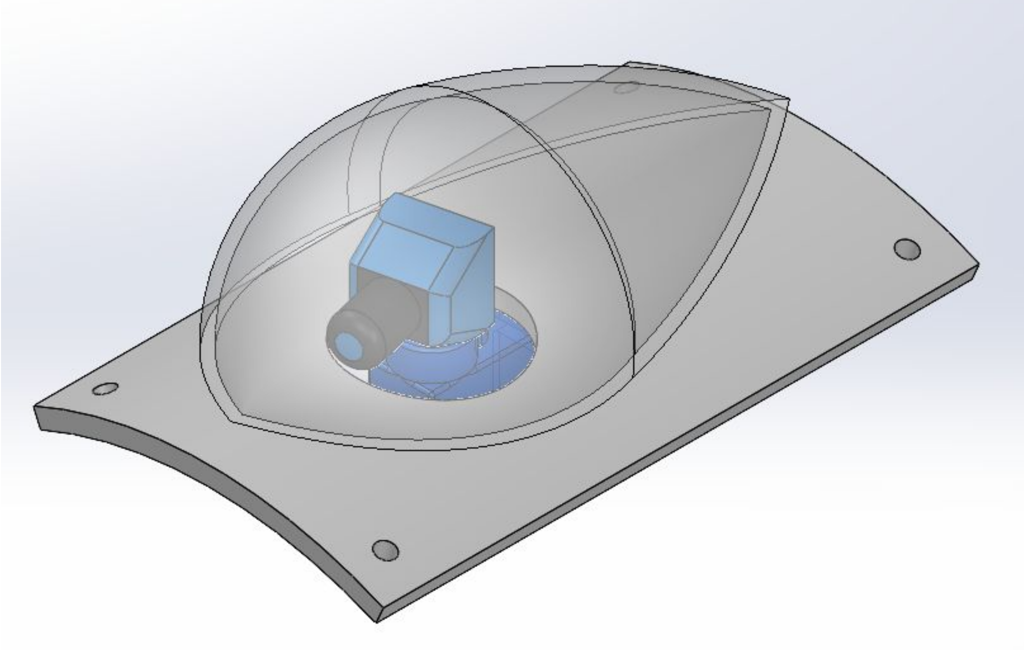
A close-up of the camera system.

Camera Subsystem Overview

- Each assembly consists of four parts:
  - Pi-compatible camera
  - Protruding camera housing
  - Servo
  - Camera mount
- Multi-camera adapter integrates the four assemblies

Camera Assembly

- Camera = Arducam IMX-219
- Servo = Feetech FS90R
- Mount = PLA plastic, custom
- Housing = Custom printed/formed



Arducam

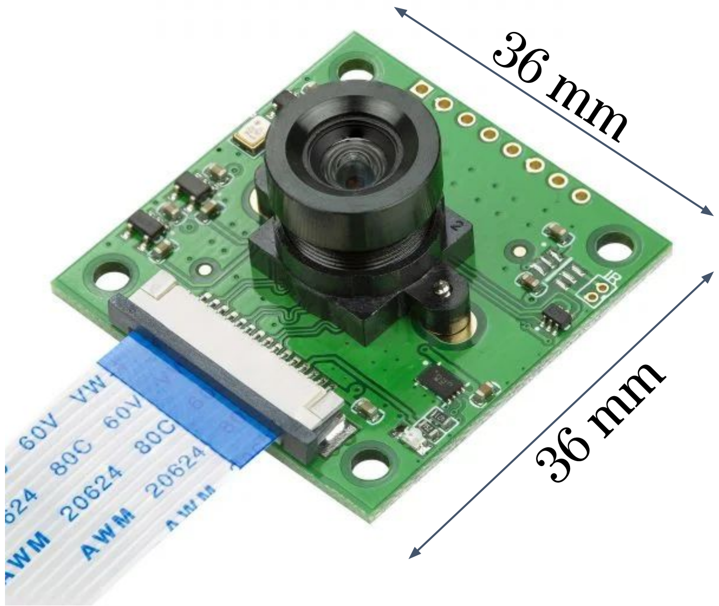


Fig. 1: The Arducam IMX-219 camera module.

- FOV up to 180°
- 36x36mm
- Compatible with multi-camera adapter

Multi-Camera Adapter Board

- Pi relay board for up to four cameras
- CSI I/O
- Camera choice made based on IMU data
- Challenges:
  - Pin headers
  - CSI fragility

