Student Launch Project Flight Readiness Review

Colorado Boulder Rocketry Association (COBRA)

University of Colorado Boulder

Revised April 28, 2014

Table of Contents

Index of Tables

Index of Figures

Acronym Definitions

Acronym	Definition
A&R	Avionics and Recovery
AAA	American Automobile Association
AGL	Above Ground Level
APCP	Ammonium Perchlorate Propellant
APPM	Applied Mathematics
APS	Astrophysics
ASEN	Aerospace Engineering Sciences
CAD	Computer Aided Design
CDR	Critical Design Review
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
COBRA	COlorado Boulder Rocketry Association

CS	Computer Science
CU/UCB	University of Colorado Boulder
ECE	Electrical and Computer Engineering
EE	Electrical Engineering
EEF	Engineering Excellence Fund
EGSE	Electrical Ground Support Equipment
EHS	Environmental Health and Safety
EIRP	Equivalent Isotropically Radiated Power
EPS	Electronic Procurement System
FAR	Federal Aviation Regulations
FAA	Federal Aviation Administration
FOS	Factor of Safety
FRR	Flight Readiness Review
GndOps/COM	Ground Operations/Communications
GPS	Global Positioning Satellite
HYDRA	Hydrodynamics, hazard Detection, and Research into Aerodynamics
ID	Inner Diameter
ITLL	Integrated Teaching & Learning Laboratory
MCEN	Mechanical Engineering
MIG	Metal Inert Gas
MS/BS	Masters/Bachelors of Science Program
MSDS	Material Safety Data Sheets
NAR	National Association of Rocketry
NASA	National Aeronautics and Space Association
NCR	Northern Colorado Rocketry
NFPA	National Fire Protection Act
P&G	Propulsion and Guidance
PDR	Preliminary Design Review
PLAR	Post-Launch Assessment Review
PPE	Personal Protection Equipment
PVC	Polyvinyl Chloride
RAM	Random Access Memory
RF	Radio Frequency
S&A	Structures and Aerodynamics
SCORE	Southern Colorado Rocketeers
SD	Secure Digital
SLC	Salt Lake City
SLS	Space Launch System
SMA	SubMiniature version A
SOFO	Student Organizations Finance Office
SOW	Statement of Work
STEM	Science, Technology, Engineering, and Math

UCEC	University of Colorado Engineering Council
UROP	Undergraduate Research Opportunity Fund
USFS	United States Forest Service
VSWR	Voltage Standing Wave Ratio

1 Summary of Report

1.1 Team summary

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1.2 Launch Vehicle Summary

This year's rocket is entitled HYDRA (**HY**drodynamics, hazard **D**etection, **R**esearch for **A**erodynamics), after the nine-headed water serpent monster from Greek mythology.

Size: 154 inches in length, 3.9-inch diameter
Wet mass: 32.1 lbs
Motor: Cessaroni L-1720 White Thunder
Recovery system: Elliptical-cupped parachutes, dual-deployment
Rail size: 12ft long 1515 rail

Milestone Review Flysheet

Institution	University of Colorado Boulder	Milestone	CDR

First Stage (Both Stages Together or Single Stage)		Second Stage (If Applicable)	
Vehicle Properties		**Vehicle Properties**	
Total Length (in)	154	Total Length (in)	N/A
Diameter (in)	3.9	Diameter (in)	N/A
Gross Lift Off Weight (lb)	32.1	Gross Weight (lb)	N/A
Airframe Material	Carbon fiber	Airframe Material	N/A
Fin Material	Carbon fiber and Aircraft Plywood	Fin Material	N/A
Motor Properties		**Motor Properties**	
Motor Manufacturer(s)	Cessaroni	Motor Manufacturer(s)	N/A
Motor Designation(s)	L-1720	Motor Designation(s)	N/A
Max/Average Thrust (lb)	437/398	Max/Average Thrust (lb)	N/A
Total Impulse (lbf-sec)	823	Total Impulse (lbf-sec)	N/A
Stability Analysis		Ignition Altitude (ft)	N/A
Center of Pressure (in from nose)	125	Ignition Timing (From 1st Stage Burnout)	N/A
Center of Gravity (in from nose)	100	Igniter Location	N/A
Static Stability Margin	6.3	**Stability Analysis**	
Thrust-to-Weight Ratio	13.5	Center of Pressure (in from nose)	N/A
Rail Size (in)	1.5	Center of Gravity (in from nose)	N/A
Rail Length (in)	144	Static Stability Margin	N/A
Rail Exit Velocity (ft/s)	97.8	Thrust-to-Weight Ratio	N/A
		Ascent Analysis	
Maximum Velocity (ft/s)	842	Maximum Velocity (ft/s)	N/A
Maximum Mach Number	0.77	Maximum Mach Number	N/A
Maximum Acceleration (ft/s^2)	453	Maximum Acceleration (ft/s)	N/A
Target Apogee (1st Stage if Multiple Stages)	6000	Target Apogee (ft)	N/A
Recovery System Properties		**Recovery System Properties**	
Drogue Parachute		**Drogue Parachute**	
Configuration	Elliptical-Cupped	Configuration	N/A
Size	39 in diameter	Size	N/A
Deployment Velocity (ft/s)	0	Deployment Velocity (ft/s)	N/A
Terminal Velocity (ft/s)	50	Terminal Velocity (ft/s)	N/A
Fabric Type	1.9 ounce rip-stop nylon	Fabric Type	N/A
Shroud Line Material	1/2 inch tubular nylon cord	Shroud Line Material	N/A
Shroud Line Length (in)	60 in	Shroud Line Length (in)	N/A
Thread Type	Dual Duty XP Heavy Thread	Thread Type	N/A
Seam Type	Rolled Hem Seams	Seam Type	N/A
Recovery Harness Type	1 in tubular Kevlar	Recovery Harness Type	N/A
Recovery Harness Length (ft)	25	Recovery Harness Length (ft)	N/A
Harness/Airframe Interface	3/8" Steel Quick Links	Harness/Airframe Interface	N/A
Main Parachute		**Main Parachute**	
Configuration	Elliptical-Cupped	Configuration	N/A

Size	94 in diameter				Size	N/A		
Deployment Velocity (ft/s)	50				Deployment Velocity (ft/s)	N/A		
Terminal Velocity (ft/s)	18.8				Terminal Velocity (ft/s)	N/A		
Fabric Type	1.9 ounce rip-stop nylon				Fabric Type	N/A		
Shroud Line Material	1/2 inch tubular nylon cord				Shroud Line Material	N/A		
Shroud Line Length (in)	175 in				Shroud Line Length (in)	N/A		
Thread Type	Dual Duty XP Heavy Thread				Thread Type	N/A		
Seam Type	Rolled Hem Seams				Seam Type	N/A		
Recovery Harness Type	1 inch tubular Kevlar				Recovery Harness Type	N/A		
Recovery Harness Length (ft)	25				Recovery Harness Length (ft)	N/A		
Harness/Airframe Interface	3/8" Steel Quick Links				Harness/Airframe Interface	N/A		
Kinetic Energy of Each Section (ft-lbs)	Section 1	Section 2	Section 3	Section 4	Kinetic Energy of Each Section (ft-lbs)	Section 1	Section 2	Section 3	Section 4
	Fin Can Assembly	Lower body tube and Avionics Bay	Upper Body Tube and Nosecone	N/A		N/A	N/A	N/A	N/A
	45.32	54.05	38.36	N/A		N/A	N/A	N/A	N/A

Milestone Review Flysheet

Institution	University of Colorado Boulder	Milestone	CDR

First Stage (or Single Stage)		Second Stage (If Applicable)	
Recovery System Properties		Recovery System Properties	
Altimeter(s)/Timer(s) (Make/Model)	Featherweight Raven (2)	Altimeter(s)/Timer(s) Make/Model	N/A
			N/A
			N/A
			N/A
Transmitters (Model-Frequency-Power)	xBee Pro S2B RF Module, 2400 MHz, 17 dBm	Locators/Frequencies (Model-Frequency-Power)	N/A
			N/A
			N/A
			N/A
Black Powder Charge Size Drogue Parachute (grams)	2 grams	Black Powder Charge Size Drogue Parachute (grams)	N/A
	3 grams (backup)		N/A
Black Powder Charge Size Main Parachute (grams)	4 grams	Black Powder Charge Size Main Parachute (grams)	N/A
	5 grams (backup)		N/A

Payloads	
Mandatory Payload	Overview
3.1	The hazard detection system shall consist of an on-board forward facing camera that is mounted in the nose cone of the rocket so that it will point at the anticipated landing site after recovery system deployment. The camera shall be hooked up to an onboard microcomputer that will analyze the incoming data for hazards, and transmit the images and analysis thereof to a ground station. The payload will use a Raspberry Pi microcomputer and hazard detection algorithm software written in MATLAB, and the data will be transmitted along with the GPS data using an xBee XSC Pro RF Module and Arduino Uno for buffer handling.
Optional	Overview

Payload 1 3.2.1.2	The liquid sloshing payload will be omitted from the final launch vehicle.
Optional Payload 2 3.2.2.2	Overview Our aerodynamic analysis payload will measure pressure on different types of protuberances on the side of the rocket. The pressure will be measured on mock "Solid Rocket Boosters" with different shapes. These pressure measurements will be used to analyze drag of the different shaped "SRBs". Furthermore, these results will be simulated against CFD results for data verification.

Test Plans, Status, and Results	
Ejection Charge Tests	Ejection charge testing for both the sub-scale and full-scale rockets was performed prior to their respective launches. They were performed under supervision of the safety officer. Only necessary personnel were present to minimize risks. Three charges were tested, a smaller than necessary charge, a theoretical optimum charge, and a larger than necessary charge to ensure that the charge sizes are sufficient to provide reliable deployment of the recovery systems. For the sub-scale it was found that the theoretical optimum was adequate, so the larger charge was utilized only as a backup. The same resulted from the ejection charge tests for the full-scale and the main chute deployed easily with the recommended charge. Prior to the next full-scale test flight, ejection charge and deployment tests will be performed for both the main and drogue chutes to verify that deployment will proceed smoothly.
Sub-scale Test Flights	The subscale of the HYDRA vehicle was tested at the SCORE (Southern Colorado Rocketeers) Hudson Ranch launch site near Pueblo, CO. This was the team's fourth attempt at a subscale test flight as the previous launches were cancelled due to inclement weather. The sub-scale vehicle reached an altitude of 3,812 feet AGL, which was lower than expected due to extremely windy launch conditions and losses due to bending of the rocket. Numerous lessons and design considerations were gained from the sub-scale launch and helped to design and construct the full-scale vehicle. These results are discussed in more detail in the addendum to the CDR.
Full-scale Test Flights	The initial attempt at a full-scale test flight occurred on April 5th, 2014. Unfortunately, the parachute deployment was not successful and the vehicle could not be recovered or repaired. The team then rebuilt the full-scale vehicle with plans to launch on April 19th, with a back-up test flight date on April 27th. Unfortunately, due to the Easter holiday weekend and inclement weather, the local rocketry clubs canceled both of these scheduled launches and the full-scale vehicle test flight could not be completed by the deadline. The team plans to complete a full-scale test launch and fly payloads at a later date independent of the competition.

Additional Comments
None.

1.3 Payload Summary

The payloads for HYDRA are as follows:

1) **HazCam**
    a. **Requirement 3.1:** Scan the surface during descent in order to detect potential landing hazards.
    b. HazCam is a camera system that scans the surface during descent in order to detect potential landing hazards, analyzes the data, and transmits data to the ground station in real time.
2) **Liquid Sloshing Experiment [Omitted]**
    a. **Requirement 3.2.1.2:** Liquid sloshing research in microgravity to support liquid propulsion system upgrades and development.
    b. The liquid sloshing payload will test an experimental method for mitigating liquid sloshing during the microgravity regime of the flight profile. The payload characterizes the differences between fuel that is free to slosh around a fuel tank and one that is contained in a plastic bag in a pressurized container. Accelerometers on both will characterize the effects of liquid slosh and a camera will view the sloshing itself. Data will be logged through a Raspberry Pi microcomputer on an SD card for post-flight analysis.
    c. **Due to budgetary and scheduling constraints, this payload will be omitted from the final launch vehicle flight.**
3) **Aerodynamic Analysis**
    a. **Requirement 3.2.2.2:** Aerodynamic analysis of structural protuberances
    b. Our aerodynamic analysis payload will measure pressure on different types of protuberances on the side of the rocket. The pressure will be measured on mock "Solid Rocket Boosters" with different shapes. These pressure measurements will be used to analyze drag of the different shaped "SRBs". Furthermore, these results will be simulated against CFD results for data verification.

2 Changes Made Since CDR

2.1 Changes Made To Vehicle Criteria

- The mass of the rocket has decreased to 29.5 kg due to the omission of the liquid sloshing payload and the addition of measured weights for the recovery system.
- Fillets of epoxy resin and chopped carbon fiber were added to various parts of the rocket to increase structural strength of components and to prevent them from separating from the vehicle.
- Due to inclement weather, a full-scale test flight was not able to be completed by the deadline. The team plans to complete a full-scale test launch and fly payloads at a later date independent of the competition.

2.2 Changes Made to Payload Criteria

HazCam:

- No major changes were made to the HazCam payload.

Liquid Sloshing:

- Due to budgetary and scheduling constraints, this payload will now be omitted from the final launch vehicle flight.

Aerodynamic Analysis:

- The largest change to the payload design since CDR is the removal of the amplification circuitry. It originally was going to be used to increase data resolution of the pressure sensors and reduce effects of noise in the signal, but the designed amplification ranges were found to be outside the bounds of the analog-to-digital circuitry used in the payload.
- Where previously PVC was going to be used for the "SRB" airframe, now carbon fiber tubes are being used instead.
- Two nose cones that were going to be manufactured by our team are now replaced with COTS nose cones

2.3 Changes Made to Project Plan

- The funding plan was updated to include finalized details for additional funding sources.
- The budget has been updated to reflect the current needs of the project.
- The schedule has been updated to accommodate for delays and changes.
- The team membership list has been updated to reflect the current active participating members of the team.

3 Vehicle Criteria

3.1 Selection, Design, and Verification of Launch Vehicle

3.1.1 Mission Statement

COBRA will design, build, test, and launch a high-power rocket that will reach an altitude of 6,000 feet above ground level (AGL) and will house three payload experiments (a hazard-detection camera, a liquid sloshing experiment, and aerodynamic vortex generators) as well as a team-designed and built recovery system, while meeting all NASA and safety requirements.

3.1.2 Vehicle Requirements

1. The rocket shall reach as close to 6,000 feet AGL as possible.
2. An altimeter shall record the apogee of the rocket for official competition purposes.
3. An additional altimeter shall be flown on the rocket for payload timing purposes.
4. All audible electronic equipment shall be able to be turned off.
5. All battery-powered electronics shall last at minimum one hour without losing any functionality.
6. Sub-scale and full-scale test launches shall be performed by the required date.
7. The recovery system shall deploy at apogee and slow every piece of the rocket so that each has no more than 75 ft-lbf of kinetic energy upon impact.
8. Pressure vessels should be designed and verified to have a minimum factor of safety of 4:1 (burst pressure to maximum expected operating pressure).
9. The recovery system shall be designed and manufactured by the team.
10. The recovery system electronics shall be completely independent of any payload electrical circuits.
11. The recovery system shall contain redundant commercial altimeters.
12. Each altimeter shall be armed by a dedicated arming switch which is accessible from the exterior of the rocket airframe when the rocket is in launch configuration on the launch pad.
13. Each altimeter shall have a dedicated power supply.
14. Each altimeter shall be capable of being locked in the ON position for launch.
15. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.
16. An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.
    - 16.1 Any rocket section or payload compartment which lands untethered to the launch vehicle shall also carry an active electronic tracking device.
    - 16.2 The electronic tracking device shall be fully functional during the official flight at the competition launch site.

3.1.3 Mission Success Criteria

1. The team meets all established deadlines; this includes deadlines for completing design reviews and presentations, test flights, and rocket construction and integration.
2. The team follows all competition requirements and regulations as defined by NASA.
3. The rocket successfully clears the launch pad.
4. Payload success is based on the following:
    a. Minimum success: Some data is collected from both payload experiments.
    b. Full success: Hazards are successfully detected and downlinked to the ground station, and pressure and velocity data are collected across all three SRBs for the duration of the entire flight, and results are within 15% of CFD results.
    c. More specific details regarding success criteria can be found in the individual payload sections.
5. The rocket is successfully recovered in a reusable condition.

3.2 System Level Design Review

The HYDRA vehicle has been divided into five separate subsystems. These subsystems include: Structures and Aerodynamics (S&A), Propulsion and Guidance (P&G), Payload, Avionics and

Recovery (A&R), and Ground Operations/Communications (GndOps/COM). The S&A subsystem is responsible for the design of all components that make up the airframe of the vehicle. This includes the nosecone, fin can assembly, coupling systems, and body tubes. P&G is responsible for the selection of the motor for the vehicle as well as the design of the motor retention system. The Payload subsystem will be discussed later in Section 4 as it pertains to the three required on-board research payloads. A&R is responsible for the sequencing of recovery system deployment, design of the main and drogue parachutes, and selection of all recovery electronics, including their mounting within the vehicle. Finally, the GndOps/COM subsystem is responsible for all telemetry between the vehicle and the ground station.

3.2.1 Structures and Aerodynamics

The functional requirements for the S&A subsystem are as follows:

Table 1 - S&A Requirements

#	Requirement	Satisfying Design Feature	Verified by:	Status
SA.1	The airframe of the vehicle must be able to survive under all expected loads experienced during flight.	Body Tubes and Couplers	Analysis, Test	Verified
SA.1.1	The airframe must survive a max longitudinal load of 400 lbf	Body Tubes and Couplers	Analysis, Test	Verified
SA.2	The airframe must be able to integrate with all on board payloads, electronics, and recovery systems.	Avionics Bay, Body Tubes	Inspection	Verified
SA.3	The airframe must integrate with the motor retention system.	Motor Tube, Motor Retainer	Inspection	Verified

The main airframe of the vehicle will be comprised of three separate 3.9” diameter body tubes that will be hand lay-up carbon fiber and epoxy composite structures. These body tubes will be manufactured in house and a detailed description of the manufacturing process can be found in Appendix B. The reasoning for this selection is the high strength to weight ratio of carbon fiber and epoxy systems. In addition, the team already has the materials needed for construction of these tubes which will significantly reduce the anticipated team expenses.

For these composite carbon fiber epoxy tubes, the team has analyzed the axial loads the rocket is predicted to experience and verified that the airframe will survive under the given loads. In order to predict the aerodynamic forces acting on the vehicle, a force balance was used. The free body diagram can be seen below in Figure 1.

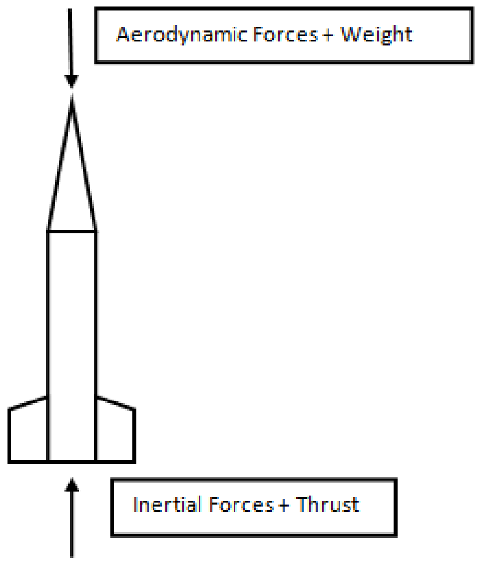


Figure 1 - Free Body Diagram of Anticipated Axial Vehicle Loads

It can be seen from Figure 1 that the four expected loads on the vehicle will be Thrust (T), Aerodynamic Forces (D), Weight (W), and Inertial Forces (F). A dynamic force balance to solve for the axial compression (A) in the body tube can be constructed as shown below in (1).

$$F = ma = T - D - W \tag{1}$$

$$A = T - W = ma + D \tag{2}$$

Where m is mass of the vehicle and a is the acceleration of the vehicle. We know that axial compression (A) occurs when thrust (T) is greater than the weight of the vehicle (W). This excess thrust can be viewed as the imparted acceleration on the vehicle that is resisted by the drag forces. Using Equation (2), a plot of the predicted axial loading of the vehicle throughout the flight can be seen below in Figure 2 - Axial Load vs. Motor Burn Time

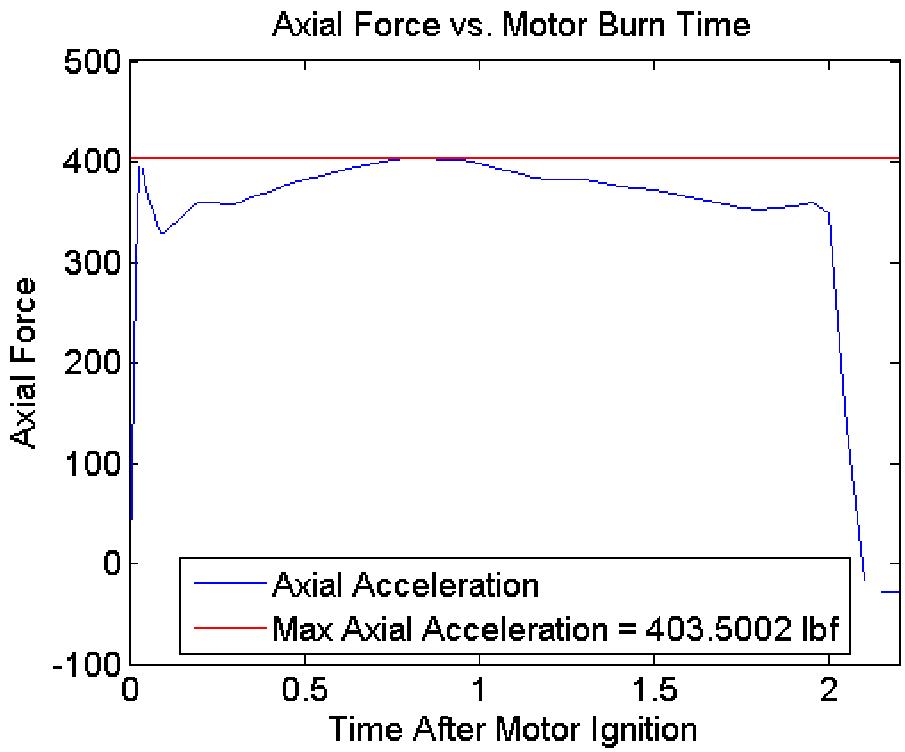


Figure 2 - Axial Load vs. Motor Burn Time

We then needed to calculate the stiffness of our manufactured body tubes and their ability to resist the compressive stresses imparted from axial flight loads. In order to determine the critical buckling load of the tubes, the following equation was used:

$$F_{cr} = \frac{\pi^2 E}{\left(\frac{L}{k}\right)^2} \tag{3}$$

Where F_{cr} is the critical buckling load, E is the modulus of elasticity of composite carbon fiber and epoxy tubes, L is the length of the tube, and k is the radius of gyration of the tube defined as $k = \sqrt{I/A}$. Note that I is defined as $I = \frac{\pi(d_o^4 - d_i^4)}{64}$. Using the following material specifications and noting that the critical load decreases with increasing length (the team used the full length of the rocket in the calculation for a conservative result). $L = 154$in, $d_o = 4$in, $d_i = 3.9$in, and $E = 10{,}200$ksi. With these conservative material specifications, we obtain a critical buckling load of $F_{cr} = 8{,}280$lbf for a factor of safety of 20.5. Knowing these results, the team decided that the airframe of the vehicle would survive all axial loads the vehicle would experience during flight.

Of the three body tubes, two will be used for housing the on board payloads and the parachutes to be used for recovery. The other tube will make up the fin can assembly. Dimensional drawings of these three sections can be seen below in Figure 3-Figure 5.

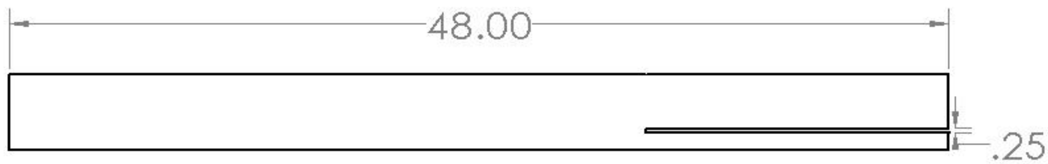


Figure 3- Fin Can Tube

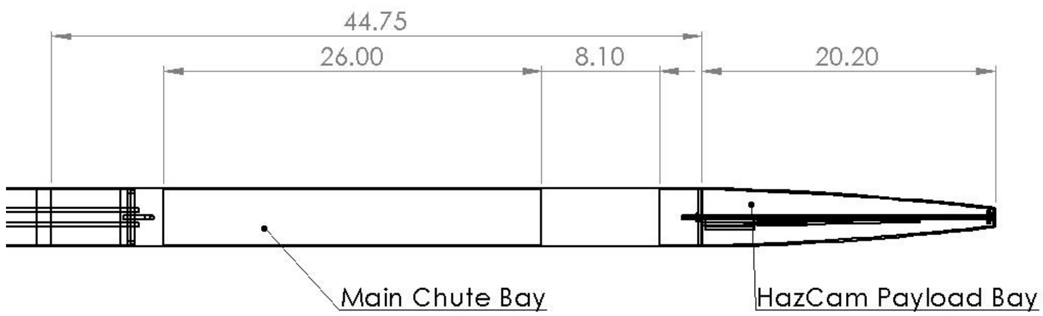


Figure 4 - Upper Section

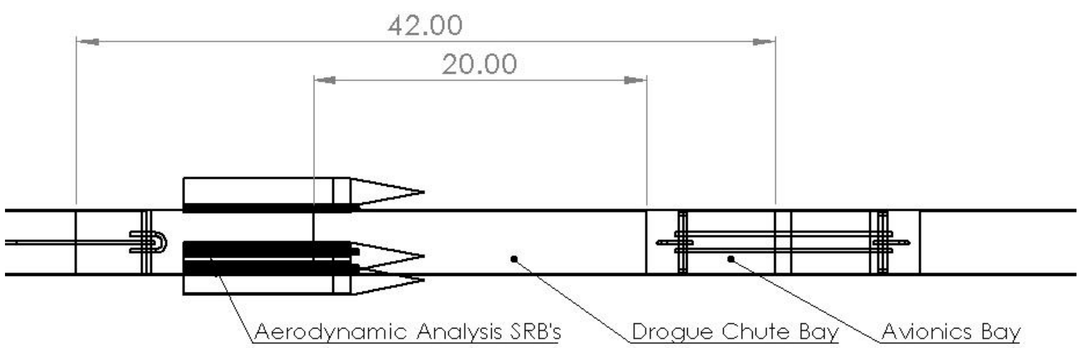


Figure 5 - Lower Section

The tube shown in Figure 3 can be seen to have slots extending partway up from the rear of the vehicle. These are for ease of integration of the fins and motor mount. The fins for the vehicle will be constructed using a 3-ply laminate structure. This consists of an aircraft plywood core that is sandwiched between plies of carbon fiber fabric impregnated with an epoxy resin. This creates a very stiff fin material that is also lightweight. The fin design can be seen below in Figure 6.

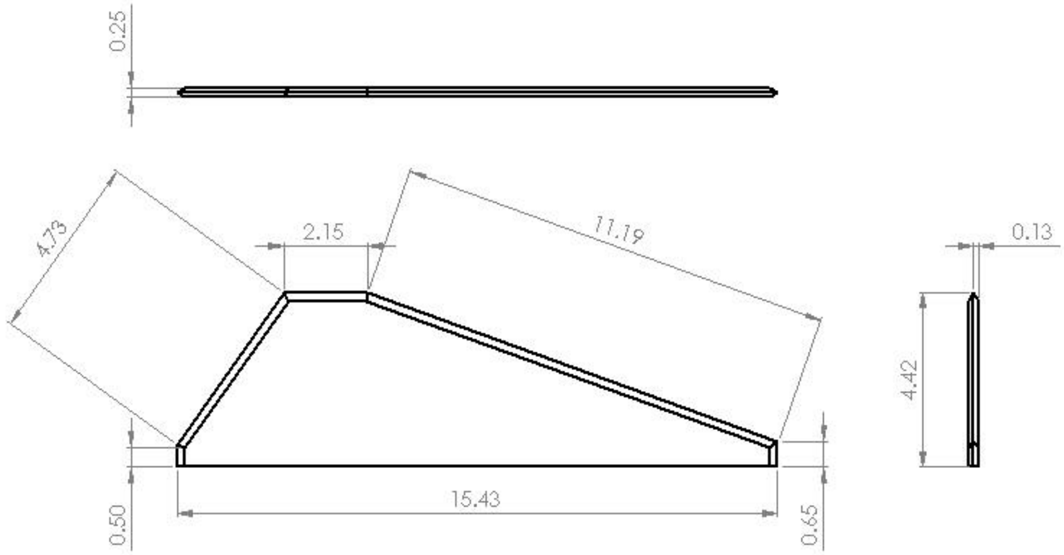


Figure 6 - Fin Design

Figure 7 - Constructed Fin

It can be seen in the above figures that the fin design has a small surface area projecting into the flow. This fin style has two purposes related to the mission of the vehicle. First, it is very low drag with a very thin profile which will minimize the effect the fins will have on the flow around the vehicle in order to get the most consistent results from the aerodynamic analysis payload. Second, as the vehicle is long and skinny, it is necessary to prevent weather cocking as much as possible due to the stability margin of the vehicle. It is also important to note that the fins are through the wall fins, as seen by the protrusion from the base of the fin. This gives the fins much more bonding surface, creating a stronger attachment to the rocket. They will first be attached to the motor mount assembly using an epoxy resin and a fin alignment guide as it is important that the fin slots and epoxied fins are, in line with each other. Fillets of epoxy mixed with chopped carbon fiber will then be applied to the joints between the fins and the motor mount tube to add strength. This assembly will then be slid into the lower body tube and fixed in place using an epoxy resin. Fillets will again be applied between the exterior of the body tube and the fin in order to further strengthen the fin attachment. The construction of the motor mount assembly will be discussed in detail in Section 3.2.2.

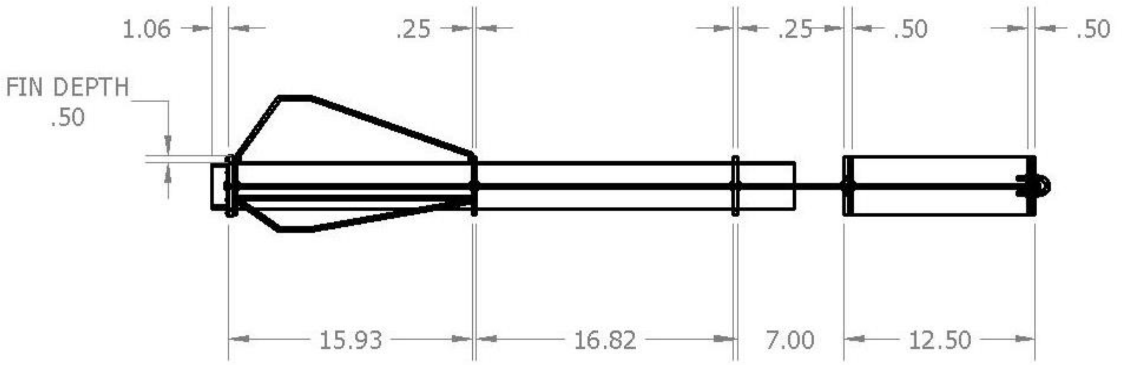


Figure 8 - Fin Can Assembly

The next component to be discussed will be the coupling systems. As seen in Figure 9 below, there are two points in the airframe where coupling is necessary. These tube couplers are filament wound fiberglass coupler tubes purchased from Giant Leap Rocketry. The dimensions of each coupler tube will vary slightly, but the overall design is the same and can be seen below in Figure 10.

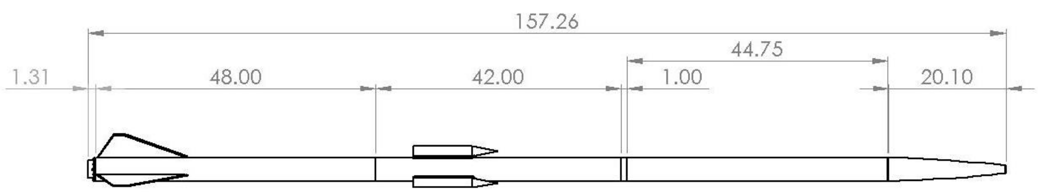


Figure 9 - HYDRA Rocket

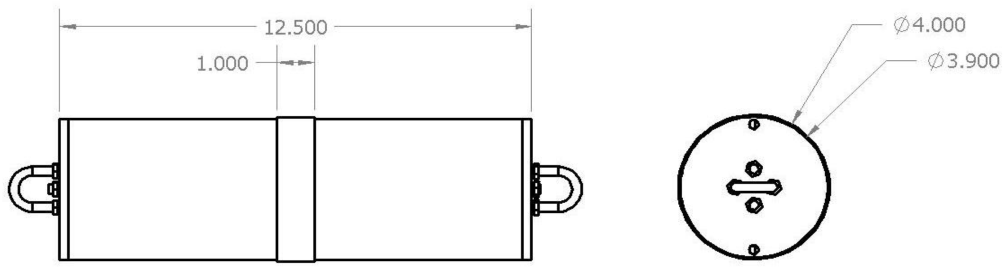


Figure 10 – Coupler Tube

The design consists of bulkheads covering both ends of the ends of the coupler tubes. These bulk heads each contain a 5/16" U-bolt on the exterior face for use as a recovery anchor. This is bolted through the entire ½" bulkhead using the supplied backing plate and 5/16"-18 nuts. All of these nuts are then coated in a layer of epoxy in order to create a more permanent attachment point. There are then two 1/4"-20 all thread pieces running through the entire coupler that secure the whole assembly together.

The final design component for this subsystem is the nosecone. The nosecone selected is a filament wound fiberglass 6 to 1 Von Karman nosecone from Wildman Rocketry. The reason for this nosecone is that it has a removable metal tip which the team plans on removing so the hazard detection camera has an unobstructed view. The team has also had good experiences with the durability and strength of this particular nosecone. This nosecone also comes with a shoulder that can be used to attach it to the rocket. A drawing of the nosecone can be seen below in Figure 11.

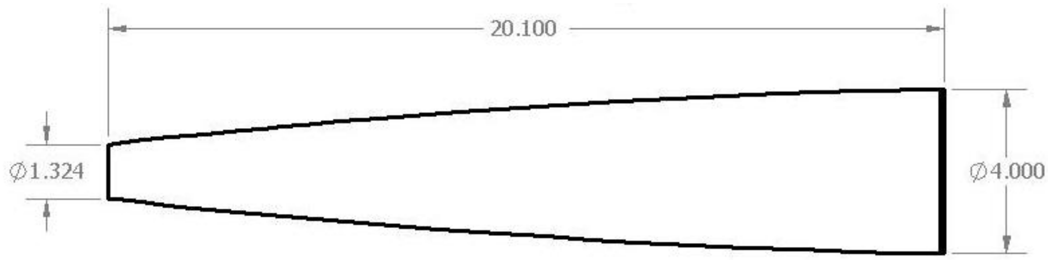


Figure 11 - Nosecone Design

3.2.2 Propulsion and Guidance

The functional requirements for the P&G subsystem are as follows:

Table 2 - P&G Requirements

#	Requirement	Satisfying Design Feature	Verified by:	Status
PG.1	The motor must stay within the vehicle at all times during flight	Motor Retainer	Analysis, test	Verified
PG.2	The motor must supply enough thrust for the vehicle to obtain the target altitude of 6,000 feet	Motor	Analysis, test	Verified

The main components to be discussed are the motor selection and the motor retention system. The reasoning for the motor selection will be detailed below in Section 3.8. The motor retention system consists of a motor mount tube with a thrust plate, two additional centering rings and a bulk head which are all connected with two continuous pieces of all thread. A drawing of the entire assembly can be seen below in Figure 12.

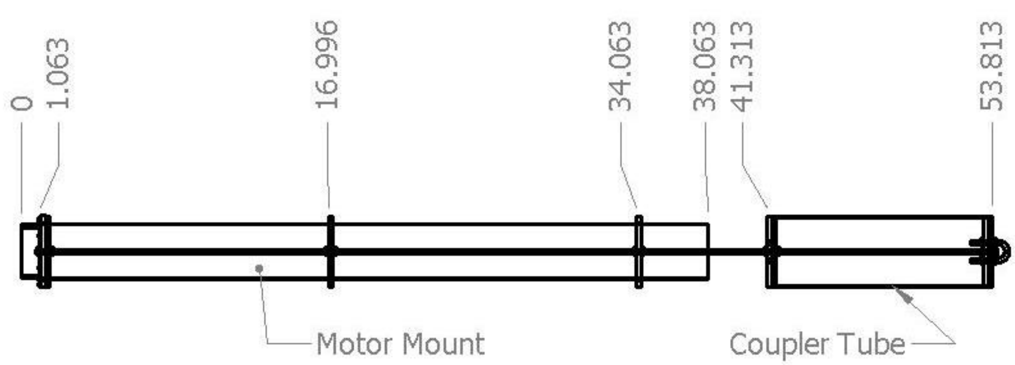


Figure 12 - Motor Retention System

Notice in the above figure that there are two pieces of continuous all thread that span the length of the motor retention system. This is to provide an additional anchor for the recovery system mounting point at the top of booster section in order to prevent inadvertent separation of the fin can assembly. The motor mount tube is a hand lay-up carbon fiber and epoxy composite structure that will be manufactured by the team. The manufacturing process can be seen in Appendix B. The diameter of this tube will need to be very close to the diameter of the 75mm motor casing being used by the team. This will ensure that the motor does not move while integrated with the rocket. A drawing of this tube can be seen below in Figure 13.

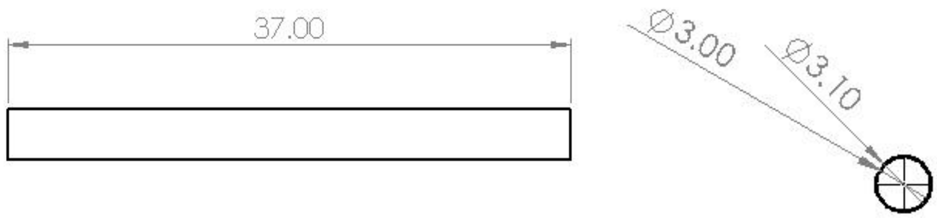


Figure 13 - Motor Mount Tube

The thrust plate is attached to the base of the motor mount tube with an epoxy resin. It will be constructed out of ½” thick aircraft plywood. Once it is attached, a fillet of epoxy resin and chopped carbon fiber will be applied to the upper surface to improve bonding strength. A drawing can be seen below in Figure 14.

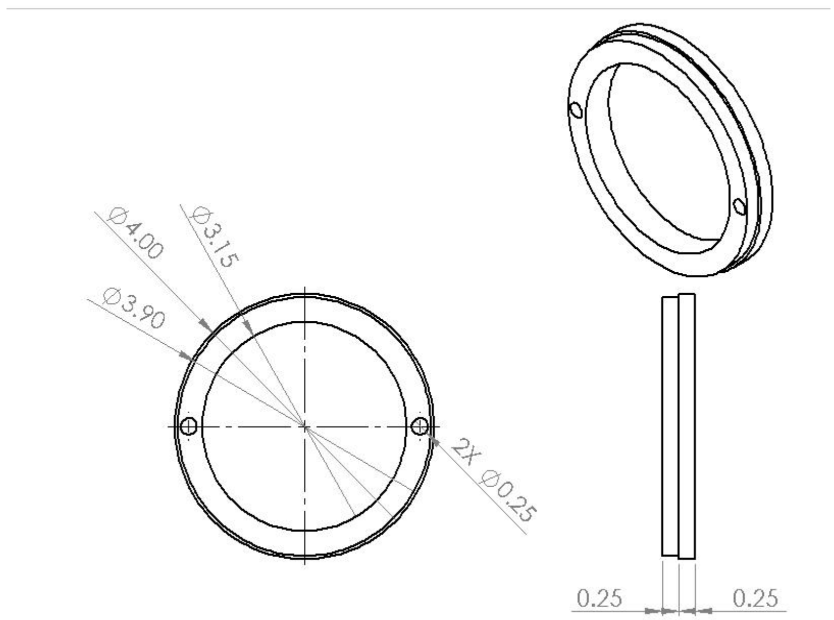


Figure 14 - Thrust Plate

This stepped design will allow for the thrust produced by the motor to be directed into the airframe through the thrust plate rather than the internal epoxy joints holding the assembly together. This design will help to ensure that the motor does not move within the rocket which would be a catastrophic failure. In order to hold the motor into the motor mount tube, an Aeropack Quick-Change, flanged motor retainer will be bolted to the base of the thrust plate. This can be seen below in Figure 15.

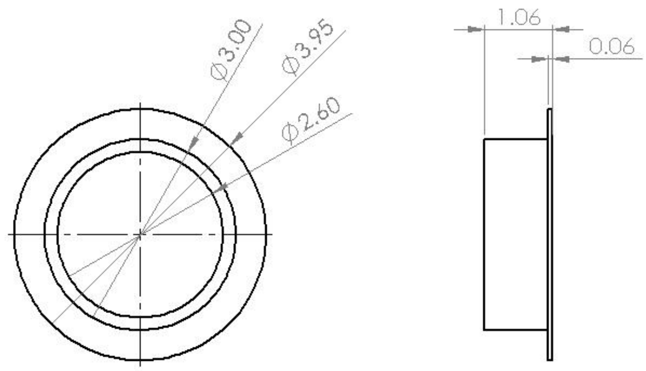


Figure 15 - Motor Retainer

The centering rings will be constructed out of ¼" aircraft plywood with diameters as specified in the drawing below in Figure 16.

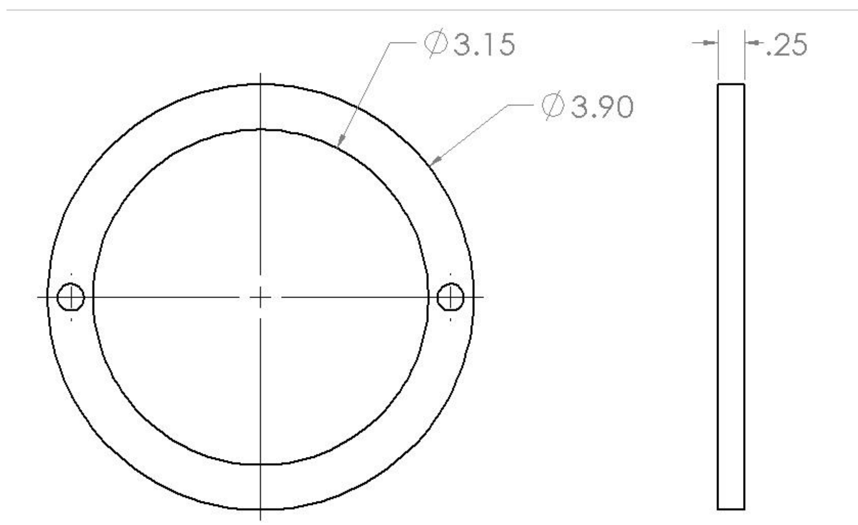


Figure 16 - Centering Ring

These will be affixed to the motor mount tube with an epoxy resin the spacing shown in Figure 12. As stated above, two pieces of ¼"-20 all thread will run the length of the entire motor mount assembly. It will also be bolted to each centering ring and bulkhead as well. This is achieved by using a tee nut that will be set into the base of the thrust plate with a hammer. It will then be secured with epoxy and the excess flange on the nut will be ground off for integration purposes. At each centering ring, there is a ¼"-20 nylon lock nut and washer on both the top and bottom of the centering ring securing the all thread to the centering ring. Before all the bolted joints are fully secured, a layer of epoxy is applied to the point where the nuts will engage the threads. The nuts are then tightened into place over top of this epoxy layer. Once this cures, a layer of epoxy resin is spread over all of the nut attachments to further ensure that the nuts do not loosen with vibration. Once the nuts are epoxyed in place, fillets of chopped carbon fiber and epoxy are applied to where the upper and lower face of each centering ring joins with the motor tube. This will further ensure that the motor tube does not separate from the centering rings in the event of a thrust plate failure. Even though this adds mass to the entire vehicle, it will prevent the fin can recovery anchor from pulling out as it is effectively bolted to the thrust plate. Although this is an unlikely failure mode of the vehicle, this system will make the likelihood of this failure occurring almost impossible. The upper bulkhead attached to this assembly acts as the bottom bulkhead of the lower coupler assembly as shown in Figure 12. This entire system is then inserted into the lower body tube with copious amounts of epoxy resin in order to ensure that all the centering ring joints have sufficient strength.

Currently most of the vehicle components have been manufactured. The only remaining duties for the vehicle are constructing and assembling the payload integration devices in addition to the installation of some of the updated recovery hardware. Both of these systems were installed in preparation for the full-scale test flight on 4/19.

3.2.3 Avionics and Recovery

Table 3 - A&R Requirements

#	Requirement	Satisfying Design Feature	Verified by:	Status
AR.1	The recovery avionics must have a completely independent backup system	Raven Featherweight Altimeters	Inspection	Verified
AR.2	The recovery avionics must fit within the allotted space in the avionics bay	Avionics Bay	Inspection	Verified
AR.3	The recovery system shall fit within the available tube space.	Recovery System, Body Tubes	Inspection	Verified
AR.4	The recovery system shall be able to be deployed while the rocket is in its flight configuration	Recovery System	Test	Verified

The recovery subsystem will consist of a main parachute (94 inches corner to corner), a drogue parachute (thirty-nine inches corner to corner), four wooden bulkheads, four steel U-bolts, six steel quick links, two high force swivels, nylon shock cord, two altimeters, and four black powder charges. The drogue parachute will be deployed at apogee with the separation of the upper body section and the electronics bay. The main parachute will deploy at 1,000 ft. AGL with the separation of the lower body section and the booster section containing the motor. This will slow the rocket so that it has a safe kinetic energy upon landing. This system is discussed more in Section 3.8.

3.2.4 Ground Operations/Communications

Table 4 – Ground Ops/COM Requirements

#	Requirement	Satisfying Design Feature	Verified by:	Status
GO.1	The wireless transmitters must be able to downlink all necessary data from the rocket in real time while in flight configuration.	Transmitter, ground computer	Test	Verified
GO.2	The range of the transmitter shall be more than two miles when installed in its flight configuration	Transmitter	Test	Verified
GO.3	The ground station must be able to store all downlinked data in real	Ground computer	Test	Verified

	time.			

