### 2014-2015 NASA Student Launch Proposal

**Institution:** United States Naval Academy

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**Project Title:** REPTAR (Rocket Equipped Payload Transportation and Autonomous Release) System

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**Competition:** Centennial Challenges Maxi-MAV
Centennial Challenges Maxi-MAV
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United States Naval Academy
Annapolis, Maryland
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<th>Description</th>
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<tbody>
<tr>
<td>AGL</td>
<td>Above Ground Level</td>
</tr>
<tr>
<td>AGSE</td>
<td>Autonomous Ground Support Equipment</td>
</tr>
<tr>
<td>AIAA</td>
<td>American Institute of Aeronautics and Astronautics</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer Numerical Control</td>
</tr>
<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
</tr>
<tr>
<td>E-glass</td>
<td>Fiberglass</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>GET IT and GO</td>
<td>Girls Exploring Technology through Innovative Topics, Girls Only</td>
</tr>
<tr>
<td>GSE</td>
<td>Ground Support Equipment</td>
</tr>
<tr>
<td>GNC</td>
<td>Guidance, Navigation, Control</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>MATLAB</td>
<td>Matrix Laboratory</td>
</tr>
<tr>
<td>MDRA</td>
<td>Maryland Delaware Rocketry Association</td>
</tr>
<tr>
<td>MESA</td>
<td>Maryland Mathematics Engineering Science Achievement</td>
</tr>
<tr>
<td>MSL</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td>NAR</td>
<td>National Association of Rocketry</td>
</tr>
<tr>
<td>NAVSEA</td>
<td>Naval Sea Systems Command</td>
</tr>
<tr>
<td>PEO IWS</td>
<td>Program Executive Officer-Integrated Warfare Systems</td>
</tr>
<tr>
<td>REPTAR</td>
<td>Rocket Equipped Payload Transportation and Autonomous Release</td>
</tr>
<tr>
<td>RSO</td>
<td>Range Safety Officer</td>
</tr>
<tr>
<td>S-glass</td>
<td>Stiff Fiberglass</td>
</tr>
<tr>
<td>SRQA</td>
<td>Safety, Reliability, and Quality Assurance</td>
</tr>
<tr>
<td>STEM</td>
<td>Science, Technology, Engineering, and Mathematics</td>
</tr>
<tr>
<td>TRA</td>
<td>Tripoli Rocketry Association</td>
</tr>
<tr>
<td>VTC</td>
<td>Video-teleconferencing and communication</td>
</tr>
<tr>
<td>USLI</td>
<td>University Student Launch Initiative</td>
</tr>
<tr>
<td>USNA</td>
<td>United States Naval Academy</td>
</tr>
<tr>
<td>USNA MSTEM</td>
<td>United States Naval Academy Midshipmen Science, Technology, Engineering, and Mathematics</td>
</tr>
</tbody>
</table>
1 General Information

1.1 Team Information

Institution: United States Naval Academy

Mailing Address: Aerospace Engineering Department
United States Naval Academy
ATTN: NASA Student Launch Capstone
Mail Stop 11B
590 Holloway Road
Annapolis, MD 21402-5042

Project Title: REPTAR (Rocket Equipped Payload Transportation and Autonomous Release) System

Competition: Centennial Challenges Maxi-MAV

1.1.1 Navy Rockets Charter

The vision of Navy Rockets is to:
- Supplement academic material in both the aerospace and engineering fields
- Expand each midshipmen’s knowledge and experience to become more proficient and well-rounded members of the engineering community
- Provide leadership opportunities in a technical environment to better serve midshipmen as future leaders in today’s Navy

As a team we strive to:
- Seek out projects that can benefit the aerospace community and reinforce our own educational objectives
- Deliver quality research and products on time, based in sound engineering and business practices, and operate to a level above client expectation

As representatives of the armed services we will:
- Conduct ourselves in a professional manner and bring credit to both the United States Naval Academy and the United States Naval service.

We are committed to excellence in practice, delivery, and conduct.
1.2 Faculty Sponsors

Capt. Kristen Castonguay, USAF
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Phone: (410) 293-6403

CAPT Ken Reightler, USN (Ret.)
Distinguished Professor, Robert A. Heinlein Chair
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1.3 NAR/TRA Mentor

Robert Utley (NAR Level 3)
President, Maryland Delaware Rocketry Association
robertu16@verizon.net

1.4 Student Contact Information

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MIDN 1/C Cole Palmer, USN; (TRA Level 1)
Safety Officer
m155376@usna.edu
Phone: (330) 219-9270

1.5 Team Organization

1.5.1 Team Members

Team Size: 8 Midshipmen

- Hayes (Astronautical Engineering, ’15)
  - Team Manager
  - GNC (Guidance, Navigation, Control) / Recovery System Chief
  - Systems Engineering/Integration Chief
• Alex (Astronautical Engineering, ’15)
  o Administrative Officer
  o Chief Engineer
  o Drafting Chief
  o Avionics Chief

• Cole (Aeronautical Engineering, ’15)
  o Proposal Manager
  o Safety Administration Officer
  o SRQA (Safety Reliability & Quality Assurance) Chief
  o Materials/Structures Chief

• Joe (Astronautical Engineering, ’15)
  o Technology Officer
  o Propulsion Chief

• Richie (Astronautical Engineering, ’15)
  o Financial Officer
  o GSE (Ground Support Equipment) Chief

• Thor (Astronautical Engineering, ’15)
  o Acquisitions Officer
  o Payload Design Chief

• Troy (Aeronautical Engineering, ’15)
  o Public Affairs/ Outreach Officer
  o Aerodynamics Chief

• Andy (Astronautical Engineering, ’16)
  o Project Assistant
1.5.2 Team Organization

Navy Rockets is split between administrative positions, shown in Figure 1, and engineering jobs, shown in Figure 2. Each member of the team has their own area of concentration; however each position overlaps to allow input from the entire group.

![Figure 1. Administrative Organization](image1)

![Figure 2. Engineering Organization](image2)

1.5.3 Team Schedule

In order for Navy Rockets to stay on track, a schedule has been created. This schedule, found in Appendix A, shows the plan for the team from the present time until the final launch.
2 Facilities and Equipment

2.1 Test and Design Facilities

Navy Rockets is headquartered in Room 31C of Rickover Hall on the United States Naval Academy in Annapolis, Maryland. This room is approximately 800 square feet and serves as the team’s primary meeting space. The room contains a design studio, work area, and storage space. The team has 24-hour access to this space.

For aerodynamic testing, Navy Rockets has access to Aerospace Engineering laboratory space within Rickover Hall. This space is accessible during standard working hours, typically 0730 to 1600 Monday through Friday. Within this space, the team has access to the multiple wind tunnels for aerodynamics testing.

2.1.1 Aerolab Open Circuit Wind Tunnel

This Eiffel Wind Tunnel has a closed test section of 44” wide by 31” high by 10’ long. It is powered by a 250 horsepower motor and reaches a maximum speed of approximately 300 feet per second. This wind tunnel is equipped with a pyramidal (virtual center) force balance and a sting force balance. Each balance has the capability to measure lift, drag, side force, pitching moment, rolling moment, and yawing moment. This wind tunnel and its test section with force balances are shown in Figures 3 and 4, respectively, below.

Figure 3. Open Circuit Wind Tunnel
2.1.2 Aerolab Closed Circuit Wind Tunnel

This closed circuit, single return wind tunnel has a closed test section of 52” wide by 38” high by 8’ long. This wind tunnel is powered by a 250 horsepower motor and reaches a maximum speed of approximately 220 feet per second. This wind tunnel is equipped with an external Schenck platform force balance, with the capability to measure lift, drag, side force, pitching moment, rolling moment, and yawing moment. This wind tunnel is pictured in Figure 5 below.
2.1.3 Motor Test Cell

In addition to the aforementioned wind tunnels, the Aerospace Engineering laboratory space also contains a rocket motor test cell. This test cell provides Navy Rockets with the capability to measure thrust curves for rocket motors and will aid in testing and development. The test cell is pictured below in Figure 6.

Figure 6. Rocket Motor Test Cell

2.2 Fabrication Facilities

For manufacturing the components necessary for the project, Navy Rockets has access to the Machine Shop in Rickover Hall. Senior design students have access to this workspace from 0730 to 1500 on weekdays, with after-hours access by request when working in pairs. Each Midshipman must be checked out on each machine by the Machine Shop staff before operating the equipment. This workspace has the following machines available for metalworking: Haas VF3 and VF11 CNC mills, Haas TL3 CNC lathes, a Haas CNC turning center, ONA wire Electrical Discharge Machine, manual lathes, manual mills, metal sheet rollers, and a water jet cutter. In addition to these machines, a large selection of band saws, circular saws, and hand tools is available for use for both metalworking and woodworking. An overview of the capabilities of the Machine Shop can be seen in Figures 7 and 8.
This same shop also contains a Composite Materials Lab, shown in Figure 9, which is accessible during the same times as the rest of the Machine Shop. This portion of the shop has the ability to work with multiple types of composite matrices—including polyester, epoxy, and vinylester—and composite reinforcements—including E-glass, S-glass, Kevlar, and carbon reinforcements. Methods used for fabrication include the use of pre-impregnated composites, custom molding, and vacuum bagging.
2.3 Computer Equipment, Web Presence, and Conferencing Capabilities

The Navy Rockets team has access to over 100 computer workstations on the USNA campus to aid in the design, modeling, and analysis of the team’s project design. These computers, in combination with the team’s personal computers, provide 24-hour access to high-speed internet, software packages, and printing. All of these computer workstations provide access to a wide range of industry-standard software products, including but not limited to:

- AutoCAD
- OpenRocket
- MathCAD
- Mathematica
- MATLAB and Simulink products
- Microsoft Office
- SolidWorks
- Systems Tool Kit

These software products and computer resources will provide Navy Rockets with full capabilities for design, modeling, and analysis of the team’s design. An example of the computer resources is pictured in Figure 10.
To facilitate video-teleconferencing (VTC) and communication throughout the USLI competition, Navy Rockets has access to a VTC Center, which includes audio-visual equipment such as an LCD projector, document camera, and computer terminal. This range of audio-visual equipment will provide full VTC capabilities to the team in a professional environment. In addition, the VTC Center has the ability to provide a multi-site VTC bridge to other locations. The team will have access to these facilities by request.

More information can be found here regarding the Naval Academy’s facilities: http://www.usna.edu/MSC/Video%20Teleconferencing/index.php

In accordance with the USLI contest rules, Navy Rockets will establish a website to host any contest-related information. This website will be hosted on the USNA network and is accessible at www.usna.edu/capstone/navyrockets. Navy Rockets will comply with the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology Accessibility Standards (36 CFR Part 1194), specifically 1194.21 Software applications and operation systems and 1194.22 Web-based intranet and Internet information and applications.

2.4 Multimedia Support Center

The Multimedia Support Center Graphics Lab, in Nimitz Library, has a full range of computers, software, printers, and varied other resources to provide graphic design support for Navy Rockets. The Graphics Lab is a self-help facility with graphic artists on hand to provide support and instruction. The team has access to this facility from 0730 to 2300 on Monday through Thursday and until 1700 on Friday. The lab is fully equipped to handle media digitizing, video-
editing, computer graphics, large format printing, vinyl graphics, poster making, laminating, and binding.

2.5 Launch Areas

Sub-scale and full-scale test launches will be conducted at launch areas sponsored by the Maryland Delaware Rocketry Association (MDRA). MDRA utilizes two primary launch sites: Higgs Farm in Price, Maryland and Central Sod Farm in Centreville, Maryland. These two launch sites are overviewed below in Figures 11 and 12, respectively. The launch pads are denoted with a blue circle and the designated launch recovery area is outlined in white.

![Figure 11. Higgs Farm Launch Site and Recovery Area](image1)

For each of these launch sites, MDRA has obtained Federal Aviation Administration (FAA) waivers for rocket launches up to 17,000 feet MSL (16,900 feet AGL). MDRA sponsored launches usually occur one weekend (Friday through Sunday) per month, providing Navy
Rockets ample opportunity for sub-scale and full-scale launch testing. However, additional launches may be possible with MDRA’s FAA flight waivers.
3 Safety

3.1 Safety Plan

Navy Rockets realizes that high power rocketry is dangerous and careful steps must be taken to mitigate the risk of any injuries that might occur. Safety plans have been developed to ensure the team, the project, and the equipment are not harmed in any way. Each member of Navy Rockets is committed to keeping a safe environment in attempt to prevent any damage or injury that may occur during the competition. The commitment can be found in Appendix B. With the competition requiring multiple events to occur during the launch the risk of injury or malfunction increases for the team and equipment. However, if safe practices are being demonstrated many of these problems will never present themselves with building, testing, or launching the rocket.

3.2 Risk Mitigation

Although the team focuses on safety, some of the activities can still be dangerous to the team or equipment. Some of the major hazards that might occur during this project can be found in Table 1 and a larger list can be found in Appendix C. The graphics for the safety scaling can be found in this appendix as well.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Risk number</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine usage</td>
<td>2E</td>
<td>Everyone will be qualified to use the equipment and will work with a partner</td>
</tr>
<tr>
<td>Chemical spills</td>
<td>3D</td>
<td>PPE will be used when working with chemicals</td>
</tr>
<tr>
<td>Unexpected explosion of motor or black powder</td>
<td>1E</td>
<td>Only certified team members will handle explosives and they will be stored properly</td>
</tr>
<tr>
<td>Misfire of the motor or black powder while testing</td>
<td>1E</td>
<td>Once the area is safe the materials will be disarmed</td>
</tr>
<tr>
<td>Improper flight of the rocket</td>
<td>2D</td>
<td>Obey the RSO and all NAR distances rules</td>
</tr>
</tbody>
</table>

The fabrication of the rocket will occur in the Rickover Hall Machine Shop at the United States Naval Academy. The shop has a dedicated staff of experts in the fields of metalwork, composite materials, and woodworking. This staff will help teach the members of Navy Rockets how to safely operate equipment under their supervision. The Machine Shop will also teach building techniques that the team will be able to use during the production of the rocket. All after hours work in the shop requires notification at least one day in advance. The Machine Shop requires that all team members have a partner when working after hours. Also, the team is only allowed to use hand tools when the shop staff is not observing the project.

During the competition, the team will be required to complete testing on the rocket and AGSE system in order to confirm the desired results are accomplished. Each test, building modification,
and rocket launch will be properly documented. Each event will also have a safety meeting before it starts so that any new hazard can be mitigated.

### 3.3 NAR/TRA Procedures

The National Association of Rocketry (NAR) and the Tripoli Rocketry Association (TRA) have developed their own safety codes. These codes can be Appendix D. The codes give an outline of procedures that have been established to keep everyone safe during launches. All members will adhere to the rules and regulations that NAR and TRA have established for high power rocketry. Also, on launch day the Range Safety Officer (RSO) will have the final inspection to determine the rocket is safe. All members will comply with any RSO decision.

The handling of hazardous material will only be done by those that are qualified to use that material. The level-one rocket motors will be handled by the team members that are certified during sub-scale testing. The purchase, storage, and transportation of higher level rocket motors will be done by the team’s MDRA mentor. This mentor will be observing at all team launches in order to share his knowledge and to ensure materials will be handled properly.

### 3.4 Safety Brief

In order to guarantee that Navy Rockets will be safe during this competition a briefing has been developed to keep the team aware of possible dangers. Before any building or material handling a safety brief will precede to discuss any precautions that exist. The material hazards and the possible risks and mitigations can be found in Appendices F and C, respectively, and will be referenced when required.

The team has agreed to focus on safety and this brief will be given before the commencement of the project:

1. **Shop Safety**
   a. Wear personal protective equipment while working:
      i. Ear plugs
      ii. Gloves (as appropriate)
      iii. Hard hats
      iv. Safety glasses
   b. Always work with a partner
2. **Accident Avoidance**
   a. Always read and understand warnings about the equipment or material that is being used.
   b. Call a training timeout if an environment becomes unsafe.
3. Launch Day Safety
   a. The RSO has the final word on the safety of the rocket.
   b. All launch instructions must be followed and the team needs to be alert while arming the systems.
   c. All laws and regulations must be followed.
4. Materials
   a. Only qualified personnel will handle dangerous materials.

3.5 Pre-Launch Brief

Before any rocket launch, Navy Rockets will go over the Pre-Launch Brief. This brief will be given by the Safety Officer and will discuss the flight plan and any concerns that arise that day. The Pre-Launch Brief is below:

1. Launch Overview
   a. Motor selection
   b. Goals
   c. Test Reasons and predicted outcomes
   d. Avionics test
2. Weather
   a. Launch concerns
3. Rocket Performance
   a. Weight
   b. Altitude
4. Flight Conduct
   a. Drogue chute deployment
   b. Main chute deployment
   c. Tracking
5. Safety
   a. ORM considerations
   b. Safety concerns
6. Emergencies
   a. General Emergencies
   b. Hazards and Mitigation
7. RSO
   a. Rules
   b. Launch check
3.6 Following the Law

The Navy Rockets team understands the laws that govern high power rockets. This includes the FAA regulation on airspace, the Federal Aviation Regulation 14 CFR: Subchapter F: Part 101: Sub-part C, the Code of Federal Regulation 27 Part 55, and the code for the use of low-explosives: NFPA 1127 Code for High Power Model Rocketry. This information can be found in Appendix E.

