Critical Design Review Presentation

Alabama Rocket Engineering Systems (ARES) Team

The University of Alabama

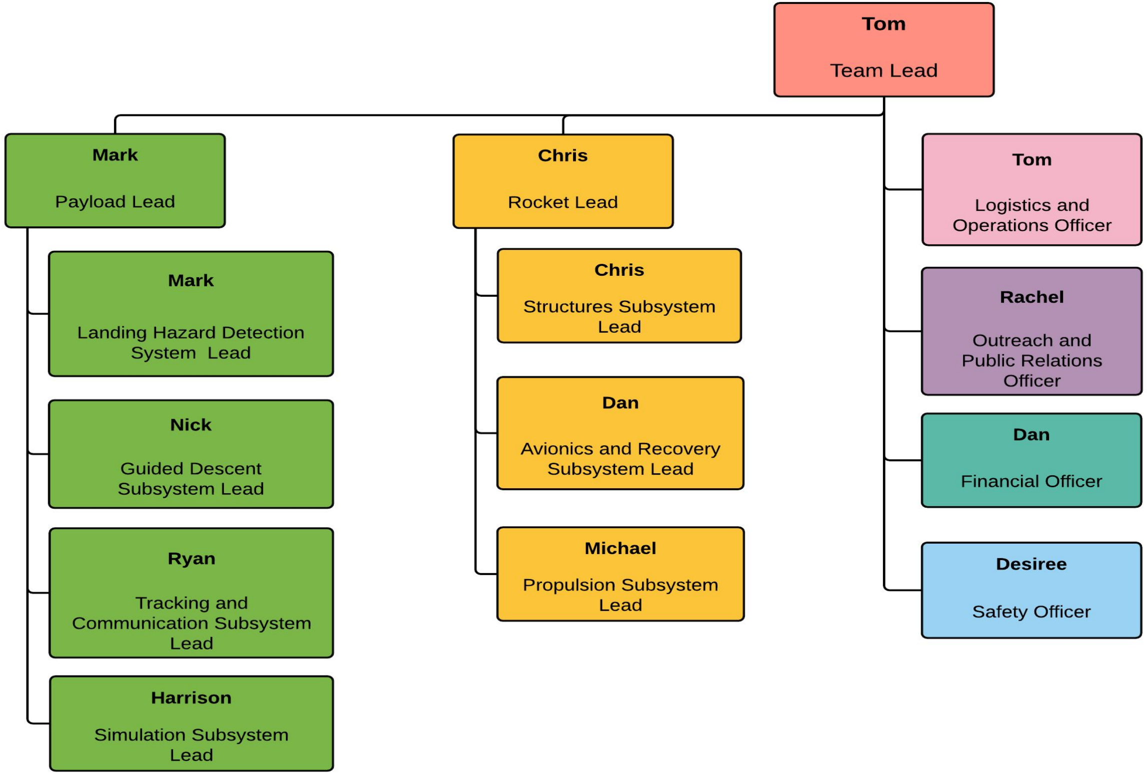
Overview

- 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

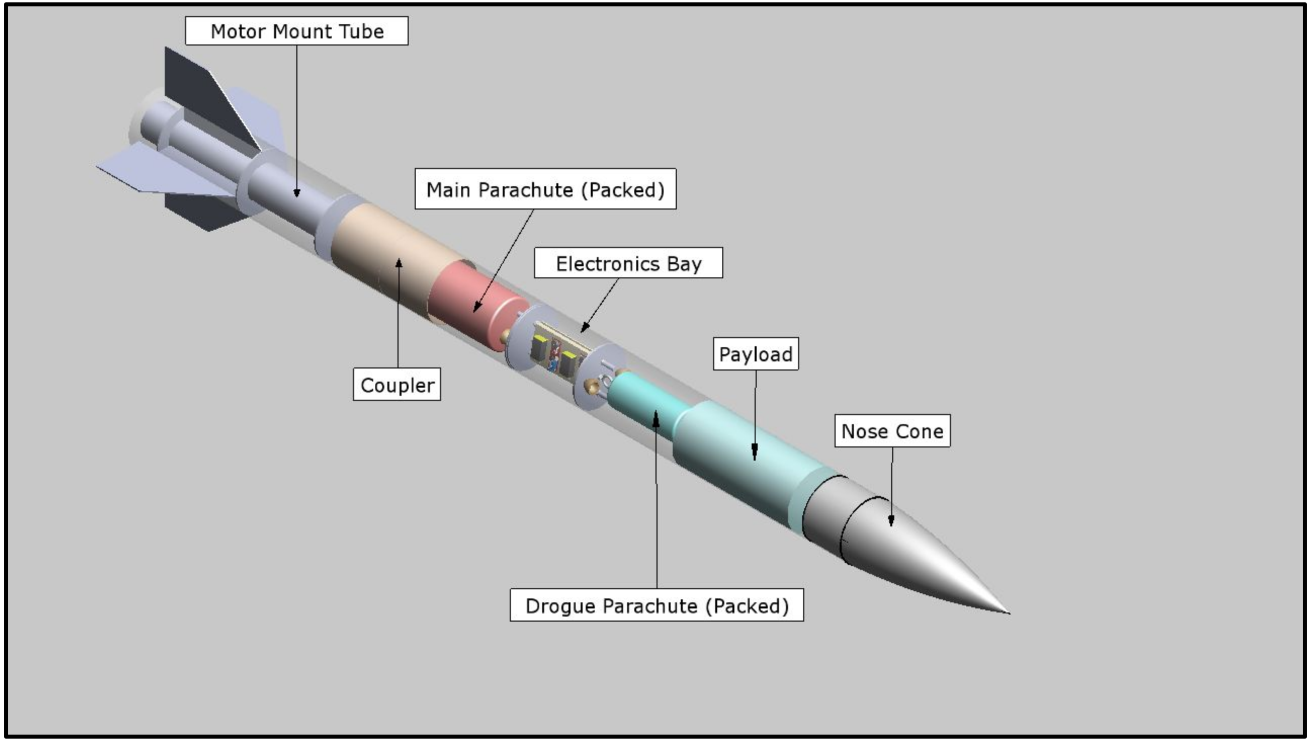


Launch Vehicle Design

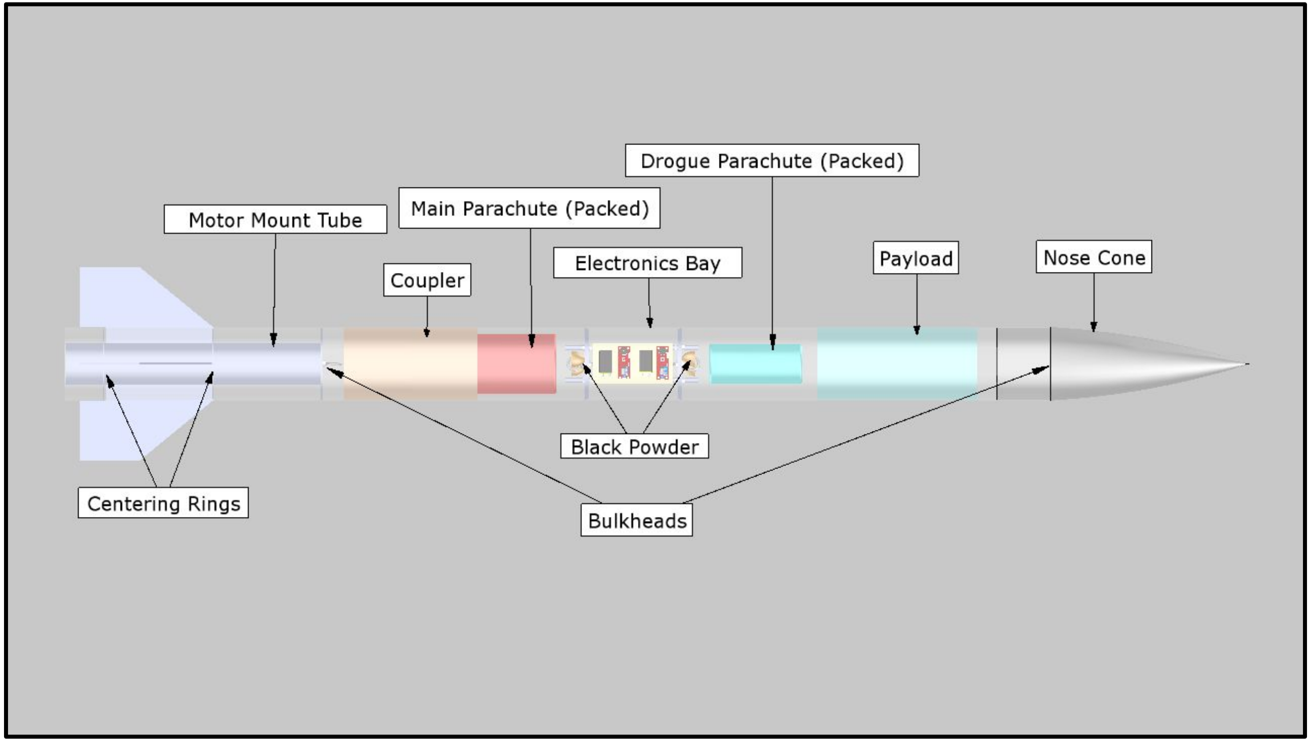
Alabama Rocket Engineering Systems (ARES) Team