The vehicle COM subsystem consists of an xBee Pro Series 2 Module using an electrically short whip antenna (“rubber ducky”) for transmission. The ground station consists of the same antenna and an identical module sending the incoming data to a laptop computer through a serial connection. The system is also capable of half-duplex communication with the ground though this capability is not utilized. The xBee module transmits at 17 dBm and has a receive sensitivity of -102 dBm and is capable of data rates up to 250 kbps. The carrier frequency can be configured on the 2.4GHz ISM band MHz to minimize interference from other sources. The data being transmitted comes from two sources, the vehicle GPS and the hazard camera payload. The data from the GPS and camera payloads are transferred over a serial connection to the RF module. As the data from these sources is only of use during the descent portion of the flight the COM subsystem will be only be powered during this phase to reduce the total power consumption of the subsystem and therefore the necessary battery capacity. The xBee module requires 3.3V and draws 295 mA during transmission, to be provided by the vehicle EPS subsystem. As the transmit antenna is located in the nosecone of the vehicle and the avionics and recovery deployment are located closer to the midsection of the rocket, inside of the carbon fiber body tube, and the transmit power is only 17 dBm there is little concern about interference between the transmitter and these systems. This assessment is supported by previous flights of the transmitter that showed no such interference.

3.2.4.1 Ground Ops/COM Verification plan

Table 5 – Ground Ops/COM Verification Plan and Test Data

Test	Success Criteria	Verification	Test Data	Notes
Antenna Gain/Pattern	Gain within 10% of nominal No nulls except on-axis VSWR < 2	Test all values using spectrum analyzer	Antenna 1 Gain: 1.0 dBi Antenna 2 Gain: 3.1 dBi Antenna 1 VSWR: -9.42 dB Antenna 2 VSWR: -9.98 dB Antenna 1 Nulls: on-axis only Antenna 2 Nulls: on-axis only	Gain values are not within 10% though normalizing antenna may not be accurate
Subsystem functionality	1) All power pins nominal voltage 2) Data pins show correct signal 3) TX Power nominal 4) EIRP nominal	1) Multimeter to verify voltages 2) Oscilloscope to check waveform 3) Spectrum Analyzer on direct wired connection 4) Spectrum Analyzer with antenna, normalized to known antenna	3.3V line: 3.28 V TX Power: 16 dBm EIRP: 19.1 dBm	TX power a bit low but within tolerance, test values used in link budget
Wired RF	1) No more than 1% dropped packets at minimum attenuation 2) Received power level at which dropped packets exceeds 10% is less than -100 dBm	Test both by monitoring serial stream out of ground RF module	Reliability: GPS Data comes through every second as it should Power Level @ 10% loss: not found as all available attenuators (370 dB) were placed in line without breaking link	Test is not that good as connectors and cabling radiate, allowing the link to remain stable
Wireless RF (EGSE)	1) No more than 1% dropped packets 2) No significant changes from wired	Monitor serial stream out of ground RF module	Reliability: GPS Data comes through every second as it should	No changes to signal from wired

Table 6 - Test Results for xBee Pro Series 2 Module

Power Out [dBm]	TX Antenna Gain [dBi]	Distance [m]	Path Loss @ 907 MHz [dB]	Signal Strength at RX Antenna [dBm]	RX Antenna Gain [dBi]	Signal Strength @ Receiver [dBm]	Receiver Sensitivity [dBm]	Margin [dB]
16	3.1	5000	105.60	-86.50	1.0	-85.50	-102	15.51

The margin of 15.51 dB is more than adequate, especially as this was assessed at a fairly large 5km.

3.2.4.2 GndOps/COM Test Plan

The ability of the COM subsystem to meet the requirements of the mission was extensively tested as its full functionality is critical to the success of the mission. Testing was divided into seven principal sections: antenna gain and pattern testing, base subsystem functionality testing, wired benchtop testing, wireless benchtop testing on EGSE, wireless benchtop testing on vehicle EPS, long-range wireless testing on EGSE, and long-range wireless testing on vehicle EPS and fully integrated.

The antenna testing consisted of checking the antenna gains against a known baseline antenna and then conducting a coarse pattern sweep. The gain check consisted of transmitting with a stable signal source, measuring the received signal strength at an appropriate distance with a spectrum analyzer connected to the already characterized antenna, then measuring the received signal strength with the spectrum analyzer connected to the flight antennas. The appropriate distance for this test is the far-field as determined by the carrier wavelength, the physical size of the antennas, and the Fraunhofer distance. For our case this distance is 0.25m. The pattern test consisted of measuring the gain as stated before, rotating the flight antenna a set angle, measuring again, and repeating as needed to build up a representative image of the gain pattern. This test also checked the voltage standing wave ratio (VSWR) with a network analyzer to ensure that it is not enough to cause damage to the RF module due to reflected power.

The base subsystem testing consisted of assembling the vehicle and ground subsystems and verifying that all electrical connections are secure and showing the appropriate voltages and signal patterns. This will be conducted using electrical ground support equipment (EGSE) in place of the vehicle EPS subsystem so that testing of the COM subsystem can be conducted without interfering with testing of the other subsystems. The voltages were verified using a multimeter and the signal patterns on the data pins will be verified using an oscilloscope. Additionally, the transmit power of the vehicle RF module was tested by connecting the RPSMA output directly to a spectrum analyzer, with appropriate attenuation inline to prevent damage to the spectrum analyzer, to measure the power output and then testing the equivalent isotropically radiated power (EIRP) of the RF module and antenna using the spectrum analyzer and calibrating against a known signal source.

The wired benchtop testing consisted of connecting the vehicle and ground COM systems with a direct audio connection (coaxial cable between the RPSMA connectors on the RF modules) to test the modulation and demodulation of data. The generation of data by the GPS was the source of data for this test. As part of this test a section of coaxial cable where the shield has been deliberately damaged was connected inline to introduce noise to the direct audio link, as a properly shielded direct link will work to very low signal strengths, and increasing amounts of attenuation will be added until the ground RF module is no longer able to decode the incoming data. This will provide some characterization of the receive sensitivity of the ground RF module for use in calculation of the link margin.

The wireless benchtop testing was essentially the same as the wired testing except replacing the direct audio link with the flight antennas. The test was run on the EGSE and on the vehicle EPS to ensure that there are no issues with power stability on vehicle EPS compromising the performance of the COM subsystem.

The long-range test was very similar to the wireless benchtop testing but was conducted at the ranges expected during flight. The test will first be conducted using just the COM subsystem running on EGSE to check out the subsystem and then will be conducted with the COM subsystem integrated to the vehicle and operating from the vehicle EPS so that the test is as close to flight configuration as possible. The orientation of the vehicle relative to the ground station for this test was determined from the expected orientations during flight and the antenna pattern data from the earlier test to ensure that there were no attitude states that would cause the link to break, which there were not.

Finally, the integration of COM/GPS with the rest of the system will be verified. The principal concern is the integration of the Raspberry Pi module that performs the data processing for the hazard camera payload. The goal is to replace the Arduino Uno that moves data from the GPS to the RF module with the RPi though if necessary the Arduino can be addressed by the RPi as a USB device. Once the hazard camera software has been verified to run on the RPi the RF assembly will be added to test the passing of data from the RPi to the RF module. As part of this testing new code will need to be written to run on the ground-side laptop to separate the hazard camera data from the GPS data. Separating the data streams will not be complicated as the formats of each are known and various programs exist to map a physical serial port to multiple virtual serial ports so that multiple applications can read from the same physical port. The physical integration of the system to the vehicle will be simple as there are no specific interface requirements other than space available. The system is physically integrated to the vehicle and the successfully powering of the RPi is verified, though the operation of the code on the RPi and the interface to the Arduino are still in progress.

3.3 Vehicle Verification Status

Table 7 below outlines the requirements from the Statement of Work (SOW) and briefly describes how each will be satisfied and verified.

Table 7 - Vehicle Requirements and Verification Plan

#	Requirement (from SOW)	Satisfied by:	Verified by:	Verification Status
1.1	The vehicle shall deliver the research payload to an altitude of 6,000 feet above ground level.	Motor, ballasts	Analysis, Test	Verified by analysis, will be verified by full scale test flight
1.1.1	The target altitude shall not exceed 20,000 feet above ground level.	Motor	Analysis	Verified
1.1.2	The final target altitude will be approved by the Range Safety Officer and Review Panel no later than CDR.	N/A	N/A	N/A
1.2	The vehicle shall carry one commercially available barometric altimeter for recording the official altitude used in the competition scoring.	Altimeter	Inspection	Verified
1.2.1	The official scoring altimeter shall report the official competition altitude via a series of beeps to be checked after the competition flight.	Altimeter	Inspection	Verified
1.2.2	Teams may have additional altimeters to	N/A	Inspection	Verified

	control vehicle electronics and payload experiments.			
1.2.2.1	At the Launch Readiness Review, a NASA official will mark the altimeter that will be used for the official scoring.	N/A	N/A	N/A
1.2.2.2	At the launch field, a NASA official will obtain the altitude by listening to the audible beeps reported by the official competition marked altimeter.	N/A	N/A	N/A
1.2.2.3	At the launch field, to aid in determining of the vehicle's apogee, all audible electronics except for the official altitude-determining altimeter shall be capable of being turned off.	All audible electronics are capable of being turned off.	Test	Verified
1.2.3	The following circumstances will warrant a score of zero for the altitude portion of the competition:	N/A	N/A	N/A
1.2.3.1	The official marked altimeter is damaged and/or does not report an altitude via a series of beeps after the team's competition flight.	N/A	N/A	N/A
1.2.3.2	The team does not report to the NASA official designated to record the altitude with their official, marked altimeter on the day of the launch.	N/A	N/A	N/A
1.2.3.3	The altimeter reports an apogee over 20,000 feet AGL.	Motor	Analysis	N/A
1.2.3.4	The rocket is not flown at the competition launch site.	The team will adhere to the schedule and deliver the rocket on time.	Inspection	N/A
1.3	The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	Recovery system	Analysis	Verified
1.4	The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.	Team will have demonstrated ability.	Test	Will be verified during full scale flight test
1.5	The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing functionality of any critical on-board component.	All battery-operated electronics will remain ready for launch for at least 1 hour without losing functionality.	Test	Will be verified on 5/1/14
1.6	The launch vehicle shall be capable of being	Motor	Inspection	Verified

	launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.			
1.7	The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).	Motor	Inspection	Verified
1.8	The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA) and/or the Canadian Association of Rocketry (CAR.)	Motor	Inspection	Verified
1.9	Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria:	N/A	N/A	N/A
1.9.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operation Pressure) shall be 4:1 with supporting design documentation included in all milestone reviews.	N/A	N/A	N/A
1.9.2	The low-cycle fatigue life shall be a minimum of 4:1.	N/A	N/A	N/A
1.9.3	Each pressure vessel shall include a pressure relief valve that sees the full pressure of the tank.	N/A	N/A	N/A
1.9.4	Full pedigree of the tank shall be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank by whom, and when.	N/A	N/A	N/A
1.10	All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration.	Schedule	Inspection	Will be verified during full scale flight test
1.10.1	The vehicle and recovery system shall have functioned as designed.	Vehicle, recovery	Test	Will be verified during full scale flight test
1.10.2	The payload does not have to be flown during the full-scale test flight. The following requirements still apply:	N/A	N/A	N/A
1.10.2.1	If the payload is not flown, mass simulators shall be used to simulation the payload mass.	Mass measurement	Inspection	Will be verified during full scale flight test
1.10.2.1.1	The mass simulators shall be located in the same approximate location on the rocket as	Mass locations	Inspection	Will be verified during full scale

	the missing payload mass.			flight test
1.10.2.2	If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems shall be active during the full-scale demonstration flight.	External surface	Inspection	Will be verified during full scale flight test
1.10.3	The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the competition flight.	Motor	Inspection	Will be verified during full scale flight test
1.10.4	The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during competition flight.	Mass measurement	Inspection	Will be verified during full scale flight test
1.10.5	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Office (RSO).	N/A	N/A	N/A

3.4 Vehicle Test Results

3.4.1 Ejection Charge Testing

Ejection charge testing has been performed for both the sub-scale and full-scale test flights that have already been performed by the team. Ejection charge testing will also be performed prior to the full-scale test flight on 4/19/2014. All ejection charge testing has been performed at a remote location under the supervision of the safety officer. All unnecessary personnel were not present for testing to minimize the risk involved in these tests. As test supervisor, the safety officer supply the black powder for building the charges. The safety officer also built the charges. For each test, three charges were tested: a smaller than necessary charge, a theoretical optimum charge, and a larger than necessary charge to ensure that the charge sizes are sufficient to provide reliable deployment of the recovery systems.

The test involves the building of the black powder charges and the wiring of the charges to the respective coupler bay. The safety officer then stands at a distance of 15 feet away, with all other present personnel at least 20 feet away and behind the safety officer. The safety officer then announces the test and commences the countdown, ensuring that all present personnel are aware the test is about to begin. At the end of the countdown, the safety officer sets off the deployment charge and the test concludes.

For both the sub-scale and full-scale ejection charge testing, it was found that the optimum charge size was sufficient to deploy the main parachute. The larger than necessary charge was then utilized as a back-up and tested to ensure that the parachute would deploy if the primary charge failed for any reason. However, during the full-scale ejection charge test, the team failed to test the deployment of the drogue parachute. The team theorizes that the subsequent full-scale test flight and catastrophic failure of the rocket were in part due to this failure to ensure the deployment of the drogue.

For the planned full-scale test flights on 4/19/2014 and 4/27/2014, before the launches were cancelled, the ejection charge testing followed the same safety protocols as all previous testing and was successfully completed. In addition, the team ensured that both the drogue and main parachute deployments were fully tested successfully so as to prevent another catastrophic failure.

3.4.2 Electronics One Hour Duration Testing

All electronics on board the vehicle must be proven to have a minimum operating life of one hour to verify Requirement 1.5 in the SOW. To verify this, a test will be performed on 5/1/2014, and will require all payloads to be completely functional and ready for flight. We will utilize fresh flight batteries and fully charged power supplies for all of the electronics. The test will involve all altimeters, the GPS system, and the electronics for both the HazCam payload and aerodynamic analysis payload. The test will begin with all electronics being integrated into the rocket, switched on and placed in flight ready, data gathering configuration. Every five minutes, a member of the corresponding subteam will verify that the electronics are still functioning based on visual indicators such as LED indicators or auditory indicators such as beeping.

If any of the electronics on board the vehicle fail, or shut down at any point during the hour long duration of the test, that entire failing system will be shut down and examined after the commencement of the rest of testing. The rest of the electronic systems will be allowed to complete the testing. If any systems failed, the system will be investigated to find whether the issue arose due to wiring, software, or hardware issues. Based on the results of these examinations, the team will decide how to proceed and will address any issues that are presented and rerun the tests as soon as the issues are addressed. By this date, in-depth testing will have been performed on all of these electronic systems, so any failure that occurs will be an anomaly at this point in the payload construction.

This test will serve to verify that the all electronics can be integrated into the rocket itself, and that they will all function while in the rocket, in addition to fulfilling Requirement 1.5.

3.4.3 Vehicle Preparation Test

This test will be completed on 5/7/2014 in order to verify that the team will be able to meet Requirement 1.4 in the SOW. The team will complete all of the necessary procedures to prep the rocket for launch without launching the vehicle. This will also allow ample time for the team to edit any checklists or procedures prior to the competition launch. In addition, all members of the team will become familiar with the launch procedures to ensure knowledge among all traveling members. Procedures for launch day preparation of the rocket can be found in Appendix C.

3.4.4 Vehicle Preparation Test

This test will be completed in order to verify that the team will be able to meet Requirement 1.4 in the SOW. The team will complete all of the necessary procedures to prep the rocket for launch without launching the vehicle. Procedures for launch day preparation of the rocket can be found in Appendix C.

3.4.5 Full-scale Flight Testing

The first full-scale test flight occurred on 4/5/2014. The flight utilized the same motor as will be used in the competition - a Cesaroni L1720. All payload structures were integrated into the rocket in order to verify structural integrity prior to the competition. No payload electronics were integrated to prevent any potential damage to them. The GPS system and avionics were all running so the team could accurately track the rocket.

The team while integrated the payloads and other components found many issues which have since been corrected in order to provide for smoother integration. In addition, all launch day checklists were tested to verify that no steps were missing and that no steps were ignored. The launch of the rocket itself was the best that could be expected. The rocket was completely stable off of the pad. However, the rocket suffered a catastrophic failure after plummeting into the ground and the entire rocket, save a few components, was destroyed. The team has since examined the remains of the rocket and deduced several possibilities for failure. The main culprit seems to be the lack of deployment of a drogue chute due to inadequate securement of the liquid sloshing payload apparatus. In order to reduce the risk of these possibilities of failure, the team has rebuilt the rocket with all new components. The tubes of the rocket were lengthened in order to add extra space for the parachutes. The liquid sloshing payload, due to budgetary and scheduling constraints, has been removed from the rocket.

The team then rebuilt the full-scale vehicle with plans to launch on April 19th, with a back-up test flight date on April 27$^{th.}$. Unfortunately, due to the Easter holiday weekend and inclement weather, the local rocketry clubs canceled both of these scheduled launches and the full-scale vehicle test flight could not be completed by the deadline. The team plans to complete a full-scale test launch and fly payloads at a later date independent of the competition.

3.5 Mass Statement

The mass budget can be found in Table 8 below.

Table 8 - Mass Budget

Component	Mass (lbs)
Nosecone	2.750
Hazard Camera Payload	0.124
GPS and Radio Transmitter	0.222
Aerodynamic Analysis Payload Total	3.960
Upper Body Tube	1.920
Drogue Parachute	0.870
Avionics Bay and Electronics	2.050
Lower Body Tube	1.360
Main Parachute	2.870
Complete Motor Assembly and Fin Can	5.820
Motor Casing	3.496
Propellant	3.869
Total	**29.311**

The mass estimate is based off of actual weights of the parts that have been manufactured to date. Using a standard scale, each of the components above was weighed except for the motor casing and propellant. The weight of the casing and propellant are pre-determined values based on information from the manufacturer. The final predicted mass of the rocket is 29.311 lbs.

According to OpenRocket simulations, the vehicle is not very sensitive to this expected mass growth; if the rocket were to launch at the maximum expected mass of 35 pounds, the projected altitude would be approximately 5,750 feet, which is 250 feet below our target altitude of 6,000 feet. The motor selected has a high enough thrust that the vehicle would have to increase in mass by over 300% in order to no longer leave the launch rail safe exit velocity.

3.6 Recovery Subsystem

Since the Critical Design Review the recovery team has completed the drogue and main parachutes, altering only the tailoring of the seams. In the subscale models of our rocket, the drogue and main parachutes were sewn using a French seam; where rip-stop nylon is sewn laterally together and flipped inside out to essentially hide the seams. Upon beginning to tailor the parachutes, the recovery team decided to use rolled hems in replace of the French seam. The rolled hem follows the same idea as the French seam but both fabric ends are folded inwards twice before stitching them together. This gives a layered seam with triple the strength while preserving the aesthetics by hiding each seam. Using heavy duty polyester thread and reinforcing the seams with tubular nylon webbing, the parachutes will exceed expectations during flight.

Due to the difference in desired decent rates, the drogue and main parachutes differ vastly in size. Spanning six and a half feet in diameter, the drogue parachute will descend at 50 feet per second after apogee deployment. The main deploying at 1000 feet AGL, spans 15.5 feet in diameter and will slow the rocket's descent rate to 18.8 feet per second. Unfortunately due to poor weather and concurrently cancelled test launches, both parachutes have yet to be tested in flight; however, we have completed several ground tests that indicate we are ready for flight. Ejection tests for the drogue and main have been conducted by assembling the rocket as described in the flight checklist. When the primary charges were triggered, it was found that the body sections separated and the chutes were ejected as intended. In addition, deployment tests have also been done through drop tests from Doing this confirmed that deployment is possible even at speeds much smaller than the speeds predicted the chutes will deploy at.

Our rocket, Hydra, contains four bulkheads that will be used as attachment hardware for the parachutes. Located between the nose cone and main, each end of the avionics bay and between the drogue and motor, the bulkheads consist of a U-bolt, a swivel, and quick links to ensure the shroud lines do not tangle or detach. When choosing the hardware components that will be used in the recovery subsystem, we chose to maintain a minimum factor of safety of at least 10. We then found the tension in the shock cord to be 100 lbs at peak acceleration and chose to use 1 inch wide tubular Kevlar. To connect the shock cord to the bulkheads, we've chosen to use $^{3}/_{8}$" Steel U-Bolts with plates for a maximum load of 1090 pounds, or a factor of safety of about 11. The quick links holding the cord and bulkhead together will be Zinc-Plated Steel with a $^{3}/_{8}$" diameter and a maximum load of 2200 pounds, a FOS of 22. Finally, when connecting to the parachute we will use a high-strength swivel with a maximum load of 2500 pounds, a FOS of 25. The connections from the bulkhead to the parachutes can be seen in Figure 17 below.

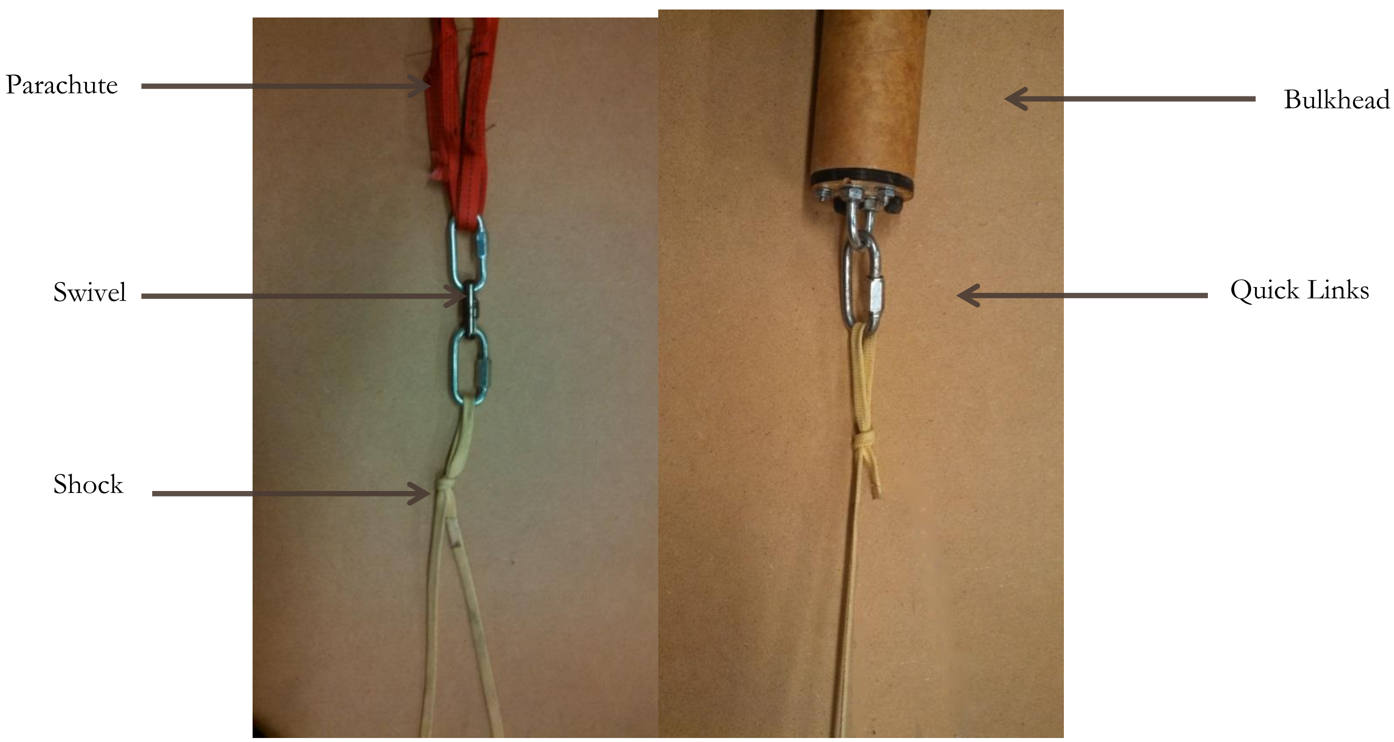


Figure 17 - Hardware Connections to and from the Parachute and Bulkheads

The system used for locating the rocket consists of a Venus638FLPx GPS module with an external antenna connected to an xBee S2B radio module operating at 2.4GHz. The GPS module updates its position every second and an Arduino Uno writes the GPS data to the xBee for transmission to ground. There is an identical xBee and Arduino at the ground station, which uses a GPS visualizer program running on a laptop computer connected to the Arduino to show the current status of the GPS position lock and the actual position of the rocket to the operators. The xBee output power is +17 dBm and the transmit antenna has a gain of 2.2 dBi for a radiated power of +19.2 dBm. The link budget predicts that the 6dB design margin in this link will not be reached until just short of 4.5 miles, which is more than sufficient range. The transmit power is too low to couple sufficient power into the electric match wires to set them off and the carbon fiber body tubes are not transparent to the radio waves there is no potential for the transmitter to interfere with the altimeters, which are about four feet behind the nose. This system has been flown previously and there has been no indication of any interference of the transmitter with the recovery system.

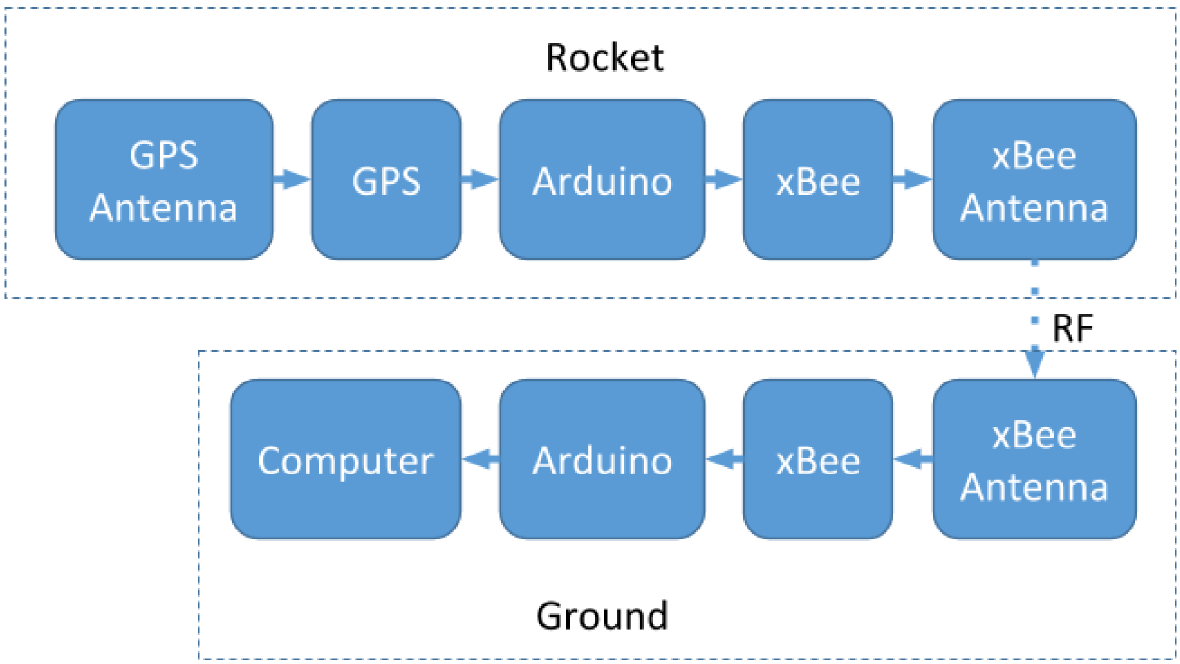


Figure 18 – Recovery system data flowchart

As detailed in the above figures, both the main and drogue parachutes connect to the avionics bay. This section of our rocket contains two on-board altimeters (a Raven and Perfect Flite Stratologger) will serve as the main avionics for the rocket. These altimeters calculate the altitude from the barometric pressure and the velocity of the rocket. To ensure deployment of the drogue and main parachutes at the correct moment, three conditions must be met. To ensure deployment at apogee the following must be true; the barometric pressure must be increasing thus indicating the rocket is falling, the velocity of the rocket is less than 400 feet per second, and the altitude above the launch pad is non-zero. Separation of the avionics bay thus commences and the drogue parachute is released. As the rocket descends under the drogue, the altimeter will deploy the main parachute when the velocity is negative, the barometric pressure is increasing, and the altitude above the launch pad is less than 1000 feet. Thus separation of the motor section will commence allowing the main parachute to deploy.

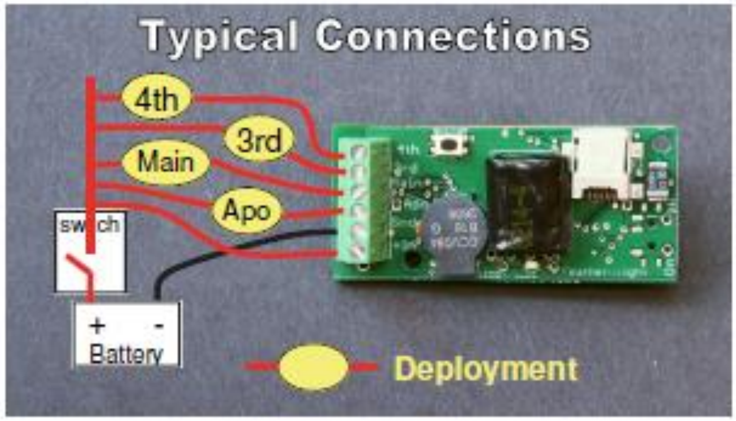


Figure 19 - Raven altimeter connections

The recovery subsystem will also include a GPS to wirelessly transmit the rocket's position in real time. This will enable the team to locate where the rocket is during the flight and after landing, especially if the rocket has landed out of direct eye sight. The GPS will be using a 900 MHz signal that has a range of 28 miles, when mostly unobstructed. The data transmitted will be over serial and will tell us altitude, exact location, and the number of satellites that are being used for triangulation. See Ground Ops/COM section for additional details.

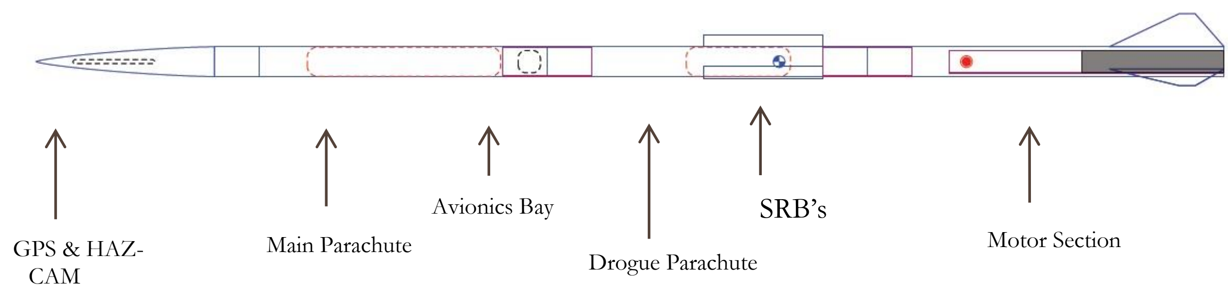


Figure 20 – Placement of Recovery Systems

For the rocket flight to be successful, it is of vital importance to choose the ideal ejection charge mass. Unfortunately with the difference in every rocket design, there is not set amount of black powder needed for the ejection charge and thus this can truly only be determined from ground testing of different sizes; however, using the ideal gas law, we can mathematically calculate an estimated mass for our ejection charge. By assuming the entire mass of the ejection charge is burned and converted to gas, the ideal gas law $PV = nRT$ can be manipulated to solve for n, the ejection charge size in grams. T represents the combustion temperature while R represents black powder gas constant, P represents the pressure inside the rocket [PSI], and V represents the Volume available for the ejection charge[1]. With the initial estimate and ground tests at a remote location we decided that three grams of black power was the optimal size for deployment of the parachutes.

3.6.1 Recovery Failure Modes

[1] Knowles, Vern, "Ejection Charge Sizing," *Vern's Rocketry*. 2002-2007. [http://www.vernk.com/EjectionChargeSizing.htm. Accessed 2/23/2014.]

The recovery system failure modes can be found in Appendix E.

3.6.2 Recovery System Testing Procedures and Results

Parachute Testing:

We will need to test 2 parts of the chute: the drag coefficient and the strength of the chute. We will do a drop test of the chute to find the drag coefficient. We will also test each component of the chute to failure in tension. Then we will determine how much force the chute on the full scale will need to take, and if it can stand that based on our findings for strength.

Part 1: Drop Test:

To test the drag coefficient, we will be attaching a test weight to our small-scale drogue chute and dropping it from roughly 36 feet. This test weight is made from a foot of 1" PVC pipe, sealed at each end with electrical tape, and partially filled with small copper BB's. The mass will be secured to the chute's shroud lines via a clip held to the weight through drilled holes in the PVC. The mass of the test weight will not exceed any dangerous thresholds, but will be enough to keep the shroud lines taught and minimize the effects of wind. We will determine the decent speed with a camera set up that will record the decent. Using a scale reference behind the chute—a spare shroud line with masking tape at 5' intervals—we will be able to take several position measurements from each drop. With this position data and the video time we will be able to determine decent rate. Using this decent rate, we will find the drag coefficients of our parachute by curve-fitting our data to Equation 4:

$$h(t) = \frac{2m\, ln\left(\cosh\left(\sqrt{\frac{Ac_d g\rho}{2m}}\,(k_1 m + t)\right)\right)}{Ac_d\rho} + k_2 \tag{4}$$

Equation 4 is derived from the solution to equation 5 below, which describes the chute's decent.

$$\ddot{h} = g - \frac{\rho A c_d \dot{h}^2}{2m} \tag{5}$$

where h is the height coordinate of the chute, g is gravitational acceleration, c_d is the drag coefficient, A is the area of our chute, ρ is the air density in Boulder, and m is the mass of our parachute-weight system.

We will also test how the chute opens when folded as though it were being deployed directly from the rocket. The fold is shown below in Figure 21:

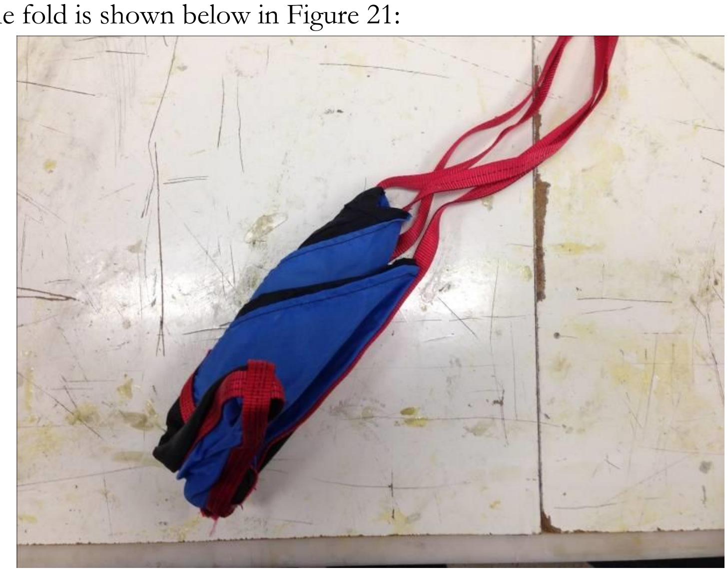


Figure 21 - Packed drogue chute

This fold is achieved by bringing together all corners of the chute, pulling out the folds of fabric between the corners, and then folding the chute in half so the top of the chute is flush with the corners. The shroud lines are tucked up alongside the chute with the mass hanging from the end of the shroud lines next to the opening of the chute. This process is called flaking.

To ensure a safe and successful test, we will do a number of things before dropping the apparatus. The first priority is to ensure safety. First we will ensure that the testing site is clear of any personnel that could be endangered during the test. After a perimeter is established, the person dropping the chute and the person recording the drop will give each other an audible confirmation to guarantee that everyone is clear of the drop site and that all equipment is ready. The person dropping the chute will initiate a countdown until the drop. Two spotters will keep the parachute in sight at all times, making sure that the apparatus will land as expected away from any property or unknowing persons.

This procedure will be repeated for all parachutes except the main chute for our full-scale rocket. This main chute will be tested during a test launch once we have completed enough tests on smaller chutes that we are confident enough the main chute will not fail.

Part 2: Strength of the chute components:

We will perform material testing on a sample seam, piece of fabric, and the shroud lines to ensure that they can more than withstand the loads that will be experienced during deployment. To test each material, we will attach the sample to a material tester and find failure stresses. We will test each component/material to failure. We will then calculate the expected loads on each section of the parachute and see if each component will withstand the expected loads.

To ensure safety for this test, the team will wear appropriate safety equipment and follow all safety protocol that the ITLL has for the use of this equipment.

Results for Part 1 Test On Subscale Drogue Chute:

Conducting the procedure detailed in Part 1 on our subscale drogue chute, we have 4 videos showing the chute deploying successfully after being dropped from about 37 feet. The mass of the attached weight was 0.2129g. As seen in Figure 28 below, we then used Logger Pro to determine the position of the chute (blue dots) using a stationary point in the background (brown dots) to stabilize the video and a scale length of 5ft in the background (green line) to find the position as a function of time. The data for these points can be found in Table 9 - Experimental data for position as a function of timebelow.

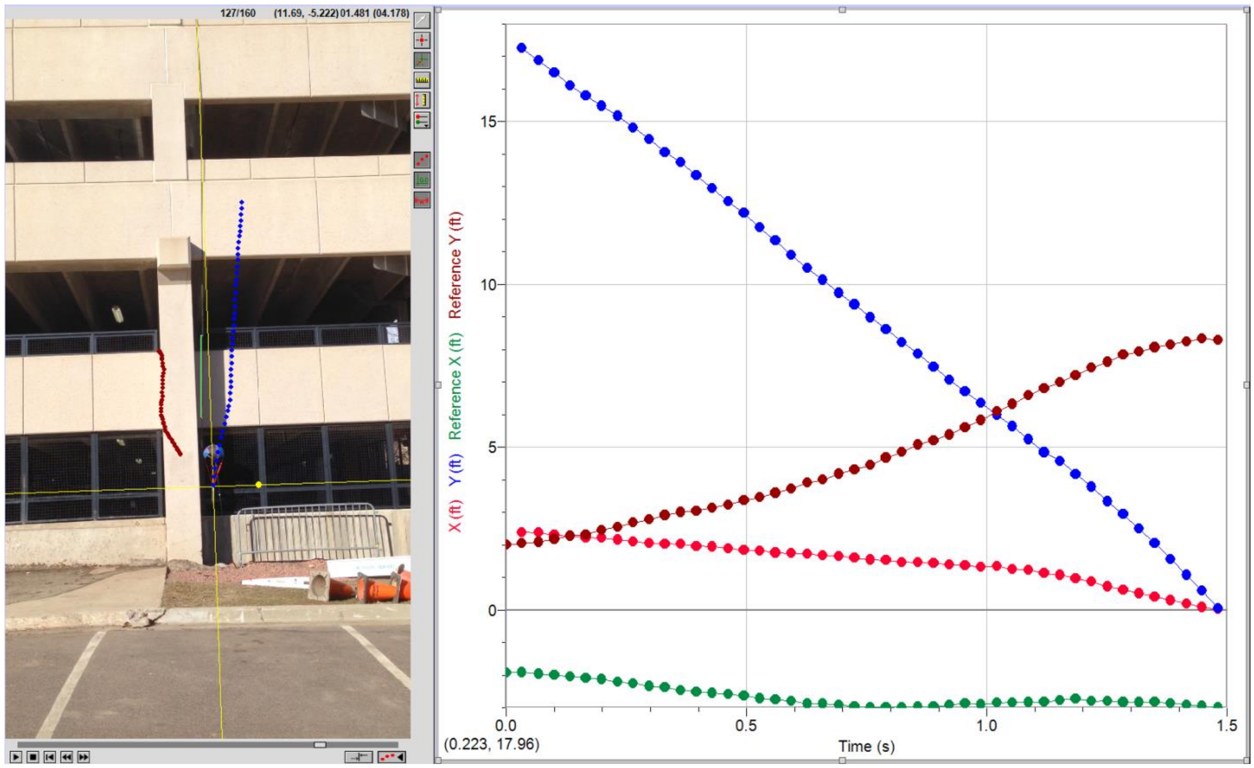


Figure 22 - Graph showing vertical and horizontal coordinates for the chute relative to the camera and vertical and horizontal coordinates for a stationary point relative to the camera.

Table 9 - Experimental data for position as a function of time

Time	X Position	Y Position
0.03287	0.465	23.46
0.06739	0.509	23.05
0.1003	0.488	22.58
0.1331	0.533	22.09
0.166	0.532	21.74
0.1989	0.577	21.29
0.2318	0.621	20.89
0.2646	0.622	20.4
0.2975	0.666	19.95
0.3304	0.711	19.42
0.3633	0.8	19.02
0.3961	0.8	18.56
0.429	0.844	18.07
0.4619	0.845	17.58
0.4948	0.845	17.09
0.5276	0.934	16.56
0.5605	0.929	16.03
0.5934	0.979	15.44
0.6263	1.069	14.86
0.6591	1.025	14.41

0.692	1.065	13.84
0.7249	1.07	13.34
0.7578	1.065	12.81
0.7906	1.065	12.22
0.8235	1.021	11.65
0.8564	1.021	11.06
0.8893	1.021	10.53
0.9221	0.936	9.95
0.955	0.886	9.37
0.9879	0.892	8.79
1.021	0.886	8.17
1.054	0.797	7.58
1.087	0.797	6.91
1.119	0.708	6.29
1.152	0.623	5.84
1.185	0.484	5.22
1.218	0.484	4.6
1.251	0.35	3.97
1.284	0.311	3.34
1.317	0.222	2.81
1.35	0.133	2.23
1.382	0.083	1.64
1.415	0.044	1.06
1.448	-0.005	0.48
1.481	0	0

We then exported this data into MATLAB and used the built-in curve-fitting tool to fit the data to Equation 4 above.

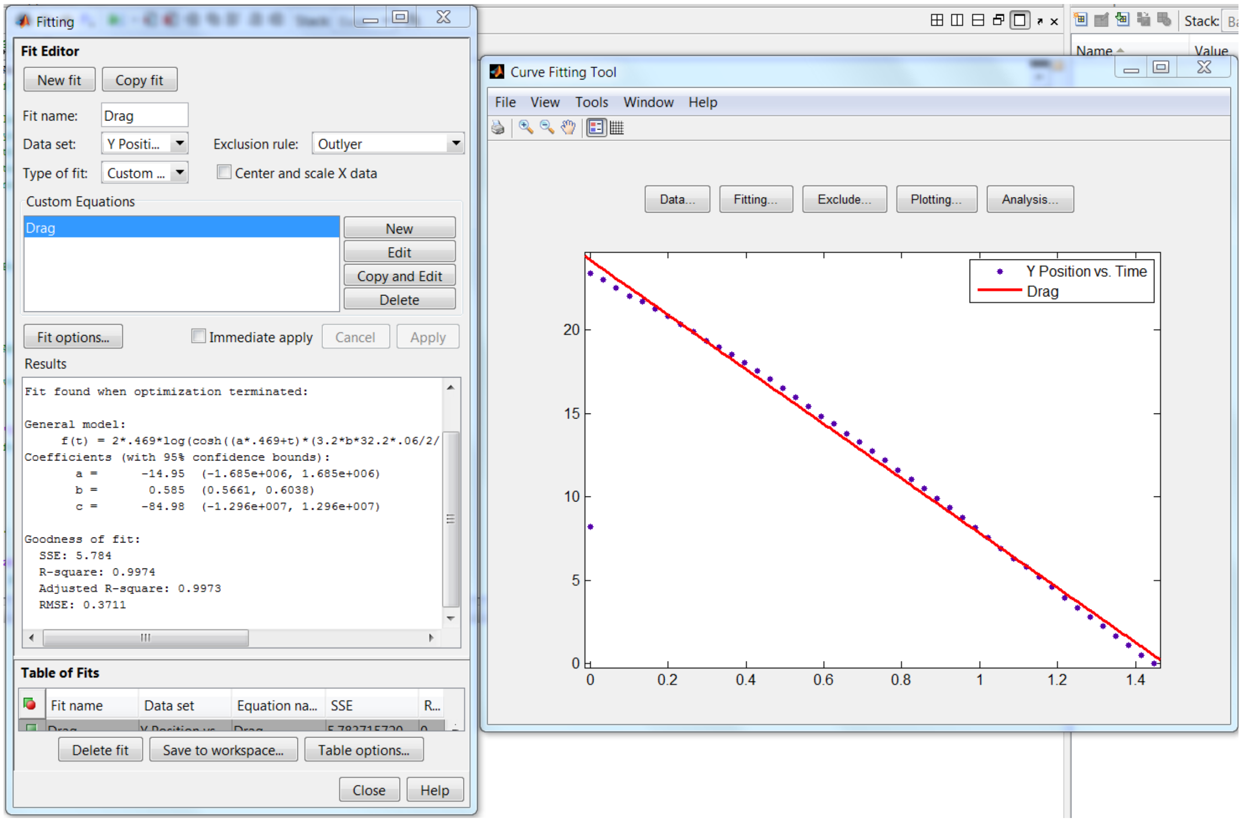


Figure 23 – MATLAB curve fitting tool with drag data

This gave great results, with predicted value of drag constant to be 0.65 on our chute calculator pictured in Figure 24 below. Test results found that the actual drag coefficient is 0.59, slightly less efficient than predicted.

	CALCULATION	ROUNDED NUMBERS	METRIC
Altitude above sea level	5670 feet	5670 feet	1,728.2 meters
Air Density	0.06 lbs/cubic foot	0.06 lbs/cubic foot	1.0 kg/cubic meter
Weight	7.504 ounces	7.504 ounces	
Weight	0.469 pounds	0.469 pounds	0.2 kg
Descent Rate	16.7 feet/second	17.6 feet/second	5.1 meters/second
	11.4 mph	12.0 mph	18.3 kph
Drag Coefficient	0.65	0.65	0.65
Xf (feet)	2.642 feet	2.5 feet	
x (inches)	31.704 inches	30 inches	0.805 meters
a = Xf × 5 -or- a = xi / 2.4	13.210 inches	12.5 inches	0.336 meters
b = a / 2	6.605 inches	6.25 inches	0.168 meters
c = b× 0.135	0.892 inches	0.84375 inches	0.023 meters
d = b × .865	5.713 inches	5.40625 inches	0.145 meters
Grid Size = a / 10	1.321 inches	1.25 inches	0.034 meters
Shroudline length (times 2, + anchor)	41 inches	39.0625 inches	1.0485425 meters
Area of Chute	2.60 square feet	2.32 square feet	0.241 square meters
	373.7 square inches	334.6 square inches	
Round chute diameter required to achieve equivalent descent rate	20.3 inches	19.3 inches	0.516 meters

Requires Input

Optional Input

Optional Calculation

All other cells are calculated

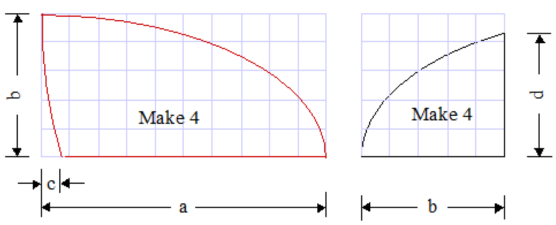


Figure 24 - Theoretical values for chute from our elliptical cupped chute calculator [Source: www.the-rocketman.com/chutes.html]

3.6.3 Kinetic Energy At Significant Phases

Table 10 below shows the kinetic energy of the rocket at key phases during flight.

