Preliminary Design Review

November 9th, 2023

Presentation Overview

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

Our Team

Hanna
Team Lead

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Structures

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Aerodynamics

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Safety Officer

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Payload Electronics

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Payload Software

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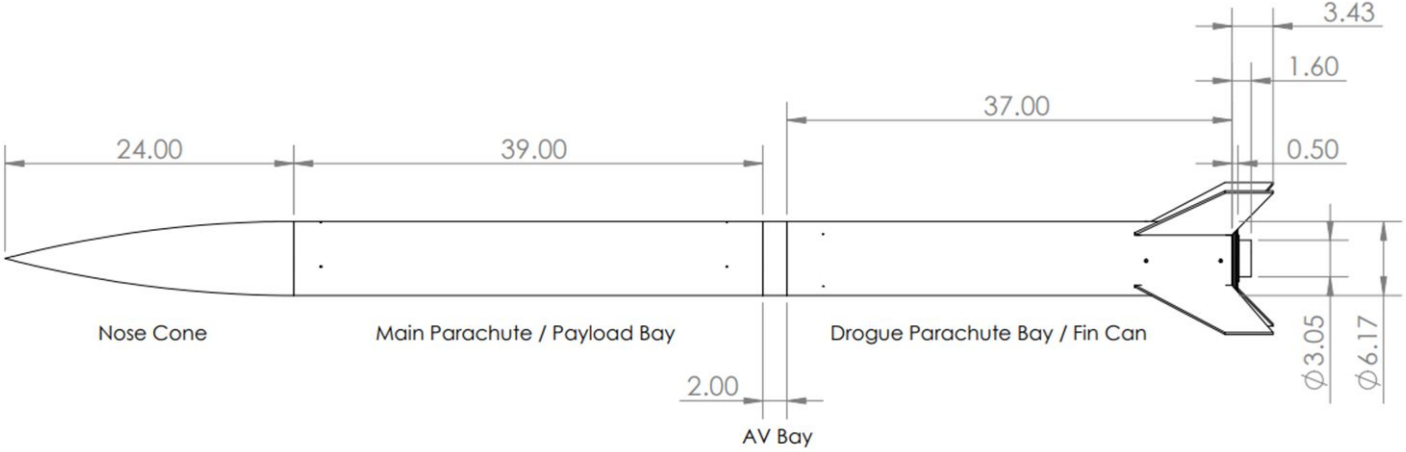
Integration

Launch Vehicle Leading Design

Launch Vehicle Dimensions

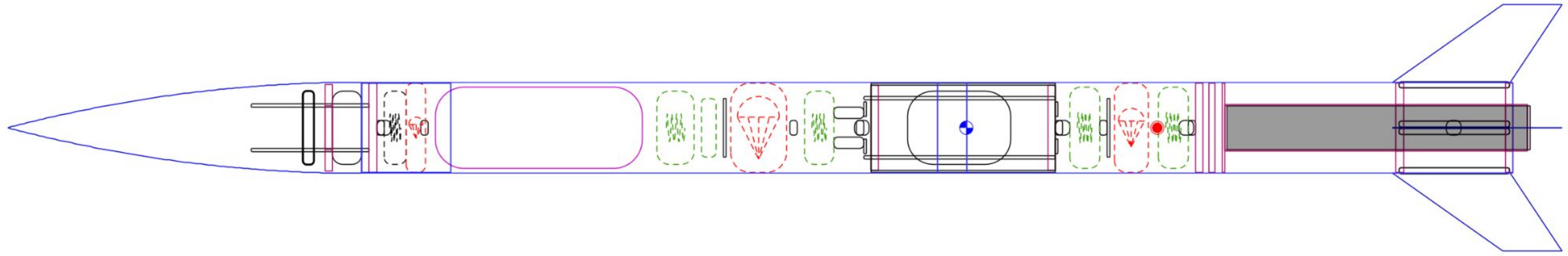


Launch Vehicle Stability

Software	Stability Margin
OpenRocket	2.10 Calibers
RocketPy	2.04 Calibers
RasAero II	2.22 Calibers
Barrowman Method	2.07 Calibers

Rocket
Length 105 in, max. diameter 6.17 in
Mass with no motors 34.6 lb
Mass with motors 42.6 lb

Stability: 2.1 cal
CG: 64.966 in
CP: 77.913 in
at M=0.52



Airframe Material

- G12 Fiberglass (Chosen Material)
  - Spirally wound fiberglass roving and epoxy
  - Widely used in high-powered rocketry
  - Extremely resistant to abrasion, cracking, shattering, etc.
  - Water resistant
  - ~1.05 oz/in^3
  - ~$45/ft.
- Blue Tube
  - Spirally wound vulcanized fiber
  - Widely used in high-powered rocketry
  - Extremely resistant to abrasion, cracking, shattering, etc.
  - <u>Not water resistant</u>
  - ~0.751 oz/in^3
  - ~$20/ft.

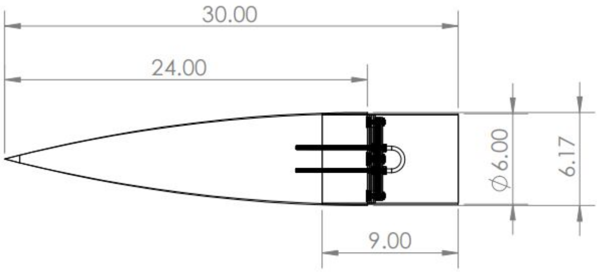
Nose Cone

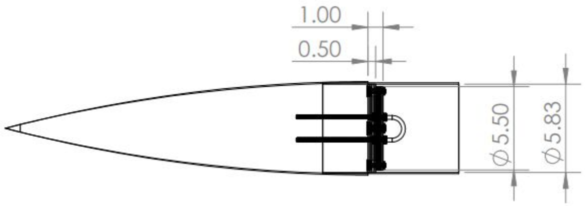
Location:

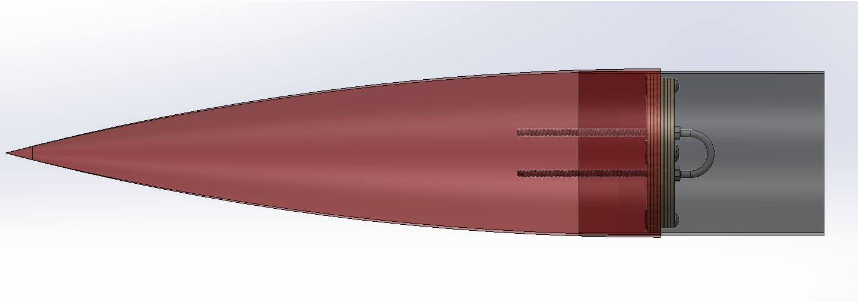
- Above the Main Parachute/Payload Bay

Contains:

- Permanent nose cone ring, removable nose cone bulkhead, payload/recovery electronics, latch

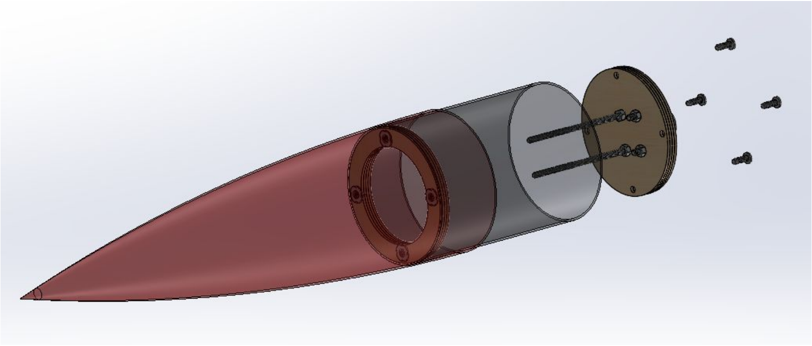


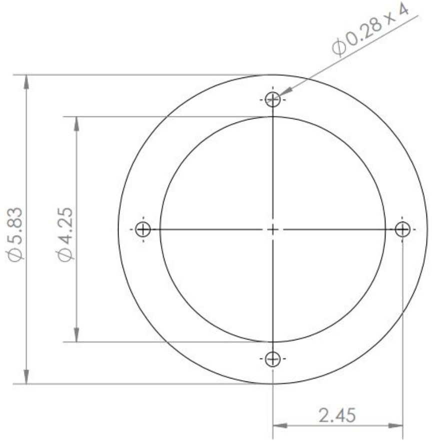




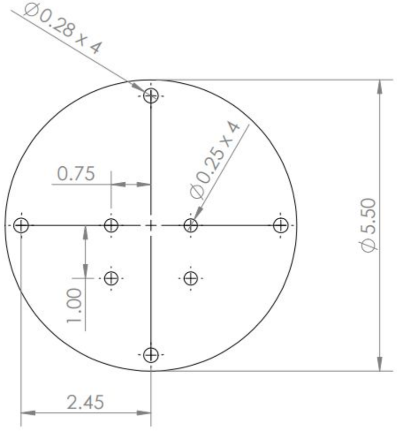
Removable Nose Cone Bulkhead

Allows for electronics for the payload/recovery system to be stored in the nose cone