All of the flight testing for the project will be done with MDRA at their launch sites. MDRA has a FAA flight waiver for an altitude of 5,000 feet every weekend of the year. This allows Navy Rockets to be able to launch whenever testing needs to be completed on both the sub-scale and full-scale launches. MDRA has a goal for zero injuries to occur during one of their launches, the group has multiple, qualified Range Safety Officers that ensure everyone is adhering to the rules.

3.7 MSDS

Many of the material used during the competition have hazards associated with them. A list of potential material hazards can be found in Appendix F and paper copies will be kept in the design room. All members of the team will be briefed on the material hazards before they are used on any part of the project by the Safety Officer.
4 Technical Design

4.1 Structural Design

Navy Rockets will launch a single stage, 98 inch solid rocket motor propelled rocket, shown in Figure 13. The 18 inch nosecone will be composed of carbon fiber. All fuselage sections of the rocket will be composed of carbon fiber, and will have a diameter of 5 inches and a wall thickness of 0.08 inches. The set of three rocket fins will be composed of carbon fiber, and will be trapezoidal in shape with a thickness of 0.125 inches and an area of 47.5 square inches. The mass of the rocket will be 22.8 pounds, without a solid rocket motor inserted into the rocket. The weight of the motor loaded rocket will be 26.4 pounds, assuming the usage of the Cesaroni K1200 motor, with the center of gravity located at a position of 52.25 inches aft of the tip of the nose cone. The center of pressure of the rocket, assuming the usage of the Cesaroni K1200 motor, is located at a position of 71.50 inches aft of the tip of the nose cone. These numbers have been generated through the use of OpenRocket, a downloadable free software tool for rocket design. The OpenRocket program was recommended to Navy Rockets by our MDRA advisor. The component sizes for each piece of the rocket can be found in Appendix G.

![OpenRocket Design](image)

Figure 13. OpenRocket Design

4.1.1 Material Selection

The materials carbon fiber and fiberglass are common in high power rocketry, in order to determine which material is the better product a house of quality was developed. The house of quality uses the Quality Function Deployment System (QFD) and this can be seen in Table 2.
The QFD system allows the two materials to be tested on important characteristics for the project. Each characteristic has a weighting of importance for the project; a one weighting represents little importance to the project, a three weighting represents medium importance, and a nine weighting means that it is critical to the project. This weighting allows the important factors to outweigh less desired characteristics. If the material agreed with the material factor it was given a positive weighting score. If the material completely disagreed it was given a negative weight score. A score of zero was given when the material met the requirements but did not standout against the other.

<table>
<thead>
<tr>
<th>Material Factors</th>
<th>Weighting Factor</th>
<th>Carbon Fiber</th>
<th>Fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost</td>
<td>3</td>
<td>-3</td>
<td>3</td>
</tr>
<tr>
<td>High availability</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Compact rocket size</td>
<td>9</td>
<td>9</td>
<td>-9</td>
</tr>
<tr>
<td>Low weight</td>
<td>9</td>
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<td>-9</td>
</tr>
<tr>
<td>Easy production</td>
<td>9</td>
<td>-9</td>
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<tr>
<td>High tensile strength</td>
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</tr>
<tr>
<td>High compressive strength</td>
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<td>9</td>
<td>0</td>
</tr>
<tr>
<td>High stiffness</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>High heat resistance</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>High Young's modulus</td>
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<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Large motor selection</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>37</td>
<td>-17</td>
<td></td>
</tr>
</tbody>
</table>

Carbon fiber was selected for its superior material strength, low weight, and relatively high availability. Although the cost of carbon fiber was significantly higher than alternative materials, such as fiberglass and cardboard, the cost difference was not significant enough to push the design out of budget. Due to the low density of carbon fiber, the dimensions of the rocket were able to be greatly reduced, as well as the motor size required to push the rocket to 3,000 feet in altitude.

### 4.1.2 Construction Methods

The rocket will be made from carbon fiber fabric as shown in section 4.1.1. The process of constructing the rocket with carbon fiber will be taught to the team by a composite specialist from the Machine Shop in Rickover Hall. All team members will wear protective gear while
using the epoxy and hardener. The body tube will be set in the inside of a PVC pipe matching the rocket dimensions. A separating agent will be placed on the inside of the pipe in order for the carbon fiber to separate from after curing. The sheets of carbon fiber will then be placed on the inside of the pipe and the epoxy and hardening mixture applied to each layer of material. After the material is set in the pipe, a pressure balloon will be place inside the entire length of pipe. This balloon will inflate and force the carbon fiber to form to the inside of the pipe. This method of construction is similar to the building of lightweight sailing masts. The fins and nose cone will then be created by layering the material, using the same layering method, on pre-cut foam shapes in the dimensions of each part. The rocket body will take approximately two weeks to construct from the carbon fiber.

4.1.3 Wind Tunnel Testing

In an effort to model the static and dynamic stability of the rocket during flight, a scale model of the rocket will be constructed and tested in the closed circuit wind tunnel. This scale model will be 3D printed in order to create pressure ports along the longitudinal axis of the rocket. Additionally, there will be pressure ports radially along the aft section of the rocket near the rocket fins. The scale model will be tested in the Eiffel Wind Tunnel at varying Reynolds numbers. The Reynolds numbers will be characteristic of the boost phase of the actual flight of the full-scale rocket. The Reynolds number will be limited by the maximum free-stream Reynolds number of the wind tunnel, and the overall size (namely the length) of the test section.

The goal of the wind tunnel testing will be to model the pressure distribution along the keel of the rocket, to measure the drag force, and to measure the moment forces on the rocket. When analyzing the overall stability of the rocket, the forces measured by the sting force balance will be taken into account. The tabulated pressures will be analyzed using MATLAB, and any instability found by the force balance will be further analyzed by the tabulated pressure readings. Moreover, the pressure readings will give insight on the locations of maximum shear stress due to skin friction on the rocket body.

Because the full-scale rocket will be made out of carbon fiber, and the scale rocket will be 3D printed, the skin-friction drag coefficient will be different. For this reason, the additive manufacturing material of the scale model will match as closely as possible the standard roughness of the full-scale rocket. Therefore, the significance of the drag calculated by the sting balance can be attributed to profile drag due to the geometry of the rocket, and not the difference in skin-friction drag due to the material of the rocket.

In order to use the Eiffel Wind Tunnel in Rickover Hall at the USNA, a test plan must be submitted to the aerospace engineering department chair. A sample of the test plan is attached in Appendix H. The sample test plan is subject to change based on the suggestion of the department, but it will remain similar in structure and concept. The test plan shows the pertinent information of the testing process, including purpose, philosophy of operations, and the testing procedure.
4.2 Payload Section

The payload section, shown in Figures 14 and 15, will utilize the nosecone structure as an entry point to the payload clamp. Once activated, via the switch, the nosecone will be slid away from the rocket body by a central worm drive, exposing the payload bay. This bay will consist of a bed on which the payload will be placed and a servomotor driven tab that will rotate over the payload to secure it inside the rocket. Once the clamp is locked, a switch will activate the worm drive system in reverse, closing the payload section back as the nosecone slides back onto the rocket body and is sealed with O-rings while the motor locks into place. The nosecone is a protective housing for the sample during the launch procedures and flight. After the nosecone separates and lands, the payload will be able to be retrieved using the same external switch to open the payload assembly again.

![Figure 14. Payload Section- Side View](image1)

![Figure 15. Payload Section- Top View](image2)

4.2.1 Payload Testing

The flight critical payload section requires the use of two separate functions, the process of securing the sample and the retraction and sealing of the nosecone, to work in tandem using both exterior and interior inputs. Therefore to ensure correct interoperability the section will undergo multiple test phases.

The first test phase will test each of the two primary functions mechanically, electronically, autonomously, and finally simulated in flight. The first test in this phase will ensure that the sample clamp and the worm drive system can physically perform their intended functions
independently and with user input. Then each system will be separately tested autonomously using the necessary inputs of the sample being placed in the clamp and the nosecone being fully retracted. Next each system will be tested on a vibration table to ensure that the sample is indeed secure within the payload section and that the nosecone is not subject to any movement during flight.

The second test phase will mate the two functions together and test the entire system in a similar fashion. The first test will test the system using user inputs, then a second test to ensure autonomy and interoperability, and finally a total system vibration test to simulate flight.

### 4.2.2 Payload Challenges

One of the main technical challenges faced in designing the payload section is the attachment of the internal payload section components to the carbon fiber rocket body. The worm drive and payload tray are both notable components that will need to be properly mounted. A suitable adhesive will need to be selected for mounting the internal payload section components to the rocket body. If a suitable adhesive is unavailable, other mounting options, such as rivets or fasteners, will be utilized.

Another technical challenge in this section of the design is supporting the nosecone as it separates and slides away from the main rocket body. To address this challenge, two rods will be affixed to the nosecone. These rods will be along the inside of the nosecone and run into the inner diameter of the payload section. These two rods will provide the structural support necessary to support the nosecone as it slides away from the body. Due to this design, the worm drive will not bear any load or stress that is perpendicular to the centerline of the rocket.

Securing the four inch payload tube into the payload section is another challenge. The payload tube is much smaller in diameter than the payload section of the rocket, and if left unsecured it can cause potential damage to the payload or the rocket itself. To address this issue, once the payload tube is placed into the tray mounted within the payload section, a servo motor will rotate a tab, which was originally parallel to the length of the tray, 90 degrees so that it is over top of the payload tube—effectively securing the payload within the tray and payload section.

### 4.3 Propulsion

The OpenRocket software allowed for testing of several motors in order to find which motor accomplished the altitude requirements. The Cesaroni 5-grain K1200 motor will be used to propel the rocket to an estimated altitude of 3,280 feet. This altitude allows the rocket to have a margin of safety for the goal of 3,000 feet. During the building process, the rocket may increase in weight from the OpenRocket calculations. Also, another concern would be that the weather conditions on launch day may alter the achievable altitude for the rocket. After construction, the
rocket will be weighed to determine if it will achieve the predicted performance from the K1200 motor. If the rocket fails to perform in the simulation a different motor may be selected.

4.4 Avionics and Recovery

The recovery system of the REPTAR launch vehicle will utilize a dual deployment system requiring two separation events to deploy three different chutes during descent. Upon apogee at a calculated delay time, the motor’s black powder ejection charge will shear four nylon shear pins holding the main body section to the avionics bay allowing a 36 inch Rocketman Enterprises low porosity chute to deploy as a drogue, slowing the descent to roughly 75.2 ft./sec. By this point two redundant PerfectFlite Stratologger altimeters will fire an electronic match and black powder charge at 1000’ AGL that shears another set of shear pins and both separates the payload section with nosecone and deploys the main recovery parachutes the two now separated sections. The main body parachute will be a 14 foot Rocketman Enterprises low porosity parachute that slows the main body descent to 11.392 ft./sec and lands with 45.10 ft-lbf. The payload section will descend on a 6 foot low porosity chute at a rate of roughly 18.25 ft./sec and landing with a total kinetic energy of 67.85 ft-lbf.

Both of the these kinetic energy values were calculated using mass data generated by the OpenRocket design file and descent rate calculator that closely models the Rocketman Enterprises parachutes. Both values include a 150% Margin of Error, due primarily to mass values and atmospheric conditions. The values with the included margin of error both fall below the 75 ft-lbf maximum kinetic energy allowed per requirement 2.3.

The avionics bay will run on a power source that is separate from any other internal subsystem in the rocket, and will utilize an arming switch that is accessible externally. Because the rocket will separate into two sections, dedicated GPS tracking systems will be installed into both electronics and avionics bays. The radio transmitter will be installed such that recovery system electronics are shielded from its emissions, as to not excite any live charges within the launch vehicle. The tracking devices will utilize a GPS receiver and radio transmitter that is then discoverable via a Ham Radio or an internet based location service developed at the Naval Academy.

4.4.1 Avionics and Recovery Challenges

A major challenge for the avionics system will be if the altimeter fails to function properly. Failure to function would result in the parachute system not deploying at correct altitudes during the flight plan. This will be mitigated using multiple altimeters to ensure that parachutes are deployed. Another major concern for a successful deployment of the parachutes is proper detonation of the black powder ejection charge. This ejection charge is signaled by the altimeters and forces a section of the rocket body to separate containing a parachute. To fix this we will use wadding inside of ejection canisters to ensure physical contact between electric match and powder charge. Also, the ejection charge will be tested to ensure that the dentation can separate the body sections.
The parachute is vital for proper and safe recovery of the rocket. We will ensure parachute deploys fully through research of different packing methods and become proficient at correctly packing the parachute via subscale/model launches. The launch itself will also test the strength of the recovery system, which if improperly handled can lead to damage to the rocket frame or hardware as a result of the initial drag force (i.e. zippering). To alleviate unnecessary stresses, all parachutes will be fastened to rocket body with eyebolts constructed in the bulkheads.

Another concern is the main chute deploying at a high rate of speed and shearing the body tube. To mitigate this, a drogue parachute will be used to slow the rocket to an ideal and safe rate of descent before the main parachute deploys.
4.5 Flight Profile

The rocket will follow a planned flight path. This path will include apogee at 3000 feet and deployment of the drogue and payload at 1000 feet. The flight plan can be seen in Figure 16.

![Figure 16. Rocket Flight Plan](image)

4.6 Autonomous Ground Support Equipment

The Autonomous Ground Support Equipment is responsible for the insertion of the payload into the rocket, as well as the placement of the rocket in the proper launch configuration. The entire
sequence will be activated remotely and will have a pause function in place for safety reasons. The AGSE shall be able to remain paused for at least one hour and still be able to complete its tasks once the pause ends. Per 3.1.3 of the Student Handbook, no prohibited technologies will be used in the AGSE.

4.6.1 Control

With the exception of the Scorbot, the AGSE will be controlled using MATLAB. When the Scorbot has completed the task of inserting the payload into the rocket body, a laptop computer running MATLAB will initiate the rocket closure process. The first step will involve using a transmitter to secure the payload in place with two small servo motors. These motors will drive tabs that rotate 90 degrees and hold the payload in place. Following this process, the rocket will then be given the command to seal the payload bay using via worm gear. Once the payload bay is sealed, the tower will be given the command to erect the rocket to the launch position. When the rocket reaches its launch position, the igniter insertion device will drive the igniter into the rocket body. Upon completion of this task, the AGSE will begin the countdown to launch.

4.6.2 Arm

The AGSE will operate under the assumption that the payload is placed within a designated drop-off area. A robotic arm no more than twelve inches away from the payload shall extend toward the payload, grip the payload, and elevate the payload to a point at least twelve inches off the ground. The arm will then rotate 180 degrees about the ground plane until it faces the rocket. The arm shall then rotate 180 degrees about the ground plane until it faces the rocket. The arm shall lower the payload until it is no more than 1.5 inches above the payload tray and then release the payload, allowing it to fall into the tray. The tray will have a locking mechanism that secures the payload once contact is made. The arm will then return back to its starting position. Affixed to the base of the arm shall be a four-sided aluminum shield that will protect the back, top, and sides of the robotic arm from the rocket exhaust. When the arm rotates, the shield will rotate with the arm, allowing the “front” of the arm to be free from obstruction at all times. When in the starting and final positions, the shield shall be directly in between the tower and the robotic arm. The robotic arm we will be using is a Scorbot ER-V, shown below in Figure 17.
The Scorbot used within the AGSE will have a command unit from which it will receive instructions. The team will input serial instructions prior to the competition. Each line of instruction will give the Scorbot a location to move the gripping mechanism to in relation to the arm’s own reference system, in the form of x, y, and z coordinates. These lines of instruction will also contain commands to make the Scorbot close or release the grip on the payload. The command unit will be connected to the Scorbot via hard line and all measures will be taken to ensure that the command unit is not at risk of being damaged during the launch segment.

4.6.3 Tower

The AGSE will incorporate a structure consisting of two vertical towers, each 10 feet tall, connected at five separate locations with horizontal connecting tubes. Each tube, or rung, will be 36 inches long. Each tower will have four horizontal feet, each welded to the base of the tower to ensure maximum integrity. The feet are shown below in Figure 18.
Each tower will have a bicycle chain oriented in vertical loop with the plane of the loop perpendicular to the horizontal rungs. Each chain will be supported by two gears, mounted on the top and bottom rungs, 2 inches in the horizontal direction away from the tower, as illustrated below in Figure 19.
The top two gears will rotate freely while the bottom two gears will be driven by an NPC-T74 motor. Both gears will be driven at the same rate to ensure that both chains rotate at the same rate. A rod will connect the two chains together. This rod will also be connected to the rocket sled. The rocket sled will lie on a horizontal plane 8 inches above the ground, perpendicular to the tower rungs and the towers themselves. The rocket will be placed on the sled with the nose cone pointed toward the tower structure. As the motor spins the lower gears, the chains will run vertically and raise the rod to a predetermined height. As this rod is raised, it will raise one end of the sled with it. The other end of the sled will roll on a wheel that runs along a 10 foot long track. This track will have a bar connected perpendicularly at the end of the track furthest from the support towers. This elevation process will erect the sled from horizontal to 5 degrees from the vertical. The tower will begin the elevation process 60 seconds after the robot arm inserts the payload and rotates to its final position. The tower and rail system is illustrated below in Figure 20.

