Project: Simple Complexity
Preliminary Design Review (PDR)
Documentation

Georgia Institute of Technology Team
A.R.E.S.
Wednesday November 5th, 2014

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1. PDR Report Summary

1.1. Team Summary

	Team Summary
School Name	Georgia Institute of Technology
Mailing Address	North Avenue NW, Atlanta GA 30332
Team Name	Team Autonomous Rocket Equipment System (A.R.E.S.)
Project Title	Simple Complexity
Launch Vehicle Name	Pyroeis
Project Lead	Victor
Safety Officer	Raef
Team Advisors	Dr. Eric Feron
NAR Section	Primary: Southern Area Launch vehiclery (SoAR) #571
NAR Contact, Number & Certification Level	Primary Contact: Joseph Mattingly NAR/TRA Number: 92646 Certification Level: Level 2 Secondary: Jorge Blanco

1.2. Launch Vehicle Summary

The Pyroeis rocket is 66.425 inches in length and projected to weigh 10.58 lbs. The rocket is designed to accommodate a 3.5 inch PVC pipe payload in the nose cone. A Cesaroni Technology 949-J150 reloadable rocket motor was chosen to propel the rocket to an apogee of 3000 feet. A 2.5 foot diameter drogue parachute will deploy from a compartment between the booster and avionics sections an apogee, and a 4.3 foot diameter main parachute will be deployed below 700 feet AGL to slow the rocket such that the kinetic energy at ground impact will be below 75 ft-lbf. The nose cone, carrying the payload, will be ejected at 1000 feet AGL and will deploy a separate 1 foot diameter parachute.

1.3. AGSE Summary

Georgia Tech's AGSE system, will be a mechanically stable platform that will house critical hardware and electrical modules in order to accomplish all mission objectives for the 2015 NASA SL Maxi-MAV/Centennial Challenge. Key components & related mission objectives of the AGSE are as follows,

- Payload Insertion System (PLIS): An open source 6 degrees of freedom (DOF) robotic arm will be used to reliably and effectively capture the standard Maxi-MAV payload
- Vehicle Erector System (VES): The VES will incorporate launch rails upon which the LV will rest and eventually exit, and a pair of worm screws, each driven by a stepper motor, offset from the launch rail.
- Igniter Insertion System (IIS): The IIS will carry out the task of autonomously inserting a live igniter into the solid rocket motor (SRM) cavity

2. Changes made since the Proposal (1-2)

2.1. Changes made to the vehicle criteria

- Change motor selection for greater thrust to Cesaroni J530

2.2. Changes made to the AGSE criteria

- Elimination of environment mapping and payload localization (SLAM techniques) via sensors for payload retrieval: team will instead exploit hard-coded positions and a known starting location of the payload.
- Selection of core designs for the robotic arm, Vehicle Erector System (VES) and Igniter Insertion System (IIS).

2.3. Changes made to the project plan

- Douglass High School Collaboration Funding Plan

3. Vehicle Criteria

3.1. Selection, Design, and Verification of Launch Vehicle

3.1.1. Overview

The mission of this launch vehicle is to carry an autonomously inserted payload to an apogee altitude of 3000 ft AGL and then to deploy the payload at 1000 ft AGL. The deployed payload and the rocket must then both impact the ground with a kinetic energy less than 75 ft-lbf.

The nose section was designed to allow the payload to be inserted autonomously on the launch pad with ejecting capabilities. This was accomplished by making the upper 4 in of the nose cone removable from the rest of the nose cone. The payload is then jettisoned with the nose cone, which has a separate recovery parachute.

An active control system will be used to correct the launch trajectory to reach an apogee of 3000 ft AGL. The system will control extension of cylindrical pins normal to the free stream with inputs of velocity, altitude, and attitude. Test flights will be conducted to verify simulated ideal trajectory profiles.

Table 1 lists the Mission Success Criteria for the launch vehicle.

Table 1: Mission Success Criteria for the Launch Vehicle

Requirement	*Design feature to satisfy requirement*	*Requirement Verification*	*Success Criteria*
The vehicle shall deliver the payload to, but not exceeding, an apogee altitude of 3,000 feet above ground level (AGL)	Control drag on rocket from altitude sampling data	Subscale test flight	Apogee within 1% of target
The rocket will launch as designed and jettison the payload at 1,000 feet AGL during descent	Nose cone carrying payload deploys from rocket	Ground deployment test of nose cone	Nose cone deploys without damage to remainder of rocket
The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	Rocket will be constructed with G10 fiberglass to resist fractures	FEA analysis will be conducted on critical structural components	Rocket body does not fracture under expected launching or landing loads

3.1.2. Internal Design Reviews

Several solutions were proposed to meet each design requirement. In this section, different proposed designs for critical systems are compared and reasoning behind the chosen design is shown in **Table 2**. The criteria to eliminate designs and ideas are the following; the payload must be autonomously inserted into the rocket and the rocket then returned to a flight ready configuration. The nose cone was chosen to hold the payload so that the entire nose cone could then jettison with the payload. **Table 2** design proposals for how the nose cone would accept the payload are listed. The removable nosecone tip was chosen because of simple operation and interface with the AGSE. The problems with the complex manufacturing are mitigated with use of 3D printing technology.

Table 2: Nosecone Internal Design Review

Design Feature	*Advantages*	*Disadvantages*
Spring loaded hinge	Easy to insert payload	May be pushed by air forces during flight. Construction would be difficult.
Part of nosecone completely removed from body tube and held in by magnetically released latch	Nosecone will stay on body tube No obstructions will create unnecessary drag forces No complex mechanism to insert payload; only magnets will be needed to release nosecone	Still more work to insert the payload. Complicated manufacturing of pieces
Nosecone screwed on and off of body tube	Secure fit back on to the body tube No obstructions will create unnecessary drag forces	Complex mechanical design to insert payload.

In order to reliably satisfy the requirement of carrying the payload to an altitude of 3000 ft AGL, the features listed in **Table 3** were proposed. A servo controlled variable drag system was chosen because of the unique ability to respond to variable launch conditions, such as wind, pressure, and variations in motor performance.

Table 3: Apogee Targeting System Design Review

Design Feature	*Advantages*	*Disadvantages*
Rely on ground simulation in selection of motor and rocket mass	No separate system would need to be developed	Simulations may not be accurate and will not fully account for variations in launch conditions
Removable masses will be configured prior to each flight based on performance of previous flights	Simple flight test based solution	May be inaccurate, will not account for variations in conditions between launches
Servo motor controls extension of cylindrical pins to vary drag force on rocket	An onboard active control system would respond to changing flight conditions	System design is complicated and unproven

3.1.3. Booster Section

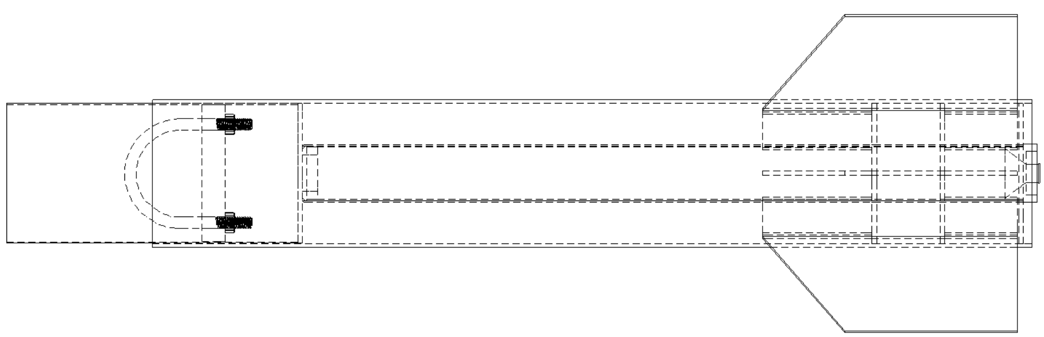


Figure 1: Booster Section Cutaway

The booster system of the Pyroeis rocket uses traditional motors combined with a unique structure. The main focus is to have a highly integrated design and to offer reliable power to the launch vehicle. The primary components of launch vehicle booster section would be the launch vehicle motor itself and multiple bulkhead structure. The layout of the booster section is shown in **Figure 1: Booster Section Cutaway**and Figure 2.

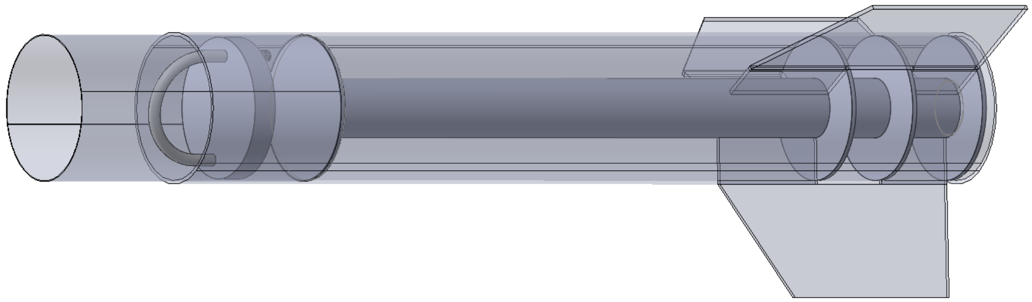


Figure 2: Booster Section Assembly

The booster section can be broken down to several modular parts. The first part is the thrust plate located at the top of the motor. The thrust plate will provide contact area or the motor to transmit thrust to the rest of the launch vehicle. The thrust plate will be in contact with a coupler at the top of the booster section. The coupler will be attached to the body tube with adhesive, and will thus result in a large area of contact for the force transmission. A pressure bulkhead above the thrust plate has a U-bolt, which will be a connection point between the booster section and the drogue parachute. The apogee targeting system will be positioned between two centering rings situated next to the fins.

The fins and bulkheads will be manufactured by water jet cutting commercially available G10 fiberglass sheets, and bulkheads will be held in the rocket with steel screws.

3.1.4. Apogee Targeting System

The apogee targeting system is composed of the pin drag mechanics, a control system operated by onboard avionics, and an onboard sensor array. The mechanical components of the system will be 3D printed to allow for rapid prototyping and verification. The control system will be designed with aid of MATLAB and Simulink. A schematic of the control system is shown in **Figure 3**.

Ideal values for altitude and velocity as a function of time will be calculated from simulation and from a series subscale test flights. Success of the system will be determined by error in apogee altitude from 3000 ft AGL.

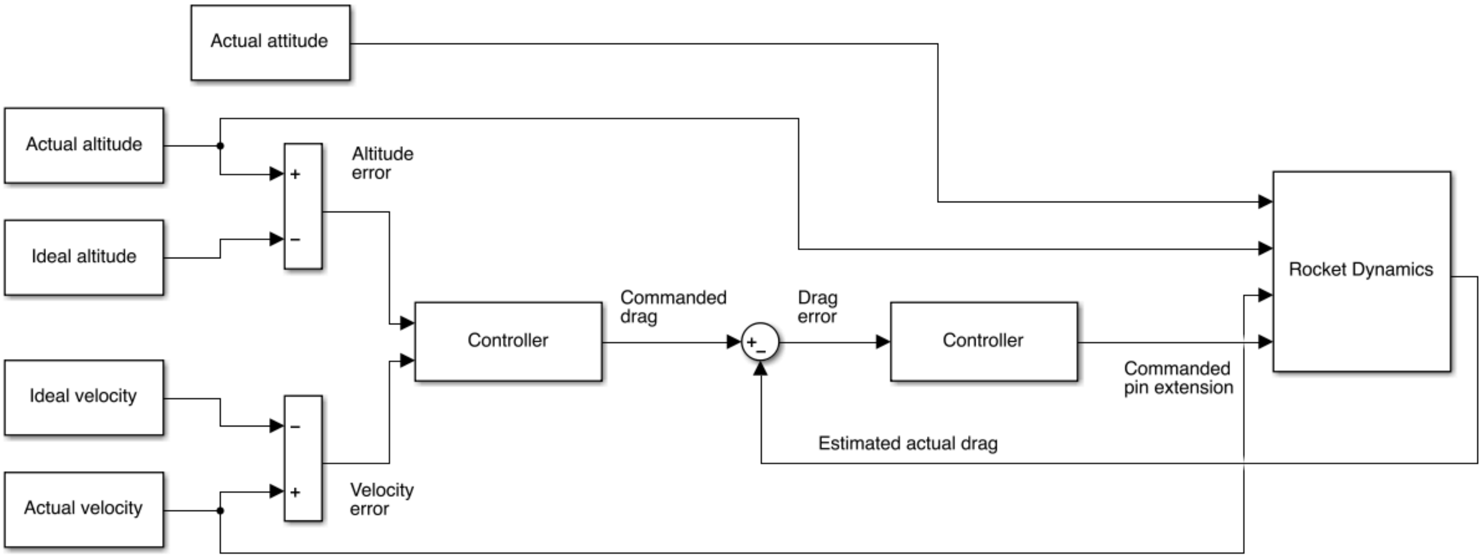


Figure 3: Apogee Targeting System Control System Breakdown

3.1.5. Avionics Section

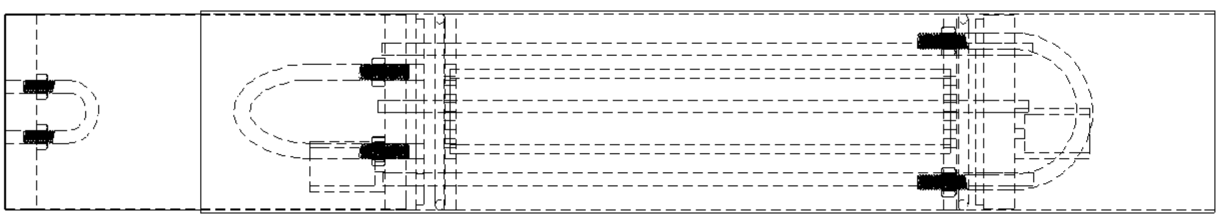


Figure 4: Avionic Section Cutaway

The avionics section, shown in **Figure 4** and **Figure 5** will house the avionics to control the rocket as well as ejection charges for both the main and drogue parachutes. Electronic components will be mounted in the avionics bay, which will be removable. The avionics bay was designed to be removable from the rocket so that the electronics can be easily accessed between flights.

Figure 5: Avionics Bay Solidworks drawing

All bulkheads in the avionics section will be manufactured from sheets of G10 fiberglass using a CNC water jet. Verification of the avionics will be conducted through ground testing of parachute ejection and drag pin control.

3.1.6. Payload Section

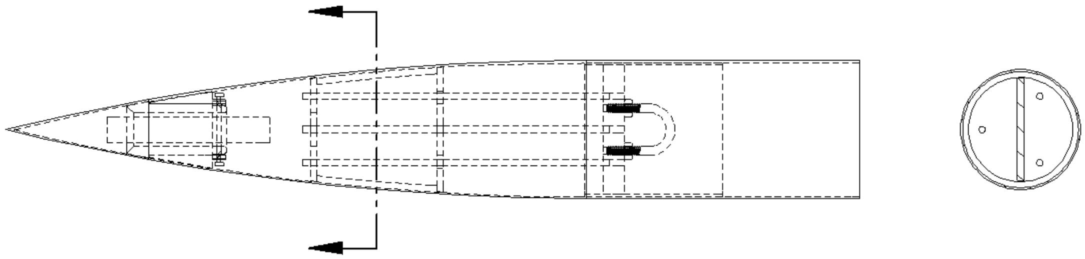


Figure 6: Nosecone Payload Bay Cutaway

The payload is located in the nose cone section of the launch vehicle, which is constructed with G10 fiberglass. An overview of the nose cone and payload section can be viewed in **Figure 6** and a 3-D view is shown in **Figure 7**.

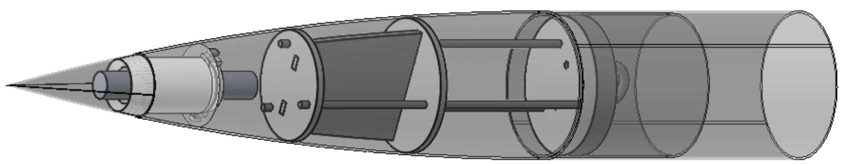


Figure 7: Nosecone Payload Bay 3-D rendering

An upper section of the nose cone is removable to account for the autonomous insertion of the payload. The removable tip of the nose cone will be held in place by magnetically released spring-loaded notches. The notches are initially locked, but when a magnet is in the vicinity surrounding the nose cone, these notches retract and allow the nose cone tip to be removed, allowing for insertion of the payload. An image of these notches in the initial state and the retracted state is shown in **Figure 8**. Payload is then inserted into the nose cone and held in place by foam insert in the nose cone. The nose cone is connected to the rest of the body by a coupler that will be inserted into the avionics section.

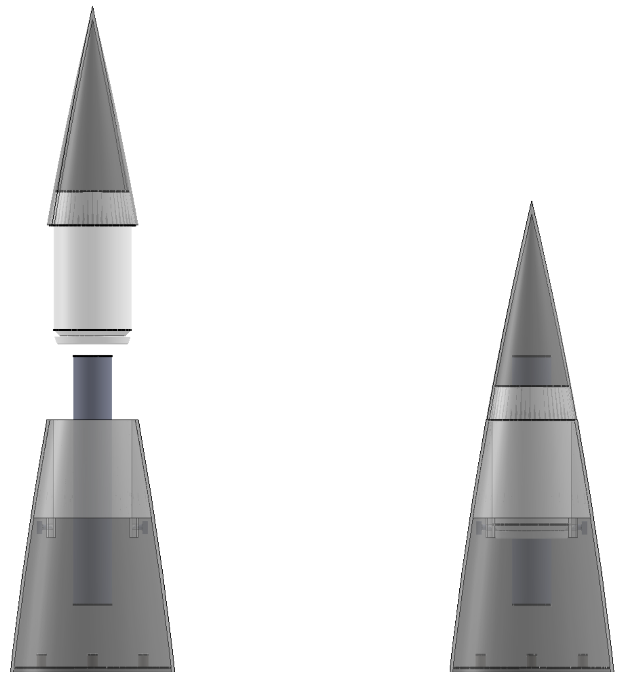


Figure 8: Nosecone Attaching Mechanism

The nosecone will be commercially bought and the magnetic notches and centerpiece will the custom made by the team. The nosecone will be made out of fiberglass, the notches will be machined out of steel or another magnetic metal alloy, and the centerpiece will be constructed of aluminum. These notches will be attached to spring so that they are pushed back in to the centerpiece to stop the nose cone from moving once the payload has been inserted.

Success of the payload section will be determined by ground testing of both ejection and AGSE payload insertion.

3.1.7. Launch Vehicle Design Requirement Overview

In addition to the primary mission objectives, several other important requirements were considered in the design of the Pyroeis rocket. An outline of requirements that significantly impacted the rocket design is listed in **Table 4**.

Table 4: Requirements for Launch Vehicle

Requirement	*Design feature to satisfy requirement*	*Requirement Verification*
Payload must not impact the ground with more than 75 ft-lb_f	Nosecone has separate recovery parachute	Nosecone deployment will be ground tested
Landing downrange distance must be minimized	A drogue parachute will deploy at apogee with the main parachute not deploying until under 700 AGL.	Ground deployment test of nose cone
The recovery system electronics shall be shielded from all interference	Electronics bay will be separated into two separate shielded sections	Interference will be measured in ground testing

3.1.8. Risk Assessment

Table 5: Risk Assessment

Risk	*Likelihood*	*Mitigation*
Drag pin system actuation fails in flight	Moderate	Drag pins will start at 50% extension, so a motor control failure will have minimal impact
Nosecone insertion will be too difficult for AGSE hardware	Moderate	Prototypes will be rapidly produced and refined using 3D printing technology
Payload section jettison will cause premature main parachute deployment	Low	Ground tests will be conducted on payload section jettison

3.1.9. Confidence and Maturity of Design

The design of the Pyroeis rocket includes procedures of varying maturity. **Table 6** lists major processes that will be implemented along with Team A.R.E.S confidence in accomplishing these processes.

Table 6: Confidence and Maturity of Design

Process	*Comment on Maturity*	*Actions*
Parachute deployment	Blasting cap method is commonly employed in high powered model rocketry. Moderate maturity.	Ground testing will be conducted
Variable drag control system	The system is untested and unproven. Low maturity.	Subscale test launches will gather data
Payload section jettison	Process used will be the same as parachute deployment. Moderate maturity.	Ground testing will be conducted
Manufacturing	Water jet CNC machines will be used, which are extremely accurate and precise. High maturity.	None

3.1.10. Assembly

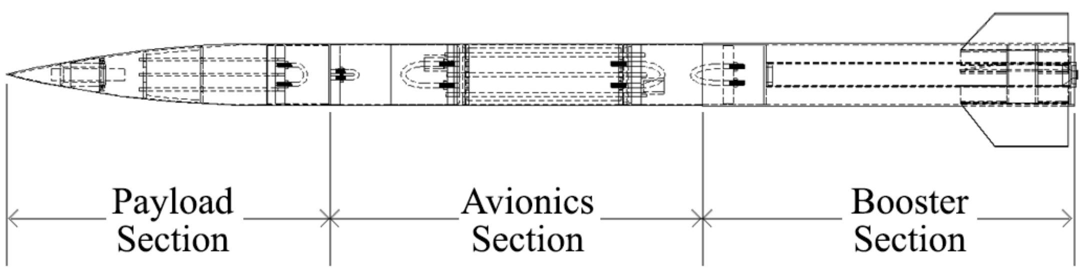


Figure 9: Assembly of Independent Sections

Table 7: Length Breakdown

Section	*Length*
Booster Section	21.175 in
Avionics Section	20.25 in
Payload Section	25 in
Total	66.425 in

3.1.11. Recovery System

To successfully complete the USLI mission, flight systems is further responsible for providing a fully functional flight computer system. Avionics is the second subsystem of Flight Systems, responsible for data acquisition, experimental control, recovery electronics, and features necessary as per the USLI Handbook. Avionics requirements are listed in ***Table 8***. The flight avionics interfaces with all sensors and controls most sensing, logging, and telemetry for the launch vehicle. The two major components of the flight avionics are the payload system and the recovery system as shown in***Figure 10***.

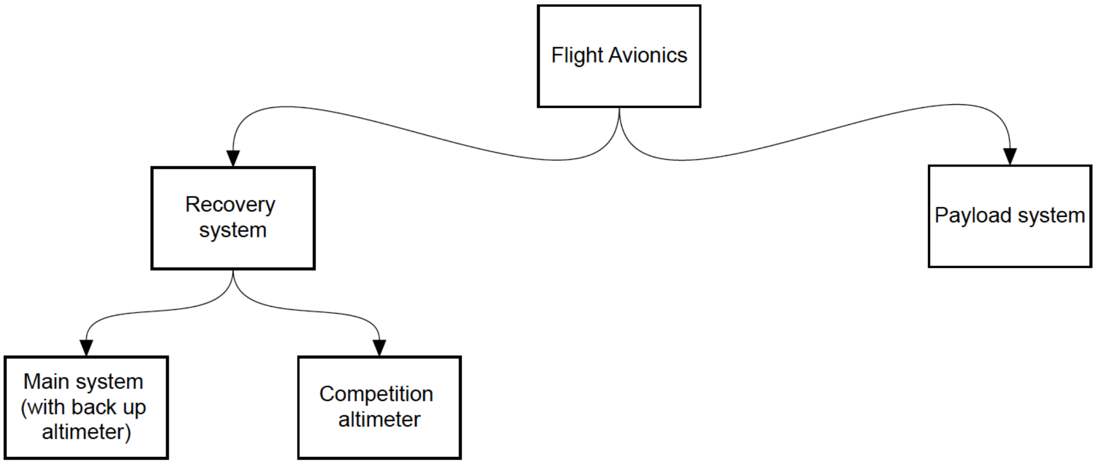


Figure 10. General components of flight avionics.