Nose Cone Permanent Ring (0.5 in. thick)



Removable Nose Cone Bulkhead (0.5 in. thick)

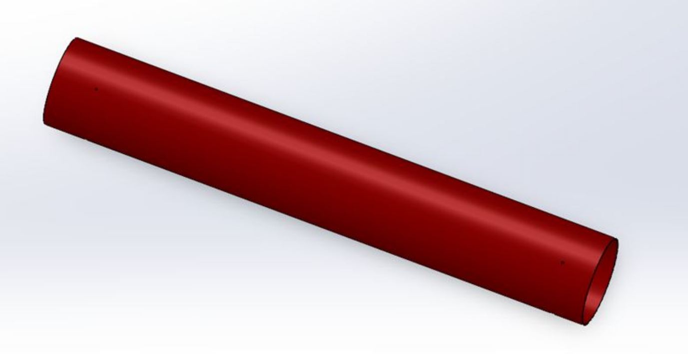
Main Parachute/Payload Bay

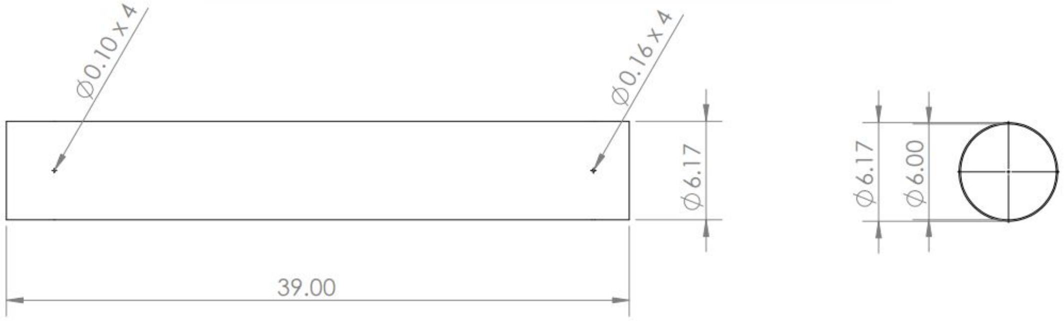
Location:

- Between nose cone and AV bay

Contains:

- Payload
- Main parachute
- Payload parachute in deployment bag
- Shock cord





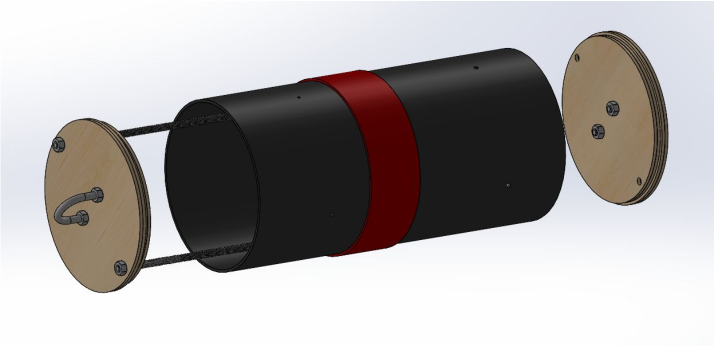
AV Bay

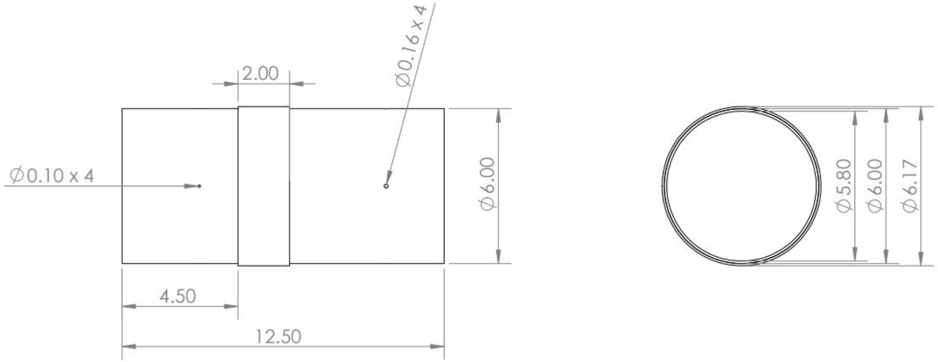
Location:

- Between the main parachute/payload bay and the drogue parachute bay/fin can

Contains

- Electronics sled, blast caps, terminal blocks





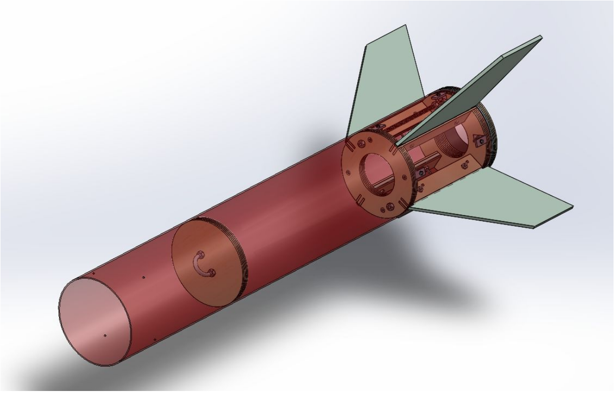
Drogue Parachute Bay/Fin Can

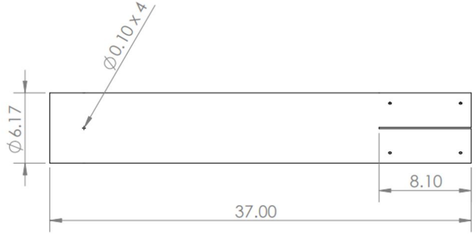
Location:

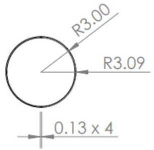
- Below the AV bay

Contains:

- Fin can bulkhead
- Drogue parachute
- Removable fin system







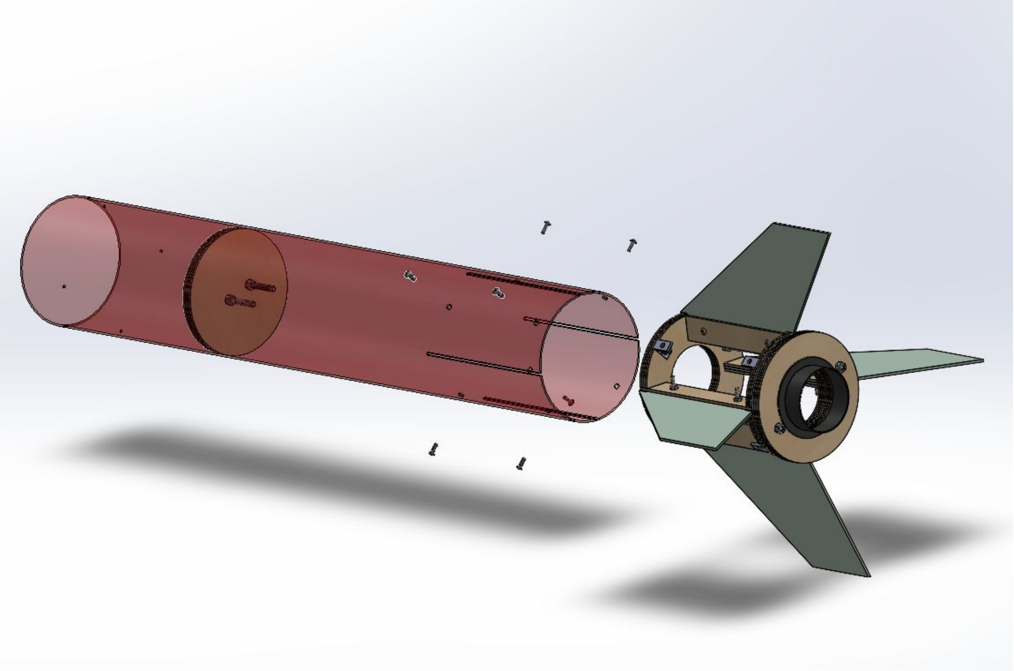
Removable Fin System

Fixed:

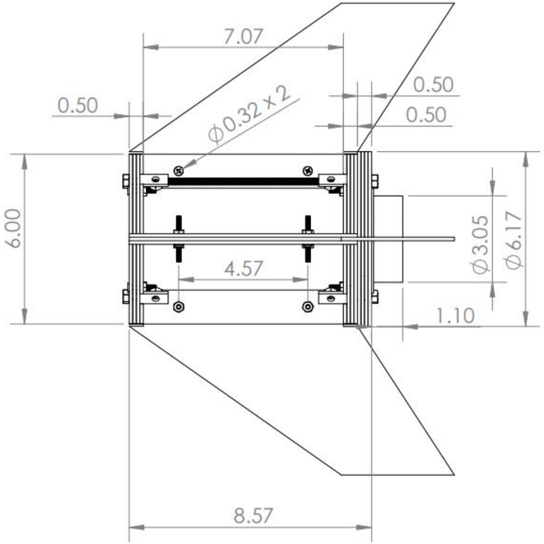
- Strong connection of fins to airframe
- Easy to manufacture
- Entire fin can must be replaced if a fin is damaged

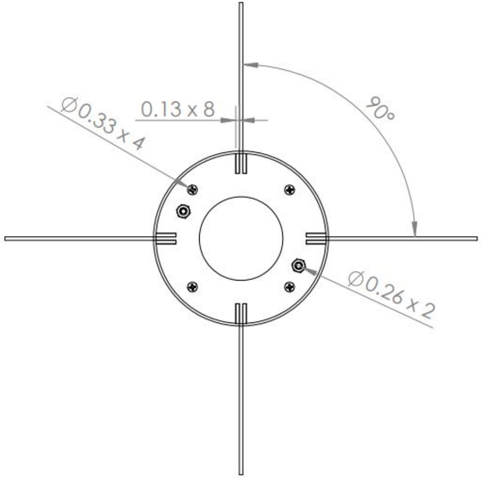
Removable:

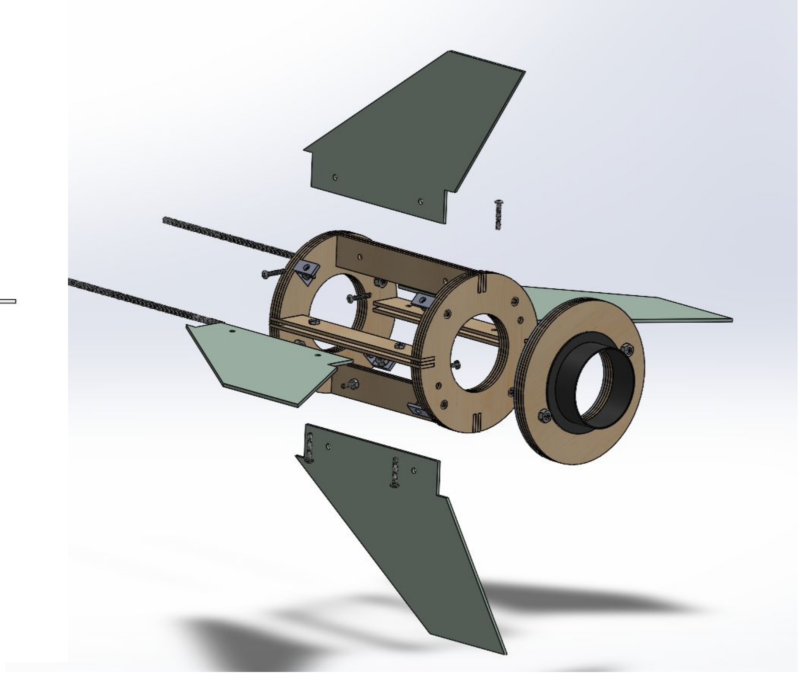
- Damaged centering rings can be replaced
- Broken fins can be easily replaced
- Ballasts can be easily added if needed



Removable Fin System







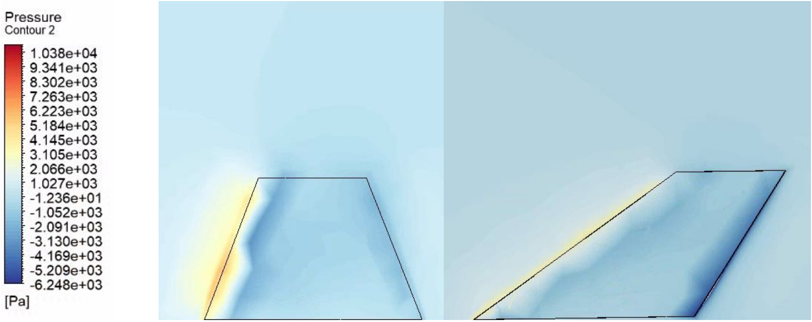
Fin Design

Symmetric:

- Streamlined manufacturing
- 4.66 lbf. of drag at launch vehicle maximum velocity
- Higher turbulence profile aft of the fin

Swept:

- Additional complexity in manufacturing angled edges
- 3.53 lbf. of drag at launch vehicle maximum velocity
- Lower turbulence profile aft of the fin



Fin Material

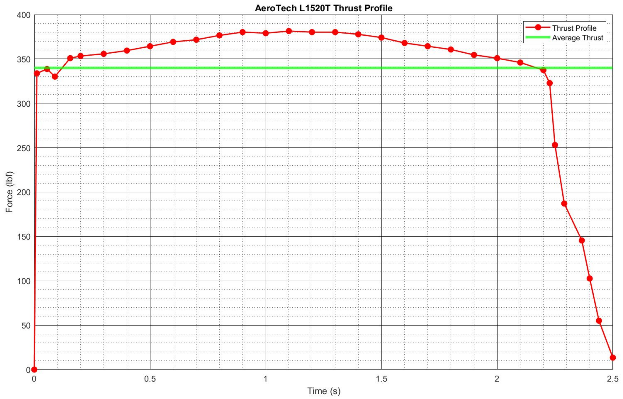
G10 Fiberglass	Aircraft-Grade Birch Plywood	Sandwich Composite
Easy to manufacture	Easy to manufacture	Difficult manufacturing process
Highly resistant to abrasion, cracking, chipping, and impacts	Moderate resistance to abrasion, cracking, chipping, and impacts	Moderate resistance to abrasion, cracking, chipping, and impacts
Known thickness	Known thickness	Unknown thickness
Heavy	Cheap	Lightweight

Motor Selection

- Current launch vehicle mass estimates allow for the AeroTech L1520T to propel the launch vehicle to the desired apogee. If mass increases, alternative motors may be used to increase the total impulse.

- Thrust to Weight Ratio: **8.27**
- Maximum Acceleration: **8.16 G's**

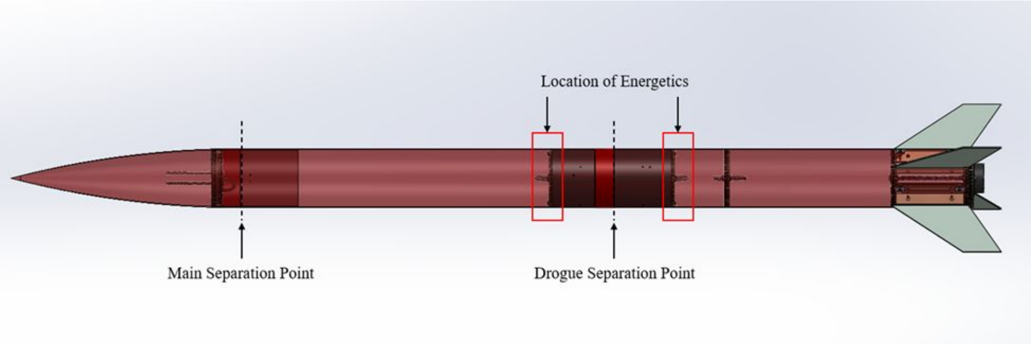
Motor	Propellant Mass (slug)	Total Mass (slug)	Total Impulse (lb•sec)	Average Thrust (lb)	Maximum Thrust (lb)	Burn Time (sec)	Casing	Length (in)
L1390G	0.1351	0.2657	887.77	313.48	376.55	2.6	RMS-75/3840	20.86
L1520T	0.1270	0.2501	835.16	352.45	396.85	2.4	RMS-75/3840	20.39
L1256WS	0.1345	0.2573	850.90	282.60	339.12	3.0	RMS-75/3840	22.08



Recovery Leading Design

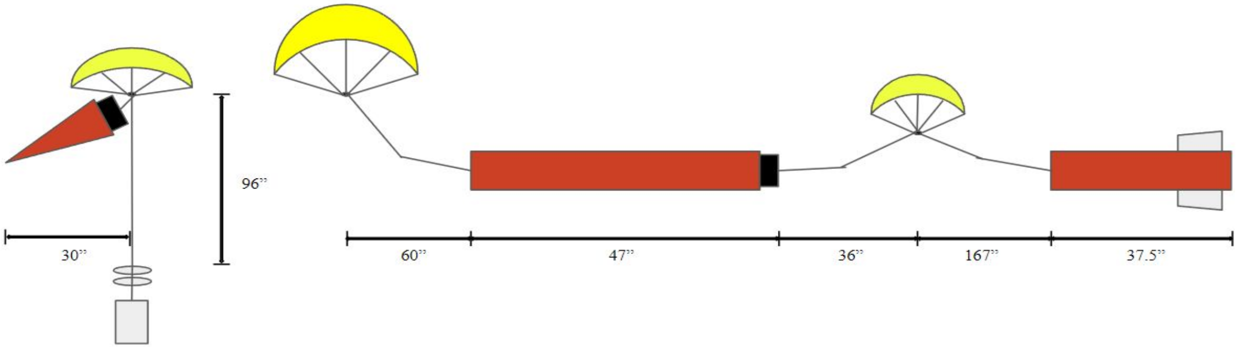
Points of Separation

- The drogue parachute is located aft of the AV Bay in the fin can
- The main parachute is located forward of the AV bay in the main parachute/payload bay
- The AV bay holds all of the recovery electronics with the exception of the tracker in the nose cone.



