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Eclipse-I Preliminary Design Review

NASA University Student Launch Initiative Proposal (2012 – 2013)

Submitted to

NASA Marshall Space Flight Center

By

University of California, Davis—SpaceED_Rockets Team

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1 SUMMARY OF PDR REPORT

1.1 *Team Summary*

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Reusable Rocket Vehicle Proposed: Eclipse-I

Team Faculty Advisor: Dr. Nesrin Sarigul-Klijn

Launch Assistance/Mentor: Steve Kendall (NAR 73704 L3 & TRA 10478 L3)

LUNAR #600
AeroPAC #445

1.2 *Launch Vehicle Summary*

The launch vehicle is designed to carry a payload, recovery system, and an air-brake system. The overall dimension of the launch vehicle evolved through a few iterations to accommodate both the airbrake system and the motor. The following table indicates the updated specification of the launch vehicle:

Table 1-1 Eclipse-I rocket specifications

Length	77.88”
Diameter	6”
Nose Cone	Elliptical at 9.25” long
Avionic/Recovery Bay	9”
Payload Bay	12”
Forward Airframe	16”
Booster/Payload Airframe	48”
Motor	Animal Motor Works L777WW-0
Total Mass	31.71 lb.

The air-brake system is designed to be deployed when the onboard avionics anticipate that the launch vehicle is approaching the target altitude too rapidly. At the apogee, the drogue parachute deploys, separating the nose cone and the forward airframe. At about 800 ft altitude, onboard avionics will deploy the main parachute, separating the forward airframe from the booster airframe.

1.3 Payload Summary

Since the team did not receive funding from NASA to continue the SMD option 3 payload, the team has selected a modified version of the SMD payload. The modified payload follows the basic requirements defined by NASA, with the exception of the following components: Eclipse-I will not measure ultraviolet radiation. The solar irradiance pressure, temperature, and relative humidity will still be measured, logged, and transmitted to a ground station.

2 CHANGES MADE SINCE PROPOSAL

2.1 ***Changes made to vehicle criteria***

The main change made to the launch vehicle is the increase in the inner diameter from 4” to 6”. Also, the airframe is sectioned into the forward airframe and the booster airframe to allow the deployment of the drogue and the main parachute. The motor selection has been changed from the CTI L1050 to the AMW L777WW since the proposed weight of the rocket has now decreased and less power is required.

2.2 ***Changes made to payload criteria***

The GaP Photodiode and KX-1 Micro color CMOS camera will not be included in the payload, as originally proposed. However, as a replacement to the CMOS camera, a standalone live video system with a CCD camera will be added. This video system will include its own 1.2GHz transmitter and receiver.

2.3 ***Charges made to project plan***

The proposed project plan listed in the main milestones has not changed.

3 VEHICLE CRITERIA

3.1 *Selection, Design, and Verification of Launch Vehicle*

The mission of the UC Davis SpaceED Rockets Team is to design, build, test, and launch a high-powered recoverable and reusable rocket. Therefore, safety and reusability are the main design drivers. To ensure a successful mission, the team must design a rocket that meets the requirements listed in Table 3-1.

Table 3-1 Launch vehicle requirements

Launch Vehicle Requirements	Implementation	Verification
Stability of rocket	Ballast weight and appropriate fin size	RockSim & analytical calculations
Reach altitude of 5280 ft AGL	L777WW motor	RockSim and test launches
Must remain strictly under 5600 ft AGL	Air-brake system	Testing and CFD simulations
Barometric altimeter reports altitude by series of audible beeps	Featherweight Raven 3 altimeters	Testing
Recoverable and reusable	Drogue and main parachute/robust airframe	RockSim & testing
Impact energy less than 75 lbf-ft	Drogue and main parachute/main deployment altitude	RockSim & testing
Drift range less than 2500 ft in a 15 mph wind	Drogue and main parachute/main deployment altitude	RockSim & testing
Solid motor	L777WW motor	Inspection
Maximum impulse remains under 5120 Ns.	L777WW motor	Inspection
No forward canards	--	Inspection
No forward firing motors	--	Inspection
No motors which expel titanium sponges	--	Inspection
No hybrid motors	--	Inspection
No cluster of motors	--	Inspection

A feasible and robust design is essential to meet these requirements. This year is the first year UCD's SpaceED Rockets team will be competing in the NASA USLI competition, so team members need to constantly inquire whether the design is feasible or not. To ensure feasibility while still implementing a challenging design, the team has decided to incorporate an air-brake system into the rocket. The robustness of the design will be determined through multiple tests and evaluations that are currently planned out for the future. RockSim and other simulation software have been used to evaluate the current rocket design. As further analytical tests are performed within the team's workshop, and that of the team mentor's at LUNAR, a higher degree of robustness will be developed for Eclipse-I.

3.1.1 Overview of the Layout of the Rocket

In order to keep the overall design simple, the team decided to follow a conventional configuration of the rocket components. The arrangement of the components from the nose to the boat-tail is as follows: main parachute, altimeter/recovery system bay, drogue parachute, payload bay, motor and air-brake bay.

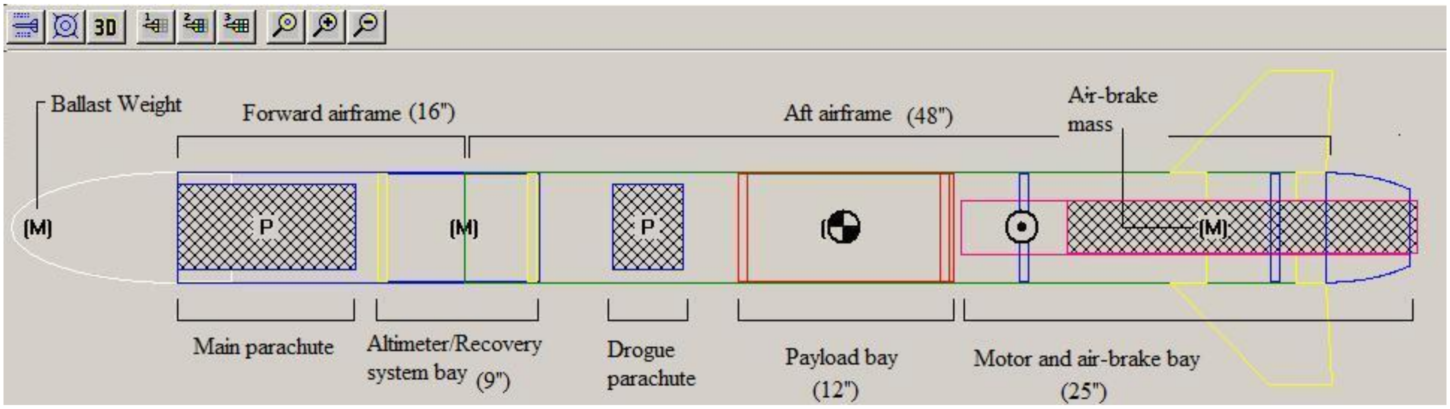

Figure 3-1 Component arrangement within the rocket

The main parachute will be housed in the forward body tube, along with the avionics/recovery system bay. The drogue parachute, payload bay, motor, and the air-brake system will be housed in the aft tube. After full deployment, three tethered sections will be hanging off of the parachutes: the nose, the forward tube, and the aft tube as shown in Figure 3-3. Originally, the team planned to have both the main and drogue parachutes housed in the forward airframe with the altimeter/recovery system bay housed in the aft airframe along with the payload bay. The deployment of the main parachute at a lower altitude after the drogue would have been made possible by using the Tender Descender device. However, the team found no major advantage in performance with this configuration. As a result, to maintain simplicity, the team decided to situate the parachute bays as indicated in Figure 3-1. In addition, with the conventional configuration, with the main chute forward and the drogue chute aft, the design will be able to maintain structure soundness upon landing. The heavier aft airframe will land first reducing the weight on the main parachute. As a consequence, the main parachute will be able to continue reducing the impact energy on the sensitive altimeter bay. The mass of each component is tabulated in Table 3-2. Impact energy analysis will be further detailed in the Mission Performance Predictions section.

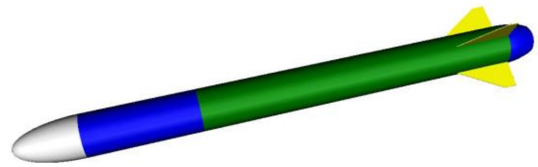

Figure 3-2 The blue section is the forward airframe and the boat-tail. The green section is the aft airframe.

Table 3-2 Mass distribution of the rocket.

Nose Cone	**3.8 lb**
Nose	1.8 lb
Ballast Weight	2.0 lb
Forward Airframe	**3.5 lb**
Airframe	0.7 lb
Main Parachute	0.4 lb
Altimeter/Recovery System Bay	2.4 lb
Aft Airframe	**14.75 lb**
Airframe	2.2 lb
Drogue Parachute	0.05 lb
Payload Bay	5.5 lb
Motor Bay	1.6 lb
Airbrake System	3.8 lb
Fins	1.1 lb
Boat-tail	0.5 lb
Total Mass without Motor	**22.05 lb**

The mass estimation is based on the RockSim model. A few assumptions were made in the process of estimating the mass of each component. First and foremost, the physical properties of Magnaframe are assumed to be identical to the kraft phenolic. This assumption was valid since Magnaframe is a phenolic material. Secondly, the thickness of some components was reasonably assumed since such data of the components were not available. Lastly, the weight of the recovery electronics was overestimated. As a result, the actual weight of the rocket could vary ± 3 lb from the simulated weight. With this tolerance, the smallest thrust-to-weight ratio is 5.2, which is still safe for the rocket. The largest weight that the rocket can get before reaching the minimum thrust-to-weight of 5 is 34.8 lb (3.1 lb increase). If the team anticipates a 25-33% increase in weight between the PDR and the delivery of the final product, the motor of choice could be too weak for the thrust-to-weight ratio. Further analysis will be conducted to decide whether or not to oversize our motor selection.