Table 10 – Kinetic Energy at Significant Phases

Flight Events	Fin Can Section (ft-lb)	Middle Section (ft-lb)	Upper Section (ft-lb)
Motor Burnout	N/A	N/A	322,348
Main Deployment	516.46	456.80	437.18
Landing	45.32	54.05	38.36

3.7 Mission Performance Predictions

3.7.1 Mission Performance Criteria

- The rocket will reach an altitude of as close to 6,000 feet AGL as possible.
- The rocket will be stable during flight.

- The drogue parachute will be deployed at apogee, and the main parachute will be deployed at 1,000 feet AGL.
- Each section of the rocket will land with kinetic energy no greater than 75 ft-lbf.

3.7.2 Simulations

3.7.3 Mission Performance Criteria

- The rocket will reach an altitude of as close to 6,000 feet AGL as possible.
- The rocket will be stable during flight.
- The drogue parachute will be deployed at apogee, and the main parachute will be deployed at 1,000 feet AGL.
- Each section of the rocket will land with kinetic energy no greater than 75 ft-lbf.

3.7.4 Simulations

Flight simulations were performed with OpenRocket software. Figure 25 below shows the flight side profile with the following assumptions:

- Average wind: 2 mph
- Total vehicle mass (with motor): 29.3 lbs
- Cesaroni L-1720 motor

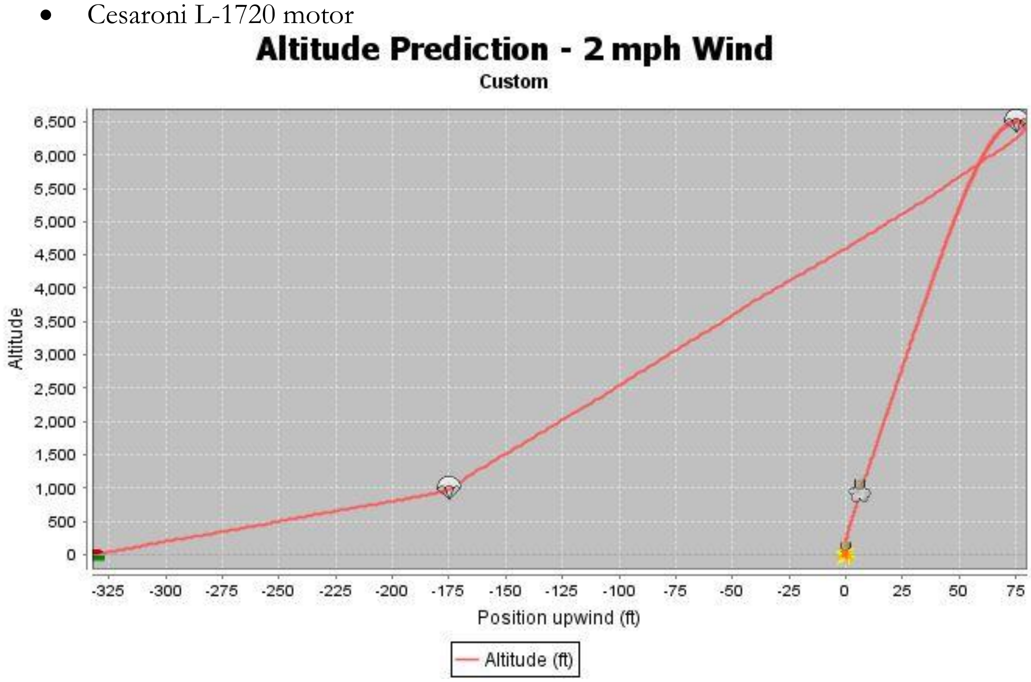


Figure 25 - Flight Simulation Position vs. Altitude

The predicted altitude is 6,505 feet, as shown above in Figure 25 - Flight Simulation Position vs. Altitude. This predicted altitude is slightly above our target altitude of 6,000 feet due to the change in mass due to the omission of the liquid sloshing payload.

The motor thrust curve simulated in OpenRocket is found below in Figure 26

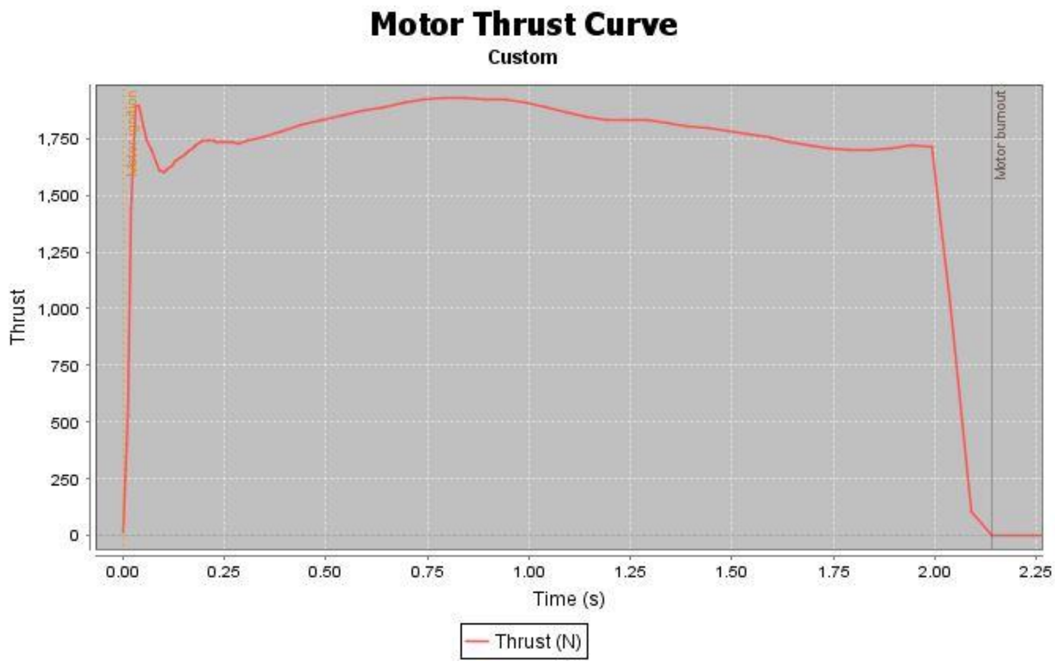


Figure 26 - Motor Thrust Curve

Figure 27 below shows the stability of the rocket during the duration of flight. The red line represents the stability margin over the course of the flight. The blue line represents the location of the center of gravity (CG), and the green line represents the center of pressure (CP) location, both in inches from the nosecone. At Mach 0.8, the CP is located approximately 125 inches from the nose, and the CG is located approximately 99 inches from the nose, with a stability value of 6.3 calibers.

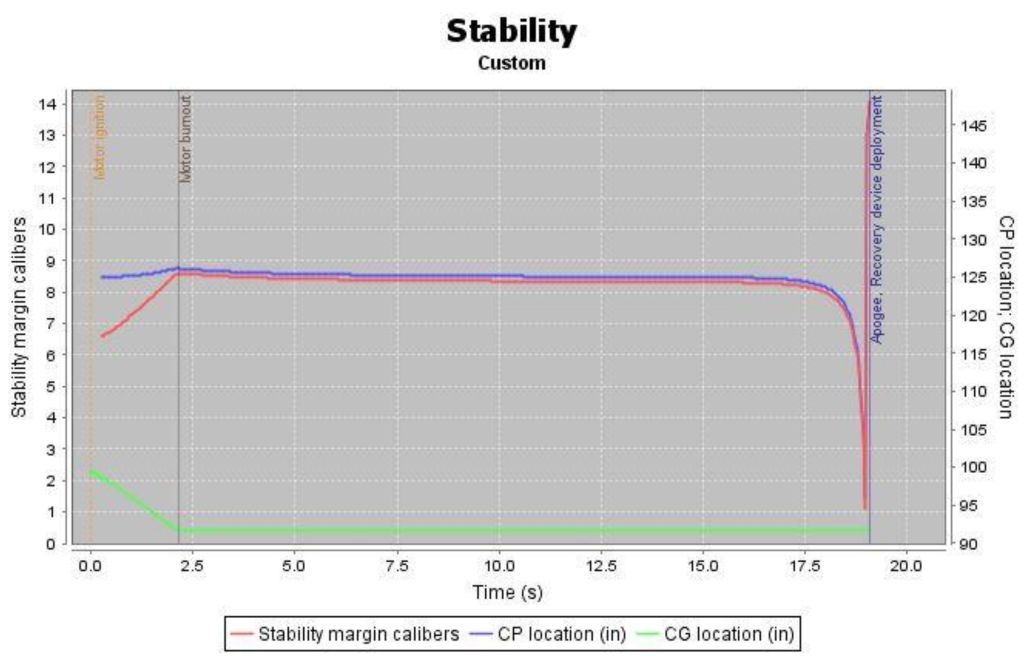


Figure 27 - Stability Chart

Figure 28 below shows the physical locations of the CG (blue circle) and CP (red circle) at 99.348 inches and 125 inches from the nose, respectively, at M = 0.30.

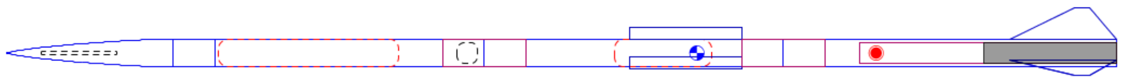


Figure 28 - CG and CP locations

Figure 29-Figure 33 show the flight side profiles indicating the drift of the rocket with five different wind cases: 0, 5, 10, 15, and 20 miles per hour (mph). Table 11 summarizes these results.

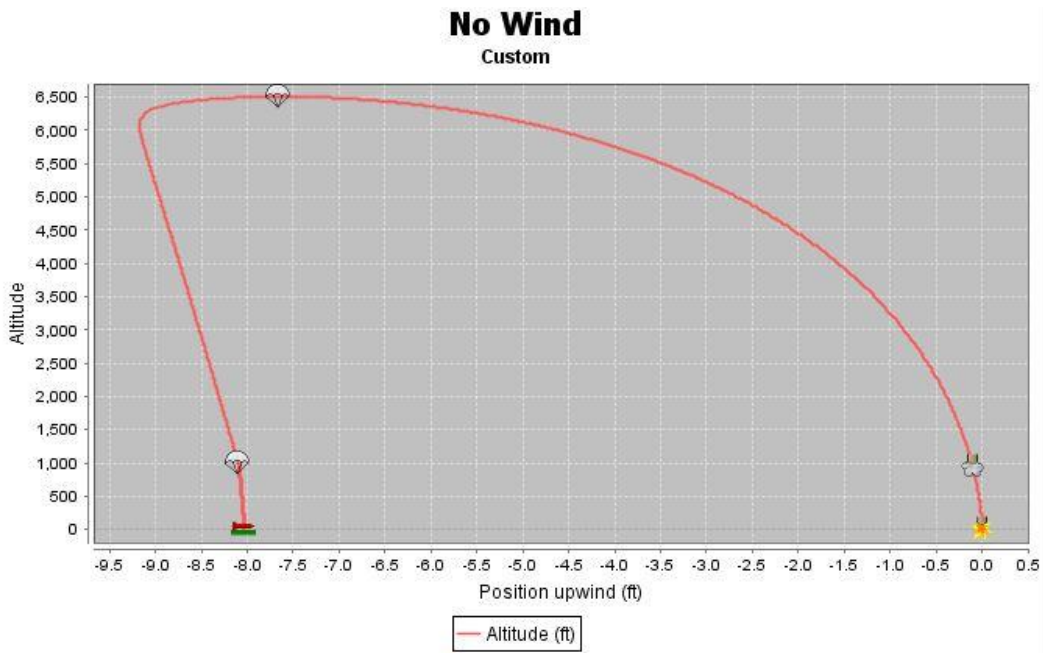


Figure 29 - Flight Simulation (Wind: 0 mph)

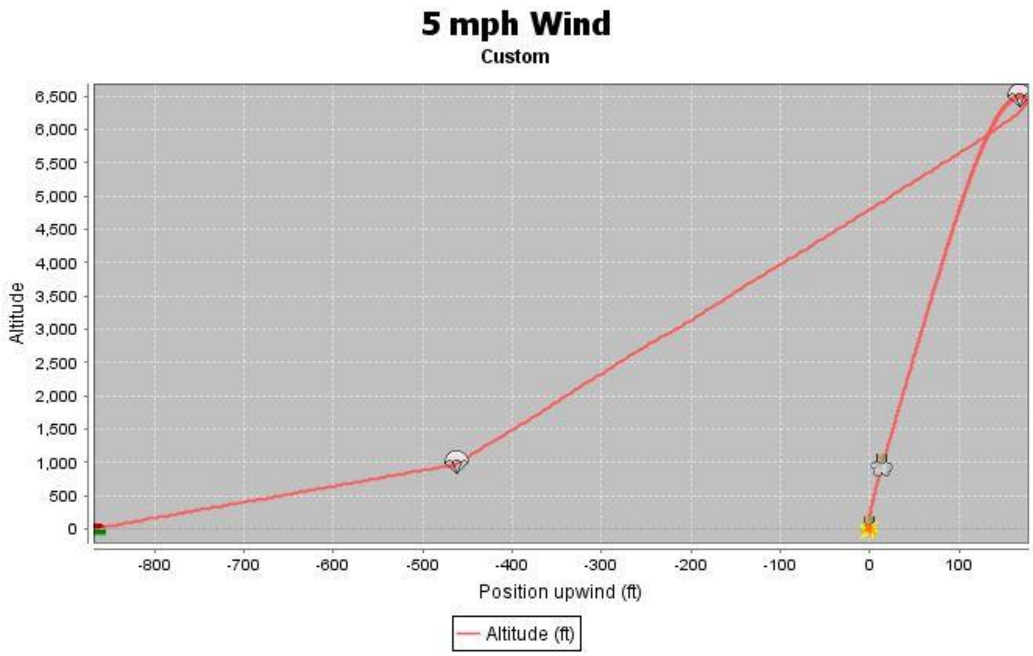


Figure 30 - Flight Simulation (Wind: 5 mph)

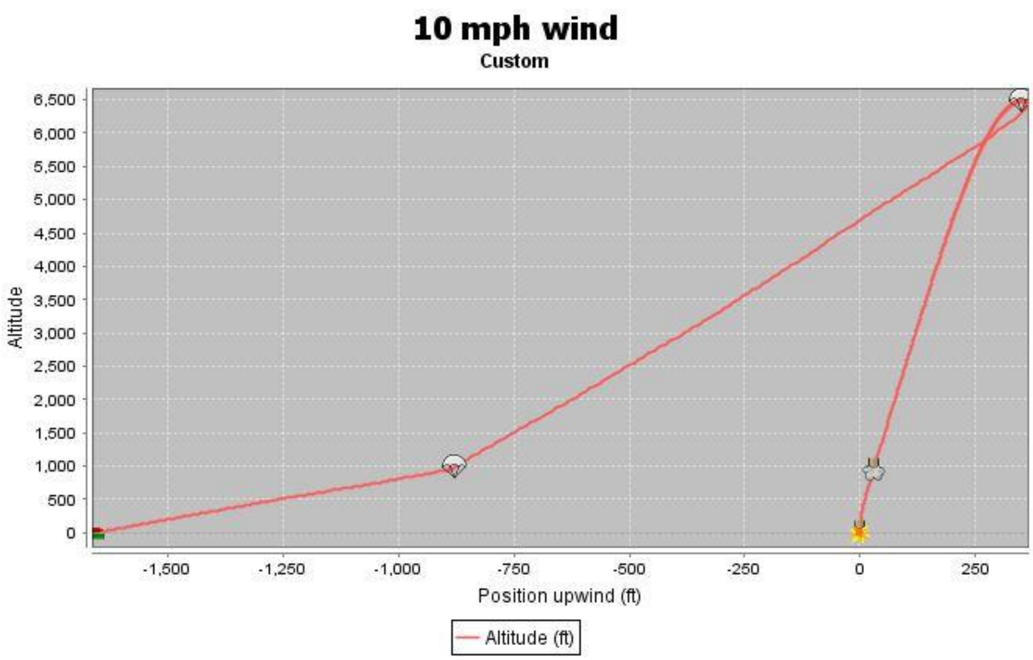


Figure 31 - Flight Simulation (Wind: 10 mph)

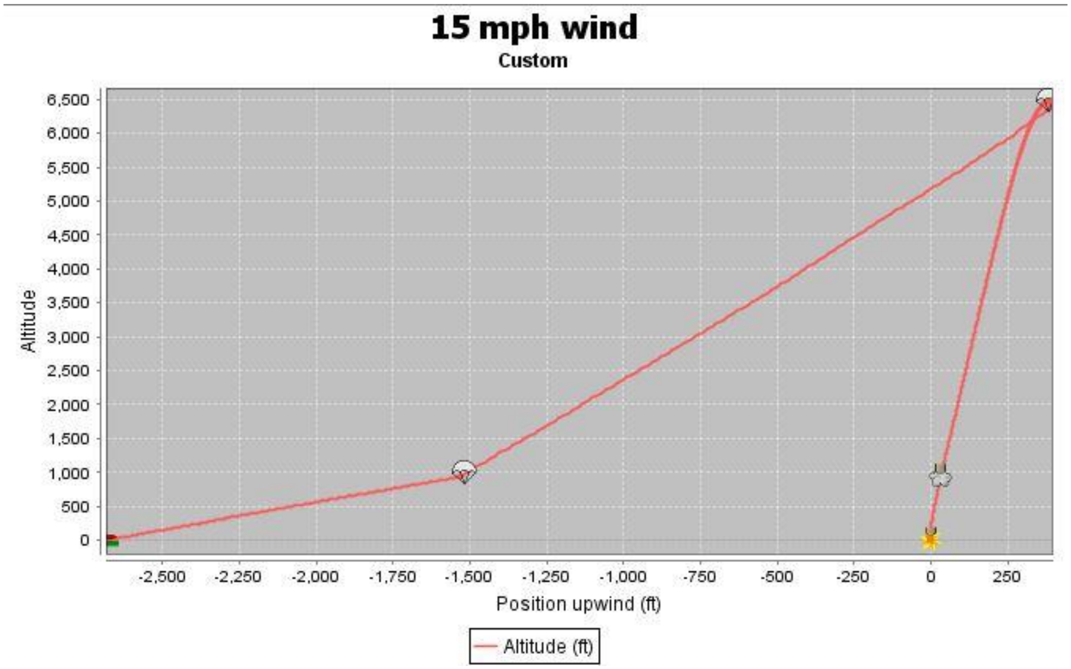


Figure 32 - Flight Simulation (Wind: 15 mph)

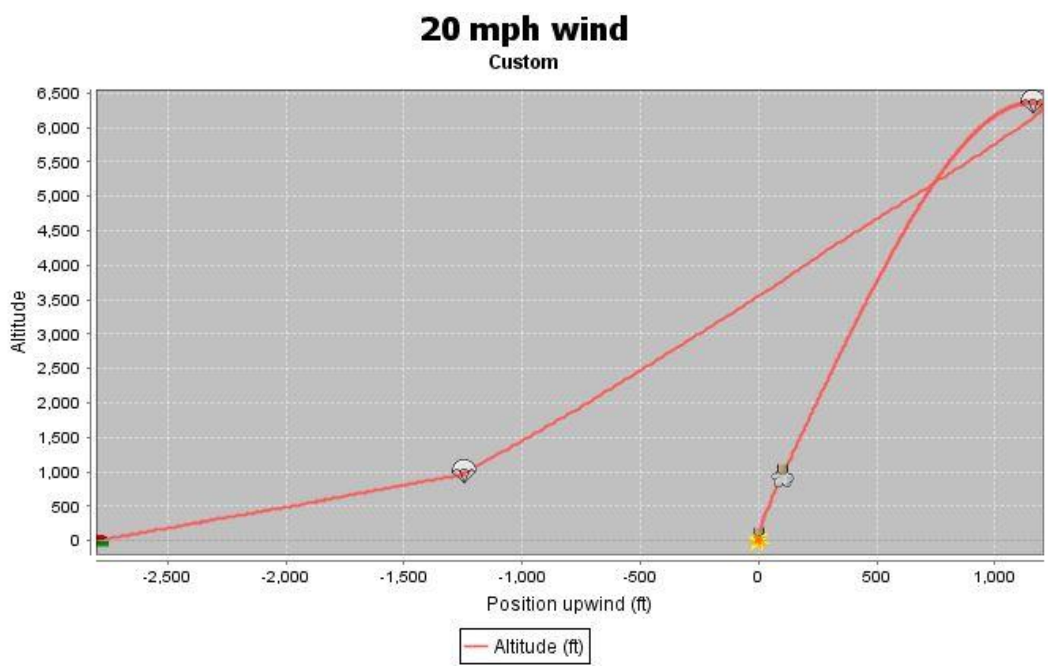


Figure 33 - Flight Simulation (Wind: 20 mph)

Table 11- Wind Speed and Total Drift

Wind Speed (mph)	Total Drift (ft)
0	8.0124
5	794.23
10	1662.00
15	2682.40
20	2802.80

The kinetic energy of each section when it hits the ground is listed below along with the calculated weight of each section:

Table 12 - Kinetic Energy Upon Landing

Kinetic Energy of Each Section (ft-lbs) *Assume Descent Rate of 17 ft/s	Section 1	Section 2	Section 3
	Fin Can Assembly (9.32 lbs)	Lower Body Tube and Avionics Bay (8.24 lbs)	Upper Body Tube and Nosecone (7.886 lbs)
	45.32	54.05	38.36

3.7.5 Subscale Simulations and Comparisons

Flight simulations were performed with OpenRocket software for the subscale in order to compare the simulations to those for the full-scale rocket. Figure 34 below shows the flight side profile with the following assumptions:

- Average wind: 2 mph
- Total vehicle length: 99.5 in.
- Total vehicle mass (with motor): 10.4 lbs
- Cesaroni K-360 motor

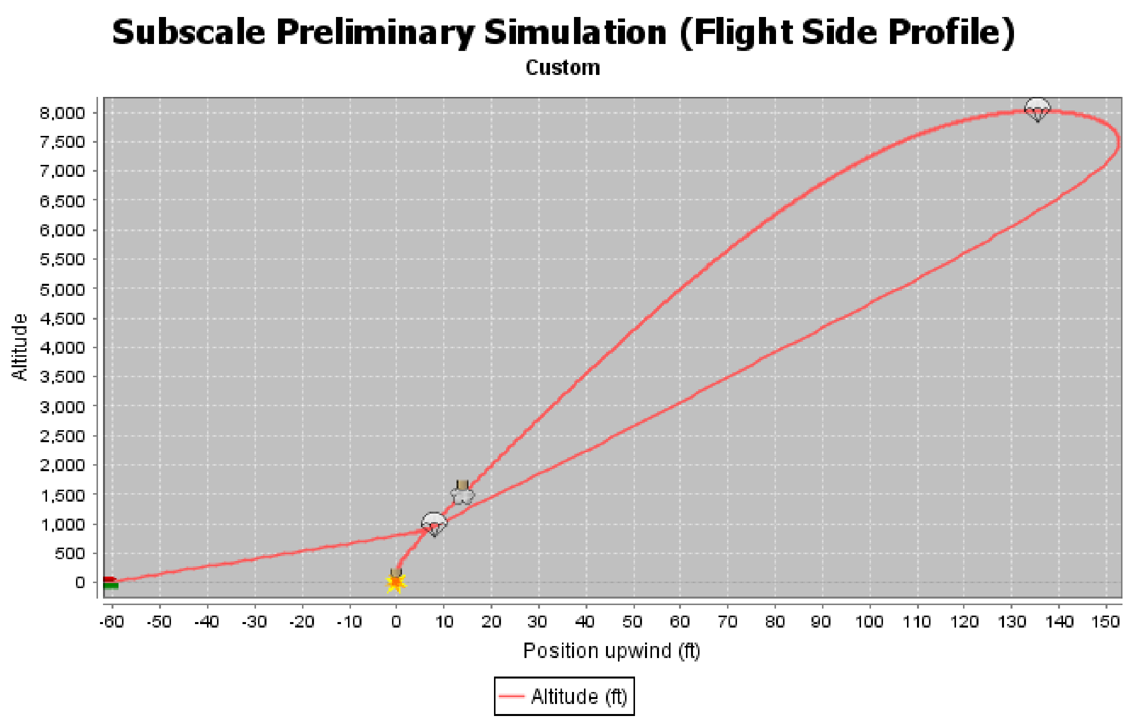


Figure 34 – Subscale Flight Side Profile

The predicted altitude is 8,021 feet, as shown below in Figure 34. Below is a plot of the rocket's altitude as a function of time in Figure 35.

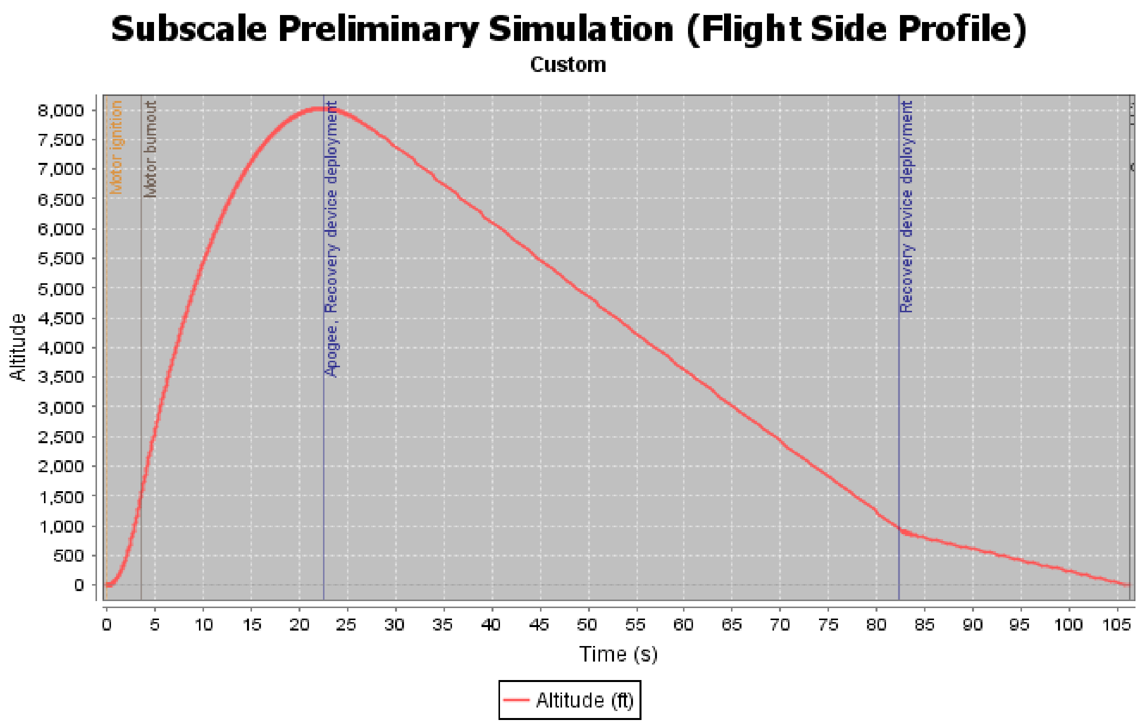


Figure 35 – Subscale Altitude vs. Time

The motor thrust curve simulated in OpenRocket is found below in Figure 36:

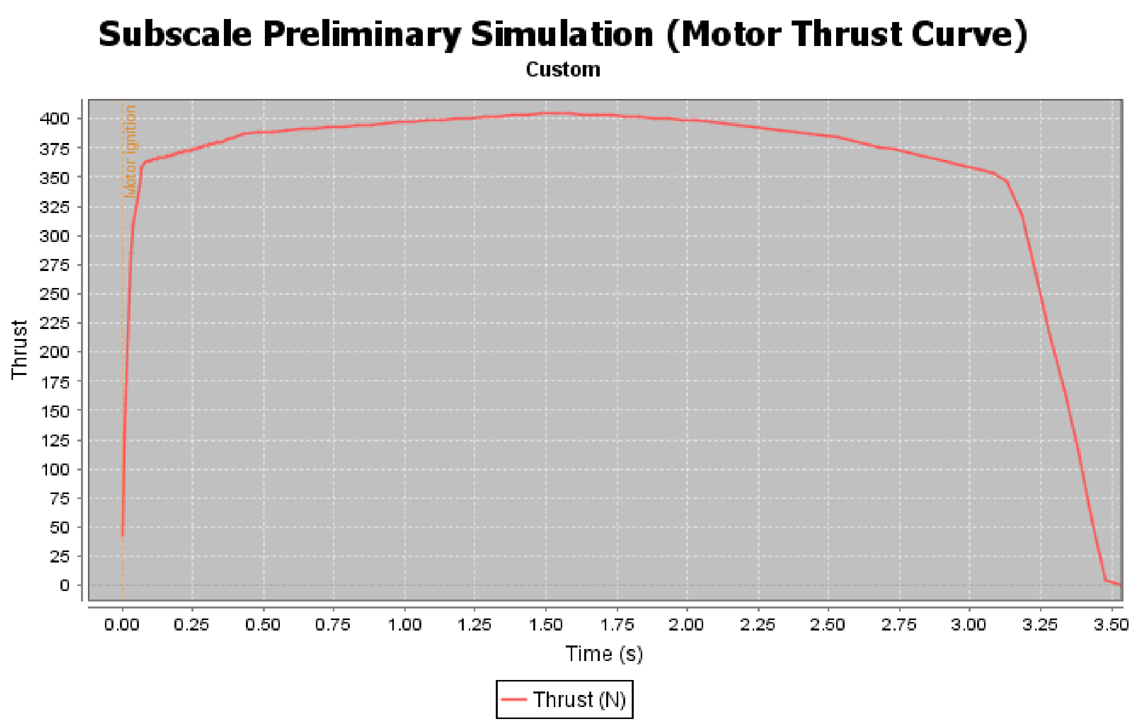


Figure 36 - Motor Thrust Curve

Figure 36 below shows the stability of the rocket during the duration of flight. The red line represents the stability margin, which varies between approximately 6 and 10 calibers over the course of the flight. The blue line represents the location of the center of gravity (CG), and the green line represents the center of pressure (CP) location, both in inches from the nosecone. At Mach 0.74, the CP is located approximately 71.88 inches from the nose, and the CG is located approximately 58.31 inches from the nose.

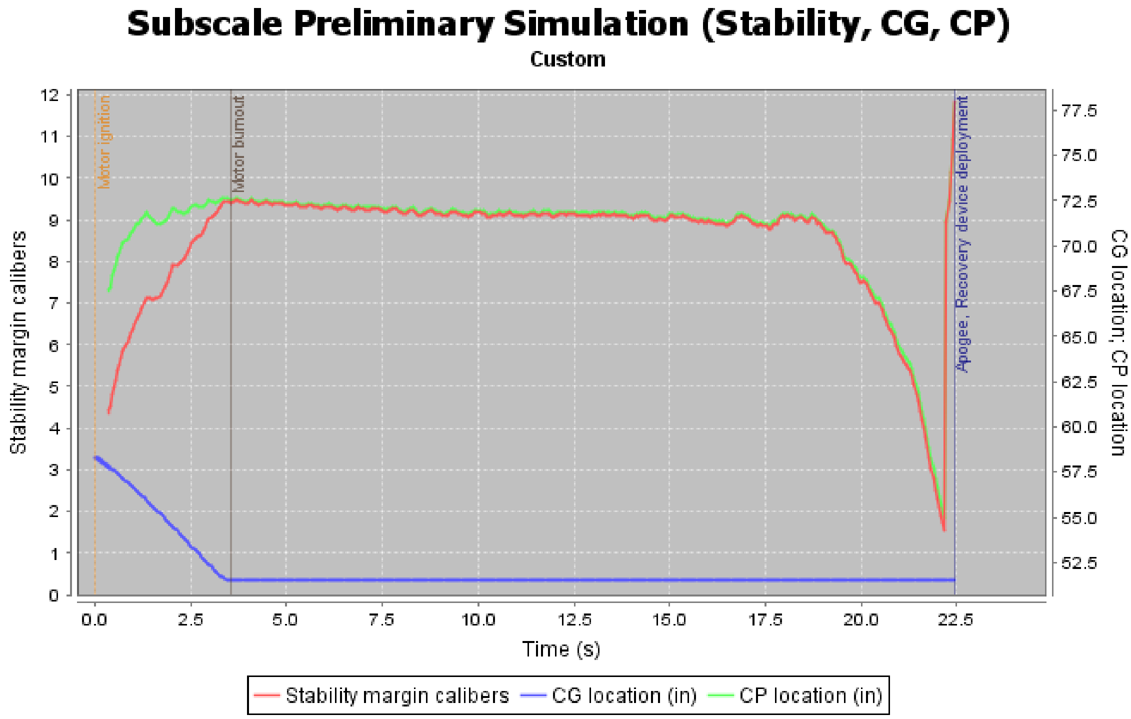


Figure 37 –Subscale Stability

The stability margins and relationship between the CG and CP match up fairly well between the full-scale simulations and the subscale simulations which indicates that in terms of scaling stability, the design was successful. The hope is that the subscale launch will provide a good indication of how the rocket reacts to liquids held within it based on the design covered in Section 4.2.

3.7.6 . Subscale Test Flight Results

The subscale of the HYDRA vehicle was tested at the SCORE (Southern Colorado Rocketeers) Hudson Ranch launch site near Pueblo, CO. This was the team's fourth attempt at a subscale test flight as the previous launches were cancelled due to inclement weather.

This section corresponds with the Critical Design Review Section 3.5.2, which was previously omitted due to the delay in completing the subscale test flight.

3.7.6.1 Vehicle Flight Overview

The launch conditions were fair with no cloud cover and sustained winds between 10-15mph with gusts up to 20mph. The vehicle was loaded onto the pad with and angled to 15° from vertical in the direction of the wind as seen below in Figure 38.

Figure 38 - Subscale Launch

When the vehicle was launched, the ground winds were 15 mph with the upper winds most likely greater than this. The vehicle took off straight but then soon after began experiencing a bending mode in flight. This severely decreased the expected performance of the vehicle although the launch was still successful. As the rocket reached an apogee of 3,812 feet, the drogue was deployed by the Raven altimeter. Unfortunately, the rivets securing the airframe to the avionics bay cut through the phenolic coupler when the ejection charge was ignited. The drogue still deployed but one of the rivets caught a wire in the avionics bay and cut the power to the altimeter.

Due to the difficulty of packing the main chute in such a small airframe, it was decided to forego the shear pins securing the main chute compartment in order to reduce the possibility of a failed recovery system deployment. This decision resulted in the main chute compartment drag separating upon drogue deployment and the main also deployed at this time. Following both chute deployments, the vehicle was safely recovered. The locations of these failure points are shown below in Figure 39.

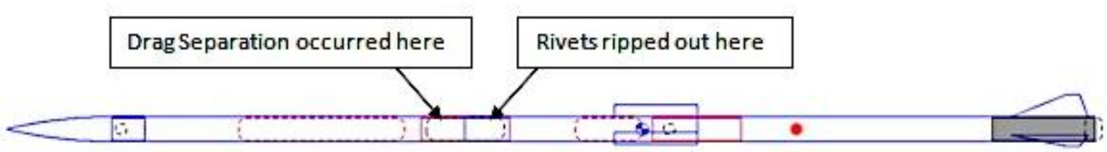


Figure 39 - Subscale Failure Locations

3.7.6.2 Flight Data

A summary of the vehicle flight data compared to the simulation data using the test flight conditions is listed below in Table 13.

Table 13: Subscale Flight Data Summary

Measurement	OpenRocket Simulation	Test Flight
Altitude [ft]	5440	3812
Max Velocity [ft/s]	835	720
Max Acceleration (During Boost) [ft/s^2]	289	250.4
Time to Apogee [s]	17.2	15.96

Unfortunately, due to the bending of the vehicle, these results are difficult to tie to the simulation predictions. The velocity, acceleration, and time to apogee are between 86% and 93% of their predicted values while altitude is 70% of its predicted value. As the difference in the velocity, acceleration, and time to apogee measurements are relatively similar, the team believes that the bending of the vehicle both vectored the thrust and increased the drag of the vehicle causing a reduction in performance. This large discrepancy in altitude could be a result of the potential thrust vectoring or signify a potential error in the altimeter measurement due to the unstable bending of the vehicle. The team will analyze the full-scale test flight results and look for any of these same anomalies.

As mentioned above, the altimeter only contains data up to apogee of the flight path due to being powered off mid flight. The first item of note is the instability upon launch that can be seen in the accelerometer readings of the Raven Altimeter as shown below in Figure 40, with axial acceleration in red and lateral acceleration in purple.

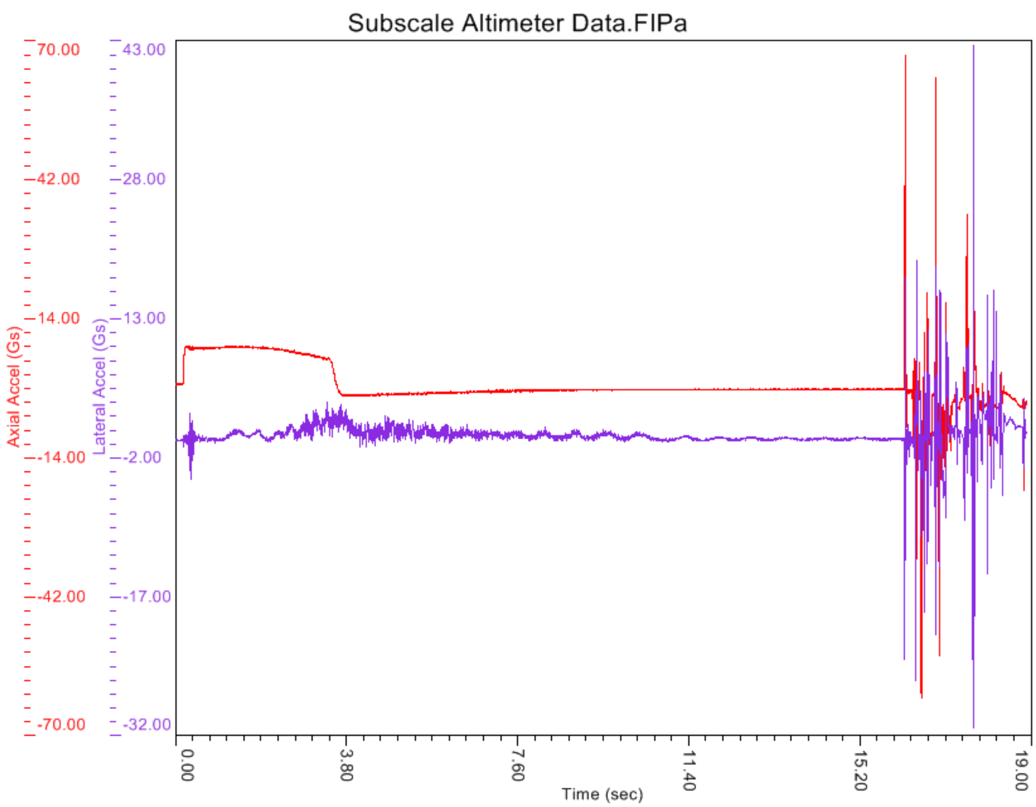


Figure 40 - Subscale Altimeter Acceleration Data

It is readily apparent from the lateral acceleration (seen in Figure 40 in purple) that the vehicle had large oscillations beginning midway through the motor burn. The team is certain that the cause of this bending was partially due to phenolic couplers being used instead of filament wound fiberglass due to lack of availability. The other major factors were the winds and the weight added to the nose of the vehicle which amplified any bending that occurred. This weight was added in order to attain the same stability margin as the full scale and to decrease the expected altitude so that the vehicle would not go over the FAA waiver of 8,000 ft. The team believes that this same instability will not be as likely to occur on the full-scale due to a better weight distribution - most payload mass is around the CG - and the use of filament wound fiberglass couplers which will be much stiffer than the phenolic used for the subscale. Although not destructive, this bending will need to be corrected in order to attain consistent flight performance. Another observation from this data is the large G amplitudes near the end of the recorded data. These are most likely due to ejection charge ignition coupled with the resistance of the rivets cutting through the altimeter bay. Similar anomalies will be looked for in the full-scale test flight in order to determine the cause.

The second item of note is the altitude achieved by the vehicle. A plot of altitude versus time can be seen below in Figure 41, with the blue showing altitude based on barometric pressure readings and black showing altitude based on acceleration readings.

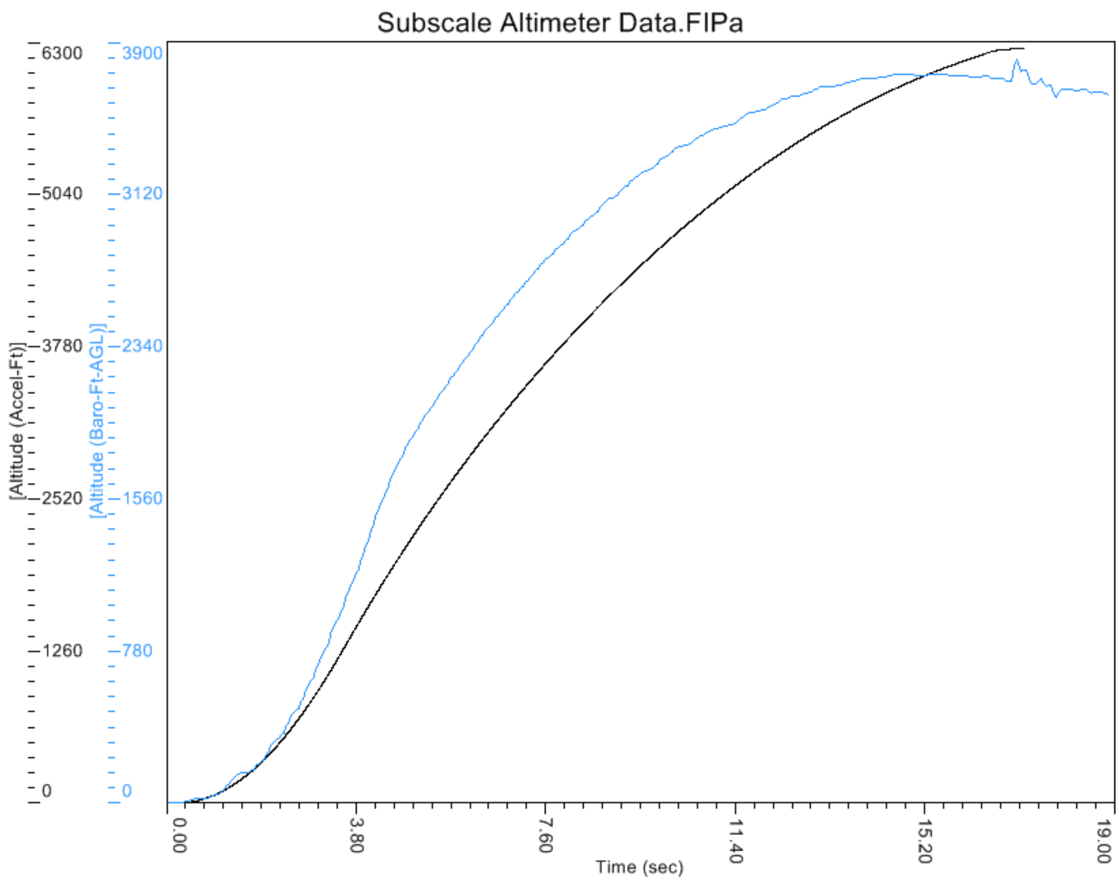


Figure 41 - Altitude Flight Data

It can be seen in the above plot that the accelerometer reported altitude does not match the barometric altitude reported. The team is more confident in the barometric readings and has reported those as the results of the test. On the full-scale flight test, there will be two different altimeters (Raven and AIM USB) in order to help determine which reading is correct.

3.7.6.3 Design Considerations for Full Scale

From the subscale flight data, it is apparent that some design changes need to occur for the full-scale vehicle to be stable and have consistent flight performance.

- The first of these is stiffer couplings. As the subscale was originally designed with filament wound fiberglass couplers but was manufactured with phenolic couplers due to lack of availability, the need for this stiffer component was confirmed. The full scale is designed with these stiffer couplers with sufficient shoulder lengths so as to reduce the airframe's ability to bend.
- The second design change is a more stable mass distribution. The subscale had approximately 22% of its mass at the nose of the rocket while the full scale has only 9.6% of its mass at the nose. This large decrease in mass should help to reduce the bending induced by the weight in the nose of the rocket.
- The third change is for shear pins to be used in all sections that are not secured together by rivets. The only reason shear pins were not used in the subscale was in order to ensure the deployment of the main chute of the subscale as it was difficult to pack the 44" chute into a 54mm tube. The larger airframe diameter of the full scale will allow more space for the main chute and the use of a deployment bag will improve the reliability of deployment. Shear pins are planned for the full-scale vehicle and recovery ground tests will be performed to ensure reliable deployment.

All of these changes have already been taken into account and were originally in the design of the full-scale vehicle. The subscale design was modified from this due to lack of building material availability and in order to comply with the FAA waiver of the resulting launch site (The waiver decreased from 12,000 ft. to 8,000 ft.) without having to purchase a new motor as the team has a limited budget.

3.7.6.4 Full-Scale Apogee Prediction

The apogee prediction for the full-scale test flight and for the competition flight remains at 6,000 feet AGL.

Due to the uncertainty of the altitude achieved by the sub-scale test flight as well as the non-ideal launch conditions (high winds), the team is unable to confidently use the sub-scale altitude to refine the prediction for the full-scale altitude. However, the suspected causes for the subscale not achieving its predicted altitude are corrected in the full-scale vehicle design, as outlined above. Furthermore, Table 14 below compares the subscale predicted and actual results and also includes the predicted performance of the full-scale test flight:

Table 14: Sub-scale and Full-scale Performance Predictions and Results

	Sub-scale		**Full-scale**
Measurement	**OpenRocket Simulation Predictions**	**Test Flight Results**	**OpenRocket Simulation Predictions**
Altitude [ft]	5440	3812	6506
Max Velocity [ft/s]	835	720	842
Max Acceleration (During Boost) [ft/s^2]	289	250.4	453
Time to Apogee [s]	17.2	15.96	19.0

As described above, for the sub-scale test flight, the velocity, acceleration, and time to apogee are between 86% and 93% of their predicted values while altitude is 70% of its predicted value. These significant reductions in performance are thought to be caused by the bending that occurred in flight, as well as potential thrust vectoring that occurred as a result of the bending and, to a lesser degree, possible error with the accelerometer. The full-scale design corrects these issues and such a significant bending and thrust-vectoring situation is not expected to occur.