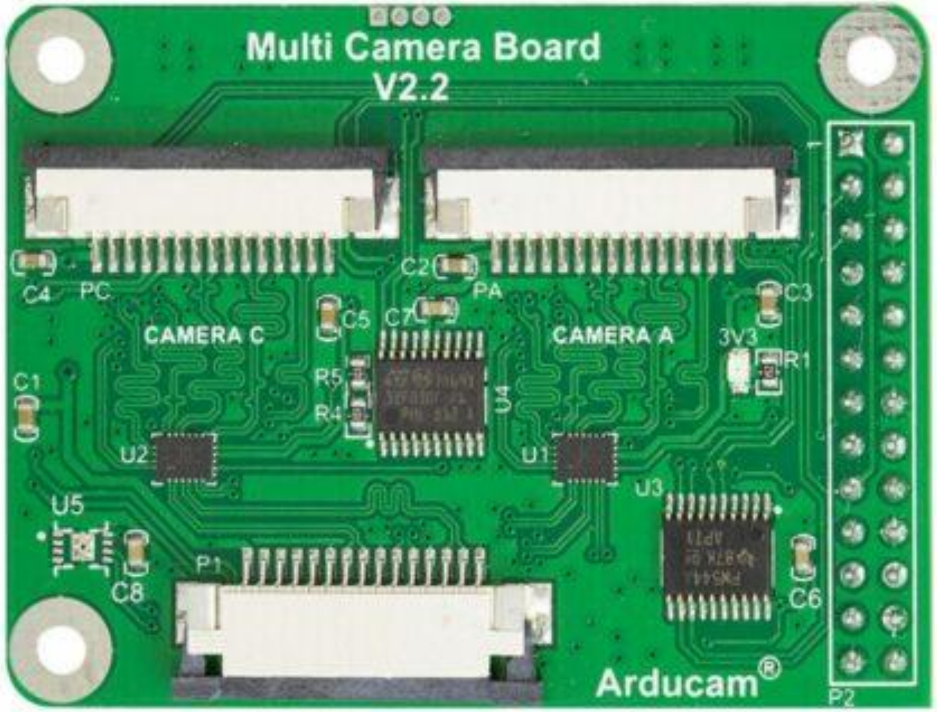
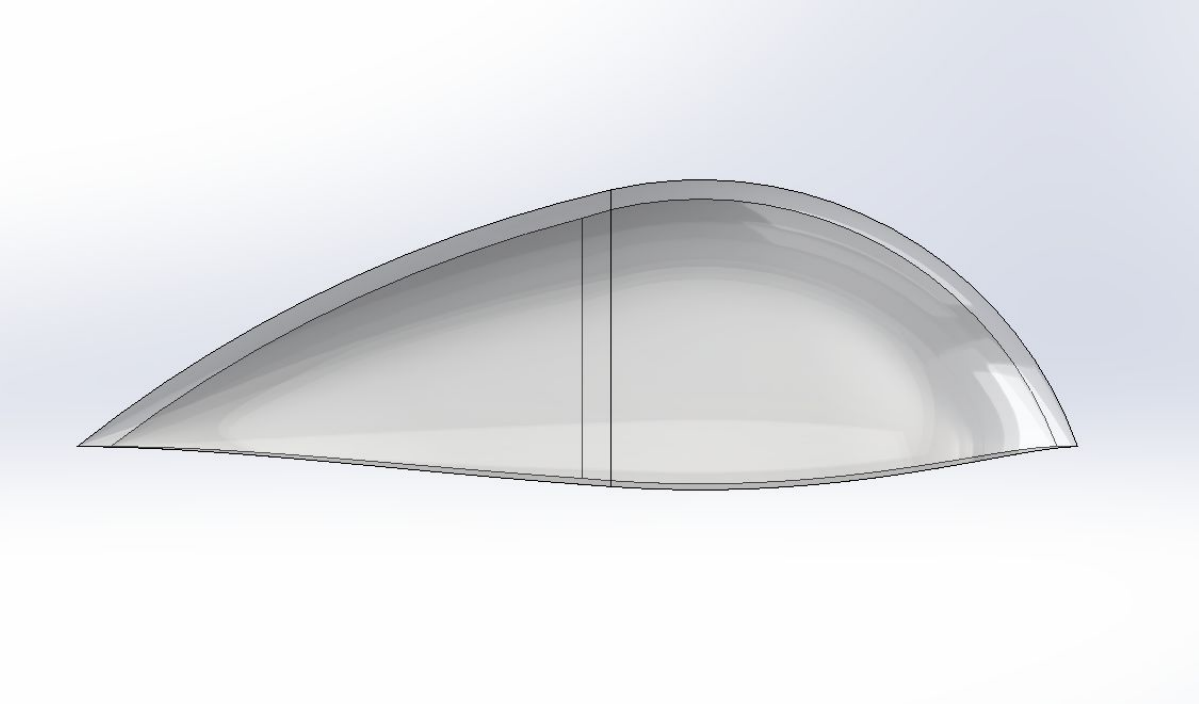


Fig. 1: The Arducam Multi Cam Adapter Board.

Transparent Camera Housing



- Housings protect from air and debris
- Teardrop vs. Dome
- Vacuum-forming vs. SLA

RAFCO Subsystem Overview

- Consists of four parts:
  - 2-meter band antenna
  - RTL-SDR dongle
  - APRS decoder and command parser software
  - Inertial Measurement Unit (IMU)
    - Used to determine orientation

2-Meter Band Antenna

- Antenna designed to receive frequencies in the 2-meter band (~144 MHz) is needed
- A variety of option are available, only a few types and sizes are viable for the intended use case
- Selection was narrowed down to ¼-wave whip antenna and ½-wave dipole antenna
- As the names suggest, these antenna types are, respectively, a quarter and half the wavelength of the selected band

Antenna Comparison

¼-Wave Whip

- ~20 in.
- Off the shelf
- Requires a large external ground plane
- Omnidirectional (except along axis)
- Must be mounted vertically (normal to ground plane)
- May bend slightly depending on formfactor

