Flight Readiness Review Presentation

Alabama Rocket Engineering Systems (ARES) Team

The University of Alabama

Overview

- Mission Overview
- Team Introduction
- Launch Vehicle Design
- Payload Design
- Project Plan
- Q & A

Mission Overview

- Launch vehicle must carry payload to 5,280 ft AGL
- Payload must eject from launch vehicle
- Payload must analyze images of the ground to detect potential landing hazards
- Payload must steer away from detected landing hazards
- All components of the rocket must be safely recovered.

Team Introduction

- **Tom** — Team Lead
  - **Mark** — Payload Lead
    - **Mark** — Landing Hazard Detection System Lead
    - **Nick** — Guided Descent Subsystem Lead
    - **Ryan** — Tracking and Communication Subsystem Lead
    - **Harrison** — Simulation Subsystem Lead
  - **Chris** — Rocket Lead
    - **Chris** — Structures Subsystem Lead
    - **Dan** — Avionics and Recovery Subsystem Lead
    - **Michael** — Propulsion Subsystem Lead
  - **Tom** — Logistics and Operations Officer
  - **Rachel** — Outreach and Public Relations Officer
  - **Dan** — Financial Officer
  - **Desiree** — Safety Officer

Launch Vehicle Design

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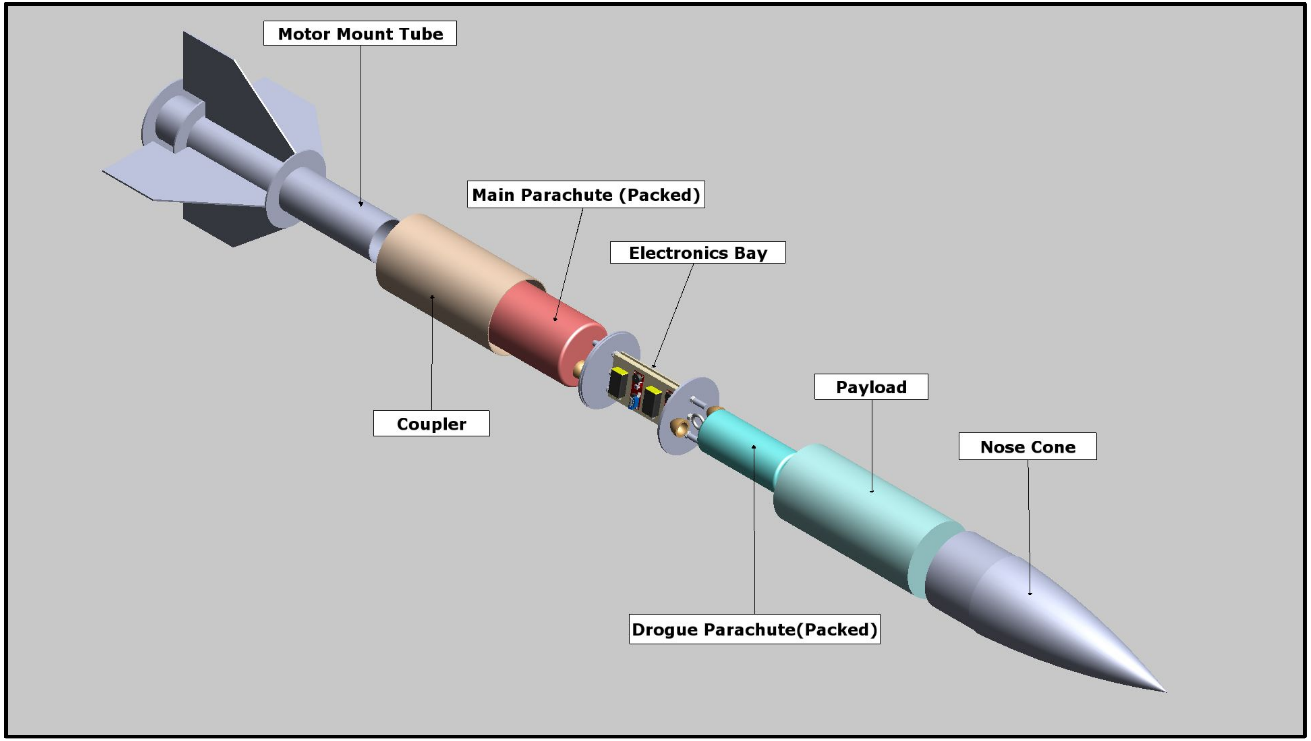
Launch Vehicle Design



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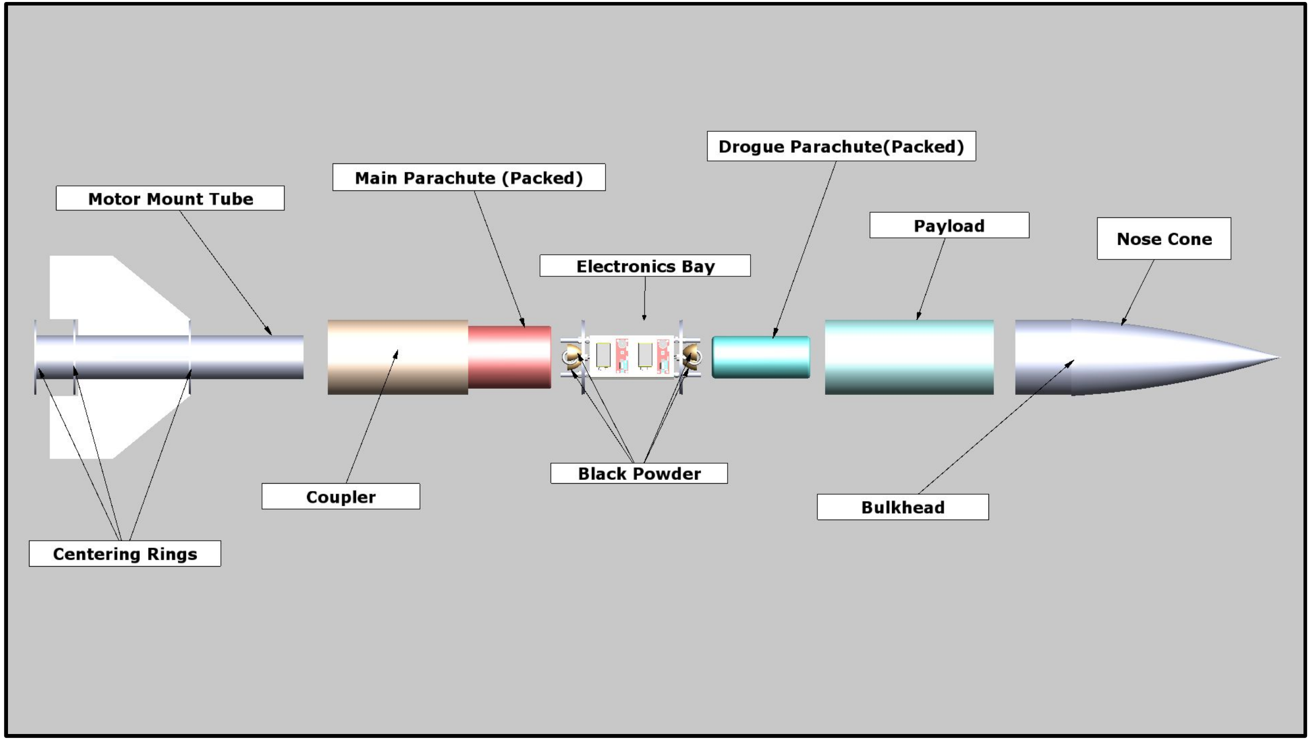
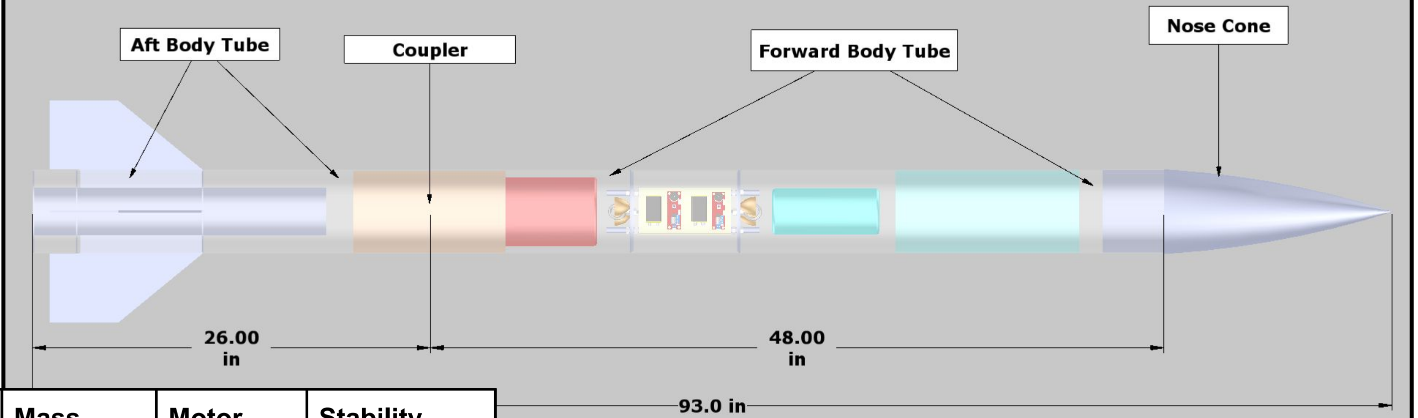
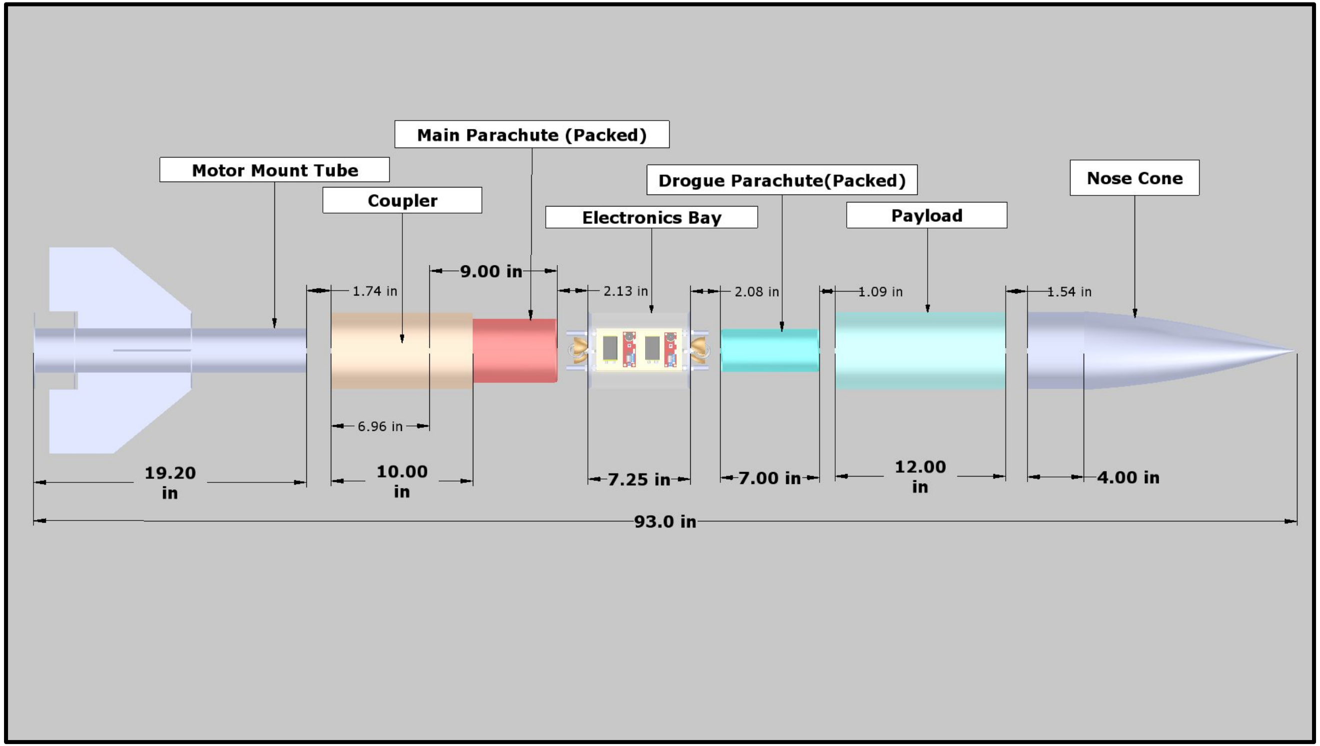


