2015-2016 NASA Student Launch

Alabama Rocket Engineering Systems (ARES) Team

Post-Launch Assessment Review

April 29, 2016

Table of Contents

1. Summary of PLAR Report

1.1 Team Summary

Team Name: Alabama Rocket Engineering Systems (ARES) Team

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Level 3 TRA Certification
TRA Section 81

1.2 Launch Vehicle Summary

Table 1.1 describes the launch vehicle as it stood on launch day at Bragg Farms and the max altitude, apogee, reached on launch day.

Length	**Diameter**	**Mass**	**Motor**	**Recovery System**	**Altitude Reached**
93 inches (2.36 m)	5.53 inches (0.141 m)	37.6.4 lb (17.06 kg)	Cesaroni L851	• 26 inch (.66 m) drogue parachute • 120 inch (3.05 m) main parachute • 21.3 x 84.6 inch (.542 x 2.15 m) payload parafoil	4704 ft

Table 1.1 Launch Vehicle Description

1.3 Payload Description

Payload Title: Hazard Avoidance Lander (HAL)

HAL consists of two subsystems, a landing hazards detection subsystem and a guided descent subsystem. HAL will descend using a parafoil and will analyze images of the ground below to detect potential landing hazards. The data collected on potential landing hazards will then be passed to the guided descent system, which will use two servo motors to pull on lines connected to the parafoil, thus steering the payload away from the detected hazards.

2. Launch Results

2.1 Vehicle Summary and Dimensions

The structure of the ARES team's launch vehicle consists of three sections; the aft section, forward section, and nosecone. The aft section contains the following components: the aft body tube, motor mount tube and centering rings, four fins, motor retainer, coupler, and two rail buttons. The motor mount assembly consists of the motor mount, centering rings, and fins. The forward section contains the following components: forward body tube, main parachute, drogue parachute, electronics bay, and payload assembly. A breakdown of each section and how it is attached to the rocket can be seen in Table 2.1, Table 2.2, and Table 2.3. The rocket component layout and dimensions can be seen below in Figure 2.1 and Figure 2.2.

Component	**Dimensions**	**Method of Attachment**
Aft Body Tube	5.5 in. diameter 26 in. length	Main structural component.
Motor Mount Tube	3 in. diameter 19 in. length	Epoxied to centering rings.
Centering Rings	3 in. inner diameter 5.38 in. outer diameter	First epoxied to motor mount tube and fins. Then epoxied to inside wall of aft body tube.
Fins	10 in. length 4.5 in. height 8 in. fin tabs	First epoxied to motor mount tube and centering rings. Epoxy/phenolic fillets on fin-body tube joint. "Tip to tip" fiberglassing.
Motor Retainer	75 mm (2.95 in)	Screwed into bottom centering ring.
Coupler	5.38 in. outer diameter 10 in. length	Epoxied 5 inches down onto inside wall of aft body tube.
Rail Buttons	1515 rail buttons 3.5 and 23 inches from aft end	Screwed into aft body tube

Table 2.1 Aft Section Dimensions and Methods of Attachment

Component	Dimensions	Method of Attachment
Forward Body Tube	5.5 in. diameter 48 in. length	Main structural component.
Shear pins	2-56 nylon screws	Drilled through forward body tube and coupler/nosecone shoulder
Air-sample holes	3/16 in diameter 4 holes	Drilled through forward body tube and electronics bay housing
Altimeter switch holes	5/16 in diameter 2 holes	Drilled through forward body tube and electronics bay housing

Table 2.2 Forward Section Structural Components

Component	Dimensions	Method of Attachment
Nosecone	5.5 in. diameter 19 in. length	Main structural component.
Nosecone Shoulder	2 in. inside 4 in. exposed	Epoxied to inside of nosecone
Nosecone Bulkhead	5.38 in. diameter	Epoxied to inside of nosecone, behind shoulder

