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Eclipse-I Critical 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

14th January 2013

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1. Summary of CDR Report

1.1 Team Summary

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Reusable Rocket Vehicle Proposed:

Eclipse-I

Team Faculty Advisor:

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Launch Assistance/Mentor:

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LUNAR #600

AeroPAC #445

1.2 Launch Vehicle Summary

The launch vehicle is designed to carry a payload and recovery system. The overall dimension of the launch vehicle evolved through a few iterations to accommodate all contract requirements as stated in the NASA USLI Handbook. The following table indicates the updated specification of the launch vehicle:

Table 1 Eclipse-I rocket specifications

Component	Final Selection
Total Length	71.5 in.
Diameter	3.89 in. ID, 4.04 in. OD
Fin Span	14.27 in.
Total Mass	11 lb.
Motor Choice	Aerotech K513FJ-M
Recovery System	*Main:* Iris Ultra 72'' made by Fruity Chutes *Drogue:* Classic Elliptical 18'' made by Fruity Chutes
Rail Size	Standard 1in. rail, but can be modified to fit large launch rod.

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 PDR

2.1 Changes made to payload criteria

1. The Range Video KX191 wireless CCD Camera has been omitted.
2. The TSL230R Light to frequency converter IC has been replaced with the TSL250R light to voltage converter
3. The MPXV7002 Airspeed sensor has been omitted.

2.2 Changes made to project plan

Since the submission of the PDR only minor changes have been made to the project plan. These changes were primarily made in order to better allocate time for testing and assembly phases. The changes made are as follows.

1. Payload testing completion milestone added for March 3rd, 2013
2. Full scale test launch milestone added for March 9th, 2013
3. Payload development and testing timeline adjusted to span from November 1st 2012 to March 3rd, 2013
4. Primary Construction phase renamed from 'Construction Phase' to distinguish from prototype construction phase.
5. Prototype construction phase added to reflect prototype construction phase from November 11th, 2012 to January 5th, 2013
6. Funding plan adjusted to include additional $1700 of sponsorship money procured through the University of California.

2.3 Airframe Material

In the Preliminary Design Review (PDR), it was proposed that the rocket's airframe be made of Magnaframe tubes, a reinforced composite material tube produced by Giant Leap Rocketry. Although Magnaframe has many admirable properties, such as its high strength to weight ratio, robustness, and durability, it was found that it would not be effective to purchase a tube that would be difficult to modify. In its description, Giant Leap Rocketry noted that special tools are required to cut into the Magnaframe tube, and the expense of customized cuts into the tube totaled to an unreasonable cost. Furthermore, the recovery bay that the team had planned on using did not fit within the tolerance of the Magnaframe's inner diameter.

As such, the team has decided that a more appropriate material to use for the rocket's airframe is fiberglass. Fiberglass has a high impact, flexural and tensile strength. A fiberglass airframe also has high dimensional stability, meaning that it is able to retain its shape when subjected to varying parameter such as temperature, moisture and stress.

2.4 Removal of Airbrakes

The air-braking system proposed in the previous PDR was dropped due to a high cost in implementing the system as well as a lack of time to properly manufacture and test the system. The original desire to control the speed of the rocket as it approached apogee via the air-braking system, to enable as to achieve the targeted distance of a mile, will therefore be solely control by the motor size. Our test launch of the full scaled rocket also revealed that the sizing of the motor can get us to the apt targeted mission.

2.5 Fin Design and Material Selection

The final material selection for the rocket's fins was G-10 fiberglass. The G-10 fiberglass is able to provide both resistance to flutter at high speeds as well as shock absorption on landing. Since fins are located at a delicate point in the rocket on landing, it is crucial that the fin material is capable of resisting impact forces. Furthermore, if the rocket is reusable, it is expected that the fins are durable and will not become weaker with every landing. Thus, G-10 fiberglass is an ideal material for the Eclipse fins.

Fin design is sensitive due to aerodynamic properties and their relation to the rocket's trajectory, so it is preferred that the fin manufacturing process is precise. It was decided that the fins would be purchased from Apogee Components since prefabricated fins that closely match our design are available. While purchasing the fins would add to the overall cost of the rocket, their manufacturing precision is guaranteed.

3. Vehicle Criteria

3.1 Design and Verification of Launch Vehicle

3.1.1 Mission Statement

The mission of the UC Davis SpaceED Rockets Team is to design, build, test, and launch a high-powered recoverable and reusable rocket, capable of participating and succeeding in the NASA University Student Launch Initiative (USLI), and thereby meeting all specified requirements within the NASA USLI handbook. Throughout all phases safety, recovery, reusability, science value, and learning opportunities will be the primary drivers and motivators of decisions.

3.1.2 Launch Vehicle Requirements

To ensure a successful mission and compliance with all guidelines specified within the USLI handbook, the team's rocket design will be ensured to meet all requirements listed in Table 2.

Table 2 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	K513FJ motor	RockSim and test launches
Barometric altimeter reports altitude by series of audible beeps	Featherweight Raven 3 altimeters	Testing
Recoverable and reusable	Drogue and main parachute/robust airframe	RockSim calculations, precisely controlled manufacturing techniques, and 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	K513FJ motor	Inspection
Maximum impulse remains under 2560 Ns.	K513FJ motor	Inspection
No forward canards	Structural and aerodynamic design	Inspection
No forward firing motors	Structural and propulsive design	Inspection
No motors which expel titanium sponges	Propulsive design and	Inspection

	motor selection	
No hybrid motors	Propulsive design and motor selection	Inspection
No cluster of motors	Propulsive design and motor selection	Inspection
Official altitude-determining altimeter shall be capable of being turned off	Stratologger Altimeter	Inspection
Launch vehicle shall remain subsonic from launch until landing	K513FJ motor	Rocksim & testing
Launch vehicle shall have a maximum of four independent sections	Design	Construction
Launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours	Design	Test and Inspection
The vehicle shall be compatible with either an 8 feet long 1 in rail, or an 8 feet long 1.5 in rail	Design	Inspection
Launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system	Design	Test and Inspection
Launch vehicle shall require no external circuitry or special ground support equipment to initiate launch	Design	Inspection
The amount of ballast, in the vehicle's final configuration, shall be no more than 10% of the unballasted vehicle mass	Design and assembly	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. The robustness of the design has been determined through multiple tests and evaluations using a prototype model. RockSim analysis and other simulation software have been used to evaluate the rocket design and checked for conformity with prototype testing results. In the remaining build phase further physical and analytical tests will performed within the team's workshop, and through assistance of the team mentor's at LUNAR, a high degree of robustness and confidence will be developed for Eclipse-I.

3.1.3 Mission Success Criteria

Mission success is defined and will be evaluated based on the requirements in Table 3.

Table 3 Mission success requirements

Mission Success Requirement	Verification
Reach altitude of 5280 ft AGL	Altitude measurement from onboard barometric pressure and accelerometer sensors
Must remain strictly under 5600 ft AGL	Altitude measurement from onboard barometric pressure and accelerometer sensors
Rocket recoverable with no sustained damaged, and capable of performing additional launches within the same day	Visual and mechanical inspection
The maximum amount teams may spend is $5000	Team treasurer will maintain accurate expense logs and approve or deny all purchasing decisions

3.1.4 Project Timeline and Configuration

The project is currently on schedule. Completion and approval of the PDR entered the project into its final pre-construction design phase and began development and testing of a prototype model. Results and lessons learned within this project phase are included and analyzed within this report and upon approval will be used in the following manufacturing and verification phase. The manufacturing and verification phase will continue through the time of the FRR, at which point all final manufacture, verification, and alteration will be complete. Within this phase, a full scale flight test will be completed to perform system level verification and ensure all functional units are operating and integrated correctly. Results from the full scale test will be included within the FRR. The major milestones and a GANTT chart depicting the project plan are presented in

Table 4 and Figure 1 Team schedule on a GANTT chart.

Table 4 Primary milestones and completion status

10-22-12	Web Presence Established	Completed
10-29-12	PDR Report Posted	Completed
11-16-12	PDR Presentation Completed	Completed
1-14-13	CDR Report Posted	In Progress
1-31-13	CDR Presentation Complete	On Track
3-3-13	Payload Testing Complete	On Track
3-9-13	Full Scale launch with payload	On Track
3-18-13	FRR Posted	On Track
4-3-13	FRR Presentation Complete	On Track
4-17-13	LRR Conducted	On Track
4-20-13	Launch Date	On Track
5-6-13	PLAR Posted	On Track

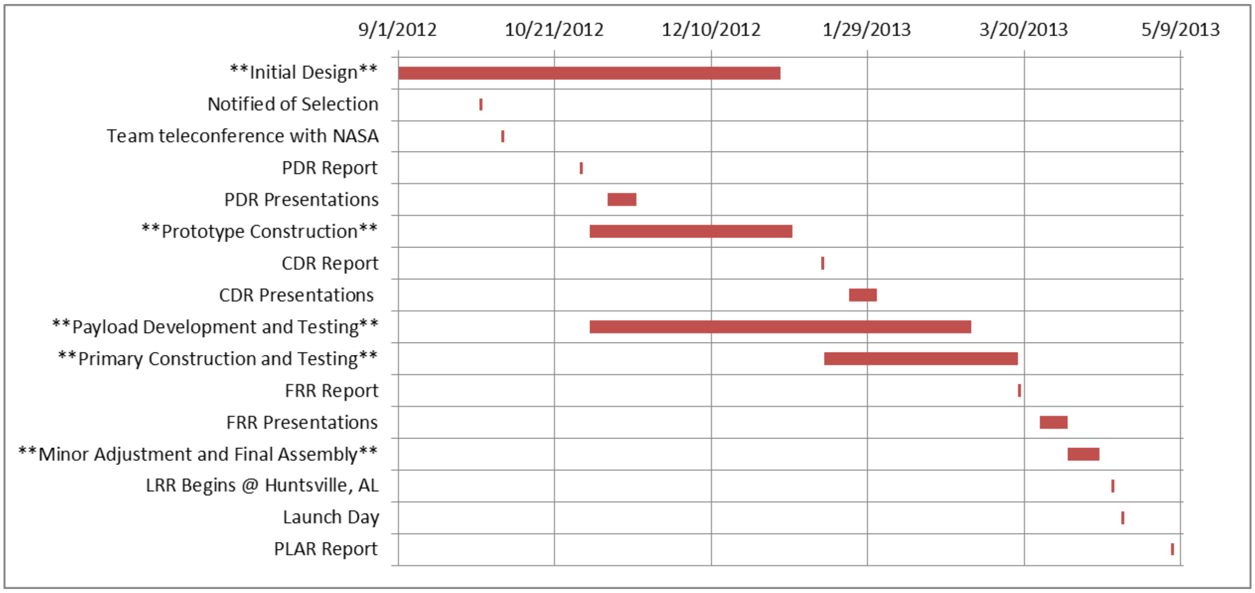


Figure 1 Team schedule on a GANTT chart

3.1.5 Interfaces and Integration

The following table lists all interface connections between main components of the rocket.

Table 5 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

3.1.6 Airframe Selection

The Magnaframe selected previously as a material for the construction of the rocket, although very durable and strong, needs specialized tools for modification. It was quickly realized that it would be very costly to have parts of the frame altered to suit our design. Therefore, it became crucial to find another material that allows for easy alteration.

Core structural components of Eclipse were chosen to be made of fiberglass. Fiberglass is a polymer structure, thus its elasticity and toughness allow it to withstand impact forces or abrasion. On landing, the rocket may experience high impact loads, and a fiberglass structure has the ability to stretch and gradually absorb the large amount of change in energy. Fiberglass is a workable material and allows for easy tailoring and implementation of our design at a less costly expense.

Table 6 Mechanical properties of fiberglass

Mechanical Properties	Value in ksi
Young's Modulus	2600
Tensile Stress	30
Flexural Stress	30

3.1.7 Nosecone Shape and Style

Since Eclipse is not designed to exceed supersonic speeds, the drag of the nosecone and the fins is not incredibly significant. A nosecone with a sharper point provides better aerodynamic properties to the rocket, but is not necessary for subsonic velocities.

Table 7 Nosecone geometry

Shape	Ogive (hollow)
Thickness	0.1180 In.
Length	15.76 In.
Diameter	4 In.
Material	G-10 Fiberglass

3.1.8 Fin Shape and Style

Because the rocket is not traveling at supersonic speeds, the fins were designed for structural integrity rather than aerodynamic efficiency. The primary goal of designing our rocket is to achieve the mission statement of reaching an altitude of 1 mile. As such, it is important that the rocket maintains and follows the appropriate orientation and flight path. To ensure this, the design and implementation of fins on the rocket is crucial. The stability of the rocket is affected mostly the center of pressure (cp) and center of gravity (cg) and their relation to each other in terms of distance.

Table 8 Calculation of cg and cp

	RockSim	Measured
CG	46.9731 In.	41.21875 In.
CP	56.2187 In.	
Cd	0.35	
Static Margin	2.31 calibers	2.375 calibers

A stable rocket has the cp aft of the cg. Since the cg is fixed by the weight of the entire rocket, it was easier to alter the cp via the fins to ensure stability. The location of the cg and cp along the rocket from its nose to attain stability was determined to be 46.9 in. and 56.2 in respectively.

In order to maintain a desirable static margin, a trapezoidal planform area was selected for the fins. Another advantage to using straight-taper fins is to avoid fractures of the fins on landing. The root of the fins along the rocket's airframe is highly sensitive to stress, thus it is suitable to have a fin-shape that will avoid high contact with the ground upon impact. Although fins that are swept back prove to have some aerodynamic advantages, they are not structurally ideal in that they would be the first to hit the ground on landing, increasing chances of a fin breaking off. G-10 fiberglass was selected for the fins' material to reduce the chances of fracture in case the rocket were to land improperly such that a fin hit the ground first.

Table 9 Fin geometry

Count	**4**
Shape	Trapezoidal
Material	G10 Fiberglass
Thickness	0.125 In.
Root chord length	5.5 In.
Tip chord length	2.5 In.
Sweep length	1.5 In.
Sweep angle	16.314 deg.
Semi Span	5.125 In.
Tab length	5.5 In.
Tab depth	0.887 In.

To properly attach the fins to the rocket, fin slots were cut into the rocket's airframe. The fins were designed to go through the airframe such that they lie on the motor bay. All connections were epoxied using 30 minute epoxy, which provides strong bonds at structural junctions that are more susceptible to fracture. Since the epoxy has a longer open time than a 5 minute epoxy, it was crucial that the fins remained in place until it hardened. To keep the fins in place, a sheet of wood was cut to match the rocket from the top view such that it could slide down the airframe and over the fins.

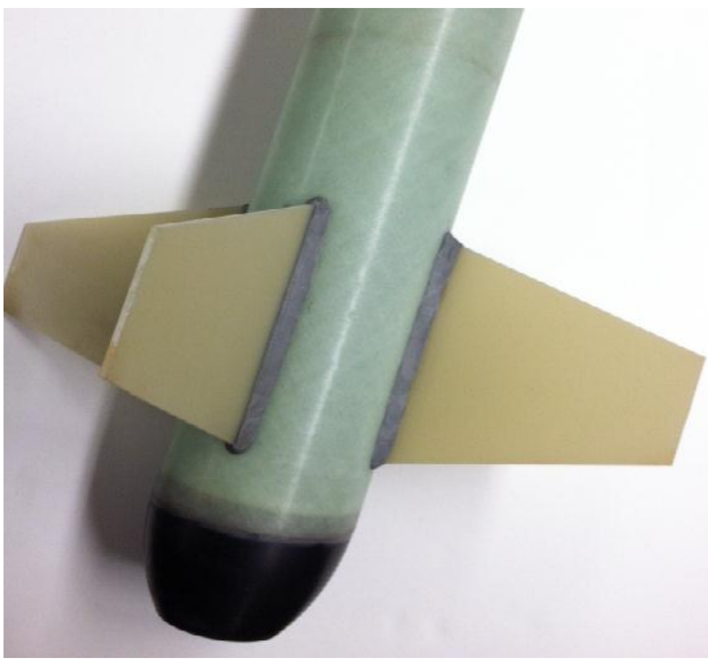


Figure 2 Fin attachment to rocket airframe

3.1.9 Motor Selection and Propulsive Design

After careful comparison of potential motors, the team has selected the Aerotech K513FJ-M motor 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. The main driver for our motor selection is to reach target altitude.

Table 10 Thrust to weight ratio

Average Thrust	125.18	lbf
Thrust to weight ratio	8.19	

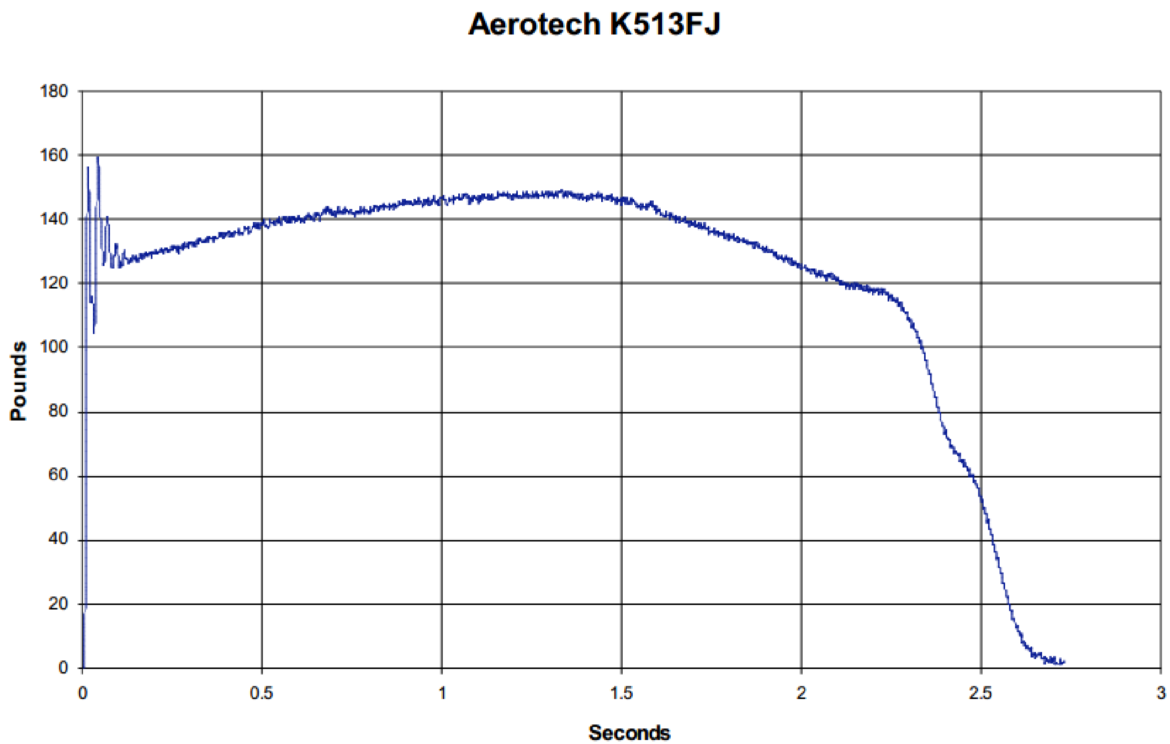


Figure 3 Motor thrust curve

Mounting and Retention

Fiberglass has strong resistance to impact and abrasion due to its polymer structure, thus it is ideal for core components of the rocket. Since the motor exerts large forces upon ignition, it is crucial that the centering rings keep the motor from shooting up through the rocket's airframe.

