2015-2016 NASA Student Launch

Alabama Rocket Engineering Systems (ARES) Team
Preliminary Design Review

November 5, 2015

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1. Summary of PDR Report

1.1 Team Summary

Team Name: Alabama Rocket Engineering Systems (ARES) Team

Mailing Address: Department of Aerospace Engineering and Mechanics
The University of Alabama
Box 870280
Tuscaloosa, AL 35487-0280

TRA Mentor: Lee Brock
Level 3 TRA Certification
TRA Section 81

1.2 Launch Vehicle Summary

Length	Diameter	Mass	Motor	Recovery System
93 inches (2.36 m)	5.5 inches (0.140 m)	26.87 lb (12.19 kg)	Cesaroni L805-P	• 54 inch (1.37 m) drogue parachute • 110 inch (2.79 m) main parachute • 12 inch (.305 m) nose cone parachute • 21.3 x 84.6 inch (.542 x 2.15 m) payload parafoil

The Milestone Review Flysheet can be found in Appendix A.

1.3 Payload Summary

Payload Title: Hazard Avoidance Lander (HAL)

HAL will consist 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. Changes Made Since Proposal

2.1 Changes Made to Vehicle Criteria

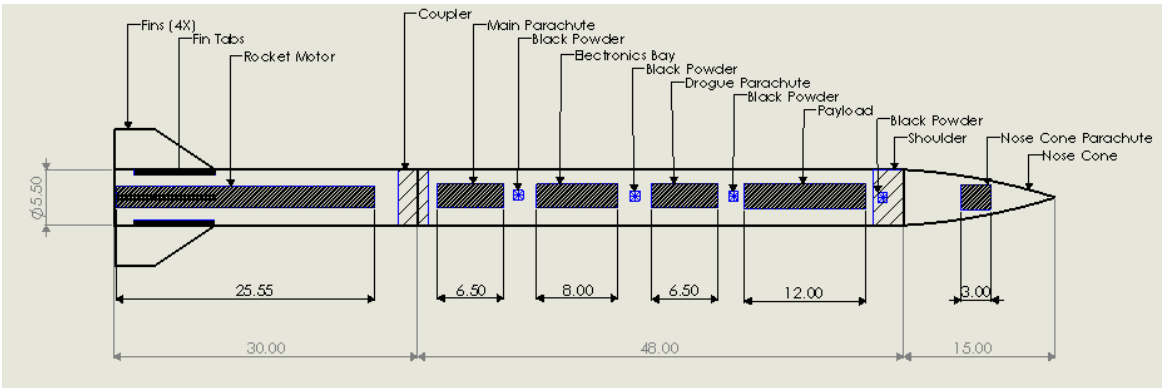

Figure 2.1. Updated Rocket Layout (inches)

The ARES Team switched the positions of the drogue parachute and the main parachute, and the rocket will now only use four black powder charges instead of five. This was based on the feedback the team received after submitting their proposal. The charge that was placed in front of where the main parachute is now was found to be unnecessary for blowing the shear pins connecting the aft tube and main tube; the charge ejecting the main parachute currently can be expected to accomplish the same goal. The packed lengths of the parachutes were determined from experimentally rolling the parachutes, since they are already owned. The fin design, seen in *Figure 3.2*, was changed to be slimmer, while keeping the same trapezoidal shape. The body length of the fin is now 10 inches (.254 m) and the opposite side of the fin is 4 inches (.102 m). The height of the fin is 4 inches (.102 m). Fin tabs and couplers were included in *Figure 2.1*. The team also changed the selected nose cone to a 15 inch (.381 m) nose cone with a 4 inch (.102 m) nose cone coupler, seen in *Figure 3.3*. These changes modified the stability margin of the vehicle from 2.56 calibers to a more favorable 1.93 calibers.

2.2 Changes Made to Payload Criteria

The ARES team has altered the HAL design in a number of ways. The most drastic change made to the payload is to the battery. The battery that was originally chosen will not provide power for long enough to meet NASA's goal of the rocket being able to sit on the launch pad for an hour and then launch. To meet this goal, the ARES Team will add an extra 12 volt, 5000mAh lithium polymer battery which can be connected in parallel provide more power for the payload. The team has also decided to change from the XBee Pro 900 Wire Antenna to the RP-SMA version. After further investigation, it appeared that the wire antenna may not provide a large enough range because it is a dipole antenna. By switching to the RP-SMA high gain antenna, the team is ensuring that the data will be able to be transmitted from the payload to the ground station. Rather than deploy the landing legs upon the payload ejection from the rocket, HAL will deploy its legs at a specified distance above the ground as to minimize the drag and moments on the payload during descent. To prevent the legs from deploying, the payload will be equipped with a solenoid which will lock the legs in place. When charge is applied to the solenoid, the lander legs will deploy.

2.3 Changes Made to Project Plan

Some additions have been made to the budget and purchases have begun. The total anticipated cost of the project has fallen due to a more detailed budget regarding the subscale rocket. Funding from the Alabama Space Grant Consortium (ASGC) and the University of Alabama Department of Aerospace Engineering and Mechanics has been received, totaling $8,300 of confirmed funds. The team is on schedule with the overall timeline and more a detailed schedule for the time until the CDR submission date has been developed.

The team has also decided to change their educational outreach plan. Instead of adopting one local middle school to create a TARC team, the ARES Team plans to meet with teachers from several local schools to teach them a curriculum about rocketry that they can then teach their students. The students from each school will then build their own rocket as a competition organized by the ARES Team.

3. Vehicle Criteria

3.1 Selection, Design, and Verification of Launch Vehicle

3.1.1 Mission Statement, Requirements, and Success Criteria

The Alabama Rocket Engineering Systems Team's mission is to design, build, and launch a high power rocket that will fly to an apogee altitude of 5,280 feet, carrying a payload that will complete two tasks. The payload will eject at apogee and descend to the ground using a parafoil. During descent, the payload will scan the ground for landing hazards and then use the data collected to steer away from detected hazards. The requirements for this mission are listed below.

<u>Mission Requirements</u>

- The launch vehicle must reach an apogee of 5,280 feet, or as close as possible.
- The launch vehicle must deploy a drogue parachute and the payload at apogee.
- The launch vehicle must deploy a main parachute at 900 feet AGL.
- The payload must take images of the ground during descent and analyze these images to detect potential landing hazards.
- The payload must transmit the collected data to the team's ground station, as well as store the data onboard.
- The payload must be able to steer itself away from the detected landing hazards.
- The rocket must be reusable after landing.

<u>Success Criteria</u>

- The launch vehicle reaches within 1% of the required apogee.
- The drogue parachute deploys at apogee
- The main parachute deploys at 900 feet AGL.
- The payload correctly identifies landing hazards, stores the data onboard and transmits the data to the ground station.
- The payload steers itself away from all landing hazards and lands in a safe area.
- All sections of the rocket and payload are reusable after landing.

3.1.2 System Level Review

The current configuration of the ARES launch vehicle is shown in *Figure 3.1* below, including dimensions of the components and sections. *Figure 3.2* and *Figure 3.3* show the fins and nose cone, respectively. The fins have tabs that will be inserted into the aft section and epoxied on both the inside and the outside of the tube. *Table 3.1* provides an overview of the components and their dimensions and masses.

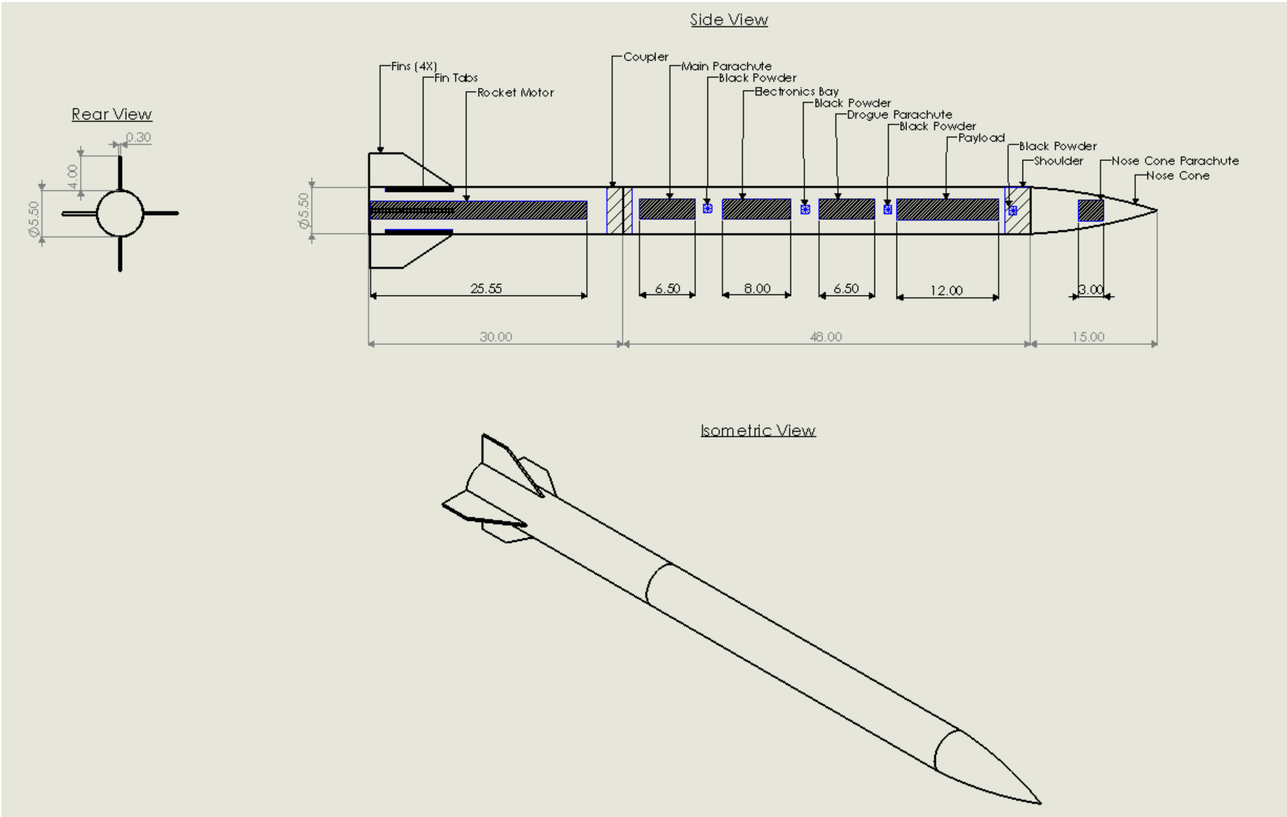

Figure 3.1. Drawing of Launch Vehicle (dimensions in inches)

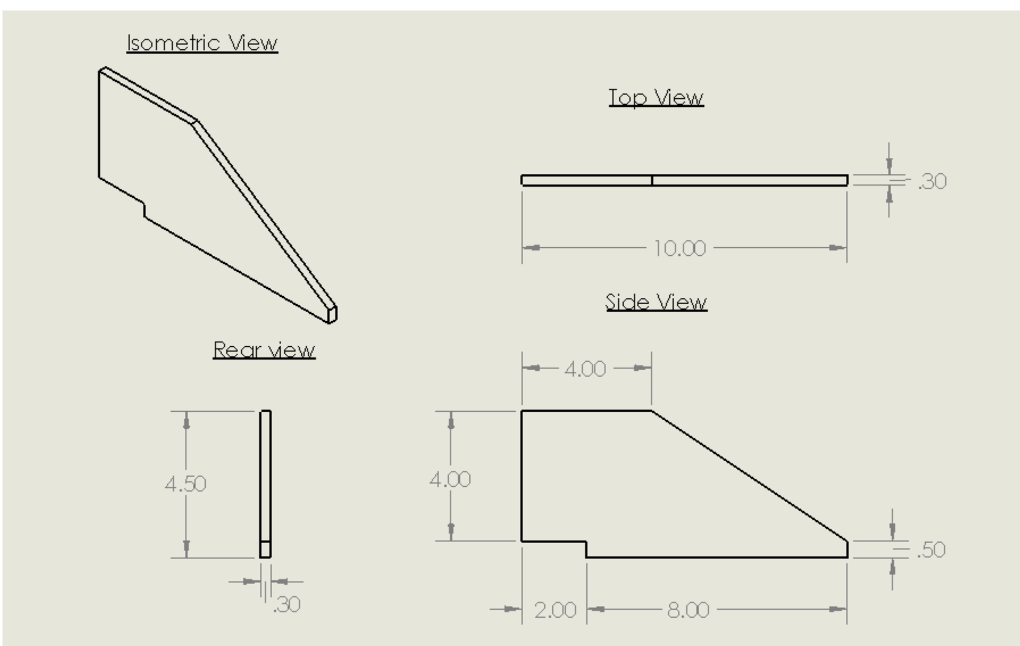

Figure 3.2. Updated Fin Dimensions (inches)

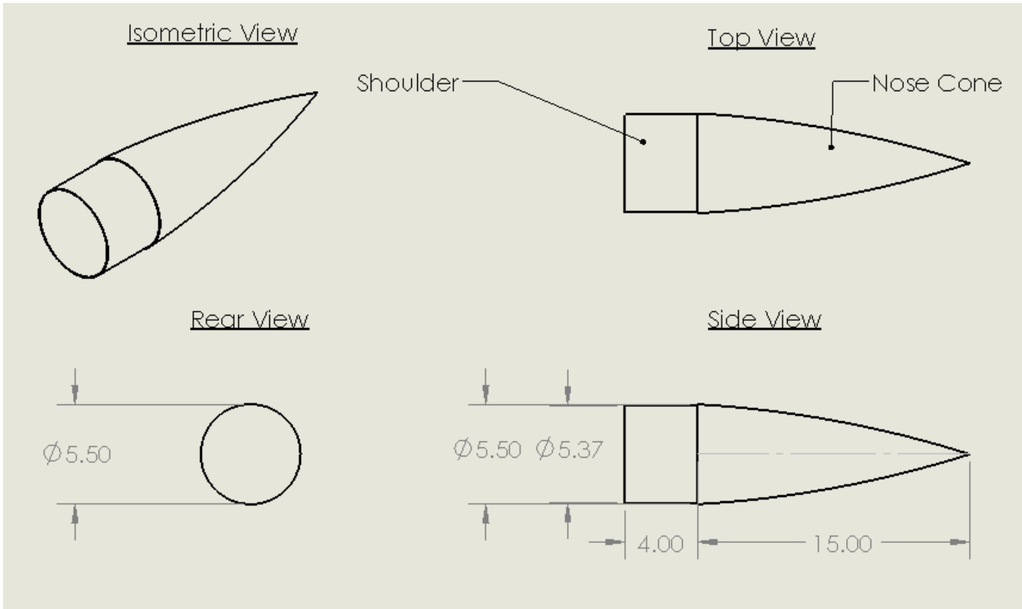

Figure 3.3. Updated Nose Cone Dimensions (inches)

Component	Mass (lb)	Length (in)	Width or Diameter (in)
Nose Cone	0.965	15	5.5
Forward Body Tube	3.45	48	5.5
Aft Body Tube	0.855	30	5.5
Payload	6.77	12	5.43
Electronics Bay	0.575	8	5.43
Main Parachute (Packed)	1.2	6.5	4.5
Drogue Parachute (Packed)	0.948	3	3
Nose Cone Parachute (Packed)	0.18	0.985	0.985
Motor w/ Propellant	6.55	25.5	2.13
Motor Propellant	3.62	25.5	2.13

Table 3.1. Launch Vehicle Component Information

The ARES launch vehicle system will have three subsystems: recovery, propulsion, and structure. The recovery subsystem will be responsible for landing all independent sections of the launch vehicle safely and under the max allowable kinetic energy of 75 ft-lb. The propulsion subsystem is responsible for the launch system reaching exactly 5,280 feet of altitude. The structure subsystem is responsible for housing and protecting all mission crucial components and providing a capable design for a successful launch. The functional requirements, the selection rationale, selected concept and characteristics for each subsystem are shown in *Table 3.2* below.

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics
Recovery	Eject drogue parachute at apogee and main parachute at 900 feet AGL	Must have reliable ejection system	Redundant altimeters	Altimeter 1 fires a black powder charge at a specified altitude. Altimeter 2 sends a charge to the black powder at a reserve altitude if Altimeter 1 fails
	Slow descent of all sections so that kinetic energy does not exceed 75 ft-lbs	Parachutes must provide adequate drag to ensure slow enough landing velocity	108 inch (2.74 m) main parachute, and 12 inch (.305 m) nose cone parachute	The parachute expands and slows the launch vehicle by drag force to a suitable landing velocity
Propulsion	Deliver launch vehicle and payload to an apogee altitude of 5,280 feet	Motor must provide proper thrust to weight ratio	Cesaroni L805	The selected motor provides a thrust to weight ratio of 13.77
Structures	Withstand aerodynamic loading	Must provide adequate strength to handle loads	Fiberglass	The launch vehicle will be constructed of Fiberglass, which will provide the strength to withstand aerodynamic loads
	Land undamaged	Must provide adequate strength to handle landing impact	Fiberglass	Fiberglass provides adequate strength to withstand the shock of landing

Table 3.2. Launch Vehicle Subsystem Requirements

3.1.3 Propulsion Subsystem

The ARES team currently plans on using the Cesaroni L805, a 54mm (2.13 in), 6 XL grain motor, with a total impulse of 2833 Newton-seconds (637 lb-seconds). This motor will be purchased from Apogee Components and handled by Mr. Lee Brock, the teams NAR/TRA Mentor. Through simulations performed in OpenRocket using a L805 motor, the current rocket design reaches the 5,280 ft altitude mark with a standard deviation of approximately 20 ft. The results of these simulations can be seen in *Table 3.3*. This verifies that the Cesaroni L805 motor is a valid choice for our propulsion subsystem.

**Note: All simulations performed in OpenRocket are at the correct latitude, longitude, and altitude for each launch site.*

Simulation	**Apogee (ft)**
Bragg Farms (0 mph)	5290
Bragg Farms (5-10 mph)	5256
Manchester (0 mph)	5304
Manchester (5-10 mph)	5280

Table 3.3. OpenRocket Apogee Simulations

3.1.4 Structures Subsystem

The ARES team currently plans to construct body tubes and fins made of glass fiber/epoxy. Fiberglass will be used because of its low weight, affordability, manufacturing ease, and strength. The team made this decision by using the weighted rating method. A chart of the team's weighted rating system is shown in *Table 3.4*. The team's ratings are based on information from previous rocketry teams at The University of Alabama, as well as research done by the team. Information on the two materials was found through Oribi Manufacturing (http://gwcomposites.com/carbon-vs-fiberglass/) and GW composites (http://oribimanufacturing.com/carbonfiber-vs-fiberglass/).

Weighted Rating of Carbon Fiber and Fiberglass					
		Carbon Fiber		**Fiberglass**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Low Weight	35	4	1.4	3	1.05
Low Cost	20	1	0.2	5	1
Easy Production	10	1	0.1	4	0.4
High Strength	35	5	1.75	4	1.4
Total	100	NA	3.45	NA	3.85

Rating	*Value*
Unsatisfactory	*1*
Just tolerable	*2*
Adequate	*3*
Good	*4*
Very good	*5*

Table 3.4. Weighted Rating of Materials

The body tube lengths were determined by the dimensions of the components they will be holding. The aft body tube is currently 30 inches (.965 m) to house the 25.5 inch (.648 m) motor. The forward body tube is currently 48 inches (1.22 m) based on the stored dimensions of the components it will contain: main parachute, drogue parachute, electronics bay, payload bay, and black powder charges. These dimensions can be obtained from *Table 3.1* and visually represented in *Figure 3.1*.

The fin dimensions chosen, seen in *Figure 3.2*, are an iterative design to easily change the rocket's stability margin. The current fin design gives a favorable stability margin of 1.93 calibers.

The team considered two 5.5 inch (.140 m) diameter nose cone options: the Filament Wound 3:1 ogive and the Filament Wound Fiberglass Von Karman (FW VK) from Madcow Rocketry. The characteristics of each nose cone are listed in *Table 3.5*.

Nose Cone	Diameter (in)	Length (in)	Weight (lb)	Material
3:1 Ogive	5.5	15	0.966	Fiberglass
FW VK	5.5	31	3.875	Fiberglass

Table 3.5 Nose Cone Selection

Using the information shown in *Table 3.5*, the FW 3:1 ogive nose cone was selected based off the necessity of low weight. The higher weight of the FW VK nosecone made it undesirable for the mission. Drawings for the 3:1 ogive nose cone can be seen in *Figure 3.3*.

3.1.5 Verification Plan

All requirements for the launch vehicle are listed in *Table 3.6* below, along with the design feature responsible for meeting each requirement and how each requirement will ultimately be verified. The requirements are taken directly from the 2016 NASA Student Launch Handbook.

#	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
1.2	The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in the competition scoring. The official scoring altimeter shall report the official competition altitude via a series of beeps to be checked after the competition flight	Redundant Altimeters in the Electronics Bay.	Altimeters will undergo vacuum bag testing prior to launches to ensure they read pressure changes. Altimeters will also be tested on the Subscale and Full Scale 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
1.4	The launch vehicle shall have a maximum of four independent sections	Launch vehicle consists of four sections	Design of launch vehicle	Verified
1.5	The launch vehicle shall be limited to a single stage	Motor Selection	Launch Vehicle is designed to	Verified

			reach desired altitude under one motor	
1.6	The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the FAA flight waiver opens	Launch Vehicle Structure	The launch vehicle will have the majority of sections constructed prior to arrival at the launch site. Construction of the Launch Vehicle during the 2 Full Scale Launch Tests at the launch site will be timed	Pending
1.7	The launch vehicle shall be capable of remaining in a launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on board component	Altimeters, Black Powder Charges, and Payload Components will be designed to hold for a minimum of 1 hour	Subscale and 2 Full Scale Launch Tests will verify	Pending
1.8	The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system	All igniters will be compatible with a standard 12 volt direct current firing system	Subscale and full scale launch tests	Pending
1.9	The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR)	Cesaroni L805 motor	NA	NA
1.10	The total impulse provided by a launch vehicle shall not exceed 5,120 Newton-seconds (L-class)	Motor Selection	Motor choice is a Cesaroni L805. The total impulse is 2833.0 Newton-seconds	Verified
1.11	Pressure vessels on the vehicle shall be approved by the RSO	No pressure vessels are included in the design of the	NA	NA

		rocket or payload		
1.12	All teams shall successfully launch and recover a subscale model of their full-scale rocket prior to CDR. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model	Subscale launch on November 22	Subscale launch test	Pending
1.13	All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. A successful flight is defined as a launch in which all hardware is functioning properly	Full scale launch on February 14	Full scale launch test	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
2.2	Teams must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches	Recovery System	Ground 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
2.4	The recovery system electrical circuits shall be completely independent of any payload electrical circuits	Electronics Bay	NA	NA
2.5	The recovery system shall contain redundant, commercially available altimeters	Redundant altimeters will be used	NA	NA
2.6	Motor ejection is not a permissible form of primary or secondary deployment. An electronic form of deployment	Motor ejection will not be used as a form of deployment	NA	NA

	must be used for deployment purposes			
2.7	A dedicated arming switch shall arm each altimeter, which is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad	Electronics Bay and Launch Vehicle Structure will be designed to allow for an arming switch	NA	NA
2.8	Each altimeter shall have a dedicated power supply	Separate battery for each altimeter	NA	NA
2.9	Each arming switch shall be capable of being locked in the ON position for launch	The arming switch will be designed to allow locking	NA	NA
2.10	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment	Launch Vehicle Structure will use removable shear pins where separation will occur. Separation will be over the parachute compartments	NA	NA
2.11	An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver. Any rocket section, or payload component, which lands untethered to the launch vehicle shall also carry an active electronic tracking device	Each separate section will carry an electronic tracking device	NA	NA
2.12	The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing)	Recovery system electronics will be separated and shielded from other electronics	NA	NA

Table 3.6. Requirements and Verification Plan

3.1.6 Project Risks

Table 3.8 shows the risks present in the project and how they have been mitigated to minimize the risks. Risk levels are defined in *Table 3.7.*

Level of Risk	Level of Permission Required
High	Highly Undesirable. High Likelihood.
Medium	Undesirable. Possible to occur.
Low	Acceptable. Not likely to occur.

Table 3.7. Risk Level Definitions

Risk	Consequence	Initial Risk Level	Mitigation	Final Risk Level
Missing Planned Launch Dates	Missing planned launch dates will put us behind schedule for the iteration of the ARES design. Any delay in the complete development and verification of the design will lead to oversights in the full scale launch at Bragg Farms. Could potentially lead to failing to be first in the Mini-MAV Competition.	Medium	The ARES team plans to have multiple launch dates selected in case of delays in construction or material delivery leads to missing the initial launch date. For example: The subscale launch is planned for November 21 in Talladega, Alabama at the Phoenix Missile Works Launch Site. A back-up date of December 19 is planned in case of delays.	Low
Going Over Time Allotted for Construction	Delays in the construction of the subscale and full scale will push all testing back. This will lead to delays in launch testing, ground testing, and other verifications. The time allotted for the construction is critical as failure to meet these deadlines will also push back verification of the payload functionality.	Medium	The ARES team has allowed for delays in the construction by initially planning for them in the time allotted to build the subscale and full scale launch vehicle.	Low

Meeting NASA Deadlines	Meeting NASA deadlines is highly dependent on the verification of all systems. If the verification of systems and the design are not met in a timely fashion there will be oversights and lapses in possible risks to the ARES team meeting all objectives.	Medium	All system testing and construction has been expected to have delays. This means that ample time will be allowed to meet deadlines despite delays.	Low
Going Over Budget	Exceeding our planned funds will cause financial cuts in our project plan. Either parts, software, travel, food, or other critical expenses will have to be reduced in order to not go into debt.	Medium	Documenting all purchases and keeping stock of parts and assets will help prevent from going over budget.	Low
Lack of Materials	Not preparing and ordering all parts or material needed could set production back weeks. Deadlines could be missed and production pushed to an accelerated rate where construction mistakes could be made.	Medium	Plan ahead, document, and order all parts and materials needed before construction. It is better to order slightly more than needed.	Low

Table 3.8. Project Risks

3.1.7 Confidence and Maturity of Design

The ARES Team is confident in the preliminary design of the launch vehicle. Simulations indicate that the current vehicle will perform to the required criteria, and the team is very confident in their ability to manufacture the current vehicle. Changes to the design are expected as the design is iterated, but the team is confident that the final design will be set by the Critical Design Review. The launch vehicle design has been put through many iterations already, and many of the problems with the proposed launch vehicle have been solved. The team will continue to plan ahead and work to develop a launch vehicle capable of meeting all competition criteria.

3.1.8 Subscale Calculations and Verification

A scaling factor of 0.8 was chosen for the subscale launch vehicle dimensions. The scaling factor was determined by matching the subscale Reynolds number for different scales to the full scale Reynolds number of 1.78E+06. The scaling factor must produce a Mach number under Mach 0.8

to avoid compressible flow complexities, so this criteria was used to determine an acceptable scale. Density, kinematic viscosity, and speed of sound were calculated at standard sea level and 25° C. These calculations can be seen in *Table 3.9.*

Subscale Diameter (in)	**Scaling Factor**	**Velocity to match FS Reynolds number (ft/s)**	**Mach Number**
5.5	1	650	0.572
4.95	.9	722.2	0.636
4.4	.8	812.5	0.716
3.85	.7	928.5	0.818
3.3	.6	1083.3	0.954
2.75	.5	1300	1.145

Table 3.9. Scaling Factor Determination

3.1.9 Recovery System Electrical Schematic

Figure 3.4 below shows the electrical schematic of the recovery system electronics. This includes two PerfectFlite Stratologger altimeters wired to black powder charges and two batteries.

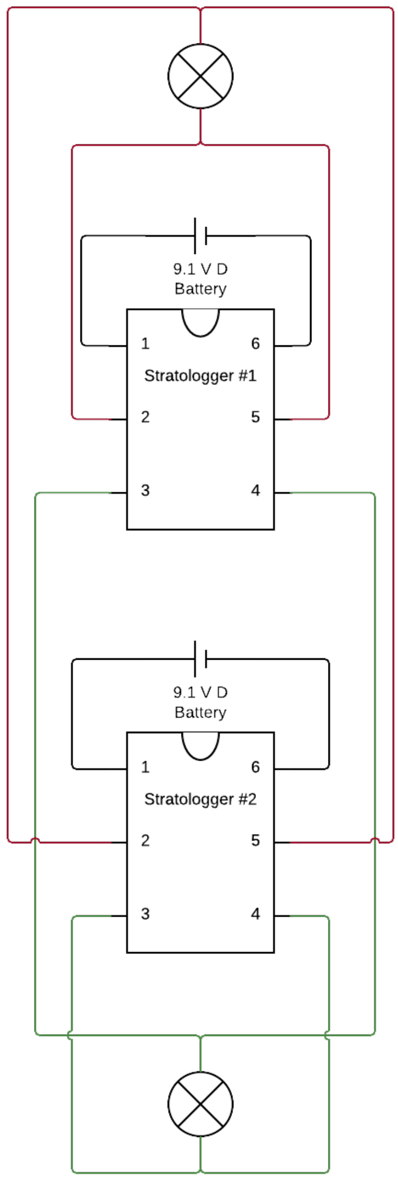

Figure 3.4. Recovery System Electronics Schematic

3.1.10 Mass Statement

The mass for the launch vehicle as it will stand on the launch pad is detailed in *Table 3.10*. Masses are based on values given by OpenRocket and the specifications of all components chosen by the team. The team is confident in the accuracy of this estimate, as OpenRocket bases masses on product specifications. The team expects a 25% increase in mass, so this increase is added to the final mass statement.

Component	Mass (lb)
Nose Cone	0.965
Forward Body Tube	3.450
Aft Body Tube	0.855
Payload	6.770
Electronics Bay	0.575
Main Parachute (Packed)	1.200
Drogue Parachute (Packed)	0.948
Nose Cone Parachute (Packed)	0.180
Motor w/ Propellant	6.550
Motor Propellant	3.620
Current Total	21.49
Total w/ Expected Increase	26.87

Table 3.10. Mass Statement

3.2 Recovery Subsystem

3.2.1 Recovery Subsystem Analysis

Given that the maximum kinetic energy of any individual section of the launch vehicle cannot exceed 75 ft-lb, the maximum allowable ground hit velocity can be calculated with the equation

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

The max ground hit velocity is determined for two individual systems: 1) nose cone and 2) forward and aft body sections. Using the “fruittychutes.com Descent Rate Calculator” we determined the appropriate sized parachutes needed to put each section at a decent rate below the max ground hit velocities. A coefficient of drag of 1.5 was used; this assumes an elliptical or circular parachute design. The elliptical shape was chosen because the team already possesses an elliptical parachute and its performance is satisfactory for the criteria set by the competition. The results from this analysis can be seen in *Table 3.11*.

System	Mass (lb)	Allowable Velocity (ft/s)	Minimum Parachute Diameter (in)	Drag Reduction Velocity from Minimum Parachute (ft/s)
Nose Cone (with parachute)	1.15	64.88	12	29.25
Forward & Aft Body Sections (Main Parachute)	17.17	16.77	83	16.17

Table 3.11 Parachute Selection

Therefore a 12 inch (.305 m) parachute for the nose cone and a 110 inch (2.79 m) main parachute for the forward & aft section are justified to safely land each individual system under the 75 ft-lb limit.