Recovery Overview

- The drogue parachute deploys at apogee
  - Secondary charge is set to a one second delay after apogee
- Main parachute deploys at 800 ft
  - Secondary charge set at 750 ft
- The nose cone parachute deploys after nose cone separation at 800 ft
- Payload is separated from the nose cone ~450 ft



Altimeter Alternatives

Desired Qualities:

- Precision
- Form factor
- Ease of use
- Reliability

Altimeter	Main Deployment Variability	Delay After Apogee	Altitude Logging Resolution	Dimensions	Data Recorded	Sampling Rate	Price	Owned by Club
Stratologger CF	100 - 9999 ft Increment: 1 ft	0 - 5 s Increment: 1 s	1 ft	L: 2" W: .84" H: 0.5"	Altitude, Velocity, Temperature	20/s	$69.95	Yes
RRC3	300 - 3000 ft Increment: 100 ft	1 - 30 s Increment: 1 s	1 ft	L: 3.92" W: .925"	Altitude, Velocity, Temperature, Time to Apogee	20/s	$101.33	Yes
Eggtimer Quasar	100 - 3000 ft	0 - 3 s Increment: .1 s or 3 - 30 s Increment: 1 s	1 ft	L: 3.816" W: 1.09" H: .5"	Altitude, Velocity, Milestone Events	20/s	$100.00	Yes
Entacore AIM	100 - 100,000 ft Increment: 1 ft	Available	1 ft	L: 2.56" W: 0.98" H: 0.59"	Altitude, Velocity, Temperature	10/s	$121.15	Yes
EasyMini	100 - 100,000 ft Increment: 100 ft on ascent, Increment: 10 ft on descent	Available	8 in	L: 1.5" W: 0.8" H: 0.6"	Altitude, Velocity, Acceleration, Voltage, Time to Apogee, Total Flight Time	100/s Ascent, 10/s Descent	$101.78	No

Tracker Alternatives

Tracker	License Required	Transmitter Power	Transmitter Frequency	Range	Owned by Club	Price	Comments
Big Red Bee 900	No	250 mW	900 MHz	6 Miles	Yes	$209.00	The simplest option.
Big Red Bee Beeline	Yes	100 mW	420 - 450 MHz	40 + Miles	No	$359.00	Various modes, too expensive.
Eggtimer Quasar	Yes	100 - 250 mW	420.250 MHz	11 + miles	Yes	$100	Functions as a GPS Tracker, and a dual-deploy altimeter.
Feather-weight GPS Tracker	No	60 mW	915 MHz	26 miles	No	$165.00	Can use with smartphone, though there will be difficulty setting up a pull-pin switch.

Drogue Parachute Alternatives

Parachute	Drag Coefficient	Descent Velocity	Descent time from Apogee to Main Deployment	Wind Drift from Apogee to Main Deployment (20 mph)	Owned by Club
Fruity Chutes 12" Classic Elliptical	1.339	175.21 ft/s	20.33 s	596.35 ft	No
Fruity Chutes 15" Compact Elliptical	1.5	101.31 ft/s	35.17 s	1031.65 ft	Yes
Fruity Chutes 18" Classic Elliptical	1.428	113.10 ft/s	31.50 s	924.00 ft	Yes
Fruity Chutes 24" Classic Elliptical	1.473	83.53 ft/s	42.66 s	1251.36 ft	Yes

Main Parachute Alternatives

Parachute	Drag Coefficient	Descent Velocity	Kinetic Energy	Descent time from Main Deployment	Wind Drift from Main Deployment (20 mph)	Owned by Club
Fruity Chutes 72” Iris Ultra Compact	2.033	18.95 ft/s	77.96 ft-lb	42.23 s	1238.75 ft	No
Fruity Chutes 84” Iris Ultra Compact	2.135	15.85 ft/s	54.56 ft-lb	50.48 s	1480.75 ft	No
Fruity Chutes 96” Iris Ultra Compact	2.088	14.02 ft/s	43.71 ft-lb	57.048 s	1673.41 ft	No
Fruity Chutes 120” Iris Ultra Compact	2.105	11.17 ft/s	27.11 ft-lb	71.61 s	2100.56 ft	Yes

Nose Cone Parachute Alternatives

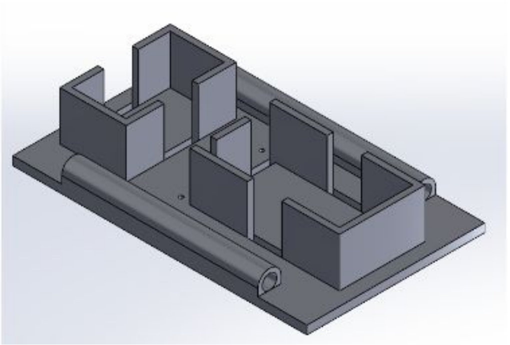
- With Payload Attached

Parachute	Drag Coefficient	Descent Velocity	Descent time from Main Deployment	Owned by Club
Fruity Chutes 36" Compact Elliptical	1.428	33.97 ft/s	10.30 s	Yes
Fruity Chutes 42" Classic Elliptical	1.421	29.19 ft/s	11.99 s	No
Fruity Chutes 48" Classic Elliptical	1.439	25.38 ft/s	13.79 s	Yes

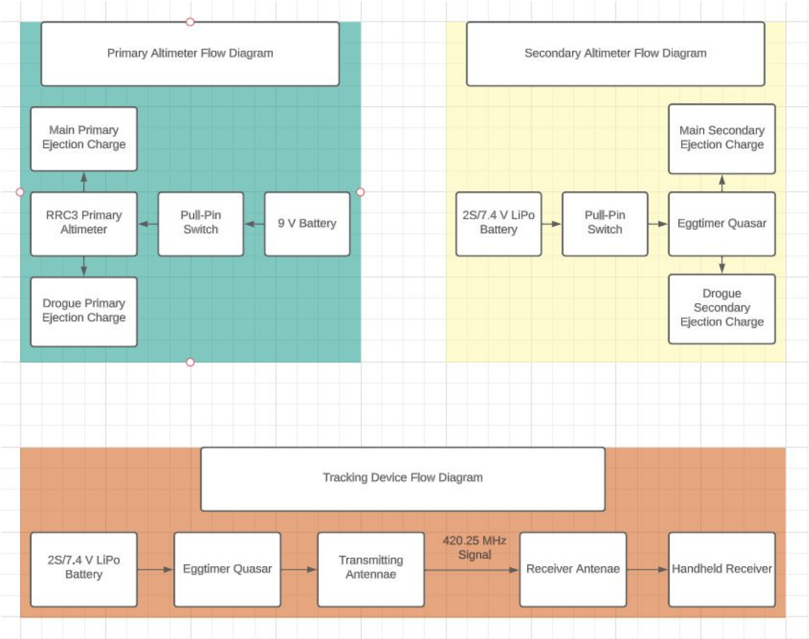
- Without Payload Attached

Parachute	Drag Coefficient	Descent Velocity	Kinetic Energy	Descent time from Payload Deployment	Wind Drift from Main Deployment (20 mph)	Owned by Club
Fruity Chutes 36" Compact Elliptical	1.428	24.74 ft/s	69.90 ft-lb	18.19 s	835.71 ft	Yes
Fruity Chutes 42" Classic Elliptical	1.421	21.26 ft/s	51.62 ft-lb	21.16 s	972.53 ft	No
Fruity Chutes 48" Classic Elliptical	1.439	18.49 ft/s	39.01 ft-lb	24.344 s	1118.65 ft	Yes