½-Wave Dipole

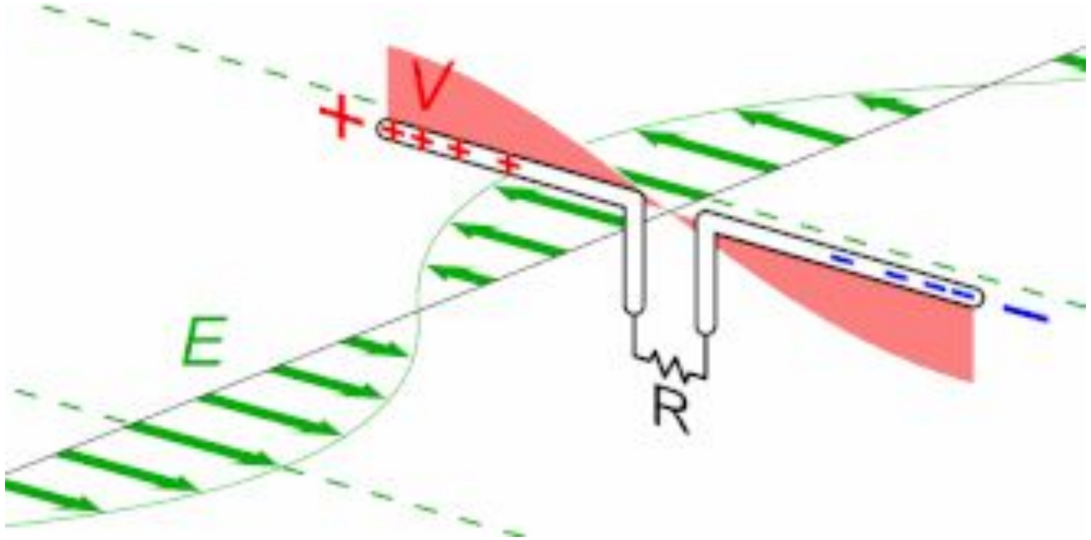
- ~40 in.
- Easily constructible
- Requires no external grounding
- Omnidirectional (except along axis)
- Can be mounted horizontally
- Can be slightly curved

Antenna Mounting

- Internal
  - Mount the antenna inside the payload bay
    - Only requires a single antenna
    - Antennas are too long for this to be feasible
    - Material attenuation and interference from other payload electronics
- Along Launch Vehicle
  - Mount the antenna along the outside of the launch vehicle
    - Requires at least two antennas so one is always clear of the ground
    - Results in some additional aerodynamic drag
    - Potential damage to antennas during landing
- Inside Fins
  - Mount antenna inside fins
    - Requires at least two antennas
    - Fins would have to be very long to fit the majority of the antenna
    - Material attenuation

Antenna Selection

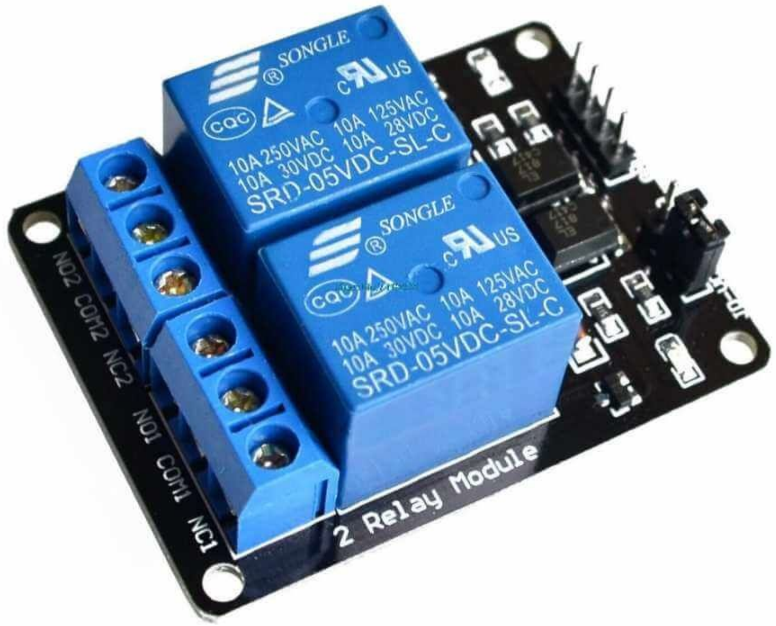
- Two ½-wave dipoles 180° apart
- Located on the outside of the fin can + payload bay
- lack of a need for vertical mounting and large ground plane



Dipole Antenna Operational Diagram

Antenna Selection (Cont.)

- Antennas cannot be connected in parallel
- Two-channel relay is used to switch which antenna is in use
- Decision is made based on IMU data