Figure 20. Tower and Rail Setup
4.6.4 **Igniter Insertion**

The igniter and its housing will be mounted onto the end of a shaft of a linear motor. This linear motor will be fixed to the bottom of the rocket sled, just underneath the nozzle, shown in Figures 22 and 23. Upon receiving the command to insert the igniter, the motor will gradually slide the igniter piece toward the nozzle and all movement will cease once the flat plate portion of the igniter housing reaches its final position. This will be done by measuring the average distance between the base of the igniter housing and the rocket nozzle. This length will be the same length of shaft moved by the motor. The shaft will remain in this position until the rocket has been launched and it has been given the command to retract.

![Figure 21. Front View of the Igniter Stand](image)
4.6.5 AGSE Challenges

Although the system will be tested the following technical problems could arise with the AGSE equipment:

- Scorbot might not function properly
  - Might not grip the payload properly and drop it
  - Might place the payload in the wrong area and miss the payload bay
  - Might place the payload in the wrong orientation and the rocket might not close properly
  - The Scorbot could fail to return to its final protected position and expose it to the harmful rocket exhaust.
- Tower motor could malfunction
  - The motor could stop before the rocket is fully erected, therefore giving it an improper launch angle
  - The motor could fail to stop and continue to drive the gears until the chains misalign
  - The motor could fail to run entirely
- Igniter insertion device could malfunction
  - The igniter and the nozzle might not be aligned properly and the igniter will fail to enter the rocket body
The linear motor might not extend fully and the igniter will fail to enter the rocket body entirely or it might not be inserted far enough to achieve proper ignition
- The launch lugs could fail to secure the rocket to the launch rail
  - The lugs could fail while the rocket is being erected and the rocket might reach the proper launch position or it could fall off the launch rail entirely

All of these challenges will be mitigated by repetitive testing during the design and building process.

4.7 Project Requirements

4.7.1 Vehicle

The vehicle will:
1. Deliver the payload to an apogee altitude of 3,000 feet AGL.
2. Carry a commercially available barometric altimeter.
3. Be recoverable and reusable.
4. Have a maximum of 4 independent sections.
5. Be limited to a single stage.
6. Be capable of being prepared for flight within 2 hours after the FAA flight waiver opens.
7. Be capable of remaining launch ready on the pad for a minimum of 1 hour.
8. Be launched by a standard 12 volt direct current firing system.
9. Use a commercially available solid motor that is certified by the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA).
10. Not exceed an impulse of 5,120 N-s.
11. Provide an inert replica of the motor to test the igniter installer.
12. Successfully launch and recover a subscale model of the rocket prior to the CDR.
13. Successfully launch and recover their full scale rocket prior to the FRR.
14. Jettison the payload at 1,000 feet AGL.

4.7.2 Recovery System

The recovery system will:
1. Stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude.
2. Perform a successful ground ejection test for both the drogue and main parachutes prior to the initial subscale and full scale launches.
3. Have a maximum kinetic energy of 75 ft-lbf at landing.
4. Be completely independent of any payload electrical circuits.
5. Contain redundant, commercially available altimeters.
6. Have a dedicated arming switch shall arm each altimeter, which is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.
7. Have a dedicated power supply for each altimeter.
8. Have arming switches capable of being locked in the ON position for launch.
9. Have removable shear pins to be used for both the main parachute compartment and the drogue parachute compartment.
10. Include an electronic tracking device installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.

4.7.3 AGSE System

The Autonomous Ground Support Equipment (AGSE) will:
1. Be limited to a budget of $10,000 on the AGSE.
2. Have the vehicle positioned horizontal at the start.
3. Include a master switch to activate all autonomous procedures and subroutines
4. Include a pause switch.
5. Include an orange/amber safety light to indicate that the power is turned on, flash at 1 Hz when the AGSE is active and be solid when paused.
6. Automatically capture and place the payload in the rocket, erect the vehicle to 5 degrees off vertical, and insert the igniter.

4.7.4 Payload

The Payload will:
1. Be cylindrical, approximately 3/4 inch in diameter, and 4.75 inches in length.
2. Be placed outside the mold line of the launch vehicle when placed horizontally.
3. Be captured, placed, sealed in the rocket, and the rocket erected in a time limit of 10 minutes. Failure to complete this is automatic disqualification from the Maxi-MAV competition.

4.8 Major Logistical Challenges

The major foreseeable challenge for Navy Rockets is team sustainability in the future. It has the possibility of being difficult to find enough interest for future years to come. Because all 4th year students on the team will not be able to be with the team next year there will be a high turnover rate. If there are not enough incoming third and second year students this could pose a problem. Adding to that, the Naval Academy is a smaller school, with a relatively small selection of students pursuing aerospace engineering.
The best solution to this challenge will be to make team information flyers and events more effective in providing interest. A way to do this will to branch outside of the aerospace engineering department when soliciting for members. The major members of the team now are all aerospace majors. In the future this will most likely not be the case with increased solicitation to, and interest from, other engineering majors.
5 Educational Engagement

Navy Rockets intends to involve itself in the community through educational outreach events. The main targets of outreach events will be primary and secondary school students interested in the areas of Science, Technology, Engineering, and Mathematics (STEM). In general, Navy Rockets participation in the outreach events will be supplementary to the overall goal of the event. All STEM events involve the rotation of interested young scholars through a myriad of engineering and technological disciplines. Navy Rockets plans to provide an opportunity for under-represented populations to experience the design and engineering process of projects during STEM events. This is to be done outside of a classroom setting through selected STEM events where participants engaged and actively participating.

5.1 STEM Coordination

According to the USNA STEM website, the outreach methodology is to:

“Utilize unique approach to recruiting and retaining technologists by actively engaging elementary/middle/high school students and teachers in a wide variety of science and engineering events (camps, mini-camps, competitions, site visits, short courses, internships) to initiate interest and enthusiasm for future STEM participation in academic and career choices. Unique approach is defined by project based, Navy-relevant curriculum, focusing on current topics, and a pyramidal structure with practicing Navy technologists/educators on top and near peer midshipmen acting as the interface with students, using the outstanding USNA resources as a backdrop for the activities.”

Navy Rockets will supplement the mission of the STEM Program by fulfilling its own requirements. The shared goals of the USNA STEM program and Navy Rockets are:

- Outreach with local communities to influence students and teachers to increase focus toward STEM-related studies and activities.

- Allow Navy Rocket participants to be intellectually challenged by creating programs for Midshipmen, and other program participants that will facilitate problem solving and critical thinking while still developing a basic technical sense of the projects.

- Create an interest in aerospace specifically, and all aspects of systems engineering that it entails. Through hands on utilization of technology and computer programs, Navy Rockets hopes to foster interest in the future of aerospace engineering and space flight.
5.2 Team Participation

It is of utmost importance that each active member of Navy Rockets participates in outreach such that they have direct educational interaction with at least 100 different participants. This will ensure that the Student Launch minimum requirement of 200 participants, at least 100 being middle school associated, is surpassed.

5.3 STEM Events

Navy Rockets plans to be involved in unique STEM events where different populations are targeted. There are four types of events that Navy Rockets plans on doing. All four events involve direct interaction with the participants. The four types include:

- Direct Educational interaction involving Aerospace Engineering
- Direct Outreach interaction involving Aerospace Engineering
- Direct Educational interaction not involving Aerospace Engineering
- Direct Outreach interaction not involving Aerospace Engineering

The four types of events will encompass Navy Rockets’ educational outreach. Of that, the events where Navy Rockets is interacting through aerospace engineering topics will be the majority of the events attended by Navy Rockets.

Navy Rockets plans on impacting the following STEM events. The events are not a comprehensive list of the events the team members attend, but they are a list of the major events that are scheduled at the time of proposal submission.

5.3.1 MESA Day

Done in collaboration with Maryland Mathematics Engineering Science Achievement (MESA), MESA day is one of the primary recurring USNA STEM events that Navy Rockets plans on doing. MESA day is a full day of involved activities that keep elementary students from local counties and Baltimore City involved and interested in STEM related activities. Along with a plethora of age-appropriate interactive activities in different STEM areas, groups are encouraged to participate in a mini engineering design competition. Navy Rockets’ involvement in MESA day would consist of creating aerospace specific activities that will keep the students engaged and attentive. MESA day occurs monthly.
5.3.2 Mini-STEM

At the Naval Academy, high schools from around the country have students come visit USNA for an overnight visit or a long weekend. This is known as a Candidate Visit Weekend. During these candidate visits, the students tour the lab spaces and technical facilities, but more importantly, spend time engaged in interactive science and engineering activities. Navy Rockets plans to bolster the candidate’s visits with helpful science and engineering activities. Navy Rockets has the ability to conduct wind tunnel experiments, load cell experiments, and much more with the mini-STEM groups. Candidate visits are held a handful of times during a semester, so there are an abundance of mini-STEM opportunities for Navy Rockets to teach students.

5.3.3 Girls-Only STEM Day

Part of the Girls Exploring Technology through Innovative Topics (GET IT and GO) Program, the girls-only STEM day focuses on engineering design and development through a comprehensive competition. The goal is to encourage female participation in STEM programs and studies because females are under-represented in STEM communities. At the competition, female students will have the opportunity to compete, and to attend workshops and meet female faculty members working on innovative technologies, and sciences. The girls-only STEM day is a one-time competition of the GET IT and GO Program.

5.4 Sustainability

Due to the fact that this is the first year of this the competition for Navy Rockets, extra measures will be taken in order to sustain the project for years to come. While it is difficult for Navy Rockets to receive funding through commercial enterprises and other businesses due to federal regulations, the team is continually lobbying for community support in other areas. Outside of the Student Launch Initiative, the Navy Rockets club is able to get continued funding and support through the USNA STEM program. Other than that, Navy Rockets has had a mutually beneficial relationship with the local AIAA student chapter, and the local amateur rocket associations. Similar to the Student Launch Initiative, the local programs ask us to perform community outreach on their behalf. Through outreach, Navy Rockets will be promoting an interest in pertinent aerospace engineering communities and technological advances.

The Navy Rockets team expends a large amount of effort to ensure sustainability and interest in Navy Rockets. Navy Rockets has attended multiple class meetings to promote rocketry, mostly on an amateur level. For example, for the last few years, members have attended aerospace open houses geared toward freshmen. At these open houses, Navy Rockets has a booth and hands out flyers with information about the team. Aside from that, Navy Rockets attends aerospace specific class-wide pre-registration briefs. At these briefs, classes are told about the classes they can
register for in the oncoming semester. Information about Navy Rockets and what the team does is also promulgated at these briefs.

5.5 Additional Learning

In an effort to attain continuity, both with our team support and within the team multiple workshops will be setup to develop the member’s knowledge in specific areas. A few workshops will be created, and each member of the team will attend the workshop. These workshops will be targeted on the process of aerospace and control systems engineering. The workshops will be led by a subject matter expert from the community or facility. Workshops will be a small amount of contact hours, but sufficient amount to give a working overview to the team. The specific workshops are shown below in a Table 3. Each workshop is subject to time change, termination and/or slight concept change based on faculty needs and input.

<table>
<thead>
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<th>Table 3. Team Workshops</th>
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<tr>
<td>Advanced MATLAB/Simulink Techniques</td>
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<tr>
<td>Introduction to Control Systems Engineering</td>
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<td>Engineering Leadership</td>
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<tr>
<td>Engineering Law and Patents</td>
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<tr>
<td>Basic Computational Fluid Dynamics</td>
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<td>Additive Manufacturing and SolidWorks</td>
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<td>Rocket Dynamics and Stability</td>
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<tr>
<td>Similarity Parameters and Scaling</td>
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<tr>
<td>Non-Destructive Testing</td>
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6 Project Plan

6.1 Budget and Funding

Currently Navy Rockets has one guaranteed source of income, along with multiple anticipated sources of income for the 2014-2015 USLI. These funding sources are listed below in Table 4. Funding proposals have been submitted to each non-finalized source listed in Table 4.

Table 4 Navy Rockets’ USLI Expected Income

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<td>USNA MSTEM*</td>
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*Denotes a non-finalized source of income.
**Denotes an unofficial income amount.

The expected expenditures of the 2014-2015 USLI competition are listed below in Table 5. These costs are presented in depth in Table 6 with an itemized budget of the full scale Maxi-MAV design.

Table 5. Navy Rockets’ USLI Expected Costs

<table>
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<td>Outreach</td>
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Table 6. Navy Rockets’ Full Scale Itemized Budget

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<td>Twill Weave Carbon Fiber Cloth</td>
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## USNA Student Launch Planner

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</table>
APPENDIX B: Written Safety Statements

Navy Rockets understands and will abide by all safety regulations and laws for high power rocketry and failure to do so will result in disqualification in the competition. These rules and regulations are included but not limited to:

1. All members will wear protective gear when required.
2. All members will adhere to all Machine Shop rules and regulations.
3. All laws will be followed to include: transportation of the rocket, handling of the materials, launching under a flight waiver, and ownership of the rocket.
4. RSO must inspect the rocket before it is flown.
5. The RSO has the final safety on all rocket safety issues and can deny a launch at any time.

Samuel Hayes Friddle

Cole R Palmer

Alexander W Vogel

Thorys J Stensrud II

Richard L Morales

Troy Mckenzie

Joseph W Gardner

Andrew S Bonn
APPENDIX C: Risk Assessment

RAC CLASSIFICATIONS

The following tables and charts explain the Risk Assessment Codes (RACs) used to evaluate the hazards identified in this report. RACs are established for both the initial hazard, that is, before controls have been applied, and the residual/remaining risk that remains after the implementation of controls. Additionally, Table 2 provides approval/acceptance levels for differing levels of remaining risk. In all cases, individual workers should be advised of the risk for each undertaking.

<table>
<thead>
<tr>
<th>Probability</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Catastrophic</td>
</tr>
<tr>
<td>A – Frequent</td>
<td>IA</td>
</tr>
<tr>
<td>B – Probable</td>
<td>IB</td>
</tr>
<tr>
<td>C – Occasional</td>
<td>IC</td>
</tr>
<tr>
<td>D – Remote</td>
<td>1D</td>
</tr>
<tr>
<td>E – Improbable</td>
<td>1E</td>
</tr>
</tbody>
</table>

**Table 1: RAC**

<table>
<thead>
<tr>
<th>Level of Risk</th>
<th>Level of Management Approval/Approving Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Risk</strong></td>
<td>Highly Undesirable. Documented approval from the MSFC EMC or an equivalent level independent management committee.</td>
</tr>
<tr>
<td><strong>Moderate Risk</strong></td>
<td>Undesirable. Documented approval from the facility/operation owner’s Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.</td>
</tr>
<tr>
<td><strong>Low Risk</strong></td>
<td>Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.</td>
</tr>
<tr>
<td><strong>Minimal Risk</strong></td>
<td>Acceptable. Documented approval not required but an informal review by the supervisor directly responsible for operating the facility or performing the operation is highly recommended. Use of a generic JHA posted on the SHE Web page is recommended, if a generic JHA has been developed.</td>
</tr>
</tbody>
</table>
### TABLE 3 Severity Definitions - A condition that can cause:

<table>
<thead>
<tr>
<th>Description</th>
<th>Personnel Safety and Health</th>
<th>Facility / Equipment</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Catastrophic</td>
<td>Loss of life or a permanent-disabling injury</td>
<td>Loss of facility, systems or associated hardware</td>
<td>Irreversible severe environmental damage that violates law and regulation</td>
</tr>
<tr>
<td>2 - Critical</td>
<td>Severe injury or occupational-related illness</td>
<td>Major damage to facilities, systems, or equipment</td>
<td>Reversible environmental damage causing a violation of law or regulation</td>
</tr>
<tr>
<td>3 - Marginal</td>
<td>Minor injury or occupational-related illness</td>
<td>Minor damage to facilities, systems, or equipment</td>
<td>Manageable environmental damage without violation of law or regulation where restoration activities can be accomplished</td>
</tr>
<tr>
<td>4 - Negligible</td>
<td>First aid injury or occupational-related illness</td>
<td>Minimal damage to facility, systems, or equipment</td>
<td>Minimal environmental damage not violating law or regulation</td>
</tr>
</tbody>
</table>