Based on this information gained from the sub-scale test flight, we predict that the full-scale vehicle will perform slightly below the OpenRocket simulation predictions, but not the extent of the sub-scale, which would be indicative of a worst-case scenario. As such, we are predicting that the rocket will achieve approximately 90-95% of the predicted results and reach an altitude of 6,000 feet AGL.

3.8 Interfaces and Integration

3.8.1 Payload Integration Plan

See payload integration descriptions below in Section 4.

3.8.2 Internal Launch Vehicle Interfaces

In order to integrate each of the payloads with the launch system, specific adjustments must be made to the launch vehicle in order to integrate the payloads to optimize performance and to simplify the integration process. Details regarding the integration of the recovery system with the rocket can be found in the Recovery System section.

The HazCam payload and GPS transmitters along with the entire wireless downlink system will all be housed completely in the RF transparent fiberglass nosecone. This will be done by utilizing a large electronics sled made of fiberglass and attaching all of the required hardware to it using zipties and screws through the board. The team has experience with this form of integration, having performed a similar integration with a previous on-board GPS system. The footprint for the HazCam side of the nosecone is shown in Figure 41 below.

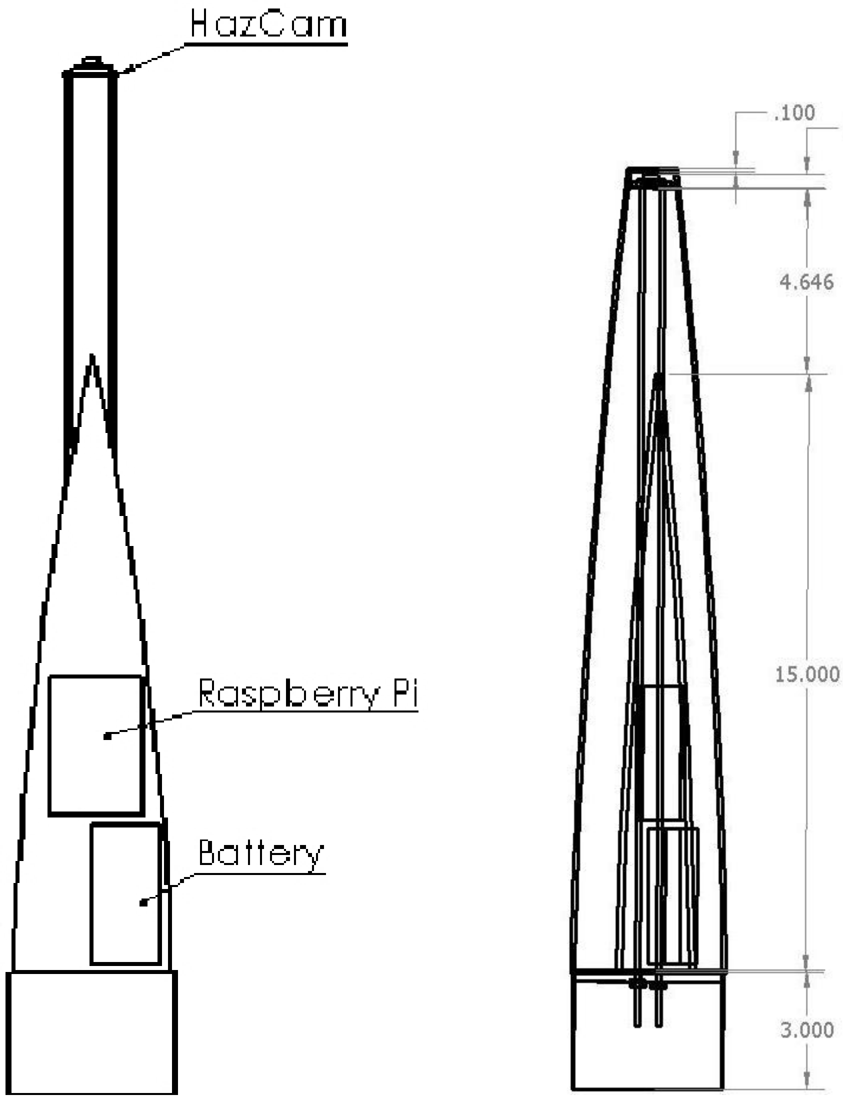


Figure 42 – HazCam Drawings

The HazCam also requires a clear acrylic lid at the top of the nosecone in order to properly view the landing site during recovery. This lid will be epoxied onto the nosecone itself and create an airtight seal that will still allow for the optimal viewing angle for the camera. The GPS system and wireless transmitter hardware will be mounted in similar fashion to the HazCam, with the GPS and transmitter hardware being mounted on the opposite side of the nosecone in order for the data collection systems work correctly. The footprint of the GPS hardware side is shown in Figure 42 below.

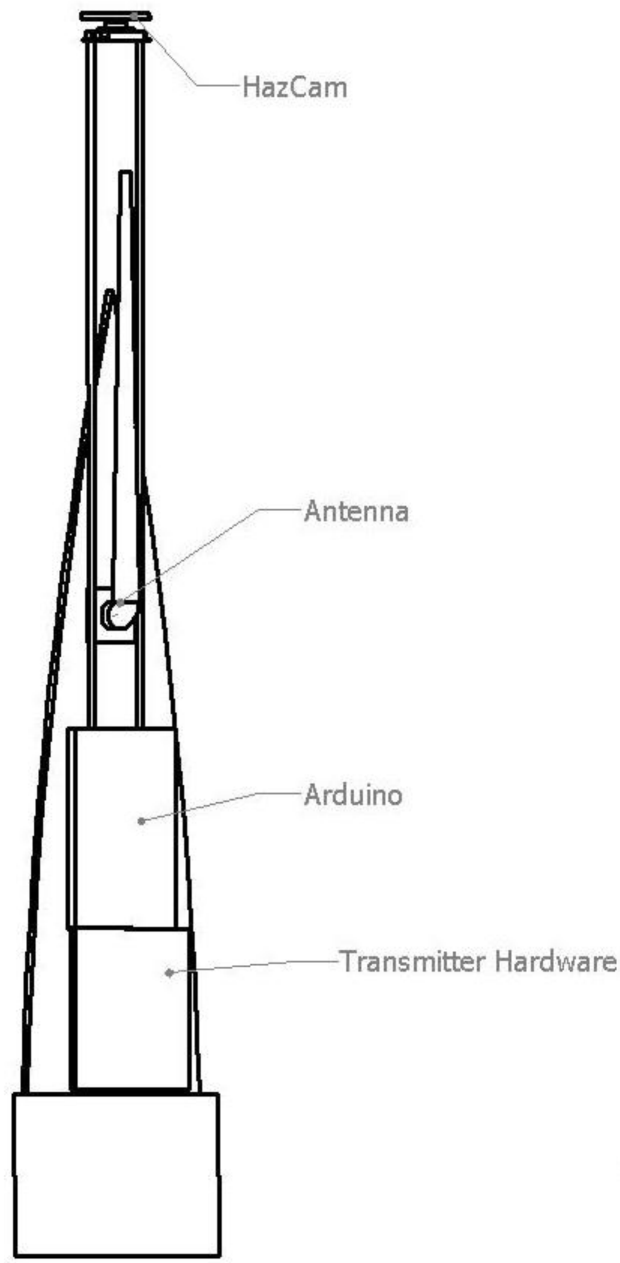


Figure 43 – GPS Hardware/Nosecone Drawing

The aerodynamic analysis payload will utilize a fairly simple integration procedure which will involve utilizing railings that are built by the team. These rails will consist of two parts, one part which is attached directly to the body tube using a custom-machined jig to position the rails in the correct orientation around the body tube of the rocket and the other part which is attached directly to the SRB models themselves. The railings will be epoxied to their respective bodies in order to minimize the amount of weight added to the rocket, minimize the number of holes that may need to be made in the body of the rocket, and to ensure a strong bond between the railings and their respective bodies. The SRB's themselves are completely contained payloads which can be attached and detached from the rocket with no interference from wiring or electronic hardware. The railing system can be seen below in Figure 44

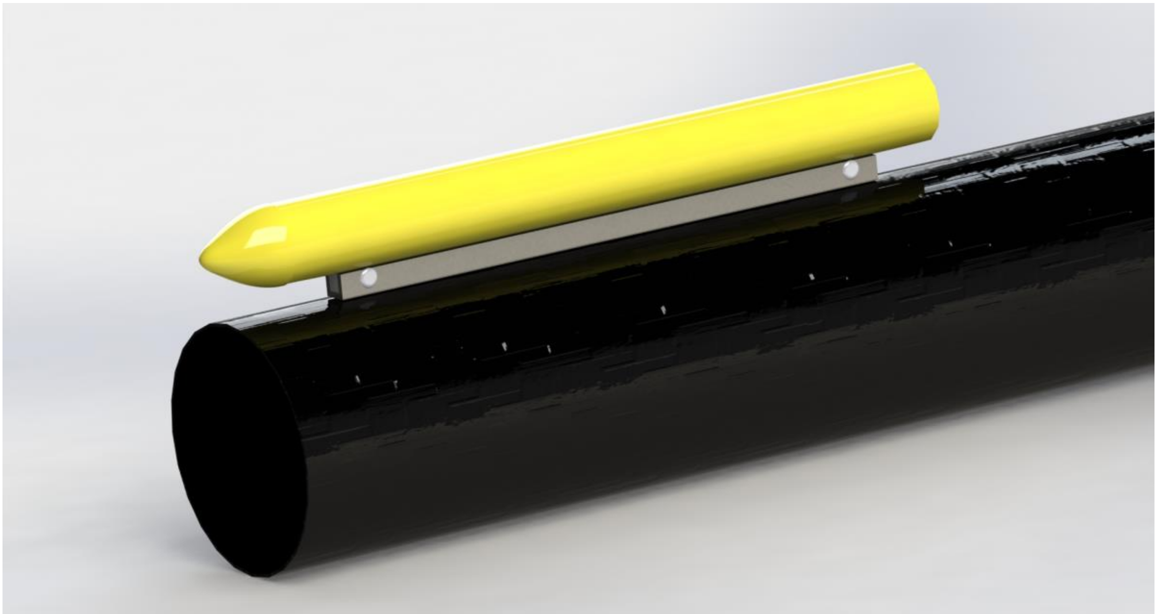


Figure 44 – Railing System for SRBs

The railing system is relatively easy to disassemble in order to remove the SRBs and subsequent electronics. A disassembled form of the same railing system is shown below in Figure 45

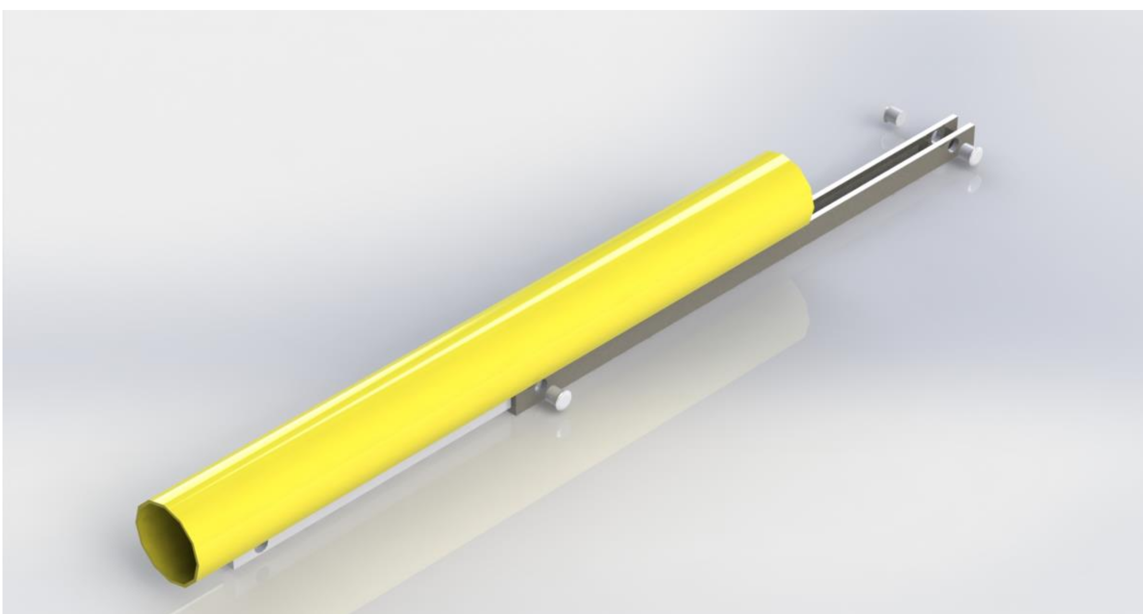


Figure 45 – Disassembled Railing System

3.8.3 Launch Vehicle/Ground Interfaces

See descriptions of the interfaces between the launch vehicle and the ground system (specifically the wireless and transmitting interfaces) above in Section 3.2.4.

3.8.4 Launch Vehicle/Ground Launch System Interfaces

The interfaces for the launch vehicle and the ground launch system are as follows:

- 1515 rail buttons on rocket attach to 20 ft.-1 ½” tower
- Alligator clips connecting to the igniter leads

3.9 Launch Operation Procedures

The checklist for launch operation procedures can be found in Appendix C. These procedures detail the assembly and integration of all vehicle and payload components to prepare for a full-scale launch. A list of all the attached procedures is shown below in alphabetical order:

- Aerodynamic Analysis Payload Checklist
- Avionics Bay Assembly Checklist
- Black Powder Charge Preparation Checklist
- Ground Station Preparation Checklist
- Hazard Camera and GPS Payload Checklist
- Igniter Installation Checklist
- Launch Pad Integration Checklist
- Launch Procedure Checklist
- Master Checklist
- Motor Assembly Checklist
- Post Launch Clean Up Checklist
- Recovery System Preparation and Final Integration Checklist

3.10 Safety and Environment (Vehicle)

3.10.1 Duties of the Safety Officer

COBRA’s team safety officer is Eric J., a Level 2 certified member of the National Association of Rocketry (#86129). He will ensure that proper safety precautions are taken during the design, fabrication, storage, and testing of all rocket materials and equipment. Specifically, Eric will check all design plans for any potential hazards and safety issues. If these issues are present, Eric will ensure that the team lead and all subsequent members are made aware of these issues and that proper precautions are taken in order to mitigate these issues and minimize risk. Eric will also investigate all test plans to ensure that proper safety precautions will be taken for a test. He will also be present for all testing to ensure guidance in the case of a hazardous situation. As safety officer, Eric will also present to all team members regarding proper safety practices and precautionary measures that could arise while working in the lab. This seminar will occur prior to any members beginning work on the rocket or subsequent components. He will also make sure the team adheres to the rules stated in the High Power Rocket Safety Code as well as NFPA Code 1127 and FAA FAR Part 101 as well as all University of Colorado Boulder lab safety rules.

Joe Hinton of Giant Leap Rocketry Inc. will handle all rocket motor and pyrotechnic related purchases for COBRA. Mr. Hinton will also serve as the NAR Mentor and Low Explosives User Permit holder for COBRA, should the team be handling any amount of low explosives in violation of 27 CFR 55.26, and will advise the club on all explosive related issues.

For launches, Eric, along with Mr. Hinton, will perform all motor assembly, with assistance from other NAR certified members. Eric and Mr. Hinton will make and connect all ejection charges and ignition charges. Before the launch, Eric and Mr. Hinton will run through the entire launch checklist, ensuring that all launch criteria are fulfilled. They will oversee the mounting of the rocket on the launch rail, and check all attachment points to make certain that the rocket is mounted properly before being launched. They will also perform an additional final check to guarantee that all systems are functioning properly before launch, and check the rocket for any anomalies in the airframe or payloads.

3.10.2 Launch Vehicle Failure Modes

Launch vehicle failure modes can be found in Appendix E.

3.10.3 Personnel Hazards and Data

A summary of personnel hazards and the associated Material Safety Data Sheets (MSDS) can be found in Appendices E and F.

3.10.4 Environmental Concerns

When dealing with rocketry equipment, there are a few environmental concerns that arise. Specifically, these pertain to motor exhaust, parts manufacturing, and chemical disposal. To ensure the development and construction of the HYDRA vehicle and its payloads have minimal impact on the environment, the team will follow all handling instructions within the MSDS sheets as well any imposed by the University of Colorado. Specific precautions have been taken with the disposal of epoxy resins or other chemicals. All MSDS sheets will be followed when disposing of epoxy or other chemicals in order to prevent any environmental harm from any spillage or unexpected mixing of chemicals.

The rocket itself has an impact on the environment due to its motor exhaust fumes which are harmful to the environment, most importantly, carbon emissions. This is not an entirely preventable situation, however the team has taken measures to ensure that its rockets will have minimal impact on the environment by using the correct motor size and eco-friendly fuel grains.

In order to minimize harm to the environment through carbon emissions, the team will take the fewest possible number of cars to launches and other locations. Most of the launch sites the team utilizes are on farms or National Forest Service land so it is of the utmost importance that the team leave the launch site as they found it. This prevents the team from having any adverse affects on local wildlife and the surrounding environment.

The team will also work with the Environmental Health and Safety (EH&S) Department of the University of Colorado to ensure that they are properly handling all hazardous materials. The Safety Officer Eric J. in addition to other team members will become a certified Hazardous Materials and Waste Management Generator through the University of Colorado EH&S Department.

4 Payload Criteria

4.1 HazCam

4.1.1 Introduction and High Level Description

The HazCam payload fulfills Requirement 3.1 from the Student Launch Handbook. This requirement states that the purpose of the payload is to "scan the surface during descent in order to detect potential landing hazards." This will be done by analyzing video taken during the flight and transmitting data from the analysis to a ground station. The system that has been designed to do is based heavily on the Raspberry Pi microcomputer due to its small foot print, relatively good performance, and low cost. Figure 45 shows a block diagram of the system.

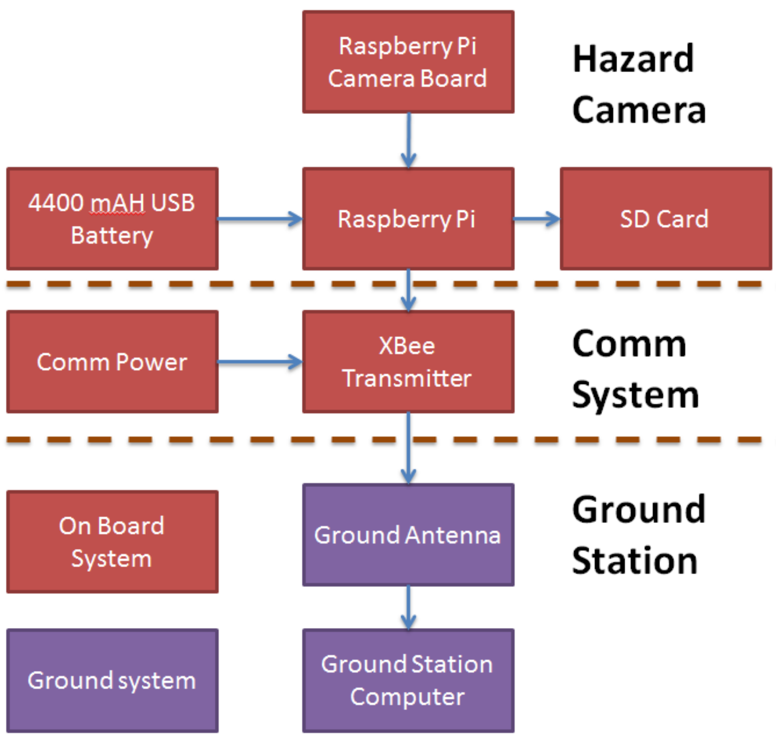


Figure 46 - Block Diagram for HazCam System

The entirety of the HazCam payload will be contained in the nose cone of the rocket. The metal tip of the nose cone will be removed leaving a hole in the top of the nose cone. The camera will rest slightly below this hole on a circular plate that will be held snug against the nose cone to keep the camera stable. Figure 47 shows how the plate and camera will be mounted in the nose cone.

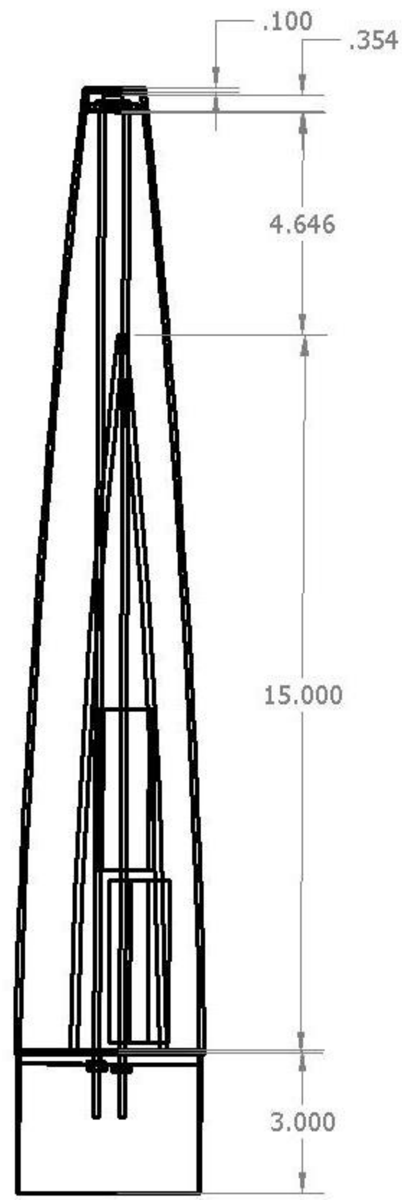


Figure 47 - Camera mounting position

The circular plate will be help in place by two 1/8th inch all thread rods that will be attached to the sled that will carry the electronics. Figure 48 shows the foot print layout of the electronics sled. The communication equipment will be located on the other side of the sled.

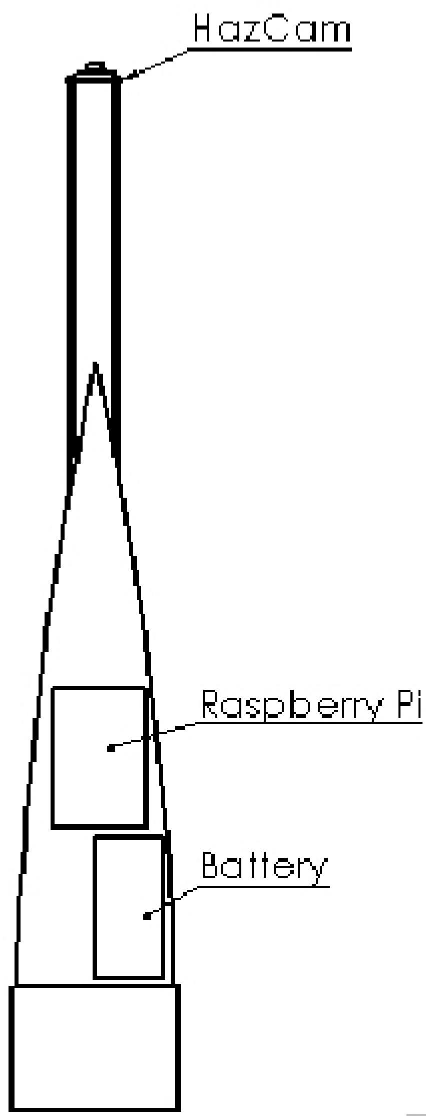


Figure 48 - HazCam Hardware Footprint

4.1.2 Requirements

Table 15 - HazCam Requirements shows the requirements for the Hazard Camera:

Table 15 - HazCam Requirements

Requirement Number			Requirement Text	V&V Method
P1			The Rocket will carry a camera to identify ground Hazards	Inspection
	P1.1		The payload shall scan the surface of the Earth during descent.	Inspection
		P1.1.1	Camera shall be mounted at the tip of the nose cone	Inspection
		P1.1.2	Nosecone shall face downward during parachute decent	Inspection
		P1.1.3	Payload shall save all video to an onboard storage device	Inspection
	P1.2		The payload shall identify ground hazards	Inspection
	P1.3		The payload shall perform all analysis of scans real time with a custom designed on-board software package.	Inspection
		P1.3.1	Payload shall save all processed video to an onboard storage device	Inspection
	P1.4		Data from the payload shall be transmitted to a ground station in real time.	Inspection
		P1.4.1	Payload must be able to transmit no less than 1 frame of video per second	Inspection
		P1.4.2	Frames transmitted will have any hazards detected highlighted	Inspection

4.1.3 Payload Subsystems

The HazCam system is broken into the subsystems of algorithm, camera, image processor, transmitter, power, and ground station.

4.1.3.1 Algorithm

The algorithm that has been developed takes advantage of the fact that the Bonneville Salt Flats are very bright compared to the objects that make up the flight line. Additionally it assumes that the flight line will be straight and will be longer than 1/3 of the images width. With these assumptions in place it is possible to use the Hough transform to identify lines that may be incomplete or segmented, much like a line of people or objects.

Figure 49 shows the flow diagram of the algorithm that has been developed. The MATLAB code used can be found in Appendix A.

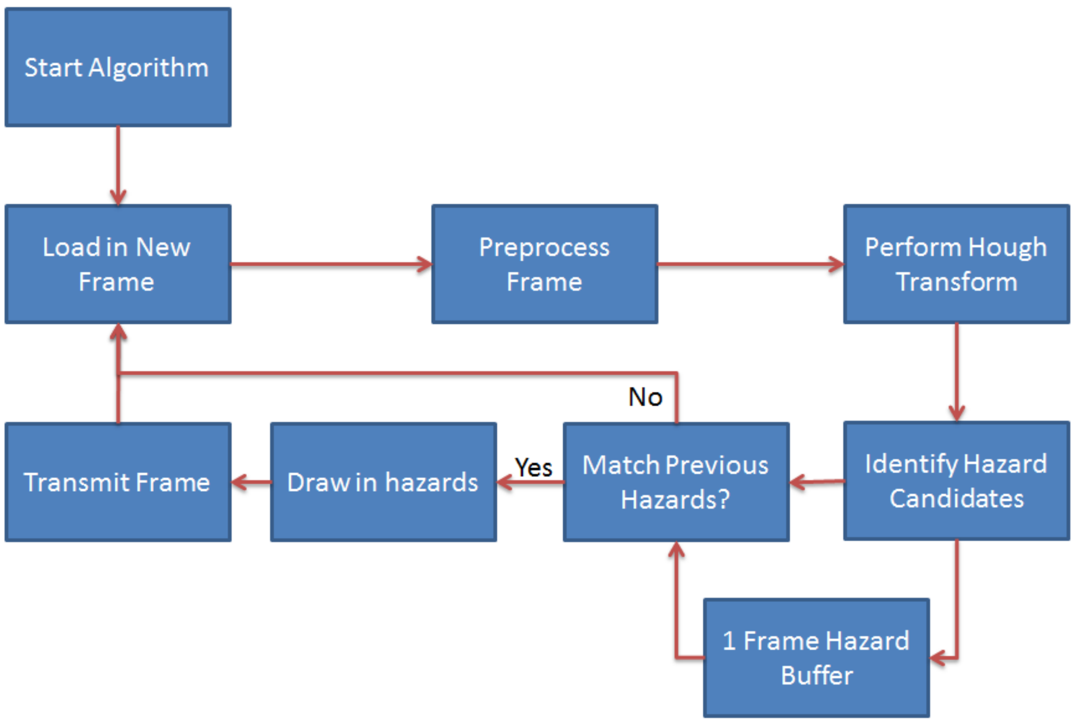


Figure 49 - Algorithm Flow Chart

The algorithm has been tested on footage obtained from a rocket flight conducted by Brigham Young University students and hosted on YouTube[2]. In the test there are several cases of false positives that occur from the contrast between background clouds but overall the results are good. The algorithm was successful in identifying the flight line as shown in Figure 50.

[2] Video Source: http://www.youtube.com/watch?v=NKaT5kclE0c

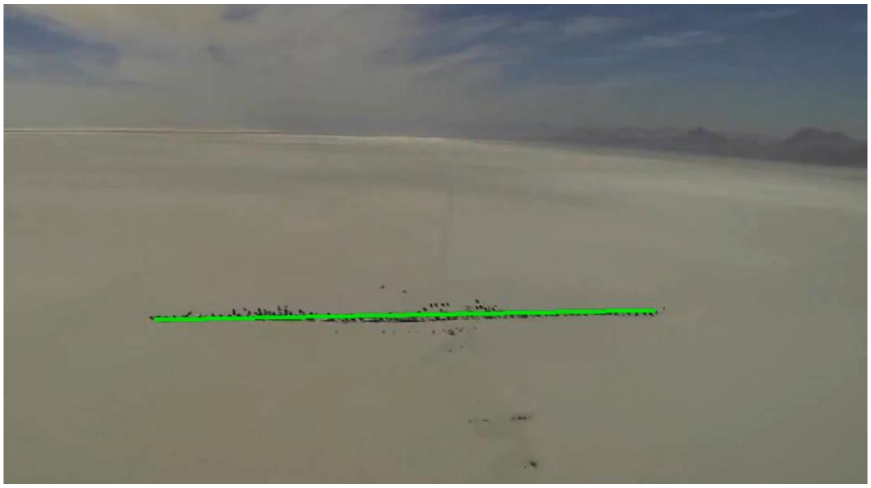


Figure 50 - Frame from Algorithm test, Green line indicates the location of the detected hazard.

Changes that are currently being made include that the code must be translated from MATLAB code to a language that can be compiled on the Raspberry Pi. The code is being modified to take live video from the camera, as well as being optimized to maximize the frames that can be processed per second and adjusted to send data to the onboard storage and the transmitter.

4.1.3.2 Image Processor

The image processor that has been selected for this system is the Raspberry Pi microcomputer. This was selected based on its relatively strong processing capabilities and its small footprint. The team has selected the Raspberry Pi B shown in Figure 51. The Raspberry Pi B will take image data from the camera, process the image, and save it to an onboard memory card. In addition when a hazard is detected it will send the image data to the transmitter.

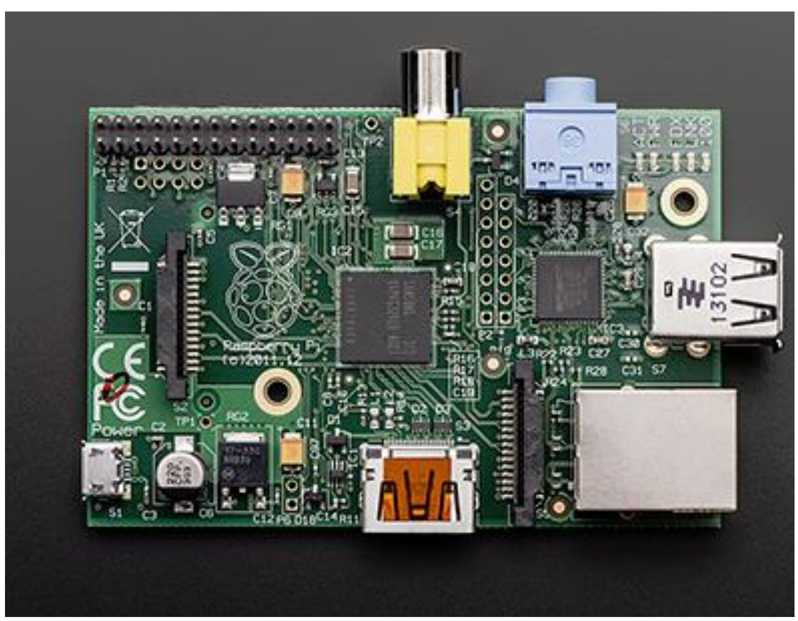


Figure 51 - Raspberry Pi type B

4.1.3.3 Camera

The camera that has been selected for this payload is the Raspberry Pi camera board. This camera was selected primarily for its ease of integration with the Raspberry Pi computer and its good image quality. Because the camera has been developed by the makers of Raspberry Pi it comes with a full library already built. This will ease the work needed to be done to interface the Raspberry Pi with the camera. A picture of the camera is shown in Figure 52.

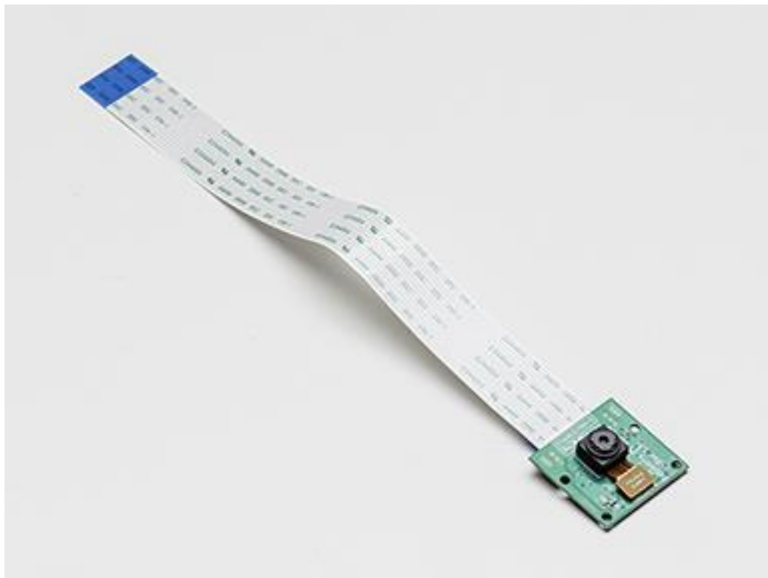


Figure 52 - Raspberry Pi Camera Board

4.1.3.4 Transmitter

The transmission of the data will be done by the communication system that is detailed above in this report. The transmitter runs on an Arduino board and is capable of transmitting 10 Kbps. At this rate the transmitter will not be capable of transmitting full video to the ground station. Instead the algorithm will wait until it has detected a hazard. Once an algorithm has been detected the frame and an overlay of where the hazard is detected will be transmitted. The minimum video resolution of the camera is 640x480p at 30 frames per second. Unfortunately the uncompressed size of a video frame is then 3072 Kb. This means that the image will need to be compressed heavily before it can be transmitted. The team is currently looking into compression methods, reducing the data to be transmitted i.e. changing the images to black and white, and upgrading the transmitter system.

4.1.3.5 Power

All power for the HazCam system will be supplied by a 5 volt 4400 mAH battery built by Adafruit. This battery was selected due to its ability to directly power a Raspberry Pi and its large capacity. The maximum current draw of the Raspberry Pi is 1 amp, and to fulfill requirement 5 of having the payload run for 1 hour on battery we need a minimum of 1000 mAH. This battery will be more than satisfactory to power the HazCam Payload.

4.1.3.6 Ground Station

The ground station will consist of a station that matches the communication system and a laptop. This has been detailed in the communication system information in Section 3.2.4.

4.1.4 Manufacturing Plan

There were be two stages of manufacturing for this payload.

1. **Prototyping and interfacing** – The first step of manufacturing the payload will be to connect all of the electronics. This part of the assembly will be used to ensure that all the parts of the system will be able to communicate. Additionally it will allow for the components to be tested in an environment that makes troubleshooting and improvements easy.
2. **Integration with the rocket –** The next step of the manufacturing will be integrating the payload onto the sled and ensuring a proper fit with the nosecone. One of the most important parts of ensuring a proper fit will be making sure that the disc that the camera rests upon is snug against the nose cone. This will be an iterative process of adjusting the position of the disc on the all thread with its retaining nuts until the appropriate fit is achieved.

4.1.5 Payload Performance

4.1.5.1 Evaluation

The performance of the payload will be defined by the three parameters:

1. **Processed Frames Per Second** – The current algorithm is too slow for real time image processing, thus it will be necessary to run the payload at a reduced frame rate. The number of frames per second (FPS) that the system can handle will be one of the metrics used to analyze the performance of the algorithm.
2. **False Positives** – With machine vision there is always the possibility of false positives. The number of falsely identified frames will be used as a metric to determine the algorithm's performance.
3. **Hazards Identified** – It is imperative that the system be able to identify hazards. The number of hazards missed by the camera will used to determine the algorithm's performance. It is important to note however that there is the possibility of hazards never entering the field of view for the camera; if this is the case then the system will be evaluated by the processes frames per second and the number of false positives alone.

4.1.5.2 Payload Success Criteria

The criteria of success for this payload will be the ability to identify the flight line that will be present on the day of launch in the Bonneville Salt Flats. An example of such a flight line is shown in Figure 53.

Figure 53 - Video from Brigham Young University Rocket launch.[3]

It can be seen that the image contains a nearly straight line of cars and tents. It is assumed that similar straight lines will be formed on the day of the launch for this project. If the camera is able to identify the flight line while it is descending then the payload will be deemed a success.

4.1.6 Payload Concept Features and Definition

4.1.6.1 Uniqueness or Significance

The significance of this payload is to help with future landing missions. During the Apollo 11 mission the initial lunar landing site turned out to be a large boulder field. Neal Armstrong then had to find a second site to land at, using fuel and risking a mission abort. The payload developed here, while highly specific to the Bonneville Salt Flats launch site, can be used to develop more general solutions.

4.1.6.2 Suitable level of Challenge

The largest challenge to this payload is the development of the algorithm to identify hazards. Machine Vision is considered to be part of the cutting edge of robotics, and computer science. As such there are no readily available software solutions available for the payload thus an algorithm has been developed from scratch to identify the presence of lines. Additionally the code must be extremely efficient due to the limited processing capabilities of microcomputers.

4.1.7 Science Value

4.1.7.1 Payload Objectives

The objective of the payload is to test a simple algorithm for identifying a limited set of ground hazards.

4.1.7.2 Preliminary Experiment Process Procedure

On the day of launch the camera will take video as it descends. This video will be processed by the hazard recognition algorithm and then transmitted to the ground with any identified hazards highlighted. The ground station will record all frames received. It is expected that the transmission will not have enough bandwidth for live video to come through, and instead the transmitter will send

[3] Video Source: http://www.youtube.com/watch?v=NKaT5kclE0c

video with a reduced frame rate. In addition the full video will be recorded to an onboard SD card. After the flight if no hazards were received by the ground station the onboard video will be used to determine if any hazards were present in the video footage. If no hazards were present in the video then no conclusions can be drawn about the algorithm that was used. If there were hazards in the video footage but the algorithm did not detect them then the algorithm can be considered to have failed and the team will make the modifications to the algorithm necessary for the hazard to be identified and document the needed changes in the Post- Launch Assessment Review.

4.1.8 Failure Modes

The HazCam failure modes can be found in Appendix E.

4.2 Liquid Sloshing Experiment

The liquid sloshing payload will no longer be included on the vehicle due to budgetary and scheduling concerns.

4.3 Aerodynamic Analysis of Protuberances

4.3.1 Payload Summary

The payload to satisfy Requirement 3.2.2.2 will measure pressure on different types of protuberances on the side of the rocket. The pressure will be measured on mock "Solid Rocket Boosters" with different shapes. These pressure measurements will be used to analyze drag of the different shaped "SRBs". Furthermore, these results will be simulated against CFD results for data verification.

4.3.2 Overview

All modern rockets use solid rocket boosters that are ejected from the rocket after they are used. While they are eventually removed from the rocket, they are an important part of the rocket's geometry during liftoff. Having a thorough understanding of how these shapes affect the overall drag of the rocket is key to conserving fuel and reducing costs.

This payload will have three different "SRBs" that will be attached to the rocket during flight. Each SRB will have a different nose cone shape. The pressure distribution across each SRB will be used to determine the drag effects due to each of the nose cone shapes. From this data, a higher performance SRB design can be achieved.

4.3.3 High Level Payload Description

The payload consists of three mock "SRBs" that are mounted to the end of the rocket. Each SRB is mounted using a sliding rail system to keep the payload modular and easily removable. Each SRB has a different shaped nose cone mounted at its tip. Pressure ports are drilled to measure the wind profile on the surface of each SRB. These pressure ports are connected to pressure sensors which are in turn connected to a microcontroller and microSD card.

4.3.3.1 Creativity and originality of payload

The payload requires creative and innovative thought to develop nose cone shapes that can produce a significant and measurable/ calculable change in the aerodynamic load of the SRB's/main rocket body

4.3.3.2 Significance

This particular payload is significant because the experiment could illuminate paths and ways of improvement in nose cone design for solid rocket boosters. Achieving a smaller drag profile through innovative nose cone design will reduce the air friction during flight and directly translate to less required thrust from the SRBs to accomplish the same payload mass delivery at a lower cost to NASA. This cost savings comes from decreasing the amount of SRB propellant.

4.3.3.3 Suitable level of challenge

The students participating in the aerodynamic analysis payload are underclassmen in a variety of scientific and mathematic fields. Few students have had exposure to even basic aerodynamic analytical courses. However, team members working on other payloads and the leadership of the COBRA club have far more experience with aerodynamic analysis and have been providing valuable mentorship to the proactive underclassmen of the aerodynamic analysis payload.

4.3.4 Science Value of Payload

4.3.4.1 Purpose

By measuring and determining the aerodynamic profiles of mock SRB's with different nose cones, an optimum design can potentially be identified. At the very least, the most inefficient designs can be eliminated from further study. By using the optimum shape of nose cone, the overall drag force on the rocket can be reduced. This in turn means the SLS core will experience less opposing force during flight and require less propellant from the SRB's or the main engines. This directly translates to lower cost per launch, promoting rapid redeployment of the SLS, and further exploration of space for lower cost.

4.3.4.2 Success Criteria

This payload levels of success are defined below:

- **Highly Successful** – Pressure and velocity data is recorded for each SRB throughout the entire flight. This post-flight drag calculations rank the nose cone shapes from lowest to highest drag. Results are consistent with CFD predictions within 15%.
- **Successful** – Pressure and velocity data is recorded for each SRB. However, data was not collected for all SRBs or for only part of the flight. Results qualitatively line up with CFD predictions, but not quantitatively.
- **Adequate** – A pressure and speed measurement were made on at least two SRBs and the drag of the nose shapes can be ranked. Results may or may not match CFD predictions. The data provides a basis for further experimentation.
- **Unsuccessful** – Data was only measured on one SRB and for only a portion of the flight. There is not enough data to correlate with CFD predictions.
- **Failure** – No data is recorded.

4.3.5 Experiment Variable Summary

4.3.5.1 Control Variables

- SRB cross-sectional area
- Pressure measurement density and distribution

4.3.5.2 Independent Variables

- SRB physical geometry
- Rocket velocity
- Flight conditions (density, atmospheric pressure, etc.)

4.3.5.3 Dependent Variables

- Total pressure on surface of SRB
  - Drag force (derived variable)
  - Coefficient of drag (derived variable)

4.3.6 Experimental Approach

A pressure profile will be measured for each of the SRBs. If the precise location of each pressure port as well as the pressure at that port is known, a drag calculation can be performed. This is done by integrating the pressure over the surface of the SRB.

$$F_D = \int P \, dx \tag{18}$$

Then, since the velocity of the rocket is known for each data point in flight, the drag force can be calculated as a function of velocity. The coefficient of drag for each nose shape can be determined from this plot.

$$C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A} \tag{19}$$

This then can be used to rank the nose cone shapes from lowest drag to highest drag.

Next, the measured rocket velocities are used as an input to the CFD simulation. The pressure distribution on each SRB can then be "measured" in software and the same calculation performed. The numeric results can then be compared for accuracy and data validation.

4.3.7 Integration of Payload to Rocket

Each of the SRBs will be functioning as an independent payload. They will have separate electronics, power, and data storage. This isolation of systems will reduce failure rate and simplify the design of the rocket.

4.3.8 Physical Integration

The mock SRBs are attached to the main rocket by a rail system. The female rail is installed on the outside edge of the main rocket body with epoxy. The male rail is installed on the mock SRBs with epoxy. The male rail allows the SRB to quickly and easily slide on and off the main body. In addition, rivets are used to keep the rail in place during flight. Figure 54 shows this mounting system in its flight configuration. Figure 55 shows the SRB in its unlocked configuration. This configuration allows for easy access to the payload while still providing a secure attachment mechanism while in flight.

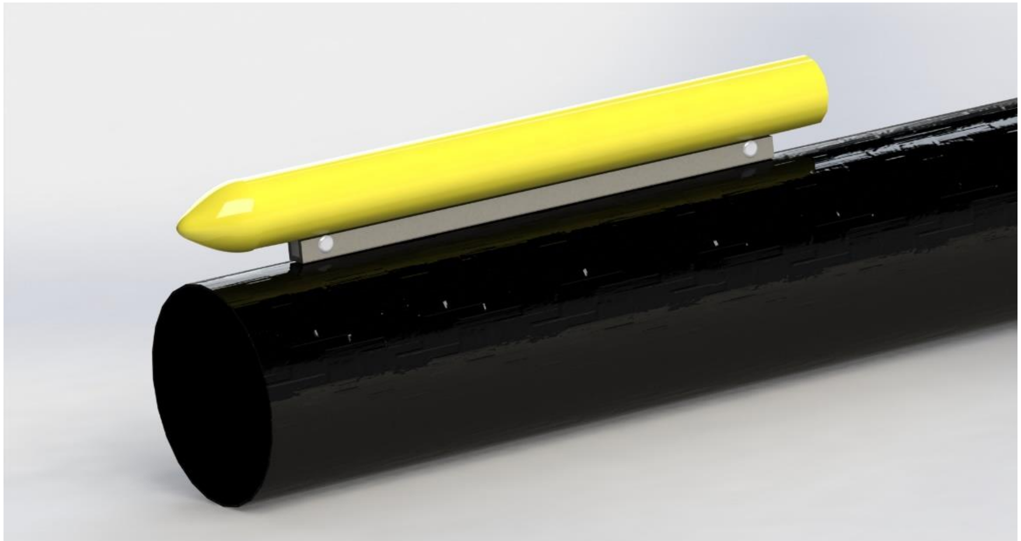


Figure 54 - SRB Rail System in Flight Configuration

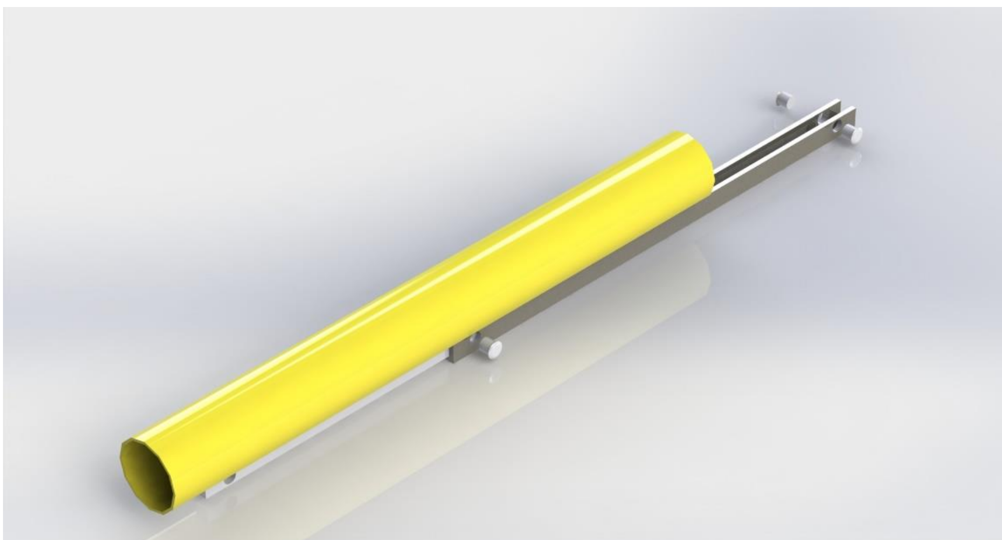


Figure 55 - SRB Rail System in Unlocked Configuration

4.3.9 Electrical Integration

As stated above, each SRB will have its own measurement, electronics, data handling, and power systems. There will be no integration of these components outside of the payload.