Launch Vehicle Dimensions



Length	Diameter	Mass	Motor	Stability Margin
93 inches (2.36 m)	5.53 inches (0.141 m)	38.4 lb (17.42 kg)	Cesaroni L851	2.14 calibers

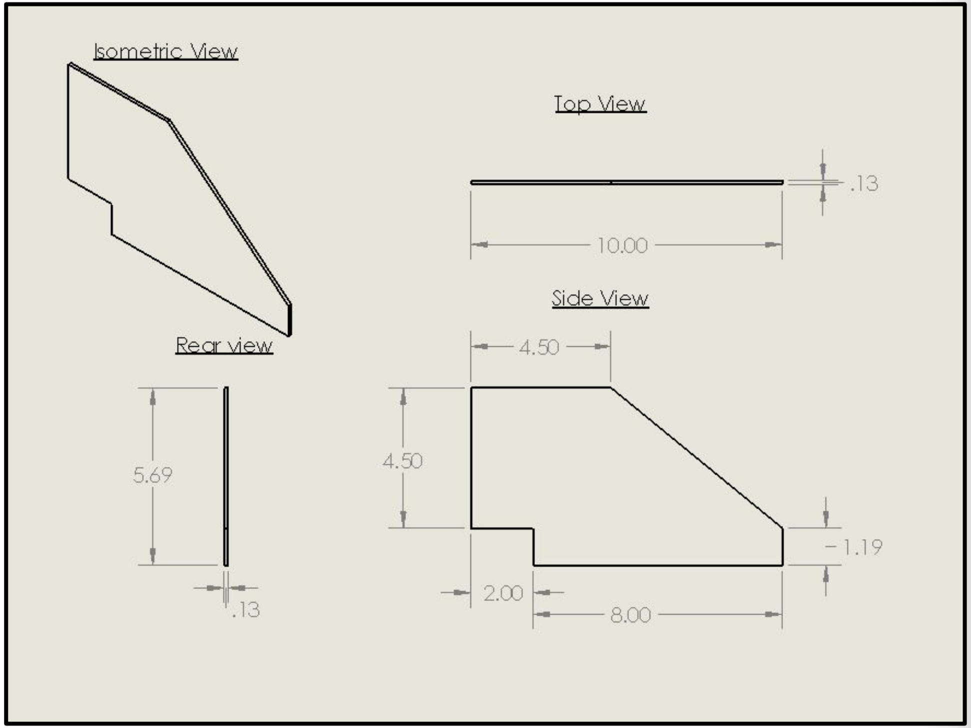
Launch Vehicle Dimensions



Vehicle Design ○ Payload Design ○ Project Plan

Key Design Feature - Fins

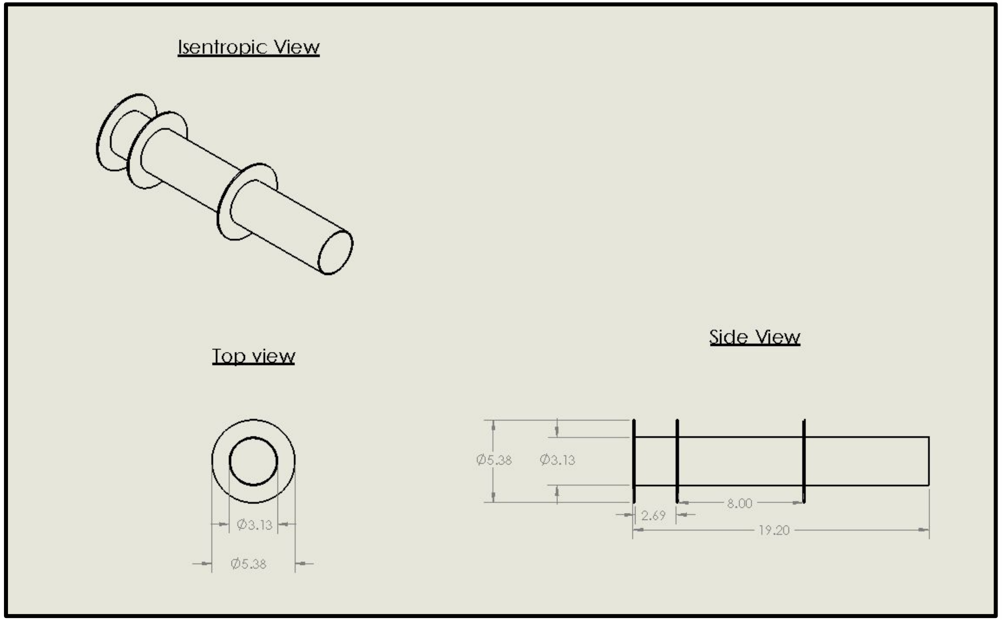
- Fins size based on creating a favorable stability margin
- Fin tabs are epoxied to the centering rings and motor mount tube
- A fillet of epoxy is between the fin face and the aft body tube



Key Design Feature - Motor Mount

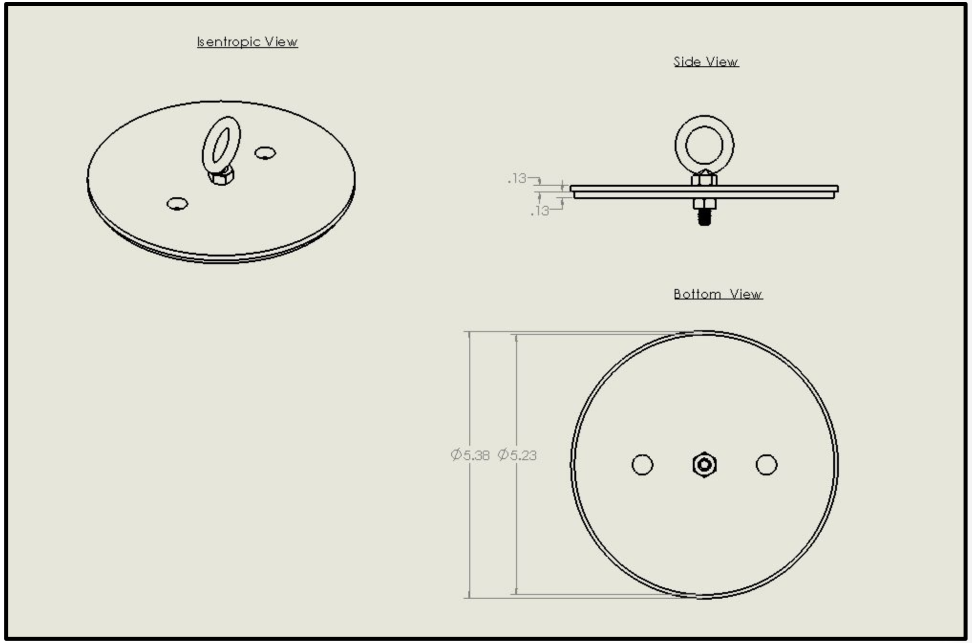
- Motor Mount contains and stabilizes the motor during flight

- Centering rings are epoxied onto the motor mount tube and the aft body tube. They are placed to give the fins extra support



Key Design Feature - Bulkhead

- Bulkheads provide eye bolts for parachute attachment
- Electronics bay bulkheads protect altimeters from adverse pressure changes
- Black powder cups are epoxied onto the electronics bay bulkheads



