NASA University Student Launch

University of Alabama in Huntsville 2013-2014

Flight Readiness Review

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THE UNIVERSITY OF
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Propulsion Research Center, Huntsville, AL 35805, 256.701.4665

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1 Summary of FRR Report

1.1 Team Summary

Charger Rocket Works University of Alabama in Huntsville 301 Sparkman Drive Huntsville, AL 35899	NAR-TRA Mentor: Mr. Jason Winningham, Comp. Sys. Engineer (Level 3 NAR: 89526/TRA: 13669) Engineering Dept., UAH Jason.Winningham@uah.edu

1.2 Launch Vehicle Summary

Prometheus will be the competition rocket. Engineered from premium carbon fiber, custom printed parts, and machined aluminum, *Prometheus* will stand 10 feet tall and weigh 34 pounds fully assembled. During launch, *Prometheus* will be guided along a 1.5 inch by 8 foot launch rail. The vehicle will be propelled using a Cesaroni Technology Inc. M4770-P motor to speeds approaching Mach 1.4 and achieving an altitude of 15,700 feet. *Prometheus* will descend at 150 feet per second under a 30 inch drogue until 1000 feet where a main chute will be deployed to provide a soft impact of 14 feet per second for a total flight time of 170 seconds.

1.3 Milestone Review Flysheet

See Appendix O: Milestone Review Flysheet.

1.4 Payload Summary

Name	Reqt #	Description
Landing Hazard Detection System	3.1	Hazard Detection Camera using onboard processor and live data feed
Microgravity Propellant Management System	3.2.1.2	Demonstrate the ability to control the position of a simulated propellant in a microgravity spacecraft tank, using Dielectrophoresis.
Supersonic Effects on Vehicle Coatings	3.2.2.4	Various common external coatings will be analyzed preflight and post flight to analyze the effect of supersonic flight on rocket coatings.
Transonic Vehicle Aerodynamics	NA	Vehicle will collect flight data through the transonic region in order to determine Axial, Normal, and Pitching Moment Coefficients.

2 Changes made since CDR

All major changes since the CDR will be listed here separated into Vehicle Changes, Payload Changes, and Project Plan Changes.

2.1 Vehicle Changes

The overall design of the vehicle remains the same. General layout and part locations have not changed, nor have part to part interactions. However, a few items have changed. They changes are as follows:

Prometheus was originally designed to accommodate a range of motor case lengths up to 33 inches long. In order to accommodate some of the changes resulting from manufacturing, the decision was made to remove this design feature. Thus the length of the lower section of the body tube was reduced such that it will only accommodate a motor the same size or shorter than the selected SLP motor, 24 inches long.

In order to provide improved access to the bulkhead on which the recovery ejection charges are mounted, an additional separation point was added to the main body tube. The separation point is located in the section of the body tube just above the main body payload bay. This new mid-section coupler will not be separating in flight, thus it will be epoxied into the middle body tube and mechanically fastened to the recovery section body tube using plastic rivets.

Because of an unavailability of facilities for printed metal parts, the material for several parts was changed. The couplers, thrust plate, fin brackets, pucks, and pitot probe were originally designed to be fabricated through a printed metal process out of titanium. The manufacturer was unable to produce the parts because of an equipment failure. Thus the printed metal parts were not available in time to support the FRR. Because of schedule and budgetary reasons, the decision was made to change the design to accommodate the unavailable printed metal parts. The pitot probe and fin brackets will be made from glass bead impregnated sintered nylon. The thrust plate was machined from aluminum. Finally, the pucks were eliminated from the design through a design change to the bulk heads, and commercially available fender washers were added.

The pitot probe is secured to the nose cone payload rod through a threaded insert epoxied into the base of the pitot probe. The original design had barbs on the end of the air tubes to secure rubber tubing from the sensors. These barbs have been removed to ease 3D printing complications and rubber tubes will now be secured by epoxy. The tube extensions were also extended to the base of the part to improve accessibility and limit the amount of support material needed for printing the parts.

The thrust ring was originally designed to be 3D printed out of titanium. Now, the thrust ring has been machined from 5086 aluminum.

Fin Brackets were intended to be printed out of titanium. A set of brackets was printed for abs plastic (Acrylonitrile butadiene styrene). They have flown successfully. Additionally, a set of brackets has been printed out of nylon and will be stronger than the plastic. The brackets were to be secured to the body tube by epoxy but are now secured with Chicago screws.

2.2 Payload Changes

No major payload changes have taken place since CDR.

2.3 Project Plan Changes

The inability to get a full-scale flight off before the FRR has cause the team to refocus efforts to aggressively work towards a launch before the final cut of day for launches on April 27th. This was due to a number of mistakes and logistical issues.

2.4 CDR Feedback

1. How have you examined the structural integrity of the rocket during Mach speed flight? Flutter of fins, flight loads, etc.?

Fin flutter has been examined and is included in this document. Flight loads have been tested on some completed parts such as body tubes and fin brackets.

2. Examine the slip joints on the rocket for fit. Be sure that everything is solid and there is enough of a shoulder for rigidity.

Slip joints have not yet been manufactured but designs of slip joints has been adjusted to insure that the joints are firmly fastened in place with mechanical fasters or shear pins.

3. Constraint for both field's drift distance is 5000 ft. Need to be sure with the full sized motor that drift will be under 5000 ft. in 20mph winds.

Drogue design was adjusted to bring the rocket down faster under drogue.

4. Highlight any safety critical steps in the procedures.

Safety critical steps require signatures to proceed with the process.

5. Place more emphasis on the failure modes and effects, particularly mitigations. Include testing done and design changes made due to the failure modes.

The failure modes section was enhanced.

6. Subscale flight data should have more discussion. Use the flight data to find the coefficient of drag of the rocket in whatever program you are using to estimate altitude. Anchor this to your full scale model to recalculate estimated altitude and stability in the FRR.

Recent data from the near full-scale or prototype rocket was tied to the drag and used to improve the predictions for drift. The different external size of the prototype makes the data mostly invalid for recalculating altitude and stability for the actual full-scale rocket.

7. Vehicle requirements and verifications are lacking.

Requirements and verifications through the document were enhanced.

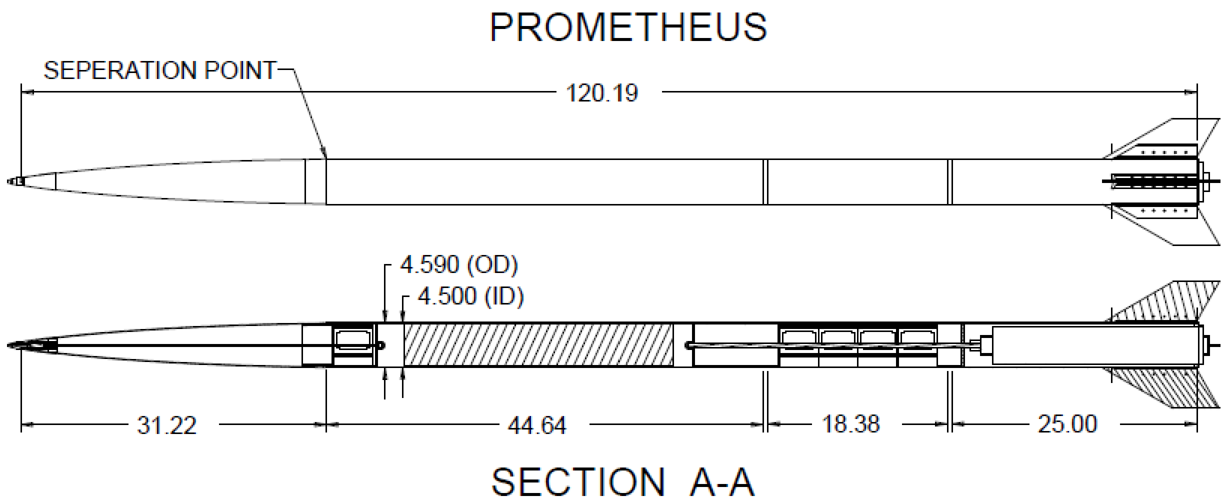
Addendum requested:

Statement of Work Verification table was submitted as requested.

3 Vehicle Criteria

3.1 Design and Construction of Vehicle

The mission of Charger Rocket Works and the Prometheus Student Launch Team is to safely launch and recover a vehicle that geometrically replicates the Nanolaunch 1200 NASA prototype for the purpose of collecting aerodynamic data in flight, as well as meeting the Payload requirements of Student Launch, and the safety guidelines of both Student Launch and NAR/TRA.



Prometheus's build is slightly behind the team's initial schedule due to manufacturing fall backs. The rocket's design originally included multiple printed titanium parts to replicate the design of the Nanolaunch 1200, but a loss in donated parts forced the team to redesign the parts to be machined out of aluminum and sinter printed aluminum.

Prometheus was originally designed to accommodate a range of motor case lengths up to 33 inches long. In order to accommodate some of the changes resulting from manufacturing, the decision was made to remove this design feature Thus the length of the lower section of the body tube was reduced such that it will only accommodate a motor the same size or shorter than the selected SLP motor, 24 inches long. With this redesign, the main body payload was shifted back in the rocket and rests against the coupler. This change resulted in a larger recovery section increasing available packing volume for the recovery system. In order to provide improved access to the bulkhead on which the recovery ejection charges are mounted, an additional separation point was added to the main body tube. The separation point is located in the section of the body tube just above the main body payload bay. The body coupler in this section is identical to the lower body coupler. This new midsection coupler will not be separating in flight, thus it will be epoxied into the middle body tube and mechanically fastened to the recovery section body tube using plastic rivets.

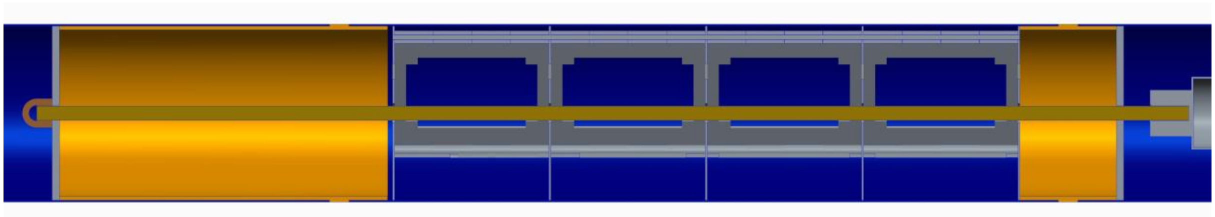


Figure 3-1 Payload Section Cross Section

In the new payload configuration (from right to left) the payload rod is threaded into the motor case, the coupler is epoxied onto the lower body tube, next the bulkhead is epoxied to the bottom of the coupler, and the middle body tube is in compression against the shoulder of the lower coupler. The bottom of the payload panel rests against the coupler. To the top (left side of Figure 3-1) the coupler is epoxied into the second body tube. The lengthened coupler is secured from the top with eight plastic rivets, two rings of four. The coupler is lengthened 1.5 diameters, 6 inches, to provide greater structural support.

Because of an unavailability of facilities for printed metal parts, the material for several parts was changed. The couplers, thrust plate, fin brackets, pucks, and pitot probe were originally designed to be fabricated through a printed metal process out of titanium. The manufacturer was unable to produce the parts because of an equipment failure. Thus the printed metal parts were not available in time to support the FRR. Because of schedule and budgetary reasons, the decision was made to change the design to accommodate the unavailable printed metal parts. The pitot probe and fin brackets will be made from glass bead impregnated sintered nylon. The thrust plate was machined from aluminum. Finally, the pucks were eliminated from the design through a design change to the bulk heads.

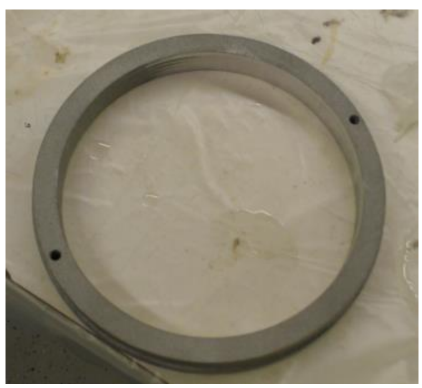


Figure 3-2: Thrust Plate

Figure 3-3: Fin Bracket

The pitot probe is secured to the nose cone payload rod through a threaded insert epoxied into the base of the pitot probe as shown in **Error! Reference source not found.**. The original design had arbs on the end of the air tubes to secure rubber tubing from the sensors. These barbs have been removed to ease 3D printing complications and rubber tubes will now be secured by epoxy. The tube extensions were also extended to the base of the part to improve accessibility and limit the amount of support material needed for printing the parts.

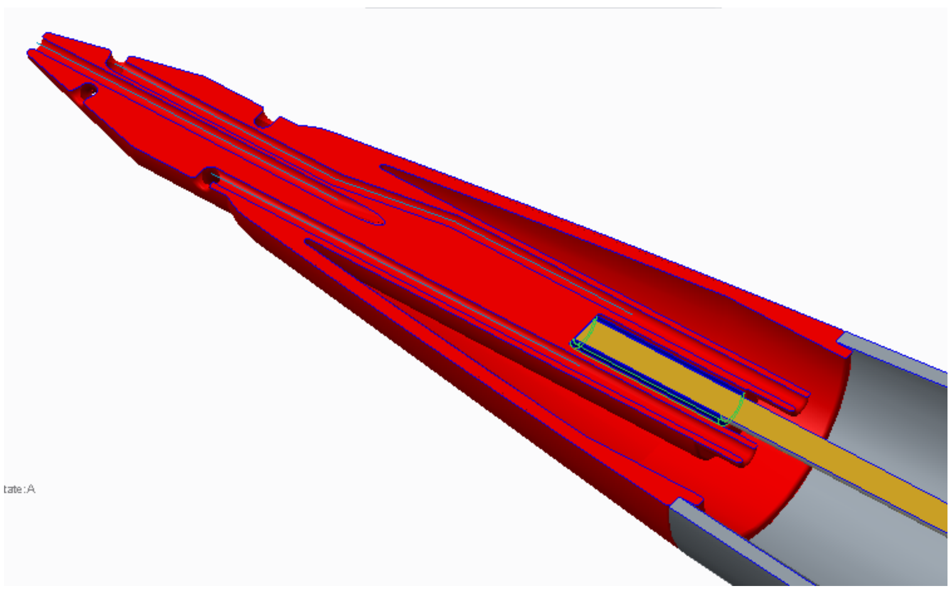


Figure 3-4: Cross section of revised pitot probe design

Initial strength estimates for the nylon printed couplers indicate that no additional reinforcement is needed. However, when parts are available the strength of the part will be evaluated. A back up design has been selected and material for that part has been ordered in the event that the nylon coupler parts are not stiff enough for Prometheus. The backup design consists of an aluminum tube with an outside diameter that matches the inner diameter of Prometheus's body tube. The aluminum tube has a 0.125 inch wall thickness which will provide ample stiffness for the coupler joints. A small section of body tube, as shown in Figure 3-6, would be cut and then epoxied onto the aluminum tube as shown in Figure 3-5. The body tubes would then be in compression with identical composite material, assuring a strong and reliable joint. The backup coupler design was shown in Figure 3-7.

Figure 3-6: Body Tube Section

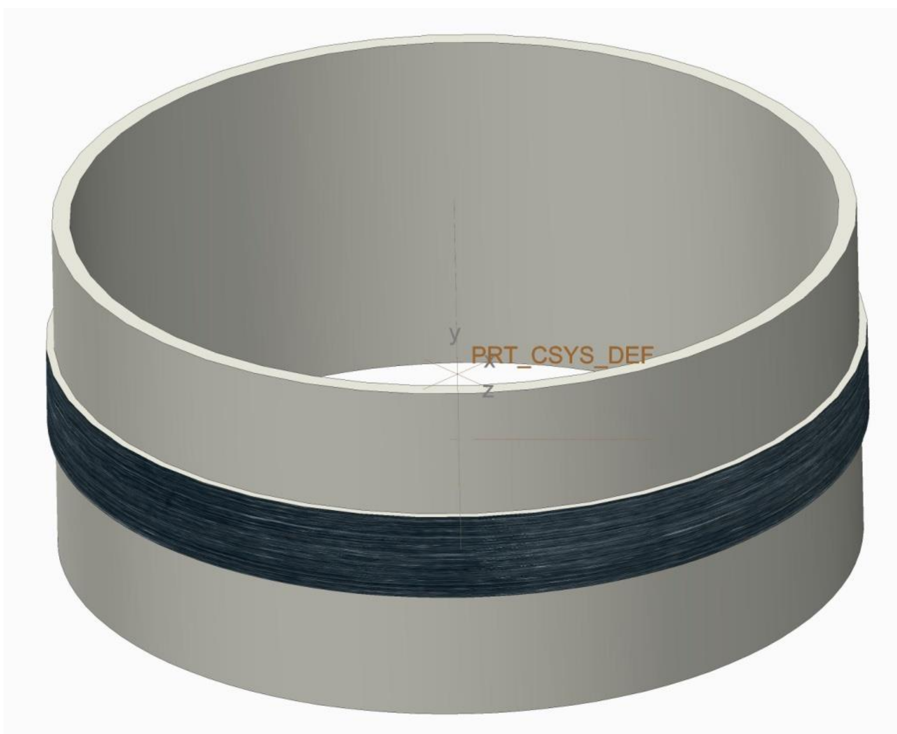


Figure 3-7: Back up coupler design

The nose cone was made in house using carbon fiber layup techniques. A mold was fabricated from a 5 inch O.D. piece of solid Polyethylene rod donated to the team from the UAH Aerophysics Research Lab. The mold was machined on a manual lathe using a trace template that was cut from 0.125 inch aluminum sheet. To create the template plate, a spline was generated in Surfcam to match the curve of the Hack-LV-1/3 nose cone and cut with a water jet at Brown Precision Inc of Huntsville, Alabama. The spline created for the template geometry had significant variation from the true profile. The full spline and close up detail of the true outer mold line for the geometry can be seen in Figure 3-8 and Figure 3-9. Despite the variation, the spline is still extremely close to desired curvature. The difference in the curve will be negligible in the final part due to variation of the outer mold line which is created by the handcraftsmanship when laying up the carbon fiber.

During fabrication of the nosecone mold, a miscommunication with the machinist resulted in the mold material being turned down to a diameter of 4.37 inches rather than the desired diameter of 4.5 inch. Although this difference has little effect on the curvature of the nose cone, it did reduce the total length of the nose cone and necessitate design changes to the nose cone coupler to accommodate the reduced diameter. Finally, the shortened nose cone resulting from the diameter change consequently reduced the vehicle’s overall length. In order to match NanoLaunch 1200’s length, the initial nose cone length was 31.19 inches. The carbon fiber portion of the nosecone, minus the length of the pitot probe, was 27.68 inches. With the decrease in diameter, the length of the carbon fiber portion of the nosecone decreased to 25.52 inches. In order to gain back the 2.16 inches, the nose cone coupler was redesigned to include a two inch linearly tapered shoulder to transition from the body outer diameter to the nosecone base outer diameter.

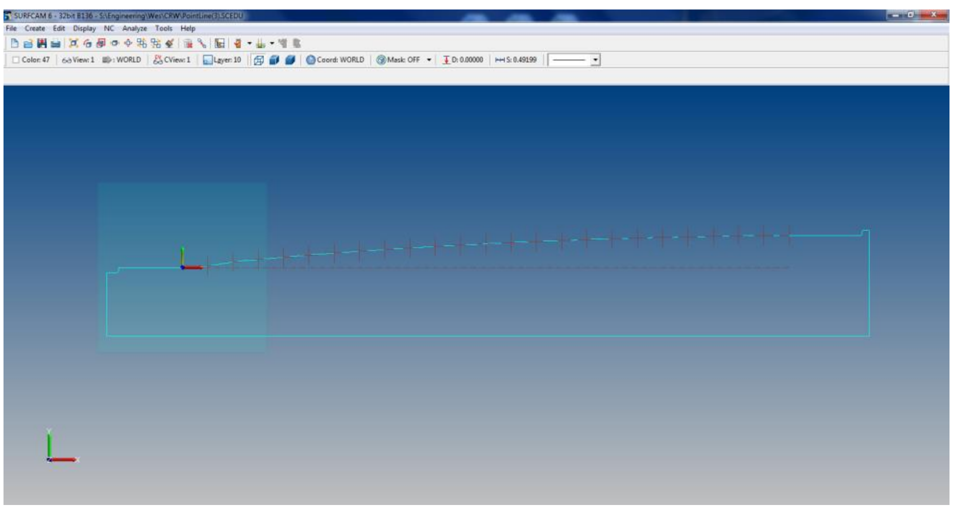


Figure 3-8: Surfcam Spline 1

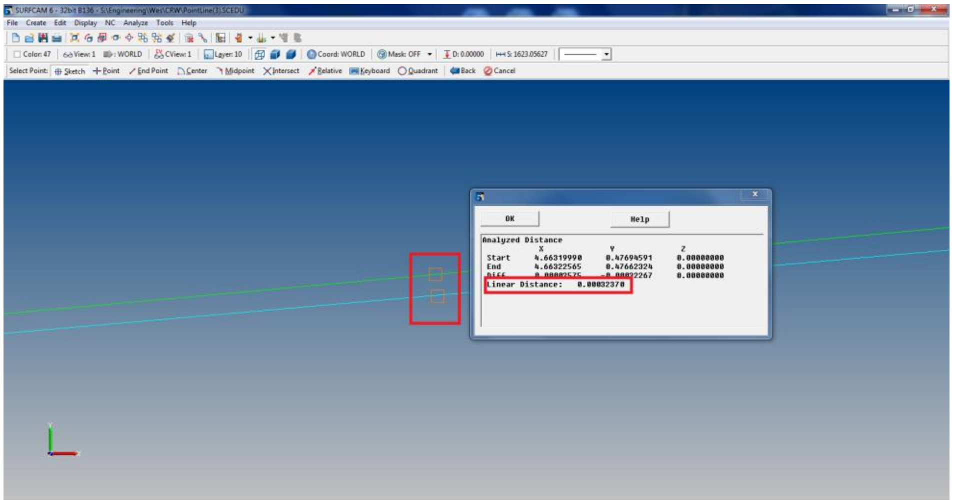


Figure 3-9: Surfcam Spline 2

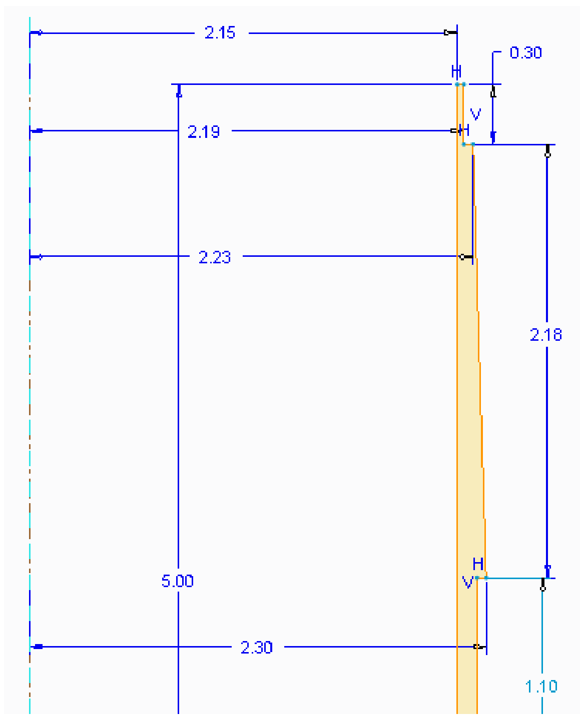


Figure 3-10: Nose Cone Coupler Transition Piece Sketch

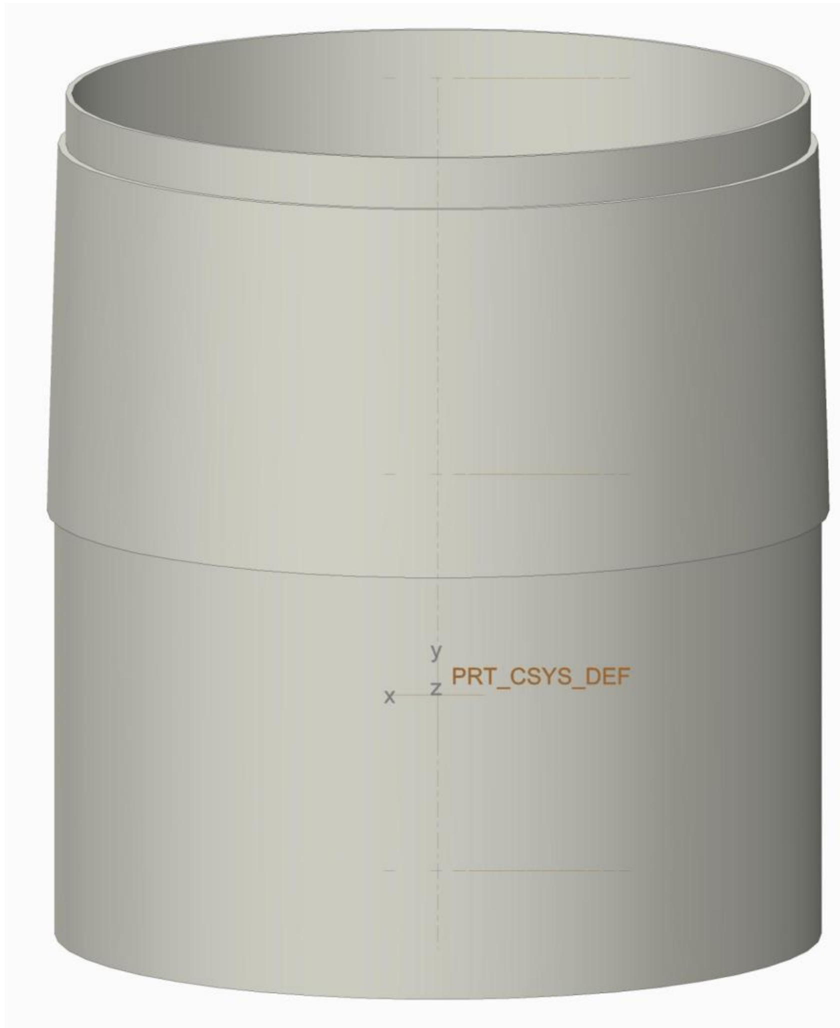


Figure 3-11: Nose Cone Coupler Transition Piece

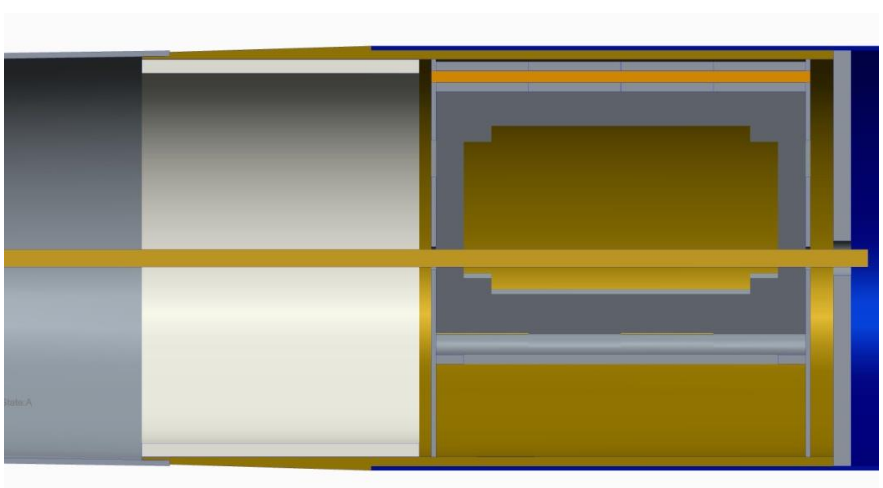


Figure 3-12: Nose Cone Payload

The thrust ring was originally designed to be 3D printed out of titanium, but because of the unavailability of the printed metal machinery, the thrust ring was machined from 5086 aluminum. 5086 aluminum is primarily alloyed with magnesium. Heat does not significantly affect the material and is often used for welding since it retains its mechanical strength. Also, 5086 is often used for sea vessels since it has good corrosion properties. The thrust ring will be held in the body of the rocket via a lip at the bottom of the motor case and the threaded rod attached to the top of the motor and the forward bulk plate.

Fin Brackets were intended to be printed out of titanium. A set of brackets was printed using ABS (Acrylonitrile butadiene styrene) and has been flown on 04/18/2014 successfully. Additionally, a set of brackets was printed out of nylon and will be stronger than the plastic. The brackets were to be secured to the body tube by epoxy but are now secured with Chicago screws. The test bed rocket fin was shown in Figure 3-13 and the individual fin bracket is shown in Figure 3-14.

Figure 3-13: Test Bed Rocket Fin

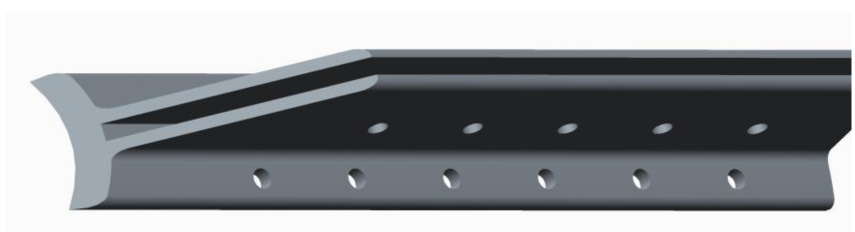


Figure 3-14: Bracket

Workmanship was recognized as crucial to every part of the project; team leadership has encouraged an attitude that every detail is important to the final product with the team as a whole, especially with the Hardware team. This has led to a tremendous amount of time spent on small details.

Several steps have been taken in order to insure a detail driven attitude is carried by all team members. Team leadership meets once a week in addition to the two normal team meetings to discuss the status of the design, and interfacing between sub teams. Additionally, all designs are reviewed by each sub team lead prior to flight approval. Lastly, the team instructor and mentor are consulted regularly, and have final veto authority for all design details.

The masses in the chart below have been determined by volume-density analysis and verified by weighting the actual parts and assemblies as shown in Table 3-1.

Table 3-1: Structures Mass Budget

System	Subsystem	Item	mass (lb.)	Quantity	Total mass (lb.)
Payload	CG Sled	Carbon Fiber Baffles	0.03	8.00	0.24
		ABS Baffle	0.00	2.00	0.00
		ABS Panel	0.03	12.00	0.37
	Forward Sled	Al Baffles	0.00	0.00	0.00
		ABS Baffle	0.00	2.00	0.00
		ABS Panel	0.03	3.00	0.09
	CG Components	(+-200G)Accelerometer ADXL377 3 axis	0.00	1.00	0.00
		ADXL345 - Triple-Axis Accelerometer (+-2g/4g/8g/16g) w/ I2C/SPI	0.00	1.00	0.00
		LifePO4 Battery	0.11	1.00	0.11
		L3GD20 (L3G4200 Upgrade) Triple-Axis Gyro Breakout Board 250,500,2000	0.00	1.00	0.00
		Beaglebone Black	0.09	1.00	0.09
		480-5550-ND Absolute Pressure Sensor(30 PSI)	0.00	4.00	0.01
	Forward Components	(+-200G)Accelerometer ADXL377 3 axis	0.00	1.00	0.00
		ADXL345 - Triple-Axis Accelerometer (+-2g/4g/8g/16g) w/ I2C/SPI	0.00	1.00	0.00
		LifePO4 Battery	0.11	1.00	0.11
		L3GD20 (L3G4200 Upgrade) Triple-Axis Gyro Breakout Board 250,500,2000	0.00	1.00	0.00
		Beaglebone Black (5 to 10 business days wait)	0.09	1.00	0.09
		480-5550-ND Absolute Pressure Sensor(30 PSI)	0.00	2.00	0.00
	Dielectrophoresis	1/8" Nut	0.01	6.00	0.09
		1/8" Bolt (shorter)	0.02	3.00	0.06
		1/8" Bolt (longer)	0.02	2.00	0.04
		HV supply (MINIMAX 7)	0.20	1.00	0.20
		7.4V Li-Po Battery	0.07	1.00	0.07
		11.1V Li-Po Battery	0.03	1.00	0.03
		Arduino Pro 328 3.3V	0.02	1.00	0.02
		Accelerometer ADXL345	0.01	1.00	0.01
		backlight LED	0.00	4.00	0.00
		Accel readout LED	0.01	2.00	0.02
		plastic bottles	0.03	2.00	0.06
		SD card interface	0.03	1.00	0.03

		FlyCamOne Eco v2	0.03	2.00	0.06
		Faraday cage copper mesh	0.00	1.00	0.00
		Corn oil	0.03	2.00	0.06
		Buzzer	0.01	1.00	0.01
		Wire and mounting parts	0.20	1.00	0.20
		Electrodes	0.07	2.00	0.14
	Perturbation System	Jaksa High Pressure Solenoid Valve	0.31	0.00	0.00
		12g CO2 Cartridge	0.15	0.00	0.00
		Puncture Device	0.14	0.00	0.00
		Adapter 1	0.00	0.00	0.00
		Adapter 2	0.00	0.00	0.00
		Stainless Steel Braided House	0.15	0.00	0.00
	LHDS	BeagleBone	0.09	1.00	0.09
		Camera Cape	0.05	1.00	0.05
		Battery	0.11	1.00	0.11
		XBee	0.02	1.00	0.02
		Carbon Fiber	0.15	1.00	0.15
		GPS	0.02	1.00	0.02
		Accelerometer	0.00	1.00	0.00
		Wire	0.04	1.00	0.04
		Antenna & Cable	0.20	1.00	0.20
		Attachment Hardware	??	??	
S tructures	Exterior	Tip with Pitot	0.39	1.00	0.39
		Nose Cone	0.80	1.00	0.80
		Lower Body Tube	0.89	1.00	0.89
		Upper Body Tube	1.50	1.00	1.50
		Interstage Coupler	0.22	2.00	0.44
		Nosecone Coupler	0.76	1.00	0.76
		fin bracket	0.15	4.00	0.60
		fin	0.15	4.00	0.59
		thrust ring	0.20	1.00	0.20
		Binding Screws (group)	0.15	1.00	0.15
		Propellant	7.30	1.00	7.30

The initial masses for analysis of custom made parts were determined by analyzing the volume of CAD models in Creo Parametric, then multiplying it by the density of the selected material. An active list was created and updated as the project progressed. Upon final fabrication, the list was updated to reflect the masses of real parts.

3.2 Buckling Analysis

Prometheus is expected to undergo strong forces from the motor and pressure from shock. It is critical that the material properties will be capable handling the possible buckling loads. Using Euler's approximation and different end fixtures, the strength of the material is evaluated under theoretical max load of the motor acting as a force on one end and the nose cone is pinned. We estimated the shear strength of the material at 1100 ksi based on results from compressive testing. Assuming the conditions for buckling are 1 fixed end and one pinned end, we should have a safety factor of 2.4. Figure 3-15 shows the geometric known, applied thrust, and Euler equation used to equate the critical modulus needed to survive buckling.

$$d_o := 4.59\text{in} \qquad d_i := 4.5\text{in} \qquad I := \frac{\pi \cdot \left(d_o^{\,4} - d_i^{\,4}\right)}{64} = 1.659 \cdot \text{in}^4$$

$$L := 10\text{ft} \qquad F_{mot} := 4770\text{N} \qquad F_{crit} := 1 \cdot F_{mot} = 1072.339 \cdot \text{lbf}$$

Euler's Equations $\quad E(K) := \dfrac{F_{crit} \cdot (K \cdot L)^2}{\pi^2 \cdot I}$

With Both Pinned: $\quad E(1.0) = 943 \cdot \text{ksi}$

Ends Fixed: $\quad E(0.5) = 236 \cdot \text{ksi}$

1 End Fixed, 1 End Pinned: $\quad E(0.699) = 461 \cdot \text{ksi}$

1 Fixed, 1 Lateral Free $\quad E(2.0) = 3772 \cdot \text{ksi}$

Figure 3-15: Simple Buckling Analysis

3.3 Fin Flutter Analysis

A primary concern of supersonic flight is the dynamic loading on flexible and pliable fin components of Prometheus. A simple flutter analysis algorithm was used estimate the shear modulus of the fin composition material such that flutter conditions were mitigated. Fin flutter is a phenomenon which is characterized as an oscillation that occurs due to wind shear producing a lift and coupled moment. Unchecked, this oscillation will diverge as a resonant frequency with amplitude magnification until the fin fatigues. The primary factors in fin flutter calculations are the shear modulus of the material, shape of the fin, temperature of the air, and density of the air.

The velocity at which a fin will flutter is characterized in the fin flutter Table 3-2 below.

Table 3-2: Fin Flutter Variables

$$V_f = a\sqrt{\frac{G\left[2(AR+2)(\frac{t}{c})^3\right]}{[1.337AR^3P(\lambda+1)]}}$$

$P = \frac{2116}{144}\left(\frac{T+459.7}{518}\right)^{5.356} psi$ $\quad a = \sqrt{\gamma RT}$ $\quad T = 59 - 0.00356h\ °\mathrm{F}$

R	$1716.59\ \frac{ft^2}{s^2}\left(\frac{1}{°R}\right)$
AR	Aspect Ratio
G	Shear Modulus
T	Fin Thickness
C	root chord
Ct	tip chord
Cr	root chord
S	Plan Form Area
b	semi span
P	Atmospheric Pressure as a Function of Temperature
T	Atmospheric Temperature as a Function of Altitude

For Prometheus' fins, special attention to fin flutter is applied to ensure a safe flight during which the fin flutter is mitigated. Below is a table of calculations for these specific fin dimensions. The final max Velocity for fin flutter was 1728 ft/s for a Shear modulus of 3.48 x 10^5 psi. The max projected Velocity of Prometheus is 1600 ft/s.

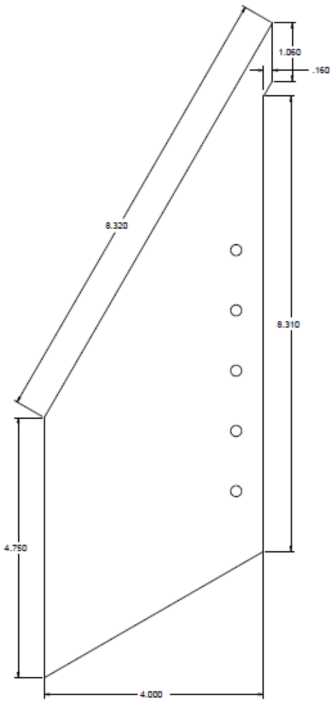


Figure 3-16: Fin Callouts

Table 3-3: Dimensions

Using t to solve for V		
Cr, C	**8.31**	inches
Ct	**4.75**	inches
t	**0.17**	inches
b	**4**	inches
G*	**3.48E+05**	psi
S	26.12	inch^2
AR	0.61	in2/in2
l	0.57	in/in
h	3000.00	feet
T	48.32	F
P	13.19	psi
a *	1105.26	ft/s
V	1728.09	ft/s

3.4 Recovery Subsystem

The recovery subsystems were identified below.

3.4.1 GPS Tracking

The GPS system used to track the rocket is built around an Antenova M10382-Al UB GPS Module (Digi Part Number 627-1030-ND) mounted on a PCB, as shown in Figure 3-40 in Section 3.7.2. The GPS sensor requires an input of 3.3 VDC and has a dynamic current consumption that can peak at up to 100 mA but typically reaches its highest average (52 mA) while acquiring initial GPS lock and then averages between 22 and 45 mA depending on how frequently GPS fixes are being sampled. The BeagleBone will be used to power the GPS system. It connects to UART pins on the BeagleBone that in turn sends the GPS (and LHDS) data through the XBee RF module to the ground station. The GPS module will be mounted on the same PCB as the XBee RF module in the main body tube of the rocket.

During perfect conditions, the GPS module documentation reports an 8 ft accuracy with 50% CEP (circular error probable). However, the module will lose GPS lock during maximum accelerations/velocities, making transmission of GPS data during powered flight unreliable to impossible. It is for this reason that the RF module is not transmitting data until after the drogue parachute deploys. If the GPS/XBee system fails, the contingency is to track the rocket visually.

GPS data, along with data from the Landing Hazard Detection System payload, is transmitted live to a ground station. All data transmission capabilities are handled by an embedded wireless radio frequency (RF) module. The module is mounted in the body section of the rocket near the parachute and transmits all GPS and Landing Hazard Detection System (LHDS) data from a dedicated BeagleBone White. The data will begin transmitting after deployment of the drogue parachute, which pulls the module from the body tube of the rocket as shown in Figure 3-20. The module that has been selected is an XBee-PRO XSC S3B; Digi Part Number XBP9B-XSCT-001. This 900 MHz spread spectrum RF module has a selectable channel mask for interference immunity, has a RF data rate of up to 20 Kbps, and has an outdoor/LoS range of up to 9 miles with the included Omni-directional dipole antenna. This module has a transmit power of 250 mW and a supply voltage requirement of 3.3 VDC. The RF module will be powered by the BeagleBone, which runs on a 6.6 V 850 mAh Life Battery.

Figure 3-17: GPS/Transmitter Ground Test

The XBee is a universal asynchronous receiver/transmitter (UART). It functions as a wireless serial port: whatever is pushed to the data radio module is broadcast through the Omni-directional antenna and picked up by the ground station. The ground station used to receive the RF data is a sparkfun XBee Explorer USB that connects a second of the above XBee transmitters to the USB port on a laptop. A custom program interprets and displays the received serial data packet stream (NMEA sentences), and the GPS information is used to recover the rocket.

A ground test of the RF transmitter and GPS system was conducted on April 11, 2014. Data rate, obstructed line-of-sight (LoS) range, and transmitted data integrity were all tested. The ground test involved setting up the ground station at a fixed location and mounting the RF/GPS module to the roof of a vehicle. The vehicle was then driven away from the ground station, placing an increasing amount of obstructions (trees, buildings, etc.) between the transmitter and receiver. The blue in Figure 3-17: GPS/Transmitter Ground Test shows the route taken during the test. Live GPS data was successfully transmitted to the ground station throughout the entire route, except at the extreme range of the test (circled in red in the figure). This data dropout corresponded to both the maximum distance of the transmitter from the ground station (in excess of 1 mile) as well as the greatest density of obstructions between the transmitter and receiver. This test was conducted at an approximate maximum speed of 40 feet per second. This ground test proved that the RF/GPS module is capable of maintaining GPS lock and transmitting the data through a greater density of LoS obstructions than can be reasonably expected during the test, full-scale, and competition launches. The minimum performance goals that must be achieved in order for the RF module to be deemed successful can be found in Table 4-15 below.

Dynamic effects of vehicle flight, including vibration and high G loads, have a potential to damage the physical attachments between electrical components and the circuit board, between the GPS and LHDS and the BeagleBone, and between all of these components and the modular payload sled to which they are mounted in the rocket. The likelihood of this damage occurring has been minimized through the use of PCBs which reduce the number of physical connections that need to be soldered, by designing component layout to ensure moment arms are as small as possible, and by fabricating support structures on the payload sled to brace components against movement caused by extreme accelerations. The range of the XBee RF transmitter is approximately 9 miles LOS and decreases with increasing terrain obstructions. To ensure the vehicle does not drift out of range of the ground station during descent, only a drogue chute is deployed at apogee. The main parachute is not deployed until the rocket is much closer to the ground, greatly decreasing the total descent time and thus the range over which it can drift. With the current parachute setup, the projected worst-case scenario for drift after drogue deployment is far less that the projected 9-mile range. Furthermore, performing flights in large, open, flat areas (such as the salt flats) neglects the possibility of encountering interference from terrain. Radio Frequency interference (both external and internal) is also cause for design consideration. The XBee RF module has a power output of only 250 mW, making it very unlikely to interfere with other team's E-matches and ejection charges, as has been a concern with high power transmitters in the past. Finally, the LHDS module (including the XBee transmitter and GPS) not being successfully ejected from the main body tube of the rocket upon parachute deploy will constitute a failure. The RF module will not be able to transmit through the carbon fiber of the body tube and no GPS or LHDS data can be received by the ground station. Careful recovery system design, black powder testing, and deployment testing are the keys to mitigating the potential of this failure. To this end, multiple ground/black powder tests were run to ensure the LHDS successfully deploys with the recovery system and does not bind during deployment. The LHDS payload sled was designed to snugly fit inside the body tube to ensure the sled does not bind while being ejected from the rocket. Successful in-flight deployment of this system was demonstrated as part of the test launch on April 12, 2014.

The integration of the GPS tracking and RF transmission components into the Landing Hazard Detection System payload is discussed further in Section 4.4.3 below.

3.4.2 Chute Design

Prometheus will feature a dual chute deployment; a small drogue chute for high altitude recovery and a main chute for near impact recovery. Engineered using nylon rip stop fabric, both the main and the drogue chutes have been tested and successfully deployed during a prototype system launch. Work drag coefficients for steady state decent of the drogue and main chute respectively are 1.6 and 1.2.

Figure 3-18: Main Parachute

The main chute is hemispherical, featuring 14 gores, a 12 foot cross section, and a 1 foot vent hole. This chute should provide the dry mass an impact velocity of 13 feet per second. The results from the prototype flight revealed the vehicle will fall approximately 400 feet until the chute full inflates. Planned deployment altitude is to be 1000 feet which will be enough to allow for safe recovery.

3.4.3 Parachute Bag/Burrito Design

The main parachute will be inside a custom designed parachute bag/burrito. This unique design allows the parachute to fit into the allotted recovery area. The bottom of the bag/burrito contains the parachute's main shroud lines. This particular portion is sewn so that the main canopy cannot enter during the launch. The upper portion of the bag/burrito contains the main canopy. This portion has elastic banding on the back side so that it will be pulled free from the canopy when the tender descenders. This upper portion is held rigid by two fiber glass rods to ensure that air cannot pull the bag open before the desired time. This custom Bag/Burrito is shown in Figure 3-19.

Figure 3-19: Deployment Bag/Burrito

3.4.4 Fixtures and Connection Points

The aft bulkhead will contain an eye nut that the main shock chord is attached to. At the end of the main shock chord a quick link is tied in. The main parachute, Landing hazard detection system, and nose cone are all anchored to this quick link. The nosecone bulk head will have an eye nut also. The drogue will be attached at this point. All the shock chords are composed of ¼" Kevlar chord. The portions of Kevlar that have potential to rub sharp edges will be encased in an extra layer of tubal Kevlar to help resist cutting.

3.4.5 Deployment Method

The recovery system is using a single separation point. Using a single separation point allows for the rocket to be constructed out of longer lengths of carbon fiber tubing, this avoided the need for body couplers and helps reduce the risk of the body buckling or flexing during launch.

Figure 3-20 and Figure 3-21 shows how the recovery section of the rocket will be packed before flight. The drogue, landing hazard detection system and the main chute will be attached to a common Kevlar suspension line. A black powder charge will set on the lower bulk head and will be used to separate the nose cone from the airframe. The main parachute will set directly above the black powder charge in a nomex deployment bag. The landing hazard detection system will be tied to the main Kevlar shock below the main parachute, but will ride on top of the deployment bag to protect it from the black power charge. Finally the drogue will be attached to the bulkhead located in the nose cone.

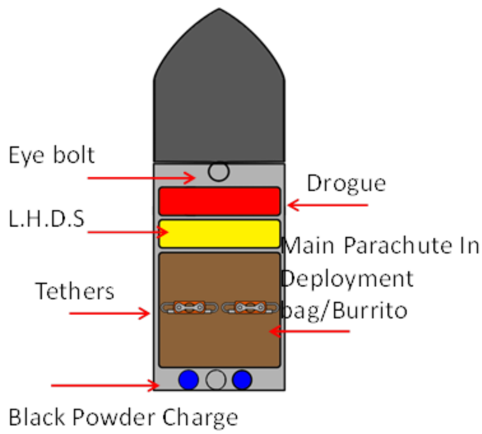


Figure 3-20: Initial Recovery System Setup

Figure 3-21: Recovery System Setup

The first event occurs two seconds after the rocket achieves apogee. The two second window is needed to simulate the zero gravity condition needed to observe dielectrophoresis. The first event in the recovery system is separation of the nose cone from the body tube. Two 3 gram black powder charges will be ignited causing the nose cone to separate from the body tube. The black powder will also push the recovery bay's contents out of the body of the rocket. This event is shown in Figure 3-22.

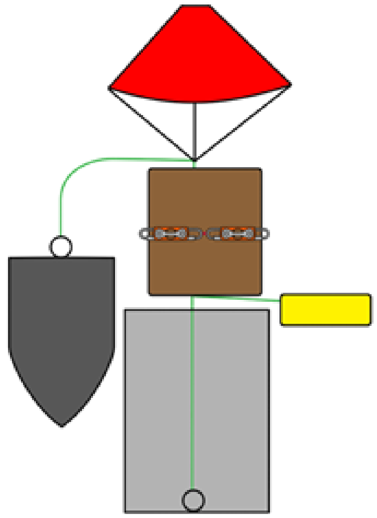


Figure 3-22: Drogue Deployment

The rocket will fall to an altitude of 1000 feet before the second event is triggered. The second event is detonating the tethers that keep the main parachute packed into the deployment bag/burrito. The tether separation will cause tender descenders to release a flap on the deployment bag/burrito allowing the air to pull the main parachute from the bag/burrito.

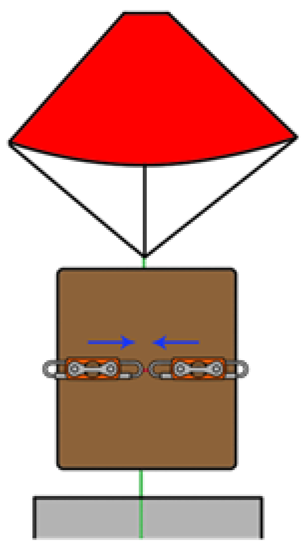


Figure 3-23: Tender Descender Orientation

The final stage of the recovery system is for the rocket to safely descent under the main parachute. Figure 3-24 shows how the rockets recovery system will look during this stage of recovery.

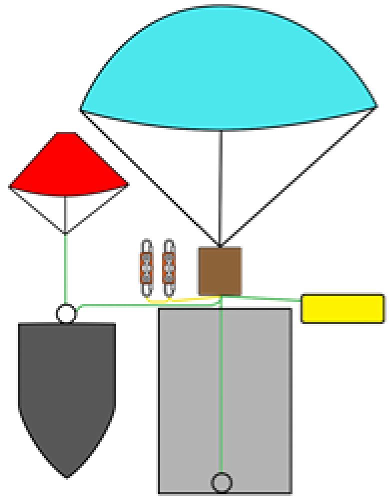


Figure 3-24: Final Stage of Recovery

3.4.6 Trigger System Design

Prometheus will use two perfect flight altimeters. Two altimeters are being used to reduce the risk of recovery system failure if one altimeter fails to operate properly during launch. The altimeters will be wired into their own black powder well, and a tender descender. The perfect flights are wired into their own black powder well and tender descender so that if an e-match comes loose during flight the other e-match will still be in the proper place and ignite the charges allowing for safe recovery of the rocket.

The other redundancy feature incorporated into Prometheus's recovery system is the way that the tender descenders are linked together. As Shown in Figure 3-23. The two tender descenders will be linked in line with one another. Linking the tender descenders in line guarantees that if one of the two charges ignites the link will be severed and nothing will be binding the deployment bag/burrito.

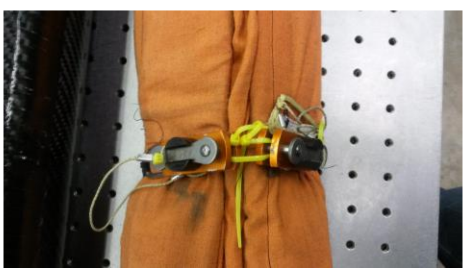


Figure 3-25: Tender Descender Configuration

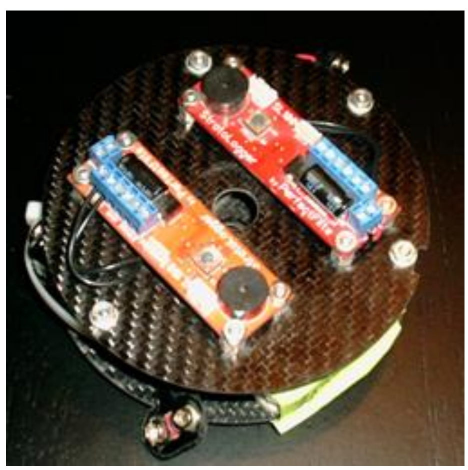


Figure 3-26: Altimeter Bay

3.4.7 Failure Modes

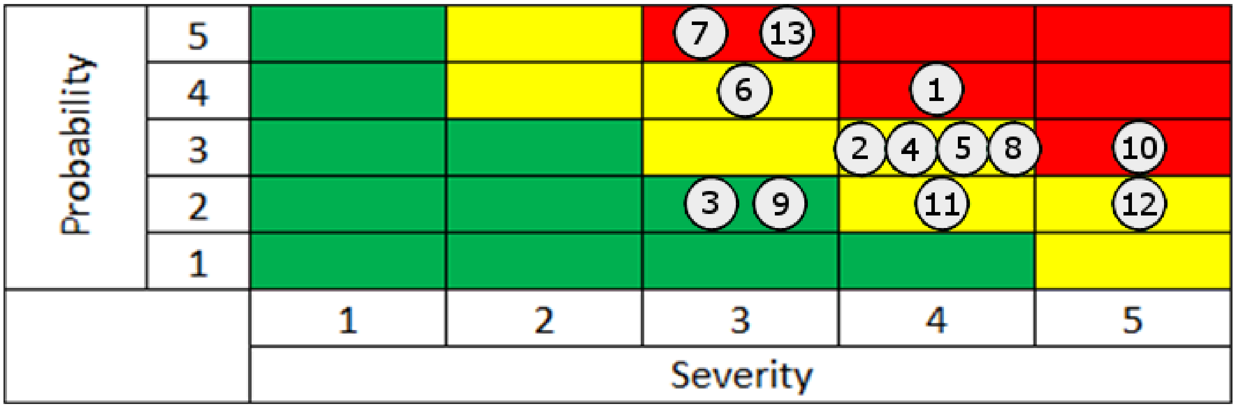


Figure 3-27: Recovery System Risk Chart

Table 3-4: Potential Recovery System Risk

Ref #	Potential Hazard	Probability	Severity	Impact	Mitigation
1	Altimeter wire breaks	4	4	Black powder charge may not discharge, and lack of recorded data	Check wires for possible breaks/fatigue prior to launch
2	Shock chord breaks	3	4	Rocket reenters with high landing velocity	Purchased strong shock cord, test methodically, Inspect prior to launching
3	Deployment bag/burrito failure	2	3	Parachute will not deploy, rocket reenters with high landing velocity	Deployment bag/burrito successfully flown on exact same setup as Prometheus.
4	E-match breaks free from powder charge	3	4	Parachute will not deploy, rocket reenters with high landing velocity	Test e-match connection to ensure solid interface, and reinforce connection with tape.
5	E-match breaks free from altimeter	3	4	Parachute will not deploy, rocket reenters with high landing velocity	Test e-match connection to ensure solid interface
6	Zippering	4	3	Severed Body Tube	Test shock cord deployment avoid zippering

7	Sharp edges around body tube	5	3	Damage to shock chord or altimeter wires.	Nomex sleeves used to protect wires and shock chord.
8	Parachute bag fails to deploy	3	4	Vehicle undergoes a high energy impact.	Full scale recovery system testing
9	Tension break	2	3	Recovery system detaches from rocket. Parts land ballistic.	Proof loading of all recovery system components.
10	Separation failure	3	5	Ballistic landing/ total vehicle loss.	Ejection charge testing with full-scale vehicle. Full scale recovery system testing
11	Stitching failure	2	4	Vehicle undergoes high energy impact due to parachute failure.	Ground and flight testing of parachute design.
12	Parachute/parachute bag fire	2	5	Vehicle undergoes high energy impact due to parachute failure.	Uses of Nomex blast cloth to prevent burns to parachutes.
13	Stitching being burnt from deployment charge	5	3	The deployment bag/burrito can choke up on the main chute lines and reef the parachute	Removed seams that are made from polyester that are exposed to black powder charges and replaced them with Nomex thread.

3.4.8 Introductory Performance from Tests

On April 12th 2014 the Recovery System was successfully flown in Manchester TN on a prototype rocket with a dry weight of 25 pounds. Figure 3-28 shows the result from the flight. The altimeter data shows that the deployment system successfully deployed that the rockets landing velocity was at 13 $\frac{ft}{s}$.

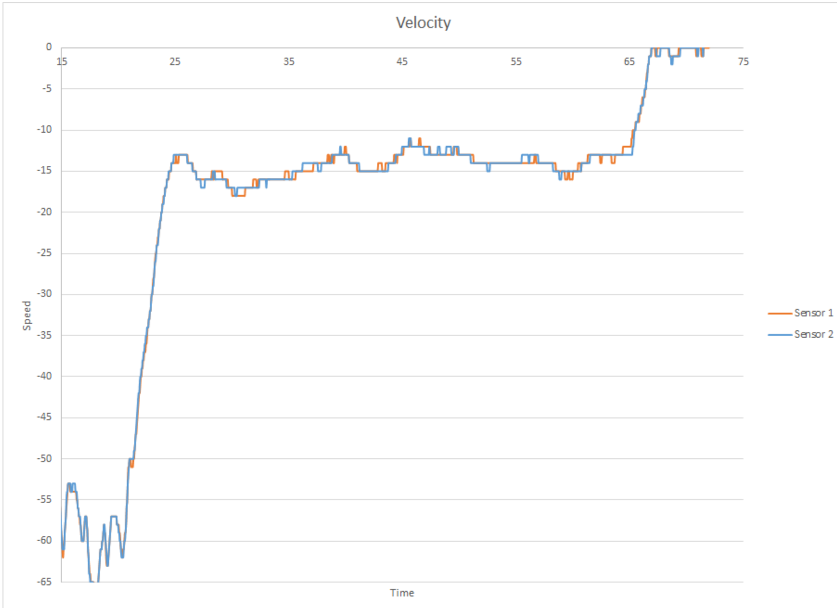


Figure 3-28: Prototype Flight Results

An important lesson learned from the prototype launch is that the stitching needs to be inspected after each launch. The deployment bag/burrito was sewn with polyester string, and was burnt from the main deployment charges. The stitches are being replaced with Kevlar threading to prevent the threads from being burnt.

3.4.9 Drag Coefficient

From the prototype recovery system simulation, low speed coefficients of drag numbers were calculated for both the drogue and main parachutes. While the vehicle is falling at 60 feet per second under drogue, the parachute has an effective drag coefficient of 1.6. Since the coefficient of drag is highly dependent on fluid speed, turbulence, and a variety of other factors, it is expected that the drag coefficient will go down as the turbulence increases which is necessary to achieve a the necessary descent speed to maintain the range drift requirement. The main chute exhibited a drag coefficient of 1.3 at 14 feet per second. This will allow Prometheus to meet the energy requirement during landing of 75 feet pound force.