3.2.2 Recovery Subsystem Components

The electronics bay, as seen in *Figure 3.5* and *Figure 3.6*, will contain two Stratologger altimeters and two 9 volt batteries. One altimeter and battery are redundant to ensure blackpowder charge detonation. The altimeters will be responsible for setting off the black charges to separate the rocket at apogee and 900 feet, deploying the drogue parachute and main parachute, respectively. Also, the altimeters will record the altitude the rocket reaches. Every independent section will have a GPS locator attached. This includes the nose cone, front payload section, aft motor section, and the payload.

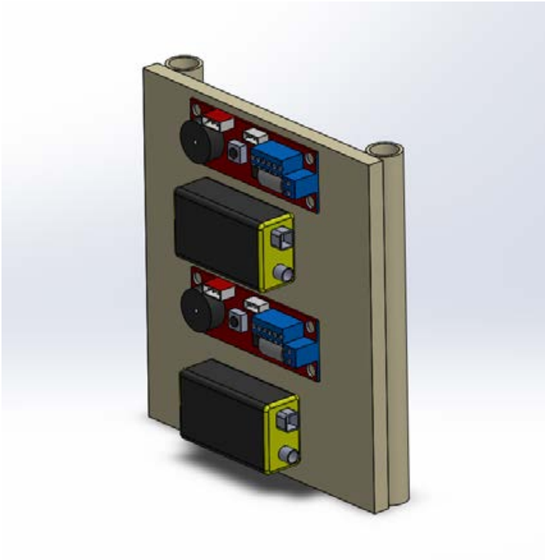

Figure 3.5. Recovery Electronics Sled Model

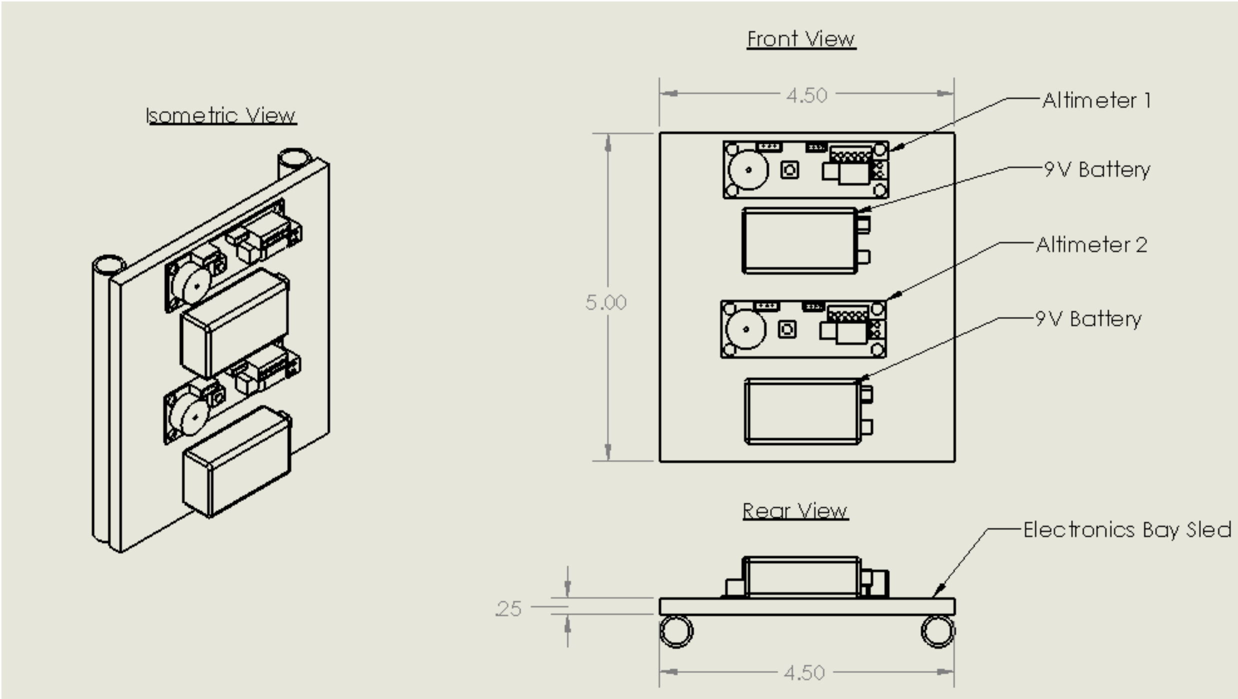

Figure 3.6. Recovery Electronics Sled Drawing

3.3 Mission Performance Predictions

3.3.1 Mission Performance Criteria

The mission performance criteria are based on the competition requirements. These criteria are listed as follows:

- The launch vehicle must have an apogee altitude of 5,280 feet.
- The launch vehicle must deploy a drogue parachute at apogee and a main parachute at 900 feet.
- The launch vehicle must have no more than 75 ft-lb kinetic energy upon contact with the ground.
- The launch vehicle must be recovered in a reusable condition.

3.3.2 Flight Profile Simulations, Altitude Predictions, and Thrust Curve

The ARES Team used OpenRocket to simulate the flight of the launch vehicle. The launch was simulated for four different scenarios: Bragg Farms with no wind, Bragg Farms with 5-10 mph wind, Manchester, TN with no wind, and Manchester, TN with 5-10 mph wind. The results of these simulations are shown in *Table 3.12.* The altitude and vertical velocity vs. time for each scenario are shown in *Figures 3.7, 3.8, 3.9, and 3.10*. In addition, the thrust curve for the Cesaroni L805 motor is displayed in *Figure 3.11*.

**Note: All simulations performed in OpenRocket are at the correct latitude, longitude, and altitude for each launch site.*

Simulation	Apogee (ft)	Max Velocity (ft/s)	Time to Apogee (s)	Flight Time (s)	Ground Hit Velocity (ft/s)
Bragg Farms (0 mph)	5290	642	18	266	11.3
Bragg Farms (5-10 mph)	5256	641	18	265	12.1
Manchester (0 mph)	5304	642	18	265	13.0
Manchester (5-10 mph)	5280	641	18	265	12.1

Table 3.12. Flight Simulation Data

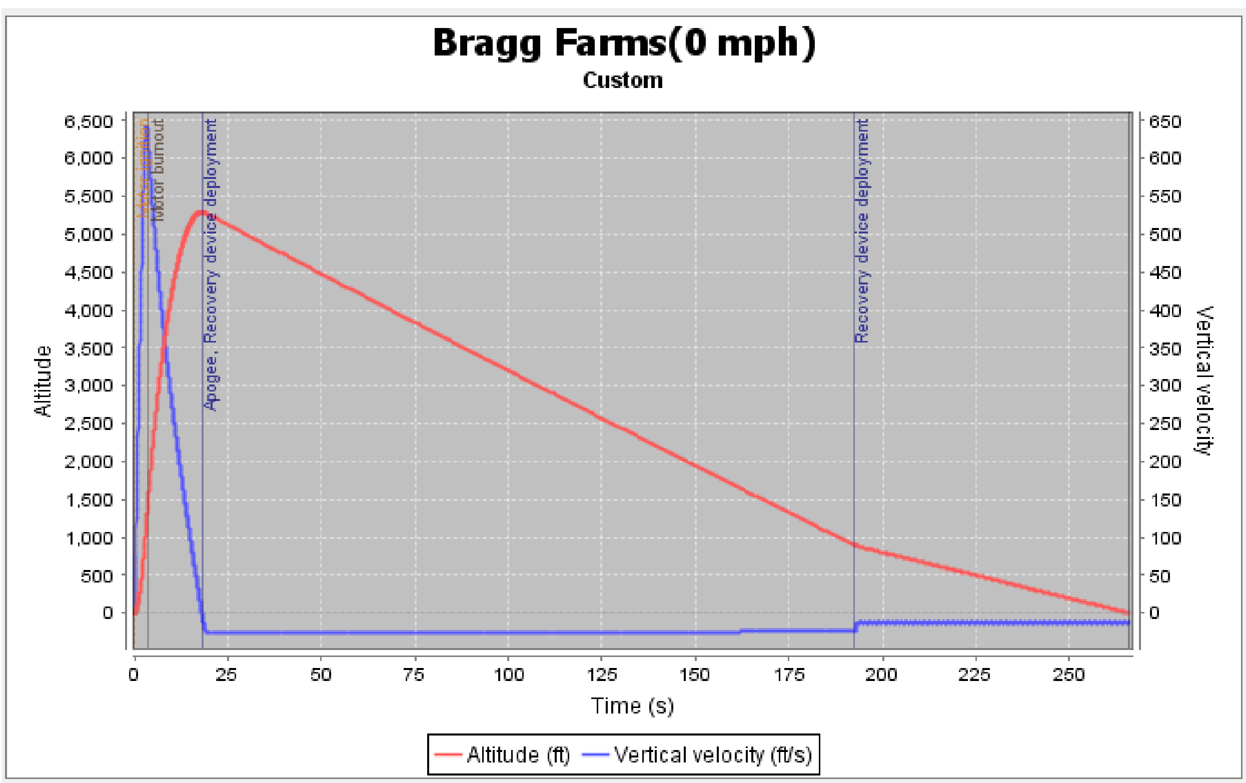

Figure 3.7. Bragg Farms (0 mph)

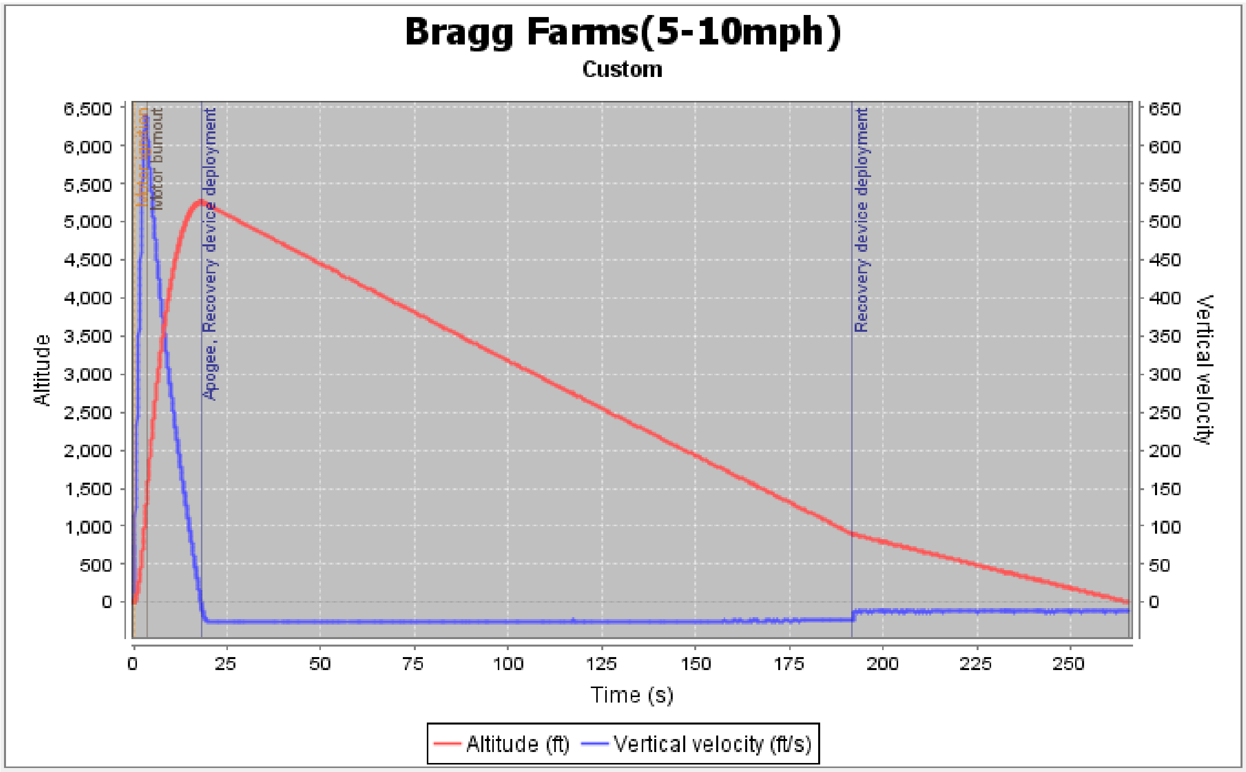

Figure 3.8. Bragg Farms (5-10 mph)

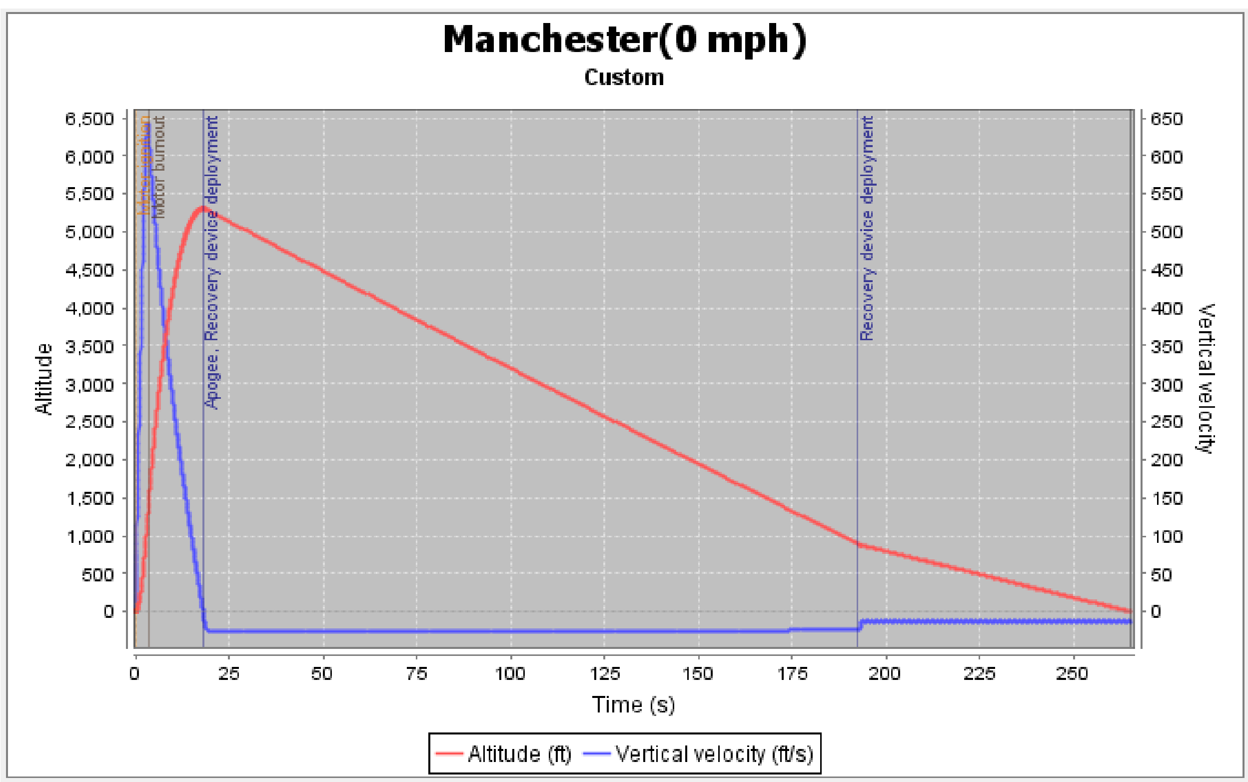

Figure 3.9. Manchester (0 mph)

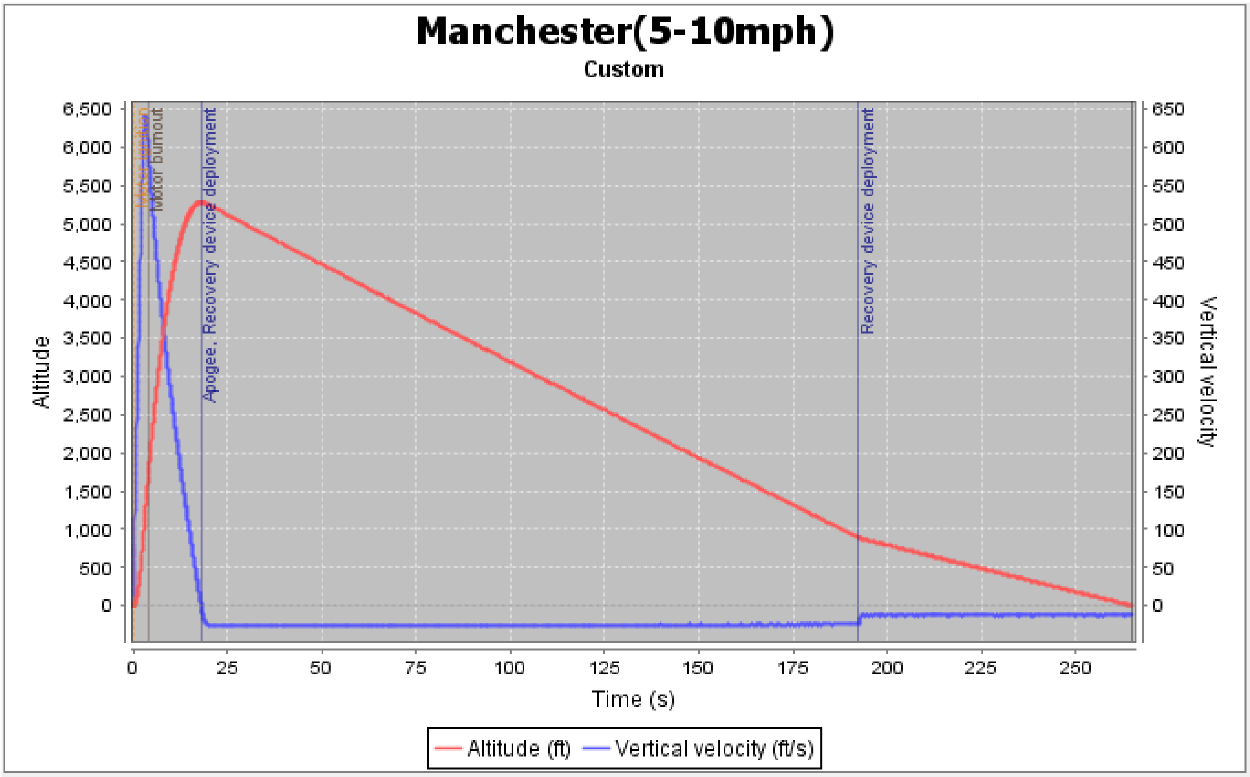

Figure 3.10. Manchester (5-10 mph)

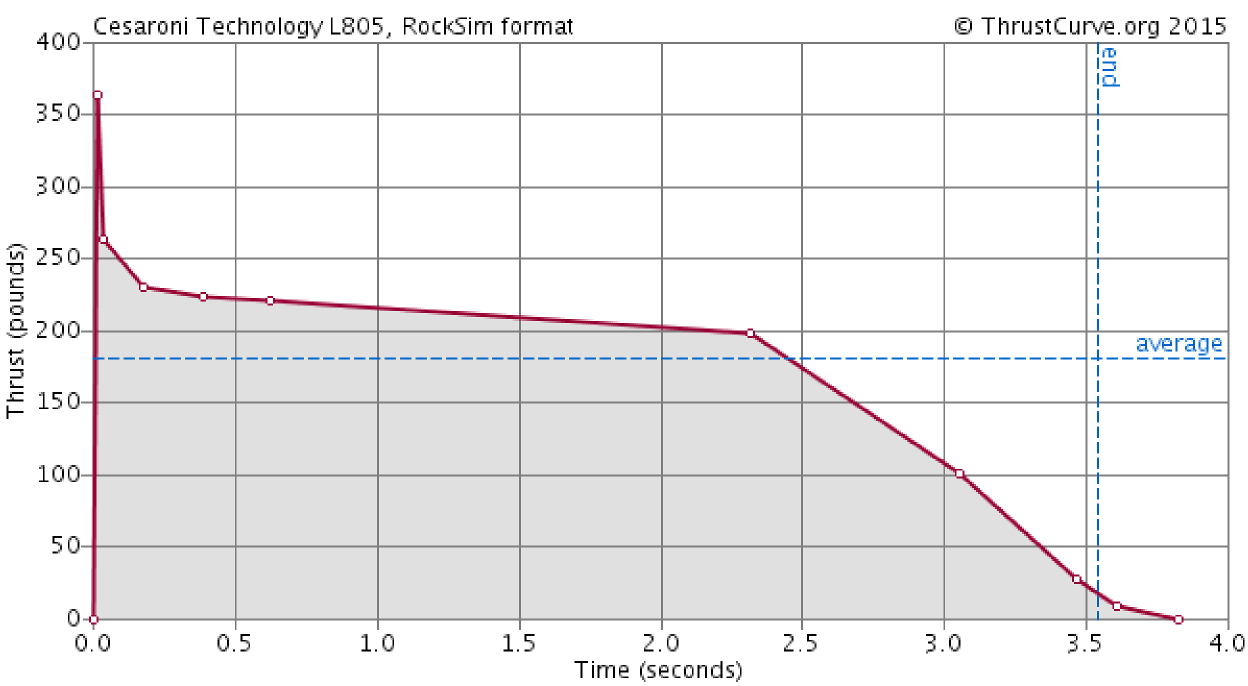

Figure 3.11. Cesaroni L805 Thrust Curve

3.3.3 Rocket Stability

The center of gravity and the center of pressure of the rocket are located 54.37 and 64.98 inches (1.38 and 1.65 m) from the tip of the nose cone, respectively. *Figure 3.12* shows the OpenRocket diagram of the launch vehicle, including the center of gravity (the blue and white circle) and the center of pressure (the red circle). This creates a favorable stability margin of 1.93 calibers.

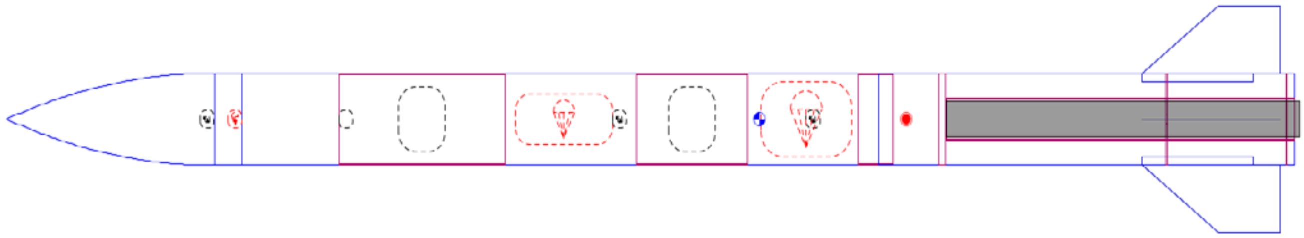

Figure 3.12. OpenRocket Diagram

3.3.4 Drift Calculations

Drift calculations performed in OpenRocket at latitude, longitude, and altitude of Bragg Farms, Huntsville, Alabama and a sod farm in Manchester, Tennessee. The sod farm in Manchester, TN is a site jointly managed by Huntsville Area Rocketry Association, (HARA), and Music City Missile Club, (MCMC), for high-powered rocketry. The drift calculations for both locations at various wind speeds can be seen in *Table 3.13* and *Table 3.14*.

Wind Speed	**0 mph**	**5 mph**	**10 mph**	**15 mph**	**20 mph**
Max Lateral Distance (ft)	7.44	1503	3020	4559	6102

Table 3.13. Bragg Farms Drift Calculations

Wind Speed	**0 mph**	**5 mph**	**10 mph**	**15 mph**	**20 mph**
Max Lateral Distance (ft)	7.50	1496	3014	4536	6064

Table 3.14. Manchester Drift Calculations

3.4 Interfaces and Integration

3.4.1 Payload Integration

The launch vehicle has designated space for the Hazard Avoidance Lander, HAL, to be stored. This designated space is illustrated in *Figure 3.1*. The payload when deployed should be able to eject cleanly, (avoid "sticking" inside the forward body tube), and be well clear of the launch vehicle. The payload has its own internal altimeters. This means the payload can operate without using any of the components of the launch vehicle electronic systems. HAL's electronic systems will be encapsulated in a fiberglass tube of about 12 inches (.305 m).

The payload will be ejected by a black powder charge immediately following apogee. Squibs, (a cup of duct tape containing black powder charge and an electronic match, e-match,) will be used for all necessary ejection charges. At apogee the nose cone will be ejected, followed by the payload, and then the drogue parachute. The payload will be designed and constructed to withstand these charges.

The payload is placed in the forward body tube in front of the drogue chute to allow clearance of the launch vehicle and avoid any possible tangling with the launch vehicle or its recovery system. The ARES team has confidence in this placement because of HAL's avoidance of any recovery system upon ejection.

Lander legs on the side of the tube will present a challenge to the ejection of HAL from the launch vehicle. The lander leg feet are constructed to provide a fin of sorts to help slow or prevent tumbling from the vehicle. These feet will be positioned towards the nose cone. The feet will be positioned prior to insertion to avoid "sticking" inside the forward body tube upon ejection.

3.4.2 Internal Integration

The launch vehicle consists of three of the four independent sections: the nose cone, forward body tube, and aft body tube. The payload, HAL, is the fourth independent section. Each of the launch vehicle's three independent sections contain subsystems and connections.

<u>3.4.2.1 Nose Cone</u>

- The nose cone will be slid into place on the forward body tube.
- The nose cone contains its own parachute which will be secured to an eye bolt in the nose cone. Upon ejection from the forward body tube the recovery system will deploy and allow the nose cone to descend safely.

3.4.2.2 Forward Body Tube

- The forward body tube contains HAL, the drogue parachute, the electronics bay, and the main parachute.
- A coupler and shear pins attach the forward body tube to the aft body tube.
- HAL will be ejected after the nose cone is ejected at apogee.
- After HAL is ejected the drogue parachute will be ejected and deployed.
- The electronics bay holds the altimeters used for ignition of the black powder charges. The altimeters will be preprogrammed to fire at specific altitudes.
- After the drogue is deployed, immediately following HAL's deployment, and the launch vehicle has descended to 900 ft a black powder charge will fire to blow the shear pins, separate the body tube sections, and eject the main parachute.
- The parachutes will be secured to eye bolts screwed into the bulk plates of the electronics bay. The electronics bay will be bolted into the forward body tube.

3.4.2.3 Aft Body Tube

- The aft body tube contains the motor, the motor tube, and the fins.
- The coupler from the forward body tube will be extended into the aft body tube. The aft body tube will be epoxied to the coupler.
- A bulk plate will protect the main parachute and any forward subsystems from the motor's ejection charge. The bulk plate will be screwed into the aft body tube. The main parachute will be secured onto the eye bolt on the bulk plate of the electronics bay and an eye bolt on the motor bulk plate.
- The motor tube on the other side of the bulk plate will hold the motor casing and the motor itself. The motor casing will fit securely in the motor tube. The motor tube will be mounted to the aft body tube by epoxying the centering rings holding the motor tube.
- The fins will be mounted to the aft body tube by epoxying the fins to the aft body tube and epoxying the fin tabs.

3.4.3 Launch Vehicle to Ground Interface

The payload will contain an XBee Pro 900 transceiver, which will communicate with the ARES Team's ground station. Data will be sent in real time from the payload to the ground station.

3.4.4 Launch Vehicle to Ground Launch System Interface

The launch vehicle will utilize rail pins to interface with the ground launch system. Theses pins will slide onto the launch rail, which will guide the rocket during launch. The rocket motor will be armed with an e-match on the launch pad to ignite the motor for launch.

3.5 Safety

3.5.1 Safety Officer

Desiree Kiss
Undergraduate in Aerospace Engineering and Mechanics
Email: dmkiss@crimson.ua.edu
Phone: (228) 243-8772

3.5.2 Final Assembly and Launch Procedures

The team has prepared a final checklist of safe assembly and launch procedures to be used immediately prior to launch. For this checklist, see Appendix B.
Each team member will be provided with a copy of this checklist at a safety briefing to be held during the week prior to the subscale launch. Safety briefings before both the full scale and competition launch will reiterate these safety procedures.

The team has also prepared a checklist of operating procedures for hazardous materials based on the Safety Data Sheets that can be found in Appendix C. This checklist includes specific procedures for each material and can be found in Appendix D.

3.5.3 Risk Assessment

The primary failure modes of the rocket lie in the possible failure of either the parachutes or the payload to properly deploy, failure of the hazard detection software, and failure of the parafoil to steer the payload appropriately during its descent. Failure modes and their associated specific risks can be found in *Table 3.18* below. Other risks, including but not limited to those associated with material and tool use, can be found in the risk assessment beginning on page 14 of the team's proposal. The team criteria for risk analysis and assessment has been reproduced below in *Tables 3.15, 3.16, and 3.17*. These tables are for risk level, severity, and probability, respectively.

Level of Risk	Level of Permission Required
High Risk	Highly Undesirable. Documented approval from NAR mentor, faculty supervisor, Safety Officer, and Team Lead.
Medium Risk	Undesirable. Documented approval from Safety Officer, Team Lead, and NAR mentor.
Small Risk	Acceptable. Documented approval from Safety Officer and Team Lead.
Minimal Risk	Acceptable. Documented approval not required but highly recommended.

Table 3.15. Risk Level Definitions

Severity Definitions			
Severity Classification	**Personnel Safety and Health Risks**	**Facility/Equipment Risks**	**Environmental Risks**
1-Catastrophic	Loss of life or irreversible disabling injury.	Irrecoverable loss of facility, systems, or associated hardware.	Irreversible severe environmental damage that violates law and regulation.
2-Critical	Severe injury or severe occupational-related illness.	Major damage to facilities, systems, or equipment.	Reversible environmental damage causing a violation of law or regulation
3- Marginal	Minor injury or minor occupational-related illness.	Minor damage to facilities, systems, or equipment.	Mitigable environmental damage without violation of law or regulation where restoration activities can be accomplished.
4-Negligible	First aid injury or occupational-related illness.	Minimal damage to facility, systems, or equipment.	Minimal environmental damage not violating law or regulation.