Table 2.3 Nosecone Section Structural Components

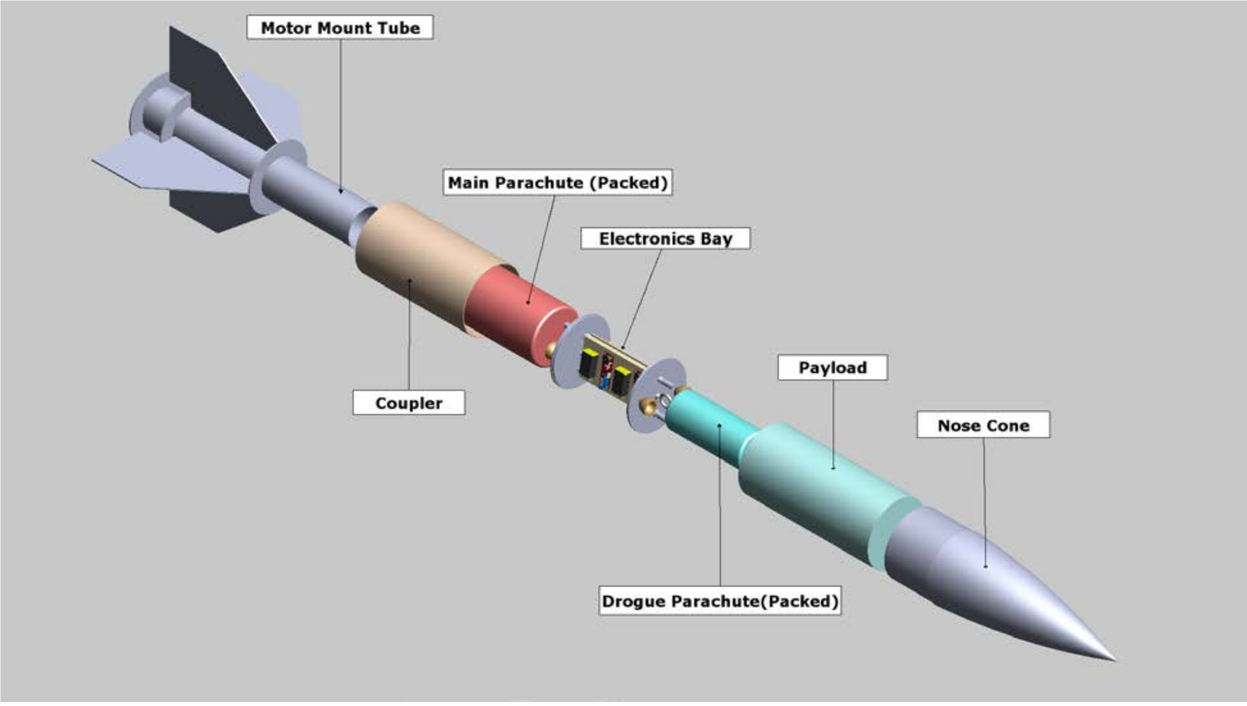

Figure 2.1 Rocket CAD Model Isentropic View

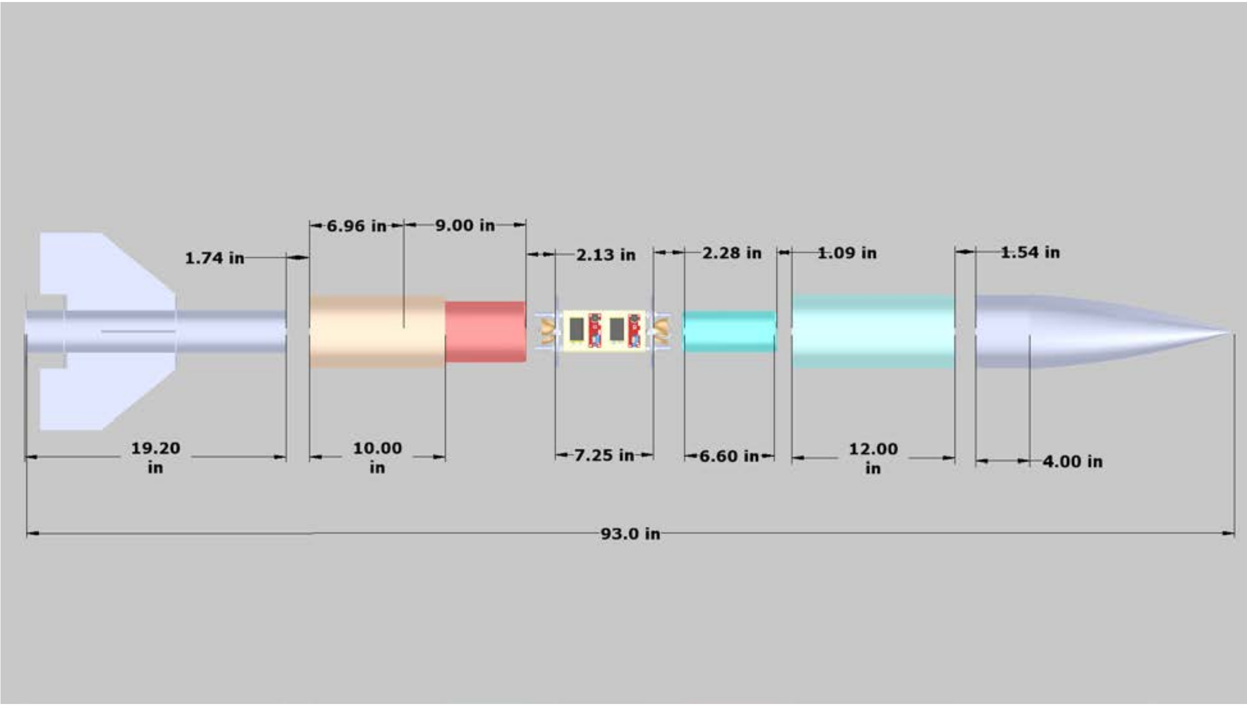

Figure 2.2 Rocket Layout Drawing (inches)

2.2 Data Analysis and Results of Launch Vehicle

The ARES launch vehicle performed well on launch day. The rocket reached an altitude of 4704 ft, under the targeted 5,280 ft mark. The wind speeds on launch day were on average around 20 mph which most likely resulted in the lower altitude achieved. Table 2.4 shows the comparison between our expected simulation data vs the actual flight data. There was a 3.63% difference between the simulation altitude and the actual altitude achieved. A slightly lower max velocity was also observed in the actual flight, most likely due to the wind speeds that went from an average of 20 (ft/s) on the ground to 30 (ft/s) at an altitude of 1000 (ft). Passive corrective pitching moments were immediately observable in the first 1000 (ft) of launch. The aft altimeter data from the flight can be seen below in Figure 2.3.

Flight (20 mph)	Apogee (ft)	Max Velocity (ft/s)	Time to Apogee (s)	Flight Time (s)
Simulation	4868	573	18.5	119
Actual	4704	516	18.1	116