3.5 Mission Performance Predictions

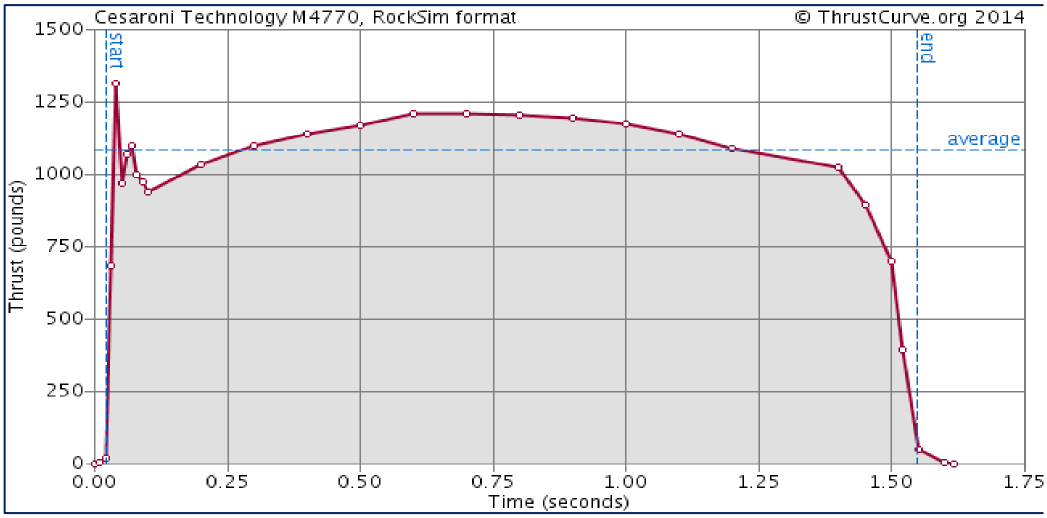


Figure 3-29: M4770 Thrust Curve

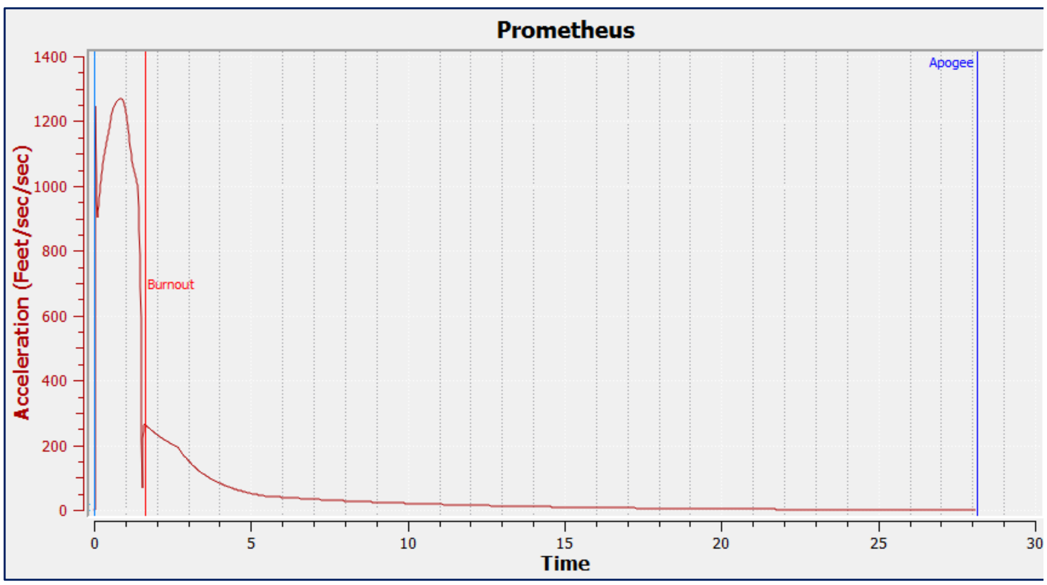


Figure 3-30: Acceleration (ft/s^2)   Max = 1693.73

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-
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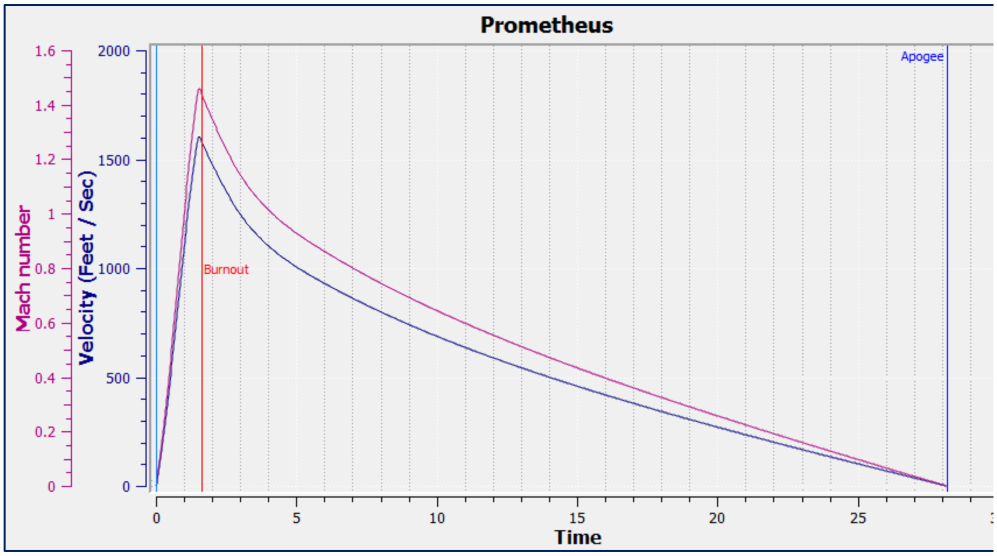


Figure 3-32: Velocity and Mach Number (ft/s) Max = 1605.93 and ~1.5

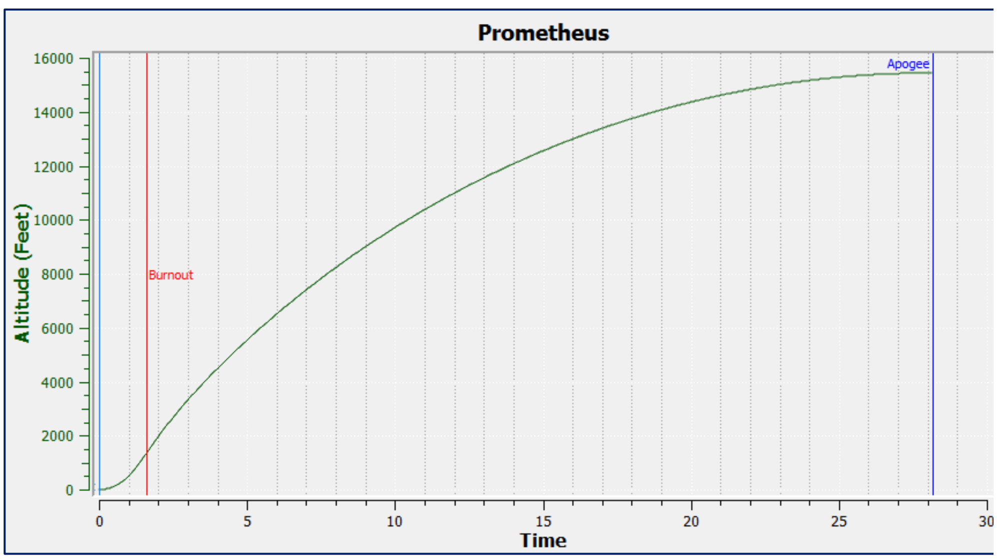


Figure 3-31: Altitude (ft) **Max = 15,442.**

The flight profile is sensitive to changing component masses, but as of now, the masses are changing relatively little.

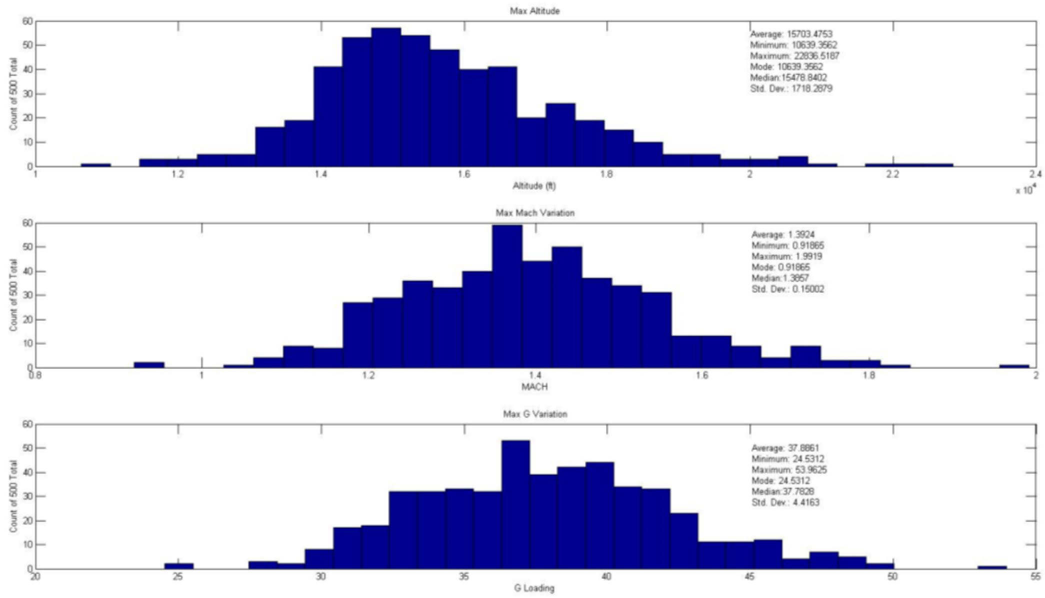


Figure 3-33: Variance for Altitude, Mach Number, and Acceleration**,** respectively.

Stability

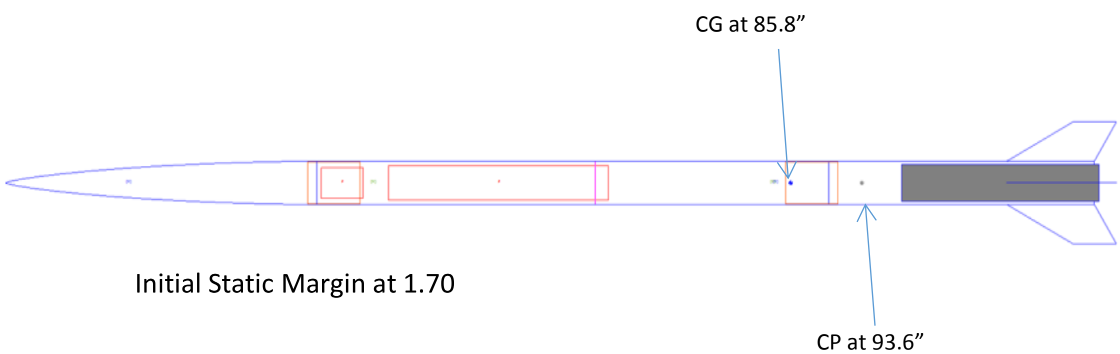


Figure 3-34: Location of CG and CP

The CG location is sensitive to small changes towards the nose of the rocket, due to the long arm of effect. Changes to the material used for the pitot probe, the exact location of the forward circuit boards, and changes in shell thickness near the nose can influence the CG, and thus the Static Margin, drastically.

The CP is sensitive to small changes in fin size. The presence of the brackets may have a tangible effect on the CP if they change the side profile.

Kinetic Energy During Descent

Under drogue descent, the vehicle's energy increases to 3391 ft*lb., but the large main parachute decreases this sharply, so that it's no more than 33 lbs by the time it impacts the ground.

Table 3-5: Kinetic Energy

Stage of Recovery	Altitude (ft)	Velocity (ft/s)	Energy (ft*lb.)
1	15190.2	50.175	878.5
2	1000	98.58	3391.23
3	0	9.702	32.87

3.5.1 Drift Calculations

As per requirement of the Student Launch Competition, vehicles are required to land within 5000 feet of the launch site. Monte Carlo simulations were used to predict the probability of the downwind range the vehicle would travel over its flight time. Eight parameters were varied which include drag coefficients, thrust, weight, and other key parameters.

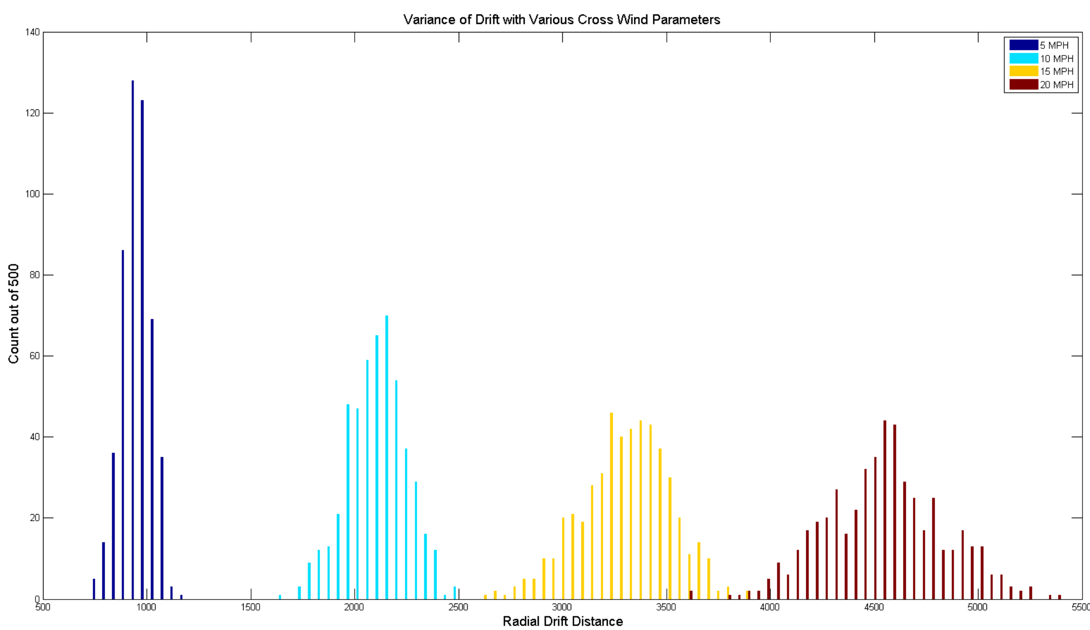


Figure 3-35: Drift Calculations

Figure 3-35 depicts the probable ranges expected for a cross wind. For any cross wind up to 20 MPH, there is high probability that the max range of the vehicle will be under 4700 feet is high. This requires a rapid decent under a drogue chute at about 120 to 150 feet per second during the high altitude recover from 15,500 feet to 1000 feet where the main chute will deploy. Total flight time is approximately 170 seconds. If one assumes the vehicle is traveling at the cross wind speed from time of launch to landing, the vehicle at 20 MPH will have traversed 4986 feet in that time. Since the Monte Carlo model is time based, fully coupled, 5th order system of differential equations which accounts for acceleration, the predictions seem accurate as the probability distributions undershoot the constant velocity model approximation.

3.6 Verification (Vehicle)

- For each requirement (in SOW), describe how that requirement has been satisfied and by what method the requirement was verified. Note: Requirements are often satisfied by design features of a product, and requirements are usually verified by one or more of the following methods: analysis, inspection, and test.
- The verification statement for each requirement should include results of the analysis, inspection, and/or test which prove that the requirement has been properly verified.

3.7 Safety and Environment (Vehicle)

3.7.1 Failure Modes and Analysis

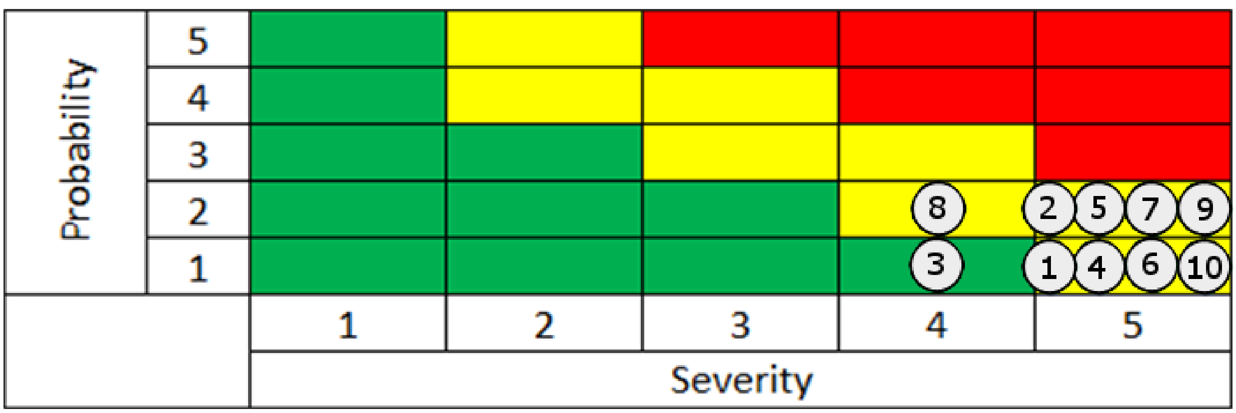


Figure 3-36: Failure Modes Risk Table

Table 3-6: Vehicle Failure Modes

Ref #	Failure Mode	Probability	Severity	Potential Hazards	Mitigations
1	Buckling of body tube due to aerodynamic loading or thrust forces.	1	5	• Unstable flight and potential loss of vehicle and payloads. • Load path shifts to central structure of vehicle. • Falling debris if vehicle breaks apart.	• Compressive tests of carbon fiber samples to forces six times greater than maximum thrust required for failure. • Sub-scale tests indicative of stable flight which will minimize

					aerodynamic forces.
2	Failure of fin brackets and/or fin bracket hardware due to aerodynamic forces or acceleration produced during launch.	2	5	• Fins or fin brackets separate from vehicle during flight. • Vehicle becomes unstable and poses a risk to ground personnel. • Falling debris.	• Fin flutter analysis performed to ensure structural integrity during supersonic flight. • Static loading of fin brackets and hardware to approximately five times the maximum expected from aerodynamic loads.
3	Buckling of central payload shaft due to thrust forces produced by motor.	1	4	• Damage to payloads. • Motor case no longer centered properly producing unstable flight.	• Preloading of payload shaft to minimize compressive forces. • Use of a thrust ring to move load path for thrust forces to body tube. • FEA performed to indicate proper factor of safety.
4	Rupture of central payload shaft.	1	5	• Separation of vehicle sections during flight. • Damage to payload. • Loss of motor tube/ thrust ring.	• Proof loading of payload shaft to expected preload. • Written launch procedures with specific steps for preloading to prevent over-torqueing. • FEA performed to indicate proper factor of

					safety.
5	Coupler failure due to bending from aerodynamic loading.	2	5	• Separation of vehicle sections during flight. • Falling debris. • Vehicle becomes unstable and poses a risk to ground personnel. •	• Proof loading of couplers to maximum predicted bending loads. • FEA performed to indicate proper factor of safety. • Proper design of all interfaces to ensure tight fit and prevent flexing.
6	Rupture of nosecone shaft due to recovery forces.	1	5	• Incomplete deployment of recovery system. • Loss of nosecone and portion of Nanolaunch payload. • Falling debris.	• Ground testing/proof loading of all associated components. • FEA performed to indicate proper factor of safety.
7	Drag separation of nosecone during flight.	2	5	• Premature recovery system deployment. • Unstable flight due to separation of vehicle.	• Use of properly sized shear pins. • Ground testing of fitment of nosecone with shear pins to ensure snug fit.
8	Failure of pitot probe threads.	2	4	• Loss of pitot probe and nosecone shell.	• Ground testing/proof loading of all components.
9	Rail buttons separate from vehicle.	2	5	• Unstable lift off and hazard to ground personnel.	• Installation of rail buttons to manufacturer specifications.
10	Motor over pressurizes.	1	5	• Motor case failure and damage to the vehicle.	• Assembly and installation of commercially available motor to manufacturer specifications.

There are a number of failure modes that are of particular concern for the design of Prometheus. Both the nosecone and central payload shafts play an integral role in keeping the internal structure of the vehicle stationary during flight. Any failure associated with these two parts would have far greater implications on the survivability of the vehicle as a whole. As mentioned earlier, the nosecone shaft is used to not only retain the avionics contained in the nosecone, but it also holds the pitot probe in place and carries the loads induced by the recovery hardware attached to it. A failure of this threaded rod would not only cause the nosecone to come apart, but it could also prevent the remainder of the recovery system from deploying properly. Of similar concern are the threads present in the pitot probe that the nosecone shaft will interface with. These threads will be part of an insert that will be epoxied in place. A failure of the epoxy joint would have the same consequences as a failure of the nosecone shaft. Over-pressurization of the motor tube is yet another major concern. Though this occurrence is unlikely, due to the extremely energetic nature of the V-max propellant used in the motor, the vehicle would likely sustain substantial damage if the motor casing were to rupture.

3.7.2 Environmental Effects

3.7.2.1 Environmental Effects on the Vehicle

The potential effects of a launch site environment weigh heavily on the decision of a go or no-go for launch. Minimizing the effects and potential implications of failing to identify environmental hazards on the launch vehicle is a goal of the CRW team. Table 3-7: Environmental Effects on Vehicle below provides a summary of the environmental conditions that could be detrimental to the vehicle's survival.

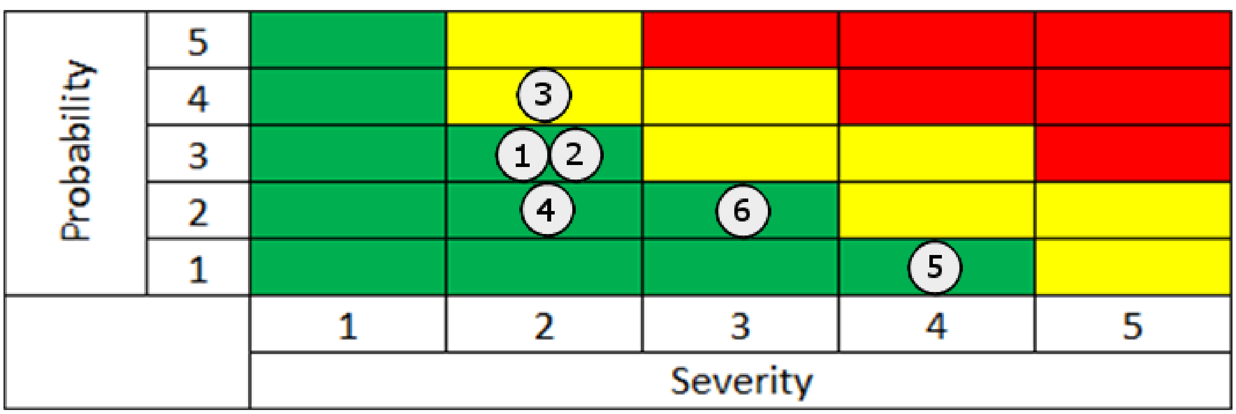


Figure 3-37: Environmental Hazards Risk Table

Table 3-7: Environmental Effects on Vehicle

Ref #	Environmental Hazard	Probability	Severity	Potential Hazard to Vehicle	Mitigation
1	High winds at launch site.	3	2	• Vehicle drifts out of visual range of ground personnel. • Vehicle lands in or on several trees. Damage could	• Avoid high winds while conducting any launches. • Lower main parachute

				result from removal. • Wind alters flight path of vehicle.	deployment to minimize drift. • Increase vehicle stability margin to compensate for wind current.
2	Dense cloud cover.	3	2	• Inability to launch vehicle on full scale motor due to lowered launch ceiling. • No visuals on vehicle during flight.	• Avoid launching in described conditions. • Use a lower impulse motor to lower maximum predicted altitude. • Use of bright colors on vehicle and/or recovery system for easier visual identification.
3	Hard landing surface.	4	2	• Damage to vehicle and components, namely fins and fin brackets.	• Appropriately sized parachute to limit descent energy to 75 ft-lbf max. • Easily replaceable fins and fin brackets in the event of a failure.
4	Bodies of water near launch field.	2	2	• Damage to vehicle electronics depending on vehicle's position upon landing.	• Point launch rail in a direction away from bodies of water. • Avoid launching into high winds that could carry vehicle towards body of water. • Avoid launch sites with bodies of water nearby.
5	Storms/ inclement weather.	1	4	• Cancellation of launch, possible programmatic delays.	• Check weather ahead of launch and schedule accordingly to

					allow for weather delays.
6	Heating of internal components.	2	3	• Possible failure of electronics and damage to batteries. • Degradation of carbon fiber/ epoxy components if undergoing multiple heating and cooling cycles.	• Detailed launch procedures to allow for quick assembly and minimal on-the-pad time. • Storage of vehicle components in a climate controlled environment.

Of particular concern to the CRW team is dense cloud cover at the launch site. As Prometheus is expected to attain somewhere in the neighborhood of 16,000 feet AGL, clear skies are not only essential for recovery, but for the ability to launch at all. This altitude demands a launch ceiling of 20,000 feet. While the two launch fields the CRW team utilizes have waivers to this altitude, the conditions must be ideal in order for the RSOs to allow a launch to this altitude. The ability to maintain a visual lock on the vehicle during its descent can also be critical for a successful recovery. If the signal between Prometheus and the ground station is lost during the descent, accurate GPS coordinates for the vehicle may not be possible. High wind is another major concern. While the launch fields are generally several miles square, the slow descent rate resulting from the large parachute employed by Prometheus could allow it to drift towards the tree line, depending on the launch rail location. If either of these two situations presents themselves, the CRW team would likely suspend a launch or employ one of the mitigations in order to increase the chances of a successful launch and recovery.

3.7.2.2 Vehicle Effects on Environment

Of equal importance to the effects of the environment on the launch vehicle, are the effects that the vehicle itself can have on the environment. The local launch fields that the CRW team utilizes all operate on privately owned farms and minimizing the impact on the environment is essential. Table 3-8: Vehicle Environmental Effects below provides a summary of potential environmental hazards and their mitigations. This table does not feature a probability and severity section, as they do not directly pertain to the success or failure of the launch vehicle.

Table 3-8: Vehicle Environmental Effects

Vehicle Hazard	Environmental Effect	Mitigation
Combustion of ammonium perchlorate propellant.	• Toxic fumes. • Burns to ground and potentially crops beneath motor.	• Use the smallest motor possible to achieve the desired results. • Use a fire blanket under the launch rail to prevent burning the ground.
Use of Li-Ion batteries.	• Hazardous material released if damaged or disposed of improperly.	• Proper shielding of batteries from puncture in payload design.

		• Use of only approved chargers and non-conductive charging bags. • Coordinate with Office of Environmental Health and Safety for battery disposal.
Loss of motor case or other metallic components.	• Severe damage to harvesting equipment. • Steep fines for local launch clubs.	• Proper motor retention. • Retrieval of any motor case or pieces that separate from launch vehicle.
Use of 4F black powder.	• Hazardous fumes generated through combustion.	• Use of smallest possible ejection charges for a successful deployment.

While the use of ammonium perchlorate propellant and black powder are largely unavoidable facets of high-powered rocketry, care must still be taken to ensure that the use of these compounds has a minimal environmental impact. As mentioned earlier, the two launch fields primarily utilized by the CRW team are on privately owned farms, so minimizing our environmental impact is critical. The large motor that Prometheus is using requires the use of fire blankets at the base of the launch rail to prevent burning the ground underneath the rail. If any pieces separate from the vehicle, it is more imperative that they are located due to the risk of damaging very expensive harvesting equipment.

3.8 Payload Integration

In total there are 5 different designs, each of them corresponding to specific needs and requirements for each payload. All of them were designed using Eagle CAD PCB Software *(V6.5)* in compliance with schematics of the circuitry provided by each payload team. After the designs were created they were proofed by the experiment lead and the team mentor. The PCBs were then ordered from OSH Park. Part of the design process involved importing pre-designed parts libraries from Adafruit and Sparkfun into Eagle CAD, recreating the necessary parts in Eagle CAD, and using those parts already available on the expansive library pre-loaded into Eagle CAD. A list of all pin connections and all schematics can be found on Appendix N – Pinlist for PCBs.

The PCBs manufacture by OSH Park use a lead free surface finish called "ENIG", which stands for "Electroless Nickel Immersion Gold". It consists of an underlying layer of nickel with a thin layer of gold over the top. The gold layer is very thin and not intended to provide the main structure of the track; it just acts as a protective coating for the nickel to prevent corrosion before it is ready to be soldered. Gold is extremely resistant to corrosion so ENIG has several good points: it can be touched with bare fingers without tarnishing, has a very long shelf life, the pads / tracks are very flat and square-edged - something that can be important for fine-pitch surface-mount parts, it complies with Restriction of Hazardous Substances (RoHS) Directive, and easy soldering compared to other surface finishes.

For the Nanolaunch payload there are 2 PCBs designs. The first one, *PCB V1.4*, shown in Figure 3-38, is referred to as a Cape because it is designed to connect to all possible pins on the Beaglebone. It carries 2 accelerometers (ADXL345 and ADXL377) and one gyroscope (L3GD20). It also contains possible external connections for I^2C pins (SCL and SCA), GPIO_17 and ground.

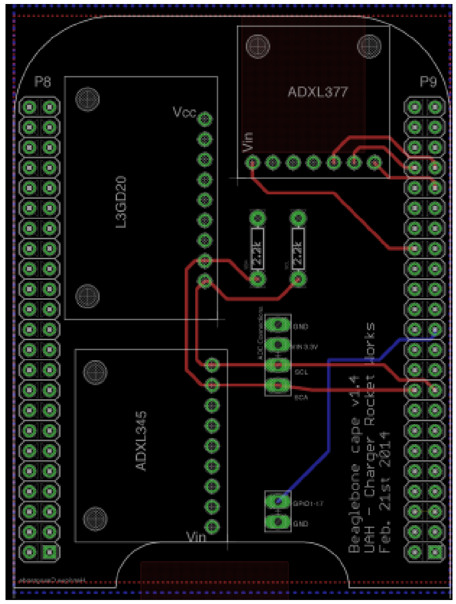
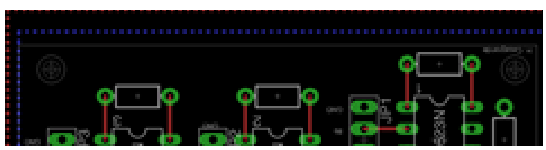


Figure 3-38: *PCB V1.4* Beaglebone Cape

The second PCB, *Pressure PCB V1.2*, carries 4 op-amps (AD623N) each connected to a pressure sensor. All of them are then connected to an Analog to Digital converter (ADS7828) as seen in Figure 3-39. The Pressure PCB V1.2 is connected to PCB V1.4, mentioned previously, and on to the Beaglebone



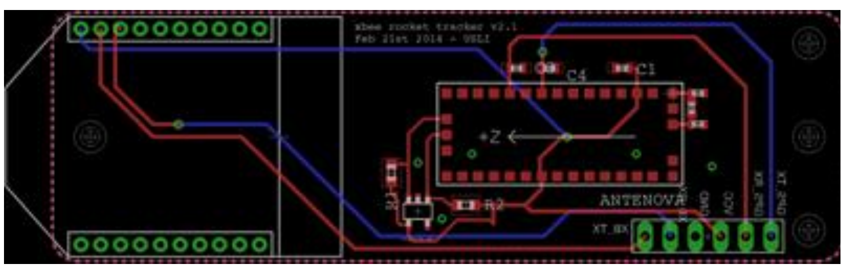


Figure 3-40: *GPS_Antenna_PCB_V1.1*

The *GPS_Antenna_PCB_V1.1* seen below in Figure 3-40 is designed to host a XBee-PRO XSC S3B and an Antenova M10382-AI. It also contains output connections compatible with the Beaglebone white in the LHDS payload.

The Dielectrophoresis uses 2 PCBs seen in Figure 3-41 and Figure 3-42. The first, *USLI PCB Dieletric Cop. V1.1*, was designed to host a level shifter (PART NAME), a micro SD slot (Part Name), an accelerometer (ADXL337), and an Arduino Pro. Additional features include extra access to voltage and ground, connections to the cameras and two warning system LEDs.

The Second PCB, *USLI Transistor PCB V1.1*, holds the heat sink, safety buzzer, pin connections to the transistor and connections to the Arduino Pro on *USLI PCB Dieletric Cop. V1.1* PCB.

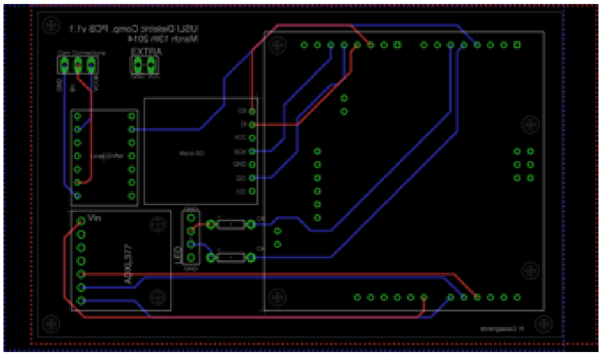


Figure 3-41: *USLI Dielectric Cop. V1.1*

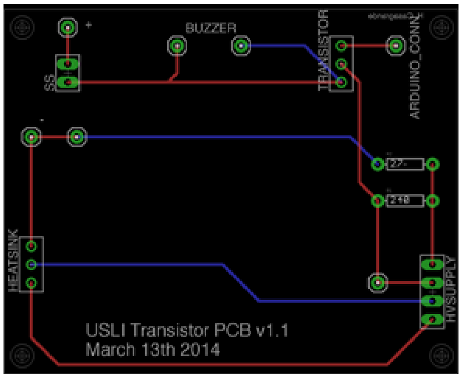


Figure 3-42: *USLI Transistor PCB V1.1*

The dielectrophoresis and Nanolaunch payloads are accommodated by a sled made primarily of 3-D printed plastic material, specifically ABS. The sled is comprised of modular levels, each with 3 panels connected like hinges and a 0.050” thick carbon fiber circular baffle between each level. The sled is attached to the payload shaft which is a 3 ft. section of 3/8 – 16 all thread rod. The sled is slid onto the rod and then secured in place by nuts and locking washers at specified points on the payload shaft. Two circular carbon fiber baffles with be used at both ends of the fully assembled payload sled to provide the support required at the interface point between the payload sled, the nuts, and the payload shaft. Once the payload sled is secured to the payload shaft, as in Figure 3-43, the body tube of the rocket will slide over the completed payload assembly and be held in place by the payload shaft.

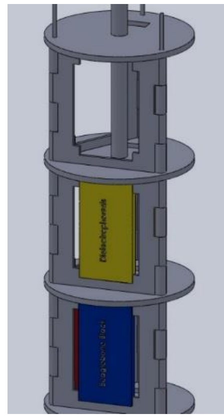


Figure 3-43: Payload Bay

The sled provides a robust and compact design that was ideal for interfacing with the multiple payloads. Unique panels were manufactured to house each component. In order for easy installation and maintenance, the sled was equipped with three removable all-thread rods used as hinge pins. Access to the interior of the panels is available by simply removing a single rod in Figure 4-14. A faraday cage will be used to separate the dielectrophoresis and aerodynamic coefficient payloads.

The LHDS payload is similar in that it employs the ABS panels and carbon fiber baffles. The payload is housed in the recovery bay with the recovery system. The payload will be attached to shock cord and deployed along with the recovery system. The LHDS assembly fits securely within the body tube, preventing the parachute from unfurling around it, but still easily deployed by the ejection charge.

4 Payload Criteria

4.1 Nanolaunch 1200

4.1.1 Experiment Concept

The Nanolaunch 1200 payload was creative and original in that it uses a unique microprocessor that exposes the team to C/C++ coding which will be something that other teams will not be able to offer. The payload consists of two separate modules, one located at the CG and one located at the nose of the rocket. The two payloads will serve to record the in-flight data and will provide a substantial amount of data encompassing the entire flight. The significance of the payload is that it will be able to act as an inexpensive replacement for subscale wind tunnel tests to determine the pitching moment, total drag coefficient, and base pressure. The empirical data that will be recorded will be crucial to providing the background data to be able to extrapolate coefficients such as the ones that would be recorded in the wind tunnel as stated above.

The significance of the Nanolaunch payload was designed in support of the Nanolaunch 1200, which is where the name comes from. The payload was successful in that great progress was made toward accomplishing the goal of being able to measure the acceleration, yaw, pitch, roll, and pressure. Further research would be necessary to perfect the design to provide more precise and accurate data for the use in extrapolating confident aerodynamic coefficients. The sensors will be able to give a “rough” estimate of the coefficients, but due to the uncertainty in the sensors’ measurements, a precise and “definite” answer cannot be certain. To move forward, more research should be done to calibration the high G accelerometer, since with its high G range it has proven quite difficult to calibration a 100 G accelerometer with more than just using gravity in each coordinate direction. The gyroscopes need calibrating. The gyroscopes will be able to currently tell us the rate of rotation of the rocket based on the periodic oscillations that it measures. The low G accelerometers do not need any additional calibration. The base drag pressure sensors located at the CG have been calibrated and the in-depth analysis is discussed later in the Science Value section. The pressure sensors could use an improved method of calibration that would allow for known pressure measurements to be made in both regions, above and below atmospheric pressure, at the same time. This would reduce the uncertainty by about half.

4.1.2 Science Value

The Nanolaunch experiment's objective was to act as an inexpensive replacement for subscale wind tunnel tests to determine the pitching moment, total drag coefficient, and base pressure. The aerodynamic coefficients will be backed out from accelerometer, gyroscopic, and pressure data collected at the center of gravity and the nose of the vehicle. The Nanolaunch 1200 system is designed to provide a low-cost alternative for launching small experimental payloads approximately 2 to 20 pounds into low earth orbit. Providing a reliable method for determining these coefficients would support the Nanolaunch 1200 system and benefit future research possibilities requiring low gravity conditions.

The success criterion for the Nanolaunch 1200 payload is outlined in Table 4-1. The table identifies the major requirements that would control the success or failure of meeting the payload's objectives.

Table 4-1: Success Criteria

Requirement	Success Criteria	Verification
Velocity Verification	Measure Pitot static pressure at the Nose to Calculate Mach	Recover pressure data from the Pitot static probes. Theoretical verification 4/4/14
Determine Axial Force	Measure axial acceleration	Recover acceleration data in the axial direction
Determine Angle of Attack	Measure gyroscope data at CG and the nose to get Yaw, Pitch, and Roll	Recover gyroscope data from both Beaglebone modules. Yaw, Pitch, and Roll calculated using gyroscope data 3/21/14
Recoverable and Reusable	Recover the payload and reuse it	Recover the payloads and be able to re-launch again in the same day. Tested 3/1/14

The flow chart in Figure 4-1 describes the basic logic used to launch, initiate data acquisition system, perturb and deploy recovery system. The approach used to formulate this procedure was the Scientific Method where each component was observed, measured, and experimented, and the formulation, testing, and modification of hypotheses is conducted when needed. The main mode of failure from the data acquisition was in the programming flow. The main source of error in the programming was due to a premature launch detect. When the Beaglebone turns on, the initial reading from the analog ports occasionally produces a spike in the data as soon as the program begins, which would trigger the recording of data. This was a problem because after the launch detect was triggered, if the launch did not take place within 7 minutes of the "accidental" initial trigger, then the data would record useless data wherever it was turned on. This was observed in the subscale launch, because we recorded data with no significant events. There was an occasional rotation signifying the rocket's parachute and other components were being assembled into the rocket under the pavilion with the accelerometers noting a change in sign. This led to the verification of the hypothesis that the cause was due to a premature spike when the Beaglebone was turned on. To mitigate this problem, a debounce was added to the program to check again after a "launch" was detected to ensure it was really a launch and not just a spike. After the first launch detect is triggered, the code waits for 5 milliseconds and then rechecks the accelerometer to see if it was really a launch. To provide additional data before the launch, a pre-launch buffer was created to record 200 entries of data prior to the launch detect. The buffer data is then written to its own text file following the completion of the recording of the 7 minute recording. The two data files are then post processed to combine the two as indicated below in the flow chart.

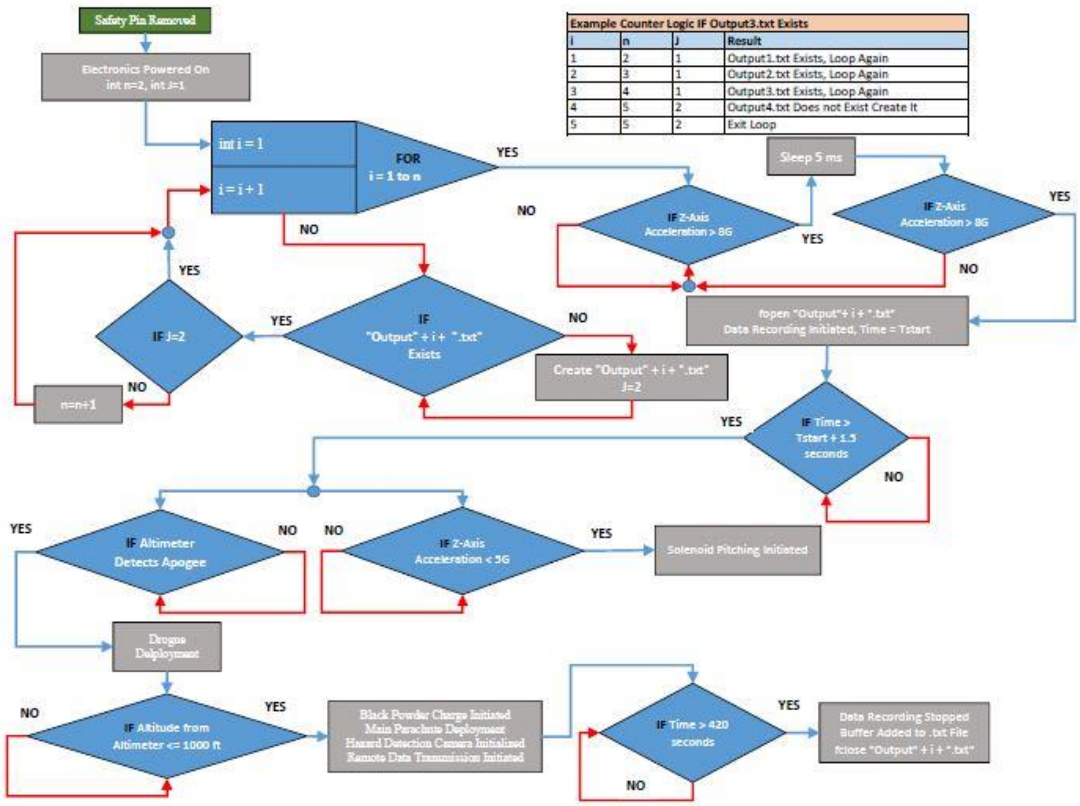


Figure 4-1: Code Flow Chart

The Nanolaunch test is quite meaningful, in that the data that is recorded gives detailed flight data that would otherwise be almost impossible to determine without a wind tunnel. The variables in the Nanolaunch experiment are the operational amplifier resistor values, the set recorded time of flight, and the set value of the required acceleration to trigger launch. Each variable can be changed to alter the flight controls. Note: If the resistor value was altered, then a recalibration would need to be made in order to re-obtain a pressure vs bit calibration curve.

Many precautions are being made to ensure that the experiment will be ready for launch and that it is capable of pulling accurate and reliable data. The Nanolaunch 1200 experiment's payload accelerometer data will be expected to match the G loading profile shown in Figure 4-2 for the 1.53

seconds. The data will have significant G changes at the following events during flight: motor burnout, apogee, drogue parachute deployment, and the main parachute deployment.

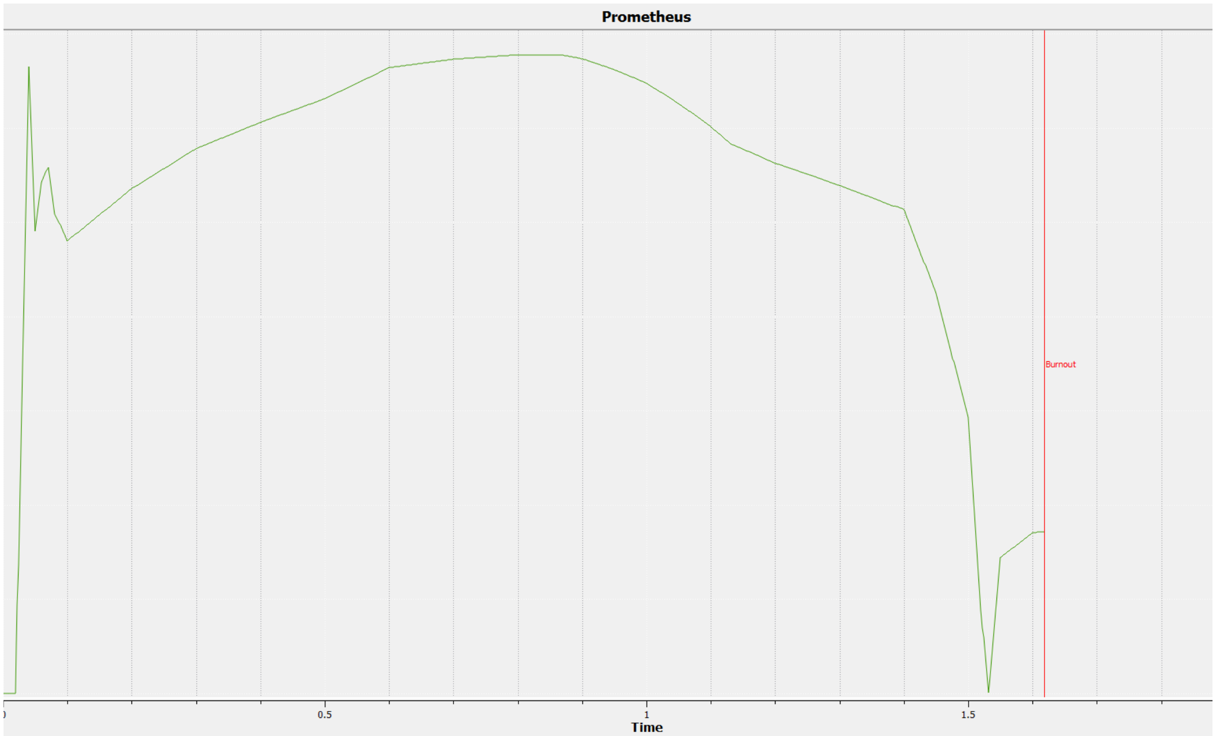


Figure 4-2: RockSim Acceleration Vs Time

Pressure Sensor Calibration

The pressure sensors were calibrated using a NASA Pb1 Strut base Pressure Model Setra 830E in the pressure range of 0 psig to 10.5 psig for the CG payload that would be used for “base” pressure readings. All 4 pressure sensors were measured sequentially in the same test with 8 unique measurements for each sensor and this is shown in Figure 4-3 below.

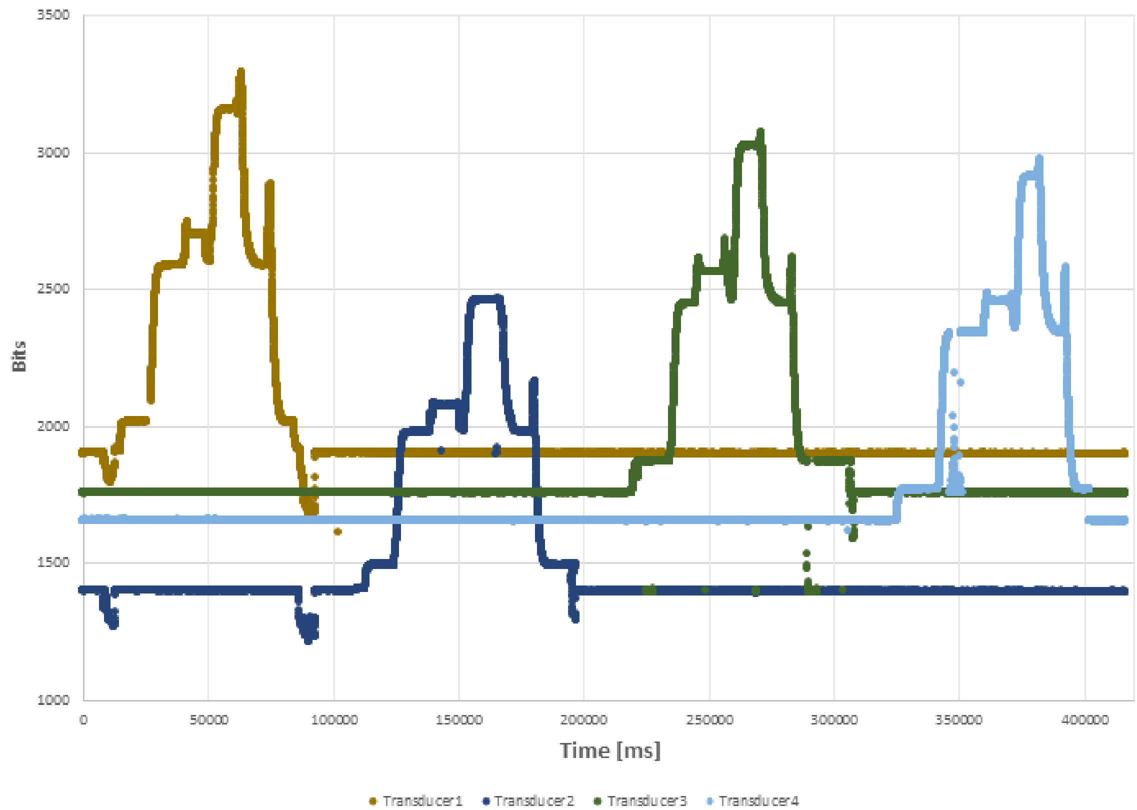


Figure 4-3: Pressure Transducer Test for Calibration

The procedure for measuring the pressure was as follows:

- The Beaglebone was turned on.
- After the "heartbeat" LED begins to blink the stopwatch was started to keep track of time. (Since the Beaglebone only records for the set 7 minutes)
- A pressure tube was hooked from the Setra 830E to the first pressure sensor.
- Weights were incrementally added to increase pressure as follows: 0 psig, 0.5 psig, 5.5 psig, 6.5 psig, 10.5 psig.
- The weights were then removed incrementally to decrease the pressure to provide additional data points as follows: 10.5 psig, 6.5 psig, 5.5 psig, 0.5 psig, and finally 0 psig.
- The piston slider corresponded to a change in pressure of 0.5 psig.
- After 8 unique measurements were made for the first sensor, the measurements were taken for the 2nd, 3rd, and 4th pressure sensors respectively.

Post processing of the data was primarily done in Excel and Mathcad. After the data reached steady state after an approximate time constant of 5τ for each transition reading between measurements, the corresponding pressure sensor plot for sensor 1 that will be used for calibration was shown in Figure 4-4 below.

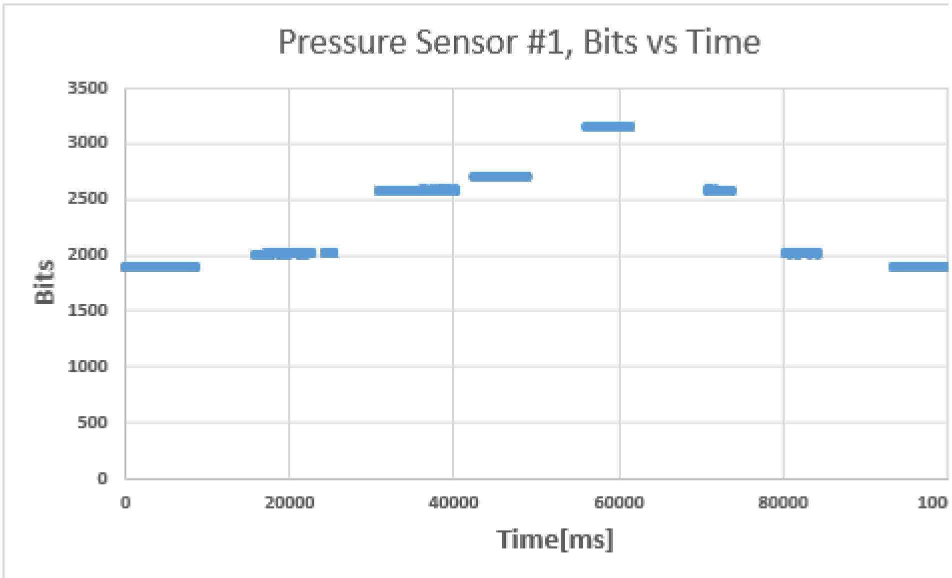


Figure 4-4: Steady State Pressure Measurements

By calculating the mean of each bit measurement, the data was translated to a set of 8 data points. The mean, standard deviation, sample size quantity, random uncertainty of the mean, pressure regression uncertainty, and the corresponding altitude uncertainty resulting in the calibration curve for all of the pressure sensors denoted in Figure 4-5. The calibration curve below incorporates a mean value taken based all of the data points after the transition regions were removed. The calibration curves below will be critical in converting the bit values to absolute pressure readings.

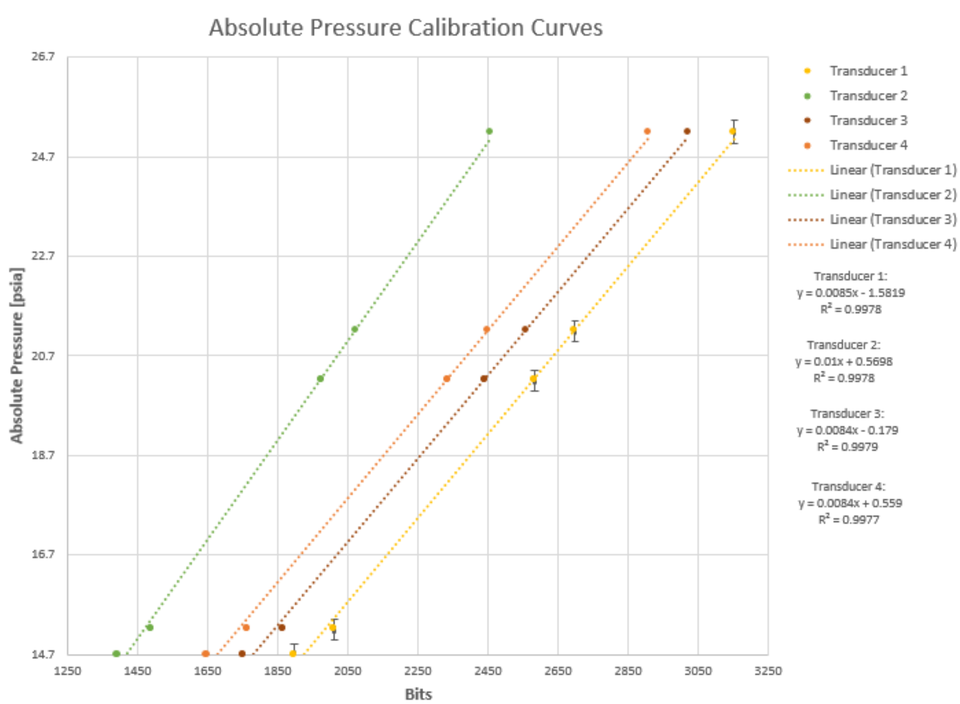


Figure 4-5: Absolute Pressure Calibration Curves

The random uncertainty of the mean was calculated using the student's t-distribution chart shown in Appendix C for a 95% confidence interval. Since the chart is "one tail" the 95% column is represented as 0.025. Since in all of the sample sizes measured N>>120, the degree of freedom can be approximated as infinity, denoting t = 1.96. The regression pressure uncertainty and the random uncertainty of the mean as indicated in Table 4-2 were both denoted in the bit uncertainty error bars in the calibration curve. The bit error bars were so small because the maximum uncertainty in the bit measurement was 4.186 which in respect to the x-axis range of 1250 to 3250 the change was so small, the bars seem inexistent. The regression pressure uncertainty bars resulted in a max uncertainty of ± 0.2350 psi (±438 ft) which was much more significant than the error in the bit measurement.

Table 4-2: Pressure Uncertainty Results

Pressure [psig]	Mean [Bits]	Stdev	N, Quantity	Random Uncertainty of Mean [Bits]	Regression Uncertainty [psi]	Altitude Uncertainty [ft]	Confidence Interval X ± U [ft]
0	1898.9	0.771	296	1.511	0.2080	386.3	X ± 386.3
0.5	2012.0	2.136	379	4.186	0.2050	380.5	X ± 380.5
5.5	2583.3	2.109	652	4.133	0.2070	384.3	X ± 384.3
6.5	2698.2	1.442	281	2.826	0.2100	390	X ± 390
10.5	3154.0	1.097	243	2.149	0.2350	438	X ± 438
5.5	2584.4	0.772	153	1.514	0.2070	384.3	X ± 384.3
0.5	2013.7	1.175	246	2.303	0.2050	380.5	X ± 380.5
0	1898.8	0.950	342	1.862	0.2080	386.3	X ± 386.3

To generate the pressure regression uncertainty bars the following uncertainty graph was generated in Mathcad using the "regress" and "interp" functions. As seen by Figure 4-6, the uncertainty varies depending on the measured bit, and the most significant uncertainty measurements occur in the lower bit range, which corresponds to below atmospheric pressure which is in the range of where most of our measurements will come from.

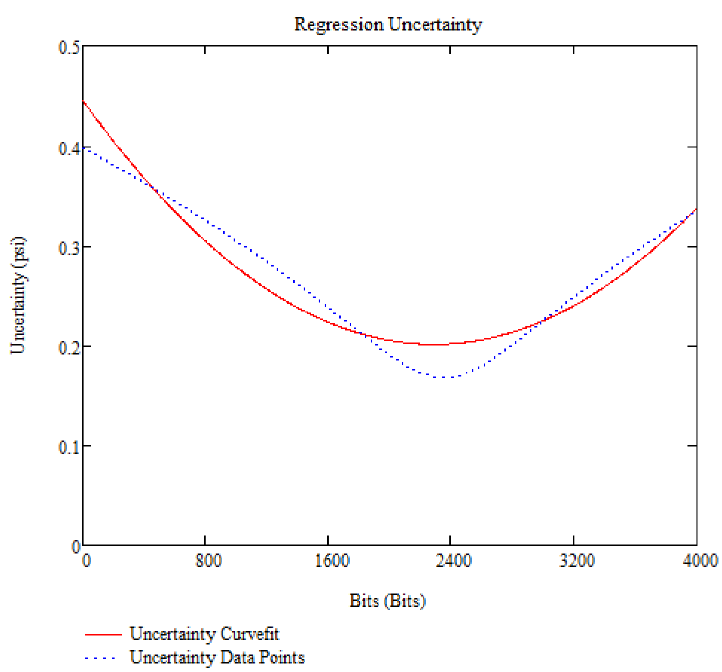


Figure 4-6: Regression Pressure Uncertainty

Ways to decrease the uncertainty:

- Increase the Bit resolution by changing the gain of the op-amp(optimize resistor value)
- Increase the number of data points in the Calibration curve especially in the vacuum region
- Change pressure sensors to a higher precision sensor. (Most probable cause of error)
    - Using the current component configuration, with the sensor's best accuracy denoted by the datasheet of ±0.25 FSS. At 30 psi as the maximum full scale reading the bits based on the calibration curve would occur at 3708.11 bits. The minimum reading of 0 psi would occur at 186.11 bits. This results in a FSS of 3522 bits. At ±0.25 % of FSS as the accuracy this gives an accuracy of 8.805 bits. The 8.805 bits corresponds to pressure accuracy of 0.0748425 psi which corresponds to a minimum uncertainty of 141.4 ft.
    - The Perfect Flight Stratologger uses a pressure sensor with an accuracy of an encompassing ±0.1 FSS.
- Change the 12 bit ADC to a higher bit such as a 24 bit ADC.
    - 12 bit = 0.008518 psi per bit split across 3522 bits of FSS
    - Possible 24 bit = 0.000001788 psi per bit split across 16777216 bits (assuming we keep the entire 16777216 bits of FSS) this effect would probably be minimum, but it would still be worth a try.

Ground Testing of Sensor Array

The array of sensors was ground tested by swinging a rope around with the payload attached to simulate a high G loading as high as 20 G's. After 170000 milliseconds the payload bay was taken inside and was set on a table. The accelerometer launch detect was triggered and after 7 seconds, the low G accelerometer that would normally "saturate" and cause lots of problems when they were maxed out would turn on after the delay to avoid this problem. The gyro's measure rotation in degrees per second, and at the time of this subscale only one pressure sensor was active in the payload for preliminary pressure sensor testing.

The recorded plots for each sensor are shown sequentially below. The high G accelerometers were used for launch detect, the low g accelerometers will be researched further to in order to be used for a pitching moment calculation when the solenoid pitching mechanism is researched further. The gyroscopes will be used to monitor the rate of oscillation throughout flight. The pressure sensor data was preliminary and was further researched with a high end level uncertainty analysis as discussed previously.

The plots of each of the recorded sensors were shown in the following figures below: Figure 4-7, Figure 4-8, Figure 4-9, Figure 4-10, Figure 4-11, Figure 4-12, and Figure 4-13. The expected flight data will be similar to the plots shown below with the exception of having an additional event of parachute deployment.