Table 3.16. Risk Severity Definitions

Probability Definitions		
Description	**Qualitative Definition**	**Quantitative Definition**
A-Frequent	High likelihood to occur immediately or expected to be continuously experienced.	Probability is > 0.1
B-Probable	Likely to occur or expected to occur frequently within time.	0.1 ≥ Probability > 0.01
C-Occasional	Expected to occur several times or occasionally within time.	0.01 ≥ Probability > 0.001
D-Remote	Unlikely to occur, but can be reasonably expected to occur at some point within time.	0.001 ≥ Probability > 0.000001
E-Improbable	Very unlikely to occur and an occurrence is not expected to be experienced within time.	0.000001 ≥ Probability

Table 3.17. Risk Probability Definitions

Risk Assessment					
Failure Mode	**Hazard**	**Cause**	**Initial Risk Assessment**	**Mitigation**	**Post Mitigation Risk Assessment**
Nose cone parachute	Ballistic nosecone; possible loss of nose cone due to damage on landing	Incorrect parachute packing and folding; failure of shear pins to break as planned (shear pins too strong and do not allow separation)	2D	Ensure parachute is properly packed and correct shear pins are used; double check shear pins and parachute prior to launch	4D
Payload deployment	Incomplete experiment and/or full experimental failure due to failure of payload to deploy	Failure of black powder charges to detonate; failure of altimeter altitude readings; failure of shear pins to	1D	Ensure payload is secure within payload bay; double check setup of altimeters and black powder charges to avoid	1E

		separate		mistakes; ensure correct shear pins are used	
Parafoil deployment	Ballistic payload; possible loss of payload due to damage from landing; inability to correctly steer payload	Incorrect parafoil packing; failure of rocket separation	1D	Double check folding and packing of parafoil prior to launch; follow all mitigation steps for failed rocket separation	1E
Parafoil control software	Inability to correctly steer payload away from ground hazards	Power failure to payload; bugs in code which prevent proper steering and response	3C	Run code repeatedly to check for bugs; ensure code is working properly during full scale launch; follow mitigation steps for payload power failure	4D
Parafoil motors	Inability to control parafoil; uncontrolled descent of payload; partial experimental failure	Power failure to payload; breakage or failure of the motors themselves	3D	Check motor manuals and possibly speak with manufacturer to prepare for and prevent common motor malfunctions	4E
Hazard detection software	Inability to detect ground hazards at altitude; partial experimental failure	Power failure to payload; bugs in code which prevent proper hazard recognition and response	3C	Run code repeatedly to check for bugs; ensure code is working properly at time of full scale launch; follow mitigation steps for payload power failure	4D
Payload power supply	Failure of hazard detection	Loose or faulty wiring; failure to test power	2D	Check to ensure all internal wiring	2E

	software and/or hazard avoidance system; partial or full experimental failure	supply prior to rocket launch		is secure prior to launch; test power supply beforehand to ensure ample and reliable power delivery to payload in flight	
Altimeters	Failure to correctly read altitude; possible effect on parachute and payload deployment	Altimeter malfunction; faulty wiring or code which may incorrectly read a working altimeter	3D	Consult altimeter manual for common altimeter defects and errors; check all wiring and code to ensure it is compatible with the altimeter data	4E
Rocket separation (early)	Deployment of payload and/or parachutes prior to apogee; full apogee not reached	Early detonation of black powder; failure to secure suitable shear pins for rocket; early breakage of shear pins	3C	Check black powder and e-match setup to ensure early detonation will not occur; choose shear pins of proper strength for rocket and charge size	4E
Rocket separation (late or failed)	Kinetic energy of rocket and/or payload may exceed limit; possible damage to rocket or payload upon landing; rocket may cause severe injury or death if a failed separation occurs over a crowded area	Delayed or failed detonation of black powder; failure of shear pins to break as expected	1C	Ensure e-matches will be able to detonate black powder at desired altitude; double-check e-match setup prior to launch; avoid choosing shear pins strong enough to prevent rocket separation	1E
Black powder (early or unexpected	Damage to rocket, payload, and	Improper storage of black powder;	1B	Store black powder securely in	2E

detonation)	equipment; severe injury to team members including burns or death	exposure of black powder to flame, temperature, or impact prior to expected detonation		explosives safe container; keep black powder away from possible sources of heat or impact; ensure black powder charges are properly secured within rocket	
Black powder (late or failed detonation)	Delayed or failed deployment of parachutes and/or payload; delayed or failed rocket separation	Failed altimeter readings; failure of e-matches to ignite black powder	2C	Ensure altimeter data is correctly read by onboard software; ensure proper setup of e-matches and black powder charges prior to launch	2E
Unsuitable launch pad for launch vehicle	The launch vehicle would be unable to launch due to the safety issues involved	Rail buttons and launch rail are not compatible	1D	Ensure that all rail guides fit standard rail launching systems. The ARES team will also look into purchasing its own launch pad to ensure successful launch	3E
Incorrect determination of center of gravity	Launch vehicle is either unstable or is susceptible to weathercocking at the extreme. A minor error in the determination is acceptable	Center of gravity is found before the final weight is calculated; the design in simulation engine is not updated	3D	Center of gravity will be found by testing the launch vehicle multiple times; design of the launch vehicle in OpenRocket will be updated	4E

				with real measurements	
Incorrect determination of center of pressure	The rocket is either unstable or is susceptible to weathercocking at the extreme. A minor error in the determination is acceptable	The Barrowman method used in the simulation engine, OpenRocket	3D	Launch vehicle in OpenRocket will be updated with real measurements; OpenRocket uses Barrowman method to determine center of pressure; an independent determination of center of pressure using computer fluid dynamics will also be undertaken as part of a paper Christopher is currently writing	4D
Launch vehicle weathercocks	The vehicle has the potential to enter an improper flight path; would lead to a lower altitude or possible issues with the deployment of the payload with a minor weathercocking	The launch vehicle became unstable	1D	Stability margin will be maintained around 1.5 calibers throughout design iterations in order to avoid any potential weathercocking	3D
Improper motor selection	Could lead to underthrust or overthrust. Underthrust	From simulations in OpenRocket, a weaker or stronger motor	1C	Utilize OpenRocket to simulate the different	3D

	would lead to a lower than desired altitude. Overthrust has the potential to make the rocket highly unstable and a danger to observers. Overthrust would lead to a higher than predicted altitude and the possibility of moderate to severe structural damage	than needed was selected		motors to predict the effect of different impulses; use knowledge from NAR mentor; ensure the Reynolds number and impulse of subscale match those of full scale	
Launch vehicle fails to be stable	The vehicle will pose an extreme hazard and danger to bystanders and observers; the payload may not deploy or operate properly	The stability margin is not close to 1.5; components shifted during launch	1D	Constantly verify that the stability margin is around 1.5 calibers	2D
Tumbling of the payload	The camera will have poor images for the processor to analyze and use to navigate away from hazards	Parafoil cords became tangled; loss of payload guidance system	2C	Parafoil will be packed to prevent tangling; tests to ensure there is enough power for the entire launch time	3D
Payload guide fails	The payload descends without guidance;	Loss of power; bugs in code used to guide payload on descent	1D	Ensure that the batteries used can last the entire launch	2D

	could cause injury if descending towards a crowd; no guarantee it will land somewhere recoverable			time; ensure batteries can withstand forces at launch; run testing on software	
Incorrect payload deployment time	Insufficient time for the processor to analyze and navigate away from hazards; too high a kinetic energy upon impact	Black powder charge failed to ignite	2C	Test all black powder charges prior to launch	3C
Structure prevents deployment of payload	Payload is unable to be deployed	Structural components got in the way of the payload ejection	2D	Fit all the parts of the rocket together; assemble the rocket with payload inside; check for any possible parts that may inhibit ejection	3E
Motor mount fails	If the motor mount becomes loose, the motor may move in the rocket; may result in misfire or an unstable launch	Improper attachment of motor mount; excessive use	1D	Ensure the motor mount is secured properly inside the rocket	3E
Incorrect determination of forces on launch vehicle	Will supply an incorrect determination of the CP	Incorrect calculations; final data not included in calculations	2C	Utilize OpenRocket to determine the forces on the launch vehicle using the most	3D

				up to date information	
Fins improperly mounted	More prone to instability if fins are uneven or become detached	Error in measurement of fin placement; improper or impatient attachment of fins	1D	Check size and placement of fins in OpenRocket; ensure they are positioned on the launch vehicle symmetrically and in the designated locations	3E
Wind gusts affect launch vehicle stability	More prone to instability if there is wind; greater chance of vehicle not flying vertically	The angle of attack exceeds the angular margin of stability	1D	Monitor the weather before all launches; listen to the RSO at all times, and specifically if conditions become questionable	2D
Wind gusts affect deployment of payload	Heavy swinging of payload once deployed; difficult for camera to analyze hazards; tangle cords of parafoil; blown too far from home base	Wind gusts tangle the parafoil cords; wind catches parafoil and carries it far from intended location	2D	Monitor all weather conditions before launch; pack the parafoil so cords do not become tangled	3D
Wind gusts affect deployment of recovery system	Launch vehicle drifts far off course; rocket may cause severe injury or death if rocket drifts over a	Wind gusts can suddenly change the direction of the rocket	1D	Monitor all weather conditions prior to launch; ensure recovery system is packed so it	2D

	crowded area, especially if recovery system deploys late; wind tangling recovery system			will not be constricted or tangled upon deployment	

Table 3.18. Risk Assessment

3.5.4 Environmental Concerns

The rocket presents several safety hazards to the environment; likewise, the environment has the potential to adversely affect the flight and mission of the rocket. Rocket hazards to the environment primarily concern possible environmental damage in the form of pollutants or physical damage to the natural surroundings. Environmental hazards to the rocket include any natural phenomenon or state that may negatively affect flight conditions. All hazards are provided below in *Tables 3.19* and *3.20*. The same criteria used in the Risk Assessment in Section 3.5.2 was used to determine environmental risk levels. All risks apply to the subscale, full scale, and competition launches.

Rocket Hazards to Environment					
Hazard	**Consequence**	**Cause**	**Initial Risk**	**Mitigation**	**Post Mitigation Risk**
Pollution	Contamination and/or death of nearby plant and animal life; possible contamination of water if leak occurs near water source; possible sickness or serious harm to team members	Paint, epoxy, or other hazardous pollutant materials left unattended or allowed to leak	2C	Ensure all hazardous materials are properly stored in rocket lab; avoid using hazardous materials near water sources; enforce team usage of proper PPE and safety guidelines	2E
Fire	Burns and/or death to any plant and animal life, including team	Unexpected firing of motor or detonation of black powder	1B	Do not allow handling of motor except by NAR mentor; do not	1E

	members, within range of the fire	charges under exceptionally dry conditions; ignition of black powder or motor when left unattended; rocket explosion on pad or crash landing		leave black powder or motor unattended without proper storage in explosives container; ensure all launch procedures are followed correctly	
Physical plant/crop damage	Minor to major damage to nearby plant life on landing, including broken tree limbs, crops crushed by rocket, etc.	Rough landing or crash of rocket, payload, or nosecone on crops or plant life	3B	Ensure proper parachute deployment and proper function of guided landing systems to minimize potential crash landings	3D

Table 3.19. Rocket Hazards to Environment

Environment Hazards to Rocket					
Hazard	**Consequence**	**Cause**	**Initial Risk**	**Mitigation**	**Post Mitigation Risk**
Adverse weather (i.e. thunderstorm)	Launch is delayed or cancelled due to weather	Failure to check weather conditions prior to conducting team launches	3A	Check weather prior leading up to launch date to ensure favorable conditions	3D
Heavy wind	Launch is delayed or cancelled due to wind	Failure to check wind speeds and conditions prior to team launches	3A	Check weather and wind conditions leading up to launch date	3D
Excessive landing hazards	Payload is unable to sufficiently steer away from hazards; possible	Failure to secure appropriately sized launch area for rocket	3C	Field is selected according to safe distance guidelines set forth by NAR;	3E

	damage to payload on landing; incomplete mission			clear field of appropriate size is secured for launches	
Water	Rocket or payload unable to be recovered on water landing	Selection of a launch area in close proximity to a body or bodies of water	3C	Launch only in an appropriately sized field; conduct launches on low-wind days to ensure minimal drifting of rocket	3E
Power lines	Rocket or payload unable to be recovered on power line landing	Selection of a launch area in close proximity to above ground power lines	3C	Launch only in an appropriately sized field; conduct launches on low-wind days to ensure minimal drifting of rocket	3E

Table 3.20. Environment Hazards to Rocket

4. Payload Criteria

4.1 Selection, Design, and Verification of Payload

4.1.1 System Level Review

The payload system is responsible for performing the two experiments selected by the ARES team. The first experiment is to detect landing hazards under the payload. The second experiment is to guide descent to a certain waypoint while avoiding hazards. The payload is divided into four distinct subsystems. The Payload Control subsystem interfaces with the other three, and runs the software for the payload. The Landing Hazards Detection Payload acquires images of the ground to be analyzed, stores the data, and transmits it back to a ground station. The Guided Descent Subsystem steers the payload to a GPS waypoint, and also avoids hazards that are detected in the area. Finally, the Payload Landing Subsystem is responsible for mitigating any velocity at landing to keep the components safe. The functional requirements of the payload are covered in *Table 4.1*.

Subsystem	Functional Requirement	Selection Rationale	Selected Concept	Characteristics
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	Parafoils fill with air
	Guide payload descent	Payload must be able to avoid any landing hazards detected		
	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
	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
Landing Hazards	Detect hazards	See Appendix E	Pixy CMUcam5	Take images of the ground

	Identify hazards	See Appendix E	Pixy CMUcam5 Raspberry Pi	Analyze images taken by the camera
	Store data onboard	See Appendix E	250GB USB Portable Solid State Drive	Stores onboard data quickly, uses less power, resistant to vibrations
	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
Control	Run software in real time	Allows for the fast response times	Python code	Allows for more up to date information
	Know altitude	See Appendix E	AltIMU-10 v4	The barometer will receive pressure readings and will output altitude
	Know orientation	See Appendix E		The gyro will provide payload attitude
	Know location	See Appendix E	Adafruit Ultimate GPS Breakout	The GPS is accurate to 3 m
	Know velocity	See Appendix E		The GPS is accurate to 0.1 m/s
	Have 1 hour and 30 minutes of power available	Contains enough charge to last one hour on the pad, launch and land the payload, and transmit data	USB Battery Pack for Raspberry Pi and LiPo battery	The batteries should last longer than what will be required with all electronics powered on
Landing	Deploy legs at a specified altitude	Minimizes drag and moments on payload	Solenoid	Release lander legs when current passes through
	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
	Absorb forward momentum	Allow for the legs to release as well	Torsion springs	Upon landing, the springs will coil up

	Absorb vertical momentum	as absorb some of the impact when landing		and absorb some of the energy to protect the payload

Table 4.1. Payload System Functional Requirements

4.1.2 Payload Subsystems

<u>4.1.2.1 Payload Control Subsystem</u>

The Payload Control Subsystem will serve as the brains of the payload system. It consists of the components whose functions or data are shared among the other payload subsystems. The Raspberry Pi 2 is the flight computer and controller of the whole system. The Pi will run the software used to detect landing hazards and control the guided descent. Data from the software will be stored on the Samsung 250GB USB 3.0 Portable SSD, which will also be running the operating system of the Pi during flight. A USB Lithium Ion battery pack will provide power for the Pi, which in turn will power all of the components except the servo motors, solenoid, and the AltImu Gyro. The Pi will receive location data from the Ultimate GPS Breakout. The Pi will receive orientation, heading, accelerations, and altitude from the AltIMU-10 V4, which contains a gyroscope, magnetometer, accelerometer, and altimeter. The Pi will interface with the servo driver and the AltIMU-10 V4 via the two I^2C pins on the GPIO bus. These will be attached to the Permi-Proto Board using the Pi Cobbler Plus as an extension cable for the GPIO pins. The Pi will interface with the SSD, XBee Pro 900, GPS, and Pixy CMUcam5 via USB ports. The battery will be plugged into the MicroUSB power port on the PI. Further details on the components can be found in section 4.1.3 and *Table 4.3*.

<u>4.1.2.2 Landing Hazards Detection Subsystem</u>

The Landing Hazards Detection Subsystem is responsible for taking images, analyzing them for landing hazards, storing the data, and transmitting it back to a ground station. Images will be acquired using a Pixy CMUCam5. This camera will be powered by and transmit images to the Raspberry Pi 2 via USB cable. The Pi will run the software which analyzes the images for landing hazards. This data is first stored on the Samsung 250GB USB3.0 Portable SSD for later recovery. In addition, data will be transmitted wirelessly via radio transmission using the XBee Pro 900 RP-SMA. The XBee Pro 900 will be mounted on the XBee Explorer Dongle, which will allow it to connect to the Pi using a USB connection. The USB connection also provides the power for the XBee Pro 900. Further details on the components can be found in section 4.1.3 and *Table 4.4*.

4.1.2.3 Guided Descent Subsystem

The guided descent subsystem will consist of two servo motors and a parafoil. The guided descent system will receive the data collected by the landing hazards detection system. Using the data received, the direction of the landing hazard will be determined. After determining the direction, the guided descent system will pull on the outermost cords on the parafoil using the servo motors. Depending on which cord was pulled, the payload will turn away from the hazard detected. An Ultimate GPS Breakout will be used to track the position and velocity of the payload during the descent. A USB to TTL Serial Cable will be used to connect the Ultimate GPS Breakout to the Raspberry Pi to save and transmit the data. Further details on the components can be found in section 4.1.3 and *Table 4.5*.

4.1.2.4 Payload Landing Subsystem

The Payload Landing Subsystem is responsible for the safe landing of the payload at the end of its descent. Because the payload uses a parafoil to slow its descent, the subsystem must be able to mitigate both a downward and forward momentum, without tipping. The system consists of 5 3-D printed lander legs, whose dynamics are inspired by the motion of a parachutists legs when they come in for a landing. Each leg consists of a thicker thigh piece, two thinner calf pieces, and two feet. The pieces are connected at each joint by a torsion spring. The spring allows the legs to fold up into a low-profile aerodynamic mode during descent. A locking mechanism will be fired by the Pi to deploy the legs shortly before landing. The springs also serve to absorb some of the energy of the landing, similar to the "tuck" maneuver performed by a professional parachutist as they land. Further details on the components can be found in section 4.1.3 and *Table 4.6*.

4.1.3 Performance Characteristics

Each subsystem within the payload has specific performance characteristics, as do the components within these subsystems. The ARES team has plans to evaluate each subsystems' and components performance and verify that the meet the specified characteristics. The characteristics and evaluation and verification metrics are presented at subsystem-level granularity in *Table 4.2*. They are listed at the component-level granularity for the Payload Control Subsystem, Landing Hazards Detection Subsystem, Guided Descent Subsystem, and Payload Landing Subsystem in *Table 4.3*, *Table 4.4, Table 4.5*, and *Table 4.6* respectively.

Component	Performance Characteristics	Evaluation and Verification Metrics
Payload Control	Monitor altitude, velocity, orientation, and GPS location in real time	The control system must be able to run the software in real-time. Ground testing will be done to verify algorithm speed and IMU accuracy.
Landing Hazard Detection	Scan the ground and detect potential hazards	Multiple software tests will be run for different images to test the algorithm accuracy. In addition, drop tests will be conducted to ensure functionality in a realistic environment
Guided Descent	Control descent of payload and steer away from all potential hazards detected	Multiple drop tests to determine lift to drag ratio and velocity, use averages to determine lift and drag coefficient
Payload Landing	Deploy landing gear	Deploy landing gear remotely via the Raspberry Pi

Table 4.2. Subsystem-Level Performance Characteristics and Evaluation and Verification Metrics

Component	Performance Characteristics	Evaluation and Verification Metrics
Raspberry Pi 2	Collect and store data from sensors	Ground test all assembled electrical components and analyze collected data
USB Battery	Provide power for 1 hour and 30 minutes	Allow for the battery to drain while hooked up to all components
Pi Cobbler Plus	Extend Raspberry Pi 2 GPIO pins	Assemble all components to ensure GPIO pins are accessible
Perma-Proto Breadboard	Provide soldered connections for electrical components	Ground test soldered connections with vibrations to ensure durability
PerfectFlite StratoLogger Altimeter	Record altitude and transmit data to Raspberry Pi 2	Conduct drop test with redundant altitude measurements to evaluate accuracy
AltIMu-10 V4	Record altitude, orientation, acceleration, and heading and transmit data to Raspberry Pi 2	Ground testing will verify that the chip and software properly identify the altitude, orientation, acceleration, and heading. Drop testing will verify accuracy in a realistic environment.

Table 4.3. Payload Control Subsystem Component-Level Performance Characteristics and Evaluation and Verification Metric

Component	Performance Characteristics	Evaluation and Verification Metrics
Samsung 250 GB Solid State Drive	Store all pictures from the Pixy CMUcam5	Determine the number of pictures to be taken and store the same amount of data onto the hard drive
XBee Pro 900	Transmit information between the rocket and ground station	Separate Raspberry Pi and a laptop by various distances and test maximum reliable distance
Pixy CMUcam5	Image the ground and detect hazards	Perform drop tests with the camera attached

Table 4.4. Landing Hazards Detection Subsystem Component-Level Performance Characteristics and Evaluation and Verification Metric

Component	Performance Characteristics	Evaluation and Verification Metrics
Parafoil	Control descent of payload, generate lift to create horizontal velocity necessary to avoid landing hazards	Multiple drop tests to determine lift to drag ratio and velocity, use average values to calculate lift and drag coefficients
HS-645MG Ultra Torque Servos	Create tension in outermost cords of parafoil to force turn, create tension in both outer cords simultaneously to emulate "flare technique" used by paragliders to slow for landing	Drop tests with set tension in cord to test tension required to force controlled turn, calibrate servos to provide set tension
Ultimate GPS Breakout	Provides position within 3 meters, velocity within 0.1 meters per second	Move payload around at different velocities to check Ultimate GPS Breakout's ability to track
USB to TTL Serial Cable	Connects GPS to Raspberry Pi	Conduct vibration tests to verify cable will remain intact and serviceable during descent

Table 4.5. Guided Descent Subsystem Component-Level Performance Characteristics and Evaluation and Verification Metric

Component	Performance Characteristics	Evaluation and Verification Metrics
Hinge (5)	Connect landing legs to payload body	Drop tests to assess structural durability of connection
Thigh (Upper landing section) (5)	Handle primary weight load	Drop tests to assess structural durability
Calf (Lower landing leg) (10)	Handles secondary weight loads and provide stability	Drop tests to assess structural durability
Landing feet (10)	Provide stable landing surface	Drop tests to assess structural durability.
Torsion springs (25)	Ensure proper deployment of legs and provide bounce	Drop tests to assess effectiveness
Locking mechanism	Lock folded-up legs into place during flight	Ground testing to ensure reliable deployment.

Table 4.6. Payload Landing Subsystem Component-Level Performance Characteristics and Evaluation and Verification Metric

4.1.4 Verification Plan

The payload verification plan consists of two main features. First, ground testing will be done to test both the accuracy of individual components and the functionality of the subsystems in a controlled environment. Second, drop tests will be performed on the payload as a whole. This will simulate the deployment of the payload from the rocket. Drop testing will give valuable data as to how the subsystems are working together to perform the key goal in a launch-like environment. The requirements, features, and verification plans are summarized in *Table 4.7*.

Relevant Subsystems	Payload Requirement	Design Feature	Verification Plan	Status
Payload Control Landing Hazards Detection Guided Descent Payload Landing	The payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	All payload components will powered by batteries, which will either be replaceable or easily charged. The software can be restarted manually. The parachute will be re-packable. Landing in a safe area specified by	After drop tests, the payload components will be reset and ground tested to ensure reusability.	In Progress

		GPS will ensure recoverability. The controlled landing protects fragile components. The legs are spring deployed, and the locking mechanism can be reset.		
Payload Control	The data collected shall be stored on board and transmitted wirelessly to the team's ground station.	The data will be stored on a Samsung 250 GB Solid State Drive to provide ample storage space, withstand vibrations, and provide necessary computational speed. An XBee Pro 900 will be used to transmit the data over a distance of at least 5280 feet.	Using The University of Alabama's shake table, the payload can be shaken at various frequencies to determine if the Solid State Drive will remain connected	In progress
Landing Hazards Detection Payload Control	The data from the hazard detection camera shall be analyzed in real time by a custom designed on-board software package that shall determine if landing hazards are present.	The team will use a Raspberry Pi 2 due to the computing power, accessibility of using Python, and dedicated GPU for image processing. In addition, the camera comes with some dedicated resources that will further increase the speed of the algorithm.	Use images previously taken by the Pixy CMUcam5 and run the image processing code on the Raspberry Pi	In progress
Landing Hazards Detection	A payload that scans the surface continuously during descent in order to detect potential landing hazards.	The team will use the Pixy CMUcam5 to detect potential landing hazards.	While performing drop tests, the Pixy CMUcam5 will be used to verify the quality	In progress
Landing Hazards Detection	The payload shall avoid hazards	The parafoil will be used to guide the	Drop tests will be conducted with	In progress

Guided Descent	within the proposed landing area	payload away from hazards	planned hazards to assess the reliability of the hazard detection system with hazards of various sizes, shapes, and colors.	
Guided Descent	The payload shall return to within 50 yards of a GPS waypoint.	When approaching landing, payload will turn so it is moving towards the GPS waypoint to minimize distance.	Velocities obtained in dropped tests will be used to determine altitude required to turn back to GPS waypoint.	In progress
Guided Descent Landing	At landing, the payload shall have a maximum kinetic energy of 75 ft-lb.	When landing, the flare maneuver will be used to slow the descent of the payload	Drop tests will be conducted using flare maneuver to estimate velocity change when.	In progress
Landing	At landing, the payload shall land upright, with components intact.	Landing legs will be deployed prior to landing. Landing legs will convert kinetic energy to elastic energy by using torsion springs to resist bending between the upper and lower legs.	Drop tests with various vertical and horizontal velocities will be conducted to assess the stability and ability to safely absorb impact.	In progress

Table 4.7. Payload Verification Plan

4.1.5 Integration Plan

Figure 4.1 shows a model-view of the assembled payload. Detailed diagrams can be found in Figures 4.3 and 4.4, in section 4.1.7. The top and the bottom of the assembly will be 4” fiberglass discs. They are supported by two 0.25” all thread aluminum rods attached with twelve hex nuts of the same size. The bracket that supports the majority of the components will be made out of aluminum. The Raspberry Pi, Ultimate GPS Breakout, and Servo Driver are all mounted with M3 screws on 10mm standoffs. The Pixy CMUCam5 is mounted to the bottom fiberglass disc with M3 screws on 25mm brackets, with a hole cut in the bottom to allow pictures to be taken of the ground. The AltIMU-10 V4 is also mounted to the bottom plate, with 2M screws and no standoffs. The Perma-Proto breadboard and XBee Pro are mounted to the bracket with M2 screws and no standoffs. The servos, solenoids, batteries, and SSD are all mounted in specially designed brackets that will be 3D printed. A 4” diameter fiberglass sleeve will surround the components. The legs will be mounted with hinges onto the fiberglass sleeve, and the legs are held in place by the ring. During landing procedures, the solenoids will retract and the rings will separate, although they are tethered, allowing the legs to deploy. The legs will have torsion springs at each joint, which will be placed there upon assembly. Each of the parafoil's toggle lines will be attached to a servo motor, and the guidelines will be bolted to the top.

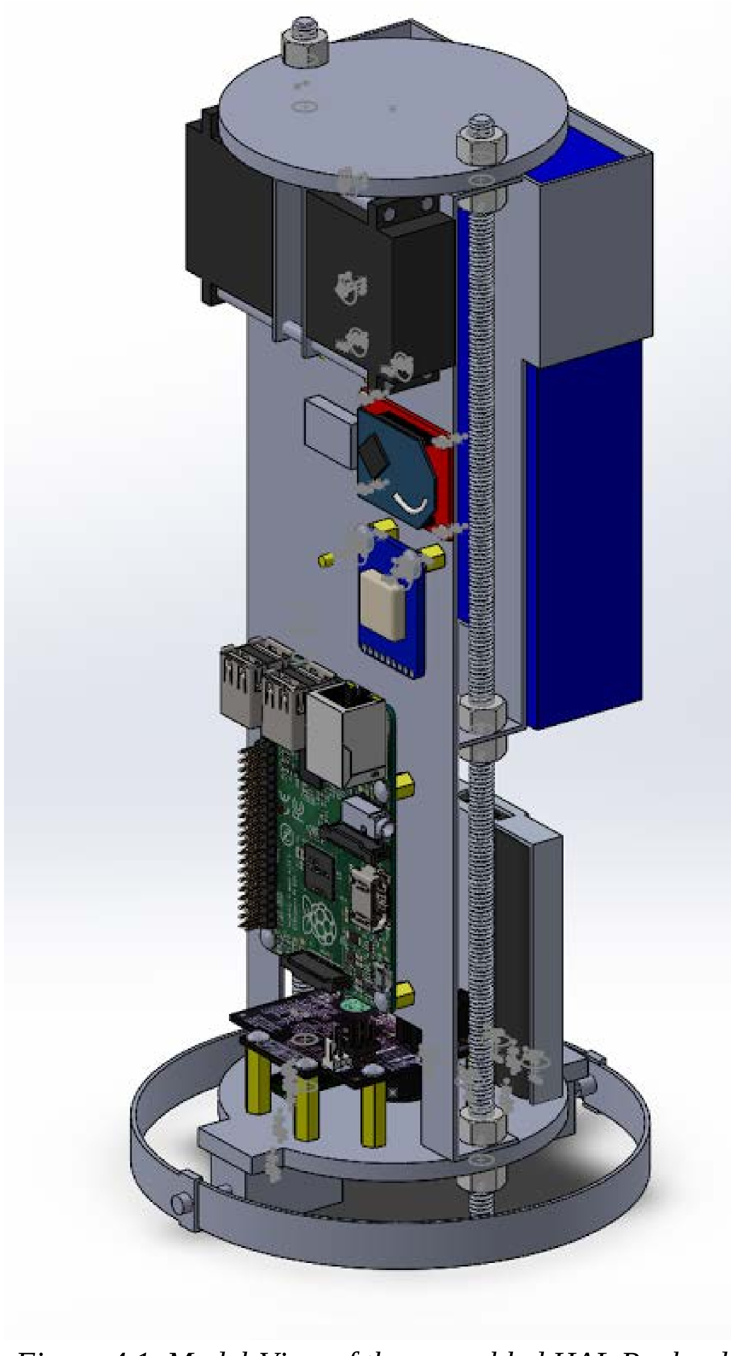

Figure 4.1. Model-View of the assembled HAL Payload

4.1.6 Instrumentation

The instrumentation on the payload is key to the ability to perform both of the selected experiments. The Landing Hazards Detection Subsystem requires data from the altimeter to assess the size of shapes that it detects, an essential step to identifying a hazard. Furthermore, the data must be stored on board and also transmitted back to a ground station wirelessly. Finally, a camera is needed to acquire the images. The Guided Descent Subsystem needs to know its location, heading, and orientation in order to plan course adjustments. Servo motors are then required to execute this motion. If any of these instruments fail, the ability of the payload to perform its specified tasks will be significantly impaired. As such, proper understanding of the payload instrumentation is imperative to the mission. A summary of the payload instrumentation is listed in *Table 4.8* on the following page.

Payload Subsystem	Instrumentation	Precision	Repeatability of Measurement	Recovery System
Guided Descent	Ultimate GPS Breakout	3 m position accuracy 0.1 m/s velocity accuracy	Can be repeated with every launch	Recovered upon safe landing of the payload
Landing Hazards Detection	Pixy CMUcam5	Captures 1280x800 image frame 50 times a second		
Landing Hazards Detection	XBee Pro 900	156 Kbps data rate 6 mile range		
Payload Control	AltIMU-10 v4	Gyro - ±245, ±500, or ±2000°/s Accelerometer: ±2, ±4, ±6, ±8, or ±16 g Magnetometer: ±2, ±4, ±8, or ±12 gauss Barometer: 26 kPa to 126 kPa		
Payload Control	HS-645MG Ultra Torque Servo Motors	Operating speed of 0.233 sec/60° with stall torque of 8.02 kg*cm		
Guided Descent	250 GB Portable Solid State Drive	450 MB/s read-write speed		

Table 4.8. Payload Instrumentation

4.1.7 Drawings and Electrical Schematics

Figure 4.2 shows the free-body diagram of a parafoil with no thrust acting on it. γ represents the flight path angle, shown negative, ϕ represents the canopy rigging angle, and α represents the angle of attack. L_c represents the lift generated by the canopy. D_c represents the drag force generated by the canopy and D_P represents the drag force generated by the payload. W represents the weight. R_{cg} is the distance from the parafoil's center of gravity to the center of gravity of the system. R_{sp} is the distance from the payload's center of gravity to the center of gravity of the system.