4.3.10 Precision of Experiment

The experimental setup of this payload allows for extremely precise measurements to be taken. The sensors themselves offer precision of up to 0.25 PSI. The ultimate experimental output though is drag forces on each SRB. The accuracy of this calculation is greatly influenced by the density and resolution of pressure measurements.

Rocket flight is an extremely noisy environment. The instrumentation allows for very good measurements to be taken. The largest source of inconsistencies in the processed results between flights will be due to the variability in the flight conditions. CFD results will be used to identify any systematic discrepancies between the flight data and simulated data.

4.3.11 Payload Design

4.3.11.1 Payload Construction

The payload is quite simple in its design and construction. Each "SRB" airframe is made of a carbon fiber tube and a matching nose cone. Two of the nose cones are COTS components made of plastic. The third is made by laying up carbon fiber on top of polystyrene foam and dissolving away the foam after the carbon fiber cures.

The electronics within the payload consist of four different blocks of components: pressure sensors, SD card circuitry, accelerometer, and microcontroller. Essentially, all eight pressure sensors and the accelerometer act as inputs to the microcontroller, the microcontroller reads these values, and stores them to the SD card. Within the payload, the circuit board is held in place with epoxy to the airframe. This ensures no movement will occur during flight.

Below is a dimensioned drawing of one SRB model. All have the same general shape, only differing in the nose cone geometry.

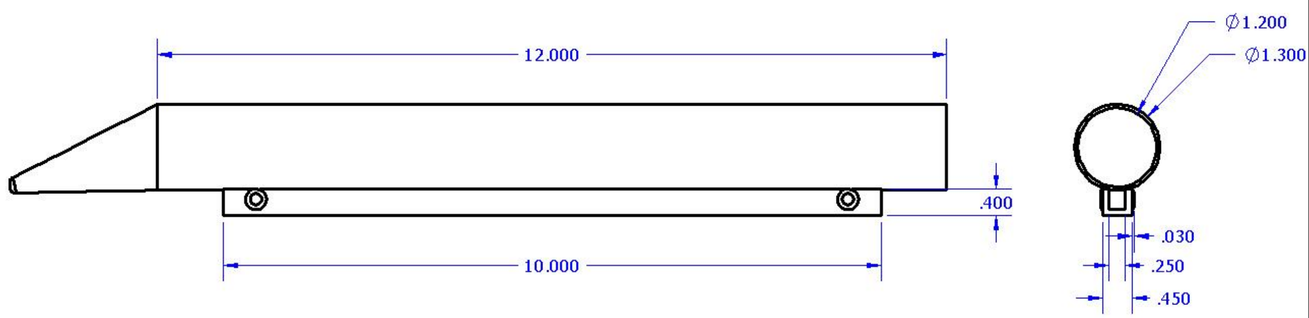


Figure 56 - SRB Dimensions

4.3.12 Specifications and Descriptions of Key Physical Design Elements

Length of SRBs - The sensors are 7mmx11mm. We can fit a up to 15 in a tube 12 inches long. However, that space includes a microcontroller, a battery, pressure sensors, and other electrical components all mounted on a circuit board.
Density and location of pressure sensors – We are placing eight pressure sensors in the mock SRB tube. We have space to include up to 15. The decision on the number of sensors is determined by the desired resolution of the measured pressure distribution.
Density of pressure ports - On each mock SRB, the pressure ports are placed at a location that optimizes data collection for the pressure distribution curve, with higher density of pressure ports near the front.

4.3.13 Analysis Results

Below are preliminary CFD results for a simulated rocket flight. It is easily seen how the different shaped nose cones produce different values for the pressure distribution. By just examining these results qualitatively, you can see that the wedge nose cone will appear to have the lowest drag, as expected.

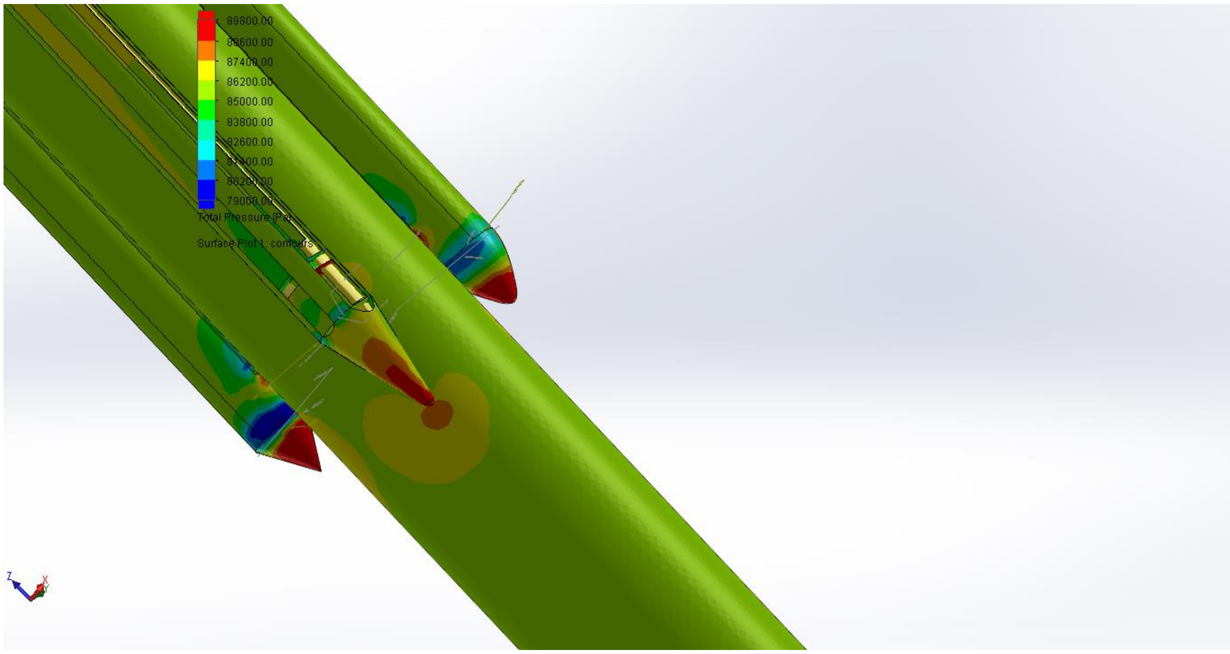


Figure 57 - Preliminary CFD Results View 1

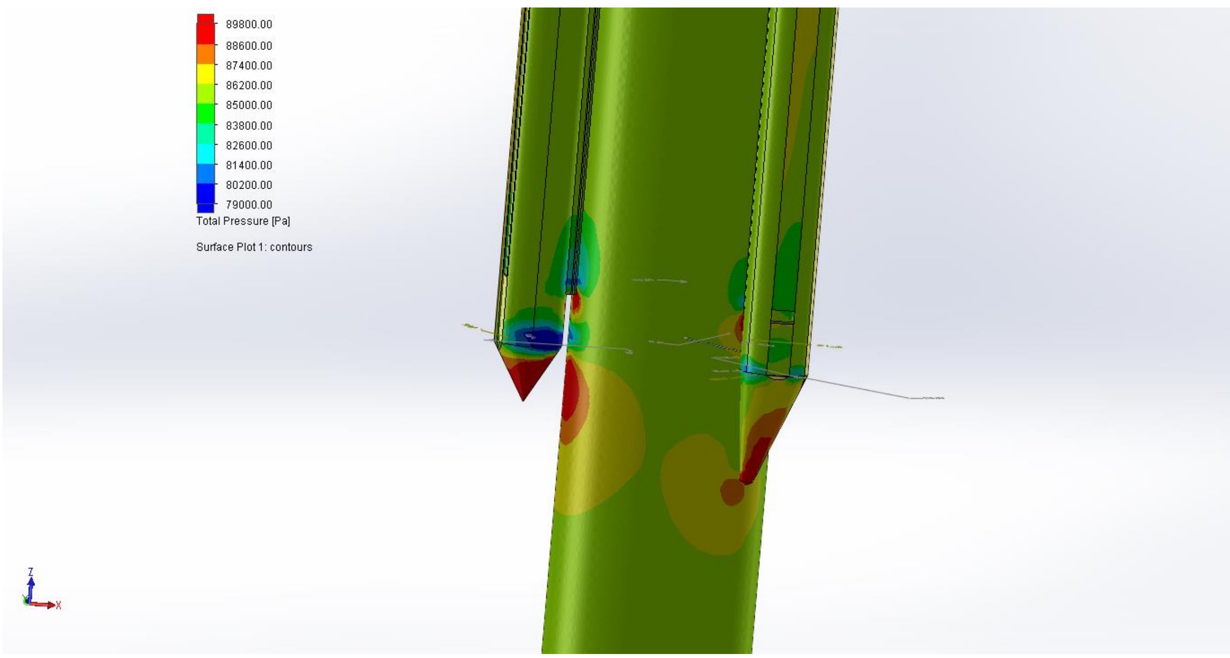


Figure 58 - Preliminary CFD Results View 2

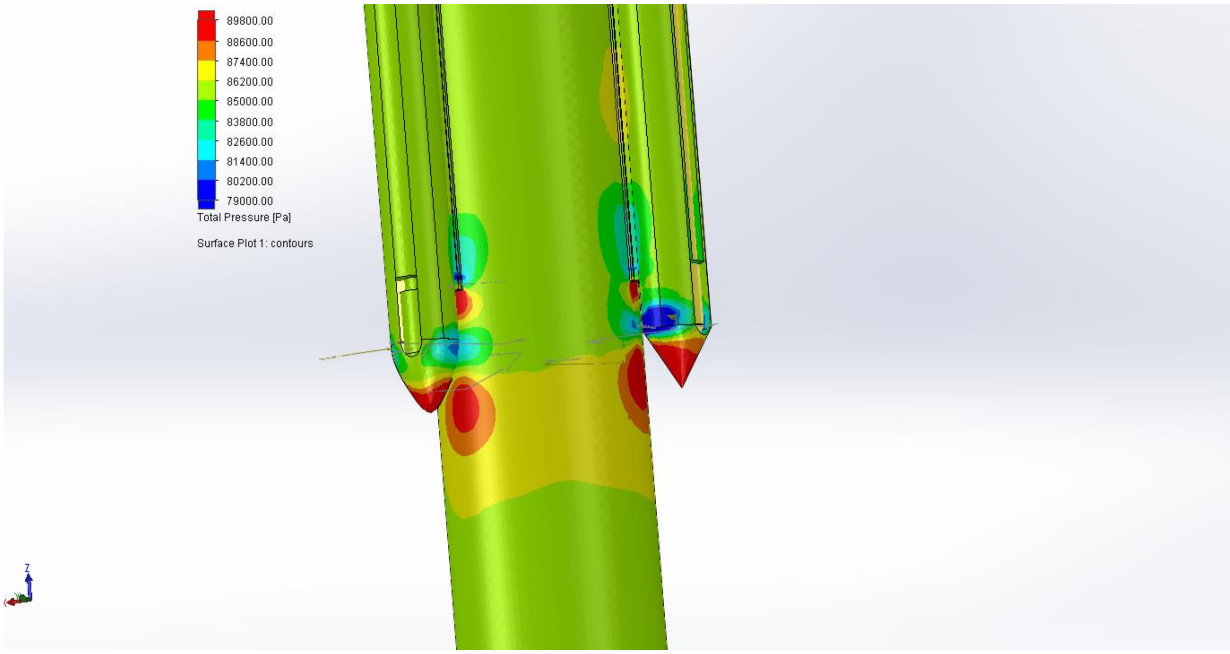


Figure 59 - Preliminary CFD Results View 3

It is important to note that while these renderings provide a prediction of the flight behavior, at this point the flight model has not fully been developed. These results are better taken in a qualitative manner rather than for a prediction of actual pressure values.

4.3.14 Integrity of Design

The first line of defense to ensure payload integrity is isolation of systems. Each of the three SRBs are entirely isolated from each other. Power, structure, data handling, and scientific sensors are all isolated. Furthermore, the payload has no moving parts and has very little chance for hardware failure other than failure due to aerodynamic forces.

4.3.14.1 Major Risks Identified

1. **Unintended separation of payload from rocket –** This payload is different from the others on the rocket due to the fact that it is mounted on the rocket rather than in line with the rocket body tube. This means that at high flight speeds, there is a realistic chance of a SRB separating from the rocket body and falling down to earth. This has relatively low severity for payload success, because all three SRBs are isolated, and only data from one payload would be contaminated. Furthermore, the data collected up until separation is still usable if the payload is retrieved. It however does present a significant safety hazard to have part of the payload fall to earth without any kind of parachute. **Probability – 4, Severity – 2**
2. **Hardware failure internal to payload –** Rocket flight is an extremely high intensity environment. As such, failure of the pressure port mounts or electronics mounts can impact the success of the payload. At worst, the entire data set for that SRB would be lost or contaminated. At best, there would be no impact to the resultant data. In either case, a failure internal to the payload would create no safety impact as all damage is contained within the payload structure. **Probability – 4, Severity – 3**
3. **Structural failure external to payload –** The failure of the SRB structure would likely invalidate all scientific data. Also, depending on the severity of the failure, it could cause a potential safety hazard if debris falls off of the rocket. However, debris at this scale would be

small and lightweight and pose little risk to the observers or the rocket itself. **Probability – 5, Severity – 3**
4. **Electronics failure –** Any electronics failure would pose no safety hazard. Impact to scientific data could be as small as missing data points, or as large as an entirely corrupt data set. Even so, since the payloads are isolated, impact is still relatively low. **Probability – 4, Severity - 3**

4.3.14.2 Failure Mitigation

1. **Unintended separation of payload from rocket –** This failure mode presents the highest risk. This is mitigated by redundancy in the mounting system. The sliding rail system used to mount each SRB to the rocket is mounted both by physical hardware connections as well as high-strength adhesive. The two interfacing rails are locked in place during flight by two separate nut/bolt connections.
2. **Hardware failure internal to payload –** Redundant mounting is also present for all components internal to the payload. Circuit boards have multiple mount points. Pressure ports and vinyl tubing are attached both by friction as well as hose clamps.
3. **Structural failure external to payload –** The weakest structural point of the payload is where the nose cone meets the body of the SRB. To combat possible failure at this point, a small support skeleton will be located within each nose cone that is attached to the SRB internal support structure. The nose cone will be adhered both to the support skeleton as well as to the joint between the SRB body and nose.
4. **Electronics failure –** Possible power loss is mitigated with redundant batteries in each payload. Possible data loss is mitigated in software. To prevent data corruption, data packets are written to SD card in small blocks. This protects old data recordings from possible corruption and also limits the data that at risk of being lost at any given point in time.

4.3.15 Workmanship

The SRBs are assembled by hand from carbon fiber pipe materials and COTS nose cones. Machine shop tools at the club's disposal were used when needed, but the majority of the work was done by hand. However, the level lines needed to align the railing system with the main rocket requires higher precision, for which as many team members were used for the workmanship as seems reasonable, along with any precision workstations available.

4.3.15.1 High precision areas identified

- Location of pressure ports
- Alignment of rail mounting system
- Size of pressure ports and adhesion of vinyl tubing

4.3.15.2 Detailed description of payload construction

The SRBs are made of cylindrical shells. The cones will be made of plastic, milled/machined/special ordered. The printed circuit board will serve as the electrical components mount. Inside the SRBs are two bulkheads that serve as conduits for the pressure sensor tubing to go to the nose cone of each SRB. Each SRB is a contained system with four to six pressure port holes drilled on the outside of each structure, tubing that connects the pressure port hole to the sensor inside the SRB, and a microcontroller that manages and stores the pressure data on a micro SD card. The outer shells of the SRB structure are screwed to the bulkheads. The SRBs use a rail mounting system similar to the one used for the main rocket for launch. The containment rail has a notch where the sliding rail slides into place. The sliding rail is adhered with epoxy to the mock SRBs, and the railing system is 10 inches long. This allows the SRBs to be quickly and easily dismounted for modifications, construction of inner circuits, and data retrieval from the internal SD cards

4.3.16 Precision of Instrumentation

The experimental setup of this payload allows for extremely precise measurements to be taken. The sensors themselves, being analog sensors, are advertised to offer precision of up to 0.15 PSI. However, due to the setup that is being used in the payload to convert from analog to digital data, the resolution is only 0.6PSI. This is not adequate for high precision measurements of drag profiles, but certainly can provide qualitative results.

The largest source of inconsistencies in the processed results between flights will be due to the variability in the flight conditions. Further features that impact the accuracy and precision of the payload are noise associated with the sensors during rocket flight and the density of the pressure ports. CFD results will be used to identify any systematic discrepancies between the flight data and simulated data.

4.3.16.1 High precision areas identified

- Location of pressure ports
- Alignment of rail mounting system
- Size of pressure ports and adhesion of vinyl tubing

4.3.16.2 Detailed description of payload construction

The SRBs will be made of cylindrical shells. The cones will be made of plastic, milled/machined/special ordered. The printed circuit board will serve as the electrical components mount. Inside the SRBs are two bulkheads that serve as conduits for the pressure sensor tubing to go to the nose cone of each SRB. Each SRB is a contained system with four to six pressure port holes drilled on the outside of each structure, tubing that connects the pressure port hole to the sensor inside the SRB, and a microcontroller that manages and stores the pressure data on a micro SD card. The outer shells of the SRB structure are screwed to the bulkheads. The SRBs use a rail mounting system similar to the one used for the main rocket for launch. The containment rail has a notch where the sliding rail slides into place. The sliding rail is adhered with epoxy to the mock SRBs, and the railing system is 10 inches long. This allows the SRBs to be quickly and easily dismounted for modifications, construction of inner circuits, and data retrieval from the internal SD cards.

4.3.17 Manufacturing Plan

4.3.17.1 Structural Manufacturing

1. The SRB shells are constructed out of PVC pipe with an inner diameter of 1.2 inches. Each SRB is cut in half lengthwise for payload access.
2. Affix at the end of the SRB a bulkhead that is used as an internal support structure and as an interface for joining the two sells is screwed in place through the wall of the pipe.
3. Drill pressure ports into SRB body
4. Adhere in one half of the shell a sled for PCB mounting
5. Adhere on outer half of one shell a female rail for mounting to rocket
6. Affix nose cone to top of SRB. Sand exterior to flush nose cone and SRB body
7. Paint

4.3.17.2 Electrical Manufacturing

1. Lay out schematics on PCB
2. Order PCB from 3rd party fabrication service

3. Cut tab routed PCBs apart
4. Drill any mount holes as necessary
5. Solder electrical components to PCB
6. Reinforce battery clip to board with extra adhesive
7. Mount board to sled in SRB shell
8. Program microcontroller

4.3.17.3 Pressure Measurement System Manufacturing

1. Measure and cut vinyl tubing to length
2. Glue one end into pressure port on SRB shell
3. Attach other end to pressure sensors on circuit board
4. Tighten connections with tube clamps

4.4 Testing Plan

4.4.1.1 Static Pressure Test

The first test will be to measure the pressure on each SRB in a static environment. This will check all essential system functionality such as: Communication between sensors and microcontrollers, data recording and storage, and validity of measured data. This test will be used to calibrate the filtering, gain, and offset of each pressure sensor

4.4.1.2 Dynamic Pressure Test

After completing the static pressure test, the same test will be repeated in a wind tunnel. This will simulate an (extremely) low speed rocket flight. This test will identify issues that are only likely to show up in flight such as: leaks in pressure measurement system, filtering of noise in pressure measurements, and validity of dynamic pressure measurements.

4.4.1.3 Endurance Test

The payload will be run in an endurance configuration. The endurance of the payload is likely to be limited by one of two factors: power or data storage capacity. The endurance test will not only identify what will limit the life of the payload, but will also ensure the life of the payload will exceed the length of launch setup, flight, and recovery operations

4.4.1.4 Structural Test

The highest risk structural failure is detachment of the SRB from the side of the rocket. Both static and dynamic forces will be applied to the payload at the interface point to ensure that there are no unforeseen failure modes.

4.4.2 Verification

Requirement Number	Requirement	Satisfied by: Verified by:
P3.1	The payload will be constructed to have flow over three different geometries	Satisfied by: SRB Shape Verified by: Inspection – three different geometries are used in the payload design
P3.1.1	The payload will have three protuberances exterior to the rocket	Satisfied by: Payload design Verified by: Inspection – three

		"SRBs" are used in the payload
P3.1.1.1	The protuberances shall be located at 0 degrees, 120 degrees, and 240 degrees around the payload	Satisfied by: Payload integration points Verified by: Inspection – each "SRB" is spaced evenly around the rocket
P3.1.2	The nose cone geometries of the SRBs will vary to produce different flow regimes	Satisfied by: SRB design Verified by: Inspection – Nose cones have three different shapes
P3.2	The pressure distribution will be measured along each protuberances on the payload	Satisfied by: Pressure Measurement System Verified by: Static/dynamic pressure testing – Pressure can be measured along each "SRB"
P3.3	The pressure data will be recorded to a SD card that will be retrieved post-flight	Satisfied by: Pressure measurement system Verified by: Static/dynamic pressure testing – Pressure data is recorded to SD card successfully
P3.3.1	The data will be recorded in CSV format simultaneous to velocity readings	Satisfied by: Firmware design in pressure measurement system Verified by: Static/dynamic pressure testing – Pressure data is in CSV format
P3.4	In addition to pressure data, velocity data will be collected and stored to a SD card for retrieval post-flight	Satisfied by: Firmware design in pressure measurement system Verified by: Static/dynamic pressure testing – Velocity data is stored to SD card successfully
P3.4.1	This data will be recorded in CSV format simultaneous to the pressure measurements	Satisfied by: Firmware design in pressure measurement system Verified by: Static/dynamic pressure testing – Velocity data is stored in CSV format simultaneous to pressure data
P3.4.2	Velocity data will be collected along three axes	Satisfied by: Accelerometer choice and firmware design Verified by: Static/dynamic pressure testing – Velocity data is recorded along all three axes
P3.5	The payload will be located immediately in front of the fin casing and motor mount	Satisfied by: Rocket design Verified by: Inspection – Integration points are located in front of fin case

5 Project Plan

5.1 Budget

5.1.1 Project Budget

Table 16 - Expenses

Item	Vendor/Model	Price Per Unit	Quantity	Total Amount
Fullscale rocket motors	Giant Leap Rocketry/Cesaroni L-1720	189.95	2	379.90
Subscale Rocket Motor	Giant Leap Rocketry/Cesaroni K-360	105.90	1	150.00
Subscale Rear Closure and Motor Retainer	Giant Leap Rocketry	97.80	1	97.80
Fiberglass Couplers	Wildman Rocketry	27.00	5	135.00
Subscale Couplers	Giant Leap Rocketry	15.95	2	31.90
Subscale Couplers	Giant Leap Rocketry	17.95	1	17.95
Bulkhead Materials	Home Depot	25.00	1	25.00
U-bolts, All-thread	McMaster-Carr	50.00	1	50.00
Swivels	CoolRocketStuff	12.50	2	25.00
Acetone	McGuckin Hardware	5.39	1	5.39
Safety Equipment (Goggles, Respirators, Masks)	Home Depot	81.40	1	81.40
Subscale Nosecone	Apogee Components	13.45	1	13.45
Replacement Subscale Nosecone	Apogee Components	21.27	1	21.27
Mylar, Peel Ply, Mold Release	ACP Composites	106.03	1	106.03
Microcontroller	Sparkfun/Raspberry Pi Model B	39.95	1	39.95
Camera	Sparkfun/Raspberry Pi Camera Board	29.95	1	29.95
5V Power Supply	Amazon.com	17.68	1	17.68
Bulkheads	Home Depot	3.00	1	3.00
Nose Cones	Estes	15.00	6	90.00
Vinyl Tubing	McGuckin	30.00	1	30.00

	Hardware			
Railing System Components	McGuckin Hardware	50.00	1	50.00
DIP Pressure Sensor (0-150 psi)	Honeywell/NBPDANN150PAUNV	9.01	24	216.24
Operational Amplifier	Microchip/MCP6S26-I/P	2.36	24	56.64
Microcontroller	Atmel/ATMega328-PU	3.49	3	10.47
6.19 kOhm Resistor	Generic	0.10	24	2.40
499 Ohm Resistor	Generic	0.10	48	4.80
20 kOhm Potentiometer	Generic	0.50	48	24.00
100 kOhm Resistor	Generic	0.10	48	4.80
200 kOhm Resistor	Generic	0.10	24	2.40
50 kOhm Potentiometer	Generic	0.50	24	12.00
Small Switches	Generic	0.50	48	24.00
300 kOhm Potentiometer	Generic	0.50	24	12.00
Printed Circuit Boards	Advanced Circuits	45.00	1	45.00
Micro SD Card Slot	Generic	2.00	3	6.00
Micro SD Card	Sandisk/4 GB	11.69	3	35.07
Accelerometer	Analog Devices/ADXL345	27.95	3	83.85
LEDs	Generic	0.35	9	3.15
Misc. Electronics	Generic	20.00	1	20.00
Transmitter	XBee/XSC Pro RF Module	44.95	2	89.90
SMA Adapter	SparkFun Electronics	3.90	1	3.90
Tubular Nylon	McGuckin Hardware	0.51	74	37.74
Rip-Stop Nylon	Joann's Fabrics	2.66	30	79.80
Deployment Bag Material	Joann's Fabrics	42.00	1	42.00
Heavy Duty Thread	Joann's Fabrics	2.19	1	2.19
Sewing Machine	SINGER	130.00	1	130.00
Presser Foot	SINGER	5.99	1	5.99
Test Parachute Material	Joann's Fabrics	6.00	1	6.00
Accelerometer	SparkFun Electronics	10.00	1	10.00

Altimeter	Featherweight Raven	155.00	1	155.00
Shock Cord	REI	15.00	1	15.00
Switches	JB Saunders	3.75	2	7.50
Misc. Hardware	N/A	50.00	1	50.00
Outreach				30.00
Miscellaneous				100.00
Travel				4518.40
TOTAL				**7245.61**

5.1.2 Funding Plan

Table 17 – Funding Sources

Source	Amount	Status
Engineering Excellence Fund (EEF) - Fall	$1,106.42	Confirmed
Engineering Excellence Fund (EEF) - Spring	$1,507	Confirmed
Aerospace Engineering Sciences Departmental Funding	$425.10	Requested
CU Engineering Honors Program (EHP)	$1,000	Confirmed
Student Government Funding Board (SGFB) - Travel	$1443	Confirmed
University of Colorado Engineering Council (UCEC) - Travel	$1,000	Confirmed
Dean's Office Matching Grant For Student Travel	$1225.10	Requested
Fundraising Activities	$800	$500 Confirmed, Additional $300 Expected
ATK Lodging & Motor Stipends	$600	Confirmed
TOTAL	**$9106.62**	

COBRA has received funding from the Engineering Excellence Fund (EEF) for the fall and spring semesters to offset the cost of supplies and materials for the vehicle and payload construction and testing.

The team has also received funding for travel through numerous University of Colorado sources including the Student Government Funding Board, the University of Colorado Engineering Council, the Aerospace Engineering Sciences Department, the Dean's office, and the Engineering Honors Program.

COBRA holds fundraising activities such as bake sales throughout the school year, which have been very successful and have raised additional funding.

There is a margin built into the funding plan and budget in order to provide sufficient funds for the project, in the event of unforeseen increases in expenses or decreases in funding. Additional fundraisers can also be held in order to raise more money in the event of a funding shortage.

5.1.3 Travel Budget

Subsidized travel to the competition is potentially available for all interested members, but is contingent on the amount of travel funds received from school grants. In the event that the necessary travel funds are not acquired through the grants listed in the Funding Plan section above, travel fees will be collected from all members to make up the deficit.

Table 28 below shows the total travel cost per person, as well as the total travel costs for the 15 interested travelling student members. The travel costs for the team mentors/advisors were not included, as school faculty must apply for travel funding through other sources.

Table 18 – Travel Expenses

Expense	Cost Per Person	**Total Cost**
Lodging	$157.33	$2,360.00
Lodging Tax	$19.93	$298.93
Meals (1 per day per person)	$60.00	$900
Transportation (Gas)	$46.67	$700.00
SUBTOTAL	$283.92	$4518.30
+ GAR/GIR 6.09%	$17.29	$259.37
TOTAL	**$301.22**	**$4518.30**

Any additional travel or personal expenses (including additional meals), any costs not covered by the travel funding sources, or other increases will be made up through travel fees and/or will be the personal responsibility of the traveling members. Special arrangements will be made in the event that a travelling member is unable to cover additional expenses.

5.2 Timeline

Table 19 – Key Dates and Events

Event	Date
CDR Due	2/28/14
Fullscale Fabrication Completion	2/28/14 – 3/15/14
Subscale Flight Test With Payload Sims	3/1/14
Payload Parts Order Finalized	3/2/14
Recovery System Parts Order Finalized	3/2/14
Fullscale Ground Test Finalized	3/10/14 – 3/14/14
Payload Fabrication	3/10/14 – 3/21/14
Recovery System Fabrication	3/10/14 – 3/21/14
Outreach Event	3/11/14
Outreach Event	3/19/14
Payload Ground Tests	3/24/14 – 3/28/14
Recovery System Drop Tests	3/24/14 – 3/28/14
Full Vehicle Integration Tests	3/31/14 – 4/4/14
Tentative Outreach Event	4/2/14
Full Scale Flight Test	4/5/14
FRR Due	4/18/14

Full-Scale Test Flight	4/19/14
Back-up Full-Scale Test Flight	4/27/14
Revised FRR Due	4/28/14
Travel/Launch Week Activities	5/13/14 – 5/19/14
LRR Due	5/14/14
NASA Launch	5/17/14 – 5/18/14
Post Process Experimental Data and Compare Results	5/18/14 – 5/25/14
PLAR Draft	5/26/14 – 5/30/14
PLAR Due	6/2/14

5.3 Educational Outreach Plan & Status

To date, the team has visited five schools to lead outreach activities and has engaged 270 middle school students and 289 K-12 students total.

For the first outreach event, we made a short presentation summarizing Newton's Laws which the students had just learned about the previous week. We discussed how these laws allow rockets to fly and discussed the other forces acting upon rockets while they are in flight. After the short refresher course on Newton's Laws, we began the activity. The task they were presented with was to build a rocket using construction paper and tape that would be launched as far as possible using an air cannon manufactured out of PVC. We guided them through the basic construction principles of these rockets, but gave them free reign to choose the size and shape of their fins, the length of their body tube, and the size and shape of their nosecone. Once we handed out the construction materials, we gave them fifteen minutes to build their rockets in teams of three that were preselected by their teacher. During the next fifteen minutes we assisted students in the building of their rockets and discussed their designs with them. Once the fifteen minutes were up, we had them put the finishing touches on their rockets. We then went outside into the main courtyard and begun the competition. Two of us pumped up the air cannons, while others readied the rockets and kept track of distances. At the end of the first round of competition, the four rockets which travelled the farthest horizontal distance were loaded onto the air cannons again and launched at a higher pressure. After that round, one team was declared the winner for the class.

We conducted a pre-activity and post-activity evaluation to find out what they were thinking about their futures and their knowledge of engineering as a profession. Our pre-activity evaluation specifically targeted what the students' views of engineering as a profession was and what their future plans are (e.g. plans to attend college, potential careers). This pre-activity survey showed that the majority of the students are already looking ahead to not only attending college, but also into potentially pursuing a career in a STEM profession. Many of the students are considering being doctors. There were actually only a small percentage of students who said that they want to be engineers specifically.

We got some very useful feedback from the teacher of the classes which we worked with. For each class that we performed the activity with, we made different tweaks to see if they were better or worse. The first few classes which we worked with were honors classes which required a somewhat more challenging form of the activity. However, the non-honors classes found this more challenging, less guided activity very difficult. We were made aware to this by the teacher after the first non-honors class. She suggested that for the non-honors classes, we guide the students through everything a little more and maybe give them a few extra minutes to work on their rockets. During the presentation at the beginning, we got the students involved by having them answer various questions regarding Newton's Laws and the design of rockets. The teacher told us we did a very good job of that and that is definitely something that we should continue to do in the future. She also complimented us on our involvement with the students during the activity. We were constantly going around the classroom showing them how to work through making the nose cones or discussing the orientation and shape of their fins with them. The teacher also discussed with us how to improve the activity for future students as well as make it more challenging if we were to do it for older students. She suggested that we try to acquire some different materials if we were to do a similar activity for high schoolers. Such as using cardboard tubing and plastic nosecones and lean away from the actually design of the rockets, and focus more on the calculations of the rocket for older students, since they will generally understand the physics of rockets a little better.

Unfortunately, after this outreach event, we were informed that due to safety concerns regarding the pressured PVC tank, we should discontinue this specific activity. For the rest of the outreach events, the team instead decided to have the students design, build, and launch rockets fueled with vinegar and baking soda. Although the materials for the construction and launching the rockets changed, the remainder of the outreach activity remained essentially the same as described above, with a lesson component followed by a hands-on rocketry activity. However, the schools and student groups which the team visited varied from small homeschool groups to after-school STEM clubs to both honors and non-honors physics classes. In all cases, the students and educators greatly enjoyed and benefited from the lessons and activities, and the team has been invited to return to many of the schools in the future to lead STEM activities apart from the competition.

5.4 Team Membership

Table 26 below identifies the team leadership, including years, majors, roles, and duties.

Table 20 - Team Leads

Name	Year	Major	Leadership Role	Duties
Emma	4th	ASEN	Project Manager/ Outreach Coordinator	Oversees all aspects of the project both technical and operational
Eric J.	4th	ASEN/ APPM	Safety Officer/Systems Engineer	Takes responsibility for the implementation of safety plans; oversees all technical aspects of project
Ben	4th	ASEN	Treasurer/ Payload #1 – Hazard Detection Camera	Responsible for overseeing team funding, budget, and purchases; in charge of the design, testing, and integration of the hazard detection camera payload
Roshan	3rd	MCEN	Operational Manager/ Modeling & Simulations Lead	Oversees all non-technical aspects of the project; assists all subsystems with modeling and simulation including computer-aided drafting (CAD) and computational fluid dynamics (CFD)
Greg	3rd	ASEN/APPM	Payload #3 – Aerodynamic Analysis	Oversees the design, construction, testing, and integration of the aerodynamic analysis of protuberances payload
Casey Z.	3rd	ECE	Webmaster/ Electronics Lead	Designs and updates team website; Assists all subsystems with design, testing, and integration of electronics, sensors, and data collection/transmission

Jeff	3rd	MCEN	Structures Lead/Avionics & Recovery Lead	Oversees design and fabrication of the rocket; Oversees the design, testing, integration, and deployment of the parachute and recovery system
Drew	3rd	ASEN	Payload #2 Lead – Liquid Sloshing	Oversees the design, construction, testing, and integration of the liquid sloshing payload
Franklin	3rd	ASEN	Ground Ops Lead	Oversees ground operations, including data transmission and GPS tracking data.

Below in Table 31 is a roster of the members of the COBRA team who do not hold leadership roles, with foreign nationals identified with asterisks.

Table 21 - Team Members

Name	Year	Major
Matthew	4th	ASEN
Bryan	3rd	MCEN
Tyler	3rd	ASEN
Nathaniel	3rd	ASEN
Brendan	3rd	ASEN
Cameron	3rd	ASEN
Jonathan	2nd	ASEN
Bryan	2nd	MCEN
Casey B.	2nd	APS
Jenny	1st	ASEN
Aspen	1st	ASEN
Antoine*	1st	ASEN
Gautham	1st	ASEN

Short biographies for team officials are included below:

5.5 Team Officials

Faculty Advisor: Dr. Ryan Starkey
Contact Information: ryan.starkey@colorado.edu
Dr. Ryan Starkey is an assistant professor in the Aerospace Engineering Sciences (ASEN) department at CU Boulder. He heads the Busemann Advanced Concepts Laboratory, and his primary research is in the fields of hypersonic flows, high-speed propulsion and aerodynamics, propulsion system design, and computational fluid dynamics.

Faculty Mentor: Dr. Jeffrey Knutsen
Contact Information: jeffrey.knutsen@colorado.edu
Dr. Jeffrey Knutsen is an instructor with the Mechanical Engineering (MCEN) department at CU Boulder. His research interests are primarily in innovative instructional methods and fluid mechanics. He is particularly interested in open-ended problems that better approximate engineering challenges that extend beyond the classroom environment. His favorite courses to teach include Fluid Dynamics, Thermodynamics, Heat Transfer, and First-Year and Senior Design.

Project Manager/Outreach Coordinator: Emma
Contact Information: emma.young@colorado.edu
Emma is a 4th year student in Aerospace Engineering. This is her third year involved with COBRA at CU Boulder, and 4th year involved with high-power rocketry. Emma has interned at Marshall Space Flight Center and the Jet Propulsion Laboratory, and plans to work in the aerospace industry upon graduation.

Safety Officer/Systems Engineer: Eric J.
Contact Information: eric.james@colorado.edu
Eric is a 4th year BS/MS student pursuing double undergraduate degrees in Aerospace Engineering and Applied Math, and a master's degree in Aerospace Engineering. This is Eric's third year involved with COBRA at CU Boulder. Eric has been involved with high-power rocketry for over five years and enjoys designing and launching amateur rockets as a Level 2 certified (#86129) member of the National Association of Rocketry (NAR). Eric has interned at United Launch Alliance, and plans to work in the aerospace industry upon graduation.

NAR Mentor: Jeffrey "Joe" Hinton
Contact Information: motojoe4glr@yahoo.com
Joe Hinton is currently certified L2 with both NAR (#77571) and Tripoli (#9824) with over 10 years of rocketry experience including projects flown at BALLS, HELLFIRE, AIRFEST, and other events here in Colorado. He is currently the President and Tripoli Prefect for NCR (Northern Colorado Rocketry) and has held these positions for the past 8 years. In addition to these positions, he also serves as the FAA (Federal Aviation Administration) Liaison as well as the USFS (United States Forest Service) Permit Holder for NCR. Joe is the current Hardware and Motor Vendor for Giant Leap Rocketry, Inc.

6 Conclusion

This Flight Readiness Review (FRR) document outlines the current design and project plans for the University of Colorado Boulder for the 2013-14 Student Launch competition.

In summary, our rocket is entitled HYDRA (HYdrodynamics, hazard Detection, Research for Aerodynamics), after the nine-headed water serpent monster from Greek mythology. HYDRA will be a 154-inch long, 3.9-inch diameter carbon fiber and fiberglass rocket, flown with a Cesaroni L-1720 motor and a student-designed and fabricated elliptical cupped parachute. The projected altitude for HYDRA is 6,000 feet. HYDRA will also contain three student designed and manufactured payloads as follows:

1. A camera system that scans the surface during descent in order to detect potential landing hazards, analyzes the data, and transmits data to the ground station in real time.
2. Aerodynamic analysis of structural protuberances.

The team has also engaged over 200 students, at least 100 of those in grades 5-9, in hands-on educational activities over the course of the competition, encouraging students to develop an interest in and pursue careers in science, technology, engineering, and math (STEM) fields.

Appendix A – HazCam MATLAB Code

```
% Written by: Ben Woeste
% NASA SLP 2013-2014
% Colorado at Boulder Rocketry Association (COBRA)
% Created: 11/29/13
% modified: 12/28/13
% This code performs the operations neccesary for the the hazard
detection
% algorithm.
%
% Currently the code is based on detecting dark areas against the
% bonneville salt flat backgrounds. The method used is the Houghs
transform
% For detecting stright lines. It uses footage from Byu Rocket
launch
%

% To Do list:
%   Add capibility to require more consecutive road detections
(Currently it
% will only display a hazard if it has been detected twice. The
algorithm
% for doing this is really sloppy)
%   Transfer code to Simulink. (I think that this will give a better
idea
% of how the code will behave when connected to software. It will
also give
% the capibility for the code to compiled in C automatically.
%   Optimize the code: Currently the code takes about 4 times longer
than
% "realtime."

close all; clear; clc;

% define file names and parameters
input_title = 'BYU Rocket Launch GoPro-1.mp4'; % source:
http://www.youtube.com/watch?v=NKaT5kclE0c
output_title = 'processed movie';

% open movie file
movieObj = VideoReader(input_title);
frames = movieObj.NumberOfFrames;

% Prepare the new video file.
vidObj = VideoWriter(output_title);
open(vidObj);

% loop through frames
old_lines = [];
for ii = 1:frames
    % load in current frame
    videoFrame = read(movieObj,ii);
    % detect the presence of roads
    [proccessed_frame, lines] = DetectHazard(videoFrame, old_lines);
```

```
        % save old road for next frame and write to video file
        old_lines = lines;
        writeVideo(vidObj,proccessed_frame);
    end

    % close and clean up
    close(vidObj);
    close all

    % Written by: Ben Woeste
    % NASA SLP 2013-2014
    % Colorado at Boulder Rocketry Association (COBRA)
    % Created: 11/29/13
    % modified: 12/28/13
    function [outputframe, lines] = DetectHazard(image, old_lines)
    % [outputframe, lines] = DetectHazard(image, old_lines)
    %   This code uses Hough's transform to detect the presence of dark
    %   straight lines. It is currently limited to working on the
Bonneville
    %   Salt Flats.
    %   The code needs to be run in a loop or else the false positive
filter
    %   will prevent the image from being detected
    % Inputs:
    %       image: RGB image from video
    %       old_lines: Structured array of lines detected by built in
matlab
    %                   code houghlines.m. Contains the fields:
    %                 point1: End-point of the line segment; two-element
vector
    %                 point2: End-point of the line segment; two-element
vector
    %                 theta:  Angle (in degrees) of the Hough transform
bin
    %                 rho:    Rho-axis position of the Hough transform
bin
    % Outputs:
    %       outputframe: RBG image with the Hazards (if detected)
overlayed as
    %                     a bright green line
    %       lines:        Lines detected by the houghs transform. This is
then
    %                     used as the input old_lines when DetectHazard
is
    %                     called again from the loop.


    %%  Convert to a grayscale image
    I = rgb2gray(image);

    [im_height, ~] = size(I);
    pixals = numel(I);
    %% convert the image to a binary image.
    % histogram based thresholding. Since we are converting to a binary
image
```

```
   % we want the darkest 5% to be what sticks out. (Essentially we
remove from
   % the image all the brightest parts.)
   bins = 32;
   [counts,x] = imhist(I,bins);
   for ii = 1:bins
       percent = sum(counts(1:ii))/pixals;
       if percent > .05
           thresh_level = x(ii - 1)/256;
           break
       end
   end
   % thresh_level = .18; % if we hard code the value this number gives
good
   % results

   % Convert the image to a Binary (black/white) image
   BW_threshed = ~im2bw(I,thresh_level);

   %% Hough transform for the detection of lines.
   % A good explination of hough's Transform can be found here:
   % http://en.wikipedia.org/wiki/Hough_transform

   % Use edge detection to remove the filling from large areas of white
(This
   % is a major slow down of the code, and I am looking into
alternatives.)
   BW = edge(BW_threshed,'sobel');

   % conduct the Hough Transform and detect the presence of straight
lines
   [H,T,R] = hough(BW);
   P  = houghpeaks(H,5,'threshold',ceil(0.5*max(H(:))));
   % This function can be paramterized to help with detection, having
the
   % fillgap (Used to connect lines that are close to each other) be
1/10th of
   % the image height and having the minlength (smallest acceptable
line
   % length) be around 1/3rd the image height works pretty well.
   lines =
houghlines(BW,T,R,P,'FillGap',im_height/10,'MinLength',im_height/3);

   %%  determine if the new lines are similar to old lines
   valid_roads = [];
   road_flag = false;
   if ~isempty(lines) && ~isempty(old_lines)
       % loop to compare all old lines with all new lines
       for ii = 1:length(lines)
           for jj = 1:length(old_lines)
               % compares the absolute difference of the rho and theta
               % paramters (from the Hough Transform) of the current
lines and
               % the lines from the previous frame
               if abs(lines(ii).theta - old_lines(jj).theta) < 15 ...
                       && abs(lines(ii).rho - old_lines(jj).rho) < 200
```

```
                valid_roads = [valid_roads lines(ii)];
                road_flag = true;
            end
        end
    end
end

%% Plot the roads (if they exist) and return the frame.
% hFig = figure('Visible','off');
% set(hFig, 'PaperPositionMode','auto')
imshow(image)
hold on

if road_flag
    for k = 1:length(valid_roads)
        xy = [valid_roads(k).point1; valid_roads(k).point2];
        plot(xy(:,1),xy(:,2),'LineWidth',3,'Color','green');
    end
end

outputframe = getframe(gcf); % this is sooooo sloooow.
clf
%% This is undocumented code that might be used to speed up the code
% outputframe = im2frame(hardcopy(hFig, '-dzbuffer', '-r0'));
% close(hFig)
end
```

Appendix B – Carbon Fiber Body Tube Manufacturing Process

The primary material that will be used to construct the rocket is carbon fiber. The team has chosen to manufacture its own carbon fiber tubes as a cost-saving measure. The team has a significant quantity of unused carbon fiber fabric from a previous rocket's construction; this allows the rocket to be built without making a purchase of body material, or the epoxy needed to lay it up. Additionally the team has experience with laying up carbon fiber rocket bodies and plans on leveraging that experience in this competition.

Carbon fiber also comes with its own benefits of having a high strength to weight ratio, making it a great material for rockets. The downside of building custom carbon fiber tubes is that it requires the team to follow more safety precautions. Additionally, because carbon fiber is not RF transparent, all communication equipment must be located in the nose cone of the rocket which will be made of fiberglass.