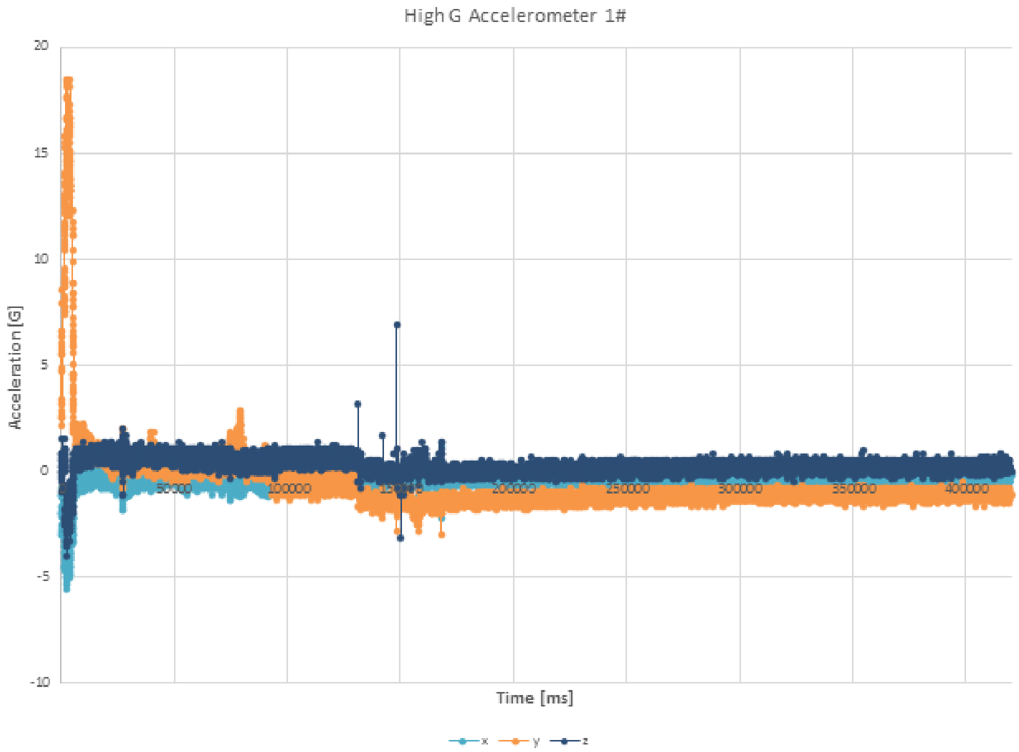


Figure 4-7: High G Accelerometer #1 Data

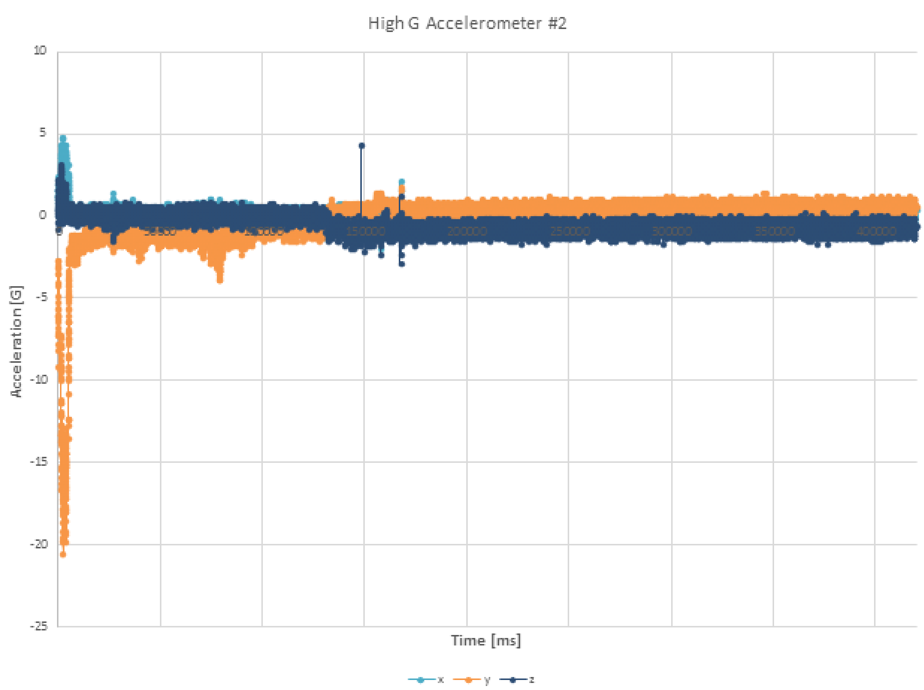


Figure 4-8: High G Accelerometer #2 Data

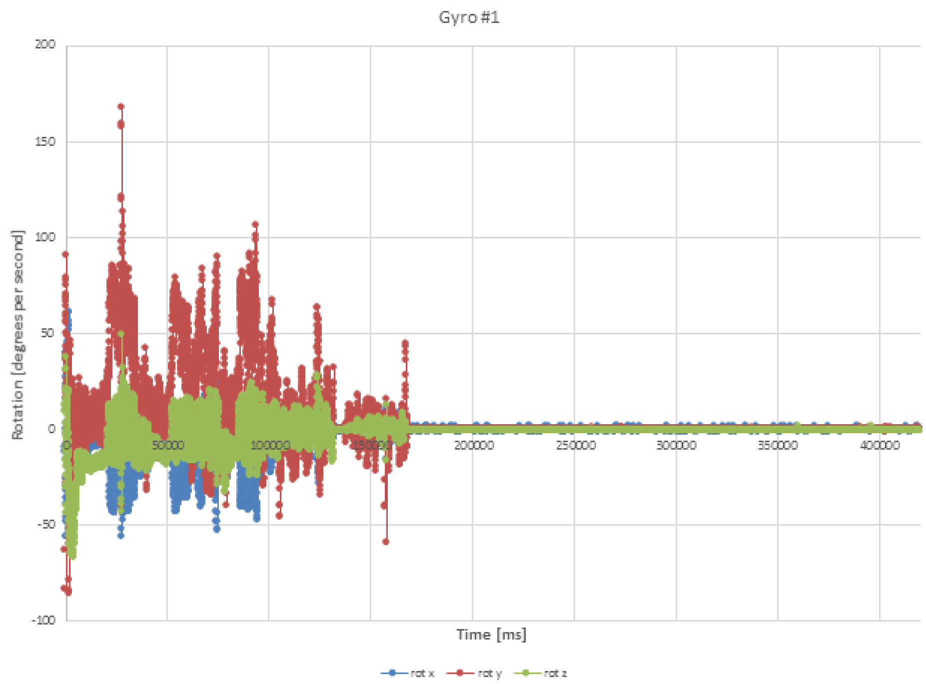


Figure 4-9: Gyro #1 Data

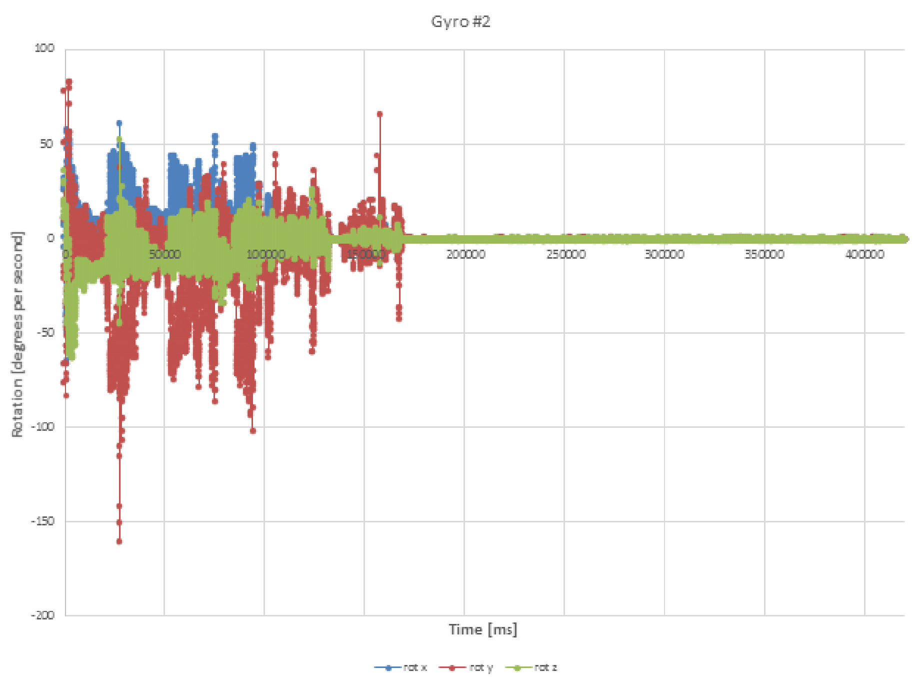


Figure 4-10: Gyro #2 Data

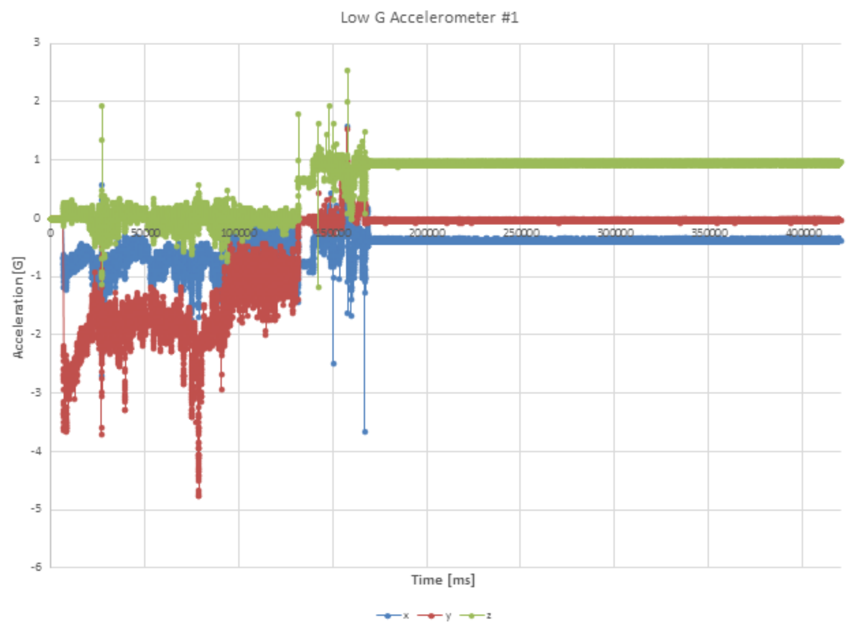


Figure 4-11: Low G Accelerometer #1 Data

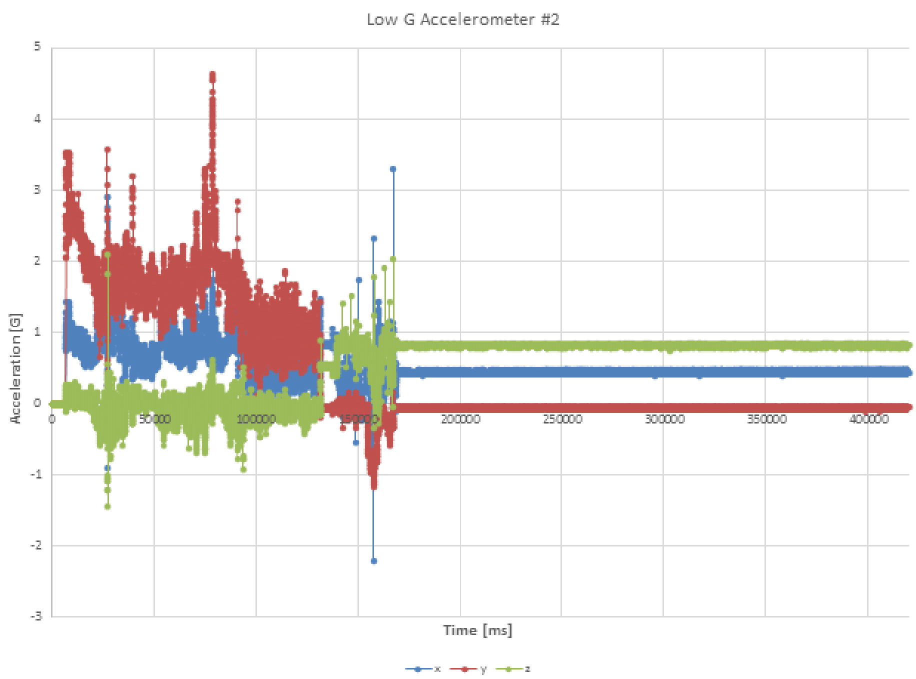


Figure 4-12: Low G Accelerometer # 2 Data

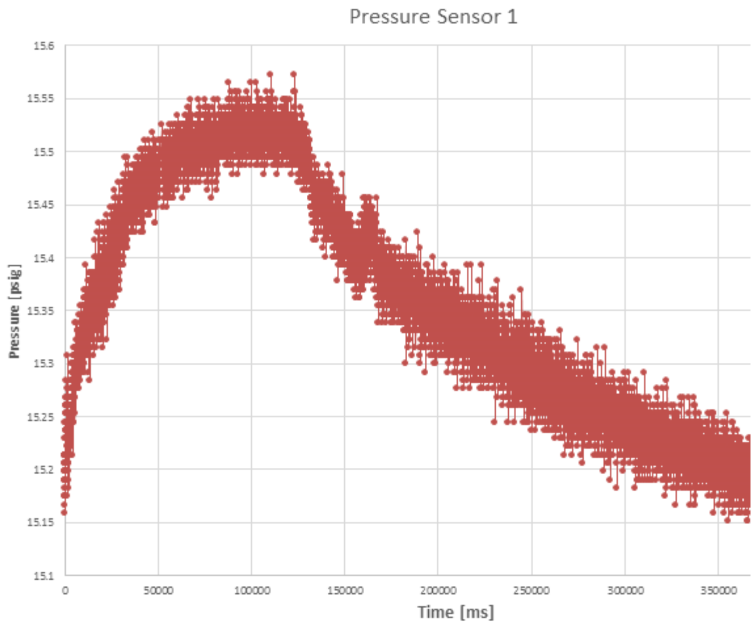


Figure 4-13: Pressure Sensor 1 Data

Experimental Procedure

The experimental test procedure is simple. To run a test using the Nanolaunch Payload the following steps must be followed:

1. Make any desired changes to the program code. (Adjust the launch detect and run time of launch, depending on expected G loading and expected flight duration)
2. Compile the C and C++ code together as well as initialize the i2c bus by running a custom designed script file by typing “sh compile.sh”. The script that it executes is shown below:

```
#!/bin/bash
echo "Building ACCELEROMETER CODE"
echo enable-i2c1 > /sys/devices/bone_capemgr.*/slots
g++ -c txtwrite.cpp
gcc -c demo.c ADXL345.c 1ddemo.c 1dADXL345.c demol.c Adafruit_L3GD20.c demok.c kAdafruit_L3GD20.c ADS7828.c demoj.c
g++ txtwrite.o demo.o ADXL345.o 1ddemo.o 1dADXL345.o demol.o Adafruit_L3GD20.o demok.o kAdafruit_L3GD20.o ADS7828.o demoj.o -o txtwrite
```

3. Execute the program 1 time while the Beaglebone is hooked up through a wired connection using the command, “ ./txtwrite “ while in the demo folder. (You must run this one time after the new program is compiled, or the start-up service will not run a boot.
4. After the program finishes, either remove the file it created (using the “rm filename” command or leave it, exit the terminal window using the “exit” command, and then close the window. Turn off the Beaglebone power and ensure a battery is charged and ready to go for launch.
5. Hook up the battery. Press the button, and the Beaglebone will sit and wait looking for a launch to trigger the recording of data.

6. After launch and the rocket is recovered, always let the program finish its 7 minute run or the file could become corrupt before turning off the processor. If the software “Putty” is available, then you may extract the data before ever turning off the Beaglebone, if “Putty” is not available at the launch site, then the Beaglebone may be turned off after the 7 minutes has expired and the data can be pulled off at another time.
7. To remove the data from the Beaglebone the following steps should be taken.

a. Hook up a USB cord to the microprocessor.
b. After the computer recognizes the Beaglebone, proceed to access it via the serial port in “Putty”. (You may have to go to your device manager to see what COM port it is currently using if you don’t know.)
c. The password is blank. Just simply hit the enter command after typing in the username “root”.
d. Proceed to the root directory by typing the command “ cd / “
e. Type the command “ls” in order to see a list of files located in the directory.
f. You should now see the “output#.txt” files from the previous launch.
g. To move them to a location that can easily be accessed, go to the BEAGLEBONE folder to store the files in the simple “Open Folder to View Files” folder for typical USB devices by typing “ cd media/BEAGLEBONE”
h. To move or copy the files, type the following:
   - i. Move: “mv /output*.txt . “ (The period is important, and the star will move all the output files that fits the wildcard.)
   - ii. Copy: “cp /output*.txt . “
i. Now the files are at a convenient location, the Beaglebone must be turned off and turned back on in order for the file change to the root directory to take place. When the microprocessor turns back on, simply click “Open folder to view files” and move and/or copy the files wherever you want them on your computer.

8. Have fun with post processing!

4.1.3 Payload design

The battery requirements for Prometheus were analyzed to ensure that a battery of sufficient size was chosen to power the rocket for the hour that it could possibly sit on the launch pad under maximum current draw. Each Beaglebone will be powered by an individual battery to ensure each microprocessor will operate independently. In the case of a malfunction with one system the other systems will not be jeopardized. The driving factor for utilizing multiple battery sources for the Nanolaunch Payload was to accommodate for the components located in the nose. Without separate battery sources, when the rocket separates for drogue deployment a battery wire running from the CG to the nose would have to break/detach from a power clip which is not feasible because the Nanolaunch Payloads needs to have power after chute deployment.

The full scale launch power budget was analyzed by documenting the full load current and voltage source located in each component’s datasheet. The payload budget was shown in Table 4-3 below.

Table 4-3: Full Scale Payload Power Budget

Fullscale Launch CG Battery Chosen : 6.6 V, 850 mAh LiFe Battery					
Component	Count	Input Voltage (V)	Unit Current (mA)	Total Current (mA)	Power (W)
Beaglebone Black	1	5	460	460	2.3
ADXL345	1	3.3	0.145	0.145	0.0005
ADXL377	1	3.3	0.3	0.3	0.0010
L3GD20 gyro	1	3.3	6.1	6.1	0.0201
Op-Amp	4	5	0.000459	0.001836	0.0000
ADC I2C	1	5	0.7	0.7	0.0035
Pressure Sensor	4	5	1.5	6	0.0300
Total (mA)	473	Powered On Time (min)	60	Needed battery (mAh)	473.2
Fullscale Launch Nose Battery Chosen : 6.6 V, 850 mAh LiFe Battery					
Component	Count	Input Voltage (V)	Unit Current (mA)	Total Current (mA)	Power (W)
Beaglebone Black	1	5	460	460	2.3
ADXL345	1	3.3	0.145	0.145	0.0005
ADXL377	1	3.3	0.3	0.3	0.0010
L3GD20 gyro	1	3.3	6.1	6.1	0.0201
Op-Amp	3	5	0.000459	0.001377	0.00001
ADC I2C	1	5	0.7	0.7	0.0035
Pressure Sensor	3	5	1.5	4.5	0.0225
Total (mA)	472	Powered On Time (min)	60	Needed battery (mAh)	472

The Nanolaunch 1200 payload subsystems were made up of 6 main components that were all crucial to meeting the payload objectives. The subsystems/components are as follows: Beaglebone Black, ADXL345, ADXL377, L3GD20, absolute pressure sensors, and remote data transmission system. These components/subsystems all play a vital role in extrapolating the aerodynamic coefficients and all of the parts are indicated in Table 4-4 with each component's corresponding location in the rocket. The Beaglebone black was chosen as the main processor because it was at affordable price of $45.00 and had a fast processor of 1GHz. The Beaglebone's fast processor speed and the fact that it operates directly in C/C++ through its Linux operating system ensures that the required data sample rate of 200Hz during the transonic region will be achieved. The Beaglebone also provides 92 pins to allow for ease of access. The parts list for the payload will consist of all the parts for the two configurations combined into one. In total, the CG configuration will consist of 13 components, and the nose configuration will consist of 11 components. The main differences in the two payloads are the quantity and type of pressure sensor. The CG configuration will have 4 30psi pressure sensors, whereas the nose configuration will have 2 60psi pressure sensors and 1 100psi pressure sensor for the main Pitot-static pressure sensor at the nose for determining the velocity.

Table 4-4: Nanolaunch 1200 Parts List

Part Name	CG Quantity	Nose Quantity
ADXL377 - Triple-Axis Accelerometer (+-200G) w/I2C	1	1
ADXL345 - Triple-Axis Accelerometer (+-2g/4g/8g/16g) w/I2C	1	1
L3GD20 - Triple-Axis Gyro Breakout Board (250,500,2000 dps) w/I2C	1	1
Beaglebone Black	1	1
I2C 12-Bit, 8-CH Analog-to-Digital Converter	1	1
AD623 Operational Amplifier	4	3
480-5550-ND Absolute Pressure Sensor(30 PSI)	4	0
480-5551-ND Absolute Pressure Sensor(60 PSI)	0	2
480-3797-ND Absolute Pressure Sensor(100 PSI)	0	1
Component Total	13	11

The ADXL345 Triple-Axis Accelerometer was chosen because of its ability to provide several different ranges of G loading: 2G, 4G, 8G, and 16G. The ADXL345 was necessary because in order for small disturbances in flight to be detected by the accelerometer for the use in post flight processing, the accelerometer must be able to detect slight acceleration changes in the rocket. This function was one that the ADXL345 provides due to its low 2G setting providing a low uncertainty.

The rocket also needed a high G accelerometer in order to be able to fully define the acceleration throughout the flight, since the G loading expected from analytical trajectory calculations was 42 which exceed the limit of most accelerometers. The ADXL377 3 axis accelerometer was chosen for its ability to measure high G loadings up to 200G. This accelerometer would provide a means to fully define the acceleration of the flight by using both accelerometers in conjunction with each other.

The L3GD20 Triple-Access Gyro was chosen because in order to fulfill the requirements of calculating the angle of attack of the rocket, as well as being able to fully define the position of the rocket. The triple access gyro allows the angles of the rocket to be measured, and with two gyros being at the CG of the rocket and the other upward towards the nose, the exact orientation of the rocket will be used to extrapolate the angle of attack of the rocket.

To accommodate for calculating the aerodynamic coefficients, the pressure at the nose of the rocket was required. To fulfill this requirement, a Pitot-static probe will be used where two sensors will be individually connected for each pressure measurement, rather than using one Pitot-static pressure sensor. This was decided because if only one pressure sensor measures the difference between the two, sometimes a huge error can be induced into the measurement. To prevent this, three individual absolute pressure sensors will be used to measure each port of the Pitot-static probe, individually. The pressure sensors chosen for this measurement was a 480-5551-ND and a 480-3797-ND Absolute Pressure Sensors, 60 PSI and a 100 PSI respectively. The 100 PSI sensor was chosen for the tip of the nose because it sees the highest pressure, and two of the 60 PSI sensors were chosen for the side of the nose cone because it sees a lower pressure. The two 60 PSI sensors will provide a redundancy for possible differences in the measurement. The reason the high pressure sensors were chosen was due to the rocket traveling at supersonic speeds.

The last measurement needed to fulfill the Nanolaunch 1200 requirements was to be able to determine the base drag of the rocket. The base drag of the rocket can be determined by calculating the pressure at the base of the rocket in several different locations to provide a better pressure estimate. 4

pressure sensors will be used to measure this pressure change. The 30 PSI 480-5550-ND Absolute Pressure Sensor was chosen for this pressure measurement because it was from the same manufacturer as the other pressure sensors used. This would provide a similar interface to the Beaglebone and the code will be able to be almost identical. A smaller magnitude sensor was chosen because the pressure at the base of the rocket sees a decrease in pressure from the nose. A 30 PSI sensor was chosen to fulfill this requirement.

- Drawings and schematics of design and assembly

The payload bay was machined and the CG Nanolaunch configuration can be seen in Figure 4-14 below. The CG payload was compacted into only taking up three panels which was achievable because of the space saving printed circuit boards as indicated in the image. The payload bays provide for smooth maintenance and quick access. Also a quick disconnect between the pressure sensor board and the board that contains the analog to digital converter with the op-amps was made to ensure for easy manipulation if the gain on the op-amps were needed to be changed.

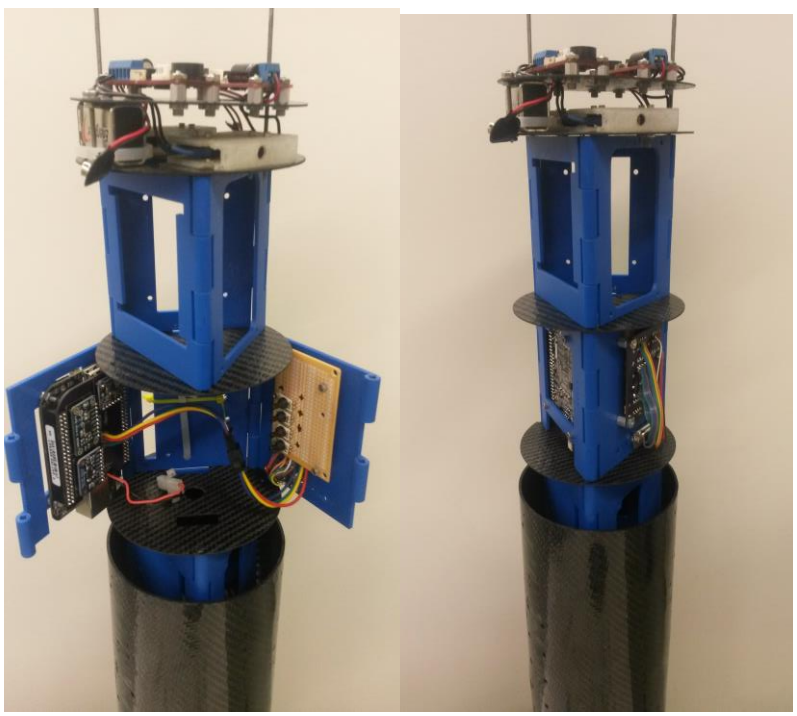


Figure 4-14: Nanolaunch CG Flight Configuration

The full scale launch's electronics will be split in two main locations, at the center of gravity and at the nose of the rocket. The Nanolaunch payload at the CG will consist of a low G (ADXL345) and a high 200G accelerometer (ADXL377), a gyroscope (L3GD20), and 4 pressure sensors that will be used to simulate base drag. The base drag sensors will be placed in the center of the rocket to provide proof of concept. The center of gravity configuration will also contain an analog to digital converter (ADC) used to convert the pressure sensors' analog output to an I2C based digital signal. The I2C pull-up resistors were already packaged in the ADC, which is why there are not any 2.2kohm resistors shown in the circuit. In order for the pressure sensor's data to be readable, the differential voltage will have to be amplified with a gain of 26 for the 30 and 60 psi pressure sensors and a gain of 43 for the 100 psi sensor. The gain was dictated by the resistance that runs from pin 1 to pin 8 in the AD623 through the use of a

2.4k ohm for the 100 psi sensor and 4k ohm resistors for the 30 and 60 psi sensors. The resistor values changed since the CDR, and the 0 ohm resistor was placed in there as a safe guard for future tests for if the pressure increased past the maximum value of the ADC, then it could be dropped through changing out the resistor. The schematic that shows the circuitry for the CG configuration can be seen below in Figure 4-15.

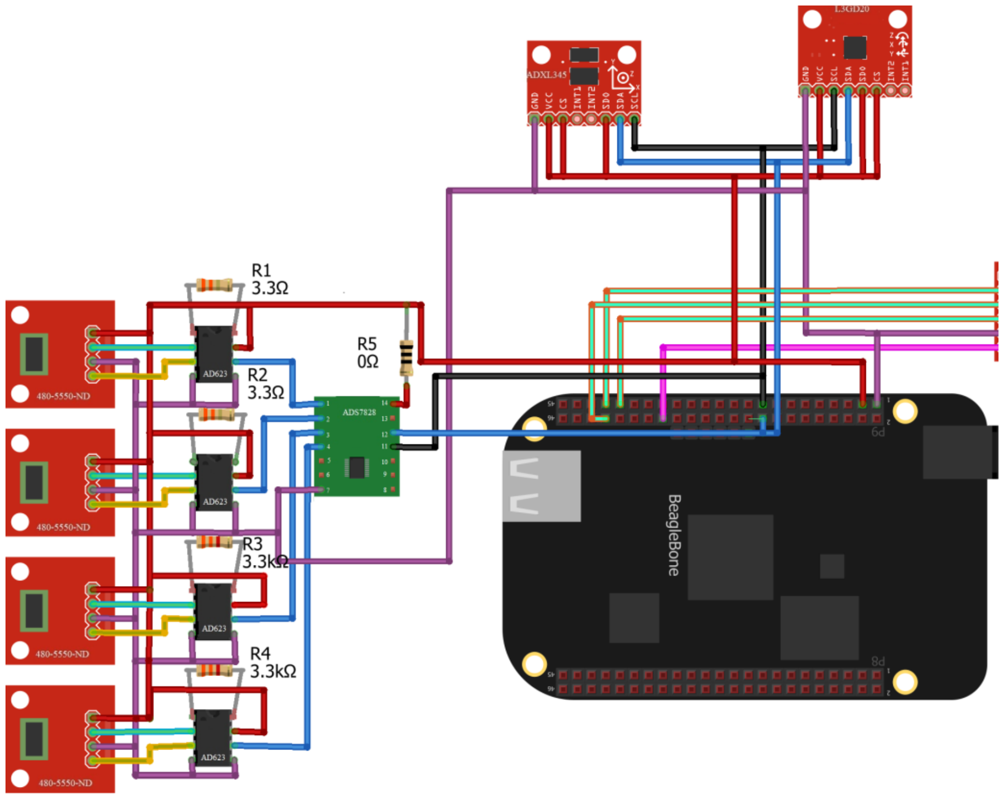


Figure 4-15: CG Payload Schematic

The wiring diagram schematic for the nose configuration consists of the 3 Pitot-static pressure sensors that will travel through the nose of the rocket. The nose configuration will also consist of a low G accelerometer (ADXL345), a high 200G accelerometer (ADXL377), and a gyroscope (L3GD20). The accelerometers in the nose will be useful in providing meaningful data from small disturbances during flight. The low G accelerometer will be able to detect more precise measurements than the 200G accelerometer because of the 200G accelerometer has to cover a much wider range with only 12 bits. The schematic for the nose of the rocket was shown in **Error! Reference source not found.**. The nose onfiguration also experienced the same changes as also reflected in the CG payload.

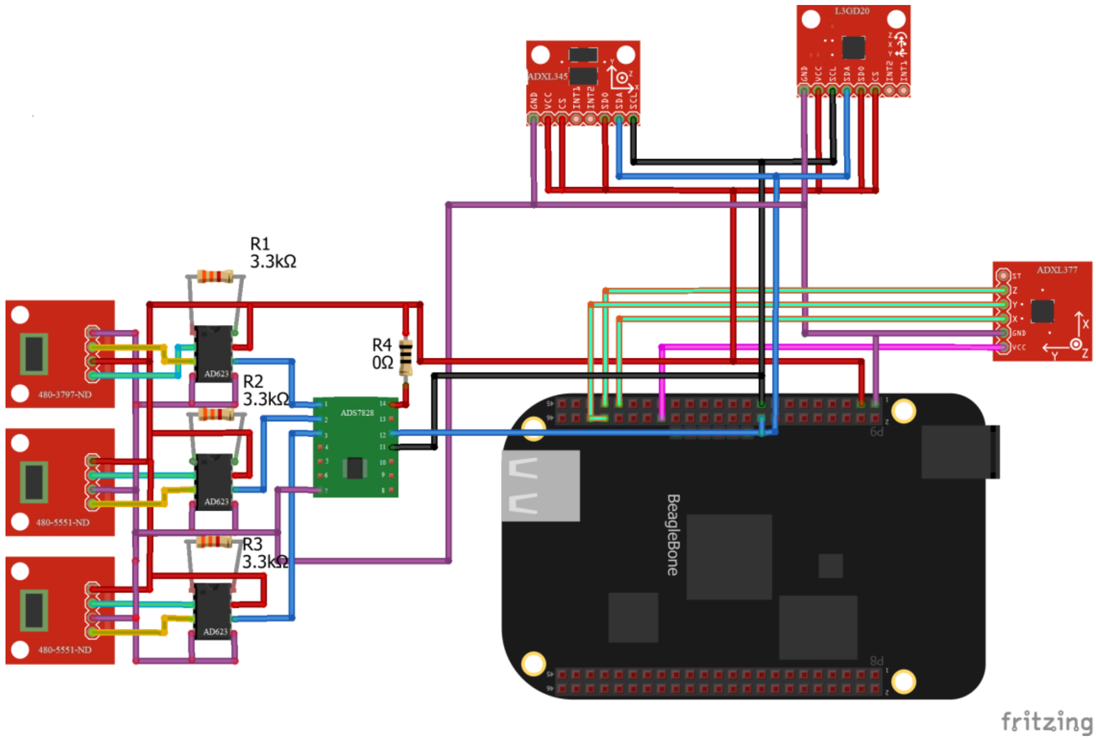


Figure 4-16:Nose Payload Schematic

- Information on precision of instrumentation and repeatability of measurement

A determination of each sensor's precision of instrumentation was shown in Table 4-5 below denoting the resolution of each sensor, Beaglebone, and Arduino as indicated by each component's respective datasheet. The Beaglebone and the Arduino's 10 and 12 bit ADC resolution is a function of the max measurement made divided by the number of bits as indicated below.

Table 4-5: Component Resolution

Component	Bit	Resolution
ADXL345 (±2G, ±4G, ±8G, ±16G)	10, 11, 12, 13	256, 128, 64, 32 LSB/g
ADXL377 (±200G)	Analog	6.5 mV/g
L3GD20(200dps, 500dps, 2000dps)	16	8.75, 17.50, 70 mdps/digit
480-5550-ND 30 PSI Pressure Sensor	Analog	21 mV/V
480-5551-ND 60 PSI Pressure Sensor	Analog	21 mV/V
480-3797-ND 100 PSI Pressure Sensor	Analog	12.6 mV/V
Beaglebone	12 bit ADC	$\frac{1}{2} * \frac{Measurement_{MAX}}{2^{12}}$
Arduino	10 bit ADC	$\frac{1}{2} * \frac{Measurement_{MAX}}{2^{10}}$

The repeatability of measurement was shown repeatedly in the uncertainty analysis section discussed above, and in the several tests in the CDR. The Nanolaunch payload is ready for a full-scale test, and the results from the flight will be highly anticipated.

The flight performance predictions were already discussed in the uncertainty analysis section denoted by the plots of each sensor. The expected G loading will be much higher on the order of 42 G's.

Many precautions are being made to ensure that the experiment will be ready for launch and that it is capable of pulling accurate and reliable data. The Nanolaunch 1200 experiment's payload accelerometer data will be expected to match the G loading profile shown in Figure 4-2 for the 1.53 seconds. The data will have significant G changes at the following events during flight: motor burnout, apogee, drogue parachute deployment, and the main parachute deployment.

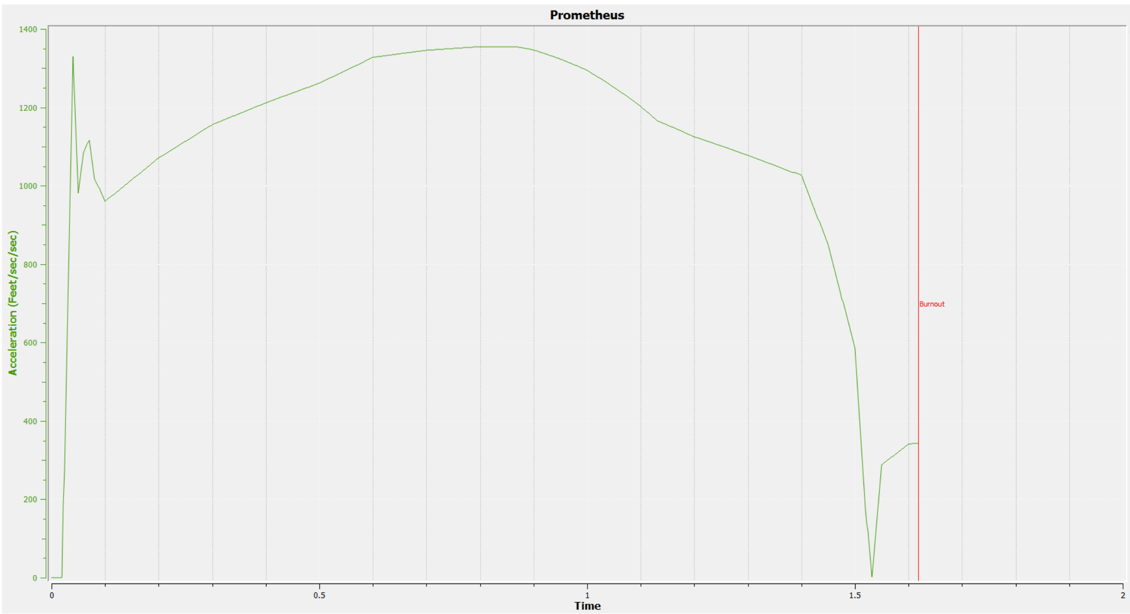


Figure 4-17: RockSim Acceleration Vs Time

The test and verification program was identified in detail will be discussed in the verification section below.

4.1.4 Verification

The risk assessments for the payloads were evaluated in Table 4-6 and Table 4-7. The risk was evaluated using a probability and severity matrix that associates a number corresponding to the extremity of the risk's occurrence on the outcome of the launch. The highest risk that was documented was the possibility of an incomplete deployment. To prevent the parachute entanglement from occurring, Prometheus's deployment mechanism will be tested methodically before launch.

Table 4-6: Nanolaunch Risk Probability

Probability						
	5					
	4					
	3			2		1
	2		7			3
	1		5	6		4
		1	2	3	4	5
		Severity				

Table 4-7: Nanolaunch Potential Hazards

Ref #	Potential Hazard	Probability	Severity	Impact	Mitigation
1	Incomplete Deployment	3	5	Destruction of Payload	Ground testing of recovery system, use of redundant deployment hardware.
2	Extensive Noise in the Data	3	3	Difficult to determine true sensor values	Ensure all sensors and payload bay are tightly secure pre-flight.
3	Lithium Ion Battery Dies	2	5	Electronics shutdown	Batteries were properly charged, appropriate battery size for required power budget.
4	Launch Detect Not Triggered	1	5	No data recorded	Tested extensively, and includes a "debounce"
5	Data Corruption	1	2	No Data	The data extraction procedure was standardized to prevent this
6	Cold Solder Joints	1	3	Electronics malfunction	Methodical testing for verification
7	Broken Wire	2	2	Electronics malfunction	Subscale flight testing to simulate G loading

The velocity verification analysis and testing was analyzed below from simulated pressure data for proof of concept. Using John D. Anderson's Compressible Flow Text, when the total stagnation pressure after the shock Po2 is known and if the atmospheric pressure P1 is known before the shock, the ratio Po2/P1 can be calculated. An image simulating the shock interactions can be seen in Figure 4-18.

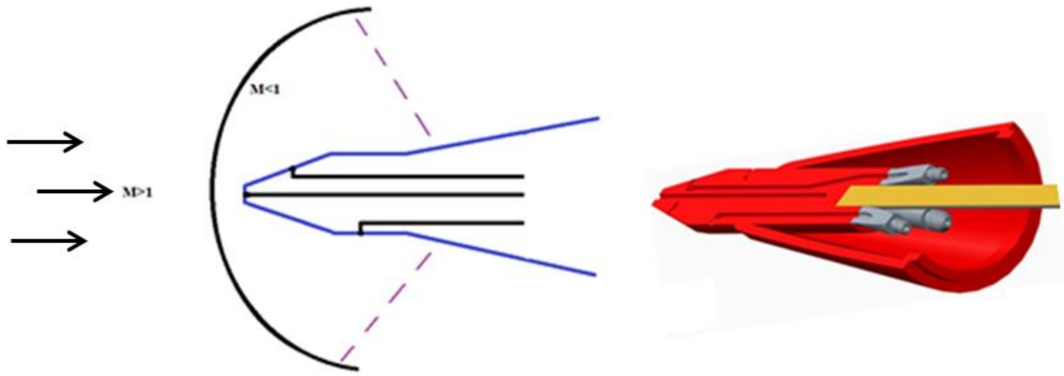


Figure 4-18: Nose Cone Shock Interactions

Using this ratio, normal shock relations may be used to calculate the respective Mach numbers before and after the shock. In Table 4-8 below, an example calculation showing the respective Mach numbers calculated based on the stagnation and static pressures. With the Mach number known, the velocity can be calculated based on the speed of sound.

Table 4-8: Sample Mach Calculation Based on Normal Shock Relations

Atmospheric Pressure	Measured Data		Calculated Ratios		Before Shock	After Shock
P1 [Pa]	Po2 [Pa]	P2 [Pa]	Po2/P1	P2/P1	M1	M2
101325	101353	101325	1.000	1.000	0.020	0.020
101325	102036	101325	1.007	1.000	0.100	0.100
101325	104191	101325	1.028	1.000	0.200	0.200
101325	107853	101325	1.064	1.000	0.300	0.300
101325	113135	101325	1.117	1.000	0.400	0.400
101325	120193	101325	1.186	1.000	0.500	0.500
101325	129240	101325	1.276	1.000	0.600	0.600
101325	140548	101325	1.387	1.000	0.700	0.700
101325	154454	101325	1.524	1.000	0.800	0.800
101325	171371	101325	1.691	1.000	0.900	0.900
101325	191801	101325	1.893	1.000	1.000	1.000
101325	216110	126150	2.133	1.245	1.100	0.912
101325	243939	153305	2.407	1.513	1.200	0.842
101325	274953	182892	2.714	1.805	1.300	0.786
101325	308964	214809	3.049	2.120	1.400	0.740
101325	345849	249057	3.413	2.458	1.500	0.701

The relationship between Mach and the stagnation pressure to static ratio was easily calculated using tabulated data, and is demonstrated in Figure 4-19.

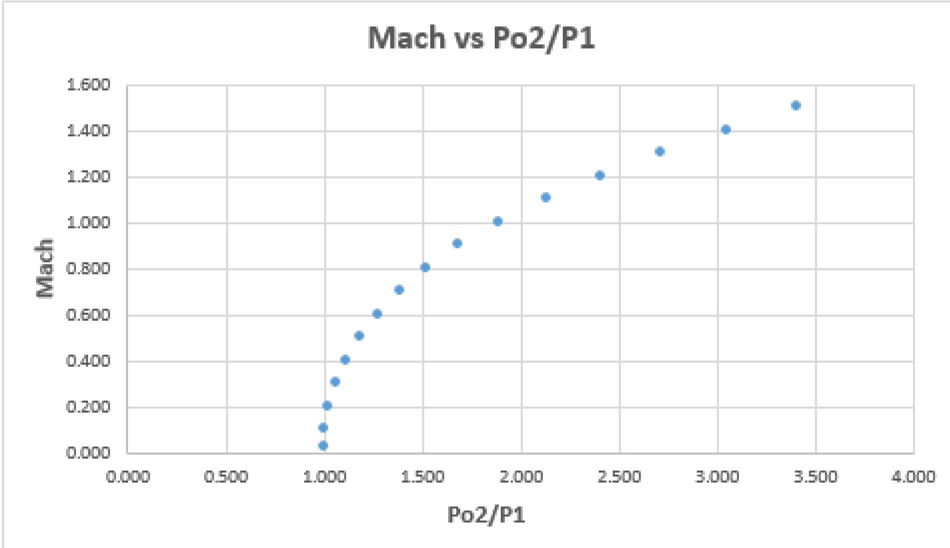


Figure 4-19: Mach vs Po2/P1 Relationship

The pressure ratios and Mach represent values that would be expected in the actual full scale data. The atmospheric pressure would be slightly different, only changing the values slightly and for demonstration purposes that was assumed to be negligible.

The Pitot static pressure ports will be used to give the stagnation pressure at the tip of the nose as well as the static pressure on the side of the nose. These two pressures will be subtracted via post processing to result in a velocity determination for the flight that can be used to compare to the altimeters.

The frequency at which the rocket rotates about the y axis (parallel to the rocket body tube) denotes the rocket spin during flight. This was measured during a ground test, and the data based on a coarse curve fit denotes that the rocket rotated at a frequency of 1.17 Hz by minimizing the R^2 value of a fit including an exponential and a sine function. The full scale recorded gyro data will be used to predict the angular rotation of the rocket in flight using the same method. If this was the true data, then the rocket would have rotated at a rate of 1.17 times a second.

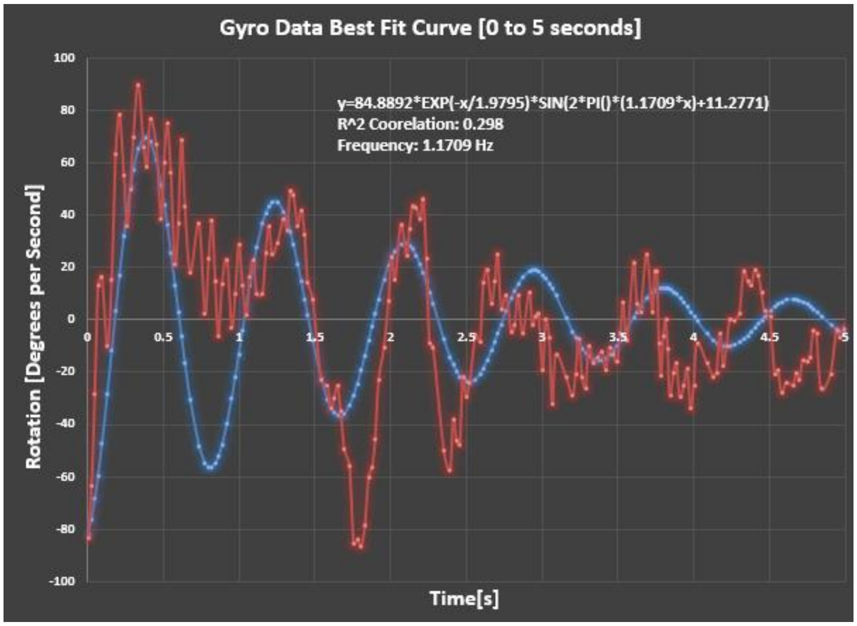


Figure 4-20: Gyro Data Frequency Determination by Minimizing R^2 Value

The 1.1709 Hz frequency was verified by generating a Mathcad FFT diagram. The main frequencies that dominate was 1.2 and 11 Hz, where the first main frequency in Figure 4-21 was due to the voltage offset.

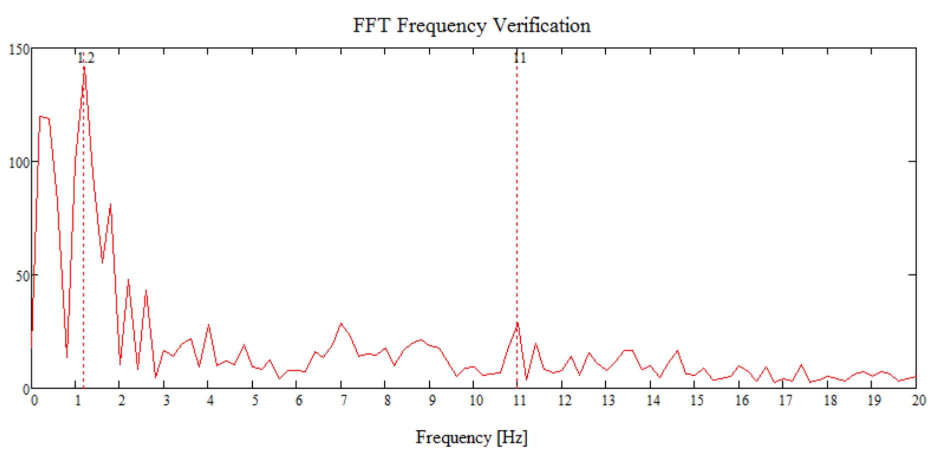


Figure 4-21: FFT Frequency Verification

4.2 Dielectrophoresis

4.2.1 Experiment Concept

Dielectrophoresis is the use of electric fields to move fluids. This is accomplished by subjecting a nonpolarized molecule with dielectric properties to an electric field. This separates the poles, which forces the molecule to be influenced in one direction or the other. The use of dielectrophoresis to collect fuels for engine restart would be an excellent alternative to current systems involving inertial rockets. The same dielectrophoresis system could also aid in preventing heat transfer to the fuel from the walls of the container, reducing boil-off of cryogenic fuels on long missions such as one to Mars. This also reduces the need for bulky insulation by using the gas already in the tank. Another advantage of this system would be that if the fuel is more concentrated in one area, it would help act as an extra barrier from radiation from the sun. The power required to establish a high voltage electric field is low, and it is operable at any time.

This experiment is very creative and original in the sense that it is still a new concept. This gives way to several different approaches that could be taken. Dr. James Blackmon laid the foundation for this experiment with his research on the collection of liquid propellants in zero gravity with electric fields. This is only the second time this experiment has been conducted by the student launch team so although the concepts may be based off of previous years studies, the setup of the payload is original and is still being based off of new designs and studies.

The type of research that has been carried out gives this dielectrophoresis experiment its unique characteristics. The payload utilizes high voltage to provide for improvement of fuel collection, preventing heat transfer to the fuel from the walls, and to reduce the amount of boil-off of cryogenic fuels for long missions. The payload is significant in that the research also could reduce the need for bulky insulation by using the gas already in the tank. The payload requires low power to generate the high voltage electric field.

4.2.2 Science Value

The scientific method will be used to analyze the experiment. The Hypothesis is that dielectrophoretic force will be the dominant force on a liquid in reduced gravity and that it will collect that liquid at the predicted locations. The behavior of fluid in a control container with no applied voltage will be compared the behavior of fluid in a container subjected to a strong magnetic field. Video footage of each container will be used to study the fluid behaviors. Measuring tapes in view of the cameras will serve as reference lengths by which to compare the results to values predicted from the dielectrophoretic force equations. The predictions would be the locations where fluid would collect, namely the locations where the electric field is strongest.

The purpose of the payload experiment to be flown on *Prometheus* is to simulate the collection of liquid propellant within fuel tanks in microgravity applications by means of dielectrophoresis. Various fluids such as corn oil, silicone oil, and peanut oil have been evaluated as the fluid to be flown in the experiment because their dielectric constants are similar to those of several liquid propellants.

The success of the payload experiment will be defined by the following three criteria that address both successful function of the payload and team safety. The three criteria are summarized in Table 4-9 below.

Table 4-9: Dielectrophoresis Success Criteria

Requirement	Success Criteria	Verification
Overall Fluid Movement	Fluid behavior significantly influenced by dielectrophoresis versus the neutral control fluid	Recover camera data from FlyCamOne
Central Movement	Fluid retention away from container walls	Recover camera data from FlyCamOne
Team Safety	All members will be unharmed by the experiment	Check for any injuries
Recoverable and Reusable	Recover the payload and reuse it	Recover the payloads and be able to relaunch again the same day

Video will be captured showing the oil in the fluid containers collected between the two electrodes as a result of dielectrophoresis when the rocket reaches apogee. This will require all components of the payload to function as expected and safely. The video taken can then be analyzed to evaluate the fluid behavior against the three criteria listed above and determine if the experiment was successful. The final criteria will be met if all team members and observers are unharmed by the experiment. The team will incorporate redundant precautions to ensure this success criteria is met.

The experiment is organized to demonstrate that dielectrophoretic displacement of the fluid within the tanks is indeed significant in microgravity, where significance is measured by the volume of fluid that moves to the desired location as determined by the geometry of the electrodes. The motion of the fluid in flight is recorded with video cameras. The behavior of the fluid in the electric field will be compared to the behavior of the control fluid with no electric field in order to show dielectrophoretic displacement. An accumulation of fluid between the electrodes in microgravity will verify that fluids can be effectively controlled with dielectrophoresis.

The point of this experiment is to collect usable data in order to further the development and the study of dielectrophoresis. If inaccurate analyses were conducted then the experiment would be of no use and could be termed unreliable. It is also good to have expectations of what the results should be. That way if the data obtained while running the experiment give results that differ from the expectations, one may be able to trace errors that were made.

To accomplish the mission the payload has 3 phases, or modes of operation: Launch Detect System (LDS), Experiment Operation, and Idle. Each phase uses different hardware capabilities and code.

The LDS's primary function is to determine whether a legitimate launch has occurred. For safety reasons we do not want to have the system turn the experiment on unless the rocket is actually launching. To accomplish this, the microcontroller will poll the accelerometer to compare the g level in the launch oriented axis to a threshold of 3.8gs. If the measured value exceeds the threshold then the program will check again after a brief delay. After three positive checks the program will move into the Experiment phase.

The Experiment Phase is where data is collected and the only phase where the high voltage power supply is active. When launch is detected the microcontroller powers on the HV supply, triggers the cameras to record, and begins writing accelerometer data to the SD card. When 30 seconds have passed since the beginning of the Experiment phase power is removed from the high voltage system and the cameras are told to cease recording. This is the idle mode of operation.

4.2.3 Payload design

The Dielectrophoresis payload system consists of dielectric fluid contained in plastic bottles, a high voltage power supply, video cameras, and other electronics for experiment control and data collection. The structure of the payload assembly was 3D printed with the electronics organized into two separate PCBs, one for the HV supply and the other for the rest of the electrical components. The three variables that have the strongest influence on the experiment are:

Voltage – The squared voltage of the system drives the strength of the electric field.

Dielectric constant of fluid – The dielectric constant of the fluid determines how strongly the fluid is influenced by dielectrophoresis.

Electrode geometry – The gradient of the electric field is dependent on the geometry of the electrodes.

The experiment will be activated automatically after launch. The high voltage supply will become powered after launch has been detected by the accelerometer and microcontroller. The cameras will also begin recording video at that time as directed by the microcontroller.

Previously for the Dielectrophoresis payload there were two electrode configurations of different geometries being considered for future use on the rocket's payload. The first case in which was under consideration is that of a cylindrical wall that surrounds a rod which is aligned axially with the cylinder as shown in Figure 4-22 below. The cylinder and the rod are the two electrodes.

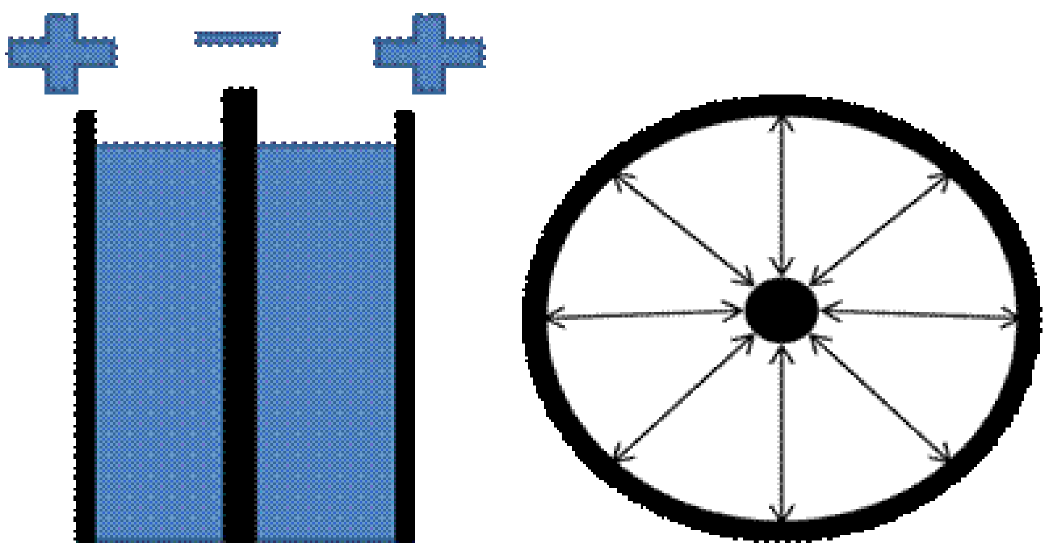


Figure 4-22: Cylindrical Electrode Configuration

This cylindrical electrode configuration is the simplest case for mathematical predictions because it has the most straight forward geometry. The electric field lines between the wall and center rod are straight radial lines. According to Blackmon, the voltage distribution of the cylindrical electrodes is

$$V(r) = \frac{V * \ln\left(\frac{r}{r_2}\right)}{\ln\left(\frac{r_1}{r_2}\right)}$$

Then the force per unit volume becomes

$$F_v = \frac{\epsilon_0 * (K-1) * (K+2) * V^2}{3 * \left(\ln\left(\frac{r_2}{r_1}\right)\right)^2 * r^3}$$

The cylindrical electrode configuration will be implemented by assembling a copper mesh around a plastic jar containing the liquid. A small copper tube will be used as the center rod electrode. The outside copper mesh electrode establishes an electric field with the center rod, and the plastic jar insulates the electrodes from each other. No electric current flows between the electrodes. The dielectrophoretic force is established only by the electric field.

The other case that was under consideration can be seen in Figure 4-23 below. This case is that of a jar that contains two parallel electrodes of opposite charge.

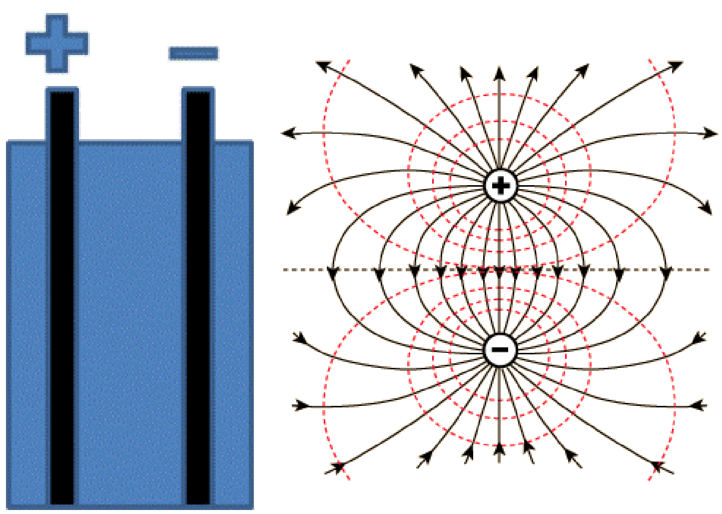


Figure 4-23: Parallel Rod Electrode Configuration

For the parallel rod case, two cylindrical rods of small diameter (approximately .25 in) will be fixed to a plastic container and spaced approximately .125 in apart so a high electric field concentration develops between the rods as shown in Figure 4-23. Once the concentration has developed, the fluid will be attracted to the concentration and will be pulled up and isolated between the rods. The mathematical predictions of the fluid behavior are more complicated for this case as there are two sets of field lines and the geometry is more complicated than the cylindrical case.

The parallel rod case was used by the 2012-13 UAH SLI team. However, for the 2013-14 competition it has been determined that the coaxial cylindrical electrode configuration will be more effective for demonstrating the dielectrophoretic effect because the consistent electric field will pull the fluid into a more focused region. Also, no fluid will get trapped outside of the electric field's concentration points.

The components that will be used in the payload are listed in Table 4-10: Dielectrophoresis Components and described in further detail below.

Table 4-10: Dielectrophoresis Components

Mass Budget		Total Mass: TBD	
Component	Mass (lbs)	Quantity	Subtotal Mass
FlyCamOne	0.03	2	0.06
HV Supply	0.405	1	0.405
Plastic Containers	0.02	2	0.04
Heat Sink	0.02	1	0.02
Camera Panel	0.045	1	0.045
Container Panel	0.04	2	0.08
HV Panel	0.035	1	0.035
HV PCB Panel	0.04	1	0.04
Component PCB Panel	0.03	1	0.03
Component PCB (with components)	0.09	1	0.09
HV PCB	0.02	1	0.02
11.1V Battery	0.034	1	0.034
7.4V Battery	0.086	1	0.086
Buzzer	0.013	1	0.013
Corn Oil	0.034	2	0.068
Switches	0.008	2	0.016

Camera

The camera that has been chosen to record video of the liquid containers in-flight is the FlyCamOne eco V2, available from Sparkfun, and can be seen in Figure 4-24to the right. One camera per fluid container will be used for flights. The cameras will be attached to a control board via a ribbon cable. The control board has a microphone, micro SD card slot, power switch, status LED, mini-USB connection, and battery connection on it. The FlyCamOne is capable of recording at a resolution of 720 x 480px at 30 frames per second. At that rate, with the maximum size

Figure 4-24: Fly Cam One

micro SD card of 8 GB, the camera should record about 80 minutes of video. Testing will be done to confirm that time. The cameras should not need to be on that long if they are interfaced with the microcontroller to turn them on when flight occurs. Also the cameras do not come with dedicated power supplies, so they connected to either the microcontroller for power or connected to a battery supply.

HV Power Supply

In order to determine the operational power of this power supply, the voltage probe in Figure 4-25 below was used in accordance with the display screen in Figure 4-26 to the right of that.

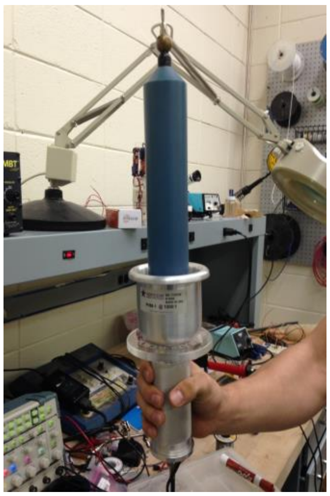


Figure 4-25: Voltage Probe

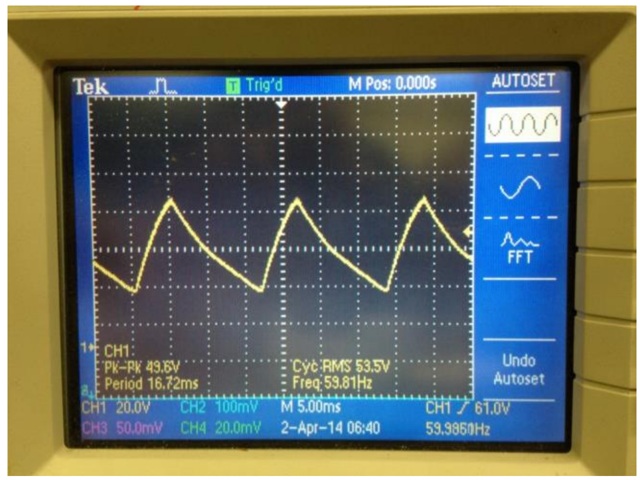


Figure 4-26: Voltage Probe Display Screen

It was determined that the high voltage supply operates at 60 kV at 10 mA with a frequency of about 50 kHz. The HV supply is the driving force behind the payload and can be seen in Figure 4-27 below. It generates the electric field necessary for dielectrophoresis.

Figure 4-27: HV Power Supply

Fluid container selection

The containers selected to contain the liquid during flight are clear plastic jars. It has a base diameter of 1.06” and a height of 2.36”, which ends up being significantly smaller than last year’s containers. The containers will not be stacked one on top of the other so smaller containers were desired in order for them to fit on the same level and still have room for the other components, cameras and center tension rod. Also, from testing it was determined that the movement of the oils was better noticed in the smaller containers.

Safety Switch

To ensure the payload will not be able to activate until it is ready for flight, a switch will be connected to the batteries, so that the circuit can be broken by the switch and not allow power to flow from the batteries to the rest of the payload system. Currently, the switch will be a micro switch attached to the altimeter bay. This will mitigate risk of electrical shock to personnel.

Transistor

A transistor, PN2222A, is going to be used as a switch for the HV supply to receive power. The transistor will receive a voltage from the microcontroller when the accelerometer indicates preset conditions. That voltage applied constantly will allow transistor to run the voltage from the HV supply’s battery to the supply itself.

Faraday cage

In order for the components of the payload to be isolated from the other components of the rocket, the payload will be wrapped in a copper mesh that will act as a Faraday cage. This will keep any high frequency electromagnetic noise from the HV supply from interfering with electrical components of the recovery system.

Backlight

A backlight will be used to ensure that the cameras record useful video. White LEDs will be on the opposite sides of the liquid containers from the cameras. White paper or some other opaque material will be used to diffuse the light.

Accelerometer

Figure 4-28: ADXL 377 Accelerometer

The accelerometer being used in the payload is the Triple Axis ADXL377 and can be found in Figure 4-28 to the right. It is a triple axis accelerometer that can detect +-200 g. This is a better fit than the ADXL 345 since the rocket may experience more than 16 g during the boost phase. The increased resolution is useful during the coast phase to determine the quality microgravity achieved.

The accelerometer will be interfacing with the microcontroller at all times during the flight. In order to provide a visual feedback for the cameras, an LED will be used with the microcontroller and accelerometer. It will be placed in clear view of the cameras.

Power line buzzer

A buzzer that is connected to the same battery as the high voltage supply will be used for auditory feedback. This will alert bystanders to let them know when the high voltage supply is active.

Accelerometer data storage

In order for data from the accelerometer to be stored, a micro SD card slot is necessary in order to be interfaced with the microcontroller. The data taken off the SD card can then be compared to the visual data given by the cameras.

Fluid selection

The fluid to be flown in the rocket will be peanut oil. It has a low dielectric constant so it can be used as a replacement to fuel that would be used in the real world application.

Battery selection

Two different batteries will be needed to power the payload. Both of the batteries will be Li-Poly batteries. The first battery being used in the payload is a Hyperion 7.4V 550mAh lithium polymer battery. It will power the Arduino and everything attached to the Arduino. The power budget for the 7.4V battery can be seen in Table 4-11 below. The other is a Hyperion 11.1V 120mAh lithium polymer battery. That battery will power the high voltage power supply and the buzzer. Its power budget can be found below in Table 4-12.