Table 8. Recovery system avionics requirements

Requirement Number	***Requirement Definition***
2.1	The launch vehicle shall stage the deployment of its recovery devices in the following order, drogue parachute, main parachute
2.2	Teams must perform a successful ground ejection test for both the drogue and main parachute
2.3	At landing, each independent section's kinetic energy shall not exceed 75 ft. lbf
2.4	The recovery system electrical circuits shall be completely independent of any payload electrical circuits
2.5	The recovery system shall contain redundant, commercially available altimeters
2.6	A arming swtich shall arm each alitmeter, which is accessible from the exterior of the rocket airframe
2.7	Each altimeter shall have a dedicated power supply
2.8	Each arming switch shall be capable of being locked in the ON position for launch
2.9	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment
2.10	An electronic tracking device shall transmit the position of the rocket
2.11	The recovery system will by shielded from magnetic waves and all onboard devices, and placed in separate compartments within the vehicle

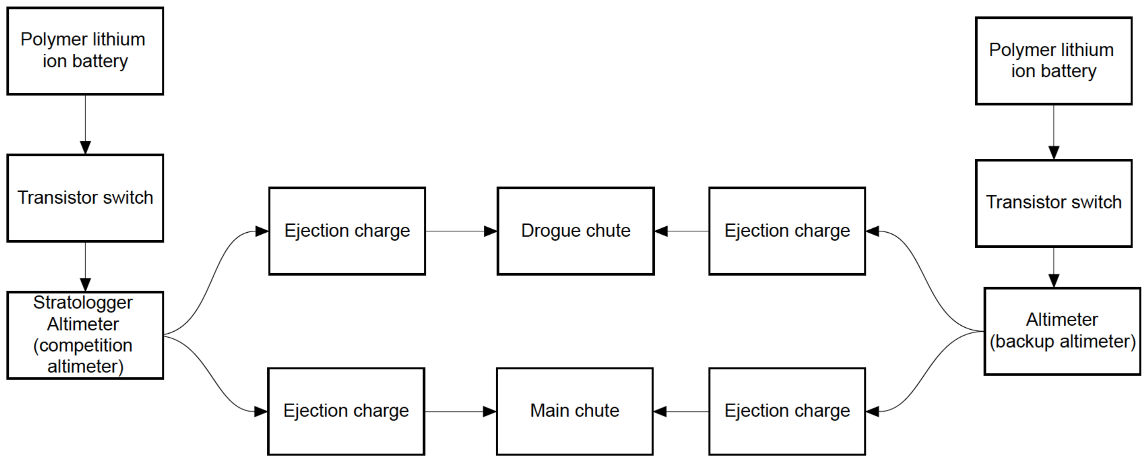


Figure 11. General schematic of the altimeter with redundancy.

Recovery system:

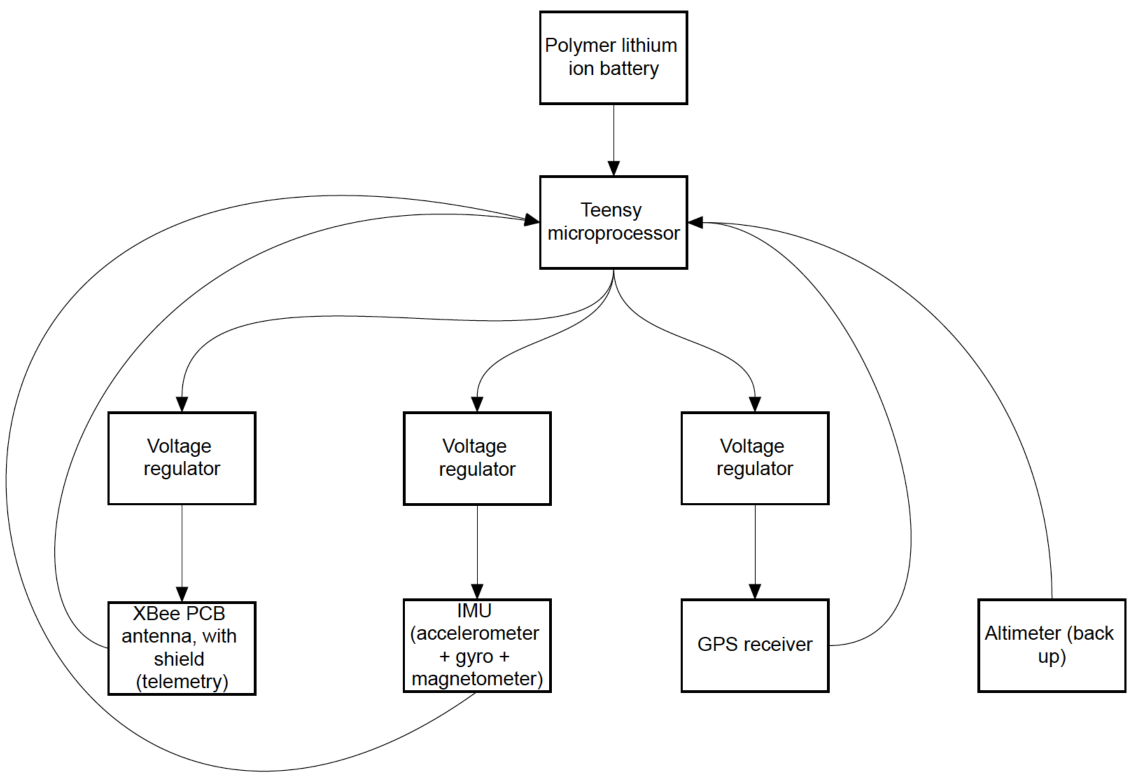


Figure 12. Generalization of the main system in the recovery system.

The recovery system uses two Teensy 3.1 microprocessors that can be programmed using Arduino IDE. One microprocessor is connected to the main system (see ***Figure 11***) and the other one is connected solely to the competition altimeter. The main tasks of the recovery system include collecting and monitoring all the relevant data from the environment around it such as the strain on the launch vehicle, environmental factors such as temperature, launch vehicle acceleration, rocket altitude and GPS position. At the required height, the altimeter will eject the drogue and main parachute using an ejection charge. Two altimeters are used for redundancy purposes in case the competition altimeter fails. The beeper is present in the altimeter itself. The competition altimeter is separate with its own dedicated power supply and microprocessor. It is to be shielded from the main system that has the XBee antenna to transmit data to the ground system.

Post-recovery, the microprocessor must switch to location and communication systems to transmit a GPS signal through the telemetry system (XBee antenna) to the ground station. ***Figure 12***and

Table 9 provide the current proposed recovery system schematic and major components, respectively.

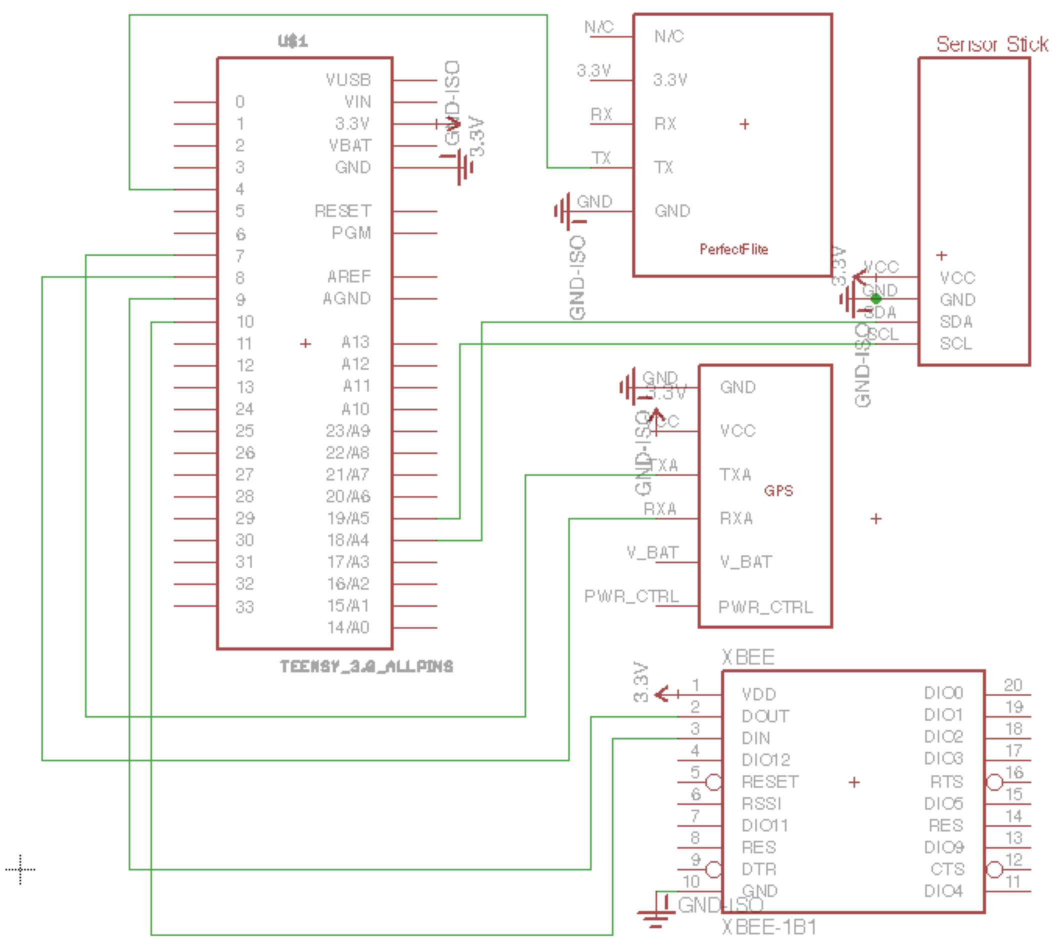


Figure 13. Schematic of main system in the recovery system

Table 9. Major recovery system components

Name	*Outout power*	*voltage (V)*	*Bus*	*Dimensions*
Teensy microprocessor	100mA @ 3.3V	3.3	I2C, SPI	1.4 x 0.7" (~35 x 18 mm)
Sensor Stick			I2C	1.37 x 0.42"
Xbee PCB Antenna	215mA @ 3.3V	3.3	Serial	1.087 x 0.866"
Polymer Lithium Ion Battery	1000mAh			0.25x2.1x2.4"
Altimeter		3.6	I2C	1.4 x 1.2"
Altimeter (Stratologger)		3.6	I2C	2.75x0.9x0.5"
Micro SD card				

`Payload system:

The payload system is completely independent of the recovery system. It consists of its own XBee antenna and GPS system so that it can be easily tracked for recovery purposes. It also has its own startologger altimeter. This is backed up by another altitude sensor that measures the altitude to within 30 cm. The microprocessor used in this system is a Teensy 3.1 as well. ***Figure 14*** includes the general layout of the payload system.

Table 10 includes the major payload system components.

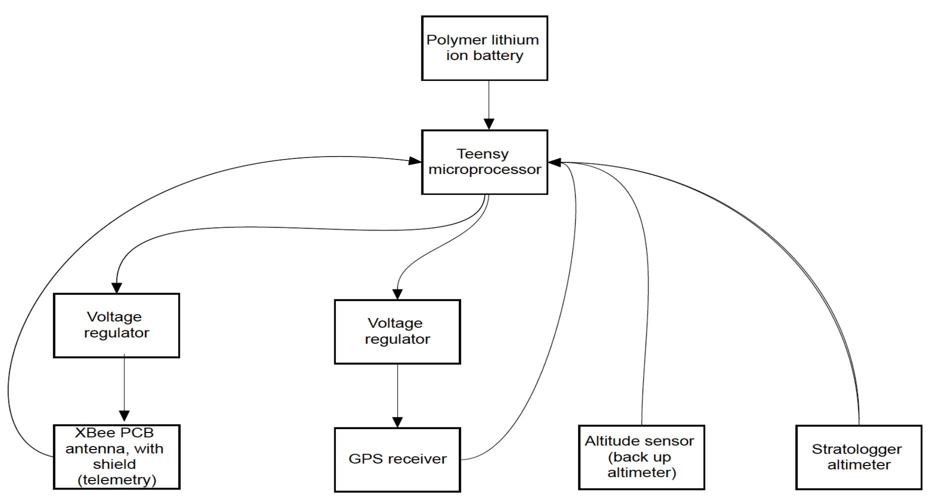


Figure 14. General layout of payload system.

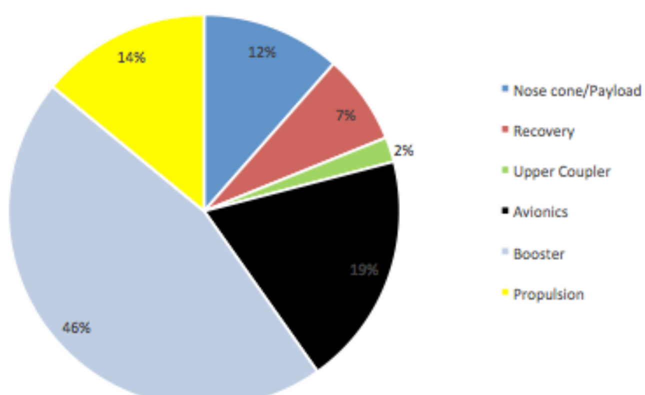
Table 10. Major components of the payload system

Name	*Outout power*	*voltage (V)*	*Bus*	*Dimensions*
Teensy microprocessor	100mA @ 3.3V	3.3	I2C, SPI	1.4 x 0.7" (~35 x 18 mm)
Altimeter		3.6	I2C	1.4 x 1.2"
Polymer Lithium Ion Battery	1000mAh			0.25x2.1x2.4"
LiPo USB charger	500mA @ 3.7V	3.7		29.4 x 10.8mm
Altimeter (Stratologger)		3.6	I2C	2.75x0.9x0.5"
GPS receiver		4.75~ 5.25	TTL serial	35 x 8 x 6.5 mm
Xbee PCB Antenna	215mA @ 3.3V	3.3	Serial	1.087 x 0.866"

3.1.12. Pyroeis Mass Statement

The weight of the rocket is expected to change while the manufacture of structural components is completed. In expectation of the mass changing, sensitivity of launch performance to launch mass has been conducted with Openrocket simulation. The limiting factor in ability to launch is velocity off the launch rod. Simulation data is listed in Table [below]. Over a pound of extra weight will cause instability during launch, especially if high winds are present. However, other rocket motors with a higher thrust that are designed for the same motor case may be chosen if a larger mass increase is required.

Parameter	*Mass (lbs)*
Nose cone/Payload	1.2
Recovery	0. 7
Upper Coupler	0.2
Avionics	1.9
Booster	4.6
Propulsion	1.4



3.2. Recovery Subsystem

3.2.1. Overview

The purpose of the recovery system is to reduce the impact of wind and prevent damage of the payload and the launch vehicle from impact. These objectives will be accomplished with a dual deployment system. Analysis from OpenRocket simulates that maximum descent rate will be 55 fps when the drogue chute is deployed at apogee. The payload will be jettisoned and have its chute deployed at 1000 ft AGL, and the main chute deployment at 600 ft AGL will decrease the launch vehicle descent rate to a maximum of 17 fps. The drogue chute is assumed to have a C_D of 1.6, and the main chute is assumed to have a C_D of 1.46. A section view of the launch vehicle and the chute location is displayed in **Figure 15**.

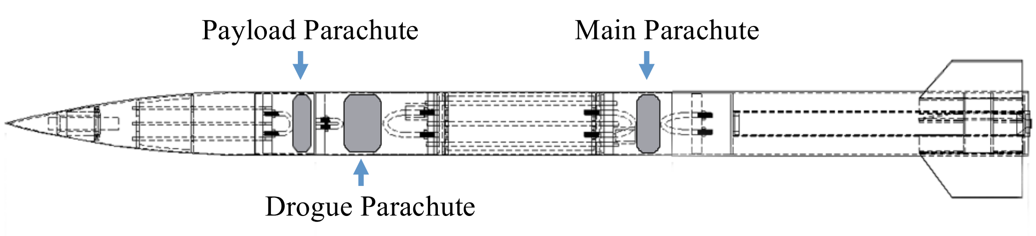


Figure 15: Recovery Subsystem Overview

3.2.2. Parachute Dimensions

The payload chute will be held right under the nose cone and is connected to a U-Bolt that is attached to the nosecone bulkhead. The drogue chute will be placed behind the avionics section and will be connected to a shock cord, with the aim of absorbing the impulse of the black powder blast and preventing the drogue chute from being stuck in the body tube. This will allow inertia to pull the drogue chute from storage during

ejection. The main chute will be housed in the compartment right above the avionics bay. Shock cords will connect the parachutes to every section of the launch vehicle so that the entire system remains a single unit during the recovery stage, save for the ejected payload. For the main chute, the shock cord is attached to a U-Bolt on the reverse side of the upper bulkhead of the avionics section and to a U-Bolt attached to the front bulkhead of the avionics mount. Similarly, the shock cord of the drogue chute will be connected to a U-Bolt attached to the back bulkhead of the avionics mount and to a U-Bolt attached to a bulkhead in the booster section. The dimensions and the weights of the parachutes are outlined in Table 11.

Table 11: Parachute Parameters

	Main Chute	*Drogue Chute*	*Payload Chute*
Dimensions	4.3 ft diameter	2.5 ft diameter	1.5 ft diameter
Surface Area	14.75 ft^2	4.91 ft^2	1.767 ft^2
Estimated C_D	1.46	1.6	1.2
Weight	12.2 oz	1.9 oz	1 oz
Target Descent Rate	17 fps	55 fps	25 fps

3.2.3. Ejection Charges

The masses of the black powder were calculated using Equation (1) with variables set in Table 12.

$$W = \frac{V\ P}{RT} \tag{1}$$

Table 12: Ejection Charge Equation Variables

Variable	Description	Units
W	Black Powder Weight (in pound mass)	$454 \cdot W_{gram}$
V	Pressurized Container Volume	in^3
P	Pressure Differential	psia
R	Gas Combustion Constant for black powder	$22.16\ \frac{ft \cdot lb_f}{lb_m \cdot R}$
T	Gas Combustion Temperature	3307 °R

The volume will be determined by the design, while the black powder sets the value of the gas constant and temperature. The pressurization will be based on the number of shear pins and the strength that will hold the parachute compartments together. One quarter-inch shear pin can withstand up to 35 pounds of shear force before failing. For the compartments housing the main chute and drogue chute, each will be held by two shear pins, meaning only a force of 70 pounds per compartment is needed to achieve separation. Frictional resistance from the tubes, however, need to be accounted for, and therefore 87.5 pounds of force will be the target. The respective amounts of black powder are listed in Table 13. The deployment of the two chutes throughout the launch vehicle is shown in **Figure 17**.

Table 13: Ejection Pressurization and Ejection Charge

	Main Parachute	Drogue Parachute	Payload Parachute
Total Pressurization	26.7 psia	26.7 psia	22.7 psia
Differential Pressurization	12 psia	12 psia	8 psia
Amount of Black Powder	0.788 grams	0.867 grams	0.245 grams

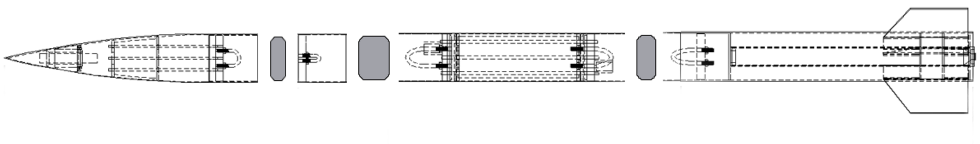


Figure 17: Parachutes after Deployment

3.2.4. Altimeters

The altimeters that will be used for the launch vehicle will be StratoLoggers, shown in **Error! Reference source not found.**. Throughout a flight, it can record flight data at twenty samples per second and is able to record flights up to 100,000 feet altitude. This data can also be accessed later through a connection to a computer. Two (2) altimeters, each with its own independent power supply, will be used and will connect to the main chute and drogue chute ejection charges. Figure 19 shows the set up for each altimeter system, and

Table **14** lists the pin connections that are going to be used. The payload section will house a DDC22 altimeter, shown in **Figure 18**, as well as a GPS. The schematic is shown in **Figure 19**.