Table 2.4 Simulation vs Flight Data

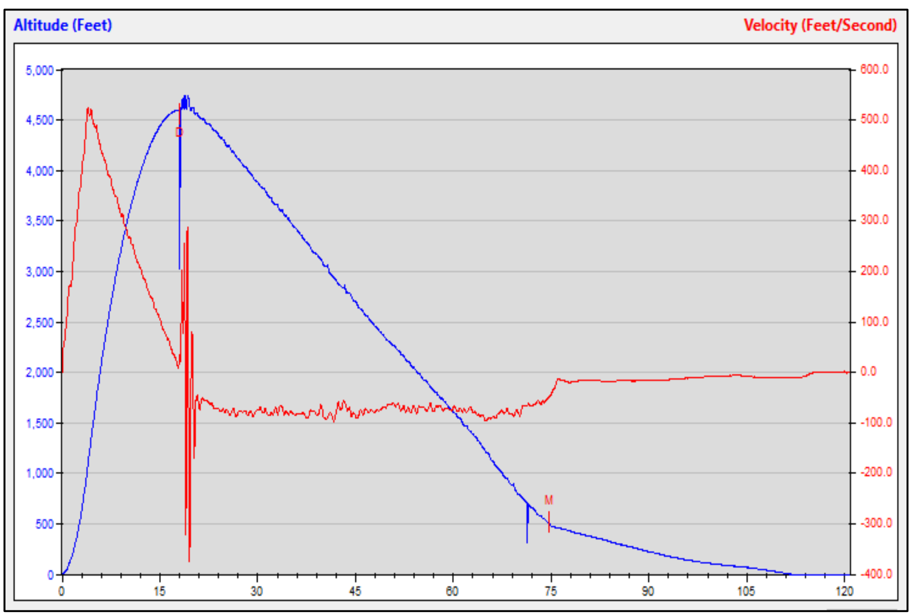

Figure 2.3 Aft Altimeter Data

2.3 Payload Summary

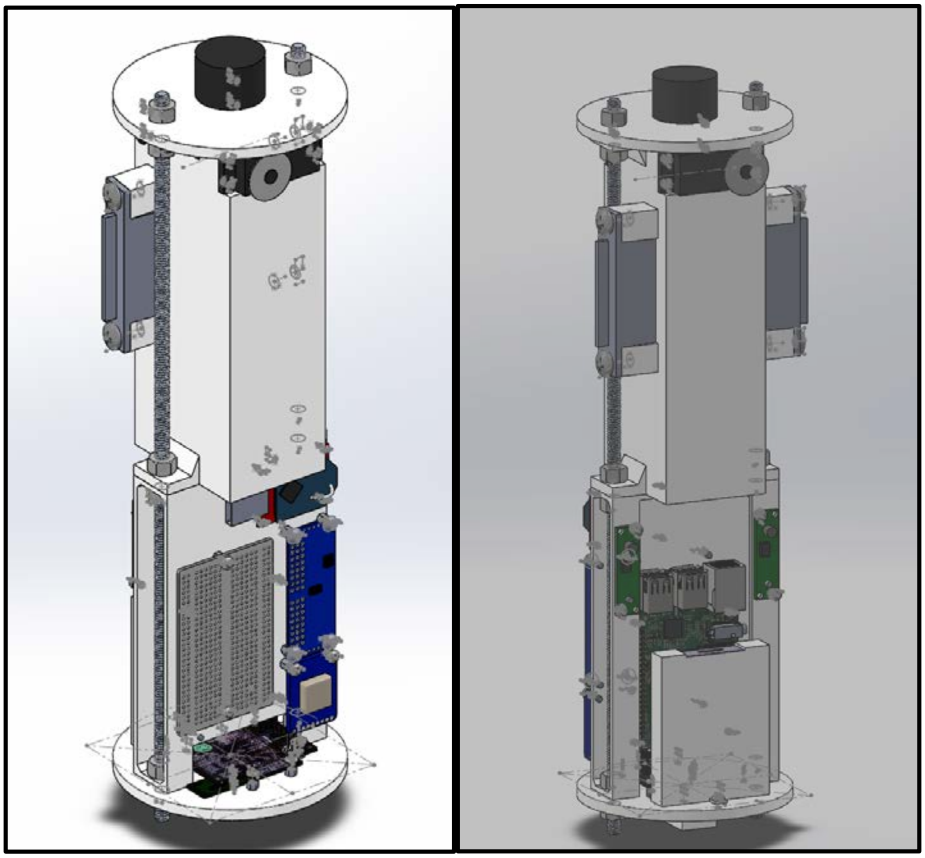

Figure 2.4 HAL Payload

The payload, shown in Figure 2.4, consisted of three main subsystems. The Hazard Detection subsystem consisted of a camera, to take images of the ground with, a XBee Pro 900, to transmit results back to a ground station, and an SSD, to store the data on. The Guided Descent subsystem consisted of a parafoil, to allow navigational control during descent, 2 servos, to control the parafoil, and a GPS, to provide navigational data. Both of these were connected and run through the Control Subsystem, which features a Raspberry Pi 2 as the flight computer. In addition, there was a powered USB hub, to power the SSD, as well as two Lipo Batteries, one for the Pi and the USB connected components, and one for the powered USB hub and the servos, which were run through 5V voltage regulators, and served as the power for the payload system. Structurally, all of these components were connected to a 3D printed bracket, which was held in place inside of a fiberglass hull by two ¼” threaded rods. The data interfaces are shown in Figure 2.5.