The University of Alabama

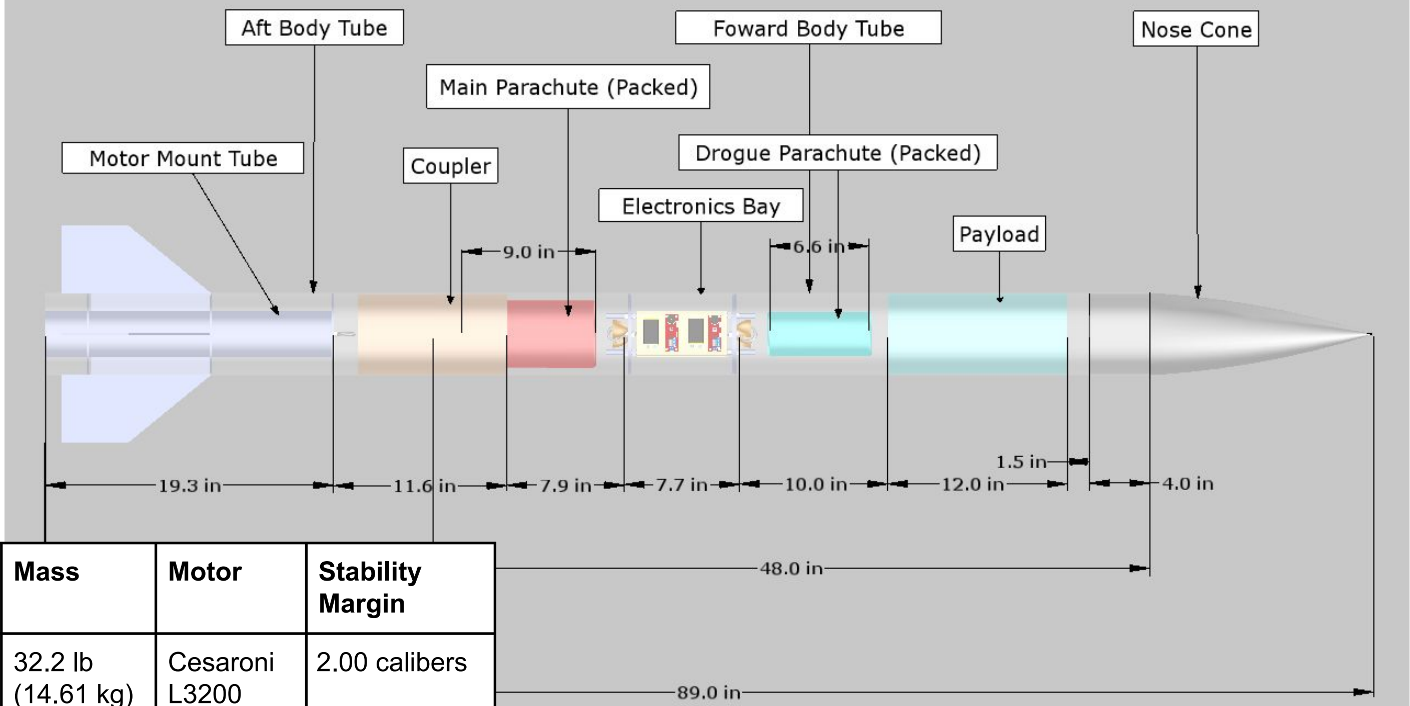
Launch Vehicle Design



Launch Vehicle Design

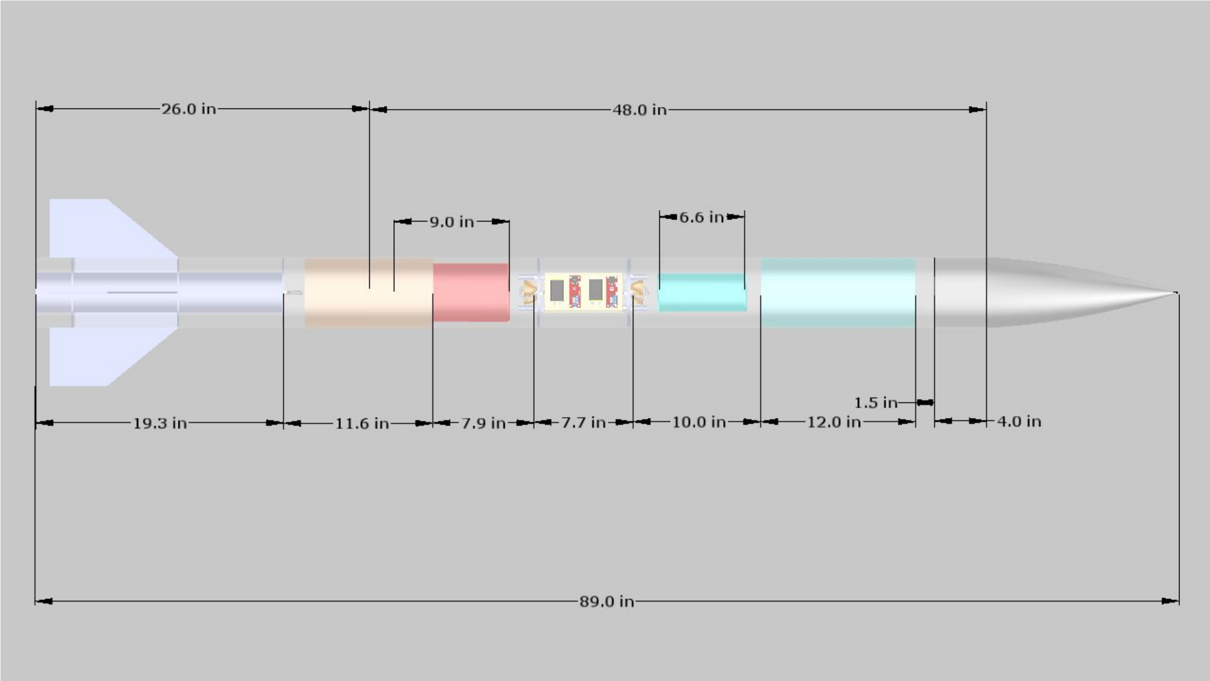


Launch Vehicle Dimensions



Length	Diameter	Mass	Motor	Stability Margin
89 inches (2.26 m)	5.53 inches (0.141 m)	32.2 lb (14.61 kg)	Cesaroni L3200	2.00 calibers