The team has experience with manufacturing custom carbon fiber rocket body tubes and plans on using this experience for the competition. Throughout the carbon fiber layup process, safety is the most important requirement. Nitrile gloves are worn at all times, and students handling the epoxy are required to wear masks, gloves, and safety goggles. The first step of building a body tube is to prepare the mandrel; for this the team uses a 48-inch long phenolic coupler tube of the appropriate diameter. The mandrel is prepared by tightly wrapping wax paper around the mandrel to aid with the release of the carbon tube once the epoxy has cured. Next, a length of carbon fiber is cut to allow the correct number of wraps around the mandrel. The cut of carbon fiber and prepared mandrel can be seen in Figure 73 below.

Figure 60 – The team checks the length of the carbon fiber before fabrication

The epoxy and resin are measured and mixed by weight and then worked into the carbon fabric as the carbon is wrapped around the tube. Once the fabric is completely wrapped around the tube a layer of peel ply fabric is wrapped around the carbon to pull out excess epoxy and to help ensure that the outermost wrap creates a strong bond with the wrap beneath it. The tube is then left to cure for the next 24 hours. After the cure is complete the peel ply is removed and the carbon tube is pulled off of the mandrel. The ends of the carbon tubes need to be cleaned up by removing the frayed edge of the tube. This is done by using a diamond cut-off wheel attached to a Dremel rotary tool. This operation produces a significant amount of carbon dust. To ensure the safety of the students, the cutting is done in the Composite Laboratory's particulate filter room, with the fan running. The students who are making the cut are required to wear goggles, gloves and dust masks. The image below shows the process of cleaning up the edge of the tube.

Figure 61 - Team members clean up the edge of the tube

The carbon tube is now ready to be finished. The finishing process consists of sanding down the outer layer of the tube with fine sandpaper and applying a finishing coat of epoxy. The sanding and finishing process is conducted with the same safety requirements as before; gloves, masks, and goggles. The final product is shown in Figure 75 below.

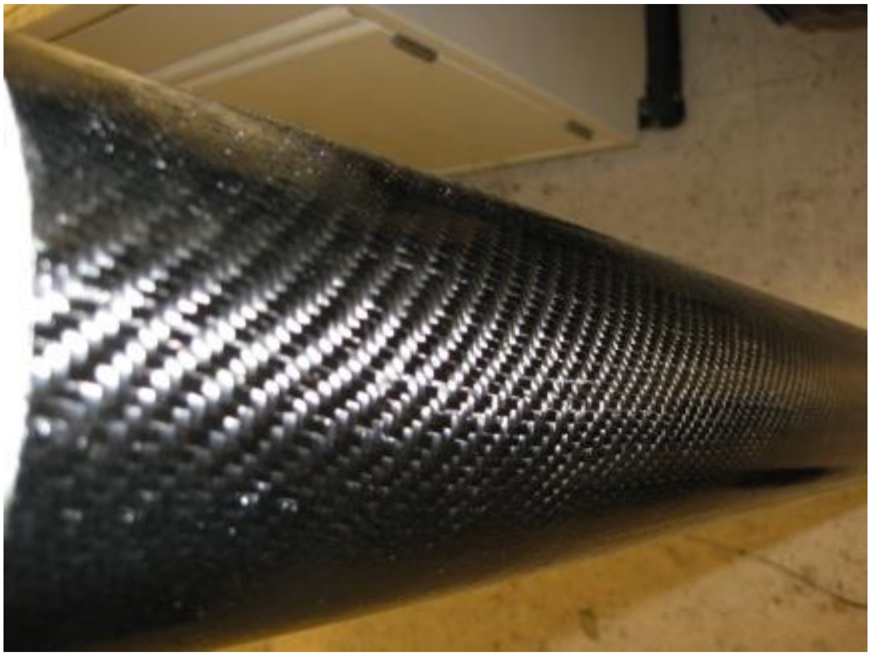


Figure 62 – A finished carbon fiber body tube

Appendix C – Checklists and Procedures

C.1 – Aerodynamic Analysis Payload

Aerodynamic Analysis Payload Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

1. Electronics Assembly

___**Step 1.1** Collect All Required Components

- Payload shell
- 2 9V batteries
- MicroSD card and MicroSD card reader
- Electrical Tape
- Computer

___**Step 1.2** Insert primary battery into battery clip

___**Step 1.3** Insert secondary battery into battery clip

___**Step 1.4** Insert MicroSD card into computer and check MicroSD card for previous data sets

- Backup and remove all previous data sets

___**Step 1.5** Insert MicroSD card into MicroSD card slot in payload

___**Step 1.6** Double check all connections are secure. Reinforce any unsatisfactory connections with Electrical Tape

2. Payload Initialization

___**Step 2.1** Flip power switch on payload circuit board

___**Step 2.2** Double check that green power LED is lit

___**Step 2.3** Double check that red error LED is not lit or blinking

- If blinking, debug payload as necessary to determine error

3. Payload Assembly

___**Step 3.1** Collect all required materials.

- x8 Screws for shell attachment

___**Step 3.2** Double check that all pressure sensors, pressure ports, and vinyl tubing is fully connected.

___**Step 3.3** Carefully line up the top SRB shell with the bottom SRB shell

- Be sure not to crush any electronics or internal support structure
- Do not let the vinyl tubing kink
- If shells do not line up, separate the shells and readjust pressure tubing until shells are flush

___**Step 3.4** Screw top shell into bottom shell

4. Payload Attachment

___**Step 4.1** Gather required materials

- x2 rivets for payload attachment

___**Step 4.2** Slide SRB onto railing on rocket, nose aligned with nose of rocket

___**Step 4.3** Insert rivets to lock SRB in place

5. Repeat for SRBs 2 and 3

C.2 – Avionics Bay Assembly Checklist

Avionics Bay Assembly Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.
- **Check above steps with Systems Engineer or Recovery team lead before continuing**

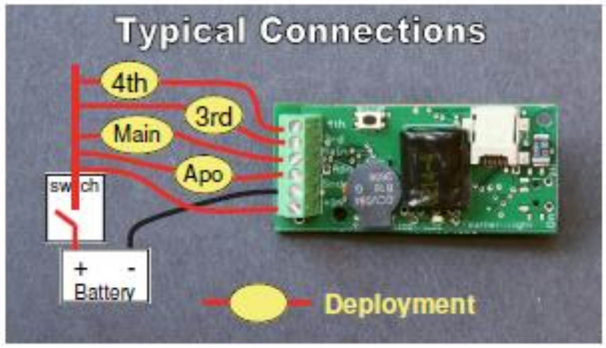
1. Avionics Bay Assembly

___**Step 1.1** Collect All Required Components

- New batteries
- Mounting board with electronics
- Bulkhead assemblies
- Coupler tube

___**Step 1.2** Connect the wires from the bulkheads to the avionics that have been previously mounted on the mounting board.

- Drogue parachute side to “apo” and the ground terminals
- Main parachute to the “main” and the ground terminals
- See figure below for reference.



___**Step 1.3** Mount the new batteries onto the mounting board.
___**Step 1.4** **Connect the batteries to the avionics**
___**Step 1.5** Slide the mounting board into the coupler tube.
___**Step 1.6** Secure the bulkhead onto the coupler tube assembly with the correct washers and bolts.
___**Step 1.7** **Turn on avionics and verify that everything works properly**
___**Step 1.8** Turn off the avionics to save the batteries until launch.

C.3 – Black Powder Charge Preparation Checklist

Black Powder Charge Preparation Checklist
Must be done by either the NAR mentor or NAR certified team member

Notes:
- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.
- **Must be done by either the NAR mentor or NAR certified team member**

****
**** DO NOT proceed until instructed to by the Systems Engineer****
****

1. Work Site Preparation
___**Step 1.1** Find a suitable work site. Must be an area protected from the elements (no wind, rain, etc.) and free of all possible ignition sources (open flames, lighters, cigarettes, etc.)
___**Step 1.2** Set up a work surface. Should be a clean, flat work surface that is sufficiently large.
___**Step 1.3** Collect Required Materials
* Black Powder (Keep away from E-matches until ready to assemble the charges)
* Miniature Scale
* Weighing paper (4"x4" square paper sheet)
* E-Matches
* Nitrile Gloves
* Electrical Tape
* Wire Strippers/cutters

* Scissors

2. Assembling the charges **This should be done one charge at a time**

___**Step 2.1** Using a pair of wire strippers/cutters, trim the E-match leads to the desired length (~6-12")

___**Step 2.2** Using the wire strippers/cutters, separate and strip the ends of the E-match leads so that ~1/2" of bare wire is exposed.

___**Step 2.3** Using a pair of scissors, cut a finger off of an unused Nitrile glove. This cut should be made at the base of the finger.

___**Step 2.4** Take scale and weighing paper. Zero out the scale with the piece of weighing paper on the scale.

___**Step 2.5** Carefully pour the required weight of black powder onto the scale. These amounts can be found in the "Recovery System Properties" section on page 2 of the "Milestone Review Fly Sheet." ****Make sure to re-seal the black powder container and place in a safe location away from ignition sources (Including E-matches) after measuring EACH charge****

___**Step 2.6** Using the weighing paper, **CAREFULLY** pour the measured amount of black powder into the cut finger of the Nitrile glove.

___**Step 2.7** Take off the cover of the E-match and insert into the black powder filled glove. Make sure the head of the match is in contact with the black powder or the charge may not light.

___**Step 2.8** Twist the glove around the E-match to ensure that the black powder is forced into contact with the head of the E-match.

___**Step 2.9** Electrical tape the glove to the E-match wires in order to ensure that the black powder will remain in contact with the E-match during flight.

___**Step 2.10** Place assembled black powder charge away from all potential ignition or voltage sources until ready for final vehicle integration

C.4 – Ground Station Preparation Checklist

Ground Station Preparation Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

1. Ground Station Preparation

___**Step 1.1** Have completed Hazard Camera and GPS Checklist

___**Step 1.2** Collect All Required Components

* Rubber ducky antenna and RPSMA to SMA adapter
* xBee module with xBee Arduino Shield and Arduino Uno
* Laptop with GPS tracking software and MATLAB installed
    1. Connect to receiving xBee using Type A USB to Type B USB Cable

___**Step 1.3** Connect components and start software

* Connect antenna to xBee module
* Connect xBee module to xBee shield, making sure it is aligned in the correct direction
* Connect xBee shield to Arduino headers
* Connect Arduino to computer using the USB cable

* Initialize GPS tracking software
* Configure GPS tracking software

___**Step 1.4** Verify connectivity

* Verify power lights on xBee Shield
* Verify that GPS software recognizes the virtual USB serial port for the Arduino
* Once vehicle GPS is powered, verify reception and parsing of signal both in the software and by checking the I/O LEDs on the Arduino Shield

C.5 – Hazard Camera and GPS Payload

Hazard Camera and GPS Payload Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

1. Hazard Camera and GPS Payload

___**Step 1.1** Collect All Required Components

* Rubber ducky antenna and RPSMA to SMA adapter
* GPS antenna
* xBee module
* xBee Arduino Shield with GPS module attached
* Arduino Uno
* Raspberry Pi
* Raspberry Pi camera board
* 5V USB Power Supply with USB cable
* Type A USB to Type B USB cable
* SD card for Raspberry Pi (should already be in the Raspberry Pi)

___**Step 1.2** Connect Raspberry Pi components

* Connect camera board to Raspberry Pi
* Connect Arduino to Raspberry Pi using the USB cable
* Connect Raspberry Pi to battery
* Connect/verify SD card is inserted

___**Step 1.3** Connect xBee/GPS Components

* Connect rubber ducky antenna to xBee module via RPSMA to SMA adapter
* Connect xBee module to xBee shield
* Connect GPS antenna to GPS module
* Connect xBee shield to Arduino

___**Step 1.4** Connect Arduino and Raspberry Pi

* Connect Raspberry Pi to Arduino via USB A to B Cable

___**Step 1.5** Verify connections

* Verify power light on Raspberry Pi
* Verify power light on xBee Shield

___**Step 1.6** Configure Raspberry Pi

* Verify GPS data from Arduino over USB serial port on Raspberry Pi

* Start MATLAB
* Start Hazard Camera program
* Verify MATLAB script is running

C.6 - Igniter Installation Checklist

Igniter Installation Checklist

**** Only to be performed by either the NAR Mentor or a NAR certified team member****

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

****Before performing the following steps, wait for the Systems Engineer's approval.****

1. Igniter Installation

___**Step 1.1** Ensure that the vehicle has been fully integrated with the pad

___**Step 1.2** Ensure all vehicle electronics have been armed and are working properly

___**Step 1.3** Ensure all team members are a safe distance from the rocket. Only **ONE** team member shall be near the vehicle during igniter installation due to the potential risk of motor ignition.

___**Step 1.4** Install the supplied igniter, ensuring that it travels forward until it is in contact with the forward closure. Securely retain the igniter to the motor nozzle with tape or (if supplied) the plastic cap, routing the wires through one of the vent holes. Ensure that whatever means is used provides a vent for igniter gases to prevent premature igniter ejection.

___**Step 1.5** Ensure power is not currently being supplied by the launcher system.

___**Step 1.6** Clean the clips of the launcher system to ensure proper contact with the igniter leads.

___**Step 1.7** Attach the launcher system clips to the igniter leads. Ensure that there is not a short circuit between the clips or igniter leads or the igniter will not work.

***At this point the rocket should be treated as armed and all team members and spectators shall back up to the minimum safe distance determined by the NAR safety code.

___**Step 1.8** Notify Systems Engineer of completion of these steps.

C.7 – Launch Pad Integration Checklist

Launch Pad Integration Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

1. Mount Vehicle on Launch Pad

___**Step 1.1** Once fully assembled launch vehicle has been approved for launch by the RSO, take vehicle out to the designated pad.

___**Step 1.2** Spray WD-40, Tri-Flow, or another lubricant onto the launch rail to ensure minimal friction during lift off.

___**Step 1.3** Tip launch rail over into the horizontal position.

___**Step 1.4** Load vehicle onto the rail ensuring that all rail buttons travel smoothly along the entire length of the rail.

___**Step 1.5** Once vehicle has been slid to the end of the rail, carefully raise the rail into the vertical position.

___**Step 1.6** Lock rail into vertical position using provided latching method.

2. Recovery System Initialization

****Either the NAR Mentor or NAR certified team member should complete these tasks****

___**Step 2.1** Have all team members back to a safe distance away from the rocket.

___**Step 2.2** Using provided ladder, ascend to the same height as the altimeter switches.

*** Do not hold onto rocket during the next steps!!**

___**Step 2.3** One at a time, turn on each of the Raven altimeters and listen for the required beep pattern.

* Should be "beep","beep","boop","boop"

___**Step 2.4** If required beeping pattern is detected for each altimeter, descend from the ladder.

C.8 – Launch Procedure and Recovery Checklist

Launch Procedure and Recovery Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

1. Launch Procedure

___**Step 1.1** Once vehicle has been armed for launch, have all team members and spectators back away to the minimum safe distance.

___**Step 1.2** Inform RSO, and/or LCO that the rocket is armed for launch.

___**Step 1.3** Check to make sure that all payloads are functioning as expected (through transmitted data) and that GPS tracker is working properly.

___**Step 1.4** When the range is closed, wait for the LCO to announce the countdown for the vehicle.

___**Step 1.5** When vehicle is launched try to keep visual track of it all the way until it touches the ground in order to make tracking of the vehicle easier.

___**Step 1.6** When recovery events are seen, be sure to announce that the vehicle is "under drogue" or "under main" to help the LCO ensure that the vehicle will not be a danger to spectators.

___**Step 1.7** Once vehicle has touched down, keep an eye on the landing site of the rocket to make recovery easier.

2. Recovery Procedure

___**Step 2.1** Required Materials

- Water, Water, Water
- Sunscreen
- Hiking Shoes
- Any other clothing to make hiking in the desert more enjoyable

___**Step 2.2** Using the GPS tracker and visual cues, hike in a straight line towards the place the rocket was predicted to have landed.

___**Step 2.3** Once the rocket is found, stuff parachutes lightly into tubes so they do not inflate.

___**Step 2.4 **Do not touch the altimeter switches****

___**Step 2.5** Bring rocket back to the RSO

- Turn off back-up altimeter so that RSO can clearly identify the altitude reported by the competition altimeter.

C.9 – Master Checklist

Master Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the appropriate sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.

1. Avionics Bay Assembly

___**Step 1.1** Follow all procedures related to assembly of the Avionics Bay. Refer to the *"Avionics Bay Assembly Checklist"* for tasks.

- Requires Initials of Avionics Sub-Team lead or Designated Representative.

2. Recovery Preparation

___**Step 2.1** Follow all procedures related to preparation of the Recovery System components. Refer to the *"Recovery System Preparation Checklist"* for tasks.

- Requires Initials of Recovery Sub-Team lead or Designated Representative.

3. Payload Preparation

___**Step 3.1** Follow all procedures related to set-up of the Hazard Camera/GPS Payload. Refer to the *"Hazard Camera and GPS Payload Checklist"* for tasks.

- Requires Initials of Hazard Camera/GPS Payload lead or Designated Representative.

___**Step 3.2** Follow all procedures related to set-up of the Aerodynamic Analysis Payload. Refer to the *"Aerodynamic Analysis Payload Checklist"* for tasks.

- Requires Initials of Aerodynamic Analysis Payload lead or Designated Representative.

4. Black Powder Charge Preparation

___**Step 4.1** Follow all procedures related to preparation of the black powder charges. Refer to the "*Black Powder Charge Preparation Checklist"* for tasks.

- **Tasks MUST be completed by NAR mentor or certified team member**

∗ Requires Initials of the NAR mentor or certified team member.

5. Final Integration

___**Step 5.1** Follow all procedures related to Final Integration of the Vehicle. Refer to the "*Final Integration Checklist*" for tasks.

∗ Requires Initials of Systems Engineer or Designated Representative.

6. Ground Station Preparation

___**Step 6.1** Follow all procedures related to Ground Station Preparation. Refer to the "*Ground Station Preparation Checklist*" for tasks.

∗ Requires Initials of Systems Engineer or Designated Representative.

7. Motor Assembly

___**Step 7.1** Follow all procedures related to Motor Assembly. Refer to the "*Motor Assembly Checklist*" for tasks.

∗ Requires Initials of NAR Mentor or certified team member.

8. Launch Pad Integration

___**Step 8.1** Follow all procedures related to Launch Pad Integration. Refer to the "*Launch Pad Integration Checklist*" for tasks.

∗ Requires Initials of Systems Engineer or Designated Representative.

___**Step 8.2** Follow all procedures related to Igniter Installation. Refer to the "*Igniter Installation Checklist*" for tasks.

∗ Requires Initials of NAR Mentor or Certified Team Member.

9. Launching and Recovery

___**Step 9.1** Follow all procedures related to Launching of the Rocket. Refer to the *"Launch Procedure Checklist"* for tasks.

∗ Requires Initials of Systems Engineer or Designated Representative.

10. Clean Up

___**Step 10.1** Follow all procedures related to Post Launch Clean Up. Refer to the *"Post Launch Clean Up Checklist"* for tasks.

∗ Requires Initials of Systems Engineer or Designated Representative.

C.10 – Motor Assembly Checklist

Motor Assembly, Igniter Installation, and Post-flight Cleanup Checklist

(These procedures are based off of the Cesaroni Pro75 High-Power Reloadable Rocket Motor Systems instructions, March 2005 revision)

Notes:

- The motor assembly is to be performed by a certified team member or NAR mentor only.
- Read all instructions carefully and check all components for damage before beginning assembly procedures. Refer to the Cesaroni Pro75 High-Power Reloadable Rocket Motor Systems instructions during the assembly.
- Ensure all NAR/Tripoli safety codes are followed at all times.
- Before beginning, ensure that you have a clean, clear, flat workspace, such as a table covered with a blanket, to facilitate motor assembly and prevent damage to components.
- This procedure works well if one team member reads the instructions out loud as the certified member performs the assembly.

1. Forward Closure Assembly

☐ **Step 1.1:** Apply a light coating of the O-ring lubricant grease to the inside cavity of the forward closure. Insert the smoke tracking charge insulator into the cavity and ensure it is fully sealed. See Figure 1 below for reference.

- ☐ **Step 1.2:** Apply a layer of O-ring lubricant grease to one end of the smoke tracking grain, ensuring the entire face is covered.
- ☐ **Step 1.3a:** Insert the smoke tracking grain into the smoke tracking charge insulator, coated end **first.**
- ☐ **Step 1.3b:** Push the grain in so that it is fully set and spread lubricant – the extra lubricant will help prevent gas leakage as well as protect the forward closure from heat and combustion products.
- ☐ **Hold:** Verify with the safety officer/NAR mentor that these steps have been done properly before proceeding.

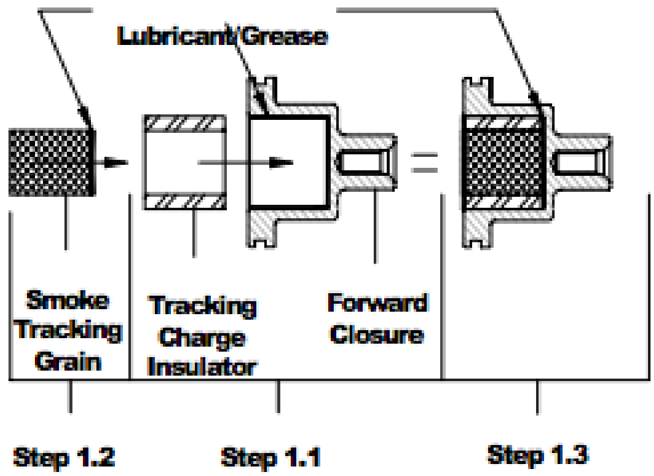


Figure 63 - Step 1

2. Motor Assembly with Pro75 Hardware

- ☐ **Step 2.1:** Check both ends of the phenolic case liner to ensure inside ends have been chamfered or deburred. If not, use a hobby knife or coarse sandpaper to remove the sharp inner edge to allow components to be easily inserted.
- ☐ **Step 2.2:** Fit the nozzle to one end of the case liner tube, pushing it carefully but with sufficient force to seat the shoulder on the nozzle all the way into the insulator tube. See Figure 2 below.

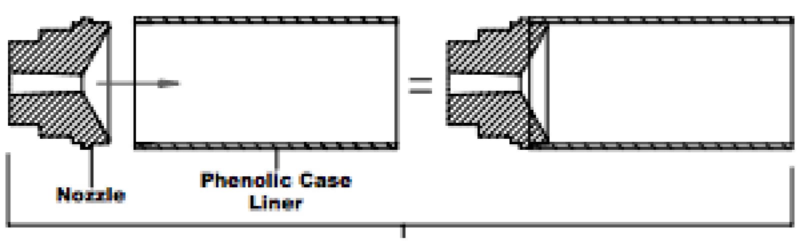


Figure 64 - Steps 1.1-1.2

- ☐ **Step 2.3a:** Locate the smaller O-ring in the P75-ORK O-ring kit.
- ☐ **Step 2.3b:** Fit the O-ring in the internal groove of the nozzle holder. Push the nozzle holder over the nozzle until fully seated, applying additional lubricant to the nozzle exit section if necessary. See Figure 3 below.

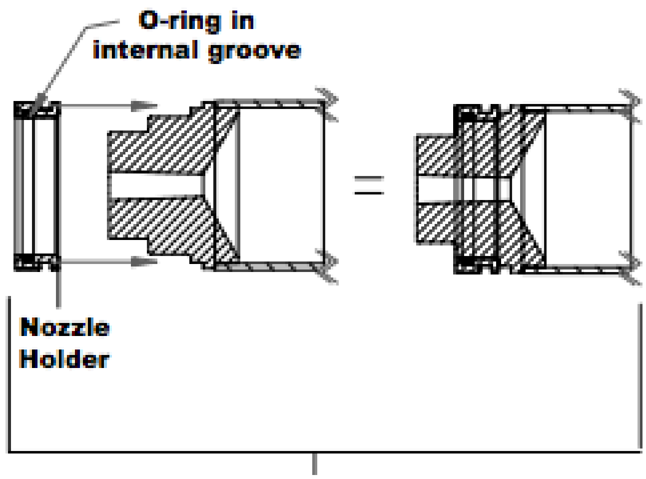


Figure 65 - Step 2.3

- ☐ **Step 2.4:** For the next two steps (2.5 – 2.6), ensure that the nozzle/case liner assembly and motor case are horizontal on the workspace.
- ☐ **Step 2.5a:** Insert one propellant grain into the forward end of the case liner, pushing it a short way into the tube. Fit one grain spacer O-ring to the top face of the grain, ensuring it sits flat on the end of the grain. Insert the second grain, pushing it in a short way into the tube. Continue this process of alternating grains with grain spacers if more than 2 grains are being used. See Figure 4 below.
- ☐ **Step 2.5b:** After the last grain is inserted, there should be space to fit the last spacer in place so that it is flush or extends only slightly from the end of the tube. If the spacer extends out by more than 1/3 of its own thickness, remove it and do not use. Only this last space may be omitted if and only if it does not fit.

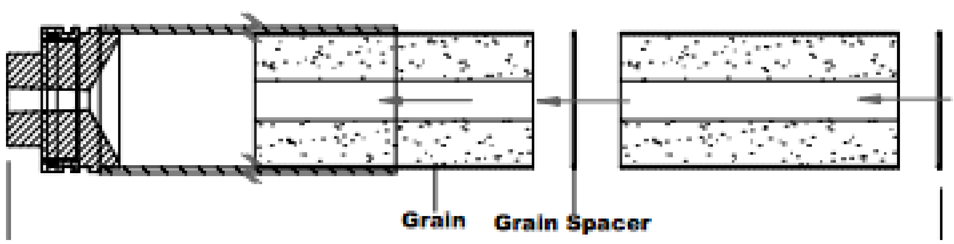


Figure 66 - Step 2.5

- ☐ **Step 2.6:** Carefully install the two larger O-rings into the external grooves of the nozzle holder and forward closure. **Handle these components very carefully from this point on as to not damage or contaminate the O-rings.** See Figure 5 below.

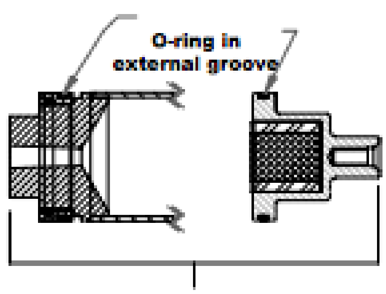


Figure 67 - Step 2.6

- ☐ **Step 2.7:** Apply a very light coat of grease on the linter exterior to aid assembly, disassembly, and clean up. Place the case liner/nozzle assembly on the work surface with the nozzle end down, and slide the motor case down read end first (end with thrust ring first) over the top of the liner towards the nozzle. See Figure 6 below.

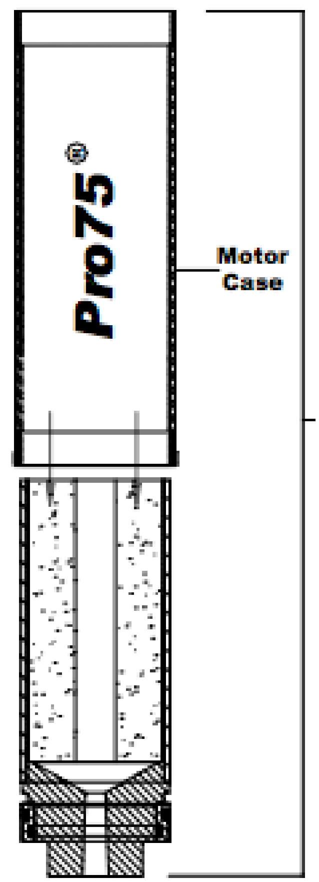


Figure 68 - Step 2.7

- ☐ **Step 2.8:** Lay the motor case assembly down horizontally, and push on the nozzle ring until the assembly is far enough inside the case that the threads are partly exposed and the screw ring can be threaded onto the rear of the case. **Don't push on the nozzle itself as you will push it out of the nozzle holder.**
- ☐ **Step 2.9:** Screw in the nozzle retaining ring using the supplied wrench, pushing the nozzle/nozzle ring/case liner assembly forward as you proceed. Screw it in **only until the retaining ring is exactly even with the end of the motor case – <u>do not thread it in as far as it will go!</u>** Then, back the retaining ring out one half of a turn. See Figure 7 below.

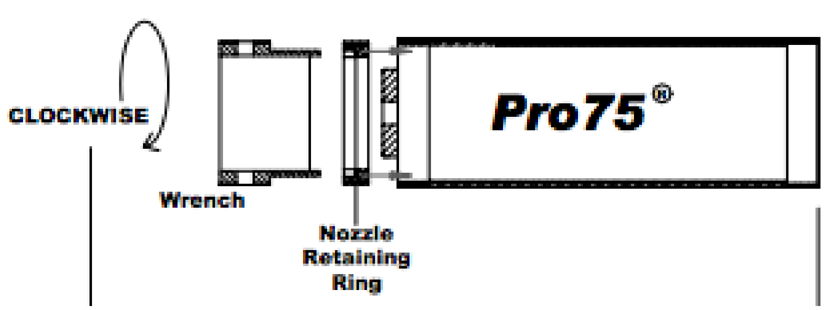


Figure 69 – Step 2.9

- ☐ **Step 2.10:** Fit the forward insulating disk to the top of the case liner, checking that the top grain space (if used) is still properly in place. See Figure 8 below.

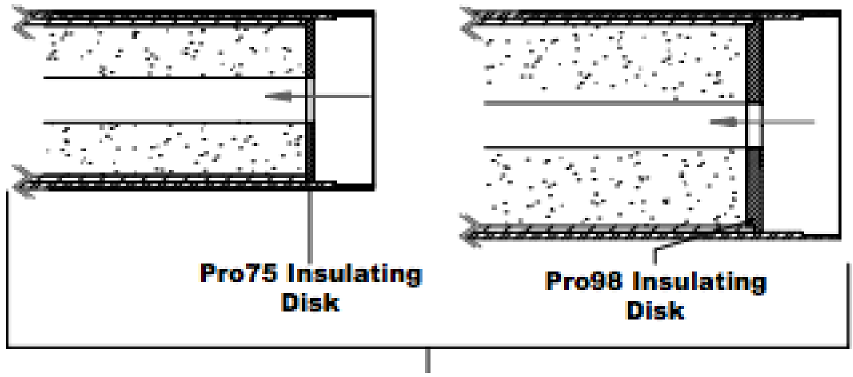


Figure 70 - Step 2.10

- ☐ **Step 2.11**: Verify that the inside of the motor case is clean ahead of the liner assembly before proceeding (checking especially for any dust, dirt, or salt). Wipe clean with a clean rag, tissue, or wet-wipe if necessary. Apply a light coat of silicone O-ring lubricant to this area after cleaning. See Figure 9 below.

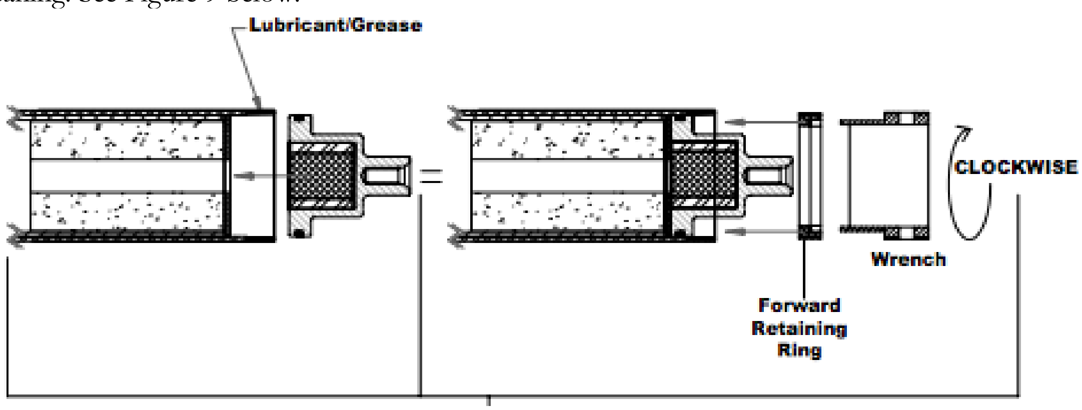


Figure 71 - Steps 2.11 and 2.12

- ☐ **Step 2.12:** Insert the assembled forward closure into the top of the motor case, pushing it down carefully with your fingers until you can thread in the retaining ring. Thread in the forward retaining ring using the wrench, until you feel it take up a load against the top of the case liner. At this point, the ring should be approximately flush with the end of the motor case, or slightly submerged. If it extends out the case at this point by more than one half a turn, check the nozzle end to make sure the ring is not screwed in too far forward. If this is the case, unscrew the nozzle retaining ring another half turn and screw the forward closure retainer in further. See Figure 9 above.
- ☐ **Note: It is better to have the forward closure retaining ring flush or slightly submerged and the nozzle retaining ring protruding by a half turn or so, than vice versa.**
- ☐ **Hold:** Verify with safety office and/or NAR mentor that the above steps have been completed properly.

Step 3: Pre-flight Preparation (corresponds with Pro75 Instructions Step 4)

- ☐ **Step 3.1:** Prepare the rocket's recovery system before motor installation. See recovery system preparation checklist. Do not proceed until go ahead is received from safety officer, NAR mentor, and/or systems engineer.
- ☐ **Step 3.2:** Install the motor in the rocket, ensuring that it is securely mounted with a positive means of retention to prevent it from being ejected during any phase of the rocket's flight.
- ☐ **Step 3.3: Important: DO NOT INSTALL THE IGNITER IN THE MOTOR UNTIL THE ROCKET IS ON THE LAUNCH PAD OR IN A SAFE AREA**

DESIGNATED BY THE RANGE SAFETY OFFICER. The NAR mentor will be responsible for the igniter installation. Follow all safety rules and regulations, as well as the National Fire Protection Association (NFPA) Code 1127 where applicable.

- ☐ **Notify the Systems Engineer of completion of these steps.**

C.11 – Post-Launch Clean-Up Checklist

C.12 – Recovery System Preparation and Final Integration Checklist

Recovery Preparation and Final Integration Checklist

Notes:

- Be sure to follow all instructions carefully. If there are any questions, ask either the Systems Engineer or the recovery sub-team lead.
- When indicated, have the appropriate team lead sign off on completed steps.
- Ensure all NAR/Tripoli safety codes are followed at all times.
- **Step requires Systems Engineer or Recovery team lead present to complete**

1) Recovery Preparation Checklist

___**Step 1.1** Collect All Required Components

- All sections of the rocket (nosecone, upper body tube, avionics bay, lower body tube, and motor section)
- Shock cord (3)
- Main parachute
- Drogue parachute
- High-force swivel (2)
- Quick links (8)

___**Step 1.2** Start only if Hazard Camera and GPS checklist has been completed.

___**Step 1.3** Pull the end of the upper shock cord labeled "nosecone" up through the upper body section.

___**Step 1.4** Attach the end of the shock cord labeled "nosecone" to the nosecone bulkhead with a quick link.

___**Step 1.5** Attach the nosecone to the upper body tube with shear pins.

___**Step 1.6** Pack the main parachute in accordance with sub-checklist 2

___**Step 1.7** Attach the deployment bag to the shock cord in the proper location with a quick link.

___**Step 1.8** **Load the deployment bag and excess shock cord into the upper body section**

___**Step 1.9** Attach nomex chute protector to shock cord behind the main and sufficiently cover the bottom of the deployment bag to protect it from the ejection gasses.

___**Step 1.10** Continue only if avionics checklist has been completed.

___**Step 1.11** Attach the end of the shock cord labeled "avionics bay" to the avionics bay bulkhead with a quick link.

___**Step 1.12** Fit the avionics bay into the upper body section but do **<u>NOT</u>** secure with rivets yet.

___**Step 1.13** Fit the lower body tube to the avionics bay and secure with rivets.

___**Step 1.14** Fold the drogue parachute in accordance with instructions.

___**Step 1.15** Attach drogue parachute and Nomex fabric to shock cord at the appropriate place using a quick link.
___**Step 1.16** **Wrap drogue parachute in Nomex fabric, and load into lower body section. **
___**Step 1.17** Attach the end of the lower shock cord labeled "motor section" to the motor section using a quick link.
___**Step 1.18** Attach the lower body section to the motor section with shear pins.
___**Step 1.19** **Install upper black powder charge to the top of the avionics bay**
___**Step 1.20** **Secure the upper body section to the avionics bay with rivets**
___**Step 1.21** Make sure to follow all procedures related to integration of the aerodynamic analysis payload.

2. Main parachute packing
___**Step 2.1** Grab the crown (top) of the parachute and stuff into the deployment bag
___**Step 2.2** Continue to stuff the deployment bag working towards the bottom of the parachute.
___**Step 2.3** When the chute has been packed to the shroud lines, fold them in a "z" pattern.
___**Step 2.4** Take the first third of the folded shroud lines, and tuck them into the elastic on the side of the deployment bag.
___**Step 2.5** Repeat the previous step with the remaining two thirds of the shroud lines.
___**Step 2.6** Check deployment bag assembly with recovery lead or systems engineer

3. Drogue parachute folding
___**Step 3.1** Hold the chute by the corners where the shroud lines attach.
___**Step 3.2** Pull the fabric between the corners out and fold them on top of each other.
___**Step 3.3** Fold in half to reduce the width to fit inside the tube.
___**Step 3.4** Fold in half lengthwise until it is the desired length.
___**Step 3.5** Fold Shroud lines in a Z pattern and place inside tube with drogue.

Appendix D – Safety Assessment, Failure Modes, Personnel Hazards

6.1 Risk Assessment Code Definitions

The following tables help to define the Risk Assessment Codes (RACs) utilized in evaluating the hazards which are identified in this report. In each hazard assessment, the RACs are provided for the hazard both before and after mitigations have been applied.

Table 22. Risk Matrix

Probability	Severity			
	1 – Catastrophic	2 - Critical	3 - Minimal	4 – Negligible
1 – Often	1-1	1-2	1-3	1-4
2 – Probable	2-1	2-2	2-3	2-4
3 – Occasional	3-1	3-2	3-3	3-4
4 – Unlikely	4-1	4-2	4-3	4-4

5 – Improbable	5-1	5-2	5-3	5-4

Table 23. Severity Definitions

Severity Definitions			
Severity	Personnel	Facilities/Equipment	Environmental
1- Catastrophic	Loss of life, severe bodily injury, or severe illness	Loss of facilities, catastrophic damage to top level system hardware	Irreversible environmental damage which violates regulations
2- Critical	Severe bodily injury or illness related to activity	Severe damage to facilities, equipment, or systems	Reversible environmental damage which violates regulations
3-Minimal	Minor bodily injury or illness related to activity	Minimal damage to facilities, equipment , or systems	Environmental damage which does not violate regulations and can be reversed with specific actions
4-Negligible	Easily mended injury or illness related to activity	Virtually no damage to facilities, equipment, or systems	Minimal environmental damage which does not violate regulations

Table 24. Probability Definitions

Probability Definitions	
Probability	Qualitative Definition
1 - Often	High probability of occurrence
2 – Probable	Medium probability of occurrence
3 – Occasional	Low probability of occurrence
4 – Unlikely	Minimal probability of occurrence
5 - Improbable	Virtually zero probability of occurrence

Table 25. Definition of Risk Assessment Levels

Definition of Risk Assessment Levels	
Risk Level	Level of harm, precaution and necessary personnel
Very High to High Risk	Very harmful. Need documented mitigations approved by Safety Officer, NAR Mentor and other relevant personnel eg. Range Safety Officer. Any and all tests must be performed under supervision of Safety Officer or NAR mentor.
High to Moderate Risk	Harmful. Need documented mitigations approved by Safety Officer, NAR Mentor and other relevant personnel eg. Range

	Safety Officer. Any and all tests must be performed under supervision of Safety Officer or NAR mentor.
Moderate to Low Risk	Allowable. Require approval of Safety Officer and full knowledge of mitigation by all personnel
Low to Minimal Risk	Allowable. Does not require approval of Safety Officer but does require knowledge of mitigation and prevention by all personnel

6.2 Recovery System

Table 26.Recovery System Failure Modes and Personnel Hazards

Hazard	Cause	Consequence	Pre-Mitigation Risk Assessment	Mitigation	Verification	Post-Mitigation Risk Assessment
Descent rate too fast or too slow	-Analysis was performed incorrectly -Components were weighed inaccurately -Parachute does not deploy or fails	- Damage upon landing - Loss of rocket or payloads - Landing in unauthorized zone	2-1	- Comprehensive testing of recovery system - Redundant systems - Extensive simulation under various potential conditions has been done -Components weighed multiple times	-Tests have and will be performed by recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Results of test flight will verify if descent rate was appropriate	4-1
Fire in parachute compartment after launch	-Deployment bag fails to protect chute from deployment charge -Motor backfires into rocket and deployment bag catches fire	- Damage to rocket or payloads - Damage to avionics or payload bays - Damage to parachute	2-2	- Separate ejection charges from flammable materials - Perform ground testing of recovery system -Verify capability of motor mount with test launch -Deployment bag utilized to protect parachute -All payloads and electronics are isolated from deployment	-Tests have and will be performed by recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Any and all design changes are must be approved by systems engineer and all affected system leads -No fires have	4-3

				charges	occurred in parachute compartment during ground testing -Deployment bag has protected parachute during ground testing -No fire will occur during full-scale test flight	
Parachute separates from rocket	-Attachment points between recovery system and rocket fail -Shroud lines of parachute fail	- Loss of parachute - Potential catastrophic damage to rocket and payloads - Potential severe injury to personnel or property on ground	3-1	- Perform load testing on system - Attached to multiple points on rocket -Verify strength of attachment by performing ground testing of recovery system	-Tests have and will be performed by recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Any and all design changes are and must be approved by systems engineer and all affected system leads -No separation has occurred in recovery system during ground testing -No separation will occur during full-scale test flight	4-1
Failure of parachute deployment	-Deployment charges fail	- Potential catastrophic	3-1	- Performed ground testing of deployment	-Tests have and will be performed by	5-1

	-Rocket does not separate -Parachute deploys unexpectedly	damage to rocket and payloads upon landing - Potential severe injury to personnel or property on ground		system	recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Any and all design changes are and must be approved by systems engineer and all affected system leads -Parachute does not fail to deploy during final ground testing -Parachute will deploy during full-scale test flight	
Melting or tearing of parachute	-Fire in parachute compartment -Deployment bag fails to protect parachute -Parachute is torn by a part of the rocket on deployment	- Damage to rocket and payloads upon landing - Loss of parachute	4-2	- Properly protected parachute from ejection charges and other rocket components - Performed ground testing of recovery system following - Selected parachute material appropriately - Inspect parachute and various materials for potential defects - Properly pack parachute in rocket pre-launch	-Tests have and will be performed by recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Any and all design changes are and must be approved by systems engineer and all affected system leads	5-2

				- Removed any potential parts of rocket that could cause tearing in parachute compartment	-Parachute does not melt or tear during ground testing of recovery system -Parachute will not melt or tear during full-scale test flight	
Parachute tangles	-Improper packing of parachute -Faulty construction of parachute	- Damage to rocket and payloads upon landing	3-2	- Recovery team will properly pack parachute in rocket pre-launch - Appropriate harnesses are being used when attaching parachutes - Performed ground testing of recovery system	-All packing and harnessing is verified by NAR Mentor -Comprehensive logs are being kept of all use of the recovery system	5-1
Separation failure	-Deployment charges fail -Shear pins do not break upon deployment	- Potential catastrophic damage to rocket and payloads upon landing - Potential severe injury to personnel or property on ground	3-1	- Performed ground testing of recovery system following - Tested altimeters extensively - Include redundant charges and altimeters - Include slightly overpowered ejection charges	-Tests have and will be performed by recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Any and all design changes are and must be approved by systems engineer and all affected system leads -Full recovery system testing will be	4-1

					performed -Separation will occur properly during full-scale test launch	

Table 27. Launch Vehicle Failure Modes and Personnel Hazards

Hazard	Cause	Consequence	Pre-Mitigation Risk Assessment	Mitigation	Verification	Post-Mitigation Risk Assessment
Center of gravity is too far back	-Inaccurate weighing of components -Inappropriate positioning of heavy and light components	- Potential unstable and dangerous flight -Damage to vehicle -Potential injury to personnel	4-2	- Add ballast to nose cone which is designed with extra room for dead weight -Reposition components to allow for better stability margin	-Verified position of center of gravity of rocket by see-saw test -Stability of rocket and validity of simulations verified by systems engineer and NAR mentor	5-2
Center of gravity is too far forward	-Inaccurate weighing of components -Inappropriate positioning of heavy and light components	- Potential unstable and dangerous flight -Damage to vehicle -Potential injury to personnel	4-2	- Increase fin size - Repositioned components to allow for better stability margin	-Verified position of center of gravity of rocket by see-saw test -Stability of rocket and validity of simulations verified by systems engineer and NAR mentor	5-2
Fin flutter or breakaway	-Improper attachment of fins to rocket -Improper handling of rocket prior to	- Potential unstable and dangerous flight -Catastrophic damage to	4-1	- Constructed using proper techniques - Utilized stiff carbon fiber laminate fins	-Fins do not fail during test launch -Fins cannot be moved by human manipulation	5-1

	launch	vehicle -Potential injury to personnel				
Rail buttons are not securely attached	-Improper attachment of fins to rocket -Improper handling of rocket prior to launch	- Rocket can break free during initial phase of launch - Potential damage to rocket - Potentially severe injury to personnel and property on ground - Potential loss of rocket and payloads	4-1	- Installed based on manufacturer recommendation - Attached to bulkheads inside rocket and fix further using washers and epoxy	-Attachment verified by systems engineer and NAR mentor -Rail buttons do not cause issues during test launch -Redundant rail buttons to further prevent issues	5-2
Bending or shearing of airframe	-Improper construction of carbon fiber airframe -Deployment and separation anomalies during flight	- Potential unstable and dangerous flight - Loss of rocket	4-1	- Utilized carbon fiber with proper epoxy lay-up practices during construction of airframe -Add stiffness to airframe by applying more epoxy if excessive flexing is noticed	-Airframe strength verified by flex test performed by systems engineer and NAR mentor -Airframe performs as expected during test launch	5-1

Premature or delayed separation of rocket	-Improper attachment of recovery systems -Malfunction of altimeter -Deployment charges are not sufficient	- Potential unstable and dangerous flight - Failure of recovery system - Inability to reach target altitude - Potentially catastrophic damage to rocket and payloads -Potential injury to personnel	3-1	- Utilized proper shear pins - Extensive ground testing with different black powder charge sizes to find appropriate charge size -Ensure deployment of parachute can occur by drag separation if necessary	-Positive results from ground testing performed with supervision by safety officer and NAR mentor -Rocket separates when expected during test launch -Verified deployment system with subscale launch	5-2
Centering ring failure	-Improper construction of motor mount -Improper material used in construction of centering ring	-Potentially catastrophic damage to rocket -Potential injury to personnel -Potentially catastrophic damage to payloads or avionics	4-1	- Centering rings are sized appropriately - Aircraft plywood utilized for construction -Redundant centering rings utilized to ensure strength if one fails -Strength tests performed on centering rings	-Proper construction verified by manufacturing lead -Strength test resulted in good factor of safety	5-2