### TABLE 4 Probability Definitions

<table>
<thead>
<tr>
<th>Description</th>
<th>Qualitative Definition</th>
<th>Quantitative Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Frequent</td>
<td>High likelihood to occur immediately or expected to be continuously experienced.</td>
<td>Probability is &gt; 0.1</td>
</tr>
<tr>
<td>B - Probable</td>
<td>Likely to occur or expected to occur frequently within time.</td>
<td>0.1 ≥ probability &gt; 0.01</td>
</tr>
<tr>
<td>C - Occasional</td>
<td>Expected to occur several times or occasionally within time.</td>
<td>0.01 ≥ probability &gt; 0.001</td>
</tr>
<tr>
<td>D - Remote</td>
<td>Unlikely to occur, but can be reasonably expected to occur at some point within time.</td>
<td>0.001 ≥ probability &gt; 0.000001</td>
</tr>
<tr>
<td>E - Improbable</td>
<td>Very unlikely to occur and an occurrence is not expected to be experienced within time.</td>
<td>0.000001 ≥ probability</td>
</tr>
<tr>
<td>Problem</td>
<td>Risk number</td>
<td>Mitigation</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>PROJECT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over budget</td>
<td>2D</td>
<td>Careful planning of spending</td>
</tr>
<tr>
<td>Fall behind on the schedule</td>
<td>2D</td>
<td>Foster a culture of firm adherence to deadlines</td>
</tr>
<tr>
<td>Material not available</td>
<td>2E</td>
<td>Order materials early to ensure delivery</td>
</tr>
<tr>
<td>Materials damaged during testing</td>
<td>2C</td>
<td>Make sure that we have replacement parts</td>
</tr>
<tr>
<td><strong>SAFETY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical burns</td>
<td>3D</td>
<td>Wear protective equipment when handling materials</td>
</tr>
<tr>
<td>Injury from power equipment</td>
<td>2E</td>
<td>Require training and to work with a partner and wear safety equipment</td>
</tr>
<tr>
<td>Motors and black powder exploding</td>
<td>1E</td>
<td>Only certified people can handle the materials</td>
</tr>
<tr>
<td><strong>WEATHER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High winds</td>
<td>3A</td>
<td>Check weather reports before launching</td>
</tr>
<tr>
<td><strong>LAUNCH</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catastrophic motor failure</td>
<td>1E</td>
<td>Ensure safe handling and installing of the motor by certified members</td>
</tr>
<tr>
<td>Igniter failure</td>
<td>4B</td>
<td>Ensure that the igniter is installed properly and it has been inspected</td>
</tr>
<tr>
<td>Ignition system failure</td>
<td>2E</td>
<td>Ensure that the system is functioning properly</td>
</tr>
<tr>
<td>Rocket frame breaks</td>
<td>2E</td>
<td>Test the materials strength before launch</td>
</tr>
<tr>
<td>Fins break</td>
<td>2E</td>
<td>Material testing to ensure the strength of the fins</td>
</tr>
<tr>
<td>Shear pins do not shear</td>
<td>1E</td>
<td>Conduct batch testing</td>
</tr>
<tr>
<td>Chute does not open</td>
<td>2D</td>
<td>Properly pack the chute so that it opens correctly</td>
</tr>
<tr>
<td>Chute burns</td>
<td>1E</td>
<td>Ensure proper placement of the protective material and use a chute able to withstand fire</td>
</tr>
<tr>
<td>Chute deploys at incorrect altitude</td>
<td>4D</td>
<td>Subscale testing of the chute systems</td>
</tr>
<tr>
<td>Exceeding kinetic energy limit in landing</td>
<td>2D</td>
<td>Model the landing to ensure compliance and allow a factor of safety</td>
</tr>
<tr>
<td>Avionics will not track</td>
<td>3D</td>
<td>Testing the equipment before use</td>
</tr>
<tr>
<td>Inaccurate location</td>
<td>3D</td>
<td>Ensure the rocket direction is being tracked on the ground</td>
</tr>
<tr>
<td>Systems do not have enough power</td>
<td>2E</td>
<td>Make sure the systems have fresh batteries</td>
</tr>
<tr>
<td>Failure to seal payload compartment</td>
<td>1D</td>
<td>System testing before allowing it to launch</td>
</tr>
<tr>
<td><strong>AGSE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chain failure</td>
<td>1E</td>
<td>Proper chain selection and testing</td>
</tr>
<tr>
<td>Sled derailing</td>
<td>2D</td>
<td>Design the track properly to ensure the sled does not separate</td>
</tr>
<tr>
<td>Motor failure</td>
<td>1D</td>
<td>Test the motor to ensure proper power supply</td>
</tr>
<tr>
<td>Robotic arm failure</td>
<td>1D</td>
<td>Extensive component testing</td>
</tr>
<tr>
<td>Loss of Power</td>
<td>1E</td>
<td>Test the system for sufficient operating power</td>
</tr>
<tr>
<td>Elevation failure</td>
<td>1E</td>
<td>Testing, maintaince, and inspecting the components</td>
</tr>
</tbody>
</table>
APPENDIX D: NAR/TRA Procedures

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 manufacturers. 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 hopping 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

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

**Note:** A complex rocket is one that is multi-staged or that is propelled by two or more rocket motors.
Code for High Power Rocketry
Tripoli Rocketry Association

This High Power Rocketry Safety Code is the product of many years of effort on behalf of the hobby by those who care about it and whose prime interest is safety. It is not a perfect standard, but adequate. This minimum requirement, if followed, will preserve the hobby in a safe environment for all who participate and for spectators. Tripoli’s Prefectures and other launch sponsors should be aware that wisdom should dictate what is safe and what is not at each launch site. With this standard as the minimum, it will be your responsibility to regulate your own launches within reason. You should be cautious not to over-restrict the activity. Our members, who sometimes travel great distances to attend launches, will expect this Safety Code to be the standard at Tripoli sanctioned launches.

This version of the safety code will appear much terser than prior versions. This version is intended to augment NFPA 1127 Code for High Power Rocketry with codes that are specific to Tripoli. The foundation of the Tripoli High Power Safety Code is NFPA 1127 as that has been adopted by many Authorities Having Jurisdiction and define the minimum set of codes required. Tripoli codes cannot relax NFPA codes; we can only add codes that are intended to increase safety at our sanctioned launches.

General Requirements

1-1 Scope

1-1.1 This code shall apply to safe operation of High Power rocket launches. It will also address some aspects of safe rocket design, and construction, as well as limitations of motor power, for use by the certified user for education, recreation and sporting use.

1-2 Purpose

1-2.1 The purpose of this code shall be to establish guidelines for reasonably safe operation of high power rocket at Tripoli sanctioned/insured launches; both “commercial” as well as Research (covered in a separate code).

1-3 Definitions For the purposes of this code, the following terms shall be defined as stated in this section. Some of these may be redundant from NFPA 1127.

High Power Rocket Flier (HPR Flier). A TRA member or a member of an approved, insured rocketry organization that is 18 years old or older.

Launch Director (LD): A Level 2 or Level 3 flier who has overall administrative responsibility for the launch.

Named Insured: Individuals that are not Tripoli Members but are members of groups that have been submitted to, and approved by the Tripoli Insurance Liaison.

Participants. Persons that are either:

7/31/2012
- HPR Fliers.
- Model Rocket Fliers.
- Invited Guests of fliers.
- Spectators. General population of non-fliers, and non-invited guests.

**Range Safety Officer (RSO).** A Level 2 or Level 3 flier whose responsibility and duty during the operation of high power rockets is to confirm a rocket’s compliance with the applicable provisions of this code, be confident that the rocket will fly in a safe manner, designate the area of the launch site, and oversee the safety of all spectators and participants.

**Sanctioned Launch.** Also called Insured Launch. Any launch of a rocket that meets **ALL** of the following constraints:

1. Responsible person of launch shall be member of Tripoli in good standing.
2. Follows the appropriate Tripoli Safety Code.
3. Legal. All AHJ (e.g. FAA waiver) requirements/regulations met and any required permits secured.
4. Landowner permission/constraints.

**Shall.** Indicates a mandatory requirement.

**Should.** Indicates a recommendation or that which is advised but not required.

**Spectator.** A nonparticipant whose primary purpose is to view a high power rocket launch.

**Spectator Area.** An area designated where spectators view a high power rocket launch.

**Tripoli (TRA).** Tripoli Rocketry Association, Inc.

### Requirements for High Power Rocket Operation

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

   a. This code;
   b. *Federal Aviation Administration Regulations*, Part 101 (Section 307,72 Statute 749, Title 49 United States Code, Section 1348, “Airspace Control and Facilities,” Federal Aviation Act of 1958); and
   c. Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.
   d. Landowner permission.


7/31/2012
2 Participation, Participation and Access at Tripoli Launches shall be limited to the following:

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

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

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

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

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

2-6 Attendance by Invited Guests and Spectators

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

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

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

Referenced Publications

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

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

NFPA 1122, Code for Model Rocketry.

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

NFPA 1117, Code for High Power Rocketry


Federal Aviation Administration Regulations, from the Code of Federal Regulations. Federal

7/31/2012
Hazardous Substances Act, from the United States Code (re. Airspace Control)

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

Articles of Incorporation and Bylaws

High Power Rocketry Safety Code

Tripoli Motor Testing Committee (TMT), Testing Policies

Appendix A - Additional Tripoli Rulings

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

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

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

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

A-5 A rocket motor shall not be ignited by using:
   a. A switch that uses mercury.
   b. “Pressure roller” switches.

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7/31/2012
APPENDIX E: Law Information

A.1 Subpart C—Amateur Rockets

101.21 Applicability.

(a) This subpart applies to operating unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply with §101.25(b)(7)(ii) and with any additional limitations imposed by the using or controlling agency.
(b) A person operating an unmanned rocket other than an amateur rocket as defined in §1.1 of this chapter must comply with 14 CFR Chapter III.

101.22 Definitions.

The following definitions apply to this subpart:
(a) Class 1—Model Rocket means an amateur rocket that:
(1) Uses no more than 125 grams (4.4 ounces) of propellant;
(2) Uses a slow-burning propellant;
(3) Is made of paper, wood, or breakable plastic;
(4) Contains no substantial metal parts; and
(5) Weighs no more than 1,500 grams (53 ounces), including the propellant.
(b) Class 2—High-Power Rocket means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.
(c) Class 3—Advanced High-Power Rocket means an amateur rocket other than a model rocket or high-power rocket.

101.23 General operating limitations.

(a) You must operate an amateur rocket in such a manner that it:
(1) Is launched on a suborbital trajectory;
(2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;
(3) Is unmanned; and
(4) Does not create a hazard to persons, property, or other aircraft.
(b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

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

(a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;
(b) At any altitude where the horizontal visibility is less than five miles;
(c) Into any cloud;
(d) Between sunset and sunrise without prior authorization from the FAA;
(e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;
(f) In controlled airspace without prior authorization from the FAA;
(g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:
   (1) Not less than one-quarter the maximum expected altitude;
   (2) 457 meters (1,500 ft.);
(h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight; and
(i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

101.27 ATC notification for all launches.

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

(a) The name and address of the operator; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;
(b) Date and time the activity will begin;
(c) Radius of the affected area on the ground in nautical miles;
(d) Location of the center of the affected area in latitude and longitude coordinates;
(e) Highest affected altitude;
(f) Duration of the activity;
(g) Any other pertinent information requested by the ATC facility.

101.29 Information requirements.

(a) *Class 2—High-Power Rockets*. When a Class 2—High-Power Rocket requires a certificate of waiver or authorization, the person planning the operation must provide the information below on each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 2 rocket expected to be flown:

(1) Estimated number of rockets,
(2) Type of propulsion (liquid or solid), fuel(s) and oxidizer(s),
(3) Description of the launcher(s) planned to be used, including any airborne platform(s),
(4) Description of recovery system,
(5) Highest altitude, above ground level, expected to be reached,
(6) Launch site latitude, longitude, and elevation, and
(7) Any additional safety procedures that will be followed.

(b) Class 3—Advanced High-Power Rockets. When a Class 3—Advanced High-Power Rocket requires a certificate of waiver or authorization the person planning the operation must provide the information below for each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 3 rocket expected to be flown:
(1) The information requirements of paragraph (a) of this section,
(2) Maximum possible range,
(3) The dynamic stability characteristics for the entire flight profile,
(4) A description of all major rocket systems, including structural, pneumatic, propellant, propulsion, ignition, electrical, avionics, recovery, wind-weighting, flight control, and tracking,
(5) A description of other support equipment necessary for a safe operation,
(6) The planned flight profile and sequence of events,
(7) All nominal impact areas, including those for any spent motors and other discarded hardware, within three standard deviations of the mean impact point,
(8) Launch commit criteria,
(9) Countdown procedures, and
(10) Mishap procedures.

A.2 Law & Regulations: NAR

User Certification
NFPA Code 1127—and the safety codes of both the NAR and TRA—require that “high power motors” be sold to or possessed by only a certified user. This certification may be granted by a “nationally recognized organization” to people who demonstrate competence and knowledge in handling, storing, and using such motors. Currently only the NAR and TRA offer this certification service. Each organization has slightly different standards and procedures for granting this certification, but each recognizes certifications granted by the other. Certified users must be age 18 or older.

Explosives Permits
Hobby rocket motors (including high power) no longer require a Federal explosives permit to sell, purchase, store, or fly. Certain types of igniters, and cans or other bulk amounts of black powder do require such permits. Under the Organized Crime Control Act of 1970 (Public Law
91-452). A Federal Low Explosives User Permit (LEUP) from the Bureau of Alcohol, Tobacco, and Firearms (BATF) is required to purchase these items outside one’s home state, or to transport them across state lines. These items, once bought under an LEUP, must thereafter be stored in a magazine that is under the control of an LEUP holder. A “Type 3” portable magazine or “Type 4” indoor magazine (described under NFPA Code 495) is required, and it can be located in an attached garage. BATF must inspect such magazines.

Federal permits can be obtained from the BATF using their Form 5400.13/5400.16, available from the ATF Distribution Center, 7943 Angus CT., Springfield, VA 22153. These are issued only to U.S. citizens, age 18 and older, who have no record of conviction of felonies and who pass a background check conducted by the BATF. This check includes a personal interview by a BATF agent.

Launch Site Requirements

The first requirement for any launch site is permission of the owner to use it for flying rockets! Use of land—even public property—without permission is usually illegal and always a bad way for a NAR member to demonstrate responsible citizenship. The NAR will issue “site owner” insurance to chartered sections to cover landowners against liability for rocket-flying accidents on their property—such insurance is normally required.

The NAR safety codes and NFPA Codes establish some minimum requirements for the size and surroundings of launch sites. Model rocket launch sites must have minimum dimensions which depend on the rocket’s motor power as specified in Rule 7 of the model rocket safety code and its accompanying table. The site within these dimensions must be “free of tall trees, power lines, buildings, and dry brush and grass”. The launcher can be anywhere on this site, and the site can include roads. Site dimensions are not tied to the expected altitude of the rockets’ flights. According to the high-power safety code, high-power rocket launch sites must be free of these same obstructions, and within them the launcher must be located “at least 1500 feet from any occupied building” and at least “one quarter of the expected altitude” from any boundary of the site. NFPA Code 1127 establishes further requirements for the high-power site: it must contain no occupied buildings, or highways on which traffic exceeds 10 vehicles per hour; and the site must have a minimum dimension no less than either half the maximum expected rocket altitude or 1500 feet, whichever is greater—or it must comply with a table of minimum site dimensions from NFPA 1127 and the high power safety code.

While model rocketry and high power rocketry, when conducted in accordance with the NAR Safety Codes, are legal activities in all 50 states, some states impose specific restrictions on the activity (California being the worst example of this) and many local jurisdictions require some form of either notification or prior approval of the fire marshal. It is prudent and highly recommended that before you commit to a launch site you meet with the fire marshal having jurisdiction over the site to make him aware of what you plan to do there and build a relationship with him just as you did with the land owner. The fact that NAR rocketry is recognized and its safety and launch site requirements are codified in Codes 1122 (Model Rockets) and 1127 (High
Power Rockets) by the National Fire Protection Association will be a very powerful part of your discussion with any fire marshal.

Airspace Clearance
The Federal Aviation Administration (FAA) has jurisdiction over the airspace of the U.S. and whatever flies in it. Their regulations concerning who may use it and under what conditions are known as the Federal Aviation Regulations (FAR)–which are also called Title 14 of the Code of Federal Regulations (14 CFR). Chapter 1, Subchapter F, Part 101 of these regulations (14 CFR 101.1) specifically exempts model rockets that weigh 16 ounces or less and have 4 ounces or less of propellant from FAA regulation as long as they are “operated in a manner that does not create a hazard to persons, property, or other aircraft.” When operated in this safe manner, model rockets may be flown in any airspace, at any time, and at any distance from an airport–without prior FAA approval.

Rockets larger than these specific limits–i.e. all high-power rockets–are referred to as “unmanned rockets” by the FARs and are subject to very specific regulations. Such rockets may not be flown in controlled airspace (which is extensive in the U.S. even at low altitudes and includes all airspace above 14,500 feet), within 5 miles of the boundary of any airport, into cloud cover greater than 50% or visibility less than 5 miles, within 1500 feet of any person or property not associated with the operation, or between sunset and sunrise. Both NFPA Code 1127 and the NAR high-power safety code require compliance with all FAA regulations.

Deviation from these FAR limits for unmanned rockets requires either notification of or granting of a “waiver” by the FAA. Such a waiver grants permission to fly but does not guarantee exclusive use of the airspace. The information required from the flier by the FAA is detailed in section S 101.25 of the FAR (14 CFR 101.25). If the rockets are no more than 1500 grams with no more than 125 grams of propellant, no notification of or authorization by the FAA is required. Larger rockets require a specific positive response from the FAA Regional Office granting a waiver before flying may be conducted; and the waiver will require that you notify a specific FAA contact to activate a Notice to Airmen 24 hours prior to launch. The waiver is requested using FAA Form 7711-2, available from any FAA office or the FAA website. This form must be submitted in triplicate to the nearest FAA Regional Office 30 days or more in advance of the launch, and it is advisable to include supplemental information with it, including copies of the Sectional Aeronautical Chart with the launch site marked on it and copies of the high-power safety code. The FAA charges no fee.