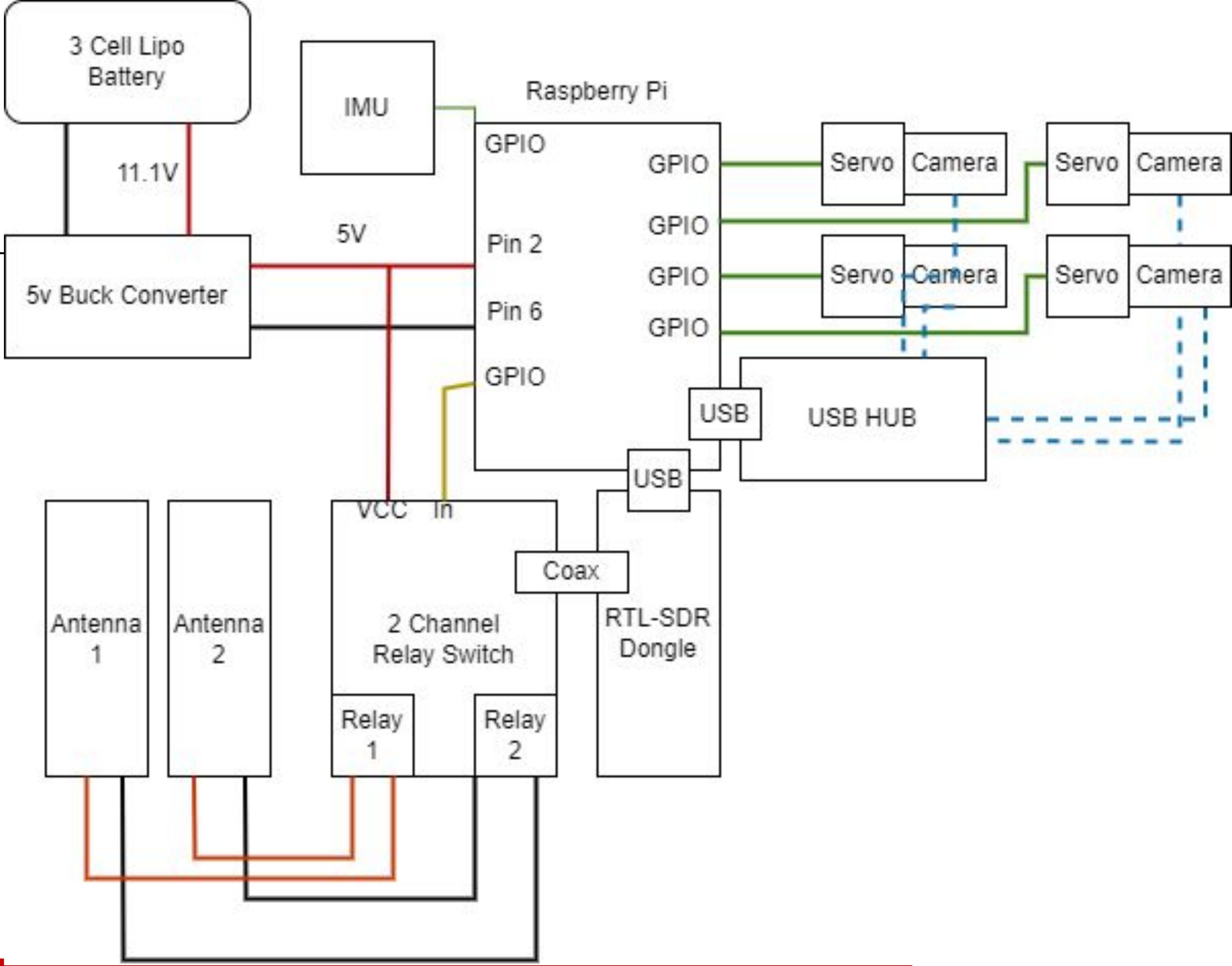


Two-Channel Relay

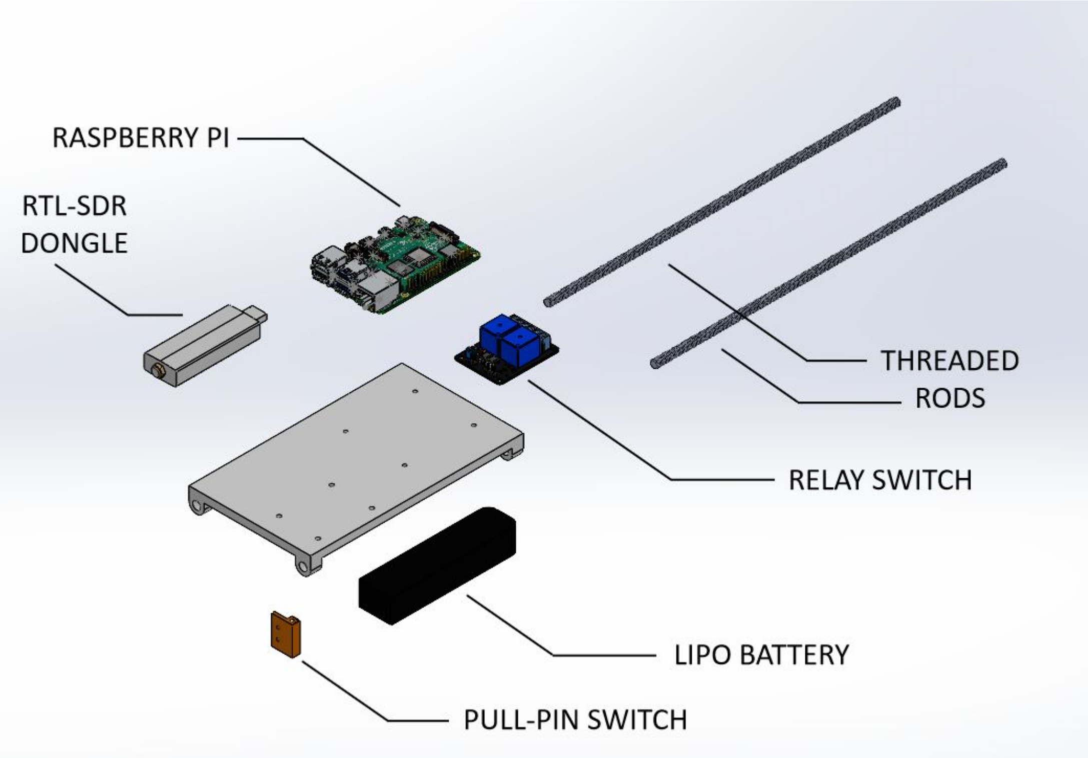
RTL-SDR Dongle

- This design will utilize a Nooelec NESDR SMArt v4 SDR
- The RTL-SDR dongle serves as the interface between the antenna(s) and the Raspberry Pi
- Converts analog signals to digital using a Realtek RTL2832U & R820T2

Payload System Block Diagram



Electronics Integration



- Rectangular Sled will be held in place by 2 threaded rods.