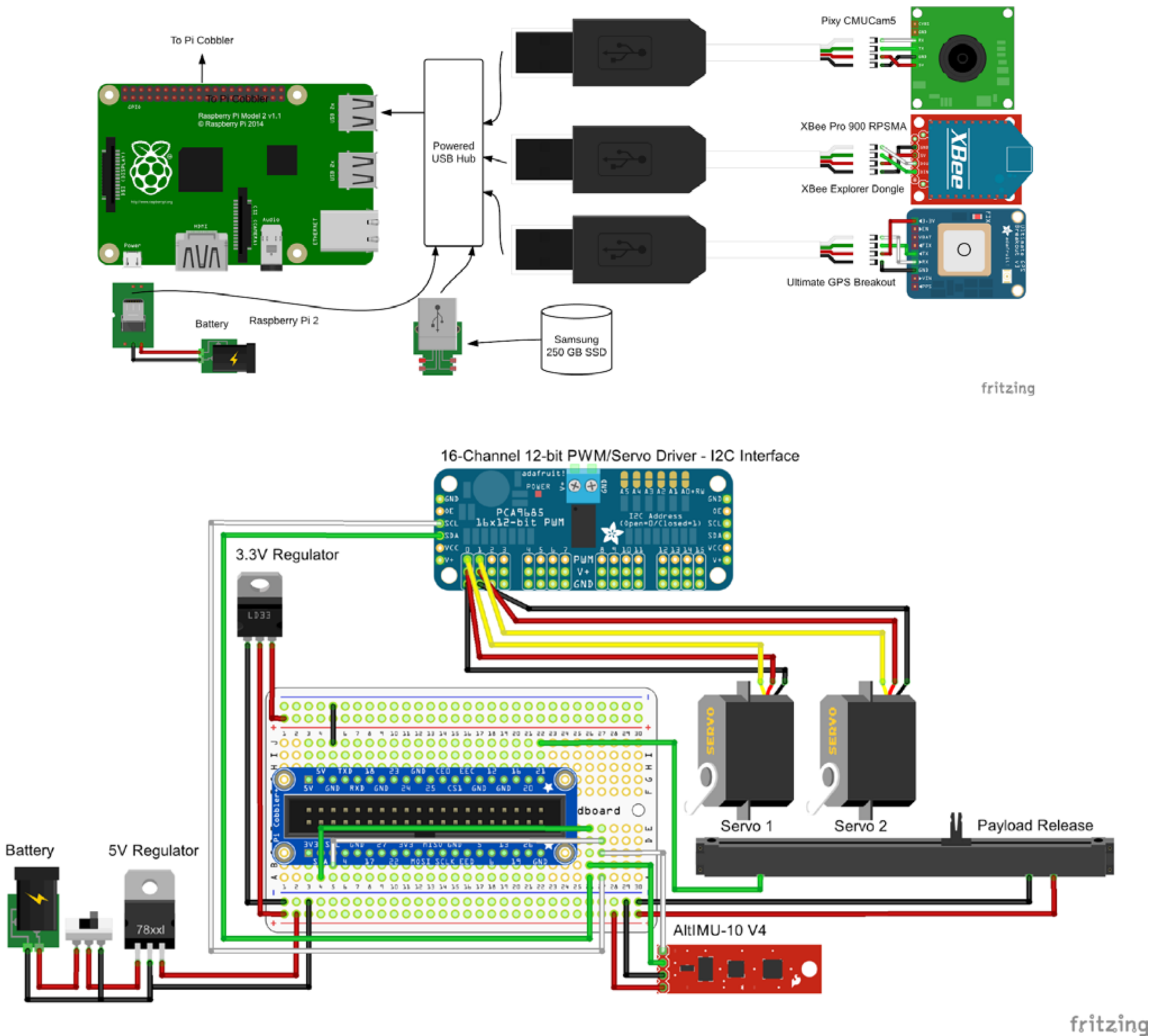

Figure 2.5 Payload Electronics

2.4 Data Analysis and Results of Payload

Due to the harsh conditions during launch, payload ejection, and landing all data was lost. While attempting to retrieve flight data it became apparent that the Raspberry Pi 2 had broken and a replacement would be needed. Once a new Raspberry Pi was obtained it was discovered that the microSD card as well as the Samsung SSD were also unusable.

Sample data received from the payload the night prior to launch is shown below.

```
2016-04-14T21:29:29.000Z,34.737996667,-86.649175,193.4,-0.1,0.067,Left
```

The data first states the date and time in Greenwich Mean Time followed by the latitude in degrees north of the equator and the latitude in degrees east of the prime meridian. The data also includes the altitude in meters, the climb rate in meters per second, the speed in m/s. The final data entry is the direction the parafoil would turn.