3.1.10 Mass Budget

All mass values are as measured for flight or flight identical components as used in the construction of the prototype model which was launched on January 5th, 2013. These values were all verified to be in accordance with previous estimations used for preliminary modeling presented in the PDR.

Table 11 Eclipse Mass Budget

Component	Weight	Units
Nose Cone	0.94	lbs
Forward Body Tube	1.25	lbs
Main Parachute + Hardware	1.63	lbs
Recovery Bay	1.60	lbs
Forward Airframe Total Weight	5.41	lbs
Drogue Parachute + Hardware	1.21	lbs
Aft Body Tube	3.06	lbs
Fins (4)	1.00	lbs
Motor	3.661	lbs
Payload Bay	0.66	lbs
Payload Hardware	0.28	lbs
Aft Airframe Total Weight	9.87	lbs
Total Launch Weight	**15.28**	**lbs**

Consideration was taking during aerodynamic and structural design to ensure sufficient mass margin to allow for adjustments to system configurations while maintaining a static margin of at least one caliber and a thrust to weight ratio of at least 5:1.

The current thrust to weight ratio and maximum allowable mass increase to maintain a 5:1 thrust to weight ratio is presented in Table 12. Although the aft airframe weight is not expected to increase, the mass margin is sufficient to allow for the addition of ballast weight to the nosecone if needed to maintain the static margin.

Table 12 Thrust to weight ratio

Average Motor Thrust (Aerotech K513FJ-M)	125.18	lbf
Total Launch Weight	15.28	lbf
Thrust to Weight Ratio	8.19	lbf
Maximum allowable mass (5:1 T:W Ratio)	25.04	lbf
Mass Margin	9.76	lbf
Allowable Percent Increase	63.88	%

3.1.11 Manufacturing Practices and Workmanship to ensure mission success

To ensure precise and effective manufacture and assembly of the final launch vehicle and payload the following guidelines were developed. Adherence to these guidelines are considered essential to prevent unexpected component failure and ensure all systems operate as designed. Proper assembly techniques mitigate risk due to unexpected component failures thereby helping to ensure mission success. Any deviation from these guidelines will be assessed and discussed within the FRR. Guidelines regarding personnel safety and potential health hazards associated with the manufacturing and handling of rocket components will be included in the safety and environment section.

Structural Assembly

-Care will be taken to ensure no foreign contaminants such as oils or residues come into contact with any structural components, especially fiberglass as it could result in modification of material properties and lead to material failure.

-All surfaces to be epoxied will be adequately prepared in accordance with manufactures instructions including but not limited to

-Cleaning and drying of the surface

-Roughing or scoring of the surface to promote adhesion

-Care will be taken to ensure that no sharp or foreign objects scratch, score, ootherwise modify any component of the structure during assembly or storage as this could create a fracture point leading to material failure

-Use of all epoxies will be in accordance with manufacturers specification regarding ambient temperature, and humidity. Care will be taken to ensure no epoxied components are disturbed until after the specified cure time.

Aerodynamic Assembly

-Care will be taken to ensure that all external glue surfaces, such as fillets along fin connections, are made consistently and smoothly as to prevent the creation of excessive or unbalanced drag on the rocket. This may require sanding of fillet after the epoxy has fully cured.

Propulsive Assembly

-Care will be taken when assembling the motor and any other propulsive components to ensure conformance with all manufacturer instructions. Particular attention will be paid to the use of all O-rings and seals to ensure they are properly greased in accordance with specification.

-Care will be taken to ensure the ignition charge is correctly placed within the motor when installed on the launch stand. The ignition charge wires will be carefully connected to the launch system to ensure reliable electrical connection and prevent misfires or improper ignition.

Recovery System Assembly

-Care is to be taken during the folding and insertion of the parachutes into the body tube to ensure reliable deployment. Specific parachute folding instructions will be included within the FRR and all recovery system operations should be performed under the supervision of the team's NAR level three certified mentor.

-Care is to be taken during the assembly of black powder ejection charges to ensure the correct quantity of black powder is included and minimize the chances of charges opening or falling apart due to vibrational or accelerative forces during launch. All ejection charge assembly should be performed under the supervision of the team's NAR level three certified mentor.

-Care will be taken in the assembly of all recovery system electronics to mitigate the risk of failure due to vibrational of accelerative forces encountered during launch. Furthermore, all static ports will be checked for correct sizing and adequate flow (no clogged ports) to ensure pressure based altitude measurements are performed correctly.

Payload and Electronics Assembly

-Care will be taken to ensure all functional components of the payload system are properly secured and assembled to prevent failure due to vibrational, accelerative, or impact forces encountered the vehicles flight.

-Care will be taken to prevent against any contamination of the sensors, (i.e. foreign substances obstructing the solar irradiance sensors lens) that could lead to incorrect or inaccurate measurements.

-Care will be taken in all electronics assembly to ensure proper wire connection and soldering procedures to reduce risk of failure due to corrosion, vibration, or thermal cycling.

3.2 Subscale Flight Results

To test the validity of the design proposed and ensure compatibility between all functional components of the launch vehicle, a prototype model was constructed and launched under vehicle and atmospheric constraints designed to approximate those specified within the NASA USLI handbook. A comparison between the prototype model as launched and the final design is presented below. Results obtained are considered successful and validate the proposed design.

The test launch of the prototype model satisfies USLI Handbook requirement to complete functional testing prior to the submission of the CDR. Although physically the same dimensions and weight configuration, the prototype model only featured simplified and lower-cost versions for certain functional systems in order to minimize losses in the event of a recovery failure. Furthermore, no payload was included. Investigation revealed that there was neither functional advantage nor significant cost savings achievable by the use of a physically smaller prototype, thus a full size launch vehicle was employed.

Aerodynamic Design

- The aerodynamic design of the prototype model was configured to exactly match that of the final launch vehicle as currently designed. All exterior physical dimensions were identical to those chosen for the final design. A summary of the specific aerodynamic design elements that were incorporated in the prototype model is presented in
- Table 13 below.

Table 13 Changes between prototype and full scale designs

Element	Prototype vs. Full Scale Design
Fins	Identical
Forward body tube	Identical
Aft body tube	Identical
Recovery Bay/Tube Coupler	Identical
Boat Tail	Identical

Structural Design

- The structural design of the prototype model was configured to exactly match the final launch vehicle as currently design with the following exceptions.
- On the prototype model fins were attached to the main body tube using FIX-IT epoxy clay. The final launch vehicle will use West Systems 105 epoxy thickened with colloidal silica filler.

Propulsive Design

- The propulsive design employed for the prototype launch vehicle is identical to that which will be used for the final launch vehicle. It will use an Aerotech K513FJ-M solid fuel motor housed within a standard reusable casing.

Recovery System Design

- The recovery system design employed for the prototype launch vehicle is identical to that which will be used for the final launch vehicle with the following exceptions. All parachute deployment altitudes were configured to be identical to those of the flight launch vehicle design.

- No redundant altimeter was included. Thus the Raven3 was the only altimeter onboard.

Payload Design

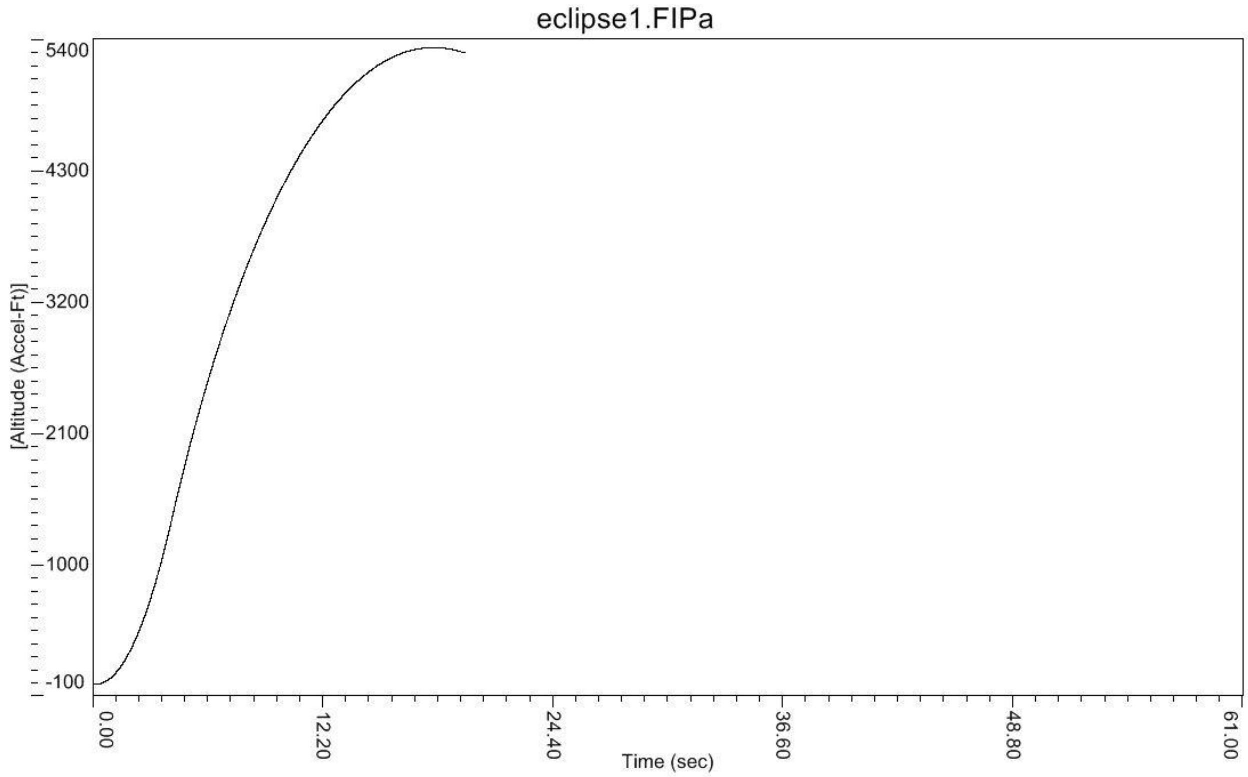
- A functional payload was not included in the prototype launch vehicle. A payload bay incorporating a predicted mass for the final payload design was included, thus conforming with all structural and mass parameters of the final launch vehicle design.

3.2.1 Prototype Launch Conditions vs. ULSI Specified Conditions

- The launch conditions were ensured to meet the launch criteria specified within the USLI handbook. The launch took place on a NAR approved range and the rocket was ignited using a standard 12v launch system.
- The measured wind speed was 10mph, thus within the USLI handbook specified conditions.

3.2.2 Prototype launch results

The following graphs illustrate the data recorded by the featherweight Raven3 altimeter during the prototype vehicle launch.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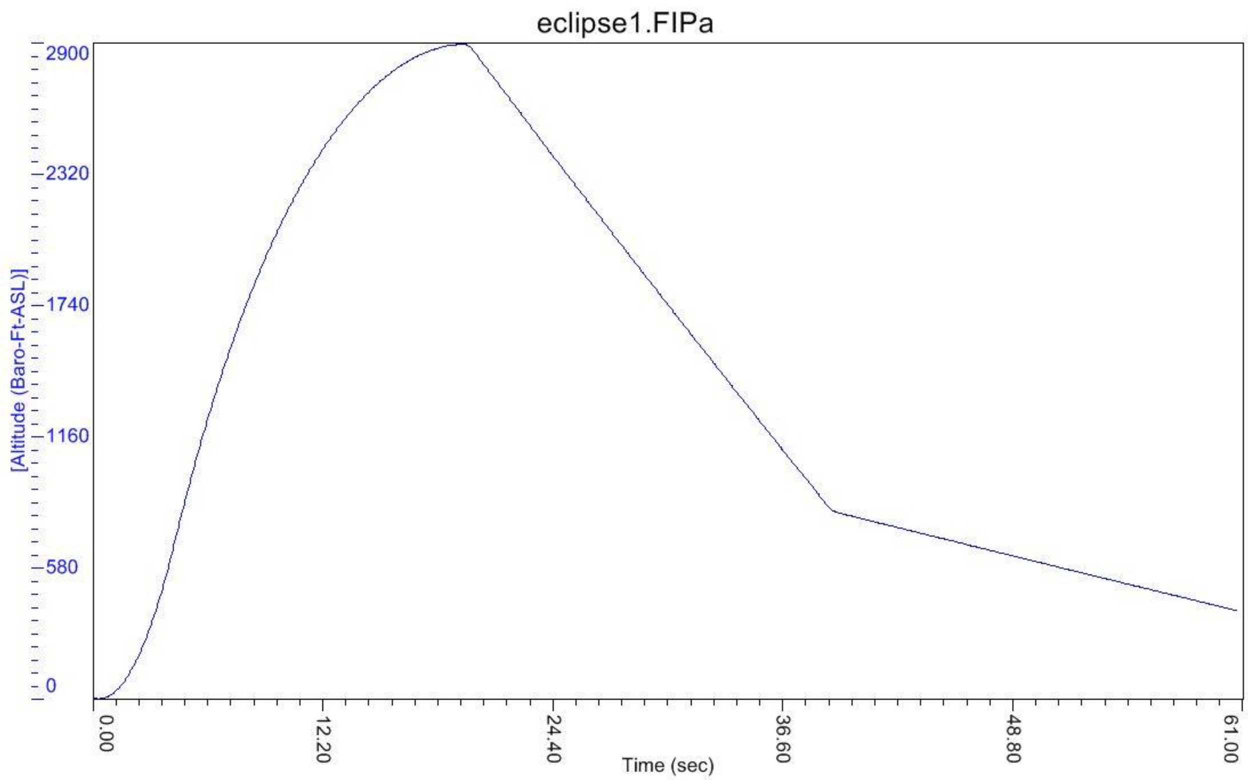
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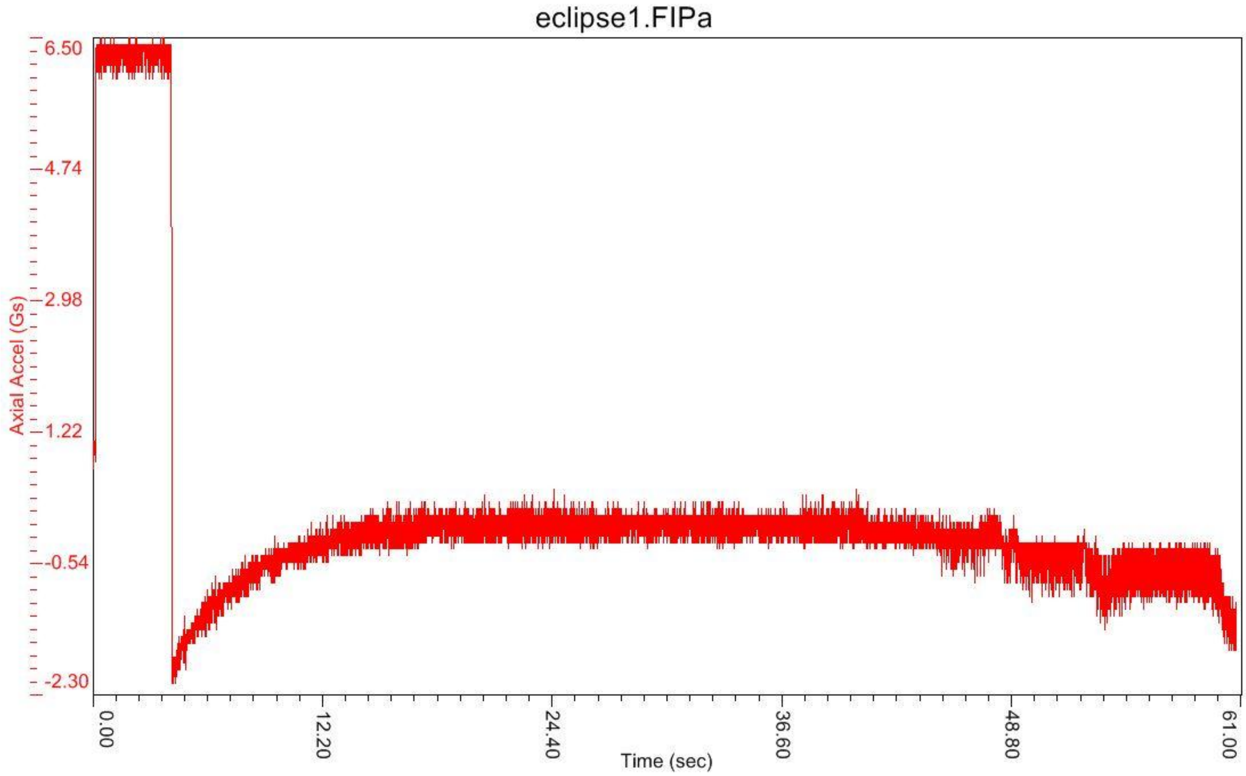
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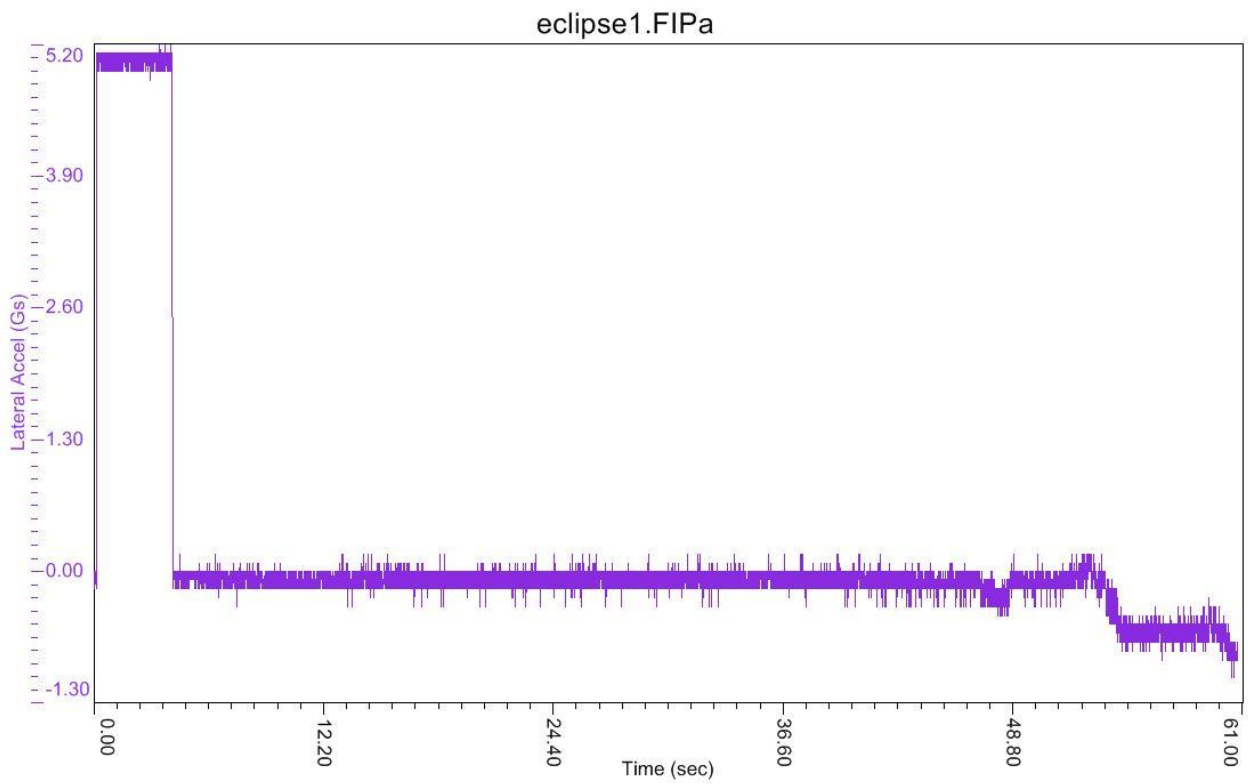
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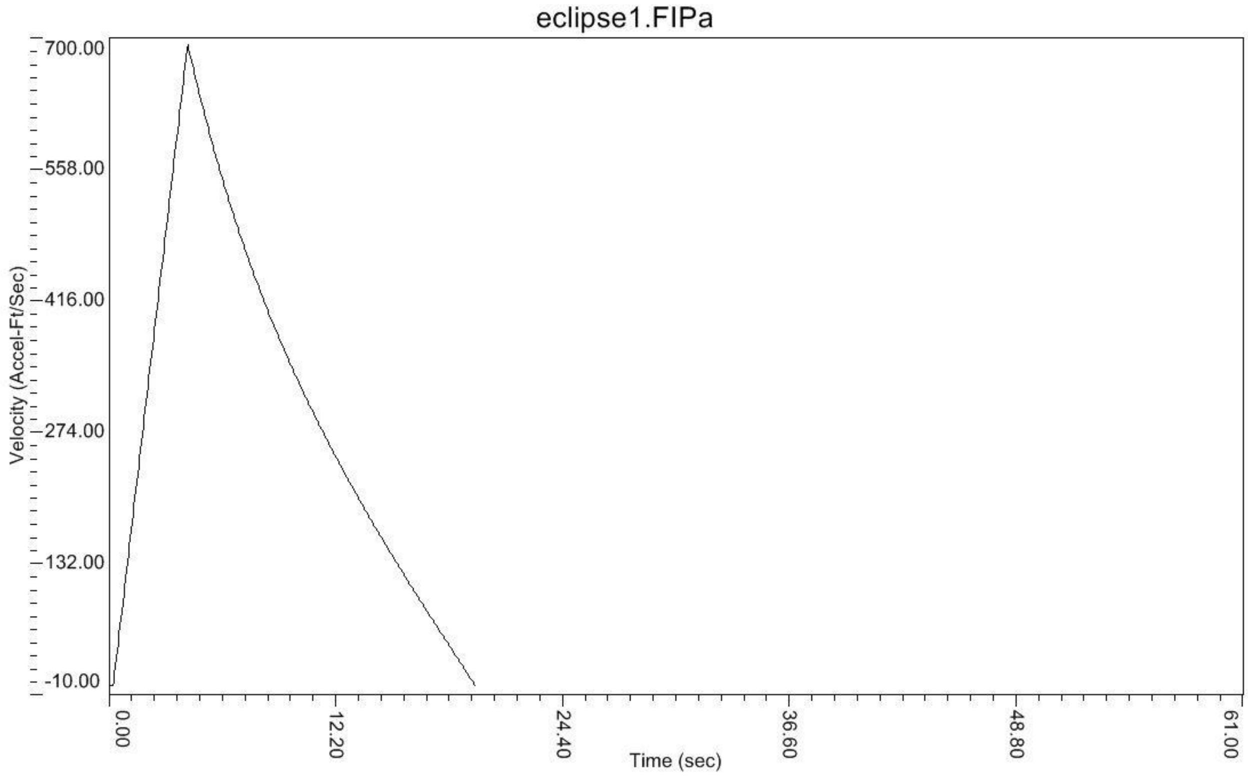
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Time (sec)