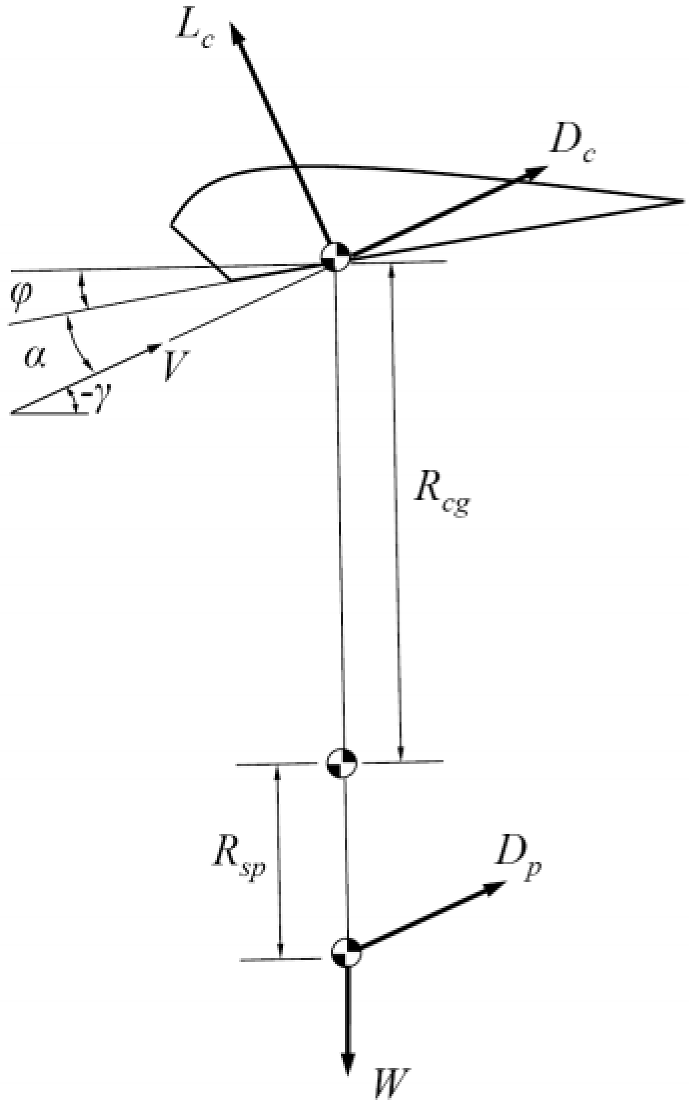

Figure 4.2. Free body diagram of parafoil system[1]

Figures 4.3 and *4.4* show a detailed diagram of the payload assembly. The payload assembly is described in detail in section 4.1.5.

[1] *Branden James Rademacher "In-flight trajectory planning and guidance for autonomous parafoils" Iowa State University 2009.*

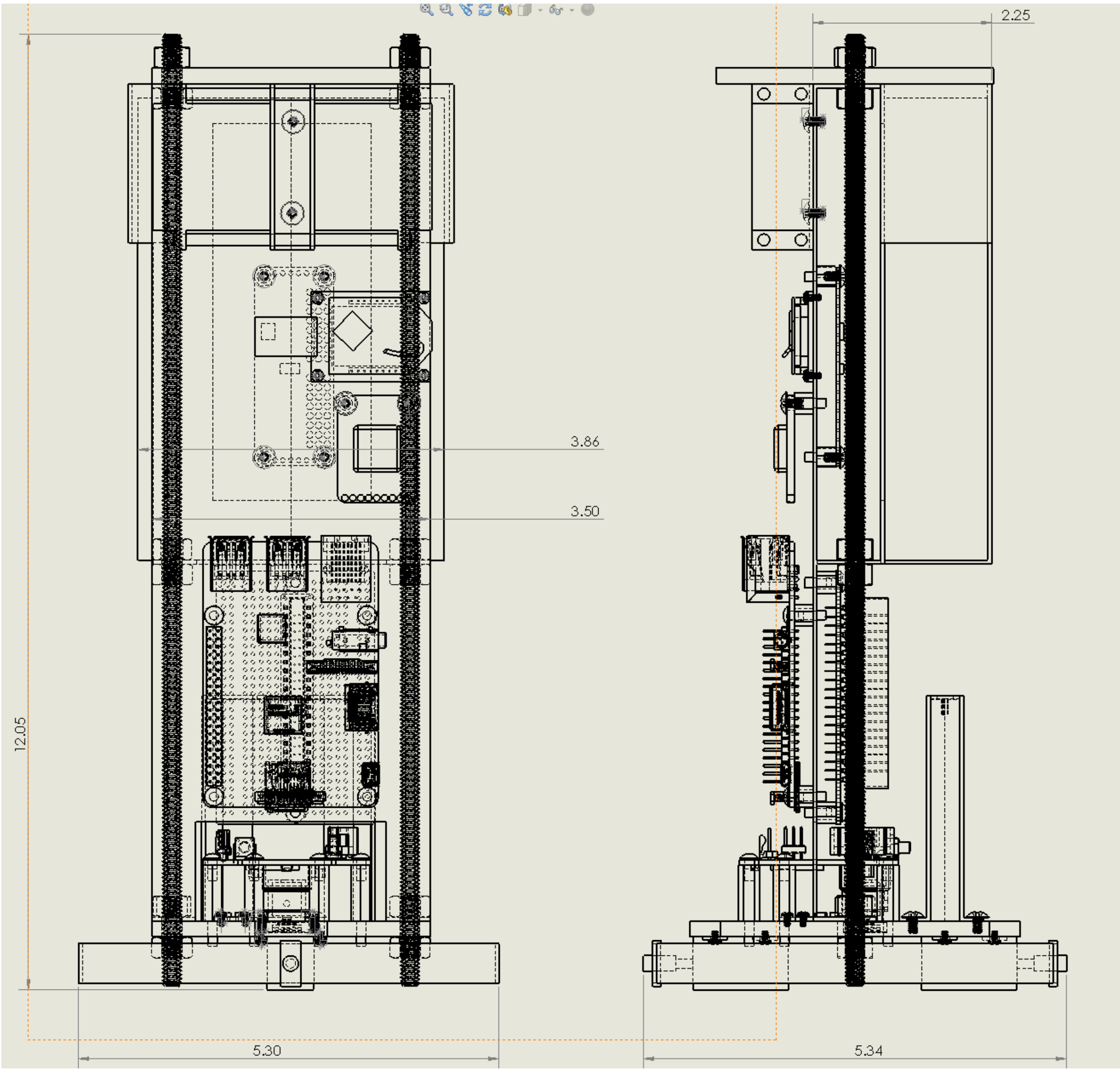

Figure 4.3. Front and Right Views of the Assembled Payload

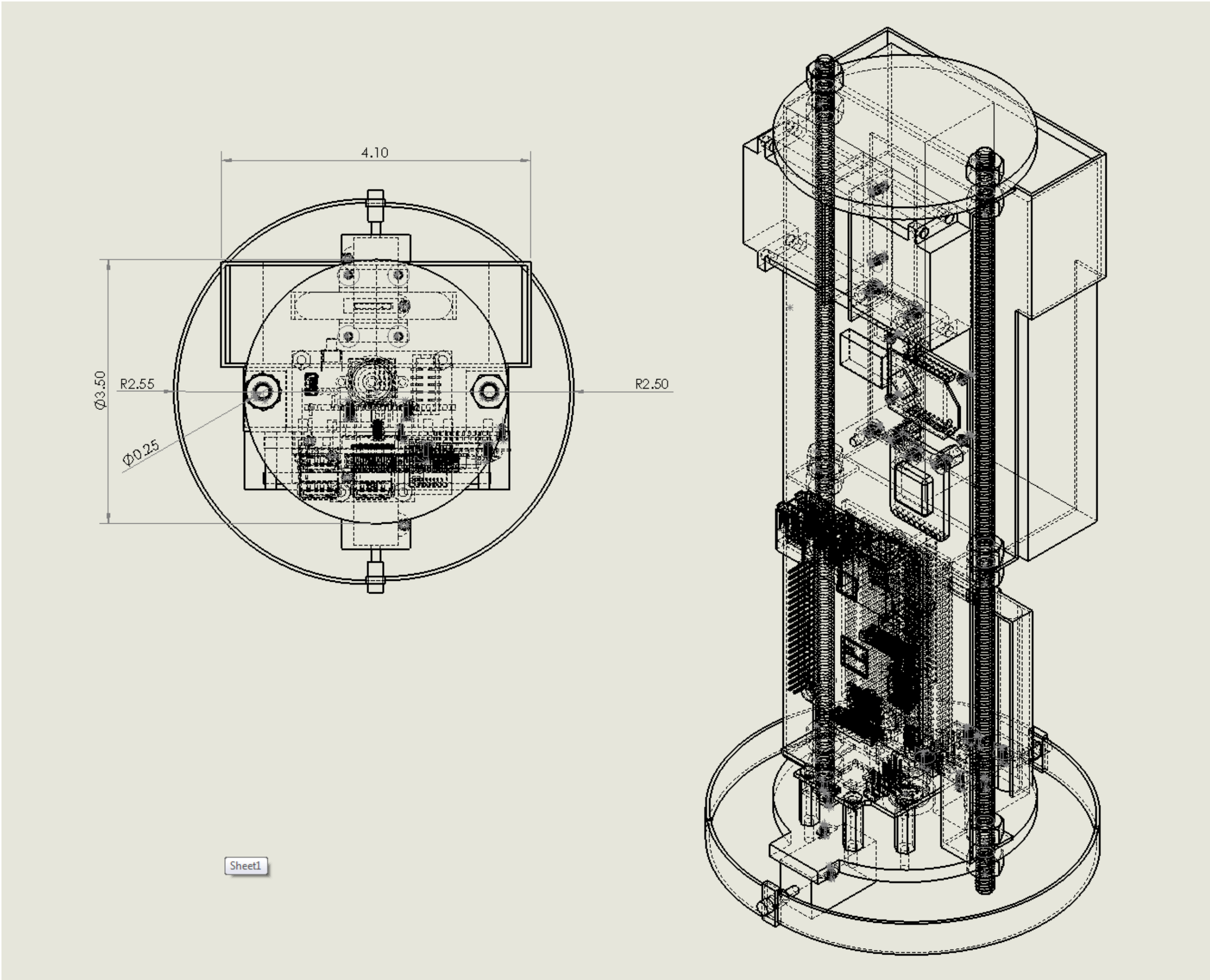

Figure 4.4. Top and Trimetric Model-View of the Assembled Payload.

Figure 4.5 demonstrates how one set of landing legs will deploy. *Figure 4.6* shows the final position with all legs displayed. The legs are designed to give a wide landing base to avoid tipping over during landing. Five legs were chosen to help absorb the forward momentum of the payload. Because the direction of this momentum is known one leg can point in that direction to absorb the forward momentum.

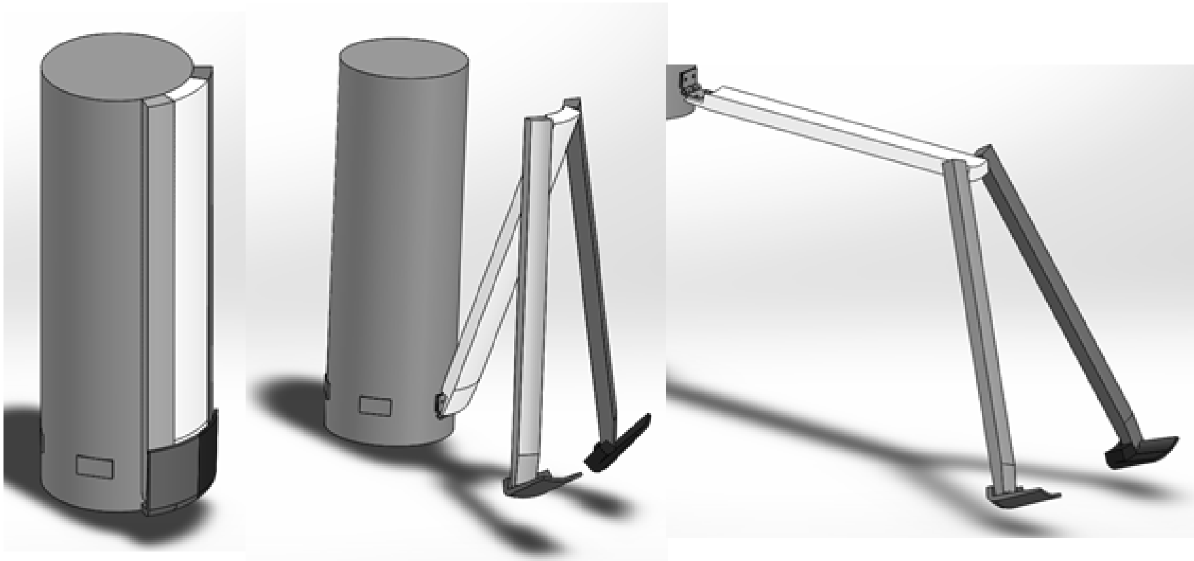

Figure 4.5. a) Position during launch and most of decent. b) Position immediately after legs are released. c) Final position before landing.

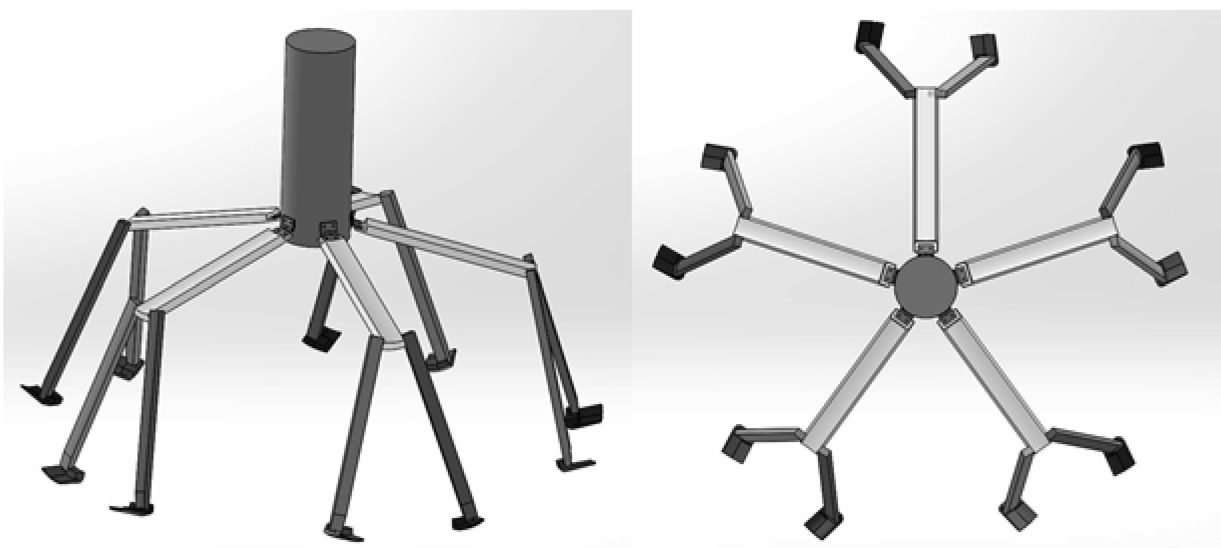

Figure 4.6. Isometric and top view of final leg positions.

Figure 4.7 shows how the Raspberry Pi will interface with the different components. All four USB ports on the Pi will be used by the Pixy CMUCam5, the XBee Pro 900 RPSMA mounted on the XBee Explorer Dongle, the Adafruit Ultimate GPS Breakout, and the Samsung 250 GB SSD. In addition, the Pi will be powered by a battery connecting into the Micro-USB port. Finally, the Pi Cobbler cable connects the 24 GPIO pins into the Perma-Proto Breadboard.

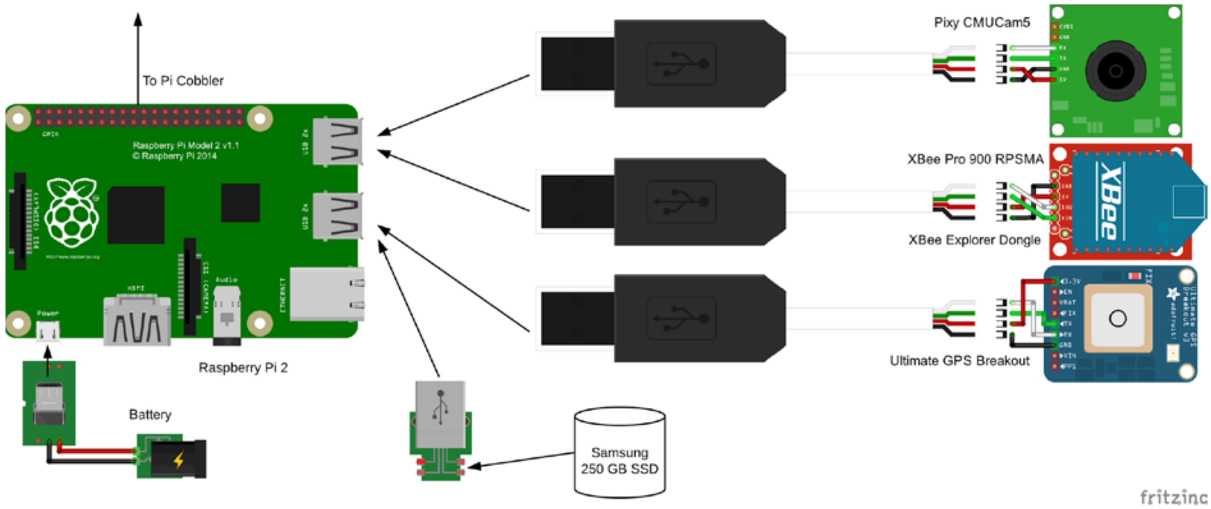

Figure 4.7. Raspberry Pi interfaces

Figure 4.8 shows how the electrical components of the payload will be wired together. For simplicity all components will be connected with 18 AWG wire. The 18 AWG wire will be able to carry any current that will run through the payload. The Perma-Proto Breadboard is connected to the Pi through the Pi Cobbler. A drawback of the Pi is that it only has one Pulse Width Modulation (PWM) pin, which is required to drive a servo. To address this, the 16-channel 12-bit PWM/Servo driver is used. It can drive up to 16 PWM components, the servos in this case, using the I^2C interface. The servo motors are then wired into the servo driver. The AltIMU-10 V4 is also connected through I^2C, so these two components must be in parallel. The solenoid will be run through one of the GPIO pins, although it must be wired through a transistor and diode, as shown. Finally, the battery will be wired into the power rails.

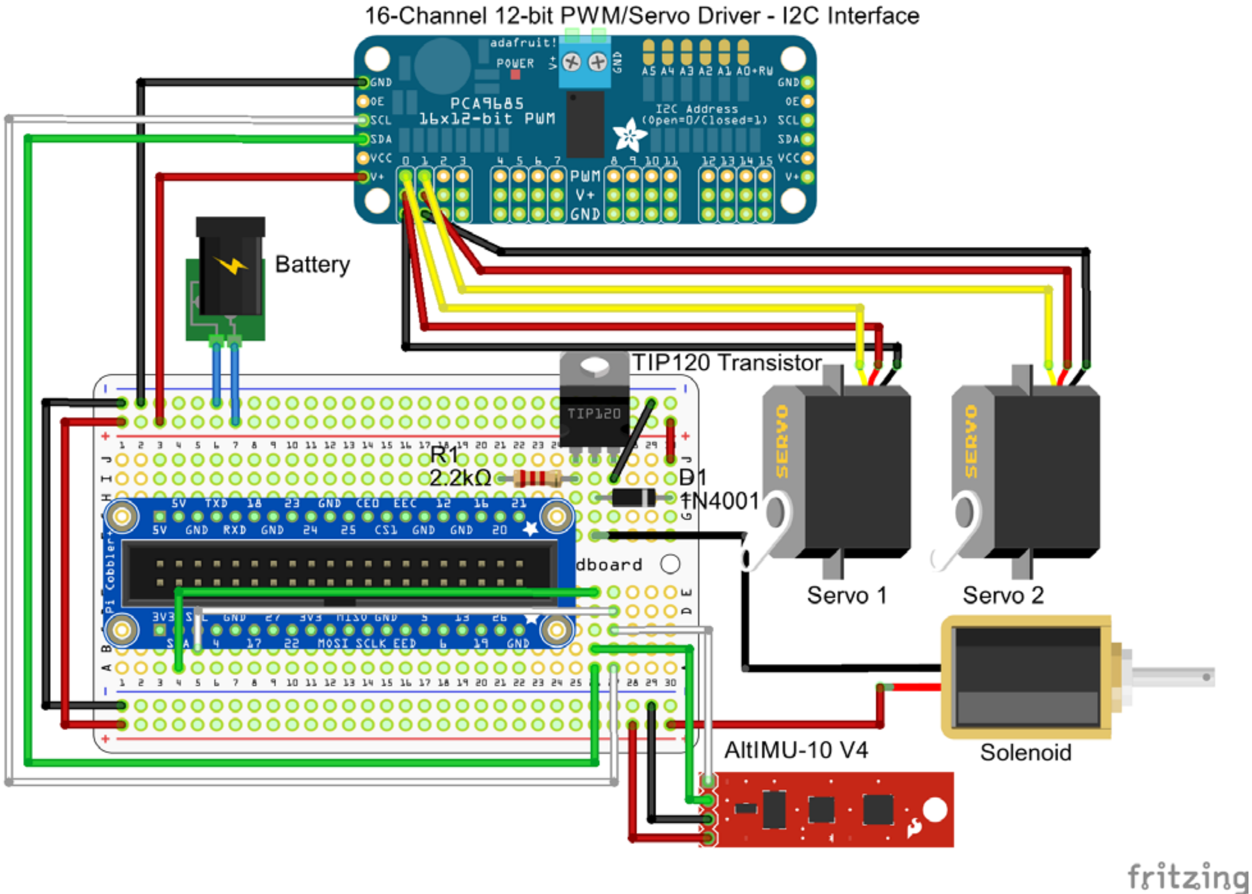

Figure 4.8. Payload wiring schematic

4.1.8 Payload Components

Figure 4.9 shows a subsystem diagram for the payload components, which are detailed in whole in *Table 4.9.* The components were organized into these subsystems based on which task used the component. The Guided Descent Subsystem and the Landing Hazards Detection Subsystem are both made up of components that are used only for that specific experiment. The Payload Landing Subsystem contains the components necessary for the legs, which ensures the safe landing of the payload. The Payload Control Subsystem contains the components that are shared among multiple tasks. As shown in the figure, the Payload Control Subsystem is the central control unit of the HAL payload. It takes data from various instruments, along with the specific data from the instruments within the Payload Control Subsystem. It then feeds these inputs to the Raspberry PI, which runs the software and outputs the commands and data to the proper subsystem. The subsystems and their components are detailed below in Tables *4.9* through *4.12.*

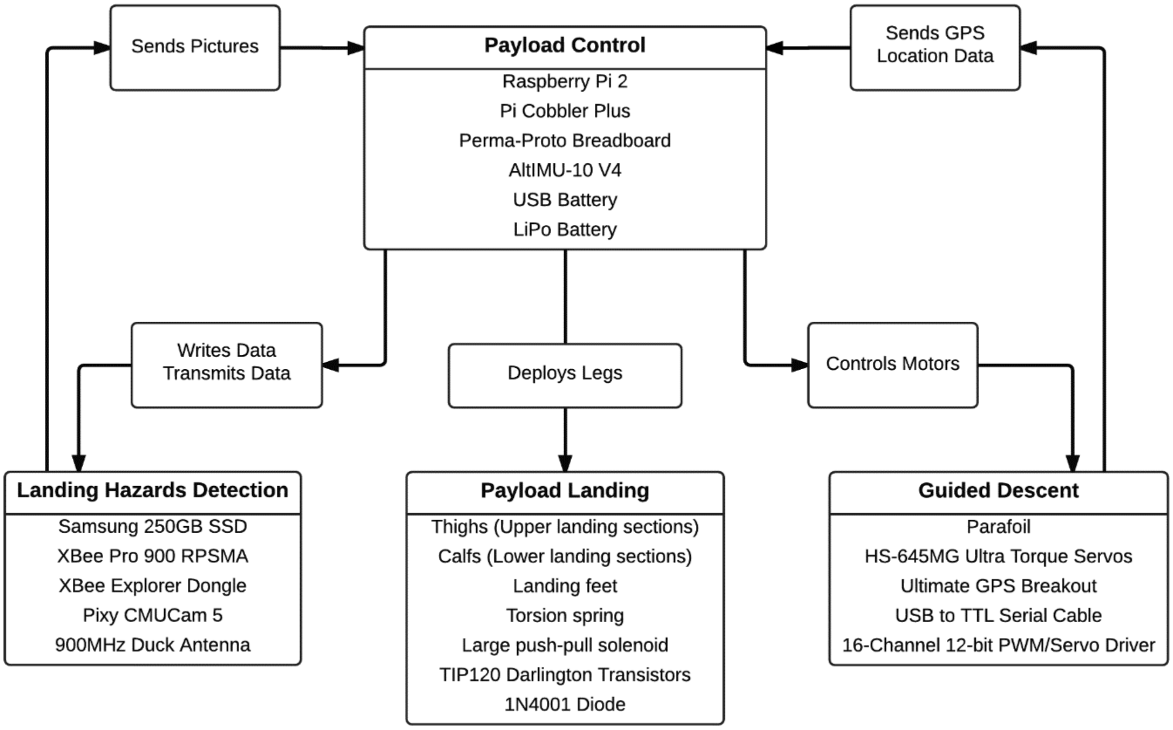

Figure 4.9. Subsystem Diagram

4.1.8.1 Control Subsystem

Component	**Qty.**	**Length (in)**	**Width (in)**	**Height (in)**	**Weight (lb)**	**Cost ($)**
Raspberry Pi 2	1	3.35	2.20	0.67	0.100	39.95
USB Battery	1	1.65	0.90	3.90	0.308	24.95
LiPo Battery	1	5.83	1.93	1.30	1.182	29.99
Pi Cobbler Plus	1	2.50	0.80	0.40	0.026	6.95
Perma-Proto Breadboard	1	3.20	2.00	0.063	0.026	4.50
AltIMu-10 V4	1	1	0.5	0.1	0.0017	27.95
Total					1.6137	134.290

Table 4.9. Control Subsystem Components

4.1.8.2 Landing Hazards Detection Subsystem

Component	Qty.	Length (in)	Width (in)	Height (in)	Weight (lb)	Cost ($)
Samsung 250 GB Solid State Drive	1	2.09	0.39	2.8	0.060	99.99
XBee Pro 900	1	1.30	0.96	0.16	0.331	54.95
Pixy CMUcam5	1	2.10	2.00	1.40	0.060	69.00
Total					0.451	223.94

Table 4.10. Landing Hazards Detection Subsystem Components

4.1.8.3 Guided Descent Subsystem

Component	Qty.	Length (in)	Width (in)	Height (in)	Weight (lb)	Cost ($)
Parafoil	1	19.69	84.65		0.419	17.90
HS-645MG Ultra Torque Servos	2	1.59	0.77	1.48	0.121	31.49
Ultimate GPS Breakout	1	1.00	1.35	0.25	0.019	39.95
USB to TTL Serial Cable	1				0.058	9.95
Total					0.738	99.29

Table 4.11. Guided Descent Subsystem Components

4.1.8.4 Payload Landing Subsystem

Component	Qty.	Length (in)	Width (in)	Height (in)	Weight (lb)	Cost ($)
Thigh (Upper landing section)	5	10.92	0.5	1.55	0.273	0.00
Calf (Lower landing section)	10	11.62	0.5	0.78	0.147	0.00
Landing feet	10	1.64	0.75	2.0	0.027	0.00
Torsion spring (Upper to Lower Connection)	10	2.654	0.404	0.625	0.01	1.36
Torsion spring (Lower to feet	10	2.288	0.288	0.50	0.01	1.39

connection)						
Hinges	5	0.85	0.047	0.98	0.022	7.20
Total					3.415	4.20

Table 4.12. Payload Landing Subsystem Components

4.2 Payload Concept Features and Definition

4.2.1 Creativity and Originality

While the landing hazard detection system was an option given by the NASA Student Launch, the ARES Team has designed their own second task, being a guided descent system used to avoid detected hazards. The team believed that this was a logical second task, as detecting hazards does not help much if you cannot avoid them. While guided descent systems have been created and implemented on larger scales, the ARES Team would like to create an original design that can work on a smaller scale and contribute to the research done on this type of system.

4.2.2 Uniqueness or Significance

A payload that can steer itself away from landing hazards during descent could be an invaluable asset on a mission to Mars, or any other destination for that matter. While the ARES Team's payload uses a parafoil, a similar system using thrusters could be made for a payload that is being sent to a destination with no atmosphere. This technology could also be used for other purposes such as relief missions to areas affected by natural disaster or war. Payloads containing food and supplies could be dropped and guided to a safe landing location. The ARES Team aims to prove that an efficient landing hazard detection and avoidance system can be made inexpensively.

4.2.3 Suitable Level of Challenge

The HAL payload poses many serious challenges concerning both the software and hardware. The ARES Team will be building custom hazard detection and parafoil guidance software, an immensely challenging task. The team is fully aware of the complexity image analysis software necessary and the difficulty of guiding a descending object away from hazards. The team also has restrictions on the size of the payload and thus the size and placement of all components included in the payload must be optimized. Other challenges are being considered as well, and more are expected to arise as the project progresses. Nevertheless, the ARES Team is determined to be successful in creating a useful scientific payload.

4.3 Science Value

4.3.1 Payload Objectives and Success Criteria

The HAL payload's mission during descent from apogee is to take images and analyze these images to detect potential landing hazards, and to then use this data and the parafoil to steer away from the detected landing hazards. The complete requirements for the payload are listed below.

- The payload must eject from the launch vehicle at apogee.
- The payload must take images of the ground and analyze these images to determine the locations of landing hazards.
- The payload must use the locations of detected landing hazards to steer itself away from those hazards.
- The payload must store all data onboard and transmit all data to the ARES Team's ground station.
- The payload must land in a safe location, with a kinetic energy no greater than 75 ft-lb.

The mission will be considered a success if the payload completes all of these requirements, within the team's budget specified in Section 5 of this report.

4.3.2 Experimental Logic, Approach, and Method of Investigation

4.3.2.1 Landing Hazards Detection Task

The experimental logic of the landing hazards detection task is based on potential rovers, probes, and landers that need to come in for a landing. Although research can be done in advance to mitigate the chances of landing in an area with dangerous debris, it is important for landing vehicles to be able to detect hazards autonomously during descent. This problem will be addressed from both a hardware and software standpoint. While they are certainly intertwined, the data from each side must be analyzed individually, though still within in the context of the operation as a whole. The investigation begins at the moment the payload is deployed, which happens at rocket apogee. At this altitude, ideally 5280 feet, the camera will start acquiring images and transmitting them back to the Pi. The software will integrate data from the altimeter to know the size of the objects it has identified. The software will then classify the likelihood that a certain object is a hazard.

4.3.2.2 Guided Descent Task

The use of a parafoil was based on the parafoils used by the military to drop supplies in a given location. Unlike in supply drops, when the payload has to steer towards a given location, this payload will experiment with steering away from obstacles discovered in real time. Unlike traditional parachutes, parafoils generate lift, which generates a horizontal velocity. Manipulating the outermost sections of the parafoil allows the parafoil to steer. Because the parafoil will allow the Hazard Avoidance Lander to change its direction, HAL can avoid any potential hazards detected by the Landing Hazards Detection Subsystem. The investigation begins when the first landing hazard is detected. Once the size and direction of the landing hazard is determined, the servo motors will be activated, forcing the payload to turn and avoid the landing hazard.