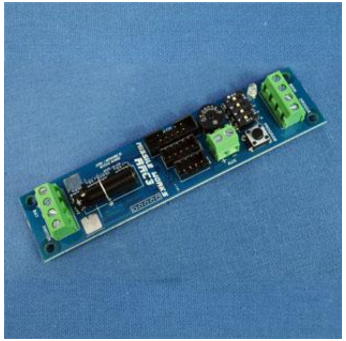
Leading Avionics Design



Model of AV Sled



Electrical Schematic of AV Bay



Missile Works RRC3 Primary Dual Deployment Altimeter

Eggtimer Quasar Tracker and Secondary Dual Deployment Altimeter

Leading Parachute Configuration

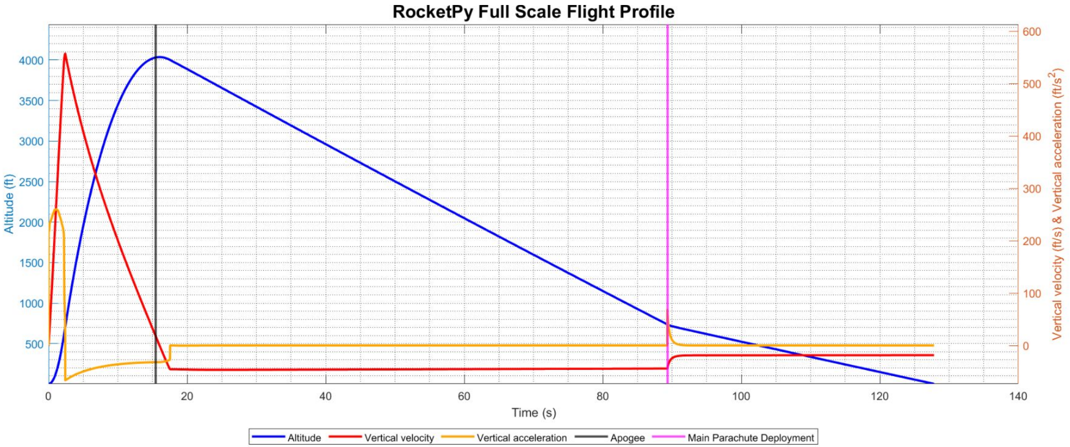
- Drogue Parachute:
  - Fruity Chutes 18 in. Classic Elliptical
  - Protected from ejection charges via Nomex cloth
- Main Parachute:
  - Fruity Chutes 84 in. Iris Ultra Compact
  - Protected from ejection charges via a deployment bag that is attached to the removable nose cone
  - Allows the landing kinetic energy of every section of the launch vehicle to be less than 65 ft-lb
- Nose Cone Parachute:
  - Fruity Chutes 48 in. Classic Elliptical
  - Protected from ejection charges via Nomex cloth

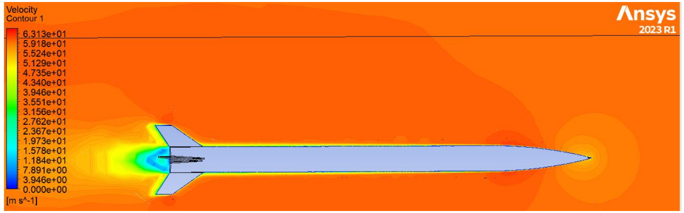
Mission Performance Predictions

Aerodynamic Performance

- Launch vehicle drag profile characterized in ANSYS Fluent
- RocketPy python module used in simulation for real time atmospheric conditions
- Center of gravity and motor performance imported from OpenRocket

- Declared apogee: **4050 ft.**





Descent Time and Wind Drift

Assumed that there is constant wind down range

Maximum Wind Drift:

- Launch Vehicle: 2404.76 ft
- Nose Cone: 2042.65 ft

Descent Time

- Launch Vehicle: 81.98 seconds
- Nose Cone: 38.134 seconds after main deployment

Wind Velocity	Launch Vehicle Drift Distance	Nose Cone Drift Distance from Main Deployment
0 mph	0 ft	0 ft
5 mph	601.19 ft	279.66 ft
10 mph	1202.38 ft	559.33 ft
15 mph	1803.57 ft	838.99
20 mph	2404.76 ft	1118.65 ft

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

$$t_n = \frac{h_m - h_p}{v_p} + \frac{h_p}{v_{nc}}$$

Kinetic Energy at Landing

Descent Velocity Requirements for Points

Section	Section of Mass	Descent Velocity Necessary to be Awarded Points	Descent Velocity Necessary to be Awarded Bonus Points
Nose Cone	.228 slugs	25.65 ft/s	23.88 ft/s
Main Parachute/ Payload Bay and Avionics Bay	.333	21.22 ft/s	19.76 ft/s
Drogue Bay/ Fin Can	.434 slugs	18.59 ft/s	17.31 ft/s

Kinetic Energy at Landing

Section	Section of Mass	Velocity Under Main Parachute	Impact Energy
Nose Cone	.228 slugs	18.49 ft/s	38.97 ft-lb
Main Parachute/ Payload Bay and Avionics Bay	.333 slugs	15.85 ft/s	41.83 ft-lb
Drogue Bay/ Fin Can	.434 slugs	15.85 ft/s	54.56 ft-lb

Maximum Opening Shock Force

Upon parachute deployment, the launch vehicle will experience a shock force

- Maximum shock force experienced by the launch vehicle from main deployment: 299.47 lbf
- The Kevlar Webbed shock cord is rated for a maximum shock force of 6600 lbf.
- Factor of Safety: 22

Equation

$$F = \frac{m\Delta v}{t}$$

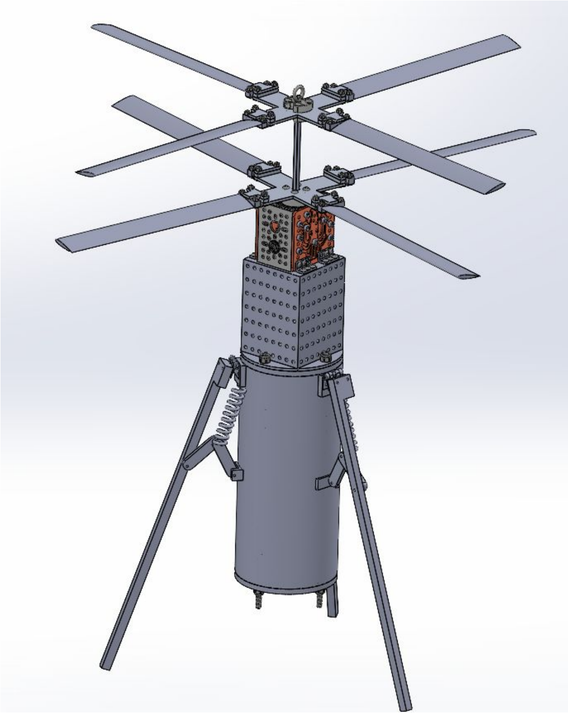
Payload Leading Design

Payload Objective and Requirements

- Design and build a lander capable of safely landing four STEMnauts without the use of parachutes or streamers
- Payload must deploy between 400 and 800 ft.
- Payload must weigh at least five lbs.
- Payload must land in a predefined orientation.
- Payload must land at a speed slower than 20 mph.

Payload Design Overview

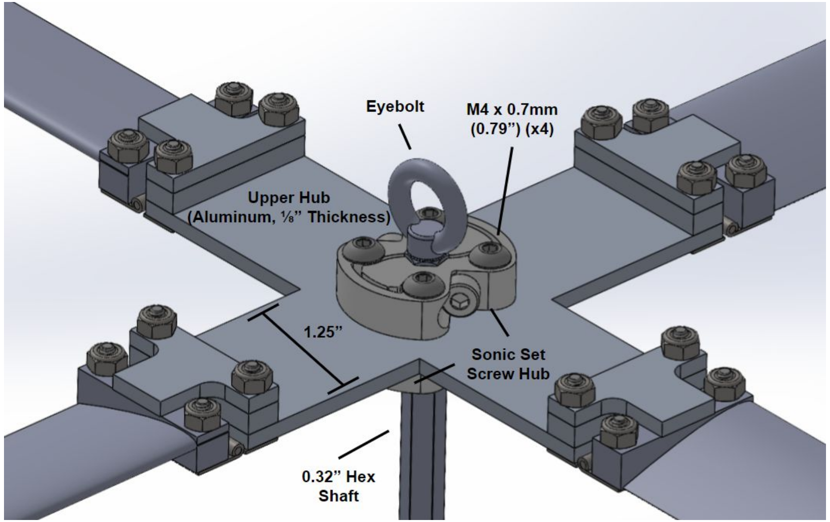
- Contra-rotating rotor blades to slow descent
- Powered by RC helicopter motor
- Rotor blades and legs will fold to allow the payload to fit inside the launch vehicle