- Sled will be angles so that it doesn't interfere with the camera housings
- Activated using Pull-Pin Switch
- Antenna attaches to RTL-SDR Dongle
- Pi decodes and parses commands

Mission Performance Predictions

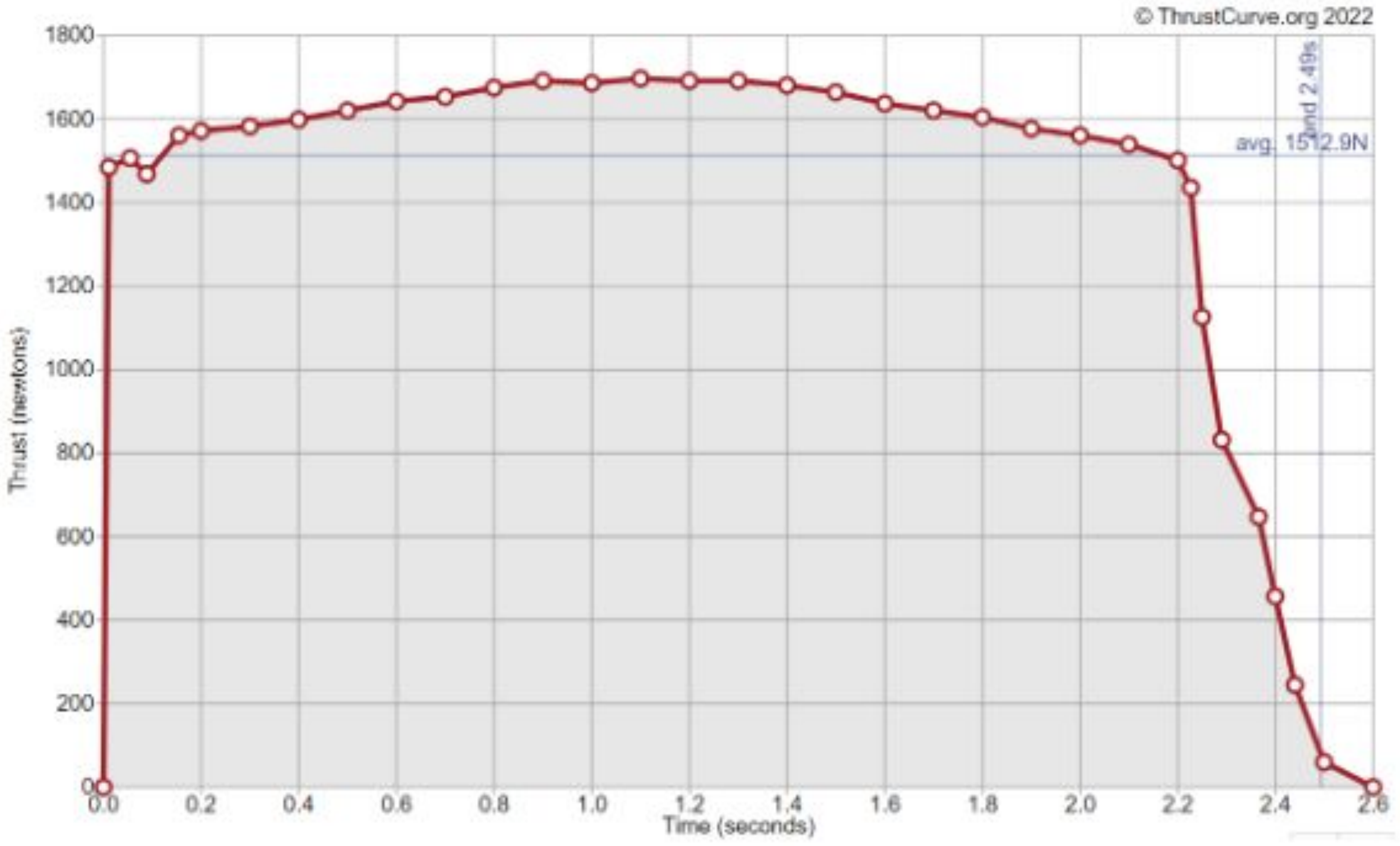
Motor Alternatives

Motor	Total Impulse (N-s)	Initial Thrust (N)	Maximum Thrust (N)	Average Thrust (N)	Burn Time (s)	Length (mm)
L1390G	3949.0	1416.5	1675.0	1390	2.6	530
L1420R	4603.0	1458.3	1814.0	1490	3.2	665
L1520T	3715.9	1545.4	1765.3	1520	2.4	518