Final Motor Choice

Manufacturer	Cesaroni Technology	**Brandname**	Pro75 3683-L851-P
Motor Dim. (mm), (in)	75.00 x 485.14, 2.95 x 19.1	**Total Impulse (N*s), (lb*s)**	3683, 828.0
Avg. Motor Efficiency	50.8%	**Maximum Thrust (N), (lb)**	989.9, 222.5
Specific Impulse (s)	178	**Avg. Thrust (N), (lb)**	849.1, 190.9
Burntime (s)	4.34	**Altitude Projection, Bragg Farms - No Wind (ft)**	4874
Thrust-to-Weight Ratio	4.97	**Impulse-to-Weight Ratio**	21.73

Final Motor Choice

The original motor selection from CDR was a Cesaroni Technology Pro 75 3300L3200-Vmax

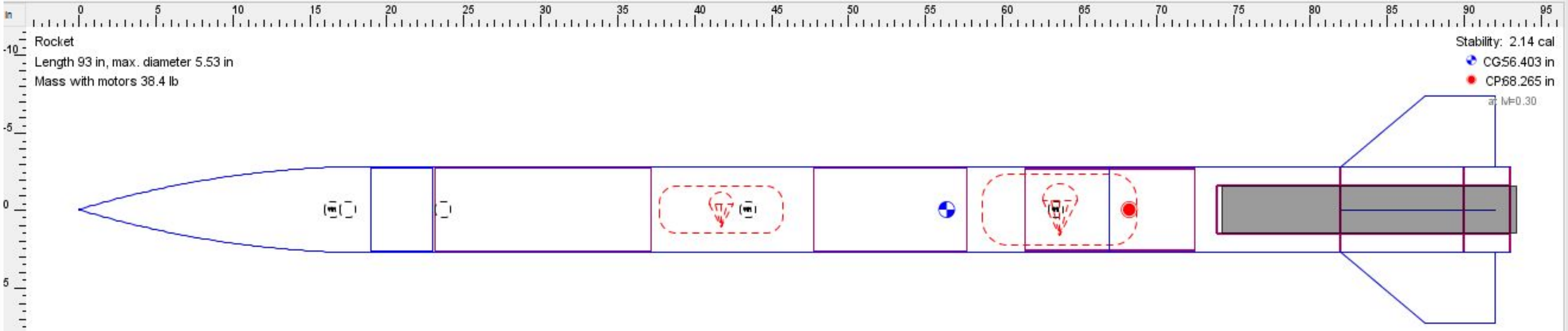
Updated to the final selection of the Pro75 3683-L851-P once the ARES team had to test the L851 due to the L3200 shipping issues

After testing both motors, the L851 put the rocket closest to the 5280 ft mark and gives the team and vehicle the best opportunity for success

The Cesaroni Pro75 3683-L851-P is available through "Chris' Rocket Supplies, LLC"

Rocket Stability

- Center of gravity and center of pressure of the rocket are located 56.40 and 68.27 inches (1.433 and 1.734 m) from the tip of the nose cone
- Stability Margin: 2.14 calibers



T/W Ratio and Rail Exit Velocity

Thrust-to-Weight Ratio	4.97
Rail Exit Velocity (ft/s)	55.8
Rail Height (ft)	12
Static Stability Margin (off launch rail)	2.02 calibers

Mass Statement & Margin

- Observed a 3.71% increase in mass
- OpenRocket full scale simulation vs mass of actual rocket mass

Component	Mass (lb)
Nose Cone	4.06
Forward Body Tube	4.5
Aft Body Tube	2.23
Motor Mount	2.41
Fins	1.86
Payload	7.0
Electronics Bay	2.69
Main Parachute (Packed)	2.81
Drogue Parachute (Packed)	1.5
Motor w/ Propellant	8.35
Motor Propellant	4.84
Simulation Total	37.0
Actual Total Measured	38.4

Kinetic Energy at Landing

Maximum kinetic energy of any individual section: 75 ft-lb

$$v = \sqrt{\frac{2*KE}{m}}$$

Descent Rate Calculator (fruitychutes.com)

System	Mass (lbf)	Allowable Velocity (ft/s)	Minimum Parachute Diameter (in)	Drag Reduction Velocity from Minimum Parachute (ft/s)
Nose Cone	4.06	34.49	24	27.52
Forward Body Section	11.5	20.49	60	18.53
Aft Body Section	10.95	21.00	54	20.09
Total Rocket	26.51	13.50	115	13.22

A 120 inch (3.08 m) main parachute for the total descending rocket is justified to safely land each independent section under the 75 ft-lb

Predicted Altitude

- OpenRocket simulation predict altitudes of 4874 ft
- Actual full scale flight test reached an altitude of 5415 ft
- Percent difference of 6.97 %
- Within this range flight will successfully complete the mission

Simulation	Apogee (ft)	Max Velocity (ft/s)	Time to Apogee (s)	Flight Time (s)
Bragg Farms (0 mph)	4874	562	18.6	119
Bragg Farms (5mph)	4854	561	18.6	118
Bragg Farms (10 mph)	4802	561	18.5	117
Bragg Farms (15 mph)	4727	559	18.3	116
Bragg Farms (20 mph)	4659	558	18.2	116

Predicted Drift

Drift calculations were performed in OpenRocket at the latitude, longitude, and altitude of Bragg Farms in Huntsville, Alabama. The current calculations are from a 700 ft. main deployment altitude with a main parachute diameter size of 120 in.

Wind Speed	**0 mph**	**5 mph**	**10 mph**	**15 mph**	**20 mph**
Max Lateral Distance (ft)	9.24	215.6	502.3	812.3	1273.6

Test Plans and Procedures

Ground Tests

- Charge tests ensure clearance from the launch vehicle
- Correct amount of black powder is determined

Sub-Scale Test

- The sub-scale flight proved that the recovery system is adequate and that the design of the rocket is stable in-flight

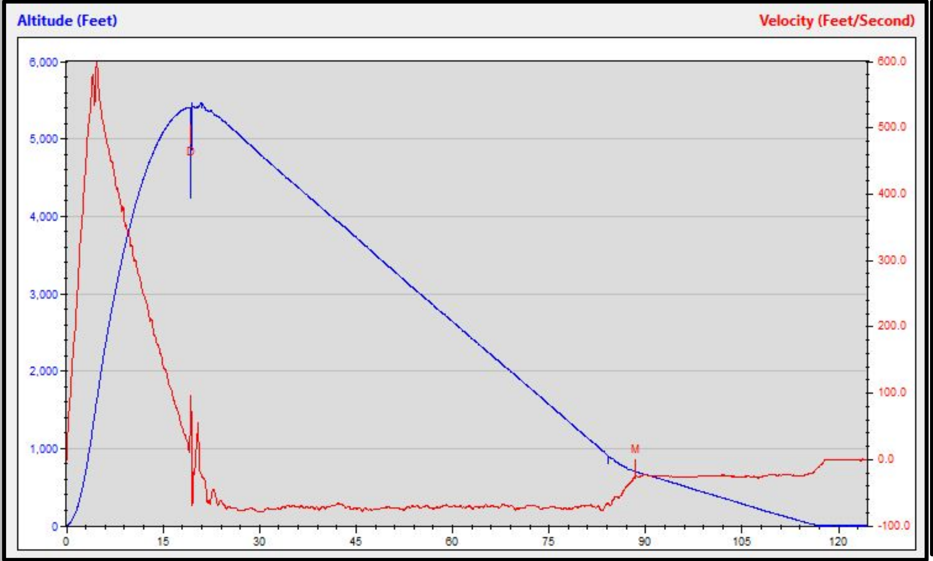
Full-Scale Test

- The full-scale flight proved that all aspects of the launch vehicle function properly

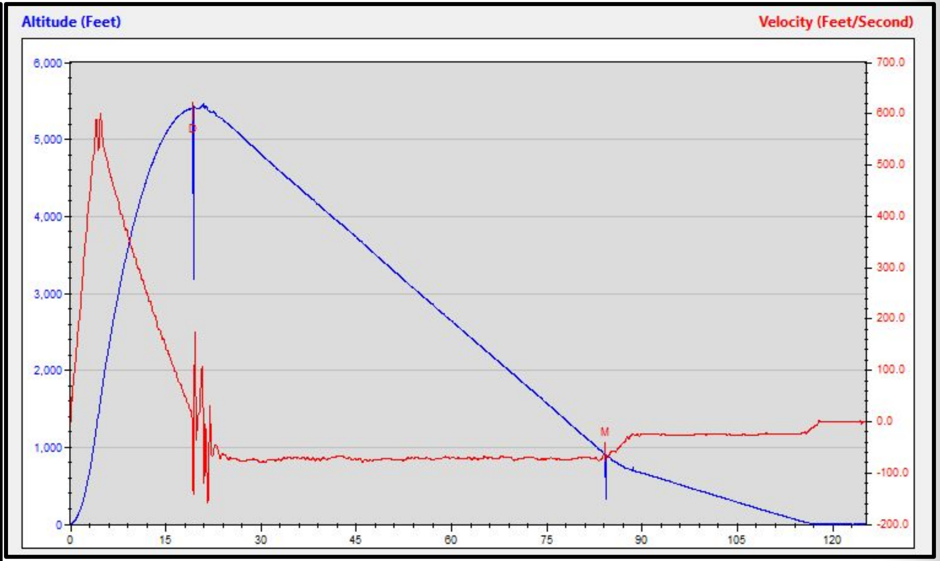
Full Scale Flight Test

- The data obtained from the L851 and L3200 full scale flight by the Stratologger CF Altimeters are featured in the next two slides.
- The data proves validates our Descent Rate Calculator, (fruitychutes.com), showing that the 75 ft-lb limit was not exceeded.
- Two successful ejections of the payload at apogee show a successful integration of the payload with the launch vehicle.
- Successful ground ejection tests and recovery on flights have finalized the process and procedures for preparation and launch.