Bulkhead failure	-Improper construction of payload and coupler bays -Improper material used in construction of bulkheads	Potentially catastrophic damage to rocket -Potential injury to personnel -Potentially catastrophic damage to payloads or avionics	4-1	- Bulkheads are sized appropriately - Aircraft plywood utilized for construction -Strength test of bulkheads	-Proper construction verified by manufacturing lead -Strength test resulted in good factor of safety	5-2
Nose cone damage	-Improper handling of rocket prior to launch -Recovery system failure	-Potentially catastrophic damage to rocket due to unusable nosecone -Potentially catastrophic damage to payload and avionics hardware	3-1	- Selected nose cone suitable for purposes based on strength, size, and shape -Verify functionality of recovery system through ground testing -Proper attachment of recovery system and nosecone	-Selection of nose cone verified by NAR mentor -Ground testing shows positive results	5-1

Table 28.Launch Failure Modes and Personnel Hazards

Hazard	Cause	Consequence	Pre-Mitigation Risk Assessment	Mitigation	Verification	Post-Mitigation Risk Assessment
Igniter failure	-Improper installation of igniter -Incorrect selection of igniter	- Rocket does not launch -Delay of rocket launch and inability to complete competition	3-2	- Ensured proper igniter selection based on manufacturer instructions - NAR mentor prepares and sets up igniter -Have multiple igniters in order to replace malfunctioning one	-NAR mentor verifies correct selection and installation of igniter -Rocket ignites at test launch	5-2
Propellant fails to ignite	-Improper installation of motor or igniter -Incorrect selection of igniter	-Rocket does not launch -Delay of rocket launch and inability to complete competition	3-2	- Ensured proper igniter selection based on manufacturer instructions - NAR mentor prepares and sets up igniter -Have multiple igniters in order to replace	-NAR mentor verifies correct selection and installation of igniter -Rocket ignites at test launch -NAR mentor verifies correct installation of motor	5-2

				malfunctioning one - Ensure proper motor assembly and igniter set-up - NAR Mentor supervises and checks all motor assembly		
Motor explodes	-Improper installation of motor or igniter	-Destruction of motor casing -Catastrophic damage to rocket and payloads -Catastrophic failure of rocket -Potentially sever injury to personnel	4-1	- Ensure proper motor assembly and igniter set-up - NAR Mentor supervises and checks all motor assembly -Follow manufacturer instructions for motor use	-NAR mentor verifies correct selection and installation of igniter -NAR mentor verifies correct installation of motor -Full-scale test launch goes as expected	5-1
Motor propellant burns through motor casing	-Improper installation of motor or igniter	- Loss of thrust during launch - Loss of stability -Catastrophic failure of rocket - Potential	4-1	- Ensure proper motor assembly and igniter set-up - Follow manufacturer instructions for motor use - NAR Mentor supervises and	- NAR mentor verifies correct selection and installation of igniter -NAR mentor verifies correct installation of motor	5-1

		catastrophic damage to rocket and payloads -Potentially severe injury to personnel		checks all motor related activities	-Full-scale test launch goes as expected	
Motor mount failure	-Improper construction of motor mount -Failure of various components in fin can -Improper construction of motor	- Motor launches through the rocket -Potential catastrophic damage to rocket and payloads - Unstable flight -Potentially severe injury to personnel	4-1	- Proper motor mount constructions - Perform load testing of motor mount following safety precautions -Strength test of centering rings	-NAR mentor verifies correct installation of motor -Full-scale test launch goes as expected	5-1
Premature motor burnout	-Failure to follow manufacturer instructions for assembly -Damage to motor casing prior to launch	- Desired altitude not reached	4-3	- Ensure proper motor assembly based on manufacturer instructions - NAR Mentor supervises and checks all motor related activities	-NAR mentor verifies correct installation of motor -Full-scale test launch goes as expected	5-1
Improper assembly	-Failure to	- Unstable	3-2	- Motor assembly	-NAR mentor	5-2

of motor	follow manufacturer instructions -Damage to motor casing prior to launch	flight - Desired altitude not reached - Potentially catastrophic damage to rocket and payloads -Potentially severe injury to personnel		performed only by certified, experienced members - Motor assembly supervised by NAR Mentor -Ensure proper motor assembly based on manufacturer instructions	verifies correct installation of motor -Full-scale test launch goes as expected	
Improper transportation or handling of motor	-Failure to follow manufacturer instructions	- Unusable motor - Inability to launch	3-2	- Ensure proper storage of motor -NAR mentor transports motor -Ensure proper motor assembly based on manufacturer instructions - Motor only handled by certified members or NAR Mentor	-NAR mentor ensures proper handling of motor	5-2

6.5 Hazard Camera Payload

Table 29. Hazard Camera Failure Modes and Personnel Hazards

Risk	Cause	Consequence	Pre-Mitigation Risk Assessment	Mitigation	Verification	Post-Mitigation Risk Assessment
Descent rate too high	-Failure of recovery system (See Table 7)	-Potentially catastrophic damage to payload hardware -Potential loss of data	2-1	- Comprehensive testing of recovery system - Redundant systems - Extensive simulation under various potential conditions has been done -Components weighed multiple times	-Tests have and will be performed by recovery team under supervision of safety officer -Comprehensive logs are being kept of each test and all use of recovery system -Results of test flight will verify if descent rate was appropriate	4-1
Antenna data connection rate too low to effectively transmit data	-Incorrect selection of transmission hardware	-Failure to fulfill requirements -Potential loss of rocket due to lack of GPS data -Potential loss of data	3-2	-Comprehensive testing of data transmission system -Full system test prior to first launch -Compression of data if necessary -Onboard data stored to prevent complete loss of data	-Proper functionality verified by ground ops and payload lead -Able to receive data from large distance from receiver	4-3

Battery does not supply sufficient power	-Improper wiring -Use of discharged batter	-Catastrophic failure of payload	4-1	-Ensure that battery has full charge prior to launch -Battery with adequate capacity has been chose	-Proper functionality verified by ground ops and payload lead	5-1
No hazards in the camera's field of view during flight	-Improper placement of camera -Recovery system malfunction -No hazards around the launch site	-Failure of payload to fulfill objectives	2-2	-Test algorithm with other videos to show that it works	-Verified by testing camera and algorithm on ground	4-4

6.6 Testing

Table 30. Testing Personnel Hazards

Risk	Cause	Consequence	Pre-Mitigation Risk Assessment	Mitigation	Post-Mitigation Risk Assessment
Deployment Testing Hazards					
Damage to rocket	-Improper sizing, preparation or placement of black powder charge -Parachute packed too tightly	-Potentially catastrophic damage to launch vehicle -Potential injury to personnel	2-1	-NAR mentor prepares all black powder charges -Oversized black powder charges are not be used -All tests are verified by NAR mentor, safety officer, and systems engineer -Parachute packing will be verified by recovery lead -Parachute must be able to be removed from rocket with minimal force	4-1
Bodily injury to personnel	-Improper or insufficient safety precautions taken -Black powder charge too large	-Potentially severe bodily injury to personnel	2-1	-All deployment testing will be performed in remote area with all personnel behind a solid protective barrier -Any unnecessary personnel will not be present -NAR mentor prepares all black powder	4-3

				charges -Oversized black powder charges are not be used -All tests are verified by NAR mentor, safety officer, and systems engineer -All participating members will have full knowledge of test procedures -A formal countdown will be used to notify members that the test is about to begin	
Fire at test site	-Improper or insufficient safety precautions taken -Improper sizing, preparation or placement of black powder charge	-Potential fire at test site	3-2	-At each test, two working fire extinguishers are present in the case of a fire -NAR mentor prepares all black powder charges -Oversized black powder charges are not be used -All tests are verified by NAR mentor, safety officer, and systems engineer	4-3

Recovery system damaged	-Improper sizing, preparation or placement of black powder charge -No deployment bag or fire protection material present	-Potentially catastrophic damage to recovery system -Potential loss of safe launch capability -Potentially catastrophic damage to rocket	2-1	-NAR mentor prepares all black powder charges -Oversized black powder charges are not be used -All tests are verified by NAR mentor, safety officer, and systems engineer -Recovery system integration is verified by recovery lead	4-3
Recovery System Testing Hazards					
Parachute failure occurs	-Inadequate strength of materials -Improper manufacturing methods -Test procedures are not followed properly	-Potentially catastrophic damage to recovery system -Loss of parachute -Potential bodily injury	2-2	-All members participating in test will have full knowledge of testing procedures -A formal countdown will be used to notify all members that the test is about to begin -Parachute will be tested close to the ground before a larger test is performed	4-3
Separation of parachute from test apparatus	-Inadequate strength of materials -Improper manufacturing methods -Test procedures are not followed	-Potentially catastrophic damage to recovery system -Loss of parachute -Potential bodily injury	2-2	-All members participating in test will have full knowledge of testing procedures -A formal countdown will be used to notify all members that the test is	4-3

	properly			about to begin -Parachute will be tested close to the ground before a larger test is performed	

6.7 Manufacturing

Table 31. Manufacturing Personnel Hazards

Manufacturing Personnel Hazards					
Risk	Cause	Consequence	Pre-Mitigation Risk Assessment	Mitigation	Post-Mitigation Risk Assessment
Bodily injury	-Lack of proper safety gear -Improper manufacturing processes -Lack of experience with manufacturing process -Improper use of drills, mills, lathes, knives, or rotary cutters	-Severe injury to hands, face, eyes, or body -Loss of human life	2-1	-All members have been properly trained on all manufacturing equipment -All inexperienced members are assisted and supervised by experienced members -Members will wear safety goggles, gloves, masks, respirators, or ear protection as dictated by the activity	4-3
Irritation of eyes, nose, and mouth	-Lack of proper safety gear while epoxying or sanding -Improper use of manufacturing equipment -Improper use of facilities	-Irritation of the eyes, skin, or nasal passages -Potential allergic reaction due to excessive contact with skin	2-3	-All members have been properly trained on all manufacturing equipment and chemicals used for construction -All inexperienced members are assisted and supervised by experienced members -Members will wear safety	2-4

				goggles, gloves, masks, respirators, or ear protection as dictated by the activity	

7 Appendix E – Material Safety Data Sheets (MSDS) Summary

Material	Risks to Health	Mitigation
West Systems 105-B Epoxy Resin	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well-ventilated, open area while wearing gloves, eye protection, and face masks. Once curing begins, utilize fume hood.
West Systems 2015-B Slow Hardener	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well ventilated, open area while wearing gloves, eye protection, and face masks. Once curing begins, utilize fume hood.
Sunnyside Acetone	Skin, eye, respiratory irritation; flammable	Use in well ventilated, open area away from heat while wearing gloves, eye protection, and face masks.
Duralco 4461SS Hardener	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well ventilated, open area while wearing gloves, eye protection, and face masks. Once curing begins, utilize fume hood.
Duralco 4461SS Resin	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well ventilated, open area while wearing gloves, eye protection, and face masks. Once curing begins, utilize fume hood.
Loctite 5 Minute Quick Set 5 Minute Epoxy Instant Mix	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well ventilated, open area while wearing gloves, eye protection, and face masks.
Proline Epoxy 4100 Resin	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well ventilated, open area while wearing gloves, eye protection, and face masks. Once curing begins, utilize fume hood.
Proline Epoxy 4100 Hardener	Skin, eye, respiratory irritation; Potential allergic reaction	Use in well ventilated, open area while wearing gloves, eye protection, and face masks. Once curing begins, utilize fume hood.
Irwin Strait Line Marking Chalk	Respiratory and eye irritation	Use in well ventilated, open area while wearing gloves, eye protection, and face masks.
ACP Composites Carbon Fiber	Skin, eye, respiratory irritation	If sanding or cutting, do so in particulate sanding booth with appropriate filtration system while wearing long sleeves, gloves, respirator, and eye protection.
ACP Composites Fiber Glass	Skin, eye, respiratory irritation	If sanding or cutting, do so in particulate sanding booth with appropriate filtration system while wearing long sleeves, gloves, respirator, and eye protection.
Solder	Respiratory irritation	Use in a well-ventilated area.
Cesaroni ProFire Igniter	Combustion and burn risk	Use outside with face and body protection. Have fire extinguishers on hand. Keep away

		from heat and potential static discharge sources. Store properly when not in use.
Black 4F Powder	Combustion, explosion, and burn risk; Respiratory irritation	Use outside with face and body protection. Have fire extinguishers on hand. Keep away from heat and store properly when not in use.
Cesaroni Solid Rocket Motor	Combustion, explosion, and burn risk	Use in accordance with NAR Safety Codes, FAA FAR 101 and NFPA 1127 codes with face and body protection. Have fire extinguishers on hand. Keep away from heat and store properly when not in use.
Electric Matches	Combustion and burn risk	Use outside with face and body protection. Have fire extinguishers on hand. Keep away from heat and potential static discharge sources. Store properly when not in use.

8 Appendix F – Material Safety

MATERIAL SAFETY DATA SHEET

Complies with OSHA Hazard Communication Standard 29 CFR 1910.1200

Date of Prep: 3/20/09

SECTION 1

SUNNYSIDE CORPORATION
225 CARPENTER AVENUE
WHEELING, ILLINOIS 60090 (847) 541-5700 - SUNNYSIDE CORPORATION
EMERGENCY TELEPHONE (800) 424-9300 - CHEM TREC

FOR INFORMATION: (847) 541-5700

Product Class: Ketone
Trade Name: ACETONE

Manufacturer's Code: 840
NPCA HMIS: Health: 1
Flammability: 3
Reactivity: 0

Product Appearance and Odor: Clear, water-white liquid; typical, pungent odor.

SECTION 2 -- HAZARDOUS INGREDIENTS

OCCUPATIONAL EXPOSURE LIMITS

INGREDIENT	CAS #	PERCENT	ACGIH TLV (TWA)	ACGIH TLV (STEL)	OSHA PEL (TWA)	OSHA PEL (STEL)	VAPOR PRESSURE
Acetone	67-64-1	100%	500 PPM	750 PPM	750 PPM	1000 PPM	213 MM Hg @ 75° F

SECTION 3 -- EMERGENCY AND FIRST AID PROCEDURES

INHALATION: Using proper respiratory protection, immediately remove the affected victim from exposure. Administer artificial respiration if breathing is stopped. If breathing is difficult, qualified medical personnel may administer oxygen and continue to monitor. Keep at rest. Get medical attention immediately.

EYE CONTACT: Flush eyes immediately with water for at least 15 minutes. Get prompt medical attention.

SKIN CONTACT: Flush with large amounts of water; use soap if available. Remove grossly contaminated clothing, including shoes, and launder before reuse. Get medical attention if skin irritation develops or persists.

INGESTION: If swallowed, do not induce vomiting. Give victim a glass of water or milk. Call a physician or poison control center immediately. Never give anything by mouth to an unconscious person.

SECTION 4 -- PHYSICAL DATA

The following data represent approximate or typical values. They do not constitute product specifications.

Boiling Range: 133° (F) (I.B.P.)

Vapor Density: Heavier than air

Evaporation Rate: Slower than ether

% Volatile By Volume: 100%

Weight Per Gallon: 6.60 Lbs.
Solubility in Water: Complete

SECTION 5 -- FIRE AND EXPLOSION DATA

Flammability Classification: Flammable Liquid - Class IB.

Flash Point: 0° (F) (Tag. Closed Cup).

Autoignition Temperature: 869° (F)

Lower Explosive Limit: 2.5% @ 77° (F)

Extinguishing Media: Either allow fire to burn under controlled conditions or extinguish with alcohol resistant foam and dry chemical. Try to cover liquid spills with foam.

Unusual Fire and Explosion Hazards: Extremely flammable. Vapors may cause a flash fire or ignite explosively. Vapors may travel considerable distance to a source of ignition and flash back. Prevent buildup of vapors or gases to explosive concentrations.

Special Fire Fighting Procedures: Use water spray to cool fire exposed surfaces and to protect personnel. Shut off "fuel" to fire. If a leak or spill has not ignited, use water spray to disperse the vapors.

SECTION 6 -- HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE: 500 PPM (ACGIH-Time weighted average).

EFFECTS OF OVEREXPOSURE

Inhalation: Vapors or mist may cause irritation of the nose and throat. Inhilation may cause dizziness, drowsiness, loss of coordination, disorientation, headache, nausea, and vomiting. In poorly ventilated areas or confined spaces, unconsciousness and asphyxiation may result.

Skin Contact: Prolonged or repeated skin contact may cause irritation, discomfort and dermatitis.

Eye Contact: Severely irritating and may injure cornea if not removed promptly. High vapor concentrations are also irritating.

Ingestion: Product may be harmful or fatal if swallowed. Material is a pulmonary aspiration hazard. Material can enter lungs and cause damage. Ingestion of this product may cause central nervous system effects, which may include dizziness, loss of balance and coordination, unconsciousness, coma and even death.

Carcinogenicity: Acetone is not listed by the NTP, IARC, or OSHA.

SECTION 7 -- REACTIVITY DATA

Stability: Stable

Conditions to Avoid: Heat, sparks and flame.

Incompatibility (Materials to Avoid): Caustics, amines, alkanolamines, aldehydes, ammonia, strong oxidizing agents, and chlorinated compounds.

Hazardous Decomposition Products: Thermal decomposition may yield carbon monoxide, carbon dioxide, adehydes and keytones.

Hazardous Polymerization: Will not occur.

SECTION 8 -- SPILL OR LEAK PROCEDURES

Steps to be taken in case material is spilled or released: Remove ignition sources, evacuate area, avoid breathing vapors or contact with liquid. Recover free liquid or stop leak if possible. Dike large spills and use absorbent material for small spills. Keep spilled material out of sewers, ditches and bodies of water. Warn occupants and shipping in surrounding and downwind areas of fire and explosion hazard and request all to stay clear.

Waste disposal method: Incinerate under safe conditions; dispose of in accordance with local, state and federal regulations.

SECTION 9 -- SAFE HANDLING AND USE INFORMATION

Respiratory Protection: Where concentrations in air may exceed occupational exposure limits, NIOSH/MSHA approved respirators may be necessary to prevent overexposure by inhalation.

Ventilation: Exposure levels should be maintained below applicable exposure limits - see Section 2. This product should not be used in confined spaces, or in a manner that will allow accumulation of high vapor concentrations. However, for controlled industrial uses when this product is used in confined spaces, heated above ambient temperatures or agitated, the use of explosion proof ventilation equipment is necessary.

Protective Gloves: Chemical resistant gloves (Neoprene or Natural Rubber).

Eye Protection: Chemical safety goggles and a face shield.

Other Protective Equipment: Impervious clothing or boots where needed, eyewash fecility and a safety shower.

SECTION 10 -- SPECIAL PRECAUTIONS

Dept. of Labor Storage Category: Flammable Liquid-Class IB.

Hygienic Practices: Keep away from heat, sparks and flame. Keep containers closed when not in use. Avoid eye contact. Avoid prolonged or repeated contact with skin. Wash skin with soap and water after contact.

Additional Precautions: Ground containers when transferring liquid to prevent static accumulation and discharge. Additional information regarding safe handling of products with static accumulation potential can be ordered by contacting the American Petroleum Institute (API) for API Recommended Practice 2003, entitled "Protection Against Ignitions Arising Out of Static, Lighting, and Stray Currents" (American Petroleum Institute, 1720 L Street Northwest, Washington,DC 20005), or the National Fire Protection Association (NFPA) for NFPA 77 entitled "Static Electricity" (National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101).

Empty Container Warning: "Empty" containers retain residue (liquid and/or vapor) and can be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind or expose such containers to heat, flame, sparks or other sources of ignition. They may explode and cause injury or death. Do not attempt to clean since residue is difficult to remove. "Empty" drums should be completely drained, properly bunged and promptly returned to supplier or disposed of in an environmentally safe manner and in accordance with governmental regulations.

SECTION 11 -- ADDITIONAL INFORMATION

This product contains the following toxic chemical(s) which are 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:

TOXIC CHEMICAL	CAS #	APPROXIMATE % BY WEIGHT
NONE	NONE	NONE

SARA Title III Hazard Categories:	Immediate (Acute) Health, Delayed (Chronic) Health, Fire
Common Names:	2-Propanone, Dimethylketone
California Proposition 65:	This product contains trace amounts of Benzene, a chemical known to the State of California to cause cancer, and Toluene, a chemical known to the State of California to cause birth defects or other reproductive harm.

TRANSPORTATION (U.S. D.O.T. land transportation in packages of 119 gallons or less)

U.S. D.O.T. Proper Shipping Name:	Acetone
U.S. D.O.T. I.D Number:	UN1090
U.S. D.O.T. Hazard Class:	3
U.S. D.O.T. Packing Group:	II
U.S. D.O.T. Hazardous Substance:	Acetone, RQ 5000 lbs

Refer to 49 CFR for additional information. Exceptions or exemptions may exist for smaller quantities.

OWEN COMPLIANCE SERVICES, INC.

Material Safety Data Sheet
(MSDS-BP)

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

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

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

WARNING

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

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

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

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

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

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

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

HEALTH HAZARDS

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

FIRST AID

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

SPILL OR LEAK PROCEDURES

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

SPECIAL PROTECTION INFORMATION

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

SPECIAL PRECAUTIONS

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

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

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

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

For further information contact:	David W. Boston, President *OWEN COMPLIANCE SERVICES, INC.* 12001 County Road 1000 P.O. Box 765 Godley, TX 76044	
	Telephone number:	817-551-0660
	FAX number:	817-396-4584
MSDS prepared by:	David W. Boston	
	Original publication date:	12/08/93
	Revision date:	12/12/05 12/03/03

MATERIAL SAFETY DATA SHEET
COTRONICS EPOXY RESINS

DURALCO 4525 DURALCO 4535 DURALCO S5H13
DURALCO 4537 DURALCO 4538 DURALCO 4540

Manufactures Name: COTRONICS CORPORATION
3379 Shore Parkway Brooklyn, NY 11235
Emergency Telephone Number: 718-646-7996

SECTION 1: PRODUCT IDENTIFICATION

Chemical Name And Synonyms: N/A Mixture
Chemical Formula: N/A
Chemical Family: Proprietary Modified Epoxy Resin.*

SECTION 2: COMPOSITION INFORMATION

Material: Proprietary Modified Epoxy Resin
All materials contained within are listed on the TSCA Inventory list
This product is compliant with the RoHS Directive.

SECTION 3: PHYSICAL PROPERTY INFORMATION

Boiling Point:	> 400°F
Vapor Density (Air=1) :	>1
Solubility In Water:	Negligible
% Volatile (By Weight) :	Negligible
Specific Gravity (Water=1) :	1.7 - 2.1
Vapor Pressure (mm Hg) :	N/A
Melting Or Freezing Point:	< 40°F
Evaporation Rate (Butyl Acetate=1) :	<1
Appearance/Odor:	Amber Transparent To Viscous Black Liquids/Slight Odor

SECTION 4: FIRE AND EXPLOSION HAZARD DATA

Flash Point:	> 295°F
Auto Ignition Temp:	N/A
Lower Explosion Limit (%) :	N/A
Upper Explosion Limit (%) :	N/A
Extinguishing Media:	Foam, C02, Dry
Chemical:	Water Spray

SECTION 5: HEALTH HAZARD DATA

Effects Of Overexposure:
Inhalation: Mist or vapor can irritate the nose and throat.
Eye Contact: Substantially irritating to eyes.
Skin Contact: Substance is moderately irritating and can cause superficial burns after prolonged contact. Not absorbed in toxic amounts
Ingestion: Possibly harmful if swallowed.
Delayed Effects: Prolonged or repeated exposure can cause allergic reaction.

SECTION 6: EMERGENCY AND FIRST AID PROCEDURES

Inhalation: Move subject to fresh air. Give artificial respiration if breathing has stopped.
Eye And Skin Contact: Flush eyes with a large amount of water for at least 15 minutes. Get prompt medical attention. Wash skin thoroughly with soap and water. Remove and wash clothing before reuse.
Ingestion: If swallowed dilute by giving 2 glasses of water to drink. See a physician. Never give anything by mouth to an unconscious person.

SECTION 7: REACTIVITY INFORMATION

Stability: Stable
Hazardous Polymerization: Will Not Occur

SECTION 8: SPILL OR LEAK PROCEDURES

Dike and absorb spill on inert material (sand, earth, etc.). Transfer diking material to containers for disposal. Wear protective clothing. Use breathing apparatus (MSHA/NIOSH approved, pressure-demand, self-contained) or air mask for large spills in confined area. Wash clothing before reuse. Destroy clothing that cannot be decontaminated (i.e. Shoes).
Waste Disposal Methods: Landfill or incinerate contaminated in accordance with local, state and federal regulations. Dispose of material in approved equipment

SECTION 9: SPECIAL PROTECTION INFORMATION

Ventilation Type: Normal room ventilation.
Respiratory Protection: None required if good ventilation is maintained. Wear respirator (MSHA/NIOSH approved or equivalent) suitable for concentrations and types of air contaminants encountered.
Protective Gloves: Impervious.
Eye Protection: Chemical splash goggles (ANSI Z-871 or approved equivalent).
Other Protective Equipment: Eyewash facility.

SECTION 10: SPECIAL PRECAUTIONS

Store away from excessive heat (e.g., steam-pipes, radiators, from sources of ignition, and from reactive materials). Do not store near food or feed. Avoid all eye and skin contact.
Note To Physician: Allergic dermatitis or respiratory response in susceptible individuals may be delayed even weeks or months after frequent and/or prolonged contact. Acute effects can include mucosa damage, severe laryngeal edema, and shock associated with corrosive agents. Possible mucosa damage may contraindicate the use of gastric lavage. (This product is not approved by FDA for internal use).

DISCLAIMER: The information supplied is not to be taken as a warranty or representation for which Cotronics Corp. assumes legal responsibility. It is offered solely for your consideration, investigation and verification. all risk of use, singly or in combination with other products, whether or not in accordance with the instructions, directions, or suggestions is borne by the user.

DATE PREPARED: 11/01/85 DATE REVISED: 04/10/07

HIMS RATING Health = 1 Fire = 0 Reactivity = 0 HAZARD RATING: 0 = Insignificant 1 = Non-Toxic, Slight 2 = Moderate 3 = High 4 = Extreme

MATERIAL SAFETY DATA SHEET

Conforms to OSHA'S Hazard Communication Standard 29 CFR 1910.1200

Identity: Electric Match (All) – BGZD, Flash, Shock Tube Initiator Igniters (UN0454, 1.4S)

Section I

Manufacturer's Name and Address:
Ultratec Special Effects, Inc.
148 Moon Dr.
Owens Cross Roads, AL 35763 USA

Emergency Telephone:(+1) 703-527-3887; 800-424-9300
Telephone Number: 256-725-4224
Date Prepared: May 26, 2009

Section II-Hazardous Ingredients/Identity Information

HAZARDOUS COMPONENTS	OSHA PEL	ACGIH TLV	OTHER LIMITS	%

Contains pyrotechnic composition, a solid mixture of oxidizer and fuel that burns if ignited. These items are classified as Igniters UN0454, 1.4S, Explosives by the U.S. Department of Transportation. No chemical composition is exposed during normal storage and handling. During function gases and smoke are produced that may contain various oxides, chlorides, and other gaseous and particulate products. Item produce a small ball of fire which may cause thermal burns.

Contains two or more of the following:

Aluminum Metal Powder, Bismuth Trioxide, Boron, Copper Thiocyanate, Cupric Oxide, Dye, Magnesium Aluminum Alloy, Nitrocellulose, Pigment, Potassium Chlorate, Potassium Ferricyanide, Potassium Perchlorate.

SECTION III-PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: N/A
Vapor Pressure (mm Hg.): N/A
Vapor Density (Air=1): N/A
Specific Gravity (H20=1): N/A
Melting Point: N/A
Evaporation Rate (Butyl Acetate=1): N/A
Solubility in Water: Slight. Article has water resistant coating
Appearance and Odor: Article appears as a small phenolic wafer with composition on the tip and soldered lead wires. Color of match varies from type: BGZD is blue-green in color, Shock Tube Initiator is red-pink in color, Flash Match is purple in color. Article is odorless.

Section IV-Fire and Explosion Hazard Data

Flash Point: N/A **Flammable Limits:** N/A **LEL** N/A **UEL** N/A
Extinguishing Media: Flood with water if a small number of pieces are involved.
Special Fire Fighting Procedures: Do not use suffocation method; device contains its own oxygen. If large quantities of items are involved, allow them to burn and prevent spread of fire.
Unusual Fire and Explosion Hazards: Items will burn rapidly in the event of fire, and items may fly if not contained.

Section V-Reactivity Data

Stability: Stable **Conditions To Avoid:** Storage at temperatures above 120° F. Avoid friction, shock, open flames, smoking or ignition sources including sparks, strong RF fields and static discharges.
Incompatibility (Materials to Avoid): Exposure to water may cause items to deteriorate
Hazardous Decomposition or Byproducts: Smoke, oxides, chlorides, and other gaseous and solid particulates.
Hazardous Polymerization: Will not occur **Conditions To Avoid:** Exposure to water may cause deterioration. Heat, sparks, flame.

Section VI-Health Hazard Data

Route(s) of Entry:	Inhalation?	Skin?	Ingestion?
	None for article	No	No

Health Hazards (Acute and Chronic): Exposure to finished items does not pose any health hazard. During function, the gases and smokes created may cause respiratory irritation if inhaled in large amounts. Device may cause thermal burns if used improperly.

Carcinogenicity:	NTP?	ARC Monographs?	OSHA Regulated?
	No	No	No

Signs and Symptoms of Exposure: Burns. Respiratory or eye irritation from combustion products is possible.
Medical Conditions Generally Aggravated by Exposure: Asthma or pre-existing respiratory conditions
Emergency and First Aid Procedures: Wash affected area with water for burns. Flush eyes with water if necessary. Move to fresh air and consult physician for respiratory irritation.

Section VII-Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled: No smoking or open flames in vicinity of broken or spilled items. Carefully pick up and place spilled items in container. Sweep up any exposed chemical composition with a natural fiber brush.
Waste Disposal Method: Dispose of by burning in compliance with Federal, State and Local regulations.
Precautions to Be Taken in Handling and Storing: Keep shipping and storage containers in cool, dry place. Do not crush, abrade, or subject these items to shock Avoid open flames, smoking, and temperatures above 120° F.
Other Precautions: Do not pick up with vacuum cleaner.

Section VIII-Control Measures

Respiratory Protection (Specify Type): None when handling finished item.
Ventilation: N/A **Local Exhaust:** N/A
Mechanical (General): N/A **Special:** N/A
Other: N/A
Protective Gloves: None required
Eye Protection: Safety Glasses for pyrotechnic operation
Other Protective Clothing and Equipment: N/A
Work/Hygienic Practices: No smoking in vicinity of item. Keep away from food. Wash hands thoroughly before eating or smoking.

All Pyrotechnics should be used and handled with extreme caution, in accordance with all relevant regulations and codes only by experienced professional pyrotechnicians

Material Safety Data Sheet

Material Name: 700 Series Board **MSDS No.: 15-MSD- 17020-01-N**

* * * Section 1 - Chemical Product and Company Identification * * *

Product Name(s): 700 Series Board, AF 220, AF 500 Series, AT-400 Series, Equipment & Appliance, Fabrication Board, Fiberglass Basic for Molding, FLEXWRAP®, Insul-Quick®, Jet-Cel Acoustical, Muffler Packing, NuKon® insulation blankets, Pipe & Tank Insulation, Railroad, SCR Board, SelectSound® Sanded Acoustical Board, SR & HT Range, TIW Thermal Insulation Wool, Transportation, Type 1000.

Owens Corning
One Owens Corning Parkway, World Headquarters
Attn. Product Stewardship
Toledo, OH 43659, USA

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): 1-800-GET-PINK,
Technical Product Information (8am-5pm ET): 1-800-GET-PINK.

* * * Section 2 - Composition / Information on Ingredients * * *

CAS #	Component	Percent by Wt.
65997-17-3	Fiber Glass Wool (Fibrous Glass)	85-96
25104-55-6	Urea, polymer with formaldehyde and phenol	4-15

Component Related Regulatory Information
This product may be regulated, have exposure limits or other information identified as the following: Fiber Glass wool, Fibrous glass, Nuisance particulates.

Component Information/Information on Non-Hazardous Components
No additional information available.

* * * Section 3 - Hazards Identification * * *

Appearance and Odor:
Pink, yellow, or tan fibrous material with faint resin odor.
Some products have a vinyl, brown paper, foil or polypropylene facing.

Emergency Overview
Acrid smoke may be generated in a fire.
High temperature applications may release significant airborne concentrations of thermal decomposition products such as ammonia, formaldehyde and carbon monoxide, especially in enclosed or poorly ventilated areas during the first high temperature cycle.

Potential Health Effects

Inhalation:
Dusts and fibers from this product may cause mechanical irritation of the nose, throat, and respiratory tract.

Skin Contact:
Dusts and fibers from this product may cause temporary mechanical irritation to the skin.

Eye Contact:
Dusts and fibers from this product may cause temporary mechanical irritation to the eyes.

Ingestion:
Ingestion of this product is unlikely.
However, ingestion of product may produce gastrointestinal irritation and disturbances.

Medical Conditions Aggravated by Exposure:
Chronic respiratory or skin conditions may temporarily worsen from exposure to these products.

* * * Section 4 - First Aid Measures * * *

Inhalation:
If inhaled, remove the affected person to fresh air.
If irritation persists get medical attention.

Skin Contact:
For skin contact, wash with mild soap and running water.
Use a washcloth to help remove fibers.
To avoid further irritation, do not rub or scratch affected areas.
Rubbing or scratching may force fibers into the skin.
If irritation persists get medical attention.

Never use compressed air to remove fibers from the skin.
If fibers are seen penetrating from the skin, the fibers can be removed by applying and removing adhesive tape so that the fibers adhere to the tape and are pulled out of the skin.

Eye Contact:
Immediately flush eyes with plenty of running water for at least 15 minutes.
If irritation persists get medical attention.

Ingestion:
Ingestion of this material is unlikely.
If it does occur, watch the person for several days to make sure that partial or complete intestinal obstruction does not occur.
Do not induce vomiting unless directed to do so by medical personnel.

* * * Section 5 - Fire Fighting Measures * * *

Flash Point:	None	**Flash Point Method:**	Not applicable
Upper Flammability Limit:	Not applicable	**Lower Flammability Limit:**	Not applicable
Flammability Classification:	Non-flammable		

Extinguishing Media:
Dry chemical, foam, carbon dioxide, water fog.

Unusual Fire & Explosion Hazards:
These products may release acrid smoke in a sustained fire.

Fire-Fighting Instructions:
Use self-contained breathing apparatus (SCBA) and protective clothing as recommended by NFPA 1500.

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

* * * Section 6 - Accidental Release Measures * * *

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

Clean-Up Procedures:
Scoop up material and put into a suitable container for disposal as a non-hazardous waste.

Response Procedures:
Isolate area.
Keep unnecessary personnel away.

Special Procedures:
None.

* * * Section 7 - Handling and Storage * * *

Handling Procedures:
Keep product in its packaging, as long as practicable to minimize potential dust generation.
Keep work areas clean.
Avoid unnecessary handling of scrap materials.

Storage Procedures:
Material should be kept dry and undercover.

* * * Section 8 - Exposure Controls / Personal Protection * * *

Exposure Guidelines:
A: General Product Information
Follow all applicable exposure limits.

B: Component Exposure Limits
ACGIH and OSHA exposure limit lists have been checked for those components with CAS registry numbers.
Fiber Glass Wool (Fibrous Glass) (65997-17-3)
ACGIH: 1 f/cc TWA for respirable fibers longer than 5 um with a diameter less than 3 um;
(Listed under "Synthetic vitreous fibers") (related to Glass wool fibers)

OSHA: 1 fiber/cc (respirable) TWA (a) (See Note Below) (related to Glass wool fiber)

Formaldehyde (50-00-0)

ACGIH: 0.3 ppm Ceiling

OSHA: 2 ppm STEL
0.75 ppm TWA

Ammonia (7664-41-7)
ACGIH: 35 ppm STEL
25 ppm TWA

OSHA: 50 ppm TWA

Carbon Monoxide (630-08-0)
ACGIH: 25 ppm TWA

OSHA: 50 ppm TWA

Notes: (a) Voluntary PEL was established by the North American Manufactures Association (NAIMA) and OSHA per the Health and Safety Partnership Program (HSPP) agreement for Synthetic Vitreous Fibers (SVF).

Ventilation:

General dilution ventilation and/or local exhaust ventilation should be provided as necessary to maintain exposures below regulatory limits.
Dust collection systems should be used in operations involving cutting or machining and may be required in operations using power tools.

PERSONAL PROTECTIVE EQUIPMENT
Respiratory Protection:

Fiber Glass Wool: If thermal decomposition products are not anticipated, a properly fitted NIOSH or MSHA approved N 95 series disposable dust respirator or equivalent should be used.

Hot Use Applications: When the temperature of the surface being insulated **exceeds** 250ºF (121ºC), including initial system startup, the binder in these products may undergo various degrees of decomposition depending on the temperature of the application. The need for respiratory protection will vary according to the airborne concentration of the decomposition products released and accumulated in the area.

If the insulation is installed on hot surfaces above 250ºF (121ºC), but below 650ºF (343ºC), a full-face respirator with cartridges approved for protection against organic vapors (or formaldehyde if available) should be used. In areas with good general and/or local exhaust ventilation where exposures are controlled below the formaldehyde, carbon monoxide, and ammonia PEL or STEL, and additive effects have been factored in, then respiratory protection is normally not needed.

Formaldehyde: In some high temperature applications these products may initially release concentrations of formaldehyde equal to or greater than 0.1 ppm, but less than 0.5 ppm. Airborne concentrations should be assessed to determine the appropriate type of respiratory protection to be used. When in doubt, use supplied air respiratory protection.

Ammonia: Significant quantities of ammonia may be released initially in high temperature applications. Ammonia has good warning properties and any respirator wearer experiencing irritation while wearing an air-purifying respirator should leave the area.

Simultaneous respiratory protection against formaldehyde and ammonia requires use of a supplied air system. A careful assessment of the workplace environment should be made to determine the appropriate respiratory protection required. If air-purifying respirator is used for ammonia protection, it should be full face with cartridges approved for ammonia.

Carbon Monoxide: Respiratory protection generally requires a supplied air system. Carbon monoxide has poor warning properties.

Use respiratory protection in accordance with respirator manufacturer's instructions and in accordance with your company's respiratory protection program, local regulations and OSHA regulations under 29 CFR 1910.134.

Skin Protection:

Normal work clothing (long sleeved shirt, long pants, and gloves) is recommended. Skin irritation is known to occur chiefly at the pressure points such as around the neck, wrists, waist and between the fingers.

Eyes/Face Protective Equipment:

Wear safety glasses, goggles or face shield.

* * * Section 9 - Physical & Chemical Properties * * *

Appearance:	Fibrous	**Odor:**	Organic
Physical State:	Solid	**pH:**	Not applicable
Vapor Pressure (mm Hg @ 20 C):	Not applicable	**Vapor Density (Air=1):**	Not applicable
Boiling Point:	Not applicable	**Solubility (H2O):**	Insoluble
Specific Gravity (Water=1):	Not applicable	**Freezing Point:**	Not applicable
Evaporation Rate (n-Butyl Acetate=1):	Not applicable	**Viscosity:**	Not applicable

Physical Properties: Additional Information

No additional information available.

* * * Section 10 - Chemical Stability & Reactivity Information * * *

Stability:

This is a stable material.

Conditions to Avoid:

None expected.

Incompatible Materials:

None expected.

Hazardous Decomposition Products:

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

Hazardous Polymerization:

Will not occur.

* * * Section 11 - Toxicological Information * * *

Acute and Chronic Toxicity:

A: General Product Information

Dusts may cause mechanical irritation to eyes and skin. Ingestion may cause transient irritation of throat, stomach and gastrointestinal tract. Inhalation may cause coughing, nose and throat irritation, and sneezing. Higher exposures may cause difficulty breathing, congestion, and chest tightness.

If this product is subject to high temperature processing, or if product is applied to hot surfaces, formaldehyde gas may be released. Ammonia gas and carbon monoxide may also be released. Formaldehyde may irritate or burn the skin and eyes. Formaldehyde is a lung sensitizer, causing an asthma-like allergy. Future exposures may cause allergic attacks with shortness of breath, wheezing, coughing and chest tightness. Repeated exposure may cause bronchitis. Formaldehyde may cause allergic skin sensitization reactions. Ammonia gas can cause respiratory tract and eye irritation. Breathing carbon monoxide can cause headaches, nausea, dizziness and can be fatal at high concentrations.

B: Component Analysis - LD50/LC50

Urea, polymer with formaldehyde and phenol (25104-55-6)
Oral LD50 Rat: 7 gm/kg
Oral LD50 Mouse: 7 gm/kg

C: Component Analysis - LD50/LC50 For Chemicals Which May Be Released During Use

Ammonia (7664-41-7)
Inhalation LC50 Rat: 2000 ppm/4H
Inhalation LC50 Mouse: 4230 ppm/1H

Carbon monoxide (630-08-0)
Inhalation LC50 Rat: 1807 ppm/4H
Inhalation LC50 Mouse: 2444 ppm/4H

Formaldehyde (50-00-0)
Inhalation LC50 Mouse: 454 mg/m3/4h
Oral LD50 Rat: 100 mg/kg
Dermal LD50 Rabbit: 270 uL/kg

Fiber Glass Wool: In October 2001, the International Agency for Research on Cancer (IARC) classified fiber glass wool as Group 3, “not classifiable as to its carcinogenicity to humans.” The 2001 decision was based on human studies and animal research that have not shown an association between inhalation exposure to dust from fiber glass wool and the development of respiratory disease. This classification replaces the IARC finding in 1987 of a Group B designation “possibly carcinogenic to humans.”

In May 1997, the American Conference of Governmental Industrial Hygienists (ACGIH) adopted an A3 carcinogen classification for glass wool fibers. The ACGIH A3 classification considers glass wool to be carcinogenic in experimental animals at relatively high doses, by routes of administration, at sites, or by mechanisms that it does not consider relevant to worker exposure. It also reviewed the available epidemiological studies and concluded that they do not confirm an increased risk of cancer in exposed humans. Overall, the ACGIH found that the available medical/scientific evidence suggests that glass wool is not likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure.

In 1994, the National Toxicology Program (NTP) classified glass wool (respirable size) as “reasonably anticipated to be a human carcinogen.” This classification was primarily based upon the 1987 IARC classification. NTP is currently considering reclassifying this material.

__Formaldehyde__

Formaldehyde (Vol. 88, 2-9 June 2004)

The International Agency for Research on Cancer (IARC) convened a working group of twenty-six scientists from ten countries in June 2004 to assess the carcinogenic hazard to humans of formaldehyde. The proceedings of that meeting have not yet been published. Based upon a press released issued by IARC, the Working Group concluded that there is sufficient evidence in humans that formaldehyde causes nasopharyngeal cancer, a rare tumor. The Working Group also concluded that there is “strong but not sufficient evidence for a causal association between leukemia and occupational exposure to formaldehyde”. These findings where based on studies of workers in industries with long term exposures at levels greatly in excess of those typically associated with fiber glass insulation

Overall, the Working Group concluded that formaldehyde is *carcinogenic to humans (Group 1)*, on the basis of *sufficient evidence* in humans and *sufficient evidence* in experimental animals—a higher classification than previous IARC evaluations.

Carcinogenicity:

A: General Product Information

No information available for the product.

B: Component Carcinogenicity

ACGIH, IARC, OSHA, and NTP carcinogen lists have been checked for those components with CAS registry numbers.

Fiber Glass Wool (Fibrous Glass) (65997-17-3)

IARC: Group 3 “not classifiable as to its carcinogenicity to humans” (related to Glasswool) October 2001 Meeting
ACGIH: A3 - animal carcinogen (related to Glass wool fibers)
NTP: Reasonably anticipated to be a human carcinogen (related to glasswool)

Formaldehyde (50-00-0)

IARC: Group 1 “carcinogens to humans” 2004 Meeting
ACGIH: A2 - suspected carcinogen
NTP: Reasonably anticipated to be a human carcinogen

* * * Section 12 - Ecological Information * * *

No data available for this product. This material is not expected to cause harm to animals, plants or fish.

* * * Section 13 - Disposal Considerations * * *

US EPA Waste Number & Descriptions:

A: General Product Information

This product, if discarded, is not expected to be a characteristic hazardous waste under RCRA.

B: Component Waste Numbers

No EPA Waste Numbers are applicable for this product's components.

Disposal Instructions:

Dispose of waste material according to Local, State, Federal, and Provincial Environmental Regulations.

* * * Section 14 - Transportation Information * * *

US DOT Information

Shipping Name: Not regulated for transport.
Hazard Class: None
UN/NA #: None
Packing Group: None
Required Label(s): None

TDG Information

Shipping Name: Not regulated for transport.
Hazard Class: None
UN/NA #: None
Packing Group: None
Required Label(s): None
Additional Info: None

Additional Transportation Regulations:

No additional information available.

* * * Section 15 - Regulatory Information * * *

US Federal Regulations:
A: General Product Information

No additional information available.

B: Component Analysis

This material contains one or more of the following chemicals required to be identified under SARA Section 302 (40 CFR 355 Appendix A), SARA Section 313 (40 CFR 372.65) and/or CERCLA (40 CFR 302.4).
None

The following is provided to aide in the preparation of SARA Section 311 and 312 reports.

SARA 311/312	
Acute Health Hazard:	Yes
Chronic Health Hazard:	Yes
Fire Hazard:	No
Sudden Release of Pressure Hazard:	No
Reactive Hazard:	No

C: Clean Air Act

The following components appear on the Clean Air Act-1990 Hazardous Air Pollutants List:
None

State Regulations:
A: General Product Information

No additional information available.

B: Component Analysis - State

The following components appear on one or more of the following state hazardous substances lists:

Component	CAS #	CA	MA	MN	NJ	PA
Fiber Glass Wool (Fibrous Glass) (related to Mineral wool fiber)	65997-17-3	Yes[1]	Yes[1]	Yes[1]	No	Yes[1]

The following statement(s) are provided under the California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65):

WARNING! This product contains a chemical known to the state of California to cause cancer.

Other Regulations:

A: General Product Information

No additional information available.