Launch Vehicle Dimensions

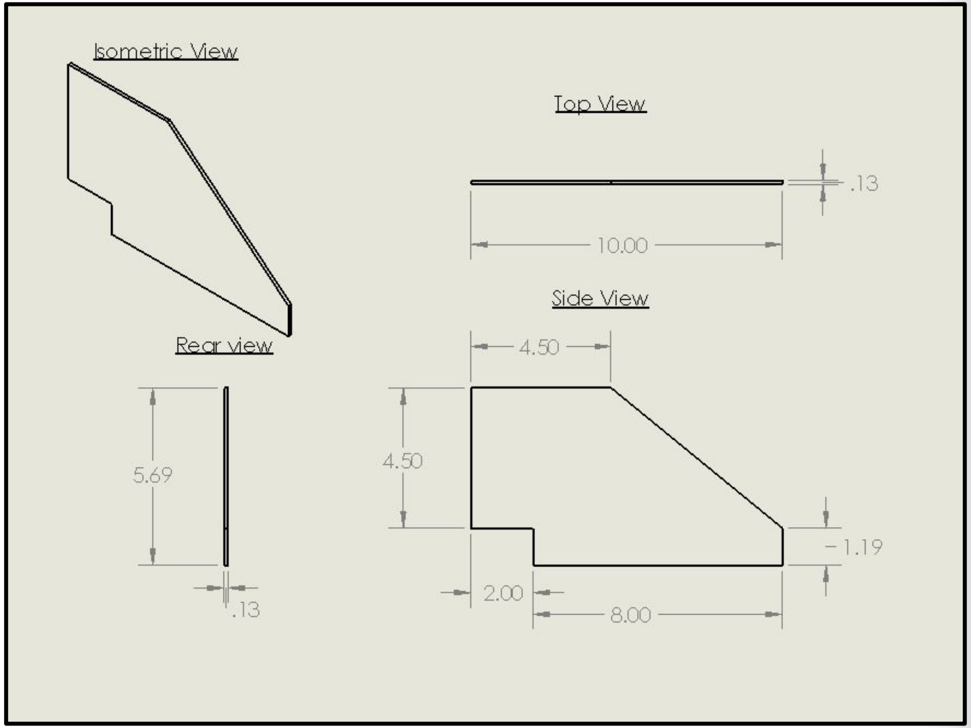


Key Design Feature - Fins

- Fins size based on creating a favorable stability margin

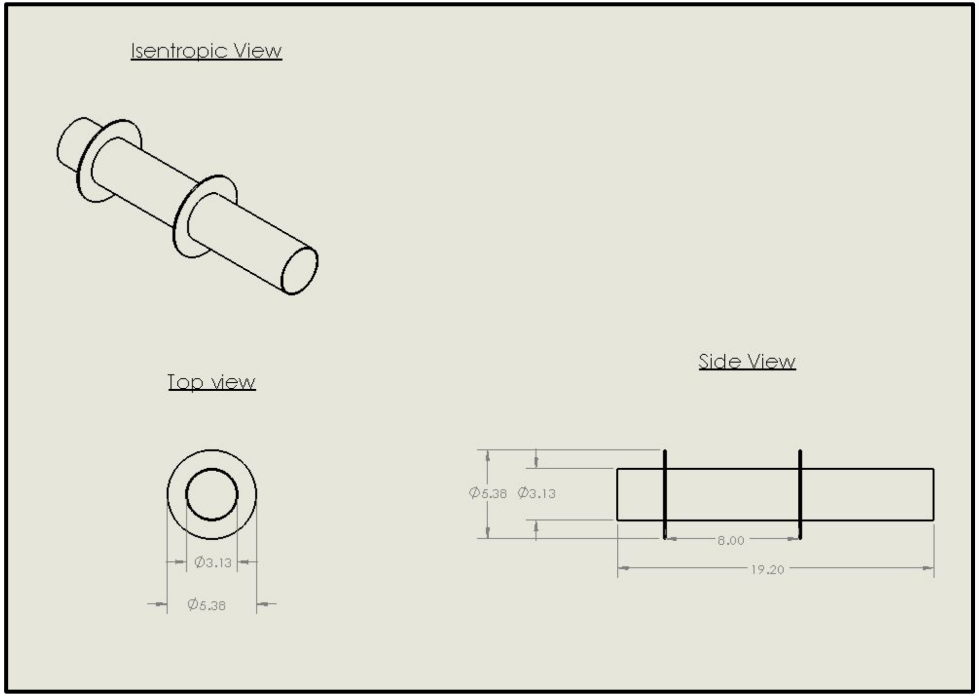
- Fin tabs are epoxied to the centering rings and motor mount tube

- A fillet of epoxy will be made between the fin face and the aft body tube



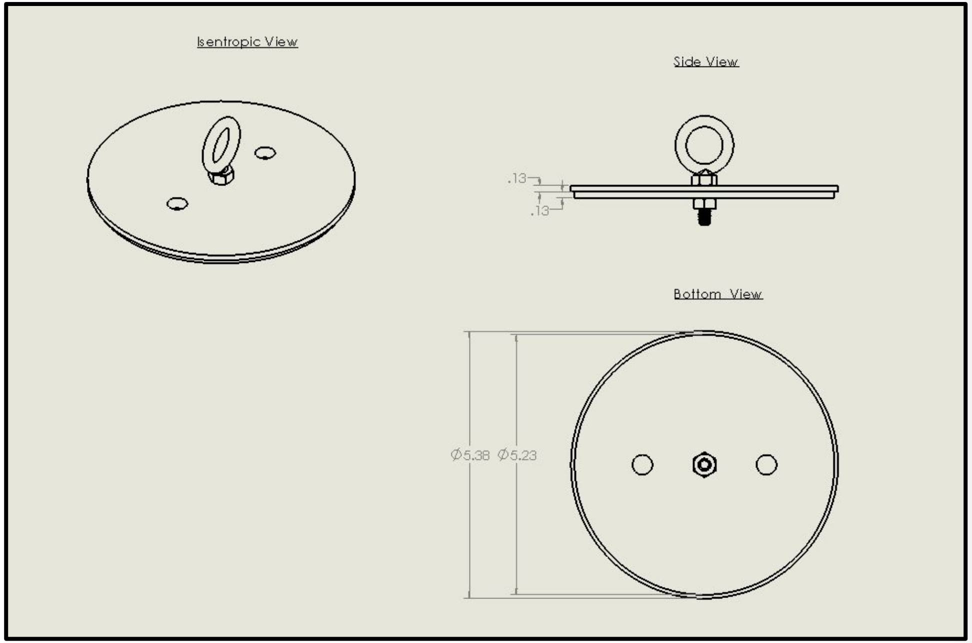
Key Design Feature - Motor Mount

- Motor Mount contains and stabilizes the motor during flight
- Centering rings will be 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 will provide eye bolts for parachute attachment
- Motor mount bulkhead transfers load to the rocket
- Electronics bay bulkheads protect altimeters from adverse pressure changes



Final Motor Choice

Manufacturer	Cesaroni Technology	**Brandname**	Pro75 3300-L3200-VMax
Motor Dim. (mm), (in)	75.00 x 485.14, 2.95 x 19.1	**Total Impulse (N*s), (lb*s)**	3300, 741.9
Avg. Motor Efficiency	50.8%	**Maximum Thrust (N), (lb)**	3723, 836.9
Specific Impulse (s)	216	**Avg. Thrust (N), (lb)**	3209, 721.4
Burntime (s)	1.03	**Altitude Projection, Bragg Farms - No Wind (ft)**	5306
Thrust-to-Weight Ratio	22.4	**Impulse-to-Weight Ratio**	22.9

Final Motor Choice

The original motor selection from PDR was a Cesaroni Technology Pro 54 2833L805-P

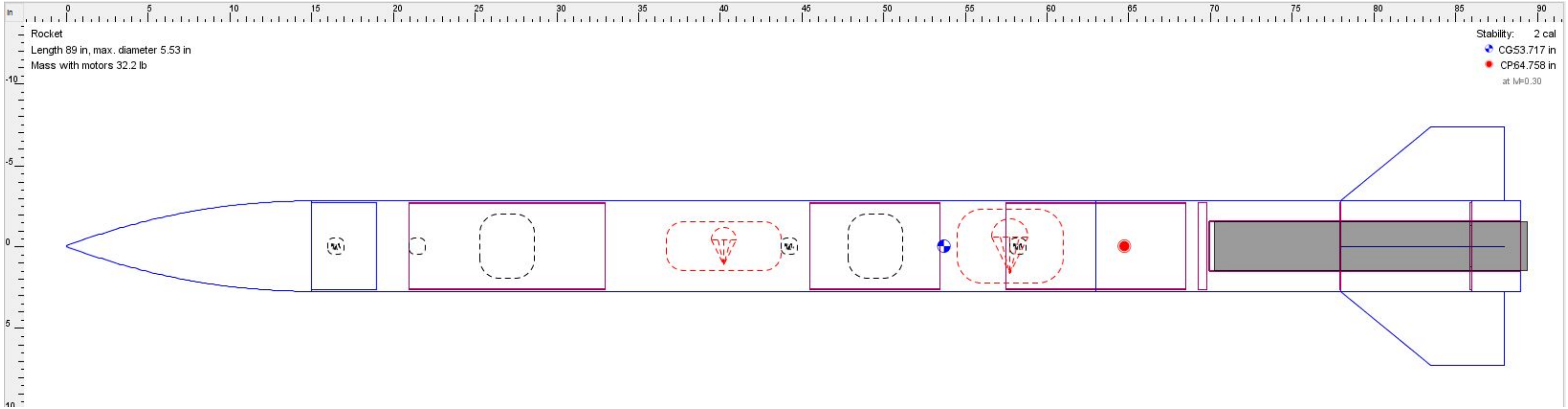
Updated to the final selection of the Pro 75 3300L3200-Vmax as the payload weight increased