Full Scale Flight Test (L851)



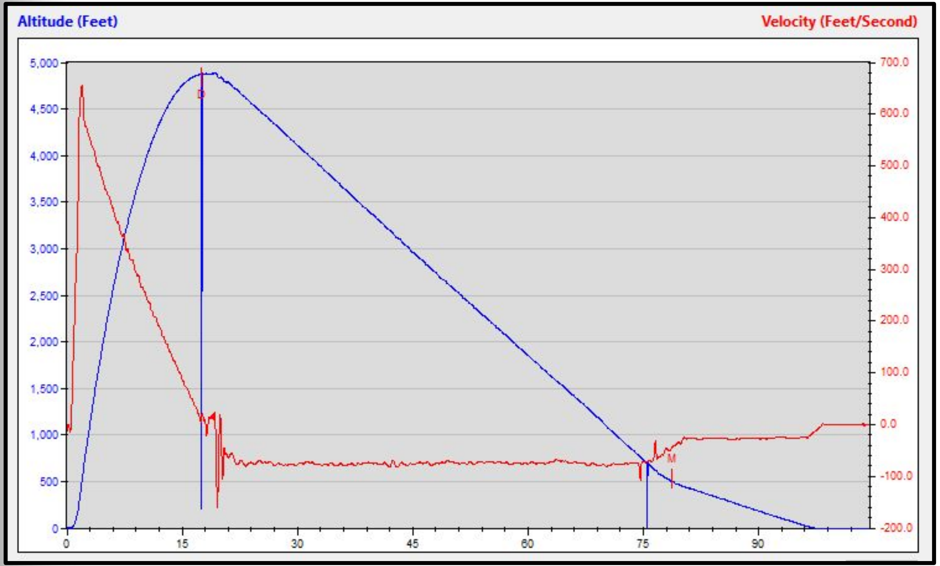
Aft Altimeter



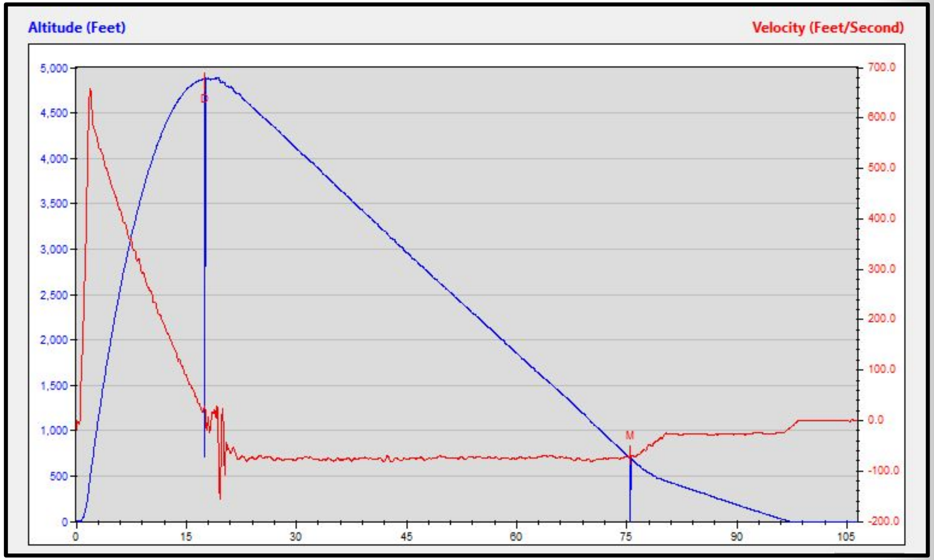
Forward Altimeter

Vehicle Design ○ Payload Design ○ Project Plan

Full Scale Flight Test (L3200)



Aft Altimeter



Forward Altimeter

Vehicle Design ○ Payload Design ○ Project Plan

Full Scale Flight Test Summary

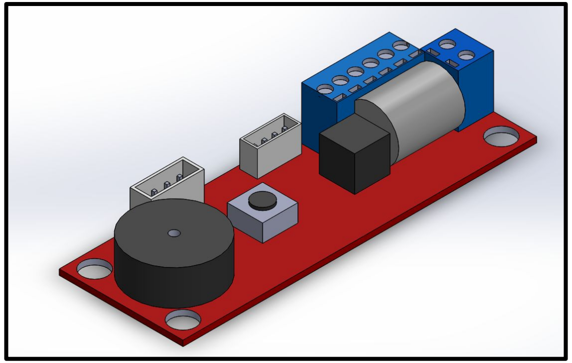
Motor	Simulation Altitude (ft)	Actual Altitude (ft)	% difference
L851	4874	5415	9.99%
L3200	4566	4876	6.36%

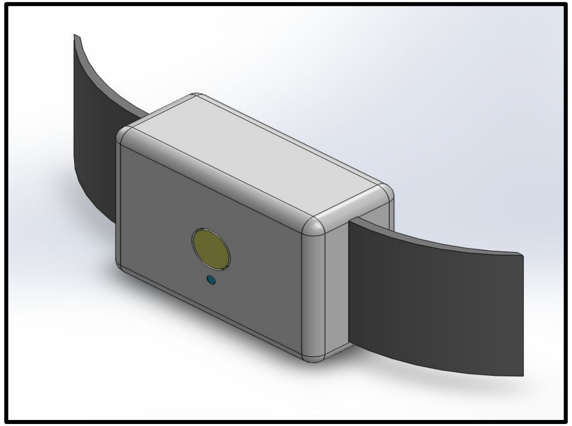
Recovery

The recovery system is governed by 2 Stratologger CF altimeters

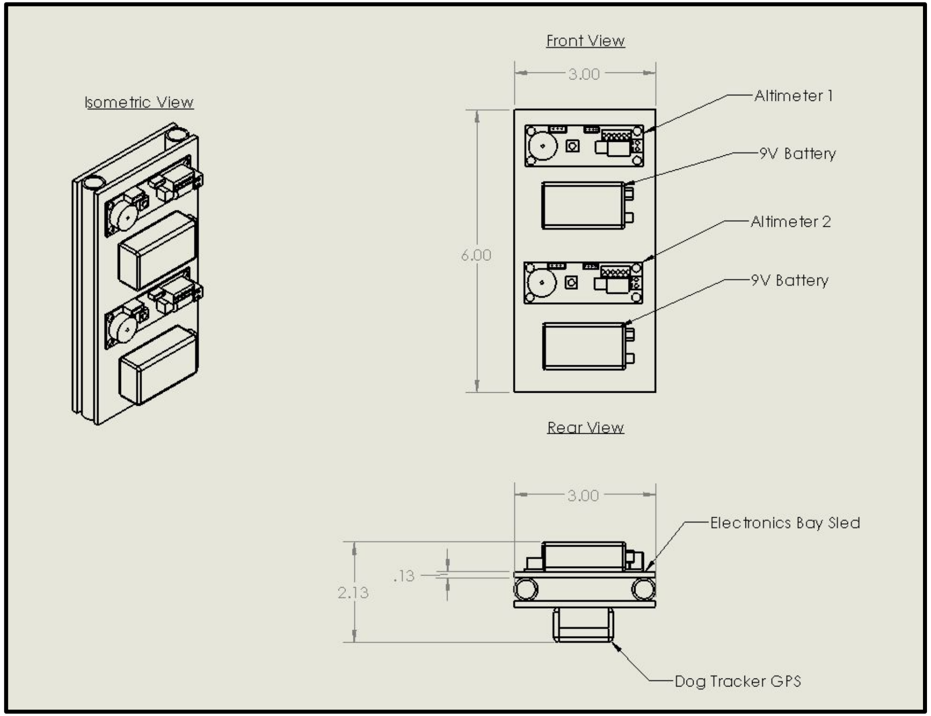
- Powered by 2, 9 volt D batteries
- Altimeters wired to a 2 screw switches
- Each altimeters sends a charge to black powder cup on either side on the electronics bay
- Backup charges are set off at a lower altitude
- A dog tracker GPS will relay position of the launch vehicle upon landing

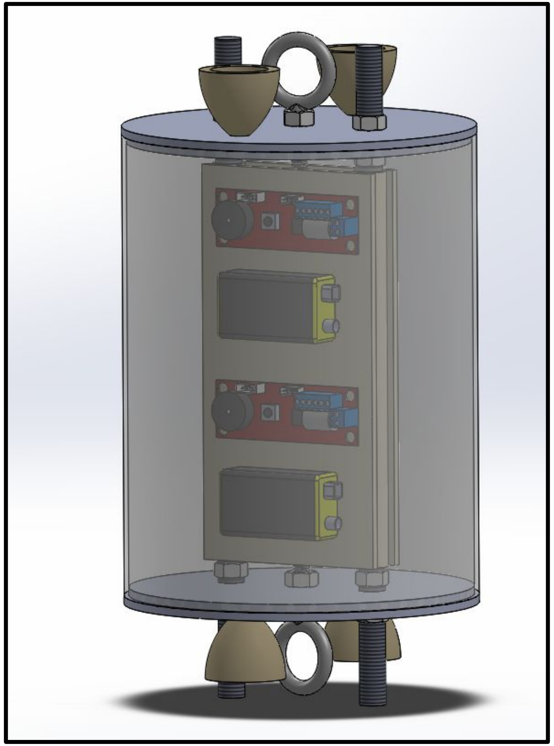
A 26” drogue parachute and a 120” main parachute will be ejected from rocket at apogee and 700 ft, respectively





Recovery





Vehicle Design ○ Payload Design ○ Project Plan

Staged Recovery Test

Workshop Tests

- Altimeters tested in vacuum container to verify readings are being taken

Ground Tests

- Checklists for tests have been and will be followed to ensure safety
- 3 feet rule is used to determine if ejection was successful

Full Scale and Subscale

- The 2 full scale flights and the subscale flight illustrated the ability of the recovery system