3.2.3 Prototype launch assessment

Aerodynamic System Assessment

- The aerodynamic systems functioned exactly as designed with the rocket maintaining stable flight and no aeroelastic instabilities were observed. Prior to launch a field test of the center of gravity with the motor installed confirmed the predicted CG location and an acceptable static margin.

Propulsive System Assessment

- The propulsive system performed as expected, properly igniting and carrying the rocket to an apogee of approximately 1 mile high.

Structural System Assessment

- The structural systems performed sufficiently, although non-critical failures required field repairs and have led to reevaluation of certain minor design elements. These failures and their resulting corrective actions are as follows.
- During pre-launch ejection charge testing, a fiberglass bulkhead supporting the recovery bay was separated from the bay due to an epoxy failure. The epoxy used was a 5-minute variety and the surfaces it was applied to had not been adequately prepared. Field repairs were made that performed acceptably through the launch, and as a future mitigation a stronger epoxy has been specified for the final launch vehicle and specific instructions regarding surface preparation and application have been formulated.
- On landing impact to one of the fins caused failure of the epoxy clay securing it to the main body tube and lead to separation. Analysis concluded that this was a secondary effect caused by a recovery system failure that did not deploy the main parachute. As a result the landing velocity exceeded the design specifications and produced excessive forces on the fin. In addition to reassessment of the recovery system, a stronger epoxy and precise surface preparation instructions have been created will mitigate the risk of fin separation even during hard landings.

3.2.4 Recovery System Assessment

Prior to the launch of the prototype launch vehicle ground tests were performed on the recovery system to ensure and optimize their performance during the flight test. These tests configurations and their results are presented as follows.

Ground Testing

To determine how much FFFFg black powder is needed to break the shear pins connecting rocket sections and separate the components, several ground tests were determined. First, 1 gram of black powder failed to separate the aft body tube from the altimeter bay coupler and release the drogue chute. On the second attempt, 2 grams of black powder successfully separated the aft body tube and released the drogue. Two grams of black powder also successfully separated the nosecone from the forward body tube and released the main chute.

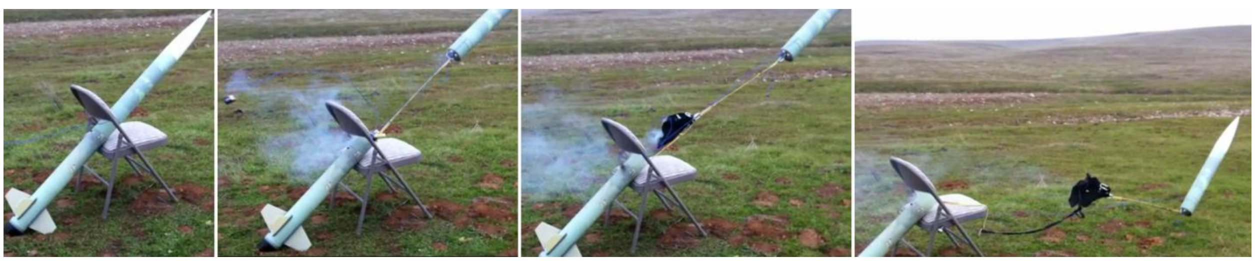


Figure 4 Ground test of drogue chute release

Figure 5 Ground test of nosecone separation and main chute release

Ground tests were also run to ensure the Raven 3 altimeter was programmed correctly. The Raven was connected to a computer and put through a simulated flight program to see if the Raven would fire the ejection charges at the right moments. LED lights were connected to the e-match terminals and all lights flashed on at the correct moments indicating the Raven was programmed correctly, in working condition, had a solid connection and that the e-match terminals are in working condition.

Flight Testing

A flight test was conducted with the Raven 3 altimeter. The StratoLogger altimeter was unavailable at the time of the flight test. The Raven 3 was programmed to use accelerometer apogee detection and to fire the main chute ejection charges at 832 ft so that the main chute could be fully deployed around 800 ft. The Raven 3 fired the drogue ejection charges and deployed the drogue chute at apogee as expected. Data from the Raven 3 shows that it fired the main ejection charges at 832 ft and the nosecone separated as programmed, however, the main chute did not deploy. The backup ejection charge fired but the chute still didn't deploy. After a post-flight investigation, it was determined that the main chute didn't deploy because of poor placement of the ejection charges, not because of the Raven 3 performance. During ground tests, the main ejection charge was placed behind the main chute just in front of the altimeter bay bulkhead in the forward body tube. After testing the main ejection charges, the altimeter bay bulkhead seal broke (Figure 6 Broken altimeter bay bulkhead after first black powder ground test) and a very small amount of ejection charge gasses entered the altimeter bay.

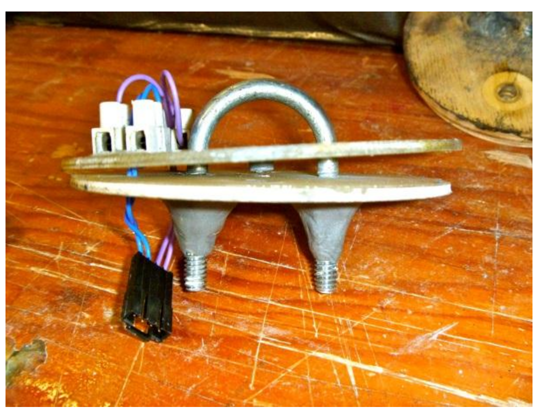


Figure 6 Broken altimeter bay bulkhead after first black powder ground test

The seal was held together with 5-minute epoxy. To avoid further damage to the altimeter bay bulkhead and potential damage to the altimeter itself, the ejection charges were placed near the nosecone bulkhead for the flight test. When the main chute ejection charge went off during descent, the blast separated the nosecone as expected but because it was between the nosecone and the chute, it also pushed the chute into the body tube. The backup ejection charge further compacted the main chute into the forward body tube. For the final ejection charge configuration, the main chute ejection charges will be placed between the main chute and altimeter bay bulkhead. In addition, the altimeter bay bulkhead seal will be glued together with west systems epoxy with colloidal silica instead of 5-minute hobby shop epoxy. The results from the post-flight test analysis revealed potential causes of recovery failure that were not considered prior to the test and allowed for changes to our final design that will increase the robustness and reliability of the design. Although the main chute didn't deploy, the Raven 3 performance was a success. Another recovery system flight test is scheduled to be completed by March 2013 that will include the StratoLogger with the Raven 3 in their final design configuration.

3.3 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.

3.3.1 Parachutes

The main parachute is the Iris Ultra 72'' made by Fruity Chutes. It is made out of rip stop nylon and has a rated descent rate of 20 fps for a 28 lb load. The Eclipse + casing weighs 12.63 lbf so we expect a slower decent rate. The shroud lines are 400 lb braided nylon and its connection point to the recovery harness is a 1500 lb swivel. The main parachute will be protected from the ejection charge gasses by a deployment sleeve and a nomex reusable fireproof parachute protector.

The drogue parachute is the Classic Elliptical 18'' made by Fruity Chutes. Flight data from the Raven 3 altimeter test flight shows the drogue had a descent rate of 106 ft/s. The shroud lines are 330 lb braided nylon and its connection point to the recovery harness is a 1000 lb swivel. The drogue parachute will be protected from the ejection charge gases by a nomex reusable fireproof parachute protector.

3.3.2 Harness

The recovery harness tethers all of the rocket components together and helps absorb the energy of the components as they separate after chute deployment. The harness is split into two sections. The first section tethers the aft body tube + payload, the drogue chute + nomex chute protector and the altimeter bay coupler + forward body tube and nosecone. The second section tethers the altimeter bay coupler + forward body tube, the main parachute + deployment sleeve and nomex chute protector, and the nosecone.

The first section of harness consist of a pre-sewn 2ft long ½'' Kevlar harness that attaches to a u-bolt on the payload bay bulkhead (that's located in the aft body tube) via a quicklink connector. This section of Kevlar is connected to 15 ft of pre-sewn nylon harness via a quicklink connector. The 15 ft of nylon is attached to another segment of pre-sewn 2 ft long ½'' Kevlar via a quicklink connector. The final attachment point of the first section of harness is the Kevlar to the u-bolt on the altimeter bay bulkhead via a quicklink connector.

The second section of harness consist of a pre-sewn 2 ft long ½''Kevlar harness that attaches to a u-bolt on the altimeter bay bulkhead via a quicklink connector. This section of Kevlar is connected to 12 ft of pre-sewn nylon harness via a quicklink connector. The nylon harness terminates in the nosecone where it is attached to the u-bolt on the nosecone bulkhead via a quicklink connector.

Figure 7 Recovery system attachment scheme

All nylon segments are pre-sewn 11/16'' climbing grade, 3,000 lb, nylon. All u-bolts are ¼'' zinc-plated steel that are attached to bulkheads by securing them with nuts and west systems epoxy with colloidal silica to ensure a permanent connection. All quicklink connectors are 9/32'' zinc-plated 1,000 lb steel.

Instead of using Kevlar for the full length of the harness, it is used in 2 ft long segments in locations where the harness will be exposed to ejection charge gasses. Climbing grade nylon was used for the remaining sections because its location allows it to be protected by either a nomex chute protector or a deployment sleeve and because nylon takes up less volume compared to Kevlar. Also, nylon is less expensive compared to Kevlar so it is more cost effective to only use Kevlar in segments that will be exposed to ejection charge gasses since Kevlar is heat resistant. Another added benefit of using segments of nylon is that nylon is more shock absorbing compared to Kevlar so it will relieve some stress on our bulkhead attachment points. Both segments of harness were designed to be as long as possible to allow the rocket components more time to decelerate after separation, thus reducing the force exerted on the bulkheads and points of attachment.

To prevent the recovery harness from tearing through the body tube in the event of a mistimed drogue deployment or during the main chute deployment, layers of guerilla tape are wrapped around the harness sections that will come into contact with body tube edges. These layers of tape will help spread the load over a larger area and ensure that the harness will not tear.

3.3.3 Altimeters

The altimeters record flight data such as altitude, pressure, axial and lateral acceleration, flight duration time, velocity and temperature as well as ignite electrical matches that detonate ejection charges. The main altimeter is the Raven 3 made by Featherweight Altimeters and the redundant altimeter is the StratoLogger made by PerfectFlite (**Error! Reference source not found.** and Figure 9 respectively).

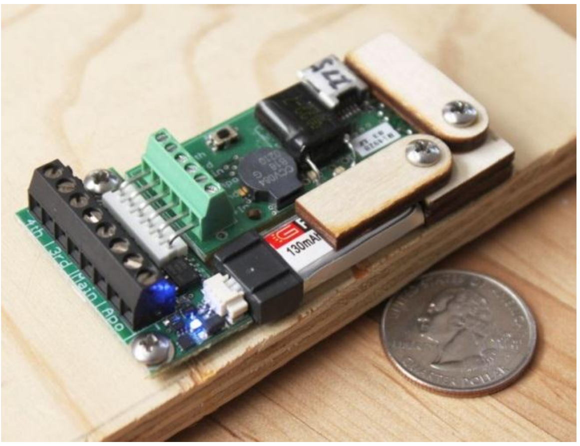


Figure 8 The Raven 3 main altimeter from Featherweight Altimeters

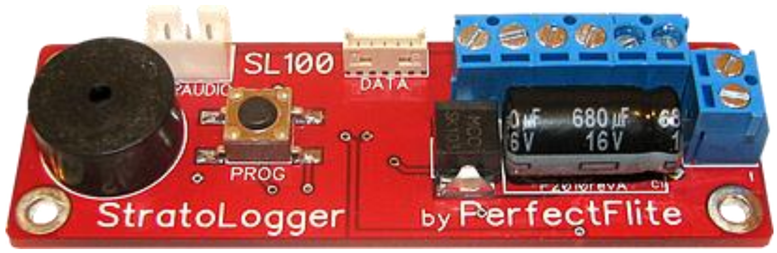


Figure 9 The StratoLogger backup altimeter from PerfectFlite

The Raven is programmed for accelerometer apogee detection and an apogee time delay will be set for the StratoLogger to avoid over pressurization and large loads on the recovery harness attachment points.

Main chute deployment is programmed for 832 ft for the Raven and the StratoLogger can be programmed in 1 ft increments to fire after the Raven to avoid over pressurization. The altimeters and the recovery system wiring diagram is shown in Figure 10.

The Raven is powered by one 3.7 V LiPo battery and is armed from the exterior of the body tube when the rocket is in the final launch configuration on the launch pad by a magnetic arming switch. The StratoLogger can also be armed in the same configuration by a screw switch and is powered by one 9 V battery. The altimeters are the only electronic components in the altimeter bay so they are shielded from all onboard transmitting devices.