There was also extensive damage to the structural support for the payload components. Figure 2.6 shows that the base of the component frame failed due to shear and the battery and servo case fractured near the top.

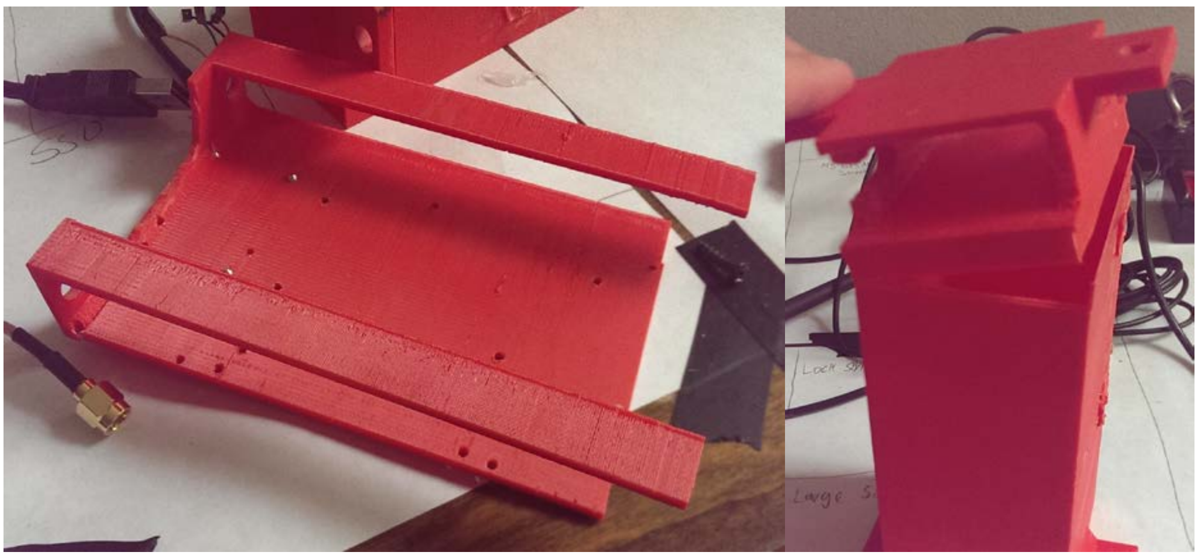

Figure 2.6 Payload Structural Failure

The image analysis algorithm used a K-Means Clustering algorithm on the color bands of the pixel to cluster the picture into areas of varying safety. An example image and its corresponding analyzed version are shown in Figure 2.7.