Ignition Safety
The NAR safety codes and the NFPA Codes both require that rockets be launched from a distance by an electrical system that meets specific design requirements. Ignition of motors by a fuse lit by a hand-held flame is prohibited, and in fact both NFPA Codes prohibit the sale or use of such fuses. All persons in the launch area are required to be aware of each launch in advance (this means a PA system or other loud signal, especially for high-power ranges), and all (including photographers) must be a specified minimum distance from the pad prior to launch. This “safe distance” depends on the power of the motors in the rocket; the rules are
different for model rockets and high-power rockets. Both the field size and the pad layout at a rocket range—particularly a high-power range—must take into account and support the size of the rockets that will be allowed to fly on the range.

For model rockets, the “safe distance” depends on the total power of all motors being ignited on the pad: 15 feet for 30 N-sec or less and 30 feet for more than 30 N-sec. For high-power rockets, the distance depends on the total power of all motors in the rocket, regardless of how many are being ignited on the pad, and on whether the rocket is “complex”, i.e. multistaged or propelled by a cluster of motors. The distance can range from 50 feet for a rocket with a single ‘H’ motor to 2000 feet for a complex rocket in the ‘O’ power class. These distances are specified in a table in NFPA Code 1127 and the NAR high-power safety code.

Motor Certification
Both NAR safety codes and both NFPA Codes require that fliers use only “certified” motors. This certification requires passing a rigorous static testing program specified in the NFPA Codes. The NAR safety codes and insurance require that NAR members use only NAR certified motors; and since the NAR currently has a reciprocity agreement with TRA on motor certification, this means that TRA-certified motors also have NAR certification. The NFPA Codes recognize certifications granted by any “approved testing laboratory or national user organization”, but only the NAR and TRA can provide this service in most parts of the country. The California Fire Marshal has his own testing program for motors in that state. Motors made by private individuals or by companies without proper explosives licenses, and motors not formally classified for shipment by the U.S. Department of Transportation, are not eligible for NAR certification and may not be used on an NAR range.

Shipping of Motors
Sport rocket motors generally contain highly flammable substances such as black powder or ammonium perchlorate, and are therefore considered to be hazardous materials or explosives for shipment purposes by the U.S. Department of Transportation (DOT). There are extensive regulations concerning shipment in the DOT’s section of the CFR–Title 49, Parts 170-179. These regulations cover packaging, labeling, and the safety testing and classification that is required prior to shipment. These regulations are of great concern to manufacturers and dealers, and there are severe penalties for non-compliance. Basically, it is illegal to send rocket motors by UPS, mail, Federal Express, or any other common carrier—or to carry them onto an airliner—except under exact compliance with these regulations. The reality of these regulations, and the shippers’ company regulations, is that it is virtually impossible for a private individual to legally ship a rocket motor of any size. Transportation of motors on airlines is very difficult to do legally and should be avoided if at all possible. It takes weeks of advance effort with the airline, and in the post-September 11 world is probably not even worth attempting.

Insurance
Most property owners, whether government bodies or private owners, will demand the protection of liability insurance as a precondition to granting permission to fly sport rockets on their property. The NAR offers such insurance to individual fliers, to chartered NAR sections, and to
flying site owners. Individual insurance is automatic for all NAR members. It covers only the insured individual, not the section or the site owner. Under the current underwriter this insurance runs for a 12 month period, coincident with NAR membership.

Sections are insured as a group for a year; remember that section insurance is coincident with the section charter and expires on April 4 each year. Site owner insurance is available to all active sections for free. Each site owner insurance certificate covers only a single site (launch field or meeting room). NAR insurance covers only activities that are conducted in accordance with the NAR safety code using NAR-certified motors. It provides $2 -million aggregate liability coverage for damages from bodily injury or property damage claims resulting from sport rocket activities such as launches, meetings, or classes and $1 million coverage for fire damage to the launch site. It is “primary” above any other insurance you may have.

References
Code of Federal Regulations, Title 14, Part 101, Federal Aviation Regulations by the FAA for unmanned rockets.
Code of Federal Regulations, Title 49, Parts 170-177, Department of Transportation hazardous material shipping regulations.
Model Rocket Safety Code, National Association of Rocketry.
APPENDIX F: MSDS

MATERIAL SAFETY DATA SHEET
West System Inc.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: WEST SYSTEM® 103 Epoxy Resin
PRODUCT CODE: 103
CHEMICAL FAMILY: Epoxy Resin.
CHEMICAL NAME: Bisphenol A based epoxy resin.
FORMULA: Not applicable.

MANUFACTURER:
West System Inc.
102 Patterson Ave.
Bay City, MI 48706, U.S.A.
Phone: 866-937-5777 or 989-684-7269
www.westsystem.com

EMERGENCY TELEPHONE NUMBERS:
Transportation: CHEMTREC: 800-424-9300 (U.S.)
Non-transportation: 703-527-3587 (international)
Poison Hotline: 800-222-1222

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
WARNING May cause skin irritation. May cause eye irritation. May cause allergic reaction. Clear, viscous liquid with mild odor.

PRIMARY ROUTE(S) OF ENTRY: Skin contact.

POTENTIAL HEALTH EFFECTS:
ACUTE INHALATION: If product is heated, vapors generated can cause headache, nausea, dizziness and possible respiratory irritation if inhaled in high concentrations.

CHRONIC INHALATION: Repeated exposure to high vapor concentrations may cause irritation of pre-existing lung allergies and increase the chance of developing allergy symptoms to this product.

ACUTE SKIN CONTACT: May cause allergic skin response in certain individuals. May cause moderate irritation to the skin such as redness and itching.

CHRONIC SKIN CONTACT: May cause sensitization in susceptible individuals. May cause moderate irritation to the skin.

EYE CONTACT: May cause irritation.

INGESTION: Low acute oral toxicity.

SYMPTOMS OF OVEREXPOSURE: Possible sensitization and subsequent allergic reactions usually seen as redness and rash.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Pre-existing skin and respiratory disorders may be aggravated by exposure to this product. Pre-existing lung and skin allergies may increase the chance of developing allergic symptoms to this product.

3. COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

<table>
<thead>
<tr>
<th>INGREDIENT NAME</th>
<th>CAS #</th>
<th>CONCENTRATION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane, 2,2-bis-[2,3-epoxypropoxy]phenyl, polymers</td>
<td>25085-99-8</td>
<td>60-100</td>
</tr>
<tr>
<td>Benzyl alcohol</td>
<td>100-51-6</td>
<td>10-30</td>
</tr>
<tr>
<td>Phenol formaldehyde polymer glycol/di ether</td>
<td>26004-14-4</td>
<td>1-10</td>
</tr>
</tbody>
</table>

4. FIRST AID MEASURES

FIRST AID FOR EYES: Flush immediately with water for at least 15 minutes. Consult a physician.

FIRST AID FOR SKIN: Remove contaminated clothing. Wipe excess from skin. Apply waterless skin cleaner and then wash with soap and water. Consult a physician if effects occur.

FIRST AID FOR INHALATION: Remove to fresh air if effects occur.

FIRST AID FOR INGESTION: No acute adverse health effects expected from amounts ingested under normal conditions of use. Seek medical attention if a significant amount is ingested.

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5. **FIRE FIGHTING MEASURES**

   **FLASH POINT:** .......................................................>200°F (Tag Closed Cup)

   **EXTINGUISHING MEDIA:** ...........................................Foam, carbon dioxide (CO₂), dry chemical.

   **SPECIAL FIRE FIGHTING PROCEDURES:** Wear a self-contained breathing apparatus and complete full-body personal protective equipment. Closed containers may rupture (due to buildup of pressure) when exposed to extreme heat.

   **FIRE AND EXPLOSION HAZARDS:** During a fire, smoke may contain the original material in addition to combustion products of varying composition which may be toxic and/or irritating. Combustion products may include, but are not limited to: phenolics, carbon monoxide, carbon dioxide.

6. **ACCIDENTAL RELEASE MEASURES**

   **SPILL OR LEAK PROCEDURES:** Stop leak without additional risk. Dike and absorb with inert material (e.g., sand) and collect in a suitable closed container. Warm, snowy water or non-flammable, safe solvent may be used to clean residuals.

7. **HANDLING AND STORAGE**

   **STORAGE TEMPERATURE** (min/max): ................................40°F (4°C)/120°F (49°C)

   **STORAGE:** Store in cool, dry place. Store in tightly sealed containers to prevent moisture adsorption and loss of volatiles. Excessive heat over long periods of time will degrade the resin.

   **HANDLING PRECAUTIONS:** Avoid prolonged or repeated skin contact. Wash thoroughly after handling. Launder contaminated clothing before reuse. Avoid inhalation of vapors from heated product. Precautionary steps should be taken when curing product in large quantities. When mixed with epoxy curing agents this product causes an exothermic, which in large masses, can produce enough heat to damage or ignite surrounding materials and emit fumes and vapors that vary widely in composition and explosivity.

8. **EXPOSURE CONTROLS/PERSONAL PROTECTION**

   **EYE PROTECTION GUIDELINES:** Safety glasses with side shields or chemical splash goggles.

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

   **RESPIRATORY/VENTILATION GUIDELINES:** Good room ventilation is usually adequate for most operations. Wear a NIOSH/MSHA approved respirator with an organic vapor cartridge whenever exposure to vapor in concentrations above applicable limits is likely.

   **Note:** West System, Inc. has conducted an air sampling study using this product or similarly formulated products. The results indicate that the components sampled for (ethylene glycol, benzyl alcohol) were either so low that they were not detected at all or they were significantly below OSHA’s permissible exposure levels.

   **ADDITIONAL PROTECTIVE MEASURES:** Practice good caution and personal cleanliness to avoid skin and eye contact. Avoid skin contact when removing gloves and other protective equipment. Wash thoroughly after handling. Generally speaking, working cleanly and following basic precautionary measures will greatly minimize the potential for harmful exposure to this product under normal use conditions.

   **OCCUPATIONAL EXPOSURE LIMITS:** No established for product as a whole. Refer to OSHA’s Permissible Exposure Limit (PEL) or the ACGIH Guidelines for information on specific ingredients.

9. **PHYSICAL AND CHEMICAL PROPERTIES**

   **PHYSICAL FORM:** Liquid

   **COLOR:** Clear

   **ODOR:** Mild

   **BOILING POINT:** > 400°F

   **MELTING POINT/FREEZE POINT:** No data

   **VIScosity:** 1000 (cP)

   **pH:** No data

   **SOLUBILITY IN WATER:** Slight

   **SPECIFIC GRAVITY:** 1.75

   **BULK DENSITY:** 9.6 (pounds/gallon)

   **VAPOR PRESSURE:** < 1 mmHg at 20°C

   **VAPOR DENSITY:** Heavier than air.

   **% VOLATILE BY WEIGHT:** ASTM D 2869-07 was used to determine the Volatile Content of mixed epoxy resin and hardener. Refer to the hardener’s MSDS for information about the total volatile content of the resin/hardener system.

10. **STABILITY AND REACTIVITY**

    **STABILITY:** Stable
HAZARDOUS POLYMERIZATION: ...Will not occur by itself, but a mass of more than one pound of product plus an aliphatic amine will cause irreversible polymerization with significant heat buildup.

INCOMPATIBILITIES: ...Strong acids, bases, amines and mercaptans can cause polymerization.

DECOMPOSITION PRODUCTS: ...Carbon monoxide, carbon dioxide and phenols may be produced during uncontrolled exothermic reactions or when otherwise heated to decomposition.

11. TOXICOLOGICAL INFORMATION

No specific oral, inhalation or dermal toxicology data is known for this product. Specific toxicology information for a bisphenol-A based epoxy resin present in this product is indicated below.

Oral: \[ \text{LD}_{50} > 5000 \text{ mg/kg (rats)} \]
Inhalation: No Data.
Dermal: \[ \text{LD}_{50} = 20,000 \text{ mg/kg (skin absorption in rabbits)} \]

TERATOLOGY: Diglycidyl ether of bisphenol-A (DGEBA) did not cause birth defects or other adverse effects on the fetus when pregnant rabbits were exposed by skin contact, the most likely route of exposure, or when pregnant rats or rabbits were exposed orally.

REPRODUCTIVE EFFECTS: ...DGEBA, in animal studies, has been shown not to interfere with reproduction.

MUTAGENICITY: ...DGEBA, in animal mutagenicity studies were negative. In vitro mutagenicity tests were negative in some cases and positive in others.

CARCINOGENICITY:

NTP: Product not listed.
IARC: Product not listed.
OSHA: Product not listed.

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

Many studies have been conducted to assess the potential carcinogenicity of diglycidyl ether of bisphenol-A. Although some weak evidence of carcinogenicity has been reported in animals, when all of the data are considered, the weight of evidence does not show that DGEBA is carcinogenic. Indeed, the most recent review of the available data by the International Agency for Research on Cancer (IARC) has concluded that DGEBA is not classified as a carcinogen.

Epikotol, an impurity in this product (<5 ppm) has been reported to produce cancer in laboratory animals and to produce mutagenic changes in bacteria and cultured human cells. It has been established by the International Agency for Research on Cancer (IARC) as a probable human carcinogen (Group 2B) based on the following conclusions: human evidence - inadequate; animal evidence - sufficient. It has been classified as an anticipated human carcinogen by the National Toxicology Program (NTP). Note: It is unlikely that normal use of this product would result in measurable exposure concentrations to this substance.

12. ECOCLOGICAL INFORMATION

In the non-curled liquid form this product may cause long-term harm if released to the environment. Prevent entry into sewers and natural waters.

Movement and Partitioning:
Biocenocclusion potential is moderate (DEP between 100 and 3000 or Log Kow between 3 and 5).

Degradation and Transformation:
Theoretical oxygen demand is calculated to be 2.35 p.p.m. 20-day biochemical oxygen demand is <2.5%.

Ectotoxicology: Materials are moderately toxic to aquatic organisms on an acute basis. LC50/EC50 between 1 and 10 mg/L in most sensitive species.

13. DISPOSAL CONSIDERATIONS

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

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

14. TRANSPORTATION INFORMATION

DOT Non-Bulk
SHIPPING NAME: Not regulated.
TECHNICAL SHIPPING NAME: Not applicable.

MSDS #105-13a
Last Revised: 26APR13
HAZARD CLASS: Not applicable.
I.N.A. NUMBER: Not applicable.
PACKING GROUP: Not applicable.

IMDG
SHIPPING NAME: Environmentally hazardous substance, liquid, n.o.s.
TECHNICAL SHIPPING NAME: Epoxy Resin.
HAZARD CLASS: Class 9.
UN NUMBER: UN3082.
PACKING GROUP: PG III.
Emg Number: F-A, S-F
MARINE POLLUTANT: Yes

ICAO/IATA
SHIPPING NAME: Environmentally hazardous substance, liquid, n.o.s.
TECHNICAL SHIPPING NAME: Epoxy Resin.
HAZARD CLASS: Class 9.
UN NUMBER: UN3082.
PACKING GROUP: PG III.
MARINE POLLUTANT: Yes

15. REGULATORY INFORMATION
OSHA STATUS: Intant.
TSCA STATUS: All components are listed on TSCA inventory or otherwise comply with TSCA requirements.
Canada WHMIS Classification: D2B - Toxic material causing other toxic effects.
CEPA Chemical Inventory Status: All components are listed or are otherwise compliant with CEPA requirements.
SARA TITLE III:
SECTION 313 TOXIC CHEMICALS: None (denimus).
STATE REGULATORY INFORMATION:
The following chemicals are specifically listed or otherwise regulated by individual states. For details on your regulatory requirements you should contact the appropriate agency in your state.

<table>
<thead>
<tr>
<th>COMPONENT NAME</th>
<th>CAS NUMBER</th>
<th>CONCENTRATION</th>
<th>STATE CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy resin</td>
<td>125-69-5</td>
<td>&lt; 5 ppm</td>
<td>CA</td>
</tr>
<tr>
<td>Benzy alcohol</td>
<td>100-51-6</td>
<td></td>
<td>WA, PA, NJ</td>
</tr>
</tbody>
</table>

1. These substances are known to the state of California to cause cancer or reproductive harm, or both.

16. OTHER INFORMATION
REASON FOR ISSUE: Changes made in Section 14 and 15.
PREPARED BY: G. M. House
APPROVED BY: G. M. House
TITLE: Health, Safety & Environmental Manager
APPROVAL DATE: April 26, 2013
SUPERSEDES DATE: March 9, 2012
MSDS NUMBER: 125-13a

This information is furnished without warranty, expressed or implied, except that it is accurate to the best knowledge of West System Inc. The data on this sheet is related only to the specific material designated herein. West System Inc. assumes no legal responsibility for use or reliance upon these data.
MATERIAL SAFETY DATA SHEET
West System Inc.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

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

MANUFACTURER:
West System Inc.
1120 Peterson Ave.
Bay City, MI 48706, U.S.A.
Phone: 800-637-8797 or 989-684-7286
www.westsystem.com

EMERGENCY TELEPHONE NUMBERS:
Transportation
Chemical Spill Operator
800-424-9300 (U.S.)
703-527-3857 (International)
Non-transportation
Poison Hotline
800-222-1222

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
DANGER. Causes burns to eyes and skin. Harmful if swallowed. Harmful if absorbed through the skin. May be harmful if inhaled. May cause allergic reaction. Amber colored liquid with ammonia odor.

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

POSSIBLE HEALTH EFFECTS:

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

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

ACUTE SKIN CONTACT: May cause severe irritation. Redness. Possible mild corrosion.