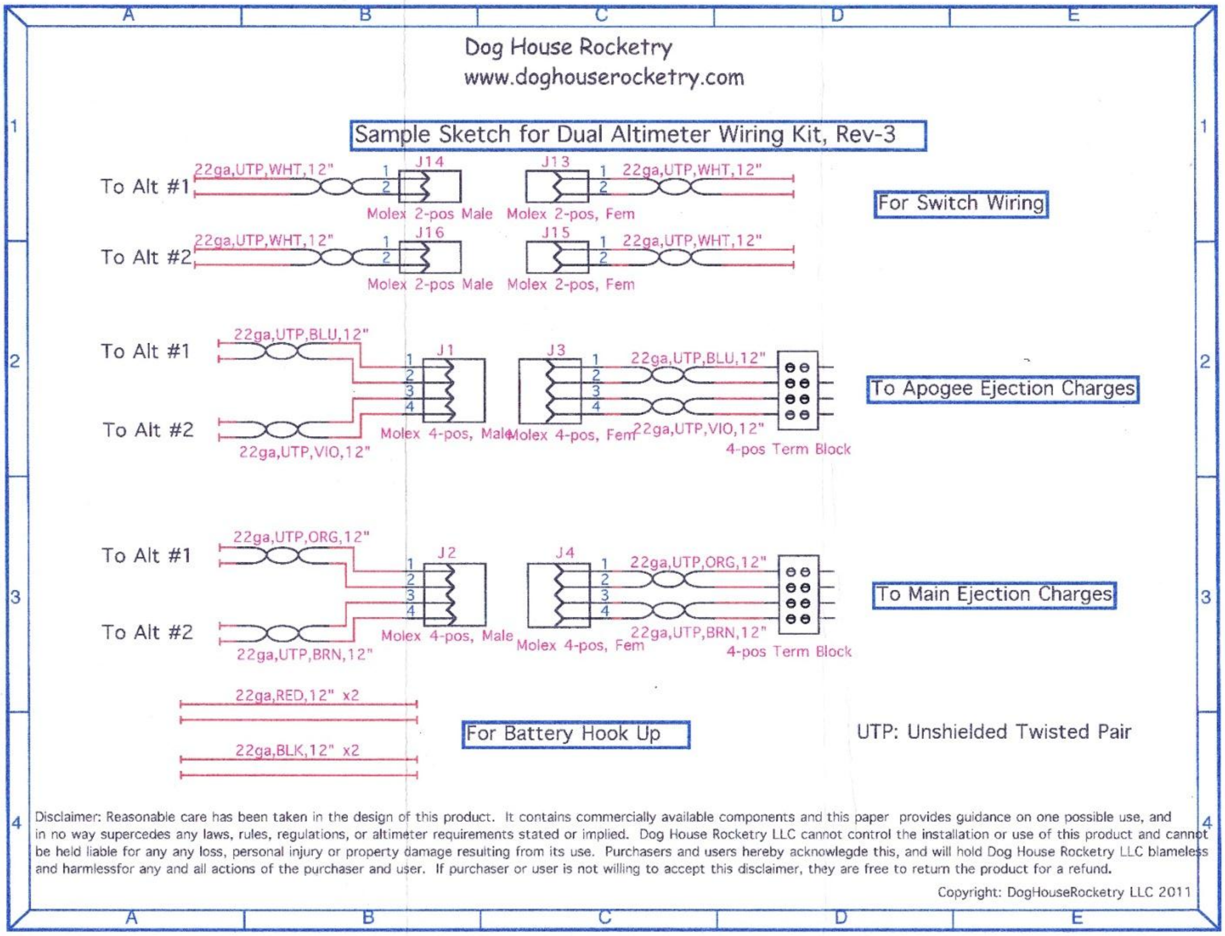
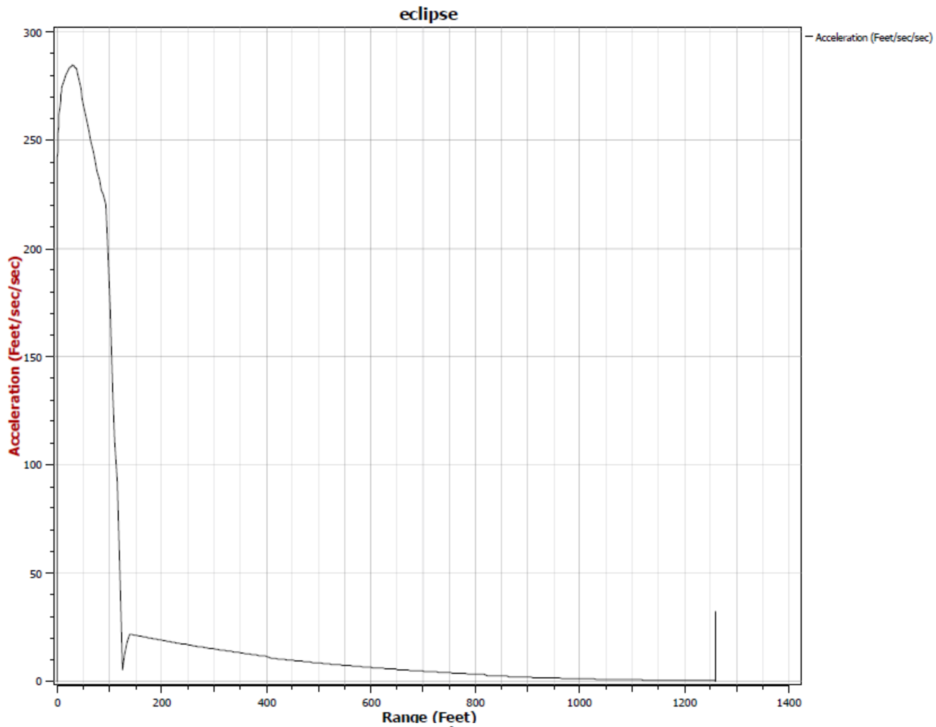
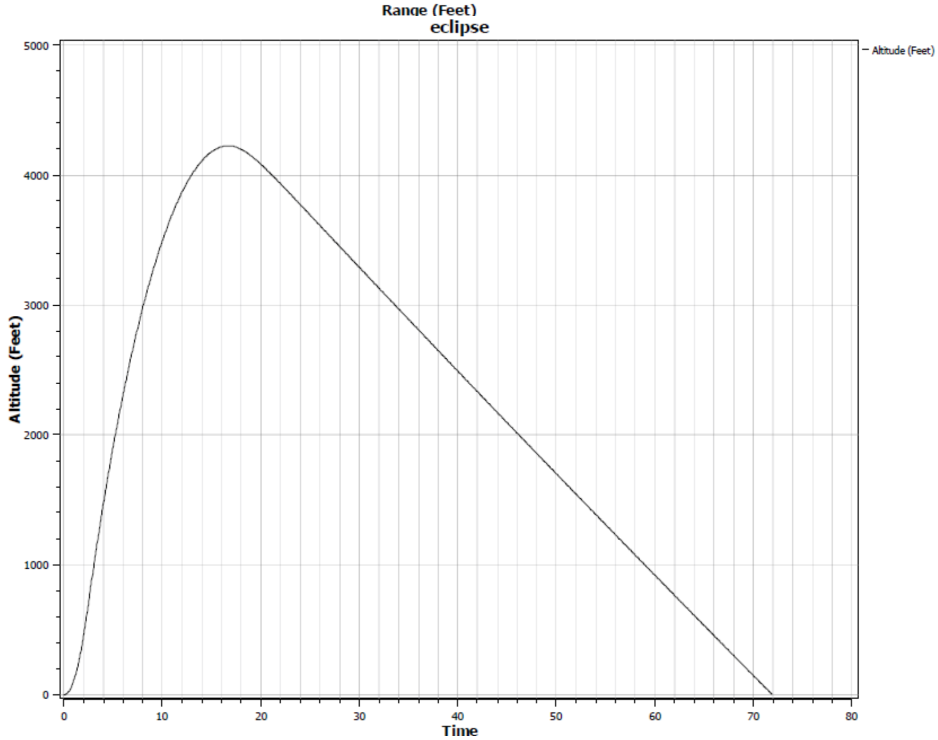


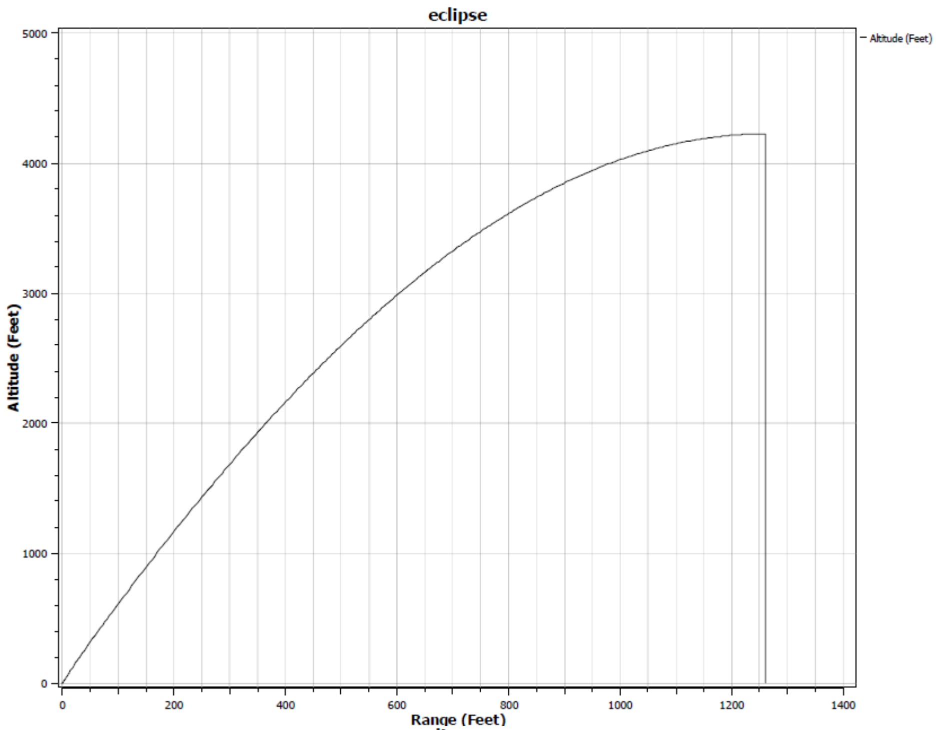
Figure 10 Recovery system electronics wiring diagram

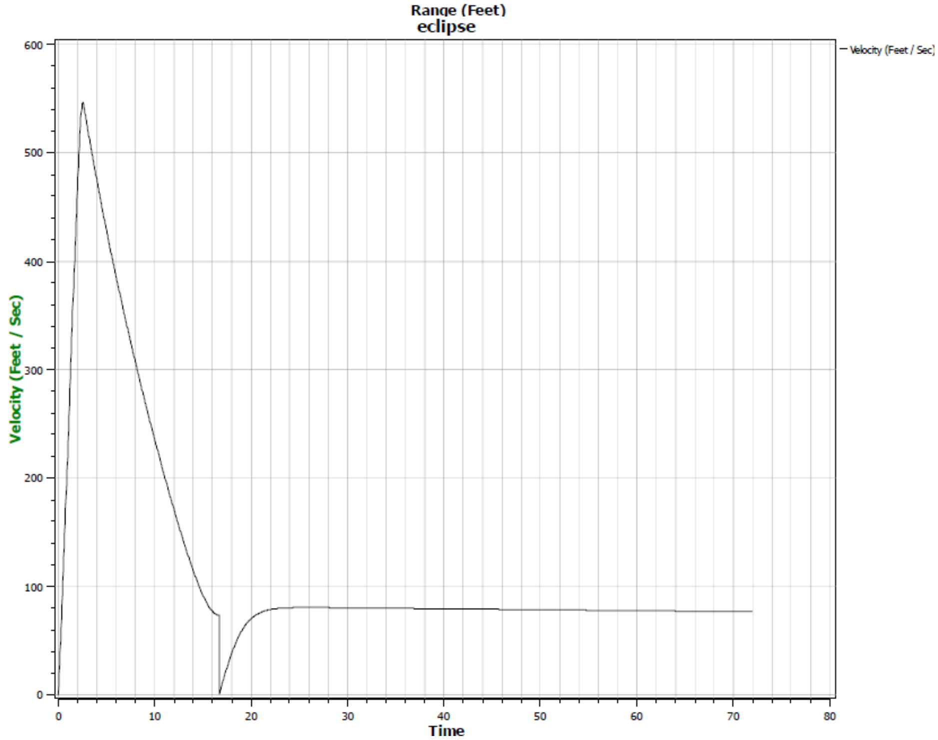
3.4 Mission Performance Predictions

Best Case Scenario: 0 MPH Crosswind:

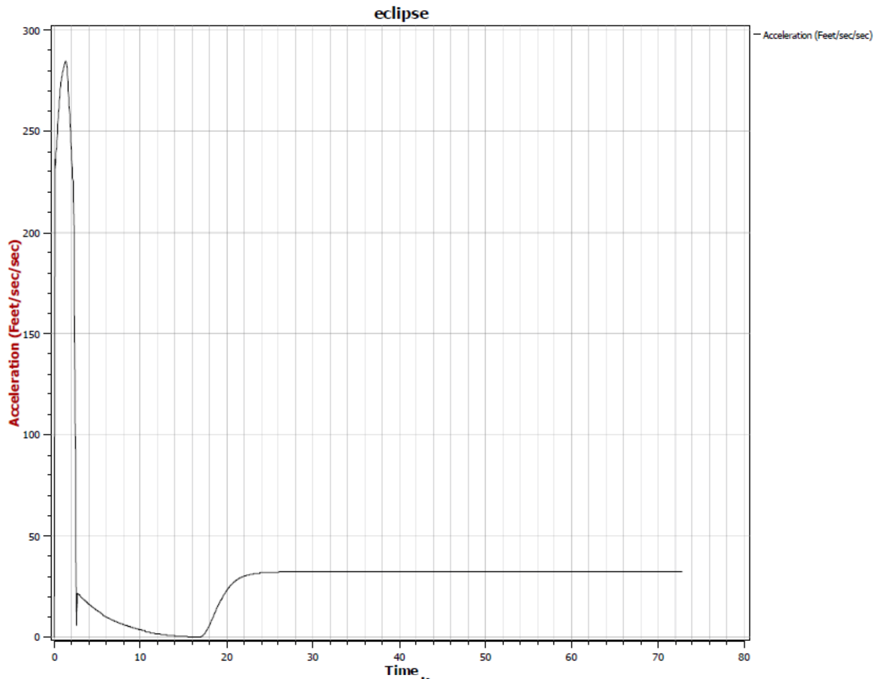


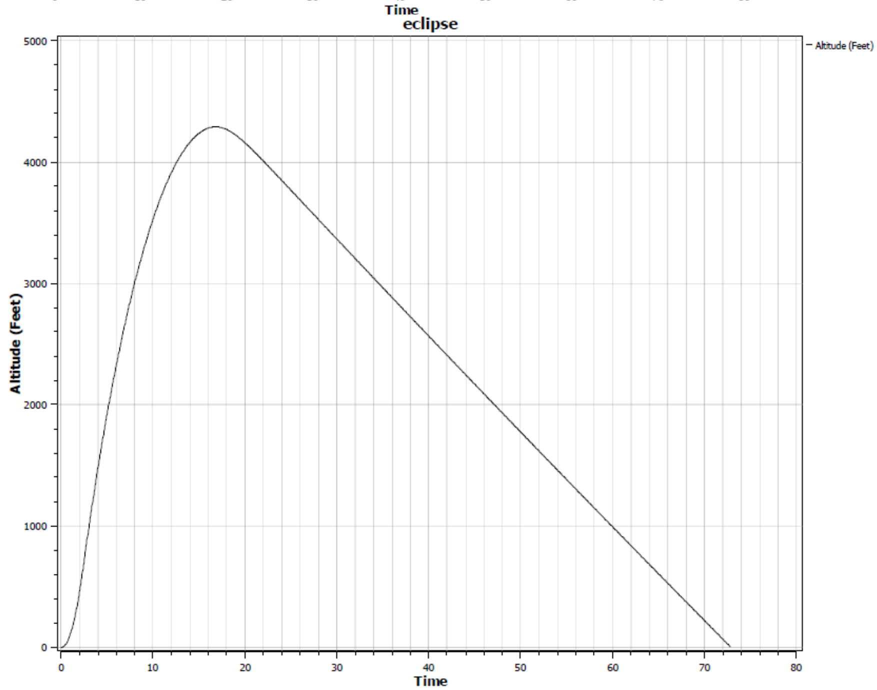



eclipse
Altitude (Feet)
Range (Feet)
Altitude (Feet)
0
1000
2000
3000
4000
5000
0
200
400
600
800
1000
1200
1400

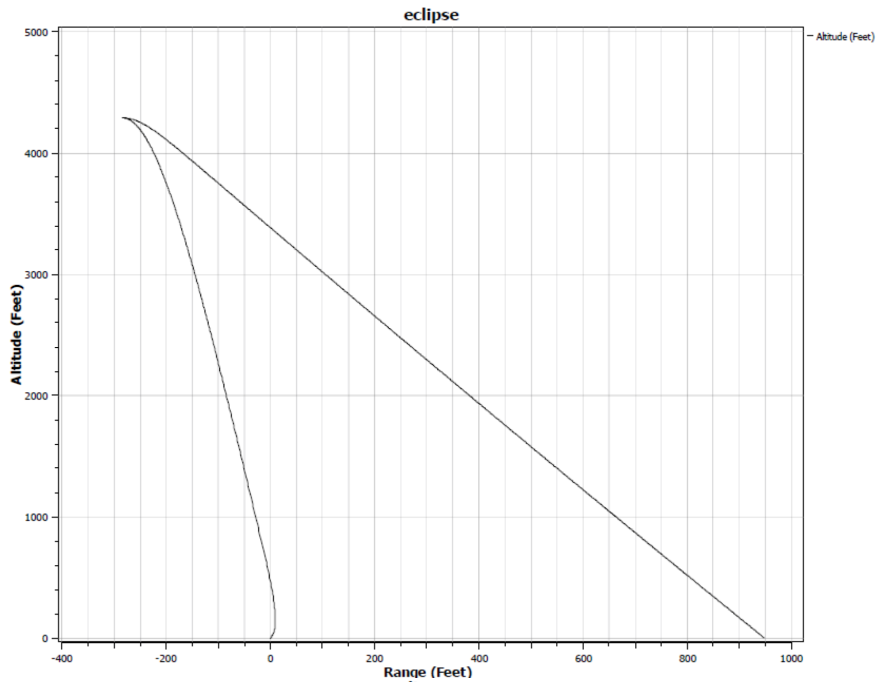

eclipse
Velocity (Feet / Sec)
Time
Velocity (Feet / Sec)
0
100
200
300
400
500
600
0
10
20
30
40
50
60
70
80