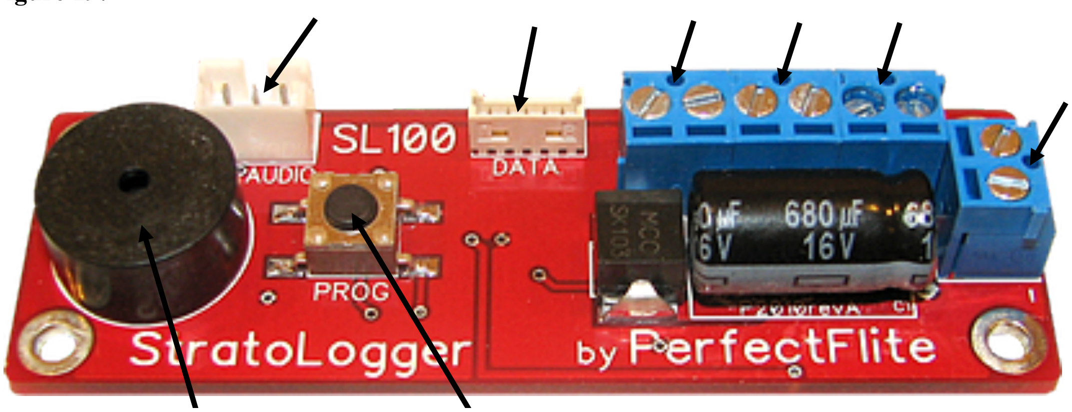


Figure 18: Stratologger

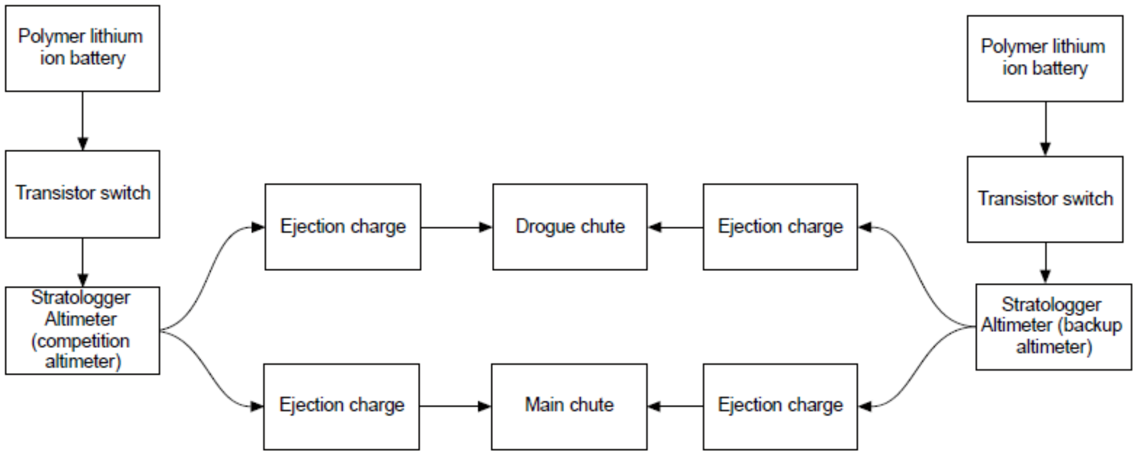


Figure 19: Electrical Schematic of Stratologger

Figure 20: DDC22

Port Name Description

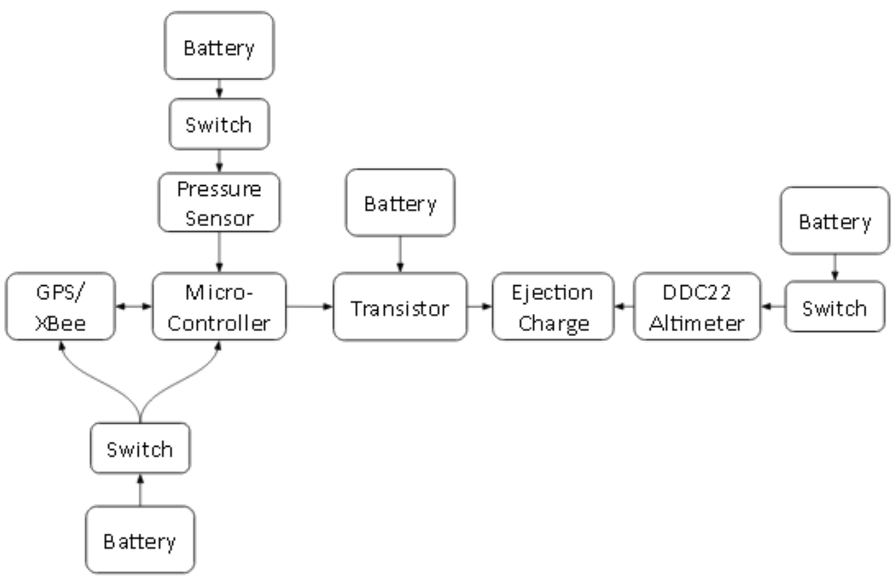


Figure 21: Electrical Schematics for Payload Recovery System

Table 14: Electrical Schematics for Recovery System Summary

Port	Name	Description
I	Battery Port	Attach to a 9 V power source
II	Power Switch Port	Attach to a power switch
III	Main Parachute Port	Attach to Main Chute E-matches
IV	Drogue Parachute Port	Connect to Drogue Chute E-matches
VII	Beeper	Reports status, data, etc. with a sequence of audible beeps

3.2.5. Testing

3.2.5.1. Assembly

The avionics section body tube will have couplers attached to the front and bottom. A bulkhead will be attached to the end of the front coupler. Two shear pins will hold the front coupler in place while the bottom coupler will be epoxied to the tube. The booster section will slide onto the bottom coupler with the drogue chute inside for the drogue chute test, shown in **Figure 22**. The body tube between the nose cone and the avionics section tube will slide onto the front coupler with the main chute inside, and shear pins will be inserted in preparation for the main chute test, shown in **Figure 23**. **Figure 24** is the testing assembly for the payload section, which is housed in the nose cone. The nose cone will slide onto another outer tube that connects with the front coupler of the avionics section tube.

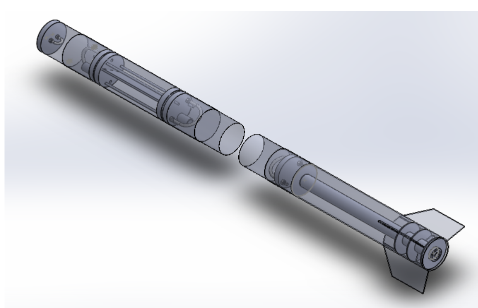


Figure 22: Drogue Parachute Test Assembly

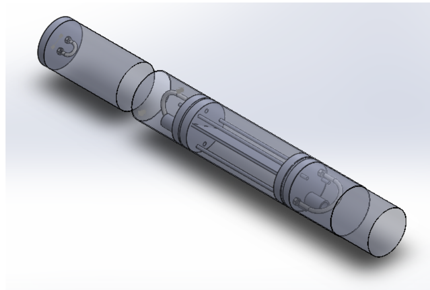


Figure 23: Main Parachute Test Assembly

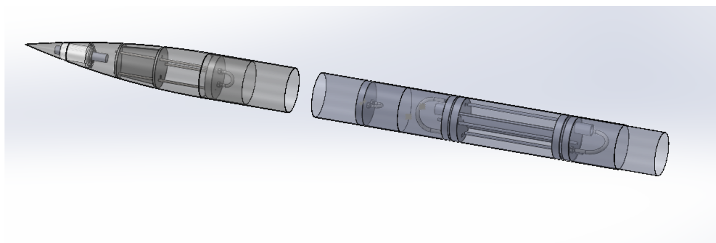


Figure 24: Nose Cone Test Assembly

3.2.5.2. Recovery Ground Test

The parachute compartments, and the bulkheads enclosing them are made of fiberglass. The ejection charges will be placed on the outer side of the avionics bulkheads and will be covered with PVC end-caps to protect it from thermal shock. For protection against thermal shock for the parachutes, a NOMEX/cloth flame shield will wrap around the chutes, and shredded cellulose will be inserted in between the chutes and the ejection charges. Ejection charge ignition will be triggered by an e-match, and each casing will go through two tests: a distance test and a feasibility test. These tests will estimate the placement of the mass both forward and aft of each compartment and will confirm whether the black powder charge amounts are enough to achieve separation. Supporting equipment will provide protection from debris and launch vehicle parts.

3.2.5.3. Testing Criteria

Testing is considered a success when it meets all of the success criteria, which is shown in Table 15. It will be considered a partial success if only some of the criteria is met. The test would be considered a failure if none of the criteria are met, or if one of the failure modes occurs. Table 16 lists the failure modes.

Table 15: Success Criteria

Success Criteria
Ignition of ejection charges
Shearing of shear pins
Launch vehicle moves half the distance of shock cord

Table 16: Failure Modes

Failure Criteria
Structural failure due to ejection charges
Shear pins fail to shear and launch vehicle remains intact
Parachute burns due to failure of NOMEX/Cloth Shield
E-match ignition failure

3.3. Mission Performance Predictions

The current performance predictions are based on assumptions that the launch vehicle will have approximately 15.13 lbs at launch including the motor which has been decided to be the Cesaroni J530. Currently all the flight condition simulations are run in Openrocket. However, we are currently creating a code in MATLAB that will enable us to make a better prediction, and once finalized, the mission performance will be updated to reflect the effects of the pin drag system on the apogee of the vehicle. Table 17 shows the assumption made when the simulation was run.

Table 17: Motor per launch vehicle weight and altitude reached

Total weight with Motor (lb)	Motor Type	Apogee (ft)
15.13	Cesaroni J530	3100

Table 18 shows the assumption made when the simulation was run. The latitude was chosen so that it would reflect the latitude of the launch site at which the rocket is launched.

Table 18: Flight Simulation Conditions

Condition	Value
Wind speed	4.47 mph
Temperature	59 °F
Latitude	34°N
Pressure	1013 hPa
Gross launch weight	15.13lb

Motor	Cesaroni J530

3.3.1. Flight Profile Simulations

Figure 25 shows the flight profile of the launch vehicle utilizing flight simulation conditions from Table 6. Velocity, altitude, and acceleration were plotted as a function of time. Apogee occurs at approximately 14 seconds. At apogee, the ejection charge for the drogue chute will fire, slowing the decent rate to 55 fps. Deployment of the main chute will occur at around 500ft above ground level to further decelerate the launch vehicle to 17 fps. The entire flight duration is approximately 96 seconds.

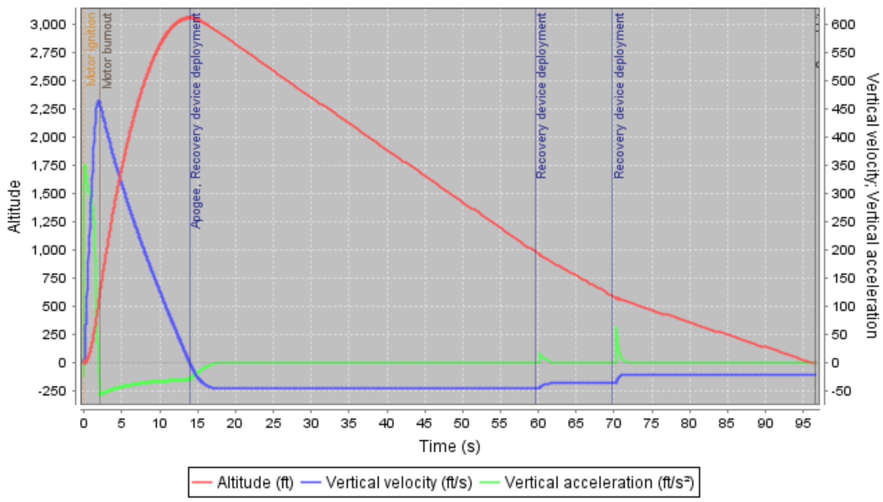


Figure 25: Flight profile with Cesarone J530

3.3.2. Altitude Predictions

The apogee of this rocket has been simulated to be 3100 ft. (0MPH wind speed). Though this is around 100ft. above the target altitude of 3000ft., this will not be a problem as we want the rocket to overshoot the target altitude than undershooting it. When flying the rocket, the pin drag system will activate to create drag and make the apogee of the rocket to be precisely 3000ft. AGL.

3.3.3. Component Weights

The component weight breakdown for Pyroeis is summarized in Table 19. The values were estimated using OpenRocket.

Table 19: Component weights for Pyroeis

Component	Mass (lb.)
Nose Cone	1.44
Payload	.3
Payload Parachute + Shock cord	0.07
Drogue Parachute + Shock cord	0.15
Main Prachute + Shock cord	0.9
Upper coupler	0.31
Avionics	2.91
Booster Structure	6.92
Cesaroni J530	2.13
Total	15.13

3.3.4. Simulated Motor Thrust Curve

The simulated thrust curve for Cesaroni J530 is shown in Figure 26. This motor will enable the launch vehicle to reach an altitude of 3,100 feet. The motor will follow this thrust curve closely, however it is important to keep in mind that the performance of the motor may vary slightly in actual flight.

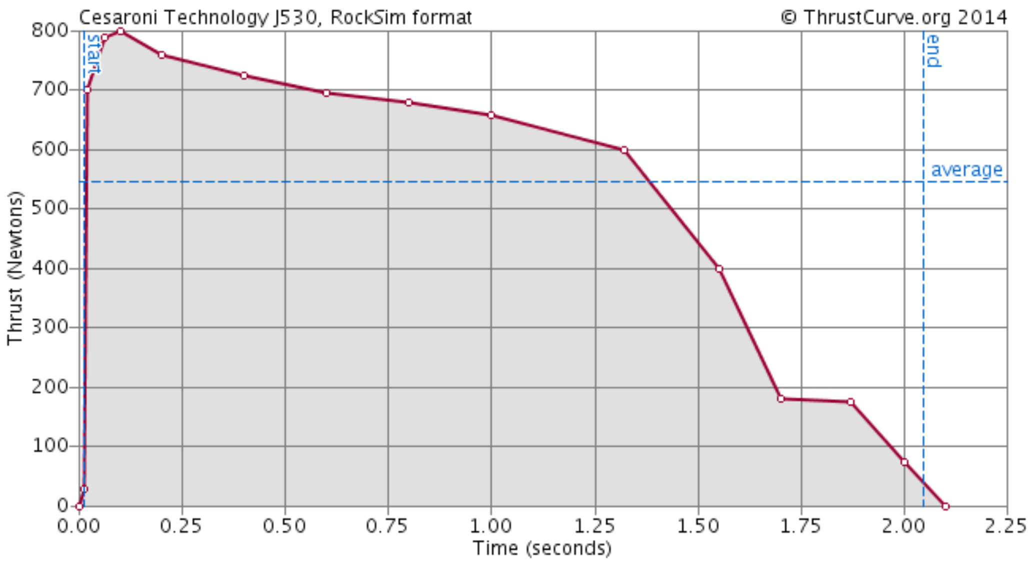


Figure 26: Thrust curve for Cesaroni J530 motor

3.3.5. Stability Margin

In addition, a stability analysis was performed to ensure a safe flight profile as shown in Figure 27. The results were a stability margin of 1.8 caliber.

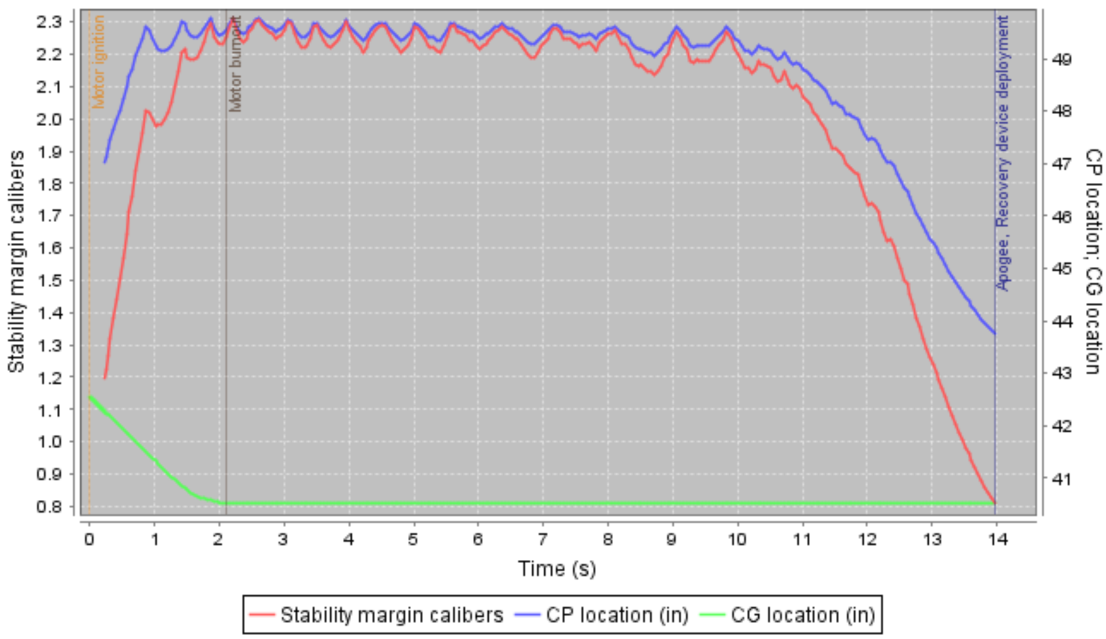


Figure 27 Stability margin calibers vs. Time

3.3.6. Kinetic Energy Upon Landing

The kinetic energy at landing for each independent and tethered section was calculated utilizing Equation (3) where m is the mass of each section and v is the velocity. The results are summarized in Table 20. From the table it can be concluded that none of the parts exceed 75ft.-lbs which is the maximum kinetic energy that each components can have. The calculations for which the kinetic energy was found is as follows:

At terminal velocity

$$\sum F = 0 = mg - D \quad (1)$$

$$mg = D = \frac{1}{2}\rho S {V_{terminal}}^2 C_D \quad (2)$$

S: area of the parachute

$$KE = \frac{1}{2}mv^2 \quad (3)$$

Table 20: Kinetic Energy at Landing

	Mass (lb.)	Velocity (ft./s)	KE(ft-lbs)
Nose Cone/Payload	1.74	23.7	15.27
Upper coupler	0.31	17.2	1.43
Avionics	2.91	17.2	13.45
Booster	6.92	17.2	31.98

3.3.7. Drift Profile Simulation

The effect of wind speeds on the lateral drift of the launch vehicle is shown in Table 21. The numbers were calculated utilizing data obtained from OpenRocket and the profile of the parachute given in the previous table. The worst possible case were simulated for each wind speed.

$$Lateral\ drift\ at\ 1000ft = ld_{1000}$$

$$ld_{total} = ld_{1000} + Windspeed(mph) * \frac{5280}{3600} * \frac{1000}{descent\ velocity}\ \ (ft)$$

Table 21: Lateral drift due to windspeed

	Nose Cone/Payload	Body/Booster Section
0 mph	5.06	5.06
5 mph	387.3	485.4
10 mph	845.7	1041.7
15 mph	1561	1855.1
20 mph	2208.3	2600.5

3.3.8. Simulated CG and CP locations

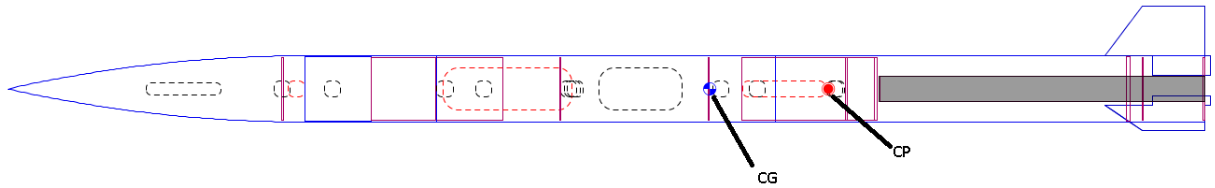


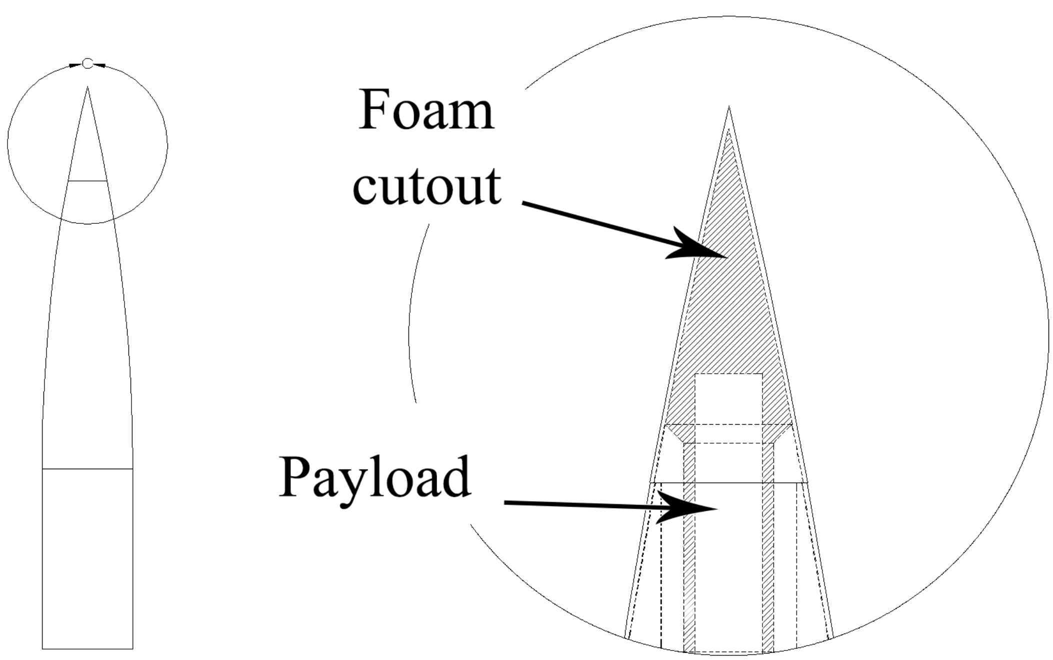
Figure 28: Center of Pressure and Center of Gravity for Pyroeis

Figure 28 shows the location of the Center of Gravity and the Center of Pressure. The CG of the rocket was simulated to be 42.5 in. from the top of the nose cone and the CP of the rocket was simulated to be 49.7 in. from the top of the nose cone. This also indicates that the rocket is stable as the center of gravity is located in the front of the center of pressure.

3.4. Interfaces and Integration

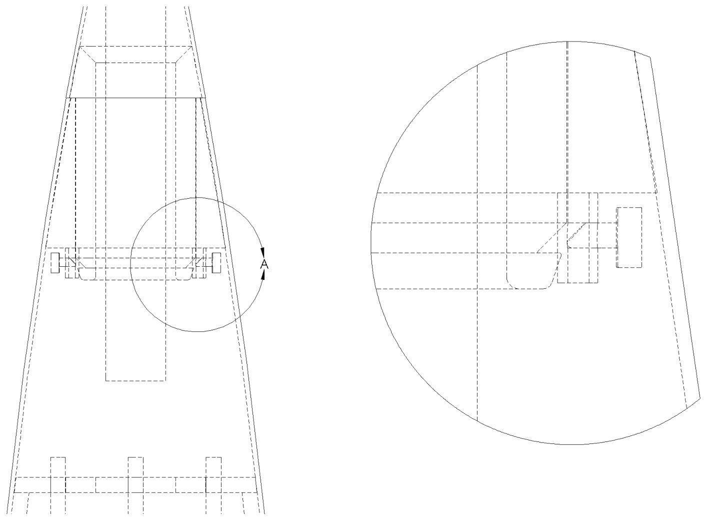
3.4.1. Payload Integration

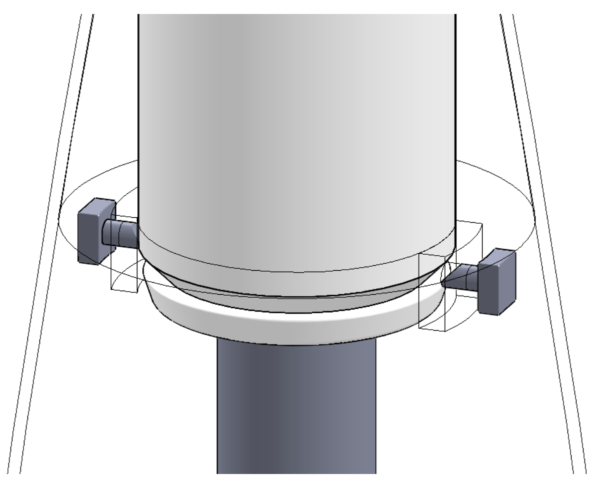
The payload will be stored in the nose cone of the rocket. The tip of the nose cone will be removable to allow for the payload to be inserted. The payload will be supported in the nose cone by a foam cutout, which will be cut to match the dimensions of the payload. The position of the payload in the nose cone is shown in Figure [below].



3.4.2. Subsystems Interface

The rocket is designed to mechanically interface with the AGSE. The payload insertion system in particular was designed with the requirements of both the AGSE and the rocket. The removable part of the nose cone must be easily removed and inserted by the AGSE, but the nose cone must also remain attached when subjected to aerodynamic loads in flight. Spring loaded pins with a magnet de-latch are used to secure the removable section of the nose cone. Figures [below] and [below] show the pin latching assembly.