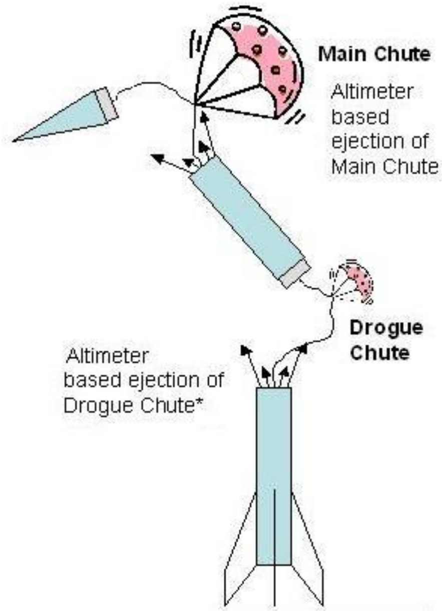

Figure 3-3 Dual deployment with drogue parachute in the mid body and the main parachute near the nose.

3.1.2 Structure Integrity

The final selection for Eclipse's airframe tube is the Giant Leap Rocketry's Magnaframe tube. The Magnaframe tube composes of a light, thin, and stiff material. Alternative tube selections included the popularly used Blue Tube, PML Phenolic tube, and Giant Leap's Dynawind. PML Phenolic was ruled out immediately since it had the lowest strength to weight ratio. Dynawind was also eliminated from the selections because it is the same as the Magnaframe tube reinforced with glass fiber; the team did not think that the additional reinforcement was necessary. Compared to the other tubes, Magnaframe is the strongest with a higher peak stress. Although Magnaframe has a lower peak load, it can

Figure 3-4 Giant Leap Rocketry's Magnaframe tubes

be used up to the peak load value, unlike Blue Tube that can only be used up to half of its peak load. One disadvantage of the Magnaframe is that the tube requires special machining due to its stiffness. Blue Tube and Magnaframe properties were compared, as seen in Table 3-3.

Table 3-3 Magnaframe compared to Blue Tube

Properties	Blue Tube	Magnaframe
ID	3.002 in	3.004 in
OD	3.128 in	3.096 in
Area	0.60662 in^2	0.43757 in^2
Modulus	574.1 ksi	823.7 ksi
Peak Load	3052.6 lb_f	2226.5 lb_f
Peak Stress	5032.1 psi	5114.0 psi

All additional components, including fins and the nosecone, will be made with fiberglass. Carbon fiber will not be used in order to prevent signal interference.

3.1.3 Motor Selection

After careful comparison of potential motors, the team has selected the Animal Motor Works L777 to carry the rocket to one mile AGL ± 320 ft. The motor was chosen to meet the minimum thrust-to-weight of 5 and maximum impulse of 5120 N-s as set by USLI. Since most L-class motors are under 5120 N-s, the requirement is not an important constraint. The main driver for our motor selection is to reach target altitude. The motor is sized to overshoot the target altitude to adjust to unforeseen atmospheric conditions. The table below shows the overshoot for five motors

Table 3-4 Potential motor for the propulsion system

Manufacturer	Motor	Overshoot (ft)
Animal Motor Works	L1080BB	1306
Cesaroni	L890SS	1104
Animal Motor Works	L1060GG	970
Animal Motor Works	L900RR	553
Animal Motor Works	L777WW	163

The final selection is the AMW L777WW; the overshoot predicted from RockSim is about 163 ft. Such an overshoot should compensate for unforeseen atmospheric conditions that could slow down the rocket. In case of favorable atmospheric conditions, 163 ft should not be a challenge for the air-brake system to shave off. The following table lists the specification of the L777WW motor.

Table 3-5 Motor specifications

Diameter	75 mm (2.95 in.)
Length	497 mm (19.6 in.)
Propellant Mass	3.89 lb
Total Mass	8.15 lb
Average Thrust	174.1 lb
Peak Thrust	224.8 lb
Total Impulse	3136.6 N-s
Thrust Duration	4.05 s

The L777 motor fits the requirement for the preliminary design. The finalized weight of the rocket will be determined once the team purchases the materials to start building the rocket. If the actual weight of the rocket is found to be larger than the estimated weight, the AMW L900RR motor will be the team's motor of choice. In that matter, upon any deviation from the estimated weight, any of the potential motors listed in Table 3-4 could be substituted.

3.1.4 Airbrake Design

For the proposed design, the addition of airbrakes has been chosen to ensure that the rocket reaches the target 1 mile apogee as accurately as possible. To account for the possibility of gust or high winds that could cause additional drag on the rocket during a launch, the rocket's propulsive system has been overpowered. The application of airbrakes would then serve to counteract the additional propulsive power in the case that the weather conditions are ideal.

In order to prevent excessive drag, the airbrakes are designed to open against the incoming airflow. Strong, perpendicular forces acting on the air brake require a robust braking system. Due to the cost and difficulty in handling Magnaframe, the airbrakes are proposed to be made out of fiberglass as an extension the rocket's body. Unlike the Magnaframe, which requires specialized and expensive tools to size and shape it, fiberglass is easier to work with. Fiber glass will be laid onto a mold based on a nose-cone with the tip cut off. Fiberglass is also to be used under the brake panel to prevent air from rushing into the rocket body. The metal disks that direct the rods down the rocket are to be manufactured in a CNC machine while all other metal components can easily be manufactured in a machine shop.

3.1.4.1 Design Evolution

Throughout the design process for the airbrakes, several alternative designs were considered. Originally, the body frame inner diameter was only 3.9 in, leaving little room around the motor mount for a brake system to be added. One idea incorporated small spikes attached to an inner tube that slides over the motor mount as shown in Figure 3-5 Original spike airbrakes. This design would use a servo motor to twist the tube on which the spikes are attached. Initially, the spikes would be flush to the body, and as they are rotated out of the body tube, the spikes would come out in a shark tooth shape to keep air from entering the tube at any time. Although this design would be efficient for compact space, the cost of cutting the Magnaframe tube for the spikes would be too expensive and the design's complexity prompted a new design.

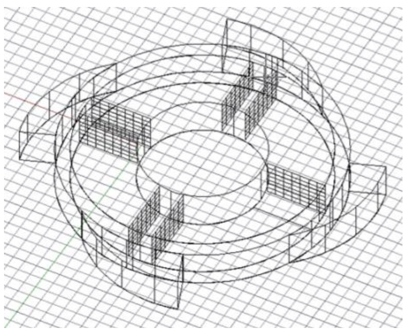

Figure 3-5 Original spike airbrakes

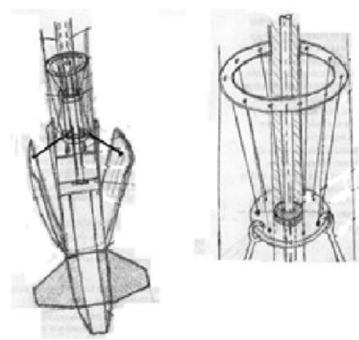

Figure 3-6 Airbrake cable system

The increased diameter of the Magnaframe tube allowed for a new mechanical airbrake system. The following design involved a suspension of wire cables from a ring attached to servo (Figure 3-6). The cables would run along the motor casing to a pushrod that opens the airbrakes. After careful consideration, it was decided that the ring is susceptible to moments caused by an imbalance in the cables as they are pulled or pushed by the servo. To reduce the number of moving parts within the system, the cables were replaced with slender vertical rods.

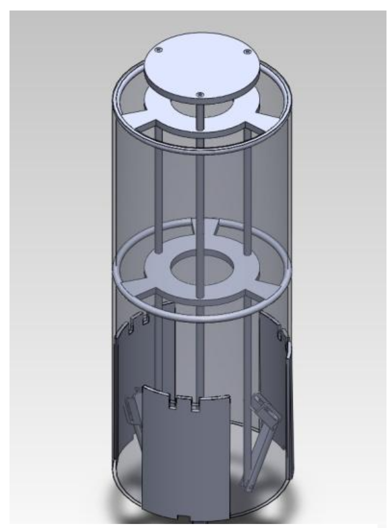

Figure 3-7 Internal structure of airbrakes, originally with only three panels to fit between the fins.

The current design consists of four panels that lie just below the Magnaframe body tube, flush to the rocket body and between the three fins. Each panel is hinged to the rocket's body so that when the airbrakes are opened, the panels are pushed out and fold upward. To ensure that all four airbrake panels open concurrently, a pneumatic piston will be used. As the rods are pulled up around the motor casing, a second rod attached at the bottom of each rod is forced to move outwards through a slit in the rocket's body where it pushes a panel. The initial angle of the elbow of the rods and the angle that the panel will open have yet to be determined; in the next iteration of this design, all dimensions will be finalized.

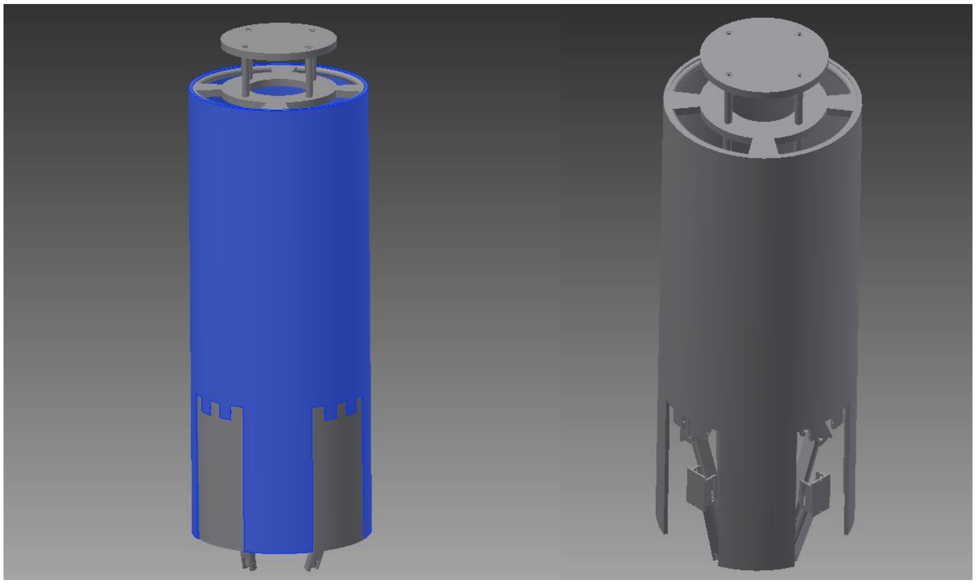

Figure 3-8 CAD drawing of the current four-panel air-brake, showing the rocket with and without the brake panels.