Vehicle Requirements Verification

All requirements have been verified by the successful full scale launches

Full requirement verification table can be found in the FRR document

#	Requirement	Design Feature	Verification	Verification Status
1.1	The vehicle shall deliver the payload to an apogee altitude of 5,280 feet AGL	Launch Vehicle Structure and Motor Selection	OpenRocket simulations, Subscale Launch, and 2 Full Scale Test Launches	Verified
1.3	The launch vehicle shall be designed to be recoverable and reusable	Launch Vehicle Structure	Subscale and full scale launch tests	Verified
2.1	The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude	Recovery System	Ground tests, subscale and full scale launch tests	Verified
2.3	At landing, each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lb	Parachutes	OpenRocket simulations, kinetic energy calculations	Verified

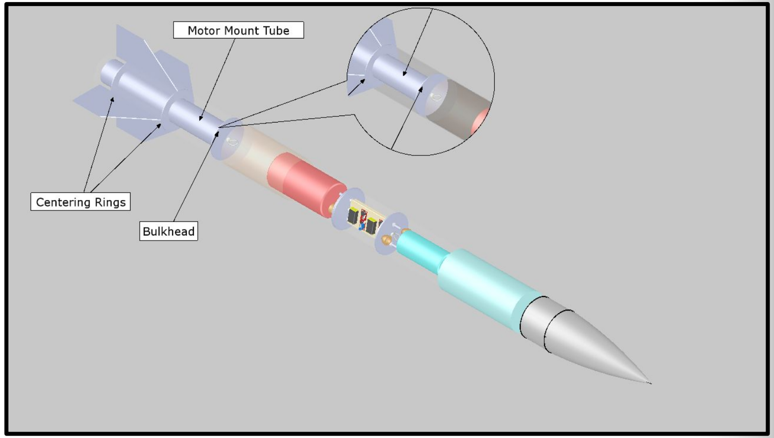
Launch Vehicle Interfaces

Motor mount

- Centering rings will be epoxied to motor mount tube and aft body tube
- The motor retainer is secured into the aft most centering ring

Fins

- Fin tabs epoxied onto motor mount tube between centering rings
- Fin-motor mount tube assembly slid into aft body tube and be epoxied
- Extra fiber glass epoxied onto aft body tube and fins using "tip-to-tip" method



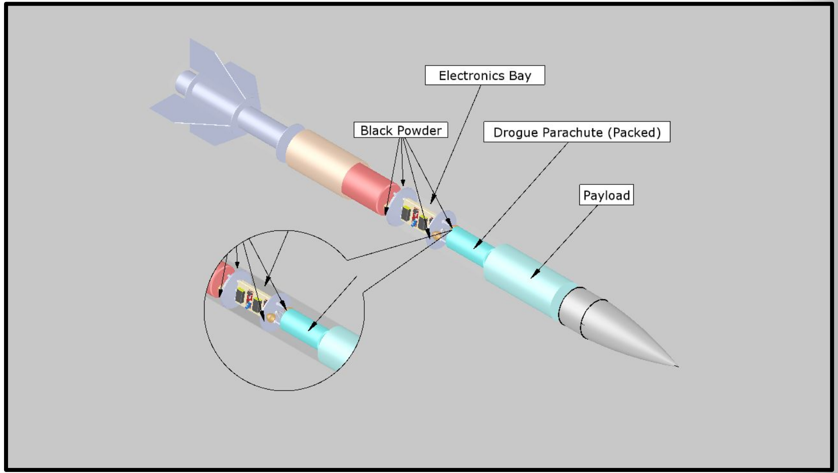
Launch Vehicle Interfaces

Electronics Bay

- Electronics bay housing is a phenolic tube; fits tightly inside forward body tube
- Secured by four screws
- Two screw switches used to turn altimeters on

HAL Payload

- Payload will sit inside the forward body tube, on top of the drogue parachute
- Payload diameter: 5.3 inches
- Body tube inner diameter: 5.38 inches



Launch Vehicle Interfaces

Section Interfaces

- Coupler is epoxied into the aft body tube; forward body tube will slide on and be secured by four shear pins
- Nose cone shoulder will slide into forward body tube and be secured by four shear pins

Launch Rail

- Rail buttons will fit a 1515 rail
- 12 ft rail will be used to maximize exit stability
- The apparent angle of attack will lower the static stability margin to 2.02 calibers

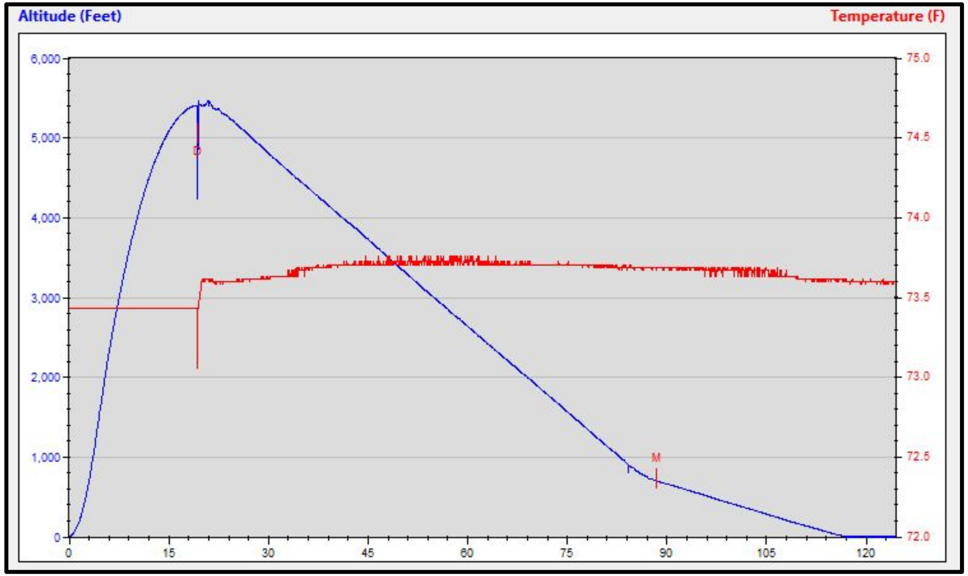
Payload Integration

The HAL payload loads into the forward body tube

- The payload sits directly forward of the drogue parachute
- The payload rests inside the body tube like the shoulder of the nose cone
- The lander leg design has been configured to allow the best possible ejection from the forward body tube

Payload Integration

The HAL payload will withstand temperature flux from the black powder charges. The max temperature experienced is 73.8 degrees Fahrenheit.



Payload Design

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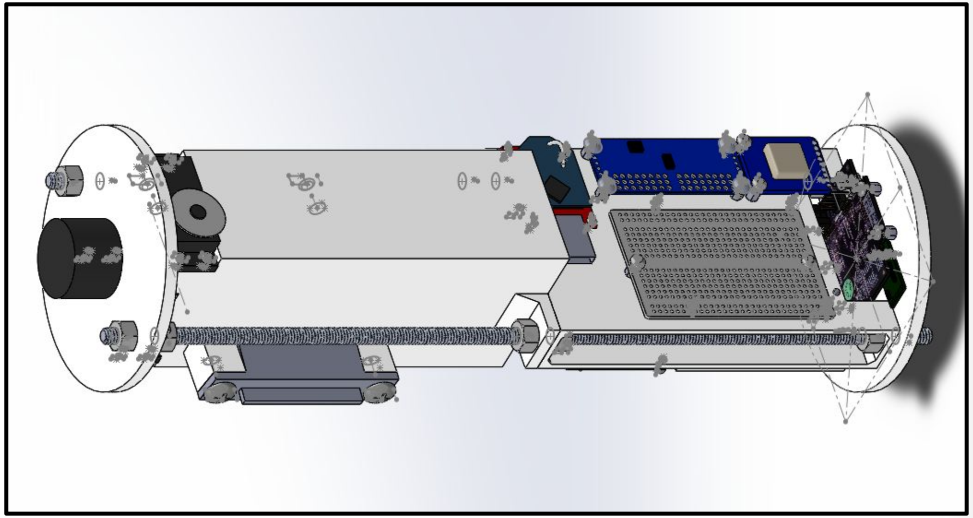
Payload Design Overview

- Rotary switch to toggle the power
- Servos control the parafoil
- Release mechanisms deploy the legs
- Electronics suite provides lots of information
- Camera for ground imaging
- Wireless transmission of data
- Raspberry Pi for processing and control



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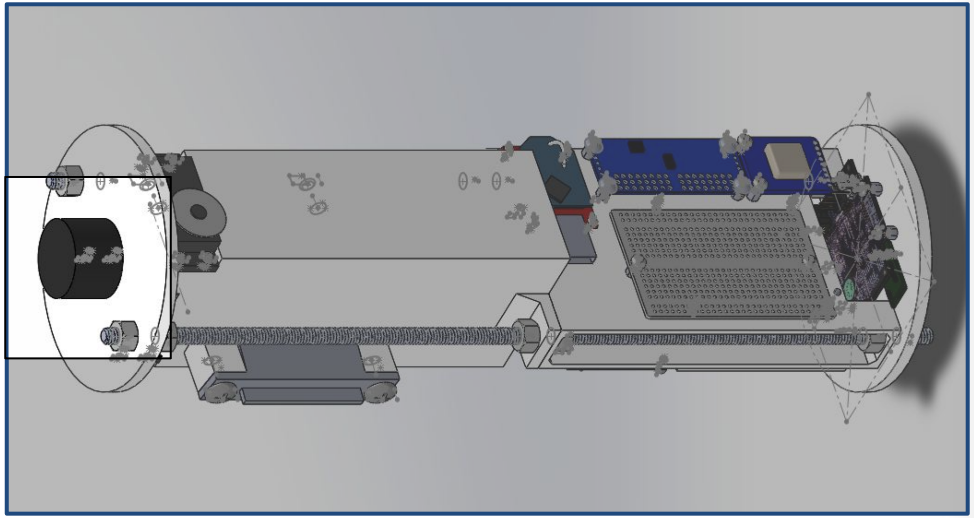