3.5. Safety

Team A.R.E.S. is dedicated to maintaining safe operating conditions for all team members and anyone involved in competition activities. Under the tutelage of the Safety Officer, Raef Eagen, Team A.R.E.S. will undergo rigorous safety briefings to ensure the integrity and safety of the entire team and equipment is unchanged. During manufacturing, fabrication, and testing of rocket vehicle and AGSE components, it is important to identify the hazards of your environment, and how following safety procedures and protocols can prevent accident and injury to oneself or damage to competition hardware. When working with construction equipment, Team A.R.E.S. members are instructed to work in minimum team sizes of two. This ensures that one team member would be available to provide immediate assistance or quickly get help should an incident occur while using the equipment. The Invention Studio, where team members use the necessary equipment for manufacturing and fabrication, is equipped with first aid kits, fire extinguishers, safety glasses, and expert supervision for the use of all equipment. During physical testing of the rocket structure, and during ejection charge testing, team members will wear safety glasses, have a first aid kit and fire extinguisher on hand, and have licensed safety officials present. In order to use the machines, all team members have been briefed on the proper protocols and procedures of using the lab machines.

Risk identification and mitigation techniques are used to assess the dangers of tools and activities to personnel, and how they may create safe operating conditions. To that end, Table lists the procedure to identify what hazards and risks may exist and how to minimize the chances of occurrence.

Table 21: Hazard Identification and Mitigation Process

Step Name	*Step Definition*
1. Hazard Identification	Use team safety and brainstorming sessions to identify all possible hazards the team is likely to encounter
2. Risk and Hazard Assessment	Determine the likelihood and the severity of consequences should the hazard be encountered and how to approach the issue
3. Risk Control and Elimination	After hazard identification and assessment, methods will be produced and implemented to prevent the issue
4. Reviewing Assessments	Review and update hazards as necessary when new information becomes available through team activities

The Operations, Rocket, and Flight Systems subteams have been briefed on the hazards possible when working to produce the structural and electrical components necessary for the competition, and how to avoid those hazards. See **Table 22** for the hazards team members may experience. The likelihood of personnel hazards being realized is lowered by briefing team members of the hazards possible, and repeatedly following proper safety protocols and procedures.

Table 22: Hazards, Risks, and Mitigations

Hazard	*Severity*	*Likelihood*	*Mitigation & Control*
Batteries Explode	Burns, skin irritation, eye irritation	Low	Wear safety glasses and gloves when handling. Make sure no shorts exist in circuits using batteries. If battery gets too hot, stop its use and disconnect it from any circuits.
Black Powder	Explosion, burns, skin irritation, eye irritation	Medium	Wear safety glasses, gloves when handling black powder. Be careful when pouring black powder. Operate in a static-free environment
Dremel	Cuts, scrapes	Medium	Only operate tools with supervision of teammates. Use tools in appropriate manner. Wear safety glasses to prevent debris from getting into eyes.
Power Tools	Cuts, punctures, scrapes	Medium	Only operate power tools with supervision of teammates. Use tools in appropriate manner. Wear safety glasses to prevent debris from getting into eyes.
Epoxy/glue	Toxic fumes, skin irritation, eye irritation	High	Wear gloves, nitrile for epoxy, face masks, and safety glasses. Work in well ventilated area.
Exacto/craft knives	Cuts, serious injury, death	Medium	Only use knives with teammate supervision. Only use tools in appropriate manner. Do not cut in the direction towards oneself.
Fire	Burns, serious injury, death	Low	Keep a fire extinguisher nearby. If an object becomes too hot, or does start a fire, remove power(if applicable) and be prepared to use the fire extinguisher.
Hammers	Bruises, serious injury,	Medium	Be aware of where you are

	broken bones		swinging the hammer, so that it does not hit yourself, others, or could bounce and hit someone.
Hand Saws	Cuts, serious injury	Medium	Only use saws with teammate supervision. Only use tools in appropriate manner. Wear safety glasses to prevent debris from getting in eyes.
Waterjet Cutter	Cuts, serious injury, flying debris	Low	Only operate under supervision of Undergraduate/Graduate Learning Instructors, and with other teammates. Follow proper operating procedures, wear safety glasses.
Improper dress during construction	Cuts, serious injury, broken bones	High	Wear closed toed shoes, tie back long hair, do not wear baggy clothing.
Power supply	Electrocution, serious injury, death	Medium	Only operate power supply with teammate supervision. Turn off power supply when working with circuitry.

The steps listed in Table 21 are being used in the production of standard operating procedures and protocols, and all subteams will have the necessary knowledge to operate safely. These protocols and procedures will be used during launch vehicle construction, AGSE construction, ground testing, and for launch day safety checklists. Material Safety Data Sheets for all materials and substances used in construction are listed in Appendix II. NAR regulations regarding high powered rockets are listed in Appendix II
Failure modes are possible and were developed and explored so that the team will have a better chance of success with the launch vehicle, payload integration, and launch operations. The modes, their effects, and procedures for mitigation are given for each failure mode are listed in **Table 23**. The mitigations will be used when producing the preflight checklist.

Table 23: Launch Vehicle failure modes

Potential Failure	*Effects of Failure*	*Failure Prevention*
Apogee Targeting System	Vehicle will not reach target altitude	Test ATS using subscale launch vehicles
Body Structure buckles on takeoff	Launch failure, damage to launch vehicle, unable to be reused, flying shrapnel towards personnel/crown	Test structure to withstand expected forces at launch with a factor of safety. Have proper sized couplers connecting sections.
Drogue Separation	Main parachute will deploy	Perform ground test and

	at high speed and may rip or disconnect from vehicle, launch vehicle may become ballistic	flight test.
Fins	Fins could fall off, causing unstable flight	Test fin at attachment points using expected forces to ensure strength of attachment method.
Ignition Failure	Failure to launch	Follow proper procedures when attaching igniter to AGSE.
Land directly on fins	Fins break or disconnect from launch vehicle, unable to be classified as reusable	Do not have fins with sharp pointed edges, ensure parachute is large enough to minimize impact kinetic energy, test fin at attachment points using expected forces to ensure strength of attachment.
Launch buttons	Launch vehicle will separate from rail, causing an unstable flight	Ensure launch rail is of proper size to accommodate the buttons, ensure buttons slide easily into rail.
Main Parachute Separation	High impact velocity may damage vehicle and make it unrecoverable, vehicle may become ballistic causing serious injury or death	Perform ground test and flight test to ensure veracity of deployment method.
Motor Failure	Motor explodes, damaging launch vehicle/AGSE beyond repair	Follow NAR regulations and manufacturer's instructions when assembling motor. Assemble motor under supervision.
Motor Retention	Motor casing falls out, lost motor case, could damage persons/property	Test reliability of motor retention system
Payload Separation	Main parachute may not deploy correctly, higher impact velocity may damage launch vehicle, or cause personnel/property damage	Perform ground and flight test to ensure veracity of deployment method
Thrust plate failure	Motor goes through vehicle, damage to vehicle, causing it to be not reuseable	Test plate and attachment method to withstand expected launch forces with a factor of safety

4. AGSE Criteria

4.1. Selection, Design, and Verification of AGSE

4.1.1. Design Options Review

4.1.1.1. Payload Insertion System

Design Options	*Advantages*	*Disadvantages*
Mobile drone/rover payload capture & insertion	Decoupling the payload capture, retrieval and insertion system from the stationary AGSE base allows for robust task completion even with	Considerable rise in power supply, software and hardware requirements. Not feasible given time and budget constraints.
Flexible, conforming "tentacle" manipulator	Able to capture payloads of various geometries including the designated cylindrical shape in a wide variety of terrain settings	Issues with correctly manipulating and controlling such a design. Complex controls would be needed to correctly orient the payload to interface with the launch vehicle.
6 DOF Robotic Arm	Able to perform most all task requirements for payload capture, transport and insertion. Wealth of knowledge behind manufacturing and controlling robotic arms.	Considerable complexity. Many points for system failure, such as motor failure. Grippers must be modified to conform to a cylindrical payload geometry.

4.1.1.2. Vehicle Erector System

Design Options	*Advantages*	*Disadvantages*
Pulley system to raise rocket guidance rail	Mechanically simple system that is easy to fabricate. Easily automated with a winch.	Excessive amounts of rope required. Large enough to interfere with placement of rocket.
Gear system at hinge to raise rocket guidance rail	Mechanically simple system with the ability to be adapted for higher gear ratios. System functions at pivot point, reducing the need for a complex structure to support it.	High torque requirements make required motor size and power unwieldy. Threat of gear backlash makes system unreliable.
Stepper motors/worm screw	The worm screw assembly	System is mechanically

attached to guidance rail for raising the rocket	easily meets the necessary torque requirements. Utilizing stepper motors allows for fine positioning control.	complex and has room for fabrication errors. Placement of screws along the guidance rail creates a large bending moment in the attachment pins.

4.1.1.3. Igniter Insertion System

Design Options	*Advantages*	*Disadvantages*
Miniaturized gripper arm (DaVinci surgical robot type manipulator)	Superior precision due to small components; allows for fine movements that would help in any small component (e.g. igniter) insertion process	Considerable mechanical complexity; fabrication challenges associated with making precision components; sensitive components
Symmetrical Rack-Pinion system to raise the igniter inserter	Provides slow, steady raise which helps in accurate and precise insertion; smooth actuation;	Low mechanical advantage; requires more power than other gear systems;

4.1.2. AGSE Subsystems & Functional Requirements

4.1.2.1. Payload Insertion System (PLIS)

An open source 6 degrees of freedom (DOF) robotic arm will be used to reliably and effectively capture the standard Maxi-MAV payload (mass: 4.0 oz, dimensions & materials: ¾ in outer diameter * 4.75 in length PVC container), transport and load it into the nose cone of the launch vehicle. Utilizing a set of hard-coded positions/servo angles for the robotic arm & a known payload position relative to the AGSE the robotic arm will be capable of accomplishing autonomous payload capture and retrieval.

The team will construct a six degrees-of-freedom arm using laser cut wood parts. Utilizing seven servos, the arm will be able to fully solve for any point in the space. The gripper design will be modified to allow for a greater degree of error. This can be achieved by designing the gripper with "encompassing" interiors which will naturally move the payload into the grooves. This will allow for multiple positions from which the robotic arm can successfully grip the payload. A preliminary SolidWorks model of this robotic arm can be seen below in **Figure 29**.

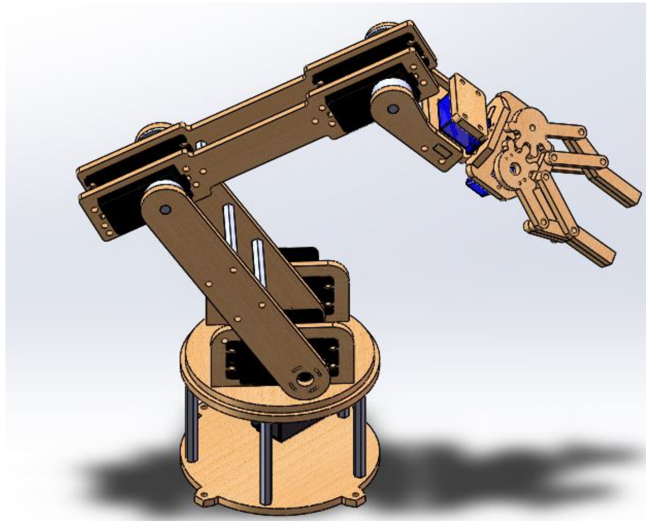


Figure 29: Robotic Arm Assembly

Customizations are often limited with pre-designed robotic arms from selected vendors. Therefore, the team will utilize open-source templates for a customizable robotic arm from thingiverse.com. All robotic arms available on this site comes with .STL files which can modified and customized to specific needs before realized by laser cutters. By leveraging open-source designs, the PLIS can more effectively utilize funds (for materials and specific components and parts), adjust materials used (to meet weight constraints for the arm) and modify production costs based on further design choices.

Robotic arms online can range from $100 to $10,000 depending on the precision required and advanced control algorithms that the manipulator ships with. Given budget and time constraints the AGSE subteam's current plan of development for the PLIS is to build a most basic version of the arm and later expand on the primary design as time and the team's remaining budget allow.

4.1.2.2. Vehicle Erector System (VES)

The VES shall raise the rocket to a position of 5 degrees from the vertical. The VES shall also act as a launch pad (utilizing launch rails and a steel blast plate) for the rocket and integrate with the rocket igniter insertion system and payload-capture system.

The driving requirement of the VES is to successfully lift the rocket to the predetermined 5 degrees from vertical. To meet this requirement several subsystem assemblies were considered. The first was a system of pulleys designed to provide a high mechanical advantage to perform the required work. A very rough sketch of this system can be seen below in **Figure 30**. The proposed pulley system has the advantage of being mechanically simple, and easily alterable with extra pulleys and rope.

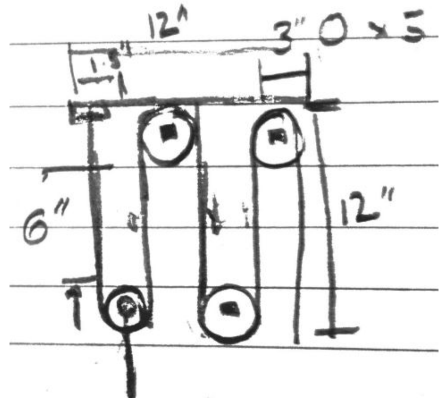


Figure 30: Pulley System Conceptual Sketch

The second subassembly considered was a simple gear train driven by a DC motor and mounted at the launch rail hinge, as seen below in **Figure 31**. This system has the advantage of providing a high amount of torque directly at the pivot hinge, and is compact enough to not necessitate and extensive support structure.

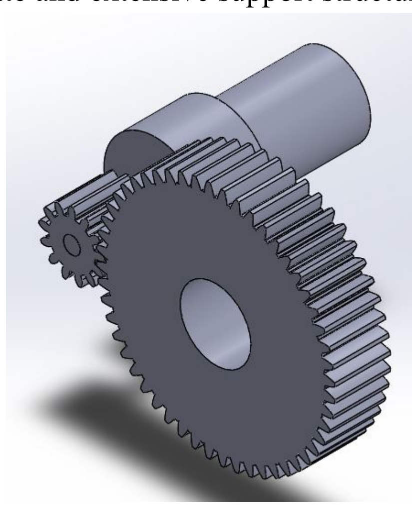


Figure 31: SolidWorks Concept Model of Gear Train Assembly

The final subassembly considered was a pair of worm screws driven by stepper motors offset from the launch rail. **Figure 32** below shows a SolidWorks model of this assembly. The VES must be robust enough to perform its key function without human interaction and with minimal chance of failure. The stepper motor and worm screw assembly was chosen because it provided enough torque to easily lift the rocket and rail, and provided an easily programmable method of fine control by using the stepper motors.

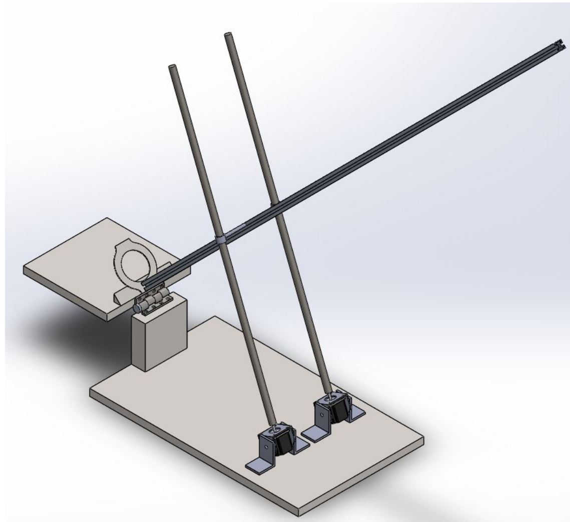
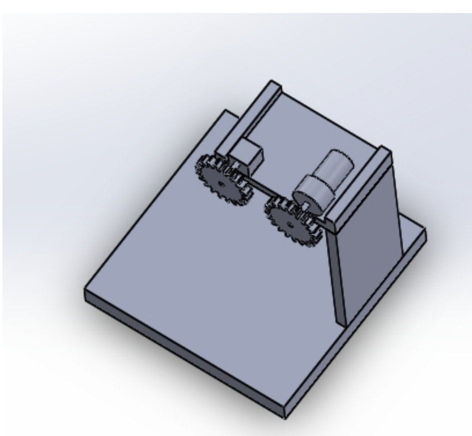


Figure 32: Stepper Motor and Worm Screw Assembly

4.1.2.3. Igniter Insertion System (IIS)

The IIS autonomously raises the igniter and inserts it into the solid rocket motor (SRM) cavity. The IIS is projected to be a steel rod with an end "cup" or "holder" for the igniter & cap: a steel blast plate is incorporated into the design to protect sensitive components such as the motor and gears. The system utilizes a rack-and-pinion style linear actuator to accomplish the task. The igniter insertion process requires precision and accuracy, and the rack and pinion system which can raise the igniter at a relatively slow and steady speed was selected. The insertion of the igniter is facilitated by a steel rod that holds the igniter and the cap at its end. The rod is composed of two linear rack gears with their flat sides in contact with each other, and it is actuated by two pinion gears that are placed on the supporting base of the IIS.



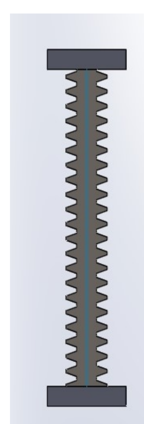


Figure 33: Base of the Igniter Insertion System *Figure 13: Inserter (Steel Rod) that inserts the igniter& cap*

One of the pinions is controlled by a DC motor, and the remaining pinion simply rotates as the rod is elevated and provides support and rigidity. Upon completion of the insertion task, the motor will be rendered passive in order to prevent damage to the motor and the gear system from launch vehicle exhaust thrust. The IIS will be installed under the launch pad.

4.1.3. Performance Characteristics

4.1.3.1 Payload Insertion System

The payload retrieval mechanism must be able to capture and position a cylindrical payload that is ¾ in diameter and 4.75 inches in length. The expected weight of the payload is 100g. The AGSE shall be equipped with 7 Turnigy TGY-S901D capable of providing at least 13 kg*cm of torque which will allow each joint to lift the 100g payload at a maximum distance of about 1 meter from the servo motor. The arm will have six degrees-of-freedom and hence capable of solving all dimensions. This additional provides flexibility in terms of payload placement and destination. Consistency and precision are the top two evaluation metrics. Specifically, the finished payload insertion system will be repeatedly tested with ad hoc payloads to verify the performance and accuracy of each trial. The robotic arm should be able to accurately grasp and transport the payload with a precision within 1 cm.

4.1.3.2 Vehicle Erector System

The VES must be able to raise the guidance rail and rocket to a position of 5 degrees off the vertical within the 10 minute time frame. A quick estimate of the speed of the NEMA 23 stepper motor suggests that with a max RPM of 150, a screw diameter of 0.75 inches, and the screws positioned 21 inches from the hinge point it will take roughly 21 seconds for the motors to raise the rail from 0 degrees to 85 degrees. This estimate falls well within the allotted time for the VES; however, in order to verify this result the motor assembly must be physically tested with a test mass placed at location along the rail coincident with the projected CG of the rocket.

4.1.3.3 Igniter Insertion System

Given the dimensions of the Vehicle Erector System, the Igniter Insertion System must raise the igniter inserter (the steel rod) by approximately 7 inches. The rod will be approximately 8 inches in order to maintain stability even when it is fully extended. The gear that will be used has an approximate circumference of 8 inches, meaning the rod will be completely raised in one rotation. A 12V DC 0.07A motor with the maximum RPM of 3.5 will be used to rotate the gear, and this leads to an estimated duration of 17 seconds for the igniter inserting process. This time measure will be verified after the system is built.

4.1.4. System Design Requirement Overview

DO	Design Objectives			
DO-1	The AGSE shall autonomously capture a payload			
DO-2	The AGSE shall autonomously insert the payload into the rocket			
DO-3	The AGSE shall autonomously raise the rocket to a safe launch angle			
DO-4	The AGSE shall autonomously insert a rocket igniter			
DO-5	The AGSE shall be fully reusable without human interference			
DSC	**Design Success Criteria**	**Source**	**Verification Method**	**Verification Status**
DSC-1	The AGSE shall raise the rocket to 5 degrees off the vertical axis	DO-3	Testing	Designed
DSC-2	The AGSE shall incorporate a blast plate to protect delicate systems	DO-5	Analysis	Designed
DSC-3	The AGSE shall pick up the payload and insert the payload into position through a mechanical arm	DO-1	Testing	Designed
DSC-4	The IIS shall raise the igniter and insert it into the solid rocket motor cavity	DO-4	Testing	Designed
SS	**Subsystems**	**Source**	**Verification Method**	**Verification Status**
SS-1	The AGSE shall be equipped with two NEMA 23 motors capable of providing at least 150 N*cm of torque	DSC-1	Inspection	Verified
SS-2	The AGSE robotic arm shall be equipped with 7 Turnigy TGY-S901D capable of providing at least 127.5 N*cm of torque	DSC-3	Testing	Designed
SS-3	The IIS shall be equipped with a 12V 3.5RPM DC motor capable of providing at least 60 N*cm of torque	DSC-4	Inspection	Designed
SS-4	The IIS motor shall be suspended when the igniter is successfully inserted into the rocket motor	DSC-4	Inspection	Designed

The AGSE team plans to begin the bulk of its manufacturing during the months of November, December of 2014 and January of 2015. Intermittent testing and System Design & Performance reviews will be conducted in order to verify that the AGSE meets all mission and functional requirements.

4.1.5. Preliminary Integration Plan

The Payload Insertion System (PLIS) will be mounted on the base of the AGSE platform such that the arm has full access to the nose cone of the rocket when the launch rail is horizontal. The placement of the arm is critical in ensuring full capability in payload capture and insertion. The vehicle erector system (VES) will be attached to the main AGSE platform, which consists of a slotted rail that guides the rocket upon launch until the desired speed has been achieved, and a base plate that is attached at a 45 degree angle to a steel blast plate. This blast plate is angled to force the rocket exhaust away from the delicate subassembly components. The rail, base plate, and blast plate are all attached to a hinge that rotates the system from the horizontal to a maximum of 5 degrees off the vertical. The igniter insertion system (IIS) is mounted on the underside of the blast plate in such a way that the insertion rod fits neatly through a small hole cut in the blast plate. This rod will be made of a material similar to the blast plate and able to withstand the rocket exhaust. The rod will extend up through the blast plate through the base plate so as to provide direct access to the rocket motor chamber. A depiction of this integration plan can be seen below in **Figure 34**.

Figure 34: Integrated AGSE

4.1.6. AGSE Electrical Subsystems

4.1.6.1. Power Requirements

The AGSE is expected to be powered by two separate 12 V, 20 Amp-hour (Ah) lead acid car/traction batteries that have relatively steady discharge profiles considering that the AGSE will have to be powered, operational and potentially remain on standby for at least two hours. Separate power sources will be used to minimize noise between electrical components and associated motor control issues.

Pulse-width modulated controllers, should additional units be needed, can be purchased and implemented in order to control the voltage and current distributions within the AGSE scheme. Examples include the RioRand ™ 12V-40V 10 A PWM DC Motor Speed Controller. Arduino compatible motor shields/drivers, should additional units be needed, can also be purchased readily and stacked for additional control capabilities.

Jumpers, wiring and heat sinks (aluminum, copper based) will also be incorporated as needed upon manufacturing and performance testing of electrical components.