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

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

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

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

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

3. COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

<table>
<thead>
<tr>
<th>INGREDIENT NAME</th>
<th>CAS #</th>
<th>CONCENTRATION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction products of triethylenetetramine with phenol/formaldehyde</td>
<td>250-10-77-5</td>
<td>40-70</td>
</tr>
<tr>
<td>Polynaphthaleimonamines</td>
<td>6131-73-7</td>
<td>10-30</td>
</tr>
<tr>
<td>Triethylenetetramine</td>
<td>112-24-3</td>
<td>5-20</td>
</tr>
<tr>
<td>Hydroxybenzene</td>
<td>108-85-2</td>
<td>1-10</td>
</tr>
<tr>
<td>Reaction products of triethylenetetramine and propylene oxide</td>
<td>2500-5-2-5</td>
<td>1-10</td>
</tr>
<tr>
<td>Tetraethylenetetramine</td>
<td>112-57-2</td>
<td>1-10</td>
</tr>
</tbody>
</table>

4. FIRST AID MEASURES

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

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

MSDS #05-13a List Revised: 26APR13
FIRST AID FOR INHALATION: Move to fresh air and consult physician if effects occur.

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

6. FIRE FIGHTING MEASURES

FLASH POINT: >270°F (PMCC)

EXTINGUISHING MEDIA: Dry chemical, alcohol foam, carbon dioxide (CO₂), dry sand, limestone powder.

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

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

7. ACCIDENTAL RELEASE MEASURES

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

HANDLING AND STORAGE

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

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

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

6. EXPOSURE CONTROLS/PERSONAL PROTECTION

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

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

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

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

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

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

PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL FORM: Liquid
COLOR: Amber
ODOR: Ammonia-like
BOILING POINT: 174°F
MELTING POINT/FREEZE POINT: Approximately 23°F
pH: Alkaline
SOLUBILITY IN WATER ................................................. Appreciable.
SPECIFIC GRAVITY .................................................. 1.05
BULK DENSITY ...................................................... 3.05 pounds/gallon.
VAPOR PRESSURE .................................................. < 1 mmHg @ 20°C.
VAPOR DENSITY ..................................................... Heavier than air.
VISCOSITY .......................................................... 1,000 cPs

% VOLATILE BY WEIGHT ............................................. ASTM D3003-97 was used to determine the volatile matter content of mixed epoxy resin and hardener. 105 Resin and 205 Hardener, mixed together at 5:1 by weight, has a density of 1137 g/L (9.49 lb/gal). The combined VOC content for 105/205 is 7.91 g/L (0.07 lb/gal).

10. STABILITY AND REACTIVITY

STABILITY: ......................................................... Stable.
HAZARDOUS POLYMERIZATION: ................................ Will not occur.
INCOMPATIBILITIES: .............................................. Avoid excessive heat. Avoid acids, oxidizing materials, halogenated organic compounds (e.g., methylene chloride). Excessive heating or self-heating could result in rapid temperature increase and serious hazard. If such a reaction were to take place in a waste drum, the drum could expand and rupture violently.
DECOMPOSITION PRODUCTS: .................................. Very toxic fumes and gases when burned or otherwise heated to decomposition. Decomposition products may include, but not limited to: oxides of nitrogen, volatile amines, ammonia, nitric acid, amines, nitroamines.

11. TOXICOLOGICAL INFORMATION

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

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

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

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

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

12. ECOLOGICAL INFORMATION

In the non-cured, liquid form, this product may be harmful if released to the environment. Do not allow into sewers, on the ground or in any body of water.

13. DISPOSAL CONSIDERATIONS

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

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

14. TRANSPORTATION INFORMATION

DOT Non-Risk
SHIPPING NAME: .................................................. Polymers, liquid, corrosive, n.o.s.
TECHNICAL SHIPPING NAME: ................................ Triethylenetetramine
HAZARD CLASS: ...................................................... Class 8
UN/NAT. NUMBER: .............................................. UN 2735
PACKING GROUP: .................................................. PG III
MARINE POLLUTANT: ............................................ No

IATA
SHIPPING NAME: .................................................. Polymers, liquid, corrosive, n.o.s.
TECHNICAL SHIPPING NAME: ................................ Triethylenetetramine
HAZARD CLASS: ...................................................... Class 8
UN/NAT. NUMBER: .............................................. UN 2735
PACKING GROUP: .................................................. PG III

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Last Revised: 26APR13

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MARINE POLLUTANT: No

IMDG
SHIPPING NAME: Polymers, liquid, corrosive, n.o.s.
TECHNICAL SHIPPING NAME: Triethylene tetramine
HAZARD CLASS: Class 5
U.N. NUMBER: UN 2733
PACKING GROUP: PG III
EnS Number: F-A, C-B
MARINE POLLUTANT: No

15. REGULATORY INFORMATION

OSHA STATUS: Corrosive, possible condenser.
TSCA STATUS: All components listed on TSCA inventory or otherwise comply with TSCA requirements.

Canada Wastes Classification: D2A — Very toxic material causing other toxic effects; C — Corrosive
CEPA Chemical Inventory Status: All components are listed or are otherwise compliant with CEPA requirements.

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

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

<table>
<thead>
<tr>
<th>COMPONENT NAME</th>
<th>CONCENTRATION</th>
<th>STATE CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetraethylene tetramine</td>
<td>112-67-2</td>
<td>MA, NJ, PA</td>
</tr>
<tr>
<td>Tetraethylene tetramine</td>
<td>112-24-3</td>
<td>MA, NJ, PA</td>
</tr>
<tr>
<td>Phenol</td>
<td>108-95-2</td>
<td>NJ, RI, PA, MA, IL</td>
</tr>
</tbody>
</table>

16. OTHER INFORMATION

REASON FOR ISSUE: Changes made in Sections 5, 10, 14 & 15.
PREPARED BY: G. M. House
APPROVED BY: G. M. House
TITLE: Health, safety & Environmental Manager
APPROVAL DATE: April 26, 2013
SUPERScedes DATE: February 10, 2011
MEPS NUMBER: 205-13a

This information is furnished without warranty, expressed or implied, except that it is accurate to the best knowledge of West System Inc. The data on this sheet is related only to the specific material designated herein. West System Inc. assumes no legal responsibility for use of reliance upon these data.

MIDS #205-13a Last Revised: 26APR13
Material Safety Data Sheet

Section 1: PRODUCT AND COMPANY IDENTIFICATION

MSDS Identification: Carbon Fabric, Sized or Un-sized
MSDS Number: 439-3227-00SU-C000-12  Date: October 1, 2002  Page: 1 of 6
Supersedes MSDS: 439-3227-00SU-C000-11

Manufacturer:               Emergency Telephone Number:
Hexcel Schwebel             800-433-5072 (24-Hour)
2200 South Murray Avenue    Information Telephone Number:
P.O. Box 2627               864-260-5799 (Normal Business Hours-ET)
Anderson, SC 29621

Product Identification: Carbon Fabric: Sized or Un-sized

Chemical Family: Woven Carbon Fabric with various types of Sized and Un-sized Carbon Fibers.

Section 2: COMPOSITION/INFORMATION ON INGREDIENTS

<table>
<thead>
<tr>
<th>Component</th>
<th>CAS Number</th>
<th>% by Weight</th>
<th>OSHA(PEL)</th>
<th>ACGIH(™)(TLV™)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon fiber,</td>
<td>7440-44-0</td>
<td>98.3-100</td>
<td>15 mg/m³(Total)</td>
<td>10 mg/m³(Total)</td>
</tr>
<tr>
<td>synthetic</td>
<td></td>
<td></td>
<td>5 mg/m³(Respirable)</td>
<td>3 mg/m³(Respirable)</td>
</tr>
</tbody>
</table>

This product is not classified as a Hazardous Chemical as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

Where specific exposure limits for component dusts are not established, the levels provided for (Total/Inhalable) dust and (Respirable) fraction reflect the classification of Particulates Not Otherwise Regulated (PNOR) by OSHA or Specified (PNOS) by ACGIH®.

Section 3: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:
Appearance and Odor:
Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.

Statement of Hazard:
Warning! May cause temporary mechanical irritation of the eyes, skin or upper respiratory tract.

If sized, vapor or fumes generated from heating or curing this product may cause eye and respiratory tract irritation.

Carbon fibers or dust are electrically conductive and may create electrical short-circuits which could result in damage to and malfunction of electrical equipment and/or personal injury.
Section 3: HAZARDS IDENTIFICATION (Continued)

EMERGENCY OVERVIEW (continued):
Primary Routes of Exposure:
Eye--Yes  Skin--Yes  Inhalation--Yes  Ingestion--No

HMIS® Rating:
Health--1  Flammability--0  Reactivity--0  Special--None

Potential Health Effects:
Eye: Contact may cause mechanical irritation to the eyes. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the eyes. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Skin: Contact may cause mechanical irritation to the skin and possible dermatitis. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Inhalation: May cause mechanical irritation to the upper respiratory tract. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the respiratory tract. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Ingestion: Ingestion unlikely under normal conditions of use. If any of this product or the cured product dust is swallowed, seek medical attention immediately.

Medical Conditions Aggravated by Exposure: Preexisting eye, skin or respiratory disorders may be aggravated by exposure to this product or to the dust from machining, grinding or sawing the cured product.

Carcinogenic Information: None of the components present in this material at concentrations equal to or greater than 0.1 % are listed or regulated by IARC, NTP, OSHA or ACGIH® as a carcinogen.

Other:

<table>
<thead>
<tr>
<th>OSHA(PEL)</th>
<th>ACGIH®(TLV®)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mg/m³(Total)</td>
<td>10 mg/m³(Inhalable)</td>
</tr>
<tr>
<td>5 mg/m³(Respirable)</td>
<td>3 mg/m³(Respirable)</td>
</tr>
</tbody>
</table>

Section 4: FIRST AID MEASURES

Eye: In case of eye contact, immediately flush eyes with large amounts of water for at least 15 minutes. Keeping the eyelids open. Get medical attention immediately.

Skin: In case of contact that causes irritation, immediately wash skin with soap and room temperature to cool running water. Use a washcloth to help remove the fibers. To avoid further irritation, do not rub or scratch irritated areas. Rubbing or scratching may force fibers into the skin. Get medical attention immediately, if the irritation persists.

Inhalation: If large amounts of dust, fiber, fumes or vapor are inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, qualified personnel may administer oxygen. Get medical attention immediately.
Section 4: FIRST AID MEASURES (Continued)

Ingestion: Ingestion of this product or the dust from it is unlikely. If swallowed, get medical attention immediately.

Section 5: FIRE FIGHTING MEASURES

Flash Point/Method of Determination: Not determined
Means of Extinction: Use water spray, dry chemical or CO₂ to extinguish fires.
Special Fire Hazards: Avoid exposure through use of a self-contained, positive-pressure breathing apparatus.

Section 6: ACCIDENTAL RELEASE MEASURES

Procedures in case of Accidental Release or Leakage: Avoid contact with skin, eyes or clothing (See Section 8). Clean up material, put into a suitable container and dispose of properly (See Section 13).

Section 7: HANDLING AND STORAGE

Precautions to be taken in Handling and Storage: Store in a cool, dry place. Maintain sealed against contamination from dirt and moisture.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Eye/face Protection: Avoid eye contact. Wear safety glasses with side shields, as necessary, when using this product or when machining, grinding or sawing the cured product.
Skin Protection: Protective clothing such as a loose fitting long sleeved shirt that covers to the base of the neck, long pants and gloves, as necessary to prevent irritation. Skin irritation is known to occur primarily at pressure points such as around the neck, wrist, waist and between the fingers.
Respiratory Protection: Not ordinarily required. If sized and sufficient vapor or fumes are being generated during heating or curing of this product, use a NIOSH approved organic vapor respirator. If sufficient dust or fibers are generated during use or when machining, grinding or sawing the cured product, use a NIOSH approved dust respirator.
Ventilation: Use local exhaust sufficient to control vapor, fumes, fibers or dust generated. If exhaust ventilation is not available or is inadequate, use a NIOSH approved respirator, as appropriate.
General Hygiene Recommendations: Before eating, drinking, smoking or using toilet facilities, wash face and hands thoroughly with soap and water. Remove any contaminated clothing and launder before reuse. Use vacuum equipment to remove fibers and dust from clothing and work areas. Compressed air is not recommended.
Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor: Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.

Melting Point (°F/°C)..................... 6512°F/3600°C
Specific Gravity (Water=1).............. 1.5-1.9
pH of Undiluted Product.................. Not determined
Volatile [Percent (%) by Weight]....... 0
Percent (%) VOC........................... Not determined
Solubility in Water....................... Negligible

Section 10: STABILITY AND REACTIVITY

Stability: Stable under proper handling and storage conditions

Incompatible Materials: None

Products evolved from Heat of Combustion or Decomposition: The products of combustion and decomposition depend on other materials present in the fire and the actual conditions of the fire. Burning will decompose the sizing system, if appropriate, and produce carbon and nitrogen oxides, phenols, aldehydes, acrolein, carboxylic acid, traces of incompletely burned carbon products and other unidentified gases and vapors that may be toxic. Avoid inhalation.

Hazardous Polymerization: Will not occur under proper conditions of use. Rapid heating of the product in bulk may produce an uncontrolled exothermic reaction that may char and decompose the sizing system, if appropriate, generating unidentified gases and vapors that may be toxic. Avoid inhalation.

Section 11: TOXICOLOGICAL INFORMATION

Component Toxicity Data:
Median Lethal Dose (Species):
Oral (LD₅₀).................. Not determined
Inhalation (LC₅₀).............. Not determined
Dermal (LD₅₀).................. Not determined

Irritation Index, Estimation of Irritation (Species):
Skin........ Not determined
Eyes........ Not determined
Inhalation........ Not determined

Section 12: ECOLOGICAL INFORMATION

No ecological data has been determined.
Section 13: DISPOSAL CONSIDERATIONS

Waste Disposal Methods: Material for disposal should be placed in appropriate sealed containers to avoid potential human and environmental exposure. It is the responsibility of the generator to comply with all federal, state, provincial and local laws and regulations. We recommend that you contact an appropriate waste disposal contractor and environmental agency for relevant laws and regulations. Under the U.S., Resource Conservation and Recovery Act (RCRA), it is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification.

Section 14: TRANSPORT INFORMATION

DOT:
Proper Shipping Name.... Not regulated
Hazard Class............... Not regulated
Identification Number..... Not regulated
Packing Group............... Not regulated
Label Required............... None

Section 15: REGULATORY INFORMATION

SARA Title III:
Section 302/304 Extremely Hazardous Substance:
None
Section 311 Hazardous Categorization:
None
Section 313 Toxic Chemicals:
None
CERCLA Section 102(a) Hazardous Substance:
None

RCRA Information:
Currently, the product is not listed in federal hazardous waste regulations 40 CFR, Part 261.33, paragraphs (e) or (f), i.e. chemical products that are considered hazardous if they become wastes. State or local hazardous waste regulations may also apply if they are different from the federal regulation. It is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification and to assure proper disposal.

WHMIS (Canada):
Classification:
None

This product has been classified in accordance with hazard criteria of the "Controlled Products Regulations" and this MSDS contains all the information required by the "Controlled Products Regulations."

Ingredient Disclosure List:
None
Section 15: REGULATORY INFORMATION (Continued)

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): Warning! The state of California has determined that the following listed component chemicals in this product may cause cancer, birth defects or other reproductive harm:

None

U.S., EPA, TSCA Information: This product is an article as defined by TSCA and is not required to be listed in the TSCA inventory.

Ozone Depletion Information: This product does not contain or is not manufactured with ozone depleting substances as identified in Title VI, Clean Air Act "Stratospheric Ozone Protection" and the regulations set forth in 40 CFR, Part 82.

Section 16: OTHER INFORMATION

Special Precautions: Airborne carbon fibers or dust are electrically conductive and may create electrical short-circuits that could result in damage to and malfunction of electrical equipment and/or personal injury.

Explanation and Disclaimer: Wherever such words or phrases as "hazardous," "toxic," "carcinogen," etc. appear herein, they are used as defined or described under state employee right-to-know laws, Federal OSHA laws or the direct sources for these laws such as the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), etc. The use of such words or phrases should not be taken to mean that we deem or imply any substance or exposure to be toxic, hazardous or otherwise harmful. Any exposure can only be understood within the entire context of its occurrence, which includes such factors as the substance's characteristics as defined in the MSDS, amount and duration of exposures, other chemicals present and preexisting individual differences in response to the exposure.

The data provided in this MSDS is based on the information received from our raw material suppliers and other sources believed to be reliable. We are supplying you this data solely in compliance with the Federal OSHA Hazard Communication Standard, 29 CFR 1910.1200 and other Federal and state laws as described in Section 15: Regulatory Information.

The information contained in this MSDS is proprietary and confidential to Hexcel Corporation. This MSDS and the information in it are not to be used for purposes other than compliance with the Federal OSHA Hazard Communication Standard. If you have received this MSDS from any source other than Hexcel Corporation or its authorized agent, the information contained in it may have been modified from the original document and it may not be the most current revision.

Liability, if any, for use of this product is limited to the terms contained in our sale terms and conditions. We do not in any way warrant (expressed or implied, including any implied warranty for merchantability or fitness for a particular purpose) the data contained or the product described in this MSDS. Additionally, we do not warrant that the product will not infringe any patent or other proprietary or property rights of others.