Hub Assembly

Upper Hub

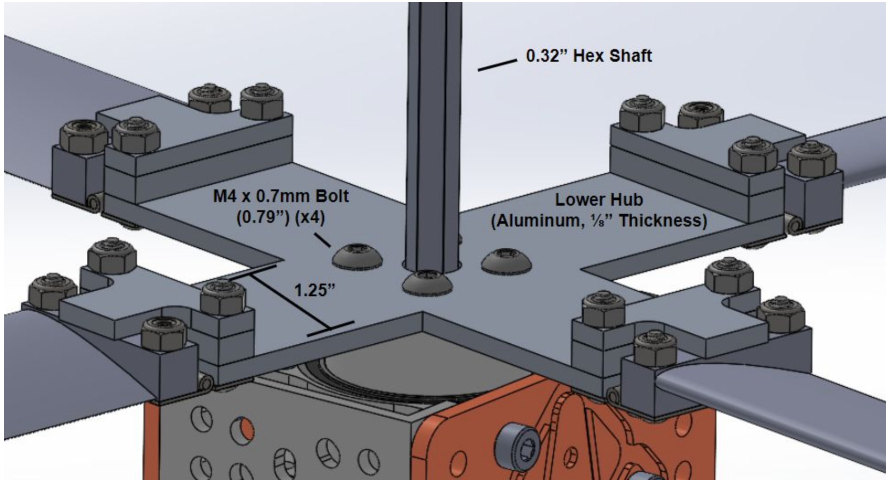
- ⅛ in. aluminum
- 1.25 in. prongs
- Eye bolt screwed into hex shaft for release mechanism
- Attached to hex shaft
  - Sonic set screw hubs bolted through hub



Hub Assembly

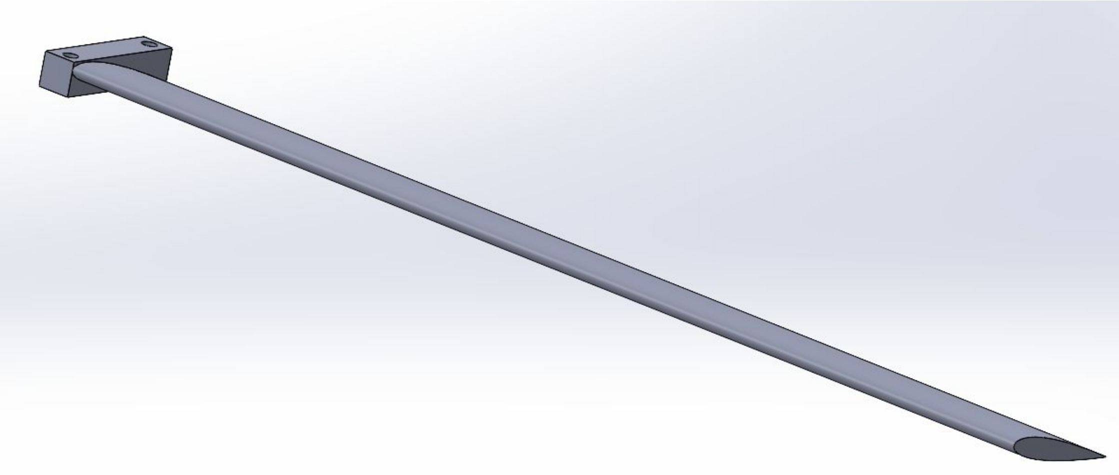
Lower Hub

- Similar to upper hub
  - Central hole size different
- Bolted to GoTube

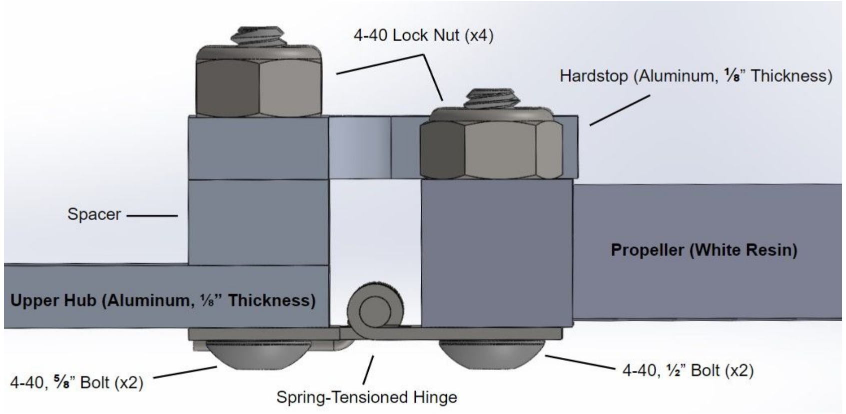


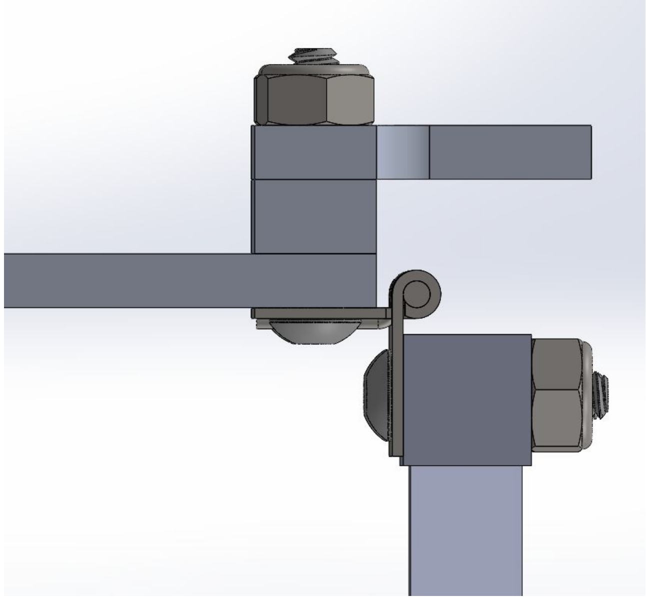
Rotor Blades

- NACA 0015 airfoil
- SLA resin printed
- 13 in. span
- 4 blades per rotor



Hub-to-Propeller Assembly

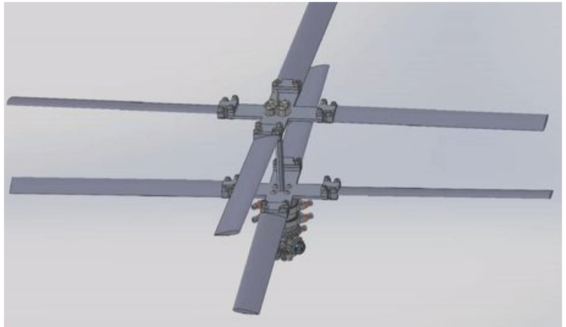


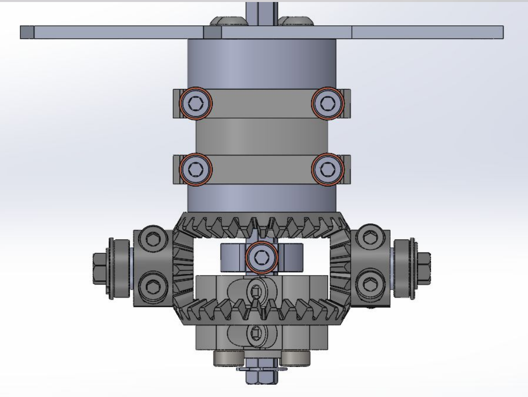


- Spring-loaded hinge
- Hub bolted to hardstop
  - Prevents propellers from moving beyond the horizontal position

Gear Box

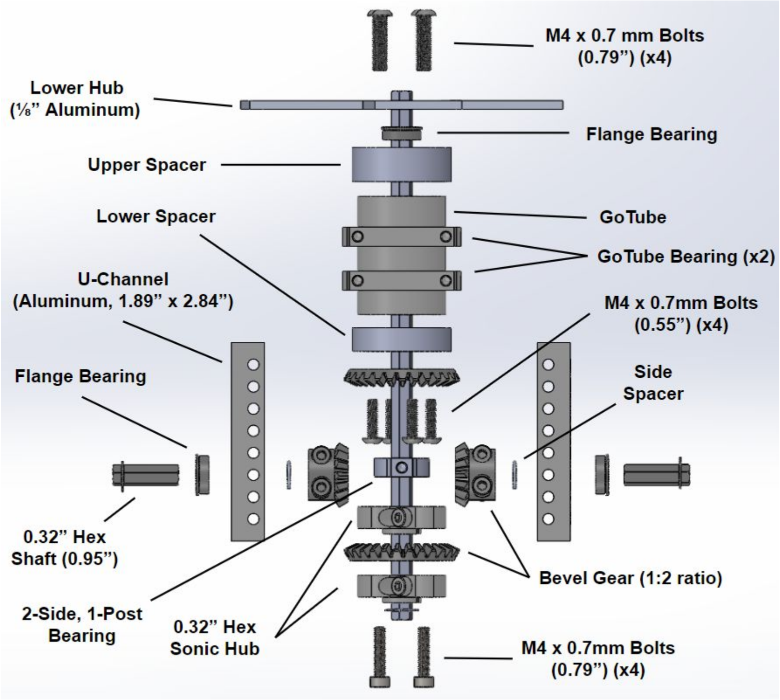
- 2 Concentric Axles
  - Bottom bevel gear - hex shaft - upper hub
  - Upper bevel gear - GoTube - lower hub
- 6 Bearings
  - 2 GoTube bearings
  - 4 hex shaft bearings
    - 1 between bevel gears
    - 1 between GoTube and hex shaft
    - 2 for vertical bevel gears
- Coaxial Rotation