Table 4-11: 7.4V Payload Power Budget

Payload Power Budget for 7.4V Battery					
Total Current of 7.4V Battery (mA) :			555.145		
Component	Quantity	Input Voltage (V)	Unit Current (mA)	Total Current (mA)	Power (W)
Arduino Pro	1	2.7 to 5.5	15	15	0.075
Accelerometer	1	2 to 3.6	0.145	0.145	0.000522
LED	1	3.0 to 3.4	20	20	0.128
SD card	1	5	60	60	0.3

Table 4-12: 11.1V HV Power Budget

HV Power Budget for 11.1V Battery				
Total Current of 11.1V Battery (mA):			1008	
Component	Quantity	Input Voltage	Unit Current	Power
HV Power Supply	1			
Buzzer	1	12	8	0.096

Microcontroller selection

The microcontroller that will serve as the primary flight computer for the payload will be the Arduino Pro 328 from Sparkfun and can be seen in Figure 4-29: MicrocontrollerFigure 4-29 to the right. It uses a 5V regulator with a max output of 150mA. It is a DC input from 5V up to 12V with a power select switch that acts as an on/off switch. This microcontroller was chosen due to its compact form and ease of use. Something small was desired in order to fit into a PCB design and needed to be able to be used with the high voltage circuit. Its compatibility with the FlyCamOne was another factor that made it an easy choice when it came to comparing this with other microcontrollers.

Figure 4-29: Microcontroller

4.2.4 Verification

The risk assessments for the dielectrophoresis payload were evaluated in and below. The risks were evaluated using a probability and severity matrix that associates a number corresponding to the extremity of the risk's occurrence on the outcome of the launch.

Table 4-13: **Dielectrophoresis Risk Probability**

Probability	5					
	4					
	3					
	2		3		1	
	1				4	2
		1	2	3	4	5
		Severity				

Table 4-14: Dielectrophoresis Potential Hazards

Ref #	Potential Hazard	Probability	Severity	Impact	Mitigation
1	High Voltage	2	4	Electronics malfunction, sensor output manipulation due to gravitational field	Implement Faraday Cage
2	Launch Detect Not Triggered	1	5	No Data recorded	Extensive program testing/verification
3	Broken Wire	2	2	Electronics malfunction	G loading analysis on parts
4	High Voltage Drains Batteries	1	4	No induced electromagnetic waves, no movement of oil	Test batteries with HV supply

4.4 Landing Hazard Detection System

4.4.1 Experiment Concept

The LHDS will be a self-contained system with independent power and data transmission capabilities, the structure for which can be seen in Figure 4-30. It will deploy with the drogue parachute approximately at apogee and scan the area beneath the vehicle for potential landing hazards. The system will use a Beaglebone white with a camera to scan the ground during decent. The system will be a pendulum hanging from the end of a tether below the rocket. A fast shutter speed is required to take images of the ground moving rapidly through the field of view of the camera. A custom software consisting of edge detection, color detection and shadow analysis will be coded using Python and OpenCV in Python as the primary language. The three detection methods were chosen because they each can help detect a different kind of threat and depending on the conditions edge detection will be difficult if pictures are too blurry. With all three methods, there is redundancy so that as long as one works, threats can be detected. A gyroscope will also be mounted to detect the orientation of the landing hazard detection system. This gyroscope will control when the camera takes the pictures so that the pictures will be of the ground below and not of the horizon.

The purpose of the LHDS is to demonstrate a novel and unique approach to hazard detection during a vehicle descent. CRW's approach has to consider the deployment method, operating conditions, and test location to create a working code to analyze photographic data. Since the system will be suspended below the rocket on a long tether, constant and unavoidable motion exactly like a pendulum is expected. Because of the uncertainty of the image quality multiple methods were chosen to ensure that the threats of each launch site are taken into consideration. For the competition flight in Utah, edge detection will not be as useful as it would be during test launches in Manchester, Tennessee. Similarly, In Manchester, the color detection will not work as well because the grass and trees will be green. The LHDS will be challenging to the Prometheus team because as a team of Mechanical and Aerospace majors, Computer vision has never been touched on in any course. The team also was not taught python or another programming which most of the image processing operations will be performed in.

4.4.2 Science Value

The objective of the LHDS is to successfully detect threat areas on the ground and relay that data back to a ground station. The success criteria will be to capture images, analyze those images on the Beaglebone using at least one of the image processing methods, and relay that information back to the ground station. A partial success would be if the LHDS deployed, but failed to take pictures or relay

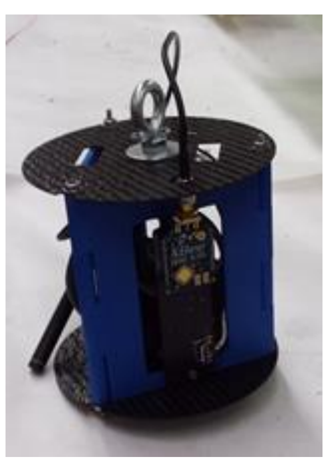


Figure 4-30: LHDS

them to the ground station.

The CRW definition of a landing hazard has applications in the exploration of the moon and other planets. For a manned mission, the landing sequence would most likely take place during the daytime hours on that planetary body. Assuming the atmosphere is sufficiently clear like the moon or Mars, shadows will be cast by prominent features like mountains, canyons, and impact craters. Smaller features akin to large boulders would cast a shadow as well but would need to be grouped in large numbers or be of a certain size to be seen from high altitudes. Once the vehicle came sufficiently close to distinguish a boulder field, the system would recognize the shadows and register the feature as a hazard. The idea of avoiding shadows is based on the assumption that the areas with no shadows are clear of objects that may cause damage during landing.

The LHDS poses a unique challenge for the CRW team as no team member has extensive knowledge of computer vision especially on a small system like a Beaglebone. The experimental method to develop the LHDS is to find a simple but effective method of analyzing images to decrease the load on the Beaglebone or its batteries. Through research, the OpenCV libraries in Python were chosen for the image processing on the Beaglebone, because there is clear documentation and examples of Open CV on Beaglebone.

The color detection software works by selecting a range of colors that a representative of a terrain found at a launch site. The software takes a picture in flight and analyzes the image looking for the pixels in the specified color range. For each range, a mask image is generated that changes pixels in that range white and all other pixels black. For the salt flats in Utah a range will be chosen that is close to the tannish color of the salt flats. In the example, an area of the Manchester launch site was used and the software was told to detect green. The original image is shown in Figure 4-31 and the mask binary is shown in Figure 4-32. To make sure the mask is correct it is transposed on the original picture to easily verify that the software picked up green which is shown in Figure 4-33. If most or all of the pixels match that color then the Beaglebone will report no threats in the area. If many pixels do not match, then the Beaglebone will send back a confirmation of hazards. The software will also run a Canny edge detection algorithm on the photo to see if there are any unexpected edges. This would be especially helpful when launching in a launch site with trees, as trees can match the green of the grass to pass the color detection. Edge detection of the Manchester area is also shown in Figure 4-34

Figure 4-31:Original Test Picture

Figure 4-32: Mask image for green pixels

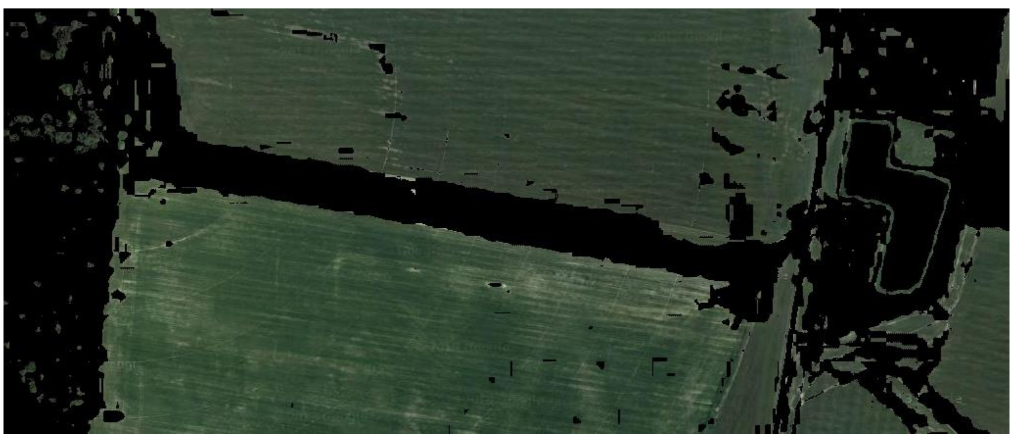


Figure 4-33:Original and mask overlay

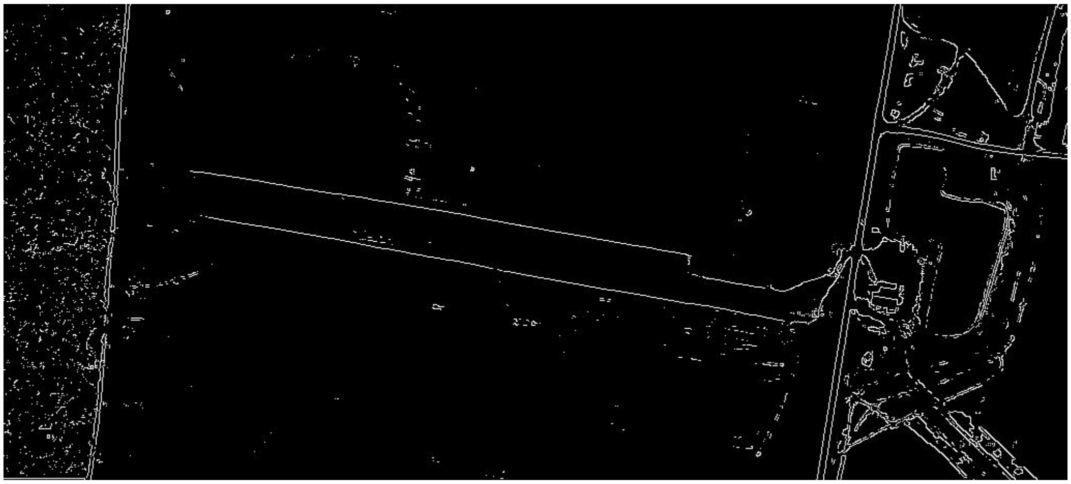


Figure 4-34: Edge Detection

Table 4-15: Success Criteria for LHDS

Requirement	Success Criteria	Verification
Transmit LHDS data in real time to a ground station.	Data is sent from RF module aboard rocket to ground station without loss or corruption.	Tested in ground test on 4/11/14. GPS module was driven around Campus while ground station was monitored
The payload shall be recoverable and reusable.	Recover the LHDS and reuse it.	Tested in recovery launch on 4/12/14. LHDS was recovered with launch in one piece.
Transmit live GPS Data	LHDS transmits live GPS data from the GPS module to the ground station.	Tested in ground test on 4/11/14. GPS was activated and data was received at ground station.
The electronic tracking device shall be fully functional during the official flight at the competition launch site.	GPS data is sent through LHDS aboard the rocket to the ground station during the competition launch.	Will be tested at official launch site on 5/18/14.
Deploys properly with recovery system.	The LHDS is deployed from the rocket.	Tested in recovery launch 4/12/14.
Hazard detection through color and edge detection.	Camera takes pictures and pictures are processed on Beaglebone	Threat detection tested on Beaglebone 3/31/14

4.4.3 Payload design

The components of the Landing Hazard Detection System payload are the Beaglebone White, GPS/Radio board and antenna, battery, camera, connectors, 3-D printed ABS panels, and carbon fiber disks. The panels are arranged in a triangular fashion and connected like hinges, and the carbon fiber disks are secured to the top and the bottom of the panels, and example of which is shown in Figure 4-30 above. Figure 4-35 below shows an example of a single panel removed from the assembly.

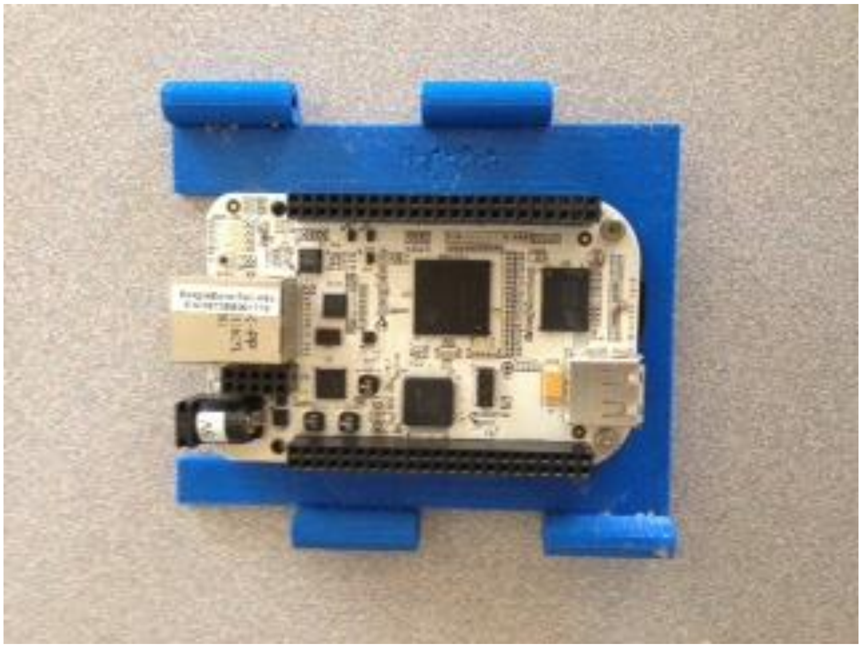


Figure 4-35: Single Panel with Beaglebone White

The primary design criteria of the LHDS payload were spatial constraints and the orientation of the GPS/Radio assembly. The spatial budget of the payload was about 4 inches vertically, and the inner diameter of the rocket body horizontally. For the GPS/Radio assembly orientation, for best results it is recommended that the board be oriented vertically and essential for the antenna to be oriented vertically. This orientation allows for the optimization of the reception of the radio waves, and therefore more accuracy with regards to location. Further, the GPS/Radio board would not fit horizontally within the rocket body diameter once the antenna and connector were attached. This led to the decision that the LHDS system would employ the printed panel housing. This allowed both for the maximization of space, and a vertical orientation for the GPS/Radio assembly, which provides the best possible satellite reception, and thus more accuracy of measurements.

Structural integrity of the assembly is largely achieved by the fact that it will see no significant structural loading. However, precautions were still taken to ensure success. The Beaglebone White, GPS/Radio board, and battery were each arranged on an individual printed panel, specifically designed for its respective component. This allows for the screws securing the component to the panel to be optimally located. Washers were paired with all nuts and screws to minimize point loading, both in the small threaded rods holding the printed panels together, and on the screws holding the components in place. The printed panel housing is secured to the two carbon fiber disks, also using washes to distribute the load as much as possible. The disks ensure a snug fit inside the body tube of the rocket, and prevent the parachute from being pushed around the payload during deployment. The antenna for the GPS/Radio board is ran through the top of the housing, and attached to shock cord above the payload. This is due to spatial constraints, as well as to maintain a vertical orientation. The camera is mounted on the bottom of the assembly in order to achieve the best view of the ground upon deployment.

The fit of the assembly is snug, but is still able to be ejected with the recovery system. Both the antenna and the payload are attached to the recovery system via shock cord. The top disk in the LHDS was fitted with an eye bolt, where it was attached to the shock cord with a knot. Its deployment was verified with a successful test of the recovery system. The configuration is shown in Figure 3-20.

4.4.4 Verification

The risk probability for the LHDS system was analyzed for high probable failures and was documented in Table 4-16 and Table 4-17.

Table 4-16 : Risk Probability

Probability						
	5					
	4					
	3			2		1
	2		7		3	
	1		5	6		4
		1	2	3	4	5
		Severity				

Table 4-17: Potential Hazards

Ref #	Potential Hazard	Probability	Severity	Impact	Mitigation
1	Incomplete Deployment / Jam	3	5	Loss of GPS signal, LHDS data, or vehicle.	Ground testing of recovery system
2	Vehicle Out of Range	3	3	Loss of LHDS/ GPS	Recovery system design to minimize drift
3	Separation of LHDS and Rocket	2	4	Loss of LHDS/GPS	Implement Faraday Cage
4	Launch Detect Not Triggered	1	5	No data recorded	Extensive program testing/verification
5	Environment	1	2	LHDS stuck in a tree	Deploy main parachute at low altitude to reduce drift

Table 4-18: LHDS Design Criteria

Requirement	Success Criteria	Verification
Recoverable and Reusable	If the Payload can be removed and replaced between subsequent flights	There are no missing screws or bolts or tools necessary to fix the LHDS.
Sustainable	The mass simulators or payload	If the payload remains inside its

	does not hinder the Rocket's takeoff or landing	design, and the Rocket launch and landing are successful.
Non-damaging	If no damage to the rocket is done by the mass simulators	If any scratches or dents are visible inside or outside the rocket near the payload
Communicable	If the RF antenna can communicate successfully without impedance from the design	If a signal is reached from the ground base.
Camera Visibility	If the camera can take pictures of the ground without any obstruction from the Rocket body after deployment	If the pictures have desired amount of ground-landing in them to be able to verify landing hazards
Communicable GPS	RF module communicates with GPS module and ground	If GPS location is communicated to ground
Functioning Electronics	If electronics are functional and record data properly	If data is recorded and readable for analysis

4.5 Paint Payload

4.5.1 Experiment Concept

The Supersonic Flight Vehicle Paint/Coatings Payload is original and unique in that it will provide useful data to further research in rocket coatings for better heat resistance and to further research in expanding the life of reusable rockets. These coatings could be seen as a more cost effective way to protect rockets bodies from wear. The payload will also incorporate a unique thermal tape that will provide temperature data on the max temperature seen by the rocket. This data would be extremely useful for verification of the rocket's thermal analysis. The thermal tape changes color when it reaches a specific temperature as seen in Figure 4-36. The challenge of using this technique in collecting temperature reading is that the tape will be subjected to skin friction. Reaction time of the thermal tape is 3-5 seconds which could produce lost data, but alternative faster reacting tape could be an alternative. The adhesion of the tape is also significant so that the friction creates enough temperature for the tape to react, but not so much that it peals the tape off the body of the rocket.

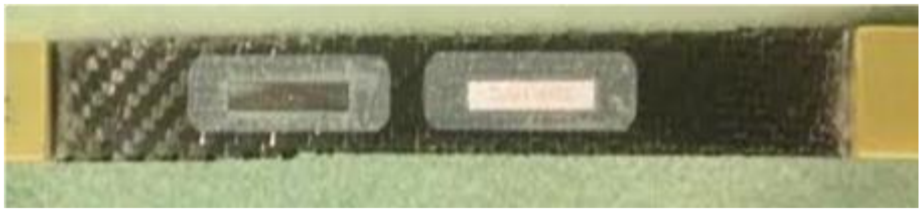


Figure 4-36: Temperature Tape Thermal Test

The coatings selected for Prometheus, epoxy primer and urethane, were selected on film thickness to weight ratio, adhesion, and heat resistance. Epoxy will be a two part system that is activated by mixing a catalyst with a reducing agent as seen in Figure 4-37.

Figure 4-37: Two Part Epoxy

This allows for adjustment of the cure time for the coating to help speed up or slow down production time. Epoxy also offers high coverage properties with low film build allowing for a better coverage with less weight. It also has excellent adhesion and anti-corrosion properties allowing for application to multiple materials. Urethane, as seen in Figure 4-38, is a good alternative although it doesn't have high adhesion when properly applied it still offers a high volume to film build ratio. It offers excellent retention along with abrasion resistance with a smooth finish.

Figure 4-38: Urethane

Urethanes heat capacity and curing times can also be altered to meet production needs. These coatings have the best durability qualities needed for a supersonic flight.

In order to test the coatings in supersonic flight each coating will cover half the rocket. Each coating will have different surface finishes with the epoxy having a rough surface and the urethane having a smooth finish. This will help show the differences between the two applications of the paintings post flight. The coatings will be analyzed post flight for any defects and compared with each other to determine their surface effectiveness. Along with the multiple coatings, a temperature tape will be applied to the rocket body. The tape will act as a visual reference to our thermal analysis to help verify the surface temperatures. The tapes being applied will be 300, 400, and 500F temperatures and were selected by a comparison of a heat and mass transfer analysis conducted by the team.

4.5.2 Science Value

The importance of finding durable paints and coatings for supersonic flight is multifold. Weight is always a major factor in space flight and minimizing weight by using lighter coatings that can withstand the rigors of supersonic flight is the objective. Cost is another driving factor and should be minimized. By testing different coatings with subscale rockets that still travel supersonic, reliable and accurate date can be gathered on a variety of paints and coatings cheaply. The importance of testing the reliability of thermal changing tape lies in the cost. Thermal tape is normally used for static temperature testing with this being the only time it's ever been tested in supersonic flight. The thermal tape has a reaction time of 3-5 seconds with multiple temperature increments to choose from with the accuracy of 1 degree of the displayed temperature. Applying the thermal tape will be pertinent to its success. If the tape can be found to withstand the stresses of supersonic flight, and display a thermal reaction a cheap alternative will have been found. Preparing the surfaces for the coatings and thermal tape will be crucial to their success. The body of the rocket will be sanded and prepped for maximum adhesion of the coatings. Once the coatings have cured, their surface will be cleaned to ensure for greatest adhesion of the thermal tape.

The success criterion for the paint and coatings payload has to meet certain standards. The coatings have to be able to withstand supersonic flight and recovery without major damage. The paint must be applied evenly and modestly in order to meet the final weight requirement. Thermal tape must stay intact in the orientation it is applied and change color to indicate a temperature change along the body of the rocket. Ensuring the success of these payloads will require procedure to be followed correctly. The body of the rocket will be sanded smooth to ensure an even, semi rough surface for the coating to adhere to. The surface of the coatings will then be cleaned and prepared for the thermal tape to be applied.

4.5.3 Payload design

In order for this payload to be a success it is important that the paint coatings are properly applied. Sanding the rocket's surfaces will give the team a smooth and uniform surface that will insure a strong bond between the paint and the rocket. Before the paint is applied the surface will be cleaned with acetone. Cleaning the rocket will clear away any residue or debris that could cause impurities or bonding failures which would cause the paint to flake off. Each layer will be approximately a millimeter thick when applied evenly to the rocket body. The number of coatings will depend on the weight requirement for the rocket. The nose cone will be coated half epoxy and half urethane to observe the effects on two different coatings. If the rocket maintains the weight that has been predicted by the team then the entire rocket will be coated. To rule out random damage not associated with the flight test samples will be coated during the painting of the rocket and stay in the lab for a control sample. These samples will then be compared with the rocket after flight and the differences will be noted.

The coatings have been tested and proved to work in an automotive environment. This coating can be a viable and cheap replacement for current coatings of rockets. The paint is expected to adhere, stay rigid, and not fracture under supersonic flight. The thermal tape has been tested during the subscale launch on the tip of the nose and is predicted to adhere to the full scale. The thermal tapes ability to indicate a temperature difference is unknown and full scale launch will only tell. Overall, the coatings should not see any significant changes due to the short supersonic time frame it will be subjected to.

4.5.4 Verification

Requirement	Success Criteria	Verification
Withstand Supersonic Flight	No visible damage including but not limited to peeling or cracking.	Visually inspect with microscope for any defects post flight
Low coating weight	Adds minimal weight to the rocket.	Weighing the rocket before and after application
Even film thickness	Coverage of the coatings is uniform and adheres correctly	Preflight inspection. Repair any flaws or record for post flight analysis
Proper application of thermal tape	Secure and uniform adhesion to surfaces	Preflight inspection. Repair any flaws or record for post flight analysis. Verified 3/22/14

5 Launch Operations Procedures

5.1 Checklist

In order to ensure proper function and assembly of all vehicle components and ensure the safety of all team members, the CRW team utilizes a comprehensive set of Launch Operations Procedures, as shown in Appendix L: Launch Operation Procedures. These procedures provide step-by-step instructions for: preparing the recovery system, vehicle and payload assembly, motor and ejection charge preparation and installation, launch rail setup, troubleshooting, and post-launch inspection. These procedures also identify the parties responsible for any processes deemed to be hazardous during the vehicle assembly, and the requirements for their approval. All potentially hazardous steps must also bear the signature of the Safety Officer and the launch team member(s) responsible for conducting them, upon their completion. All completed launch procedures are saved digitally, following their completion, in order to maintain a record of any required procedure deviations, and allow for the necessary updates to the procedure in order to reflect those changes.

Note: The procedures currently in the appendix are for the sub-scale launches. They will be updated once the full-scale vehicle is complete.

6 Project Plan

In order to successfully run a large scale project such an all-encompassing project plan must be developed that covers budget, timeline, and additional requirements such as outreach.

6.1 Budget

A budget is a crucial part of any project and must be planned with care to ensure that the required funding is maintained through till the project completion. This sometimes means making design decision based upon available funding. To minimize this risk a careful budget and funding plan was kept.

6.1.1 Total Program Expense

Figure 6-1 shows the projected total cost for the program. The travel expenses shown in the figure is the expense for the entire team to travel to Utah. The cost is broken down into two major categories, core and travel, similar to the funding. The travel is broken down into its major components and the core expense is broken down into payload, propulsion, structure, and recovery. The core expenditure should not be confused with on the pad cost. The core expenditure includes overheads such as spare, unused, and broken parts that were ordered for that portion of the program. The on the pad cost includes only the cost of the components that are actually in a rocket resting on the pad.

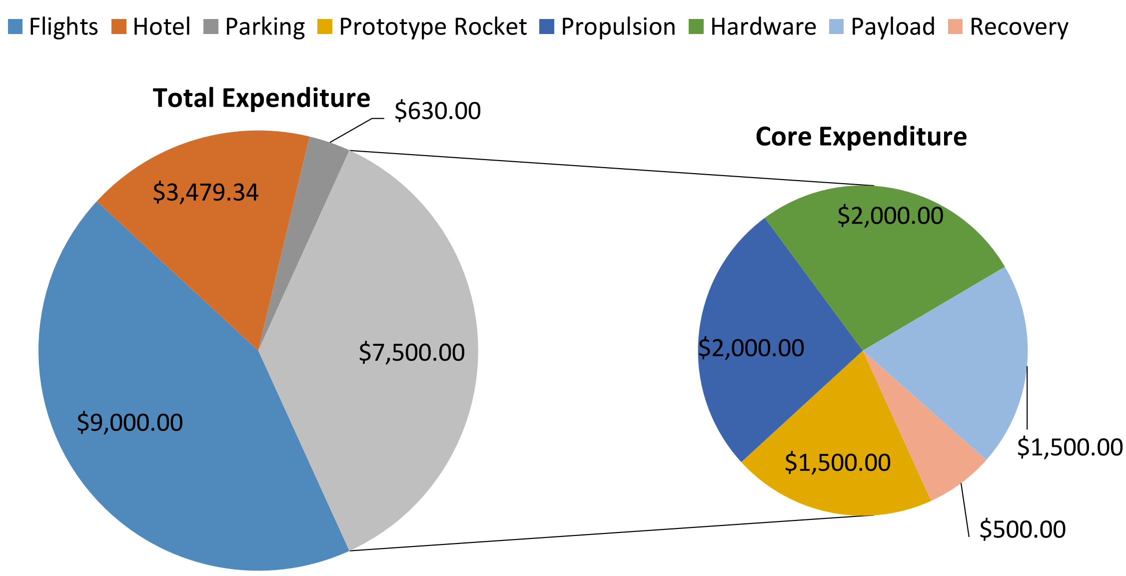


Figure 6-1: Program Expenditures

As can be seen in the figure travel drives the majority of the expense of the program due to all team members traveling out to the launch. The core expenditure portion of the project covers only $7,500 and the remaining $13,109 is due to travel. The travel and funding sections below will cover alternative travel plans and how the required amount of money for travel will be raised.

These numbers were reached by summing up the estimated cost of each individual component estimated to be required for the rocket as seen in Figure 6-2. The results were then rounded to the nearest hundred to catch any minor errors in the estimated costs.

Hardware	Total Cost		Propulsion System	Total Cost
Carbon Fiber (50"x120')	$ 800.00		Motor Case	$ 450.00
Epoxy + Mold Release	$ 440.00		M Class Grain Loads (x2)	$ 1,000.00
PVC Pipe Mold	$ 40.00		Subscale Grain Load	$ 200.00
Nosecone Mold Materials	$ 200.00		Shipping + Misc	$ 300.00
Misc	$ 500.00			
			Total	$ 1,950.00
Total	$ 1,980.00			
Payload System	**Total Cost**		**Recovery System**	**Total Cost**
Beaglebones Black (x2)	$ 90.00		Parachute Material	$ 300.00
Beaglebone White	$ 90.00		Shock Cords	$ 100.00
Sensors	$ 800.00		Charges/e-Matches	$ 25.00
Wires + Misc	$ 500.00		Misc	$ 75.00
Total	$ 1,480.00		**Total**	$ 500.00

Figure 6-2: Estimated Cost Source

Several of these sections contain sub sections cost rolled into a single entry to keep the table to a reasonable size. Areas such as “Sensors” also contain the printed circuit boards as well as wires, connectors, and resistors to enable the sensors to work, this is then rounded up. The “Misc” section for Hardware ended up taking the brunt of the cost associated with the 3D printing which was not originally budgeted. The results from estimating travel cost can be seen below section 6.1.4.

Changes since CDR

The overall program expense decreased from the CDR. This was due to a number of refined numbers concerning travel. Even though the cost of the core expenditure increased the decrease in the travel, which was the primary cost driver, drove the decrease for the project. The cost increase in the Core Expenditure was due to the inability to obtain the 3D printed parts at no cost as originally expect and the desire to launch a “prototype” rocket. The decrease in the travel was driven by a more accurate hotel cost with the actual reservations being made, by several team members’ inability to travel to the launch event, and the fact that team members are responsible for their own food. These changes combined result in a decrease of more than $5,000 from the CDR for the total expected cost for the overall project.

6.1.2 Core Program Expense

The core program expenditures covers all cost not associated with travel to the launch site. This covers any training, subscale components, full-scale components, backup parts, and testing fees. Travel reimbursement to local launches are covered under funding for the class and do not come out of CRW funding. As can be seen in Figure 6-3, the original total predicted cost of $6,000 for the rocket expense is given a linear growth over the approximately 190 days until the project ends on June 2nd. The actual cost quickly overtook the linear growth rate but settled down during Christmas break. The jump seen 70 days into the project represents the start of the new semester. However, due to complications during the full-scale launch a new updated budget was made to encompass the expected changes.

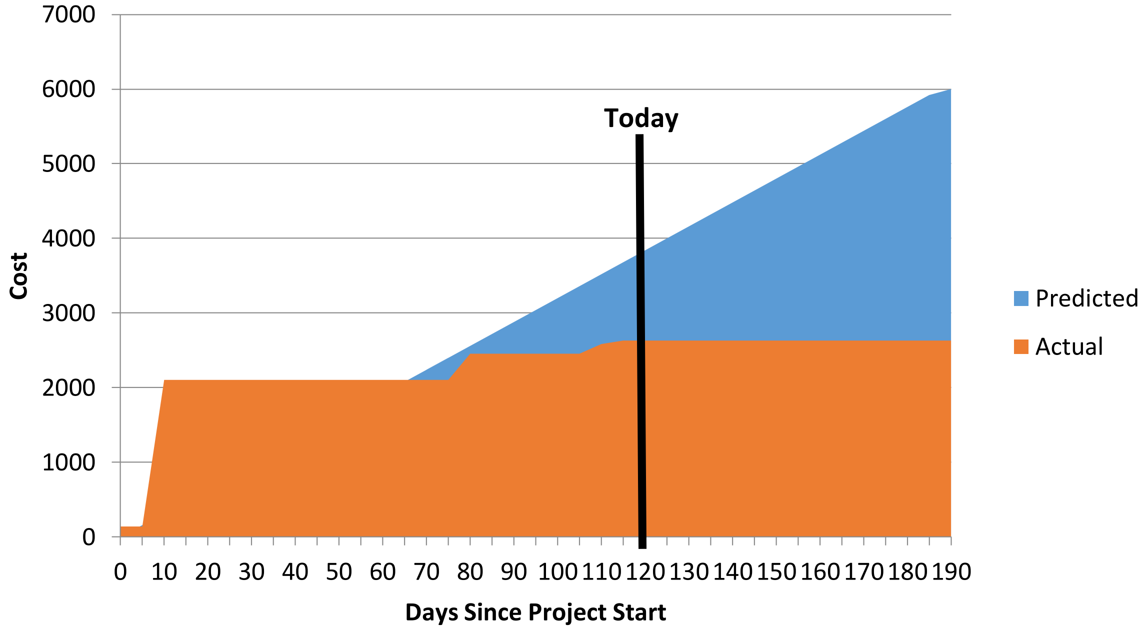


Figure 6-3: Original Cost Prediction as of CDR

Changes since CDR

The delay in the complete full-scale flight meant that a second “prototype” rocket would need to be designed. This prototype rocket would carry the full-scale recovery system in a near full-scale flight. This rocket needed to be assembled in a short amount of time. This meant purchasing kit parts of sufficient size and strength to handle the required payloads which increased the cost of the project. The free 3D printed parts fell through and required the team to purchase replacement 3D parts which also drove the cost of the rocket up. These additional purchases pushed the budget over its original $6,000 predicted. To accommodate this change a new budget from the FRR moving forward was developed to predict the remaining cost associated with finishing the rocket and flying for the competition. This can be seen in Figure 6-4 by the rapid climb in the weeks leading up to the FRR.

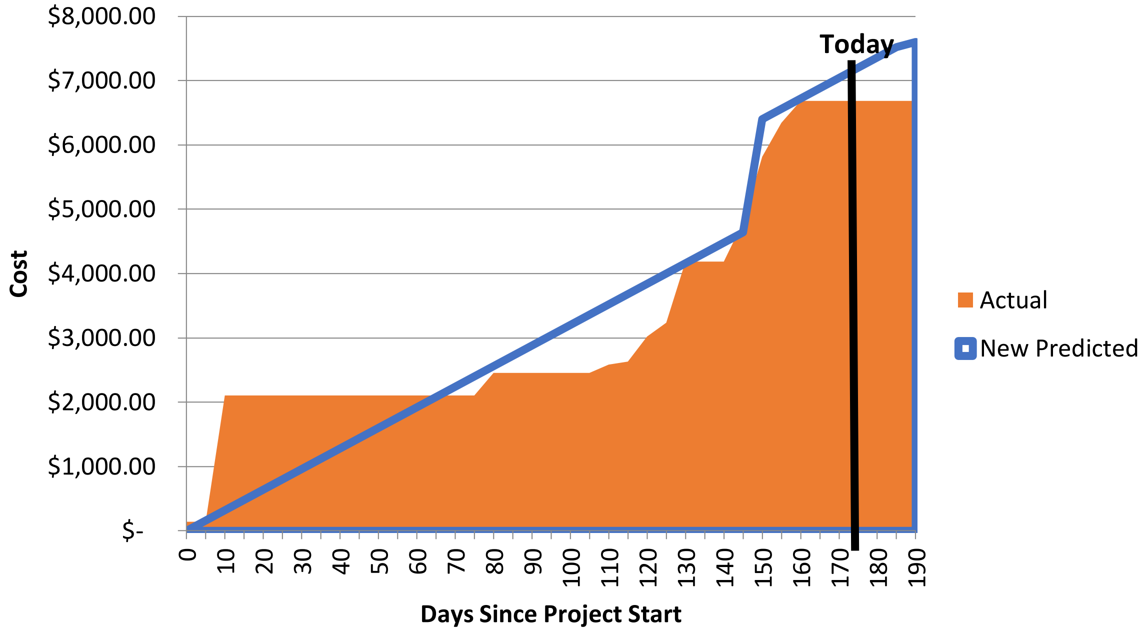


Figure 6-4: Updated Core Expenditures

The new projected cost is $1,600 dollars higher than the original. This is to catch the prototype rocket as well as the 3D printed parts which came to an approximate total of that amount. This change can be seen by the sudden step increase in the predicted cost once the prototype rocket concept was proposed. This required the entire budget to be rebalanced around the new numbers.

Launch Week

Due to the amount off in the past predictions additional consideration must be given to the launch week and any expenses accrued correcting the rocket there. A small subset of team members plans to drive to the launch site, besides transporting the rocket, a large number of tools and spare parts can be brought as well to aid in the adjusting or repairing the rocket at launch week. This should minimize any additional cost during launch week. The motor will be purchased ahead of time and drove out to the launch site to prevent any unexpected motor change. Due to the spare parts that will be brought as well as the tools that can be transported to the launch site no unexpected cost should be incurred for launch week.

6.1.3 On the Pad Cost

The on the pad cost of the rocket has changed significantly due to the failure to obtain 3D printed parts at no cost as had been previously expected. The actual cost of the rocket went up due to the 3D printed parts but since all of the cost is paid for by the team the theoretical cost vs actual cost has gone away as seen in Figure 6-5. The cost of the rocket is lower than normal for a rocket with the size, speed, complexity, and materials of this rocket. A large portion of the cost of the rocket was saved by laying up carbon fiber in house instead of buying premade carbon fiber tubes. Despite the cost savings from laying up the carbon fiber in-house the cost of the 3D printed parts drives the hardware cost above both propulsion and payloads. The section of the rocket with the smallest cost by far is the recovery system. The individual components that make up the on the pad cost can be seen in Table 6-1.

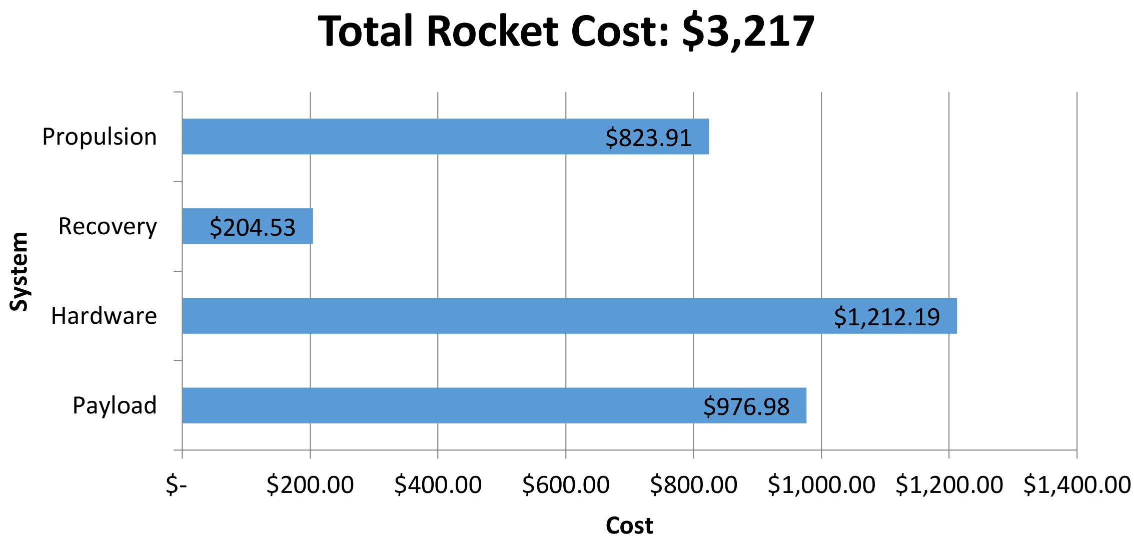


Figure 6-5: On Pad Cost

Table 6-1: On Pad Cost Components

Part	**Unit Cost**	**Quantity**	**Cost**
Payloads			
Beaglebone Black	$ 45.00	2	$ 90.00
Beaglebone White	$ 88.95	1	$ 88.95
High-G Triple-Axis Accelerometer (±200g)	$ 24.95	2	$ 49.90
Triple-Axis Accelerometer (±2g/4g/8g/16g)	$ 19.95	2	$ 39.90
Triple-Axis Gyro Breakout Board	$ 24.95	2	$ 49.90
SENSOR 30 PSIA UNAMPLIFIED DIP	$ 9.01	2	$ 18.03
SENSOR 60 PSIA UNAMPLIFIED DIP	$ 12.32	2	$ 24.64
SENSOR PRESS ABSOLUTE 100 PSI	$ 29.91	2	$ 59.82
HOLDER BATTERY COIN 12MM DIA THM	$ 0.53	2	$ 1.06
HOLDER BATTERY FOR LITHIUM 2/3 A	$ 1.60	2	$ 3.20
BATTERY HOLDER CR123A NYLON SMD	$ 2.10	2	$ 4.20
XBEE PRO XSC S3B 900MHZ 250MW	$ 42.00	1	$ 42.00
AD623ANZ-ND Operation Amplifier	$ 4.23	6	$ 25.38
PCB	$ 30.00	1	$ 30.00
Misc Backup	$ 100.00	1	$ 100.00
3D Printed Plastic (approx)	$ 350.00	1	$ 350.00
		Payload Total:	$ 976.98
Hardware			

Carbon Fiber (50in wide per yard)	$ 19.99	17	$ 339.83
Mold Release	$ 19.99	1	$ 19.99
Resin	$ 114.98	1	$ 114.98
Shrink Tube	$ 119.70	1/3	$ 39.90
3M Structural Epoxy	$ 114.98	1/3	$ 38.33
Epoxy Tips (12 per pack)	$ 23.38	1	$ 23.38
Shear Pins (100 per pack)	$ 7.88	1/10	$ 0.79
e-Matches	$ 2.00	4	$ 8.00
Misc (screws, nuts)	$ 100.00	1	$ 100.00
3D Printed Parts	$ 527.00	1	$ 527.00
		Hardware Total:	$ 1,212.19
Recovery			
Ripstop Nylon	$ 71.53	1	$ 71.53
Thread (approx)	$ 20.00	1	$ 20.00
Shroud Lines (approx)	$ 30.00	1	$ 30.00
Kevlar Shock Cord	$ 75.00	1	$ 75.00
e-Matches	$ 2.00	4	$ 8.00
		Recovery Total:	$ 204.53
Propulsion			
98-3G Motor Case	$ 413.95	1	$ 413.95
M4770 Vmax Load	$ 404.96	1	$ 404.96
Igniter	$ 5.00	1	$ 5.00
		Propulsion Total:	$ 823.91
		On Pad Total:	$ 3,217.61

6.1.4 Travel Expense

As seen from the Figure 6-1 earlier the projected travel expense is the primary cost of the project. The budget for travel out to the launch can be seen in Table 6-2 below.

Table 6-2: Two Travel Options

Travel	Total Cost
$500 Delta Flight HSV to SLC (x18 People)	$ 9,000.00
$180 Night (x6 Nights)(x6 rooms)	$ 3,479.34
$10 Parking fee (x7 Days)(x9 cars)	$ 630.00
Total	$ 13,109.34

One of the primary changes to the travel was the removal of the backup travel plan where only a subset of team members would travel to the launch. The current plan is to fly the entire team with the members themselves making up and cost difference that may develop between the amount that the budget can cover and the actual cost. The current budget covers the entire cost of travel so any difference that may develop should be minor and not cause and issues for members traveling out to the launch.

This was updated from the CDR with a lower hotel cost since the actual hotel reservations have come in under the predicted values. Several team members' inability to travel decreased the estimated cost of travel for the entire team. Team members will also be responsible for their own food while out during launch. All of these changes decreased the cost of travel by nearly $8,000. These changes brought the cost of travel within the range of travel funding despite getting less travel funding than originally expected.

6.1.5 Funding

Similar to the cost analysis the funding was split into two main categories: The core funding, which covers the core expenditures, and travel funding, which covers the travel expenses.

Core Funding

Core funding came from three primary sources. The main source was the Nanolaunch 1200 project as well as the MAE depart of UAH. A small amount was leftover from last semesters funding and was applied to this project. The MAE depart was new funding no expected during the CDR and provides enough to cover the expected increase in core expenditure discussed above. The core funding matches the estimated core cost because the

Table 6-3: Core Funding

Core Funding		
Source	**Amount**	**Status**
Previous Years	$1,000.00	Acquired
Nanolaunch 1200	$5,000.00	Acquired
UAH MAE Department	$2,000.00	Acquired
Total	$ 8,000.00	
Est Core Cost	$ 7,500.00	
Ending Balance	$ 500.00	

necessary funding was pulled from travel until the cost of the core program could be covered. Any additional funding that may arrive will go to the core funding to either cover unexpected cost or to roll over to next year's team.

Travel Funding

Travel funding came from Alabama Space Grant, Student Government Association, UAH Vice President of Research, and the UAH Dean of Engineering. One of the major changes since the CDR was the major gap between the expected funding from the Student Government Association and what was actually received. This was considered in large to be how the project was pitched to the Student Government Association. Moving forward for future teams a greater focus must be spent on obtaining funding from available sources inside the university earlier in the program. The difference between the Travel Funding and the estimated Travel Cost is only $390. This is largely due to the fact that all of the spare travel funding was pulled into the funding for the core program.

Table 6-4: Travel Funding

Travel Funding		
Source	**Amount**	**Status**
Student Government	$1,500.00	Acquired
Alabama Space Grant	$5,000.00	Acquired
UAH VP of Research	$3,500.00	Acquired
UAH Dean of Engineering	$3,500.00	Acquired
Total Funding	$ 13,500.00	
Est Travel Cost	$ 13,109.34	
Ending Balance	$ 390.66	

Changes since CDR

Besides the changes in funding covered above one of the major changes was the inability of the team to obtain a sponsor for the project. The compressed timeline and later start of the project made seeking a sponsor more difficult. A sponsorship packet was constructed but an opportunity to present it to an interested company never arose. Because of the inability to find an external sponsor the budget has very little room to slip past its current cost.

6.2 Timeline

A high level Gantt chart was developed to give a guideline of when major milestones will be met. This shows the critical path of the project. The critical path, seen in Figure 6-6, flows through the Proposal, Preliminary Design Review, Critical Design Review, Flight Readiness Review, Launch, and Post Launch Assessment Review. Several other critical events such as subscale launch and full-scale preliminary launch are contained within the other critical path events. A detailed description of the critical path events is provided below.

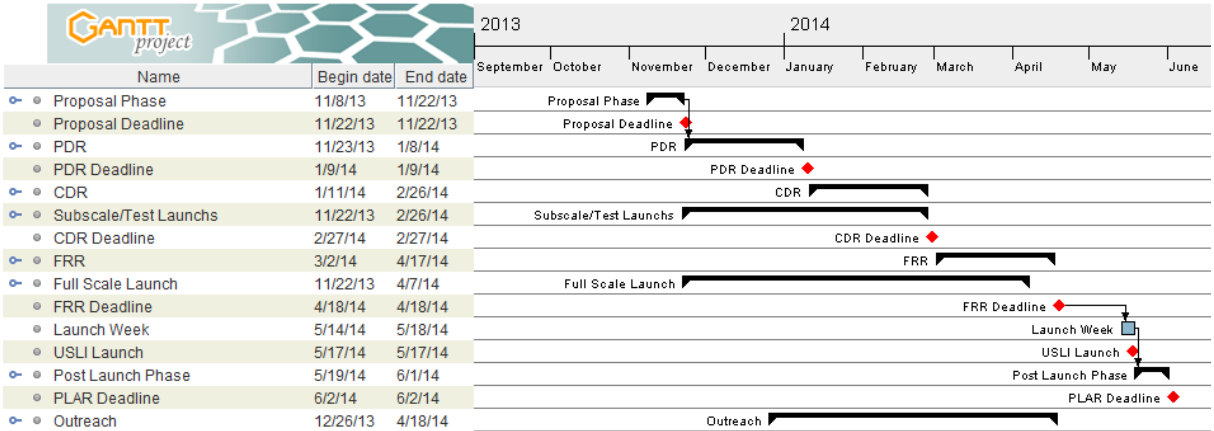


Figure 6-6: Overview Schedule

Proposal (11/22/2013) (Completed)

A proposal was submitted to NASA Student Launch competition proposing a rocket that fulfils both the Nanolaunch 1200 requirements as well as the requirements set by the competition. The details of the Nanolaunch 1200 project were covered and concepts were pitched to NASA in a proposal. The project was at a Technology Readiness Level (TRL) of 1. [Appendix 18]

Preliminary Design Review (PDR) (1/10/14) (Completed)

Preliminary design work was completed and a path forward was proposed. Early modeling and simulation work had begun to verify the design. The design work and modeling were presented to both the Nanolaunch 1200 program as well as the NASA student launch competition in a Preliminary Design Review. This was accompanied by a presentation to further explain the design and allow any questions to be answered. The project was at a TRL stage 4 which is toward the lower end of stages considered to be in the PDR.

Critical Design Review (CDR) (2/28/14) (Completed)

CDR	1/11/14	2/26/14
Carbon Fiber Analysis	1/31/14	2/10/14
Carbon Fiber Test	2/11/14	2/11/14
Brainstorming LHDS	2/1/14	2/8/14
LHDS Hardware Design	2/9/14	2/11/14
Report Writing	1/11/14	2/12/14
Report Draft Due	2/13/14	2/13/14
Presentation Writing	2/10/14	2/18/14
Practice Presentation Due	2/19/14	2/19/14
Report and Presention Finalize	2/19/14	2/26/14
Subscale/Test Launches	11/22/13	2/26/14
Subscale Part Order	11/22/13	1/10/14
Parts Manufacturing	1/11/14	2/2/14
Subscale Payload Coding	1/1/14	2/3/14
First Subscale Assemble	2/4/14	2/7/14
First Subscale Launch	2/8/14	2/8/14
First Post Flight Analysis	2/8/14	2/16/14
Second Subscale Assemble	2/17/14	2/21/14
Second Subscale Launch	2/22/14	2/22/14
Second Post Flight Analysis	2/22/14	2/26/14
CDR Deadline	2/27/14	2/27/14

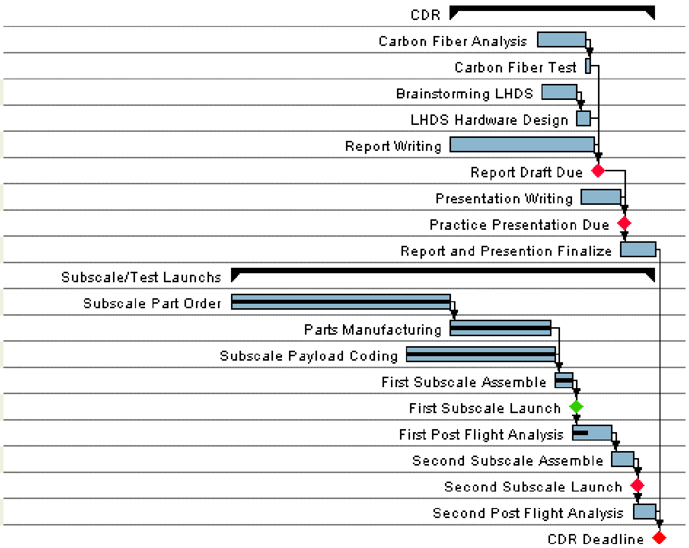


Figure 6-7: CDR Detailed Schedule

The critical design review represents the end of the major design phase. By this time the design is very mature and has begun to enter the testing phase. The design is at a TRL level of 6-7. The design work leading up to the report draft can be seen in the top portion of Figure 6-7. A rough draft of the CDR report was assembled on February 14. This gave two weeks between the CDR rough draft and the final report. This lead time drove the design of the project and forced the design to be primarily finished by this date. By doing this it allowed minor changes that always occur after the CDR to appear before the actual final CDR date. This will minimize changes after the CDR.

The subscale launch follows a separate timeline since it is not bound by the design of the payloads. It does however feed into the final report. The first subscale launch flew on February 8th to test the stability. Due to the fins not being sufficiently epoxied on, a second flight to test the dual deploy recovery system was not possible.

A second subscale launch was performed to test the payload and the dual recovery system on February 22nd. The results from both tests were analyzed and discussed earlier in the document.

The subscale launches and design come together as two separate critical paths and merge at the CDR report. This will set off the path forward through the FRR and begin the majority of the testing phase.

Flight Readiness Review (FRR) (4/18/14)

The flight readiness review drove the requirement to get a full-scale launch off before its due date. This date was slipped due to a number of issues. Because of this the entire schedule after the FRR was redone to account for this change. The prototype rocket was introduced to get a full-scale test of the recovery system off before the FRR and the full-scale launch was shifted back to the 26th of April. An updated Gantt chart for the FRR and full-scale launch can be seen in Figure 6-8 below.

Full Scale Launch	11/22/13	4/11/14
Fullscale Parts Order	11/22/13	3/1/14
Model Printed Circuit Boards	2/13/14	2/24/14
Purchase Approval	2/25/14	2/26/14
Wait for Delivery	2/27/14	3/10/14
Test Board and Assemble	3/11/14	3/23/14
Carbon Fiber Lay Up	2/15/14	3/5/14
Nose Tip 3D Printed	2/5/14	3/22/14
Nanolaunch Coding	2/5/14	3/4/14
Finalized Code and Testing	3/5/14	3/23/14
Practice Assemble	3/24/14	3/27/14
Full Scale Launch Day	3/28/14	3/28/14
Recovery System Building	3/20/14	3/22/14
Recovery System Assemble	3/23/14	3/23/14
Prototype Designed	4/3/14	4/3/14
Parts Ordered + Shipped	4/4/14	4/8/14
Backup FS Launch Day Prep	4/9/14	4/10/14
Ground Test Deployment	4/11/14	4/11/14
Prototype Launch Day	4/12/14	4/12/14
FRR Deadline	4/18/14	4/18/14
FRR Presentation	4/22/14	4/22/14

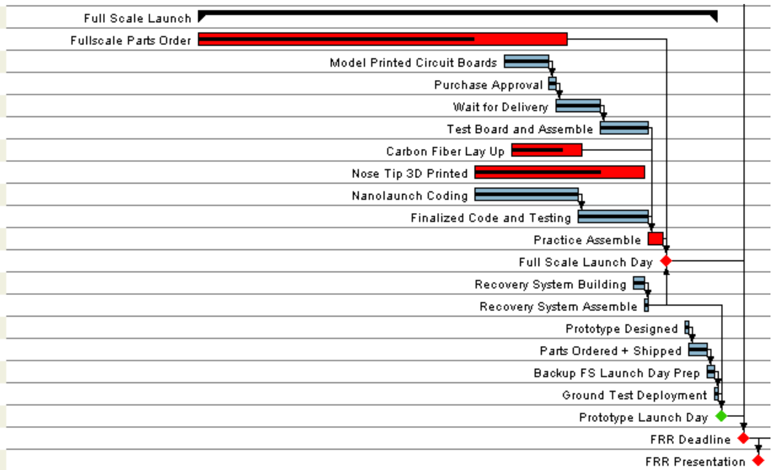


Figure 6-8: FRR Detailed Schedule

The paths highlighted in red represent the paths that lead to a full-scale launch that failed. These were all parts of the critical path that lead up to the full-scale launch and a failure and any one would have grounded the full-scale rocket. Due to failure in three of the paths the realization was reached that even the backup full-scale launch would not obtained before the FRR. A prototype rocket was built by the backup launch day to test the full-scale recovery system which could still be completed in time. This prototype rocket was considered part of the critical path for the FRR so that progress would still be evident even without the full-scale flight. Part of the critical path for the prototype rocket was the recovery system since the primary purpose of the prototype rocket was to test the full-scale recovery. This was also a requirement for the full-scale rocket and was competed in time and was not one of the failed critical paths leading into the full-scale. The red paths represent dead paths and will be recreated under the newer shorter more compressed timeframe.

New Full-scale Launch	2/15/14	4/28/14
Carbon Fiber Lay Up	2/15/14	4/19/14
Nylon Parts Ordered + Shipped	4/7/14	4/21/14
Order Parts + Shipping	4/15/14	4/21/14
Assemble Rocket	4/22/14	4/24/14
Ground Test Deployment	4/25/14	4/25/14
Full-Scale Flight	4/27/14	4/27/14
Addendum Writting	4/22/14	4/28/14
Addendum Due	4/29/14	4/29/14
Launch Week	5/14/14	5/18/14

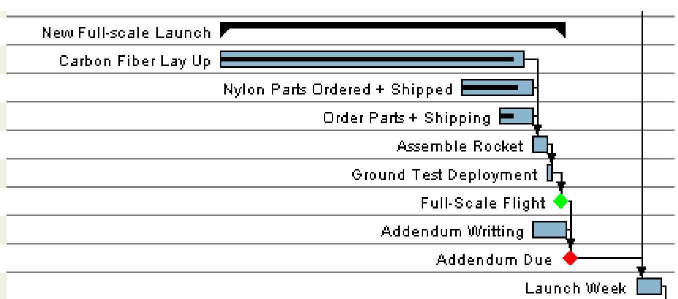


Figure 6-9: Post FRR Detailed Schedule

The full-scale launch is not part of the critical path for the FRR report directly since the last acceptable launch date was pushed to April 27th. It is a part of the critical path for the launch week since a full-scale launch is required before the team can continue in the competition as seen in Figure 6-9. Part of the critical path leading up to the full-scale is the new 3D parts order. This represents the new nylon parts ordered once the free 3D printed titanium parts fell through. The carbon fiber layup extends back to when the layups were originally started and extends to the newer date. This is similarly a critical path for the full-scale launch.

6.3 Outreach

Prior to the start of the NASA Student Launch competition CRW participated in several outreach events. The Mechanical and Aerospace engineering open house event was target at college age students and CRW members supported a booth to get potential engineering students interested in the program here at UAH. The Girls in Science and Engineering Day was targeted at girls from 3rd to 6th grade and had CRW team members present with several of the previous year's rockets which the girls were able to hold and ask questions about as seen in Figure 6-10. CRW also participated in a joint outreach effort at the Propulsion Research Center for homeschoolers where the students were given a tour of the PRC. Several key lessons were learned from these events that helped guide the outreach effort of the CRW team. Having a structured event with an end goal is critical for a good outreach plan. Having an activity that supports the concepts learned during an information stage in the event is critical for engaging the students and enforcing the concepts learned.

Figure 6-10: Girls in Science and Engineering Day

Charger Rocket Works has constructed an outreach packet that can be pitched to various schools and STEM events to cover the basics of rockets. This packet is modular in nature and this allows it to be easily adjusted to match different grade levels and fill different time slots. This will be done by separating the information in the outreach packet into categories that correspond to different difficulties. More complex concepts such as drag or how thrust curves are used to predict apogee could be placed in slides reserved for more advanced classes or when more time can be devoted to their explanation. Slides have been constructed and plans are in place to consult an elementary school teacher and a middle school teacher to insure the slides are appropriate for their age groups.

The primary focus of the slides is based around soda bottle rockets. These allow the students to explore the concepts of rockets in a safe controlled environment but still in a hands on manner. Rather than just see a rocket launch demonstrated they get to see the results their decisions had on the flight of the rocket. This is a powerful tool that will leave a lasting impression on the students and inspire them to continue exploring.

Outside of the dedicated outreach packet the team supported the Science Olympiad and the MAE Open house. The Science Olympiad is a national competition where middle and high school students compete in various competitions that are all based around concepts of science and engineer. Eight team members assisted the student's in four different competitions. The students were divided into teams and competed against each other under strict rules. The MAE Open house is an opportunity for potential freshmen to visit the school and see what the Mechanical and Aerospace depart has to offer. Charger Rocket Works brought previous rockets and discussed the team's involvement in the NASA Student Launch competition.

Table 6-5: Current Outreach Results

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4	88			
5-9	318		600	
10-12	58			
12+				120
Educators (5-9)	2		3	
Educators (other)				

6.3.1 Outreach Schedule

Although outreach is a required part of the competition its timeline, seen in Figure 6-11: Outreach Schedule is not tied to the launch of the rocket and is outside of the critical path.

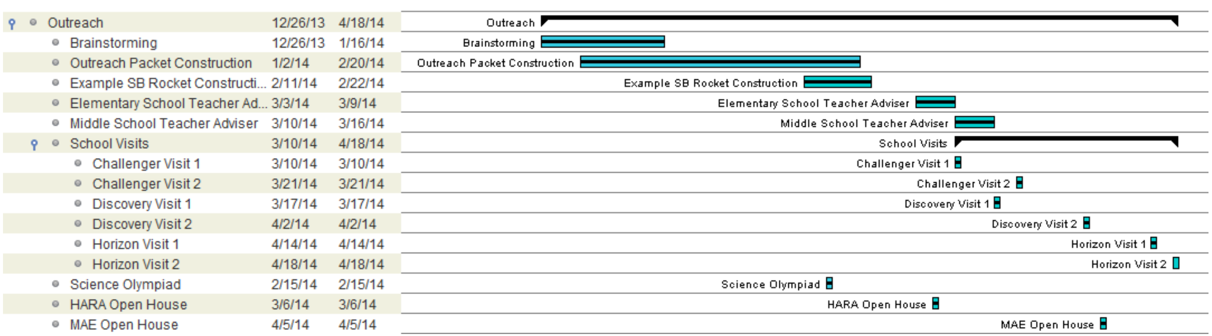


Figure 6-11: Outreach Schedule

Brainstorming (1/16/14) (Complete)

Various ideas for an informational and engaging experience will be considered. A modular package that can be adjusted to fill different timeslots and grade levels will be strongly considered. This way the outreach program can be pitched to various classroom settings and Science, Technology, Engineering, and Math (STEM) events.

Outreach Packet Construction (2/20/14) (Complete)

A set of slides were developed based upon the ideas generated from the Brainstorming session. An outline of the information covered in the slides and the activities was made. These outlines and slides were given to teachers and coordinators to allow them to know what to expect and allow them to work with the teams outreach program. The outreach packet focuses on using soda bottle rockets to back up basic science and allows the students to get hands on experience building their own soda bottle rockets. The complexity of the outreach and the fact that it requires two visits drives down the total outreach numbers but increases the quality of the outreach.

School Visits (4/18/14) (Complete)

Three different schools were visited as part of the outreach directly to schools. Challenger Elementary, Discovery Middle, and Horizon Elementary were the focus of the outreach efforts. Several other schools were contacted with no response. The outreach to the schools involved two trips per school. The first trip was to introduce the students to the basics of rockets and present the students with the challenge. The second trip was to launch the rockets for the students. The middle school students were originally supposed have a more compact timeline for their rocket launch to make it more difficult but this was stretched due to scheduling conflicts. They were encouraged to attempt a parachute design with the extra time.

6.4 Programmatic Challenges

With any program there will be challenges that have to be faced and overcome for a successful project. Figure 6-12 and Table 6-6 identifies expected programmatic challenges, their risk level, program impact, and mitigation steps to be performed. Identifying potential challenges and taking steps to prevent them early on can greatly decrease their effect on the project. As with most projects externally funded several programmatic challenges will lie outside of the control of CRW and must be mitigated with careful budgeting.