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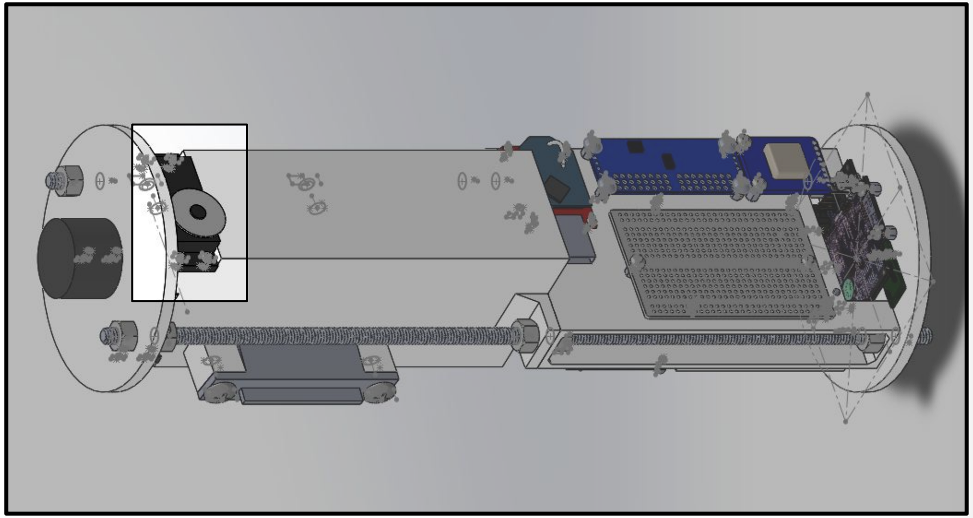

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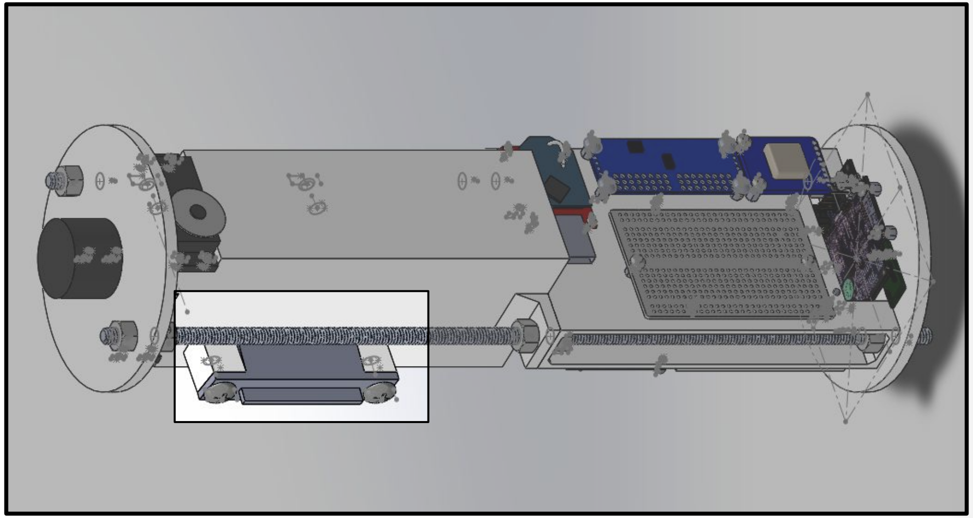

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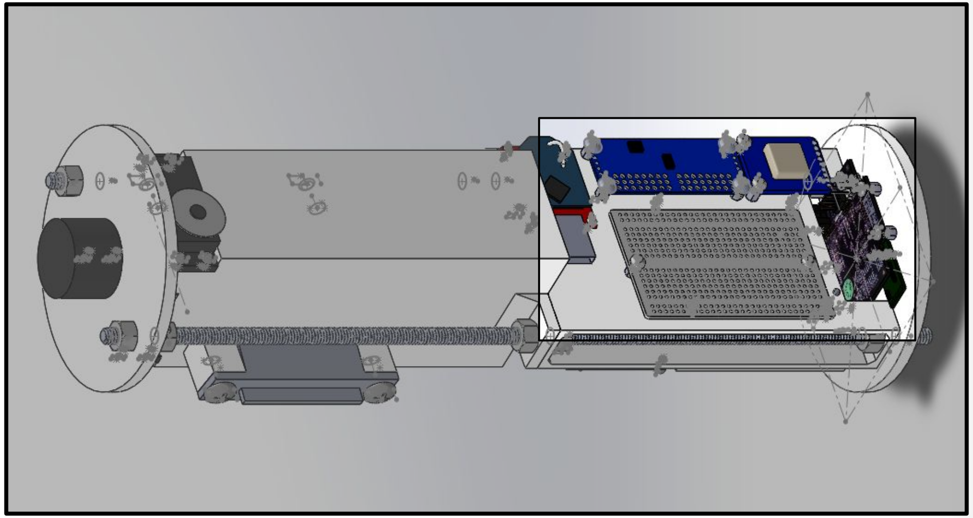

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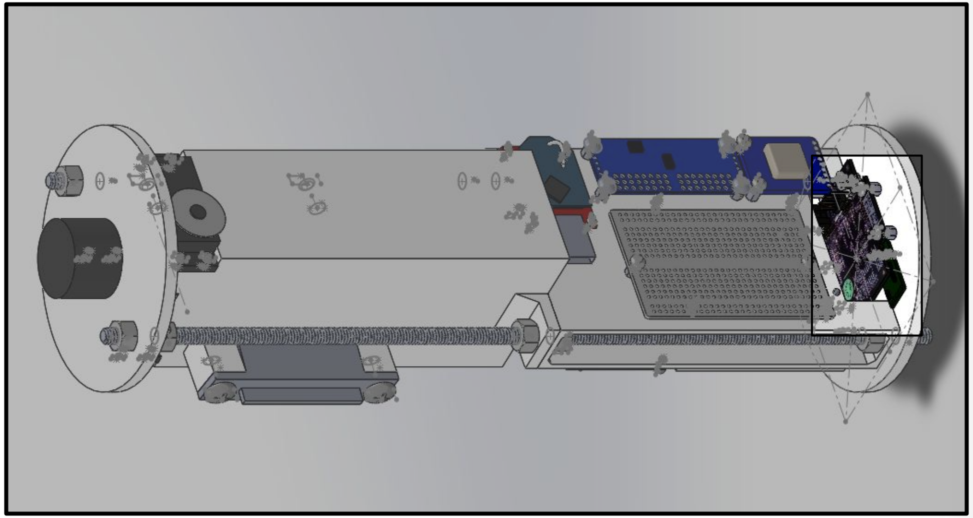

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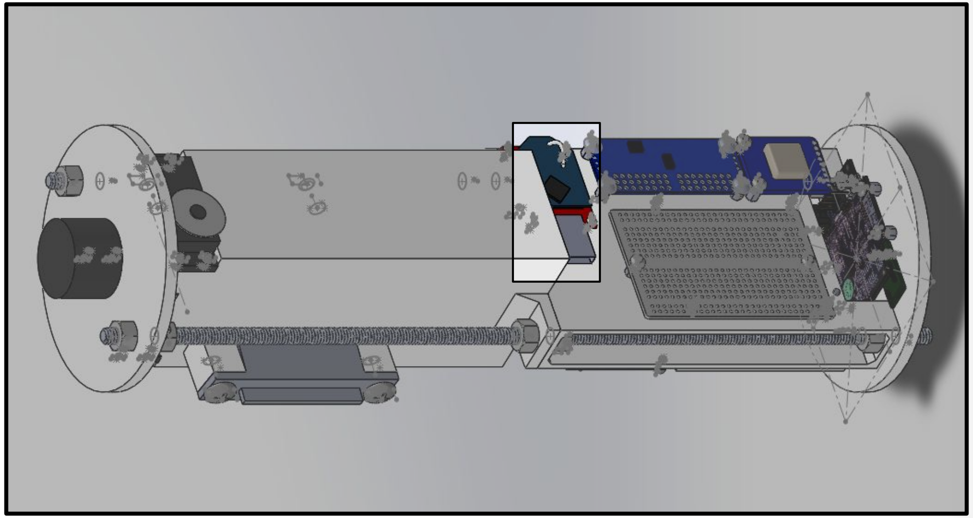