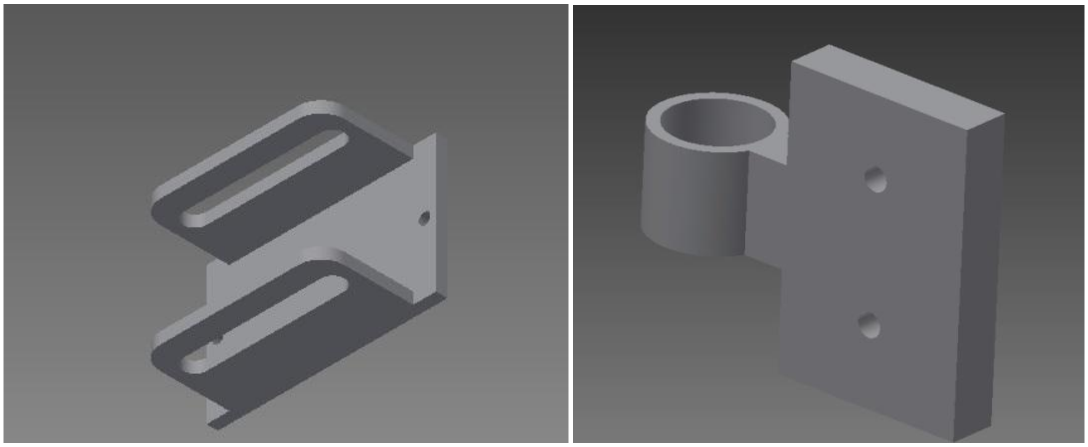

Figure 3-9 [Left] Hinge that will be screwed onto airbrake panel. As the rod pushes the panel outward, the pin through the rod will slide along the slits seen here. [Right] Hinge that connects the airbrake panel to the bottom disk in Figure 3-7.

3.1.4.2 Design Advantages

The rocket's airbrakes are designed to be simple. A simple design with few parts – and fewer mobile parts – makes the system less susceptible to malfunction and simplifies the manufacturing process. The final design is composed of only 21 parts, including all pins needed but not the compressed air chamber. System components are listed in Table 3-6 Breakdown of components of the airbrake system below.

Table 3-6 Breakdown of components of the airbrake system

Component	Quantity	Dimensions
Circular Rod	4	0.25 in OD x 0.12 in ID x 18 in L
Rectangular Rod	4	0.5 in x 0.25 in x 3 in
Pins	4	0.125 in OD x 0.5125 in L
Pins	4	0.125 in OD x 0.76 in L
Rod Mount	1	3 in diameter
Body Tube Disks	2	3 in ID x 6in OD
Panel Connector	4	1.25 in x 0.75 in x 0.5 in
Airbrake Panels	4	0.0625 in x 6.283 in x 6 in
Pneumatic System	1	TBD

The rods running along the motor mount require a lot of force in order to transfer the load through the second rod and onto the airbrake panel; therefore a servo is not the best option. Thus, a compressed air chamber is selected to be the power supply for the rocket's airbrake system. In addition, a compressed air system is more reliable than a servo joint. A servo joint has a higher probability of malfunctioning. However, a compressed air system only depends on opening a nozzle and this ensures that all panels will open simultaneously.

3.1.4.3 Prevention for Malfunctioning

Mechanical systems are often susceptible to malfunction, thus it is important to predict all possible sources of failure and to address them. For instance, if all four panels do not fold out simultaneously, the aerodynamic properties of the rocket will be affected and the rocket could stray from its trajectory. To ensure that all panels move simultaneously, it is necessary to have each of the four components of the system be identical. Having the four main rods fixed to each other helps synchronize the movement of the panels. Further calculations will derive the optimal angle between the two rods that will ensure the panel is pushed outward when the brakes are applied.

3.1.5 Verification Plan

Testing and evaluation of all the subsystems before any test launch is crucial; the main concerns are safety and validation. Each group leader is responsible for supervising the testing and evaluation of his/her respective subsystem. The safety officer and the team leader will supervise the general safety of all testing and evaluation. The verification plan includes the validation of the avionics, the motor, and the entire rocket. All testing and evaluation will be done in two locations: within university facilities and at the LUNAR sites.

All of the electronics components will be separately tested and calibrated. First, the APM 2.5 motherboard and GPS daughterboard will be programmed as a single functioning unit and then tested for accuracy via a 100 MHz oscilloscope. The output signal from the I/O pins will be checked for delay, and the GPS and the internal sensors for accuracy. For the high g-force testing, a centrifuge device is used to see how the APM 2.5 performs under high accelerations. From testing, the motherboard will be programmed and calibrated. Next, the MPXV7002 pressure sensor will be tested for accuracy. To test this unit, it will be placed under flow fields at varying velocity to resolve an error function of the gathered data. Depending on the accuracy of results received, the sensor will be calibrated using a linear program in the APM 2.5 that will execute before the data is stored. Similarly, with the AM2302 humidity and temperature sensor, tests are performed in a controlled environment to check the accuracy of the sensor and then calibrate accordingly. The controlled environment will include the use of a humidifier, or steam from boiling water, to achieve a relative humidity. Once the target humidity is reached, the AM2302 data will be compared to data from a simple digital hygrometer.

A different method is planned for testing our solar irradiance meter. The solar irradiance meter will be first built as a standalone system using an LCD display screen and a 1Hz sampling rate. The TSL230R will be calibrated under an assortment of varying intensity light covering its full spectrum from 350 nm to 1100 nm. Once the standalone system is built and displays at a minimum 90% accuracy, it will be integrated into the APM 2.5 and calibrated once again to ensure accuracy. If the amount of data from the TSL230R exceeds the processing capabilities of the APM 2.5, the sampling rate will be decreased and a floating point rounding function will be used. This will decrease the amount of input data and prevent stack overflow of the main processor. Finally, the KX191 CCD camera will be tested for functionality. The CCD camera, as opposed to a CMOS camera, takes images frame by frame so it is less prone to distortion due to vibrations within the rocket. It will be wired to its standalone transmitter system and tested for a line of sight range to see what actual distance can be expected. Similarly, the 3DR wireless transmitters will be tested in the same fashion.

Motor testing and evaluation is a critical step for safety and success of the mission. Axial and lateral forces will be measured. The sensors used for force measurements are not yet determined. Thermocouples will be mounted on the casing to measure the temperature. This temperature should be under the operating limits of the flight hardware.

3.2 Recovery Subsystem

The Eclipse rocket will utilize a dual deployment recovery system with electronically-activated ejection charges. The deployment process will consist of two stages. During stage 1, a drogue parachute is deployed at apogee (near 5,280 ft altitude). The main parachute is fully deployed at an altitude of 800 ft during stage 2. An advantage of dual deployment is that it minimizes drift by using a drogue chute that stabilizes the rocket and allows it to descend at a faster rate compared to the main chute.

The Eclipse was run through multiple RockSim simulations to determine the size of the parachutes and at what altitude the main parachute should be fully deployed. The simulations determined that, for a 15 mph wind, the Eclipse should use a 36 in. diameter drogue and an 84 in. diameter main parachute to be fully deployed by 800 ft in order to land with a kinetic energy less than 75 ft-lbf and within 2,500 ft of the launch pad.

A Featherweight Raven 3 altimeter will be used to ignite ejection charges via an electric match during each stage to initiate parachute deployment. The ejection charge fills the parachute bay with gas upon combustion, increasing the pressure and causing the bay to separate by breaking the shear pins. The Raven 3 was chosen because of its built in backup outputs for the drogue and main chute deployments as well as its ability to store flight data for analysis. A redundant altimeter will be included as a backup and programmed to fire its ejection charges shortly after the main altimeter. Both altimeters will be housed separately, with no other electronics or transmitting devices, and with their own dedicated power supplies and dedicated arming switches accessible from the exterior of the rocket airframe in the altimeter bay.

3.2.1 Attachment Scheme/Components

The main parachute bay will be located just under the nose cone. The altimeter bay coupler will be located just under the main parachute bay and directly above the drogue parachute bay. The recovery harness tethers all of the rocket components together and helps absorb the energy of the components as they separate after chute deployment. To mitigate a potential recovery harness failure, the team chose 1/4 in Kevlar for its strength and heat resistance properties. The recovery harness will be three to four times the length of the Eclipse rocket to minimize the risk of failure at attachment points. A longer recovery harness allows the rocket components more time to decelerate after separation, thus reducing the force exerted on the bulkheads and closed eyebolts. To ensure the robustness of the bulkheads and points of attachment, the recovery harness will be attached to a closed eyebolt screwed into a bulkhead, with epoxy applied to its threads, via a quick-link connector. The size of the closed eyebolt will be determined after thorough testing.

To prevent the recovery harness from tearing through the body tube in the event of a mistimed drogue deployment, the body tube opening will be moved above the payload section.

The parachute material chosen is rip-stop nylon for its proven robustness in high power rocketry. The parachutes will be protected by Nomex reusable fireproof parachute protectors to avoid the risk of damaging the parachutes from the ejection charge gases.

A global positioning system tracking device will be included in the payload bay to assist in recovery of the Eclipse-I.

3.2.2 Testing

After the preliminary rocket design is approved, the team will conduct tests to ensure the robustness of the design. Multiple ground parachute deployment tests with the altimeters will be used to determine the amount of black powder necessary for component separation. In addition, loads will be applied to points of attachment and bulkheads to ensure their strength. After necessary ground tests are completed, our recovery system on a prototype model rocket during a live flight will be tested to guarantee the altimeters are programmed and wired correctly and that the points of attachment hardware and bulkheads are strong enough to withstand the expected loads.

Table 3-7 Potential operational

Risk	Probability	Mitigation
Altimeter fails to ignite eject charge	Medium	Take care to wire altimeter bay correctly. Use fresh batteries. Add steps in pre-flight checklist to ensure we arm altimeters. Include a redundant altimeter and redundant ejection charges
Ejection charges are not powerful enough to separate rocket.	Low	Test ejection charges to determine amount of black powder needed to separate rocket and then add a little more to be sure.
Failure of recovery harness attachment points	Medium	Test attachment points under a load to ensure they're strong enough. Apply epoxy to eyebolt threads. Use closed eyebolts and quick links to ensure a strong connection.