Contact: David M. Rubin,
Hexcel Schwebel Environmental, Health and Safety Manager
1. PRODUCT AND COMPANY IDENTIFICATION

Product name: Loctite Epoxy Heavy Duty Resin
Product type: 2-Component epoxy adhesive
IDH number: 1071245
Region: United States
Company address:
Henkel Corporation
One Henkel Way
Rocky Hill, Connecticut 06067

2. HAZARDS IDENTIFICATION

Emergency Overview

Physical state: Liquid
Color: Translucent, Clear
Odor: None

Health: 2
Flammability: 1
Physical Hazard: 0

Personal Protection: See MSDS Section 8

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

Relevant routes of exposure: Skin, Inhalation, Eyes

Potential Health Effects

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

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

This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200). See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous components

<table>
<thead>
<tr>
<th>Component</th>
<th>CAS NUMBER</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxyloxydihydric, -4,4'-bispropylene diphenol resin</td>
<td>20068-33-6</td>
<td>&gt; 90</td>
</tr>
</tbody>
</table>

4. FIRST AID MEASURES

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

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

Eye contact: In case of contact with the eyes, rinse immediately with plenty of water for 15 minutes, and seek immediate medical attention.
5. FIRE FIGHTING MEASURES

Flash point: > 249 °C (> 480.2 °F) Pensky Martens closed cup
Autoignition temperature: Not available.
Flammable/Explosive limits - lower: Not available.
Flammable/Explosive limits - upper: Not available.
Extinguishing media: Foam, dry chemical or carbon dioxide.
Special firefighting procedures: Wear self-contained breathing apparatus and full protective clothing, such as turnout gear.
Unusual fire or explosion hazards: In case of fire, keep containers cool with water spray. Closed containers may rupture (due to build up of pressure) when exposed to extreme heat.

6. ACCIDENTAL RELEASE MEASURES

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

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

7. HANDLING AND STORAGE

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

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

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

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

<table>
<thead>
<tr>
<th>Hazardous components</th>
<th>ACGIH TLV</th>
<th>OSHA PEL</th>
<th>AIHA WEEL</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epichlorohydin-4,4'-isopropylene dipheno resin</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Engineering controls: Provide adequate local exhaust ventilation to maintain worker exposure below exposure limits.
Respiratory protection: Use a NIOSH-approved air-purifying respirator if the potential to exceed established exposure limits exists.
Eye/face protection: Safety goggles or safety glasses with side shields.
Skin protection: Chemical resistant, impermeable gloves.

IDH number: 1071245

Page 2 of 4

Product name: Loctite Epoxy Heavy Duty Resin
9. PHYSICAL AND CHEMICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical state</td>
<td>Liquid</td>
</tr>
<tr>
<td>Color:</td>
<td>Translucent, Clear</td>
</tr>
<tr>
<td>Odor:</td>
<td>None</td>
</tr>
<tr>
<td>Odor threshold:</td>
<td>Not available</td>
</tr>
<tr>
<td>pH:</td>
<td>Not available</td>
</tr>
<tr>
<td>Vapor pressure:</td>
<td>0.03 mm Hg</td>
</tr>
<tr>
<td>Boiling point/Range:</td>
<td>&gt; 250.2 °C (&gt; 500.4 °F)</td>
</tr>
<tr>
<td>Melting point/range:</td>
<td>Not available</td>
</tr>
<tr>
<td>Specific gravity:</td>
<td>1.17</td>
</tr>
<tr>
<td>Vapor density:</td>
<td>Not available</td>
</tr>
<tr>
<td>Flash point:</td>
<td>&gt; 245 °C (&gt; 485.2 °F) Pensky Martens closed cup</td>
</tr>
<tr>
<td>Flammable/Explosive limits - lower:</td>
<td>Not available</td>
</tr>
<tr>
<td>Flammable/Explosive limits - upper:</td>
<td>Not available</td>
</tr>
<tr>
<td>Autoignition temperature:</td>
<td>Not available</td>
</tr>
<tr>
<td>Evaporation rate:</td>
<td>Not available</td>
</tr>
<tr>
<td>Solubility in water:</td>
<td>Slight</td>
</tr>
<tr>
<td>Partition coefficient (n-octanol/water):</td>
<td>Not available</td>
</tr>
<tr>
<td>VOC content:</td>
<td>0.10 % (value for resin and hardener together)</td>
</tr>
</tbody>
</table>

10. STABILITY AND REACTIVITY

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>Stable</td>
</tr>
<tr>
<td>Hazardous reactions</td>
<td>Will not occur.</td>
</tr>
<tr>
<td>Hazardous decomposition products</td>
<td>None</td>
</tr>
<tr>
<td>Incompatible materials</td>
<td>Strong oxidizing agents, Strong bases, Strong acids, Amines.</td>
</tr>
<tr>
<td>Conditions to avoid</td>
<td>Excessive heat, store away from incompatible materials.</td>
</tr>
</tbody>
</table>

11. TOXICOLOGICAL INFORMATION

<table>
<thead>
<tr>
<th>Hazardous components</th>
<th>NTP Carcinogen</th>
<th>IARC Carcinogen</th>
<th>OSHA Carcinogen (Specifically Regulated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eponolohydin-4,4'-isopropylidene diphenoil resin</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Eponolohydin-4,4'-isopropylidene diphenoil resin</td>
<td>Health Effects/Target Organs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eponolohydin-4,4'-isopropylidene diphenoil resin</td>
<td>Allergen, Irritant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. ECOLOGICAL INFORMATION

| Ecological Information | Not available. |

13. DISPOSAL CONSIDERATIONS

<table>
<thead>
<tr>
<th>Information provided is for unused product only.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended method of disposal:</td>
</tr>
<tr>
<td>Hazardous waste number:</td>
</tr>
</tbody>
</table>

14. TRANSPORT INFORMATION

<table>
<thead>
<tr>
<th>U.S. Department of Transportation Ground (49 CFR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper shipping name:</td>
</tr>
<tr>
<td>Hazard class or division:</td>
</tr>
<tr>
<td>Identification number:</td>
</tr>
<tr>
<td>Packing group:</td>
</tr>
</tbody>
</table>

IDM number: 1071248
**International Air Transportation (ICAO/IATA)**
- Proper shipping name: Environmentally hazardous substance, liquid, n.o.s. (Bisphenol-A Epoxy Resin resin)
- Hazard class or division: 9
- Identification number: UN 3052
- Packing group: III

**Water Transportation (IMOI/MDG)**
- Proper shipping name: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S. (Bisphenol-A Epoxy Resin resin)
- Hazard class or division: 9
- Identification number: UN 3052
- Packing group: III
- Marine pollutant: Bisphenol-A Epoxy Resin resin

### 15. REGULATORY INFORMATION

#### United States Regulatory Information
- TSCA 8(b) Inventory Status: All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.
- TSCA 12(b) Export Notification: None above reporting de minimis
- CERCLA/USARA Section 302 EHS: None above reporting de minimis
- CERCLA/USARA Section 111/112: Not available.
- CERCLA/USARA 313: None above reporting de minimis
- California Proposition 65: This product contains a chemical known in the State of California to cause cancer. This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

#### Canada Regulatory Information
- CEPA DSL/INDS Status: All components are listed on or are exempt from listing on the Canadian Domestic Substances List.

### 15. OTHER INFORMATION
This material safety data sheet contains changes from the previous version in sections: Not available.

Prepared by: Donna Houston, Regulatory Affairs Specialist

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Material Safety Data Sheet

Revision Number: 004.0 Issue date: 12/27/2011

1. PRODUCT AND COMPANY IDENTIFICATION

Product name: Loctite Epoxy Heavy Duty Hardener
Product type: Epoxy hardener
ID number: 1137985
Item number: 103465
Region: United States

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

Contact Information:
Telephone: 860-571-5100
MEDICAL EMERGENCY Phone: Poison Control Center 1-877-671-4505 (toll free) or 1-303-592-1711
TRANSPORT EMERGENCY Phone: CHEMTREC 1-800-424-9300 (toll free) or 1-703-527-3587
Internet: www.henkelca.com

2. HAZARDS IDENTIFICATION

Physical state: Liquid
Color: Amber, Clear
Odor: Amine, Mercaptan

EMERGENCY OVERVIEW

HEALTH: 3
FLAMMABILITY: 1
PHYSICAL HAZARD: 1
Personal Protection: See MSDS Section 8

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

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

Potential Health Effects

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

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

Eye contact: Burns. Severe eye irritation. Redness. Tissue damage. May be harmful if swallowed. May cause burns of mouth and throat if swallowed.

Ingestion: Eye, skin, and respiratory disorders. Skin allergies.

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

See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

<table>
<thead>
<tr>
<th>Hazardous components</th>
<th>CAS NUMBER</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly[oxy[methylene-1,2-ethanediyl]]-2,2-bis(hydroxyethyl)ether, with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptop</td>
<td>72244-99-5</td>
<td>60 - 100</td>
</tr>
<tr>
<td>N-Aminoethylpiperazine</td>
<td>140-31-8</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Aliphatic Amines</td>
<td>Unknown</td>
<td>5 - 10</td>
</tr>
<tr>
<td>2,4,6-Tris(dimethylaminoethyl)phenol</td>
<td>90-72-2</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Silica, amorphous, fumed, crystal-free</td>
<td>112945-52-5</td>
<td>1 - 5</td>
</tr>
</tbody>
</table>

ID number: 1137985
4. FIRST AID MEASURES

Inhalation: Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. If symptoms develop and persist, get medical attention.

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

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

Ingestion: DO NOT induce vomiting unless directed to do so by medical personnel. Keep individual calm. Get medical attention.

5. FIRE FIGHTING MEASURES

Flash point: > 90 °C (~ 194.4 °F) Tegliabue closed cup

Autoignition temperature: Not available.

Flammable/Explosive limits - lower: Not available.

Flammable/Explosive limits - upper: Not available.

Extinguishing media: Water spray (foam), foam, dry chemical or carbon dioxide.

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

Unusual fire or explosion hazards: In case of fire, keep containers cool with water spray.


6. ACCIDENTAL RELEASE MEASURES

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

Environmental precautions: Do not empty into drains / surfoot water / ground water.

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

7. HANDLING AND STORAGE

Handling: Keep away from heat, spark and flame. Keep container closed. Avoid breathing vapors or mists of this product. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.

Storage: For safe storage, store at or below 37.8 °C (100°F). Store in original container until ready to use. Keep in a cool, well ventilated area away from heat, sparks and open flame. Keep container tightly closed until ready for use.

For information on product shelf life contact Henkel Customer Service at (800) 243-4874.
8. EXPOSURE CONTROLS / PERSONAL PROTECTION

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

<table>
<thead>
<tr>
<th>Hazardous components</th>
<th>ACGIH TLV</th>
<th>OSHA PEL</th>
<th>AIHA WEEL</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyoxymethylene-1,2-ethanediyl), 3-hydroxy-2,2-bis(hydroxymethyl)-1,3-propanediol (2:1), 2-hydroxy-3-mercaptop</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>N-Aminoethylpiperazine</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Aliphatic Amines</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2,4,6-Tris(dimethylaminomethyl)phenol</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Silica, amorphous, fumed, crystal-free</td>
<td>10 mg/m³ TWA Inhalable dust. 3 mg/m³ TWA Respirable fraction.</td>
<td>25 MPCCF TWA 0.8 mg/m³ TWA</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Engineering controls:
Use local ventilation if general ventilation is insufficient to maintain vapor concentration below established exposure limits.

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

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

Skin protection:
Chemical resistant, impervious gloves.

9. PHYSICAL AND CHEMICAL PROPERTIES

- Physical state: Liquid
- Color: Amber, Clear
- Odor: Amines,Mercaptan
- Odor threshold: Not available.
- pH: Not available.
- Vapor pressure: Not available.
- Boiling point/range: Not available.
- Melting point/range: Not available.
- Specific gravity: 1.04
- Vapor density: Not available.
- Flash point: > 93 °C (199.4 °F) Tagliatue closed cup

Flammable/Explosive limits - lower: Not available.
Flammable/Explosive limits - upper: Not available.
Autoignition temperature: Not available.
Evaporation rate: Not available.
Solubility in water: Slightly soluble
Partition coefficient (n-octanol/water): Not available.
VOC content: 0.38 %; 37 g/l EPA Method 24

10. STABILITY AND REACTIVITY

- Stability: Stable
- Hazardous reactions: Will not occur.
- Hazardous decomposition products: None
- Conditions to avoid: Excessive heat. Store away from incompatible materials.
11. TOXICOLOGICAL INFORMATION

<table>
<thead>
<tr>
<th>Hazardous components</th>
<th>NTP Carcinogen</th>
<th>IARC Carcinogen</th>
<th>OSHA Carcinogen (Specifically Regulated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly[oxy(methyl-1,2-ethanediyl)]-3-hydroxy-4-hydroxy, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercapto</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N-Aminooctylpiperazine</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Aliphatic Amines</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2,4,6-Tris(dimethylaminomethyl)phenol</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Silica, amorphous, fused, crystal-free</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazardous components</th>
<th>Health Effects/Target Organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly[oxy(methyl-1,2-ethanediyl)]-3-hydroxy-4-hydroxy, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercapto</td>
<td>No Records</td>
</tr>
<tr>
<td>N-Aminooctylpiperazine</td>
<td>Irritant, Corrosive, Allergen</td>
</tr>
<tr>
<td>Aliphatic Amines</td>
<td>No Data</td>
</tr>
<tr>
<td>2,4,6-Tris(dimethylaminomethyl)phenol</td>
<td>Irritant, Allergen</td>
</tr>
<tr>
<td>Silica, amorphous, fused, crystal-free</td>
<td>Nuisance dust</td>
</tr>
</tbody>
</table>

12. ECOLOGICAL INFORMATION

Ecological information: Not available.

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

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

Hazardous waste number: Not a RCRA hazardous waste.

14. TRANSPORT INFORMATION

U.S. Department of Transportation (49 CFR)

<table>
<thead>
<tr>
<th>Hazard class or division:</th>
<th>Identification number:</th>
<th>Packing group:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amines, liquid, corrosive, n.o.s.</td>
<td>UN 2735</td>
<td>II</td>
</tr>
</tbody>
</table>

International Air Transportation (ICAO/IATA)

<table>
<thead>
<tr>
<th>Hazard class or division:</th>
<th>Identification number:</th>
<th>Packing group:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amines, liquid, corrosive, n.o.s.</td>
<td>UN 2735</td>
<td>II</td>
</tr>
</tbody>
</table>

Water Transportaton (IMO/IMDG)

<table>
<thead>
<tr>
<th>Hazard class or division:</th>
<th>Identification number:</th>
<th>Packing group:</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMINES, LIQUID, CORROSIVE, N.O.S.</td>
<td>UN 2735</td>
<td>II</td>
</tr>
</tbody>
</table>

15. REGULATORY INFORMATION

United States Regulatory Information

TSCA 1(b) Inventory Status: All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.

TSCA 12(b) Export Notification: None above reporting de minimis

IDH number: 1137985

Product name: Loctite Epoxy Heavy Duty Hardener

Page 4 of 5
16. OTHER INFORMATION

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

Prepared by: Gary Pilson, Manager, Regulatory Affairs

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ProX Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: Pro29, Pro38, Pro54, Pro75, and Pro98 Rocket Motor Reload Kits
Battery Motor
Proper Shipping Name: Articles, Explosive, N.O.S. (Ammonium Perchlorate)
Propellant grains: P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX
where: T = reload type (A = adjustable delay, C = C-slot)
# = number of grains & XX = propellant type

Product Use: Solid fuel motor for propelling rockets
Manufacturer: Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: 1-905-857-2370
24 Hour Emergency Telephone Number: 1-613-996-6656 (CANJTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Propellant

<table>
<thead>
<tr>
<th>Ingredient Name</th>
<th>CAS Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Perchlorate</td>
<td>7790-96-9</td>
<td>48-55 %</td>
</tr>
<tr>
<td>Metal Powders</td>
<td></td>
<td>1-4 %</td>
</tr>
<tr>
<td>Synthetic Rubber</td>
<td></td>
<td>13-30 %</td>
</tr>
</tbody>
</table>

Black Powder Ignition pellet

<table>
<thead>
<tr>
<th>Ingredient Name</th>
<th>CAS Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Nitrate</td>
<td>7757-79-1</td>
<td>72-76 %</td>
</tr>
<tr>
<td>Charcoal</td>
<td>n/a</td>
<td>5-18 %</td>
</tr>
<tr>
<td>Sulphur</td>
<td>7734-34-9</td>
<td>9-20 %</td>
</tr>
<tr>
<td>Graphite</td>
<td>7752-42-5</td>
<td>trace</td>
</tr>
</tbody>
</table>

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

These articles contain cylinders of ammonium perchlorate composite propellant, ensheathed in inert plastic parts. The forward closure also contains a few grams of black powder. ProX Rocket motor reload kits are classified as explosives, and may cause serious injury, including death if used improperly. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations. Avoid inhaling exhaust products.
General Appearance:
Cardboard tubes contain various plastic parts. Inside the plastic tube are cylinders of composite propellant (rocket fuel). The forward closure also contains a small quantity of black powder. All parts are odourless solids.