OpenRocket's library of motors allowed the ARES team to experiment with different motors to find the best motor choice for the launch vehicle

The Cesaroni Pro 75 3300L3200-Vmax is available through "Chris' Rocket Supplies, LLC"

Rocket Stability

- Center of gravity and the center of pressure of the rocket are located 53.72 and 64.76 inches (1.36 and 1.64 m) from the tip of the nose cone
- Stability Margin: 2.00 calibers



T/W Ratio and Rail Exit Velocity

Thrust-to-Weight Ratio	22.4
Rail Exit Velocity (ft/s)	130.5
Rail Height (ft)	12
Static Stability Margin (off launch rail)	1.66 calibers

Mass Statement & Margin

- Expecting a 5% increase in mass
- OpenRocket subscale simulation vs mass of actual subscale

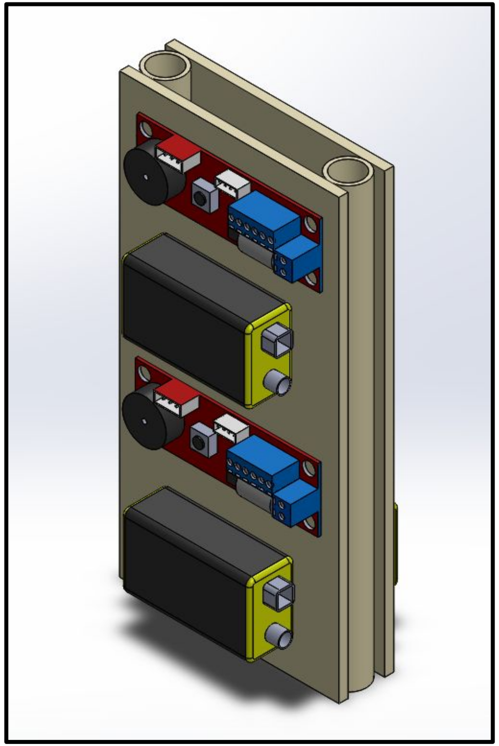
Component	Mass (lb)	Length (in)	Width or Diameter (in)
Nose Cone	1.31	15	5.5
Forward Body Tube	4.12	48	5.5
Aft Body Tube	2.23	30	5.5
Payload	6.20	12	5.43
Electronics Bay	2.4	8	5.43
Main Parachute (Packed)	1.2	6.5	4.5
Drogue Parachute (Packed)	0.948	3	3
Motor	7.2	19.1	2.95
Fins	1.86	10	4.5
Current Total	32.2	N/A	N/A
Total w/ expected increase	33.81	N/A	N/A

Recovery

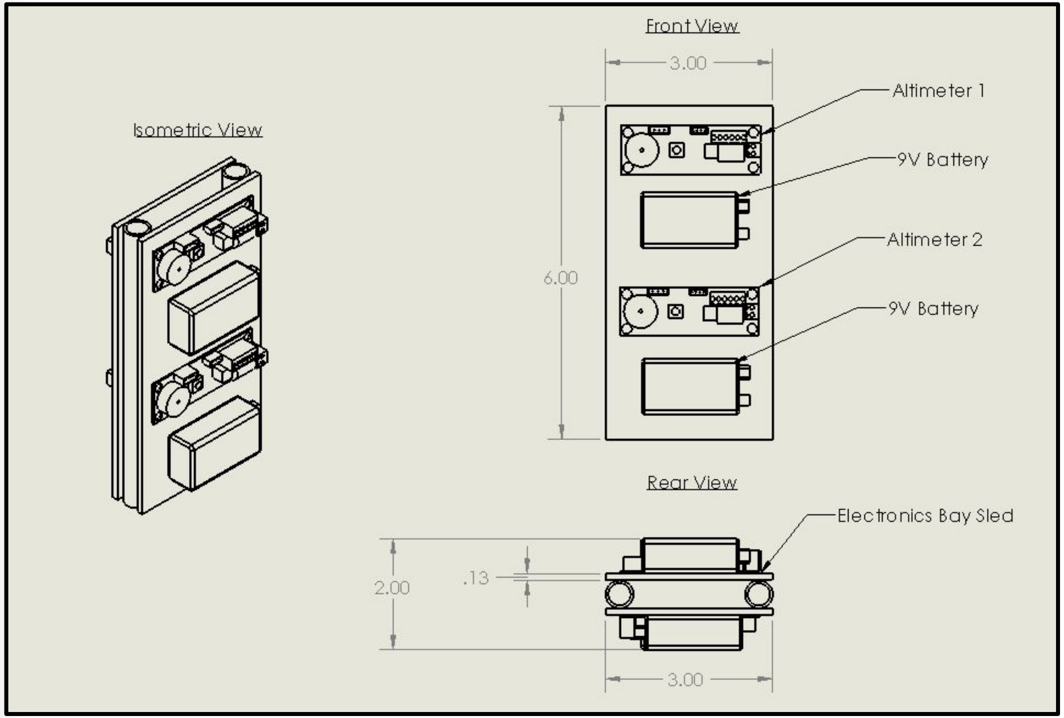
The recovery system is governed by 4 Stratologger CF altimeters

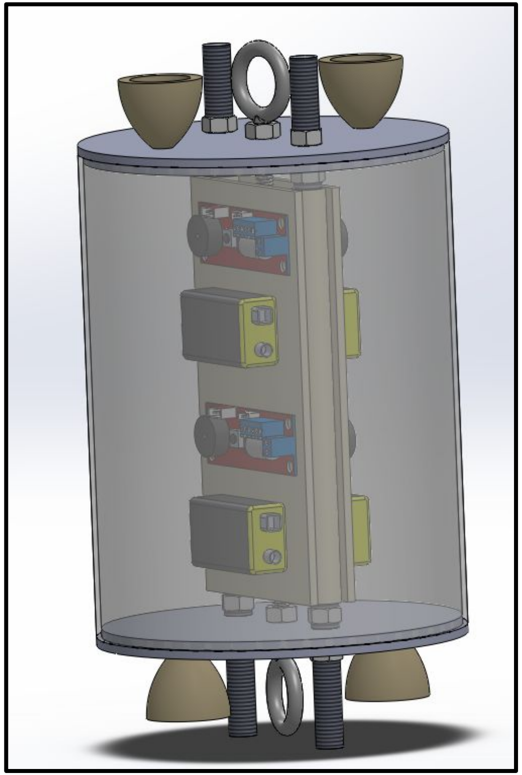
- Powered by 4, 9 volt D batteries
- Altimeters wired to a rotary switch
- Primary altimeters sends a charge to black powder cup
- Backup altimeters sends a back-up charge to a backup black powder cup at a lower altitude

A 54" drogue parachute and a 110" main parachute will be ejected from rocket at apogee and 900 ft, respectively



Recovery





Vehicle Design ○ Payload Design ○ Project Plan

Kinetic Energy at Landing

Maximum kinetic energy of any individual 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	1.31	60.72	12	33.34
Forward Body Section	8.43	23.94	42	22.66
Aft Body Section	9.99	21.98	54	19.19
Total Rocket	19.73	15.64	96	15.17

A 110 inch (2.79 m) main parachute for the total descending rocket is justified to safely land each independent section under the 75 ft-lb

Test Plans and Procedures

Ground Tests

- Charge tests will ensure clearance from the launch vehicle
- Altimeters will be tested in vacuum container to verify altitude readings

Sub-Scale Test

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

Full-Scale Test

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

Scale Model Flight Test

The subscale was built geometrically similar subscale rocket

- 72.7 % scaling ratio

The team chose to match the Mach number and impulse to weight ratio of the subscale as closely as possible to the full scale:

- Subscale motor: Cesaroni L585
- Estimated subscale Mach number: .60
- Estimated full scale Mach number: .65
- Impulse to weight ratio of subscale and full scale: 22.9