- Motors fit RMS-75/3840 motor casing

Motor Selection

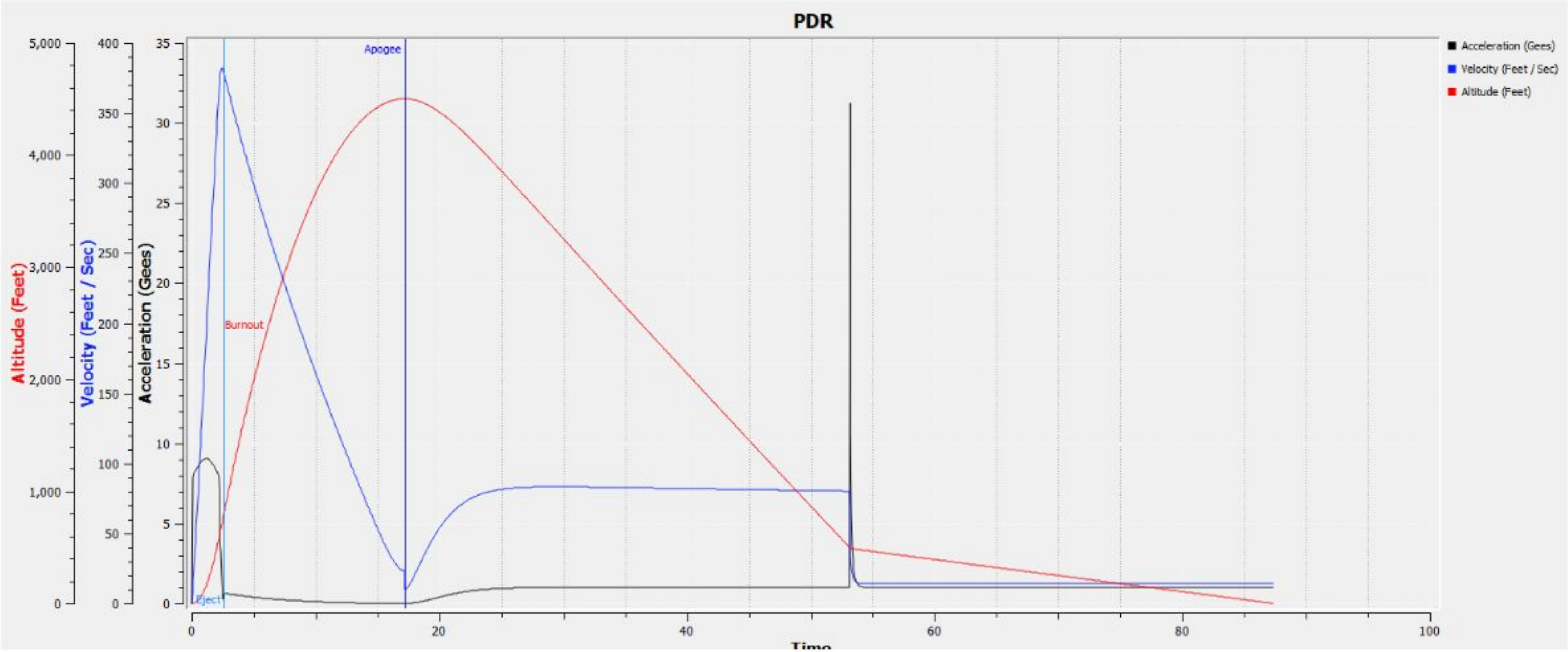
- Aerotech L1520T
- RMS 75/3840 Casing



Performance

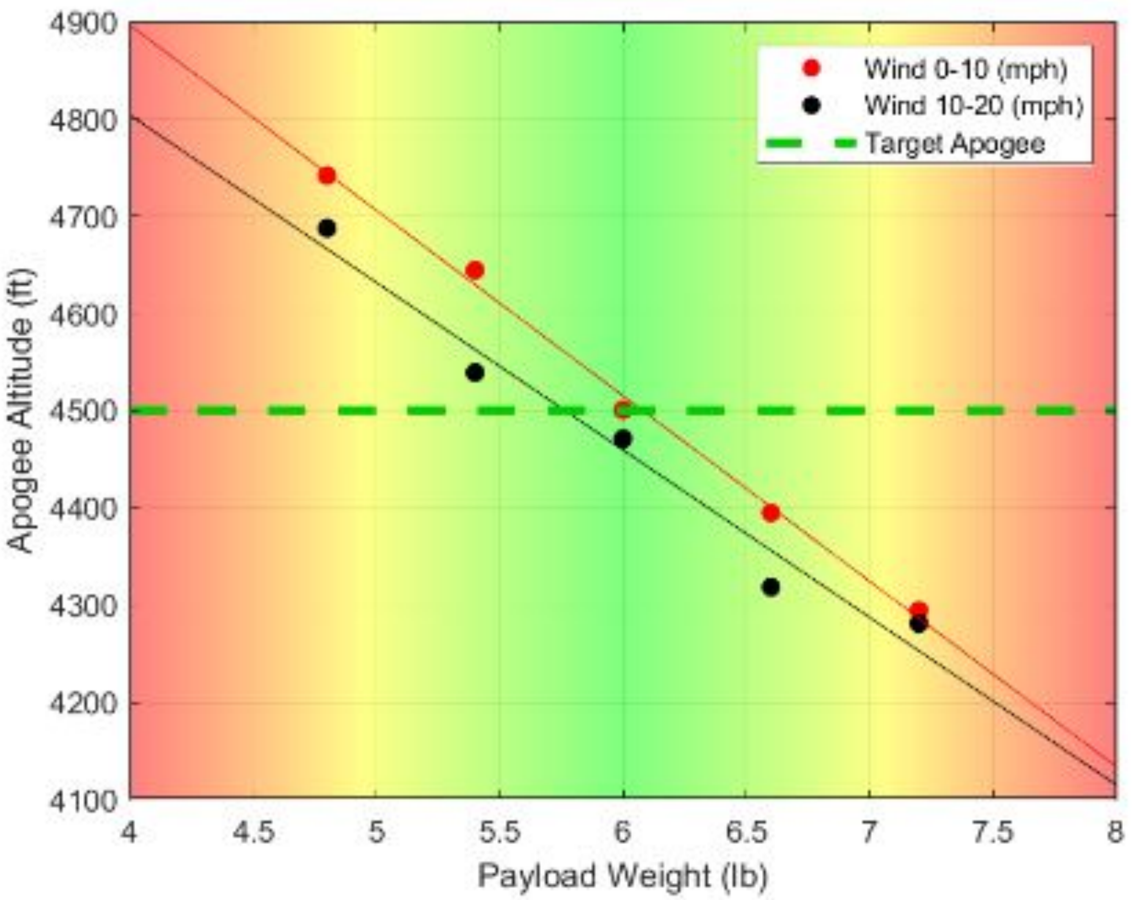
- Target Apogee: 4,500 ft.
- Based on
  - Rocksim model with
    - 5-15 mph winds
    - 5° cant
    - 144 in. launch rail
  - Hand Calculations (4,455 ft)