Power supply detaches and electronics fail	Low	Use zip ties in addition to a battery holder to secure batteries to electronics board.
Ejection charge fires too early or too late, potentially deploying the recovery harness while rocket is moving too fast, causing the harness to rip through the body tube	Medium	Conduct detailed flight simulations using RockSim. Take care in sizing static ports correctly to ensure pressure inside altimeter bay is equal to ambient pressure. Ensure altimeter bay isn't placed near fins or nosecone where turbulent air can cause unequal pressure between alt. bay and ambient air. Consider adding a layer of fiberglass or Kevlar to the lip of the booster section
Drogue ejection charge separates nosecone at apogee, deploying the main chute and potentially causing our rocket to drift too far	Low	Use plastic or nylon shear pins to keep nosecone attached until main ejection charge fires. Add step in pre-flight checklist to ensure shear pins are attached.
Booster section separates during upward ascent due to drag.	Low	Use plastic or nylon shear pins to keep booster section attached until drogue ejection charge fires. Add step in pre-flight checklist to ensure shear pins are attached.
Rocket drifts too far away.	High	Conduct detailed flight simulations using RockSim to accurately size parachutes and predict drift for 15mph winds. Perform flight tests under windy conditions to ensure recovery system design works as designed

3.3 ***Mission Performance Predictions***

The mission performance and predictions of the Eclipse were simulated using RockSim v7.0. The final design of the rocket was a result of many iterations of changing design parameters such as parachute size, motor size, fin size, etc. The design drivers are as follow:

1. One mile AGL altitude
2. Drift range less than 2500 ft in 15 MPH wind condition
3. Impact energy must be less than 75 lbf-ft
4. Rocket must be stable.

Using RockSim v7.0, we are able model the rocket to the best or our ability.

The location of each component is arranged in such a way to keep the CG as forward as possible from the CP and to minimize sensitive equipment from impact damage from landing. The current component arrangement (from nose to boat-tail) is as follow: main parachute, avionics/recovery system bay, drogue parachute, payload bay and motor and air-brake system. Figure 3-10 indicates the approximate location of each component.

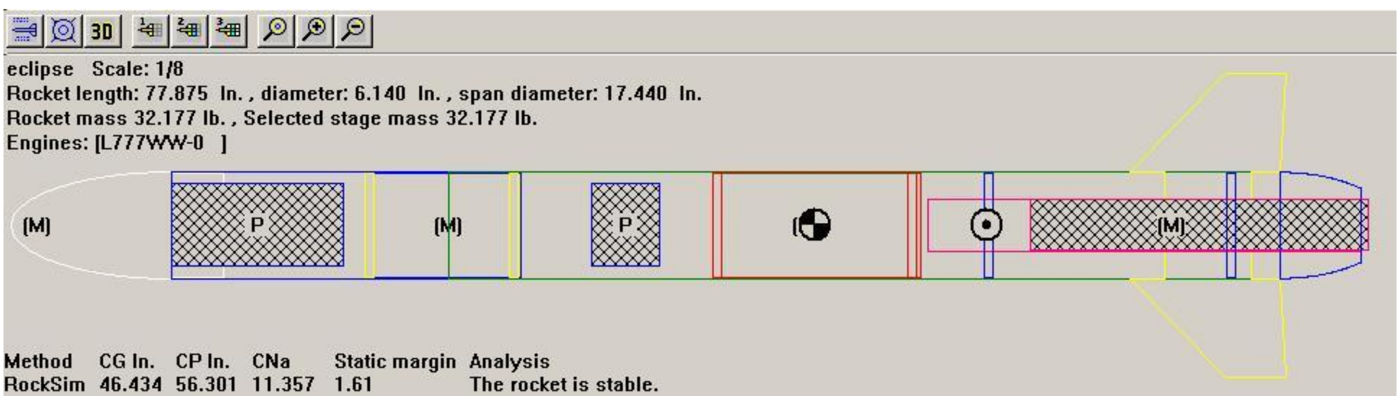

Figure 3-10 RockSim model of the rocket. The CG is approximately 46.4" from the nose and the CP is approximately 56.3" from the nose. As a result, the static margin is approximately 1.6 caliber with the motor loaded.

The tube coupler between the two yellow bulkheads is the avionics/recovery system bay, with length at 9 in. The tube coupler between the two red bulkheads is the payload bay, with length at approximately 1 ft. The mass element in the nose cone represents a 2 lb ballast weight to bring the CG of the rocket forward. The mass element at the motor bay represents the weight of the airbrake system at about 4 lb. With this configuration, the simulated CG is about 46.4 in away from the nose and the CP is about 56.3 in from the nose cone giving a static margin of about 1.6.

With the AMW L777WW motor loaded, the rocket is able to reach an altitude of 5443 ft. To get to exactly one mile, the airbrake system will be used. The following figure shows the change in altitude against time during the different stages of the flight.

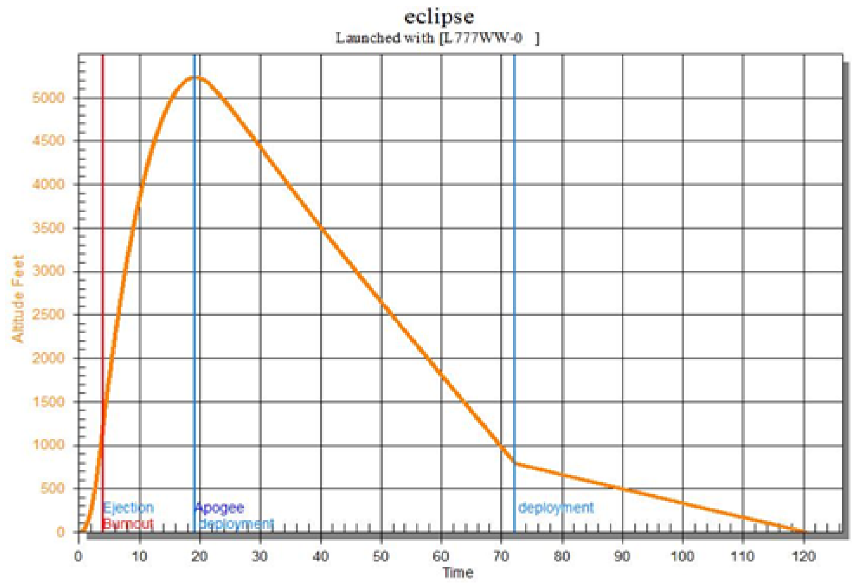

Figure 3-11 Altitude simulation results using RockSim

The max altitude decreases and drift range increases with an increase in the wind speed. Figure 3-12 LEFT: profile is under perfect no wind conditions. RIGHT: profile is under a 15 MPH wind condition. shows two different flight profiles under two different wind conditions. The calculated drift for various wind speeds is presented in Table 3-8.

Table 3-8 Drift range against various wind speed

Wind Speed (MPH)	Range (ft)
5	512
10	822
15	2207
20	3187

Figure 3-12 LEFT: profile is under perfect no wind conditions. RIGHT: profile is under a 15 MPH wind condition.

Under a 15 mph wind, the drift range is about 2200 ft, which meets the drift cylinder of 2500 ft as set by the SLP criteria.

In the Figure 3-13 Velocity profile of the rocket during the entire flight, velocity is compared over time. The maximum velocity of the rocket during flight is roughly 603 ft/s, which occurs at the instance of burnout. The velocity at apogee is zero, as expected. At apogee, the drogue parachute is deployed such that the rocket begins to free fall until it reaches a terminal velocity of nearly 74 ft/s. At an altitude of about 800 ft, the main parachute is deployed to further slow down the rocket to a safe impact speed. With the current design, the impact speed of the rocket is estimated to be 17.12 ft/s. When the rocket lands at this speed, the impact energy of the heavier section (the aft body tube) will be about 67 lbf-ft, which is less than 75 lbf-ft, as required by the SLP criteria.

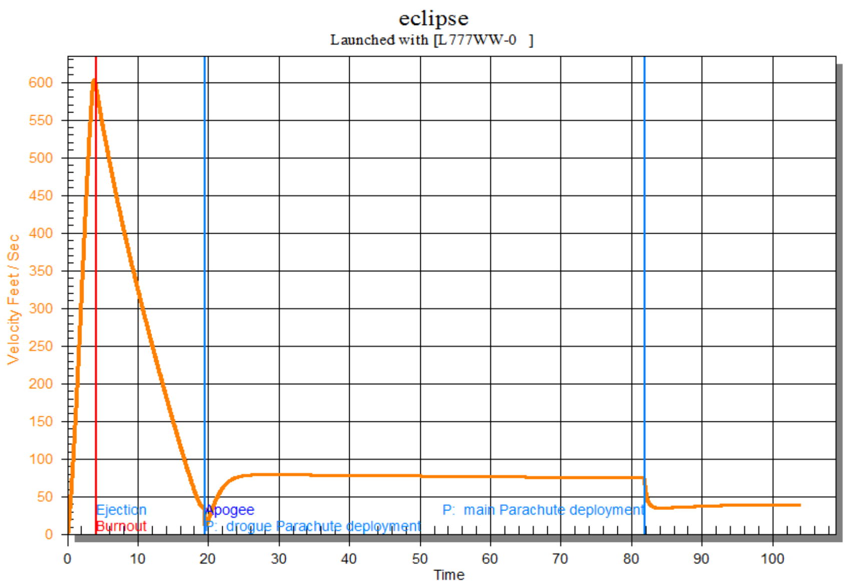

Figure 3-13 Velocity profile of the rocket during the entire flight

Furthermore, the maximum acceleration that the rocket will experience is about 8 G. The airframe, Magnaframe, is capable of handling such loading. However, the avionics might not be able to function in such loading. The team will further investigate this design aspect. Nevertheless, the avionics do not need to be fully functional at the time when the rocket is pulling 8 G. Figure 3-14 below shows the acceleration against the total flight time of the rocket.