Staged Recovery Test

Workshop Tests

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

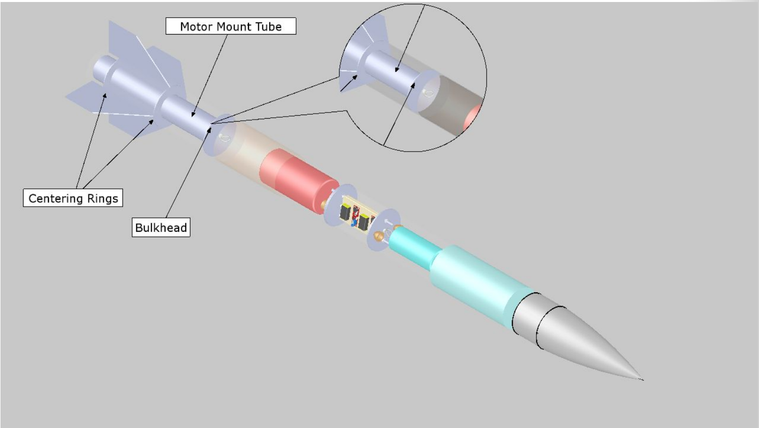
Ground Tests

- Checklists for tests will be followed to ensure safety
- Recovery and Ejection tests will ensure clearance from the launch vehicle
- Will be performed under supervision of Lee Brock
- 3 feet rule will be used to determine separation successful

Launch Vehicle Interfaces

Motor mount

- Centering rings and bulkhead will be epoxied to motor mount tube and aft body tube
- Motor mount bulkhead will transfer the load from the motor to the rest of the vehicle



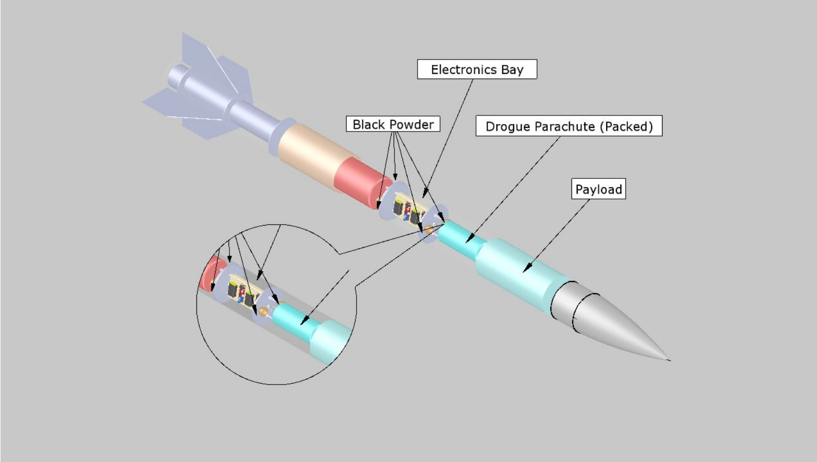
Fins

- Fin tabs will slide into slots on the aft body tube and be epoxied to the motor mount tube
- Epoxy will be used to create a fillet between the fin face and the aft body tube

Launch Vehicle Interfaces

Electronics Bay

- Electronics bay housing will be a fiberglass tube; will fit tightly inside forward body tube
- Secured by two screws
- Rotary switch 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 will be epoxied into the aft body tube; forward body tube will slide on and be secured by shear pins
- Nose cone shoulder will slide into forward body tube

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 1.66 calibers

Vehicle Requirements Verification

Many requirements are still pending verification

- Will be verified by full scale launch

Full requirement verification table can be found in the CDR 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	OpenRocket verified. Launch tests pending
1.3	The launch vehicle shall be designed to be recoverable and reusable	Launch Vehicle Structure	Subscale and full scale launch tests	Pending
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	Pending
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

Payload Integration

The HAL payload will be loaded into the forward body tube

- The payload will sit directly forward of the drogue parachute
- The payload will rest 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 Design

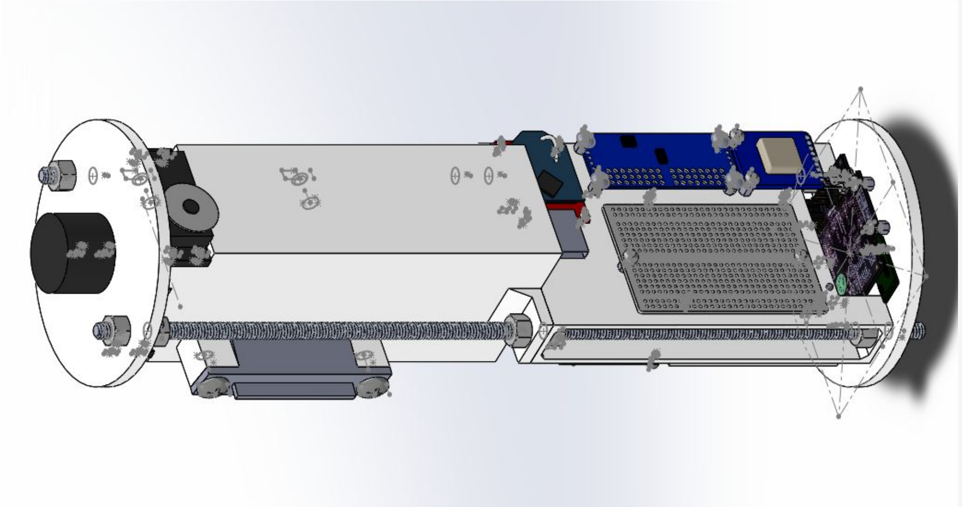
Alabama Rocket Engineering Systems (ARES) Team

The University of Alabama

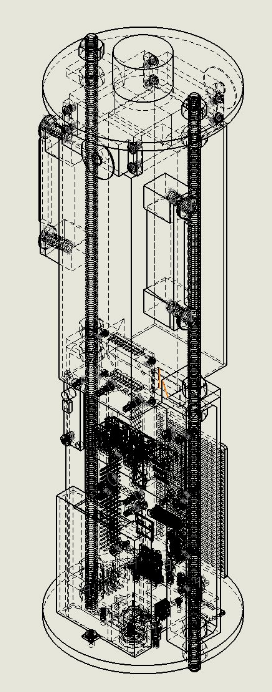
Payload Design Overview

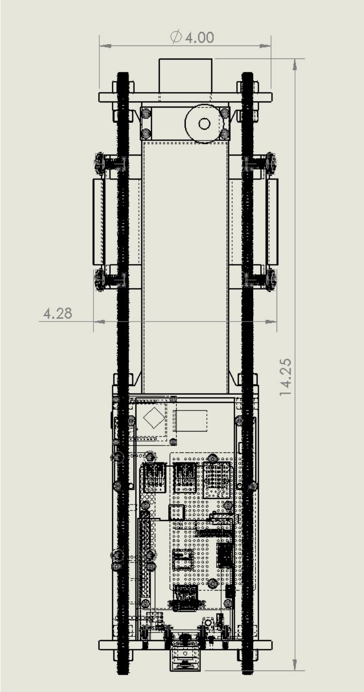
Key changes from PDR

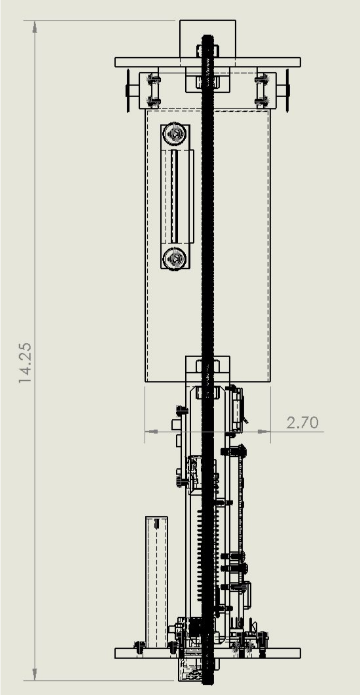
- Rotary power switch
- New leg release mechanism
- Minor structural changes