4.3.3 Measurement, Variables, and Controls

4.3.3.1 Landing Hazards Detection Task

Since this task is not a traditional experiment, measurement is not conducted in a physical sense. Rather, the task is deemed to have been completed successfully, and then the data is analyzed to understand what worked and what didn't. Bearing this in mind, the measurements for this task are the data that is stored in the SSD to be transmitted to the ground station. Since radio transmission is slow, only one image will be stored for every ten seconds. In addition, data will be stored when a potential hazard is detected, identified, and classified. All of this data will be transmitted wirelessly back to the ground station. The raw image data can be compared to the hazard identification results to serve as a control variable.

4.3.3.2 Guided Descent Task

The task of steering the payload is not a traditional experiment and measurement cannot be taken. The task will be judged on whether it can successfully avoid the hazards detected. Images taken from the landing hazards detection subsystem will be used to determine whether the payload was successfully able to steer around landing hazards. For the task of limiting landing velocity, measurements taken by the altimeter on board the payload will be used to if the task was successful. Wind speed is a big variable when limiting landing speed. The velocities obtained during tests drops will be used as control variables.

4.3.4 Data Relevance and Accuracy/Error Analysis

4.3.4.1 Landing Hazards Detection Task

The relevance of the data depends on the intended application of the results. For example, if this combination of hardware and software is being evaluated for eventual use on Mars, then the use of color to distinguish between features would not be reliable as currently configured, which is one of the ways the system identifies a hazard. However, the ability to detect and identify hazards is certainly relevant to a multitude of engineering applications in the abstract, and using colors and altitude is a useful configuration for UAVs and satellites specifically.

The accuracy of the software will be determined upon post-flight analysis. Each raw image will be compared to the amount of potential hazards detected and identified. A post-flight inspection of the area will be done to identify what hazards actually exist. All of these hazards will then be organized into bins classifying them by their size, color, and location. Comparing these bins to the raw images will give the amount of hazards the hardware was able to capture based on height and size of the object to be detected. The hazards that are captured by the raw image will then be compared to the software results yielding the percent of hazards properly identified. Because the hazards are classified, further data mining will be done to determine if the payload struggled with certain categories of hazard.

4.3.4.2 Guided Descent Task

The results of the guided descent task is relevant in any guided payload system that must react to hazards in real time. This experiment will show the ability of a parafoil to deliver a payload near a predetermined area while being able to avoid hazards in real time. These concepts can be relevant to many engineering applications such as military supply drops and the landing of rovers on other planets.

The data from the Landing Hazards Detection Subsystem will pave the way for future landing detection systems for use on other worlds. By analyzing the raw pictures taken by the Pixy CMUcam5 and comparing them to the pictures analyzed by the Raspberry Pi and the Pixy CMUcam5, we can determine how accurately the system detected the hazards.

By aiming for a 50 yard radius around a predetermined location, the accuracy of the Guided Descent Subsystem can be determined.

4.3.5 Experiment Process Procedures

1. Component Testing
    a. Payload Control
        i. The Raspberry Pi will be configured to run from the SSD and tested.
        ii. Configure the AltIMU to verify hardware and software accuracy.
    b. Landing Hazards Detection System
        i. Test images will be acquired from the camera.
        ii. Load test data into the SSD and transmit the data through the XBee.
        iii. Test images will be run through the hazard detection software.
    c. Guided Descent
        i. The GPS will be mounted to a car and driven around. The data will be transmitted through the XBee to test transmission.
        ii. Parafoil will be test dropped with a dummy payload.
        iii. Servo motors will be tested on a breadboard to ensure functionality.
    d. Landing
        i. The 3-D printed parts will be inspected for defects.
2. Ground Testing
    a. A prototype implementation of the full payload electronics system will be tested using a breadboard for full functionality and battery duration.

b. The leg release mechanism will be tested repeatedly to check for reliability.
c. A weighted payload shell with legs attached will be dropped to test the leg structures and landing dynamics.
d. Low altitude drop tests will be conducted using a mass similar to that of the payload to approximate the lift to drag ratio, lift coefficient and drag coefficient of the parafoil.

3. Drop/Prototype Testing
    a. Payload will be fully assembled and run through a battery cycle to ensure component functionality
    b. Low altitude drop testing will be done to test the flare maneuver and landing legs
    c. Perform weather balloon drop testing
4. Full-Scale Test
    a. The payload will be loaded into the rocket and deployed using launch day procedures.
    b. Extra data will be stored for analysis after the flight, although it may not be transmitted due to battery life concerns
5. Launch Day
    a. Launch day procedures will be carried out.
    b. The payload will be recovered.

Prior to launch, all of the payload's components will be tested. The ARES Team will ensure that the Pixy CMUcam5 takes pictures and will identify appropriate hazards while conducting drop tests. The Raspberry Pi's code will be tested using pictures taken from the Pixy CMUcam5. The XBee Pro 900 will be tested by placing the two Xbees at various distances and transmitting data to a computer. The team can then ensure that the Xbees will communicate at a large enough distance to reach the maximum expected distance the payload will be away from the ground station. After rigorous ground testing, the payload will be tested on the full sized rocket prior to the final launch date.

5. Project Plan

5.1 Budget Plan

At this point in the project, some parts have been added to the budget. The process of ordering parts has begun, in particular elements related to the payload testing process, which is anticipated to be an ongoing process until the first full-scale launch. The revised itemized budget is given below. The category "Purchase:" denotes items that the team will buy with funding, while the "Pre-Owned/ Manufactured:" category denotes items which are already in the team's inventory. The budget does not include shipping costs.

Category	Component	Vendor	Description	Cost per Unit	Quantity	Total Cost
			Structure			
Purchase:	Ogive Nose Cone	Madcow Rocketry	Improves aerodynamics	$115.00	1	$115.00
	Payload Bay		Holds payload	$150.00	1	$150.00
	Motor Closure	Apogee Components		$42.75	1	$42.75
	Motor Case	Apogee Components		$84.69	1	$84.69
	Motor	Apogee Components	Powers rocket ascent	$120.86	2	$241.72
	Resin			$34.80	1	$34.80
	Black Powder	Gander Mountain	Separates stages	$39.99	1	$39.99
Pre-Owned/ Manufactured:	4.5" Fiberglass Tubes	Fabricated in lab	Body structures	$150.00	4	$600.00
	Fins		Improves stability	$15.00	4	$60.00
	Motor Tube			$70.00	1	$70.00
				Structure Total:		**$1,438.95**
			Hazard Detection Payload			
Purchase:	Camera	Amazon	Provides data for landing hazard detection	$69.00	1	$69.00
	Solid State Drive	Newegg	Records data	$99.99	1	$99.99
	Battery	Adafruit	Powers payload systems	$24.95	1	$24.95
	LiPo Battery	HobbyKing	Powers payload systems	$29.99	1	$29.99
	Raspberry Pi 2	Adafruit	Processes imaging	$39.95	1	$39.95

	Antenna	Sparkfun	Receives transmissions	$54.95	2	$109.90
	Dongle	Sparkfun		$24.95	1	$24.95
	Half-size Breadboard	Adafruit	Platform for wiring	$5.00	1	$5.00
	Breadboarding Wire Bundle	Adafruit	Wiring	$6.00	1	$6.00
	Pi Cobbler Plus for Pi 2	Adafruit		$6.95	1	$6.95
	Electrical Wiring	Home Depot		$5.00	1	$5.00
	XBee Pro 900	Sparkfun	Signal Transmitter	$109.90	1	$109.90
	Interface Cable	RF Products	Component Communication	$4.95	1	$4.95
	GPS	Adafruit	Tracking	$39.95	1	$39.95
	USB to TTL Cable	Adafruit	Pi Testing	$9.95	1	$9.95
	Instrument Board	Pololu	Measurements	$27.95	1	$27.95
	Servo Driver	Adafruit	Servo Control	$14.95	1	$14.95
	Lock-Style Solenoid	Adafruit	Securing Payload	$14.95	1	$14.95
	Transistors	Adafruit		$2.50	1	$2.50
	Diodes	Adafruit		$1.50	1	$1.50
				Hazard Detection Payload Total:		**$648.28**
Guided Descent Payload						
Purchase:	Servo Motors	RobotShop	Control payload steering	$50.00	2	$100.00
	Parafoil	HobbyKing	Controlled descent for payload	$20.40	2	$40.80
	Mesh	Home Depot	Connects parachute to payload	$45.00	1	$45.00
				Guided Descent Payload Total:		**$122.90**
Recovery						
Purchase:	Accelerometers		Measures Acceleration	$45.00	2	$90.00
	Drogue Chute	Fruity Chutes	Stage separation and deceleration	$60.00	1	$60.00
	Hinge	Home Decor Hardware	Attach upper leg to payload	$1.44	5	$7.20

	Torsion Spring (Thigh to Calf)	Grainger	Packs of 6	$8.16	2	$16.32
	Torsion Spring (Calf to Foot)	Grainger	Packs of 6	$8.34	2	$16.68
Pre-Owned:	Altimeters	Jolly Logic	Monitors Altitude	$49.95	6	$299.70
	Main Parachute	Fruity Chutes	Rocket body deceleration in descent	$265.00	2	$530.00
	Thigh (Upper landing section)	The Cube	Main landing support	$0.00	5	$0.00
	Calf (Lower landing section)	The Cube	Secondary landing support	$0.00	10	$0.00
	Landing Feet	The Cube	Tertiary landing support	$0.00	10	$0.00
				Recovery Total:		**$1019.90**
			Subscale Rocket			
Purchase:	Fiberglass Sheets	Fibre Glast	Molded into body tubes	$27.45	2	$54.90
	Nosecone	Apogee Components	Aerodynamics	$19.90	1	$19.90
	Motor Casing	Apogee Components		$69.55	1	$69.55
	Motor Closure	Apogee Components		$40.66	1	$40.66
	Motor	Apogee Components	J motor	$67.40	1	$67.40
	Bulkheads	Home Depot	Separates bays	$5.00	2	$10.00
	Fasteners	Home Depot	Bind Components	$5.00	1	$5.00
Pre-Owned/ Manufactured :	Parachute		Vehicle recovery	$160.00	1	$160.00
				Estimated Subscale Total:		**$427.41**
			Safety			
Purchase:	Safety Eyewear	Home Depot	Packs of 4	$19.97	3	$59.91
	Work Gloves	Home Depot		$10.00	3	$30.00
	Plastic Sheeting	Home Depot		$20.97	1	$20.97
	Aprons	Home Depot		$6.00	10	$60.00
				Safety Total:		**$170.88**
			Outreach			

Purchase:	Demonstration Supplies	Various		$500.00	1	$500.00
				Outreach Total:		**$500.00**
Travel						
Purchase:	Van Rental	University of Alabama	Travel from Tuscaloosa to Huntsville	$100.00	3	$300.00
	Hotel Costs	Holiday Inn	3 night stay for 11 people	$100.00	12	$1200.00
	Food		Average of $15 per person per meal	$150.00	9	$1350.00
				Travel Total:		**$2,850.00**
				Purchase Total:		$5,458.62
				Pre-Owned Total:		$1,719.70
				Rocket/Payload Total:		**$3,230.03**
				Project Total:		**$7,188.32**

Table 5.1. Estimated Project Costs

The current balance of the team's funding and history of purchases is given in *Table 5.2* below. The differences between budgeted cost and the recorded expenses can be attributed to a bigger kit for the Raspberry Pi 2 and different suppliers for the camera and parafoil. Price increases were anticipated, although the team will mitigate these errors going forward to avoid overspending.

Purchase	Actual Cost	Budgeted Cost	Difference
Raspberry Pi 2 Kit	$99.95	$57.95	$42.00
Pixy CMUcam5	$74.95	$69.00	$5.95
Parafoil	$20.40	$17.90	$2.50
Total Expenses:	*$195.30*	*Error:*	*$50.45*
Funding Received:	*$8,300.00*		
Balance:	***$8,104.70***		

Table 5.2. Purchase History

5.2 Funding Plan

The ARES Team has thus far received funding from the Alabama Space Grant Consortium (ASGC) and the University of Alabama Department of Aerospace Engineering and Mechanics. The ASGC has agreed to fund the team to the fullest of their ability, totaling $7,650. The categorical spending requirements of the ASGC's funding are detailed in *Table 5.3*.

Category	Amount
Materials	$4,500.00
Travel	$2,500.00
Outreach	$650.00
Total	*$7,650.00*

Table 5.3. ASGC Funding

Funding from the Alabama Student Government Association (SGA) is awarded on a semesterly basis and requires the funding to be used within a 60 day period after allotment. The majority of the SGA funding is required to be spent on travel within the state of Alabama. For these reasons, the ARES team has decided to wait until next semester, when both full-scale launches are planned, to apply for this funding. The sponsorship from Airbus is no longer anticipated for the ARES team. Funding information can be seen in *Table 5.4*. Other team fundraising initiatives would be on an as needed basis, although the funding already received is projected to cover all anticipated expenses.

Funding Source	Amount	Status
ASGC	$7,650.00	Confirmed
SGA	$2,400.00	Pending
Department of Aerospace Engineering and Mechanics	$650.00	Confirmed
Fundraising	$500.00	Unconfirmed
Projected Total:	**$11,200.00**	
Confirmed Total:	**$8,300.00**	

Table 5.4. Updated Funding Plan

5.3 Timeline

The ARES Team is on schedule in accordance with the initial project timeline, seen in the *Figure 5.1* below. The project proposal submission and the web presence establishment milestones were met on time.

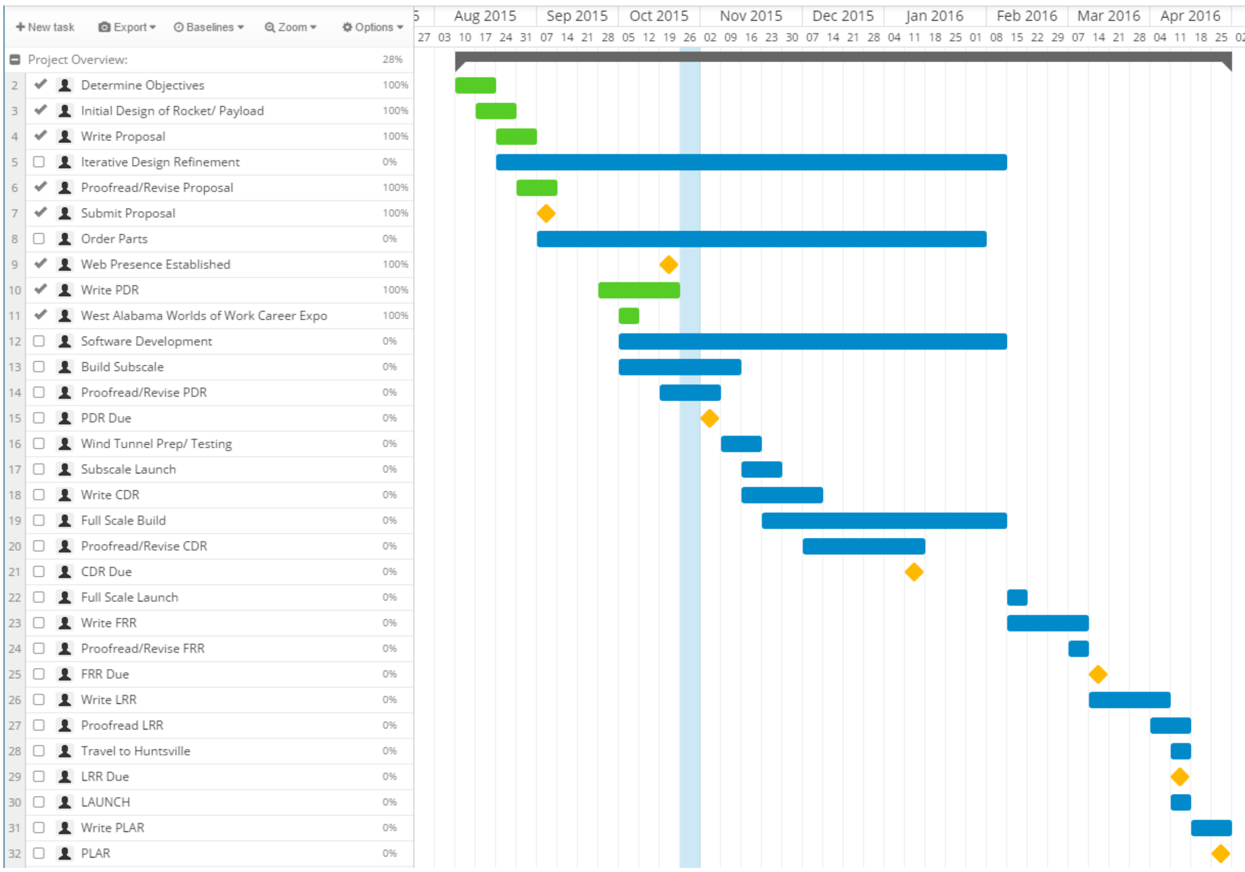

Figure 5.1. Gantt Chart

The ARES team has many objectives to meet before the CDR submission date. In order to ensure that all requirements are met, a more detailed timeline has been developed, spanning from the PDR submission date to the CDR submission date. The Gantt chart in *Figure 5.2* details the timelines and the critical paths associated with the subsystems of the project. A magnified timeline can be seen in Appendix F. Important considerations in the timeline regard breaks in the University of Alabama's academic calendar. Thanksgiving Break, November 25-29, and Winter Break, December 12 - January 12, are major obstacles to team progress. Bearing these in mind, the timeline is intended to avoid heavy workloads or objectives which require much cooperation among team members during these breaks.

Figure 5.2. PDR to CDR Gantt Chart

5.4 Educational Engagement Plan

The outreach goal for the Alabama Rocket Engineering Systems team is to teach students of all ages about rocketry, while creating a sustainable outreach program for years to come. The team has reached out to local Boy Scout troops, middle schools, and high schools, with the intention of teaching them the fundamentals of rocketry so they are able to build one on their own and participate in a competition that the team will host in early spring.

5.4.1 Completed Events

Although only direct educational outreach counts towards the 200 required students, the team has indirectly reached over 900 people to spread awareness of the ARES Team, model rocketry, and the STEM fields. These events and the results of them can be seen in *Table 5.5*. Through these events, the team has captivated students and their educators, resulting in future direct educational engagement activities.

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	25	10-12	Direct
Hillcrest High School	10/29/2015	50	10-12	Direct

Table 5.5. Completed Educational Engagement Events

5.4.2 Upcoming Scheduled Events

The schedule of future events can be seen in *Table 5.6*.

Name of Event	**Date**	**Expected Number of Students**	**Grades of Students**	**Direct or Indirect**
Al's Pals	11/9/2015, 11/10/2015, 11/12/2015	270	1-5	Direct
Girl Scouts "Women in Science" Day	11/14/2015	98	1-5, 5-9	Direct

Table 5.6. Scheduled Events

5.4.3 Future Plans

Due to the high amount of interest from local schools, the team is preparing lesson plans that fit into the science curriculum in Alabama, so that teachers can incorporate rocketry into their teaching, as well as allow the team to reach out to a greater number of students.

All of the team's outreach efforts will culminate in a competition to be held in the early spring. Students that we have taught about rocketry will be invited to participate by building a rocket on their own or in groups of less than 3, and launching it at the competition. The specific requirements have yet to be determined, but the team is in the process of securing a location, creating the competition requirements, and spreading the word to students.

5.4.4 Social Media

The team has created a Facebook profile, Twitter, and Instagram to show the progress of the ARES rocket, as well as give updates on outreach events. *Table 5.7* provides the ARES Team's social media pages.

Platform	**Name**
Facebook	Alabama Rocket Engineering Systems
Instagram	@alabama_rocketry
Twitter	@alabamarocketry

Table 5.7. Social Media Presence

5.4.5 Evaluation

Following each event that directly engages students, the teacher or Scout leader is given an evaluation form. This form asks the team to be rated on a scale of 1-5 (with 5 being the best) on preparedness, helpfulness, organization, and knowledge. Given the feedback from this form, the team can make changes for future presentations.

6. Conclusion

The ARES Team will design, build and launch a 93 inch (2.36 m) rocket capable of carrying the Hazard Avoidance Lander (HAL). The rocket will deliver this payload to an apogee of 5,280 feet. After ejection from the launch vehicle at apogee, HAL will take and analyze images during its descent to detect and identify landing hazards on the ground. Using a parafoil controlled by two servo motors, HAL will then steer itself away from the detected landing hazards. The ARES launch vehicle and HAL will be recoverable and reusable.

The ARES Team has spent the time since the submission of their proposal planning the rest of the project, iterating the design of the rocket and payload, and dealing with the challenges that have arisen thus far. The team is confident in their current design, and has a detailed plan for the coming months. This puts the ARES Team well on their way to the Critical Design Review phase of the project. Over the following months, the team will conduct subscale testing and a subscale launch, payload component testing and balloon drop testing, and will continue to organize and complete educational outreach activities. The team is prepared and excited to take on any new challenges that arise, and looks forward to the next phase of design.

Appendix A - Milestone Review Flysheet

Milestone Review Flysheet

Institution	The University of Alabama

Milestone	Preliminary Design Review

Vehicle Properties	
Total Length (in)	93
Diameter (in)	5.5
Gross Lift Off Weigh (lb)	26.87
Airframe Material	Fiberglass
Fin Material	Fiberglass
Drag	0.467

Motor Properties	
Motor Manufacturer	Cesaroni Technology Inc.
Motor Designation	L805
Max/Average Thrust (lb)	367.3
Total Impulse (lbf-s)	6296
Mass Before/After Burn	12.072/10.678
Liftoff Thrust (lb)	244.1

Stability Analysis	
Center of Pressure (in from nose)	64.98
Center of Gravity (in from nose)	54.37
Static Stability Margin	1.93 calibers
Static Stability Margin (off launch rail)	0.47
Thrust-to-Weight Ratio	13.77
Rail Size and Length (in)	118
Rail Exit Velocity	71.5

Ascent Analysis	
Maximum Velocity (ft/s)	642
Maximum Mach Number	0.58
Maximum Acceleration (ft/s^2)	385
Target Apogee (From Simulations)	5290
Stable Velocity (ft/s)	62.62
Distance to Stable Velocity (ft)	7.94

Recovery System Properties				
Drogue Parachute				
Manufacturer/Model		Giant Leap Rocketry/TAC-1 (pre-owned)		
Size		54		
Altitude at Deployment (ft)			5280	
Velocity at Deployment (ft/s)			2.313	
Terminal Velocity (ft/s)			24.5	
Recovery Harness Material			Kevlar	
Harness Size/Thickness (in)			0.5	
Recovery Harness Length (ft)			4.17	
Harness/Airframe Interfaces		Parachute harness will be secured to an eye bolt on the electronics bay bulk plate		
Kinetic Energy of Each Section (Ft-lbs)	Nose Cone	Forward	Aft	
	20.64	107.5	6.9	

Recovery System Properties				
Main Parachute				
Manufacturer/Model		Giant Leap Rocketry/TAC-1 (pre-owned)		
Size		110		
Altitude at Deployment (ft)			900	
Velocity at Deployment (ft/s)			24.44	
Terminal Velocity (ft/s)			12.14	
Recovery Harness Material			Kevlar	
Harness Size/Thickness (in)			0.625	
Recovery Harness Length (ft)			5.58	
Harness/Airframe Interfaces		Parachute harness will be secured to eye bolts on the electronics bay bulk plate and the aft section bulk plate.		
Kinetic Energy of Each Section (Ft-lbs)	Nose Cone	Forward	Aft	
	20.64	26.5	1.68	

Recovery Electronics	
Altimeter(s)/Timer(s) (Make/Model)	PerfectFlite Stratologger
Redundancy Plan	Team will use two Stratologgers to ensure ignition of black powder charges
Pad Stay Time (Launch Configuration)	1 hour and 30 minutes

Recovery Electronics	
Rocket Locators (Make/Model)	Adafruit Ultimate GPS and Tagg Pet Trackers
Transmitting Frequencies	900 Hz
Black Powder Mass Drogue Chute (grams)	4
Black Powder Mass Main Chute (grams)	4

Milestone Review Flysheet

Institution	The University of Alabama	Milestone	Preliminary Design Review

Autonomous Ground Support Equipment (MAV Teams Only)	
Capture Mechanism	Overview
Container Mechanism	Overview
Launch Rail Mechanism	Overview
	Include Description of rail locking mechanism
Igniter Installation Mechanism	Overview

Payload	
Payload 1	Overview
	Payload 1 will be a landing hazards detection system. This system will use a camera to take images of the ground during descent and analyze these images to detect hazards.
Payload 2	Overview
	Payload 2 will be a guided descent system. This system will use the data from the landing hazards detection system and the Raspberry Pi to control servo motors, which will in turn control the payload's parafoil.

Test Plans, Status, and Results	
Ejection Charge Tests	The team plans to use ground testing of the black powder charges to ensure the charge will produce the correct pressure to eject the parachutes. The test will be a static ignition of full scale charges at the Phoenix Missile Works launch area.
Sub-scale Test Flights	The team plans to build a sub-scale launch vehicle with a scaled payload, weight, and motor. The sub-scale will model the flight of the full scale as closely as possible. The team currently plans to launch the sub-scale rocket on November 22.
Full-scale Test Flights	The team will test all sub-systems and components of the full scale rocket, and at least one full scale mission will be flown. Full scale flights will provide the team with data on altitude, stability, and performance of the recovery system of the rocket.

Milestone Review Flysheet

Institution	The University of Alabama	Milestone	Preliminary Design Review

Additional Comments
Stability Velocity, Distance to stable velocity, and Static stability margin (off launch rail) were all calculated at a wind speed of 20 mph.

Appendix B - Launch Preparation Checklist and Procedures

Ejection Charge Test:

- ❏ Build the rocket as if it were to launch dummy weights for the payload can be used, and only the motor casing should be in place.
- ❏ Build the squibs (see Electronics Bay Prep Checklist) for deployment of the parachute and separation of to the payload bay. Instead wiring the squibs to the electronics bay run them through the switch holes in the electronics body tube.
- ❏ Receive permission from the RSO to perform the test and go to the designated area for such a test.
- ❏ Attach 10 feet of wire to each e-match wire. The person running the test will stand at the end of the wire, all spectators should stand another 10 feet back.
- ❏ After announcing the test, a countdown from 10 should be completed for each charge.
- ❏ If the parachute is pulled out between the electronics and booster bay, approximately three feet, then it was a successful test the three feet rule will be used to deem the payload separation successful.

Electronics Bay Preparation Checklist:

- ❏ Using the multi-meter, test the voltage from the batteries for a voltage of at least 9.1 V.
- ❏ Using the multi-meter, test the resistance of the two e-matches to be at least 1 Ω.
- ❏ Connect a battery to the holder and wire the switch and battery to the altimeter.
- ❏ Turn the altimeter on and listen for the beeps to ensure that the drogue and main charge are set to the specified altitudes.
  Drogue/Payload: _______, Main: _______
- ❏ Turn the altimeters off
- ❏ Connect a fresh battery and zip tie it to the sled
- ❏ Make a “cup” using duct-tape and place the head of the e-match just inside the bottom of the cup and seal the bottom. This is known as a squib. Pour in the required amount of black powder around the e-match and seal the top. Be sure to mark each squib as the drogue or main.
- ❏ Run the main e-match through the hole in the bulk plate so that the squib is resting against the bulk plate.
- ❏ Tape the e-match down and seal the hole using putty.
- ❏ Cut the e-matches so that they are 1 inch longer than is required.
- ❏ Allow no exposed wiring to show.
- ❏ Connect the e-match to the altimeters in the main port.
- ❏ Put the coupler/body tube between the drogue bulk plate and the electronics in the bay.
- ❏ Make a “cup” using duct-tape and place the head of the e-match just inside the bottom of the cup and seal the bottom. This is known as a squib. Pour in the required amount of

black powder around the e-match and seal the top. Be sure to mark each squib as the drogue or main.

- ❏ Run the main e-match through the hole in the bulk plate so that the squib is resting against the bulk plate.
- ❏ Tape the e-match down and seal the hole using putty.
- ❏ Cut the e-matches so that they are 1 inch longer than is required.
- ❏ Allow no exposed wiring to show.
- ❏ Connect the e-match to the altimeters in the drogue port.
- ❏ Place the drogue bulk plate on the threaded rods and begin to work it into place. Ensure the belt is aligned with the switch holes in the body tube.
- ❏ Place the bulk plate on the coupler and bolt it together.

Motor Loading Procedures Checklist:

- ❏ Check for dents in the motor casing.
- ❏ Open reloadable motor reload package.
- ❏ Push motor into the casing, forward end first.
- ❏ Screw on the aft enclosure.

Recovery Prep Checklist:

- ❏ Fold the drogue parachute and wrap it leaving enough of the shroud line to connect to the quick link.
- ❏ Prepare electronics bay as outlined; ensure it is secure on both ends.
- ❏ Attach the parachute shroud lines and parachute protector using a quick link to the desired point on the shock cord.
- ❏ Connect the parachute shock cord to the coupler eye-bolt using a quick link.
- ❏ Fold the shock cords to the point just below the parachute quick link, tape together using one layer of painters tape.
- ❏ Put dog barf in the parachute bay before sliding the drogue parachute and shock cord into the parachute bay, then place more dog barf in the bay prior to sliding the electronics coupler in place.
- ❏ Bolt the forward electronics bay bulk plate in place.
- ❏ Fold the main parachute and wrap it leaving enough of the shroud line to connect to the quick link.
- ❏ Prepare electronics bay as outlined; ensure it is secure on both ends.
- ❏ Attach the parachute shroud lines and parachute protector using a quick link to the desired point on the shock cord.
- ❏ Connect the parachute shock cord to the coupler eye-bolt using a quick link.
- ❏ Fold the shock cords to the point just below the parachute quick link, tape together using one layer of painters tape.

- ❏ Put dog barf in the parachute bay before sliding the main parachute and shock cord into the parachute bay, then place more dog barf in the bay prior to sliding the electronics coupler in place.
- ❏ Bolt the aft electronics bay bulk plate in place.
- ❏ Connect the two body tubes with shear pins.

Motor Installment Procedures:

- ❏ Once all rivets and shear pins are in place, place the rocket on the ground. Ensure the nose cone is pointed in a direction opposite of any crowds or vehicles.
- ❏ Push the motor into place.
- ❏ Screw on the motor retainer.
- ❏ Ensure everything is tight and secure.

Launch Pad Procedure:

- ❏ Arrive at the selected launch site.
- ❏ Speak with the RSO to determine where to set up the launch pad.
- ❏ Place the pad in the specified location.
- ❏ Have the rocket inspected by the RSO.
- ❏ Once approved by the RSO, take the rocket to the pad.
- ❏ Disarm the launch box.
- ❏ Carefully load the rocket onto the launch rail and check to make sure it slides smoothly down the length of the rail.
- ❏ Adjust the pad if necessary.
- ❏ Arm the electronics bay. Wait to hear chirping from both altimeters.
- ❏ Place the igniter inside the motor. Push the igniter into the motor till it hits the top and then secure it in place using the motor cap.
- ❏ Attach the igniter leads to the launch controller.
- ❏ Retreat to the necessary safe distance.
- ❏ Launch.
- ❏ Recover the rocket, nose cone, and payload. **Caution: MOTOR CASING WILL BE HOT.**
- ❏ Any or all of these may not be recovered in the event of a hazardous landing (water landing, power lines, etc.).
- ❏ Inspect for damage.
- ❏ Wait until the motor casing has cooled. Remove it and then clean it thoroughly.
- ❏ Go to the competition tent to have the altimeter read and determine the rocket apogee. For the subscale and full scale launches, the altimeter will be read by team members.
- ❏ Recover the payload data for analysis.