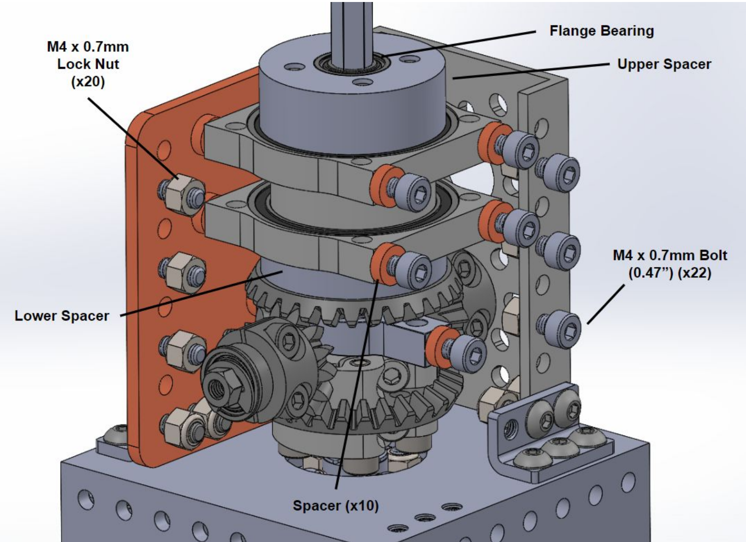
Gear Box

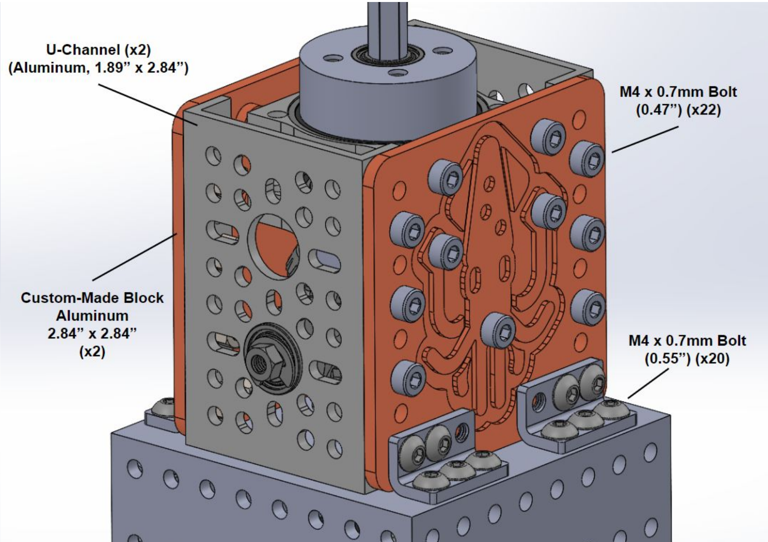
- Spacers
  - Upper and lower spacer
    - Prevents lower hub - upper bevel gear assembly from moving
  - Side Spacer (2x)
    - Prevents vertical bevel gear shaft from sliding
- GoTube
  - Fastened to upper bevel gear
- Sonic Hub (x2)
  - Fastened to lower bevel gear



Gear Box

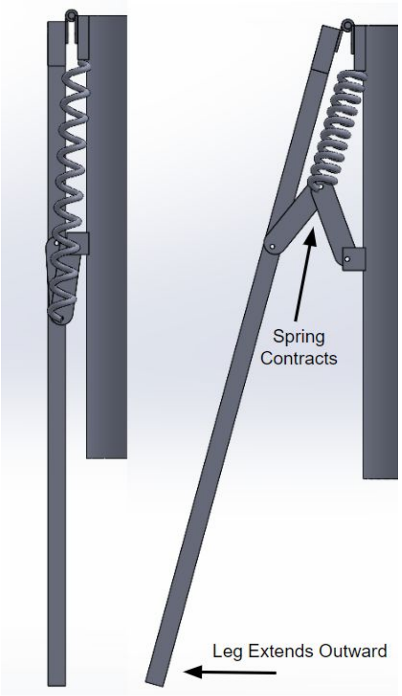
- Outer Structure
  - U-Channels and plates bolted together
  - Plates bolted to bearings
  - L-brackets secure the gearbox to the motor housing





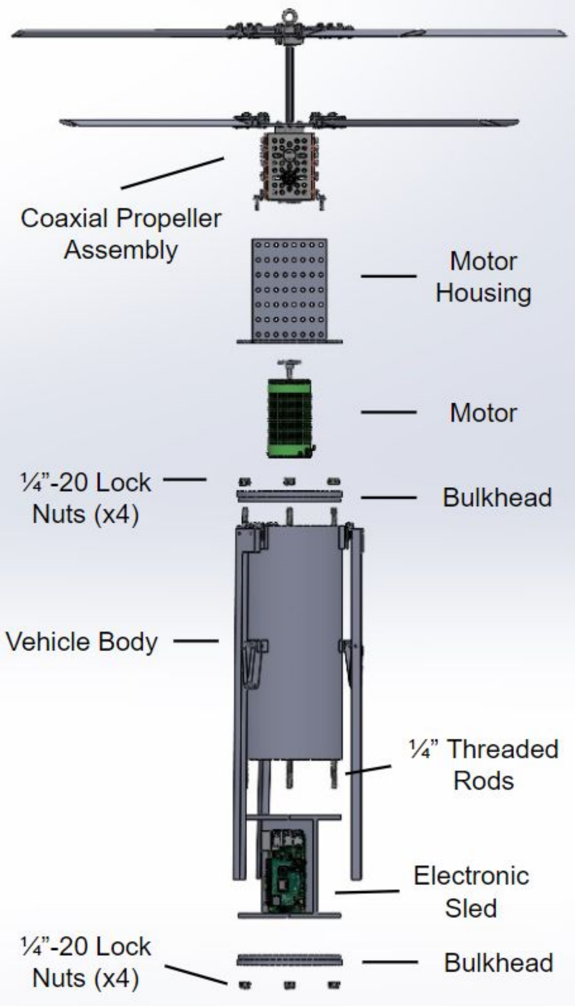
Landing Legs

- Spring loaded folding mechanism
- Made of aluminum
- Fabricated using a water jet



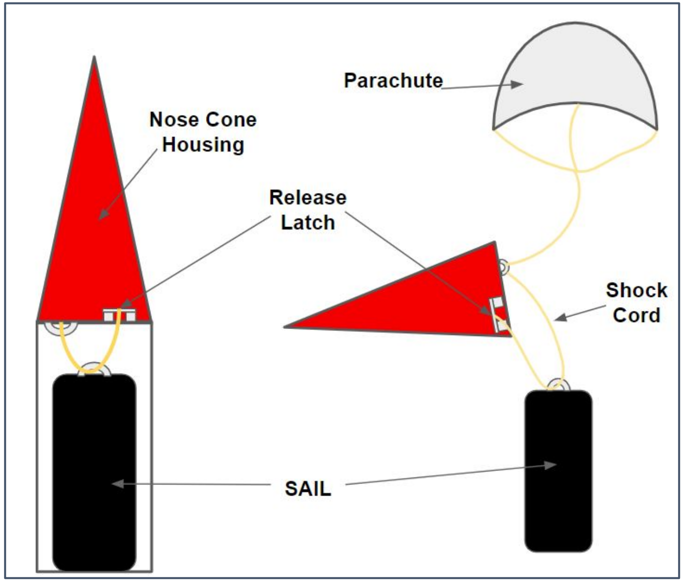
Payload Body Assembly

- Body made from 4.5 in. diameter fiberglass
- The major components will be fixed in place using threaded rods and lock nuts
- Electronics will be mounted on 3D printed sleds