4.1.6.2. Computational Requirements

The Arduino Due micro-controller will be used to control each of the different subsystems within the AGSE. With a 32-bit core that runs at 84 MHz, the Due supports 4-bytes wide data operations within each clock Combined with 512Kbytes of Flash memory and a DMA controller, the chip easily provides sufficient computational power to control the AGSE subsystem and provides storage for the program of the autonomous agent.
Since most mechanical components are controlled by servo motors, the team also needs a board with a large amount of digital I/O pins. The Due provides 54 digital I/O pins and 12 of those provides pulse-width modulation (PWM) output that will be used to control the servo motors. Other available I/O pins allow for control of other miscellaneous AGSE subsystems such as the master pause switch, and safety light indicator. On the other hand, the board is also ideal for relaying information from various serial sensors. Should the AGSE team decide to add sensors and environment-data processing, the Due controller provides an ideal platform to implement such capabilities.

Lastly, the board is capable of operating on an external supply of six to 20 volts. While this is fairly standard for Arduino micro-controllers, the wide range for the external power source provides more flexibility when evaluating trade-offs when considering power.

4.1.6.3. Safety Electronics

There will be a master switch and a power switch used in order to halt the operation of the AGSE in emergency situations. An ON/OFF toggle switch will be connected between the power source and the rest of the system to separate all parts of the AGSE from the power source. When the master switch is pressed, all components of the AGSE will shut down. A pause switch will consist of a push-button type switch directly connected to the Arduino micro-controller as an input. When the push-button is pressed and sends a signal to the micro-controller as an input, the micro-controller will pause, or temporarily terminate all actions performed by the AGSE. When this is pressed again, all actions will resume and start from where they have paused. An orange-colored light will be controlled by the micro-controller to flash at a frequency of 1Hz while the AGSE is powered on, and will only be solid color when the pause button is pressed. When the push button is pressed and power is off (because the master switch is off or power source is disconnected), the LED should be neither solid nor lit because there will should be no power supplied beyond the master switch. A simple schematic of the AGSE connections is shown below in Figure 15:

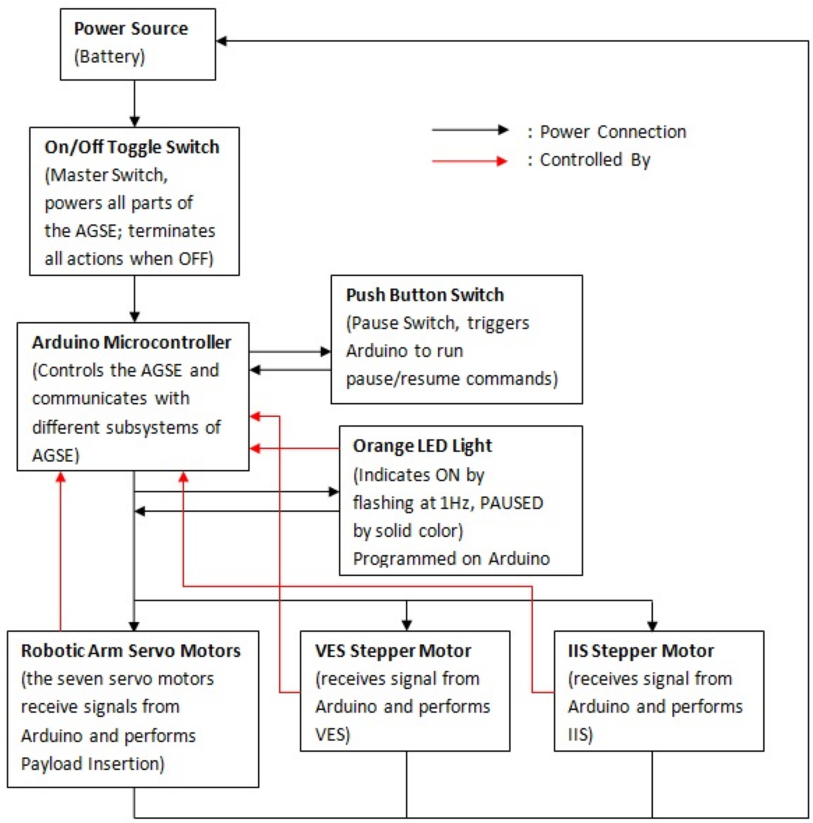


Figure 15: AGSE Electrical Block Diagram

4.2. AGSE Concept Features and Definition

Georgia Tech's AGSE stresses practicality and feasibility of successful mission completion, and in the spirit of good engineering, desires to be as cost-effective as possible.

Many avenues for creativity exist in the process of building, testing and refining the current preliminary design, where team members can come up with innovative technical design solutions to optimize and refine AGSE performance. The team acknowledges the value and reliability of heritage or mature technologies and incorporates them extensively in the design of the AGSE.

The challenge of fabricating a high-performance system in the most economical fashion possible reflects "real-world" constraints imposed by budget and time limitations and is an exercise in the efficient use of resources in a variety of technology based R&D projects. The process and end-product of navigating through various constraints presented both from NASA SL mission criteria and limitations in financial & human resources are significant: students learn to work efficiently and creatively while delivering cost-effective solutions that can be scaled up and deployed in more rigorous and challenging NASA missions. In particular this year's Maxi-MAV (Mars Ascent Vehicle)/Centennial Challenge will have considerable applicability to NASA's current efforts to explore and study Mars.

The AGSE subteam along with the assistance of other subteams under the Georgia Tech NASA SL team are equipped with the technical & engineering knowledge and skill in order to complete all steps related to the manufacturing, testing and integration of AGSE subsystems.

5. Project Plan

5.1. Status of activities and schedule

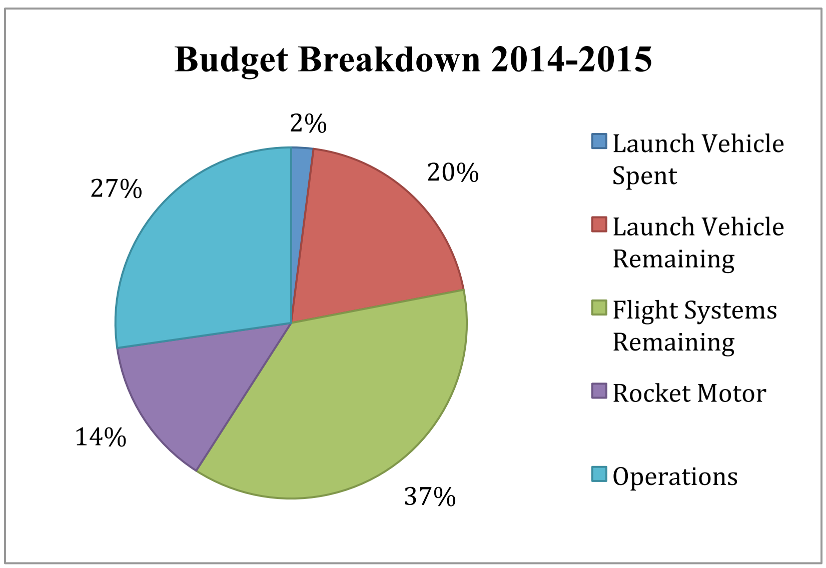
5.1.1. Budget Plan

Our team has at its disposal many Georgia Tech faculty members, many of whom are our professors, for their advice and expertise in the current Team A.R.E.S. day-to-day dealings. To acquire additional funds to build the rocket and the AGSE, as well as travel expenses, we plan to solicit help from local companies.

As of right now, we plan to collaborate with a local Atlanta Public School, Douglass High School, to potentially form a partnership to solicit funds from local companies. Our plan is to approach companies (with the high school as a partner) with an emphasis on using our tools and materials to build the rocket and AGSE while doing our outreach portion and having the high school students come up with their own designs and possible launches. For companies that donate money to our Georgia Tech NASA SL team, they will be acknowledged on all of our merchandise and reports. For those that donate large sums of money will have their logo placed on the rocket. For the rocket test launches, the team plans to work with SoAR to coordinate launches and minimize costs.

As shown in **Error! Reference source not found.**, the total budget for the 2014-2015 Team A.R.E.S. is $6,4100.55. Of that amount, only $1,000 has been granted through the Georgia Tech Space Grant Consortium. We are actively trying to solicit more donations/sponsorships and with the partnership with the Douglass High School, we plan to quickly acquire funding. Figure [] illustrates the percentage breakdown of the budget and **Error! Reference source not found.** shows the actual money allotted to each subsystem.

Subsystem	***Amount ($)***
Launch Vehicle & Motors	1,461.83
Flight Systems	2,721.18
Operations	2,000.00
Total:	6189.01



5.1.2. Funding Plan

In order to achieve the maximum goal of raising $10,000 for the rocket and the AGSE and other supports for 2014-2015 Student Launch competition, Team A.R.E.S. have sought sponsorships through four major channels :

- Georgia Tech Alumni
  Companies that team members have interned
- Local Companies in Atlanta area
- Local High Schools

The fund raising actions were started with the connections that can be reached on campus. Operation sub-team talked to several professors separately and obtained the contact information of Georgia Tech Alumni working in the Aerospace field. At the same time, all Team A.R.E.S. members were working together to provide contact information of past companies. Additionally, we compile a list of local high schools with s=lower than average engineering curriculum and we, as a team, arrive and do lots of outreach events. Simultaneously we'll partner with the high school to provide whatever is necessary for the completion of our products.

After compiling this information, the Outreach and Budget managers reached out to potential sponsors via phone calls and email. In order to explain the project further, either in-person meetings or virtual meetings via Skype are scheduled to speak with these potential sponsors. Lastly, the Team has also received a dedicated room at Georgia Tech in which the Team can construct and store their launch vehicle, payload, and other non-explosive components.

5.1.3. Timeline

The Simple Complexity project is driven by the design deadlines set forth by the NASA SL Program office. These deadlines are listed in .

Deadline	Date
Proposal	6 OCT
Web Presence Established	31 OCT
PDR Documentation	5 NOV
PDR Teleconference	7-21 NOV
CDR Documentation	16 JAN
CDR Teleconference	21-31 JAN
FRR Documentation	16 MAR
FRR Teleconference	18-27 MAR
Competition	7-10 APR
PLAR Documentation	29 APR

For a broader overview using a Gantt Chart, please visit Appendix I.

5.1.4. Educational Engagement

In addition to competing in Huntsville, the 2014-2015 Georgia Tech *Team A.R.E.S.* has the objective of reaching out to the community of Atlanta and to educational institutions in disadvantaged areas. Georgia Tech's Vertically Integrated Program (VIP) particularly encourages this outreach. The VIP Program unites undergraduate education and faculty research in a team-based context, providing the students time and context to learn and practice professional skills and encouraging others in the community to develop these skills. As part of this experience, the USLI team takes on the responsibility to contribute in turn to the community and promote scientific and engineering knowledge to high school students throughout Atlanta, particularly those in inner city areas.

The goal of Georgia Tech's outreach program is to promote and invigorate interest in the Science, Technology, Engineering, and Mathematics (STEM) fields. *Team A.R.E.S.* is currently in the process of conducting various outreach programs targeting middle and high school Students and Educators. *Team A.R.E.S.* currently has an outreach request form on their webpage for Educators to request presentations or hands-on activities for their classroom. The team is in the process of answering visit requests from schools in disadvantaged areas of Atlanta, with the goal of encouraging students there to seek careers in STEM fields.

5.1.4.1. First Lego League

FIRST Lego League is an engineering competition designed for middle school children, the goal of which is to program an autonomous robot to score points in a "Robot Game". Annual competitions are held centered on a theme exploring a real-world problem. *Team A.R.E.S.* plans to be present at the Georgia Tech FIRST Lego League Tournament. The team's booth at the competition will demonstrate how the skills and ideas utilized in FIRST Lego League translate to real world applications. The team will demonstrate how these skills are used to build a launch vehicle and autonomous ground support equipment.

5.1.4.2. Georgia Tech NSBE

The Georgia Tech chapter of the National Society of Black Engineers (NSBE) is one of the largest student-governed organizations at Georgia Tech. According to its mission statement, NSBE's mission is "*to increase the number of culturally responsible black engineers who excel academically, succeed professionally and positively impact the community".* *Team A.R.E.S.* is currently in the process of engaging the chapter, coordinating with them on engineering outreach-related events to further both organizations' outreach goals, and targeting the organization (among others) in the team's recruiting efforts for the spring semester.

5.1.4.3. Frederick Douglass High School

Team A.R.E.S. will visit Frederick Douglas High School in northwest Atlanta during the November/December time frame to demonstrate to students the methods the team uses to design and build a launch vehicle and autonomous ground support equipment. The team will accomplish this while demonstrating hands-on design work and encouraging the students to participate in said work during the visiting session. Following the hands-on session, demonstration of the foundations and theory behind this work will commence. The team will focus on demonstrating that Georgia Tech engineering is an achievable goal and an attainable career path.

6. Conclusion

In conclusion, the Georgia Tech Team A.R.E.S. is well underway and after successful completion of the PDR Teleconference, we will be geared towards the next phase of our schedule, the CDR.

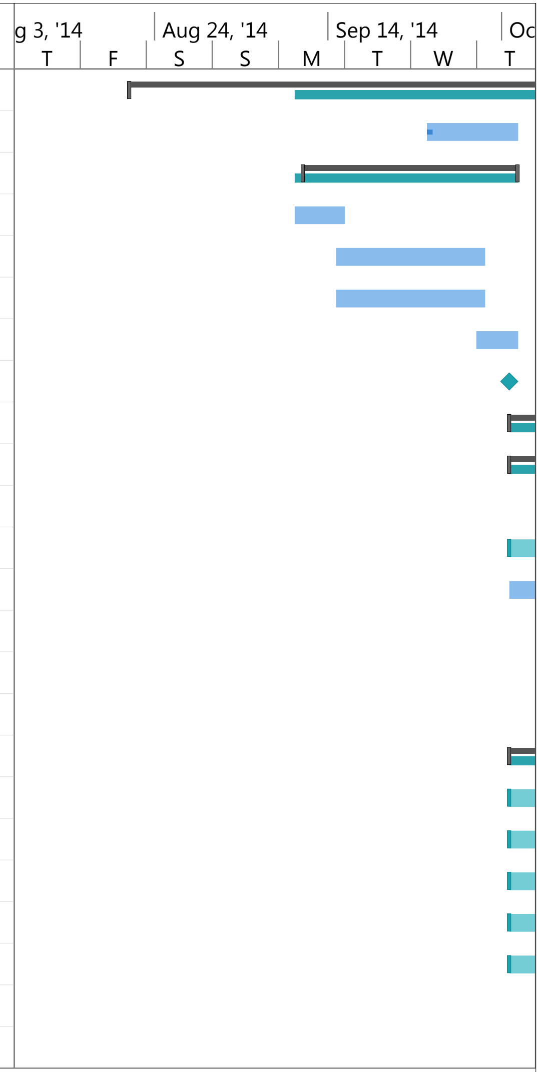
For the buildup into the CDR, we will have to perform the following tasks; complete static and structural testing, construct a subscale rocket, perform black powder testing, and test the AGSE components.

To summarize the AGSE, there will be 3 main systems for the AGSE; the Payload Insertion System, the Vertical Erector System, and the Igniter Insertion System. All of the systems have just completed the design phase are well under way for the testing and construction phase. Each subsystem will be put under rigorous testing to ensure that the functionality is not compromised.

Additionally, the rocket is designed to reach and Apogee of 3,100 ft. with a total mass of 15.13 lbs. The rocket will be subject to static testing on key components such as the in assembly, and the structure drop test.

Appendix I: Gantt Chart

ID	Task Name	Start	Finish
1	**Project Simple Complexity**	**Thu 8/21/14**	**Mon 5/11/15**
2	RFP Released by NASA	Fri 9/26/14	Mon 10/6/14
3	**Proposal**	**Thu 9/11/14**	**Mon 10/6/14**
4	Team Formation	Wed 9/10/14	Mon 9/15/14
5	Initial Rocket Design	Mon 9/15/14	Thu 10/2/14
6	Initial AGSE Design	Mon 9/15/14	Thu 10/2/14
7	Internal Proposal Review	Thu 10/2/14	Mon 10/6/14
8	Proposal Submitted	Mon 10/6/14	Mon 10/6/14
9	**Prelimary Design Review**	**Mon 10/6/14**	**Tue 12/16/14**
10	**Rocket**	**Mon 10/6/14**	**Thu 10/30/14**
11	Rocket Structure Design and Simulations	Thu 10/23/14	Thu 10/30/14
12	Recovery System Design and Simulation	Mon 10/6/14	Thu 10/30/14
13	Apogee Targeting System Design and Simulations	Mon 10/6/14	Fri 10/10/14
14	Apogee Targeting System Testing	Mon 10/13/14	Thu 10/30/14
15	Electronic Schematics for the Recovery System	Fri 10/17/14	Thu 10/30/14
16	Rocket Internal Review	Thu 10/30/14	Thu 10/30/14
17	**Flight Systems**	**Mon 10/6/14**	**Thu 10/30/14**
18	Payload Insertion System Design and Simulation	Mon 10/6/14	Thu 10/9/14
19	Vertical Elevating System Design and Simulation	Mon 10/6/14	Thu 10/16/14
20	Igniter Insertion System Design	Mon 10/6/14	Thu 10/16/14
21	AGSE Dimension Design and Simulation	Mon 10/6/14	Thu 10/30/14
22	Control System Prelimary Design	Mon 10/6/14	Thu 10/30/14
23	Control System Internal Review	Thu 10/23/14	Thu 10/30/14
24	AGSE System Internal Review	Thu 10/23/14	Thu 10/30/14



Project: FirstLaunch
Date: Wed 10/29/14

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Name	Start	Finish
25	**Project Level**	**Mon 10/6/14**	**Wed 11/5/14**
26	Establish Web Presence	Mon 10/6/14	Fri 10/31/14
27	Fundraising and Sponsorship	Mon 10/6/14	Fri 10/31/14
28	Outreach Event	Mon 10/20/14	Fri 10/24/14
29	Internal Prelimanry Design Review	Thu 10/23/14	Wed 11/5/14
30	Preliminary Design Review Documentation submitted	Thu 10/30/14	Thu 10/30/14
31	Prelimary Design Review Submitted	Wed 11/5/14	Wed 11/5/14
32	Prelimiary Design Review Teleconference	Fri 11/7/14	Fri 11/21/14
33	**Critical Design Review**	**Fri 11/21/14**	**Wed 2/4/15**
34	**Rocket**	**Fri 11/21/14**	**Sat 1/10/15**
35	Small Scale Testing	Fri 11/21/14	Fri 12/5/14
36	Recovery System Ground Testing	Fri 11/21/14	Sat 11/22/14
37	Competition Rocket Construction	Mon 1/5/15	Fri 1/9/15
38	Initial Rocket Flight	Sat 1/10/15	Sat 1/10/15
39	**Flight Systems**	**Fri 11/21/14**	**Sat 1/10/15**
40	Control System Detailed Design	Fri 11/21/14	Fri 12/12/14
41	Control System Internal Review	Fri 12/12/14	Fri 12/12/14
42	Payload Insertion System Construction	Fri 11/21/14	Thu 11/27/14
43	Igniter Insertion System Construction	Fri 11/21/14	Thu 11/27/14
44	Vertical Elevating System Construction	Fri 11/21/14	Thu 11/27/14
45	AGSE Integration of all Systems	Fri 11/21/14	Thu 11/27/14
46	AGSE System Internal Review	Thu 11/27/14	Thu 11/27/14
47	**Project Level**	**Fri 11/21/14**	**Mon 1/5/15**
48	Update Website	Fri 12/12/14	Mon 1/5/15

Project: FirstLaunch
Date: Wed 10/29/14

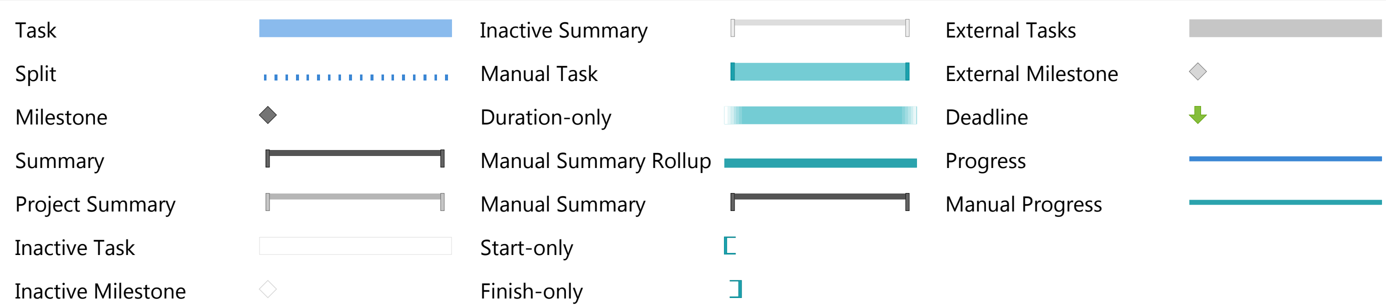
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