Safety Officer Signature for Checklists and Procedures:
X____

Appendix C - Safety Data Sheets

C.1 ProFire Igniter

MATERIAL SAFETY DATA SHEET

ProFire Igniter

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: ProFire Igniter
Synonyms: Igniter, Initiator
Proper Shipping Name: Igniters
Part Number: INI-150
Product Use: Igniter for solid fuel rocket motor

Manufacturer: Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: 1-905-887-2370
24 Hour Emergency Telephone Number: 1-613-996-6666 (CANUTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Overdip composition

Ingredient Name	CAS Number	Percentage
Barium chromate	10294-40-3	31-32 %
Magnesium powder	7439-95-4	42-43 %
Viton fluoroelastomer	n/a	26-27 %

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

The igniter functions by burning rapidly at high temperature, releasing hot gas and particles that ignite the propellant of a rocket motor when in close proximity. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations.

General Appearance:
Cardboard tubes containing one igniter. Igniter has coiled wire leads terminating in the ignition device itself. Ignition device consists of a small electrical initiator (fuse head) dipped in a rubbery, silver-grey composition. All parts are essentially odourless solids, though trace odors of process solvents may be present.

Potential Health Effects:

Eye:
Not a likely route of exposure. May cause eye irritation.

Skin:
Not a likely route of exposure. Low hazard for usual industrial handling.

Ingestion:
Not a likely route of exposure.

Inhalation:
Not a likely route of exposure. May cause respiratory tract irritation.

4.0 FIRST AID MEASURES

Eyes:
Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.

Skin:
Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

Ingestion:
Induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

Inhalation:
Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Burns: Burns can be treated as per normal first aid procedures.

5.0 FIRE FIGHTING MEASURES

Extinguishing Media:
In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam to contain surrounding fire.

Exposure Hazards During Fire:
Exposure to extreme heat may cause ignition.

Combustion Products from Fire:
During a fire, irritating and toxic gases may be generated by thermal decomposition or combustion.

Fire Fighting Procedures:
Keep all persons and hazardous materials away. Allow material to burn itself out. As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear.

Special Instructions / Notes:
Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

6.0 ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

Spills: Clean up spills immediately. Replace articles in packaging and boxes and seal securely. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Sweep or scoop up using non-sparking, non-static producing tools.

7.0 HANDLING AND STORAGE

Handling: Keep away from heat, sparks and flame. Avoid contamination. Do not get in eyes, on skin or on clothing. Do not taste or swallow. Avoid prolonged or repeated contact of black powder with skin.

Storage: Store in a cool, dry place away from sources of heat, spark or flame. Keep in shipping packaging when not in use.

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls:
Use adequate explosion proof ventilation to keep airborne concentrations low. All equipment and working surfaces must be grounded.

Personal Protective Equipment:

Eyes:
Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin:
Wear appropriate gloves to prevent skin exposure if handling pellets.

Clothing:

Wear appropriate protective clothing to prevent skin exposure if handling pellets. Clothing should be appropriate for handling pyrotechnic substances.

Respirators:

A respirator is not typically necessary. Follow the OSHA respirator regulations found in 29CFR1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	solid
Appearance:	Rubbery silver-grey composition
Odour:	May have residual odor of process solvents.
Odour Threshold:	Not available.
pH:	6.0-8.0
Vapour Pressure:	Not available.
Vapour Density:	Not available.
Viscosity:	Not available.
Evaporation Rate:	Not available.
Boiling Point:	Not available.
Freezing/Melting Point:	Not available.
Coefficient of water/oil distribution:	Not available.
Autoignition Temperature:	Approximately 285°C (550°F).
Flash Point:	Not available.
Explosion Limits, lower (LEL):	Not available.
Explosion Limits, upper (UEL):	Not available.
Sensitivity to Mechanical Impact:	Composition can be ignited by impact
Sensitivity to Static Discharge:	Composition – low. Initiator may be activated by static discharge
Decomposition Temperature:	Not available.
Solubility in water:	soluble in water
Specific Gravity/Density:	1.7-2.1
Molecular Formula:	Not applicable.
Molecular Weight:	Not available.

10.0 STABILITY AND REACTIVITY

Chemical Stability:
Stable under normal temperatures and pressures.
Conditions to Avoid:
Heat, static electricity, friction, impact
Incompatibilities with Other Materials:
Combustible or flammable materials, explosive materials
Hazardous Products Of Decomposition:
Oxides and fluorides of barium, magnesium. Chromium.
Hazardous Polymerization:
Will not occur.

11.0 TOXICOLOGICAL INFORMATION

Routes of Entry:
Skin contact – not likely
Skin absorption – not likely
Eye contact – not likely
Inhalation – not likely
Ingestion – not likely

Effects of Acute Exposure to Product:
No data available

Effects of Chronic Exposure to Product:
No data available

Exposure Limits:

Overdip composition

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Barium chromate	10294-40-3		
Magnesium powder	7439-95-4		
Viton fluoroelastomer	n/a		

Irritancy of the Product:
No data available

Sensitization to the Product:
No data available

Carcinogenicity:
Not listed by IARC, NTP, or OSHA

Reproductive Toxicity:
No data available

Teratogenicity:
No data available

Mutagenicity:
No data available

Toxically Synergistic Products:
No data available

LD50:
No data available

12.0 ECOLOGICAL INFORMATION

Environmental Data:

Ecotoxicity Data:
Not determined.

EcoFaTE Data:
Not determined.

13.0 DISPOSAL CONSIDERATIONS

Product As Sold: Pack firmly in hole in ground with nozzle pointing up. Ignite motor electrically from a safe distance and wait 5 minutes before approaching. Dispose of spent components in inert trash.

Product Packaging: Dispose of used packaging materials in inert trash.
Special Considerations: Consult local regulations about disposal of explosive materials.

14.0 TRANSPORT INFORMATION

Shipping Information – Canada

TDG Classification: Class 1.4 Explosive
Proper Shipping Name: Igniters
UN Number: 0454
UN Classification Code: 1.4 S
Packing Group: II
UN Packing Instruction: 142

Shipping Information - USA / IATA / IMO

Proper Shipping Name: Igniters
UN Number: 0454
UN Classification Code: 1.4 S
US DOT Classification Reference Number: EX2002100114
DOT / IMO / IATA Label: Class 1 – Explosive – Division 1.4 S

15.0 REGULATORY INFORMATION

Canada

This product has been classified according to the hazard criteria of the Canadian Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

WHMIS Classification: Not Controlled (explosive)

CAS# 10294-40-3 ($BaCrO_4$) is listed on Canada's DSL List.
CAS# 10294-40-3 ($BaCrO_4$) is not listed on Canada's Ingredient Disclosure List.
CAS# 7439-95-4 (Mg) is listed on Canada's DSL List.
CAS# 7439-95-4 (Mg) is not listed on Canada's Ingredient Disclosure List.

Canadian Explosives Classification: Class 6.1
This product is an authorized explosive in Canada. (File # XP 2050-C50 03091601)

This product may be considered "Controlled Good" in Canada under the Controlled Goods Regulations.

United States of America

TSCA Inventory Status:

CAS# 10294-40-3 ($BaCrO_4$) is listed on the TSCA inventory.
CAS# 7439-95-4 (Mg) is listed on the TSCA inventory

Hazardous Chemical Lists

CERCLA Hazardous Substance (40 CFR 302.4)	No
SARA Extremely Hazardous Substance (40CFR 355)	No
SARA Toxic Chemical (40CFR 372.65)	No

European/International Regulations

The product on this MSDS, or all its components, is included on the following countries' chemical inventories:
EINECS – European Inventory of Existing Commercial Chemical Substances

European Labelling in Accordance with EC Directives

Hazard Symbols: Explosive.

Risk Phrases:

R 2	Risk of explosion by shock, friction, fire or other sources of ignition.
R 44	Risk of explosion if heated under confinement.

Safety Phrases:

S 1/2	Keep locked up and out of the reach of children.
S 8	Keep container dry.
S 15	Keep away from heat.
S 16	Keep away from sources of ignition – No smoking.
S 17	Keep away from combustible material.
S 18	Handle and open container with care.
S 33	Take precautionary measures against static discharges.
S 41	In case of fire and/or explosion do not breathe fumes.

16.0 OTHER INFORMATION

US DoD Hazard Characteristic Code (HCC): E2 (Explosives, Low Risk)

MSDS Prepared by:

Regulatory Affairs Department
Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, ON
Canada L0H 1G0

Telephone: 905-887-2370 x239
Fax: 905-887-2375
Web Site: www.cesaronitech.com www.Pro38.com

C.2 ProX Rocket Motor Reload Kits

MSDS – ProX Rocket Motor Reload Kits Page 1/6 Version 2.02
Revision Date. 8 Feb 2010

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MATERIAL SAFETY DATA SHEET

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ProX Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: Pro29, Pro38, Pro54, Pro75, and Pro98 Rocket Motor Reload Kits
Synonyms: Rocket Motor
Proper Shipping Name: Articles, Explosive, N.O.S. (Ammonium Perchlorate)
Part Numbers: Reload kits: P29R-Y-#G-XX, P38R-Y-#G-XX, P54R-Y-#G-XX, P29R-Y-#GXL-XX, P38R-Y-#GXL-XX, P54R-Y-#GXL-XX,
Propellant grains: P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX
Where: Y = reload type (A = adjustable delay, C = C-slot)
# = number of grains &
XX = propellant type

Product Use: Solid fuel motor for propelling rockets

Manufacturer: Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: 1-905-887-2370
24 Hour Emergency Telephone Number: 1-613-996-6666 (CANUTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Propellant

Ingredient Name	CAS Number	Percentage
Ammonium Perchlorate	7790-98-9	40-85 %
Metal Powders		1-45 %
Synthetic Rubber		10-30 %

Black Powder Ignition pellet

Ingredient Name	CAS Number	Percentage
Potassium Nitrate	7757-79-1	70-76 %
Charcoal	n/a	8-18 %
Sulphur	7704-34-9	9-20 %
Graphite	7782-42-5	trace

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

There articles contain cylinders of ammonium perchlorate composite propellant, encased in inert plastic parts. The forward closure also contains a few grams of black powder. ProX Rocket motor reload kits are classified as explosives, and may cause serious injury, including death if used improperly. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations. Avoid inhaling exhaust products.

General Appearance:
Cardboard tubes contain various plastic parts. Inside the plastic tube are cylinders of composite propellant (rocket fuel). The forward closure also contains a small quantity of black powder. All parts are odourless solids.

Potential Health Effects:

Eye:
Not a likely route of exposure. May cause eye irritation.

Skin:
Not a likely route of exposure. Low hazard for usual industrial/hobby handling.

Ingestion:
Not a likely route of exposure.

Inhalation:
Not a likely route of exposure. May cause respiratory tract irritation. Do not inhale exhaust products.

4.0 FIRST AID MEASURES

Eyes:
Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.

Skin:
Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

Ingestion:
Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

Inhalation:
Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Burns: Burns can be treated as per normal first aid procedures.

5.0 FIRE FIGHTING MEASURES

Extinguishing Media:
In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam to contain surrounding fire.

Exposure Hazards During Fire:
Exposure to extreme heat may cause ignition.

Combustion Products from Fire:
During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Fire Fighting Procedures:
Keep all persons and hazardous materials away. Allow material to burn itself out. As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear.

Special Instructions / Notes:
These articles burn rapidly and generate a significant flame for a short period of time. Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement. Do not inhale exhaust products.

6.0 ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

Spills: Clean up spills immediately. Replace articles in packaging and boxes and seal securely. Sweep or scoop up using non-sparking tools.

7.0 HANDLING AND STORAGE

Handling: Keep away from heat, sparks and flame. Avoid contamination. Do not get in eyes, on skin or on clothing. Do not taste or swallow. Avoid prolonged or repeated contact with skin. Follow manufacturer's instructions for use.

Storage: Store in a cool, dry place away from sources of heat, spark or flame. Keep in shipping packaging when not in use.

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls:
Use adequate explosion proof ventilation to keep airborne concentrations low. All equipment and working surfaces must be grounded.

Personal Protective Equipment:

Eyes:
Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin:
Clothing should be appropriate for handling pyrotechnic substances.

Clothing:
Clothing should be appropriate for handling pyrotechnic substances.

Respirators:
A respirator is not typically necessary. Follow the OSHA respirator regulations found in 29CFR1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	solid
Appearance:	rubber cylinders inside plastic parts
Odour:	none
Odour Threshold:	Not available.
pH:	Not available.
Vapour Pressure:	Not available.
Vapour Density:	Not available.
Viscosity:	Not available.
Evaporation Rate:	Not available.
Boiling Point:	Not available.
Freezing/Melting Point:	Not available.
Coefficient of water/oil distribution:	Not available.
Autoignition Temperature:	280°C
Flash Point:	Not available.
Explosion Limits, lower (LEL):	Not available.
Explosion Limits, upper (UEL):	Not available.
Sensitivity to Mechanical Impact:	unprotected black powder can be ignited by impact
Sensitivity to Static Discharge:	unprotected black powder can be ignited by static discharge
Decomposition Temperature:	> 400°C
Solubility in water:	black powder is soluble in water
Specific Gravity/Density:	black powder = 1.7-2.1 Propellant = not available
Molecular Formula:	Not applicable
Molecular Weight:	Not applicable.

10.0 STABILITY AND REACTIVITY

Chemical Stability:
Stable under normal temperatures and pressures.

Conditions to Avoid:
Heat, static electricity, friction, impact

Incompatibilities with Other Materials:
Combustible or flammable materials, explosive materials

Hazardous Products Of Decomposition:
Oxides of nitrogen

Hazardous Polymerization:
Will not occur.

11.0 TOXICOLOGICAL INFORMATION

Routes of Entry:
Skin contact – not likely
Skin absorption – not likely
Eye contact – not likely
Inhalation – not likely
Ingestion – not likely

Effects of Acute Exposure to Product:
No data available

Effects of Chronic Exposure to Product:
No data available

Exposure Limits:

Black Powder Pellets

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Potassium Nitrate	7757-79-1	not established	not established
Charcoal	n/a	not established	not established
Sulphur	7704-34-9	not established	not established
Graphite	7782-42-5	2.5 mg/m^3	15 mmpct (TWA)

Propellant

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Ammonium Perchlorate	7790-98-9	not established	not established
metal powder		varies	varies
Synthetic Rubber		not established	not established

Irritancy of the Product:
No data available

Sensitization to the Product:
No data available

Carcinogenicity:
Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA

Reproductive Toxicity:
No data available

Teratogenicity:
No data available

Mutagenicity:
No data available

Toxically Synergistic Products:
No data available

LD50:
No data available

12.0 ECOLOGICAL INFORMATION

Environmental Data:
Ecotoxicity Data:
Not determined.

EcoFaTE Data:
Not determined.

13.0 DISPOSAL CONSIDERATIONS

Product As Sold: Pack firmly in hole in ground with nozzle pointing up. Ignite motor electrically from a safe distance and wait 5 minutes before approaching. Dispose of spent components in inert trash.

Product Packaging: Dispose of used packaging materials in inert trash.

Special Considerations: Consult local regulations about disposal of explosive materials.

14.0 TRANSPORT INFORMATION

Shipping Information – Canada

TDG Classification:	Class 1.4 Explosive
Proper Shipping Name:	Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number:	0351
UN Classification Code:	1.4 C
Packing Group:	II
UN Packing Instruction:	101

Shipping Information - USA / IMO

Proper Shipping Name:	Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number:	0351
UN Classification Code:	1.4 C
DOT / IMO Label:	Class 1 – Explosive – Division 1.4C

Shipping Information - IATA

Proper Shipping Name:	Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number:	0351
UN Classification Code:	1.4 C
IATA Labels:	Class 1 – Explosive – Division 1.4C Cargo Aircraft Only

15.0 REGULATORY INFORMATION

Canada

This product has been classified according to the hazard criteria of the Canadian Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

WHMIS Classification: Not Controlled (explosive)

Domestic Substance List (DSL) Status:
All ingredients are listed on Canada's DSL List.

Canadian Explosives Classification: Class 7.2.5
This product is an authorized explosive in Canada.

These products are not considered "Controlled Good" in Canada under the Controlled Goods Regulations.

United States of America

TSCA Inventory Status:
All ingredients are listed on the TSCA inventory.

Hazardous Chemical Lists

CERCLA Hazardous Substance (40 CFR 302.4)	No
SARA Extremely Hazardous Substance (40CFR 355)	No
SARA Toxic Chemical (40CFR 372.65)	No

European/International Regulations

The product on this MSDS, or all its components, is included on the following countries' chemical inventories:
EINECS – European Inventory of Existing Commercial Chemical Substances

European Labelling in Accordance with EC Directives
Hazard Symbols: Explosive.
Risk Phrases:

- **R 2** Risk of explosion by shock, friction, fire or other sources of ignition.
- **R 11** Highly flammable
- **R 44** Risk of explosion if heated under confinement.

Safety Phrases:

- **S 1/2** Keep locked up and out of the reach of children.
- **S 8** Keep container dry.
- **S 15** Keep away from heat.
- **S 16** Keep away from sources of ignition -- No smoking.

S 17	Keep away from combustible material.
S 18	Handle and open container with care.
S 33	Take precautionary measures against static discharges.
S 41	In case of fire and/or explosion do not breathe fumes.

16.0 OTHER INFORMATION

MSDS Prepared by:

Regulatory Affairs Department
Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, ON
Canada L0H 1G0

Telephone: 905-887-2370 x239
Fax: 905-887-2375
Web Sites: www.cesaronitech.com
www.Pro38.com

C.3 Fibre Glast Style 120 E-Glass

Fibre Glast Developments Corporation

GHS SAFETY DATA SHEET (SDS)

SECTION 1 - PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: PART #573 Style 120 E-Glass

FIBRE GLAST DEVELOPMENTS CORP.
385 CARR DRIVE
BROOKVILLE, OH 45309

TELEPHONE: (937) 833-5200
FAX: (937) 833-6555
FOR CHEMICAL EMERGENCY
CALL (800) 424-9300 24 HRS.

RECOMMENDED USE: Woven textile product for use with Standard Composite Manufacturing

SECTION 2 – HAZARDS IDENTIFICATION

GHS CLASSIFICATION

This finished product has not been tested. Hazards identified are based on hazards of the ingredients. This product contains a hazardous chemical, as defined by OSHA at 29 CFR 1910.1200.

Skin irritation	: Category 3
Specific target organ toxicity – single exposure	: Category 3 (Respiratory tract irritation)

GHS Label Element
Hazard pictograms :

Signal word : Warning

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Hazard statements	: H316 Causes mild skin irritation. H335: May cause respiratory tract irritation.
Precautionary statements	: P261 Avoid breathing dusts or fibers. P271 Use only outdoors or in a well-ventilated area. P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. P312: Call a POISON CENTER or doctor/physician if you feel unwell. P332+P313: If skin irritation occurs, get medical advice/attention. P501: Dispose of contents/container in accordance with local/regional/ national/international regulations.
Relevant route of exposure and/or target organs	: Dermal, Inhalation

SECTION 3 – COMPOSITION/INFORMATION ON INGREDIENTS

COMPONENT	CAS#	%
Glass, oxide, chemicals	65997-17-3	>99.4
Fibrous glass dust	Not assigned	Not assigned
Werner chrome complex[A] (Cr^{+3})	Not assigned	<0.3
Silane Coupling Agents[A]	Not assigned	<0.3

* Amount will be dependent upon method of handling.

[A] – Chemically bound to the fiberglass

SECTION 4 – FIRST AID MEASURES

Skin contact: Flush with ample cool water followed by washing with mild soap to remove accumulated fibers.

Eye contact: Flush with flowing water for 15 minutes—seek medical attention.

Inhalation: Move to fresh air.

Ingestion: Not likely to occur through normal use. Should ingestion occur, seek medical attention.

Most important symptoms/effects: Direct skin contact with fibrous glass or its dust may cause mechanical irritation and transitory dermatitis. Breathing of fibers or dust may cause mechanical irritation of the mouth, nose, and throat.

Indication of immediate medical attention and special treatment needed: Get medical attention if product comes into contact with skin or eyes, or if it is inhaled or ingested.

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SECTION 5 – FIRE-FIGHTING MEASURES

Extinguishing media: Water, dry powder, or foam (needed for packaging only)

Hazardous combustion products: Not applicable

Protective equipment: Firefighters should be equipped with self-contained breathing apparatus and turn-out gear.

Fire-fighting procedures/precautions: Fiberglass itself will not support combustion, but in a sustained fire, proper protection against products of combustion from the fuel must be worn.

SECTION 6 – ACCIDENTAL RELEASE MEASURES

Personal precautions: A release of this product is not expected to pose risks to workers under normal circumstances. If the material is involved in a fire, or if dusts are produced, no action shall be taken involving any personal risk or without suitable training. Keep unnecessary and unprotected personnel from entering. Put on appropriate personal protective equipment.

Protective equipment: Wear protective gloves/eye protection/skin protection.

Methods/Materials for containment and cleaning up: Dust or loose fibers can be vacuumed or swept with the aid of a dust suppressant. Dispose of in accordance with all government regulations. Do not discharge into waterways or sewer systems without proper authority.

SECTION 7 – HANDLNG AND STORAGE

Precautions: This product should be handled under conditions of good industrial hygiene and in conformity with any local regulations to avoid unnecessary exposure. Use in a well-ventilated area. Do not breathe the dust. Avoid contact with skin.

Storage: Store in a well-ventilated, dry location.

SECTION 8 – EXPOSURE CONTROLS/PERSONAL PROTECTION

EXPOSURE CONTROLS
Component: Fibrous dust
OSHA/PEL: 5 mg/m^3
ACGIH/TLV: 5 mg/m^3
*Dust may be produced during handling.

Engineering controls: Normal area ventilation is sufficient in most cases to keep dust and fiber levels below the TLV or PEL.

PERSONAL PROTECTION MEASURES/EQUIPMENT

Skin protection: Barrier creams, gloves, and long-sleeve, loose-fitting clothing may be required for certain workers who have sensitive skin or contact dermatitis. Work clothing should be laundered separately from other clothing before reuse.

Eye protection: Not normally required, but as a good safety work practice, eye protection such as safety glasses/side shields or equivalent whenever use of the product releases airborne fibrous glass.

Respiratory protection: If airborne fibrous glass exceeds the regulatory limits, or if upper respiratory irritation occurs, use a N95 particulate filtering respirator.

Other protection: Observe good personal hygiene.

SECTION 9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance	: Solid
Color	: White
Odor	: Odorless
Odor Threshold	: None
pH	: None
Freezing Point (Melting point/freezing point)	: >800^{0}C (>1472^{0}F)
Initial Boiling Point	: Not applicable
Flash point	: Not applicable
Evaporation rate	: Not applicable
Upper/Lower Flammability	: Not applicable
Upper/Lower Explosive Limits	: Not applicable
Vapor pressure	: Not applicable
Vapor Density	: Not applicable

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Relative Density/ Specific Gravity	:	2.4 to 2.7
Solubility	:	Insoluble
Partition Coefficient	:	Not known
Auto-ignition Temperature	:	Not known
Decomposition Temperature	:	Not known
Volatility	:	Not known
Viscosity	:	Not applicable

SECTION 10 - STABILITY AND REACTIVITY

Reactivity: Not self-reactive, water-reactive, or spontaneously combustible.

Chemical stability: This product is stable.

Hazardous reactions: Under normal conditions of storage and use, hazardous reaction will not occur.

Conditions to avoid: When exposed to high temperatures, may produce hazardous decomposition products.

Incompatible products: None known.

Hazardous decomposition products: Fiberglass products may release small amounts of acetic acid and other organic materials at elevated temperatures.

Hazardous polymerization: Will not occur.

SECTION 11 – TOXICOLOGICAL INFORMATION

Relevant route of exposure/Target organs: Dermal, Inhalation

Symptoms: Causes mild skin irritation. May cause irritation of the mouth, nose, and throat after inhalation exposure.

Delayed and immediate effects: Not known

Chronic effects (short and long term exposure): Not known

Numerical measures of toxicity: None

Carcinogenicity: No ingredient is listed as a carcinogen by the NTP, IARC, or OSHA at 29 CFR 1910 Subpart Z.

Mutagenicity: No data available

Reproductive Toxicity: No data available

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SECTION 12 - ECOLOGICAL INFORMATION

No data available

SECTION 13 - DISPOSAL CONSIDERATIONS

Do not discharge into waterways or sewer systems without proper authority. Dispose of in accordance with all government regulations.

SECTION 14 - TRANSPORT INFORMATION

Not regulated as a hazardous material/dangerous good for transportation in all modes of transportation (US DOT, ICAO/IATA, IMO).

SECTION 15 - REGULATORY INFORMATION

TSCA Inventory Status: Exempt per section 8 (a), 710.2 (f), and 704.5 (a)
SARA Title III Section 302: None
SARA Title III Section 304: None
SARA Title III Section 311/312 Hazard Categories: Immediate (acute)
SARA Title III Section 313: This product does not contain components that are subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right to Know Act of 1986 (ESCRA or SARA Title III) and 40 CFR 372.
CERCLA RQ: Not listed
California Proposition 65: Not known
Massachusetts Right to Know: Less than reportable quantity
New Jersey Right to Know: Less than reportable quantity
Pennsylvania Right to Know: Less than reportable quantity

Canada: All components of this product are included on the Domestic Substances List (DSL) or are not required to be listed on the Canadian DSL.

Europe: All components of this product are included on the European Inventory of Existing Commercial Chemical Substances (EINECS) or are not required to be listed on the EINECS.

China: All components of this product are included on the Chinese Inventory (IECSC) or are not required to be listed on the Chinese IECSC.

Japan: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese inventory.

Korea: All components of this product are included on the Korean (ECL) inventory or are not required to be listed on the Korean ECL.

Philippines: All components of this product are included on the Philippine (PICCS) or are not required to be listed on the Philippine PICCS.

Australia: All components of this product are included on the Australian (AICS) or are not required to be listed on the Australian AICS.

SECTION 16 – OTHER INFORMATION

This product is classified as a Skin Irritant Category 3. However, OSHA does not include Category 3 substances in its hazard classification system.

Abbreviations	
ACGIH/TLV	American Conference of Industrial Hygienists Threshold Limit Value
CAS	Chemical Abstracts Service
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	US Code of Federal Regulations
DOT	US Department of Transportation
EPCRA	Emergency Planning and Right to Know Act
GHS	UN Globally Harmonized System of Classification and Labeling of Chemicals
HCS	Hazard Communication Standard
IARC	International Agency for Research and Cancer
ICAO/IATA	International Civil Aviation Organization/International Air Transport Association
IMO/IMDG	International Maritime Organization/International Maritime Dangerous Goods Code
LD_{50}	Lethal dose to half of test animals
NTP	National Toxicology Program
OSHA	US Occupational Safety Health Administration
PEL	Permissible exposure limit
RQ	Reportable quantity
SARA	Superfund Amendments and Reauthorization Act
SDS	Safety data sheet
TSCA	Toxic Substances Control Act
UN	United Nations
US/USA	United States (of America)

The information accumulated herein is believed to be accurate but is not warranted to be, whether originating with **Fibre Glast Developments Corporation** or not. Recipients are advised to confirm in advance of need that the information is current, applicable, and suitable to their circumstances.

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C.4 Fibre Glast System 2000 Epoxy Resin

Fibre Glast
Developments Corporation

GHS SAFETY DATA SHEET (SDS)

SECTION 1 - PRODUCT AND COMPANY IDENTIFICATION

PRODUCT: Part #2000 System 2000 Epoxy Resin

FIBRE GLAST DEVELOPMENTS CORP.
385 CARR DRIVE
BROOKVILLE, OH 45309

TELEPHONE: (937) 833-5200
FAX: (937) 833-6555
FOR CHEMICAL EMERGENCY
CALL (800) 424-9300 24 HRS.

RECOMMENDED USE: Industrial Epoxy Resin supplied exclusively for workplace use.

SECTION 2 – HAZARDS IDENTIFICATION

GHS CLASSIFICATION

Eye Irritation	:	Category 2A
Acute Toxicity (Oral)	:	Category 5
Skin Irritation	:	Category 2
Skin Sensitizer	:	Category 1
Chronic Aquatic Toxicity	:	Category 2

GHS Label Element
Hazard pictogram :

Signal Word : Warning

Hazard statements : H319 Causes serious eye irritation.
H303 May be harmful if swallowed.
H315 Causes skin irritation.
H317 May cause an allergic skin reaction.
H411 Toxic to aquatic life with long lasting effects.

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Precautionary statements : P202 Do not handle until all safety precautions have been read/understood.
P261 Avoid breathing dust/fume/gas/mist/vapours/spray.
P270 Do not eat, drink or smoke when using this product.
P281 Use personal protective equipment as required.
P285 In case of inadequate ventilation wear respiratory protection.
P273 Avoid release to the environment.

NO.	CANCER	REPRO-TOX	TARGET ORGANS	ACGIH/TLV	OSHA/PEL
P	NO	NO	UNKNOWN	N.A.mg/M^3	N.A.mg/M^3
2	NO	NO	UNKNOWN	N.A.mg/M^3	N.A.mg/M^3

NOTE: CONTAINS MATERIAL(S) REGULATED AS DUST HAZARDS, DISPERSED IN A NON-HAZARDOUS FORM. IF DUST IS RECREATED, APPROPRIATE RESPIRATORY AND/OR EXPLOSION PRECAUTIONS MUST STILL BE USED.

SECTION 3 – COMPOSITION / INFORMATION ON INGREDIENTS

UNDER GHS-OSHA §4.11 THE PRECISE COMPOSITION OF THIS PRODUCT IS WITHHELD AS CONFIDENTIAL BUSINESS INFORMATION (CBI). A MORE COMPLETE DISCLOSURE CAN BE PROVIDED TO A HEALTH, OR SAFETY PROFESSIONAL WHEN NECESSARY.

Substance/Mixture: Mixture

NO.	COMPONENT	CAS. NO.	PERCENT
P	EPOXY RESIN BASED MIXTURE	N.A.	< 100%
2	MULTIFUNCTIONAL ACRYLATE	15625-89-5	< 2%

SECTION 4 – FIRST AID MEASURES

EMERGENCY AND FIRST AID PROCEDURES:

- **EYES:** IMMEDIATELY FLUSH EYES WITH LARGE AMOUNTS OF WATER FOR 15 MINUTES. GET MEDICAL ATTENTION.
- **SKIN:** WASH AFFECTED AREA IMMEDIATELY WITH LARGE AMOUNTS OF SOAP AND WATER. REMOVE AND WASH CONTAMINATED CLOTHING BEFORE REUSE. CONTACT A PHYSICIAN IF IRRITATION OCCURS.
- **INHALATION:** REMOVE VICTIM TO FRESH AIR AND PROVIDE OXYGEN IF BREATHING IS DIFFICULT. GET MEDICAL ATTENTION.
- **INGESTION:** DO NOT INDUCE VOMITING. GIVE LARGE QUANTITIES OF WATER. CALL A PHYSICIAN IMMEDIATELY. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON.

SECTION 5 – FIRE-FIGHTING MEASURES

FLASH POINT: ≥210°F (FOR PRODUCT OR LOWEST FLASH POINT INGREDIENT)
FLAMMABILITY CLASSIFICATION: COMBUSTIBLE CLASS (IIIB)
EXTINGUISHING MEDIA: WATER FOG, DRY CHEMICAL, CARBON DIOXIDE, OR FOAM.
NOTE: EITHER ATMOSPHERE-SUPPLY OR AIR-PURIFYING RESPIRATORS SHOULD BE AVAILABLE FOR FIRE FIGHTERS (20 CFR 1910.134).