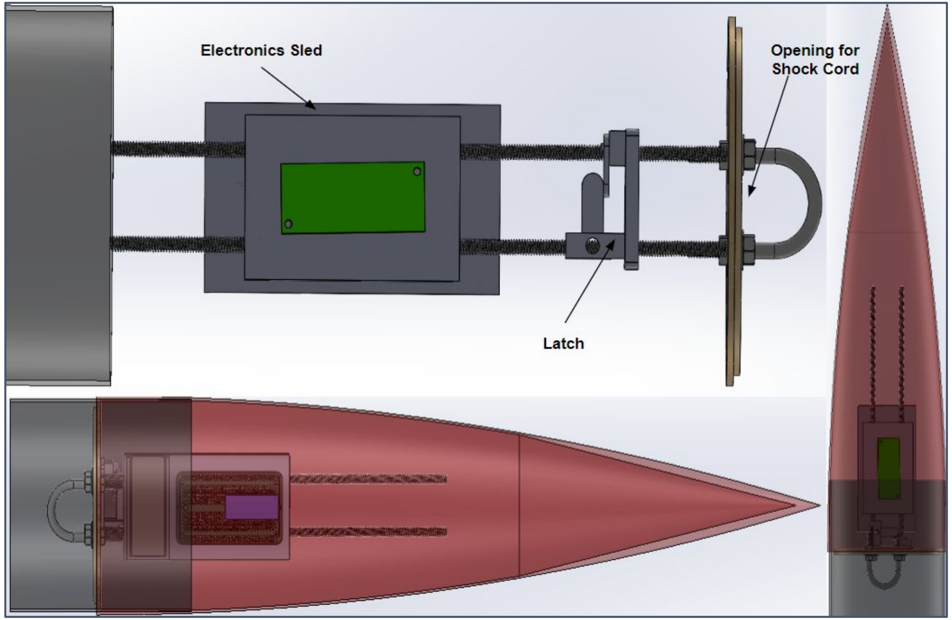
Release Configuration

- Nose cone will separate from payload bay, with drogue pulling out SAIL
- SAIL will descend under parachute until RSO permission is given
- Latch will release, feeding shock cord through eye bolt, releasing SAIL



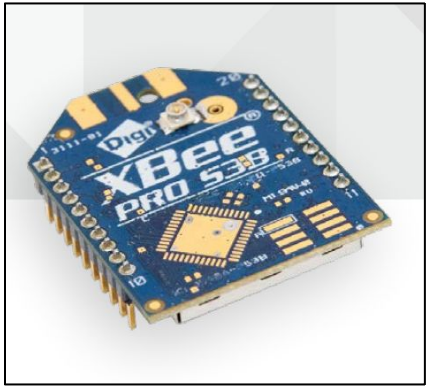
Release System Components

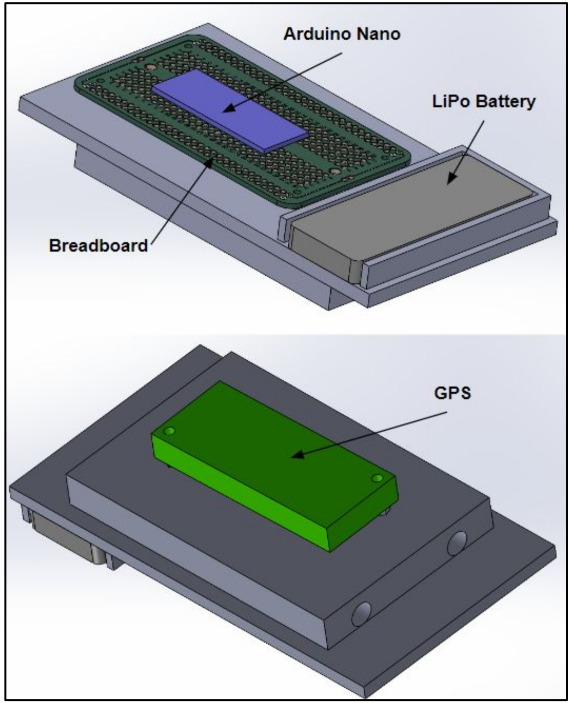
- Electronics and latch will be stored in nosecone
- Latch will be mounted on top of the nose cone bulkhead
- Electronics on 3D printed sled



Release Electronics

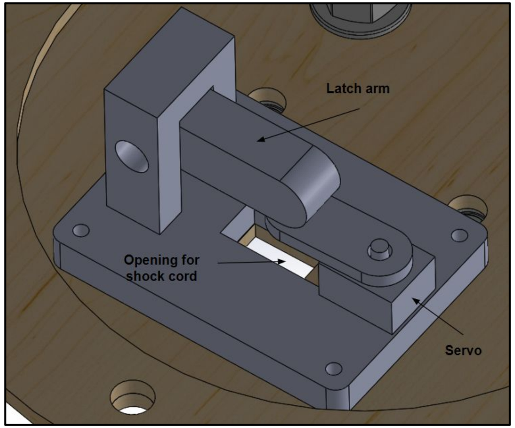
- RF command to release - XBee Pro
- Command processing - Arduino Nano
- Latch Release - Servo
- GPS for nose cone
- LiPo Battery

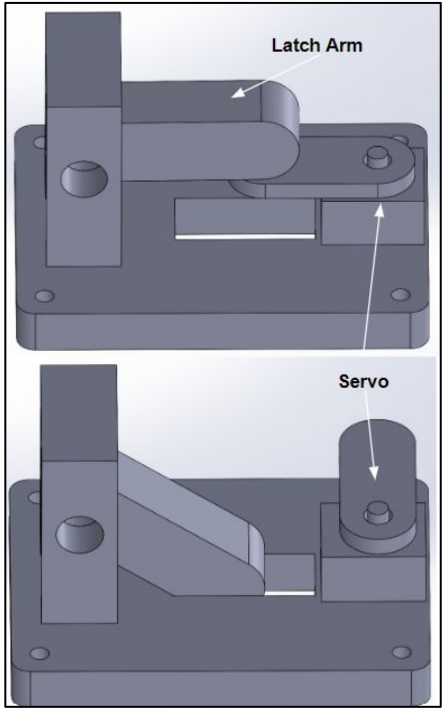




Latch Structure

- Shock cord fitted onto latch arm, will release upon servo movement.
- Preliminary ideas for material
  - Needs to withstand shocks
  - Carbon fiber PETG, metal
- Can be easily modified if needed after testing.





STEMnauts

- Commander Jeffrey
- Flight experience in the 2022-2023 SLI
- Approximately 0.47 in. long, 0.47 in. wide and 0.52 in. tall
- Weighs 0.003 lbs.

Requirements Compliance

Requirements Compliance

- Each requirement has its own success criteria
- Requirements verified with analysis will be completed by CDR
- Test plans included in CDR will be verified by FRR
- Inspection and Demonstration requirements verified by FRR

* Most success criteria require full scale to be built or launched

Team Derived Requirements

- Determined for Vehicle, Recovery, Payload and Safety
- Created to increase safety during project flight and fabrication as well as increase chances of launch vehicle/payload success

- Examples:
  - LVF 4 - the launch vehicle SHALL be designed with removable ballast.
  - PD 1 - The SAIL SHALL land with an impact velocity of less than 15 mph.

Risk Assessment Matrix

- Additional risk assessment
- Monitors likelihood of failure
- Different risk levels
- Probability analysis

		Level of Severity			
		1 Low Risk	2 Medium Risk	3 High Risk	4 Severe Risk
Likelihood of Occurrence	A Very Unlikely	1A	2A	3A	4A
	B Unlikely	1B	2B	3B	4B
	C Likely	1C	2C	3C	4C
	D Very Likely	1D	2D	3D	4D

Project Plan

Funding Schedule

Organization	Fall Semester	Spring Semester	Academic Year
Educational and Technology Fee	$0	$2,000	$2,000
Engineering Enhancement Fund	$0	$7,500	$7,500
NC State Student Government	$2,000	$2,000	$4,000
North Carolina Space Grant	$5,000	$0	$5,000
Sponsorship	$500	$500	$1,000
Total Funding:			**$20,500.00**
Total Expenses:			**$20,202.87**
Difference:			**$297.13**

Development Timeline

2023-24 Student Launch Competition Development Gantt Chart

				Aug				Sept				Oct				Nov				Dec				Jan				Feb				Mar				Apr			
Task Name	Task Number	Start Week	End Week	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36
Brainstorming	1	W02	W05		1	1	1	1																															
Vehicle Design	2	W05	W08					2	2	2	2																												
Payload Design	3	W05	W16					3	3	3	3	3	3	3	3	3	3	3	3																				
Subscale Parts Ordering	4	W08	W16								4	4	4	4	4	4	4	4	4																				
Subscale Manufacturing	5	W10	W14										5	5	5	5	5																						
Subscale Launch	6	W14	W14														6																						
Payload Parts Ordering	7	W16	W17																7	7																			
Fullscale Parts Ordering	8	W18	W21																		8	8	8	8															
Fullscale Manufacturing	9	W21	W25																					9	9	9	9	9											
Payload Manufacturing	10	W21	W28																					10	10	10	10	10	10	10	10								
Fullscale Components Testing	11	W23	W26																							11	11	11	11										
Recovery System Testing	12	W23	W26																							12	12	12	12										
Vehicle Launch Window	13	W25	W28																									13	13	13	13								
Payload Testing	14	W25	W29																									14	14	14	14	14							
Payload Launch	15	W29	W32																													15	15	15	15				
Competition Launch	16	W34	W34																																		16		