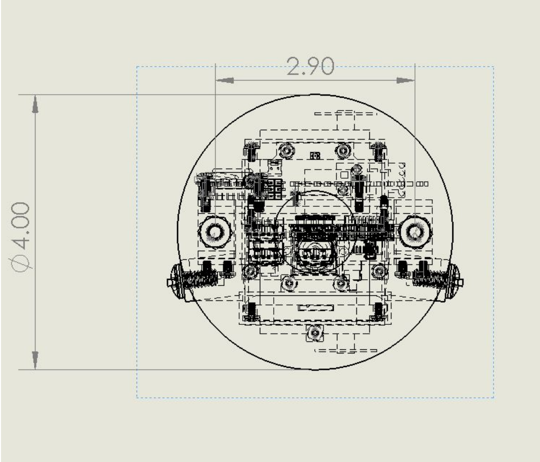


Payload Dimensions





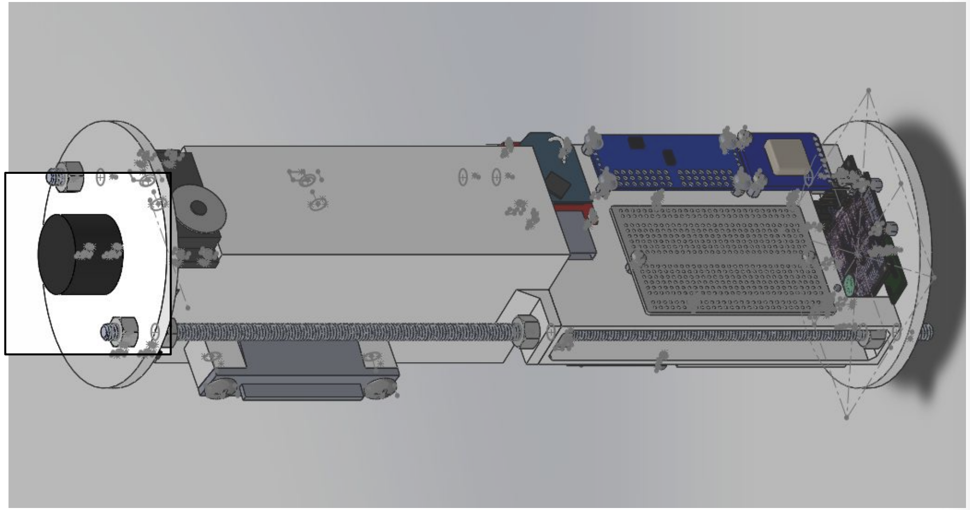




Vehicle Design ○ **Payload Design** ○ Project Plan

Payload Design - Key Features

- 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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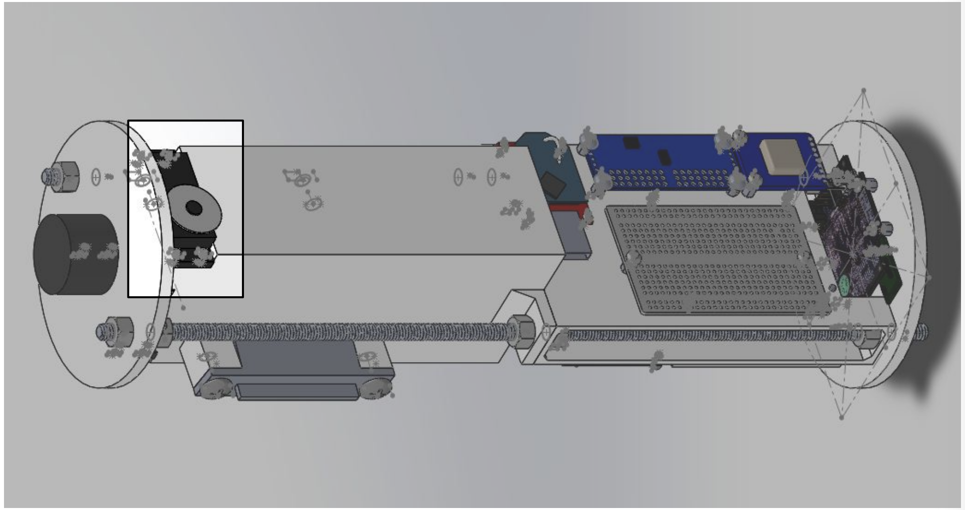

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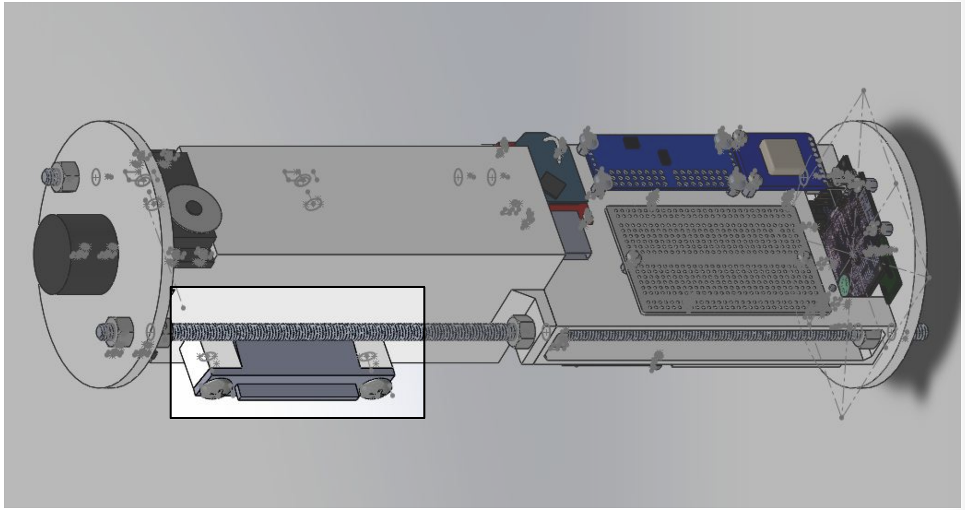

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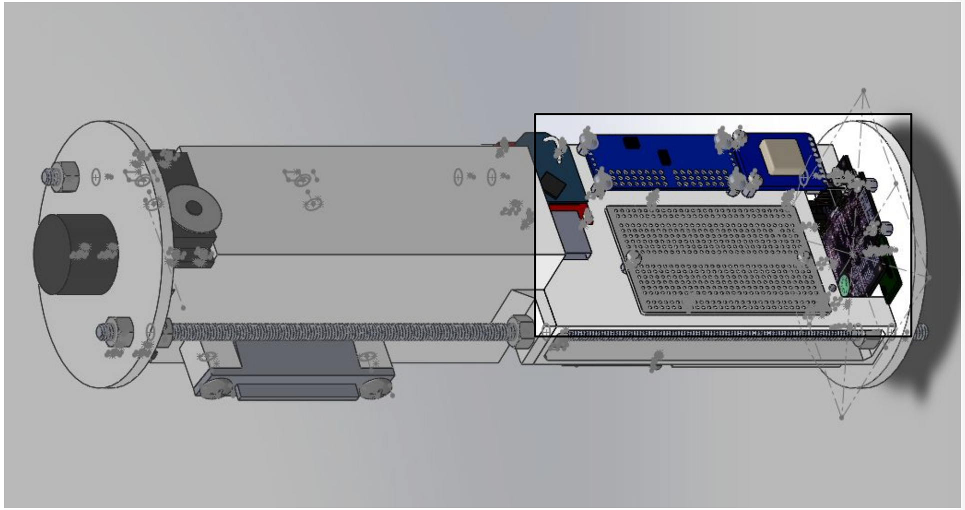

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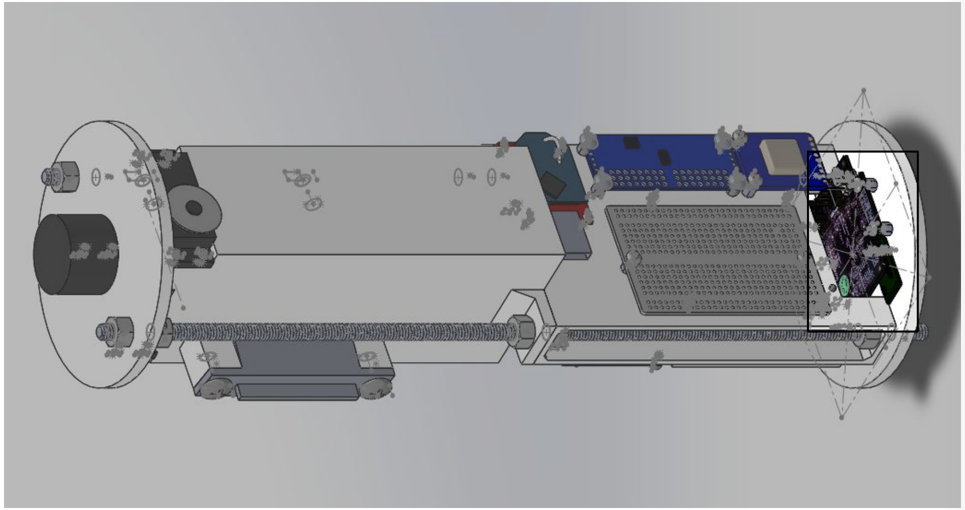