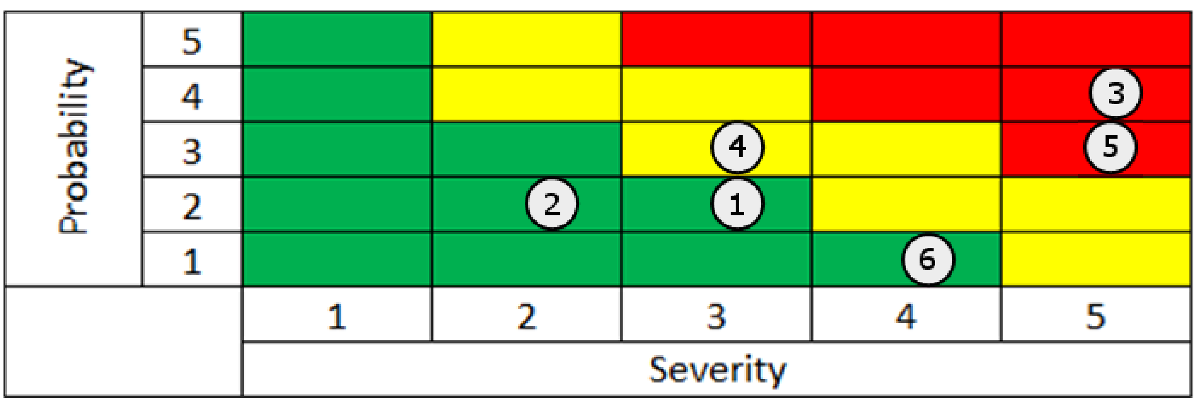


Figure 6-12: Program Risk Chart

Table 6-6: Programmatic Challenges

Ref #	Potential Hazard	Probability	Severity	Impact	Mitigation
1	Funding Loss	2	3	Reduced funding for the project and potential not enough funding to finish	Use financial reserves to finished project and develop backup plans should funding not be obtained
2	Overspending	2	2	Reduced funding for the project and potential not enough funding to finish	Closely monitor funding and ensure purchases are not wasted on hardware or test that are not used
3	Vehicle Failure	4	5	Significant cut into budget and major schedule delays	Carefully perform ground test and calculations to ensure no points of failure in primary vehicle load bearing members or recovery system
4	Purchase Orders Are Delayed	3	3	If parts are delayed in shipping the schedule could be delayed or rush order may be required	Orders will be placed well in advance of the time they are required and only order from reputable sources with known turnaround times
5	Team Falls Behind Schedule	3	5	Poorer quality work from rushed deadlines which further delay the project	Target dates will be placed ahead of actual due dates to drive the team and allow some slip
6	Team Conflicts	1	4	Reduced productivity and poorer design through poor communication	Strong leadership that addresses conflicts quickly and makes corrections to avoid further conflict and show solidarity between the team leads.

7 Conclusion

Charger Rocket Works is building a rocket, Prometheus, which is geometrically similar to the NASA Nanolaunch 1200. In support of the Nanolaunch 1200 project the rocket will carry an advanced avionics payload that will measure acceleration, rotation, and pressures to back out several key aerodynamic coefficients. In support of the NASA student launch three payloads to meet the requirements will be carried. The Dielectrophoresis experiment will test using electric fields to pull fluid away from the container wall. A coats and painting payload will test two different paints and temperature sensitive tape at supersonic speeds. A Landing Hazard Detection System will scan the landing site during decent for hazards. Charger Rocket Works is running behind schedule due to a number of different reasons. Mistakes on the teams part coupled with expected resources dropping out have placed the team behind schedule. The current technology readiness level is 7. This is behind the level 8 that a project should be at for an FRR. A rescaled project schedule will aggressively focus on the necessary components to complete a full-scale flight in time for the extended launch date.

The path forward for Charger Rocket Works consists of completing the rocket build within time to fly before the extended launch date. Further analysis of the new design components and any changes done during the build will be covered in a post full-scale addendum. This addendum will be submitted no later than April 28th. This will provide the final full-scale verification of the rocket design and allow Charger Rocket Works to continue participating in the NASA student launch competition.

8 Appendix A: CRW Safety Plan

The CRW safety plan is the method by which the Safety Officer, Project Manager, and Team Leads can ensure that all members are conducting all tests and experiments safely. If any type of mishap occurs, all CRW team members follow the proper procedures to ensure the well-being of all affected members and ensure that proper measures are taken to reduce any future risks.

8.1 Management, Leadership, and Employee Participation Policy

Of vital importance to the CRW team are the safety of all personnel, property, test facilities, the environment, airspace, and the general public. This policy shall be the foundation upon which participation in the SLP competition will be based.

8.2 Goals and Objectives

The CRW team will implement all safety policies and procedures to meet the goals and objectives spelled out in Table 8-1.

Table 8-1: Safety Plan Goals and Objectives

Goal	Objectives
Demonstrate a complete team commitment to safety and health.	• Definition and implementation of proper hazard control procedures by all leadership personnel. • All CRW team members assist with the creation and proper implementation of the health and safety program.
Identify all hazards associated with CRW operations and facilities.	• CRW team leadership will conduct an initial risk assessment and hazard analysis to be updated as necessary by workplace changes. • All CRW team members will review the initial assessments and propose recommendations on any revisions.
Prevent or control CRW team member exposure to identified hazards.	• CRW team leadership will designate, implement, and ensure compliance with all necessary hazard mitigation. • All CRW team members will review the hazard mitigation and propose necessary revisions.
Train all CRW team members in safe work and manufacturing processes, hazard recognition, and emergency response.	• CRW team leadership will specify and document all appropriate work practices and emergency response procedures for hazardous situations. • All CRW team members will be familiar with all plans, emergency procedures, and working documents.

8.3 Team Leadership Roles

The CRW personnel who shall maintain an active role in the team safety plan include: the Program Manager, Safety Officer, Team Leads, and all involved UAH and PRC faculty members. This group's expertise will be used for all risk assessment, hazard analysis, and for the definition and documentation of all hazard mitigation procedures. The Safety Officer has the ultimate responsibility for the safety of all members throughout the duration of the project, and is responsible for the implementation of all aspects of the CRW safety plan. All other CRW leadership shall demonstrate their commitment to the health and safety plan through the conduction of any necessary inspections and through the verification of proper hazard mitigation by all team members.

8.4 Team Member Involvement

The goal of CRW is to foster cooperation and collaboration between all members, regardless of whether or not they hold management positions within the team. Ensuring the safety and well-being of all CRW members during all testing and experimentation requires a team effort, as does the completion of all necessary documentation. The Project Proposal, Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR), and all other milestone documents will be divided up amongst all team members whenever it is practical or feasible to do so. Any design or safety concerns of the team members will be referred to their respective Team Lead, who will bring said issue to the Systems Integration team if it is deemed necessary. Team Leaders and the Systems Integration Team are expected to see that closure of each issue is obtained in a manner consistent with all design and safety parameters set forth. Recommendations will be requested from team members to resolve any issues at hand, and any feedback regarding the decisions made is desired. The safety responsibilities of all team members are shown below in Table 8-2: Safety Responsibilities

Table 8-2: Safety Responsibilities

Personnel	Safety Program Responsibilities
Program Manager	• Ensure that any and all safety documents are available to all team members. • Work with Team Safety Officer to ensure that all team members are following their safety plans.
Team Safety Officer	• Work with Team Leads to develop and implement Safety Plan. • Review and approve all Standard Operating Procedures. • Facilitate training for Team Leads on safe procedures for all design, testing, manufacturing, and launching activities.
Team Leads	• Develop Standard Operating Procedures for all testing and launch operations pertaining to their subsystem. • Facilitate training for team members on proper equipment and power tool operation before their use.
Team Members	• Follow all safety plans, procedures, and regulations. • Identify any hazardous work conditions and file appropriate documentation. • Ensure that fellow team members are following all safety protocols. • Offer recommendations for improving safety protocols.

8.5 Training

A CPR/AED and First Aid training is made available for members of the CRW to encourage and properly educate about safety. These tests will be encouraged for all members and mandatory for Red Team (see below) members. A White/Red/Blue card system is in place for the MAE workshop. To enter the shop requires a basic safety class which earns the White card. The Red card requires more advanced training and grants the holder the ability to operate a number of the machines in the shop with supervision from a Blue Card holder. A Blue card requires a comprehensive course that covers how to safely operate the machines in the workshop and grants the user the access to the machine shop and to act as supervisor to those operating under a Red card.

8.6 Material Hazard Communication Program

The Hazard Communication Program will identify all stored hazardous materials and those used in all project facilities and operations. The Safety Officer shall collect Material Safety Data Sheets (MSDSs) for these products and ensure that they have been correctly labeled. The Safety Officer shall also provide all CRW team members with the proper information and training to effectively mitigate any hazards present. This program shall serve to ensure compliance with the Occupational Safety and Health Administration (OSHA) regulation, 29 CFR Part 1910.1200, Hazard Communication. Hazardous materials shall be defined as any chemical which is classified as a physical hazard, health hazard, simple asphyxiant, combustible dust, pyrophoric gas, or any other hazard defined as such.

The product identifiers listed on any MSDSs must match those kept in the CRW Inventory of Hazardous Materials (see Appendix D) and the identifier displayed on the container labels. All CRW team members are responsible for ensuring that these labels are displayed in accordance with the appropriate OSHA regulations. Any chemicals transferred to containers for storage or transportation must also be labeled in this manner. A printed copy of each MSDS shall be kept in the Propulsion Research Center (PRC) by the Safety Officer. These MSDSs must be easily accessible by all CRW team members for reference, and for any emergency response purposes.

For hazardous chemicals present at the beginning of a work assignment, and any that are subsequently introduced into the work area, it shall be the duty of the Safety Officer to provide all CRW team members with the appropriate information and training in order for their safe use. This information and training shall comply with the requirements given in 29 CFR Part 1910.1200(h). Methods to mitigate chemical exposure shall also be incorporated into written standard operating procedures, hazardous operations procedures, and emergency procedures whenever possible.

8.7 Hazardous Materials Inventory

The Safety Officer shall maintain an inventory of all the hazardous materials stored and used in the CRW facilities and operations. All materials will be identified in the same manner as the MSDS. The inventory will be updated at the onset of each semester. Appendix D lists all of the current hazardous materials expected to be used throughout the project.

8.8 Purchasing and Procurement

All motors and energetic materials will only be purchased from licensed vendors by NAR or TRA certified members within CRW. Those motors and energetic materials will be stored in the propellant bunker.

8.9 Workplace Analysis

The CRW team will work to identify all hazards within the workplace for the duration of the project. This information will come from a combination of surveys, analyses, workplace inspections, mishap investigations, and collection of all health and safety data reports. These reports will include: reports of spills and releases of chemicals to the environment, facilities-related incidents related to partial or complete loss of a system function, and any reports of hazards by CRW members.

All hazards identified that pose an immediate threat to the life or health of any CRW members will be immediately brought to the attention of the Safety Officer, the Program Manager, and PRC faculty members to ensure that proper action to correct the hazard is taken. All of the current safety plans and any other working documents or procedures will immediately be reviewed by PRC faculty members.

8.10 Inspections

Inspections of work areas will be performed and documented each semester by the CRW team leadership. Any discrepancies between the safety requirements and the observed conditions will be recorded along with the personnel tasked for implementing the corrective measures. All corrective measures will be tracked to closure by the Safety Officer. Scheduled inspections for fire and other explosive hazards will be conducted in accordance with UAH policies and procedures.

8.11 Employee Reports of Hazards

All members of the CRW team are encouraged to report any hazardous conditions and analyze and prevent any apparent hazards. All CRW team leadership will ensure that reprisal-free reporting occurs, and will use safety training and all project life cycle reviews to incorporate all CRW team members into hazard prevention activities.

8.12 Mishap Reporting and Investigation

If any mishap occurs, it shall be promptly reported to the affected team lead and the Safety Officer, who will ensure the required procedures are carried out for any fire, hazardous material release, or other emergency. All of the CRW team leadership will be immediately notified of the incident by the Safety Officer, who will also submit all subsequently required documentation.

The Safety Officer shall then conduct an investigation into the cause(s) of the mishap and what actions must be taken to rectify the situation and ensure no future incidents occur. A safety meeting will then be conducted with all CRW team members to ensure they are aware of any and all potential safety problems and hazards.

8.13 Hazard Prevention and Control

8.13.1 Appropriate Controls

In order to mitigate or eliminate any potential hazards, the CRW team will use a multi-level hazard reduction sequence comprised of engineering controls, administrative controls, and personal protective equipment. Engineering controls involve designing the facility, equipment, or process in a way to reduce or eliminate any potential hazards. Administrative controls include: standard operating procedures (SOPs), work permits, training and safe work practices, exposure limits, alarms, signs and other warnings, and the use of a buddy system. Personal protective equipment will never be used as the sole avenue for mitigating risk and preventing hazards. It is to be used in conjunction with the engineering and administrative controls if they alone do not eliminate any possible hazards, or during emergencies when the aforementioned engineering controls would no longer be feasible.

Any risk remaining after all mitigation and controls is designated as residual risk. The CRW team leadership may, as a group, accept this risk based on risk assessment results and other factors pertaining to the SLP competition. However, residual risk that violates basic health and safety standards may not be acceptable. Any accepted risk will be communicated to the rest of the CRW team.

8.13.2 Hazardous Operations

Hazardous operations involve materials or equipment that, if used or handled improperly, pose a high risk of resulting in loss of life, serious injury or illness to personnel, or damage to systems, equipment, and facilities. All CRW personnel will be notified before the conduction of any hazardous operations is to take place and will be notified of any hazards which present themselves. This notification shall come from both procedural documentation, and from real-time communication, if necessary. Written procedures with emphasis on the safety steps will be developed before any hazardous operations commence to ensure that all regulatory requirements have been met.

General workshop safety rules are posted in all workshops and each tool or machine will display the proper operating procedures. It is required that more than one person be in the workshop to offer assistance if something does go wrong. First aid kits are also present in each of the work area AED locations.

8.13.3 Protective Equipment

The Occupational Safety & Health Administration (OSHA) requires the use of the personal protective equipment (PPE) at the workplace. The use of PPE is meant to reduce employee exposure to hazards when engineering and administrative controls are not effective in reducing these exposures to acceptable levels. Employers are required to determine if PPE should be used to protect their workers. The Safety Officer for CRW will be responsible for educating team members on the proper implementation for protective gear. CRW team members are required to wear appropriate PPE to perform hazardous activities. The requirements for PPEs will be based on the MSDS of the materials required to complete a task and the assessment of hazards that exist in the work environment. PPEs will be provided and maintained in the laboratory and all USLI related work spaces and will be taken to all field activities. The Safety Officer as well as Propulsion Research staff will monitor the proper use of the PPE. The expected PPE for the project includes but is not limited to:

1. Safety Glasses
2. Face Shields
3. Lab Coats

4. Hearing Protection
5. Work Gloves
6. Welding Protective Equipment (sleeves, face shield, etc.

8.14 Propulsion Research Center Procedures

The Propulsion Research Center affords the members of CRW the ability to perform numerous types of ground tests for propulsion, recovery, and other critical rocket subsystems. The facility is available for various research purposes including: externally sponsored research projects, Propulsion Research Center staff and Graduate Student research projects, and selected Undergraduate projects. Below is a list of safety protocols that all users of the PRC facilities must follow:

UAH Propulsion Research Center- Facility Usage Policy

1. All PRC Test operations are under the authority of the PRC Director and UAH campus safety practices.
2. All personnel involved in testing are UAH employees, UAH students under PRC supervision, customers with an active contract with UAH, or those with other formal arrangements agreed to in writing by the University.
3. All tests involving pressures over 100 psi, high voltage, combustion, or other sources of possibly injury require a Standard Operating Procedure (SOP), reviewed and signed by the test Red Team (see below), and approved by the PRC Director.
4. The tests are conducted by a designated Red Team who has at least one UAH staff member and has at least two members who are Red Cross Safety and CPR/AED Certified.
5. After any major test anomaly, all PRC test operations are automatically suspended until a determination of the basic cause of the incident is determined and all active SOPs are reviewed in light of the findings of the incident before resuming testing. A verbal report of the incident will be given to the V.P. of Research and a representative of Campus Safety within 24 hours of the incident.
6. If the need to evacuate the Johnson Research Center becomes apparent due to inclement weather, fire, or any other hazards, all CRW members will follow the evacuation plan provided in Appendix A.

All pertinent procedures from the UAH Emergency Procedures Handbook will be followed in the event of any mishap or injury. Any mishap or injury will be reported to the Safety Officer and the affected Team Lead as per UAH's Non-Employee Accident Report Form. Any other affected CRW Team Members and University staff will be notified to ensure that all required documentation is completed. The Safety Officer will then work to determine the cause(s) of the mishap and ensure that the proper corrective action is taken. A debrief of the incident will be provided to all CRW members in order to prevent any further mishaps from occurring.

8.15 Supervision

For tests, PRC and MAE staff will be present to supervise to ensure all safety measures are followed. A NAR/TRA mentor will help ensure rocket launches are safe and offer pointers to take safety beyond what is in the regulations. No test or launch will be performed without consultation and supervision from experienced staff or mentor.

8.16 Buddy System

No test will be undertaken by a single individual. All tests must not only have supervision but more than one person working on the test. A safety review will be conducted prior to any test. The safety officer will ensure that every member is aware of the appropriate information pertaining to any tests.

8.17 Accountability

All CRW team members will be held accountable to perform all assigned tasks in a safe and healthful manner, for identifying and reporting any apparent safety issues or non-compliances, and following all other provisions of the CRW safety plan. As stated earlier, any apparent safety issues shall be brought to the attention of the affected team lead(s), who will report the issues to the safety officer and the project manager if deemed necessary. Any issues that cannot be resolved by the CRW team will be brought to the appropriate faculty members. If disciplinary action is required, it may only be administered by faculty members.

8.18 Emergency Response

If cardiopulmonary resuscitation is required, certified personnel will administer the required aid using the AED machines located in each of the facility used by CRW. Any first aid certified CRW team member may also administer general first aid if it is required. If this basic first aid is not sufficient, the appropriate emergency procedures shall be followed to notify emergency responders. All CRW team members will be aware of the proper fire and tornado evacuation routes as depicted on the Johnson Research Center Emergency Evacuation in Appendix B.

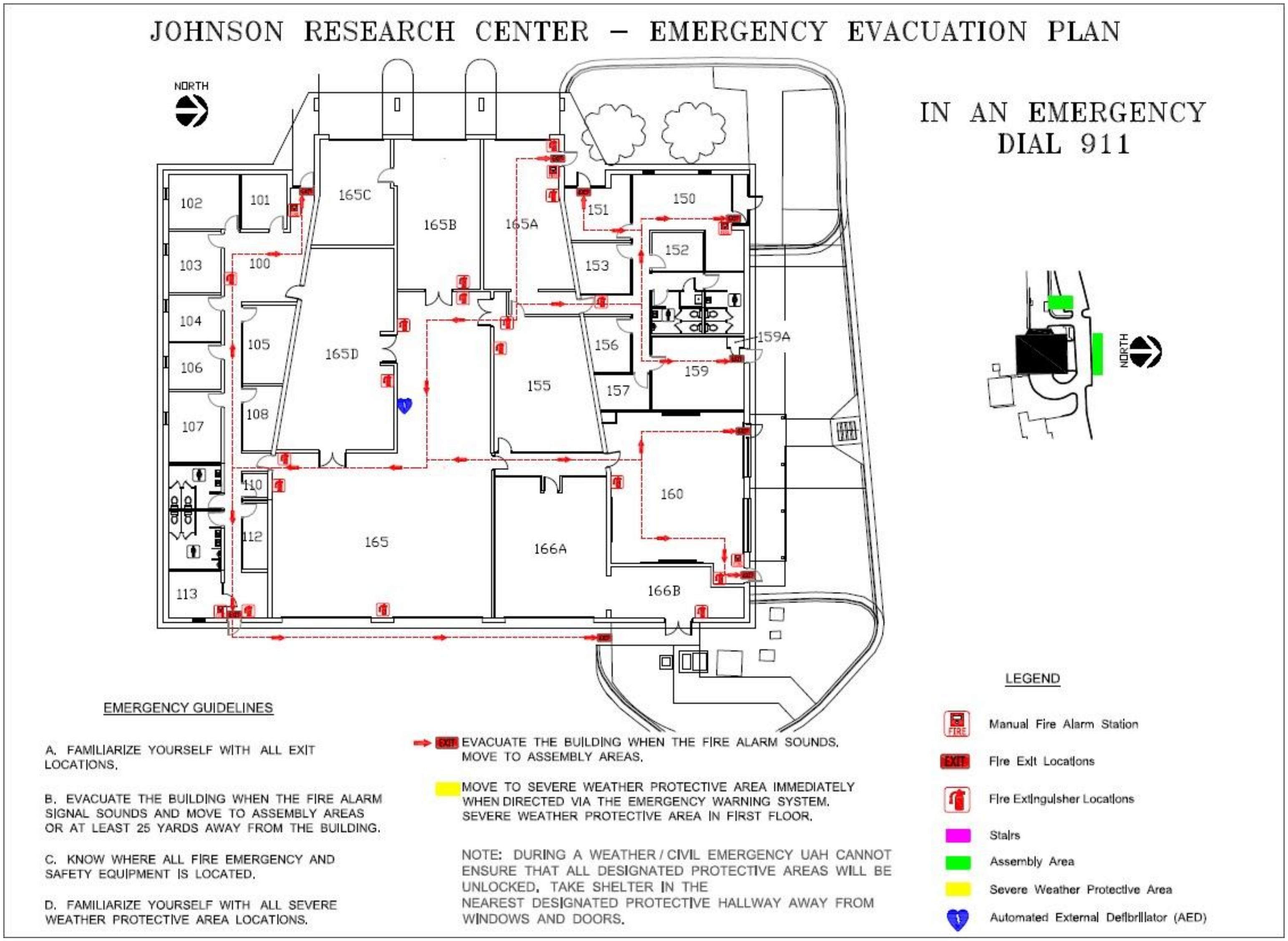
8.19 Periodic Safety Meetings

The Safety Officer will provide a safety briefing to the whole CRW team on a biweekly basis with information on any mishaps that may have occurred, any upcoming safety hazards that will affect the majority of the team, and safety information on any upcoming tests or launches.

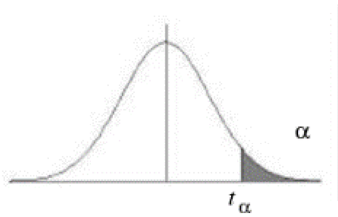
8.20 State and Federal Regulations

The CRW team will agree adhere to all pertinent state and federal regulations throughout the duration of the project. The Federal Aviation Association (FAA), National Association of Rocketry (NAR), Department of Transportation (DOT), and Tripoli Rocketry Association (TRA) are the primary creators of regulation pertaining to amateur rocketry. All regulations can be found in Appendix C.

9 Appendix B: Johnson Research Center Evacuation Plan



10 Appendix C, Student t-Distribution



	α					
df	0.250	0.100	0.050	0.025	0.010	0.005
1	1.000	3.078	6.314	12.706	31.821	63.657
2	0.816	1.886	2.920	4.303	6.965	9.925
3	0.765	1.638	2.353	3.182	4.541	5.841
4	0.741	1.533	2.132	2.776	3.747	4.604
5	0.727	1.476	2.015	2.571	3.365	4.032
6	0.718	1.440	1.943	2.447	3.143	3.707
7	0.711	1.415	1.895	2.365	2.998	3.499
8	0.706	1.397	1.860	2.306	2.896	3.355
9	0.703	1.383	1.833	2.262	2.821	3.250
10	0.700	1.372	1.812	2.228	2.764	3.169
11	0.697	1.363	1.796	2.201	2.718	3.106
12	0.695	1.356	1.782	2.179	2.681	3.055
13	0.694	1.350	1.771	2.160	2.650	3.012
14	0.692	1.345	1.761	2.145	2.624	2.977
15	0.691	1.341	1.753	2.131	2.602	2.947
16	0.690	1.337	1.746	2.120	2.583	2.921
17	0.689	1.333	1.740	2.110	2.567	2.898
18	0.688	1.330	1.734	2.101	2.552	2.878
19	0.688	1.328	1.729	2.093	2.539	2.861
20	0.687	1.325	1.725	2.086	2.528	2.845
21	0.686	1.323	1.721	2.080	2.518	2.831
22	0.686	1.321	1.717	2.074	2.508	2.819
23	0.685	1.319	1.714	2.069	2.500	2.807
24	0.685	1.318	1.711	2.064	2.492	2.797
25	0.684	1.316	1.708	2.060	2.485	2.787
26	0.684	1.315	1.706	2.056	2.479	2.779
27	0.684	1.314	1.703	2.052	2.473	2.771
28	0.683	1.313	1.701	2.048	2.467	2.763
29	0.683	1.311	1.699	2.045	2.462	2.756
30	0.683	1.310	1.697	2.042	2.457	2.750
40	0.681	1.303	1.684	2.021	2.423	2.704
60	0.679	1.296	1.671	2.000	2.390	2.660
120	0.677	1.289	1.658	1.980	2.358	2.617
∞	0.674	1.282	1.645	1.960	2.326	2.576

11 Appendix D: Sample Altimeter Data

PerfectFlite SL100				
Firmware: 1.0				
Software: 1.0				
Serial Number: 1949				
Apogee: 1573' AGL				
Ground Elevation: 203' MSL				
NumSamps: 1416				
Flight Number: 8				
Main Setting: 700' AGL				
Apogee Delay: 1 Seconds				
Drogue At: 11.45 Seconds				
Main At: 39.95 Seconds				
Comments:				
Data: (Time	Altitude	Velocity	Temperature (F)	Voltage)
0	1	0	63.57	9.4
0.05	2	0	63.57	9.4
0.1	0	20	63.57	9.4
0.15	3	24	63.59	9.4
0.2	4	30	63.57	9.4
0.25	7	37	63.57	9.4
0.3	8	44	63.57	9.4
0.35	11	52	63.57	9.4
0.4	13	61	63.57	9.4
0.45	17	72	63.57	9.4
0.5	21	85	63.57	9.4
0.55	26	99	63.57	9.4
0.6	31	113	63.57	9.4
0.65	38	127	63.57	9.4
0.7	45	140	63.57	9.4
0.75	53	149	63.57	9.4
0.8	62	154	63.57	9.4
0.85	70	155	63.57	9.4
0.9	78	153	63.57	9.4
0.95	85	150	63.57	9.4
1	92	151	63.57	9.4
1.05	98	155	63.57	9.4
1.1	106	164	63.57	9.4
1.15	114	177	63.57	9.4
1.2	125	191	63.57	9.4
1.25	136	205	63.57	9.4
1.3	147	218	63.57	9.4
1.35	157	229	63.57	9.4
1.4	170	238	63.57	9.4
1.45	182	245	63.57	9.4
1.5	196	249	63.57	9.4
1.55	208	251	63.57	9.4

12 Appendix E: Launch Operations Checklist

12.1.1.1 T-48+ Hours

1. Vehicle Inspection –Components
    a. Recovery System
        i. Main Parachutes
            1. Visually inspect for holes, patches, and verify sizing.
            2. Double check descent rates as mass is added or subtracted.
            3. Verify equipment for dual deploy system.
        ii. Drogue's (if Applicable)
            1. If "yes", then visually inspect for holes or harness defects.
            2. Verify if ejection charge release system is being used.
        iii. Shock Cord
            1. Visual inspection for failure points.
            2. Check structural integrity of attachment points.
        iv. Black Powder Charge Capsules with E-matches
            1. Drill holes in bases of caps.
            2. If possible, attach e-match with epoxy or electrical tape.
        v. Trigger System (PerfectFlite StratoLogger)
            1. Ensure StratoLoggers are working properly.
            2. Check that fresh batteries are available (1 per altimeter).
        vi. Deployment System
            1. Perform successful tests of black powder ejection charge system with all flight hardware in vehicle.
            2. Perform successful tests of parachute release hardware.

    b. Airframe
        i. Consult with Analysis Team on proper vehicle geometry / configuration.
        ii. Estimate CG using finger/rope balance test.
        iii. Check separation points
            1. Verify holes for rivets are properly oriented and of the proper diameter.
            2. Verify shear pins are in stock and that the proper holes for them have been drilled.
            3. Verify that no-interference is present between internal components and fixtures.
            4. Check epoxy joints to ensure they are structurally sound.
            5. Paint vehicle if desired.

    c. Payloads
            1. Verify that payloads function through ground tests.
            2. Verify automation scripts run correctly.
            3. Verify that all sensors are working correctly.
            4. Verify location of CG within the rocket body.
            5. Verify that batteries for payloads are charged.

2. Stability Determination
    a. Fully assemble launch vehicle.
    b. Use a scale to weigh the vehicle.
    c. Determine CG location using rope/finger test
    d. Simulate CP location with RockSim and/or OpenRocket.
3. Prepare Team
    a. Submit travel authorization forms to PRC office for all team members driving to launch.
    b. Ensure that all team members attending launch have a means to get there.
    c. Arrange team meals for launch day (who will be purchasing meals, what will meals consist of).

12.1.1.2 T – 24+ hrs.

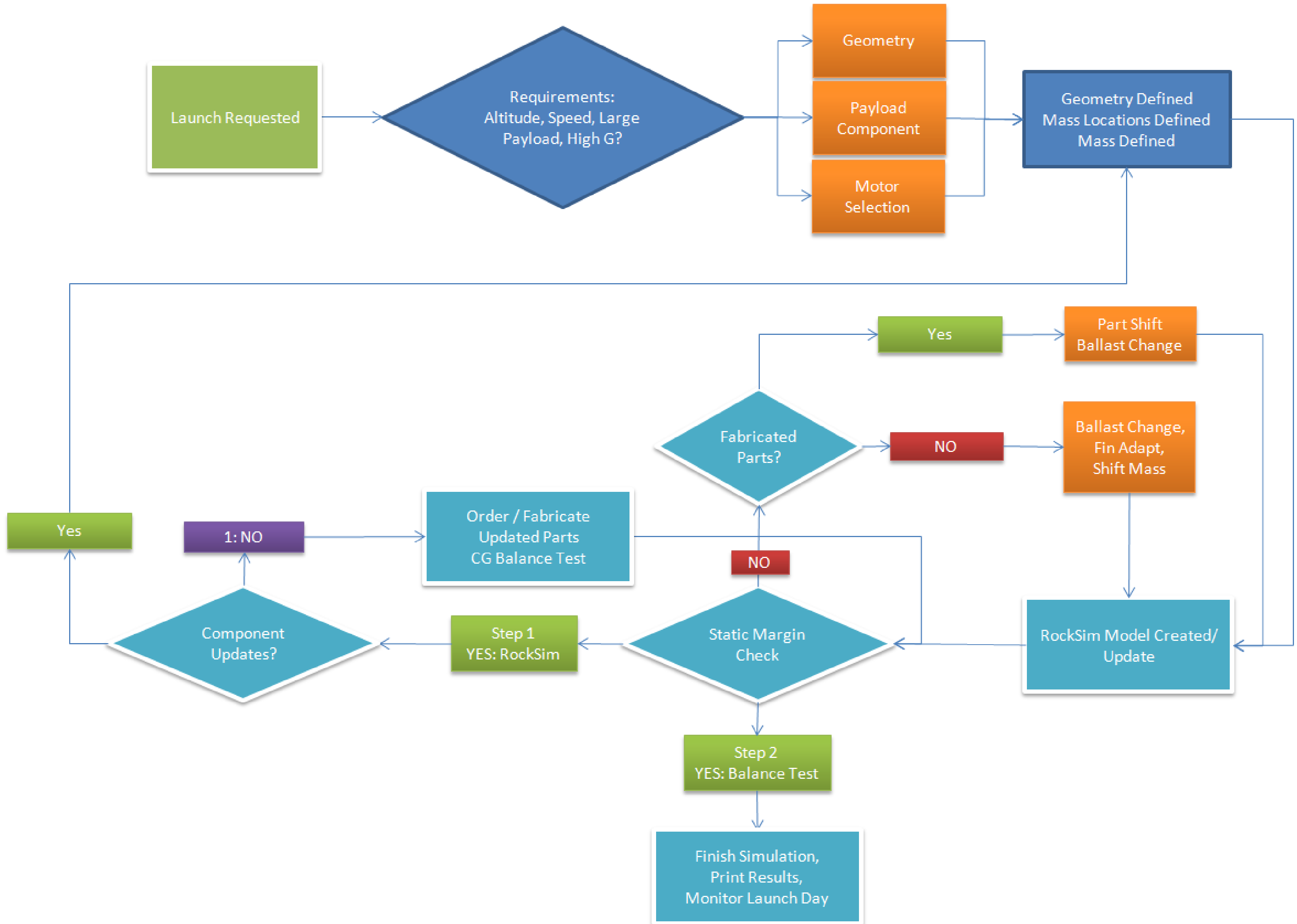
1. Verify any final changes made to vehicle geometry and payloads.
    a. Perform electronics check.
    b. Test fit all vehicle components once more.
2. Re-measure CG for any mass changes.
3. Re-validate CP location if geometry has changed.
4. Determine on-the-pad static stability margin.
5. Gather required flight equipment to be loaded for travel (See Launch Checklist).
6. Print flight cards or detailed flight plans.
    a. Vehicle weight.
    b. Motor selection.
    c. Stability margin.
    d. Predicted maximum altitude.
    e. Predicted rail exit velocity.
    f. Rocketeer with NAR/ TRA certification for motor selection.
        i. Amit Patel, NAR L2
        ii. David Lineberry, NAR L1
        iii. Jason Winningham, NAR/TRA L2
        iv. Chris Spalding, NAR L1
7. Check weather conditions
    a. Wind speed.
    b. Possibility of cloud cover.
    c. Expected temperature.
8. Verify launch is projected to continue and notify all team members traveling to launch of final go/no-go for launch.
9. Verify that equipment is packed or set aside for vehicle loading.

12.1.1.3 Launch Day – Pre Flight Setup

1. Verify All Components
    a. Double check interferences between vehicle airframe and payloads.
    b. Double check all rivet's interference with internal components.
2. Verify Electronic Components are Working
    a. Altimeters
        i. Ensure batteries and switches are connected and secured.
        ii. Ensure boards are secured to housing unit.
        iii. Listen for "Ready Status" chirp (3 short beeps every 2 seconds).
        iv. Connect wire leads for ejection charges and release hardware to altimeters.
    b. Check Payload Power System
        i. Use only freshly charged batteries.
        ii. Verify that start up program runs and boards reach "Ready" state.
        iii. Power off until launch.
3. Recovery System
    a. Fill ejection charges to prescribed mass of black powder determined from ground tests.
    b. Assemble recovery system components.
    c. Fill release mechanisms with manufacturer prescribed quantity of black powder.
    d. Install ejection charges in vehicle.
    e. Pack remainder of recovery system in the vehicle.
4. Just Prior to Launch
    a. Install motor (NAR/TRA mentor) and motor retention hardware.
    b. Weigh fully assembled rocket.
    c. Re-Verify stability margin.
    d. Re-Verify predicted flight trajectory values.
    e. Inform RSO of team status.
5. During Launch Setup
    a. Inform RSO that vehicle is ready for launch.
    b. RSO performs safety check and stability verification.
6. Launch Vehicle.

12.1.1.4 Post Flight

7. Recover Vehicle
    a. Take pictures of vehicle upon landing.
    b. Check recovery system status.
    c. Identify vehicle failure points.
    d. Record drift distance from launch stand.
    e. Record max altitude recorded by altimeters (from beeps).
    f. Weigh recovered rocket for descent mass.
    g. Recover data stored on perfect flights and onboard storage
8. Re Prep Rocket for Secondary Launch (if applicable)


Launch Requested
Requirements: Altitude, Speed, Large Payload, High G?
Geometry
Payload Component
Motor Selection
Geometry Defined Mass Locations Defined Mass Defined
Yes
Part Shift Ballast Change
Fabricated Parts?
NO
Ballast Change, Fin Adapt, Shift Mass
Yes
1: NO
Order / Fabricate Updated Parts CG Balance Test
NO
Component Updates?
Step 1 YES: RockSim
Static Margin Check
RockSim Model Created/ Update
Step 2 YES: Balance Test
Finish Simulation, Print Results, Monitor Launch Day

13 Appendix F: Launch Items Checklist

1) Rocket
2) Motors/ Motor Tubes/ Adapter Tubes
3) E-Matches
4) Black Powder
5) Dog Barf
6) Tool Box
7) Drill/Drill Bits/ Drill Batteries
8) Shear Pins
9) Rivets
10) Avionics Batteries (Li-Po, 9Vs)
11) Folding Table
12) Pop-Up Canopy
13) Parachutes/Recovery Hardware
14) Zip-Ties
15) Epoxy
16) Epoxy Mixing Tips
17) Extra Fasteners for Payload
18) Scale
19) Shovel
20) Extra Shock Chord
21) Chairs
22) Charge Caps
23) Sustenance (Food/Water)
24) Personal Protective Equipment
25) Launch Operations Checklist
26) Garbage Bags
27) Duct Tape/ Electrical Tape
28) Motor Tube Brushes
29) Paper Towels
30) Ballast/ Bags for Ballast
31) Tape Measure
32) Rocket Cradles
33) Isopropyl Alcohol
34) Q-Tips
35) Soldering Iron/ Tips/ Solder
36) Li-Po Battery Charger
37) Li-Po Charging Bag
38) GPS Trackers
39) Precision Screwdriver Set
40) Calipers
41) Sand Paper
42) Car Battery
43) Extension Wire
44) Ignition Circuitry

14 Appendix G: State and Federal Regulations

6.1.6a FAA Regulations, CFR, Title 14, Part 101, Subpart C, Amateur Rockets

101.21 Applicability.

(a) This subpart applies to operating unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply with §101.25(b) (7) (ii) and with any additional limitations imposed by the using or controlling agency.

(b) A person operating an unmanned rocket other than an amateur rocket as defined in §1.1 of this chapter must comply with 14 CFR Chapter III.

101.22 Definitions.

The following definitions apply to this subpart:

(a) Class 1—Model Rocket means an amateur rocket that:

(1) Uses no more than 125 grams (4.4 ounces) of propellant;

(2) Uses a slow-burning propellant;

(3) Is made of paper, wood, or breakable plastic;

(4) Contains no substantial metal parts; and

(5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

(b) Class 2—High-Power Rocket means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

(c) Class 3—Advanced High-Power Rocket means an amateur rocket other than a model rocket or high-power rocket.

101.23 General operating limitations.

(a) You must operate an amateur rocket in such a manner that it:

(1) Is launched on a suborbital trajectory;

(2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;

(3) Is unmanned; and

(4) Does not create a hazard to persons, property, or other aircraft.

(b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

101.25 Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets.

When operating Class 2-High Power Rockets or Class 3-Advanced High Power Rockets, you must comply with the General Operating Limitations of §101.23. In addition, you must not operate Class 2-High Power Rockets or Class 3-Advanced High Power Rockets—

(a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;

(b) At any altitude where the horizontal visibility is less than five miles;

(c) Into any cloud;

(d) Between sunset and sunrise without prior authorization from the FAA;

(e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;

(f) In controlled airspace without prior authorization from the FAA;

(g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:

(1) Not less than one-quarter the maximum expected altitude;

(2) 457 meters (1,500 ft.);

(h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight; and

(i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

101.27 ATC notification for all launches.

No person may operate an unmanned rocket other than a Class 1—Model Rocket unless that person gives the following information to the FAA ATC facility nearest to the place of intended operation no less than 24 hours before and no more than three days before beginning the operation:

(a) The name and address of the operator; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;

(b) Date and time the activity will begin;

(c) Radius of the affected area on the ground in nautical miles;

(d) Location of the center of the affected area in latitude and longitude coordinates;

(e) Highest affected altitude;

(f) Duration of the activity;

(g) Any other pertinent information requested by the ATC facility.

6.1.6b NAR High Power Rocket Safety Code

1. **Certification**. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

2. **Materials**. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.

3. **Motors**. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.

4. **Ignition System**. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.

5. **Misfires**. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

6. **Launch Safety**. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.

7. **Launcher**. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table,

and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

8. **Size**. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

9. **Flight Safety**. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. **Launch Site**. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).

11. **Launcher Location**. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. **Recovery System**. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. **Recovery Safety**. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

6.1.6c National Fire Protection Association Regulations

NFPA 1122: Code for Model Rocketry

'Model rockets' are rockets that conform to the guidelines and restrictions defined in the NFPA 1122 document. These rockets weigh less than 1500 grams, contain less than 125 grams of total fuel, have no motor with more than 62.5 grams of fuel or more than 160 NS of total impulse, use only pre-manufactured, solid propellant motors, and do not use metal body tubes, nose cones or fins. One inconsistency with this is the CPSC definition of a model rocket motor, which by their definition must contain no more than 80NS total impulse. NFPA 1122 contains the most complete definition of a model rocket and the model rocket safety code. This is the same safety code as adopted by NAR. 'Large Model Rockets' is a term used in the FAA FAR 101 regulations. It refers to NAR/NFPA model rockets that are between 454 and 1500 grams (1 to 3.3 pounds) total liftoff weight and contain more than 113 grams but less than 125 grams of total fuel.

NFPA 1127: Code for High Powered Rocketry

'High power rockets' are rockets that exceed the total weight, total propellant or single motor total impulse restrictions of model rockets, but otherwise conform to the same guidelines for construction materials and pre-manufactured, commercially made rocket motors. High power rockets also allow the use of metal structural components where such a material is necessary to insure structural integrity of the rocket. High power rockets have no total weight limits, but do have a single motor limit of no more than O power (40,960NS maximum total impulse) and have a total power limitation of 81,920NS total impulse. NFPA document 1127-1985 contains the most complete definition of a high power rocket and also the high power rocketry safety code. This safety code has been adopted by both the NAR and TRA. Metal bodied rockets are allowed by NFPA 1127 where metal is required to insure structural integrity of the rocket over all of its anticipated flight.

6.1.6d State of Alabama Regulations

11-47-12. Gunpowder and explosives storage

It is the duty of the corporate authorities of every city or town to provide a suitable fireproof building without the limits of the town or city for the storage of gunpowder or other explosive material on such terms as the corporate authorities my prescribe.

13A-11-224. Keeping gunpowder or explosives in city or town

Any person who keeps on hand, at any one time, within the limits of any incorporated city or town, for sale or for use, more than 50 pounds of gunpowder or other explosives shall, on conviction, be fined not less than $100.00. The explosive material on such terms as the corporate authorities may prescribe.

6.1.6e Tripoli Rocketry Association Requirements for High Power Rocket Operation

1 Operating Clearances: A person shall fly a high power rocket only in compliance with:

a. This code;

b. Federal Aviation Administration Regulations, Part 101 (Section 307, 72 Statute 749, Title 49 United States Code, Section 1348, “Airspace Control and Facilities,” Federal Aviation Act of 1958); and

c. Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.

d. Landowner permission.

2 Participation, Participation and Access at Tripoli Launches shall be limited to the following:

2-1 HPR Fliers may access and conduct flights from the High Power Launch Area and/or Model Rocket Launch Area.

2-2 Non-Tripoli Members age 18 and over that are students of an accredited educational institution may participate in joint projects with Tripoli members. These individuals are allowed in the High Power Launch Area and/or Model Rocket Launch Area if escorted by a Tripoli member. The maximum number of non-member participants shall not exceed five (5) per Tripoli Member.

2-3 Non-Tripoli Members that are members of a Named Insured Group may participate in joint projects with Tripoli members. These individuals are allowed in the High Power Launch Area and/or Model Rocket Launch Area if escorted by a Tripoli member. The maximum number of non-member participants shall not exceed five (5) per Tripoli Member.

2-4 Tripoli Junior Members that have successfully completed the Tripoli Mentoring Program Training may access and conduct flights from the High Power Launch Area while under the direct supervision of a Tripoli Senior member in accordance with the rules of the Tripoli Mentored Flying program. The Tripoli Senior member may provide supervision for up to five (5) individuals that have successfully completed the Tripoli Mentoring Program Training at a time in the High Power Launch Area.

2-5 Children younger than 18 years of age may conduct flights from the Model Rocket Launch Area under the direction of a HPR Flier.

2-6 Attendance by Invited Guests and Spectators

2-6.1 An invited guest may be permitted in the Model Rocket Launch Area and preparation areas upon approval of the RSO.

2-6.2 An invited guest may be allowed in the High Power Launch Area if escorted by a HPR Flier. A HPR Flier may escort and be accompanied by not more than five (5) non-HPR fliers in the High Power Launch Area. The HPR flier escort is required to monitor the actions of the escorted non-HPR fliers, and the escort is fully responsible for those actions and for the safety of those escorted.

2-6.3 Spectators, who are not invited guests, shall confine themselves to the spectator areas as designated by the RSO and shall not be present in the High Power Launch Area or Model Rocket Launch Area.

Referenced Publications

The following documents or portions thereof are referenced within this code. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

3-1 NFPA Publications. National Fire Protection Association, I Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

NFPA 1122, Code for Model Rocketry.

NFPA 1125, Code for the Manufacture of Model Rocket Motors.

NFPA 1127, Code for High Power Rocketry

3-2 Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington DC 20402.

Federal Aviation Administration Regulations, from the Code of Federal Regulations. Federal 7/31/2012

Hazardous Substances Act, from the United States Code (re. Airspace Control)

3-3 TRA Publications. Tripoli Rocketry Association, Inc., P. O. Box 87, Bellevue NE 68005.

Articles of Incorporation and Bylaws

High Power Rocketry Safety Code

Tripoli Motor Testing Committee (TMT), Testing Policies

Appendix A - Additional Tripoli Rulings

A-1 NFPA 1127 was adopted by the Tripoli Board of Directors as the Tripoli Safety Code. (Tripoli Report, April 1994, Tripoli Board Minutes, New Orleans, 21 January 1994, Motion 13.) Since this adoption, the code has gone through some revisions. Such is the way with codes – they are constantly undergoing change to improve and update them when safety prompts, or when the federal regulations change or are reinterpreted

A-2 All Tripoli members who participate in Association activities shall follow the Tripoli Certification Standards.

A-3 Any Board action(s), with regard to safety, made previous to or after publication of this document shall be a part of the Tripoli Safety Code.

A-4 Increased descent rates for rocket activities conducted at the Black Rock Desert venue are acceptable if needed to insure a controlled descent to remain inside the FAA approved Dispersion Area.

A-5 A rocket motor shall not be ignited by using:

a. A switch that uses mercury.

b. “Pressure roller” switches

15 Appendix H: Hazardous Materials Inventory

	Potential Hazard	Hazard Ranking	Hazard Controls

	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical Handling: 3M Scotch-Weld Structural Plastic Adhesive, DP-8005, Black, Part A (Epoxy)	• Corrosive eye burns in direct contact • Moderate eye irritation from exposure to vapor during curing, or to dust created by cutting, grinding, sanding, machining • Severe skin and • Respiratory irritation. Gastrointestinal irritation from ingestion • Combustible liquid and vapor • Vapor may travel long distance along ground or floor to source of ignition and flash back • Hazardous in contact with strong acids, strong oxidizing agents, heat, sparks and/or flames • Fire	• Rating: Potentially Hazardous Operation • Probability: Low • Severity: Moderate to Severe	• Engineering: local exhaust ventilation for machining processes • Administrative: MSDS; SOP; safe work practices; exposure time limitations; training • PPE: safety glasses with side shields or indirect vented goggles; gloves; protective clothing to prevent skin contact if appropriate • Respiratory Protection: not usually required; Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical Handling: 3M Scotch-Weld Structural Plastic Adhesive, DP-8005, Black, Part B (Epoxy)	• Moderate eye irritation from exposure to vapor during curing, or to dust created by cutting, grinding, sanding, machining • Moderate skin irritation • Respiratory irritation from inhaling vapor or dust • Gastrointestinal irritation from ingestion • Contains a carcinogenic chemical • Hazardous in contact with strong acids, strong oxidizing agents • Fire	• Rating: Potentially Hazardous Operation • Probability: Low • Severity: Mild to Severe	• Engineering: local exhaust ventilation for cutting, grinding, sanding, or machining; shop exhaust ventilation • Administrative: MSDS; SOP; safe work practices; exposure time limitations; training • PPE: safety glasses with side shields; gloves (butyl rubber, nitrile rubber, polyethylene, or polyvinyl alcohol); protective clothing to prevent skin contact, if appropriate to task • Respiratory Protection: not usually required; NIOSH approved air-purifying respirator with organic vapor cartridge and particulate prefilter, when ventilation is inadequate • Residual Risk: accepted

	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical Handling: Black Powder, Loose	• Division 1.1 Explosive • Sources of friction, impact, heat, low level electrical current, and electrostatic or RF energy may detonate • Improper clothing may generate static, resulting in detonation • Detonation may cause severe physical injury, even death • Fire • Facility/equipment damage (unlikely due to small quantities in use)	• Rating: Hazardous Operation • Probability: Low • Severity: Moderate to Severe	• Engineering: ventilation; storage • Administrative: MSDS; HOP; safe work practices; training; personnel certification; access control; only non-sparking tools • PPE: impervious rubber gloves; clothing must be metal-free AND non-static producing • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical Use: UNO HD SC bases & colors without lead	• Contains carcinogenic chemicals • Skin and/ or respiratory tract irritation from inhalation/exposure • CNS depression from inhalation • Fire	• Rating: Hazardous Operation • Probability: High • Severity: Mild to Severe	• Engineering: proper ventilation; storage • Administrative: SOP; MSDS; safe work practices; training; segregated from strong oxidizing agents, bases, and/ or acids • PPE: safety glasses with side shields; gloves (butyl rubber, nitrile rubber, polyethylene, or polyvinyl alcohol); protective clothing to prevent skin contact, if appropriate to task; NIOSH approved air-purifying respirator with organic vapor cartridge and particulate prefilter, when ventilation is inadequate; tight fitting safety goggles (chemical goggles) • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical Use: White Epoxy Primer	• Skin and/ or respiratory tract irritation from inhalation/exposure • CNS depression from inhalation • Chemical asthma from long-term exposure • Neurological system damage from long-term exposure • Fire	• Rating: Hazardous Operation • Probability: High • Severity: Mild to Severe	• Engineering: proper ventilation; storage • Administrative: SOP; MSDS; safe work practices; training; segregated from strong oxidizing agents, bases, and/ or acids • PPE: solvent resistant gloves (nitrile rubber); isocyanate approved respirator; chemical splash goggles • Residual risk: Accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical CRW Handling: Carbon Fabric, Sized or Unsized	• Temporary mechanical irritation of eyes, skin (primarily at pressure points such as neck, wrist, waist, between fingers), upper respiratory tract • Eye and respiratory tract irritation from fumes or vapor generated by heating or curing sized product • Electrically conductive carbon fibers and dust may cause electrical short-circuits, resulting in damage to and malfunction of electrical equipment and/or personnel injury • Product or dust may aggravate pre-existing eye, skin, or respiratory disorders	• Rating: Potentially Hazardous Operation • Probability: Low • Severity: Mild to moderate	• Engineering: shop and/or local exhaust ventilation • Administrative: MSDS; SOP; safe work practices; exposure time limitations; training • PPE: safety glasses with side shields for product use or machining, grinding, or sawing cured product; loose-fitting long sleeved shirt that covers to base of neck; long pants; gloves • Respiratory Protection: not usually required; use NIOSH approved organic vapor respirator if needed for heating or curing sized product; use NIOSH approved dust respirator if needed for machining, grinding, or sawing cured product • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Chemical Handling: Fiberglass Fabric	• Mechanical skin irritant (primarily at pressure points such as neck, wrist, waist, between fingers) • Mechanical eye irritant • Mouth, nose, and throat irritation if inhaled • Mechanical stomach and intestine irritant if ingested • Fiber release during cutting or sanding	• Rating: Potentially Hazardous Operation • Probability: Moderate • Severity: Mild	• Engineering: shop exhaust ventilation and/or local exhaust ventilation • Administrative: MSDS; SOP; safe work practices; exposure time limitations; training • PPE: safety goggles or safety glasses with side shields; loose-fitting long sleeved shirt that covers to base of neck; long pants; gloves • Respiratory Protection: not usually required; NIOSH/MSHA approved disposable dust respirator, when ventilation is inadequate or irritation occurs • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Ejection Charge Handling: Assembly	• Accidental ignition • Skin burn • Impact injury • Chemical exposure to black powder • Bystander injury • Facility/equipment damage	• Rating: Hazardous Operation • Probability: Moderate • Severity: Moderate to Severe	• Engineering: isolate ejection charge from strong electric fields and heat sources • Administrative: HOP; safe work practices; training; personnel certification • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Ejection Charge Handling: Testing	• Failure of ejection charge retention system releases projectile • Premature combustion • Injury to personnel • Facility/equipment damage • Unauthorized entry of test cell	• Rating: Hazardous Operation • Probability: High • Severity: Moderate to Severe	• Engineering: conduct test in blast-proof test cell; large safety factor designed into retention system • Administrative: written test procedures; safe work practices; supervision by Level 2 certified NAR Mentor; controlled access; training; personnel certification • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Machine Use: Lathe	• Injury to or loss of hand, limb • Laceration by shrapnel • Eye injury by shrapnel • Bystander injury • Facility/equipment damage	• Rating: Hazardous Operation • Probability: Moderate • Severity: Mild to Severe	• Engineering: machine selection; shop design • Administrative: SOP; safe work practices; training and qualification; supervision by experienced personnel; controlled access • PPE: eye protection • Residual Risk: accepted
Machine Use: Milling Machine	• Injury to or loss of hand, limb • Laceration by shrapnel • Eye injury by shrapnel • Bystander injury • Facility/equipment damage	• Rating: Hazardous Operation • Probability: Moderate • Severity: Mild to Severe	• Engineering: machine selection; shop design • Administrative: SOP; safe work practices; training and qualification; supervision by experienced personnel; controlled access • PPE: eye protection • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Motor Handling: Installation	• Accidental ignition • Skin burn • Impact injury • Bystander injury • Facility/equipment damage	• Rating: Hazardous Operation • Probability: Moderate • Severity: Moderate to Severe	• Engineering: isolate ejection charge from strong electric fields and heat sources • Administrative: HOP; safe work practices; training; personnel certification; performed only by Level 3 certified NAR Mentor • Residual Risk: accepted
Motor Handling: Testing	• Motor retention system failure resulting in uncontrolled motor movement • Premature combustion • Injury to personnel • Chemical exposure to ammonium perchlorate • Facility/equipment damage • Unauthorized entry of test cell	• Rating: Hazardous Operation • Probability: High • Severity: Moderate to Severe	• Engineering: conduct test in blast-proof test cell; large safety factor designed into retention system • Administrative: written test procedures; safe work practices; supervision by Level 2 certified NAR Mentor; controlled access; training; personnel certification • Residual Risk: accepted

Work Task	Potential Hazard	Hazard Ranking	Hazard Controls
Tool Use: Sanding/Grinding	• Skin abrasion • Laceration by shrapnel • Eye injury by shrapnel or dust • Respiratory irritation • Bystander injury • Facility/equipment damage • Chemical exposure if material being worked is hazardous • Catastrophic failure of grinding wheel resulting in high velocity	• Rating: Potentially Hazardous Operation • Probability: Low • Severity: Mild to Severe	• Engineering: machine selection; shop design; shop exhaust ventilation • Administrative: SOP; safe work practices; exposure time limitations; training; supervision by experienced personnel • PPE: eye protection • Residual Risk: accepted
Tool Use: Soldering, Electrical	• Skin burn • Damage to components • Fire	• Rating: Hazardous Operation • Probability: High • Severity: Mild to Severe	• Engineering: tool selection • Administrative: SOP; safe work practices; training • Residual Risk: accepted

16 Appendix I: EMI Test Plan

EM Interference Testing Rationale:

1. Attempt to induce failure in other components in a controlled worst case design scenario
    a. Long, unshielded wires, close proximity
    b. Measure threshold for failure
2. Measure effectiveness of mitigation techniques
    a. Hold all other variables constant and add shielded wire etc.

Test 1

Goal: Determine what component of the system induces the highest signal on a test wire.

High level procedure:

1. Set up payload with approximate 6 inches each between the battery, transformer, and test chamber.
2. Attach a shielded coaxial wire to an oscilloscope; at the end of this attach a short (approximately 3 in) wire to act as a test probe.
3. Turn the payload on. measure the peak to peak open circuit voltage induced on the test probe (with the oscilloscope) at approximately 1 in away from the:
    a. Battery
    b. Wire from battery to transformer
    c. Transformer
    d. Wire from transformer to test chamber
    e. Test chamber
4. Note any observations about where the induced signal is greatest

Test 2

Goal: Determine response to probe wire length and gage

High level Procedure

1. Set up payload as in test 1
2. At location determined to induce the highest signal test a range of lengths of probe wire
    a. 1 in to 6 in in .5 inch increments
    b. Record Open Circuit voltage induced
3. At most responsive length test three different gages of wire the same way

Test 3

Goal: determine the power developed in a worst case scenario

1. Set up payload as in 1
2. At location determined to induce highest signal, using the worst case length and gage, measure The open circuit voltage
3. Attach different resistors from the open end of the test probe back to the ground of the oscilloscope until a range is found which reduces the voltage by an amount measureable in the range of the oscilloscope.
4. Measure the closed circuit voltage at three different resistances
5. Use these measurements to determine power developed using Power=Voltage^2/resistance

Test 4

Goal: attempt to provoke altimeter failure

High level procedure:

1. Set up payload as in Test 1
2. Place altimeter within 1 inch of the area which was identified in test 1 as inducing the greatest signal
3. Test altimeter with hand-held vacuum pump
4. Turn payload on
5. Measure induced voltage in manner
6. Repeat step 3
7. Compare results and note any observations

Test 5

Goal: attempt to provoke E-match Failure

High Level Procedure:

1. Set up payload as described in test 1
2. Set up simulated recovery system with the wire that we will have running through the payload area at the worst case scenario location.
3. Use the handheld vacuum pump to simulate operation at altitude
4. Reset recovery system with new match
5. Turn payload on
6. Repeat step 3
7. Compare results

Test 6

Goal: test shielded wire effectiveness

High Level Procedure

1. Set up payload as described in test 1
2. Measure at highest induced signal location
3. Replace unshielded test probe wire with shielded test probe wire
4. Repeat measurement
5. If worst case location is, as predicted, the wire from the transformer to the test chamber, then replace that wire with a shielded one
6. Repeat measurement (this time with both shielded)
7. Re-install the un-shielded test probe wire
8. Repeat measurement

Test 7

Goal: determine faraday cage effectiveness

1. Assemble payload as it would be in the rocket but without a faraday cage
2. Take measurements similar to test 1 using unshielded test probe
3. Add faraday cage, repeat measurements.

17 Appendix J: Black Powder Ejection System Standard Operating Procedure

UAHuntsville Propulsion Research Center

Standard Operating Procedure For:

Black Powder Ejection System

SOP #: USLI – SOP – TC - 003

Revision: 03

Operation: Black Powder Ejection System

Test Location: PRC Test Cell Facility and NAR/TRA approved test fields

Test Date: ____________________

Test Time Start: _______________ Finish: ________________

Test Team

Name	Role

Notes: ____

____

____

____

☐ Procedure Deviations Required (provide reasoning below)

Revision Block

Revision #	Reason For Revision	Development Hours
3	New SOP for New red team members and update to current procedure and ignition control circuit. Based on USLI-Black_Powder_Ejection_System-SOP_Rev02 and PRC–SOP–JRC-001.	18

Active Waivers

The following waivers have been reviewed by the procedure approval team and are accepted based on assessment of additional mitigations put into effect for conducting the test.

#	Description	Mitigation	Expires	Responsibility
	No Active Waivers	None	N/A	N/A

Procedure Approval:

I have personally reviewed each of the operational steps of the SOP and have no questions that the operation can be performed safely and efficiently. I approve all red team personnel assigned in this document and verify that they have proper training to act in the prescribed test roles outlined in this procedure.

Amit Patel: ______________________________ Date: ____________

Author

Tony Hall: ______________________________ Date: ____________

Facility Engineer

Dr. David Lineberry: ______________________________ Date: ____________

Laboratory Supervisor

Dr. Robert Frederick: ______________________________ Date: ____________

PRC Director

Reviewed By:

Marcia Pendleton: ______________________________ Date: ____________

Director UAH OEHS

Authorized Red Team Members

Individuals identified below are authorized to participate in test operations as *Red Team Members* through the SOP approval signatures. By signing the document below, the individuals acknowledge that they have reviewed the procedure and understand the general and specific safety requirements, personnel limits, and work descriptions necessary to accomplish their part of the operation.

Additional Red Team Members may be added to this document without a procedure revision pending approval of the PRC Director or Laboratory Supervisor or Facility Engineer prior to participating in the experiment. Additional members require signatures of both the individual to be added and the approver.

Authorized test individuals agree to abide by and follow the procedure outlined in this document for conducting the described experiment. Any individual not following procedure during testing in a manner which jeopardizes other test members will be immediately removed from the red team and reported to the PRC director.

Red Team Members	Affiliation	First Aid/CPR-AED Certification Dates	Signature
Amit Patel	PRC Staff	6/22/2012	
David Lineberry	PRC Staff	9/20/2013	
Tony Hall	PRC Staff	9/20/2013	
Robert Frederick	PRC Director	10/19/2012	
Jason Winningham	USLI L2 Mentor	2/12/2012	
Wesley Cobb	USLI Avionics Lead	9/20/2013	
Brian Roy	USLI Safety Officer	1/24/2014	

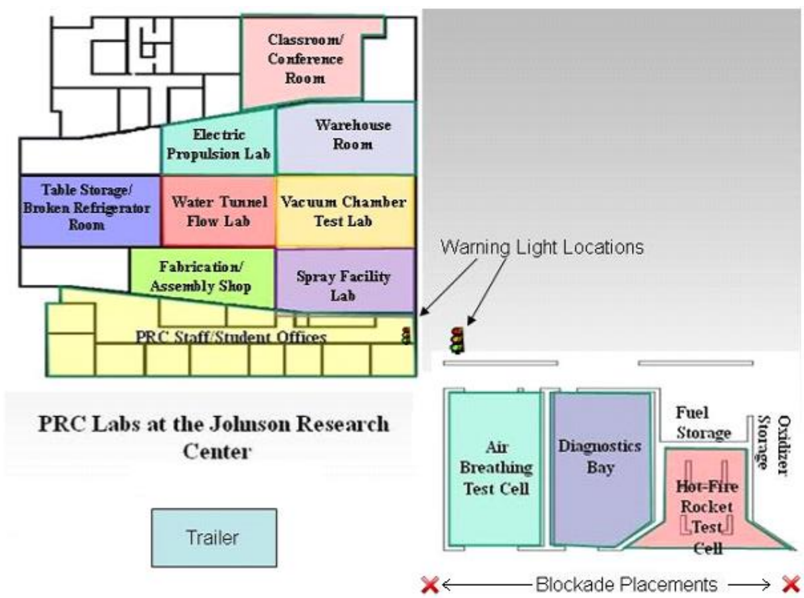
Section I. Declarations

Objective

This SOP establishes procedures and defines safety precautions that will be used to verify the amount of black powder needed to safely separate rocket body at break points in order to ensure proper deployment of recovery system as part of pre-flight testing.