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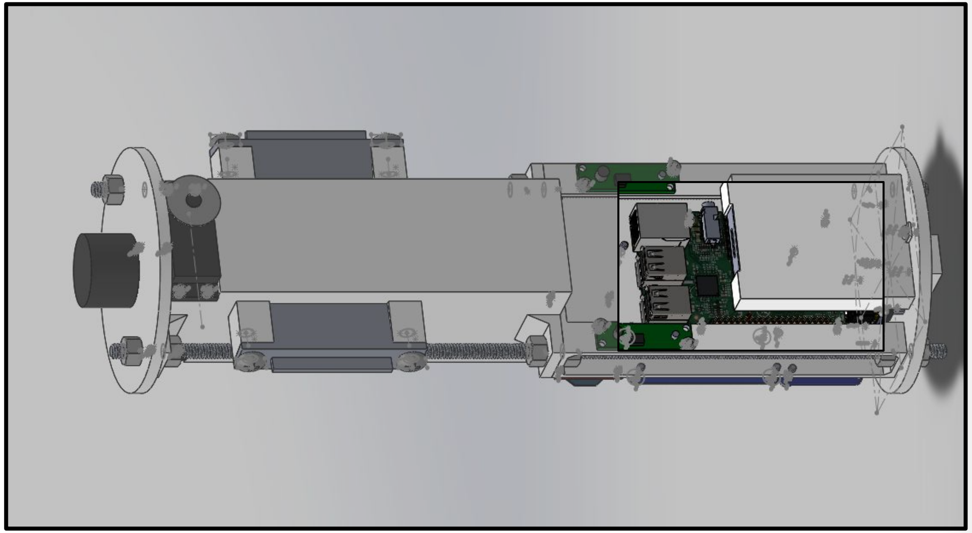
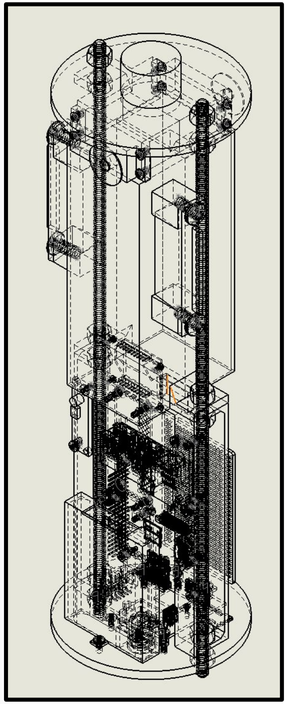
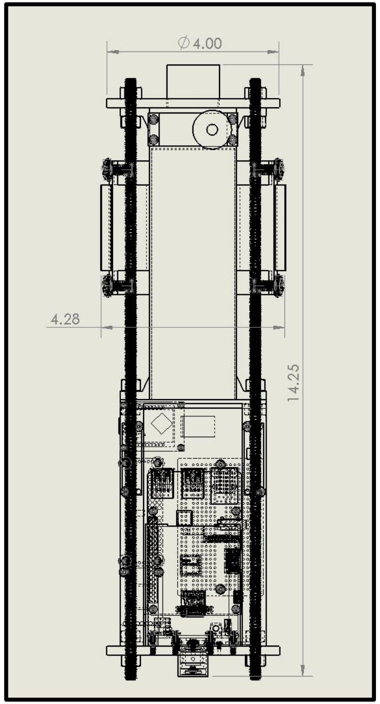
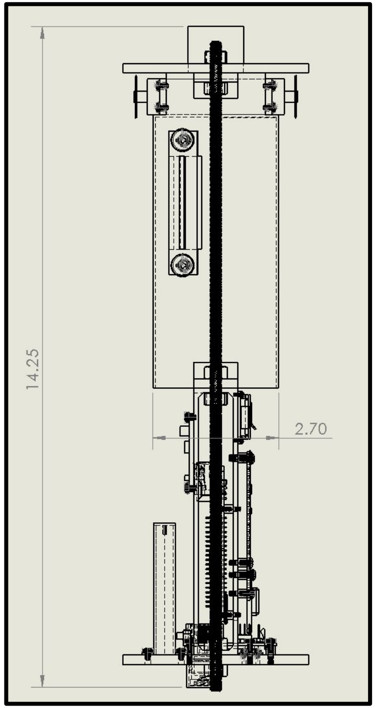
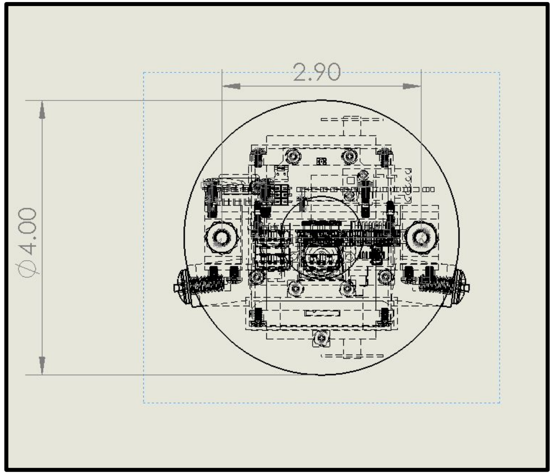


Payload Dimensions





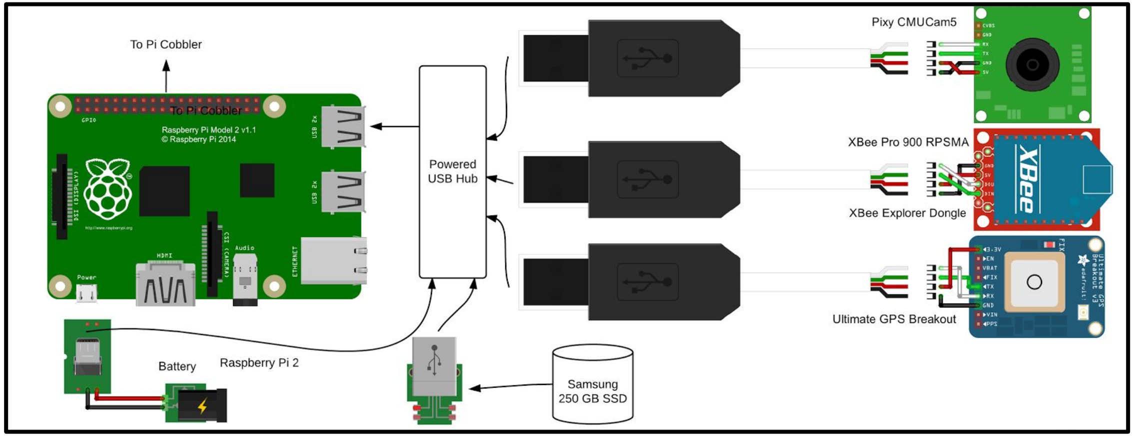




Payload Interfaces

USB Connections:

- CMUCam5
- XBee Pro
- GPS
- SSD



New Addition:
Powered USB Hub

Payload Interfaces

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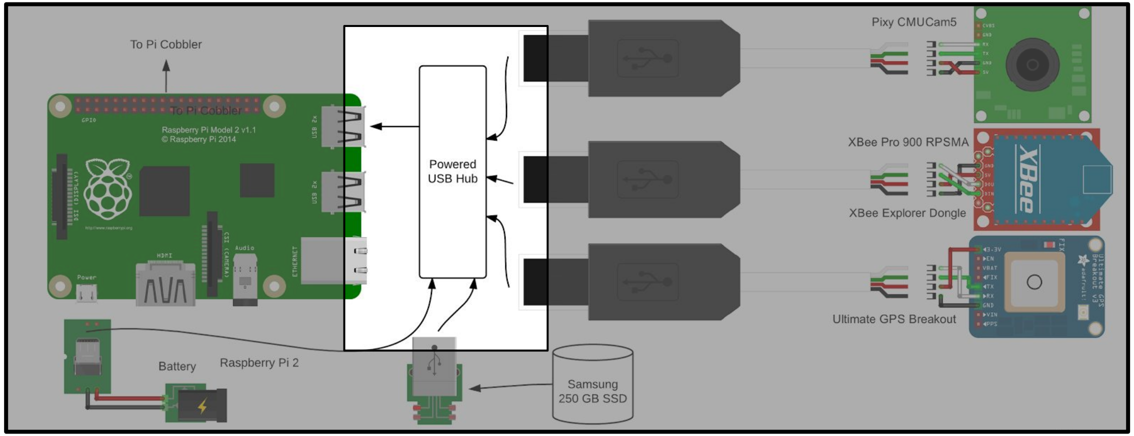

New Addition:
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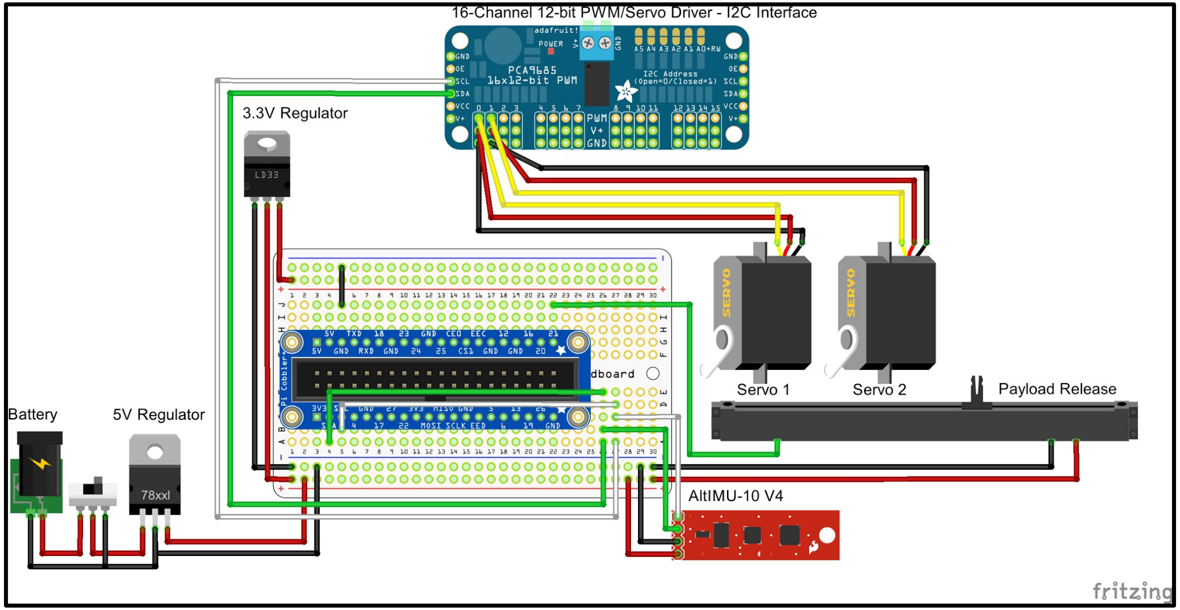
Payload Interfaces

GPIO Connections

- Servos (2)
- Payload release (2)
- AltIMU-10



Payload Interfaces

Physical Interfaces:

- Parafoil guidelines attach to the bolts on the top disc
- Parafoil toggle lines attach to the servo motors
- Leg hinges are epoxied to the fiberglass hull of the payload
- Hull is held by the top and bottom discs, which are bolted together on top of the brackets
- Most components are screwed into the brackets