- Thrust to Weight Ratio: 8.03
- Rail Exit Velocity: 74.6 ft/s

Predicted Altitude, Velocity, and Acceleration



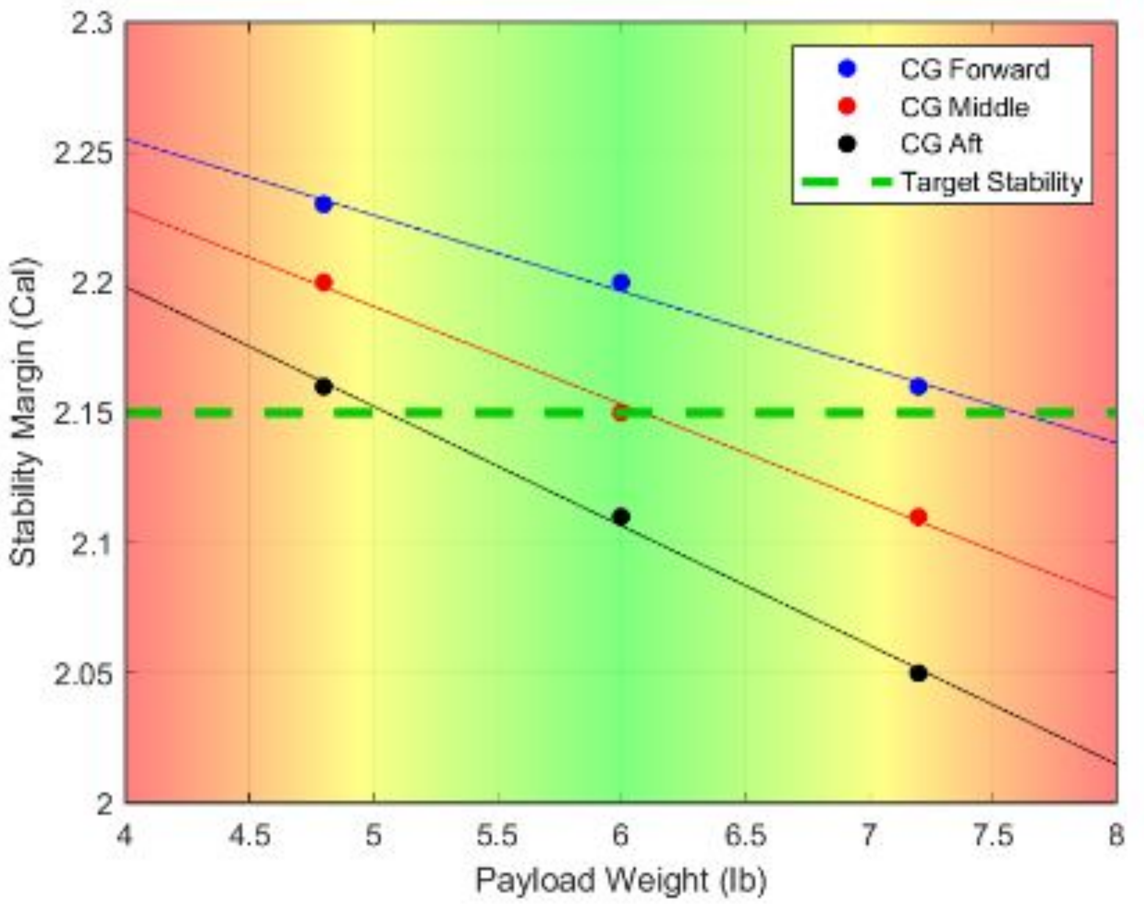
Payload Weight Apogee Study

- Payload weight will affect apogee
- Weights between 5 lb. and 7 lb. acceptable
    - Ideal payload weight is 6 lb.
- Frames payload weight changes as it relates to apogee