Test Location

This procedure is open to testing in the PRC Test Cell Facility Laboratory and NAR/TRA approved test fields. Due to Fire Code Restrictions and exposure concerns, no more than 5 people are allowed in the test area at one time. All personnel will be at least 30 ft away.



Warning Barricade Placement

Roles and Responsibilities

This procedure requires a minimum of 2 test operators. No more than one (1) Test Conductor/Safety Monitor, one (1) Test Operator, one (1) person for Instrumentation and two (2) Test Observers at any time. At least one PRC Staff or USLI L2 Mentor must be present to perform test. Operator roles will be assigned on the day of testing. Each operator will be assigned a role and that role will be identified on the procedure cover sheet (pg 1). Test operator roles are identified below:

Test Conductor/Safety Monitor: Reads Procedure, Insures proper number of Red team members for test, Keeps test area isolated from guests, Makes sure all test materials are in place.

Test Operator: Handles loading of black powder and control of ignition circuit.

Instrumentation: Handles all other areas of instrumentation, camera, etc. If only two people are present for the test, this task may be handled by either the Test Operator of Test Conductor.

Test Observers (Optional): Observers are to remain in designated locations set forth by the Safety Monitor. They may be available to assist with test at request of the Test Conductor.

Observer Policy

Observers will be allowed under this test procedure pending approval of the PRC Staff. The occupation limitations of the test area apply to observers as well as test participants. Any observer must be briefed on the experiment hazards, emergency procedures prior to test operations, and listed on the title page of the procedure. An observer is required to remain behind remote physical caution boundaries at all times- during all operations.

Before operations commence, an observer must be briefed on the potential hazards of the facility, including:

- Explosions
- Temperature Burns
- Debris
- Fires

Additionally, an observer must be provided personal safety equipment and advised of its use as defined in Table 1.

Safety Policy

All PRC test operations require a minimum of two operators with First Aid, CPR, and AED training. Test operations are carried out according to the PRC Facility Usage Policy outlined in PRC-SOP-001-R01 and supplied in Appendix C. A copy of the facility usage policy will be provided upon request or may be found on the PRC website http://UAH.edu/prc. In addition to standard safety requirements the following special requirements apply for this procedure: All personnel involved with this operation have been empowered to stop any portion of this operation at any time if they feel it is not proceeding in a safe manner. The PRC Director, PRC Research Engineer/Laboratory Supervisor, PRC Facility Engineer, and other required personnel will be notified and a decision on whether to continue the operation will be made at that time. No safety interlock will be modified, bypassed, or defeated unless the test team has concurred and are aware of the inherent risks associated with the change. Otherwise, the offender will be permanently expelled from the PRC and all of its facilities.

Safety Requirements

- Only red team members are allowed to assist in loading and operating the triggering system in an environment clear of prohibited members.
- At least two red team members must be present at a test.
- Protective eyewear must be worn at all times during the test procedure.
- Canisters of black powder must be stored in approved a clearly-labeled containers. Bulk black powder must be contained and away from test operations during testing.
- In the event that the charge fails to trigger, a complete disarming of system must occur. Steps 67-75: Disarming/Failure Checklist must be followed to ensure involuntary ejection does not occur.

- Only proper installation tools should be used to load the Black Powder Ejection System. All tools should be verified to be in good working order before the test begins.

Personal Protective Equipment (PPE)

Test personnel must wear safety glasses at all times during test operations. Long pants and close toed shoes are required for testing. Cotton clothing is required. The following PPE are approved through the procedure and **Table 1** show when PPEs are necessary:

- Lab Glasses,
- Lab Goggles,
- Personal Spectacles with Side Shields
- Ear Plugs,
- Ear Muffs

Table 1 – Personal Safety Equipment

Equipment	Period
Approved eye protection	All Times
Closed-toed footwear	All Times
Approved hearing protection (Optional)	Firing Procedures

Weather/Emergency

Testing will not be conducted during unfavorable weather conditions. Additionally testing may not be conducted if lightning is expected in the area or if there is lightning in a 25 mile radius. Testing may be stopped if high or variable winds are present in the test area. In the event of non-weather related emergency test operations must be stood down so test personnel can evacuate test facility. If time does not permit safe mitigation of hazards, any immediate hazards should be identified to PRC Staff and emergency response personnel

Procedure Deviations

At any point during the execution of this SOP any team member may call for a stand down of test operations to discuss any concern related to safety. Additionally, during the execution of the SOP any deviation to the procedures outlined in this document must be noted on the procedure and it must be identified on the cover page that deviations were conducted. Revisions to the procedure may be required prior to the next test operation. Prior to each test, verify that the procedures do not require modification due to specific test plan requirements. In the event that redlines are required during execution, ensure that redlines present no safety, efficiency, or environmental concerns.

Materials Needed

Safety Glasses

Assembled Rocket Air Frame

Black Powder

E-Match

Black Powder Cap

Long wire

Fire Extinguisher (verify availability at site)

Wire cutters

Test stand

E-match Ignition Circuit

Volumetric measuring device

Electrical tape

Ear plugs

Battery

First Aid Kit (includes bottled water)

Parachute

Shock cord

D-Ring

Measuring tape

Multimeter

SECTION II. Test Procedures

Pretest Laboratory Preparation

1. Make sure you have a partner. You must observe the two-man rule. NO experiments shall be performed alone.
2. Ensure that every person involved in test is aware of all procedure.
3. Inform all guests of emergency exits and other pertinent safety information.
4. Identify nearest AED location to team and guests.
5. Place all jewelry and electronic devices, including cell phones, tablets, and radios in an approved location.
6. Make sure the two phones work in case an emergency occurs.
7. In case of an emergency, call campus police at: (256) 824-6911.
8. At any point during a test, any red team member can call for the test to be stopped at any point and for any reason.
9. Make sure all personnel are wearing the proper PPE, e.g., safety glasses, goggles, face shield, hearing protection (if needed).
10. Safety glasses are required when lines are pressurized (i.e. once warning light turned to Yellow).
11. If testing at the JRC, the 'Warning' barricades should be set up at each corner of the test area (see section 2 and Appendix F for barrier placement).
12. If testing at the JRC, warning light should be turned to RED during the set-up procedure and throughout the experiment.
13. New Red Team members must be certified in writing by Dr. Lineberry or Mr. Hall.
14. Observers must be approved by either Dr. Lineberry or Mr. Hall.

Preparing the Black Powder Charge

CAUTION

15. Failure to restrict access to the testing area could result in inadvertent personnel traffic which could lead to personnel injury.
16. Verify non Red Team members have vacated the testing area and PPEs are available.
17. Setup camera to record test (optional).
18. Inspect E-Match for frayed wires.
19. Cut a hole in the bottom of charge cap.
20. Secure E-Match into charge cap and seal with electrical tape.
21. Secure charge cap into position (i.e. bulkhead, nosecone, etc).
22. Twist e-match leads together to shunt circuit.
23. Remove black powder from designated container.
24. Measure specified amount of black powder to be tested in a volumetric measuring device.
25. Record the volume of the black powder: ________________.
    a. NOTE: Start with half the amount needed and work up.

!!! RED TEAM ONLY

!!! RED TEAM ONLY !!!

26. Insert specified amount of black powder into charge cap.
27. Pack charge cap with wadding material.
28. Close charge cap and ensure seal.
29. Return black powder to designated container and move container away from test area.
30. Assemble rocket components to be tested for separation.
31. If necessary, insert shear pins into rocket halves to be tested for proper shear.
32. Place rocket on designated test stand.
33. Ignition Circuit Setup
34. Verify Safety Monitor is in possession of arm key
35. Ensure ignition circuit is disconnected from battery
36. Shunt ends of wires.
37. Connect Igniter Cable into Ignition Circuit Extension Cord at rocket test stand.
38. Connect Ignition Box Cable Leads to Ignition Circuit Extension Cord at control station.
39. Connect battery leads to multimeter to perform continuity check on ignition circuit.
40. Hold control circuit arm key in ignition and press “fire” button to perform continuity check.
41. Remove control circuit arm key and hand to Safety Monitor
42. Disconnect battery leads from multimeter.
43. Connect E-Match leads to ignition circuit.
44. Remove all attending personnel at least thirty (30) feet radius from explosive zone.
45. Return to Operator Area
46. Person performing detonation should then take one last observation to ensure that no one is near explosive zone before detonation.

> ONLY Red Team allowed in test cell area from this point forward.

Testing Procedure

47. Verify that the battery is disconnected from igniter circuit.
48. Verify that the Safety Monitor has possession of the control circuit arm key.
49. Announce “CLEAR AREA.”
50. Confirm from Safety Monitor that test fire is a “GO.”
51. Unshunt ends of wire.
52. Connect Battery to Ignition Circuit
53. Inform Safety Monitor that Rocket is ready for ignition
54. Insert control circuit arm key into control box and hold in to perform continuity check.
55. Perform a countdown of 5,4,3,2,1, FIRING CHARGE.
56. While holding in control circuit arm key, press and hold the fire button for 5 seconds.
57. If the charge fails to fire within 30 seconds,
58. First Failure: repeat steps 38 – 54.
59. Second Failure: Skip to Steps 67-75: Disarming/Failure Checklist.
60. Wait for charge to burn completely
61. Disconnect Battery
62. Remove control circuit arm key and hand to Safety Monitor

63. Wait 60 seconds.
64. All attendees should then remain in their safe zone until given the go ahead from test conductor.
65. Test operator should then approach the E-Match charges and ensure that all black powder was expelled from the E-Match charge and detonated.
66. In is now safe for all attendees to return to the test area to examine the results of the tests.
67. Record all results: ____ ____ ____ ____ ____ ____ ____ ____ ________________________
68. All components should be inspected for damage.
69. If repeating test, return to step 15 and mark procedure with different check indicators.

Disarming/Failure Checklist

70. If the charge fails to fire a second time, remove power from the ignition circuit.
71. Remove key from box and hand to Safety Monitor.
72. Disconnect battery.
73. Shunt ends of wires.
74. Wait another 30 seconds, and then approach charges carefully.
75. Disconnect E-match leads from ignition cable.
76. Twist E-match leads together.
77. Remove rocket frame from test stand.
78. Ensure proper disposal of black powder and E-Match.
79. Administrative & Documentation Tasks
80. Update black powder inventory after a successful test or relocation of propellant.
81. Indicate on this SOP how data will be backed up.
82. Upon completion, the SOP needs to be signed by the participating Red Team members, scanned, and uploaded to the SOP database per direction of Dr. Lineberry.

!!! RED TEAM ONLY !!!

APPENDIX A. Cross Referenced Procedures

The following procedures are referenced in this SOP and are required for verification purposes.

	SOP Doc #	Description
		UAH PRC Safety Program, 22-Feb-2013.
	PRC-SOP-001	UAH Propulsion Research Center – Facility Usage Policy, 1-Apr-2012.
	PRC-SOP-HiPSF-003	General Spray Facility SOP
	PRC-SOP-JRC-001	Solid Rocket Motor Ground Testing
	USLI-Black_Powder_Ejection_System_Test SOP	Previous Black Powder SOP
	PRC-SOP-HPL-002 R00V01	ESP Ultrasonic Burn Rate SOP

APPENDIX B. STORAGE AND TRANSPORTATION OF BLACK POWDER

The following are instructions for the storage and transportation of black powder.

- The black powder will be stored in the PRC's Day Box. The Day Box will be locked.
- When transporting the black powder to launch sites, it will be stored in the locked Day Box.
- The Day Box will be transported in a non-confined space on a vehicle (i.e. the bed of a truck). It will not be transported inside any vehicle.

The following are instructions for the proper disposal of black powder.

- The black powder will be stored in a container separate from the unused powder.
- The black powder will be burned at the next available opportunity.

APPENDIX C. RISK ASSESSMENT

Hazard Ranking

		Hazard Probability				
		Frequent	Likely	Occasional	Seldom	Unlikely
Hazard Severity	Catastrophic	4	4	3	3	2
	Critical	4	3	3	2	1
	Moderate	3	2	2	1	1
	Negligible	2	1	1	1	1

Hazard	Rank	Effect	Reaction	Mitigation
Explosions	2	• Damage to facility • Injury from debris	• Assess situation before proceeding to test area • Stop test/disconnect circuit • Evacuate laboratory as necessary • Report incident	• Access to test area is restricted when testing • Start with smaller amount of black powder. • Inspect structure for points of failure.

Hazard	Rank	Effect	Reaction	Mitigation
High Temperature Burns	3	• Burns on Skin	• Alert on site personnel • Call emergency response	• Wait 60 seconds after test • Heat Gloves • Handle with helping hands.
Inadvertent firing of the Black Powder charge	2	• Laboratory Fire • Injury • Debris	• Get affected person out of hazard • Clear lab • Assess situation (do not try to fight any fire) • Report incident to Police as necessary • Report incident to PRC Director	• Igniter leads are shorted while personnel around rocket • Arm key provides physical break in igniter circuit • Work is conducted on a grounded work surface • Verify no voltage on igniter circuit before connecting it to the igniter • Always point rocket away from all personnel

Test stand structural failure	1	• Uncontrolled BP charge • Debris • Injury • Fire	• Assess Situation before proceeding to test stand • Stop test/disconnect circuit • Evacuate lab and report incident	• Assess Structure before returning to operating area
Hazard	**Rank**	**Effect**	**Reaction**	**Mitigation**
Inhalation of fumes from Black Powder products	2	• Long term health affects	• Exit laboratory • Report incident to OEHS	• Test areas are naturally vented

APPENDIX D. UAH PRC FACILITY USAGE POLICY

UAH Propulsion Research Center – Facility Usage Policy

The Propulsion Research Center (PRC) conducts research, produces publications, and mentors students in advanced propulsion technologies and their applications. The PRC connects the academic research community and propulsion community through interdisciplinary collaboration. Use of the facility requires prior written approval of the PRC Director.

The Propulsion Research Center laboratories were established to provide UAHuntsville faculty, staff, and students, state-of-the-art facilities for conducting basic and applied research on propulsion systems and related sciences. The PRC was established to provide students a "hands-on" education in propulsion. The facilities may be used for sponsored research projects, PRC staff and Graduate Student research projects, and approved UAHuntsville undergraduate research projects. The Propulsion Research Center acknowledges that hazards are inherent to the nature of the research conducted in the facilities that require strict adherence to facility rules and protocols for anyone engaged in research in the PRC laboratories. PRC facility protocol is as follows:

1. All PRC Test operations are under the authority of the PRC Director and UAH campus safety practices.
2. All personnel involved in testing are UAH employees, UAH students under PRC supervision, customers with an active contract with UAH, or those with other formal arrangements agreed to in writing by the University.
3. All tests involving pressures over 100 psi, high voltage, combustion, or other sources of possibly injury require a Standard Operating Procedure (SOP), reviewed and signed by the test Red Team (see below), and approved by the PRC Director.
4. The tests are conducted by a designated Red Team who has at least one UAH staff member and has at least two members who are Red Cross Safety and CPR/AED Certified.
5. After any major test anomaly, all PRC test operations are automatically suspended until a determination of the basic cause of the incident is determined and all active SOPs are reviewed in light of the findings of the incident before resuming testing. A verbal report of the incident will be given to the V.P. of Research and a representative of Campus Safety within 24 hours of the incident.

Robert A Frederick

________________________________ 4/1/2012

Robert Frederick
Interim Director PRC

APPENDIX E. EMERGENCY CONTACT INFORMATION

In the event of an emergency, respond in accordance with off-nominal procedures defined in this SOP and in accordance with the appropriate section in the UAH PRC Safety Program dated 22-Feb-2013.

Emergency contact numbers are provided below.

Emergency Phone Numbers	
Police	911 (256) 824-6911 (6911 from campus phone)
Fire Department	
Hazardous Materials Incident	
Utility Failure	
PRC Contacts	
Tony Hall	Office : (256) 824-2887
David Lineberry	Office : (256) 824-2888 Cell: (256) 348-8978
Robert Frederick	Office : (256) 824-7200 Cell: (256) 503-4909
PRC Main Office	(256) 824-7209
High Pressure Lab Phone	(256) 824-6031
JRC Test Stand	(256) 824-2857
Marcia Pendleton/OEHS (Office of Environmental Health and Safety)	(256) 824-6053
Other Emergency Numbers of Interest	
UAH Campus Police Department	(256) 824-6911
Huntsville Police Department	(256) 722-7100
Madison County Sheriff's Office	(256) 722-7181
Alabama State Troopers	(334) 242-4371
Huntsville Hospital	(256) 265-1000

In the event of a non-emergency reportable incident call the numbers below in the following order.

1. Dr. Robert Frederick (Dr. David Lineberry as an alternate)

   Office: (256) 824-7200

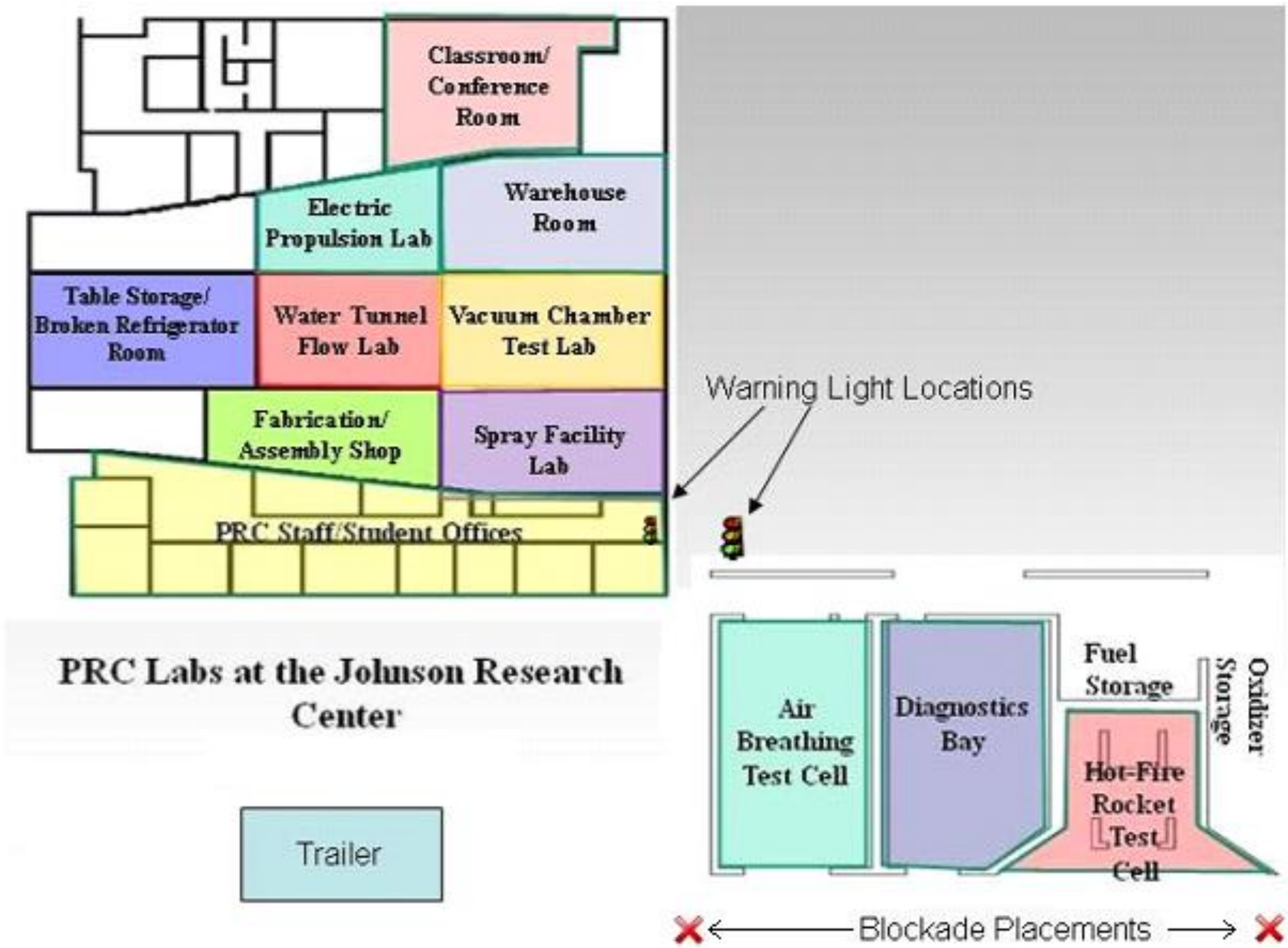
   Cell: (256) 503-4909

2. UAHuntsville Police (Non-Emergency)

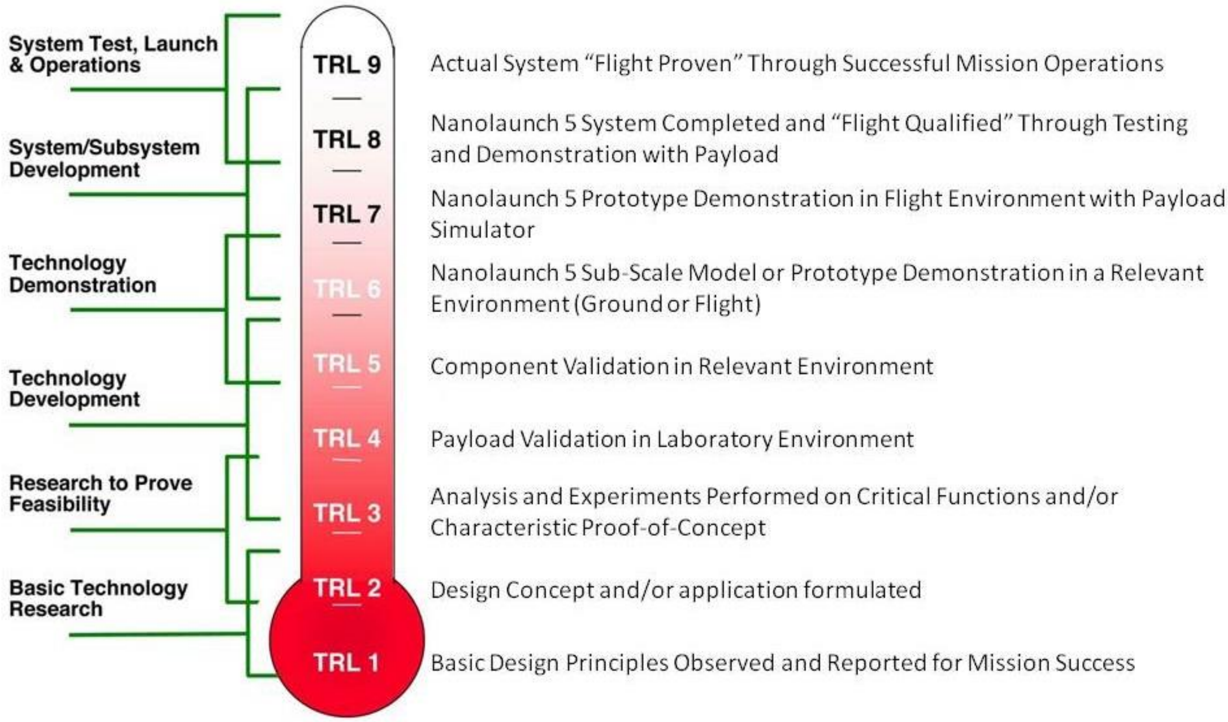
   (256) 824-6596

   6596 (from campus phone)

Appendix F: Warning Barricade Placement



18 Appendix K: Technology Readiness Level



19 Appendix L: Launch Operation Procedures

NASA University Student Launch Initiative

University of Alabama in Huntsville 2013-2014

Subscale Launch Operation Procedures

March 8, 2014

Section I: Declarations

1. Objective

This SOP establishes the proper procedures for the assembly of any launch vehicle being flown by the Charger Rocket Works team.

2. Test Location

This procedure is to be used for launches conducted at NRA/TRA approved fields in accordance with all state and federal laws regarding high-powered rocketry.

3. Roles and Responsibilities

This procedure requires a minimum of 2 Launch Team members. No more than one (1) Safety Monitor, one (1) Test Operator, one (1) person for the payload, and one (1) NAR/TRA certified flier. All other observers must be wearing proper PPEs in order to be present during the vehicle assembly. The roles of the Launch Team members are identified below:

Safety Monitor: Reads procedure, insures proper number of Launch Team members for test, and ensures that all observers are wearing proper PPEs.

Test Operator: Handles loading of black powder into ejection charges and Tender Descenders and ensures that recovery system circuitry is properly constructed.

Payloads: Responsible for ensuring proper function and installation of the avionics package into the launch vehicle.

NAR/TRA Flier: Responsible for loading motor into motor case and ensuring that motor has been properly secured into launch vehicle. They should also perform a final inspection of the vehicle before approaching the RSO to launch.

4. Observer Policy

Observers will be allowed under this procedure provided that sufficient PPEs are available that all observers can be provided with them. All observers must be briefed on the hazards present during the vehicle assembly and the associated emergency procedures, prior to the conduction of the launch operations.

Before operations commence, an observer must be briefed on the potential hazards, including:

- Explosions
- Temperature Burns

- Debris
- Fires

Additionally, an observer must be provided personal safety equipment and advised of its use as defined in Table 1.

5. Safety Policy

The Test Operator must have First Aid, CPR, and AED training. Additionally, the Test Operator must be an approved Red Team member on the **USLI-SOP-TC-003 R3 Black Powder Ejection System Test SOP.** The NAR/TRA flier must have all appropriate certifications to fly the designated motor class for the launch. Any member of the Launch Team may ask any observers to exit the area if they feel as though the observers are conducting themselves in an unsafe manner.

6. Safety Requirements

- Only Launch Team members are allowed to assist in assembling the launch vehicle in an environment clear of prohibited members.
- At least two Launch Team members must be present during the vehicle assembly.
- Protective eyewear must be worn at all times during the vehicle assembly.
- Canisters of black powder must be stored in approved a clearly-labeled containers. Bulk black powder must be contained and away from test operations during testing.
- Only proper installation tools should be used to load the Black Powder Ejection System. All tools should be verified to be in good working order before the test begins.

7. Personal Protective Equipment (PPE)

Launch Team members must wear safety glasses at all times during vehicle assembly. Long pants and closed toed shoes are required.

Table 1 – Personal Safety Equipment

Equipment	Period
Approved eye protection	All Times
Closed-toed footwear	All Times
Approved hearing protection (Optional)	Firing Procedures

8. Weather/ Emergency

Launch Operations will not be conducted during unfavorable weather conditions. Launch Operations may be stopped if high or variable winds are present at the launch site. In the event of a non-weather emergency, launch operations must be halted until the emergency has been properly handled.

9. Procedure Deviations

At any point during the execution of the launch procedures, any team member may call for a stand down of launch operations to discuss any concern related to safety. Additionally, during the execution of the launch procedures any deviation to the procedures outlined in this document must be noted on the procedure and it must be identified on the cover page that deviations were conducted. Revisions to the procedure may be required prior to the next test operation. Prior to each test, verify that the procedures do not require modification due to specific launch requirements. In the event that redlines are required during execution, ensure that redlines present no safety, efficiency, or environmental concerns.

10. Materials Needed

Safety Glasses

Launch Vehicle Components

Black Powder

E-matches (4 for recovery system, 1 for motor)

Black Powder Caps

Long Wire

Wire Cutters

Table

Volumetric Measuring Device

Electrical Tape

Wire Nuts

Avionics/Avionics Bay

Motor/ Motor Tube

Batteries (recovery altimeters/avionics)

Parachutes (Drogue/Main(s))

Shock Chord

D Rings

Measuring Tape

Shear Pins

Rivets

Masking Tape

Tender Descenders (2)

Deployment Bag

Drill/Drill Bits

Altimeters/ Altimeter Bay

Section II: Launch Procedures

Pre-Launch Preparation

1. Ensure all members of the Launch Team are present.
2. Ensure that every person involved is aware of all steps in the procedure.
3. At any point during the launch operations, any Launch Team member can call for the launch operations to be stopped for any reason.
4. Make sure that all personnel, including observers, are wearing the proper PPE.
5. Ensure that all required materials are present.

Payload Preparation

6. Place battery in designated slot on avionics sled.
7. Ensure that there are no loose connections or broken solder joints present on any components.
8. Turn on the Dog Tracker and attach to avionics sled.
9. Attach battery to avionics circuit.
10. Turn on Beagle Bone to ensure that the program is running properly.
11. Beagle Bone displays a blinking light with a uniform frequency (similar to a heartbeat).
12. Insert avionics sled into lower half of the vehicle.
13. Insert rivets into lower half of the vehicle to hold the avionics sled in place.

Altimeter Bay Preparation

14. Mark wire leads going to Tender Descenders and wire leads going to ejection charges.
15. Attach battery and switch leads to altimeters at their respective posts.
16. Turn switches to **ON** (110V) position to ensure both altimeters are functioning properly.
17. Turn switches to **OFF** (220V) position to deactivate altimeters.
18. Attach one set of Tender Descender wire leads to the “Main” posts on each of the altimeters.
19. Attach one set of ejection charge wire leads to the “Drogue” posts on each of the altimeters.
20. Pull on wire leads to ensure they are properly secured to the altimeters.
21. Perform continuity check of wire leads by placing one multi-meter lead at the end of the wire, and the other multi-meter lead on the altimeter post the wire is attached to.
22. Insert altimeter bay into rocket coupler tube.
23. Insert coupler tube into lower half of the rocket and insert rivets to affix it.
24. Slide upper half of rocket over the coupler tube and insert rivets to attach it.
25. Double check that altimeter switches are accessible through the ports in the rocket body.

TEST OPERATOR ONLY !!!

Recovery System Preparation

26. Fold main parachute(s) and place inside of the deployment bag.
27. Place all additional shock cord inside deployment bag and set it aside.
28. Ensure that Tender Descenders are arranged in such a way that they will be the default load path for the recovery system after deployment.
29. Ensure that Tender Descenders are properly tethered to recovery system hardware to prevent their loss after deployment.

Ejection Charge/ Tender Descender Preparation

30. Verify that all Launch Team members are wearing appropriate PPE.
31. Inspect E-matches for frayed wires.
32. Cut holes in the bottoms of two charge caps (if not already prepared).
33. Secure E-Match into charge cap and seal with electrical tape.
34. Twist E-Match leads together to shunt circuit.
35. Remove black powder from designated container.
36. Measure specified amount of black powder to be used in a volumetric measuring device.
37. Record the volume of the black powder: ________________.
38. Insert specified amount of black powder into charge cap.
39. Pack charge cap with wadding material.
40. Close charge cap and ensure seal.
41. Repeat steps 36-40 for backup charge cap.
42. Attach each charge cap to a set of wire leads corresponding to the ejection charge circuit for one of the altimeters.
43. Separate each Tender Descender into its two halves.
44. Insert an E-Match into each Tender Descender and secure it with electrical tape.
45. Measure specified amount of black powder to be used in a volumetric measuring device.
46. Record the volume of the black powder: ________________.
47. Insert specified amount of black powder into Tender Descender.
48. Reassemble two halves of Tender Descender and ensure proper connection to the recovery system hardware.
49. Repeat steps 45-48 for the second tender Descender.
50. Attach each Tender Descender to a set of wire leads corresponding to the Tender Descender circuit for one of the altimeters.

Safety Officer:________________________________ Test Conductor:____________________

Final Vehicle Assembly

51. Ensure charge caps are seated near the base of the recovery bay.
52. Insert deployment bag into recovery bay, followed by any additional shock cord.

NAR/
TRA FLIER

53. Insert Tender Descenders into recovery bay.
54. Fold drogue parachute and insert into recovery bay.
55. Insert nosecone into end of rocket body and secure with shear pin(s).
56. Remove motor from designated container.
57. Insert motor grains into motor case.
58. Insert motor case into rocket body and ensure that a proper fit is present. If fit is too loose, apply masking tape to outside of motor case until issue is resolved.
59. Attach motor retention hardware to base of the rocket.

Safety Officer: ______________________ NAR/TRA Flier:__________________________

Final Pre-Flight Verifications

60. Perform "balance test" with either a string or finger to measure CG.
61. Measure distance between CG and CP given by simulations.
62. Weigh vehicle to obtain final mass for simulations.
63. NAR/TRA Flier should perform final check of vehicle to ensure that all joints have a proper fit and no vehicle pieces are loose or otherwise damaged.
64. Test Conductor, Safety Monitor, and NAR/TRA initial below to confirm that flight a go.

TEST CONDUCTOR:	SAFETY MONITOR:	NAR/TRA FLIER:

65. Take vehicle to RSO and wait for permission to approach launch rail.

Launch Rail Prep

NAR/
TRA FLIER

66. Tilt launch rail until it is parallel with the ground and slide launch lugs into rail.
67. Slide rocket to base of the launch rail before raising it from its horizontal position.
68. Activate altimeters via ports on the rocket body.
69. Insert E-match or igniter into motor.
70. Place plug into motor to secure E-match or igniter into place.
71. Attach E-match or igniter to ignition circuit.
72. Confirm that rocket is ready for launch and return to staging area.

Post-Flight

73. If motor does not successfully light, follow directions of RSO regarding use of additional igniters or removal of the rocket from the launch rail.
74. If flight is successful, document the vehicle's state upon landing (parts broken, max altitude reached, successful recovery system deployment).

75. Return vehicle to staging area and remove burned E-matches and dispose of them properly.
76. Deactivate altimeters and avionics payload.
77. If desired, download data from avionics payload before performing any subsequent flights.

20 Appendix M: Material Safety Data Sheets

MATERIAL SAFETY DATA SHEET

Soller Composites, LLC

SECTION 1
CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: Carbon Fiber

Product Codes: Carbon Fiber Fabric, 1K, 3K, 6K, 12K

Manufacturer's/Distributor's Name: Soller Composites, LLC

Manufacturer's/Distributor's Address:

Soller Composites, LLC
55 Industrial Park Dr
Franklin, NH 03235
603 9671 7016
815 642 9593

Emergency Telephone Number: **603 671 7016**
[9:00 am - 9:00 pm, M - F, EST]

Date Prepared: 6, 2013

SECTION 2
COMPOSITION AND INFORMATION ON INGREDIENTS

Ingredient	CAS Registry No.	Weight %	Exposure Limits
Carbon fiber	7440-44-0	≥ 99%	See Note 1 below
Respirable fibrous carbon dust	not assigned	not known*	not known*

Notes on *Composition and Information on Ingredients*

*AMOUNT WILL BE DEPENDENT UPON METHOD OF HANDLING
NE = Not established

[1] OSHA and ACGIH have not established air contaminant limits for carbon fibers. Under certain conditions, this substance may be a nuisance dust. OSHA has an established standard for particulates not otherwise regulated (nuisance dust) set at 5 mg/m^3 (respirable fraction) and 15 mg/m^3 (total dust). ACGIH has established an exposure value of 3 mg/m^3 (respirable fraction) and 10 mg/m^3 (inhalable fraction) for particulates not otherwise classified.

SECTION 3

HAZARDS IDENTIFICATION

Emergency Overview

Black continuous carbon fiber. Not expected to present an immediate concern for emergency response personnel. Not expected to present an immediate acute health, reactivity, or flammability hazard. Not expected to present an environmental hazard.

POTENTIAL HEALTH EFFECTS

SKIN: May cause skin irritation. Mechanical irritation may occur from carbon fiber abrading or becoming imbedded ir skin. Chemical irritation may occur from exposure to sizing present on the carbon fiber.

EYES: Fragments of this product may cause mechanical eye irritation. Chemical irritation may occur from exposure to sizing present on the carbon fiber.

INHALATION: Inhalation exposure to respirable fibers of this product is not expected to occur under normal industrial conditions. Under very limited circumstances, however, exposure to respirable fibers of this product can occur and ma result in respiratory tract irritation.

INGESTION: Not expected to occur during industrial activities since ingestion is not a relevant route of exposure.

CHRONIC EFFECTS/CARCINOGENICITY: Not regulated as a carcinogen. There are no chronic effects/carcinogenicity are available on this product. Under very limited circumstances, exposure to respirable fibers of this product can occur may result in respiratory tract irritation; prolonged exposure may result in more adverse effects. <u>See</u> Section 11 – *Toxicological Information* for information on subchronic toxicity.

NTP: *Not listed*
IARC: *Not listed*
OSHA: *Not listed*

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: None known.

INCOMPATIBILITY: Not known.

SIGNS AND SYMPTOMS OF EXPOSURE: May result in slight skin and eye irritation.

SECTION 4
FIRST AID MEASURES

FIRST AID MEASURES

SKIN: Wash fibers off of skin with water and soap. If fibers are imbedded in the skin, remove with tweezers. Discard clothing that may contain imbedded fibers. Get medical attention if exposure results in adverse effects.

EYES: Immediately flush with a continuous water stream for at least 20 minutes. Washing immediately after exposure expected to be effective in preventing damage to the eyes. Get medical attention.

INHALATION: If there is inhalation exposure to the fibers of this product, remove source of exposure and move victim fresh air. If not breathing give artificial respiration. If there is breathing difficulty, give oxygen. Get immediate medica attention for any respiratory problems.

INGESTION/SWALLOWED: Not expected to occur since ingestion is not a likely route of exposure for this product. If ingestion does occur, do not induce vomiting. Nothing by mouth if unconscious. Get immediate medical attention.

SECTION 5
FIRE FIGHTING MEASURES

FLASH POINT: Not applicable

EXPLOSION/FLAMMABLE LIMITS: Not applicable

AUTOIGNITION TEMPERATURE: Not applicable

EXTINGUISHING MEDIA: This material is not expected to burn in a fire. If this product is present in a fire, fight fire ba on the presence of flammable materials.

SPECIAL FIRE FIGHTING PROCEDURES: As in any fire, wear a self-contained breathing apparatus pressure demand (MSHA/NIOSH approved or equivalent) and full protective gear. Fight fires from a safe distance or protected areas. F hoses with fog nozzles may be used for controlling fires but care must be exercised not to spread flaming. Water may n always be effective for large fires.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Under high heat (> 750 °C), this product may react with oxygen to give c carbon oxides and other decomposition products.

OTHER INFORMATION: This product is not expected to burn. Do not incinerate carbon fibers since airborne fibers ma cause electrical malfunctions. See Section 13 – *Disposal Considerations* for additional information.

SECTION 6
ACCIDENTAL RELEASE MEASURES

SPILL/RELEASE AND CLEANUP PROCEDURES: In case of spill, collect (*e.g.*, sweep up, vacuum, etc.) spilled material a either reuse or dispose of properly. Chopped or milled carbon fibers may be slippery if spilled posing an accident risk. personal protective equipment as described in Section 8 during cleanup activities.

SECTION 7
HANDLING AND STORAGE

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Store in a cool, dry place. Wash hands with soap and wat after handling. Wear appropriate protective clothing as described in Section 8 during handling activities.

SECTION 8
EXPOSURE CONTROLS AND PERSONAL PROTECTION

RESPIRATORY PROTECTION: Normal use and processing of this product are not expected to generate carbon fiber dus Respirable fibers of this product under certain very limited circumstances can be generated. In such circumstances, HE respiratory protection should be used to prevent exposure

PROTECTIVE GLOVES: Latex gloves should be worn when handling this product. Rinse and remove gloves after use, a wash hand thoroughly with soap and water. Gloves should be removed and replaced if there are any signs of degradati breakthrough.

PROTECTIVE CLOTHING: Wear protective clothing to minimize the potential for skin contact. An emergency shower should be readily accessible. Discard any clothing that has become contaminated.

EYE PROTECTION: Wear safety goggles or glasses when handling or processing this product in any form.

AIR MONITORING: No information is available.

EXPOSURE GUIDELINES: OSHA and ACGIH have not established air contaminant limits for carbon fibers. Under cert conditions, this substance may be a nuisance dust. OSHA has an established standard for particulates not otherwise regulated (nuisance dust) set at 5 mg/m^3 (respirable fraction) and 15 mg/m^3 (total dust). ACGIH has established an exposure value of 3 mg/m^3 (respirable fraction) and 10 mg/m^3 (inhalable fraction) for particulates not otherwise classi

SECTION 9
PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Black continuous fiber
Odor:	None
Specific Gravity:	1.75 - 1.85
Vapor Pressure:	None
Melting Point:	Not applicable
Solubility in Water:	Insoluble

SECTION 10
STABILITY AND REACTIVITY

STABILITY: Stable.

CONDITIONS TO AVOID: None.

INCOMPATIBILITY/MATERIALS TO AVOID: Do not expose to strong oxidizing agents such as fluorine. Carbon fiber ca react violently with such compounds.

HAZARDOUS DECOMPOSITION OR BYPRODUCTS: Not expected under normal conditions of processing and use. Ther decomposition of sizing may begin to occur at high temperatures (> 120 °C) resulting in the release of small amounts nitrogen oxides, carbon monoxide, organic compounds, and other potentially hazardous substances.

HAZARDOUS POLYMERIZATION: Will not occur.

SECTION 11
TOXICOLOGICAL INFORMATION

ACUTE TOXICOLOGICAL DATA: There are no acute toxicological data available on this product. The oral, dermal, and inhalation acute toxicity are expected to be very low.

EYE IRRITATION DATA: No data are available.

SKIN IRRITATION DATA: No data are available.

SKIN SENSITIZATION DATA: No data are available.

SUBCHRONIC TOXICITY: Two subchronic inhalation tests in rats exposed to carbon fibers have been conducted. In on rats were exposed to fibers for 16 weeks. Pulmonary function tests performed on the test animals before necropsy did show any significant or consistent changes. The only pulmonary finding related to exposure was the occurrence of phagocytosis by alveolar macrophages. No inflammation or fibrosis was observed. In the second study, rats were also exposed to carbon fibers for 16 weeks. Based on clinical signs, no effects due to exposure were observed. Histopathol evaluation revealed non-fibrous particles in the pulmonary lymphoid clearance system and in alveolar macrophages. T were no signs of fibrosis.

REPRODUCTIVE TOXICITY: No data are available.

TERATOGENICITY (birth defects): No data are available.

MUTAGENICITY: Several *in vitro* mutagenicity tests have been performed on carbon fibers. Carbon fibers have been fo to be negative in the gene mutation assay in bacteria (Ames test), did not cause sister chromatid exchanges in Chinese hamster ovary (CHO) cells, and did not cause unscheduled DNA synthesis in rat liver cells or forward mutations in stu with CHO cells.

CHRONIC EFFECTS/CARCINOGENICITY: No data are available.

SECTION 12
ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL DATA: No data are available.

ENVIRONMENTAL FATE DATA: No data are available.

PHYSICAL/CHEMICAL PROPERTIES: No data are available.

SECTION 13
DISPOSAL CONSIDERATIONS

RCRA CLASSIFICATION: If discarded in its manufactured form, this product is not expected to be a characteristic or specifically listed hazardous waste under RCRA. However, it is the responsibility of the user to determine at the time o disposal whether a material containing the product or derived from the product should be classified as a hazardous was

SPECIAL INSTRUCTIONS: Do not incinerate carbon fibers since airborne fibers may cause electrical malfunctions. Any disposal practices must be in compliance with federal, state, and local requirements.

SECTION 14
TRANSPORT INFORMATION

U.S./INTERNATIONAL SHIPPING INFORMATION UNDER DOT/IMO/IATA REGULATIONS: This product is not regulated dangerous or hazardous goods under DOT, IMO, ICAO, IATA, or UN shipping regulations.

SECTION 15
REGULATORY INFORMATION

REGULATORY STATUS: This product, as well as its impurities, may trigger specific reporting, recordkeeping, and testi requirements under TSCA, EPCRA/SARA III, RCRA, CERCLA, CAA, SDWA, and CWA.

CALIFORNIA PROPOSITION 65: This product contains no chemicals known to the state of California to cause cancer o reproductive toxicity.

OTHER STATE CHEMICAL LISTS: This product contains no chemicals known to be present on any state chemical lists.

EPCRA/SARA TITLE III SECTION 313: This compound contains no toxic chemicals at or above the de-minimus thresho subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Ac 1986 and 40 CFR 372.

SECTION 16
OTHER INFORMATION

DISCLAIMER: This information is furnished without warranty, expressed or implied, except that it is believed to be acc to the best knowledge of Soller Composites, LLC. The information presented in this MSDS is related only to the speci material designated herein. Soller Composites, LLC. assumes no legal responsibility for the use or reliance upon these The user should review any recommendation in the specific context of the intended use to determine whether appropri

Soller Composites, LLC assumes no responsibility for the use, misuse, and/or results of either, as related to any materials, product(s), information, and/or suggestions. Customers are strongly encouraged to, and should/must, research the proper safe use of such products and determine the suitability of each product for his or her individual application(s). Purchase of products from Soller Composites, LLC constitutes acceptance of these terms and any and all liability. Soller Composite, LLCs sole responsibility and/or liability are limited to the replacement of product or refund of purchase price.

3M

Material Safety Data Sheet

SECTION 1: PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: 3M(TM) Scotch-Weld(TM) Structural Plastic Adhesive DP-8005, Black (Part B)
MANUFACTURER: 3M
DIVISION: Industrial Adhesives and Tapes Division

ADDRESS: 3M Center
St. Paul, MN 55144-1000

EMERGENCY PHONE: 1-800-364-3577 or (651) 737-6501 (24 hours)

Issue Date: 11/09/2007
Supercedes Date: 08/21/2007

Document Group: 09-5331-5

Product Use:
Specific Use: Part B of 2-Part Acrylic Adhesive
Intended Use: Industrial use

SECTION 2: INGREDIENTS

Ingredient	C.A.S. No.	% by Wt
Tetrahydrofurfuryl Methacrylate	2455-24-5	40 - 70
Acrylonitrile-Butadiene-Styrene Resin	9003-56-9	10 - 30
2-Ethylhexyl Methacrylate	688-84-6	10 - 30
Impact Modifier	20882-04-6	1 - 5
Glass Spheres	68131-74-8	1 - 5
Carbon Black	1333-86-4	0.1 - 1

SECTION 3: HAZARDS IDENTIFICATION

3.1 EMERGENCY OVERVIEW

Odor, Color, Grade: Black, acrylate odor
General Physical Form: Liquid
Immediate health, physical, and environmental hazards: Contains a chemical or chemicals which can cause cancer.

3.2 POTENTIAL HEALTH EFFECTS

Eye Contact:
Moderate Eye Irritation: Signs/symptoms may include redness, swelling, pain, tearing, and blurred or hazy vision.

Vapors released during curing may cause eye irritation. Signs/symptoms may include redness, swelling, pain, tearing, and blurred or hazy vision.

Dust created by cutting, grinding, sanding, or machining may cause eye irritation. Signs/symptoms may include redness, swelling, pain, tearing, and blurred or hazy vision.

Skin Contact:
Moderate Skin Irritation: Signs/symptoms may include localized redness, swelling, itching, and dryness.

Inhalation:
Respiratory Tract Irritation: Signs/symptoms may include cough, sneezing, nasal discharge, headache, hoarseness, and nose and throat pain.

Dust from cutting, grinding, sanding or machining may cause irritation of the respiratory system. Signs/symptoms may include cough, sneezing, nasal discharge, headache, hoarseness, and nose and throat pain.

Ingestion:
Gastrointestinal Irritation: Signs/symptoms may include abdominal pain, stomach upset, nausea, vomiting and diarrhea.

Carcinogenicity:
Contains a chemical or chemicals which can cause cancer.

Ingredient	C.A.S. No.	Class Description	Regulation
Carbon Black	1333-86-4	Group 2B	International Agency for Research on Cancer

SECTION 4: FIRST AID MEASURES

4.1 FIRST AID PROCEDURES

The following first aid recommendations are based on an assumption that appropriate personal and industrial hygiene practices are followed.

Eye Contact: Flush eyes with large amounts of water. If signs/symptoms persist, get medical attention.

Skin Contact: Remove contaminated clothing and shoes. Immediately flush skin with large amounts of water. Get medical attention. Wash contaminated clothing and clean shoes before reuse.

Inhalation: Remove person to fresh air. If signs/symptoms develop, get medical attention.

If Swallowed: Do not induce vomiting unless instructed to do so by medical personnel. Give victim two glasses of water. Never give anything by mouth to an unconscious person. Get medical attention.

SECTION 5: FIRE FIGHTING MEASURES

5.1 FLAMMABLE PROPERTIES

Autoignition temperature	*No Data Available*
Flash Point	218 °F [*Test Method:* Closed Cup]
Flammable Limits - LEL	*No Data Available*
Flammable Limits - UEL	*No Data Available*
OSHA Flammability Classification:	Class IIIB Combustible Liquid

5.2 EXTINGUISHING MEDIA
Use fire extinguishers with class B extinguishing agents (e.g., dry chemical, carbon dioxide).

5.3 PROTECTION OF FIRE FIGHTERS

Special Fire Fighting Procedures: Water may not effectively extinguish fire; however, it should be used to keep fire-exposed containers and surfaces cool and prevent explosive rupture. Water may be used to blanket the fire. Wear full protective equipment (Bunker Gear) and a self-contained breathing apparatus (SCBA).

Unusual Fire and Explosion Hazards: No unusual fire or explosion hazards are anticipated.

Note: See STABILITY AND REACTIVITY (SECTION 10) for hazardous combustion and thermal decomposition information.

SECTION 6: ACCIDENTAL RELEASE MEASURES

Accidental Release Measures: Observe precautions from other sections. Call 3M- HELPS line (1-800-364-3577) for more information on handling and managing the spill. Evacuate unprotected and untrained personnel from hazard area. The spill should be cleaned up by qualified personnel. Ventilate the area with fresh air. For large spill, or spills in confined spaces, provide mechanical ventilation to disperse or exhaust vapors, in accordance with good industrial hygiene practice. Warning! A motor could be an ignition source and could cause flammable gases or vapors in the spill area to burn or explode. Contain spill. For larger spills, cover drains and build dikes to prevent entry into sewer systems or bodies of water. Working from around the edges of the spill inward, cover with bentonite, vermiculite, or commercially available inorganic absorbent material. Mix in sufficient absorbent until it appears dry. Collect as much of the spilled material as possible. Clean up residue with an appropriate solvent selected by a qualified and authorized person. Ventilate the area with fresh air. Read and follow safety precautions on the solvent label and MSDS. Collect the resulting residue containing solution. Place in a closed container approved for transportation by appropriate authorities. Dispose of collected material as soon as possible.

In the event of a release of this material, the user should determine if the release qualifies as reportable according to local, state, and federal regulations.

SECTION 7: HANDLING AND STORAGE

7.1 HANDLING
Avoid eye contact. Do not eat, drink or smoke when using this product. Wash exposed areas thoroughly with soap and water. Keep away from heat, sparks, open flame, pilot lights and other sources of ignition. Avoid skin contact. Avoid breathing of vapors. Avoid static discharge. Keep out of the reach of children. Keep container closed when not in use. Avoid breathing of dust created by cutting, sanding, grinding or machining. For industrial or professional use only. Avoid contact with oxidizing agents. Use general dilution ventilation and/or local exhaust ventilation to control airborne exposures to below Occupational Exposure Limits. If ventilation is not adequate, use respiratory protection equipment.

7.2 STORAGE

Store away from acids. Store away from heat. Store out of direct sunlight. Keep container in well-ventilated area. Keep container tightly closed. Store away from oxidizing agents.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 ENGINEERING CONTROLS

Provide appropriate local exhaust for cutting, grinding, sanding or machining. Use general dilution ventilation and/or local exhaust ventilation to control airborne exposures to below Occupational Exposure Limits and/or control dust, fume, or airborne particles. If ventilation is not adequate, use respiratory protection equipment.

8.2 PERSONAL PROTECTIVE EQUIPMENT (PPE)

8.2.1 Eye/Face Protection

Avoid eye contact.
The following eye protection(s) are recommended: Safety Glasses with side shields.

8.2.2 Skin Protection

Avoid skin contact.

Select and use gloves and/or protective clothing to prevent skin contact based on the results of an exposure assessment. Consult with your glove and/or protective clothing manufacturer for selection of appropriate compatible materials.
Gloves made from the following material(s) are recommended: Butyl Rubber, Nitrile Rubber, Polyethylene, Polyvinyl Alcohol (PVA).

8.2.3 Respiratory Protection

Avoid breathing of vapors. Avoid breathing of dust created by cutting, sanding, grinding or machining.
Select one of the following NIOSH approved respirators based on airborne concentration of contaminants and in accordance with OSHA regulations: Half facepiece or fullface air-purifying respirator with organic vapor cartridges and P95 particulate prefilters, Half facepiece or fullface air-purifying respirator with organic vapor cartridges and N95 particulate prefilters, Half facepiece or fullface air-purifying respirator with organic vapor cartridges and P100 particulate prefilters. Consult the current 3M Respiratory Selection Guide for additional information or call 1-800-243-4630 for 3M technical assistance.

8.2.4 Prevention of Swallowing

Do not eat, drink or smoke when using this product. Wash exposed areas thoroughly with soap and water.

8.3 EXPOSURE GUIDELINES

Ingredient	Authority	Type	Limit	Additional Information
Carbon Black	ACGIH	TWA	3.5 mg/m3	Table A4
Carbon Black	CMRG	TWA	0.5 mg/m3	
Carbon Black	OSHA	TWA	3.5 mg/m3	Table Z-1

SOURCE OF EXPOSURE LIMIT DATA:
ACGIH: American Conference of Governmental Industrial Hygienists
CMRG: Chemical Manufacturer Recommended Guideline
OSHA: Occupational Safety and Health Administration
AIHA: American Industrial Hygiene Association Workplace Environmental Exposure Level (WEEL)

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

Odor, Color, Grade:	Black, acrylate odor
General Physical Form:	Liquid
Autoignition temperature	*No Data Available*
Flash Point	218 ºF [*Test Method:* Closed Cup]
Flammable Limits - LEL	*No Data Available*
Flammable Limits - UEL	*No Data Available*
Boiling point	>=83 ºC [@ 18 mmHg]
Density	0.984 g/ml
Vapor Density	*No Data Available*
Vapor Pressure	<=0.1 mmHg [@ 68 ºF]
Specific Gravity	0.984 [*Ref Std:* WATER=1]
pH	*Not Applicable*
Melting point	*Not Applicable*
Solubility in Water	Negligible
Evaporation rate	*No Data Available*
Volatile Organic Compounds	392 g/l [*Test Method:* tested per EPA method 24A]
Percent volatile	65 - 75 % weight
VOC Less H2O & Exempt Solvents	392 g/l [*Test Method:* tested per EPA method 24A]
Viscosity	13000 - 30000 centipoise [@ 73.4 ºF]

SECTION 10: STABILITY AND REACTIVITY

Stability: Stable.

Materials and Conditions to Avoid: Strong acids; Strong oxidizing agents

Hazardous Polymerization: Hazardous polymerization will not occur.

Hazardous Decomposition or By-Products

Substance	Condition
Hydrocarbons	During Combustion
Carbon monoxide	During Combustion
Carbon dioxide	During Combustion
Hydrogen Cyanide	During Combustion
Oxides of Nitrogen	During Combustion

SECTION 11: TOXICOLOGICAL INFORMATION

Please contact the address listed on the first page of the MSDS for Toxicological Information on this material and/or its components.

SECTION 12: ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION

Not determined.

CHEMICAL FATE INFORMATION

Not determined.

SECTION 13: DISPOSAL CONSIDERATIONS

Waste Disposal Method: Dispose of completely cured (or polymerized) wastes in a sanitary landfill. Incinerate in an industrial or commercial facility in the presence of a combustible material.

EPA Hazardous Waste Number (RCRA): Not regulated

Since regulations vary, consult applicable regulations or authorities before disposal.

SECTION 14:TRANSPORT INFORMATION

ID Number(s):
62-2779-8530-5, 62-2779-9530-4

Please contact the emergency numbers listed on the first page of the MSDS for Transportation Information for this material.

SECTION 15: REGULATORY INFORMATION

US FEDERAL REGULATIONS
Contact 3M for more information.

311/312 Hazard Categories:
Fire Hazard - No Pressure Hazard - No Reactivity Hazard - No Immediate Hazard - Yes Delayed Hazard - Yes

Section 313 Toxic Chemicals subject to the reporting requirements of that section and 40 CFR part 372 (EPCRA):

Ingredient	C.A.S. No	% by Wt
Glass Spheres (VANADIUM COMPOUNDS)	68131-74-8	1 - 5

STATE REGULATIONS
Contact 3M for more information.

CHEMICAL INVENTORIES

The components of this product are in compliance with the chemical notification requirements of TSCA.

All applicable chemical ingredients in this material are listed on the European Inventory of Existing Chemical Substances (EINECS), or are exempt polymers whose monomers are listed on EINECS.

Contact 3M for more information.

INTERNATIONAL REGULATIONS

Contact 3M for more information.

WHMIS: Hazardous

This MSDS has been prepared to meet the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200.

SECTION 16: OTHER INFORMATION

NFPA Hazard Classification

Health: 2 **Flammability:** 1 **Reactivity:** 0 **Special Hazards:** None

National Fire Protection Association (NFPA) hazard ratings are designed for use by emergency response personnel to address the hazards that are presented by short-term, acute exposure to a material under conditions of fire, spill, or similar emergencies. Hazard ratings are primarily based on the inherent physical and toxic properties of the material but also include the toxic properties of combustion or decomposition products that are known to be generated in significant quantities.

Revision Changes:
Section 14: ID Number Heading Template 1 was added.
Section 14: ID Number(s) Template 1 was added.
Section 2: Ingredient table was added.
Section 15: EPCRA 313 information was added.
Section 15: EPCRA 313 text was added.
Section 8: Exposure guidelines ingredient information was added.
Section 8: Exposure guidelines data source legend was added.
Section 3: Carcinogenicity table was added.
Section 3: Carcinogenicity heading was added.

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3M MSDSs are available at www.3M.com

Material Safety Data Sheet

Acetone

Section 1. Chemical product and company identification

Product name	: Acetone
Supplier	: AIRGAS INC., on behalf of its subsidiaries 259 North Radnor-Chester Road Suite 100 Radnor, PA 19087-5283 1-610-687-5253
Synonym	: 2-Propanone; β-Ketopropane; Dimethyl ketone; Dimethylformaldehyde; Methyl ketone; Propanone; Pyroacetic ether; (CH3)2CO; Dimethylketal; Ketone propane; Ketone, dimethyl-; Acetone oil; Chevron acetone; Rcra waste number U002; UN 1090; UN 1091; Sasetone; propan-2-one
Material uses	: Other non-specified industry: CHEMICALS (METHYL ISOBUTYL KETONE, METHYLISOBUTYL CARBINOL; METHYL METHACRYLATE; BISPHENOL-A); PAINT, VARNISH AND LACQUER SOLVENT; CELLULOSE ACETATE, ESPECIALLY AS SPINNING SOLVENT; TO CLEAN AND DRY PARTS OF PRECISION EQUIPMENT; SOLVENT FOR POTASSIUM IODIDE AND PERMANGANATE; DELUSTERANT FOR CELLULOSE ACETATE FIBERS; SPECIFICATION TESTING OF VULCANIZED RUBBER PRODUCTS.
MSDS #	: 001088
Date of Preparation/Revision	: **4/30/2012.**
In case of emergency	: 1-866-734-3438

Section 2. Hazards identification

Physical state	: Liquid. [COLORLESS LIQUID WITH A FRAGRANT, MINT-LIKE ODOR]
Emergency overview	: DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. FLAMMABLE. VAPOR MAY CAUSE FLASH FIRE. MAY CAUSE TARGET ORGAN DAMAGE, BASED ON ANIMAL DATA. Extremely flammable liquid. Keep away from heat, sparks and flame. Avoid breathing vapor or mist. Avoid contact with skin and clothing. May cause target organ damage, based on animal data. Use only with adequate ventilation. Keep container tightly closed and sealed until ready for use.
Target organs	: May cause damage to the following organs: upper respiratory tract, skin, eyes, central nervous system (CNS).
Potential acute health effects	
Eyes	: May cause eye irritation.
Skin	: May cause skin irritation.
Inhalation	: No known significant effects or critical hazards.
Ingestion	: No known significant effects or critical hazards.
Potential chronic health effects	
Target organs	: May cause damage to the following organs: upper respiratory tract, skin, eyes, central nervous system (CNS).
Medical conditions aggravated by over-exposure	: Pre-existing disorders involving any target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

See toxicological information (Section 11)

Section 3. Composition, Information on Ingredients

United States

Name	CAS number	% Volume	Exposure limits
2-Propanone	67-64-1	100	**ACGIH TLV (United States, 1/2008).** STEL: 1782 mg/m³ 15 minute(s). STEL: 750 ppm 15 minute(s). TWA: 1188 mg/m³ 8 hour(s). TWA: 500 ppm 8 hour(s). **NIOSH REL (United States, 6/2008).** TWA: 590 mg/m³ 10 hour(s). TWA: 250 ppm 10 hour(s). **OSHA PEL (United States, 11/2006).** TWA: 2400 mg/m³ 8 hour(s). TWA: 1000 ppm 8 hour(s). **OSHA PEL 1989 (United States, 3/1989).** STEL: 2400 mg/m³ 15 minute(s). STEL: 1000 ppm 15 minute(s). TWA: 1800 mg/m³ 8 hour(s). TWA: 750 ppm 8 hour(s).

Section 4. First aid measures

Eye contact : Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.

Skin contact : In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention immediately.

Inhalation : Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

Ingestion : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention immediately.