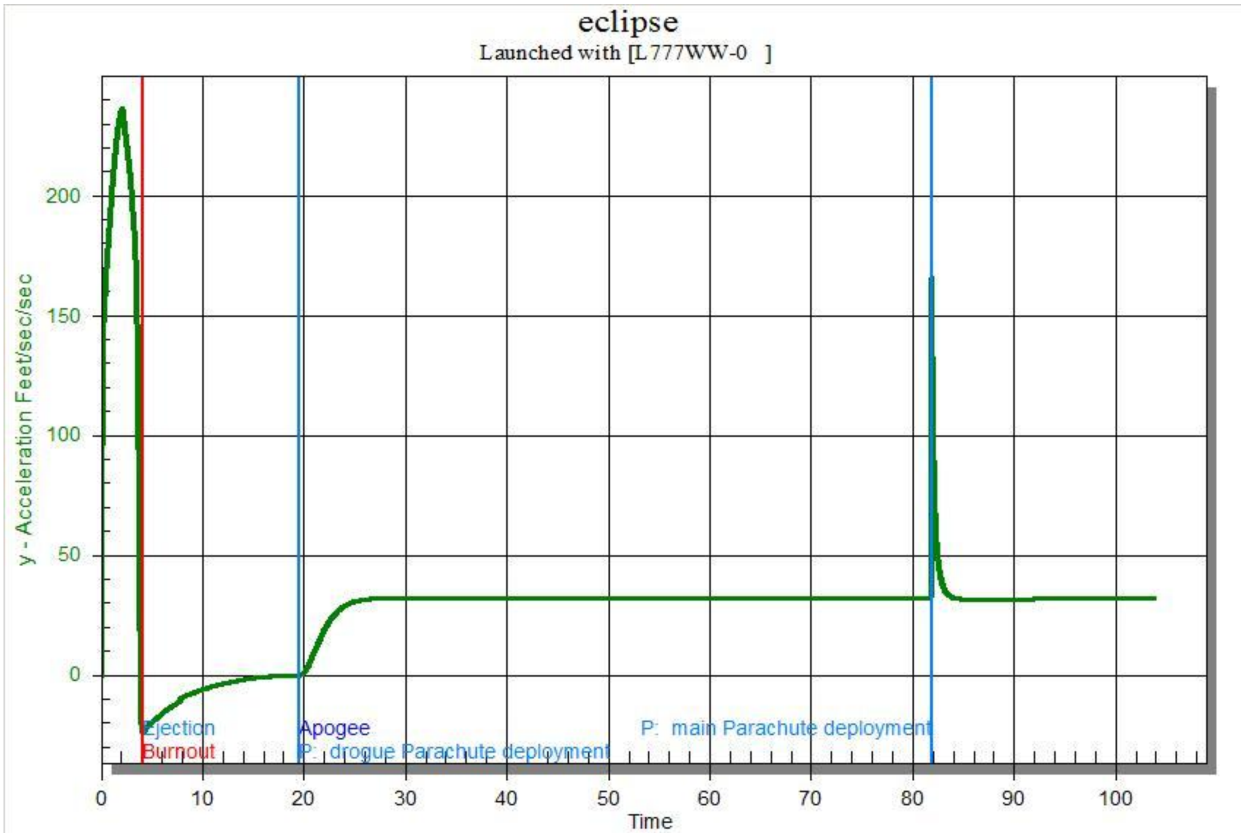

Figure 3-14 Acceleration during flight

Within the first two seconds of flight, the rocket experiences its maximum acceleration. As the rocket continues to burnout, acceleration rapidly changes from +260 ft/s^2 to -50 ft/s^2. This is one of the two most critical parts of the flight; the other being the rapid decrease in velocity during impact. The present design of the rocket is robust enough to handle these two conditions.

3.4 *Interfaces and Integration*

Table 3-9 Detailed list of structural interfaces lists the interface connections between main components of the rocket.

Table 3-9 Detailed list of structural interfaces

Connecting Components		Interface
Nosecone	Main Parachute	Tether
	Avionics Bay	Nylon shear pins
Avionics Bay	Main Parachute	Tether
	Main Body	Nylon shear Pins
	Drogue Parachute	Tether
Main Body	Motor Mount	Bulkheads
	Airbrakes	Bulkheads, Epoxy
Fins	Main Body	Epoxy
	Motor Mount	Epoxy
	Airbrakes	Screws

The avionics bay consists of a removable drawer that houses all electronic components, as shown in Figure 3-15 below. To preserve mass, the housing will be made of wood. Sensors are secured to a flat wooden plate that lies between two wooden disks that fit tightly in the body tube; two hollow aluminum rods of 3/8 in outer diameter are bolted between the disks on opposite sides of the flat plate with sensors adding to the structural strength against the forces exerted when the parachutes are deployed. If necessary, an L-bracket will also be placed to line the corners touching the flat plate and flat disks (four corners total). A flat plate can then be screwed onto the outer disk faces such that the screws go through the wood and the L-bars on the other side of the disks. The removable avionics compartment will be secured within the body frame by L-brackets that are screwed and epoxied onto the frame.

The payload compartment is designed to match the avionics compartment, primarily due to its simplicity. Because of the possible temperature rise and fire hazard, metal might be used instead of wood.

Interfaces between the launch vehicle and the ground will be wireless. Eclipse will transmit tracking data to the ground along with other data provided by the payload

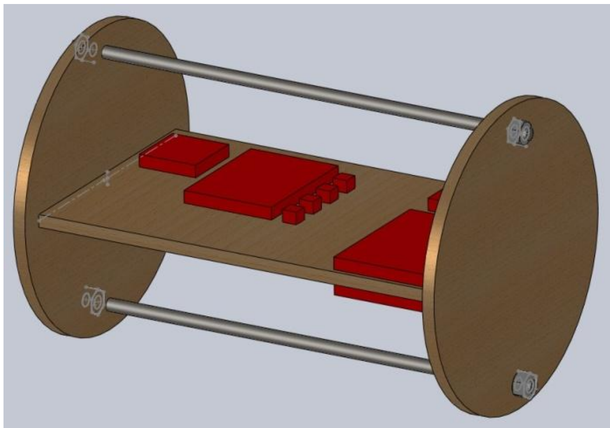

Figure 3-15 Removable avionics compartment

sensors. As for the interface between the launch vehicle and the ground launch system, Eclipse will be compatible with the rail launch method such that it will have a rod epoxied to the outside of the rocket's body tube. Screws will be added if necessary. The only interface during the rocket launch is the firing system.

3.5 Launch Operation Procedures

To ensure that the launching operation procedure is documented properly, the following checklist was created. The checklist also provides consistency.

Payload System Preparation
- ❑ Inspect payload bay and electronics
- ❑ Ensure electronics are wired correctly
- ❑ Ensure air brake system is properly assembled

Recovery System Preparation
- ❑ Inspect main and drogue parachutes for any damage
- ❑ Load and secure 4 black powder ejection charges
- ❑ Load and secure electronic matches
- ❑ Fold chutes and cover with fire proof Nomex chute protector
- ❑ Ensure quick links are attached at the following locations:
    - ❑ Main chute
    - ❑ Drogue chute
    - ❑ Nosecone bulkhead
    - ❑ Altimeter bay (2 points of attachment)
    - ❑ Booster section bulkhead
- ❑ Load drogue chute into drogue bay
- ❑ Check altimeter bay components and verify altimeters are properly wired
- ❑ Attach drogue chute to harness and harness to eye bolt on altimeter bay bulkhead
- ❑ Load altimeter bay
- ❑ Install shear pins
- ❑ Attach main chute to harness and harness to eye bolt on altimeter bay bulkhead
- ❑ Attach nose cone
- ❑ Install shear pins
- ❑ Arm altimeters

Motor System Preparation
- ❑ Ensure motor is properly assembled
- ❑ Install motor retention system
- ❑ Insert and secure igniter in motor (after rocket is secured on the launch rod and vertical)
- ❑ Wrap igniter leads around alligator clips and ensure a solid connection is established

3.6 *Safety and Environment*

Safety precautions have been taken both with the rocket and with the project as a whole. All anticipated risks are accounted for and mitigations planned in order to help carry out the project efficiently and smoothly. Several failure modes for the payload and the propulsion system are also observed in detail, as seen in Table 3-11 and Table 3-12.

The risks of delivering the Eclipse on time lie on the availability of materials and on the amount of time that team members can give to the project. The team currently has very dedicated members who manage to work on the "Eclipse" project as well as focus their attention to upper division engineering classes. The risks specifically lie in electronic malfunction; therefore we have planned out to test these components thoroughly before assembling the final rocket.

Table 3-10 General risk and mitigation

Risk	Probability	Impact	Mitigation
Arduino Board is not wired correctly	Medium Probability	Could keep the project from progressing on time	Test the Arduino board with ample time
Funds are not available to purchase project Supplies	Highly Probable	Team could not proceed with building and testing	Borrow funds either by loan or from the University until Sponsorship funds are available
Members cannot complete their assignments on time	Highly Probable	The project will not run smoothly and several components either in the vehicle or documentation will be rushed	Have other equally qualified members step in and finish the job.
Rocket Tests are not conducted due to no one on the team being qualified	Medium Probability	Rockets could not be tested by the team and must be tested by a hired qualified individual	Start working on qualifying team members to operate high power rockets early in the project

Table 3-11 Failure Modes and Effects Analysis of Propulsion System

Function	Potential Failure Mode	Potential Effects of Failure	Failure Prevention
1	Ignition Failure	Mission could not be completed	Make sure ignition system is tested and working prior to launch
2	Combustion Instability	Rocket will not exert a constant thrust	Inspect the gun powder and make sure it complies with standard
3	Nozzle Failure	Rocket will not have constant thrust and the direction of thrust could change	Inspect Nozzle for deformations and manufacturing defects before utilizing it
4	Case Burst	Mission could not be completed	Check nozzle and bore for defects before flight

Table 3-12 Failure Modes and Effects Analysis of the Payload

Function	Potential Failure Mode	Potential Effects of Failure	Failure Prevention
1	Arduino Pilot is not powering on	Payload mission cannot be completed	Inspect the Arduino and make sure it powers on before connecting all the components to the processor
2	Pitot tubes become plugged before flight	An accurate airspeed will not be recorded and airbrakes will not deploy to plan	Inspect pitot tubes to make sure they are free of any debris.
3	Malfunctioning transmitter	Data cannot be acquired during flight	Test the transmitter before flight at the distance of 1 mile

Table 3-13 Hazard during construction

Hazard	Effect of Hazard	Mitigation
Spray paints and primers	Respiratory irritation	Wear a respiratory mask which will allow for the air to be filtered
Carbon fiber layup (Fins)	Respiratory irritation	Wear a respiratory mask in an area specifically equipped for working with composites
Epoxy resin and hardener	Skin and respiratory irritation	Wear a respiratory mask, which will allow for the air to be filtered, and epoxy resistant gloves
Rocket motor failing and causing an explosion	Pieces of the vehicle could fly in all directions after the explosion	Make sure motor is loaded correctly and all procedures are followed when installing the motor

3.6.1 Failure Modes

The failure modes and their mitigations were tabulated for the overall rocket, the payload integration, and the launch operation of the rocket.