SECTION 6 – ACCIDENTAL RELEASE MEASURES

- **IF MATERIAL IS SPILLED:** AVOID CONTACT WITH MATERIAL. PERSONS NOT WEARING PROPER PROTECTIVE EQUIPMENT (SEE BELOW) SHOULD BE EXCLUDED FROM THE AREA UNTIL CLEAN UP IS COMPLETE. DIKE AREA TO PREVENT SPILL SPREADING AND SCOOP UP EXCESS TO RECOVERY CONTAINERS. ABSORB REMNANT ON NONCOMBUSTIBLE MATERIAL SUCH AS CLAY AND SHOVEL INTO CONTAINERS FOR DISPOSAL.
- **WASTE DISPOSAL METHOD:** DISPOSE OF ANY WASTE(S) GENERATED ABOVE IN ACCORDANCE WITH FEDERAL, STATE, AND LOCAL REGULATIONS.

SECTION 7 – HANDLING AND STORAGE

- AVOID SKIN AND EYE CONTACT.
- AVOID BREATHING VAPOR, MIST OR FUMES.
- ENSURE THAT ALL CONTAINERS ARE PROPERLY LABELED TO PREVENT ACCIDENTAL INGESTION OR IMPROPER DISPOSAL.
- RESEAL PARTLY USED CONTAINERS.
- WASH WITH SOAP AND WATER BEFORE EATING, DRINKING OR USING TOILET FACILITIES.
- STORE UNDER COOL, DRY CONDITIONS AND AWAY FROM OPEN FLAMES AND HIGH TEMPERATURES.
- OBSERVE CONDITIONS OF GOOD INDUSTRIAL HYGIENE AND SAFE WORKING PRACTICE.

SECTION 8 – EXPOSURE CONTROLS/PERSONAL PROTECTION

- **RESPIRATORY PROTECTION:** NOT NORMALLY NECESSARY UNLESS THE MATERIAL IS BEING USED IN SUCH A WAY AS TO PRODUCE DUST, MIST, VAPOR, FUMES, OR SMOKE, IN WHICH CASE NIOSH APPROVED RESPIRATORY PROTECTION SHOULD BE USED.
- **VENTILATION:** SHOULD BE SUFFICIENT TO CONTROL ANY DUST, MIST, VAPOR OR FUMES PRODUCED BY PROCESSING OR HANDLING METHOD. BREATHING OF VAPOR MUST BE AVOIDED.
- **HAND PROTECTION:** IMPERVIOUS GLOVES, NEOPRENE OR NILRILE RUBBER GLOVES.
- **EYE PROTECTION:** SPLASH PROOF GOGGLES OR SAFETY GLASSES WITH SIDE SHIELDS.
- **OTHER PROTECTIVE EQUIPMENT:** CLEAN, BODY COVERING CLOTHING AND FOOTWEAR.

SECTION 9 – PHYSICAL AND CHEMICAL PROPERTIES

- PHYSICAL STATE......: LIQUID
- ODOR........................: BLAND
- COLOR.......................: AMBER
- pH.............................: NEUTRAL
- SP. GR......................: 1.14
- DENSITY....................: 9.5 lbs. / gal.
- VAPOR PRESSURE....: NEGLIGIBLE

NOTE: OTHER PROPERTIES ARE EITHER NOT AVAILABLE, OR DO NOT APPLY.

SECTION 10 – STABILITY AND REACTIVITY

- **STABILITY:** STABLE UNDER NORMAL STORAGE CONDITIONS. UNSTABLE AT ELEVATED TEMPERATURES.
- **INCOMPATIBILITY:** STRONG OXIDIZING AGENTS, STRONG LEWIS OR MINERAL ACIDS, AND STRONG MINERAL AND ORGANIC BASES / ESPECIALLY ALIPHATIC AMINES.
- **HAZARDOUS DECOMPOSITION PRODUCTS:** CARBON OXIDES, ALDEHYDES, ACIDS, PHENOLICS, AND OTHER UNKNOWN COMPOUNDS.

SECTION 11 – TOXICOLOGICAL INFORMATION

EFFECTS OF OVEREXPOSURE:

ACUTE:
- **EYES:** PRODUCT IS MODERATELY IRRITATING TO THE EYES.
- **SKIN:** PRDUCT IS MODERATELY IRRITATING TO THE SKIN AND MAY CAUSE SKIN SENSITIZATION.
- **INHALATION:** BECAUSE OF ITS LOW VOLATILITY THIS PRODUCT IS NOT LIKELY TO BE AN INHALATION HAZARD.
- **INGESTION:** PRODUCT IS CONSIDERED TO HAVE A LOW ORDER OF ACUTE ORAL TOXICITY.

CHRONIC:
- NO SPECIFIC HAZARDS KNOWN. PREEXISTING EYE, SKIN, OR LUNG DISORDERS MAY BE AGGRAVATED BY EXPOSURE TO THIS PRODUCT.

SECTION 12 – ECOLOGICAL INFORMATION

ECOTOXICITY EFFECTS:
- **AQUATIC TOXICITY:** NO DATA IS AVAILABLE ON THE PRODUCT ITSELF.
- **TOXICITY TO OTHER ORGANISMS:** NO DATA AVAILABLE.

PERSISTANCE AND DEGRADABILITY:
- **MOBILITY:** NO DATA IS AVAILABLE ON THE PRODUCT ITSELF.
- **BIOACCUMULATION:** NO DATA IS AVAILABLE ON THE PRODUCT ITSELF.

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SECTION 13 – DISPOSAL CONSIDERATIONS

- **WASTE DISPOSAL METHOD:** DISPOSE OF WASTE IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL REGULATIONS.
- **CONTAINER DISPOSAL:** SINCE EMPTIED CONTAINERS RETAIN PRODUCT RESIDUE, ALL LABELED HAZARD PRECAUTIONS MUST BE OBSERVED. CONSULT WITH FEDERAL, STATE, AND LOCAL AUTHORITIES FOR DEFINITIONS OF "EMPTY" AND PROPER DISPOSAL PRACTICES.

SECTION 14 – TRANSPORT INFORMATION

- **U.S. Department of Transportation Ground (49 CFR)**

UN NUMBER.......................................: N.A.
PROPER SHIPPING NAME.........................: PLASTIC MATERIAL LIQUID, N.O.I.
CONTAINS.......................................: NOT REGULATED*
HAZARD CLASS...................................: N.A.
PACKAGING GROUP...............................: N.A

- **International Air Transportation (ICAO/IATA)**

UN NUMBER.......................................: N.A.
PROPER SHIPPING NAME.........................: PLASTIC MATERIAL LIQUID, N.O.I.
CONTAINS.......................................: NOT REGULATED*
HAZARD CLASS...................................: N.A.
PACKAGING GROUP...............................: N.A.

- **Water Transportation (IMO/IMDG)**

UN NUMBER.......................................: N.A.
PROPER SHIPPING NAME.........................: PLASTIC MATERIAL LIQUID, N.O.I.
CONTAINS.......................................: NOT REGULATED*
HAZARD CLASS...................................: N.A.
PACKAGING GROUP...............................: N.A
MARINE POLLUTANT...............................: NO

*Non-Bulk Packages may be shipped as Non-Regulated under §49 CFR 173.150(f).

SECTION 15 – REGULATORY INFORMATION

CAL SAFE DRINKING WATER & TOXIC ENFORCEMENT ACT OF 1986

NO.	CHEMICAL NAME	CAS. NO.	CANCER/REPRO.TOX	QUANTITY

THIS PRODUCT MAY CONTAIN TRACES OF PROP. 65 LISTED CHEMICALS AS IMPURITIES. HOWEVER, ANY USED AS INGREDIENTS ARE LISTED ABOVE.

CERCLA — §40 CFR 302.4
RELEASES EXCEEDING THE REPORTABLE QUANTITY **(RQ)** MUST BE REPORTED TO THE NATIONAL RESPONSE CENTER. (800)424-8802

RQ NOT ESTABLISHED OR REQUIRED FOR THIS PRODUCT.

RCRA — §40 CFR 261.33

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NOT A HAZARDOUS WASTE BY RCRA CRITERIA (40CFR261.20-24).

SARA TITLE III — §52 CFR 13378, §52 CFR 21152

NO.	RQ(lbs.) (•1)	TPQ(lbs.) (•2)	SEC.313 (•3)	313 CAT. (•4)	311/312 (•5)
P	NONE	NOT LISTED	NOT LISTED	NONE	H1
2	NONE	NOT LISTED	NOT LISTED	NONE	H1

•1 = REPORTABLE QUANTITY OF EXTREMELY HAZARDOUS SUBSTANCE, SEC. 302
•2 = THRESHOLD PLANNING QUANTITY, EXTREMELY HAZARDOUS SUBSTANCE, SEC. 302
•3 = TOXIC CHEMICAL, SEC. 313 (INDIVIDUAL CHEMICAL LISTED)
•4 = TOXIC RELEASE INVENTORY FORM CATEGORY SEC. 313 (40 CFR 372.65 C)
•5 = HAZARD CATEGORY FOR SARA SEC. 311/312 REPORTING
H1 = IMMED. (ACUTE) HEALTH HAZARD **H2** = DELAYED (CHRONIC) HEALTH HAZARD
P3 = FIRE HAZARD **P4** = SUDDEN PRESSURE RELEASE HAZARD **P5** = REACTIVE HAZ.

VOC — SCAQMD RULES

NO.	CHEMICAL	QUANTITY	VP mm HG	gms./l. @ 20ºC
	NIL			

NOTE: THIS PRODUCT DOES NOT CONTAIN SOLVENTS, BUT MAY CONTAIN INGREDIENTS WITH VP'S LOW ENOUGH TO BE EMITTED IF HEATED ALONE. WHEN 2 PART RESINS AND HARDENERS ARE PROPERLY MIXED TOGETHER THESE INGREDIENTS REACT TOGETHER AND ARE CONSUMED WITHOUT SIGNIFICANT ATMOSPHERIC EMISSIONS.

INTERNATIONAL CHEMICAL INVENTORY STATUS:

EINECS-EU	Listed, Exempted, Polymer substance, or as no longer polymer.
AICS-AUSTRALIA	All components are listed or exempted.
ENCS-JAPAN	All components are listed or exempted.
ISHL-JAPAN	All components are listed or exempted.
KECI/ECL-KOREA	All components are listed or exempted.
IECSC/SEPA-CHINA	All components are listed or exempted.
PICCS-PHILIPPINES	All components are listed or exempted.
DSL-CANADA	All components are listed or exempted.
TSCA-USA	All components are listed or exempted.

WHMIS (CANADA)

- WHMIS: D2B Materials Causing Other Toxic Effects – Toxic Material

SECTION 16 – OTHER INFORMATION

HMIS III CODES:		RATINGS:
HEALTH.............................=**2**	0 = MINIMAL	3 = SERIOUS
FLAMMABILITY..................=**1**	1 = SLIGHT	4 = SEVERE
REACTIVITY.......................=**0**	2 = MODERATE	

PERSONAL PROTECTION RATING TO BE SUPPLIED BY USER DEPENDING ON CONDITIONS OF USE.

The information accumulated herein is believed to be accurate but is not warranted to be, whether originating with **Fibre Glast Developments Corporation** or not. Recipients are advised to confirm in advance of need that the information is current, applicable, and suitable to their circumstances.

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C.5 Spray Paint

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Safety Data Sheet

RUST-OLEUM CORPORATION
*** Trusted Quality Since 1921 ***
www.rustoleum.com

1. Identification

Product Name:	STRUST SSPR 6PK FLEXIDIP RED	**Revision Date:**	4/21/2015
Product Identifier:	276291	**Supercedes Date:**	New SDS
Product Use/Class:	Topcoat/Aerosols		
Supplier:	Rust-Oleum Corporation 11 Hawthorn Parkway Vernon Hills, IL 60061 USA	**Manufacturer:**	Rust-Oleum Corporation 11 Hawthorn Parkway Vernon Hills, IL 60061 USA
Preparer:	Regulatory Department		
Emergency Telephone:	24 Hour Hotline: 847-367-7700		

2. Hazard Identification

EMERGENCY OVERVIEW: Extremely flammable liquid and vapor. Vapors may cause flash fire or explosion. Harmful if inhaled. May affect the brain or nervous system causing dizziness, headache or nausea. Contents Under Pressure. May cause eye, skin, or respiratory tract irritation. KEEP OUT OF REACH OF CHILDREN. Harmful if inhaled. Harmful if swallowed. Causes eye irritation. Use ventilation necessary to keep exposures below recommended exposure limits, if any. Vapor Harmful. Causes Eye, Skin, Nose, and Throat Irritation.

Classification

Symbol(s) of Product

Signal Word

Danger

Possible Hazards

58% of the mixture consists of ingredient(s) of unknown acute toxicity

GHS HAZARD STATEMENTS

Flammable Aerosol, category 1	H222	Extremely flammable aerosol.
Flammable Liquid, category 1	H224	Extremely flammable liquid and vapour.
Acute Toxicity, Oral, category 5	H303	May be harmful if swallowed.
Acute Toxicity, Dermal, category 5	H313	May be harmful in contact with skin.
Skin Irritation, category 2	H315	Causes skin irritation.
Eye Irritation, category 2	H319	Causes serious eye irritation.
Acute Toxicity, Inhalation, category 4	H332	Harmful if inhaled.
STOT, single exposure, category 3, RTI	H335	May cause respiratory irritation.
STOT, single exposure, category 3, NE	H336	May cause drowsiness or dizziness.
Aspiration Hazard, category 2	H305	May be harmful if swallowed and enters airways.
Eye Irritation, category 2B	H320	Causes eye irritation.
Flammable Aerosol, category 1	H280	Contains gas under pressure; may explode if heated

Germ Cell Mutagenicity, category 1B	H340	May cause genetic defects. Classified as mutagenic Category 1 if one ingredient is present at or above 0.1%. Applies to liquids, solids (w/w units) and gases (v/v). The substance may also have its own exposure limit. Routes of exposure are dependent on ingredient form.
Carcinogenicity, category 1B	H350	May cause cancer. Classified as carcinogenic Category 1 on the basis of epidemiological and/or animal data. Mixtures are classified as carcinogenic when at least 1 ingredient has been classified as carcinogenic and is present at 0.1% or above Routes of exposure are dependant on ingredient form.

GHS PRECAUTIONARY STATEMENTS

P211	Do not spray on an open flame or other ignition source.
P220	Keep/Store away from clothing/.../combustible materials.
P235	Keep cool.
P251	Pressurized container: Do not pierce or burn, even after use.
P375	Fight fire remotely due to the risk of explosion.
P102	Keep out of reach of children.
P103	Read label before use.
P202	Do not handle until all safety precautions have been read and understood.
P234	Keep only in original container.
P260	Do not breathe dust/fume/gas/mist/vapours/spray.
P261	Avoid breathing dust/fume/gas/mist/vapours/spray.
P262	Do not get in eyes, on skin, or on clothing.
P264	Wash ... thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P281	Use personal protective equipment as required.
P285	In case of inadequate ventilation wear respiratory protection.
P312	Call a POISON CENTER or doctor/physician if you feel unwell.
P351	Rinse cautiously with water for several minutes.
P374	Fight fire with normal precautions from a reasonable distance.
P402	Store in a dry place.
P210	Keep away from heat/sparks/open flames/hot surfaces. - No smoking.
P410+P412	Protect from sunlight. Do not expose to temperatures exceeding 50°C / 122°F.
P240	Ground/bond container and receiving equipment.
P241	Use explosion-proof electrical/ventilating/lighting/.../ equipment.
P242	Use only non-sparking tools.
P243	Take precautionary measures against static discharge.
P303+P361+P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P370+P378	In case of fire: Use ... for extinction.
P403+P235	Store in a well-ventilated place. Keep cool.
P501	Dispose of contents/container to ...
P321	Specific treatment (see ... on this label).
P352	Wash with plenty of soap and water.
P362	Take off contaminated clothing and wash before reuse.
P332+P313	If skin irritation occurs: Get medical advice/attention.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313	If eye irritation persists: Get medical advice/attention.
P304+P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P405	Store locked up.
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P201	Obtain special instructions before use.
P308+P313	IF exposed or concerned: Get medical advice/attention.
P302+P350	IF ON SKIN: Gently wash with plenty of soap and water.

3. Composition/Information On Ingredients

HAZARDOUS SUBSTANCES

Chemical Name	CAS-No.	Wt.% Range	GHS Symbols	GHS Statements
Aliphatic Hydrocarbon	64742-89-8	10-25	GHS08	H340-350
Propane	74-98-6	10-25		
n-Butyl Acetate	123-86-4	10-25	GHS02-GHS07	H225-336
Methyl Isobutyl Ketone	108-10-1	10-25	GHS02-GHS06	H225-331-335-319
Methyl Acetate	79-20-9	10-25	GHS02-GHS06	H225-310-336-319
n-Butane	106-97-8	2.5-10		
Ethyl Acetate	141-78-6	2.5-10	GHS02-GHS06	H225-310-336-319
Ethylbenzene	100-41-4	0.1-1.0	GHS02-GHS07	H225-332
Titanium Dioxide	13463-67-7	0.1-1.0		

The text for GHS Hazard Statements shown above (if any) is given in the "16. Other Information" section.

4. First-aid Measures

FIRST AID - EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes holding eyelids open. Get medical attention. Do NOT allow rubbing of eyes or keeping eyes closed.

FIRST AID - SKIN CONTACT: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists.

FIRST AID - INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention. Do NOT use mouth-to-mouth resuscitation. If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately.

FIRST AID - INGESTION: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention. If swallowed, get medical attention.

5. Fire-fighting Measures

EXTINGUISHING MEDIA: Alcohol Film Forming Foam, Carbon Dioxide, Dry Chemical, Dry Sand, Water Fog

UNUSUAL FIRE AND EXPLOSION HAZARDS: FLASH POINT IS LESS THAN 20°F. EXTREMELY FLAMMABLE LIQUID AND VAPOR!Water spray may be ineffective. Closed containers may explode when exposed to extreme heat due to buildup of steam. Closed containers may explode when exposed to extreme heat. Vapors may form explosive mixtures with air. Vapors can travel to a source of ignition and flash back. Isolate from heat, electrical equipment, sparks and open flame. Perforation of the pressurized container may cause bursting of the can. No unusual fire or explosion hazards noted. Keep containers tightly closed.

SPECIAL FIREFIGHTING PROCEDURES: Full protective equipment including self-contained breathing apparatus should be used. Evacuate area and fight fire from a safe distance. Water may be used to cool closed containers to prevent pressure buildup and possible autoignition or explosion. Use water spray to keep fire-exposed containers cool. Containers may explode when heated.

6. Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Isolate the hazard area and deny entry to unnecessary and unprotected personnel. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers. Ventilate area, isolate spilled material, and remove with inert absorbent. Dispose of contaminated absorbent, container, and unused contents in accordance with local, state, and federal regulations.

7. Handling and Storage

HANDLING: Wash thoroughly after handling. Wash hands before eating. Remove contaminated clothing and launder before reuse. Use only with adequate ventilation. Follow all MSDS/label precautions even after container is emptied because it may retain product residues. Avoid breathing fumes, vapors, or mist. Avoid contact with eyes, skin and clothing.

STORAGE: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Contents under pressure. Do not store above 120 ° F. Store large quantities in buildings designed and protected for storage of NFPA Class I flammable liquids. Product should be stored in tightly sealed containers and protected from heat, moisture, and foreign materials. Store in a dry, well ventilated place. Keep container tightly closed when not in use. Keep away from heat, sparks, flame and sources of ignition. Avoid excess heat.

8. Exposure Controls/Personal Protection

Chemical Name	CAS-No.	Weight % Less Than	ACGIH TLV-TWA	ACGIH TLV-STEL	OSHA PEL-TWA	OSHA PEL-CEILING
Aliphatic Hydrocarbon	64742-89-8	20.0	350 ppm	N.E.	500 ppm	N.E.
Propane	74-98-6	20.0	1000 ppm	N.E.	1000 ppm	N.E.
n-Butyl Acetate	123-86-4	15.0	150 ppm	200 ppm	150 ppm	N.E.
Methyl Isobutyl Ketone	108-10-1	15.0	20 ppm	75 ppm	100 ppm	N.E.
Methyl Acetate	79-20-9	15.0	200 ppm	250 ppm	200 ppm	N.E.
n-Butane	106-97-8	10.0	1000 ppm	1000 ppm	N.E.	N.E.
Ethyl Acetate	141-78-6	10.0	400 ppm	N.E.	400 ppm	N.E.
Ethylbenzene	100-41-4	1.0	20 ppm	125 ppm	100 ppm	N.E.
Titanium Dioxide	13463-67-7	1.0	10 mg/m3 (Total Dust)	N.E.	15 mg/m3 [Total Dust]	N.E.

PERSONAL PROTECTION

ENGINEERING CONTROLS: Use explosion-proof ventilation equipment. Provide general dilution of local exhaust ventilation in volume and pattern to keep TLV of hazardous ingredients below acceptable limits. Prevent build-up of vapors by opening all doors and windows to achieve cross-ventilation. Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits.

RESPIRATORY PROTECTION: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

SKIN PROTECTION: Use gloves to prevent prolonged skin contact. Nitrile or Neoprene gloves may afford adequate skin protection.

EYE PROTECTION: Use safety eyewear designed to protect against splash of liquids.

OTHER PROTECTIVE EQUIPMENT: Refer to safety supervisor or industrial hygienist for further guidance regarding types of personal protective equipment and their applications.

HYGIENIC PRACTICES: Wash thoroughly with soap and water before eating, drinking or smoking. Remove contaminated clothing immediately and launder before reuse.

9. Physical and Chemical Properties

Appearance:	Aerosolized Mist	**Physical State:**	Liquid
Odor:	Solvent Like	**Odor Threshold:**	N.E.
Relative Density:	0.738	**pH:**	N.A.
Freeze Point, °C:	N.D.	**Viscosity:**	No Information
Solubility in Water:	Negligible	**Partition Coefficient, n-octanol/ water:**	No Information
Decompostion Temp., °C:	No Information		
Boiling Range, °C:	-11 - 999	**Explosive Limits, vol%:**	0.9 - 16.0
Flammability:	Does not Support Combustion	**Flash Point, °C:**	-105
Evaporation Rate:	Faster than Ether	**Auto-Ignition Temp., °C:**	No Information
Vapor Density:	Heavier than Air	**Vapor Pressure:**	No Information

(See "Other information" Section for abbreviation legend)

10. Stability and Reactivity

CONDITIONS TO AVOID: Avoid temperatures above 120 ° F. Avoid contact with strong acid and strong bases. Avoid all possible sources of ignition.

INCOMPATIBILITY: Incompatible with strong oxidizing agents, strong acids and strong alkalies.

HAZARDOUS DECOMPOSITION: Contains solvents which may form carbon monoxide, carbon dioxide, and formaldehyde. By open flame, carbon monoxide and carbon dioxide. When heated to decomposition, it emits acrid smoke and irritating fumes.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

STABILITY: May form peroxides of unkown stability. This product is stable under normal storage conditions.

11. Toxicological Information

EFFECTS OF OVEREXPOSURE - EYE CONTACT: Causes Serious Eye Irritation

EFFECTS OF OVEREXPOSURE - SKIN CONTACT: May cause skin irritation. Allergic reactions are possible.

EFFECTS OF OVEREXPOSURE - INHALATION: High gas, vapor, mist or dust concentrations may be harmful if inhaled. High vapor concentrations are irritating to the eyes, nose, throat and lungs. Harmful if inhaled. Avoid breathing fumes, spray, vapors, or mist. Prolonged or excessive inhalation may cause respiratory tract irritation.

EFFECTS OF OVEREXPOSURE - INGESTION: Harmful if swallowed.

EFFECTS OF OVEREXPOSURE - CHRONIC HAZARDS: IARC lists Ethylbenzene as a possible human carcinogen (group 2B). Contains Titanium Dioxide. Titanium Dioxide is listed as a Group 2B-"Possibly carcinogenic to humans" by IARC. No significant exposure to Titanium Dioxide is thought to occur during the use of products in which Titanium Dioxide is bound to other materials, such as in paints during brush application or drying. Risk of overexposure depends on duration and level of exposure to dust from repeated sanding of surfaces or spray mist and the actual concentration of Titanium Dioxide in the formula. (Ref: IARC Monograph, Vol. 93, 2010)May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headaches, paralysis, and blurred vision) and/or damage.

PRIMARY ROUTE(S) OF ENTRY: Eye Contact, Ingestion, Inhalation, Skin Absorption, Skin Contact

ACUTE TOXICITY VALUES
The acute effects of this product have not been tested. Data on individual components are tabulated below:

CAS-No.	Chemical Name	Oral LD50	Dermal LD50	Vapor LC50
64742-89-8	Aliphatic Hydrocarbon	N.I.	3000 mg/kg Rabbit	N.I.
74-98-6	Propane	N.I.	N.I.	658 mg/L Rat
123-86-4	n-Butyl Acetate	N.I.	>17600 mg/kg Rabbit	N.I.
108-10-1	Methyl Isobutyl Ketone	2080 mg/kg Rat	>16000 mg/kg Rabbit	8.2 mg/L Rat
79-20-9	Methyl Acetate	>5000 mg/kg Rat	>5 g/kg Rabbit	N.I.
141-78-6	Ethyl Acetate	5620 mg/kg Rat	>20 mL/kg Rabbit	N.I.
100-41-4	Ethylbenzene	3500 mg/kg Rat	15354 mg/kg Rabbit	17.2 mg/L Rat
13463-67-7	Titanium Dioxide	>10000 mg/kg Rat	N.I.	N.I.

N.I. - No Information

12. Ecological Information

ECOLOGICAL INFORMATION: Product is a mixture of listed components.

13. Disposal Information

DISPOSAL INFORMATION: Dispose of material in accordance to local, state, and federal regulations and ordinances. Do not allow to enter waterways, wastewater, soil, storm drains or sewer systems.

14. Transport Information

	Domestic (USDOT)	International (IMDG)	Air (IATA)	TDG (Canada)
UN Number:	N.A.	1950	1950	N.A.
Proper Shipping Name:	Paint Products in Limited Quantities	Aerosols	Aerosols	Paint Products in Limited Quantities
Hazard Class:	N.A.	2.1	2.1	N.A.
Packing Group:	N.A.	N.A.	N.A.	N.A.
Limited Quantity:	Yes	Yes	Yes	Yes

15. Regulatory Information

U.S. Federal Regulations:

CERCLA - SARA Hazard Category

This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

Fire Hazard, Pressure Hazard, Reactive Hazard, Acute Health Hazard, Chronic Health Hazard

Sara Section 313:

This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

Chemical Name	CAS-No.
Methyl Isobutyl Ketone	108-10-1
Ethylbenzene	100-41-4

Toxic Substances Control Act:

This product contains the following chemical substances subject to the reporting requirements of TSCA 12(b) if exported from the United States:

Chemical Name	CAS-No.
Acetaldehyde	75-07-0

CALIFORNIA PROPOSITION 65:

Chemical Name	CAS-No.
Methyl Isobutyl Ketone	108-10-1
Ethylbenzene	100-41-4
Titanium Dioxide	13463-67-7
Ethanol	64-17-5

CALIFORNIA PROPOSITION 65 REPRODUCTIVE TOXINS

Chemical Name	CAS-No.
Ethanol	64-17-5

International Regulations:

CANADIAN WHMIS:

This SDS has been prepared in compliance with Controlled Product Regulations except for the use of the 16 headings.

16. Other Information

HMIS RATINGS

Health:	2*	**Flammability:**	4	**Physical Hazard:**	0	**Personal Protection:**	X

CANADIAN WHMIS CLASS: AB5 D2A

NFPA RATINGS

Health:	2	**Flammability:**	4	**Instability**	0

VOLATILE ORGANIC COMPOUNDS, g/L: 656

MSDS REVISION DATE: 4/21/2015

REASON FOR REVISION: No Information

Legend: N.A. - Not Applicable, N.E. - Not Established, N.D. - Not Determined

Text for GHS Hazard Statements shown in Section 3 describing each ingredient:

H225	Highly flammable liquid and vapour.
H310	Fatal in contact with skin.
H319	Causes serious eye irritation.
H331	Toxic if inhaled.
H332	Harmful if inhaled.
H335	May cause respiratory irritation.
H336	May cause drowsiness or dizziness.
H340	May cause genetic defects <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
H350	May cause cancer <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.

Icons for GHS Pictograms shown in Section 3 describing each ingredient:

GHS02 

GHS06 

GHS07 

GHS08 

Rust-Oleum Corporation believes, to the best of its knowledge, information and belief, the information contained herein to be accurate and reliable as of the date of this safety data sheet. However, because the conditions of handling, use, and storage of these materials are beyond our control, we assume no responsibility or liability for personal injury or property damage incurred by the use of these materials. Rust-Oleum Corporation makes no warranty, expressed or implied, regarding the accuracy or reliability of the data or results obtained from their use. All materials may present unknown hazards and should be used with caution. The information and recommendations in this material safety data sheet are offered for the users' consideration and examination. It is the responsibility of the user to determine the final suitability of this information and to comply with all applicable international, federal, state, and local laws and regulations.

C.6 Black Powder

OWEN COMPLIANCE SERVICES, INC.

Material Safety Data Sheet
(MSDS-BP)

PRODUCT IDENTIFICATION	
Product Name	BLACK POWDER
Trade Names and Synonyms	N/A
Manufacturer/Distributor	GOEX, Inc. (Doyline, LA) & various international sources
Transportation Emergency	**800-255-3924 (24 hrs — *CHEM • TEL*)**

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

The prevention of accidents in the use of explosives is a result of careful planning and observance of the best known practices. The explosives user must remember that he is dealing with a powerful force and that various devices and methods have been developed to assist him in directing this force. He should realize that this force, if misdirected, may either kill or injure both him and his fellow workers.

WARNING

All explosives are dangerous and must be carefully handled and used following approved safety procedures either by or under the direction of competent, experienced persons in accordance with all applicable federal, state, and local laws, regulations, or ordinances. If you have any questions or doubts as to how to use any explosive product, **DO NOT USE IT** before consulting with your supervisor, or the manufacturer, if you do not have a supervisor. If your supervisor has any questions or doubts, he should consult the manufacturer before use.

HAZARDOUS COMPONENTS				
Material or Component	**%**	**CAS No.**	**TLV**	**PEL**
Potassium nitrate[1]	70-76	007757-79-1	NE	NE
Sodium nitrate[1]	70-74	007631-99-4	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite[2]	Trace	007782-42-5	15 mppct (TWA)	2.5 mg/m^3
N/A = Not assigned NE = Not established				

[1] Black Powder contains either potassium nitrate ***or*** sodium nitrate in the percentages indicated. Black powder ***does not contain both.***

[2] Not contained in all grades of black powder.

PHYSICAL DATA	
Boiling Point	N/A
Vapor Pressure	N/A
Vapor Density	N/A
Solubility in Water	Good
Specific Gravity	1.70 - 1.82 (mercury method) • 1.92 - 2.08 (pycnometer)
PH	6.0 - 8.0
Evaporation Rate	N/A
Appearance and Odor	Black granular powder. No odor detectable.