Section 5. Fire-fighting measures

Flammability of the product : Flammable.

Auto-ignition temperature : 464.85°C (868.7°F)

Flash point : Closed cup: -18.15°C (-0.7°F).

Flammable limits : Lower: 2.6% Upper: 13%

Products of combustion : Decomposition products may include the following materials:
carbon dioxide
carbon monoxide

Extinguishing media

Suitable : Use dry chemical, CO_2, water spray (fog) or foam.

Not suitable : Do not use water jet.

Special exposure hazards : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Move containers from fire area if this can be done without risk. Use water spray to keep fire-exposed containers cool.

Extremely flammable liquid. In a fire or if heated, a pressure increase will occur and the container may burst, with the risk of a subsequent explosion. The vapor/gas is heavier than air and will spread along the ground. Vapors may accumulate in low or confined areas or travel a considerable distance to a source of ignition and flash back. Runoff to sewer may create fire or explosion hazard.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Shut off all ignition sources. No flares, smoking or flames in hazard area. Avoid breathing vapor or mist. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see Section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Methods for cleaning up : Stop leak if without risk. Move containers from spill area. Approach release from upwind. Prevent entry into sewers, water courses, basements or confined areas. Wash spillages into an effluent treatment plant or proceed as follows. Contain and collect spillage with non-combustible, absorbent material e.g. sand, earth, vermiculite or diatomaceous earth and place in container for disposal according to local regulations (see section 13). Use spark-proof tools and explosion-proof equipment. Dispose of via a licensed waste disposal contractor. Contaminated absorbent material may pose the same hazard as the spilled product. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Section 7. Handling and storage

Handling : Put on appropriate personal protective equipment (see Section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Do not ingest. Avoid contact with eyes, skin and clothing. Avoid breathing vapor or mist. Use only with adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Do not enter storage areas and confined spaces unless adequately ventilated. Keep in the original container or an approved alternative made from a compatible material, kept tightly closed when not in use. Store and use away from heat, sparks, open flame or any other ignition source. Use explosion-proof electrical (ventilating, lighting and material handling) equipment. Use non-sparking tools. Take precautionary measures against electrostatic discharges. To avoid fire or explosion, dissipate static electricity during transfer by grounding and bonding containers and equipment before transferring material. Empty containers retain product residue and can be hazardous. Do not reuse container.

Storage : Store in accordance with local regulations. Store in a segregated and approved area. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Eliminate all ignition sources. Separate from oxidizing materials. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

Section 8. Exposure controls/personal protection

Recommended monitoring procedures : If this product contains ingredients with exposure limits, personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.

Engineering measures : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. The engineering controls also need to keep gas, vapor or dust concentrations below any lower explosive limits. Use explosion-proof ventilation equipment.

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

Personal protection

Eyes	: Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.
Skin	: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Respiratory	: Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.
Hands	: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.
Personal protection in case of a large spill	: Self-contained breathing apparatus (SCBA) should be used to avoid inhalation of the product.

Product name	**Exposure limits**
United States	
2-Propanone	**ACGIH TLV (United States, 1/2008).** STEL: 1782 mg/m³ 15 minute(s). STEL: 750 ppm 15 minute(s). TWA: 1188 mg/m³ 8 hour(s). TWA: 500 ppm 8 hour(s). **NIOSH REL (United States, 6/2008).** TWA: 590 mg/m³ 10 hour(s). TWA: 250 ppm 10 hour(s). **OSHA PEL (United States, 11/2006).** TWA: 2400 mg/m³ 8 hour(s). TWA: 1000 ppm 8 hour(s). **OSHA PEL 1989 (United States, 3/1989).** STEL: 2400 mg/m³ 15 minute(s). STEL: 1000 ppm 15 minute(s). TWA: 1800 mg/m³ 8 hour(s). TWA: 750 ppm 8 hour(s).

Section 9. Physical and chemical properties

Physical state	: Liquid. [COLORLESS LIQUID WITH A FRAGRANT, MINT-LIKE ODOR]
Odor	: RESIDUAL; KETONIC, PLEASANT, NON-RESIDUAL
Molecular weight	: 58.09 g/mole
Molecular formula	: C3-H6-O
Boiling/condensation point	: 56.1°C (133°F)
Melting/freezing point	: -94.2°C (-137.6°F)
Critical temperature	: 234.9°C (454.8°F)
Specific gravity	: 0.791 (Water = 1)
Vapor density	: 2 (Air = 1)
Evaporation rate	: 6.06 compared with butyl acetate
VOC	: NA

Section 10. Stability and reactivity

Stability and reactivity	: The product is stable.
Incompatibility with various substances	: Extremely reactive or incompatible with the following materials: oxidizing materials.
Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Hazardous polymerization	: Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Toxicity data

Product/ingredient name	Result	Species	Dose	Exposure
2-Propanone	LD50 Intravenous	Rat	5500 mg/kg	-
	LD50 Oral	Rat	5800 mg/kg	-
	LDLo Intraperitoneal	Rat	500 mg/kg	-
	LDLo Dermal	Rabbit	20 mL/kg	-
	TDLo Oral	Rat	5 mL/kg	-
	LC50 Inhalation Vapor	Rat	50100 mg/m3	8 hours
	LC50 Inhalation Vapor	Rat	59528 ppm	1 hours

IDLH : 2500 ppm

Chronic effects on humans : **CARCINOGENIC EFFECTS**: A4 (Not classifiable for humans or animals.) by ACGIH. May cause damage to the following organs: upper respiratory tract, skin, eyes, central nervous system (CNS).

Other toxic effects on humans : Hazardous by the following route of exposure: of eye contact (irritant).

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Reproduction toxicity : No known significant effects or critical hazards.

Section 12. Ecological information

Aquatic ecotoxicity

2-Propanone	-	Acute LC50 6900 mg/L Fresh water	Daphnia - Water flea - Daphnia magna	48 hours
	-	Acute LC50 5.54 to 6.33 ml/L Fresh water	Fish - Rainbow trout,donaldson trout - Oncorhynchus mykiss - 1 g	96 hours
	-	Acute LC50 12100000 ug/L Fresh water	Daphnia - Water flea - Daphnia magna - <24 hours	48 hours
	-	Acute LC50 11000000 to 11300000 ug/L Marine water	Fish - Bleak - Alburnus alburnus - 8 cm	96 hours
	-	Acute LC50 10700000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 25 mm	96 hours
	-	Acute LC50 9218000 to 14400000 ug/L Fresh water	Daphnia - Water flea - Daphnia magna - Neonate - <12 hours	48 hours
	-	Acute LC50 9100000 to 9482000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 2 to 3 months - 19 mm - 0.06 g	96 hours
	-	Acute LC50 8800000 ug/L Fresh water	Daphnia - Water flea - Daphnia pulex - <24 hours	48 hours
	-	Acute LC50 8300000 ug/L Fresh water	Fish - Bluegill - Lepomis	96 hours

Acetone

			macrochirus - 5.3 to 7.2 cm - 3.5 to 3.9 g	
	-	Acute LC50 8120000 to 8760000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 33 days - 22.6 mm - 0.159 g	96 hours
	-	Acute LC50 8098000 to 8640000 ug/L Fresh water	Daphnia - Water flea - Ceriodaphnia dubia - Neonate - <12 hours	48 hours
	-	Acute LC50 7810000 ug/L Fresh water	Daphnia - Water flea - Daphnia cucullata - 11 days	48 hours
	-	Acute LC50 7550000 ug/L Fresh water	Crustaceans - Aquatic sowbug - Asellus aquaticus	48 hours
	-	Acute LC50 7460000 ug/L Fresh water	Daphnia - Water flea - Daphnia cucullata - 11 days	48 hours
	-	Acute LC50 7280000 to 7880000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 28 days - 19.2 mm - 0.076 g	96 hours
	-	Acute LC50 6210000 to 7030000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 32 days - 18 mm - 0.087 g	96 hours
	-	Acute LC50 >100000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - Juvenile (Fledgling, Hatchling, Weanling) - 0.2 to 0.5 g	96 hours
	-	Acute LC50 10000 ug/L Fresh water	Daphnia - Water flea - Daphnia magna	48 hours
	-	Acute LC50 13300000 ug/L Fresh water	Daphnia - Water flea - Daphnia magna - <24 hours	48 hours
	-	Acute LC50 12600000 ug/L Fresh water	Daphnia - Water flea - Daphnia magna - <24 hours	48 hours

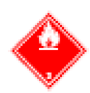
Products of degradation :

Section 13. Disposal considerations

Waste disposal : The generation of waste should be avoided or minimized wherever possible. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe way. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.

Product removed from the cylinder must be disposed of in accordance with appropriate Federal, State, local regulation.Return cylinders with residual product to Airgas, Inc.Do not dispose of locally.

Section 14. Transport information

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN1090	ACETONE	3	II		**Reportable quantity** 5000 lbs. (2270 kg) **Limited quantity** Yes. **Packaging instruction** **Passenger aircraft** Quantity limitation: 5 L **Cargo aircraft** Quantity limitation: 60 L **Special provisions** IB2, T4, TP1
TDG Classification	UN1090	ACETONE	3	II		**Explosive Limit and Limited Quantity Index** 1 **Passenger Carrying Ship Index** Forbidden **Passenger Carrying Road or Rail Index** 5

Acetone						
Mexico Classification	UN1090	ACETONE	3	II		**<u>Reportable quantity</u>** 5000 lbs. (2270 kg) **<u>Limited quantity</u>** Yes. **<u>Packaging instruction</u>** **Passenger aircraft** Quantity limitation: 5 L **Cargo aircraft** Quantity limitation: 60 L **<u>Special provisions</u>** IB2, T4, TP1

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Section 15. Regulatory information

United States

HCS Classification : Flammable liquid
Target organ effects

U.S. Federal regulations : **United States inventory (TSCA 8b):** This material is listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: 2-Propanone
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: 2-Propanone: Fire hazard, Immediate (acute) health hazard, Delayed (chronic) health hazard

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

State regulations : **Connecticut Carcinogen Reporting:** This material is not listed.
Connecticut Hazardous Material Survey: This material is not listed.
Florida substances: This material is not listed.
Illinois Chemical Safety Act: This material is not listed.
Illinois Toxic Substances Disclosure to Employee Act: This material is not listed.
Louisiana Reporting: This material is not listed.
Louisiana Spill: This material is not listed.
Massachusetts Spill: This material is not listed.
Massachusetts Substances: This material is listed.
Michigan Critical Material: This material is not listed.
Minnesota Hazardous Substances: This material is not listed.
New Jersey Hazardous Substances: This material is listed.
New Jersey Spill: This material is not listed.
New Jersey Toxic Catastrophe Prevention Act: This material is not listed.
New York Acutely Hazardous Substances: This material is listed.
New York Toxic Chemical Release Reporting: This material is not listed.
Pennsylvania RTK Hazardous Substances: This material is listed.
Rhode Island Hazardous Substances: This material is not listed.

Canada

WHMIS (Canada) : Class B-2: Flammable liquid
Class D-2B: Material causing other toxic effects (Toxic).

CEPA Toxic substances: This material is listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

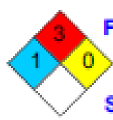
Section 16. Other information

Label requirements : EXTREMELY FLAMMABLE LIQUID AND VAPOR. FLAMMABLE. VAPOR MAY CAUSE FLASH FIRE. MAY CAUSE TARGET ORGAN DAMAGE, BASED ON ANIMAL DATA.

Hazardous Material Information System (U.S.A.) :

Health	*	1
Flammability		3
Physical hazards		0

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

Health 

Flammability
Instability
Special

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

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MATERIAL SAFETY DATA SHEET

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ProX Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: 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:	260°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

Material Safety Data Sheet

Revision Number: 005.0 **Issue date:** 04/19/2013

1. PRODUCT AND COMPANY IDENTIFICATION

Product name:	**FREKOTE® FMS™MOLD SEALER PART NO. 38413**	**IDH number:**	548976
Product type:	Mold Release	**Item number:**	38413
		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

Contains one or more components for which a Toxic Substances Control Act (TSCA) Low Volume Exemption (LVE) applies. See Section 15.

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

HMIS:

Physical state:	Liquid	**HEALTH:**	*2
Color:	Colorless	**FLAMMABILITY:**	3
Odor:	Mild, Solvent	**PHYSICAL HAZARD:**	0
		Personal Protection:	See MSDS Section 8

WARNING: FLAMMABLE LIQUID AND VAPOR.
ASPIRATION HAZARD IF SWALLOWED.
CAN ENTER LUNGS AND CAUSE DAMAGE.
CAUSES EYE, SKIN AND RESPIRATORY TRACT IRRITATION.
MAY CAUSE CENTRAL NERVOUS SYSTEM EFFECTS.

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

Potential Health Effects

Inhalation: Vapors and mists will irritate nose and throat and possibly eyes. High vapor concentrations (greater then approximately 1000 ppm) may cause headaches, dizziness, anesthesia, drowsiness, unconsciousness, and other central nervous system effects, including death.

Skin contact: Solvent action can dry and defat the skin, causing the skin to crack, leading to dermatitis.

Eye contact: Moderate eye irritation. Liquid or vapor can cause moderate to severe irritation.

Ingestion: May be harmful if swallowed. Aspiration may occur during swallowing or vomiting, resulting in lung damage. Central nervous system depression, including dizziness, drowsiness, fatigue, nausea, headache, unconsciousness.

Existing conditions aggravated by exposure: Dermatitis. Eczema. Other pre-existing skin conditions. Asthma. Other respiratory disorders (bronchitis, emphysema, bronchial hyperreactivity).

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	%
Hydrotreated heavy naphtha	64742-48-9	60 - 100
Dibutyl ether	142-96-1	10 - 30
Octane	111-65-9	1 - 5
Proprietary Resin	Proprietary	1 - 5

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). If skin irritation persists, call a physician. Wash clothing before reuse.

Eye contact: Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get immediate medical attention.

Ingestion: Keep individual calm. Do not induce vomiting: contains petroleum distillates and/or aromatic solvents. If vomiting occurs, prevent aspiration by keeping the patient's head below the knees. Get immediate medical attention.

5. FIRE FIGHTING MEASURES

Flash point: 31 °C (87.8 °F)

Autoignition temperature: Not available.

Flammable/Explosive limits - lower: 1.5 % (value for solvent)

Flammable/Explosive limits - upper: 7.6 % (value for solvent)

Extinguishing media: Water spray (fog), foam, dry chemical or carbon dioxide. Do not use high volume water jet.

Special firefighting procedures: Keep personnel upwind of fire. Wear self-contained breathing apparatus and full protective clothing, such as turn-out gear. Water may be unsuitable as an extinguishing media, but may be helpful in keeping adjacent containers cool.

Unusual fire or explosion hazards: Vapors may form explosive mixtures with air. Hydrocarbon solvents are basically non-conductors of electricity and can become electrostatically charged during mixing, filtering or pumping at high flow rates. If this charge reaches a significantly high level, sparks can form that may ignite vapors of flammable liquids. Do not handle or store near an open flame, heat or other sources of ignition.

Hazardous combustion products: Oxides of carbon. Irritating organic vapours. Collect contaminated fire extinguishing water separately. This must not be discharged into drains.

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: Prevent further leakage or spillage if safe to do so. This product is insoluble in water and will float on surface. Do not allow product to enter sewer or waterways. Advise authorities if product has entered or may enter sewers, water sources or extensive land areas.

Clean-up methods: Ventilate area. Remove all sources of ignition. Keep upwind of the spilled material and isolate exposure. Wear suitable protective clothing, gloves and eye/face protection. Use non-sparking tools for clean-up. Soak up with inert absorbent material (e.g. sand, silica gel, acid binder, universal binder, sawdust). Store in a partly filled, closed container until disposal.

7. HANDLING AND STORAGE

Handling: Do not breathe gas/fumes/vapor/spray. For operations where eye or face contact could occur, provide safety shower and eyewash fountain. Avoid contact with eyes, skin and clothing. During use and until all vapors are gone: Keep area ventilated - do not smoke; extinguish all flames, pilot lights, and heaters; turn off stoves, electrical tools and appliances, and any other sources of ignition. Make sure containers are properly grounded before use or transfer of material. Wash thoroughly after handling.

Storage: For safe storage, store between 5 °C (41°F) and 25 °C (77°F)
Store away from heat, sparks, flames, or other sources of ignition. Keep container closed.

For information on product shelf life contact Henkel Customer Service at (800) 243-4874.

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
Hydrotreated heavy naphtha	None	None	None	196 ppm TWA
Dibutyl ether	None	None	None	None
Octane	300 ppm TWA	500 ppm (2,350 mg/m3) TWA	None	None
Proprietary Resin	None	None	None	None

Engineering controls: Use explosion-proof mechanical ventilation and local exhaust to control contaminants to within their occupational exposure limits during the use of this product.

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

Eye/face protection: Safety goggles or safety glasses with side shields. Full face protection should be used if the potential for splashing or spraying of product exists. Safety showers and eye wash stations should be available.

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: Colorless
Odor: Mild, Solvent
Odor threshold: Not available.
pH: Not available.
Vapor pressure: Not available.
Boiling point/range: 141 °C (285.8 °F) (1,013 hPa)
Melting point/ range: Not determined
Specific gravity: 0.754
Vapor density: Heavier than air.
Flash point: 31 °C (87.8 °F)
Flammable/Explosive limits - lower: 1.5 % (value for solvent)
Flammable/Explosive limits - upper: 7.6 % (value for solvent)
Autoignition temperature: Not available.
Evaporation rate: Slower than ether.

Solubility in water:	Not miscible or difficult to mix
Partition coefficient (n-octanol/water):	Not available.
VOC content:	99.25 %; 749 g/l

10. STABILITY AND REACTIVITY

Stability:	Risk of ignition.May form explosive peroxides with prolonged exposure to air or oxygen, especially under anhydrous conditions.Stable under normal conditions of storage and use.
Hazardous reactions:	Will not occur.
Hazardous decomposition products:	Peroxides. Hydrocarbons.
Incompatible materials:	Strong acids and strong bases. Strong oxidizing agents. Reacts with air to form peroxides.
Conditions to avoid:	Avoid static discharge. Will slowly degrade with exposure to oxygen (air). Spray mist may be flammable at temperatures below the flash point. Keep away from open flames, hot surfaces and sources of ignition. Vapors may form explosive mixtures with air. Fire or intense heat may cause violent rupture of packages. Direct sunlight.

11. TOXICOLOGICAL INFORMATION

Hazardous components	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen (Specifically Regulated)
Hydrotreated heavy naphtha	No	No	No
Dibutyl ether	No	No	No
Octane	No	No	No
Proprietary Resin	No	No	No

Hazardous components	Health Effects/Target Organs
Hydrotreated heavy naphtha	Irritant
Dibutyl ether	Irritant, Central nervous system, Cardiac, Kidney, Gastrointestinal, Mutagen
Octane	Central nervous system, Irritant, Lung
Proprietary Resin	No Data

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:	D001: Ignitable.

14. TRANSPORT INFORMATION

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

Proper shipping name:	Resin solution
Hazard class or division:	3
Identification number:	UN 1866
Packing group:	III

International Air Transportation (ICAO/IATA)

Proper shipping name:	Resin solution
Hazard class or division:	3
Identification number:	UN 1866
Packing group:	III

Water Transportation (IMO/IMDG)

Proper shipping name:	RESIN SOLUTION (Octane)
Hazard class or division:	3
Identification number:	UN 1866
Packing group:	III
Marine pollutant:	Octane

15. REGULATORY INFORMATION

United States Regulatory Information

TSCA 8 (b) Inventory Status:	All components of this product are listed on the U.S. Toxic Substances Control Act (TSCA) Inventory or are exempt from listing because a Low Volume Exemption (LVE) has been granted in accordance with 40 CFR 723.50.
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, Fire
CERCLA/SARA 313:	None above reporting de minimis
CERCLA Reportable quantity:	Dibutyl ether (CAS# 142-96-1) 100 lbs. (45.4 kg) Octane (CAS# 111-65-9) 100 lbs. (45.4 kg)
California Proposition 65:	No California Proposition 65 listed chemicals are known to be present.

Canada Regulatory Information

CEPA DSL/NDSL Status:	One or more components are not listed on, and are not exempt from listing on either the Domestic Substances List or the Non-Domestic Substances List.
WHMIS hazard class:	B.2, D.2.B

16. OTHER INFORMATION

This material safety data sheet contains changes from the previous version in sections: This Material Safety Data Sheet contains changes from the previous version in Section(s): 15, 16

Prepared by: Michele Oltra, Regulatory Affairs Specialist

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Material Safety Data Sheet

Revision Number: 001.0

Issue date: 10/17/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name:	**FREKOTE 770-NC AEROSOL/400ML**	**IDH number:**	398489
Product type:	Mold Release	**Item number:**	83469
		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

Contains one or more components for which a Toxic Substances Control Act (TSCA) Low Volume Exemption (LVE) applies. See Section 15.

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

HMIS:

Physical state:	Aerosol	**HEALTH:**	*1
Color:	Clear colorless	**FLAMMABILITY:**	4
Odor:	Slight	**PHYSICAL HAZARD:**	0
		Personal Protection:	See MSDS Section 8

DANGER: EXTREMELY FLAMMABLE LIQUID AND VAPOR.
VAPOR MAY CAUSE FLASH FIRE.
CONTENTS UNDER PRESSURE.
MAY CAUSE CENTRAL NERVOUS SYSTEM EFFECTS.
CAUSES EYE, SKIN AND RESPIRATORY TRACT IRRITATION.

Relevant routes of exposure: Skin, Inhalation, Eyes

Potential Health Effects

Inhalation: Vapors and mists will irritate nose and throat and possibly eyes. High vapor concentrations (greater then approximately 1000 ppm) may cause headaches, dizziness, anesthesia, drowsiness, unconsciousness, and other central nervous system effects, including death.

Skin contact: Solvent action can dry and defat the skin, causing the skin to crack, leading to dermatitis.

Eye contact: Vapors may irritate eyes. Contact with eyes will cause irritation.

Ingestion: May cause central nervous system effects, such as headache, nausea, vomiting, abdominal pain, dizziness, confusion, and breathing difficulties.

Existing conditions aggravated by exposure: Dermatitis. Eczema. Other pre-existing skin conditions. Asthma. Other respiratory disorders (bronchitis, emphysema, bronchial hyperreactivity).

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	%
Alkanes, C7-10-iso-	90622-56-3	60 - 100
Propane	74-98-6	10 - 30
Naphtha (petroleum), light alkylate	64741-66-8	10 - 30
Proprietary Resin	Unknown	1 - 5

4. FIRST AID MEASURES

Inhalation: Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. Get immediate 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. Wash clothing before reuse.

Eye contact: Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get medical attention.

Ingestion: Keep individual calm. Do not induce vomiting: contains petroleum distillates and/or aromatic solvents. If vomiting occurs, prevent aspiration by keeping the patient's head below the knees. Get immediate medical attention.

Notes to physician: This material is an aspiration hazard. Potential danger from aspiration must be weighed against possible oral toxicity when deciding whether to induce vomiting.

5. FIRE FIGHTING MEASURES

Flash point: Flammable by flame extension.

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. Do not use high volume water jet.

Special firefighting procedures: Wear self-contained breathing apparatus and full protective clothing, such as turn-out gear. Water may be unsuitable as an extinguishing media, but may be helpful in keeping adjacent containers cool. Keep personnel upwind of fire.

Unusual fire or explosion hazards: Contents under pressure. Do not puncture or incinerate pressurized containers. Containers exposed to fire should be cooled with water to prevent vapor pressure buildup which could result in container rupture. If a leak or spill has not ignited, use water spray to disperse vapors. The liquid is volatile and gives off invisible vapors. Do not handle or store near an open flame, heat or other sources of ignition. Hydrocarbon solvents are basically non-conductors of electricity and can become electrostatically charged during mixing, filtering or pumping at high flow rates. If this charge reaches a significantly high level, sparks can form that may ignite vapors of flammable liquids. Vapors may form explosive mixtures with air.

Hazardous combustion products: Oxides of carbon. Acrid smoke and fumes. Collect contaminated fire extinguishing water separately. This must not be discharged into drains.

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. Advise authorities if product has entered or may enter sewers, water sources or extensive land areas. This product is insoluble in water and will float on surface.

Clean-up methods: Remove all sources of ignition. Ventilate area. Keep upwind of the spilled material and isolate exposure. Soak up with inert absorbent material (e.g. sand, silica gel, acid binder, universal binder, sawdust). Store in a partly filled, closed container until disposal. Vapors are heavier than air and may travel along the ground or be moved by ventilation and subsequently ignited by heat, pilot lights or other ignition sources at locations distant from the material handling point. Refer to Section 8 "Exposure Controls / Personal Protection" prior to clean up.

7. HANDLING AND STORAGE

Handling: During use and until all vapors are gone: Keep area ventilated - do not smoke; extinguish all flames, pilot lights, and heaters; turn off stoves, electrical tools and appliances, and any other sources of ignition. Prevent contact with eyes, skin and clothing. Do not breathe vapor and mist. Wash thoroughly after handling. Do not taste or swallow. Do not puncture or incinerate pressurized containers. Refer to Section 8. For operations where eye or face contact could occur, provide safety shower and eyewash fountain.

Storage: For safe storage, store at or below 48.8 °C (119.8 °F)
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 contact Henkel Customer Service at (800) 243-4874.

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
Alkanes, C7-10-iso-	None	None	None	None
Propane	1,000 ppm TWA	1,000 ppm (1,800 mg/m3) TWA	None	None
Naphtha (petroleum), light alkylate	None	None	None	261 ppm TWATotal Hydrocarbons
Proprietary Resin	None	None	None	None

Engineering controls: Use explosion-proof mechanical ventilation and local exhaust to control contaminants to within their occupational exposure limits during the use of this product.

Respiratory protection: Use a NIOSH approved supplied air respirator with an organic cartridge if the potential to exceed established exposure limits exists.

Eye/face protection: Safety goggles or safety glasses with side shields. Full face protection should be used if the potential for splashing or spraying of product exists. Safety showers and eye wash stations should be available.

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

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	Aerosol
Color:	Clear colorless
Odor:	Slight
Odor threshold:	Not available.
pH:	Not available.
Vapor pressure:	Not available.
Boiling point/range:	Compressed Gas.
Melting point/ range:	Not determined
Specific gravity:	0.712
Vapor density:	Heavier than air.
Flash point:	Flammable by flame extension.
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Autoignition temperature:	Not available.
Evaporation rate:	Not determined
Solubility in water:	Insoluble
Partition coefficient (n-octanol/water):	Not determined
VOC content:	90.55 %; 644 g/l

10. STABILITY AND REACTIVITY

Stability:	Risk of ignition.
Hazardous reactions:	Will not occur.
Hazardous decomposition products:	Oxides of carbon. Hydrocarbons. Irritating organic vapours.
Incompatible materials:	Strong oxidizing agents. Humid air. Water.
Conditions to avoid:	Keep away from open flames, hot surfaces and sources of ignition. Do not puncture, incinerate, or expose to temperatures above 48.9 °C (120 °F). Vapors may form explosive mixtures with air. Exposure to air or moisture over prolonged periods. Fire or intense heat may cause violent rupture of packages. Store away from incompatible materials.

11. TOXICOLOGICAL INFORMATION

Hazardous components	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen (Specifically Regulated)
Alkanes, C7-10-iso-	No	No	No
Propane	No	No	No
Naphtha (petroleum), light alkylate	No	No	No
Proprietary Resin	No	No	No

Hazardous components	Health Effects/Target Organs
Alkanes, C7-10-iso-	Central nervous system, Irritant, Lung, Cardiac
Propane	Cardiac, Central nervous system, Irritant
Naphtha (petroleum), light alkylate	Irritant
Proprietary Resin	No Data

12. ECOLOGICAL INFORMATION

Ecological information:	Not available.

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

Recommended method of disposal:	Do not puncture or incinerate pressurized containers. Dispose of according to Federal, State and local governmental regulations.
Hazardous waste number:	D001: Ignitable.

14. TRANSPORT INFORMATION

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

Proper shipping name:	Aerosols
Hazard class or division:	2.1
Identification number:	UN 1950
Packing group:	None

International Air Transportation (ICAO/IATA)

Proper shipping name:	Aerosols, flammable
Hazard class or division:	2.1
Identification number:	UN 1950
Packing group:	None

Water Transportation (IMO/IMDG)

Proper shipping name:	AEROSOLS
Hazard class or division:	2.1
Identification number:	UN 1950
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:	Fire, Pressure, Immediate Health, Delayed Health
CERCLA/SARA 313:	None above reporting de minimis
CERCLA Reportable quantity:	Propane (CAS# 74-98-6) 100 lbs. (45.4 kg)
California Proposition 65:	No California Proposition 65 listed chemicals are known to be present.

Canada Regulatory Information

CEPA DSL/NDSL Status:	One or more components are not listed on, and are not exempt from listing on either the Domestic Substances List or the Non-Domestic Substances List.
WHMIS hazard class:	A, B.5, D.2.B

16. OTHER INFORMATION

This material safety data sheet contains changes from the previous version in sections: First issue.

Prepared by: Michele Oltra, Regulatory Affairs Specialist

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MATERIAL SAFETY DATA SHEET

Product: Heat Shrink Tubing

1. PRODUCT AND COMPANY IDENTIFICATION
PRODUCT NAME: (Composite) Heat Shrinkable Tubing
PRODUCT DESCRIPTION: Flame Retarded Heat Shrinkable Tubing
PRODUCT CODE: Comp-Shrink

EMERGENCY TELEPHONE NUMBERS
Soller Composites, LLC
87 Hill Rd
Franklin, NH 03235
www.sollercomposites.com
603 998 1947
Emergency Phone: 603 998 1947 9:00 am – 9:00 pm EST

2. HAZARDS IDENTIFICATION
The flame-retarded chemicals inside the tubing do not contain toxic elements (i.e. Cadmium and Lead). However, if the tubing is overheated or burned, harmful vapors may be released. Under normal conditions of processing and handling, the product is stable and no likelihood of exposure exists.

3. PHYSICAL AND CHEMCIAL DATA
NORMAL CONDITION – Solid State
BOILING POINT – Not applicable
MELTING POINT – Base polymer 90°C, Tubing will not melt at 90°C.
SPECIFIC GRAVITY – 1.35-1.40
VAPOR DENSITY (AIR = 1) – Not applicable
EVAPORATION RATE (BUTYL ACETATE = 1) – Not applicable
SOLUBILITY IN WATER – Negligible
APPEARANCE & ODOR – All in tubing form. Odorless

4. FIRE FIGHTING MEASURES
FLASH POINT: >200°C
FLAMMABLE LIMITS IN AIR: Not applicable
FLAMMABILITY: The outer jacket is self-extinguishing.

5. REACTIVITY DATA
STABILITY: Stable
CONDITIONS TO AVOID: Avoid overheating and burning
INCOMPATIBILTY: Organic solvents
HAZARDOUS DECOMPOSTION PRODUCTS: None in normal operation
HAZARDOUS POLYMERIZATION: Will not occur

6. HEALTH HAZARD INFORMATION
INHALATION: No hazard under normal operating condition
INGESTION: Non digestible
SKIN: May cause thermal burns when heated. In rare cases, may cause skin irritation.
EYES: Not applicable
UNUSUAL CHRONIC TOXICITY: No known associated with the industrial use of this product
SIGNS AND SYMPTOMS OF EXPOSURE: Not applicable

7. FIRST AID MEASURES
THERMAL BURNS: Cool rapidly with fresh water. Consult a physician

8. PRECAUTIONS AND SAFE HANDLING PROCEDURES
SPILL OR LEAK: Collect in container
STORAGE: Store in dry place, avoid excessive heat
WASTE DISPOSAL: Local disposal regulation (Not recyclable)
OTHER PRECAUTIONS: None

9. CONTROL MEASURES
VENTILATION: General ventilation is adequate under normal manufacturing environment
PROTECTIVE GLOVES: Necessary when handling the heated tubing
PROTECTIVE CLOTHING: Not necessary under operating condition. Wash hands after working with tubing.

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Material Safety Data Sheet

Airgas

Isopropyl Alcohol (Isopropanol)

Section 1. Chemical product and company identification

Product name : Isopropyl Alcohol (Isopropanol)

Supplier : AIRGAS INC., on behalf of its subsidiaries
259 North Radnor-Chester Road
Suite 100
Radnor, PA 19087-5283
1-610-687-5253

Synonym : 2-Propanol; sec-Propyl Alcohol; Alcojel; Alcosolve 2; Avantin; Avantine; Combi-Schutz; Dimethylcarbinol; Hartosol; Imsol A; Isohol; Isopropanol; Lutosol; Petrohol; Propol; PRO; Takineocol; 1-Methylethyl Alcohol; iso-C3H7OH; 2-Hydroxypropane; Propane, 2-hydroxy-; sec-Propanol; Propan-2-ol; i-Propylalkohol; Alcohol, rubbing; Alcolo; Alcool isopropilico; Alcool isopropylique; Alkolave; Arquad DMCB; iso-Propylalkohol; Isopropyl alcohol, rubbing; IPA; Lavacol; Visco 1152; Alcosolve; Chromar; i-Propanol; 2-Propyl alcohol; Spectrar; Sterisol hand disinfectant; UN 1219; (-)-2,3-O-Isopropyl alcohol; Alcohol; Alcowipe; DuPont zonyl FSA fluorinated surfactants; DuPont zonyl FSJ fluorinated surfactants; DuPont zonyl FSN fluorinated surfactants; DuPont zonyl FSP fluorinated surfactants; I.P.S.; n-Propan-2-ol; Rubbing alcohol; Sec-propyl; Sterets pre-injection swabs; 1-methylethanol; Propanol-2

MSDS # : 001105

Date of Preparation/Revision : **4/25/2013.**

In case of emergency : 1-866-734-3438

Section 2. Hazards identification

Physical state : Liquid. [COLORLESS LIQUID WITH THE ODOR OF RUBBING ALCOHOL]

Emergency overview : WARNING!

FLAMMABLE LIQUID AND VAPOR. MAY CAUSE TARGET ORGAN DAMAGE, BASED ON ANIMAL DATA.

Flammable liquid. Keep away from heat, sparks and flame. Avoid breathing vapor or mist. Avoid contact with skin and clothing. May cause target organ damage, based on animal data. Use only with adequate ventilation. Keep container tightly closed and sealed until ready for use.

Target organs : May cause damage to the following organs: upper respiratory tract, skin, eyes, central nervous system (CNS).

Potential acute health effects

Eyes : Irritating to eyes.

Skin : Irritating to skin.

Inhalation : Harmful by inhalation.

Ingestion : Harmful if swallowed.

Potential chronic health effects

Target organs : May cause damage to the following organs: upper respiratory tract, skin, eyes, central nervous system (CNS).

Medical conditions aggravated by over-exposure : Pre-existing disorders involving any target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

See toxicological information (Section 11)

Section 3. Composition, Information on Ingredients

United States

Name	CAS number	% Volume	Exposure limits
Isopropyl alcohol	67-63-0	100	**ACGIH TLV (United States, 1/2009).** TWA: 200 ppm 8 hour(s). STEL: 400 ppm 15 minute(s). **OSHA PEL 1989 (United States, 3/1989).** TWA: 400 ppm 8 hour(s). TWA: 980 mg/m³ 8 hour(s). STEL: 500 ppm 15 minute(s). STEL: 1225 mg/m³ 15 minute(s). **NIOSH REL (United States, 6/2009).** TWA: 400 ppm 10 hour(s). TWA: 980 mg/m³ 10 hour(s). STEL: 500 ppm 15 minute(s). STEL: 1225 mg/m³ 15 minute(s). **OSHA PEL (United States, 11/2006).** TWA: 400 ppm 8 hour(s). TWA: 980 mg/m³ 8 hour(s).

Section 4. First aid measures

Eye contact : Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.

Skin contact : In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention immediately.

Inhalation : Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

Ingestion : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention immediately.

Section 5. Fire-fighting measures

Flammability of the product : Flammable.

Auto-ignition temperature : 399°C (750.2°F)

Flash point : Open cup: 11.85°C (53.3°F).

Flammable limits : Lower: 2% Upper: 12%

Products of combustion : Decomposition products may include the following materials:
carbon dioxide
carbon monoxide

Extinguishing media

Suitable : Use dry chemical, CO_2, water spray (fog) or foam.

Not suitable : Do not use water jet.

Special exposure hazards : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Move containers from fire area if this can be done without risk. Use water spray to keep fire-exposed containers cool.

Flammable liquid. In a fire or if heated, a pressure increase will occur and the container may burst, with the risk of a subsequent explosion. The vapor/gas is heavier than air and will spread along the ground. Vapors may accumulate in low or confined areas or travel a considerable distance to a source of ignition and flash back. Runoff to sewer may create fire or explosion hazard.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Shut off all ignition sources. No flares, smoking or flames in hazard area. Avoid breathing vapor or mist. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see Section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Methods for cleaning up : Stop leak if without risk. Move containers from spill area. Approach release from upwind. Prevent entry into sewers, water courses, basements or confined areas. Wash spillages into an effluent treatment plant or proceed as follows. Contain and collect spillage with non-combustible, absorbent material e.g. sand, earth, vermiculite or diatomaceous earth and place in container for disposal according to local regulations (see section 13). Use spark-proof tools and explosion-proof equipment. Dispose of via a licensed waste disposal contractor. Contaminated absorbent material may pose the same hazard as the spilled product. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Section 7. Handling and storage

Handling : Put on appropriate personal protective equipment (see Section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Do not ingest. Avoid contact with eyes, skin and clothing. Avoid breathing vapor or mist. Use only with adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Do not enter storage areas and confined spaces unless adequately ventilated. Keep in the original container or an approved alternative made from a compatible material, kept tightly closed when not in use. Store and use away from heat, sparks, open flame or any other ignition source. Use explosion-proof electrical (ventilating, lighting and material handling) equipment. Use non-sparking tools. Take precautionary measures against electrostatic discharges. To avoid fire or explosion, dissipate static electricity during transfer by grounding and bonding containers and equipment before transferring material. Empty containers retain product residue and can be hazardous. Do not reuse container.

Storage : Store in accordance with local regulations. Store in a segregated and approved area. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Eliminate all ignition sources. Separate from oxidizing materials. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

Section 8. Exposure controls/personal protection

Recommended monitoring procedures : If this product contains ingredients with exposure limits, personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.

Engineering measures : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. The engineering controls also need to keep gas, vapor or dust concentrations below any lower explosive limits. Use explosion-proof ventilation equipment.

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

Personal protection

Isopropyl Alcohol (Isopropanol)

Eyes	: Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.
Skin	: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Respiratory	: Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.
Hands	: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.
Personal protection in case of a large spill	: Self-contained breathing apparatus (SCBA) should be used to avoid inhalation of the product.

Product name	**Exposure limits**
United States	
Isopropyl alcohol	**ACGIH TLV (United States, 1/2009).** TWA: 200 ppm 8 hour(s). STEL: 400 ppm 15 minute(s). **OSHA PEL 1989 (United States, 3/1989).** TWA: 400 ppm 8 hour(s). TWA: 980 mg/m³ 8 hour(s). STEL: 500 ppm 15 minute(s). STEL: 1225 mg/m³ 15 minute(s). **NIOSH REL (United States, 6/2009).** TWA: 400 ppm 10 hour(s). TWA: 980 mg/m³ 10 hour(s). STEL: 500 ppm 15 minute(s). STEL: 1225 mg/m³ 15 minute(s). **OSHA PEL (United States, 11/2006).** TWA: 400 ppm 8 hour(s). TWA: 980 mg/m³ 8 hour(s).

Section 9. Physical and chemical properties

Physical state	: Liquid. [COLORLESS LIQUID WITH THE ODOR OF RUBBING ALCOHOL]
Odor	: NONRESIDUAL
Molecular weight	: 60.11 g/mole
Molecular formula	: C3-H8-O
Boiling/condensation point	: 82.5°C (180.5°F)
Melting/freezing point	: -88.9°C (-128°F)
Specific gravity	: 0.785 (Water = 1)
Vapor density	: 2.07 (Air = 1)
Evaporation rate	: 1.7 compared with butyl acetate
VOC	: 100 % (w/w)

Section 10. Stability and reactivity

Stability and reactivity	: The product is stable.
Incompatibility with various substances	: Highly reactive or incompatible with the following materials: acids and moisture.
Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Hazardous polymerization	: Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Toxicity data

Product/ingredient name	Result	Species	Dose	Exposure
Isopropyl alcohol	LD50 Dermal	Rabbit	12800 mg/kg	-
	LD50 Intraperitoneal	Rat	2735 mg/kg	-
	LD50 Intravenous	Rat	1088 mg/kg	-
	LD50 Oral	Rat	5045 mg/kg	-
	LD50 Oral	Rat	5000 mg/kg	-
	TDLo Intraperitoneal	Rat	800 mg/kg	-
	LC50 Inhalation Gas.	Rat	45248 ppm	1 hours
	LC50 Inhalation Gas.	Rat	16000 ppm	8 hours

IDLH : 2000 ppm

Chronic effects on humans : **CARCINOGENIC EFFECTS**: A4 (Not classifiable for humans or animals.) by ACGIH, 3 (Not classifiable for humans.) by IARC.
May cause damage to the following organs: upper respiratory tract, skin, eyes, central nervous system (CNS).

Other toxic effects on humans : Hazardous by the following route of exposure: of eye contact (irritant).

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Reproduction toxicity : No known significant effects or critical hazards.

Section 12. Ecological information

Aquatic ecotoxicity

Isopropyl alcohol	-	Acute LC50 11130000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - Juvenile (Fledgling, Hatchling, Weanling) - 4 to 8 weeks - 1.1 to 3.1 cm	96 hours
	-	Acute LC50 10400000 to 10600000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 29 days - 20 mm - 0.103 g	96 hours
	-	Acute LC50 9640000 to 10000000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 31 days - 20.6 mm - 0.117 g	96 hours
	-	Acute LC50 6550000 to 7450000 ug/L Fresh water	Fish - Fathead minnow - Pimephales promelas - 31 days - 17.4 mm - 0.082 g	96 hours
	-	Acute LC50 4200000 ug/L Fresh water	Fish - Harlequinfish, red rasbora - Rasbora heteromorpha - 1	96 hours

			to 3 cm	
	-	Acute LC50 >1400000 ug/L	Fish - Western mosquitofish - Gambusia affinis - 20 to 30 mm	96 hours
	-	Acute LC50 1400000 to 1950000 ug/L Marine water	Crustaceans - Common shrimp, sand shrimp - Crangon crangon	48 hours

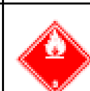
Products of degradation : Products of degradation: carbon oxides (CO, CO_2) and water.

Section 13. Disposal considerations

Waste disposal : The generation of waste should be avoided or minimized wherever possible. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe way. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.

Product removed from the cylinder must be disposed of in accordance with appropriate Federal, State, local regulation.Return cylinders with residual product to Airgas, Inc.Do not dispose of locally.

Section 14. Transport information

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN1219	ISOPROPANOL OR ISOPROPYL ALCOHOL	3	II		**Limited quantity** Yes. **Packaging instruction** **Passenger aircraft** Quantity limitation: 5 L **Cargo aircraft** Quantity limitation: 60 L **Special provisions** IB2, T4, TP1
TDG Classification	UN1219	ISOPROPANOL; OR ISOPROPYL ALCOHOL	3	II		**Explosive Limit and Limited Quantity Index** 1 **Passenger Carrying Road or Rail Index** 5

Isopropyl Alcohol (Isopropanol)						
Mexico Classification	UN1219	ISOPROPANOL OR ISOPROPYL ALCOHOL	3	II		**Limited quantity** Yes. **Packaging instruction** **Passenger aircraft** Quantity limitation: 5 L **Cargo aircraft** Quantity limitation: 60 L **Special provisions** IB2, T4, TP1

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Section 15. Regulatory information

United States

HCS Classification : Flammable liquid
Target organ effects

U.S. Federal regulations : **United States inventory (TSCA 8b):** This material is listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: Isopropyl alcohol
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: Isopropyl alcohol: Fire hazard, Immediate (acute) health hazard, Delayed (chronic) health hazard

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

SARA 313

	Product name	CAS number	Concentration
Form R - Reporting requirements :	Isopropyl alcohol	67-63-0	100
Supplier notification :	Isopropyl alcohol	67-63-0	100

SARA 313 notifications must not be detached from the MSDS and any copying and redistribution of the MSDS shall include copying and redistribution of the notice attached to copies of the MSDS subsequently redistributed.

State regulations : **Connecticut Carcinogen Reporting:** This material is not listed.
Connecticut Hazardous Material Survey: This material is not listed.
Florida substances: This material is not listed.
Illinois Chemical Safety Act: This material is not listed.
Illinois Toxic Substances Disclosure to Employee Act: This material is not listed.
Louisiana Reporting: This material is not listed.
Louisiana Spill: This material is not listed.
Massachusetts Spill: This material is not listed.
Massachusetts Substances: This material is listed.
Michigan Critical Material: This material is not listed.
Minnesota Hazardous Substances: This material is not listed.
New Jersey Hazardous Substances: This material is listed.
New Jersey Spill: This material is not listed.
New Jersey Toxic Catastrophe Prevention Act: This material is not listed.
New York Acutely Hazardous Substances: This material is not listed.

New York Toxic Chemical Release Reporting: This material is not listed.
Pennsylvania RTK Hazardous Substances: This material is listed.
Rhode Island Hazardous Substances: This material is not listed.

Canada

WHMIS (Canada) : Class B-2: Flammable liquid
Class D-2B: Material causing other toxic effects (Toxic).

CEPA Toxic substances: This material is not listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

Section 16. Other information

Label requirements : FLAMMABLE LIQUID AND VAPOR. MAY CAUSE TARGET ORGAN DAMAGE, BASED ON ANIMAL DATA.

Hazardous Material Information System (U.S.A.) :

Health	*	1
Flammability		3
Physical hazards		0

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

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

The Chemical Company

Safety data sheet
UNO HD SC bases & colors without lead

1. Substance/preparation and company identification

Company
BASF CORPORATION
100 Park Avenue
Florham Park, NJ 07932
USA

24 Hour Emergency Response Information
CHEMTREC: 1-800-424-9300
BASF HOTLINE: 1-800-832-HELP (4357)

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical name	CAS Number	Content (weight%)
n-butyl acetate OSHA PEL 150 ppm 710 mg/m3 ACGIH STEL 200 ppm; TWA 150 ppm	123-86-4	0 - 50
solvent naphtha, light aromatic PEL/TLV not established	64742-95-6	0 - 30
hindered amine light stabilizer PEL/TLV not established	Proprietary	0 - 20
1,2,4-trimethylbenzene ACGIH TWA 25 ppm	95-63-6	0 - 10
parachlorobenzotrifluoride PEL/TLV not established	98-56-6	0 - 65
acetone OSHA PEL 1000 ppm 2400 mg/m3 ACGIH STEL 750 ppm; TWA 500 ppm	67-64-1	0 - 15
diisobutyl ketone OSHA PEL 50 ppm 290 mg/m3 ACGIH TWA 25 ppm	108-83-8	0 - 5
ethylbenzene OSHA PEL 100 ppm 435 mg/m3 ACGIH STEL 125 ppm; TWA 100 ppm	100-41-4	0 - 5
methyl isobutyl ketone OSHA PEL 100 ppm 410 mg/m3 ACGIH STEL 75 ppm; TWA 50 ppm	108-10-1	0 - 10
copper phthalocyanine blue PEL/TLV not established	147-14-8	0 - 10
copper phthalocyanine PEL/TLV not established	1328-53-6	0 - 10
carbon black OSHA PEL 3.5 mg/m3 ACGIH TWA 3.5 mg/m3	1333-86-4	0 - 5
barium sulfate OSHA PEL 5 mg/m3 R; PEL 15 mg/m3 T	7727-43-7	0 - 5

ACGIH TWA 10 mg/m3		
iron oxide pigment	51274-00-1	0 - 15
PEL/TLV not established		
aluminum hydroxide	21645-51-2	0 - 5
PEL/TLV not established		
talc	14807-96-6	0 - 15
ACGIH TWA 2 mg/m3		
C.I. pigment green	14302-13-7	0 - 10
PEL/TLV not established		
bismuth vanadium oxide	14059-33-7	0 - 35
PEL/TLV not established		
titanium dioxide	13463-67-7	0 - 40
OSHA PEL 15 mg/m3 T		
ACGIH TWA 10 mg/m3		
stoddard solvent	8052-41-3	0 - 5
OSHA PEL 500 ppm 2900 mg/m3		
ACGIH TWA 100 ppm		
aluminum	7429-90-5	0 - 10
ACGIH TWA 5 mg/m3		
xylene	1330-20-7	0 - 10
OSHA PEL 100 ppm 435 mg/m3		
ACGIH STEL 150 ppm; TWA 100 ppm		
iron oxide	1309-37-1	0 - 15
ACGIH TWA 5 mg/m3		
propylene glycol methyl ether acetate	108-65-6	0 - 10
PEL/TLV not established		
1,3,5-trimethylbenzene	108-67-8	0 - 5
ACGIH TWA 25 ppm		
toluene	108-88-3	0 - 5
OSHA CLV 300 ppm; TWA 200 ppm; max. conc. 500 ppm		
ACGIH TWA 50 ppm		
methyl amyl ketone	110-43-0	0 - 60
OSHA PEL 100 ppm 465 mg/m3		
ACGIH TWA 50 ppm		
amorphous precipitated silica	112926-00-8	0 - 10
PEL/TLV not established		
trimethylbenzene	25551-13-7	0 - 5
ACGIH TWA 25 ppm		

R Respirable fraction
T Total dust

3. HAZARD IDENTIFICATION

HMIS III RATING
Health: 2* Flammability: 3 Physical hazard: 0

HMIS uses a numbering scale ranging from 0 to 4 to indicate the degree of hazard. A value of zero means that the substance possesses essentially no hazard; a rating of four indicates high hazard.

EMERGENCY OVERVIEW

WARNING
FLAMMABLE LIQUID

HARMFUL IF INHALED
CAN CAUSE CENTRAL NERVOUS SYSTEM DAMAGE
CAN CAUSE LIVER DAMAGE
CAN CAUSE KIDNEY DAMAGE
MAY CAUSE EYE, SKIN AND RESPIRATORY TRACT IRRITATION
CONTAINS MATERIAL THAT MAY CAUSE ALLERGIC SKIN REACTION
CONTAINS A MATERIAL WHICH HAS BEEN IDENTIFIED AS A SUSPECT CANCER HAZARD.
MAY CAUSE PULMONARY EDEMA
INGESTION MAY CAUSE GASTRIC DISTURBANCES

POTENTIAL HEALTH EFFECTS

Primary routes of exposure:
Routes of entry for solids and liquids include eye and skin contact, ingestion and inhalation. Routes of entry for gases include inhalation and eye contact. Skin contact may be a route of entry for liquefied gases.
Solvents are absorbed through the skin.

Acute toxicity:
Inhalation may cause CNS depression, blurred vision, dizziness and drowsiness.
Overexposure may cause nausea and vomiting.
Inhalation causes headache and nausea.
Vapors have a suffocating effect.
Intentional misuse by deliberately concentrating and inhaling this product may be harmful or fatal.
May cause sensitization by skin contact.

Information on: 2-heptanone
Inhalation of 2-heptanone (methyl amyl ketone) may lead to upper respiratory tract irritation and central nervous system effects like headache, nausea and dizziness.

Information on: acetone
Acute exposures to relatively large amounts of acetone can result in local effects, such as irritation to eyes, nose, throat, and respiratory tract as well as systemic effects such as central nervous system (CNS) depression, which can range in severity from lightheadedness to loss of consciousness depending on the magnitude and length of the exposure.

Information on: aluminum hydroxide
Prolonged or excessive large doses of Aluminum hydroxide via oral ingestion may cause encephalopathy, adverse CNS effects, G.I. obstruction, constipation, neurological effects and musculoskeletal effects.

Information on: n-butyl acetate
Inhalation of butyl acetate vapors may result in headache, dizziness, nausea, irritation of the respiratory tract, and CNS depression. Prolonged inhalation exposures have been known to produce upper respiratory tract irritation and acute transient signs of reduced activity at concentrations at 1500 ppm and above in rats, with no cumulative neurotoxic effects. Overexposure may cause irritation of the eyes, nose and throat.

Information on: barium sulfate
Ingestion of soluble barium salts produces muscle stimulation, followed by severe gastric disturbances, increased blood

pressure, and central nervous system effects.

Information on: carbon black

Acute exposure to carbon black dusts may be irritating to the eyes, skin and respiratory tract.

Information on: ethyl benzene

Vapors are readily absorbed through the lungs. Inhalation of ethylbenzene vapors causes drowsiness, narcosis, headaches, cramps, and tightness of the chest. Severe overexposure can cause death due to respiratory center paralysis. If aspiration occurs, chemical pneumonitis or pulmonary edema may result. Ingestion may result in kidney or liver damage. Ethyl benzene is absorbed through the skin at a low rate.

Information on: methyl isobutyl ketone

Acute inhalation overexposures to methyl isobutyl ketone causes lightheadedness, dizziness, headache, nausea, weakness, incoordination, and vomiting. The vapors are highly irritating to the eyes, nose and throat and overexposures to extremely high concentrations may result in narcosis and possibly death. Direct contact has been reported to cause eczema.

Information on: parachlorobenzotrifluoride

Inhalation of Parachlorobenzotriflouride may produce symptoms of CNS depression including headache, dizziness, nausea, loss of balance and drowsiness. Ingestion may cause damage to the lining of the G.I. tract.

Information on: stoddard solvent

Inhalation of low concentrations of stoddard solvent causes CNS effects and irritation to the eyes, nose and throat. Contact with the skin may result in irritation.

Information on: talc

Acute exposures to high concentrations of talc may produce cough, dyspnea, chest pain and weakness.

Information on: 1,2,4 trimethylbenzene

Inhalation of 1,2,4-trimethylbenzene may result in CNS effects including CNS depression, nausea, anxiety and headache. Aspiration of the liquid into the lungs may result in pulmonary edema and chemical pneumonitis. Asthmatic bronchitis may be aggravated by 1,2,4-trimethylbenzene exposure.

Information on: toluene

Inhalation may be irritating and result in fatigue, headaches,CNS effects and narcosis. Severe inhalation overexposures may cause death by paralysis of the respiratory tract. Aspiration of toluene into the lungs can cause chemical pneumonitis which can be fatal.

Information on: xylene

Aspiration of xylene may result in chemical pneumonitis, pulmonary edema and hemorrhage. Ingestion and skin absorption may lead to CNS depression, symptoms may include nausea, dizziness and blurred vision.

Irritation:

Skin contact may result in irritation, defatting and dermatitis. Vapors cause irritation to the respiratory tract and the eyes. Prolonged inhalation of product vapor can result in irritation of the mucous membranes.

Information on: light stabilizer

This product contains an additive that may cause an allergic skin reaction.

Information on: ethyl benzene

Ethylbenzene is extremely irritating to the eyes, skin and upper respiratory tract. Eye contact may result in conjunctivitis and corneal injury.

Repeated dose toxicity:

Information on: 2-heptanone

Repeated inhalation exposures to 2-heptanone (methyl amyl ketone) have been known to produce neurological effects in experimental animals at 1000 ppm. Repeated oral exposures in rats have been known to produce liver and kidney effects at 500 mg/kg/day.

Information on: n-butyl acetate

In a teratogenicity study, pregnant rabbits were exposed to n-butyl acetate vapors at 0 or 1500 ppm from day 1 to day 19 of gestation; pregnant rats were exposed at the same concentrations from day 1 to day 16 of gestation. Body weight changes were observed in the rats but not the rabbits. Reproductive performance was not affected. Rabbit fetus size was not affected by exposure, but fetal size in all exposed groups of rats was reduced, suggesting embryotoxicity.

Information on: acetone

High doses of acetone (500 and 2500 mg/kg/day) administered by oral gavage to rats for 90 consecutive days resulted in some clinical chemistry and blood changes as well as increased absolute/relative liver and kidney weights. Histopathological examination of both organs showed acetone did not affect the liver but appeared to accentuate the kidney changes which accompany aging. No effects were observed at 100 mg/kg/day. Chronic occupational exposures to acetone at levels ranging from 300 to 100 ppm have reportedly been associated with irritation and mild CNS effects but have not affected clinical chemistry parameters or worker mortality.

Information on: carbon black

Prolonged inhalation exposures may produce cough, phlegm, tiredness, chest pain and headache. Dermal, inhalation or mucosal exposures may cause irritation. Chronic exposures to carbon black have been known to produce pneumoconiosis (chronic inflammatory and fibrotic lung disease) in workers. IARC has classified carbon black in Group 2B (sufficient evidence of carcinogenicity in animals).

Information on: copper compounds

Chronic overexposure to copper compounds can lead to anemia, and damage to the liver, kidneys, lungs and spleen. The copper in copper phthalocyanines is covalently bound and has been found to be biologically unavailable.

Information on: diisobutyl ketone

Animal studies indicate that chronic overexposure to diisobutyl ketone may cause liver and kidney damage.

Information on: ethyl benzene

Animal studies indicate that chronic overexposure to ethylbenzene may cause liver and kidney injury. Increased liver and kidney weight were found in rats exposed to 400 ppm for 186 days. Animal studies indicate that the vapors may be embryotoxic. Prolonged skin contact will cause edema and blistering. In NTP 2-year inhalation studies, clear evidence of carcinogenicity of ethylbenzene in male rats was noted based on increased incidences of kidney neoplasms. Incidences of testicular adenoma were also increased. In female rats, male mice and female mice there was some evidence of carcinogenicity, based on kidney adenoma, lung neoplasms and liver neoplasms, respectively. The International Agency for Research on Cancer (IARC) has classified ethylbenzene in Category 2B, sufficient evidence of carcinogenicity in animals.

Information on: iron oxide
Chronic overexposure to iron oxide fume or dust has been associated with x-ray changes of the lungs; however, it does not result in illness. Changes are due to a benign lung condition called siderosis, or iron pigmentation. Animal studies indicate that chronic overexposure to iron oxide dust does not cause lung impairment or fibrosis. However, workers exposed to iron oxide fume in the presence of silica may develop mixed dust pneumoconiosis. Direct contact with dust or fume may result in burns to the skin and eyes and may produce damage.

Information on: methyl isobutyl ketone
Animal studies indicate that chronic overexposure to methyl isobutyl ketone could result in liver and kidney effects. Behavioral effects with impaired memory have been reported in experimental animals exposed to concentrations of 50 ppm for 7 days. MIBK has been found to be fetotoxic, but not embryotoxic in rats and mice at maternally toxic doses of 3000 ppm only. No such effects were found at lower concentrations.

Information on: parachlorobenzotrifluoride
Studies conducted on laboratory animals indicate that exposures to parachlorobenzotriflouride via inhalation and ingestion may result in liver and kidney damage.

Information on: stoddard solvent
Repeated dermal contact with stoddard solvent may result in follicular dermatitis. Repeated exposures may result in irreversible effects on the CNS system and kidney damage, liver damage and pulmonary congestion.

Information on: talc
Prolonged or repeated exposure to talc can result in a form of pulmonary fibrosis (talc pneumoconiosis), possibly due to asbestos content. In a National Toxicology Program (NTP) inhalation study, talc exhibited some evidence of carcinogenicity in male rats, clear evidence in female rats and no evidence in mice. It is thought that the effects, which were reported at the high dose, were due to overburdening of the lungs.

Information on: titanium dioxide
In a National Cancer Institute (NCI) feeding study, titanium dioxide was not carcinogenic to rats or mice at maximum tolerated doses. In another study, TiO_2 caused fibrosis and lung cancer in rats exposed to 250 mg/m3 by inhalation. However, no effects were seen at lower airborne concentrations.

Information on: 1,2,4 trimethylbenzene
In a subchronic toxicity study, male rats were gavaged with either 0.5 or 2.0 g/kg 1,2,4-trimethylbenzene once daily, for 5 days/week for four weeks. Mortality occured in 1 rat from the low dose group; all rats died in the high dose group during the study.

Information on: toluene
Chronic overexposure to toluene may result in liver and kidney damage. Animal studies indicate that toluene is embryotoxic and teratogenic when administered at high doses.

Information on: xylene
The chronic effects of overexposure to xylene include possible liver and kidney damage. A mixture of o, m, and p-xylenes was teratogenic and embryo toxic to mice by the oral route; however, these effects were accompanied by maternal toxicity. Rats exposed to 1000 mg/m3 by inhalation exhibited no teratogenic effects; however, minor skeletal abnormalities occurred.

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4. FIRST-AID MEASURES

General advice:
Remove contaminated clothing.
Contact the local poison control center or call BASF Emergency Response at 1-800-832-HELP (4357).

If inhaled:
Keep patient calm, remove to fresh air.
If breathing difficulties develop, aid in breathing and seek immediate medical attention.

If on skin:
Wash affected areas with water for at least 15 minutes.
If irritation develops, seek medical attention.

If in eyes:
Flush with copious amounts of water for at least 15 minutes.
Hold eyelids open to facilitate rinsing.
Seek medical attention.

If swallowed:
Rinse mouth and then drink plenty of water.
Do not induce vomiting due to aspiration hazard.
Never induce vomiting or give anything by mouth if the victim is unconscious or having convulsions.
Immediate medical attention is required.
Ingestion may cause irritation of the gastrointestinal tract.
Aspiration may result in chemical pneumonitis, which may be fatal.

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5. FIRE FIGHTING MEASURES

Flash point: 28 - 96 °F ((-2.2)- 35.6 °C) +/- 3 °F Setaflash Closed Cup (measured)
Lower explosion limit: 0.7 VOL%
Upper explosion limit: 12.8 VOL%

Suitable extinguishing media:
Dry extinguishing media
Carbon dioxide
Foam

Unsuitable extinguishing media for safety reasons:

Water spray

Hazards during firefighting:
Vapors and/or decomposition products are irritants and/or toxic.
If product is heated above decomposition temperatures, acrid smoke and fumes will be released.

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

Further information:
Vapors are heavier than air and may accumulate in low areas and travel a considerable distance up to the source of ignition. Flash fire may occur.
Remove product from areas of fire or otherwise cool sealed containers with water in order to avoid pressure build-up due to heat.
Do not flood burning material with water due to potential spreading of fire.
Contain contaminated water/firefighting water.
Run-off water from fire may cause pollution.
Notify proper authorities.