Table 3-14 Overall Rocket failure modes

Failure mode 1	Rocket motor mount failing and causing the engine to thrust through the rocket.
Mitigation 1	Make sure the rocket motor is properly cemented to the Magnaframe tube.
Failure mode 2	Altimeters malfunction and air brakes are deployed too long and cause the rocket to not reach the 1 mile mark.
Mitigation 2	Make sure that Altimeters are tested both out of the rocket and inside the prototype before assembling the final rocket.
Failure mode 3	Main parachute does not deploy and rocket cannot be recovered successfully.
Mitigation 3	Make sure that the delay on the engine is set properly and that the parachute is properly loaded into the rocket and free to catch air and expand at the time of its deployment.
Failure mode 4	System which ignites the rocket fails and the rocket cannot be ignited.
Mitigation 4	Make sure that the ignition system has been tested and there is current traveling to the igniter.

Table 3-15 Payload Integration failure modes

Failure mode 5	Batteries on board do not deliver current.
Mitigation 5	Make sure the battery is charged and delivers current before installing it with the electronics.
Failure mode 6	Electrical wires happen to shear and cause avionics and payload to malfunction.
Mitigation 6	Make sure all electrical wires are in good health, they are free of any scrapes or cuts before every launch.

Table 3-16 Launch Operations failure modes

Failure Mode 7	Not advising FAA of proposed high power rocket launch.
Mitigation 7	Make sure that FAA is advised about the area of launch and that they agree to clear the airspace.
Failure Mode 8	Not making sure that the area is large enough, and is clear of trees, for the high power rocket launch.
Mitigation 8	Make sure that the area is large enough according to the data given in the chart below for the particular motor being flown.
Failure Mode 9	Not bringing a fire extinguisher in case the rocket happens to catch on fire before liftoff.
Mitigation 9	Make sure to bring several fire extinguishers to the site and make sure that they are all charged.
Failure Mode 10	Not installing an engine flare shield on the pad.
Mitigation 10	Make sure that there is a metal shield which will protect the grass or field from the flare of the engine.
Failure Mode 11	Not insuring that the launch gear is in good condition and launch control works properly.
Mitigation 11	Test the controller by using a volt meter across the two terminals which feed out of the controller.
Failure Mode 12	Not waiting 60 seconds after rocket has been activated for launch after a misfire.
Mitigation 12	Make sure to wait 60 seconds before touching the terminals from the launch control and disconnect the terminals while analyzing the problem.
Failure Mode 13	Having spectators too close to the launch pad.
Mitigation 13	Make sure that spectators are as far as NAR rules permit and only certified Rocketeers are flying the rocket.

3.6.2 Environmental Concerns

If the weather is much too windy, as per NAR rules, the launch should be postponed to a later date in order to not have the rocket fly towards an undesired location or not be successfully recovered due to air drift.

Sources: http://ti.arc.nasa.gov/tech/dash/pcoe/solid-rocket-motor-failure-prediction/introduction/
http://www.rocketryplanet.com/content/view/3458/38/#axzz2Af4XTFjR

4 PAYLOAD CRITERIA

4.1 Selection, Design, and Verification of Payload Experiment

The avionics payload will consist of the ArduPilot Mega 2.5 (APM 2.5) as a data acquisition system with the ATMega 2560 as the core processor. Its flexibility in programming combined with the built-in sensors make the APM 2.5 the best choice for the payload application. Within the APM 2.5 motherboard, sensors that will be utilized are the digital compass, 3 axis gyro, and daughterboard GPS unit. Additionally, the team will incorporate external sensors measuring air velocity as a function of barometric pressure, solar irradiance using a linear correlation of between light and frequency, and finally a temperature and humidity sensor. Also, the team will couple the APM 2.5 with a 915 MHz transmitter that will provide a display of real time data to a laptop ground station. The gathered atmospheric data combined with acceleration and velocity data will allow for improvements to be made on the designs performance and adaptations. Finally, the team will incorporate an on board camera that stands alone from the APM 2.5 with its own 1.2 GHz transmitter and receiver set.

The design of the payload is as follows:

As stated, the main systems control hardware and data acquisition system is the ArduPilot Mega 2.5 motherboard. The ATMega 2560 processor will be the control system for all the analog and digital data for the internal and external sensors. The internal sensors that will be utilized on the APM 2.5 are the are the digital compass powered by the Honeywell HMC5883L-TR chip, the MPU-6000 3 axis gyro and accelerometer, and the pulse width modulation (PWM) digital I/O pins. The Honeywell compass will work in conjunction with the MPU-6000 chip to send digital data via a stack algorithm to the main processor. The data will then be stored in the 16 Mb's flash memory and encoded for wireless transmission. The sensors within the board will be reprogrammed via the ATMega 32U2 USB interface to ensure data is recorded over each sensors full range. For instance, the MPU-6000 will be programmed to read accelerations of ±16 G, which is this sensors full capability. Wiring diagrams can be seen below of each the respective internal sensors, as well as the ATMega 2560 main processer. Each pin is designated by its connection to the main processor.

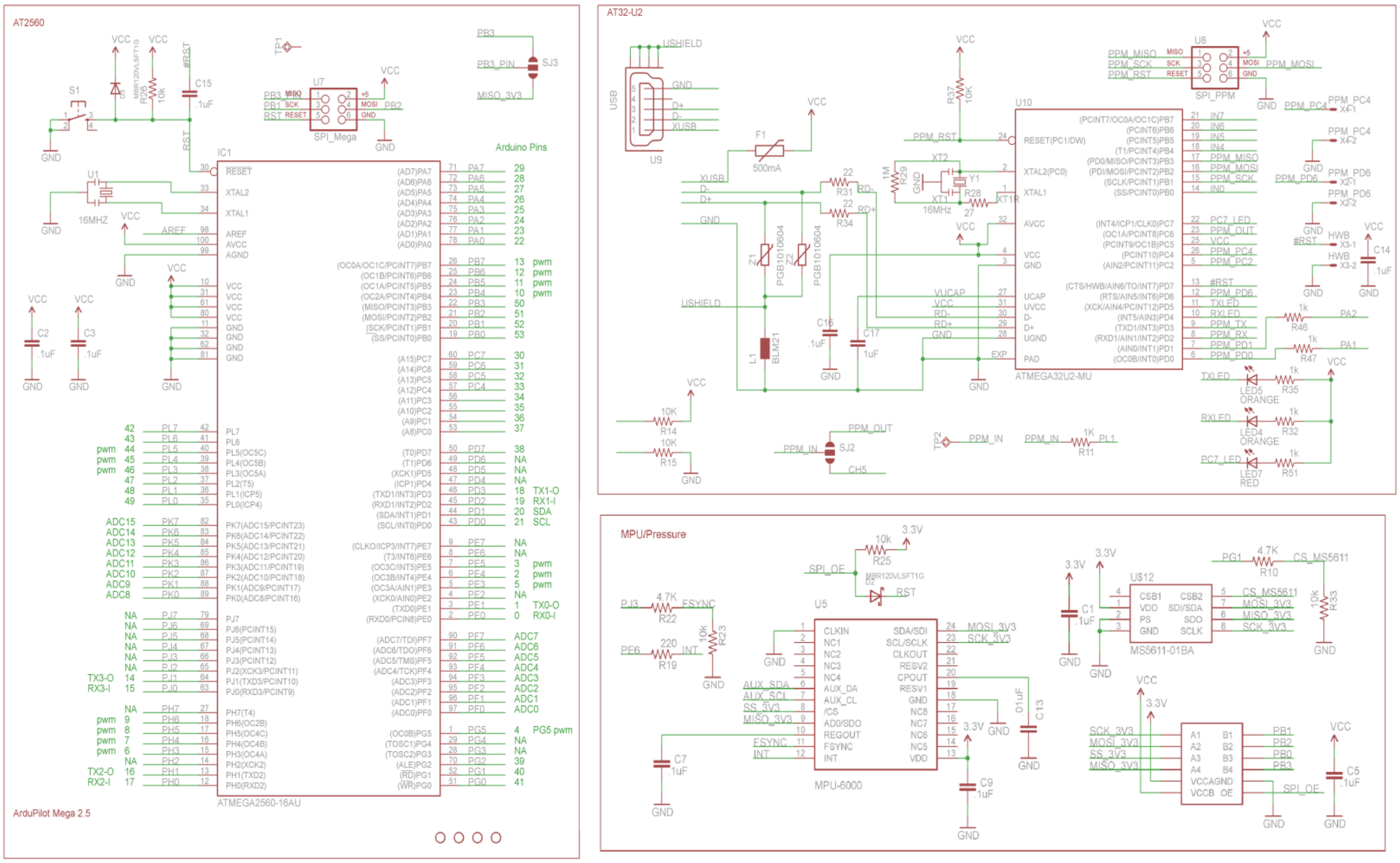

Figure 4-1 Schematic diagram for Payload electronics.