HAZARDOUS REACTIVITY	
Instability	Keep away from heat, sparks, and open flame. Avoid impact, friction, and static electricity.
Incompatibility	When dry, black powder is compatible with most metals; however, it is hygroscopic, and when wet, attracts all common metals except stainless steel. Black powder must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials, and other similar materials, situations, and equipment.
Hazardous decomposition	Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.
Polymerization	Polymerization will not occur.

FIRE AND EXPLOSION DATA	
Flashpoint	Not applicable
Auto ignition temperature	Approx. 464°C (867°F)
Explosive temperature (5 sec)	Ignites @ approx. 427°C (801°F)
Extinguishing media	Water
Special fire fighting procedures	**ALL EXPLOSIVES: DO NOT FIGHT EXPLOSIVES FIRES.** Try to keep fire from reaching explosives. Isolate area. Guard against intruders. Division 1.1 Explosives (heavily encased): Evacuate the area for 5000 feet (1 mile) if explosives are heavily encased. Division 1.1 Explosives (not heavily encased): Evacuate the area for 2500 feet (½ mile) if explosives are not heavily encased. Division 1.1 Explosives (all): Consult the *2000 Emergency Response Guidebook, Guide 112* for further details.
Unusual fire and explosion hazards	Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

HEALTH HAZARDS	
General	Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state, and local laws, regulations, and ordinances.
Carcinogenicity	None of the components of Black powder are listed as a carcinogen by NTP, IARC, or OSHA.

FIRST AID	
Inhalation	*Not a likely route of exposure.* If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention.
Eye and skin contact	*Not a likely route of exposure.* Flush eyes with water. Wash skin with soap and water.
Ingestion	*Not a likely route of exposure.*. If ingested, induce vomiting immediately by giving two glasses of water and sticking finger down throat.
Injury from detonation	Seek prompt medical attention.

SPILL OR LEAK PROCEDURES	
Spill/leak response	Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in cleanup procedures. Carefully pick up spills with non-sparking and non-static producing tools.
Waste disposal	Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with federal regulations under the authority of the *Resource Conservation and Recovery Act* (40 CFR Parts 260-271).

SPECIAL PROTECTION INFORMATION	
Ventilation	Use only with adequate ventilation.
Respiratory	None
Eye	None
Gloves	Impervious rubber gloves.
Other	Metal-free *and* non-static producing clothes

SPECIAL PRECAUTIONS

- Keep away from friction, impact, and heat. Do not consume food, drink, or tobacco in areas where they may become contaminated with these materials.
- Contaminated equipment must be thoroughly water cleaned before attempting repairs.
- Use only non-spark producing tools.
- No smoking.

STORAGE CONDITIONS
Store in a cool, dry place in accordance with the requirements of *Subpart K, ATF: Explosives Law and Regulations* (27 CFR 55.201-55.219).

SHIPPING INFORMATION		
Proper shipping name	Black powder	
Hazard class	1.1D	
UN Number	UN0027	
DOT Label & Placard	DOT Label	EXPLOSIVE 1.1D
	DOT Placard	EXPLOSIVES 1.1
Alternate shipping information	Limited quantities of black powder may be transported as "Black powder for small arms", NA0027, class 4.1 pursuant to U.S. Department of Transportation authorization EX-8712212.	

The information contained in this Material Safety Data Sheet is based upon available data and believed to be correct; however, as such has been obtained from various sources, including the manufacturer and independent laboratories, it is given without warranty or representation that it is complete, accurate, and can be relied upon. OWEN COMPLIANCE SERVICES, INC. has not attempted to conceal in any manner the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, OWEN COMPLIANCE SERVICES, INC. cannot anticipate nor control the many situations in which the product or this information may be used; there is no guarantee that the health and safety precautions suggested will be proper under all conditions. It is the sole responsibility of each user of the product to determine and comply with the requirements of all applicable laws and regulations regarding its use. This information is given solely for the purposes of safety to persons and property. Any other use of this information is expressly prohibited.

For further information contact: David W. Boston, President
OWEN COMPLIANCE SERVICES, INC.
12001 County Road 1000
P.O. Box 765
Godley, TX 76044
Telephone number: 817-551-0660
FAX number: 817-396-4584

MSDS prepared by: David W. Boston
Original publication date: 12/08/93
Revision date: 12/12/05
12/03/03

Appendix D - Hazardous Material Operating Procedures

Igniter:

- ❏ Store in cool, dry place away from heat or flame. An explosives box is the preferred method of storage.
- ❏ Avoid extensive contact with skin; do not ingest or rub in eyes.
- ❏ Wear Personal Protective Equipment (PPE) when handling, including safety glasses and lab gloves. Also be sure to wear clothing safe for pyrotechnics.
- ❏ Do not rub or abruptly hit as friction or impact can cause ignition.
- ❏ Dispose of spent materials and packaging in inert trash.

Rocket Motor:

- ❏ Store in cool, dry place away from heat or flame. Explosives box is required.
- ❏ Do not handle directly. The team's NAR mentor will handle the purchase and transport of all motors.
- ❏ Avoid contact via skin, eyes, or mouth.
- ❏ Wear safety glasses and pyrotechnic safe clothing at all times when near the motor in case of unexpected ignition.
- ❏ Do not rub or abruptly hit as friction or impact can cause ignition.
- ❏ Dispose of spent materials and packaging in inert trash.

Fiberglass:

- ❏ Store and handle only in well-ventilated areas.
- ❏ Do not breathe in dust; fibers are damaging to lungs. Avoid extensive contact with skin as fibers can also cause skin irritation.
- ❏ Wear PPE when handling, including safety glasses, lab gloves, and respirator. Sleeves are also recommended.
- ❏ Dispose of spent materials in inert trash. Do not release materials into waterways.

Epoxy:

- ❏ Store in cool, dry place.
- ❏ Avoid contact with skin or eyes. Do not breathe in any vapor or fumes epoxy may produce.
- ❏ Wear PPE when handling, including safety glasses and lab gloves.
- ❏ Wash hands thoroughly after working with or handling epoxy and before eating.
- ❏ Dispose of excess epoxy and containers in inert trash.

Spray Paint:

- ❏ Keep containers tightly closed and store in cool, dry place away from sources of heat or flame.
- ❏ Store and use only in well-ventilated areas.
- ❏ Avoid breathing fumes or mist. Avoid contact with eyes and skin. Paint can stain clothing; bear this in mind when handling.
- ❏ Wear PPE when handling, including safety glasses, lab gloves, and respirator.
- ❏ Wash hands thoroughly after working with or handling paint and before eating.
- ❏ Do not allow disposal into waterways.
- ❏ Dispose of excess paint and containers in inert trash.

Black Powder:

- ❏ Store only in cool, dry place away from sources of heat or flame. Explosives box storage required.
- ❏ Wear PPE when handling, including safety glasses and lab gloves. Avoid ingestion or contact with skin or eyes.
- ❏ Do not rub or hit as friction or impact can cause ignition.
- ❏ Dispose of excess or spent powder in inert trash.

Appendix E - Weighted Ratings Tables

Weighted Rating of Flight Controller							
		Raspberry Pi 2		**Arduino Uno**		**Beagleboard**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
USB Ports	17	5	0.85	1	0.17	1	0.17
RAM	17	5	0.85	1	0.17	2	0.34
GPU	20	5	1	1	0.2	3	0.6
Power Consumption	12	2	0.24	5	0.6	5	0.6
Size	12	4	0.48	5	0.6	4	0.48
Weight	12	4	0.48	5	0.6	4	0.48
Cost	10	4	0.4	5	0.5	1	0.1
Total	100	NA	4.3	NA	2.84	NA	2.77

Weighted Rating of Camera							
		Pixy CMUcam5		**5MP Camera Module**		**NoIR Camera Module**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Resolution	10	3	0.3	5	0.5	5	0.5
Size	30	5	1.5	5	1.5	5	1.5
Interface Options	20	5	1	2	0.4	2	0.4
Processing Speed	20	5	1	3	0.6	3	0.6
Weight	10	2	0.2	5	0.5	5	0.5
Cost (total)	10	2	0.2	5	0.5	4	0.4
Total	100	NA	4.2	NA	4	NA	3.9

Weighted Rating of GPS					
		Adafruit Ultimate GPS Breakout		**GlobalSat BU-353 S4 GPS**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Sensitivity	10	5	0.5	4	0.4
Position Accuracy	15	4	0.6	5	0.75
Velocity Accuracy	15	4	0.6	4	0.6
Reacquisition rate	16	4	0.64	4	0.64
Size	16	4	0.64	3	0.48
Weight	16	5	0.8	2	0.32
Cost (total)	12	3	0.36	2	0.24
Total	100	NA	4.14	NA	3.43

Weighted Rating of Communications Device					
		XBee Pro 900		**XBee Pro 60mW**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Range	40	5	2	1	0.4
Data rate	20	4	0.8	5	1
Power Consumption	15	4	0.6	4	0.6
Size	15	4	0.6	5	0.75
Cost (total)	10	3	0.3	4	0.4
Total	100	NA	4.3	NA	3.15

Weighted Rating of Orientation Device					
		MinIMU-9 v3		**AltIMU-10 v4**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Gyro Accuracy	22	4	0.88	4	0.88
Accelerometer Accuracy	22	4	0.88	4	0.88
Magnetometer Accuracy	20	4	0.8	4	0.8
Barometer Accuracy	22	1	0.22	4	0.88
Cost (total)	14	4	0.56	3	0.42
Total	100	NA	3.34	NA	3.86

Weighted Rating of Storage Device							
		Samsung 250 GB SSD		**Transcend 256 GB SSD**		**SanDisk 240 GB SSD**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Storage Capacity	30	4	1.2	4	1.2	3	0.9
Size	30	4	1.2	3	0.9	2	0.6
Weight	25	4	1	3	0.75	2	0.5
Cost (total)	15	3	0.45	4	0.6	3	0.45
Total	100	NA	3.85	NA	3.45	NA	2.45

Weighted Rating of Solenoid							
		Lock-style		**Large push-pull**		**Small push-pull**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Force	30	1	0.3	5	1.5	2	0.6
Voltage	25	4	1	2	0.5	2	0.5
Size	15	3	0.45	4	0.6	5	0.75
Weight	20	3	0.6	3	0.6	5	1
Cost	10	4	0.4	4	0.4	5	0.5
Total	100	NA	2.75	NA	3.6	NA	3.35

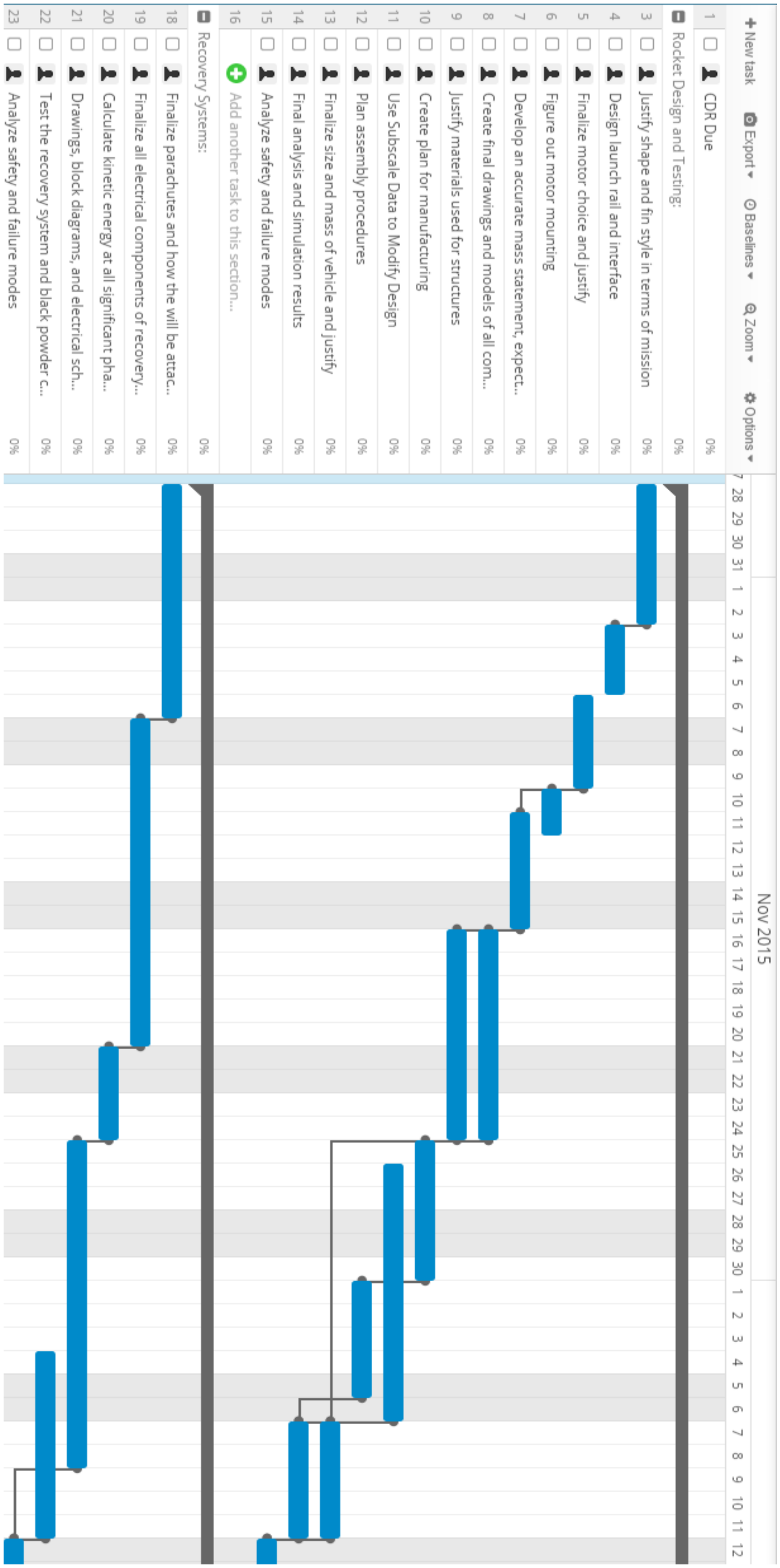
Weighted Rating of Battery System							
		2 6V Lantern Batteries (26000mAh)		USB Battery Pack for Raspberry Pi (3300mAh) & 4s LiPo battery (6000mAh)		USB Battery Pack for Raspberry Pi (4400mAh) & 4s LiPo battery (5000mAh)	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Overall Storage Capacity	25	5	1.25	3	0.75	3	0.75
Size	25	1	0.25	4	1	5	1.25
Weight	25	2	0.5	3	0.75	4	1
Rechargeability	20	1	0.2	5	1	5	1
Cost	5	5	0.25	2	0.1	3	0.15
Total	100	NA	2.45	NA	3.6	NA	4.15

Weighted Rating of Servo Motors							
		HS-645MG Ultra Torque		Power HD AR-1201MG Robot Servo		Continuous Rotation Servo - FeeTech FS5103R	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Stall Torque	15	3	0.45	5	0.75	1	0.15
Operating Voltage	10	4	0.4	4	0.4	4	0.4
Operating Speed	15	4	0.6	4	0.6	3	0.45
Rotation Angle	25	5	1.25	2	0.5	5	1.25
Size	15	4	0.6	4	0.6	2	0.3
Weight	15	3	0.45	3	0.45	5	0.75
Cost (total)	5	1	0.05	5	0.25	4	0.2
Total	100	NA	3.8	NA	3.55	NA	3.5

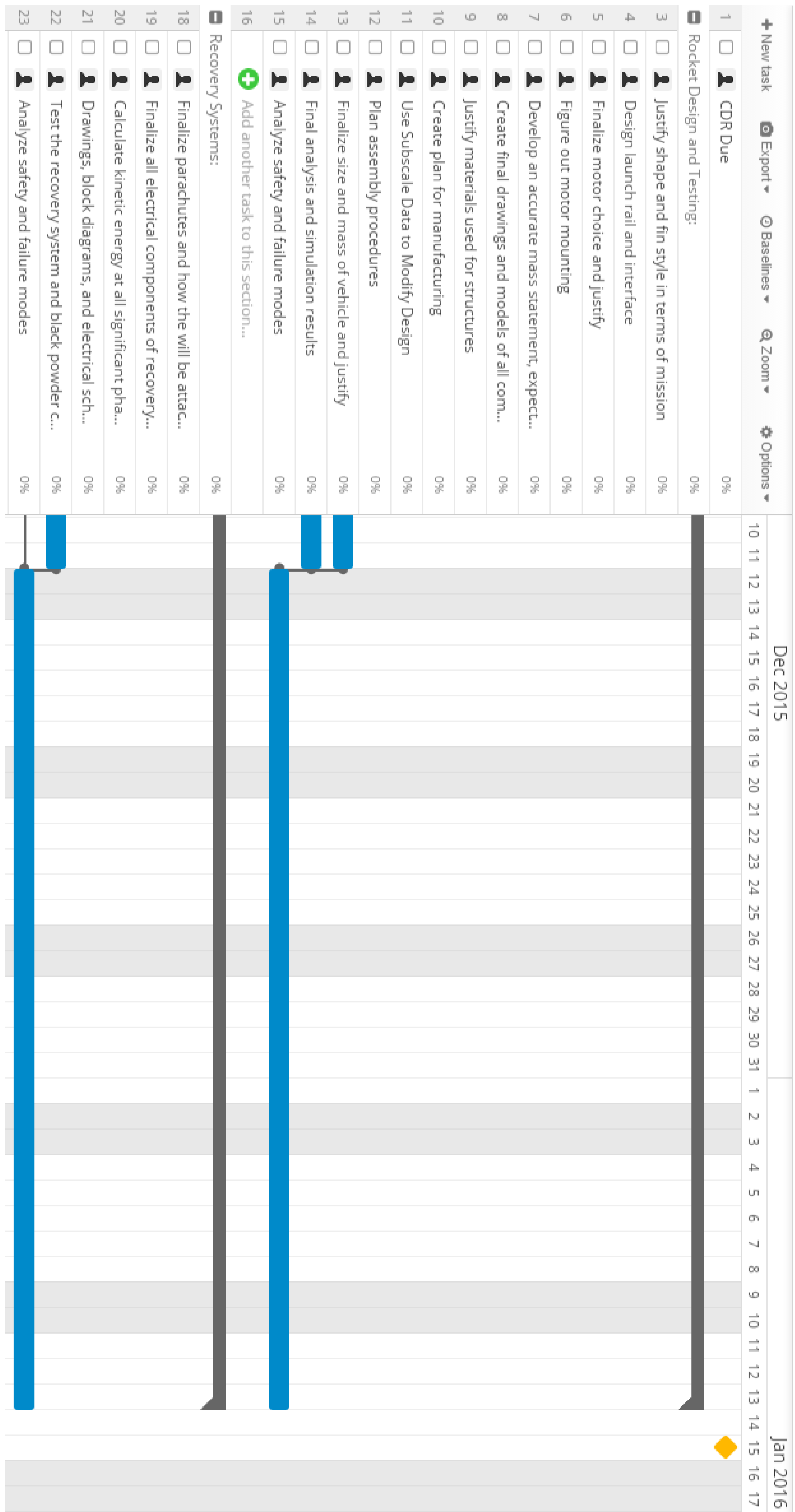
Weighted Rating of Payload Control System							
		Parafoil		**Traditional Parachute**		**Deployable Glider Wings**	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Reliable Deployment	25	5	1.25	5	1.25	1	0.25
Control	25	5	1.25	1	0.25	4	1
Descent Speed	25	4	1	5	1.25	2	0.5
Weight	15	5	0.75	5	0.75	2	0.3
Cost (total)	10	4	0.4	5	0.5	2	0.2
Total	100	NA	4.65	NA	4	NA	2.25

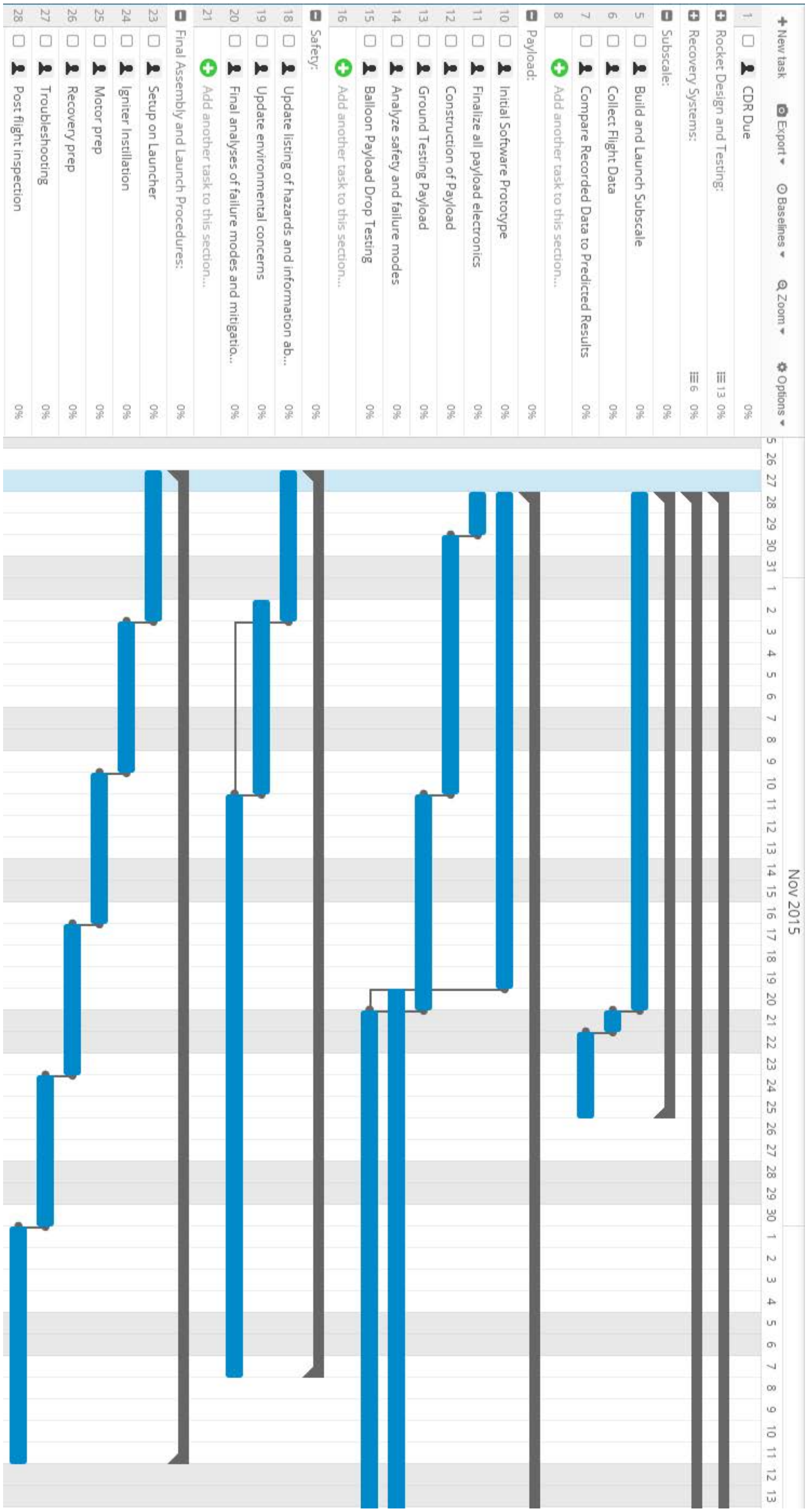
Appendix F - Expanded Gantt Chart

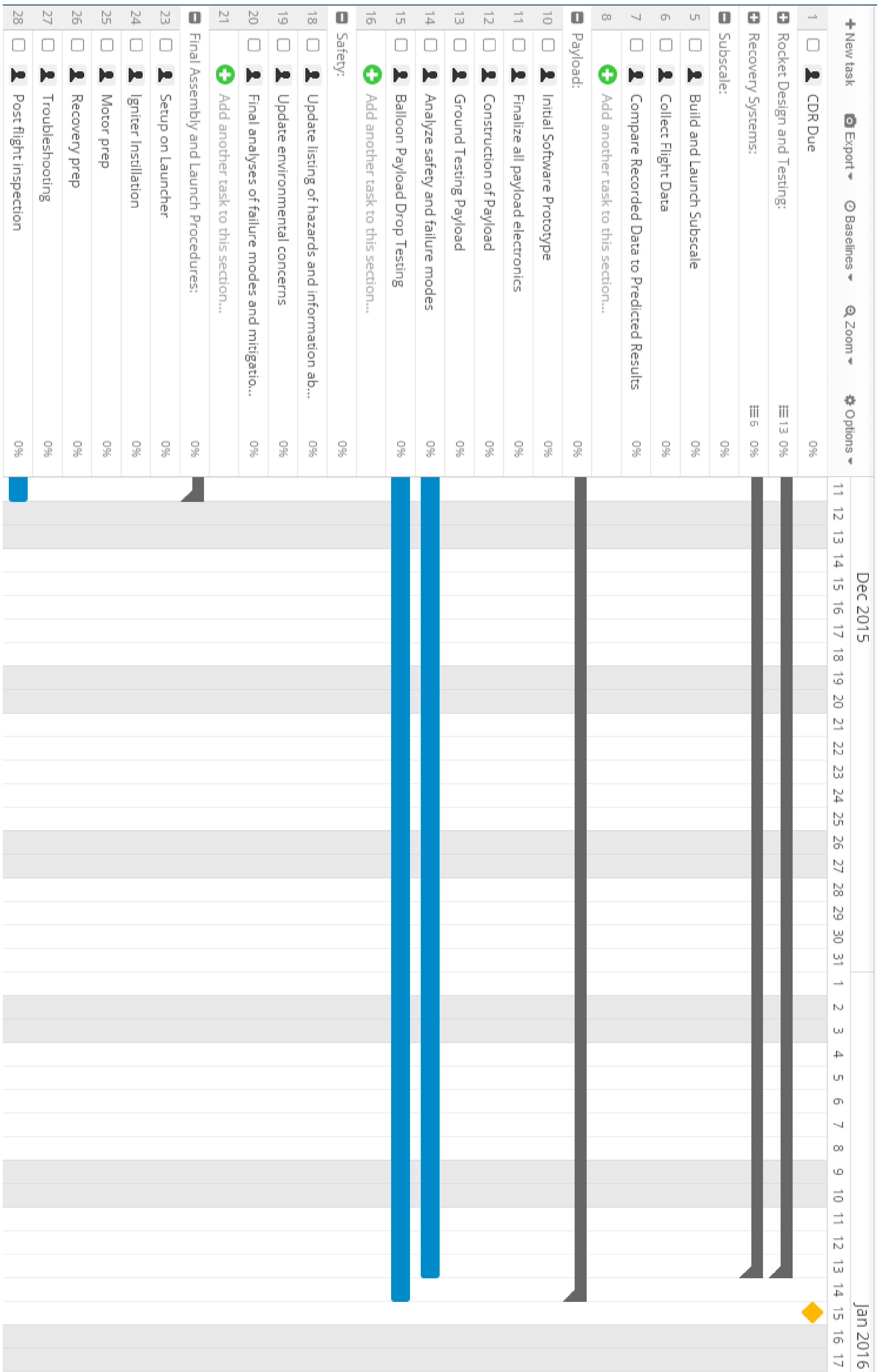
All gantt charts were generated using the Instagantt app. Each system has two images, one for the time until winter break begins at the University of Alabama and another spanning winter break until the CDR submission deadline, January 15th. The chart will be found on the following pages.



New task
Export
Baselines
Zoom
Options
Nov 2015
1 CDR Due 0%
Rocket Design and Testing: 0%
3 Justify shape and fin style in terms of mission 0%
4 Design launch rail and interface 0%
5 Finalize motor choice and justify 0%
6 Figure out motor mounting 0%
7 Develop an accurate mass statement, expect... 0%
8 Create final drawings and models of all com... 0%
9 Justify materials used for structures 0%
10 Create plan for manufacturing 0%
11 Use Subscale Data to Modify Design 0%
12 Plan assembly procedures 0%
13 Finalize size and mass of vehicle and justify 0%
14 Final analysis and simulation results 0%
15 Analyze safety and failure modes 0%
16 Add another task to this section...
Recovery Systems: 0%
18 Finalize parachutes and how the will be attac... 0%
19 Finalize all electrical components of recovery... 0%
20 Calculate kinetic energy at all significant pha... 0%
21 Drawings, block diagrams, and electrical sch... 0%
22 Test the recovery system and black powder c... 0%
23 Analyze safety and failure modes 0%


New task
Export
Baselines
Zoom
Options
Dec 2015
Jan 2016
1 CDR Due 0%
Rocket Design and Testing: 0%
3 Justify shape and fin style in terms of mission 0%
4 Design launch rail and interface 0%
5 Finalize motor choice and justify 0%
6 Figure out motor mounting 0%
7 Develop an accurate mass statement, expect... 0%
8 Create final drawings and models of all com... 0%
9 Justify materials used for structures 0%
10 Create plan for manufacturing 0%
11 Use Subscale Data to Modify Design 0%
12 Plan assembly procedures 0%
13 Finalize size and mass of vehicle and justify 0%
14 Final analysis and simulation results 0%
15 Analyze safety and failure modes 0%
16 Add another task to this section...
Recovery Systems: 0%
18 Finalize parachutes and how the will be attac... 0%
19 Finalize all electrical components of recovery... 0%
20 Calculate kinetic energy at all significant pha... 0%
21 Drawings, block diagrams, and electrical sch... 0%
22 Test the recovery system and black powder c... 0%
23 Analyze safety and failure modes 0%


+ New task
Export
Baselines
Zoom
Options
1 CDR Due 0%
Rocket Design and Testing: 13 0%
Recovery Systems: 6 0%
Subscale: 0%
5 Build and Launch Subscale 0%
6 Collect Flight Data 0%
7 Compare Recorded Data to Predicted Results 0%
8 Add another task to this section...
Payload: 0%
10 Initial Software Prototype 0%
11 Finalize all payload electronics 0%
12 Construction of Payload 0%
13 Ground Testing Payload 0%
14 Analyze safety and failure modes 0%
15 Balloon Payload Drop Testing 0%
16 Add another task to this section...
Safety: 0%
18 Update listing of hazards and information ab... 0%
19 Update environmental concerns 0%
20 Final analyses of failure modes and mitigatio... 0%
21 Add another task to this section...
Final Assembly and Launch Procedures: 0%
23 Setup on Launcher 0%
24 Igniter Instillation 0%
25 Motor prep 0%
26 Recovery prep 0%
27 Troubleshooting 0%
28 Post flight inspection 0%
Nov 2015


+ New task
Export
Baselines
Zoom
Options
Dec 2015
Jan 2016
1 CDR Due 0%
Rocket Design and Testing: 13 0%
Recovery Systems: 6 0%
Subscale: 0%
5 Build and Launch Subscale 0%
6 Collect Flight Data 0%
7 Compare Recorded Data to Predicted Results 0%
8 Add another task to this section...
Payload: 0%
10 Initial Software Prototype 0%
11 Finalize all payload electronics 0%
12 Construction of Payload 0%
13 Ground Testing Payload 0%
14 Analyze safety and failure modes 0%
15 Balloon Payload Drop Testing 0%
16 Add another task to this section...
Safety: 0%
18 Update listing of hazards and information ab... 0%
19 Update environmental concerns 0%
20 Final analyses of failure modes and mitigatio... 0%
21 Add another task to this section...
Final Assembly and Launch Procedures: 0%
23 Setup on Launcher 0%
24 Igniter Instillation 0%
25 Motor prep 0%
26 Recovery prep 0%
27 Troubleshooting 0%
28 Post flight inspection 0%