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6. ACCIDENTAL RELEASE MEASURES

Personal precautions:
Extinguish sources of ignition nearby and downwind.
Wear suitable personal protective clothing and equipment.
Ensure adequate ventilation.
Avoid prolonged inhalation.
Avoid contact with skin and eyes.
Use antistatic tools.

Environmental precautions:
Do not discharge into drains/surface waters/groundwater.
A spill of or in excess of the reportable quantity requires notification to state, local and national emergency authorities.
Acutely toxic for aquatic organisms.

Cleanup:
Dike spillage.
Place into appropriately labeled waste containers.
Spills should be contained, solidified, and placed in suitable containers for disposal.

---

7. HANDLING AND STORAGE

HANDLING

General advice:
Ensure adequate ventilation.
Do not puncture, drop or slide containers.
Use static lines when mixing and transferring material.
Handle and open container with care.
Avoid contact with the skin, eyes and clothing.

WARNING: Empty containers may still contain hazardous residue.
Do not apply to hot surfaces.
Proper ventilation and respiratory protection is required when sanding, flame cutting, welding or brazing coated surfaces.

Protection against fire and explosion:
Use antistatic tools.
Exhaust fans should be explosion proof.
Provide adequate ventilation to remove solvent vapors from lower levels or work areas and to prevent solvent contact with ignition sources.
Sealed containers should be protected against heat as this results in pressure build-up.
Risk of explosion if heated under confinement.
Avoid all sources of ignition: heat, sparks, or open flame.

STORAGE

General advice:
Keep container tightly closed.
Protect from direct sunlight.
Protect from temperatures above 49C/ 120F.
Consult local fire marshal for storage requirements.

Storage incompatability:
General: Segregate from incompatible substances.
Segregate from oxidizing agents.
Segregate from strong bases.
Segregate from strong acids.

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8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

COMPONENTS WITH WORKPLACE CONTROL PARAMETERS
See section 2.

ADVICE ON SYSTEM DESIGN
General mechanical ventilation should comply with OSHA 1910.94.

PERSONAL PROTECTIVE EQUIPMENT

Respiratory protection:
Wear respiratory protection if ventilation is inadequate.
Wear NIOSH-certified (or equivalent) organic vapor respirator.
Particulate filters should be added during spray operations.
Do not exceed the maximum use concentration for the respirator facepiece/cartridge combination.
Observe OSHA regulations for respirator use (29 CFR 1910.134).

Hand protection:
Use appropriate chemically resistant gloves as determined by an evaluation of glove performance characteristics and the hazards and potential hazards identified, including but not limited to butyl, natural and synthetic rubber, nitrile, or neoprene.

Eye protection:
Tightly fitting safety goggles (chemical goggles).
Wear face shield if splashing hazard exists.

Body protection:
Body protection must be chosen based on activity level and exposure.

General safety and hygiene measures:
Work place should be equipped with a shower and eye wash.
Contact lenses should not be worn.
Remove contaminated clothing.
Contaminated equipment or clothing should be cleaned after each use or disposed of.
Hands and/or face should be washed before breaks and at the end of the shift.

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9. PHYSICAL AND CHEMICAL PROPERTIES

Form:	liquid
Odour:	solvent-like
Colour:	various
Boiling range:	133 - 412 °F
Vapour pressure:	not available
Weight per gallon:	7.90 - 11.90 lb/gal CALC
Vapour density:	heavier than air
Solids content:	approx. 32 - 73 %

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10. STABILITY AND REACTIVITY

Conditions to avoid:
Avoid all sources of ignition: heat, sparks or open flames.
Avoid electrostatic discharge.

Substances to avoid:
Strong bases
Strong oxidizing agents
Oxidizing agents
Strong acids

Hazardous reactions:
This product is chemically stable.

Decomposition products:
Carbon monoxide
Carbon dioxide

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11. TOXICOLOGICAL INFORMATION

No data available.

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12. ECOLOGICAL INFORMATION

No data available.

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13. DISPOSAL CONSIDERATIONS

Waste disposal of substances:
Dispose of in accordance with national, state and local regulations.
The use and processing of this product, or addition of other constituents, may cause it to be considered a hazardous waste.
It is the waste generators responsibility to determine if a particular waste is hazardous under RCRA.
Do not discharge into drains/surface waters/groundwater.
Incinerate or dispose of in a RCRA licensed facility.
Do not incinerate closed containers.

Contaminated packaging:
WARNING: Empty containers may still contain hazardous residue.
Dispose of in accordance with national, state and local regulations.

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14. TRANSPORT INFORMATION

Reference bill of lading.

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15. REGULATORY INFORMATION

FEDERAL REGULATIONS

TSCA, US released / listed

SARA 313:

HD10:
ethylbenzene 3.4%; 1,2,4-trimethylbenzene 4.5%; xylene 13.7%

HD14:
ethylbenzene 0.8%; 1,2,4-trimethylbenzene 1.8%; xylene 3.2%;
aluminum powder 3.8%

HD15:
ethylbenzene 0.8%; 1,2,4-trimethylbenzene 1.7%; xylene 3.1%;
aluminum powder 6.0%

HD17:
ethylbenzene 1.5%; 1,2,4-trimethylbenzene 7.1%; xylene 6.2%;
aluminum 8.0%

HD18:
ethylbenzene 1.8%; 1,2,4-trimethylbenzene 6.7%; xylene 7.1%;
aluminum 8.0%

HD45:
1,2,4-trimethylbenzene 5.9%; copper phthalocyanine 3.1%

HD60:
ethylbenzene 0.5%; xylene 2.0%

HD81:
ethylbenzene 0.7%; xylene 2.8%

HD65:
ethylbenzene 1.0%; xylene 4.1%

HD67:
ethylbenzene 1.0%; xylene 3.8%

SC00:
ethylbenzene 0.4%; toluene 1.6%; xylene 1.5%

SC01:
ethylbenzene 1.3%; 1,2,4-trimethylbenzene 1.7%; xylene 5.3%

SC03:
1,2,4-trimethylbenzene 1.9%; toluene 2.3%

SC10:
ethylbenzene 0.1%; 1,2,4-trimethylbenzene 7.9%;
methyl isobutyl ketone 4%

SC20:
1,2,4-trimethylbenzene 7.1%; methyl isobutyl ketone 4.5%

SC25:
ethylbenzene 0.2%; 1,2,4-trimethylbenzene 6.9%;
methyl isobutyl ketone 2.7%; xylene 1.3%

SC29:
1,2,4-trimethylbenzene 7.3%; methyl isobutyl ketone 5.2%

SC30:
ethylbenzene 0.1%; 1,2,4-trimethylbenzene 6.8%;
methyl isobutyl ketone 2%

SC31:
1,2,4-trimethylbenzene 8.2%; methyl isobutyl ketone 4.0%

SC40:
1,2,4-trimethylbenzene 6.7%; methyl isobutyl ketone 5.5%

SC403:
ethylbenzene 0.4%; 1,2,4-trimethylbenzene 6%;
methyl isobutyl ketone 2%; xylene 2.1%

SC44:
1,2,4-trimethylbenzene 6.6%; methyl isobutyl ketone 4.8%

SC46:
ethylbenzene 0.1%; 1,2,4-trimethylbenzene 6.6%;
methyl isobutyl ketone 7.6%

SC49:
1,2,4-trimethylbenzene 7.2%; methyl isobutyl ketone 7.4%

SC54:
ethylbenzene 0.1%; 1,2,4-trimethylbenzene 6.4%;
methyl isobutyl ketone 5.6%

SC56:
ethylbenzene 0.1%; 1,2,4-trimethylbenzene 6.6%;
methyl isobutyl ketone 4.9%

SC59:
1,2,4-trimethylbenzene 7.3%; methyl isobutyl ketone 6%

SC61:
1,2,4-trimethylbenzene 4.5%; methyl isobutyl ketone 4%;
bismuth vanadium oxide 32.5%

SC62:
ethylbenzene 0.4%; 1,2,4-trimethylbenzene 5.8%;
methyl isobutyl ketone 1.7%; xylene 2%

SC66:
ethylbenzene 0.1%; 1,2,4-trimethylbenzene 4.6%;
methyl isobutyl ketone 2.7%

SC67:
ethylbenzene 0.4%; 1,2,4-trimethylbenzene 6.4%;
methyl isobutyl ketone 3.2%

SC69:
1,2,4-trimethylbenzene 7.2%; methyl isobutyl ketone 3.5%

SC74:
1,2,4-trimethylbenzene 4.9%; methyl isobutyl ketone 3%

SC77:
1,2,4-trimethylbenzene 6.1%; methyl isobutyl ketone 3.3%

SC79:
1,2,4-trimethylbenzene 7.3%; methyl isobutyl ketone 6.8%

SC804:
ethylbenzene 1.3%; 1,2,4-trimethylbenzene 7%;
methyl isobutyl ketone 4.2%; xylene 7.3%

SC82:
1,2,4-trimethylbenzene 5.5%; methyl isobutyl ketone 5.4%

SC85:
1,2,4-trimethylbenzene 5%; methyl isobutyl ketone 1.1%

SC86:
1,2,4-trimethylbenzene 5.9%; methyl isobutyl ketone 1.1%

SC88:
1,2,4-trimethylbenzene 6.2%; methyl isobutyl ketone 5%

SC90:
ethylbenzene 0.7%; xylene 2.8%

SC99:
1,2,4-trimethylbenzene 7%; methyl isobutyl ketone 2.6%

ULV90:
NO SARA 313 COMPONENTS

ULV403:
NO SARA 313 COMPONENTS

16. OTHER INFORMATION

Recommended use: FOR INDUSTRIAL USE ONLY.

IMPORTANT: WHILE THE DESCRIPTIONS, DESIGNS, DATA AND INFORMATION CONTAINED HEREIN ARE PRESENTED IN GOOD FAITH AND BELIEVED TO BE ACCURATE, IT IS PROVIDED FOR YOUR GUIDANCE ONLY. BECAUSE MANY FACTORS MAY AFFECT PROCESSING OR APPLICATION/USE, WE RECOMMEND THAT YOU MAKE TESTS TO DETERMINE THE SUITABILITY OF A PRODUCT FOR YOUR PARTICULAR PURPOSE PRIOR TO USE. NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE MADE REGARDING PRODUCTS DESCRIBED OR DESIGNS, DATA OR INFORMATION SET FORTH, OR THAT THE PRODUCTS, DESIGNS, DATA OR INFORMATION MAY BE USED WITHOUT INFRINGING THE INTELLECTUAL PROPERTY RIGHTS OF OTHERS. IN NO CASE SHALL THE DESCRIPTIONS, INFORMATION, DATA OR DESIGNS PROVIDED BE CONSIDERED A PART OF OUR TERMS AND CONDITIONS OF SALE. FURTHER, YOU EXPRESSLY UNDERSTAND AND AGREE THAT THE DESCRIPTIONS, DESIGNS, DATA AND INFORMATION FURNISHED BY BASF HEREUNDER ARE GIVEN GRATIS AND BASF ASSUMES NO OBLIGATION OR LIABILITY FOR THE DESCRIPTION, DESIGNS, DATA AND INFORMATION GIVEN OR RESULTS OBTAINED. ALL SUCH BEING GIVEN AND ACCEPTED AT YOUR RISK.

MATERIAL SAFETY DATA SHEET
Gougeon Brothers, 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:
Gougeon Brothers, Inc.
100 Patterson Avenue
Bay City, MI 48706, U.S.A.
Phone: 989-684-7286

EMERGENCY TELEPHONE NUMBERS:
Transportation
CHEMTREC: 800-424-9300
Non-transportation
Poison Hotline: 800-222-1222

2. COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

INGREDIENT NAME	CAS #	CONCENTRATION
Bisphenol-A type epoxy resin	25085-99-8	> 50%
Benzyl alcohol	100-51-6	< 20%
Bisphenol-F type epoxy resin	28064-14-4	< 20%
Ethylene glycol monobutyl ether	111-76-2	< 0.3%

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

HMIS Hazard Rating: **Health - 2** **Flammability - 1** **Reactivity - 0**

WARNING! May cause allergic skin response in certain individuals. May cause moderate irritation to the skin. Light yellow liquid with mild odor.

PRIMARY ROUTE(S) OF ENTRY: .... Skin contact.

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION:.. Not likely to cause acute effects unless heated to high temperatures. If product is heated, vapors generated can cause headache, nausea, dizziness and possible respiratory irritation if inhaled in high concentrations.

CHRONIC INHALATION:................................... Not likely to cause chronic effects. 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. Repeated exposure is not likely to cause other adverse health effects.

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.

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. Remove with 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 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.

6. ACCIDENTAL RELEASE MEASURES:

SPILL OR LEAK PROCEDURES .... Soak up in absorbent material or scrape up. Residual can be removed with non-flammable solvent, but solvent should be used sparingly and with appropriate precautions.

7. HANDLING AND STORAGE:

STORAGE TEMPERATURE (min./max.): .... 40°F (4°C) / 120°F (49°C)

SHELF LIFE:.. Three years or more in original sealed container.

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.

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.

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 to pale yellow.
ODOR: .... Mild.
BOILING POINT: .... > 400°F.
MELTING POINT/FREEZE POINT:................... No data.
VISCOSITY: .... 1,000 cPs.
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: .... EPA Method 24, as described in 40 CFR Part 60, was used to determine the Volatile Matter Content of mixed epoxy resin and hardener. This method states that two-component coating systems should be tested by mixing the individual components together at the proper ratio. Refer to the hardener's MSDS for information about the total volatile content of the resin/hardener system.

10. 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 and carbon dioxide fumes may be produced when 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.

Ethylene glycol monobutyl ether (present at < 0.3 %) causes harm to the fetus in laboratory animal studies. Harm to the fetus occurs at exposure levels that harm the pregnant animal. The relevance of these findings to humans is uncertain.

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.

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).

12. ECOLOGICAL INFORMATION:

Prevent entry into sewers and natural waters. May cause localized fish kill.

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:

D.O.T. SHIPPING NAME: .... Not regulated by DOT.
TECHNICAL SHIPPING NAME:........................... Not applicable.
D.O.T. HAZARD CLASS: .... Not applicable.
U.N./N.A. NUMBER:.. Not applicable.
PACKING GROUP: .... Not applicable.

15. REGULATORY INFORMATION:

OSHA STATUS: .... Slight irritant; possible sensitizer.
TSCA STATUS: .... All components are listed on TSCA inventory.
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
Phenyl glycidyl ether 122-60-1	<5ppm	[1]CA
Ethylene Oxide 75-21-8	<0.15%	[1]CA
Ethylene glycol monobutyl ether 111-76-2	< 0.3%	NJ, PA

[1.] These substances are known to the state of California to cause cancer or reproductive harm, or both.

16. OTHER INFORMATION:

REASON FOR ISSUE:.. Update in Section 16.
PREPARED BY:.. T. J. Atkinson
APPROVED BY: .... G. M. House
TITLE:.. Health, Safety & Environmental Manager
APPROVAL DATE:.. January 5 , 2004
SUPERSEDES DATE: .... January 5, 2001
MSDS NUMBER: 105-04a

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

MATERIAL SAFETY DATA SHEET
West System Inc.

1. **CHEMICAL PRODUCT AND COMPANY IDENTIFICATION**

PRODUCT NAME:.................................. WEST SYSTEM® 206™ Slow Hardener.
PRODUCT CODE:.................................. 206
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. **COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS**

INGREDIENT NAME	CAS #	CONCENTRATION
Polyoxypropylenediamine	9046-10-0	30-50%
Polymer of epichlorohydrin, bisphenol-A, and DETA	31326-29-1	< 30%
Tetraethylenepentamine (TEPA)	112-57-2	< 30%
Diethylenetriamine (DETA)	111-40-0	< 12%
Reaction products of TETA and propylene oxide	26950-63-0	< 12%
Triethylenetetramine (TETA)	112-24-3	< 12%

3. **HAZARDS IDENTIFICATION**

EMERGENCY OVERVIEW

HMIS Hazard Rating: **Health - 3** **Flammability - 1** **Reactivity - 0**

DANGER! Corrosive. Strong skin sensitizer. May cause severe chemical burns to eyes and skin. Harmful if swallowed. Harmful if absorbed through the skin. Can cause respiratory irritation. Light-yellow colored liquid with ammonia odor.

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

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION:...Excessive exposure to vapor or mist is irritating to the upper respiratory tract, causing nasal discharge, coughing, and discomfort in eyes, nose, throat and chest. Severe cases may cause difficult breathing and lung damage.

CHRONIC INHALATION: ....May cause lung damage. May cause respiratory sensitization in susceptible individuals. Repeated exposures may cause internal organ damage.

ACUTE SKIN CONTACT:...Corrosive. Prolonged contact may cause skin damage with burns and blistering. Wide spread contact may result in material being absorbed in harmful amounts.

CHRONIC SKIN CONTACT: ....May cause persistent irritation or dermatitis. Repeated contact may cause allergic reaction/sensitization and possible tissue destruction. Can be absorbed through the skin in amounts that can cause internal organ damage.

EYE CONTACT: ....Corrosive. May cause blurred vision. May cause irritation with corneal injury resulting in permanent vision impairment or even blindness.

INGESTION: ....Moderately toxic. May cause gastrointestinal irritation or ulceration. May cause burns of the mouth and throat.

SYMPTOMS OF OVEREXPOSURE: ....Skin irritation, burns and blistering. Irritation of the nose and throat, headache, nausea and vomiting. Eye irritation and blurred vision.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:
Existing respiratory conditions, such as asthma and bronchitis. Existing skin conditions.

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: ....> 200°F (Open Cup)

EXTINGUISHING MEDIA: ....Water spray, dry chemical, alcohol foam and carbon dioxide (CO_2).

FIRE AND EXPLOSION HAZARDS: ....Burning can generate toxic fumes. When mixed with sawdust, wood chips, or other cellulosic material, spontaneous combustion can occur under certain conditions. If hardener is spilled into or mixed with sawdust, heat is generated as the air oxidizes the amine. If the heat is not dissipated quickly enough, it can ignite the sawdust.

SPECIAL FIRE FIGHTING PROCEDURES: ....Use full-body protective gear and a self-contained breathing apparatus. If spill has ignited, use water spray to disperse vapors and protect personnel attempting to stop leak. Use water to cool fire-exposed containers.

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 - dilute with water and recover or use inert, non-combustible absorbent material (*e.g.*, sand) 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 with adequate ventilation.

HANDLING PRECAUTIONS: ....Use only with adequate ventilation. Do not breath vapors or mists from heated material. Avoid contact with skin and eyes. 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 goggles, full-face shield or full-face respirator.

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:
General mechanical or local exhaust ventilation. With inadequate ventilation, use a NIOSH/MSHA approved air purifying respirator with an organic vapor cartridge.

ADDITIONAL PROTECTIVE MEASURES: .... Use where there is immediate access to safety shower and emergency eye wash. Provide proper wash/cleanup facilities for proper hygiene. Contact lens should not be worn when working with this material.

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 .... Light-yellow.
ODOR .... Ammonia-like.
BOILING POINT .... > 480°F.
MELTING POINT/FREEZE POINT .... No data.
pH 11.4
SOLUBILITY IN WATER .... Appreciable.
SPECIFIC GRAVITY 1.01
BULK DENSITY .... 8.45 pounds/gallon.
VAPOR PRESSURE .... < 1 mmHg @ 20°C.
VAPOR DENSITY .... Heavier than air.
VISCOSITY .... 200 cPs
% VOLATILE BY WEIGHT .... EPA Method 24, as described in 40 CFR Part 60, was used to determine the Volatile Matter Content of mixed epoxy resin and hardener. This method states that two-component coating systems should be tested by determining weight loss after mixing the individual components together at the proper ratio, dissolving them in an appropriate solvent, and subjecting them to a temperature of 230°F. 105 Resin and 206 Hardener, mixed together at 5:1 by weight, has a density of 1176 g/L (9.81 lbs/gal). The combined VOC content for 105/206 is 49.5 g/L (0.41 lbs/gal).

10. REACTIVITY:

STABILITY: .... Stable.

HAZARDOUS POLYMERIZATION: .... Will not occur.

INCOMPATIBILITIES: .... May react violently when in contact with oxidizing materials, acids or halogenated compounds such as methylene chloride. Reactions may be slow initially, then may rapidly generate heat and vapor pressure.

DECOMPOSITION PRODUCTS: .... Burning or excessive heat may produce toxic levels of ammonia, oxides of nitrogen and irritating aldehydes.

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.

This product contains no known carcinogens in concentrations greater than 0.1%.

12. ECOLOGICAL INFORMATION:

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

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:

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

15. REGULATORY INFORMATION:

OSHA STATUS:...Corrosive; strong irritant; sensitizer.
TSCA STATUS:..All components are listed on TSCA inventory.
SARA TITLE III:
SECTION 313 TOXIC CHEMICALS:..........................None.

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	CONCENTRATION	STATE CODE
Tetraethylenepentamine 112-57-2	<30%	FL, MA, NJ, PA
Tetraethylenetriamine 112-24-3	<12%	FL, MA, NJ, PA

16. OTHER INFORMATION:

REASON FOR ISSUE:...Update in Section 1.
PREPARED BY:...T. J. Atkinson
APPROVED BY:...G. M. House
TITLE:...Health, Safety & Environmental Manager
APPROVAL DATE:..January 3, 2001
SUPERSEDES DATE:..January 5, 2004
MSDS NUMBER:..206-05a

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

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M A T E R I A L   S A F E T Y   D A T A   S H E E T

PRODUCT CODE: EP210W

PRODUCT NAME: WHITE EPOXY PRIMER

HMIS CODES: H F R P
3*4 1 X

================= SECTION I - MANUFACTURER IDENTIFICATION ================

MANUFACTURER'S NAME: LUSID TECHNOLOGIES, INC.
ADDRESS : 5195 WEST 4700 SOUTH
KEARNS, UT 84118
EMERGENCY PHONE : 800-535-5053
INFORMATION PHONE : 801-966-5300
NAME OF PREPARER: LUSID TECHNOLOGIES, INC.

REVISION DATE10/20/2011

========= SECTION II - HAZARDOUS INGREDIENTS/SARA III INFORMATION ========

REPORTABLE COMPONENTS	CAS NUMBER	VAPOR PRESSURE MM HG	@ TEMP	WEIGHT PERCENT
TITANIUM DIOXIDE	13463-67-7			
OSHA PEL 15 mg/3m TWA				
ACGIH TLV 10 mg/3m TWA				
TRIFLUOROMETHYL	98-56-6	5.3	20 C	
OSHA PEL NE				
ACGIH TLV NE				
POLYAMIDE RESIN	68082-29-1	<1	20 C	
METHYL n-AMYL KETONE	110-43-0	2.14	20 C	
ACGIH TLV 50 PPM				
OSHA PVEL 100 PPM				
* ACETONE	67-64-1	181	20 C	2.811
OSHA PEL 1000 PPM TWA				
ACGIH TLV 500 PPM TWA				
ACGIH TLV 750 PPM STEL				
* ZINC PHOSPHATE	7779-90-0	NA		1.791
OSHA PEL 10 mg/m3				
ACGIH TLV 10 mg/m3				
* XYLENE	1330-20-7	19	100 F	.941
ACGIH TLV 100 PPM - TWA				
OSHA PEL 100 PPM - TWA				
LIGHT PETROLEUM DISTILLATE	64742-47-8	2.6	20 C	
OSHA PEL 200 PPM TWA				
ACGIH TLV 100 PPM TWA				

* Indicates toxic chemical(s) subject to the reporting requirements of section 313 of SARA Title III and of 40 CFR 372.

=============== SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS ============

BOILING RANGE: 133 F - 2500-3000 C
VAPOR DENSITY: Heavier than air
COATING V.O.C.: 1.74 lb/gl
208 g/l
MATERIAL V.O.C.: 1.19 lb/gl
143 g/l
APPEARANCE AND ODOR: Clear, organic solvent odor
EVAPORATION RATE: Slower than ether

SPECIFIC GRAVITY (H2O=1 G/L): 1.6208
WEIGHT/GAL: 13.4958 lb/gl
SOLUBILITY IN WATER: No

================ SECTION IV - FIRE AND EXPLOSION HAZARD DATA ============

FLASH POINT: 1.4 F **METHOD USED: TCC**
FLAMMABLE LIMITS IN AIR BY VOLUME- LOWER: .6 **UPPER: 12.8**

EXTINGUISHING MEDIA:

Foam, Alcohol Foam, CO2, Dry Chemical, Water Fog

SPECIAL FIREFIGHTING PROCEDURES:

A self contained breathing apparatus should be worn. Although water may be ineffective, a water fog may be used to cool closed containers that are exposed to heat.

UNUSUAL FIRE AND EXPLOSION HAZARDS:

Pressure may build up in closed containers that are exposed to heat. Solvent vapors are heavier than air and may travel a considerable distance along the ground to an ignition source and flash back.

SECTION V - REACTIVITY DATA

STABILITY:

Stable

CONDITIONS TO AVOID:

Heat, sparks, open flame, static discharge.

INCOMPATIBILITY (MATERIALS TO AVOID):

Water, amines, strong bases, alcohols, metal compounds.

HAZARDOUS DECOMPOSITION OR BYPRODUCTS:

Oxides of carbon and nitrogen, hydrogen cyanide, hexamethylene diisocyanate(HDI).

HAZARDOUS POLYMERIZATION:

Will not occur.

SECTION VI - HEALTH HAZARD DATA

INHALATION HEALTH RISKS AND SYMPTOMS OF EXPOSURE:

ACUTE: Nasal and respiratory irritaion, anesthetic and other central nervous system effects, weakness, fatigue, nausea, headache, bronchitis, bronchial spasms, asthmatic condions, chemical pneumonitis, pulmonary edema.
CHRONIC: As a result of previous repeated overexposures or a single large dose, certain individuals will develope isocyanate sensitization (chemical asthma) which will cause them to react to a later exposure at levels well below the TLV. These symptoms, which can include chest tightness, wheezing, cough, shortness of

breath or asthmatic responses. Chronic exposure to organic solvents has been associated with various neurotoxic effects including permanent brain and nervous system damage. Symptoms include loss of memory, loss of intellectual ability and loss of coordination.

SKIN AND EYE CONTACT HEALTH RISKS AND SYMPTOMS OF EXPOSURE:

ACUTE SKIN: Isocyantes react with skin protein and moisture and cause irritation. Symptoms may include: reddening, swelling, rash, scaling or blistering.
CHRONIC SKIN: Prolonged contact with isocyanates can cause, reddening, swelling, rash, scaling or blistering. Individuals who developed a skin sensitization can develop these symptoms as a result of contact with small amounts of material.
ACUTE EYE: Irritation, redness, pain, blurred vision, sensation of seeing halos around lights and reversible damage.
CHRONIC EYE: May result in corneal opacity.

INGESTION HEALTH RISKS AND SYMPTOMS OF EXPOSURE:

Gastrointestinal distress and symptoms of systemic poisoning

HEALTH HAZARDS (ACUTE AND CHRONIC):

ACUTE - Shortness of breath, burning sensation of respiratory passages, nausea, headache and increased proneness to accident. An allergic respiratory reaction similar to an asthma attack can occur in some individuals with prolonged or repeated previous exposure or a single large exposure to isocyanates. CHRONIC - Narcosis, kidney and liver dysfunction with possible central nervous system effects.

CARCINOGENICITY: NTP CARCINOGEN: No IARC MONOGRAPHS: No OSHA: No

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:

Respiratory difficulty or pre-existing skin sensitization, or previous acute sllergic respiratory reaction to isocyanates.

EMERGENCY AND FIRST AID PROCEDURES:

IF AFFECTED BY INHALATION OF VAPORS - Move person to fresh air. Give oxygen if breathing is difficult. If breathing stops, apply artificial respiration and seek immediate medical attention.
EYE CONTACT - Flush with large quantities of water for 15 minutes and get medical attention.
SKIN CONTACT - Wash thoroughly with soap and water. Launder contaminated clothing and shoes before reuse.
INGESTION - Do NOT induce vomiting. Contact physician immediately. Never give anything by mouth to an unconscious person.

========== SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE ==========

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:

Ventilate spill area, eliminate all sources of ignition. Confine spill as quickly as possible. Absorb with inert absorbent and dispose in accordance with local regulations for ignitable hazardous waste.

WASTE DISPOSAL METHOD:

Dispose of in accordance with federal, state or local regulations for ignitable hazardous waste.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:

Store in a cool dry place. Outside or detached storage is preferable. Inside should be in a standard flammable liquid storage room or cabinet. Ground containers when transferring liquid from one metal container to another. Do not reuse empty product container for any purpose.

OTHER PRECAUTIONS:

If a second component is added to this product, or if any additives or thinners are introduced into this product, read all product labels and all Material Safety Data Sheets prior to use.

SECTION VIII - CONTROL MEASURES

RESPIRATORY PROTECTION:

Exhaust ventilation sufficient to keep airborne concentration of solvent, HDI and polyisocyanate below TLV's must be utilized. A respirator that is recommended for use in isocyanate-containing environments may also be necessary. When concentrations are not known, or work is in a confined space, the use of a positive air pressure respirator is mandatory.

VENTILATION:

Local ventilation should be sufficient to reduce airborne vapor concentrations to below LEL and TLV to be considered adequate.

PROTECTIVE GLOVES:

Recommended where skin contact is likely. Use solvent resistant gloves such as nitrile rubber.

EYE PROTECTION:

Chemical splash goggles are recommended if potential for splashing into the eyes is high.

21 Appendix N – Pinlist for PCBs

Pinlist

Exported from PCB V1.4.sch at 4/4/14 10:52 AM

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Part	Pad	Pin	Dir	Net
ACC1	CS	CS	io	VIN
	3V3	3V3	io	*** unconnected ***
	GND	GND	io	GND
	SCL	SCL	io	SCL
	SDA	SDA	io	SDA
	SDO	SDO	io	*** unconnected ***
	VIN	VIN	io	VIN
	INT1	INT1	io	*** unconnected ***
	INT2	INT2	io	*** unconnected ***
ACC2	T	T	io	*** unconnected ***
	X	X	io	N$5
	Y	Y	io	N$4
	Z	Z	io	N$1
	3V	3V	io	*** unconnected ***
	GND	GND	io	GND
	VIN	VIN	io	VCC
GYRO1	3V	3VOUT	io	*** unconnected ***
	CS	CS	io	*** unconnected ***
	GND	GND	io	GND
	SAO	SA0	io	*** unconnected ***
	SCL	SCL	io	SCL
	SDA	SDA	io	SDA
	VCC	VCC	io	VIN
	DRDY	DRDY	io	*** unconnected ***
	INT1	INT1	io	*** unconnected ***
JP1	1	1	io	GND
	2	2	io	GPIO1_17
JP2	1	1	io	SDA
	2	2	io	SCL

	3	3	io	VIN
	4	4	io	GND
SCL	P$1	1	pas	SCL
	P$2	2	pas	VIN
SDA	P$1	1	pas	SDA
	P$2	2	pas	VIN
U$1	1	GND	pwr	GND
	2	GND	pwr	GND
	3	GPIO1_6	pas	*** unconnected ***
	4	GPIO1_7	pas	*** unconnected ***
	5	GPIO1_2	pas	*** unconnected ***
	6	GPIO1_3	pas	*** unconnected ***
	7	TIMER4	pas	*** unconnected ***
	8	TIMER7	pas	*** unconnected ***
	9	TIMER5	pas	*** unconnected ***
	10	TIMER6	pas	*** unconnected ***
	11	GPIO1_13	pas	*** unconnected ***
	12	GPIO1_12	pas	*** unconnected ***
	13	EHRPWM2B	pas	*** unconnected ***
	14	GPIO0_26	pas	*** unconnected ***
	15	GPIO1_15	pas	*** unconnected ***
	16	GPIO1_14	pas	*** unconnected ***
	17	GPIO0_27	pas	*** unconnected ***
	18	GPIO2_1	pas	*** unconnected ***
	19	EHRPWM2A	pas	*** unconnected ***
	20	GPIO1_31	pas	*** unconnected ***
	21	GPIO1_30	pas	*** unconnected ***
	22	GPIO1_5	pas	*** unconnected ***
	23	GPIO1_4	pas	*** unconnected ***
	24	GPIO1_1	pas	*** unconnected ***
	25	GPIO1_0	pas	*** unconnected ***
	26	GPIO1_29	pas	*** unconnected ***
	27	GPIO2_22	pas	*** unconnected ***
	28	GPIO2_24	pas	*** unconnected ***
	29	GPIO2_23	pas	*** unconnected ***
	30	GPIO2_25	pas	*** unconnected ***
	31	UART5_CTSN	pas	*** unconnected ***
	32	UART5_RTSN	pas	*** unconnected ***
	33	UART4_RTSN	pas	*** unconnected ***
	34	UART3_RTSN	pas	*** unconnected ***
	35	UART4_CTSN	pas	*** unconnected ***

36	UART3_CTSN	pas	*** unconnected ***
37	UART5_TXD	pas	*** unconnected ***
38	UART5_RXD	pas	*** unconnected ***
39	GPIO2_12	pas	*** unconnected ***
40	GPIO2_13	pas	*** unconnected ***
41	GPIO2_10	pas	*** unconnected ***
42	GPIO2_11	pas	*** unconnected ***
43	GPIO2_8	pas	*** unconnected ***
44	GPIO2_9	pas	*** unconnected ***
45	GPIO2_6	pas	*** unconnected ***
46	GPIO2_7	pas	*** unconnected ***
47	GND	pwr	GND
48	GND	pwr	GND
49	VDD_3V3EXP	pwr	VIN
50	VDD_3V3EXP	pwr	VDD_3V3EXP
51	VDD_5V	pwr	VDD_5V
52	VDD_5V	pwr	VDD_5V
53	SYS_5V	pwr	SYS_5V
54	SYS_5V	pas	*** unconnected ***
55	PWR_BUT	pas	*** unconnected ***
56	SYS_RESETN	pas	*** unconnected ***
57	UART4_RXD	pas	*** unconnected ***
58	GPIO1_28	pas	*** unconnected ***
59	UART4_TXD	pas	*** unconnected ***
60	EHRPWM1A	pas	*** unconnected ***
61	GPIO1_16	pas	*** unconnected ***
62	EHRPWM1B	pas	*** unconnected ***
63	I2C1_SCL	pas	SCL
64	I2C1_SDA	pas	SDA
65	I2C2_SCL	pas	*** unconnected ***
66	I2C2_SDA	pas	*** unconnected ***
67	UART2_TXD	pas	*** unconnected ***
68	UART2_RXD	pas	*** unconnected ***
69	GPIO1_17	pas	GPIO1_17
70	UART1_TXD	pas	*** unconnected ***
71	GPIO3_21	pas	*** unconnected ***
72	UART1_RXD	pas	*** unconnected ***
73	GPIO3_19	pas	*** unconnected ***
74	SPI1_CS0	pas	*** unconnected ***
75	SPI1_DO	pas	*** unconnected ***
76	SPI1_DI	pas	*** unconnected ***
77	SPI1_SCLK	pas	*** unconnected ***
78	VDD_ADC	pas	VCC
79	AIN4	pas	*** unconnected ***

80	GNDA_ADC	pas	*** unconnected ***
81	AIN6	pas	*** unconnected ***
82	AIN5	pas	*** unconnected ***
83	AIN2	pas	N$5
84	AIN3	pas	*** unconnected ***
85	AIN0	pwr	N$1
86	AIN1	pas	N$4
87	CLKOUT2	in	*** unconnected ***
88	GPIO0_7	pas	*** unconnected ***
89	GND	pwr	GND
90	GND	pwr	GND
91	GND	pwr	GND
92	GND	pwr	GND

Pinlist

Exported from Pressure PCB v1.2.sch at 4/4/14 10:48 AM

Part	Pad	Pin	Dir	Net
1	1	RG	pas	N$3
	2	-	in	1IN-
	3	+	in	1IN+
	4	-V	pwr	GND
	5	REF	pas	GND
	6	OUT	out	OP1
	7	+V	pwr	VCC
	8	RG	pas	N$4
2	1	RG	pas	N$5
	2	-	in	2IN-
	3	+	in	2IN+
	4	-V	pwr	GND
	5	REF	pas	GND
	6	OUT	out	OP2
	7	+V	pwr	VCC
	8	RG	pas	N$6
3	1	RG	pas	N$8
	2	-	in	3IN-
	3	+	in	3IN+
	4	-V	pwr	GND

	5	REF	pas	GND	
	6	OUT	out	OP3	
	7	+V	pwr	VCC	
	8	RG	pas	N$7	
4	1	RG	pas	N$9	
	2	-	in	4IN-	
	3	+	in	4IN+	
	4	-V	pwr	GND	
	5	REF	pas	GND	
	6	OUT	out	OP4	
	7	+V	pwr	VCC	
	8	RG	pas	N$10	
BB_CONNECTIONS	1	1	io	VCC	
	2	2	io	GND	
	3	3	io	SDA	
	4	4	io	SCL	
JP1	1	1	io	GND	
	2	2	io	1IN-	
	3	3	io	1IN+	
	4	4	io	VCC	
JP2	1	1	io	GND	
	2	2	io	2IN-	
	3	3	io	2IN+	
	4	4	io	VCC	
JP3	1	1	io	GND	
	2	2	io	3IN-	
	3	3	io	3IN+	
	4	4	io	VCC	
JP4	1	1	io	GND	
	2	2	io	4IN-	
	3	3	io	4IN+	
	4	4	io	VCC	
R2	P$1	1	pas	N$6	
	P$2	2	pas	N$5	
R3	P$1	1	pas	N$7	
	P$2	2	pas	N$8	

R4	P$1	1	pas	N$10
	P$2	2	pas	N$9
R5	P$1	1	pas	N$1
	P$2	2	pas	VCC
U$1	NC	NC	io	*** unconnected ***
	CH0	CHO	io	OP1
	CH1	CH1	io	OP2
	CH2	CH2	io	OP3
	CH3	CH3	io	OP4
	CH4	CH4	io	*** unconnected ***
	CH5	CH5	io	*** unconnected ***
	CH6	CH6	io	*** unconnected ***
	CH7	CH7	io	*** unconnected ***
	GND	GND	io	GND
	REF	REF	io	*** unconnected ***
	SCL	SCL	io	SCL
	SDA	SDA	io	SDA
	VCC	VCC	io	N$1
WARNING!	P$1	1	pas	N$4
	P$2	2	pas	N$3

Pinlist

Exported from GPS_Atenna_v1.1.sch at 2/25/14 8:54 AM

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Part	Pad	Pin	Dir	Net
ANTENOVA	1	ANT_IN	io	N$2
	2	GND	io	GND
	3	ANT_OUT	io	N$1
	4	GND	io	GND
	5	VIO	io	VCC
	6	USB_DP	io	*** unconnected ***
	7	USB_DM	io	*** unconnected ***
	8	MISO	io	*** unconnected ***

	9	SCK	io	*** unconnected ***
	10	SPI_CS	io	*** unconnected ***
	11	TX	io	GPS_TX
	12	V_TH	io	GND
	13	RX	io	GPS_RX
	14	GND	io	GND
	15	V_BCKP	io	*** unconnected ***
	16	MOSI	io	*** unconnected ***
	17	GND	io	GND
	18	SDA	io	SDA
	19	SCL	io	SCL
	20	SAFEBOOT	io	*** unconnected ***
	21	GND	io	GND
	22	TCK	io	*** unconnected ***
	23	TIMEPULSE	io	*** unconnected ***
	24	GND	io	GND
	25	VDD_RF	io	*** unconnected ***
	26	GND	io	GND
	27	VCC	io	VCC
	28	GND	io	GND
	29	EXTINT	io	*** unconnected ***
	30	V_EN	io	*** unconnected ***
	31	CFG	io	*** unconnected ***
	32	P$32	io	GND
	33	GND	io	GND
	34	GND	io	GND
	35	GND	io	*** unconnected ***
	36	GND	io	GND
C1	1	1	pas	VCC
	2	2	pas	GND
C3	1	1	pas	GPS_RX
	2	2	pas	GND
C4	1	1	pas	GPS_TX
	2	2	pas	GND
C5	1	1	pas	N$1
	2	2	pas	N$2
JP1	1	1	io	XB_TX
	2	2	io	XB_RX
	3	3	io	GND

	4	4	io	VCC
	5	5	io	GPS_RX
	6	6	io	GPS_TX
L1	1	1	pas	GND
	2	2	pas	N$1
L2	1	1	pas	GND
	2	2	pas	N$2
R1	1	1	pas	SDA
	2	2	pas	VCC
R2	1	1	pas	SCL
	2	2	pas	VCC
U$1	1	SCL	io	SCL
	2	VSS	pwr	GND
	3	SDA	io	SDA
	4	VCC	pwr	VCC
	5	WP	in	GND
XBEE	1	VDD	pwr	VCC
	2	DOUT	out	XB_TX
	3	DIN	in	XB_RX
	4	DIO12	io	*** unconnected ***
	5	RESET	in	*** unconnected ***
	6	RSSI	io	*** unconnected ***
	7	DIO11	io	*** unconnected ***
	8	RES	io	*** unconnected ***
	9	DTR	io	*** unconnected ***
	10	GND	pwr	GND
	11	DIO4	io	*** unconnected ***
	12	CTS	out	*** unconnected ***
	13	DIO9	io	*** unconnected ***
	14	RES	io	*** unconnected ***
	15	DIO5	io	*** unconnected ***
	16	RTS	in	*** unconnected ***
	17	DIO3	io	*** unconnected ***
	18	DIO2	io	*** unconnected ***
	19	DIO1	io	*** unconnected ***
	20	DIO0	io	*** unconnected ***

Pinlist

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Part	Pad	Pin	Dir	Net
ACC1	T	T	io	*** unconnected ***
	X	X	io	A0
	Y	Y	io	A1
	Z	Z	io	A2
	3V	3V	io	*** unconnected ***
	GND	GND	io	GND
	VIN	VIN	io	3.3
CAM_CONN	1	1	io	LVLGND
	2	2	io	VCAM
	3	3	io	B1
EXTRA	1	1	io	GND
	2	2	io	VCC
LED	1	1	io	GND
	2	2	io	LED2
	3	3	io	LED1
	4	4	io	GND
R1	P$1	1	pas	LED1
	P$2	2	pas	5
R2	P$1	1	pas	LED2
	P$2	2	pas	4
U$1	+	+	io	*** unconnected ***
	-	-	io	*** unconnected ***
	0	0	io	*** unconnected ***
	1	1	io	*** unconnected ***
	2	2	io	*** unconnected ***
	3	3	io	3
	4	4	io	4
	5	5	io	5
	6	6	io	*** unconnected ***
	7	7	io	*** unconnected ***

	8	8	io	*** unconnected ***
	9	9	io	*** unconnected ***
	++	++	io	*** unconnected ***
	--	--	io	*** unconnected ***
	10	10	io	10
	11	11	io	11
	12	12	io	12
	13	13	io	13
	A0	A0	io	A0
	A1	A1	io	A1
	A2	A2	io	A2
	A3	A3	io	*** unconnected ***
	A4	A4	io	*** unconnected ***
	A5	A5	io	*** unconnected ***
	RST	RST	io	*** unconnected ***
	VIN	VIN	io	3.3
	AREF	AREF	io	*** unconnected ***
	GND1	GND1	io	GND
	GND2	GND2	io	GND
	GND3	GND3	io	GND
	GND4	GND4	io	GND
	GND5	GND5	io	GND
	ISP1	ISP1	io	*** unconnected ***
	ISP2	ISP2	io	*** unconnected ***
	ISP3	ISP3	io	*** unconnected ***
	ISP4	ISP4	io	*** unconnected ***
	ISP5	ISP5	io	*** unconnected ***
	ISP6	ISP6	io	*** unconnected ***
	REST	RESET	io	*** unconnected ***
	RX-1	RX-1	io	*** unconnected ***
	TX-0	TX-0	io	*** unconnected ***
	VCC1	VCC1	io	*** unconnected ***
	VCC2	VCC2	io	VCC
	5/3.3V	5/3.3V	io	*** unconnected ***
U$2	A1	A1	io	3
	A2	A2	io	*** unconnected ***
	A3	A3	io	*** unconnected ***
	A4	A4	io	*** unconnected ***
	B1	B1	io	B1
	B2	B2	io	*** unconnected ***
	B3	B3	io	*** unconnected ***
	B4	B4	io	*** unconnected ***
	OE	OE	io	*** unconnected ***

GND GND io LVLGND
OEA OEA io *** unconnected ***
P$14 P$14 io *** unconnected ***
VCCA VCCA io VCC
VCCB VCCB io VCAM

U$3 CD CD io *** unconnected ***
CS CS io 10
DI DI io 11
DO DO io 12
GND GND io GND
SCK SCK io 13
VCC VCC io VCC

Pinlist

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Part Pad Pin Dir Net

+ 1 1 pas N$1

- 1 1 pas -

ARDUINO_CONN 1 1 pas N$3

BUZZER 1 1 pas N$4

BUZZER1 1 1 pas N$4

HEATSINK 1 1 io N$8
2 2 io N$2
3 3 io -

HVSUPPLY 1 1 io 1
2 2 io 2
3 3 io N$2
4 4 io N$8

JP8 1 1 pas 2

JP13 1 1 pas -

R1	P$1	1	pas	2
	P$2	2	pas	1
R2	P$1	1	pas	-
	P$2	2	pas	1
SS	1	1	io	N$4
	2	2	io	N$1
TRANSISTOR	1	1	io	N$4
	2	2	io	2
	3	3	io	N$3

Appendix O: Milestone Review Flysheet

Milestone Review Flysheet			
Institution	University of Alabama in Huntsville	Milestone	Flight Readiness Review
First Stage (Both Stages Together or Single Stage)		**Second Stage (If Applicable)**	
Vehicle Properties		**Vehicle Properties**	
Total Length (in)	120.179"	Total Length (in)	
Diameter (in)	4.59"	Diameter (in)	
Gross Lift Off Weight (lb.)	34.0 lbs	Gross Weight (lb.)	
Airframe Material	Carbon Fiber	Airframe Material	
Fin Material	Carbon Fiber	Fin Material	
Motor Properties		**Motor Properties**	
Motor Manufacturer(s)	Cesaroni Technology Inc.	Motor Manufacturer(s)	
Motor Designation(s)	M-4770 (Vmax)	Motor Designation(s)	
Max/Average Thrust (lb.)	1362.01/ 1073.3	Max/Average Thrust (lb.)	
Total Impulse (lbf-sec)	1645.29	Total Impulse (lbf-sec)	
Stability Analysis		Ignition Altitude (ft)	
Center of Pressure (in from nose)	93.6	Ignition Timing (From 1st Stage Burnout)	
Center of Gravity (in from nose)	85.8	Igniter Location	
Static Stability Margin	2.37	**Stability Analysis**	
Thrust-to-Weight Ratio	38	Center of Pressure (in from nose)	
Rail Size (in)	1.5	Center of Gravity (in from nose)	
Rail Length (in)	120	Static Stability Margin	
Rail Exit Velocity (ft/s)	130	Thrust-to-Weight Ratio	
Ascent Analysis		**Ascent Analysis**	
Maximum Velocity (ft/s)	1600	Maximum Velocity (ft/s)	
Maximum Mach Number	1.4	Maximum Mach Number	
Maximum Acceleration (ft/s^2)	1416.8	Maximum Acceleration (ft/s)	
Target Apogee (1st Stage if Multiple Stages)	15,800 ft	Target Apogee (ft)	
Recovery System Properties		**Recovery System Properties**	
Drogue Parachute		**Drogue Parachute**	
Configuration	Conical	Configuration	
Size	30 inch diameter	Size	
Deployment Velocity (ft/s)	50	Deployment Velocity (ft/s)	
Terminal Velocity (ft/s)	120	Terminal Velocity (ft/s)	
Fabric Type	Rip-Stop Nylon	Fabric Type	
Shroud Line Material	Polyester	Shroud Line Material	
Shroud Line Length (in)	45 in	Shroud Line Length (in)	
Thread Type	Polyester	Thread Type	
Seam Type	Straight stich/zig zag	Seam Type	
Recovery Harness Type	1/4" Diameter Kevlar	Recovery Harness Type	
Recovery Harness Length (ft)	3	Recovery Harness Length (ft)	
Harness/Airframe Interface	Eyebolt/ Swivel/ Quick Links	Harness/Airframe Interface	
Main Parachute		**Main Parachute**	
Configuration	Semi-Hemispherical	Configuration	
Size	12 ft. Diameter	Size	

Deployment Velocity (ft/s)	120	Deployment Velocity (ft/s)	
Terminal Velocity (ft/s)	14 ft/s	Terminal Velocity (ft/s)	
Fabric Type	Rip-Stop Nylon	Fabric Type	
Shroud Line Material	Polyester	Shroud Line Material	
Shroud Line Length (in)	240 in	Shroud Line Length (in)	
Thread Type	Polyester	Thread Type	
Seam Type	Straight stich/zig zag	Seam Type	
Recovery Harness Type	1/4" Diameter Kevlar	Recovery Harness Type	
Recovery Harness Length (ft)	20	Recovery Harness Length (ft)	
Harness/Airframe Interface	Eyebolt/ Swivel/ Quick Links	Harness/Airframe Interface	

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
	0.83	55	2						
	Nose Cone	Airframe	LHDS w Recov.						

Milestone Review Flysheet

Institution	University of Alabama in Huntsville	Milestone	Flight Readiness Review
First Stage (or Single Stage)		**Second Stage (If Applicable)**	
Recovery System Properties		**Recovery System Properties**	
Altimeter(s)/Timer(s) (Make/Model)	PerfectFlite Stratologger (SL100) (X2)	Altimeter(s)/Timer(s) Make/Model	
Transmitters (Model-Frequency-Power)	Xbee-PROXSC S3B-900 MHz-250 mW	Locators/Frequencies (Model-Frequency-Power)	
	Antenova M10382-Al UB		
	Tagg Tracker		
Black Powder Charge Size Drogue Parachute (grams)	3	Black Powder Charge Size Drogue Parachute (grams)	
Black Powder Charge Size Main Parachute (grams)	0.5	Black Powder Charge Size Main Parachute (grams)	

Institution	University of Alabama in Huntsville	Milestone	Flight Readiness Review
First Stage (or Single Stage)		**Second Stage (If Applicable)**	
Recovery System Properties		**Recovery System Properties**	
Altimeter(s)/Timer(s) (Make/Model)	PerfectFlite Stratologger (SL100) (X2)	Altimeter(s)/Timer(s) Make/Model	
Transmitters (Model-Frequency-Power)	Xbee-PROXSC S3B-900 MHz-250 mW	Locators/Frequencies (Model-Frequency-Power)	
	Antenova M10382-Al UB		
	Tagg Tracker		
Black Powder Charge Size Drogue Parachute (grams)	3	Black Powder Charge Size Drogue Parachute (grams)	
Black Powder Charge Size Main Parachute (grams)	0.5	Black Powder Charge Size Main Parachute (grams)	

<table>
<tr><th>Institution</th><th>University of Alabama in Huntsville</th><th>Milestone</th><th>Flight Readiness Review</th></tr>
<tr><th colspan="2">First Stage (or Single Stage)</th><th colspan="2">Second Stage (If Applicable)</th></tr>
<tr><th colspan="2">Recovery System Properties</th><th colspan="2">Recovery System Properties</th></tr>
<tr><td rowspan="4">Altimeter(s)/Timer(s) (Make/Model)</td><td>PerfectFlite Stratologger (SL100) (X2)</td><td rowspan="4">Altimeter(s)/Timer(s) Make/Model</td><td></td></tr>
<tr><td></td><td></td></tr>
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<tr><td></td><td></td></tr>
<tr><td rowspan="2">Black Powder Charge Size Main Parachute (grams)</td><td>0.5</td><td rowspan="2">Black Powder Charge Size Main Parachute (grams)</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="4">Additional Comments</th></tr>
<tr><td colspan="4">We will be submitting a late addendum for the delayed full scale launches.</td></tr>
</table>

23 Appendix P: Statement of Work Requirements Table

Statement of Work Requirements Verification Table - Addendum

Vehicle Requirements

Requirement	Success Criteria	Verification
1.1	No specific design requirement exists for the altitude. The altitude is a function of obtaining supersonic flight for the supersonic payloads	Multiply methods of prediction predict an altitude and generate similar results. (Rocksim, OpenRocket, Custom Monty Carlo)
1.1.1.	Obtaining the predicted altitude of 15,800ft	Pull altitude from the altimeters after full-size motor flight. (Expected at competition launch)
1.1.2.	The Range Safety Officer approves the altitude by the CDR	Predicted altitude is below the specified maximum
1.2	The vehicle shall use a COTS barometric altimeter for recording official altitude	Both altimeters will be PerfectFlite StratoLoggers
1.2.1	Altimeter successfully recovered and presented to NASA official while still beeping	Successful recovery of Prometheus following competition launch
1.2.2	The vehicle shall have additional altimeters to control vehicle electronics and payload experiments	By design two altimeters will be used to successfully trigger the recovery system. The competition altimeter and a redundant device
1.2.2.1	Present altimeter to be marked as official altimeter.	Designate official altimeter ahead of launch to NASA official
1.2.2.2	Altimeter successfully recovered and presented to NASA official while still beeping	See requirement 1.2.1
1.2.2.3	Silence all other altimeters in the rocket.	All other altimeters will be placed into silence mode during rocket setup on ground

1.2.3	See Sub Requirements	See Sub Requirements
1.2.3.1	The official altimeter is presented to the RSO undamaged while still reporting an altitude	See requirement 1.2.1
1.2.3.2	The team will report to the RSO in a timely manner after recovery of the vehicle	Team will develop and follow specified launch day procedures practiced during full-scale launch
1.2.3.3	Current predictions do not exceed 16,000 feet AGL	Simulations in Rocksim predict max altitude of 15,800 ft. AGL
1.2.3.4	CRW current plans to have a team in Utah for the competition flight of Prometheus	Funding for travel obtained, awaiting final FRR approval to finalize travel purchases
1.3	Rocket will be designed to land slow enough so no hardware is damaged	Tested with comparable weight rocket and full-size recovery system on April 12th. Landing left all hardware undamaged
1.4	Payloads and recover system will be simple in design and allow the rocket to be assembled in 2 hours from waiver opening.	Ground testing of payload and recovery system designs to ensure quick assembly. Launch procedures detailing all steps in assembly. Will be tested during full-scale flight April 26th.
1.5	Vehicle shall remain in launch configuration for at least one hour.	Batteries have been selected so that individual systems remain functional for 1.75 hours
1.6	The vehicle shall be able to be launched by a 12V ignition system that will be provided	By design Motors selected for subscale and full scale flights are commercially available and can be ignited using a 12V system
1.7	Vehicle shall not require any external circuitry to initiate	The ignition system provided by NASA will be

	launch	the only circuitry external to the vehicle
1.8	The vehicle shall use a COTS motor propulsion system using APCP	The selected motor will be a CTI M4770- Vmax
1.9	Prometheus will not have a pressure vessel.	Prometheus will not have a pressure vessel.
1.10	See Sub Requirements	See Sub Requirements
1.10.1	The vehicle and recovery system will be flown and operate correctly during a full-scale flight.	The rocket will be visually inspected and flight data will be used to confirm recover system results. Expected flight April 26th.
1.10.2	See Sub Requirements	See Sub Requirements
1.10.2.1	See Sub Requirements	See Sub Requirements
1.10.2.1.1	If all payloads are not prepared mass simulators will be placed in the approximate location as the unfinished payload.	Mass simulators will be based on latest know expected payload mass
1.10.2.2	Prometheus contains no external surface changing payloads or energy management systems	Prometheus contains no external surface changing payloads or energy management systems
1.10.3	A full-scale flight with a full-scale or near full-scale motor will be flown to validate design and test payloads.	The full-scale flight will validate launch calculations, payload design, vehicle design, and recovery system design.
1.10.4	A full-scale flight with complete ballast shall be flown before the FRR.	A full-scale flight with all payloads in flight ready configuration or with simulated weight will be flown and safely recovered.
1.10.5	After competition of a full-scale flight the system will be completely designed and not require a redesign.	Should anything need to be changed, concurrence must be obtained from the Range Safety Officer (RSO) priory

		to design change.

Recovery System Requirements

Requirement	Success Criteria	Verification
2.1	Use a dual deploy system that can bring the rocket down fast enough to keep drift under 5000ft for a 20 mph wind.	Recovery system tested on near full-scale flight on April 12th. Data will be tied to predictions to verify max drift
2.2	A completely custom made parachute designed and manufactured by the UAH Charger Rocket Works team	Completed recovery system designed and assembled by Charger Rocket Works team
2.3	The highest landing energy will belong to the large body of the rocket and will be maintained near the current prediction of 33 ft.*lb	Recovery system tested on near full-scale flight on April 12th. Data will be extracted to verify low landing energy
2.4	The recovery system circuit will be designed to be completely self-contained and isolated from the payload circuits.	The recovery system circuit tested during near full-scale flight on April 12th. System worked without flaw
2.5	Two commercial altimeters will provide redundancy to insure recovery system deployment. Both the drogue and main will have redundant altimeters	Ground test prior to near full-scale verified successful redundancy in recovery system as well as successful recovery from near full-scale on April 12th
2.6	Dual arming switches to insure both altimeters are armed and keep both systems separate from each other	Dual arming switches were able to be activated from outside the rocket on near full-scale rocket on April 12th
2.7	Each altimeter will have a dedicated power supply to completely isolate each recovery system and prevent a single failure point.	Altimeters performed correctly on separate batteries during near full-scale flight.
2.8	Pull pins will be used and the system will be designed to be on once the pins are removed.	Dual arming switches were able to be activated using pull pins from outside the rocket on near full-scale rocket on April 12th

2.9	Shear pins will keep the single deploy point (Nosecone) attached. The shear pins will be removable to access the recovery system.	The shear pins will be checked to insure they can be removed before launch and they will be tested in shearing during the full-scale launch and ground tests.
2.10	See Sub Requirements	See Sub Requirements
2.10.1	The rocket will return tethered together. The rocket will have GPS broadcasting in real time during the descent and have a dog tracker as a backup solution.	The GPS is included with the LHDS which is tethered to the main body with shock cord.
2.10.2	The tracking system will be functional and integrated with the Landing Hazard Detection System.	The LHDS has been designed to include the GPS and the setup has been tested on 4/11/14
2.11	See Sub Requirements	See Sub Requirements
2.11.1	The recovery system will be located in a different compartment from the LHDS, the only broadcasting system.	The altimeters have been placed in their own compartment and the bottom carbonfiber plate of the LHDS separates the Radio from the rest of the recover bay.
2.11.2	No onboard devices will be transmitting until the recovery system has already deployed.	Tested during full-scale flight to insure radio does not power on until clear of the rocket.
2.11.3	The recovery system will be separated from energy producing payloads and the energy producing payload will reside in a faraday cage.	Ground tests will insure recovery system is properly isolated from energy producing payloads and tested during full-scale flight.
2.11.4	No devices will interfere with the operation of the recovery system electronics through any means.	Several sub-scale tests, ground tests, and full-scale test will insure the recovery system remains un affected by other payloads.

Payload Requirements

Requirement	Success Criteria	Verification
3.1	See Sub Requirements	See Sub Requirements
3.1.1	Landing Hazard Detection System will include a COTS camera to scan the ground during descent for hazards and use one of three different methods or a combination of them to detect hazards.	A COTS camera has been purchased and tested with Beaglebone using the different methods on 3/31/14.
3.1.2	Use a Beaglebone to provide sufficient processing to analyze the image in real time by the computer on the rocket.	Beaglebone successfully tested processing images in real time 3/31/14.
3.1.3	The presence of hazards or lack thereof will be transmitted back to a ground station in real time using a COTS radio solution connected to the Beaglebone.	The Xbee radio will transmit Camera data and GPS data back to the ground station. Initial ground testing 4/11/14 with more to follow.
3.2	Fly additional payloads 3.2.1.2 and 3.2.2.4	Ensure that each payload meets its separate payload requirements from the CDR
3.3	Design payload to have easily changeable batteries and remain undamaged on landing so the system can be easily re-flown without requiring repairs.	Batteries are designed to secure to the outside of the payload panels so they can be easily replaced
3.4	3.4 and sub requirements are not applicable	3.4 and sub requirements are not applicable

General Requirements

Requirement	Success Criteria	Verification
4.1	Launch and safety checklist made and tested for full-scale launch.	Launch checklist will be tested and run through during full-scale launch to insure completeness.
4.2	A successful mission flown and built completely by students at Charger Rocket Works of University of Alabama in Huntsville	Although external sources shall be used for advice, all construction, design work, and writing will be performed by students.
4.3	Project plan will contain details concerning all aspects of the project and lay out a path forward till the project's completion.	A final project binder containing purchases, timeline, organization chart, outreach details, and more shall be made before the flight day.
4.4	Mentor will be identified and be certified at the appropriate level by full-scale launch.	Jason Winningham NAR Level 3
4.5	All team members, instructors, and mentors will be identified to NASA including Foreign nationals	Completed. List submitted before CDR.
4.6	Foreign Nationals will be identified by PDR and informed of potential separation during launch week activities	Completed. List submitted before PDR.
4.7	Follow all generally accepted safety procedures as well as any additional safety procedures that are imposed by the RSO at any local club launches.	Check with RSO before each launch and insure they approved of the flight.
4.8	Complete an outreach packet that is modular in nature and easily adaptable to different age groups to reach as many students as possible. Lay groundwork for future teams to	Request feedback from outreach students and educators to evaluate worth of outreach program and improve. Put outreach slides and plans on flash

	build upon outreach. Reach at least 200 students at least half of those being middle schools.	drive and give to instructor to present to next class.
4.9	A new custom hand crafted HTML5 website will be designed for the Charger Rocket Works team. This will be used to spread information concerning the team and its efforts in both outreach and project. Allow easy access to all documentation made by the team. Website should be complete by Launch Day with only flight results left to post.	Use online HTML verifiers to insure HTML5 compliance and test document download to insure they work correctly. Check website and insure completeness by launch day.
4.9.1	Post documents to website in an easily accessible manner. Email NASA when documents are posted.	PDR: Completed CDR: Completed FRR: Partial (Awaiting Full-scale Flight)