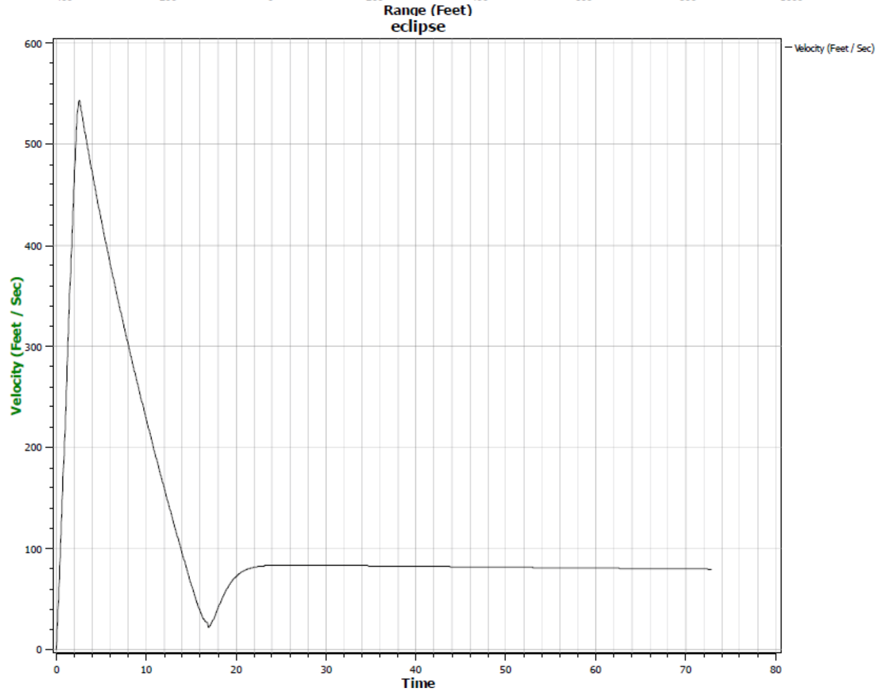
Worse Case Scenario: 15 MPH Crosswind:





ECLIPSE
University of California, Davis
http://mae.ucdavis.edu/~rocket


eclipse
Altitude (Feet)
Range (Feet)
- Altitude (Feet)


eclipse
Velocity (Feet / Sec)
Time
- Velocity (Feet / Sec)

3.5 Payload Integration

The following describes the ease of integration of Eclipse:

- The payload bay will located between the drogue parachute and above the motor casing. The drogue chute will be attached to the U bolt on the forward bulkhead of the payload bay through a quick link. As a result of this integration procedure, the payload bay will be sustaining loads during the drogue chute separation stage, as well as the descent stage of the rocket through the drogue chute.
- The payload bay electronics are self-contained, and no electronics will be powered by, or interacting with, any of the rocket outside of the payload bay.
- The payload bay will be held in the rocket using 3 equidistance (120 degree separation) screw and weld nuts. The weld nuts will be epoxied inside the bay itself, allowing for the easy removal of the screws from the exterior of the rocket casing.
- The payload bay and drogue chute interface will be sealed with plumber's putty to seal off the rocket from the black powder discharge gases.
- The bay can be easily installed and removed by hooking/unhooking the drogue parachute quick link, and unscrewing the 3 exteriors screws on the rocket casing. Afterwards, the bay can be pulled out of the casing by pulling on the forward bulkhead's U-bolt.
- Within the payload bay, all of the sensors are compatibility with the ArduPilot analog inputs, and the data will be compiled and sent through the same serial data stream from the 3DR radio transmitter, which is also compatibility with the ArduPilot. Even further, the 9V lithium battery will power all of the analog and digital I/O pins, and is compatible with the ArduPilot.
- The payload bay electronics being isolated from the rest of the rocket adds simplicity to the integration procedure. Even further, the 9V lithium battery will be off the shelf, and will not require special chargers such as those for lithium-polymer batteries, allowing for the powering of our payload electronics much easier, therefore making the entire electronics integration process much simpler as well.

3.6 Launch Concerns and Operation Procedures

See Appendix section 7.2 for detailed checklist of launch preparation.

3.7 Safety and Environment (Vehicle)

Alejandro Pensado Valle is the Safety Officer for SpaceED Rockets. He is knowledgeable and has prior experience with rocketry. He will provide oversight over the final construction of the rocket.

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 17 and Table 18.

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 14 General risk and mitigation

Risk	Probability	Impact	Mitigation
Funds are not available to purchase project Supplies	Medium Probability	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	Medium Probability	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	Low Probability	Rockets could not be tested by the team and must be tested by a hired qualified individual	Work with our mentor, Steve, who has level 3 certification.

Table 15 Hazards 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
Fiberglass	Respiratory and skin irritation	Wear a respiratory mask, gloves, and clothes 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
Misuse of equipment (Drill press, mill, etc.)	Injury of a student	All individuals planning to use equipment must go through safety procedures beforehand.

3.7.1 Failure Modes

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

Table 16 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 fiberglass tube.
Failure mode 2	Main parachute does not deploy and rocket cannot be recovered successfully.
Mitigation 2	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 3	System which ignites the rocket fails and the rocket cannot be ignited.
Mitigation 3	Make sure that the ignition system has been tested and there is current traveling to the igniter.

Table 17 Failure Modes and Effects Analysis of Propulsion System

Function	Potential Failure Mode	Impact	Mitigation
1	Ignition Failure	Reset ignition charge	Make sure ignition system is tested and working prior to launch
2	Combustion Instability	Rocket will not exert a constant thrust	Assemble motor under the direction of our qualified mentor
3	Nozzle Failure	Rocket will not have constant thrust and the direction of thrust could change	Inspect nozzle for deformations and for manufacturing
4	Case Burst	Mission could not be completed	Check nozzle, casing, and bore for defects before flight

Table 18 Failure Modes and Effects Analysis of the Payload

Function	Potential Failure Mode	Impact	Mitigation
1	Arduino Pilot is not powering on	Payload mission cannot be completed	Ensure robust power supply system
2	Malfunctioning transmitter	Data cannot be acquired during flight	Test the transmitter before flight at the distance of 1 mile
3	G-force and vibration damages	Data cannot be acquired during flight	Carefully secure all wires and compoenents
4	Sensor saturation	Usable science data is limited	Test all sensors across operating range prior to launch

Table 19 Payload Integration failure modes

Failure mode 4	Batteries on board do not deliver current.
Mitigation 4	Make sure the battery is charged and delivers current before installing it with the electronics.
Failure mode 5	Electrical wires happen to shear and cause avionics and payload to malfunction.
Mitigation 5	Make sure all electrical wires are in good health, they are free of any scrapes or cuts before every launch

Table 20 Failure Modes and Effects Analysis of Structure

Function	Failures/Risk	Impact	Mitigation
1	Young's modulus of fiberglass decreases with an increase in temperature	Material strength becomes compromised, leading to structural failure of the rocket	Make sure the motor temperature does not exceed 200 degree Fahrenheit as this will lead to a 50% reduction in material strength
2	Failure due to load acting in a direction that is not parallel to the glass fibers	Structural failure upon takeoff since the rocket feels the most load.	Make sure the glass fibers are oriented in the direction of maximum loading.
3	Fiberglass gets contaminated/scratched	Comprises the structural integrity of the rocket.	During final assembly fiberglass should and will be handled with care
4	Booster section separates during upward ascent due to drag	Failure in rocket meeting goal	Add step in pre-flight checklist to ensure shear pins are attached.

Table 21 Failure Modes and Effects Analysis of Recovery

Function	Potential Failure Mode	Probability	Mitigation
1	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
2	Altimeter is not programmed correctly or is not calibrated.	Medium	Add steps to pre-flight checklist to ensure altimeter is calibrated and programmed correctly. To ensure altimeter is correctly programmed, run altimeter through test flight on computer and see if it powers the correct terminal connections at the correct time.
3	Ejection charges are not powerful enough to separate rocket.	Low	Perform ground testing to determine the amount of black powder necessary.

4	Failure of recovery harness attachment points	Medium	Test attachment points under a load to ensure they're strong enough. Apply epoxy to u-bolt threads. Use u-bolts and quick links to ensure a strong connection.
5	Power supply detaches and electronics fail	Low	Tightly secure batteries to electronics board.
6	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	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. Wind layers of guerilla tape around areas of harness that will come into contact with body tube edge.
7	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.
8	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.
9	Rocket drifts too far away or rocket drifts too far away and is lost.	High	Conduct detailed flight simulations using RockSim to accurately size parachutes, determine at which altitude to deploy the main, and predict drift for 15mph winds. Utilize a GPS transmitter.
10	Ejection charge gases damage terminal connections on altimeter bay bulkheads, any other part of bullheads or damage altimeters by entering altimeter bay.	High	Protect terminal connections by covering them with tape and fill all small openings leading into the altimeter bay with painter putty.

11	Ejection charge gases damage parachute or recovery harness	Medium	Carefully wrap drogue chute and nylon portion of harness in nomex chute protector. Carefully wrap main chute in deployment sleeve and in nomex chute protector. Use small sections of kevlar for the areas of the harness that are close to ejection charges.

Table 22 Failure Modes and Effects Analysis of Aerodynamics

Function	**Potential Failure Mode**	**Impact**	**Mitigation**
1	Instability at launch	Unpredictable rocket trajectory	Verify stability margin before launch
2	Fins coming off during launch/flight	Rocket becomes unstable	Inspect fins before flight
3	Fin damage due to landing impact	Rocket is not reusable for additional launches on the same day	Test recovery system before flight
4	Rocket drifts too far away	Disqualify the team	Conduct detailed flight simulation using RockSim to accurately size parachutes and predict drift for 15 mph winds. Perform flight tests under windy conditions to ensure recovery system works as designed.

Table 23 Launch Operations failure modes

Failure Mode 6	Not advising FAA of proposed high power rocket launch.
Mitigation 6	Make sure that FAA is advised about the area of launch and that they agree to clear the airspace.
Failure Mode 7	Not making sure that the area is large enough, and is clear of trees, for the high power rocket launch.
Mitigation 7	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 8	Not bringing a fire extinguisher in case the rocket happens to catch on fire before liftoff.
Mitigation 8	Make sure to bring several fire extinguishers to the site and make sure

	that they are all charged.
Failure Mode 9	Not installing an engine flare shield on the pad.
Mitigation 9	Make sure that there is a metal shield which will protect the grass or field from the flare of the engine.
Failure Mode 10	Not insuring that the launch gear is in good condition and launch control works properly.
Mitigation 10	Test the controller by using a volt meter across the two terminals which feed out of the controller.
Failure Mode 11	Not waiting 60 seconds after rocket has been activated for launch after a misfire.
Mitigation 11	Make sure to wait 60 seconds before touching the terminals from the launch control and disconnect the terminals while analyzing the problem.
Failure Mode 12	Having spectators too close to the launch pad.
Mitigation 12	Make sure that spectators are as far NAR rules permit and only certified Rocketeers are flying the rocket.

Table 24 Aerodynamic risk mitigation

Function	Failures/Risk	Impact	Mitigation
1	Instability at launch	Unpredictable rocket trajectory	Verify stability margin before launch
2	Fins coming off during launch/flight	Rocket becomes unstable	Inspect fins before flight
3	Fin damage due to landing impact	Rocket is not reusable for additional launches on the same day	Test recovery system before flight

3.7.2 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.

4. Payload Criteria

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 to measure solar irradiance, relative humidity and ambient temperature. 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.

4.1 Testing and Design of Payload Experiment

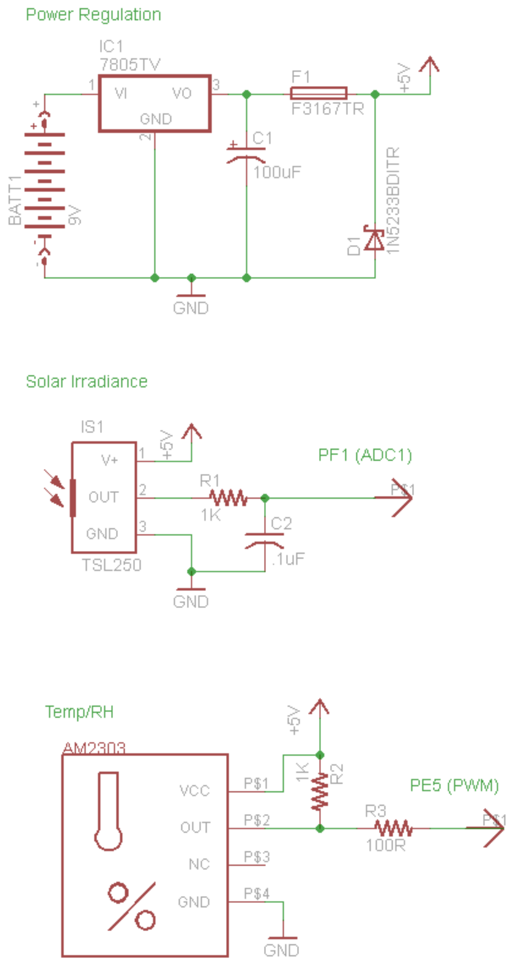


Figure 11 Payload power supply and external sensor connections

As stated, the payload data acquisition system is the based around APM 2.5 embedded system. Included on the APM 2.5 board is a Honeywell HMC5883L-TR digital compass, a 6-axis MPU-6000 inertial measurement unit (3 axis gyroscope + 3 axis accelerometer), and MS5611 barometric pressure sensor. An additional daughterboard which will be mechanically isolated from the airframe to reduce g-load exposure features a MediaTek MT3329 GPS module. All sensors will be sampled at a period of no more than 5 seconds. Analog sensors not mounted within the APM 2.5 board will also feature a hardware implemented low pass filter to reduce EMI interference caused by the wireless transceiver and other external noise sources.

Custom firmware running on the APM 2.5 board will assemble measurements from all sensors into discrete packets which will be both wirelessly sent to a ground station, and logged in onboard non-volatile memory. Wireless transmission protocols will be developed to feature redundancy and error checking, with the ability to resend any dropped packets using those stored in memory. The firmware will optimize the sampling rate of each sensor to allow for sufficient averaging and signal processing to remove noise and increase measurement fidelity.

A ground station will be implemented via the construction of custom software to receive and parse the wireless data transmitted from the rocket. The communication protocol implemented between the ground station and the rocket will feature sufficient redundancy to allow the extraction of all measured data from the rockets onboard nonvolatile memory in the event a packet is dropped or communication is temporarily interrupted. Data will be displayed as graphs and will be exportable in the form of a comma separate value list which can be used for subsequent post-processing in the preparation of the PLAR.

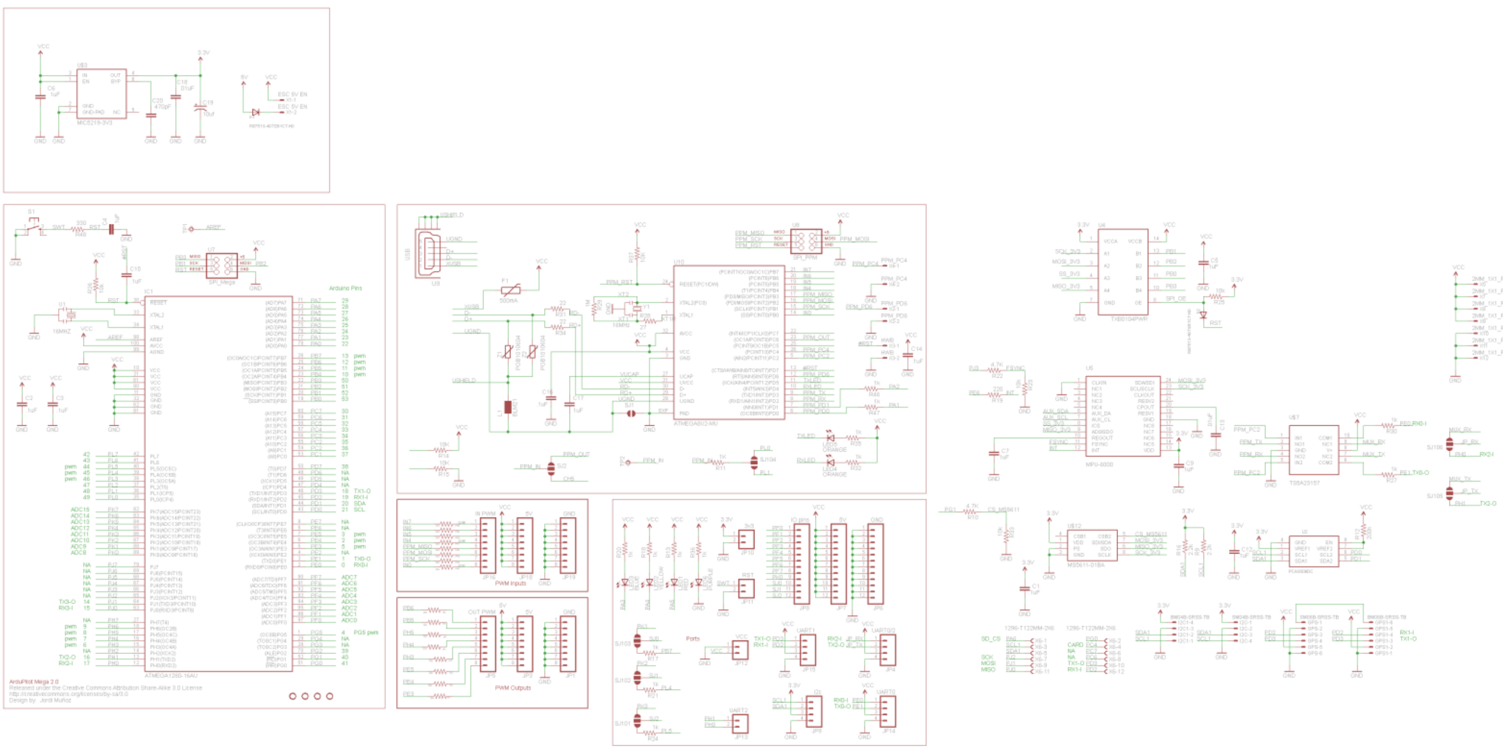


Figure 12 Schematic diagram for Payload electronics.