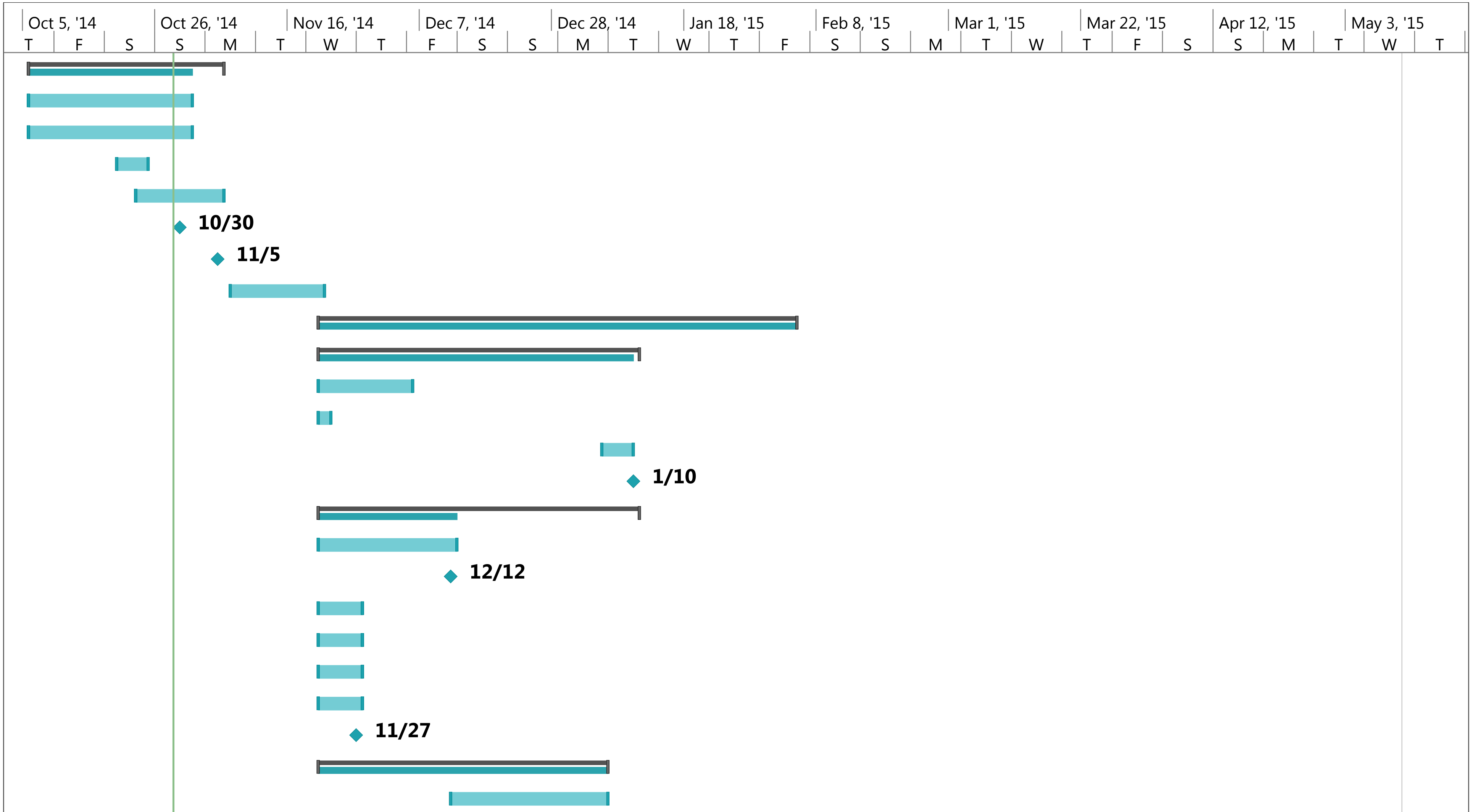
ID	Task Name	Start	Finish	g 3, '14 T F / Aug 24, '14 S S M / Sep 14, '14 T W / Oc T
49	Outreach Events	Fri 11/21/14	Mon 1/5/15	
50	Critical Design Internal Review	Mon 1/5/15	Fri 1/16/15	
51	Critical Design Review Submitted	Fri 1/16/15	Fri 1/16/15	
52	Critical Design Review Teleconference	Wed 1/21/15	Wed 2/4/15	
53	**Flight Readiness Review**	**Wed 2/4/15**	**Fri 3/27/15**	
54	**Rocket**	**Wed 2/4/15**	**Thu 2/19/15**	
55	Final Test Preparation	Wed 2/4/15	Thu 2/12/15	
56	Final Test Flight	Wed 2/4/15	Thu 2/19/15	
57	Competition Launch Preparation	Wed 2/4/15	Thu 2/19/15	
58	**Flight Systems**	**Wed 2/4/15**	**Fri 2/20/15**	
59	AGSE Refinement	Wed 2/4/15	Fri 2/20/15	
60	Control System Refinement	Wed 2/4/15	Fri 2/20/15	
61	**Project Level**	**Wed 2/4/15**	**Fri 3/27/15**	
62	Website Updates	Wed 2/4/15	Mon 3/16/15	
63	Outreach Events	Wed 2/4/15	Fri 3/27/15	
64	Flight Readiness Review Submitted	Mon 3/16/15	Mon 3/16/15	
65	Flight Readiness Review Teleconferences	Wed 3/18/15	Fri 3/27/15	
66	**Huntsville Alabama**	**Tue 4/7/15**	**Wed 4/15/15**	
67	Launch Readiness Review	Tue 4/7/15	Tue 4/7/15	
68	Launch Day	Sat 4/11/15	Sat 4/11/15	
69	Post Launch Assessment Review Submitted	Wed 4/29/15	Wed 4/29/15	
70	Winning Team Announced	Mon 5/11/15	Mon 5/11/15	

Project: FirstLaunch
Date: Wed 10/29/14

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Project: FirstLaunch
Date: Wed 10/29/14





Project: FirstLaunch
Date: Wed 10/29/14

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
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Inactive Task	Start-only	
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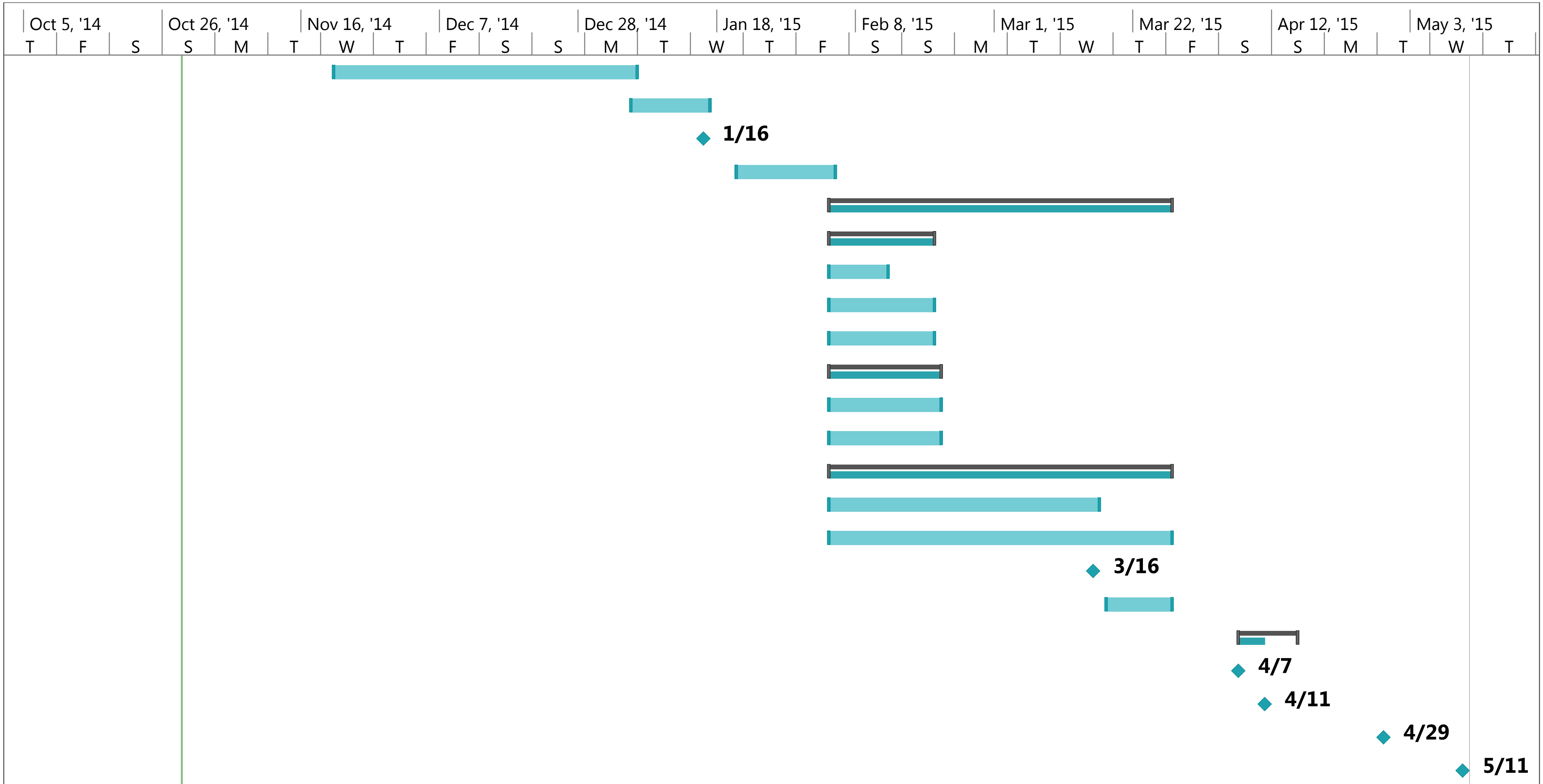


Project: FirstLaunch
Date: Wed 10/29/14

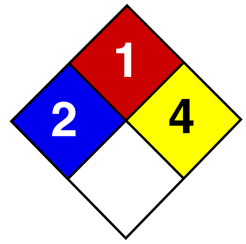
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Appendix II: MSDS Safety Sheet and Preliminary Launch Checklist

Prepare Payload Recovery System	
	Ensure batteries and switches are wired correctly
	Ensure batteries, power supply, switches, microprocessor, GPS, XBee is/are wired correctly
	Install and secure fresh batteries into battery holders
	Insert payload recovery electronics into payload recovery bay
	Connect appropriate wires
	Arm altimeter with output shorted to verify jumper settings. This is done to verify battery power and continuity
	Disarm Altimeter, un-short outputs
	Insert Payload Recovery Bay into Payload Section
Prepare Body Recovery System	
	Ensure batteries and switches are wired correctly
	Ensure batteries, power supply, switches, microprocessor, GPS, XBee is/are wired correctly
	Install and secure fresh batteries into battery holders
	Insert body recovery electronics into payload recovery bay
	Connect appropriate wires
	Arm altimeter with output shorted to verify jumper settings. This is done to verify battery power and continuity
	Disarm Altimeter, un-short outputs
	Insert Body Recovery Bay into Payload Section
Assemble Charges	
	Test e-match resistance to see if it is within specifications
	Remove protective cover from e-match
	Measure amount of black powder used in testing
	Place e-match on tape with sticky side up
	Pour black powder over e-match
	Seal Tape
	Re-test e-match
Check Altimeters	
	Ensure altimeters are disarmed
	Connect charges to ejection wells
	Turn on altimeters to verify continuity
	Disarm altimeters
Pack Parachutes	
	Connect drogue shock cord to booster section and body section
	Attach drogue parachute to drogue shock cord
	Pack drogue parachute
	Fold excess shock cord so it does not tangle
	Attach Nomex cloth to shock cord so it will enclose and shield the parachute while exposing only the Kevlar shock cord to ejection charge
	Insert cellulose wadding into drogue parachute bay between ejection charges and parachute
	Insert drogue parachute and shock cord into drogue parachute bay

	I nsert booster section into lower body section, and secure with shear pins
	Attach main parachute shock cord to upper body section and lower payload parachute bay
	Attach main parachute to main parachute shock cord
	Pack main parachute
	Fold excess shock cord so it does not tangle
	Attach Nomex cloth to shock cord so it will enclose and shield the parachute while exposing only the Kevlar shock cord to ejection charge
	Insert cellulose wadding into main parachute bay between ejection charges and parachute
	Insert main parachute and shock cord into main parachute bay and
	Insert upper body section into the lower section of the payload parachute bay, and secure with shear pins
	Attach payload parachute shock cord to payload section
	Attach parachute to the end of the payload parachute shock cord
	Pack payload section parachute
	Fold excess shock cord so it does not tangle
	Attach Nomex cloth to shock cord so it will enclose and shield the parachute while exposing only the Kevlar shock cord to ejection charge
	Insert cellulose wadding into upper payload parachute bay between ejection charges and parachute
	Insert drogue parachute and shock cord into upper payload parachute bay
	Insert payload section into payload parachute bay and secure with shear pins
Assemble motor	
	Follow manufacturer's instructions
	Do not get grease on propellant grains or delay grain
	Do not install igniter
	Install Motor in launch vehicle
	Secure motor retention system
Launch Vehicle Prep	
	Inspect launch vehicle, check CG and make sure it is within specified range
	Bring launch vehicle to Range Safety Officer(RSO) for inspection
	Bring launch vehicle to Autonomous Ground Support Equipment(AGSE) platform
	Install launch vehicle on AGSE
	Install motor igniter on AGSE
	Touch igniter clips together to make sure they will not fire the igniter when connected
	Make sure igniter clips are not shorted to each other or any section of the AGSE
	Connect igniter clips to motor igniter
AGSE Prep	
	Activate AGSE master switch and ensure safety light is flashing in color
	Activate AGSE pause switch and ensure safety light is solid in color
	All nonessential personnel evacuate to safe launch distance
	Deactivate AGSE pause switch and start stopwatch to time AGSE routines
	Stop stopwatch when AGSE routines are complete and record time from pause

	switch deactivation to rocket erection
	Essential personnel will arm altimeters via switches and ensure continuity
	All personnel will evacuate to safe launch distance
Launch	
	Watch flight so launch vehicle sections do not get lost
Post Launch Payload/Vehicle Recovery	
	Recover Payload Section and tethered Body/Booster Section
	Disarm Altimeters if there are unfired charges
	Disassemble launch vehicle, clean motor case, other parts, and inspect for damage
	Record altimeter data



Health	2
Fire	1
Reactivity	4
Personal Protection	E

Material Safety Data Sheet
Ammonium perchlorate MSDS

Section 1: Chemical Product and Company Identification

Product Name: Ammonium perchlorate

Catalog Codes: SLA2725

CAS#: 7790-98-9

RTECS: SC7520000

TSCA: TSCA 8(b) inventory: Ammonium perchlorate

CI#: Not available.

Synonym:

Chemical Formula: NH4ClO4

Contact Information:

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

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

Order Online: ScienceLab.com

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

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

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

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Ammonium perchlorate	7790-98-9	100

Toxicological Data on Ingredients: Ammonium perchlorate LD50: Not available. LC50: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects:
Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Prolonged exposure may result in skin burns and ulcerations. Over-exposure by inhalation may cause respiratory irritation.

Potential Chronic Health Effects:
Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to blood, kidneys. Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures

Eye Contact:

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact:
In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminated clothing and shoes. Cold water may be used.Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact:
Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation:
Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances: Flammable in presence of shocks, of heat, of reducing materials, of combustible materials, of organic materials.

Explosion Hazards in Presence of Various Substances:
Extremely explosive in presence of open flames and sparks, of shocks, of heat, of reducing materials, of organic materials. Slightly explosive in presence of acids.

Fire Fighting Media and Instructions:
Oxidizing material. Do not use water jet. Use flooding quantities of water. Avoid contact with organic materials.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill: Use appropriate tools to put the spilled solid in a convenient waste disposal container.

Large Spill:
Oxidizing material. Stop leak if without risk. Avoid contact with a combustible material (wood, paper, oil, clothing...). Keep substance damp using water spray. Do not touch spilled material. Prevent entry into sewers, basements or confined areas; dike if needed. Eliminate all ignition sources. Call for assistance on disposal.

Section 7: Handling and Storage

Precautions:
Keep away from heat. Keep away from sources of ignition. Keep away from combustible material.. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not breathe dust. Take precautionary measures against electrostatic discharges. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If you feel unwell, seek medical attention and show the label when possible. Avoid contact with skin and eyes. Keep away from incompatibles such as reducing agents, combustible materials, organic materials, acids.

Storage:
Keep container tightly closed. Keep container in a cool, well-ventilated area. Separate from acids, alkalies, reducing agents and combustibles. See NFPA 43A, Code for the Storage of Liquid and Solid Oxidizers.

Section 8: Exposure Controls/Personal Protection

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

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

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

Exposure Limits: Not available.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Crystals solid.)

Odor: Not available.

Taste: Not available.

Molecular Weight: 117.49 g/mole

Color: Colorless.

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

Boiling Point: Not available.

Melting Point: Decomposes.

Critical Temperature: Not available.

Specific Gravity: 1.95 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: See solubility in water, methanol, acetone.

Solubility:
Soluble in cold water, methanol. Partially soluble in acetone. Insoluble in diethyl ether.

Section 10: Stability and Reactivity Data

Stability: Unstable.

Instability Temperature: Not available.

Conditions of Instability: No additional remark.

Incompatibility with various substances:
Extremely reactive or incompatible with reducing agents, combustible materials, organic materials. Reactive with acids.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Eye contact. Inhalation. Ingestion.

Toxicity to Animals:
LD50: Not available. LC50: Not available.

Chronic Effects on Humans: Causes damage to the following organs: blood, kidneys.

Other Toxic Effects on Humans: Hazardous in case of skin contact (irritant), of ingestion, of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

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

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation: Possibly hazardous short/long term degradation products are to be expected.

Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: CLASS 5.1: Oxidizing material.

Identification: : Ammonium Perchlorate UNNA: UN1442 PG: II

Special Provisions for Transport: Not available.

Section 15: Other Regulatory Information

Federal and State Regulations:
Pennsylvania RTK: Ammonium perchlorate Massachusetts RTK: Ammonium perchlorate TSCA 8(b) inventory: Ammonium perchlorate

Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).

Other Classifications:

WHMIS (Canada): CLASS C: Oxidizing material.

DSCL (EEC):
R8- Contact with combustible material may cause fire. R36/38- Irritating to eyes and skin.

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 1

Reactivity: 4

Personal Protection: E

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

Health: 2

Flammability: 1

Reactivity: 4

Specific hazard:

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

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

Created: 10/09/2005 03:57 PM

Last Updated: 05/21/2013 12:00 PM

NAR High Power Rocket Safety Code

Effective August 2012

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 keep smoking, open flames, and heat sources at least 25 feet away from 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 launching or 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 the 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 there is no dry grass within a clear distance of each launch pad determined by 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, or 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 at least one half the minimum launch site dimension, or 1500 feet (whichever is greater) 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 may recover in spectator areas or outside the launch site, or attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE

Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Clear Distance (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 - 320.00	H or smaller	50	100	200
320.01 - 640.00	I	50	100	200
640.01 - 1280.00	J	50	100	200
1280.01 - 2560.00	K	75	200	300
2560.01 - 5120.00	L	100	300	500
5120.01 - 10,240.00	M	125	500	1000
10,240.01 - 20,480.00	N	125	1000	1500
20,480.01 - 40,960.00	O	125	1500	2000

Note: A complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Material Safety Data Sheet
(MSDS-BP)

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

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

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

WARNING

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

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

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

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

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

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

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

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

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

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

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

SPECIAL PRECAUTIONS

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

STORAGE CONDITIONS

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

SHIPPING INFORMATION

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

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

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MSDS prepared by:

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Original publication date: 12/08/93
Revision date: 12/12/05
12/03/03

MATERIAL SAFETY DATA SHEET

Prepared to U.S. OSHA, CMA, ANSI and Canadian WHMIS Standards .This Material Safety Data Sheet is offered pursuant to OSHA's Hazard Communication Standard (29 CFR 1910.1200). Other government regulations must be reviewed for applicability to these products.

WARNING: PRODUCT COMPONENTS PRESENT HEALTH AND SAFETY HAZARDS. READ AND UNDERSTAND THIS MATERIAL SAFETY DATA SHEET (M.S.DS.). ALSO, FOLLOW YOUR EMPLOYER'S SAFETY PRACTICES. This product may contain Chromium and/or Nickel which are listed by OSHA, NTP, or IARC as being a carcinogen or potential carcinogen. Use of this product may expose you or others to fumes and gases at levels exceeding those established by the American Conference of Governmental Industrial Hygienists (ACGIH) or the Occupational Safety and Health Administration (OSHA) The information contained herein relates only to the specific product. If the product is combined with other materials, all component properties must be considered. **BE SURE TO CONSULT THE LATEST VERSION OF THE MSDS. MATERIAL SAFETY DATA SHEETS ARE AVAILABLE FROM HARRIS PRODUCTS GROUP** salesinfo@jwharris.com 513-754-2000 **www.harrisproductsgroup.com**

STATEMENT OF LIABILITY-DISCLAIMER

To the best of the Harris Products Group knowledge, the information and recommendations contained in this publication are reliable and accurate as of the date prepared. However, accuracy, suitability, or completeness are not guaranteed, and no warranty, guarantee, or representation, expressed or implied, is made by Harris Products Group as to the absolute correctness or sufficiency of any representation contained in this and other publications; Harris Products Group. assumes no responsibility in connection therewith; nor can it be assumed that all acceptable safety measures are contained in this and other publications, or that other or additional measures may not be required under particular or exceptional conditions or circumstances . Data may be changed from time to time.

PART I *What is the material and what do I need to know in an emergency?*

1. PRODUCT IDENTIFICATION

TRADE NAME (AS LABELED): **LEAD SOLDER**
CHEMICAL NAME/CLASS: Metal Alloy
SYNONYMS: Not Applicable
PRODUCT USE: Soldering
DOCUMENT NUMBER: 0126
SUPPLIER/MANUFACTURER'S NAME: **HARRIS PRODUCTS GROUP**
ADDRESS: 4501 Quality Place, Mason, Ohio 45040
EMERGENCY PHONE: CHEMTREC: 1-800-424-9300
BUSINESS PHONE: 513-754-2000 **FAX** 513-754-8778
DATE OF PREPARATION: August 13, 2010

2. COMPOSITION and INFORMATION ON INGREDIENTS

NOMINAL COMPOSITION WEIGHT % Wire

TRADE NAME	30/70	40/60	50/50	60/40	63/37	70/30	90/10
Tin (Sn)	30%	40%	50%	60%	63%	70%	90%
Lead (Pb)	70%	60%	50%	40%	37%	30%	10%

NOMINAL COMPOSITION WEIGHT % Flux Core

TRADE NAME	Activated Rosin CAS # 8050-09-7	Ammonium Chloride CAS #	Zinc Chloride CAS # 7646-85-7	Water CAS #
ACID CORE		< 20%	< 70%	Balance
ROSIN CORE	100%			

2. COMPOSITION and INFORMATION ON INGREDIENTS (Continued)

CHEMICAL NAME	CAS #	% w/w	EXPOSURE LIMITS IN AIR					
			ACGIH-TLV		OSHA-PEL		NIOSH	OTHER
			TWA mg/m^3	STEL mg/m^3	TWA mg/m^3	STEL mg/m^3	IDLH mg/m^3	mg/m^3
Activated Rosin Exposure limits are for Rosin Core Solder Decomposition Products, as resin-acids-colophony	8050-09-7	See Table Previous Page	Sensitizer; reduce exposure to as low as possible	NE	NE	NE	NE	DFG MAK: TWA = Danger of sensitization of the skin.
Ammonium Chloride Exposure limits are for Ammonium Chloride, fume	12125-02-9	See Table Previous Page	10	20	10 (Vacated 1989 PEL)	20 (Vacated 1989 PEL)	NE	NIOSH REL: TWA = 10 STEL = 20
Lead Exposure limits are for Lead, elemental & inorganic compounds, as Pb	7439-92-1	See Table Previous Page	0.05 , A4 (Not Classifiable as a Human Carcinogen)	NE	0.05 (see 29 CFR 1910.1025)	NE	100	NIOSH RELs: TWA = < 0.1 (blood Pb < 0.060 mg/100 g whole blood) DFG MAKs: TWA = 0.1 (Inhalable Fraction) PEAK = 10•MAK 30 min., average value DFG MAK Pregnancy Risk Classification: B Carcinogen: EPA-B2, IARC-2B, TLV-A3
Tin Exposure limits are for Tin, Metal	7440-31-5	See Table Previous Page	2	NE	2	NE	100	NE
Zinc Chloride Exposure limits are for Zinc Chloride, fume	7646-85-7	See Table Previous Page	1	2	1	2 (Vacated 1989 PEL)	50	NIOSH RELs: TWA = 1 STEL = 2 Carcinogen: EPA-D

NE = Not Established. See Section 16 for Definitions of Terms Used.

NOTE (1): The ACGIH has an established exposure limit for Welding Fumes, Not Otherwise Classified. The Threshold Limit Value is 5 mg/m^3. NIOSH classifies welding fumes as carcinogens. Single values shown are maximum, unless otherwise noted.

NOTE (2): ALL WHMIS required information is included in appropriate sections based on the ANSI Z400.1-1998 format. These products have been classified in accordance with the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.

3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW: These products consist of odorless, lead/tin alloy wires, which have a metallic luster and may have a flux core. There are no immediate health hazards associated with these products, as wires. When heated during soldering operations, these products may generate irritating and toxic fumes of lead oxide, tin oxides, hydrogen chloride, zinc oxides, and ammonium compounds. There is a danger of cumulative effects if fumes or dusts from these products are inhaled or ingested. Contact with the rosin core of these wires can result in allergic reaction and sensitization to the skin in susceptible persons. These products are not reactive. If involved in a fire, these products may generate irritating fumes and a variety of metal oxides, as described above. Finely divided dusts of these products may result in explosive air/dust mixtures. Emergency responders must wear personal protective equipment suitable for the situation to which they are responding.