To determine the flight path of the rocket, the MediaTek MT3329 10Hz GPS daughterboard will be added to the APM 2.5 via a 12 pin DIP vertical header soldered to the APM 2.5 motherboard. The GPS unit can support up to 66 channels and has jammer detection and reduction as an interface to help with possible interference. One drawback of the GPS unit is the functionality is limited to 4 G maximum acceleration; therefore, it will be programmed to display the rockets position once the MPU-6000 detects acceleration less than 4 G (the coasting phase and decent phases of the rocket). As an addition to the GPS, the upgraded MS5611-01BA03 variometer will be included onboard. The main purpose of this sensor is to act as an altimeter. The pressure sensor in the variometer will convert an analog voltage output from its piezoresistive pressure transducer to a digital signal while simultaneously gathering temperature data. The conversion is achieved via the chip's analog-to-digital converter (ADC) and internal oscillator. The digital data will be sent to the 128 bit PROM on each module and then transferred to the main data processor. The team will control the rate at which this data is stored within the 16 Mb of data logging memory to match the imposed limits on data sampling.

Moving into the external sensors, the first sensor will measure the air velocity of the rocket. To achieve an accurate velocity reading, the team will use the MPXV7002 as a barometric pressure sensor. The MPXV7002 is another piezoresistive transducer that uses a pressure differential to acquire data. The pressure differential will be created using a pitot tube mounted on the outside of the rocket along with a static pressure tube. Within the APM 2.5 motherboard, an algorithm is created to convert the analog pressure differential data to information on the velocity of the rocket. In addition to airspeed, the team will be measuring the relative humidity and temperature during the rockets flight. To accomplish this, the team will use the AM2302 humidity and temperature sensor. This sensor has an 8 bit digital module that provides calibrated temperature and humidity readings. This will be connected to the digital input pins of the APM 2.5, where the information will be conditioned and sent through the main processor for data storage and transfer. One downside of using the AM2302 is the team can only sample the data at 0.5Hz due to its one pin digital input; however, the team concluded this is offset by its low cost and ease of integration. Wiring schematics for both the MPXV7002 and the AM2302 can be seen below.

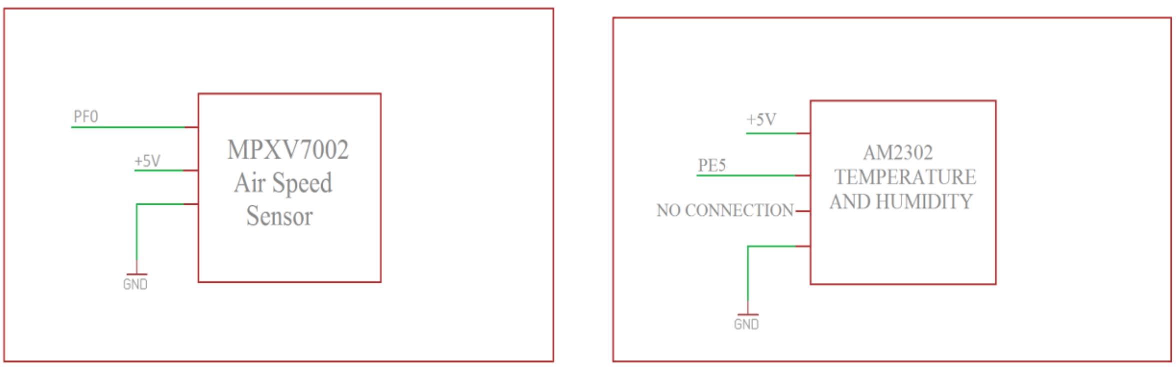

Figure 4-2 [Left] The air seed sensor schematic diagram and pin connections. [Right] The temperature and humidity sensor.

The last sensor the team will use is the Parallax TSL230R light to frequency converter. The output of the sensor will be a stream of pulses proportional to irradiance. The TSL230R will be connected to the digital input and PWM pins of the APM 2.5. Using the scaling function of the TSL230R chip the team will control the rate at which the digital signal is recorded. The reason the team needs to scale the output of the TSL230R is it gives frequency pulses on the nanosecond scale; however, due to the clockspeed of the APM 2.5 the team can only read data when it in the microsecond or larger scale. Therefore, after scaling and buffing the output signal, the APM 2.5 will be able to read the output pulse stream of the TSL230R. Finally, through an algorithm the team programmed be able linearly correlate the pulse stream to solar irradiance measured in microwatts per square centimeter. Once again to ensure the team does not overload the processor, the sampling rate will be on 3 second intervals. The schematic for the TSL230R can be seen below along with its pin connections to the main processor.

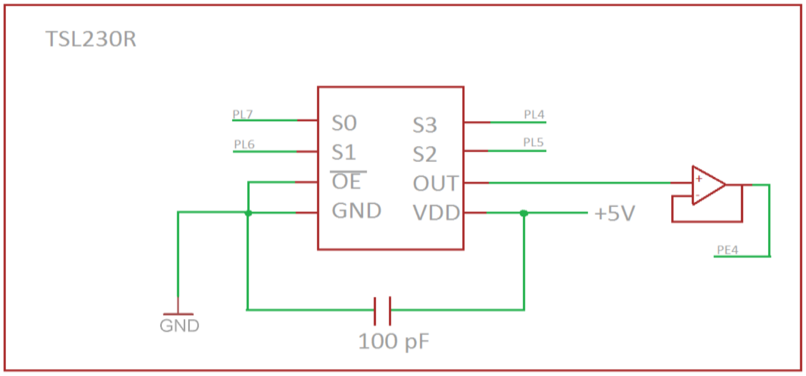

Figure 4-3 Connection scheme of the TSL230R Light to Frequency Converter

To transmit the data from the APM 2.5 board to the ground station, the team will use the 3DR 915 MHz air module and USB ground station from DIYDrones. The 915 MHz signal will give the team a range of approximately 1 mile; however, if this is not adequate the team will add a high gain antenna so the team does not lose signal as the rocket reaches apogee. Once the data is recorded on the APM 2.5 motherboard, it will be sent to the USB ground station where the team will display and store the real time data for further analysis. A wiring schematic for both the transmitter and receiver are shown below. The transmitter is wire directly to the APM 2.5 UART 0/2 jack via a 4 pin header.

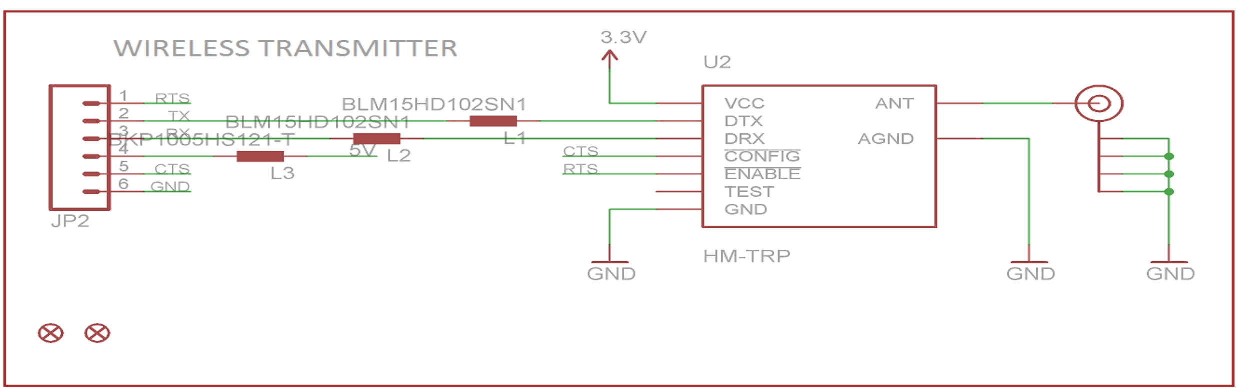

Figure 4-4 Wireless transmitter schematic diagram

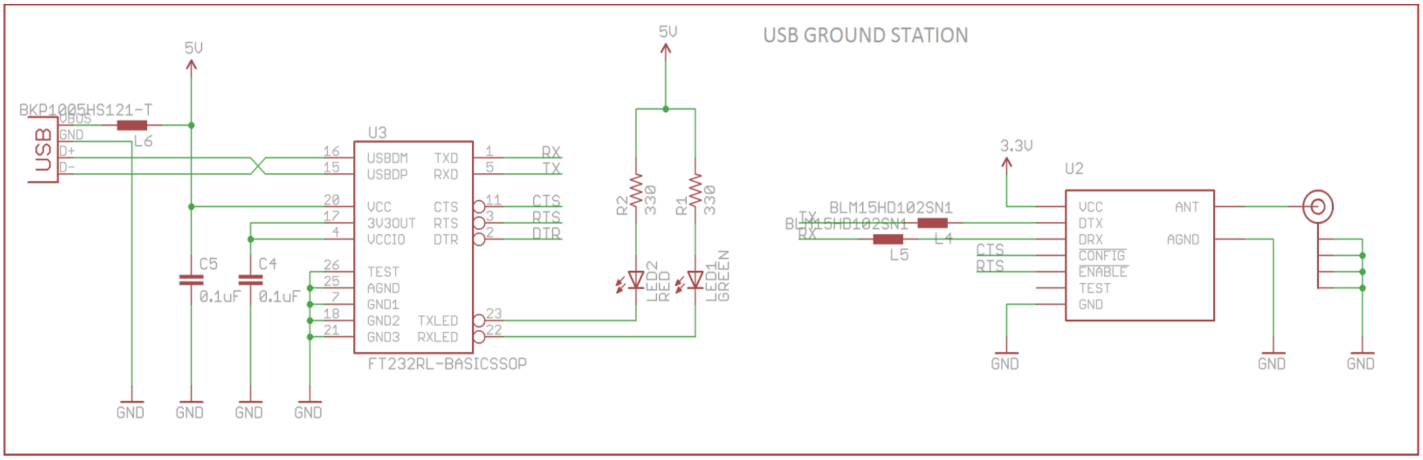

Figure 4-5 USB receiver ground station schematics

Finally, to capture live video for the flight of the rocket, the team will use the KX191 CCD camera from Range Video. This camera will be wired to its own transmitter receiver combo where it will transmit live video at 1.2 GHz. The 1.2 GHz frequency was chosen as to not interfere with the already broadcasting 915 MHz signal from the APM 2.5. The transmitter receiver combo the team will use is the 1.2 GHz 1W LawMate. The transmitter has a light weight of 1oz and has a range of up to 3 miles. The transmitter and camera package will be powered by an 11.1V Li-Po battery pack, which will provide enough power for the flight of the rocket.