Payload Requirements Verification

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics	Verification Method
Guided Descent	Descend at a controlled velocity	Payload must descend at a safe velocity that is held relatively constant	Parafoil will be used instead of traditional parachute	Parafoil fills with air and resembles and airfoil. The parafoil will be deployed in a turning state to mitigate the effects of loss of control.	Testing
	Guide payload descent	Payload must be able to avoid any landing hazards detected			Inspection
	Deploy parafoil in a reliable manner during payload descent	Deployment must limit risk of tangling and limit number of black powder charges used	Deploy parafoil while payload releases	Upon deployment, parafoil will fill with air and begin working	Analysis
	Limit landing velocity	Payload must land with less than 75 ft-lb kinetic energy, so velocity must be minimized before landing	Flare Technique	Pulling on both parafoil wires, will slow the payload down when landing	Analysis
	Angle of incidence	Payload must descend at a slow vertical speed and with a good glide ratio.	Angle of incidence of -3.75° (See *Figures 4.14 and 4.15*)	Lines will be sewn to maintain consistent angle of incidence.	Testing

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	Deploy parafoil in a reliable manner during payload descent	Deployment must limit risk of tangling and limit number of black powder charges used	Deploy parafoil while payload releases	Upon deployment, parafoil will fill with air and begin working	Analysis
	Limit landing velocity	Payload must land with less than 75 ft-lb kinetic energy, so velocity must be minimized before landing	Flare Technique	Pulling on both parafoil wires, will slow the payload down when landing	Analysis
	Angle of incidence	Payload must descend at a slow vertical speed and with a good glide ratio.	Angle of incidence of -3.75° (See *Figures 4.14 and 4.15*)	Lines will be sewn to maintain consistent angle of incidence.	Testing

Payload Requirements Verification

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics	Verification Method
Landing Hazards	Detect hazards	See Appendix E	Pixy CMUcam5	Take images of the ground	Testing
	Identify hazards	See Appendix E	Pixy CMUcam5 Raspberry Pi	Analyze images taken by the camera	Testing
	Store data onboard	See Appendix E	250GB USB Portable Solid State Drive	Stores onboard data quickly, uses less power, resistant to vibrations	Testing
	Transmit data to ground station	See Appendix E	XBee Pro 900	The XBee on the payload will communicate with another XBee at the ground station	Testing

Payload Requirements Verification

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics	Verification Method
Landing Hazards	Detect hazards	See Appendix E	Pixy CMUcam5	Take images of the ground	Testing
	Identify hazards	See Appendix E	Pixy CMUcam5 Raspberry Pi	Analyze images taken by the camera	Testing
	Store data onboard	See Appendix E	250GB USB Portable Solid State Drive	Stores onboard data quickly, uses less power, resistant to vibrations	Testing
	Transmit data to ground station	See Appendix E	XBee Pro 900	The XBee on the payload will communicate with another XBee at the ground station	Testing

Payload Requirements Verification

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics	Verification Method
Control	Run software in real time	Allows for the fast response times	Python code	Allows for more up to date information	Analysis
	Know altitude	See Appendix E	AltIMU-10 v4	The barometer will receive pressure readings and will output altitude	Testing
	Know orientation	See Appendix E		The gyro will provide payload attitude	Testing
	Know location	See Appendix E	Adafruit Ultimate GPS Breakout	The GPS is accurate to 3 m	Testing
	Know velocity	See Appendix E		The GPS is accurate to 0.1 m/s	Testing

Payload Requirements Verification

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics	Verification Method
Landing	Deploy legs at a specified altitude	Minimizes drag and moments on payload	Payload Release	Release lander legs when current passes through	Testing
	Keep upright and stable upon touchdown	Allow for ease of communication between the payload and the ground station	Use lander with large leg spread	Longer legs will increase the difficulty of tipping the payload	Testing
	Absorb forward momentum	Allow for the legs to release as well as absorb some of the impact when landing	Torsion springs	Upon landing, the springs will coil up and absorb some of the energy to protect the payload	Testing

Project Plan

Alabama Rocket Engineering Systems (ARES) Team

The University of Alabama

Budget Overview

Current Projected Budget: $7,980.77

Increases are attributed to additional components and expedited shipping.

Report	**Budget Total**
Proposal	$7,454.12
PDR	$7,188.32
CDR	$7,607.52
FRR	**$7,980.77**

Categorical Spending

Category	Current Expenses	Budgeted Expenses	Difference
Structures	$1,840.96	$1,438.95	-$402.01
Hazard Detection Payload	$774.36	$920.18	$145.82
Guided Descent Payload	$161.20	$155.80	-$5.40
Recovery	$1,022.61	$720.20	-$302.41
Subscale	$743.71	$851.51	$107.80
Safety	$89.91	$170.88	$80.97
Outreach	$257.05	$500.00	$343.95
Travel	-	$2,850.00	$2,850.00
Total Expenditures:	**$4,889.80**	**Total Remaining in Budget:**	**$2,818.76**

Current Fund Balances

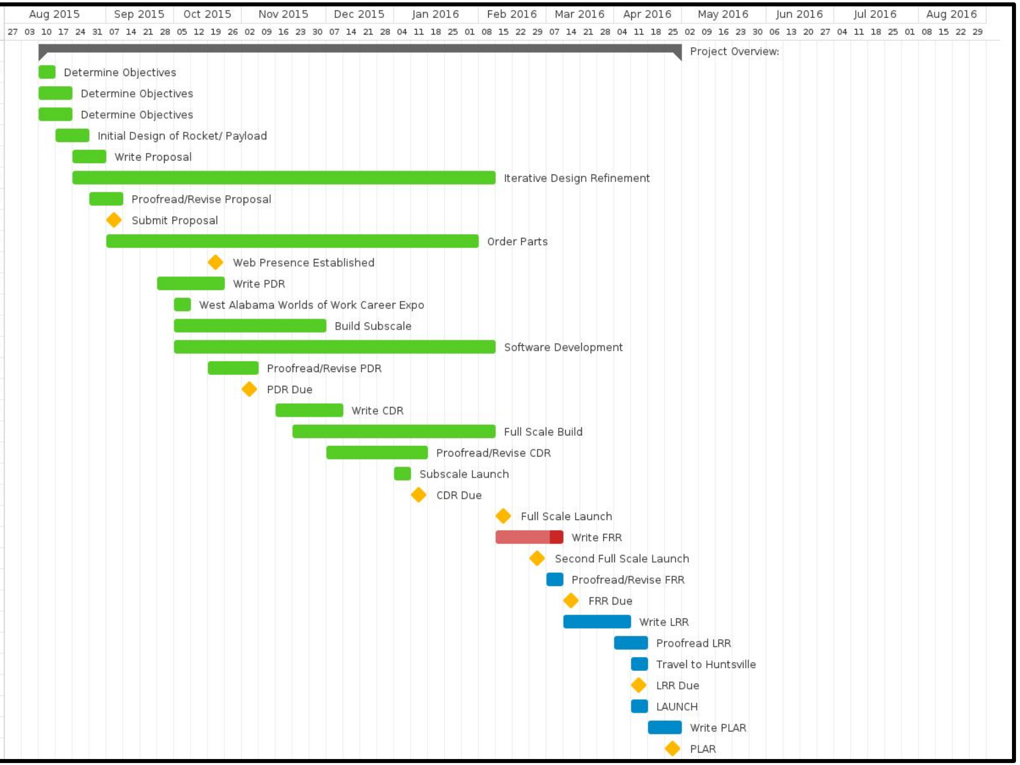
Fund Name	Sum	Expenses	Remaining Total
ASGC	$7,650.00	$3,576.12	$4,073.88
Department of Aerospace Engineering and Mechanics	$650.00	$635.83	$14.17
Orbital ATK Travel Stipend	----	----	----

The team has $4,088.05 of funds remaining.

Timeline Overview

Gantt Chart

	Project Overview:	69%
2	Determine Objectives	100%
3	Determine Objectives	100%
4	Determine Objectives	100%
5	Initial Design of Rocket/ Payload	100%
6	Write Proposal	100%
7	Iterative Design Refinement	100%
8	Proofread/Revise Proposal	100%
9	Submit Proposal	100%
10	Order Parts	100%
11	Web Presence Established	100%
12	Write PDR	100%
13	West Alabama Worlds of Work Career Expo	100%
14	Build Subscale	100%
15	Software Development	100%
16	Proofread/Revise PDR	100%
17	PDR Due	100%
18	Write CDR	100%
19	Full Scale Build	100%
20	Proofread/Revise CDR	100%
21	Subscale Launch	100%
22	CDR Due	100%
23	Full Scale Launch	100%
24	Write FRR	80%
25	Second Full Scale Launch	0%
26	Proofread/Revise FRR	0%
27	FRR Due	0%
28	Write LRR	0%
29	Proofread LRR	0%
30	Travel to Huntsville	0%
31	LRR Due	0%
32	LAUNCH	0%
33	Write PLAR	0%
34	PLAR	0%



Vehicle Design ○ Payload Design ○ **Project Plan**

Educational Outreach

The ARES Team has reached a total of 1553 students through educational outreach

- 583 of these students were reached directly through activities pertaining to rocketry

The team partnered with SEDS to hold a bottle rocket competition for three local middle schools

Name of Event	Date(s)	Number of Students Reached	Grades of Students	Direct or Indirect
Get on Board Day	8/27/2015	211	12+	Indirect
Boy Scouts	9/22/2015, 10/6/2015	18	5-9	Direct
E-Day	10/1/2015	186	5-9, 10-12	Indirect
West Alabama Works WOW Expo	10/8/2015, 10/9/2015	573	5-9, 10-12, 12+, educators	Indirect
Northridge High School	10/23/2015, 11/13/2015	25	10-12	Direct
Hillcrest High School	10/29/2015	50	10-12	Direct
Al's Pal's	11/9/2015, 11/10/2015, 11/12/2015	270	1-5	Direct
Girl Scouts "Women in Science" Day	11/14/2015	130	1-5, 5-9	Direct
Northridge High School	2/25/2016	19	10-12	Direct
SEDS Tuscaloosa Rocketry Challenge	2/25/2016, 3/2/2016, 3/3/2016	71	6-8	Direct

Questions?