Since failures may occur due to a wide range of circumstances (i.e. loose wires, batteries dying, loss of radio transmission, g-force and vibration damages, and sensor saturation) carefully designed tests will be performed to evaluate the likelihood of each failure mode and implement necessary mitigation steps. These tests will include battery life testing, radio communication interruption, and sensor calibration across operating ranges. Mechanical failures such as loose wires and g-force/vibrational damages will be mitigated by carefully securing all components and isolation mounting of the GPS daughterboard. The effectiveness of these mounting systems will be evaluated during the full scale launch occurring prior to the FRR.

4.2 Payload Changes Made

a. Since the team did not receive funding from NASA to pursue the SMD option 3 payload, the team has selected to develop a modified version of the SMD payload, titled the Rocket Performance and Atmospheric Evaluation Module (RPAEM). This module will perform the following tasks:

    i. The RPAEM will measure atmospheric temperature, static pressure, relative humidity, solar irradiance, acceleration, angular velocity, and GPS location through all phases of operation (preflight, launch, ascent, descent, landing, and post-landing), with the following exception:

        1. Due to high velocities and accelerations, the GPS may not be able to maintain a satellite lock throughout launch and ascent. If this occurs, it will relock at or before landing and return to normal position sampling.

    ii. All measurements will be taken at least once every 5 seconds throughout all operation phases, unless the exception above holds true.

    iii. The data from the RPAEM will be both continuously transmitted to a ground station and logged in onboard memory. If wireless communications are interrupted any lost data will be retransmitted from the data stored in memory.

    iv. 1.3.1.4. The RPAEM will remain enclosed within the main body tube of the rocket throughout all operation phases, which will remain tethered to all other structural sections before, throughout, and after parachute deployment.

v. 1.3.1.5 The RPAEM will be configured in such a way to ensure data is recorded throughout all flight phases, and to ensure that data from all flight phases will not be lost or overwritten due to memory, power, or other electrical resource constraints.

b. The RPAEM follows the basic requirements defined by NASA for the SMD payload, with the following exceptions:

   i. The RPAEM will not measure ultraviolet radiation.

   ii. The RPAEM will not include a camera or possess photographic capabilities.

   iii. The sampling and data logging rates of the sensors within the RPAEM will not change or be adjusted in any phase of operation except by user commands sent from a ground station

c. Following launch all data and measurements obtained from the RPAEM will be scientifically analyzed and presented within the Post-Launch Assessment Review

d. The RPAEM will feature any form of UAV of separating module that becomes untethered or jettisoned from the rockets primary airframe.

e. The RPAEM will be implemented such that it can easily be reset and reused for subsequent launches within the same day, without any modification with the following exception

f. The RPAEMS primary battery may be replaced between launches depending on the total operating time of the RPAEM and estimated charge within the battery.

g. Battery replacement operations will be configured to require no more than one hour to perform

4.3 Science Value

The payload was designed to collect necessary science data to assess to measure atmospheric and solar incidence conditions as a function of altitude. The hypothesis is made that as the launch vehicle ascends in altitude, solar irradiance will increase, as temperature, relative humidity, barometric pressure decrease. This hypothesis is based upon the following assumptions:

1. According to the U.S. standard atmosphere model, density, pressure and temperature will approximately linearly decrease within the troposphere as altitude is increased.
2. As temperature decreases, water within the atmosphere will condense into liquid form, thus lowering the relative humidity.
3. Since air has a nonzero absorptivity within the solar wavelength range and as measured by the TSL250R sensor, a decrease in density and decreased distance from altitude to the outer edge of the atmosphere will result in a greater solar irradiance.

Using the science data collected by the payload sensors this hypothesis will be evaluated. Furthermore, in preparation for the FRR and after considering the exact response characteristics of the each sensor, mathematical models will be developed for to express this hypothesis. These mathematical models will then be compared to the experimental data obtained during the actual flight and analysis will be presented within the PLAR.

In addition to obtaining science data to be used in the evaluation of the hypothesis presented above, inertial measurements taken from the APM 2.5's gyroscope and accelerometer, in addition with barometric pressure and GPS readings will be recorded and used to evaluate the rockets performance. These performance measurements will be essential to better understand the conditions within the launch vehicle and will be considered in later rocket design efforts.

4.4 Safety and Environment (Payload)

The integration of the payload into the launch vehicle has been designed to minimize the risks of physical damage to the payload electronics by exposure to extreme environments encountered in rocketry. Although physically located close to the motor, both the propulsive system and payload bay have been designed to physically and thermally isolate the payload electronics. Since all electronics are completely contained within the payload bay there are no opportunities for foreign contaminants to ingress, with the exception of through the static ports. Consequently, care will be taken to ensure the static ports are remain clear and are protected during handling and storage of the rocket.

The electronics of the payload have been designed to maximize robustness through the use of the APM 2.5 which contains nearly all sensors on a single platform. This significantly reduces risks of failure due to mechanical vibration since there are very few wires and physical connections.

Although self-contained, the power supply for the payload has been designed with integrated voltage protection and low-impedance grounding paths to prevent the risk of static electricity damage.

5. Project Plan

5.1 Major Challenges and Solutions

Since this is the team's first year participating in the USLI competition, the main challenges the team will face are designing and handling the high power propulsion system and the payload avionics. Accurate calculation of the correct size and impulse of the motor is needed in order reach the one mile AGL altitude. Similarly, the avionics must be integrated properly in the payload bay to relay the altitude of the rocket to the ground crew at least once every 5 seconds. The team has paired with a local mentor from the Livermore Unit of the National Associate of Rocketry, who has provided an invaluable introduction and resources into the realm of high powered rocketry.

5.2 Community Support and Team Sustainability

The sustainability of the team can be ensured through the mutual learning process between the team and the community. Twice a quarter, the team hosts low power rocket launches on university campus to engage university students and K-12 students in the Davis community. To accommodate the multidisciplinary nature of designing rockets the team has recruited engineering students from a wide variety of backgrounds including electrical, mechanical, aerospace, material science, and civil.

5.3 Budget Plan

The teams accounting is handled by a dedicated treasurer, who is responsible for tabulating all purchases, invoices and accounts receivable. While not a primary design factor, effort was made throughout design phases to minimize costs and thus ensure a sufficient safety blanket within the budget for unexpected costs.

Table 25 Material and assembly costs of Eclipse

	Payload	**Cost**
Payload	Shielding	$20.00
	Ardu Pilot Mega 2.5 Micro Controller	$200.00
	AM2302 Humidity and Temp. Sensor	$15.00
	TSL230R (Light to Frequency Converter)	$2.43
	3DR Radio Telemetry Kit	$74.99
	5 Volt Linear Voltage Regulator - MC7805	$0.49
Propulsion	Aerotech K513FJ-M	$98.30
	54mm Ogive Tail Cone Motor Retainer	$40.12
Structures	Fiber Glass Airframe	
	Fiber Glass Nosecone	
	Fiber Glass Motor Mount	
	Fiber Glass Centering Rings	
	Fiber Glass Altimeter Bay Coupler with Fiber Glass Bulkheads	
	Total Structures Costs	$239.95
Recovery System	StratoLogger Altimeter (Redundant)	$71.96
	Raven 3 Altimeter (Main)	$131.75
	Raven Power Perch	$35.00
	L3 Dual Altimeter Av-Bay Wiring Kit	$17.00
	3.7V 120mAh 10C LiPo Battery (x3)	$22.95
	Wall Charger for 3.7V LiPo Batteries	$21.25
	13’’ Nomex Blanket Parachute Protector (x2)	$25.50
	For Drogue: 5 yards of Pre-sewn 11/16’’ Climbing Grade Nylon (3,000 lb test)	$12.75
	For Main: 4 yards of Pre-sewn 11/16’’ Climbing Grade Nylon (3,000 lb test)	$11.57
	2 Feet of Pre-sewn 1/2" Kevlar Harness (10,000 lb test) (x3)	$38.25
	9/32" Diameter Oval Threaded Zinc-Plated Steel Quicklink Connector (1,000 lb test) (x7)	$8.47
	1/4" Steel U-Bolts (x4)	$7.16
	Other Hardware (Nuts, Bolts, Washers)	$5.00
	Iris Ultra 72" Main Parachute	$140.25
	Classic Elliptical 18" Drogue Parachute	$34.00
Miscellaneous	Standard rail buttons	$3.07
	Total Expenses of Rocket	**$1,277.21**

The primary milestones and their completion status for the team are listed as follows in table 5-2:

Table 26 Primary Milestones and Completion Status

10-22-12	**Web Presence Established**	**Completed**
10-29-12	PDR Report Posted	Completed
11-16-12	PDR Presentation Completed	Completed
1-14-13	CDR Report Posted	In Progress
1-31-13	CDR Presentation Complete	On Track
3-3-13	Payload Testing Complete	On Track
3-9-13	Full Scale launch with payload	On Track
3-18-13	FRR Posted	On Track
4-3-13	FRR Presentation Complete	On Track
4-17-13	LRR Conducted	On Track
4-20-13	Launch Date	On Track
5-6-13	PLAR Posted	On Track

The team is currently on track to achieve all major milestones, with the largest uncertainty revolving around the completion of the payload testing. At the current date only preliminary component-level testing of the payload has been completed and the software development is in its infancy. Despite this uncertainty, all payload development and testing thus far has been successful and milestone completions are expected to be on time.

The Gantt chart (Figure 1 Team schedule on a GANTT chart) shows the relationship between primary milestones, build, and test cycles. 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 primary design phase took place during between October and November, with refinement and preliminary testing occurring between December and January. Lessons learned from the December to January refinement and testing phase are included within this CDR and will be incorporated into the final assembly and testing cycle, occurring between January and April.

5.4 Educational Engagement

In the fall, SpaceEd Rockets has engaged nearly three hundred elementary and middle school students. At each school visit, the team gave a brief two minute presentation that introduced the basics of rocketry. Following the presentation, students were shown how to make a small paper rocket, which they built with teams and launched off of a pressurized PVC pipe that only required a bike pump. After school hours, the team then held model rocket launch demos.

The following is a list of schools visited and students that attended the SpaceEd Rockets Seminars:

Table 27 Students engaged in education focused on rocketry

Date	School	# of Students
26 Aug. 2012	Antelope Crossing M.S.	64
9 Nov. 2012	American Canyon M.S.	42
16 Nov. 2012	Elkorn Village Elementary	35
29 & 30 Nov. 2012	Riverbank Elementary	40
3 Dec. 2012	Sacramento's School of Engineering and Science	150
	Total:	**331 Students**

Figure 13Thank you notes from American Canyon

6. Conclusion

6.1 Aerodynamics

Because the rocket is not traveling at supersonic speeds, the fins and nosecone were designed for structural integrity rather than aerodynamic efficiency. Thus, while a sharper nosecone or airfoiled fins would be ideal for better aerodynamic characteristics, the time and manufacturing costs they require are not worth the minimal increase in efficiency. A combination of both RockSim analyses and experimental verification demonstrate that the current design meets all vehicle and mission requirements.

6.2 Propulsion

Both Rocksim analyses and the prototype launch vehicle have confirmed that the K513FJ-M motor is suitable for the design and meets all mission and launch vehicle requirements. In the event that unforeseen circumstances require a total mass increase of the launch vehicle the same motor bay can accommodate a the more powerful K550FJ motor, although this is change is considered unlikely to be necessary.

6.3 Structures

Fiberglass provides the necessary strength to absorb loads from landing impacts. Since fiberglass has a high impact, flexural and tensile strength, it was ideal for core structural components including the airframe, centering rings, and fins. The use of a fiberglass airframe also provided high dimensional stability, meaning that the frame was able to retain its shape when subjected to varying parameters such as temperature, moisture and stress. The current structural design has been proven very effective and design changes are not anticipated to be necessary for the final launch vehicle.

6.4 Payload

Although still in early stages of assembly and test, the payload electronics have so far proven reliable and successful. Currently no major concerns exist regarding the ability to complete payload assembly and integration by the specified milestones.

6.5 Educational Engagement

To date the team has reached over 300 elementary and middle school students thus completing the requirements for educational engagement. Although not required by the USLI competition the team hopes to develop plans for continued educational engagement and interaction with the local community.

6.6 Project Plan

Through precise accounting and careful planning the team has been able to stay on track to meet all remaining milestones and budget requirements on time. Upon approval of the CDR the team will begin investigation of additional revenue sources and sponsorship opportunities to ensure all necessary travel expenses are covered.

7. Appendix

7.1 Pre-Launch Checklist

Day-Before Preparation

Adept P5 Battery Discharge-Recharge Cycle

- ❑ Discharge/Recharge battery evening before flight per manual instructions. (Time needed: 3.5hrs discharge, 10hrs recharge.)

Ejection Canister preparation

- ❑ Select and check for continuity 4 ejection matches.
- ❑ Install 2 ejection matches into Apogee election canister and 2 into Main ejection canister.
- ❑ Re-wrap wires, re-twist and cover ends.
- ❑ Seal wire holes of ejection canisters with silicone sealant. Set aside to cure.

Motor Preparation

Prepare Motor

- ❑ Prepare motor per packaged instructions for launch.
- ❑ Verify that ejection charge was installed in the motor. If motor is already secured, take it out and visually verify.
- ❑ Select correct size igniter for engine. Inspect for continuity, resistance, and check pyrogen for cracks or flaws.
- ❑ Secure motor and igniter for later installation into rocket.
- ❑ DO NOT install igniter until rocket is secure on the pad.

Recovery System Preparation

Recovery System, Drogue Main Parachute:

- ❑ Check shock cords for cuts, burns, and tangles.
- ❑ Check all shroud lines -- no tangles.
- ❑ Check main parachute for tears and burns.
- ❑ Check deployment bag for tears.

- *Check all connections. Ensure all devices are in good condition and properly secured:*

- ❑ Coupler shock cord to parachute
- ❑ Aft assembly shock cord to parachute

- *Pack main parachute in deployment bag, keep lines even and straight.*

  - ❑ Fold main parachute per manufacturer's instructions.
  - ❑ Ensure shroud lines are free from tangles.
  - ❑ Ensure all quick links are secure.
  - ❑ Insert ejection charge protection.
  - ❑ Insert main bag/chute into forward recovery compartment

- ❑ Slide Nomex chute protector and strap protector onto drogue tubular nylon strap.
- ❑ Attach buckles to drogue tubular nylon strap.
- ❑ Attach threaded quick-links to forward and middle loops in tubular nylon strap.
- ❑ Attach threaded quick-links to loops in drogue “seat belt” strap.
- ❑ Connect forward end of “seat belt” strap to aft end of tubular nylon strap.
- ❑ Connect parachute to quick-link in loop of tubular nylon strap.
- ❑ “Z” fold and lightly secure tubular nylon strap allowing for tube length.
- ❑ “Z” fold and lightly secure “seat belt” strap.
- ❑ Fold and pack drogue chute and wrap in nomex chute protector.
- ❑ Thread recovery harness through drogue tube, “seat belt” strap toward aft end.
- ❑ Connect threaded quick-links attached to “seat belt” strap to U-bolts of booster section.
- ❑ Pack straps and parachute into drogue tube so that nomex surfaces take brunt of the ejection charge and allowing for needed travel through tube. Make sure forward end of tubular nylon strap is accessible for connection to altimeter bay U-bolt.

Recovery System, Sustainer Main Parachute:

- ❑ Check shock cords for cuts, burns, and tangles.
- ❑ Check all shroud lines -- no tangles.
- ❑ Check main parachute for tears and burns.
- ❑ Check deployment bag for tears.

- *Check all connections. Ensure all devices are in good condition and properly secured:*

- ❑ Nose Cone shock cord to main parachute
- ❑ Avionics bay shock cord to main parachute

- *Pack main parachute in deployment bag, keep lines even and straight.*

- ❑ Fold main parachute per manufacturer's instructions.
- ❑ Ensure shroud lines are free from tangles.
- ❑ Ensure all quick links are secure.
- ❑ Insert ejection charge protection.
- ❑ Insert main bag/chute into forward recovery compartment
- ❑ Slide the drogue tube onto booster section coupler and align marks.

-*Main recovery preparation*:

- ❑ Attach buckles to main tubular nylon strap.
- ❑ Attach threaded quick-links to forward and middle loops in tubular nylon strap.
- ❑ Attach threaded quick-links to loops in main “seat belt” strap.
- ❑ Connect forward end of “seat belt” strap to aft end of tubular nylon strap.
- ❑ Connect parachute to quick-link in loop of tubular nylon strap.
- ❑ “Z” fold and lightly secure tubular nylon strap.
- ❑ “Z” fold and lightly secure “seat belt strap allowing for tube length.
- ❑ Pack main chute into nomex deployment bag.
- ❑ Thread recovery harness through front of main tube, “seat belt” strap toward aft end.
- ❑ Pack straps and parachute into main tube so that nomex surfaces take brunt of the ejection charge and allowing for needed travel through tube. Make sure aft end of “seat belt” strap is accessible for connection to altimeter bay U-bolt.

- Slide nose cone into front of main tube and align marks.
- Install shear pins in holes and secure.

Electronics

ARRD Preparation

- Prepare two Daveyfire N28B e-matches by removing green plastic cover over pyrogen and cutting wire leads to 8” in length.
- Insert both N28Bs into ARRD charge holder.
- Insert N28B leads through ARRD aluminium base – ensure leads are straight with no kinks.
- Continue to pull leads through ARRD base until plastic charge holder rests in ARRD aluminium base.
- Carefully bend N28B pyrogen head to fit in plastic charge holder.
- Insert small piece of rubber insulation material between pyrogen heads to prevent possibility of shorting.
- Pour 4F black powder into cavity in plastic ARRD base.
- Cover plastic ARRD base with sticker to prevent loss of black powder.
- Thread ARRD aluminium base into ARRD main body.