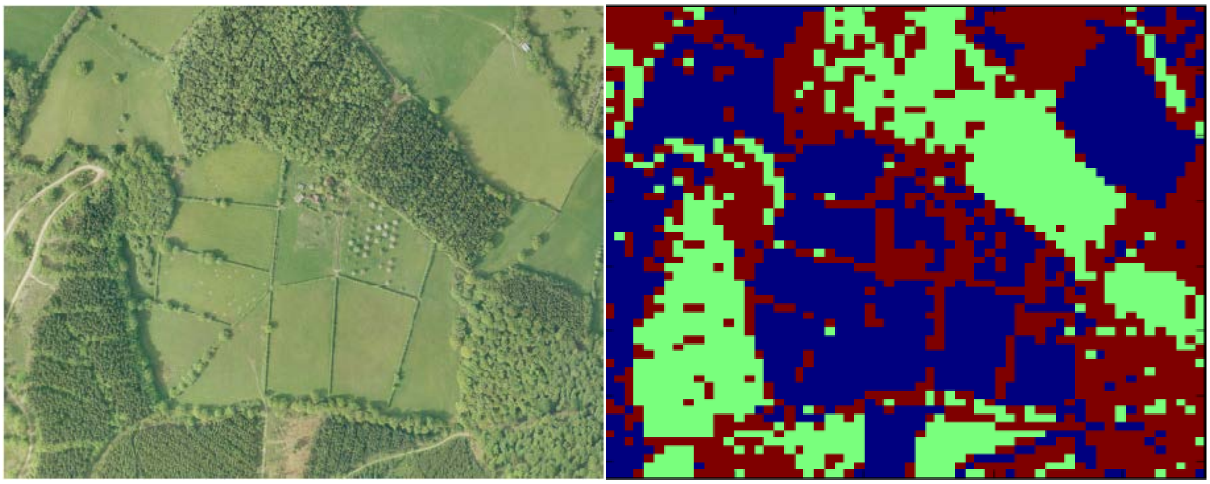

Figure 2.7 Image Analysis

2.5 Scientific Value

Although data was not successfully recovered, the scientific value of the mission is self-apparent. In fact, halfway through the project, it was discovered that NASA had attempted a similar mission at JPL with the ALHAT, as shown in Figure 2.8. Image analysis is a very hot field right now, across many different utilizations. Being able to leverage analysis algorithms for lander guidance would make interplanetary landings much safer. Although the use of a parafoil would be impractical for use on planets such as Mars, due to the much thinner atmosphere, it is of use here on Earth. In fact, the U.S. Army uses a similar system to guide supply drops to set waypoints. These projects exemplify the fact that data obtained from these experiments would be very useful for future design problems.

ALHAT: Key Mission Facts

- The Autonomous Landing and Hazard Avoidance Technology project will provide a state-of-the-art automated descent and landing system for planetary lander craft.
- Precision landing will be based on a sophisticated, surface-tracking sensor suite with real-time hazard avoidance capabilities -- assessing altitude and velocity of the descending vehicle and the topography of the landing site.
- ALHAT algorithms combined with sensor date will navigate the descending craft to the "pre-mission landing aim point," where it will quickly and autonomously identify safe landing areas and help guide the craft to touchdown.
- The technology provides an unprecedented procedure for safe planetary landing procedures -- for future crewed as well as robotic missions.
- The technology works in any lighting conditions -- from the harsh glare of an unshielded sun to the cloudy, gaseous murk of a distant solar system body.

Figure 2.8 ALHAT Mission Facts

2.6 Visual Data Observed

During the descent, the toggle lines of the parafoil and three connecting lines tore. It is important to note that the lines tore and did not burn, so the team's efforts to protect the lines from the black powder were successful. It is unclear what caused the lines to tear or when it occurred, but it is believed that the lines tore due to the forces endured during deployment. This hurt the parafoil's ability to steer and control the payload. However, as predicted, the parafoil was still able to limit the payload's descent speed and functioned similarly to a parachute. Figure 2.9 show the payload at different times during the descent, in chronological order. At the beginning of the descent, the payload appears to flip over the parafoil, but as the payload falls, it appears to gather itself under the parafoil, allowing the parafoil to function better.

(a)Early Descent *(b) Mid-flight Descent* *(c) Near Ground Descent*

Figure 2.9 Payload Descent

2.7 Lessons Learned

Through this project many lessons have been learned. Through the building process it is very important to take your time to ensure everything is built properly to ensure success. There were many times when the team could have rushed through building parts of the rocket, but taking our time and thinking about issues thoroughly when we came across them helped us be successful. Another lesson learned was not waiting until launch day to prepare the rocket. During the full scale test launches the team waited until launch day to fold and pack the parachutes and assemble the electronics bay. This lead to many hours prepping on the launch field. Before the competition launch the team packed the parachutes and prepped the electronics bay the night before. This allowed the team the time to make sure it was done right and saved valuable time during launch day. One of the most important lesson the ARES team learned was to rely on and learn from those who have done it before. If not for the expertise and knowledge of the team's mentor, Lee Brock, the ARES team would not have been as successful as they were. He was able to answer any questions and gave the team countless pieces of advice how to make the ARES rocket better and safer.

3. Educational Engagement Summary

Throughout the whole project, the ARES team reached 583 students through direct educational engagement, and an additional 970 through indirect educational engagement. The indirect events allowed the team to create a presence in the community, and connect with students and teachers who were interested in working with the team to learn more about rocketry. The direct engagement events brought topics of science and rocketry into classrooms that otherwise would not have been exposed to the topic.