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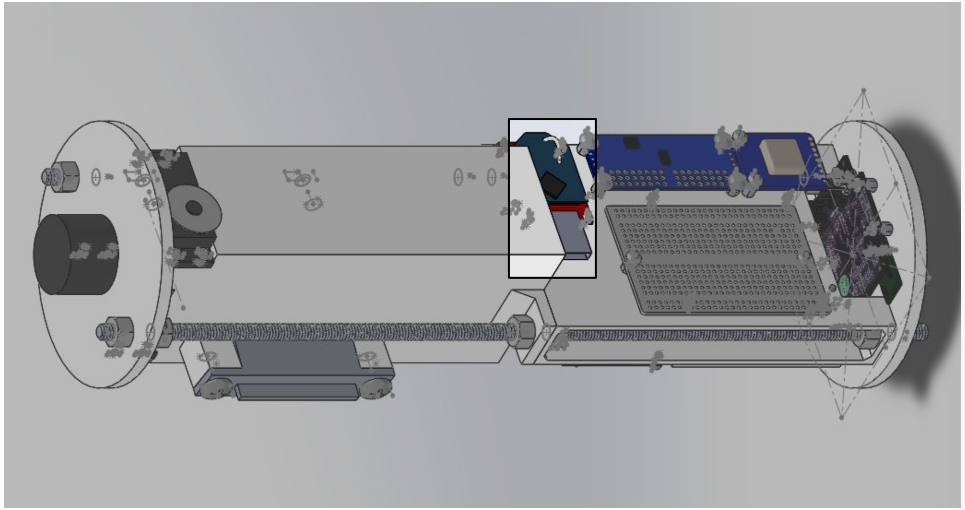

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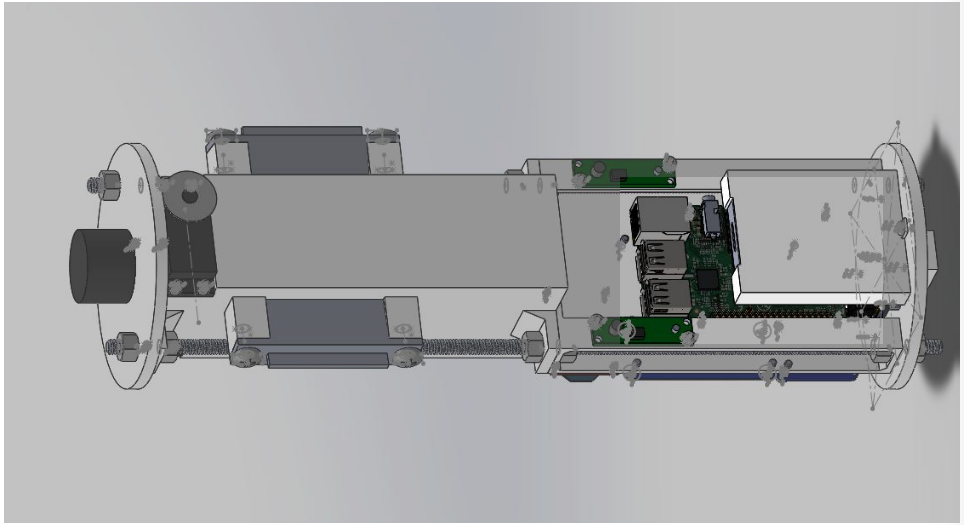
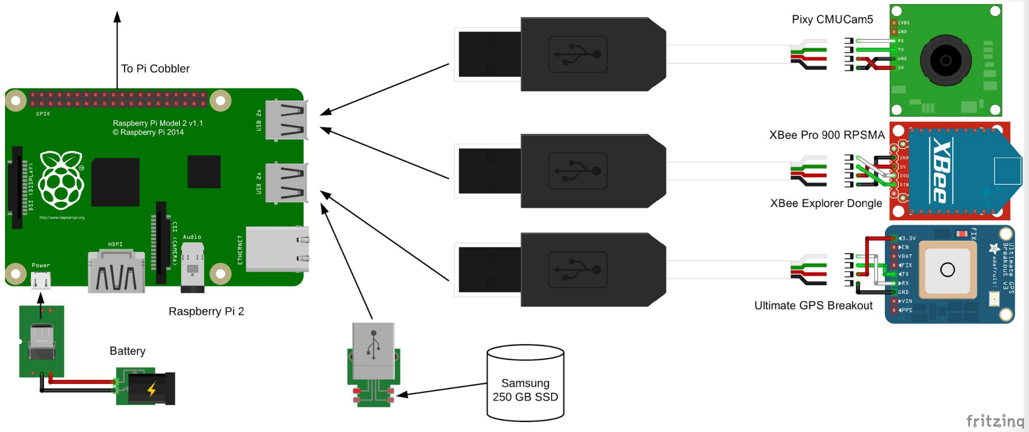


Payload Interfaces

USB Connections:

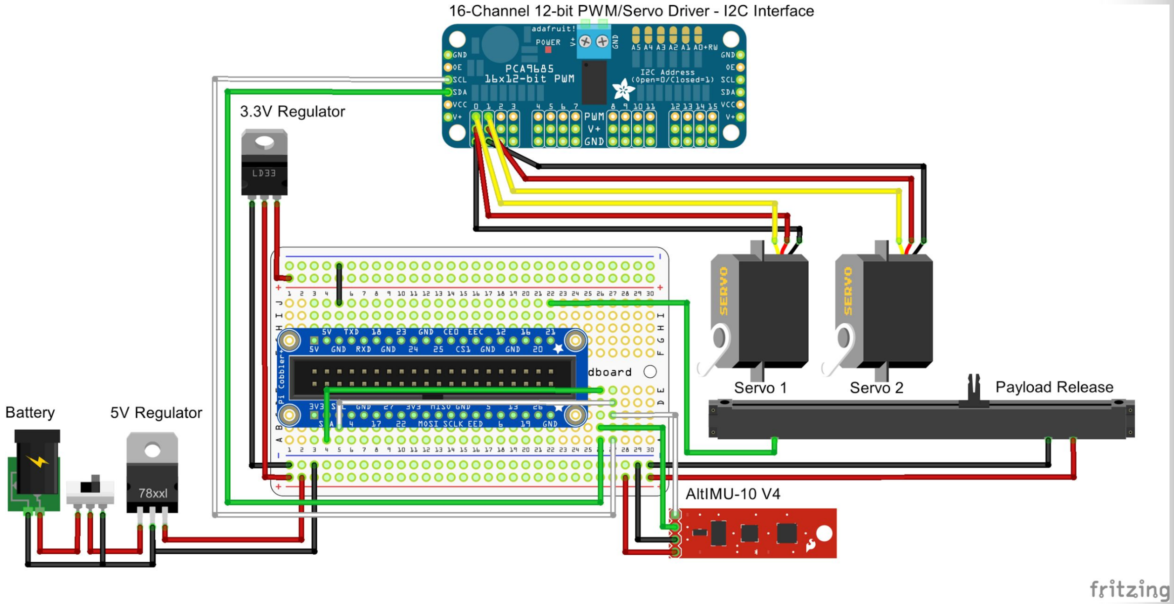
- CMUCam5
- XBee Pro
- GPS
- SSD



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

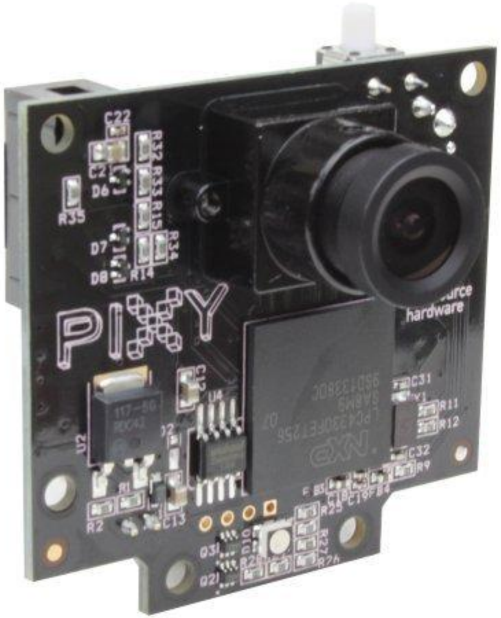
Guided Descent Requirements

- Descend at controlled velocity
- Steer payload to launch site
- Limit landing velocity