ARRD Mounting

- With 3/8” all thread rod installed loosely in ejection bulkhead, slide ARRD assembly into position in ejection tube.
- Run N28B e-match leads from ARRD through ejection bulkhead into altimeter bay.
- Slid 3/16” ARRD threaded mounting rod through ejection bulkhead while sliding 3/8” all thread rod in unison with ARRD until both bottom out in ejection bulkhead.
- Secure ARRD to ejection bulkhead by threading split washer and nut onto ARRD threaded mounting rod from altimeters bay side.

Prepare avionics #1

- Be sure all arming switches are off.
- Voltage meter test of NEW battery under load
- Install battery in battery harness.
- Secure battery in place with positive battery retention system. Verify that unit is correctly oriented to front of rocket.
- Altimeter properly programmed and verified.
- Ready avionics bay for altimeter.
- Install avionics in rocket. Verify that unit is correctly oriented to front of rocket.
- Ensure all pyrotechnics are in disarmed mode during electronics final installation.
- ENSURE ALL ARMING AND POWER SWITCHES ON ALTIMETER BAY AND ELECTRONICS ARE OFF!

- Insert wires for apogee and main connections into their respective connections on altimeter and tighten retaining screws. Verify that apogee and main are NOT reversed.

Altimeter Bay Assembly, #1

- Align Altimeter Support Frame with Altimeter Bay.
- Plug Switch Harness connector into locking header on Altimeter Support Frame. Verify locking tabs are engaged.
- Slide Altimeter Support Frame into Altimeter bay and center between ends.

Prepare avionics #2

- Be sure all arming switches are off.
- Voltage meter test of NEW battery under load
- Install battery in battery harness.
- Secure battery in place with positive battery retention system. Verify that unit is correctly oriented to front of rocket.
- Altimeter properly programmed and verified.
- Ready avionics bay for altimeter.
- Install avionics in rocket. Verify that unit is correctly oriented to front of rocket.
- Ensure all pyrotechnics are in disarmed mode during electronics final installation.
- ENSURE ALL ARMING AND POWER SWITCHES ON ALTIMETER BAY AND ELECTRONICS ARE OFF!
- Insert wires for apogee and main connections into their respective connections on altimeter and tighten retaining screws. Verify that apogee and main are NOT reversed.

Altimeter Bay Assembly, #2

- Align Altimeter Support Frame with Altimeter Bay.
- Plug Switch Harness connector into locking header on Altimeter Support Frame. Verify locking tabs are engaged.
- Slide Altimeter Support Frame into Altimeter bay and center between ends.

Note: All pyrotechnic devices must remain in an unarmed mode until rocket is on pad ready to launch.

Pyrotechnics, drogue

Note: Keep all loaded charges pointed away from self and other individuals.

- CLEAR PEOPLE FROM IMMEDIATE AREA IN FRONT OF CHARGE PREP AREA!
- PUT ON SAFETY GLASSES!
- Select canister and inspect for integrity and proper seal at wires.
- Load canister with 4gm of ffffG Black Powder.
- Fill remaining volume of canister with flame-proof wadding.
- Cover end of canister with tape dot and secure well with masking tape.
- Screw Apogee ejection canister into Aft Altimeter Bulkplate.
- Prepare aft deployment pyrotechnic device and ready for installation into rocket.

- Load aft charge into rocket, Ensure at all times the devices are safed until final launch readiness.
- Connect aft pyrotechnic leads to electronic deployment devices drogue chute connections.
- Verify that apogee and main are NOT reversed
- Utilizing external disarming mechanisms to Ensure all electronically discharged pyrotechnics are disabled until final launch readiness.

Pyrotechnics

- Select canister and inspect for integrity and proper seal at wires.
- Load canister with 6gm of ffffG Black Powder.
- If volume remains, fill remainder of canister with flame-proof wadding.
- Cover end of canister with tape dot and secure well with masking tape.
- Screw Apogee ejection canister into Front Altimeter Bulkplate.
- Prepare forward deployment pyrotechnic device and ready for installation into rocket.
- Load forward charge into rocket, Ensure at all times the devices are safed until final launch readiness.
- Connect forward pyrotechnic leads to electronic deployment devices main parachute connections.
- Verify that apogee and main are NOT reversed.
- Utilizing external disarming mechanisms to Ensure all electronically discharged pyrotechnics are disabled until final launch readiness.

Rocket Mid-section Assembly

- Install threaded quick-connect from Apogee Recovery Harness onto Altimeter Bay aft U-bolt.
- Slide aft end of Altimeter Bay coupler into Apogee Tube and align marks.
- Install and tighten 5 retaining screws for Apogee tube.
- Attach rail button to remaining hole in Apogee tube with counter-sink screw.
- Install threaded quick-connect from Main Recovery Harness onto Altimeter Bay front U-bolt.
- Slide Main tube onto front Altimeter Bay coupler and align marks.
- Install and tighten 6 retaining screws for Main tube.

Motor Installation

- Tape motor casing for snug fit in motor tube.
- Install motor and retaining devices.
- Ensure all electronic deployment devices are in the non-dischargeable safed mode.

Final Launch Preparations

Load Rocket on Pad

- ❑ Prepare launch pad.
- ❑ Load rocket on launch rod.

Prepare Igniter

- ❑ Insert igniter. Be sure it is completely forward and touching fuel grain.
- ❑ Secure igniter in position
- ❑ Assure that launcher is not hot. Disconnect battery from relay box. Assure that key IS NOT in remote control device and that arming switch is off.
- ❑ Attach leads to ignition device.
- ❑ Be sure all connectors are clean.
- ❑ Be sure they don't touch each other or that circuit is not grounded by contact with metal parts.
- ❑ Check tower's position and be sure it is locked into place and ready for launch.
- ❑ Assure that key IS NOT remote device and that arming switch is off.
- ❑ Connect battery to relay box.

Final Launch Sequence

- ❑ Arm all devices for launch.
- ❑ Apogee 1
- ❑ Apogee 2
- ❑ Main 1
- ❑ Main 2
- ❑ Power
- ❑ Ensure Flight Witnesses are in place and ready for launch.
- ❑ Signal LCO & RSO that rocket is ready for launch.

Misfire Procedures

- ❑ Safe all pyrotechnic to pre-launch mode.
- ❑ Turn off Altimeter power. Power MUST REMAIN off for at least 1MINUTE before turning on again.
- ❑ Remove failed igniters.
- ❑ Resume checklist at "Final Launch Preparations/Prepare Igniters."

Post-Recovery Checklist

This is the post-flight checklist as required as part of the Certification Package. This checklist includes steps required to ensure the rocket is in a safe condition after completion of a flight.

Normal Post Flight Recovery

- ❑ Safe ejection circuits without cutting power to altimeters.

- ❑ Check for non-discharged pyrotechnics.
- ❑ Safe all ejection circuits.
- ❑ Remove any non-discharged pyrotechnics.
- ❑ Record RDAS 1 data ____________
- ❑ Record RDAS 2 data __________
- ❑ Turn off power to altimeters.
- ❑ Fold and repack recovery components and re-assemble rocket for return to launch area.

Flight Failure Checklist

- ❑ Disarm all non-fired pyrotechnic devices.
- ❑ Safe ejection circuits without cutting power to altimeters.
- ❑ Disassemble Aft and Main tubes from Altimeter Bay. Continue Normal Post Flight Recovery procedures.

7.2 MSDS Data Sheets

Science Lab.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.

Created: 10/09/2005 05:33 PM

Last Updated: 11/06/2008 12:00 PM

MATERIAL SAFETY DATA SHEET West System Inc.

1.	CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: .... WEST SYSTEM® 205 Fast Hardener®
PRODUCT CODE: 205
CHEMICAL FAMILY: .... Amine.
CHEMICAL NAME: .... Modified aliphatic polyamine.
FORMULA: .... Not applicable.

MANUFACTURER:
West System Inc.
102 Patterson Ave.
Bay City, MI 48706, U.S.A.
3887 (International) Phone: 866-937-8797 or 989-684-7286
www.westsystem.com

EMERGENCY TELEPHONE NUMBERS:
Transportation
CHEMTREC: ....800-424-9300 (U.S.)
703-527-
Non-transportation
Poison Hotline: 800-222-1222

2.	HAZARDS IDENTIFICATION

<u>EMERGENCY OVERVIEW</u>

HMIS Hazard Rating: **Health - 3** **Flammability - 1** **Physical Hazards - 0**

DANGER! Corrosive. Skin sensitizer. Moderate to severe skin, eye and respiratory tract irritant. May cause allergic reactions. Amber colored liquid with ammonia odor.

PRIMARY ROUTE(S) OF ENTRY:... Skin contact, eye contact, inhalation.

<u>POTENTIAL HEALTH EFFECTS:</u>

ACUTE INHALATION: .... May cause respiratory tract irritation. Coughing and chest pain may result.

CHRONIC INHALATION:... May cause respiratory tract irritation, coughing, sore throat, shortness of breath or chest pain.

ACUTE SKIN CONTACT: .... May cause strong irritation, redness. Possible mild corrosion.

CHRONIC SKIN CONTACT:.. Prolonged or repeated contact may cause an allergic reaction and possible sensitization in susceptible individuals. Large dose skin contact may result in material being absorbed in harmful amounts.

EYE CONTACT:... Moderate to severe irritation with possible tissue damage. Concentrated vapors can be absorbed in eye tissue and cause eye injury. Contact causes discomfort and possible corneal injury or conjunctivitis.

INGESTION:... Single dose oral toxicity is moderate. May cause gastrointestinal tract irritation and pain. Aspiration hazard.

SYMPTOMS OF OVEREXPOSURE:... Respiratory tract irritation. Skin irritation and redness. Possible allergic reaction seen as hives and rash. Eye irritation. Possible liver and kidney disorders upon long term skin absorption overexposures.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: .... Chronic respiratory disease, asthma. Eye disease. Skin disorders and allergies.

3.	COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

INGREDIENT NAME	CAS #	CONCENTRATION
Reaction products of TETA with Phenol/Formaldehyde	32610-77-8	> 25%
Polyethylenepolyamine	68131-73-7	< 25%
Triethylenetetramine (TETA)	112-24-3	< 10%
Hydroxybenzene	108-95-2	< 10%
Reaction Products of TETA and propylene oxide	26950-63-0	< 10%
Tetraethylenepentamine (TEPA)	112-57-2	< 10%

4. FIRST AID MEASURES

FIRST AID FOR EYES:... Immediately flush with water for at least 15 minutes. Get prompt medical attention.

FIRST AID FOR SKIN:.. Remove contaminated clothing. Immediately wash skin with soap and water. Do not apply greases or ointments. Get medical attention if severe exposure.

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FIRST AID FOR INHALATION:.. Move to fresh air and consult physician if effects occur.

FIRST AID FOR INGESTION:.. Give conscious person at least 2 glasses of water. Do not induce vomiting. Aspiration hazard. If vomiting should occur spontaneously, keep airway clear. Get medical attention.

5. FIRE FIGHTING MEASURES

FLASH POINT:... >270°F (PMCC)

EXTINGUISHING MEDIA:.. Dry chemical, alcohol foam. carbon dioxide (CO_2), dry sand, limestone powder.

FIRE AND EXPLOSION HAZARDS: .... During a fire, smoke may contain the original materials in addition to combustion products of varying composition which may be toxic and/or irritating. Combustion products may include, but are not limited to: oxides of nitrogen, carbon monoxide, carbon dioxide, volatile amines, ammonia, nitric acid, nitrosamines. When mixed with sawdust, wood chips, or other cellulosic material, spontaneous combustion can occur under certain conditions. If hardener is spilled into or mixed with sawdust, heat is generated as the air oxidizes the amine. If the heat is not dissipated quickly enough, it can ignite the sawdust.

SPECIAL FIRE FIGHTING PROCEDURES:.. Use full-body protective gear and a self-contained breathing apparatus. Use of water may generate toxic aqueous solutions. Do not allow water run-off from fighting fire to enter drains or other water courses.

6. ACCIDENTAL RELEASE MEASURES

SPILL OR LEAK PROCEDURES:... Stop leak without additional risk. Wear proper personal protective equipment. Dike and contain spill. Ventilate area. Large spill - dike and pump into appropriate container for recovery. Small spill - recover or use inert, non-combustible absorbent material (*e.g.*, sand, clay) and shovel into suitable container. Do not use sawdust, wood chips or other cellulosic materials to absorb the spill, as the possibility for spontaneous combustion exists. Wash spill residue with warm, soapy water if necessary.

7. HANDLING AND STORAGE

STORAGE TEMPERATURE (min./max.):... 40°F (4°C) / 90°F (32°C).

STORAGE:... Store in cool, dry place away from high temperatures and moisture. Keep container tightly closed.

HANDLING PRECAUTIONS:... Use with adequate ventilation. Do not breath vapors or mists from heated material. Avoid exposure to concentrated vapors. Avoid skin contact. Wash thoroughly after handling. When mixed with epoxy resin this product causes an exothermic reaction, which in large masses, can produce enough heat to damage or ignite surrounding materials and emit fumes and vapors that vary widely in composition and toxicity.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION GUIDELINES:.. Chemical splash-proof goggles or face shield.

SKIN PROTECTION GUIDELINES:... Wear liquid-proof, chemical resistant gloves (nitrile-butyl rubber, neoprene, butyl rubber or natural rubber) and full body-covering clothing.

RESPIRATORY/VENTILATION GUIDELINES: .... Use with adequate general and local exhaust ventilation to meet exposure limits. In poorly ventilated areas, use a NIOSH/MSHA approved respirator with an organic vapor cartridge.

Note: West System, Inc. has conducted an air sampling study using this product or similarly formulated products. The results indicate that the components sampled for (phenol, formaldehyde and amines) were either so low that they were not detected at all or they were well below OSHA's permissible exposure levels.

ADDITIONAL PROTECTIVE MEASURES:.. Use where there is immediate access to safety shower and emergency eye wash. Wash thoroughly after use. Contact lens should not be worn when working with this material. Generally speaking, working cleanly and following basic precautionary measures will greatly minimize the potential for harmful exposure to this product under normal use conditions.

OCCUPATIONAL EXPOSURE LIMITS: .... Not established for product as whole. Refer to OSHA's Permissible Exposure Level (PEL) or the ACGIH Guidelines for information on specific ingredients.

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL FORM.. Liquid.
COLOR .... Amber.
ODOR.. Ammonia-like.
BOILING POINT.. > 440°F.
MELTING POINT/FREEZE POINT... Approximately 23°F.
pH .... Alkaline.
SOLUBILITY IN WATER.. Appreciable.
SPECIFIC GRAVITY 1.05

BULK DENSITY .... 8.85 pounds/gallon.
VAPOR PRESSURE .... < 1 mmHg @ 20°C.
VAPOR DENSITY .... Heavier than air.
VISCOSITY .... 1,000 cPs
% VOLATILE BY WEIGHT.................... ASTM 2369-07 was used to determine the Volatile Matter Content of mixed epoxy resin and hardener. 105 Resin and 205 Hardener, mixed together at 5:1 by weight, has a density of 1137 g/L (9.49 lbs/gal). The combined VOC content for 105/205 is 7.91 g/L (0.07 lbs/gal).

10. STABILITY AND REACTIVITY

STABILITY:.................... Stable.

HAZARDOUS POLYMERIZATION:.................... Will not occur.

INCOMPATIBILITIES:.................... Avoid excessive heat. Avoid acids, oxidizing materials, halogenated organic compounds (*e.g.*, methylene chloride). External heating or self-heating could result in rapid temperature increase and serious hazard. If such a reaction were to take place in a waste drum, the drum could expand and rupture violently.

DECOMPOSITION PRODUCTS:.................... Very toxic fumes and gases when burned or otherwise heated to decomposition. Decomposition products may include, but not liminted to: oxides of nitrogen, volatile amines, ammonia, nitric acid, nitrosamines.

11. TOXICOLOGICAL INFORMATION

No specific oral, inhalation or dermal toxicology data is known for this product.

Oral: .... Expected to be moderately toxic.
Inhalation:.................... Expected to be moderately toxic.
Dermal:.................... Expected to be moderately toxic.

Adsorption of phenolic solutions through the skin may be very rapid and can cause death. Lesser exposures can cause damage to the kidney, liver, pancreas and spleen; and cause edema of the lungs. Chronic exposures can cause death from liver and kidney damage.

CARCINOGENICITY:
NTP.................... No.
IARC .... No.
OSHA.................... No.

No ingredient of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA, NTP or IARC.

12. ECOLOGICAL INFORMATION

Wastes from this product may present long term environmental hazards. Do not allow into sewers, on the ground or in any body of water.

Hydroxybenzene (phenol) (CAS # 108-95-2) biodegradability = 99.5% at 7 days.

13. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD:.................... Evaluation of this product using RCRA criteria shows that it is not a hazardous waste, either by listing or characteristics, in its purchased form. It is the responsibility of the user to determine proper disposal methods.

Incinerate, recycle (fuel blending) or reclaim may be preferred methods when conducted in accordance with federal, state and local regulations.

14. TRANSPORTATION INFORMATION

DOT
SHIPPING NAME:.................... Polyamines, liquid, corrosive, n.o.s.
TECHNICAL SHIPPING NAME:.................... (Triethylenetetramine)
D.O.T. HAZARD CLASS: .... Class 8
U.N./N.A. NUMBER:.................... UN 2735
PACKING GROUP: .... PG III

IATA
SHIPPING NAME:.................... Polyamines, liquid, corrosive, n.o.s.
TECHNICAL SHIPPING NAME:.................... (Triethylenetetramine)
HAZARD CLASS:.................... Class 8
U.N. NUMBER:.................... UN 2735
PACKING GROUP: .... PG III

15. REGULATORY INFORMATION

OSHA STATUS:.. Corrosive; possible sensitizer.

MSDS #205-11a Last Revised: 10FEB11

TSCA STATUS:... All components listed on TSCA inventory or otherwise comply with TSCA requirements.

Canada WHIMIS Classification: D2A, D2B, E

SARA TITLE III:

SECTION 313 TOXIC CHEMICALS:... This product contains hydroxybenzene (phenol) and is subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

STATE REGULATORY INFORMATION:

The following chemicals are specifically listed or otherwise regulated by individual states. For details on your regulatory requirements you should contact the appropriate agency in your state.