5 PROJECT PLAN

The general project plan has not been changed since the proposal. The design is on schedule and is within expectations.

5.1 Budget Plan

Payload/Recovery Electronics	
Shielding	\$20.00
Ardu Pilot Mega 2.5 Micro Controller	\$200.00
MPXV7002 Pressure Sensor	\$25.00
AM2302 humidity and temp. Sensor	\$10.00
TSL230R (Light to Frequency Converter)	\$6.00
KX191 CCD Camera	\$105.00
3DR Radio	\$75.00
Raven3 Altimeter	\$155.00
1.2 GHz 1W Lawmate	\$135.00
Battery	\$50.00
Propulsion Operations	
AMW L777WW-0 (75 mm diameter) Hardware	\$180.00
5 Slugs of Propellant for 5 fires @ \$201.49 each	\$1,007
Type III Magazine	\$40.00
Structures	
Magna Frame	\$147.00
Fins	\$20.00
Airbrake System	
Aluminum	\$50.00
Hardware	\$25.00
Pneumatic Actuator and Cylinder	\$65.00
Total:	**\$2,341.00**

5.2 ***Funding Plan***

Current Sponsorship Money

University of California Davis College of Engineering	$2,000
University of California Davis MAE Department	$1,000
University of California Davis Club Finance Council	$2,000
Various Stores from the Community (Target and Wal-Mart)	$1,000

Future Sponsorship Plan

Travel Expenses will be paid by Companies currently being contacted

- AutoDesk Inventor
- NAVAIR
- The Livermore Unit of the National Association of Rocketry (LUNAR)

5.3 *Timeline*

The following Gantt chart shows the team's major milestones. To successfully design and build a rocket for the USLI competition, the team will follow the engineering design process: design, construction, test, and redesign. The design phase will take place during Fall quarter. Major construction will take place during mid-Fall Quarter and the entire Winter Quarter. As the team builds the rocket, testing and simulations will be conducted. Any redesign and reconstruction will be the main focus in the Spring Quarter.

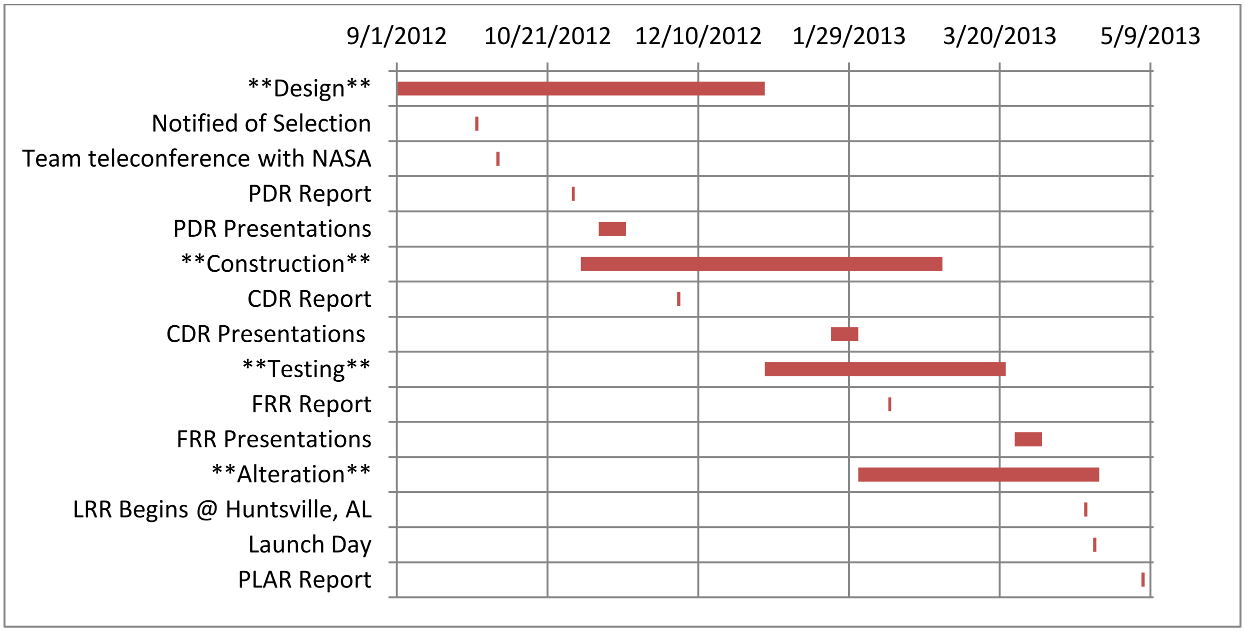

Figure 5-1 Timeline of team's progress towards competition

5.4 *Educational Engagement Plan and Status*

The team held a rocket launch in the middle of August 2012 where fellow students and professors were invited to participate in the launches. Fifteen different sized rockets were launched. There were several types of motors used. And some malfunctions occurred. In one of the rockets, the motor exploded on the launch pad and did not launch the rocket into the air.

On October 26, 2012 the team engaged a group of 42 middle school students. Several rockets were presented to this group along with a video and presentation about the team. The students were motivated after the presentation and asked for information in order to purchase a hobby rocket themselves.

SpaceED Rockets has also arranged to visit American Canyon Middle School in Napa Unified on Friday, November 16th, 2012. On this visit, the team will be meeting about 40 sixth grade students who will be introduced to the basics of rocketry. The students' teacher, Tammy Lee, would like to incorporate the concept of design through scaling and measurement. Students will measure and weigh model rockets using metric units and develop proportional relationships such as distance/time. The team will also give a brief presentation to the students, showing them a brief history of rocketry and introducing them to the relevance of rockets in modern lives. For example, a video clip of a rocket launch carrying a communication satellite will be shown, relating it to the popular use of cell-phones.

The team has also arranged to visit two sixth grade classes, a total of 60 students, at Riverbank Elementary school November 29th and 30th, 2012. Jada Saul, a science teacher at the elementary school, would like the team to introduce students to rocketry with a hands-on project. Students will likely be constructing small model rockets that they can use to visualize the different components of a rocket. Again, the team will give a brief presentation about rocketry and its current applications.

Currently, the team is in contact with several other schools, including the following:

- Hiram W. Johnson High School – Sacramento City Unified School District
- Elkhorn Village Elementary – Washington Unified School District
- Saint Francis High School – Private School (Catholic Diocese)
- School of Engineering and Sciences – Sacramento City Unified School District
- Esparto Middle School – Esparto Unified School District

We have been asked to present to the listed schools and hope to be able to schedule meetings with them in the near future.

6 APPENDIX

ScienceLab.com
Chemicals & Laboratory Equipment

Health	1
Fire	0
Reactivity	0
Personal Protection	E

Material Safety Data Sheet
Ferrosoferric Oxide, Black Powder MSDS

Section 1: Chemical Product and Company Identification

Product Name: Ferrosoferric Oxide, Black Powder

Catalog Codes: SLF1477

CAS#: 1317-61-9

RTECS: Not available.

TSCA: TSCA 8(b) inventory: Ferrosoferric Oxide, Black Powder

CI#: Not available.

Synonym: Iron Oxide

Chemical Name: Ferrosoferric Oxide, Black Powder

Chemical Formula: Fe3-O4

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Ferrosoferric Oxide, Black Powder	1317-61-9	100

Toxicological Data on Ingredients: Ferrosoferric Oxide, Black Powder: ORAL (LD50): Acute: 5000 mg/kg [Rat].

Section 3: Hazards Identification

Potential Acute Health Effects: Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), . Non-irritant for lungs.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: Classified None. by NTP, None. by OSHA, None. by NIOSH.
MUTAGENIC EFFECTS: Not available.
TERATOGENIC EFFECTS: Not available.
DEVELOPMENTAL TOXICITY: Not available.
The substance is toxic to lungs, upper respiratory tract.
Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact: No known effect on eye contact, rinse with water for a few minutes.

Skin Contact:
After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cover the irritated skin with an emollient. If irritation persists, seek medical attention.

Serious Skin Contact: Not available.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation: Not available.

Ingestion:
Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Non-flammable.

Auto-Ignition Temperature: Not applicable.

Flash Points: Not applicable.

Flammable Limits: Not applicable.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances: Not applicable.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available.
Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions: Not applicable.

Special Remarks on Fire Hazards: Material is not combustible. Use extinguishing media suitable for other combustible material in the area

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:
Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system.

Section 7: Handling and Storage

Precautions:

Do not ingest. Do not breathe dust. If ingested, seek medical advice immediately and show the container or the label.

Storage:
No specific storage is required. Use shelves or cabinets sturdy enough to bear the weight of the chemicals. Be sure that it is not necessary to strain to reach materials, and that shelves are not overloaded.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits: Not available.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Solid powder.)

Odor: Odorless.

Taste: Not available.

Molecular Weight: Not available.

Color: Black

pH (1% soln/water): Not available.

Boiling Point: 1000°C (1832°F)

Melting Point: Not available.

Critical Temperature: Not available.

Specific Gravity: 4.6 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility: Not available.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Not available.

Corrosivity: Not available.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Dermal contact. Eye contact. Inhalation.

Toxicity to Animals: Acute oral toxicity (LD50): 5000 mg/kg [Rat].

Chronic Effects on Humans:
CARCINOGENIC EFFECTS: Classified None. by NTP, None. by OSHA, None. by NIOSH.
The substance is toxic to lungs, upper respiratory tract.

Other Toxic Effects on Humans:
Slightly hazardous in case of skin contact (irritant), .
Non-irritant for lungs.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:
California prop. 65: This product contains the following ingredients for which the State of California has found to cause cancer, birth defects or other reproductive harm, which would require a warning under the statute: Ferrosoferric Oxide, Black Powder
Massachusetts RTK: Ferrosoferric Oxide, Black Powder
New Jersey: Ferrosoferric Oxide, Black Powder
TSCA 8(b) inventory: Ferrosoferric Oxide, Black Powder

Other Regulations:
OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).
EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada): CLASS D-2B: Material causing other toxic effects (TOXIC).

DSCL (EEC):
This product is not classified according to the EU regulations.

HMIS (U.S.A.):

Health Hazard: 1

Fire Hazard: 0

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 1

Flammability: 0

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves.
Lab coat.
Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate.
Safety glasses.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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