3.1 Completed Events

The team completed a variety of events that included both direct and indirect engagements with the community. *Table 3.1* shows the events that the team took part in throughout the year.

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. 4/25/2016	19	10-12	Direct
SEDS Tuscaloosa Rocketry Challenge	2/25/2016, 3/2/2016, 3/3/2016	71	6-8	Direct

Table 3.1Completed Educational Outreach Events

3.2 Future of ARES Outreach

The team created connections in the community that will outlast the length of this competition, and will carry over for future years. Numerous teachers, scout troop leaders, and student organizations have expressed interest in maintaining collaboration between the team and their students. The presence the team established this year will be built upon by future teams, allowing for even greater opportunities to incite a passion in science and rocketry in the students of Tuscaloosa.

4. Budget Summary

The ARES team's total funding totaled $8,650.00 with the addition of the Orbital ATK stipend. The team managed to stay within these limits with the total expenses being $6,138.95. This number does not account for the money spent on vans or food at the competition, as those totals are not yet known. Spending is broken down categorically in Table 4.1 below.

Category	**Expenses**
Structures	$1,688.35
Hazard Detection Payload	$980.12
Guided Descent Payload	$284.32
Recovery	$406.85
Subscale	$767.52
Safety	$89.91
Outreach	$144.88
Travel	$1,777.00 +++
Total Expenditures:	**$6,138.95**

Table 4.1 - Expenses by Category

A concerted effort was made to keep expenses low, so the team itemized the components needed for competition, resulting in projected project total of $7,980.77. By doing so, actual expenses could be compared to the predicted expenses in order to form a sense of accountability. It was understood there would be unexpected expenses, and many of these came from redundant purchases and high costs of expedited shipping. Total shipping costs for the project were $451.32.

The team used the remaining funds in the travel section of the budget to pay for the use of university vans and reimburse the members for some meals on the trip. The total cost of the full scale rocket as it stood on the pad, payload included, was $3,790.83.

Fund Name	Sum	Expenses	Remaining Total
ASGC	$7,500.00	$5,503.12	$1,996.88
Department of Aerospace Engineering and Mechanics	$650.00	$635.83	$14.17
Orbital ATK Travel Stipend	$500.00	----	----

Table 4.2 - Expenses by Fund

5. Summary of Overall Experience and Conclusion

The ARES team undertook a very ambitious project for NASA SL. The team wanted to try to do something challenging, and something that hadn't been done before. This is what drove the team to choose such a difficult, yet exciting payload task. The challenge of designing and building a reliable, high-performance launch vehicle as well as a landing-hazard-detecting and steerable payload was what kept the team motivated throughout the year.

The ARES launch vehicle performed admirably on all three launches this spring. The structure of the rocket proved to be more than capable of sustaining the forces involved with flight as well as recovery. In addition, the recovery system worked flawlessly on each launch. When the fact that a majority of team members had never built or launched a rocket before this year is taken into account, the fact that the launch vehicle worked so well is even more impressive. The construction of such a reliable vehicle could not have happened without the team's mentor, Lee Brock, from whom the team learned an immense amount about rocketry. Overall, the ARES team is very pleased with the design and performance of their launch vehicle.

The HAL payload was a massive undertaking from the very beginning. The goal for the payload was to be able to take and analyze images of the ground to detect landing hazards, and to steer away from the hazards to a safe spot (the launch pad). The team encountered innumerable problems throughout the year which were accentuated by the fact that the team had very little electronics experience. The problems persisted right up through launch day, when the team had to work frantically to solve some last minute issues. Even with the many roadblocks throughout the year and the lack of experience and knowledge of electronics, the team was able to come up with a novel design, and to construct this design. Due to time constraints, the payload was not subjected to as much testing as the team would have liked, and the first full powered flight was on launch day. Although the payload did not perform as planned, the team is still very satisfied with the way they problem solved in the face of adversity and grateful to have had the opportunity to learn so much.

The ARES team feels that they gained invaluable experience in engineering design, technical writing, communication, and teamwork. This project has shown the team what it is like to work on a long term engineering project, and has helped enforce many of the principles learned through coursework. Despite the frustrations and shortcomings, the ARES team is satisfied with the decisions they made and proud of what they accomplished throughout the past eight months. Thank you for your time.