COMPONENT NAME /CAS NUMBER	CONCENTRATION	STATE CODE
Tetraethylenepentamine 112-57-2	<10%	MA, NJ, PA
Tetraethylenetriamine 112-24-3	<10%	MA, NJ, PA
Phenol 108-95-2	<10%	NJ, RI, PA, MA, IL

16. OTHER INFORMATION

REASON FOR ISSUE:... Changes made in Sections 5, 10, 14 & 15.
PREPARED BY: .... G. M. House
APPROVED BY: .... G. M. House
TITLE: .... Health, Safety & Environmental Manager
APPROVAL DATE: .... February 10, 2011
SUPERSEDES DATE: .... January 3, 2008
MSDS NUMBER: 205-11a

Note: The Hazardous Material Indexing System (HMIS), cited in the Emergency Overview of Section 3, uses the following index to assess hazard rating: 0 = Minimal; 1 = Slight; 2 = Moderate; 3 = Serious; and 4 = Severe.

ICS

MATERIAL SAFETY DATA SHEET

1. PRODUCT AND COMPANY IDENTIFICATION

Product Identifier: ICS-Colloidal Silica
MSDS Number: ICS-007
Product Use: Colloidal silica based primary binder for investment casting

MANUFACTURER:
International Casting Supply Inc.
6915 Louis Sicard St.
St. Leonard, QC H1P 1T6 CANADA
Information: (514) 327-6688

Emergency #: (514) 327-6688 (During working hours)

2. COMPOSITION / INFORMATION ON INGREDIENTS

Components	wt. %	CAS Number	TLV-TWA mg/m^3	TLV-STEL mg/m^3	LD50 mg/kg (oral, rat)	LC50 (inh, rat)
Amorphous Silica	<50	7631-86-9	0.1*	N.E.	N.E.	N.E.
Dipotassium Flourescein	<10	6417-85-2	N.E.	N.E.	N.E.	N.E.
Oxirane polymer With 2 ethyl hexyl di-hydrogen phosphate	<10	68460-10-6	N.E.	N.E.	N.E.	N.E.

Notes: * Respirable N.E = Not Established

3. HAZARDS IDENTIFICATION

PRIMARY ROUTES OF ENTRY:

[X] Eye Inhalation [X] Skin Ingestion

POTENTIAL HEALTH EFFECTS:
Eye Contact: May cause eye irritation.
Ingestion: Not a likely route of exposure.
Inhalation: Not a likely route of exposure.
Skin Contact: May tend to dry out skin.
Chronic: Not established

4. FIRST AID MEASURES

Eye Contact: Flush with flowing water for at least 15 minutes. If irritation persists, consult a physician.
Ingestion: Not applicable.
Inhalation: If symptoms of discomfort or irritation occur, remove affected person to fresh air. If irritation persists, consult a physician.
Skin Contact: Wash with soap and water.

5. FIRE FIGHTING MEASURES

Flash Point: Not applicable **Method**: Not applicable
Auto-Ignition Temperature: Not applicable
Upper Flammability Limits (% vol.): Not applicable
Lower Flammability Limits (% vol.): Not applicable
Fire Hazard Comments: Not combustible
Extinguishing Media: Use extinguishing media appropriate for surrounding fire.
Special Fire Fighting Procedures: Not applicable
Explosion Data – Sensitivity to: **Mechanical Impact:** Not applicable
Static Discharge: Not applicable

6. ACCIDENTAL RELEASE MEASURES

Spill or Leak Procedures: Spills should be contained and placed in suitable containers for disposal in a licensed facility. Clean up promptly as spills are a slipping hazard.

7. HANDLING AND STORAGE

Handling Procedure/Equipment: Contains alkaline material. May cause irritation. Avoid contact with eyes, skin and clothing.
Storage Requirements: Keep from freezing. Binder stored in transparent or translucent containers should be sheltered from direct sunlight.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls: Local exhaust
PERSONAL PROTECTIVE EQUIPMENT:
Eyes: Not normally necessary but recommended. Chemical worker goggles.
Respirator: A NIOSH approved N95 approved respirator with a dust cartridge is recommended.
Skin: Protective gloves.
Other: Avoid ingestion of this material. Avoid eye contact. Maintain good housekeeping.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State: **GAS** ☒ **LIQUID** **SOLID**

Appearance: Yellow
Odour: Odourless
Odour Threshold: Not applicable
Specific Gravity: 1.180
Vapour Pressure: 17.5 mmHg
Vapour Density: 0.016
Volatile Organic Compound VOC (g/L): 65%

Evaporation Rate (n-butyl acetate = 1): Not applicable
Boiling Point: 100°C (212°F)
Melting Point: 0°C (32°F)
pH: 10.6 (typical)
Coefficient of Water/Oil Distribution: Not established
Solubility in Water: 100%

10. STABILITY AND REACTIVITY

Chemical Stability: Stable
If not, under what conditions: Not applicable
Conditions of Reactivity: Not established.
Conditions to Avoid / Incompatible Materials: Avoid freezing. Acids. Metal salts will coagulate product.
Hazardous Dec./Comb.: See Section 11.
Hazardous Polymerization: Will not occur.

11. TOXICOLOGICAL INFORMATION

Carcinogenicity: **NTP**: Not listed
OSHA: Not regulated
IARC: Not evaluated

Although amorphous silica is not a carcinogen as purchased in this product, portions of it may convert to crystalline silica (cristobalite) when subjected to higher temperatures (1700°F). IARC and NTP define silica, crystalline (respirable) as a known human carcinogen.

LD50: Not established **LC50**: Not established
Irritancy of Product: May cause irritation.
Reproductive Toxicity: Not established
Teratogenicity: Not established
Sensitization to Product: Not applicable
Mutagenicity: Not established
Synergistic Products: Not established

12. ECOLOGICAL INFORMATION

No exotoxicity data is available. This product is not expected to present an environmental hazard.

13. DISPOSAL CONSIDERATIONS

Waste Disposal Method: Dispose of waste materials and containers in a licensed facility.

14. TRANSPORT INFORMATION

Proper Shipping Name. Not Regulated

15. REGULATORY INFORMATION

WHMIS Classification: D2B

This product contains trace amounts of 1, 3 Butadiene, a chemical known to the State of California to cause cancer.

This product has been classified in accordance with the hazard criteria of the Canadian Controlled Products Regulation (CPR) and the American OSHA Hazard Communication Standard.

16. OTHER INFORMATION

NFPA Hazard Ratings: **Health -**1
none → extreme **Fire -** 0
0 → 4 **Reactivity -**0

Preparation Date: 10/18/2005
Prepared By: Cameron W. Sherry, Les Consultants LBCD Inc.

The information and recommendations contained herein are, to the best of International Casting Supply's knowledge and belief, accurate and reliable as of the date issued. International Casting Supply does not warrant or guarantee their accuracy or reliability, and International Casting Supply shall not be liable for any loss or damage arising out of the user thereof.

The information and recommendations are offered for the user's consideration and examination, and it is the user's responsibility to satisfy itself that they are suitable and complete for its particular use. If buyer repackages this product, legal counsel should be consulted to insure proper health, safety and other necessary information is included on the container.

MATERIAL SAFETY DATA SHEET

Section 1: Product and Company Information

Product Name(s): Woven Unidirectional Fiberglass Fabric (A-Style Warp Unidirectional), Stitchbonded Fiberglass Fabric, Woven Fiberglass Fabric

Manufacturer: Owens-Corning, World Headquarters, One Owens-Corning Parkway
Attn. Product Stewardship, Toledo, OH, 43659,
Telephone: 1-419-248-8234 (8am-5pm ET weekdays).
OC Fabrics, 1851 S. Sequin Ave., New Braunfels, TX, 78130
Telephone: 1-210-629-4009 (8am-5pm CT weekdays).

Emergency Contacts:
Emergencies ONLY (after 5pm ET and weekends): 1-419-248-5330,
CHEMTREC (24 hours everyday): 1-800-424-9300,
CANUTEC (Canada- 24 hours everyday): 1-613-996-6666.

Health and Technical Contacts:
Health Issues Information (8am-5pm ET):1-419-248-8234,
Technical Product Information (8am-5pm ET): 1-800-GET-PINK.

Section 2: Composition and Ingredient Information

Common Name	Chemical Name	CAS No.	Wt. %
Non-Hazardous Ingredients			
Fiber Glass Continuous Filament (non respirable)	Fibrous Glass	65997-17-3	94-100
Size	Size	None	0-2
Polyester Yarn	Polyester Yarn	None	0-4

Note: See Section 8 of MSDS for exposure limit data for these ingredients.

MATERIAL SAFETY DATA SHEET

Section 3: Hazards Identification

Appearance and Odor: White/off-white colored solid with no odor.

Emergency Overview

No unusual conditions are expected from this product

Primary Route(s) of Exposure: inhalation, skin, eye

Potential Health Effects:

ACUTE (short term): Fiber glass continuous filament is a mechanical irritant. Breathing dusts and fibers may cause short term irritation of the mouth, nose and throat. Skin contact with dust and fibers may cause itching and short term irritation. Eye contact with dust and fibers may cause short term mechanical irritation. Ingestion may cause short term mechanical irritation of the stomach and intestines. See Section 8 for exposure controls.

CHRONIC (long term): There is no known health effects connected with long term use or contact with this product. See Section 11 of MSDS for more toxicological data.

Medical Conditions Aggravated by Exposure: Long term breathing or skin conditions that are aggravated by mechanical irritants may be at a higher risk for worsening from use or contact with this product.

Section 4: First Aid Measures

Inhalation: Move person to fresh air. Seek medical attention if irritation persists.

Eye Contact: Flush eyes with running water for at least 15 minutes. Seek medical attention if irritation persists.

Skin Contact: Wash with mild soap and running water. Use a washcloth to help remove fibers. To avoid more irritation, do not rub or scratch affected areas. Rubbing or scratching may force fibers into skin. Seek medical attention if irritation persists.

Ingestion: Ingestion of this material is unlikely. If it does occur, watch the person for several days to make sure that intestinal blockage does not occur.

Section 5: Fire Fighting Measures

Flash Point and Method: None

Flammability Limits (%): None.

Auto Ignition Temperature: Not Applicable.

Extinguishing Media: Water, foam, CO_2 or dry chemical.

Unusual Fire and Explosion Hazards: None known.

Fire Fighting Instructions: Use self contained breathing apparatus (SCBA) in a sustained fire.

Hazardous Combustion Products: Primary combustion products are carbon monoxide, carbon dioxide and water. Other undetermined compounds could be released in small quantities.

OWENS CORNING ™ **MATERIAL SAFETY DATA SHEET**

Section 6: Accidental Release Measures

Land Spill: Scoop up material and put into suitable container for disposal as a non-hazardous waste.

Water Spill: This material will sink and disperse along the bottom of waterways and ponds. It can not easily be removed after it is waterborne; however, the material is non-hazardous in water.

Air Release: This material will settle out of the air. If concentrated on land it can then be scooped up for disposal as a non-hazardous waste.

Section 7: Handling and Storage

Storage Temperature: Not applicable.

Storage Pressure: Not applicable.

General: No special storage or handling procedures are required for this material.

OWENS CORNING™

MATERIAL SAFETY DATA SHEET

Section 8: Exposure Controls and Personal Protection

Ingredient	OSHA PEL (8-hr TWA)	ACGIH TLV (8-hr TWA)
Fiber Glass Continuous Filament	5 mg/m^3 (respirable dust) 15 mg/m^3 (total dust 1 fiber/cc (proposed)	10 mg/m^3 (inhalable) 3 mg/m^3 (respirable)
Size	None Established	None Established
Polyester Yarn	5 mg/m^3 (respirable dust) 15 mg/m^3 (total dust	10 mg/m^3 (inhalable) 3 mg/m^3 (respirable)

Ventilation: General dilution ventilation and/or local exhaust ventilation should be provided as necessary to maintain exposures below regulatory limits.

Personal Protection:

Respiratory Protection: A properly fitted NIOSH/MSHA approved disposable dust respirator such as the 3M model 8210 (or 8710) or model 9900 (in high humidity environments) or equivalent should be used when: high dust levels are encountered; the level of glass fibers in the air exceeds the OSHA permissible limits; or if irritation occurs. Use respiratory protection in accordance with your company's respiratory protection program, local regulations and OSHA regulations under 29 CFR 1910.134.

Skin Protection: Loose fitting long sleeved shirt that covers to the base of the neck, long pants and gloves. Skin irritation is known to occur chiefly at pressure points such as around neck, wrist, waist and between fingers.

Eye Protection: Safety glasses or goggles.

Work and Hygienic Practices: Handle using good industrial hygiene and safety practices. Avoid unnecessary contact with dusts and fibers by using good local exhaust ventilation. Remove material from the skin and eyes after contact. Remove material from clothing using vacuum equipment (never use compressed air and always wash work clothes separately from other clothing. Wipe out the washer or sink to prevent loose glass fibers from getting on other clothing). Keep the work area clean of dusts and fibers made during fabrication by using vacuum equipment to clean up dusts and fibers (avoid sweeping or using compressed air as these techniques re-suspend dusts and fibers into the air.)
Have access to safety showers and eye wash stations.

Section 9: Physical and Chemical Properties

Vapor Pressure (mm Hg @ 20 ^{o}C): Not Applicable **pH:** Not Applicable

Vapor Density (Air=1): Not Applicable

Specific Gravity (Water=1): 2.60

Boiling Point: Not Applicable

Solubility in Water: Insoluble

Viscosity: Not Applicable

Appearance: Solid

Physical State: Solid

Odor Type: None

Freezing Point: Not Applicable

Evaporation Rate (n-Butyl Acetate=1): Not Applicable

MATERIAL SAFETY DATA SHEET

Section 10: Stability and Reactivity

General: Stable

Incompatible Materials and Conditions to Avoid: None

Hazardous Decomposition Products: Sizings or binders may decompose in a fire. See Section 5 of MSDS for combustion products statement.

Hazardous Polymerization: Will not occur.

Section 11: Toxicological Information

CARCINOGENICITY: The table below indicates whether or not each agency has listed each ingredients as a carcinogen:

Ingredient	ACGIH	IARC	NTP	OSHA
Fiber Glass Continuous Filament	A4	3	No	No
Size	No	No	No	No
Polyester Yarn	No	No	No	No

	LD_{50} Oral (g/kg)	LD_{50} Dermal (g/kg)	LC_{50} Inhalation (ppm, 8 hrs.)
Fiber Glass Continuous Filament	Not Available	Not Available	Not Available
Size	Not Available	Not Available	Not Available
Polyester Yarn	Not Available	Not Available	Not Available

MATERIAL SAFETY DATA SHEET

Fiber Glass Continuous Filament: The International Agency for Research on Cancer
(IARC) in June, 1987, categorized fiber glass continuous filament as not classifiable with respect to human carcinogenicity (Group 3). The evidence from human as well as animal studies was evaluated by IARC as insufficient to classify fiber glass continuous filament as a possible, probable, or confirmed cancer causing material.

Section 12: Ecological Information

This material is not expected to cause harm to animals, plants or fish.

Section 13: Disposal Considerations

RCRA Hazard Class: Non-hazardous.

MATERIAL SAFETY DATA SHEET

Section 14: Transport Information

DOT Shipping Names: Not regulated

Hazard Class or Division: None

Secondary: None

Identification No.: None

Packing Group: None

Label(s) required (if not excepted): None

Special Provisions: None

Packaging Exceptions: None

Non-bulk Packaging: None

Bulk packaging: None

EPA Hazardous Substances: None

RQ: None

Quantity Limitations: **Passenger Aircraft:** None
Cargo Aircraft: None

Marine Pollutants: None

Freight Description: None

Hazardous Material Shipping Description: None

™ MATERIAL SAFETY DATA SHEET

Transportation of Dangerous Goods - Canada

Proper Shipping Name: Not Regulated

TDG Hazard Classification: (Primary): None **(Secondary):** None

IMO Classification: None

ICAO/IATA Classification: None

Product Identification Number: None

Packing Group: None

Control Temperature: None **Emergency Temperature:** None

Schedule XII Quantity Restriction: None

Reportable Quantity for US Shipments: None

IATA Packing Instructions:

Passenger/Cargo: None
Cargo Only: None
Limited Quantity: None

Maximum Net Quantity per Package:

Passenger/Cargo: None
Cargo Only: None
Limited Quantity: None

Special Provisions: None

™ **MATERIAL SAFETY DATA SHEET**

Section 15: Regulatory Information

TSCA Status: Each ingredient is on the Inventory.

NSR Status (Canada): Each ingredient is on the DSL.

SARA Title III:

Hazard Categories:

Acute Health:	Yes
Chronic Health:	No
Fire Hazard:	No
Pressure Hazard:	No
Reactivity Hazard:	No

Reportable Ingredients:

Sec. 302/304:	None
Sec. 313:	None

California Proposition 65: No ingredient is listed.

Clean Air Act: No ingredient is listed.

WHMIS (Canada): **Status:** Not Controlled
WHMIS Classification(s): None

Section 16: Other Information

HMIS and NFPA Hazard Rating:

Category	HMIS	NFPA
Acute Health	1	1
Flammability	0	0
Reactivity	0	0

NFPA Unusual Hazards: None.
HMIS Personal Protection: To be supplied by user depending upon use.

Revision Summary: This is a new MSDS. (Reformatted 11/25/98)

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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

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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.

FIRST AID MEASURES

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.

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.

ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

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

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.

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:

Exposure Limits: No data available

Black Powder Pellets

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

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.

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

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REGULATORY INFORMATION

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.

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

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MATERIAL SAFETY DATA SHEET

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ProX Rocket Motor Reload Kits & Fuel Grains

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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)
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Ingredient Name	CAS Number	Percentage
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Metal Powders		1-45 %
Synthetic Rubber		10-30 %

Black Powder Ignition pellet

Ingredient Name	CAS Number	Percentage
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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.

FIRST AID MEASURES

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.

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.

ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

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

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.

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
	n/a	not established	not established
	7704-34-9	not established	not established
	7782-42-5	2.5 mg/m^3	15 mmpct (TWA)

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.

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

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REGULATORY INFORMATION

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.

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

The data in this Material Safety Data Sheet relates only to the specific material or product designated herein and does not relate to use in combination with any other material or in any process.

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no way shall the company be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if the company has been advised of the possibility of such damages.