Payload Stability Margin Study

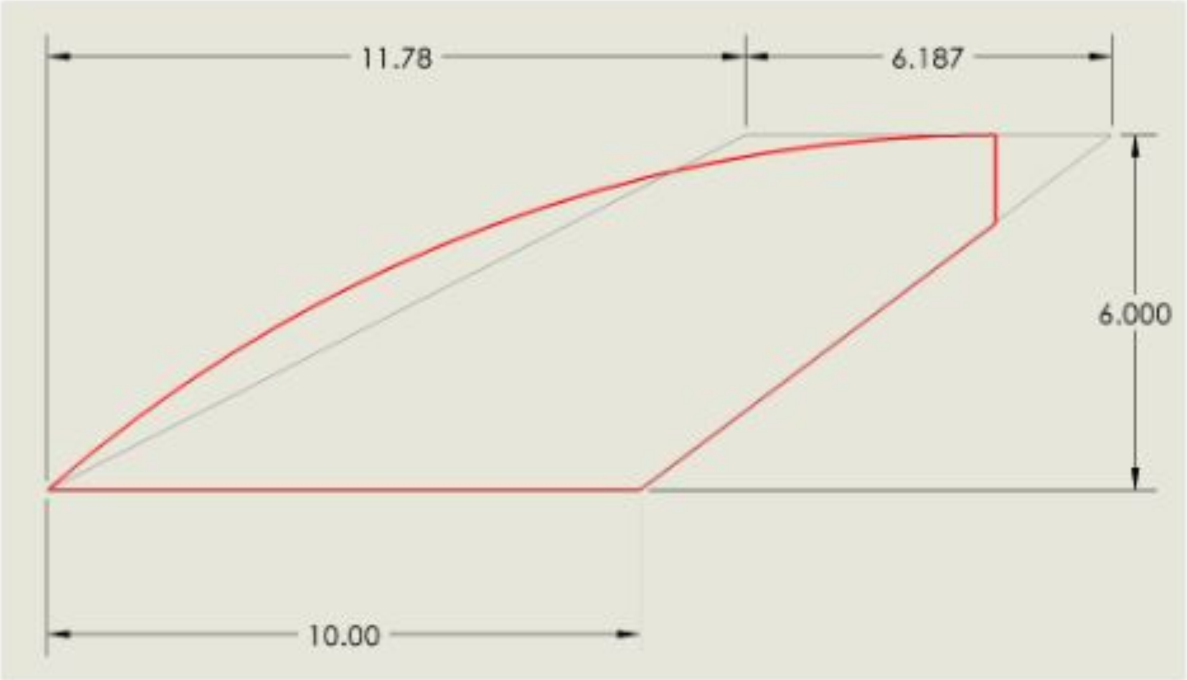
- Aft located payload greatly affects stability
- Changes in both overall payload weight and the location of weight within the payload affect stability.



Fin Stability Study

- Stability margin was calculated via RockSim and by hand calculations.
- Hand calculations assumed trapezoidal fin area.

Method	Result	Comparison
RockSim	2.15 calibers	$\%_{diff} = 21.58\%$
Barrowman's Method	2.67 calibers	



Requirements Compliance

Requirements Compliance Plan

- Each requirement has its own needs
- Requirements verified by analysis done by CDR
- Test plans supplied with CDR, verified by FRR
- Inspection/Demonstration requirements verified by FRR
- Most require full scale to be built and/or launched

Team Derived Requirements

- Developed for Vehicle, Payload, Recovery and Safety
- Designed to increase chance for success of the launch vehicle and payload and the increased safety of the project
- EX
- PD 3: The antenna SHALL face upwards upon landing regardless of landing orientation.
- LVE 2: The launch vehicle SHALL be water-resistant.

Risk Assessment Matrix

- Supplementary hazard analysis
- Difference in failure modes before/after mitigation
- 65 failure modes pre-mitigation: 50.39%
- 19 failure modes post-mitigation: 14.73%

Risk Assessment Before Mitigation

		Level of Severity			
		1 Low Risk	2 Medium Risk	3 High Risk	4 Severe Risk
Likelihood of Occurrence	A Very Unlikely	0.08%	1.55%	5.43%	5.43%
	B Unlikely	3.88%	6.98%	7.75%	3.10%
	C Likely	5.43%	6.20%	6.98%	5.43%
	D Very Likely	6.20%	17.83%	15.50%	1.55%

Risk Assessment After Mitigation

		Level of Severity			
		1 Low Risk	2 Medium Risk	3 High Risk	4 Severe Risk
Likelihood of Occurrence	A Very Unlikely	8.53%	14.73%	7.75%	6.20%
	B Unlikely	8.53%	10.08%	8.53%	4.65%
	C Likely	7.75%	10.85%	6.98%	1.55%
	D Very Likely	1.55%	2.33%	0.00%	0.00%

Questions?