Payload Requirements Verification

Landing Hazards Requirements

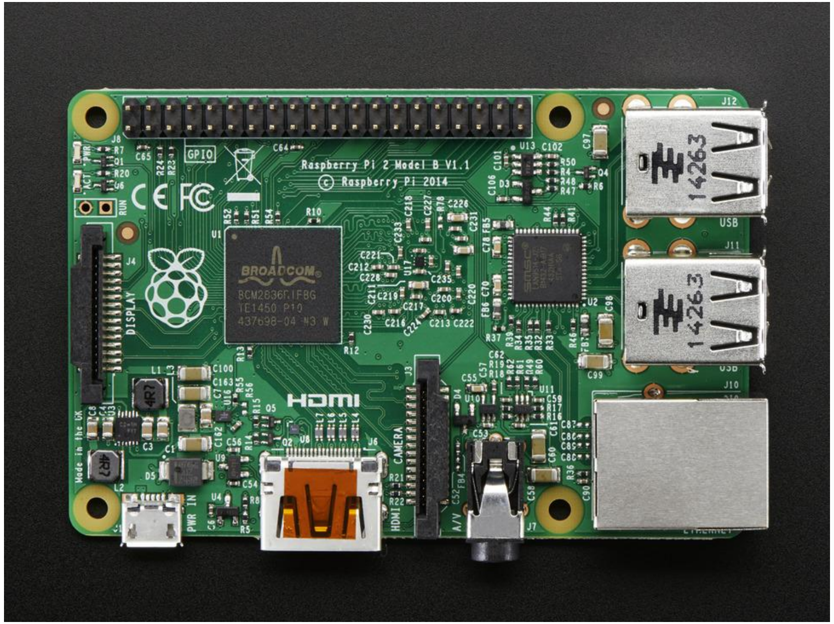
- Take images of ground
- Identify hazards from images
- transmit data to ground station



Payload Requirements Verification

Control Requirements

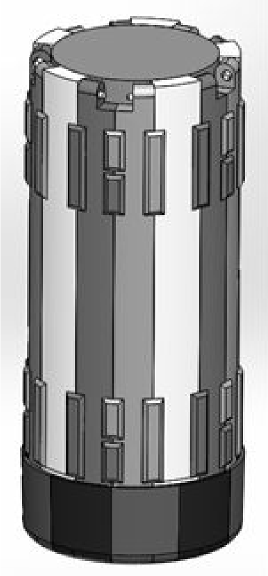
- Run software in real time
- Know location, altitude and velocity of payload

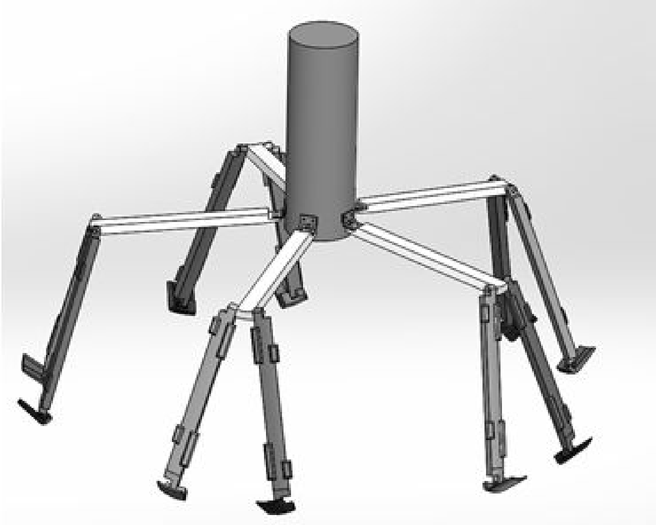


Payload Requirements Verification

Landing Requirements

- Reliably deploy legs
- Prevent tipping
- Absorb momentum at impact





Project Plan

Alabama Rocket Engineering Systems (ARES) Team

The University of Alabama

Budget Overview

Current Projected Budget: $7,607.52

Increases are attributed to additional components and expedited shipping.

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

Categorical Spending

Category	Current Expenses	Budgeted Expenses	Difference
Structures	-	$1,438.95	$1,438.95
Hazard Detection Payload	$911.02	$920.18	$9.16
Guided Descent Payload	$140.78	$155.80	$15.02
Recovery	$23.81	$720.20	$696.39
Subscale	$521.56	$851.51	$329.95
Safety	$89.91	$170.88	$80.97
Outreach	$48.93	$500.00	$451.07
Travel	-	$2,850.00	$2,850
Total Expenditures:	**$1,736.08**	**Total Remaining in Budget:**	**$5,871.44**

Current Fund Balances

Fund Name	Sum	Expenses	Remaining Total
ASGC	$7,650.00	$1,271.33	$6,378.67
Department of Aerospace Engineering and Mechanics	$650.00	$464.75	$185.25
SGA	$2,400.00	-	-

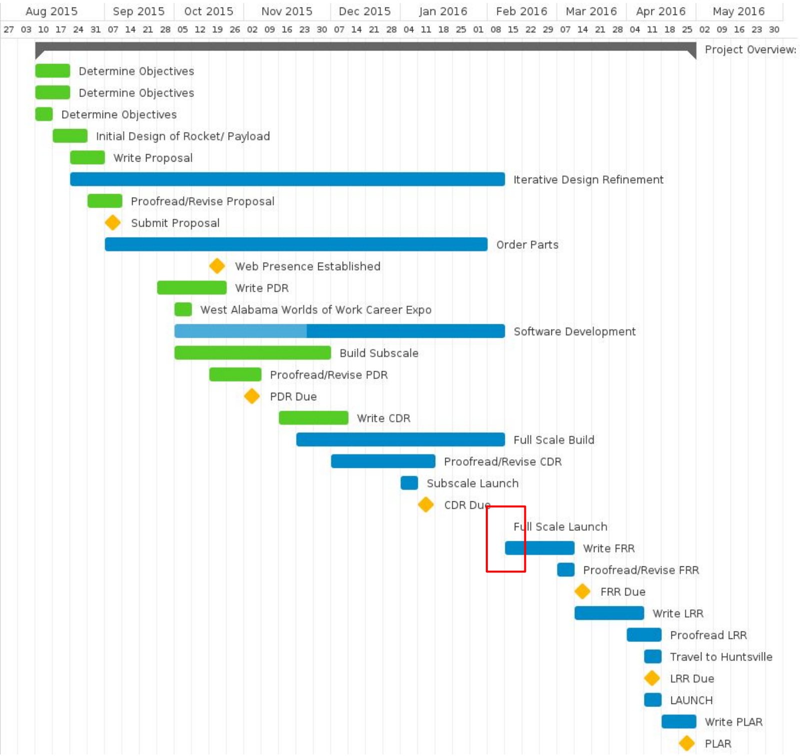
Student Government Association (SGA) funding will be sought in upcoming weeks.

The team is well within the $8,300.00 of confirmed funding.

Timeline Overview

Gantt Chart

	Project Overview:	41%
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	0%
8	Proofread/Revise Proposal	100%
9	Submit Proposal	100%
10	Order Parts	0%
11	Web Presence Established	100%
12	Write PDR	100%
13	West Alabama Worlds of Work Career Expo	100%
14	Software Development	40%
15	Build Subscale	100%
16	Proofread/Revise PDR	100%
17	PDR Due	0%
18	Write CDR	100%
19	Full Scale Build	0%
20	Proofread/Revise CDR	0%
21	Subscale Launch	0%
22	CDR Due	0%
23	Full Scale Launch	0%
24	Write FRR	0%
25	Proofread/Revise FRR	0%
26	FRR Due	0%
27	Write LRR	0%
28	Proofread LRR	0%
29	Travel to Huntsville	0%
30	LRR Due	0%
31	LAUNCH	0%
32	Write PLAR	0%
33	PLAR	0%



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

Contingency Plans

Contingency days in the event of launch failure or cancellation:

- February 20th
- March 5th

These dates would provide sufficient time to prepare for FRR

In the event of a catastrophic failure, the team would begin fundraising efforts to compensate for the incurred material losses

Educational Outreach

The ARES Team has reached a total of 1463 students through educational outreach

The team has engaged 493 students directly in activities pertaining to rocketry and engineering

Plans for several more visits and a student competition are being finalized

Name of Event	Date	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

Questions?