SYMPTOMS OF OVER-EXPOSURE BY ROUTE OF EXPOSURE: During soldering operations, the most significant route of over-exposure is via inhalation of fumes.

INHALATION: Inhalation of large amounts of particulates generated by these products during soldering operations may be physically irritating and cause deposits of dust in nasal passages. Due to the presence of lead, inhalation of fumes or dusts from these products can result in lead poisoning. Symptoms of poisoning include headache, fatigue, nausea, metallic taste in the mouth, abdominal cramps, joint pain, metallic taste in the mouth, vomiting, constipation, bloody diarrhea, and harmful effects on the central nervous system. Exposure to lead can cause significant cumulative toxic effects, effects on the reproductive system and may cause cancer. See information under “Other Health Effects” for additional information. When heated to decomposition, the rosin core of some of these products can include toxic compounds, including formaldehyde, acetaldehyde, or malonaldehyde. Inhalation of these fumes can result in irritation to the respiratory system.

3. HAZARD IDENTIFICATION (Continued)

INHALATION (continued): Exposure to dust or fumes of the Tin components is known to cause a benign

FOR WIRES

HAZARDOUS MATERIAL IDENTIFICATION SYSTEM

HEALTH	(BLUE)	0
FLAMMABILITY	(RED)	0
REACTIVITY	(YELLOW)	0
PROTECTIVE EQUIPMENT		X

EYES	RESPIRATORY	HANDS	BODY
	See Section 8		See Section 8

For routine industrial applications for the rods

See Section 16 for Definition of Ratings

FOR FUMES OR DUSTS

HAZARDOUS MATERIAL IDENTIFICATION SYSTEM

HEALTH	(BLUE)	3
FLAMMABILITY	(RED)	0
REACTIVITY	(YELLOW)	0
PROTECTIVE EQUIPMENT		X

EYES	RESPIRATORY	HANDS	BODY
	See Section 8		See Section 8

For routine industrial applications for the rods

See Section 16 for Definition of Ratings

pneumoconiosis (stannosis). This form of pneumoconiosis produces distinctive progressive x-ray changes of the lung as long as exposure persists, but there is no distinctive fibrosis, no evidence of disability, and no special complicating factors. In addition, inhalation of large amounts of dusts or fumes of these products, can cause metal fume fever. Symptoms of metal fume fever include flu-like symptoms, metallic taste, fever, sweating, chills, cough, weakness, chest pain, muscle pain, cardiac abnormalities, and increased white blood cell count. Damage to lungs can occur. Symptoms of metal fume fever can be delayed 24-48 hours. Refer to Section 10 (Stability and Reactivity) for information on the specific composition of soldering fumes and gases. There is some evidence that inhalation of fumes from the Ammonium Chloride component of these products may cause respiratory sensitization in susceptible individuals. Symptoms may include difficulty breathing, persistent coughing and wheezing.

CONTACT WITH SKIN or EYES: Contact of the wire form of these products with the skin is not anticipated to be irritating. Contact with the wire form of these products can be physically damaging to the eye. Fumes generated during soldering operations can be irritating to the skin and eyes. Symptoms of skin over-exposure may include irritation and redness; prolonged or repeated skin over-exposures may lead to dermatitis. Contact with the rosin core can result in allergic reaction and skin sensitization in susceptible individuals. Symptoms could include dermatitis, itching and persistent rash. Contact with the molten core or wire will burn contaminated skin or eyes.

SKIN ABSORPTION: Skin absorption is not known to be a significant route of over-exposure for any component of these products.

INGESTION: Ingestion is not anticipated to be a route of occupational exposure for these products; however, if proper hygiene (e.g. washing of hands) is not followed during handling and use of these products, ingestion of lead from contamination of the hands can occur, resulting is Lead poisoning.

INJECTION: Though not a likely route of occupational exposure for these products, injection (via punctures or lacerations in the skin) may cause local reddening, tissue swelling, and discomfort.

OTHER HEALTH EFFECTS: Due to the presence of Lead in these products, exposure to dusts or fumes may result in significant adverse acute and chronic health effects, as follows. Long-term, low-level lead exposure has resulted in harm to the central nervous system and brain function. Symptoms of chronic, low to moderate levels include forgetfulness, irritability, tiredness, headache, fatigue, impotence, decreased libido, dizziness, altered mood states and depression.

(continued on following page)

OTHER HEALTH EFFECTS (continued): Symptoms of chronic exposure to moderate to high lead levels include disturbances in hand to eye coordination, reaction times, visual motor performance, mental performance, gradual decrease in visual acuity with slow recovery or possible blindness, changes in hearing ability, and in worse cases, encephalopathy (a progressive degeneration of the brain and its functions). Early symptoms of encephalopathy include dullness, irritability, poor attention span, muscular tremor, headache, and loss of memory and hallucinations. Severe, chronic exposure to Lead at high concentration can result in symptoms on the central nervous system, including delirium, lack of coordination, convulsions, paralysis, coma and death.

Exposure to Lead can also result in significant adverse results on the peripheral nervous system, including harm to nerves in hands, legs and feet. These effects can be reversible if exposure is short term (5 months or less) and treatment is received; if not, these effects can become permanent. A syndrome known as "Lead Palsy" can occur, with symptoms such as weakness of legs or arms, weakness and paralysis of the wrist, fingers and ankles. At lower exposure levels decreased hand dexterity has been reported. At higher exposure levels an ability to hold the foot or hand in extended position can occur.

Exposure to Lead can also cause adverse effects on the gastrointestinal system, including loss of appetite, inflammation of the stomach walls (gastritis), colic, severe abdominal pain, cramps, nausea, vomiting, constipation, anorexia, weight loss and decreased urination. In severe cases of Lead poisoning, a deposit of Lead occurs in the gums near the base of the teeth, resulting in a visible blue-gray line. Reversible kidney injury has been observed in some cases of workers exposed to Lead at chronic, low to moderate levels. Death due to kidney failure has occurred to workers chronically exposed to Lead at moderate levels.

Exposure to Lead can cause harmful effects to certain types of blood cells, including reduced hemoglobin production and reduced life-span and function of red blood cells. This harm can cause anemia in workers exposed to moderate levels. Low, moderate and high level exposure to Lead may increase blood pressure, especially in men. Some studies have indicated that moderate exposure to Lead can result in electrocardiographic abnormalities. There is some evidence that low-level exposure to Lead can cause harmful effects on the thyroid and immune systems, including possible susceptibility to colds and flu infections.

Exposure to Lead, especially at high levels, has resulted in significant adverse effects in the reproductive systems of both men and women. Refer to Section 11 (Toxicological Information, Reproductive Toxicity Information) for additional information.

HEALTH EFFECTS OR RISKS FROM EXPOSURE: An Explanation in Lay Terms. Symptoms associated with over-exposure to these products and the fumes generated during soldering operations are as follows:

ACUTE: Inhalation of large amounts of particulates generated by these products during metal processing operations may be physically irritating and cause deposits of dust in nasal passages. Inhalation of dusts and fumes of these products can cause metal fume fever or irritation of the respiratory system. Contact with the molten material will burn contaminated skin or eyes. Significant adverse effects on the blood, kidneys, gastrointestinal system, central and peripheral nervous systems.

CHRONIC: Chronic skin over-exposure to the fumes of these products during soldering operations may produce dermatitis (red, inflamed skin). Repeated or prolonged over-exposures, via inhalation, to the dusts generated by these products may cause pulmonary fibrosis (scarring of lung tissue). Chronic inhalation of fumes or dusts of the components of these products, can result in severe, adverse effects on the blood and heart, kidneys, thyroid and immune systems, and central and periphery nervous system, due to the presence of Lead. Contact with the rosin core of some of these products can cause an allergic skin reaction and sensitization in susceptible individuals. Due to the presence of the Ammonium Chloride compound in the flux core of some of these products, inhalation of fumes from soldering may cause allergic respiratory reaction and respiratory sensitization in susceptible individuals. Due to the Lead component in these products, contact may result in significant adverse effects on the reproductive system. See Section 11 (Toxicological Information) for additional information.

TARGET ORGANS: For fumes: ACUTE: Skin, eyes, respiratory system, blood system, central nervous system, peripheral nervous system, gastrointestinal system. CHRONIC: Skin, central nervous system, kidneys, heart, blood, central nervous system, thyroid, immune system, reproductive system.

PART II *What should I do if a hazardous situation occurs?*

4. FIRST-AID MEASURES

Victims of chemical exposure must be taken for medical attention. Rescuers should be taken for medical attention, if necessary. Take a copy of label and MSDS to health professional with victim.

SKIN EXPOSURE: If fumes generated by soldering operations involving these products contaminate the skin, begin decontamination with running water. If molten material contaminates the skin, immediately begin decontamination with cold, running water. Minimum flushing is for 15 minutes. Victim must seek medical attention if any adverse reaction occurs.

4. FIRST-AID MEASURES (Continued)

EYE EXPOSURE: If fumes generated by soldering operations involving these products enter the eyes, open victim's eyes while under gently running water. Use sufficient force to open eyelids. Have victim "roll" eyes. <u>Minimum</u> flushing is for 15 minutes. Victim must seek immediate medical attention.

INHALATION: If fumes generated by soldering operations involving these products are inhaled, remove victim to fresh air. If necessary, use artificial respiration to support vital functions.

INGESTION: If swallowed call physician immediately! Do not induce vomiting unless directed by medical personnel. Rinse mouth with water if person is conscious. Never give fluids or induce vomiting if person is unconscious, having convulsions, or not breathing.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Skin, respiratory, blood, central nervous system and peripheral system, and kidney disorders, may be aggravated by prolonged over-exposures to the dusts or fumes generated by these products.

RECOMMENDATIONS TO PHYSICIANS: Basic Treatment: Establish a patent airway. Suction if necessary. Watch for signs of respiratory insufficiency and assist ventilations if necessary. Administer oxygen by non-rebreather mask at 10 to 15 L/minutes. Monitor for shock and treat if necessary. Anticipate seizures and treat if necessary. For eye contamination, flush eyes immediately with water. Irrigate each eye continuously with normal saline during transport. Do not use emetics. For ingestion, rinse mouth and administer 5 mL/kg up to 200 mL of water for dilution if the patient can swallow, has a strong gag reflex, and does not drool. Administer activated charcoal.

Advanced Treatment: Consider orotracheal or nasotracheal intubation for airway control in the patient who is unconscious. Use hyperventilation to help control increased intracranial pressure. Start an IV with lactated Ringer's to support vital signs. For hypotension with signs of hypovolemia, administer fluid cautiously. Watch for signs of fluid overload. Treat seizures with diazepam (Valium). Use proparacaine hydrochloride to assist eye irrigation. The treatment of lead poisoning is based on the prompt termination of exposure and on the use of chelating agents. The first requirement is categorical. The second is determined by the severity of poisoning; at present, the greatest issue is whether a symptomatic patients should be treated or not. The most commonly used therapeutic chelating agents are CaEDTA, BAL, and D-penicillamine can be given. DMSA should also be considered.

5. FIRE-FIGHTING MEASURES

FLASH POINT: Not flammable.

AUTOIGNITION TEMPERATURE: Not applicable for products. Dust clouds of Lead, a possible main component of these products, have a minimum ignition temperature range of 270-790°C (518-1454°F).

FLAMMABLE LIMITS (in air by volume, %):

<u>Lower (LEL)</u>: Not applicable.
<u>Upper (UEL)</u>: Not applicable.

FIRE EXTINGUISHING MATERIALS: These products are not flammable; use fire-extinguishing agents appropriate for surrounding materials.

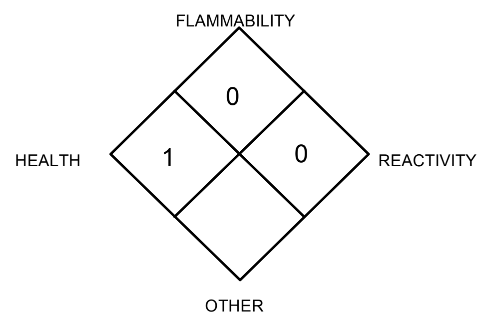
<u>Water Spray</u>: YES	<u>Carbon Dioxide</u>: YES
<u>Halon</u>: YES	<u>Foam</u>: YES
<u>Dry Chemical</u>: YES	<u>Other</u>: Any "ABC" Class

UNUSUAL FIRE AND EXPLOSION HAZARDS When involved in a fire, these products may decompose and produce lead oxide, tin oxides, hydrogen chloride, zinc oxides, and ammonium compounds. The hot material can present a significant thermal hazard to firefighters.

<u>Explosion Sensitivity to Mechanical Impact</u>: Not sensitive.

<u>Explosion Sensitivity to Static Discharge</u>: Although these products are not sensitive to static discharge, dusts of these products can form explosive air/dust mixtures and can be ignited by static discharge.

NFPA RATING



<u>See Section 16 for Definition of Ratings</u>

SPECIAL FIRE-FIGHTING PROCEDURES: Lead and its decomposition products are hazardous to health. Fire-fighters should not enter an area in which a fire involves these products without wearing specialized protective equipment suitable for potential Lead exposure. Normal fire-fighter bunker gear is not adequate to protect against exposure to Lead and its decomposition products. A full-body, encapsulating chemical resistant suit with positive-pressure Self-Contained Breathing Apparatus may be necessary.

6. ACCIDENTAL RELEASE MEASURES

SPILL AND LEAK RESPONSE: Not applicable.

7. HANDLING and STORAGE

WORK PRACTICES AND HYGIENE PRACTICES: As with all chemicals, avoid getting these products ON YOU or IN YOU. Wash thoroughly after handling these products. Do not eat or drink while handling these products. Use ventilation and other engineering controls to minimize potential exposure to these products. If dusts or fumes of these products are present, use of a suitable NIOSH approved respirator must commence immediately to protect against possible Lead poisoning. Unprotected workers must avoid all contact with these products.

STORAGE AND HANDLING PRACTICES: All employees who handle these products should be trained to handle it safely, following the requirements of the OSHA Lead Standard (29 CFR 1910.1025). Use in clearly posted areas(s) indicating Lead hazard. Access doors must remain closed while these products are being used or stored. When handling Lead powder on a large scale, closed-handling systems for processes should be used. If this is not possible, use in the smallest possible amounts in appropriate labeled, containment devices (e.g. fume hood). Containment devices should be made of smooth, unbreakable compatible material. Maintain containment devices at appropriate air-flow and negative pressure. Check regularly. Use in a well-ventilated location. Avoid the generation of dusts and prevent the release of fumes to the workplace. Avoid breathing fumes of these products generated during soldering operations. Open containers on a stable surface. Cover surfaces in which these products are being used with compatible, chemical resistant and/or disposable material for easier containment and clean-up. Good housekeeping is very important. Keep work areas clean. Packages of these products must be properly labeled. When these products are used during soldering operations, follow the requirements of the Federal Occupational Safety and Health Welding and Cutting Standard (29 CFR 1910 Subpart Q) and the safety standards of the American National Standards Institute for welding and cutting (ANSI Z49.1). Store packages in a cool, dry location. Store away from incompatible materials (see Section 10, Stability and Reactivity).

PROTECTIVE PRACTICES DURING MAINTENANCE OF CONTAMINATED EQUIPMENT: Not applicable.

8. EXPOSURE CONTROLS - PERSONAL PROTECTION

VENTILATION AND ENGINEERING CONTROLS: As per the OSHA Lead Standard, 29 CFR 1910.1025, the employer shall assure that no employee is exposed to Lead at concentrations greater than 50 μg/cubic meter averaged over an 8-hour period. If an employee is exposed to Lead for more than 8 hours in any work day, the permissible exposure limit, as a TWA for that day, shall be reduced according to the following formula: Maximum permissible limit (in μg/cubic meter) = 400 divided by the number of hours worked in the day. Use with adequate ventilation to ensure exposure levels are maintained below these limits and the limits for Lead and other components of these products provided in Section 2 (Composition and Information on Ingredients). Prudent practice is to ensure eyewash/safety shower stations are available near areas where these products are used.

RESPIRATORY PROTECTION: Maintain airborne contaminant concentrations below guidelines listed in Section 2 (Composition and Information on Ingredients). If respiratory protection is needed (i.e. a Weld Fume Respirator, or Air-Line Respirator for welding in confined spaces), U.S. Federal OSHA Standard (29 CFR 1910.134), applicable U.S. State regulations, or the Canadian CSA Standard Z94.4-93 and applicable standards of Canadian Provinces. Respiratory Protection is recommended to be worn during welding operations. Oxygen levels below 19.5% are considered IDLH by OSHA. In such atmospheres, use of a full-facepiece pressure/demand SCBA or a full facepiece, supplied air respirator with auxiliary self-contained air supply is required under OSHA's Respiratory Protection Standard (1910.134-1998). The following are NIOSH recommendations for respirator selection for Ammonium Chloride, Lead, Welding fumes, Rosin Core, Pyrolysis Products, Tin and Zinc Chloride, and are provided for additional information:

LEAD

CONCENTRATION	**RESPIRATORY PROTECTION**
Up to 0.5 mg/m^3:	Any Air-Purifying Respirator with a high-efficiency particulate filter, or any Supplied-Air Respirator (SAR).
Up to 1.25 mg/m^3:	Any SAR operated in a continuous-flow mode, or any powered, air-purifying respirator with a high-efficiency particulate filter.
Up to 2.5 mg/m^3:	Any Air-Purifying, Full-Facepiece Respirator with a high-efficiency particulate filter, or any SAR that has a tight-fitting facepiece and is operated in a continuous-flow mode, or any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter, or any Self-Contained Breathing Apparatus (SCBA) with a full facepiece, or any SAR with a full facepiece.
Up to 50 mg/m^3:	Any SAR operated in a pressure-demand or other positive-pressure mode.
Up to 100 mg/m^3:	Any SAR that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.

(continued on following page)

RESPIRATORY PROTECTION (continued): NIOSH recommendations for respiratory protection, continued.

LEAD CONCENTRATION **RESPIRATORY PROTECTION (continued):**

Emergency or Planned Entry into Unknown Concentrations or IDLH Conditions: Any SCBA that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode, or any SAR that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary SCBA operated in pressure-demand or other positive-pressure mode.

Escape: Any Air-Purifying, Full-Facepiece Respirator with a high-efficiency particulate filter, or any appropriate escape-type, SCBA.

ROSIN FLUX PYROLYSIS PRODUCTS

CONCENTRATION **RESPIRATORY PROTECTION**

At Concentrations above the NIOSH REL, or where there is no REL, at any Detectable Concentration: Any Self-Contained Breathing Apparatus (SCBA) that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode, or any Supplied-Air Respirator (SAR) that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary SCBA operated in pressure-demand or other positive-pressure mode.

Escape: Any Air-Purifying, Full-Facepiece Respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister having a high-efficiency particulate filter, or any appropriate escape-type, SCBA.

TIN CONCENTRATION **RESPIRATORY PROTECTION**

Up to 10 mg/m^3: Any dust and mist respirator.

Up to 20 mg/m^3: Any dust and mist respirator except single-use and quarter-mask respirators, IF NOT present as a fume, or any Supplied-air Respirator (SAR).

Up to mg/m^3: Any SAR operated in a continuous-flow mode, or any Powered, Air-Purifying Respirator with a dust and mist filter, IF NOT present as a fume.

Up to 100 mg/m^3: Any Air-Purifying, Full-Facepiece Respirator with a high-efficiency particulate filter, or any Self-Contained Breathing Apparatus (SCBA) with a full facepiece, or any SAR with a full facepiece.

Emergency or Planned Entry into Unknown Concentrations or IDLH Conditions: Any SCBA that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode, or any SAR that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary SCBA operated in pressure-demand or other positive-pressure mode.

Escape: Any Air-Purifying, Full-Facepiece Respirator with a high-efficiency particulate filter, or any appropriate escape-type, SCBA

WELDING FUMES

CONCENTRATION **RESPIRATORY EQUIPMENT FOR WELDING FUMES**

At Concentrations above the NIOSH REL, or where there is no REL, at any Detectable Concentration: Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode; or any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive-pressure mode.

Escape: Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister having a high-efficiency particulate filter; or any appropriate escape-type, self-contained breathing apparatus

NOTE: IDLH Concentration: Potential NIOSH carcinogen. [Not determined yet].

ZINC CHLORIDE

CONCENTRATION **RESPIRATORY PROTECTION**

Up to 10 mg/m^3: Any dust, mist, and fume respirator, or any Supplied-Air Respirator (SAR).

Up to 25 mg/m^3: Any SAR operated in a continuous-flow mode, or any Powered, Air-Purifying Respirator (PAPR) with a dust, mist, and fume filter.

Up to 50 mg/m^3: Any Air-Purifying, Full-Facepiece Respirator with a high-efficiency particulate filter, or any PAPR with a tight-fitting facepiece and a high-efficiency particulate filter, or any Self-Contained Breathing Apparatus (SCBA) with a full facepiece, or any SAR with a full facepiece.

Emergency or Planned Entry into Unknown Concentrations or IDLH Conditions: Any SCBA that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode, or any SAR that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary SCBA operated in pressure-demand or other positive-pressure mode.

Escape: Any Air-Purifying, Full-Facepiece Respirator with a high-efficiency particulate filter, or any appropriate escape-type, SCBA.

8. EXPOSURE CONTROLS - PERSONAL PROTECTION (Continued)

EYE PROTECTION: Safety glasses. When these products are used in conjunction with soldering, wear safety glasses, goggles, or face-shield with filter lens of appropriate shade number (per ANSI Z49.1-1988, "Safety in Welding and Cutting") and U.S. OSHA 29 CFR 1910.133 and appropriate Canadian Standards.

HAND PROTECTION: Wear gloves for routine industrial use. When these products are used in conjunction with soldering, wear gloves that protect from sparks and flame (per ANSI Z49.1-1988, "Safety in Welding and Cutting"). If necessary, refer to U.S. OSHA 29 CFR 1910.138 and appropriate Standards of Canada.

BODY PROTECTION: Use body protection appropriate for task. If a hazard of injury to the feet exists due to falling objects, rolling objects, where objects may pierce the soles of the feet or where employee's feet may be exposed to electrical hazards, as described in U.S. OSHA 29 CFR 1910.136.

9. PHYSICAL and CHEMICAL PROPERTIES

The following information is for Lead, a possible main component:

RELATIVE VAPOR DENSITY (air = 1): Not applicable.
EVAPORATION RATE (nBuAc = 1): Not applicable.
SPECIFIC GRAVITY @ 20°C (water = 1): 11.34
FREEZING/MELTING POINT: 327.4°C (621.36°F)
SOLUBILITY IN WATER: Insoluble.
pH: Not applicable.
VAPOR PRESSURE, mm Hg @ 980°C: 1
BOILING POINT: 1740°C (3164°F)
ODOR THRESHOLD: Not applicable.
VAPOR DENSITY (air = 1): 7.14
COEFFICIENT OF OIL/WATER DISTRIBUTION (PARTITION COEFFICIENT): Not applicable.