B: Component Analysis - Inventory

Component	CAS #	TSCA	DSL	EINECS
Fiber Glass Wool (Fibrous Glass)	65997-17-3	Yes	Yes	Yes
Urea, polymer with formaldehyde and phenol	25104-55-6	Yes	Yes	No

C: Component Analysis - WHMIS IDL

The following components are identified under the Canadian Hazardous Products Act Ingredient Disclosure List:

Component	CAS #	
Fiber Glass Wool (Fibrous Glass)	65997-17-3	1% item 768 (884) (related to Fibrous glass)

WHMIS Status: Not Controlled
WHMIS Classification: N/A

* * * Section 16 - Other Information * * *

HMIS and NFPA Hazard Ratings:	Category	HMIS	NFPA
	Acute Health	1	2
	Flammability	0	2 (facing, packaging)
	Reactivity	0	0

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

Reasonable care has been taken in the preparation of this information, but the manufacturer makes no warranty of merchantability or any other warranty, expressed or implied, with respect to this information. The manufacturer makes no representations and assumes no liability for any direct, incidental or consequential damages resulting from its use.

Key/Legend:

EPA = Environmental Protection Agency; TSCA = Toxic Substance Control Act; ACGIH = American Conference of Governmental Industrial Hygienists; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; OSHA = Occupational Safety and Health Administration; NFPA = National Fire Protection Association; HMIS = Hazardous Material Identification System; CERCLA = Comprehensive Environmental Response, Compensation and Liability Act; SARA = Superfund Amendments and Reauthorization Act; DSL = Canadian Domestic Substance List; EINECS = European Inventory of New and Existing Chemical Substances; WHMIS = Workplace Hazardous Materials Information System; CAA = Clean Air Act

Revision Summary:

This is a revised MSDS, which replaces 15-MSD-17020-01-M with the addition of formaldehyde information in sections 8, 11 and 15. Please review the MSDS carefully.

Get OC MSDS electronically via Internet: http://www.owenscorning.com or by calling 1-800-GET-PINK.

NuKon is a registered trademark of Performance Contracting Inc.

This is the end of 15-MSD-17020-01-N

MATERIAL SAFETY DATA SHEET

ProFire Igniter

1.0 PRODUCT / COMPANY IDENTIFICATION

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

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

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

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Overdip composition

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

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

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

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

Potential Health Effects:

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

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

Ingestion:
Not a likely route of exposure.

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

4.0 FIRST AID MEASURES

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

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

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

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

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

5.0 FIRE FIGHTING MEASURES

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

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

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

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

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

6.0 ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

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

7.0 HANDLING AND STORAGE

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

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

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

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

Personal Protective Equipment:

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

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

Clothing:

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

Respirators:

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

9.0 PHYSICAL AND CHEMICAL PROPERTIES

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

10.0 STABILITY AND REACTIVITY

Chemical Stability:
Stable under normal temperatures and pressures.

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

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

Hazardous Products Of Decomposition:
Oxides and fluorides of barium, magnesium. Chromium.

Hazardous Polymerization:
Will not occur.

11.0 TOXICOLOGICAL INFORMATION

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

Effects of Acute Exposure to Product:
No data available

Effects of Chronic Exposure to Product:
No data available

Exposure Limits:

Overdip composition

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

Irritancy of the Product:
No data available
Sensitization to the Product:
No data available
Carcinogenicity:
Not listed by IARC, NTP, or OSHA
Reproductive Toxicity:
No data available
Teratogenicity:
No data available
Mutagenicity:
No data available
Toxically Synergistic Products:
No data available
LD50:
No data available

12.0 ECOLOGICAL INFORMATION

Environmental Data:
Ecotoxicity Data:
Not determined.
EcoFaTE Data:
Not determined.

13.0 DISPOSAL CONSIDERATIONS

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

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

14.0 TRANSPORT INFORMATION

Shipping Information – Canada

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

Shipping Information - USA / IATA / IMO

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

15.0 REGULATORY INFORMATION

Canada

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

WHMIS Classification: Not Controlled (explosive)

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

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

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

United States of America

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

Hazardous Chemical Lists

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

European/International Regulations

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

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

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

Safety Phrases:

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

16.0 OTHER INFORMATION

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

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

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

Material Safety Data Sheet

Revision Number: 001.0 **Issue date:** 09/17/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name: **Loctite Instant Mix Epoxy Part A**
Product type: Epoxy resin

IDH number: 1071291

Region: United States

Company address:
Henkel Corporation
One Henkel Way
Rocky Hill, Connecticut 06067

Contact information:
Telephone: 860.571.5100
Emergency telephone: 860.571.5100MEDICAL EMERGENCY
Phone: Poison Control Center
1-877-671-4608 (toll free) or 1-303-592-1711
TRANSPORT EMERGENCY Phone: CHEMTREC
1-800-424-9300 (toll free) or 1-703-527-3887
Internet: www.henkelna.com

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

HMIS:

Physical state:	viscous, liquid	**HEALTH:**	2
Color:	clear	**FLAMMABILITY:**	1
Odor:	None	**PHYSICAL HAZARD:**	0
		Personal Protection:	See MSDS Section 8

WARNING: MAY CAUSE ALLERGIC SKIN REACTION.
MAY CAUSE EYE, SKIN AND RESPIRATORY TRACT IRRITATION.

Relevant routes of exposure: Skin, Inhalation, Eyes

Potential Health Effects

Inhalation: Mild respiratory tract irritation.
Skin contact: Allergic skin reaction. Moderate skin irritation. Itching. Redness.
Eye contact: Moderate eye irritation. Redness.
Ingestion: Not expected under normal conditions of use.

Existing conditions aggravated by exposure: Skin disorders. Skin allergies.

This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous components	CAS NUMBER	%
Epichlorohydrin-4,4'-isopropylidene diphenol resin	25068-38-6	60 - 100

4. FIRST AID MEASURES

Inhalation: Move to fresh air. If symptoms develop and persist, get medical attention.

Skin contact: Immediately flush skin with plenty of water (using soap, if available). Remove contaminated clothing and footwear. If symptoms develop and persist, get medical attention.

Eye contact: Immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention.

Ingestion: Keep individual calm. DO NOT induce vomiting unless directed to do so by medical personnel. If symptoms develop and persist, get medical attention.

5. FIRE FIGHTING MEASURES

Flash point: > 150 °C (> 302°F) Supplier method

Autoignition temperature: Not available.

Flammable/Explosive limits - lower: Not available.

Flammable/Explosive limits - upper: Not available.

Extinguishing media: Foam, dry chemical or carbon dioxide.

Special firefighting procedures: Wear self-contained breathing apparatus and full protective clothing, such as turn-out gear.

Unusual fire or explosion hazards: In case of fire, keep containers cool with water spray. Closed containers may rupture (due to build up of pressure) when exposed to extreme heat.

Hazardous combustion products: Oxides of carbon. Irritating organic fragments.

6. ACCIDENTAL RELEASE MEASURES

Use personal protection recommended in Section 8, isolate the hazard area and deny entry to unnecessary and unprotected personnel.

Environmental precautions: Do not allow product to enter sewer or waterways.

Clean-up methods: Remove all sources of ignition. Immediately contact emergency personnel. Scrape up as much material as possible. Clean residue with soap and water. Store in a partly filled, closed container until disposal.

7. HANDLING AND STORAGE

Handling: Do not breathe gas/fumes/vapor/spray. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling. Keep container closed.

Storage: Store in original container until ready to use. Keep in a cool, well ventilated area away from heat, sparks and open flame. Keep container tightly closed until ready for use.

For information on product shelf life, please review labels on container or check the Technical Data Sheet.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Employers should complete an assessment of all workplaces to determine the need for, and selection of, proper exposure controls and protective equipment for each task performed.

Hazardous components	ACGIH TLV	OSHA PEL	AIHA WEEL	OTHER
Epichlorohydrin-4,4'-isopropylidene diphenol resin	None	None	None	None

Engineering controls: Provide adequate local exhaust ventilation to maintain worker exposure below exposure limits.

Respiratory protection: Use a NIOSH approved air-purifying respirator if the potential to exceed established exposure limits exists.

Eye/face protection: Safety goggles or safety glasses with side shields.

Skin protection: Chemical resistant, impermeable gloves.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	viscous, liquid
Color:	clear
Odor:	None
Odor threshold:	Not available.
pH:	Not applicable
Vapor pressure:	< 0.13 kPa (180 °C (356°F)) Supplier method
Boiling point/range:	> 260.2 °C (> 500.4 °F) > 149 °C (> 300.2 °F)
Melting point/ range:	Not available.
Specific gravity:	1.04
Vapor density:	Not available.
Flash point:	> 150 °C (> 302°F) Supplier method
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Autoignition temperature:	Not available.
Evaporation rate:	Not available.
Solubility in water:	low solubility
Partition coefficient (n-octanol/water):	Not available.
VOC content:	0.1 % (value for resin and hardener together)

10. STABILITY AND REACTIVITY

Stability: Stable

Hazardous reactions: Will not occur.

Hazardous decomposition products: None

Incompatible materials: Strong acids. Strong oxidizing agents. Halogenated compounds. Strong mineral acids. Reactive metals. Sodium hypochlorite. Calcium hypochlorite. Nitrous acid and other nitrosating agents.

Conditions to avoid: Excessive heat. Store away from incompatible materials.

11. TOXICOLOGICAL INFORMATION

Hazardous components	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen (Specifically Regulated)
Epichlorohydrin-4,4'-isopropylidene diphenol resin	No	No	No

Hazardous components	Health Effects/Target Organs
Epichlorohydrin-4,4'-isopropylidene diphenol resin	Allergen, Irritant

12. ECOLOGICAL INFORMATION

Ecological information: Not available.

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

Recommended method of disposal:	Follow all local, state, federal and provincial regulations for disposal.
Hazardous waste number:	It is the responsibility of the user to determine if an item is hazardous as defined in the Resource Conservation and Recovery Act (RCRA) at the time of disposal. Product uses, transformations, mixtures, processes, etc., may render the resulting material hazardous, under the criteria of ignitability, corrosivity, reactivity and toxicity characteristics of the Toxicity Characteristics Leaching Procedure (TCLP) 40 CFR 261.20-24.

14. TRANSPORT INFORMATION

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

Proper shipping name:	Not regulated
Hazard class or division:	None
Identification number:	None
Packing group:	None

International Air Transportation (ICAO/IATA)

Proper shipping name:	Environmentally hazardous substance, liquid, n.o.s. (Bisphenol-A Epichlorhydrin resin)
Hazard class or division:	9
Identification number:	UN 3082
Packing group:	III

Water Transportation (IMO/IMDG)

Proper shipping name:	ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S. (Bisphenol-A Epichlorhydrin resin)
Hazard class or division:	9
Identification number:	UN 3082
Packing group:	III

15. REGULATORY INFORMATION

United States Regulatory Information

TSCA 8 (b) Inventory Status:	All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.
TSCA 12(b) Export Notification:	None above reporting de minimus
CERCLA/SARA Section 302 EHS:	None above reporting de minimis
CERCLA/SARA Section 311/312:	Immediate Health, Delayed Health
CERCLA/SARA 313:	None above reporting de minimis
California Proposition 65:	This product contains a chemical known in the State of California to cause cancer. This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

Canada Regulatory Information

CEPA DSL/NDSL Status:	All components are listed on or are exempt from listing on the Canadian Domestic Substances List.
WHMIS hazard class:	D.2.A, D.2.B, E

16. OTHER INFORMATION

This material safety data sheet contains changes from the previous version in sections: New Material Safety Data Sheet format.

Prepared by: Donna Houston, Regulatory Affairs Specialist

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Material Safety Data Sheet

Revision Number: 001.0 **Issue date:** 09/17/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name: **Loctite Instant Mix Epoxy Part B**
Product type: Not available.

IDH number: 1071250

Region: United States

Company address:
Henkel Corporation
One Henkel Way
Rocky Hill, Connecticut 06067

Contact information:
Telephone: 860.571.5100
MEDICAL EMERGENCY Phone: Poison Control Center
1-877-671-4608 (toll free) or 1-303-592-1711
TRANSPORT EMERGENCY Phone: CHEMTREC
1-800-424-9300 (toll free) or 1-703-527-3887
Internet: www.henkelna.com

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Physical state:	liquid	**HMIS:**	
		HEALTH:	*3
Color:	opaque	**FLAMMABILITY:**	1
Odor:	amine-like	**PHYSICAL HAZARD:**	1
		Personal Protection:	See MSDS Section 8

DANGER: CAUSES EYE, SKIN AND RESPIRATORY TRACT BURNS.
MAY CAUSE ALLERGIC SKIN AND RESPIRATORY REACTION.
MAY BE HARMFUL IF SWALLOWED OR ABSORBED THROUGH SKIN.

Relevant routes of exposure: Skin, Inhalation, Eyes, Ingestion

Potential Health Effects

Inhalation: Allergic respiratory reaction. May cause respiratory tract irritation. May cause irritation to nose and throat. Lung damage. Respiratory tract burns.

Skin contact: May cause skin burns. Allergic skin reaction. Harmful if absorbed through skin. Rash. Redness. Tissue damage.

Eye contact: Burns. Severe eye irritation. Redness. Tissue damage.

Ingestion: May be harmful if swallowed. May cause burns of mouth and throat if swallowed.

Existing conditions aggravated by exposure: Skin disorders. Skin allergies. Respiratory disorders. Eye disorders. Asthma.

This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous components	CAS NUMBER	%
1,3-bis[3-(dimethylamino)propyl]urea	52338-87-1	10 - 30
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptop	72244-98-5	60 - 100

4. FIRST AID MEASURES

Inhalation:	Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. Get medical attention.
Skin contact:	Remove contaminated clothing and footwear. Immediately flush skin with plenty of water (using soap, if available). Thoroughly clean shoes before reuse. Wash clothing before reuse. If symptoms develop and persist, get medical attention.
Eye contact:	Immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention.
Ingestion:	DO NOT induce vomiting unless directed to do so by medical personnel. Keep individual calm. Get immediate medical attention.

5. FIRE FIGHTING MEASURES

Flash point:	257 °C (494.6 °F) Supplier method
Autoignition temperature:	Not available.
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Extinguishing media:	Water spray (fog), foam, dry chemical or carbon dioxide.
Special firefighting procedures:	Wear self-contained breathing apparatus and full protective clothing, such as turn-out gear.
Unusual fire or explosion hazards:	In case of fire, keep containers cool with water spray.
Hazardous combustion products:	Oxides of carbon. Oxides of nitrogen. Ammonia. Amines. Nitric acid. Nitrosamines. Irritating organic fragments.

6. ACCIDENTAL RELEASE MEASURES

Use personal protection recommended in Section 8, isolate the hazard area and deny entry to unnecessary and unprotected personnel.

Environmental precautions:	Do not allow product to enter sewer or waterways.
Clean-up methods:	Remove all sources of ignition. Immediately contact emergency personnel. Scrape up as much material as possible. Clean residue with soap and water. Store in a partly filled, closed container until disposal.

7. HANDLING AND STORAGE

Handling:	Keep away from heat, spark and flame. Do not breathe gas/fumes/vapor/spray. Avoid contact with eyes, skin and clothing. Keep container closed. Wash thoroughly after handling.
Storage:	Store in original container until ready to use. Keep in a cool, well ventilated area away from heat, sparks and open flame. Keep container tightly closed until ready for use.

For information on product shelf life, please review labels on container or check the Technical Data Sheet.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Employers should complete an assessment of all workplaces to determine the need for, and selection of, proper exposure controls and protective equipment for each task performed.

Hazardous components	ACGIH TLV	OSHA PEL	AIHA WEEL	OTHER
1,3-bis[3-(dimethylamino)propyl]urea	None	None	None	None
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptop	None	None	None	None

Engineering controls: Use local exhaust ventilation if the potential for airborne exposure exists.

Respiratory protection: Use a NIOSH approved air-purifying respirator if the potential to exceed established exposure limits exists.

Eye/face protection: Safety goggles or safety glasses with side shields.

Skin protection: Use chemical resistant, impermeable clothing including gloves and either an apron or body suit to prevent skin contact.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	liquid
Color:	opaque
Odor:	amine-like
Odor threshold:	Not available.
pH:	Not available.
Vapor pressure:	Not available.
Boiling point/range:	> 149 °C (> 300.2 °F)
Melting point/ range:	Not available.
Specific gravity:	1.1000
Vapor density:	Not available.
Flash point:	257 °C (494.6 °F) Supplier method
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Autoignition temperature:	Not available.
Evaporation rate:	Not available.
Solubility in water:	Dispersible
Partition coefficient (n-octanol/water):	Not available.
VOC content:	0.1 % (value for resin and hardener together)

10. STABILITY AND REACTIVITY

Stability: Stable

Hazardous reactions: Will not occur.

Hazardous decomposition products: None

Incompatible materials: Strong acids. Strong oxidizing agents. Halogenated compounds. Strong mineral acids. Reactive metals. Sodium hypochlorite. Calcium hypochlorite. Nitrous acid and other nitrosating agents.

Conditions to avoid: Excessive heat. Store away from incompatible materials.

11. TOXICOLOGICAL INFORMATION

Hazardous components	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen (Specifically Regulated)
1,3-bis[3-(dimethylamino)propyl]urea	No	No	No
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptop	No	No	No

Hazardous components	Health Effects/Target Organs
1,3-bis[3-(dimethylamino)propyl]urea	No Target Organs
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptop	No Records

12. ECOLOGICAL INFORMATION

Ecological information: Not available.

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

Recommended method of disposal: Follow all local, state, federal and provincial regulations for disposal.

Hazardous waste number: It is the responsibility of the user to determine if an item is hazardous as defined in the Resource Conservation and Recovery Act (RCRA) at the time of disposal. Product uses, transformations, mixtures, processes, etc., may render the resulting material hazardous, under the criteria of ignitability, corrosivity, reactivity and toxicity characteristics of the Toxicity Characteristics Leaching Procedure (TCLP) 40 CFR 261.20-24.

14. TRANSPORT INFORMATION

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

Proper shipping name: Not regulated
Hazard class or division: None
Identification number: None
Packing group: None

International Air Transportation (ICAO/IATA)

Proper shipping name: Not regulated
Hazard class or division: None
Identification number: None
Packing group: None

Water Transportation (IMO/IMDG)

Proper shipping name: Not regulated
Hazard class or division: None
Identification number: None
Packing group: None

15. REGULATORY INFORMATION

United States Regulatory Information

TSCA 8 (b) Inventory Status: All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.
TSCA 12(b) Export Notification: None above reporting de minimus

CERCLA/SARA Section 302 EHS: None above reporting de minimis
CERCLA/SARA Section 311/312: Immediate Health, Delayed Health
CERCLA/SARA 313: None above reporting de minimis

California Proposition 65: No California Proposition 65 listed chemicals are known to be present.

Canada Regulatory Information

CEPA DSL/NDSL Status: All components are listed on or are exempt from listing on the Canadian Domestic Substances List.
WHMIS hazard class: D.2.A, D.2.B, E

16. OTHER INFORMATION

This material safety data sheet contains changes from the previous version in sections: New Material Safety Data Sheet format.

Prepared by: Donna Houston, Regulatory Affairs Specialist

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MATERIAL SAFETY DATA SHEET

==

ProX Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: Pro24, 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: P24R-Y-#G-XX, P29R-Y-#G-XX, P38R-Y-#G-XX, P54R-Y-#G-XX, P24R-Y-#GXL-XX, P29R-Y-#GXL-XX, P38R-Y-#GXL-XX, P54R-Y-#GXL-XX,
Propellant grains: P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX
Where: Y = reload type (A = adjustable delay, C = C-slot)
# = number of grains &
XX = propellant type

Product Use: Solid fuel motor for propelling rockets

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

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

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Propellant

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

Black Powder Ignition pellet

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

3.0 HAZARDS IDENTIFICATION

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

General Appearance:

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

Potential Health Effects:

Eye:

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

Skin:

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

Ingestion:

Not a likely route of exposure.

Inhalation:

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

4.0 FIRST AID MEASURES

Eyes:

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

Skin:

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

Ingestion:

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

Inhalation:

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

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

5.0 FIRE FIGHTING MEASURES

Extinguishing Media:

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

Exposure Hazards During Fire:

Exposure to extreme heat may cause ignition.

Combustion Products from Fire:

During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Fire Fighting Procedures:

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

Special Instructions / Notes:

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

6.0 ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

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

7.0 HANDLING AND STORAGE

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

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

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

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

Personal Protective Equipment:

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

Skin:
Clothing should be appropriate for handling pyrotechnic substances.

Clothing:
Clothing should be appropriate for handling pyrotechnic substances.

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

9.0 PHYSICAL AND CHEMICAL PROPERTIES

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

10.0 STABILITY AND REACTIVITY

Chemical Stability:
Stable under normal temperatures and pressures.

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

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

Hazardous Products Of Decomposition:
Oxides of nitrogen

Hazardous Polymerization:
Will not occur.

11.0 TOXICOLOGICAL INFORMATION

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

Effects of Acute Exposure to Product:
No data available

Effects of Chronic Exposure to Product:
No data available

Exposure Limits:

Black Powder Pellets

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

Propellant

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

Irritancy of the Product:
No data available

Sensitization to the Product:
No data available

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

Reproductive Toxicity:
No data available

Teratogenicity:
No data available

Mutagenicity:
No data available

Toxically Synergistic Products:
No data available

LD50:
No data available

12.0 ECOLOGICAL INFORMATION

Environmental Data:

Ecotoxicity Data:
Not determined.

EcoFaTE Data:
Not determined.

13.0 DISPOSAL CONSIDERATIONS

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

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

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

14.0 TRANSPORT INFORMATION

Shipping Information – Canada

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

Shipping Information - USA / IMO

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

Shipping Information - IATA

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

15.0 REGULATORY INFORMATION

Canada

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

WHMIS Classification: Not Controlled (explosive)

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

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

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

United States of America

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

Hazardous Chemical Lists

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

European/International Regulations

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

European Labelling in Accordance with EC Directives
Hazard Symbols: Explosive.
Risk Phrases:
- **R 2** Risk of explosion by shock, friction, fire or other sources of ignition.
- **R 11** Highly flammable
- **R 44** Risk of explosion if heated under confinement.

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

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

16.0 OTHER INFORMATION

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

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

HEXCEL

Material Safety Data Sheet

Section 1: PRODUCT AND COMPANY IDENTIFICATION

MSDS Identification: Carbon Fabric, Sized or Unsized
MSDS Number: 439-3227-00SU-C000-12 **Date:** October 1, 2002
Supersedes MSDS: 439-3227-00SU-C000-11

Manufacturer:
Hexcel Schwebel
2200 South Murray Avenue
P.O. Box 2627
Anderson, SC 29621

Emergency Telephone Number:
800-433-5072 (24-Hour)

Information Telephone Number:
864-260-5799 (Normal Business Hours-ET)

Product Identification: Carbon Fabric: Sized or Unsized

Chemical Family: Woven Carbon Fabric with various types of Sized and Unsized Carbon Fibers.

Section 2: COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS® Number	% by Weight	OSHA(PEL)	ACGIH®(TLV®)
Carbon fiber, synthetic	7440-44-0	98.5-100	15 mg/m^3(Total) 5 mg/m^3(Respirable)	10 mg/m^3(Total) 3 mg/m^3(Respirable)

This product is not classified as a Hazardous Chemical as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

Where specific exposure limits for component dusts are not established, the levels provided for (Total/Inhalable) dust and (Respirable) fraction reflect the classification of Particulates Not Otherwise Regulated (PNOR) by OSHA or Specified (PNOS) by ACGIH®.

Section 3: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:
Appearance and Odor:
Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.

Statement of Hazard:
Warning! May cause temporary mechanical irritation of the eyes, skin or upper respiratory tract.

If sized, vapor or fumes generated from heating or curing this product may cause eye and respiratory tract irritation.

Carbon fibers or dust are electrically conductive and may create electrical short-circuits which could result in damage to and malfunction of electrical equipment and/or personal injury.

Section 3: HAZARDS IDENTIFICATION (Continued)

EMERGENCY OVERVIEW (continued):

Primary Routes of Exposure:

Eye--Yes Skin--Yes Inhalation--Yes Ingestion--No

HMIS® Rating:

Health--1 Flammability--0 Reactivity--0 Special--None

Potential Health Effects:

Eye: Contact may cause mechanical irritation to the eyes. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the eyes. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Skin: Contact may cause mechanical irritation to the skin and possible dermatitis. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Inhalation: May cause mechanical irritation to the upper respiratory tract. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the respiratory tract. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Ingestion: Ingestion unlikely under normal conditions of use. If any of this product or the cured product dust is swallowed, seek medical attention immediately.

Medical Conditions Aggravated by Exposure: Preexisting eye, skin or respiratory disorders may be aggravated by exposure to this product or to the dust from machining, grinding or sawing the cured product.

Carcinogenic Information: None of the components present in this material at concentrations equal to or greater than 0.1 % are listed or regulated by IARC, NTP, OSHA or ACGIH® as a carcinogen.

Other:	**OSHA(PEL)**	**ACGIH®(TLV®)**
Exposure limits for cured product dust as [Particulates Not Otherwise Regulated (PNOR) by OSHA or Specified (PNOS) by ACGIH®]:	15 mg/m^3(Total) 5 mg/m^3(Respirable)	10 mg/m^3(Inhalable) 3 mg/m^3(Respirable)

Section 4: FIRST AID MEASURES

Eye: In case of eye contact, immediately flush eyes with large amounts of water for at least 15 minutes, keeping the eyelids open. Get medical attention immediately.

Skin: In case of contact that causes irritation, immediately wash skin with soap and room temperature to cool running water. Use a washcloth to help remove the fibers. To avoid further irritation, do not rub or scratch irritated areas. Rubbing or scratching may force fibers into the skin. Get medical attention immediately, if the irritation persists.

Inhalation: If large amounts of dust, fiber, fumes or vapor are inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, qualified personnel may administer oxygen. Get medical attention immediately.

Section 4: FIRST AID MEASURES (Continued)

Ingestion: Ingestion of this product or the dust from it is unlikely. If swallowed, get medical attention immediately.

Section 5: FIRE FIGHTING MEASURES

Flash Point/Method of Determination: Not determined

Means of Extinction: Use water spray, dry chemical or CO_2 to extinguish fires.

Special Fire Hazards: Avoid exposure through use of a self-contained, positive-pressure breathing apparatus.

Section 6: ACCIDENTAL RELEASE MEASURES

Procedures in case of Accidental Release or Leakage: Avoid contact with skin, eyes or clothing (See Section 8). Clean up material, put into a suitable container and dispose of properly (See Section 13).

Section 7: HANDLING AND STORAGE

Precautions to be taken in Handling and Storage: Store in a cool, dry place. Maintain sealed against contamination from dirt and moisture.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Eye/Face Protection: Avoid eye contact. Wear safety glasses with side shields, as necessary, when using this product or when machining, grinding or sawing the cured product.

Skin Protection: Protective clothing such as a loose fitting long sleeved shirt that covers to the base of the neck, long pants and gloves, as necessary to prevent irritation. Skin irritation is known to occur primarily at pressure points such as around the neck, wrist, waist and between the fingers.

Respiratory Protection: Not ordinarily required. If sized and sufficient vapor or fumes are being generated during heating or curing of this product, use a NIOSH approved organic vapor respirator. If sufficient dust or fibers are generated during use or when machining, grinding or sawing the cured product, use a NIOSH approved dust respirator.

Ventilation: Use local exhaust sufficient to control vapor, fumes, fibers or dust generated. If exhaust ventilation is not available or is inadequate, use a NIOSH approved respirator, as appropriate.

General Hygiene Recommendations: Before eating, drinking, smoking or using toilet facilities, wash face and hands thoroughly with soap and water. Remove any contaminated clothing and launder before reuse. Use vacuum equipment to remove fibers and dust from clothing and work areas. Compressed air is not recommended.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor...Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.
Melting Point ($^oF/^oC$)......................... 6512^{o}F/3600^{o}C
Specific Gravity (Water=1)................ 1.5-1.9
pH of Undiluted Product....................Not determined
Volatile [Percent (%) by Weight].......0
Percent (%) VOC...............................Not determined
Solubility in Water.............................Negligible

Section 10: STABILITY AND REACTIVITY

Stability: Stable under proper handling and storage conditions

Incompatible Materials: None

Products evolved from Heat of Combustion or Decomposition: The products of combustion and decomposition depend on other materials present in the fire and the actual conditions of the fire. Burning will decompose the sizing system, if appropriate, and produce carbon and nitrogen oxides, phenols, aldehydes, acrolein, carboxylic acid, traces of incompletely burned carbon products and other unidentified gases and vapors that may be toxic. Avoid inhalation.

Hazardous Polymerization: Will not occur under proper conditions of use. Rapid heating of the product in bulk may produce an uncontrolled exothermic reaction that may char and decompose the sizing system, if appropriate, generating unidentified gases and vapors that may be toxic. Avoid inhalation.

Section 11: TOXICOLOGICAL INFORMATION

Component Toxicity Data:
Median Lethal Dose (Species):
Oral (LD_{50})...Not determined
Inhalation (LC_{50})...Not determined
Dermal (LD_{50})...Not determined

Irritation Index, Estimation of Irritation (Species):
Skin...Not determined
Eyes...Not determined
Inhalation...Not determined

Section 12: ECOLOGICAL INFORMATION

No ecological data has been determined.

Section 13: DISPOSAL CONSIDERATIONS

Waste Disposal Methods: Material for disposal should be placed in appropriate sealed containers to avoid potential human and environmental exposure. It is the responsibility of the generator to comply with all federal, state, provincial and local laws and regulations. We recommend that you contact an appropriate waste disposal contractor and environmental agency for relevant laws and regulations. Under the U.S., Resource Conservation and Recovery Act (RCRA), it is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification.

Section 14: TRANSPORT INFORMATION

DOT:
Proper Shipping Name.... Not regulated
Hazard Class.................. Not regulated
Identification Number..... Not regulated
Packing Group............... Not regulated
Label Required...............None

Section 15: REGULATORY INFORMATION

SARA Title III:
Section 302/304 Extremely Hazardous Substance:
None

Section 311 Hazardous Categorization:
None

Section 313 Toxic Chemicals:
None

CERCLA Section 102(a) Hazardous Substance:
None

RCRA Information:
Currently, the product is not listed in federal hazardous waste regulations 40 CFR, Part 261.33, paragraphs (e) or (f), i.e. chemical products that are considered hazardous if they become wastes. State or local hazardous waste regulations may also apply if they are different from the federal regulation. It is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification and to assure proper disposal.

WHMIS (Canada):
Classification:
None

This product has been classified in accordance with hazard criteria of the "Controlled Products Regulations" and this MSDS contains all the information required by the "Controlled Products Regulations."

Ingredient Disclosure List:
None

Section 15: REGULATORY INFORMATION (Continued)

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): Warning! The state of California has determined that the following listed component chemicals in this product may cause cancer, birth defects or other reproductive harm:
None

U.S., EPA, TSCA Information: This product is an article as defined by TSCA and is not required to be listed in the TSCA inventory.

Ozone Depletion Information: This product does not contain or is not manufactured with ozone depleting substances as identified in Title VI, Clean Air Act "Stratospheric Ozone Protection" and the regulations set forth in 40 CFR, Part 82.

Section 16: OTHER INFORMATION

Special Precautions: Airborne carbon fibers or dust are electrically conductive and may create electrical short-circuits that could result in damage to and malfunction of electrical equipment and/or personal injury.

Explanation and Disclaimer: Wherever such words or phrases as "hazardous," "toxic," "carcinogen," etc. appear herein, they are used as defined or described under state employee right-to-know laws, Federal OSHA laws or the direct sources for these laws such as the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), etc. The use of such words or phrases should not be taken to mean that we deem or imply any substance or exposure to be toxic, hazardous or otherwise harmful. **Any exposure can only be understood within the entire context of its occurrence, which includes such factors as the substance's characteristics as defined in the MSDS, amount and duration of exposures, other chemicals present and preexisting individual differences in response to the exposure.**

The data provided in this MSDS is based on the information received from our raw material suppliers and other sources believed to be reliable. We are supplying you this data solely in compliance with the Federal OSHA Hazard Communication Standard, 29 CFR 1910.1200 and other Federal and state laws as described in Section 15: Regulatory Information.

The information contained in this MSDS is proprietary and confidential to Hexcel Corporation. This MSDS and the information in it are not to be used for purposes other than compliance with the Federal OSHA Hazard Communication Standard. If you have received this MSDS from any source other than Hexcel Corporation or its authorized agent, the information contained in it may have been modified from the original document and it may not be the most current revision.

Liability, if any, for use of this product is limited to the terms contained in our sale terms and conditions. We do not in any way warrant (expressed or implied, including any implied warranty for merchantability or fitness for a particular purpose) the data contained or the product described in this MSDS. Additionally, we do not warrant that the product will not infringe any patent or other proprietary or property rights of others.

Contact: David M. Rubin,
Hexcel Schwebel Environmental, Health and Safety Manager

Proline Epoxy 4100 System – Resin and Hardener

DESCRIPTION

Proline is a 100% reactive low viscosity, unfilled, clear laminating resin with high performance characteristics. This resin and hardener combination make a very strong laminate capable of high temperature with standard room temp cure. Minimum odor and good color along with its excellent wetting characteristics make it an excellent choice for high performance laminations of glass, carbon fiber, and Kevlar.

SPECIFICATIONS

Resin
Viscosity at 25 °C 500 – 700 cPs
Color Gardner 1 max.
Mix ratio 100 Parts by weight
Physical Form Clear Liquid
Pounds/Gallon @ 25°C 9.2 Lbs
Hardener
Viscosity at 25 °C 100-200 cPs
Color Gardner <6
Mix ratio 20 Parts by weight
Pounds/Gallon at 25 °C 8.5 Lbs

PROPERTIES

Laminate Neat
Mix Ratio 100:20 By Weight -
Pot Life at 72F 20 minutes -
Mixed Viscosity at 72F 800-875 cPs -
Cured Hardness 90 Shore D* 92 Shore D
Specific Gravity Grams/CC 1.17 1.17
Tensile Strength PSI 46,120* 10,548
Flexural Strength, PSI 71,251* 17,210
Heat Deflection Temp (Tg) 245F * / ** 235F**
* Properties testing with A 10 Ply Laminate Style 7628 Glass Fabric, 60% Glass / 40% Resin
**TG with standard room temp cure, higher TG can be accomplished with a Post Cure

CURING

Standard cure time at room temperature is approximately 24 hours, can be handled and demolded in as little as 8 hours. Faster cure times can be accomplished by using elevated temperature, example full cure in approximately 2 hours at 150F. Do not cure or post cure at temperatures over 300F. Ensure proper ventilation when curing or post curing with temps over 125F.

SAFETY and HANDLING

Avoid contact with skin, eyes and clothing Avoid prolonged or repeated contact with skin, eyes and clothing Wash thoroughly after handling. (Always use gloves) Only mix as much as you will need for a 15 minute period, it is better to mix several smaller amounts than to mix a single large amount as this helps decrease exothermic reactions. Wash with soap and water before eating, drinking, and smoking. Launder contaminated clothing before reuse

Sold by Wildman Rocketry

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.
Phone: 866-937-8797 or 989-684-7286
www.westsystem.com

EMERGENCY TELEPHONE NUMBERS:
Transportation
CHEMTREC:.................... 800-424-9300 (U.S.)
703-527-3887 (International)
Non-transportation
Poison Hotline:................. 800-222-1222

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

DANGER Causes burns to eyes and skin. Harmful if swallowed. Harmful if absorbed through the skin. May be harmful if inhaled. May cause allergic reaction. Amber colored liquid with ammonia odor.

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

POTENTIAL HEALTH EFFECTS:

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 triethylnetetramine with phenol/formaldehyde	32610-77-8	40-70
Polyethylenepolyamines	68131-73-7	10-30
Triethylenetetramine	112-24-3	5-20
Hydroxybenzene	108-95-2	1-10
Reaction products of triethylenetetramine and propylene oxide	26950-63-0	1-10
Tetraethylenepentamine	112-57-2	1-10

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.

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. 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. 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, aldehydes, 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

In the non-cured, liquid form, this product may be harmful if released to the environment. Do not allow into sewers, on the ground or in any body of water.

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 Non-Bulk
SHIPPING NAME: .... Polyamines, liquid, corrosive, n.o.s.
TECHNICAL SHIPPING NAME:.................... Triethylenetetramine
HAZARD CLASS: .... Class 8
U.N./N.A. NUMBER: .... UN 2735
PACKING GROUP:.................... PG III
MARINE POLLUTANT: .... No

ICAO/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

MARINE POLLUTANT: .... No

IMDG
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
EmS Number: .... F-A, S-B
MARINE POLLUTANT .... No

15. REGULATORY INFORMATION

OSHA STATUS: .... Corrosive; possible sensitizer.
TSCA STATUS:.. All components listed on TSCA inventory or otherwise comply with TSCA requirements.

Canada WHMIS Classification:... D2A – Very toxic material causing other toxic effects; E – Corrosive
CEPA Chemical Inventory Status: .... All components are listed or are otherwise compliant with CEPA requirements.

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		MA, NJ, PA
Tetraethylenetriamine 112-24-3		MA, NJ, PA
Phenol 108-95-2		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: .... April 26, 2013
SUPERSEDES DATE:.. February 10, 2011
MSDS NUMBER:.. 205-13a

MATERIAL SAFETY DATA SHEET
West System Inc.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME:..WEST SYSTEM® 105 Epoxy Resin
PRODUCT CODE:..105
CHEMICAL FAMILY:..Epoxy Resin.
CHEMICAL NAME:..Bisphenol A based epoxy resin.
FORMULA:..Not applicable.

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

EMERGENCY TELEPHONE NUMBERS:
Transportation
CHEMTREC:.................... 800-424-9300 (U.S.)
703-527-3887 (International)
Non-transportation
Poison Hotline: 800-222-1222

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

WARNING May cause skin irritation. May cause eye irritation. May cause allergic reaction. Clear, viscous liquid with mild odor.

PRIMARY ROUTE(S) OF ENTRY:.. Skin contact.

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION:.. If product is heated, vapors generated can cause headache, nausea, dizziness and possible respiratory irritation if inhaled in high concentrations.

CHRONIC INHALATION: .... Repeated exposure to high vapor concentrations may cause irritation of pre-existing lung allergies and increase the chance of developing allergy symptoms to this product.

ACUTE SKIN CONTACT:.. May cause allergic skin response in certain individuals. May cause moderate irritation to the skin such as redness and itching.

CHRONIC SKIN CONTACT:... May cause sensitization in susceptible individuals. May cause moderate irritation to the skin.

EYE CONTACT: .... May cause irritation.

INGESTION:... Low acute oral toxicity.

SYMPTOMS OF OVEREXPOSURE: .... Possible sensitization and subsequent allergic reactions usually seen as redness and rashes.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:................ Pre-existing skin and respiratory disorders may be aggravated by exposure to this product. Pre-existing lung and skin allergies may increase the chance of developing allergic symptoms to this product.

3. COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

INGREDIENT NAME	CAS #	CONCENTRATION (%)
Propane, 2,2-bis[p-(2,3-epoxypropoxy)phenyl]-, polymers	25085-99-8	60-100
Benzyl alcohol	100-51-6	10-30
Phenol-formaldehyde polymer glycidyl ether	28064-14-4	1-10

4. FIRST AID MEASURES

FIRST AID FOR EYES... Flush immediately with water for at least 15 minutes. Consult a physician.

FIRST AID FOR SKIN.. Remove contaminated clothing. Wipe excess from skin. Apply waterless skin cleaner and then wash with soap and water. Consult a physician if effects occur.

FIRST AID FOR INHALATION... Remove to fresh air if effects occur.

FIRST AID FOR INGESTION... No acute adverse health effects expected from amounts ingested under normal conditions of use. Seek medical attention if a significant amount is ingested.

5. FIRE FIGHTING MEASURES

FLASH POINT: .... >200°F (Tag Closed Cup)

EXTINGUISHING MEDIA: .... Foam, carbon dioxide (CO_2), dry chemical.

SPECIAL FIRE FIGHTING PROCEDURES: .... Wear a self-contained breathing apparatus and complete full-body personal protective equipment. Closed containers may rupture (due to buildup of pressure) when exposed to extreme heat.

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: phenolics, carbon monoxide, carbon dioxide.

6. ACCIDENTAL RELEASE MEASURES

SPILL OR LEAK PROCEDURES: .... Stop leak without additional risk. Dike and absorb with inert material (*e.g.*, sand) and collect in a suitable, closed container. Warm, soapy water or non-flammable, safe solvent may be used to clean residual.

7. HANDLING AND STORAGE

STORAGE TEMPERATURE (min./max.): .... 40°F (4°C) / 120°F (49°C)

STORAGE: .... Store in cool, dry place. Store in tightly sealed containers to prevent moisture absorption and loss of volatiles. Excessive heat over long periods of time will degrade the resin.

HANDLING PRECAUTIONS: .... Avoid prolonged or repeated skin contact. Wash thoroughly after handling. Launder contaminated clothing before reuse. Avoid inhalation of vapors from heated product. Precautionary steps should be taken when curing product in large quantities. When mixed with epoxy curing agents this product causes an exothermic, 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: .... Safety glasses with side shields or chemical splash goggles.

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: .... Good room ventilation is usually adequate for most operations. Wear a NIOSH/MSHA approved respirator with an organic vapor cartridge whenever exposure to vapor in concentrations above applicable limits is likely.

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 (epichlorohydrin, benzyl alcohol) were either so low that they were not detected at all or they were significantly below OSHA's permissible exposure levels.

ADDITIONAL PROTECTIVE MEASURES: .... Practice good caution and personal cleanliness to avoid skin and eye contact. Avoid skin contact when removing gloves and other protective equipment. Wash thoroughly after handling. 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: .... Clear.
ODOR: .... Mild.
BOILING POINT: .... > 400°F
MELTING POINT/FREEZE POINT: .... No data.
VISCOSITY: .... 1000 (cP)
pH: .... No data.
SOLUBILITY IN WATER: .... Slight.
SPECIFIC GRAVITY: 1.15
BULK DENSITY: .... 9.6 (pounds/gallon)
VAPOR PRESSURE: .... < 1 mmHg @ 20°C.
VAPOR DENSITY: .... Heavier than air.
% VOLATILE BY WEIGHT: .... ASTM D 2369-07 was used to determine the Volatile Content of mixed epoxy resin and hardener. Refer to the hardener's MSDS for information about the total volatile content of the resin/hardener system.

10. STABILITY AND REACTIVITY

STABILITY: .... Stable.

HAZARDOUS POLYMERIZATION:.. Will not occur by itself, but a mass of more than one pound of product plus an aliphatic amine will cause irreversible polymerization with significant heat buildup.

INCOMPATIBILITIES: .... Strong acids, bases, amines and mercaptans can cause polymerization.

DECOMPOSITION PRODUCTS: .... Carbon monoxide, carbon dioxide and phenolics may be produced during uncontrolled exothermic reactions or when otherwise heated to decomposition.

11. TOXICOLOGICAL INFORMATION

No specific oral, inhalation or dermal toxicology data is known for this product. Specific toxicology information for a bisphenol-A based epoxy resin present in this product is indicated below:

Oral:.. LD_{50} >5000 mg/kg (rats)
Inhalation: .... No Data.
Dermal: .... LD_{50} = 20,000 mg/kg (skin absorption in rabbits)

TERATOLOGY: ....………………Diglycidyl ether bisphenol-A (DGEBPA) did not cause birth defects or other adverse effects on the fetus when pregnant rabbits were exposed by skin contact, the most likely route of exposure, or when pregnant rats or rabbits were exposed orally.

REPRODUCTIVE EFFECTS:............................………………..DGEBPA, in animal studies, has been shown not to interfere with reproduction.

MUTAGENICITY: ....…………………..DGEBPA in animal mutagenicity studies were negative. In vitro mutagenicity tests were negative in some cases and positive in others.

CARCINOGENICITY:

NTP .... Product not listed.
IARC... Product not listed.
OSHA .... Product not listed.

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.

Many studies have been conducted to assess the potential carcinogenicity of diglycidyl ether of bisphenol-A. Although some weak evidence of carcinogenicity has been reported in animals, when all of the data are considered, the weight of evidence does not show that DGEBPA is carcinogenic. Indeed, the most recent review of the available data by the International Agency for Research on Cancer (IARC) has concluded that DGEBPA is not classified as a carcinogen.

Epichlorohydrin, an impurity in this product (<5 ppm) has been reported to produce cancer in laboratory animals and to produce mutagenic changes in bacteria and cultured human cells. It has been established by the International Agency for Research on Cancer (IARC) as a probable human carcinogen (Group 2A) based on the following conclusions: human evidence – inadequate; animal evidence – sufficient. It has been classified as an anticipated human carcinogen by the National Toxicology Program (NTP). Note: It is unlikely that normal use of this product would result in measurable exposure concentrations to this substance.

12. ECOLOGICAL INFORMATION

In the non-cured liquid form this product may cause long-term harm if released to the environment. Prevent entry into sewers and natural waters.

Movement and Partitioning:
Bioconcentration potential is moderate (BCF between 100 and 3000 or Log Kow between 3 and 5).

Degradation and Transformation:
Theoretical oxygen demand is calculated to be 2.35 p/p. 20-day biochemical oxygen demand is <2.5%.

Ecotoxicology:
Material is moderately toxic to aquatic organisms on an acute basis. LC50/EC50 between 1 and 10 mg/L in most sensitive species.

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 Non-Bulk
SHIPPING NAME:.. Not regulated.
TECHNICAL SHIPPING NAME: .... Not applicable.

HAZARD CLASS:........ Not applicable.
U.N./N.A. NUMBER:........ Not applicable.
PACKING GROUP:........ Not applicable.

IMDG
SHIPPING NAME:........ Environmentally hazardous substance, liquid, n.o.s.
TECHNICAL SHIPPING NAME:........ Epoxy Resin.
HAZARD CLASS:........ Class 9.
U.N. NUMBER:........ UN3082.
PACKING GROUP:........ PG III.
EmS Number:........ F-A, S-F
MARINE POLLUTANT........ Yes

ICAO/IATA
SHIPPING NAME:........ Environmentally hazardous substance, liquid, n.o.s.
TECHNICAL SHIPPING NAME:........ Epoxy Resin.
HAZARD CLASS:........ Class 9.
U.N. NUMBER:........ UN3082.
PACKING GROUP:........ PG III.
MARINE POLLUTANT:........ Yes

15. REGULATORY INFORMATION

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

Canada WHMIS Classification:........ D2B - Toxic material causing other toxic effects.
CEPA Chemical Inventory Status:........ All components are listed or are otherwise compliant with CEPA requirements.

SARA TITLE III:
SECTION 313 TOXIC CHEMICALS........ None (deminimus).

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
Epichlorohydrin 106-89-8	< 5ppm	[1]CA
Benzyl alcohol 100-51-6		MA, PA, NJ

1. These substances are known to the state of California to cause cancer or reproductive harm, or both.

16. OTHER INFORMATION

REASON FOR ISSUE:........ Changes made in Section 14 and 15.
PREPARED BY:........ G. M. House
APPROVED BY:........ G. M. House
TITLE:........ Health, Safety & Environmental Manager
APPROVAL DATE:........ April 26, 2013
SUPERSEDES DATE:........ March 9, 2012
MSDS NUMBER:........ 105-13a

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