The following information is for Tin, a possible main component:

RELATIVE VAPOR DENSITY (air = 1): Not applicable.
EVAPORATION RATE (nBuAc = 1): Not applicable.
SPECIFIC GRAVITY @ 20°C (water = 1): 7.28
FREEZING/MELTING POINT: 232°C (4506°F)
SOLUBILITY IN WATER: Insoluble.
pH: Not applicable.
VAPOR PRESSURE, mm Hg @ 1492°C: 0
BOILING POINT: 2270°C (4118°F)
ODOR THRESHOLD: Not applicable.
VAPOR DENSITY (air = 1): Not applicable.
COEFFICIENT OF OIL/WATER DISTRIBUTION (PARTITION COEFFICIENT): Not applicable.

The following information is for the products:

APPEARANCE AND COLOR: These odorless products consist of tin/lead alloy with a metallic lust and may have a flux core.

10. STABILITY and REACTIVITY

STABILITY: Normally stable. These products can oxidize rapidly to form an insoluble layer of basic lead carbonate.

DECOMPOSITION PRODUCTS: Lead oxide, tin oxides, hydrogen chloride, zinc oxides, and ammonium compounds.

NOTE: The composition and quality of soldering fumes and gases are dependent upon the metal being soldered, the process, the procedure, and the alloys used. Other conditions that could also influence the composition and quantity of fumes and gases to which workers may be exposed include the following: any coatings on metal being welded (e.g. paint, plating, or galvanizing), the number of work stations and the volume of the work area, the quality of ventilation, the position of the work stations with respect to the fume plume, and the presence of other contaminates in the atmosphere. When the alloy is consumed, the fume and gas decomposition products generated are different in percent and form from the ingredients listed in Section 2 (Composition and Information on Ingredients). Fume and gas decomposition products, and not the ingredients in the solders, are important. Concentration of the given fume or gas component may decrease or increase by many times the original concentration. New compounds may form. Decomposition products of normal operations include not only those originating from volatilization, reaction, or oxidation of the product's components but also those from base metals and any coating (as noted previously). The best method to determine the actual composition of generated fumes and gases is to take an air sample from the breathing zone. For additional information, refer to the American Welding Society Publication, "Fumes and Gases in the Welding Environment".

MATERIALS WITH THESE PRODUCTS ARE INCOMPATIBLE: These products will be attacked or can react with strong acids, strong bases, hydrogen peroxide (52% or greater- in presence of manganese dioxide), sodium azide, ammonium nitrate, sodium acetylides, sodium carbide, zirconium, or chlorine trifluoride. The flux or rosin core of these products are incompatible with potassium, strong acids, alkalis, interhalogens, strong oxidizers, ammonium nitrate, hydrogen cyanide, potassium chlorate and lead salts (not lead metal) and silver salts.

HAZARDOUS POLYMERIZATION: Will not occur.

CONDITIONS TO AVOID: Avoid uncontrolled exposure to extreme temperatures and incompatible materials.

11. TOXICOLOGICAL INFORMATION

TOXICITY DATA: Presented below are human toxicological data available for the components of these products present in concentration greater than 1%. Other data for animals are available for the components of these products, but are not presented in this Material Safety Data Sheet.

LEAD:

Cytogenetic Analysis-Human-Unreported 50 µg/m

TCLo (Inhalation-Human) 10 µg/m^3: Gastrointestinal tract effects: LIV

TDLo (Oral-Woman) 450 mg/kg/6 years: Peripheral nervous system effects: Central nervous system effects

ZINC CHLORIDE:

TCLo (Inhalation-Man) 4800 mg/m^3/30 minutes: Pulmonary system effects

TCLo (Inhalation-Human) 4800 mg/m^3/3 hours

LCLo (inhalation, human) = 300 µg/m^3/ 10 years/ intermittent; systemic effects

ZINC CHLORIDE (continued):

TDLo (Oral-Child) 169 mg/kg: Lungs, Thorax, or Respiration: dyspnea; Blood: changes in serum composition (e.g. TP, bilirubin, cholesterol); Skin and Appendages: dermatitis, other (after systemic exposure)

SUSPECTED CANCER AGENT: The components of these products are listed as follows:

LEAD: ACGIH TLV-A3 (Confirmed Animal Carcinogen), EPA-B2 (Probable Human Carcinogen - Sufficient Evidence from Animal Studies; inadequate evidence or no data from epidemiologic studies); IARC-2B (Possibly Carcinogenic to Humans)

ZINC CHLORIDE: EPA-D [dusts & mists] (Not Classifiable as to Human Carcinogenicity)

The other components of these products are not found on the following lists: FEDERAL OSHA Z LIST, NTP, IARC, and CAL/OSHA and therefore are not considered to be, nor suspected to be, cancer-causing agents by these agencies.

IRRITANCY OF PRODUCT: Dusts or fumes of these products may be irritating to contaminated skin and eyes. Fumes may be irritating to the respiratory system.

SENSITIZATION TO THE PRODUCT: There is some evidence that inhalation of fumes from the Ammonium Chloride component of some of these products may cause respiratory sensitization in susceptible individuals. Symptoms may include difficulty breathing, persistent coughing and wheezing. Contact with the rosin core can result in allergic reaction and skin sensitization in susceptible individuals.

REPRODUCTIVE TOXICITY INFORMATION: Listed below is information concerning the effects of these products and their components on the human reproductive system.

Mutagenicity: These products are not reported to produce mutagenic effects in humans. Cytogenic analysis studies of human cells (cell type and duration of exposure unreported) have produced positive results at a level of 50 µg/mL. In *vitro* assays of human lymphocytes indicate that the Zinc Chloride may cause chromosomal aberrations. In animal studies, positive mutagenic results (chromosome aberrations) have been reported in rats, mice and monkeys exposed orally to the Lead component of these products. Positive results were obtained in chromosomal aberrations tests involving the Ammonium Chloride component of these products using cultured Chinese hamster fibroblast cells, with no metabolic agitation.

Embryotoxicity These products are not reported to produce embryotoxic effects in humans. There is evidence that high Lead levels in human mother's blood can significantly increase the risk of spontaneous abortions. The Lead, and Zinc Chloride components of these products have produced embryotoxic effects in animal studies.

Teratogenicity: These products are not reported to cause teratogenic effects in humans. Lead has an adverse effect on human fetuses, particularly in the later stages of development. Distribution of lead in fetal tissues was examined in a case in which a woman was exposed during pregnancy. The female worker was exposed to lead dust for 8 hours daily when conception occurred. Measurements of Lead content were started after the end of the exposure and continued for 6 months until normal values were obtained. Because of half-life of nearly 20 days for lead elimination from blood, the estimated body burden at the end of exposure was about 1200 ppb. The fetal tissue samples contained between 0.4 (brain) and 7.9 (liver) µg Pb/grams dry weight. The fetal lead was stored mainly in bone, blood, and liver. The Lead component of this product has produced teratogenic effects in animal studies.

Reproductive Toxicity: These products are not reported to cause reproductive effects in humans; however, the Lead component of this product has produced embryotoxic effects in humans. There is convincing evidence that Lead is transferred to neonates via maternal milk. It appears that maternal milk might be a source of Lead for the neonates, particularly when metal levels are elevated in the mother. Chronic exposure to Lead in human males has been found to produce infertility, germinal epithelium damage, oligospermia and testicular degeneration, decreased sperm motility, and prostatic hyperplasia. The Lead component of this product has produced reproductive effects in animal studies. Injections of the Zinc Chloride component of these products has produced testicular tumors in animal tests.

A mutagen is a chemical, which causes permanent changes to genetic material (DNA) such that the changes will propagate through generational lines. An embryotoxin is a chemical, which causes damage to a developing embryo (i.e., within the first eight weeks of pregnancy in humans), but the damage does not propagate across generational lines. A teratogen is a chemical, which causes damage to a developing fetus, but the damage does not propagate across generational lines. A reproductive toxin is any substance, which interferes in any way with the reproductive process.

11. TOXICOLOGICAL INFORMATION (Continued)

BIOLOGICAL EXPOSURE INDICES: The following BEIs are applicable to the Lead component of these products.

CHEMICAL DETERMINANT	SAMPLING TIME	BEI
LEAD • Lead in blood Note: Women of child-bearing potential, whose blood Pb exceeds10μg/dl, are at risk of delivering a child with a blood Pb over the current Centers for Disease control guideline of 10μg/dl. If the blood Pb of such children remains elevated, they may be at increased risk of cognitive deficits. The blood Pb of these children should be closely monitored and appropriate steps should be taken to minimize the child's exposure to environmental Lead.	• Not Critical	• 30 μg/100 mL

12. ECOLOGICAL INFORMATION

ALL WORK PRACTICES MUST BE AIMED AT ELIMINATING ENVIRONMENTAL CONTAMINATION.

ENVIRONMENTAL STABILITY: Components of these products will react with water and air to form a variety of stable metal oxides.

EFFECT OF MATERIAL ON PLANTS or ANIMALS: Due to the Lead component, adverse effect may occur to animals which come into contact with these products. No data is available on the components of these products and plants

EFFECT OF CHEMICAL ON AQUATIC LIFE: Due to the Lead component of these products, a release of product to an aquatic environment may have a significant adverse effect.

13. DISPOSAL CONSIDERATIONS

PREPARING WASTES FOR DISPOSAL: Waste disposal must be in accordance with appropriate Federal, State, and local regulations. These products, if unaltered by use, may be disposed of by treatment at a permitted facility or as advised by your local hazardous waste regulatory authority.

EPA WASTE NUMBER: Wastes of these products should be tested per the Toxicity Characteristic Leaching Procedures requirements of RCRA to determine if such wastes meet the following characteristics: D008 (Lead).

14. TRANSPORTATION INFORMATION

THESE PRODUCTS ARE NOT HAZARDOUS (Per 49 CFR 172.101) BY THE U.S. DEPARTMENT OF TRANSPORTATION.

PROPER SHIPPING NAME: Not applicable.
HAZARD CLASS NUMBER and DESCRIPTION: Not applicable.
UN IDENTIFICATION NUMBER: Not applicable.
PACKING GROUP: Not applicable.
DOT LABEL(S) REQUIRED: Not applicable.
NORTH AMERICAN EMERGENCY RESPONSE GUIDEBOOK NUMBER, 2000: Not applicable.
MARINE POLLUTANT: No component of these products is designated as a marine pollutant by the Department of Transportation (49 CFR 172.101, Appendix B).

TRANSPORT CANADA TRANSPORTATION OF DANGEROUS GOODS REGULATIONS: These products are not considered as dangerous goods, per regulations of Transport Canada.

15. REGULATORY INFORMATION

ADDITIONAL U.S. REGULATIONS:

U.S. SARA REPORTING REQUIREMENTS: The components of these products are subject to the reporting requirements of Sections 302, 304 and 313 of Title III of the Superfund Amendments and Reauthorization Act, as follows:

CHEMICAL NAME	SARA 302 (40 CFR 355, Appendix A)	SARA 304 (40 CFR Table 302.4)	SARA 313 (40 CFR 372.65)
Ammonium Chloride	NO	YES	NO
Lead	NO	YES	YES
Zinc Chloride	NO	YES	NO

U.S. SARA THRESHOLD PLANNING QUANTITY: There are no specific Threshold Planning Quantities for any component of these products. The default Federal MSDS submission and inventory requirement filing threshold of 10,000 lb (4,540 kg) may apply, per 40 CFR 370.20.

15. REGULATORY INFORMATION (Continued)

ADDITIONAL U.S. REGULATIONS (continued):

U.S. TSCA INVENTORY STATUS: The components of these products are listed on the TSCA Inventory.

U.S. CERCLA REPORTABLE QUANTITY (RQ): Ammonium Chloride = 5000 lb (2270 kg); Lead = 10 lb (4.540 kg); Zinc Chloride = 1000 lb (454 kg)

OTHER U.S. FEDERAL REGULATIONS: Components of these products have requirements under other U.S. Federal regulations, as follows:

AMMONIUM CHLORIDE: EPA: Ammonium Chloride is designated as a hazardous substance under Section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. These regulations apply to discharges of this substance.

LEAD: EPA: Lead is listed as a hazardous air pollutant (HAP) generally known or suspected to cause serious health problems. The Clean Air Act, as amended in 1990, directs EPA to set standards requiring major sources to sharply reduce routine emissions of toxic pollutants. EPA is required to establish and phase in specific performance based standards for all air emission sources that emit one or more of the listed pollutants. Lead is included on this list. Lead is designated as a toxic pollutant, pursuant to Section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. Lead is designated as a hazardous substance under Section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. These regulations apply to discharges of Lead.

OSHA: Employers are required to follow the exposure limits and other requirements as defined under the Lead Standard, 29 CFR 1910.1025.

ZINC CHLORIDE: EPA: Zinc Chloride is designated as a hazardous substance under Section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. These regulations apply to discharges of this substance. Zinc Chloride is a designated as a toxic pollutant designated pursuant to Section 307(a)(1) of the Clean Water Act and is subject to effluent limitations.

U.S. STATE REGULATORY INFORMATION: The components of these products are covered under specific State regulations, as denoted below:

Alaska-Designated Toxic and Hazardous Substances: Ammonium Chloride, Lead, and Zinc Chloride.
California-Permissible Exposure Limits for Chemical Contaminants: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
Florida-Substance List: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
Illinois-Toxic Substance List: Ammonium Chloride, Lead, and Zinc Chloride.
Kansas-Section 302/313 List: Lead.
Massachusetts-Substance List: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
Michigan - Critical Materials Register: Lead.
Minnesota-List of Hazardous Substances: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
Missouri-Employer Information/Toxic Substance List: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
New Jersey-Right to Know Hazardous Substance List: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
North Dakota-List of Hazardous Chemicals, Reportable Quantities: Ammonium Chloride, Lead, and Zinc Chloride.
Pennsylvania-Hazardous Substance List: Ammonium Chloride, Lead, Tin, and Zinc Chloride.
Rhode Island-Hazardous Substance List: Ammonium Chloride, Tin, and Zinc Chloride.
Texas-Hazardous Substance List: Lead, Tin, and Zinc Chloride.
West Virginia-Hazardous Substance List: , Tin, Zinc Chloride.
Wisconsin-Toxic and Hazardous Substances: Lead, Tin, and Zinc Chloride.

CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT (PROPOSITION 65): The Lead component of these products is on the California Proposition 65 Lists. **WARNING: These products contain a chemical that is known to the State of California to cause cancer and reproductive harm. In addition, these products, when used for soldering may produce fumes or gases containing chemicals, known to the State of California to cause cancer, and/or birth defects (or other reproductive harm.)**

LABELING (Precautionary Statements): DANGER OF CUMULATIVE EFFECTS IF DUSTS OR FUMES ARE INHALED! POSSIBLE CANCER AND REPRODUCTIVE HAZARD. CONTAINS POTENTIAL TERATOGEN AND/OR MUTAGEN.

WARNING:

PROTECT yourself and others. Read and understand this information.
FUMES AND GASES can be hazardous to your health.
ARC RAYS can injure your eyes and burn skin.
ELECTRIC SHOCK can kill.

- Before use, read and understand the manufacturer's instructions. Material Safety Data Sheets (MSDSs), and your employer's safety policies.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- See American National Standard Z49.1 *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126. OSHA Safety and Health Standards, *29 CFR 1910*, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

15. REGULATORY INFORMATION (Continued)

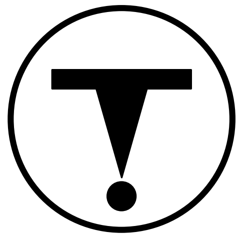
ADDITIONAL CANADIAN REGULATIONS:

CANADIAN DSL/NDSL INVENTORY STATUS: The components of these products are on the DSL Inventory.

OTHER CANADIAN REGULATIONS: Not applicable.

CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) PRIORITIES SUBSTANCES LISTS: No component of these products are on the CEPA Priority Substances Lists (PSL).

CANADIAN WHMIS SYMBOLS: **D2A:** Poisonous and Infections Material - Other Effects: Very Toxic (chronic toxicity, embryotoxicity, teratogenicity, reproductive toxicity, carcinogenicity); **D2B:** - Poisonous and Infections Material - Other Effects: Toxic (mutagenicity).



16. OTHER INFORMATION

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This Material Safety Data Sheet is offered pursuant to OSHA's Hazard Communication Standard (29 CFR 1910.1200). Other government regulations must be reviewed for applicability to these products. The information contained herein relates only to the specific products. If the products are combined with other materials, all component properties must be considered. To the best of the Harris Products Group knowledge, the information and recommendations contained in this publication are reliable and accurate as of the date of issue. However, accuracy, suitability, or completeness are not guaranteed, and no warranty, guarantee, or representation, expressed or implied, is made by Harris Products Group., Inc. assumes no responsibility in connection therewith; nor can it be assumed that all acceptable safety measures may not be required under particular or exceptional conditions or circumstances. Data may be changed from time to time. Be sure to consult the latest edition.

DEFINITIONS OF TERMS

A large number of abbreviations and acronyms appear on a MSDS. Some of these, which are commonly used, include the following:

CAS #: This is the Chemical Abstract Service Number, which uniquely identifies each constituent.

EXPOSURE LIMITS IN AIR:

ACGIH - American Conference of Governmental Industrial Hygienists, a professional association which establishes exposure limits. **TLV -** Threshold Limit Value - an airborne concentration of a substance, which represents conditions under which it is generally believed that nearly all workers, may be repeatedly exposed without adverse effect. The duration must be considered, including the 8-hour Time Weighted Average **(TWA)**, the 15-minute Short Term Exposure Limit, and the instantaneous Ceiling Level **(C)**. Skin absorption effects must also be considered.

OSHA - U.S. Occupational Safety and Health Administration.

PEL - Permissible Exposure Limit - This exposure value means exactly the same as a TLV, except that it is enforceable by OSHA. The OSHA Permissible Exposure Limits are based in the 1989 PELs and the June, 1993 Air Contaminants Rule (Federal Register: 58: 35338-35351 and 58: 40191). Both the current PELs and the vacated PELs are indicated. The phrase, "Vacated 1989 PEL," is placed next to the PEL, which was vacated by Court Order. **IDLH -** Immediately Dangerous to Life and Health **-** This level represents a concentration from which one can escape within 30-minutes without suffering escape-preventing or permanent injury. **The DFG - MAK** is the Republic of Germany's Maximum Exposure Level, similar to the U.S. PEL. **NIOSH** is the National Institute of Occupational Safety and Health, which is the research arm of the U.S. Occupational Safety and Health Administration (**OSHA**). NIOSH issues exposure guidelines called Recommended Exposure Levels (**REL**s). When no exposure guidelines are established, an entry of **NE** is made for reference.

HAZARD RATINGS:

HAZARDOUS MATERIALS IDENTIFICATION SYSTEM: Health Hazard: **0** (minimal acute or chronic exposure hazard); **1** (slight acute or chronic exposure hazard); **2** (moderate acute or significant chronic exposure hazard); **3** (severe acute exposure hazard; onetime overexposure can result in permanent injury and may be fatal); **4** (extreme acute exposure hazard; onetime overexposure can be fatal). Flammability Hazard: **0** (minimal hazard); **1** (materials that require substantial pre-heating before burning); **2** (combustible liquid or solids; liquids with a flash point of 38-93°C [100-200°F]); **3** (Class IB and IC flammable liquids with flash points below 38°C [100°F]); **4** (Class IA flammable liquids with flash points below 23°C [73°F] and boiling points below 38°C [100°F]. Reactivity Hazard: **0** (normally stable); 1 (material that can become unstable at elevated temperatures or which can react slightly with water); **2** (materials that are unstable but do not detonate or which can react violently with water); **3** (materials that can detonate when initiated or which can react explosively with water); **4** (materials that can detonate at normal temperatures or pressures).

NATIONAL FIRE PROTECTION ASSOCIATION: Health Hazard: **0** (material that on exposure under fire conditions would offer no hazard beyond that of ordinary combustible materials); **1** (materials that on exposure under fire conditions could cause irritation or minor residual injury); **2** (materials that on intense or continued exposure under fire conditions could cause temporary incapacitation or possible residual injury); **3** (materials that can on short exposure could cause serious temporary or residual injury); **4** (materials that under very short exposure causes death or major residual injury). Flammability Hazard and Reactivity Hazard: Refer to definitions for "Hazardous Materials Identification System".

FLAMMABILITY LIMITS IN AIR:

Much of the information related to fire and explosion is derived from the National Fire Protection Association (**NFPA**). Flash Point - Minimum temperature at which a liquid gives off sufficient vapors to form an ignitable mixture with air. Autoignition Temperature: The minimum temperature required to initiate combustion in air with no other source of ignition. LEL - the lowest percent of vapor in air, by volume, that will explode or ignite in the presence of an ignition source. UEL - the highest percent of vapor in air, by volume, that will explode or ignite in the presence of an ignition source.

TOXICOLOGICAL INFORMATION:

Human and Animal Toxicology: Possible health hazards as derived from human data, animal studies, or from the results of studies with similar compounds is presented. Definitions of some terms used in this section are: **LD_{50}** - Lethal Dose (solids & liquids) which kills 50% of the exposed animals; **LC_{50}** - Lethal Concentration (gases) which kills 50% of the exposed animals; **ppm** concentration expressed in parts of material per million parts of air or water; **mg/m^3** concentration expressed in weight of substance per volume of air; **mg/kg** quantity of material, by weight, administered to a test subject, based on their body weight in kg. Other measures of toxicity include **TDLo**, the lowest dose to cause a symptom and **TCLo** the lowest concentration to cause a symptom; **TDo**, **LDLo**, and **LDo**, or **TC**, **TCo**, **LCLo**, and **LCo**, the lowest dose (or concentration) to cause lethal or toxic effects. **Cancer Information:** The sources are: **IARC** - the International Agency for Research on Cancer; **NTP** - the National Toxicology Program, **RTECS** - the Registry of Toxic Effects of Chemical Substances, **OSHA** and **CAL/OSHA**. IARC and NTP rate chemicals on a scale of decreasing potential to cause human cancer with rankings from 1 to 4. Subrankings (2A, 2B, etc.) are also used. **Other Information: BEI** - ACGIH Biological Exposure Indices, represent the levels of determinants which are most likely to be observed in specimens collected from a healthy worker who has been exposed to chemicals to the same extent as a worker with inhalation exposure to the TLV. **Ecological Information:** EC is the effect concentration in water. **BCF** = Bioconcentration Factor, which is used to determine if a substance will concentrate in lifeforms which consume contaminated plant or animal matter. Coefficient of Oil/Water Distribution is represented by **$\log K_{ow}$** or **$\log K_{oc}$** and is used to assess a substance's behavior in the environment.

REGULATORY INFORMATION:

This section explains the impact of various laws and regulations on the material. **U.S.: EPA** is the U.S. Environmental Protection Agency. **DOT** is the U.S. Department of Transportation. **SARA** is the Superfund Amendments and Reauthorization Act. **TSCA** is the U.S. Toxic Substance Control Act. **CERCLA (or Superfund)** refers to the Comprehensive Environmental Response, Compensation, and Liability Act. Labeling is per the American National Standards Institute (**ANSI Z129.1**). **CANADA: CEPA** is the Canadian Environmental Protection Act. **WHMIS** is the Canadian Workplace Hazardous Materials Information System. **TC** is Transport Canada. **DSL/NDSL** are the Canadian Domestic/Non-Domestic Substances Lists. **The CPR is the Canadian Product Regulations.** This section also includes information on the precautionary warnings, which appear, on the materials package label.