Potential Health Effects:
- **Eye:** Not a likely route of exposure. May cause eye irritation.
- **Skin:** Not a likely route of exposure. Low hazard for usual industrial/hobby handling.
- **Ingestion:** Not a likely route of exposure.
- **Inhalation:** Not a likely route of exposure. May cause respiratory tract irritation. Do not inhale exhaust products.

4.0 FIRST AID MEASURES

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

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

**Ingestion:** Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

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

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

5.0 FIRE FIGHTING MEASURES

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

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

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

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

**Special Instructions / Notes:** These articles burn rapidly and generate a significant flame for a short period of time. Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement. Do not inhale exhaust products.

6.0 ACCIDENTAL RELEASE MEASURES

**Safeguards (Personal):**

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

7.0 HANDLING AND STORAGE

**Handling:** Keep away from heat, sparks and flame. Avoid contamination. Do not get in eyes, on skin or on clothing. Do not taste or swallow. Avoid prolonged or repeated contact with skin. Follow manufacturer's instructions for use.
Storage: Store in a cool, dry place away from sources of heat, spark or flame. Keep in shipping packaging when not in use.

6.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

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

Personal Protective Equipment:

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

Skin:
Clothing should be appropriate for handling pyrotechnic substances.

Clothing:
Clothing should be appropriate for handling pyrotechnic substances.

Respirators:
A respirator is not typically necessary. Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Physical State: solid
Appearance: rubber cylinders inside plastic parts
Odour: none
Odour Threshold: Not available.

pH: Not available.

Vapour Pressure: Not available.

Vapour Density: Not available.

Viscosity: Not available.

Evaporation Rate: Not available.

Boiling Point: Not available.

Freezing/Melting Point: Not available.

Coefficient of Water/Oil Distribution: Not available.

Autoignition Temperature: 200°C

Flash Point: Not available.

Explosion Limits, Lower (LEL): Not available.

Explosion Limits, Upper (UEL): Not available.

Sensitivity to Mechanical Impact: unprotected black powder can be ignited by impact

Sensitivity to Static Discharge: unprotected black powder can be ignited by static discharge

Decomposition Temperature: > 450°C

Solubility in Water: black powder is soluble in water

Specific Gravity/Density: black powder = 1.7-2.1

Molecular Formula: Not applicable

Molecular Weight: Not applicable.

10.0 STABILITY AND REACTIVITY

Chemical Stability:
Stable under normal temperatures and pressures.

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

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

Hazardous Products of Decomposition:
Oxides of nitrogen

Hazardous Polymerization:
Will not occur.
11.0 TOXICOLOGICAL INFORMATION

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

 Effects of Acute Exposure to Product: No data available
 Effects of Chronic Exposure to Product: No data available

 Exposure Limits:

 Black Powder Pellets

<table>
<thead>
<tr>
<th>Ingredient Name</th>
<th>CAS Number</th>
<th>OSHA PEL</th>
<th>ACGIH TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Nitrate</td>
<td>7757-79-1</td>
<td>not established</td>
<td>not established</td>
</tr>
<tr>
<td>Charcoal</td>
<td>n/a</td>
<td>not established</td>
<td>not established</td>
</tr>
<tr>
<td>Sulphur</td>
<td>7784-34-9</td>
<td>not established</td>
<td>not established</td>
</tr>
<tr>
<td>Graphite</td>
<td>7758-42-5</td>
<td>2.5 mg/m³</td>
<td>15 ppm (TWA)</td>
</tr>
</tbody>
</table>

 Propehlant

<table>
<thead>
<tr>
<th>Ingredient Name</th>
<th>CAS Number</th>
<th>OSHA PEL</th>
<th>ACGIH TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Penthionate</td>
<td>7730-95-9</td>
<td>not established</td>
<td>not established</td>
</tr>
<tr>
<td>Metal powder</td>
<td></td>
<td>varies</td>
<td>not established</td>
</tr>
<tr>
<td>Synthetic Rubber</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

12.0 ECOLOGICAL INFORMATION

 Environmental Data:
 Ecotoxicity Data: Not determined.
 EcoFoSTE Data: Not determined.

13.0 DISPOSAL CONSIDERATIONS

 Product As Sold: Pack firmly in hole in ground with nozzle pointing up. Ignite motor electrically from a safe distance and wait 5 minutes before approaching. Dispose of spent components in inert trash.
 Product Packaging: Dispose of used packaging materials in inert trash.
 Special Considerations: Consult local regulations about disposal of explosive materials.
14.0 TRANSPORT INFORMATION

Shipping Information – Canada

TDG Classification: Class 1.4 Explosive
Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number: 0351
UN Classification Code: 1.4 C
Packing Group: III
UN Packing Instruction: 101

Shipping Information – USA / IMO

Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number: 0351
UN Classification Code: 1.4 C
DOT / IMO Label: Class 1 – Explosive – Division 1.4C

Shipping Information – IATA

Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number: 0351
UN Classification Code: 1.4 C
IATA Labels: Class 1 – Explosive – Division 1.4C
Cargo Aircraft Only

15.0 REGULATORY INFORMATION

Canada

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

VRMD Classification: Not controlled (explosive)

Domestic Substance List (DSL) Status: All ingredients are listed on Canada’s DSL List.

Canadian Explosives Classification: Class 7.2.5

This product is an authorized explosive in Canada.

These products are not considered “Controlled Good” in Canada under the Controlled Goods Regulations.

United States of America

TSCA Inventory Status: All ingredients are listed on the TSCA Inventory.

Hazardous Chemical Lists

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

European/International Regulations

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

European Labeling in Accordance with EC Directives

Hazard Symbols: Explosive.

Risk Phrases:
R 2 Risk of explosion by shock, friction, fire or other sources of ignition.
R 11 Highly flammable
R 44 Risk of explosion if heated under confinement.

Safety Phrases:
S 1/2 Keep locked up and out of the reach of children.
S 8 Keep container dry.
S 15 Keep away from heat.
S 14c Keep away from sources of ignition – No smoking.
16.0 OTHER INFORMATION

MSDS Prepared by: Regulatory Affairs Department
Cesaroni Technology Inc.
P.O. Box 249
2551 Stouffville Rd.
Gormley, ON
Canada L0H 1G0

Telephone: 905-897-2370 x239
Fax 905-897-2375
Web Sites: www.cesaronitech.com
www.ProX8.com

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

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

Material Safety Data Sheet

MSDS-BP (Potassium Nitrate)

Revised 3/17/09

<table>
<thead>
<tr>
<th>PRODUCT INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Name</td>
</tr>
<tr>
<td>Trade Names and Synonyms</td>
</tr>
<tr>
<td>Manufacturer/Distributor</td>
</tr>
<tr>
<td>Transportation Emergency</td>
</tr>
</tbody>
</table>

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 transported, handled, stored, and used following proper 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. ALWAYS look up explosive materials and keep away from children and unauthorized persons. 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.

<table>
<thead>
<tr>
<th>HAZARDOUS COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material or Components</td>
</tr>
<tr>
<td>Potassium nitrate</td>
</tr>
<tr>
<td>Charcoal</td>
</tr>
<tr>
<td>Sulfur</td>
</tr>
<tr>
<td>Graphite*</td>
</tr>
</tbody>
</table>

N/A = Not assigned  NE = Not established

* Not contained in all grades of black powder.

P.O. Box 659, Dayline, LA 71023-6590, (318) 385-9300

www.goexpowder.com

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PHYSICAL DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>N/A</td>
</tr>
<tr>
<td>Vapor Pressure</td>
<td>N/A</td>
</tr>
<tr>
<td>Vapor Density</td>
<td>N/A</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>Good</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.70 – 1.82 (mercury method) 1.92 – 2.08 (pycnometer)</td>
</tr>
<tr>
<td>PH</td>
<td>6.0 – 8.0</td>
</tr>
<tr>
<td>Evaporation Rate</td>
<td>N/A</td>
</tr>
<tr>
<td>Appearance and Odor</td>
<td>Black granular powder. No odor detectable.</td>
</tr>
</tbody>
</table>

HAZARDOUS REACTIVITY

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instability</td>
<td>Keep away from heat, sparks, and open flames. Avoid impact, friction and static electricity.</td>
</tr>
<tr>
<td>Incompatibility</td>
<td>When dry, black powder is compatible with most metals; however, it is hygroscopic and when wet, attacks 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.</td>
</tr>
<tr>
<td>Hazardous decomposition</td>
<td>Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.</td>
</tr>
<tr>
<td>Polymerization</td>
<td>Polymerization will not occur.</td>
</tr>
</tbody>
</table>

FIRE AND EXPLOSION DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashpoint</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Auto Ignition Temperature</td>
<td>Approx. Range: 392°F-887°F / 200°C-464°C</td>
</tr>
<tr>
<td>Explosive temperature (5 sec)</td>
<td>Ignites @ approx. 427°C (801°F)</td>
</tr>
<tr>
<td>Extinguishing media</td>
<td>Water</td>
</tr>
<tr>
<td>Special fire fighting procedures</td>
<td>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 5,000 feet (approximately 1 mile) if explosives are heavily encased. Division 1.1 Explosives (not heavily encased): Evacuate the area for 2,500 feet (approximately ¾ mile) if explosives are not heavily encased. Division 1.1 Explosives (all): Consult U.S. DOT Emergency Response Guide 112 for further details.</td>
</tr>
<tr>
<td>Unusual fire and explosion hazards</td>
<td>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.</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>HEALTH HAZARDS</strong></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>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, regulation and ordinances.</td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td>None of the components of Black Powder are listed as a carcinogen by NTP, IARC, or OSHA.</td>
</tr>
<tr>
<td><strong>FIRST AID</strong></td>
<td></td>
</tr>
<tr>
<td>Inhalation</td>
<td>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. Avoid when possible.</td>
</tr>
<tr>
<td>Eye and skin contact</td>
<td>Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water.</td>
</tr>
<tr>
<td>Ingestion</td>
<td>Not a likely route of exposure. If ingested, dilute by giving two glasses of water and induce vomiting. Avoid when possible.</td>
</tr>
<tr>
<td>Injury from detonation</td>
<td>Seek prompt medical attention.</td>
</tr>
<tr>
<td><strong>SPILL OR LEAK PROCEDURES</strong></td>
<td></td>
</tr>
<tr>
<td>Spill/leak response</td>
<td>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 clean up procedures. Carefully pick up spills with non-sparking and non-static producing tools.</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Disposal of in compliance with Federal Regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271).</td>
</tr>
<tr>
<td><strong>SPECIAL PROTECTION INFORMATION</strong></td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td>Use only with adequate ventilation. (If required)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>None</td>
</tr>
<tr>
<td>Eye</td>
<td>None</td>
</tr>
<tr>
<td>Gloves</td>
<td>Impervious rubber gloves. (If required)</td>
</tr>
<tr>
<td>Other</td>
<td>Metal-free and non-static producing clothes</td>
</tr>
</tbody>
</table>
### SPECIAL PRECAUTIONS
- Keep away from friction, impact, and heat and open flame. 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
<table>
<thead>
<tr>
<th>Proper shipping name</th>
<th>Black Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard class</td>
<td>1.1D</td>
</tr>
<tr>
<td>UN Number</td>
<td>UN0027</td>
</tr>
<tr>
<td>DOT Label &amp; Placard</td>
<td>DOT Label EXPOSIVES 1.1D</td>
</tr>
<tr>
<td>DOT Placard</td>
<td>EXPOSIVES 1.1</td>
</tr>
<tr>
<td>Alternate shipping</td>
<td>Limited quantities of GOEX black powder (1# cans only) may be transported as “Black powder for small arms – flammable solid” pursuant to U.S. Department of Transportation 49 CFR.</td>
</tr>
</tbody>
</table>

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, military and independent laboratories, it is given without warranty or representation that it is complete, accurate, and can be relied upon. GOEX, Incorporated, has not attempted to conceal in any manner the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, GOEX, Incorporated, cannot anticipate nor control the many situations in which the product or this information may be used; there is no guarantee that the health and safety precautions suggested will be proper under all conditions. It is the sole responsibility of each user of the product to determine and comply with the requirements of all applicable laws and regulations regarding its use. This information is given solely for the purposes of safety to persons and property. Any other use of this information is expressly prohibited.

For further information contact: GOEX Powder, Incorporated
P. O. Box 659
Dayline, LA 71623-0006
Telephone Number: (318) 382-9300
Fax Number: (318) 382-9303
<table>
<thead>
<tr>
<th>BLACK POWDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRICITION TEST</td>
</tr>
<tr>
<td>PA</td>
</tr>
<tr>
<td>Steel – Snaps</td>
</tr>
<tr>
<td>Fiber – Unaffected</td>
</tr>
<tr>
<td>IMPACT TEST</td>
</tr>
<tr>
<td>PA</td>
</tr>
<tr>
<td>16 Inches (10% Point)</td>
</tr>
<tr>
<td>ELECTROSTATIC DISCHARGE TEST</td>
</tr>
<tr>
<td>Bureau of Mines</td>
</tr>
<tr>
<td>0.8 Joules (Confined)</td>
</tr>
<tr>
<td>12.5 Joules Unconfined</td>
</tr>
<tr>
<td>STABILITY</td>
</tr>
<tr>
<td>70°C International Heat Test – 0.31% Loss</td>
</tr>
<tr>
<td>Vacuum Stability – 0.5cc @ 100°C</td>
</tr>
<tr>
<td>BRISANCE – Sand Test 8 gm</td>
</tr>
<tr>
<td>VELOCITY</td>
</tr>
<tr>
<td>In the open, trains of black powder burn very slowly, measurable in seconds per foot. Confined, as in steel pipe, speeds of explosions have been timed at values from 550 feet per second for very coarse granulations to 2,070 feet per second for the finer granulations. Confinement and granulation will affect the values.</td>
</tr>
<tr>
<td>CHEMICAL DECOMPOSITION</td>
</tr>
<tr>
<td>Use water to dissolve the potassium nitrate. By leaching out the potassium nitrate, the residue of sulfur and charcoal is non-explosive but combustible when dry – dispose separately</td>
</tr>
</tbody>
</table>

| SPECIAL REQUIREMENTS: |
| Black Powder 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. |
| When dry, it is compatible with most metals. However, it is hygroscopic and when wet, attacks all common metals except stainless steel. |
| CAUTION: Explosives must be tested for compatibility with any material not specified in the procurement specification or 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. Explosives include propellants and pyrotechnics. |
MATERIAL SAFETY DATA SHEET

ProFire Igniter

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: ProFire Igniter
Synonyms: Igniter, Initiator
Proper Shipping Name: Igniters
Part Number: Pro150
Product Use: Igniter for solid fuel rocket motor
Manufacturer: Casaroli Technology Inc.,
P.O. Box 248
2511 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: 1-905-887-2370
24 Hour Emergency Telephone Number: 1-813-996-6686 (CANUTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Overdip composition

<table>
<thead>
<tr>
<th>Ingredient Name</th>
<th>CAS Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium chromate</td>
<td>10294-40-3</td>
<td>31-32 %</td>
</tr>
<tr>
<td>Magnesium powder</td>
<td>7439-05-4</td>
<td>42-43 %</td>
</tr>
<tr>
<td>Viton fluoroelastomer</td>
<td>n/a</td>
<td>26-27 %</td>
</tr>
</tbody>
</table>

3.0 HAZARDS IDENTIFICATION

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

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

Potential Health Effects:

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

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

Ingestion:
Not a likely route of exposure.

Inhalation:
Not a likely route of exposure. May cause respiratory tract irritation.
### APPENDIX G: Rocket Dimensions

**Sustainer**

<table>
<thead>
<tr>
<th>Parts Detail</th>
<th>Carbon fiber ( (1.76 \text{ g/cm}^3) )</th>
<th>Ogive</th>
<th>Length: 18 in</th>
<th>Mass: 0.942 lb</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nose cone</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Ogive</td>
<td>Length: 18 in</td>
<td>Mass: 0.942 lb</td>
</tr>
<tr>
<td><strong>Mass component</strong></td>
<td>Diam 2.984 in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Body tube</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 8 in</td>
<td>Mass: 0.716 lb</td>
</tr>
<tr>
<td><strong>Bulkhead</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 0.08 in</td>
<td>Mass: 0.095 lb</td>
</tr>
<tr>
<td><strong>Body tube</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 15 in</td>
<td>Mass: 1.17 lb</td>
</tr>
<tr>
<td><strong>Parachute</strong></td>
<td>Ripstop nylon ( (1.7 \text{ g/m}^2) )</td>
<td>Diam 72 in</td>
<td>Length: 5.5 in</td>
<td>Mass: 0.450 lb</td>
</tr>
<tr>
<td><strong>Shroud Lines</strong></td>
<td>Tubular nylon ( (14 \text{ mm}, 9/16 \text{ in}) )</td>
<td>Lines: 4</td>
<td>Length: 19.811 in</td>
<td></td>
</tr>
<tr>
<td><strong>Parachute</strong></td>
<td>Ripstop nylon ( (1.7 \text{ g/m}^2) )</td>
<td>Diam 188 in</td>
<td>Length: 6.5 in</td>
<td>Mass: 2.23 lb</td>
</tr>
<tr>
<td><strong>Shroud Lines</strong></td>
<td>Tubular nylon ( (25 \text{ mm}, 1 \text{ in}) )</td>
<td>Lines: 4</td>
<td>Length: 17.811 in</td>
<td></td>
</tr>
<tr>
<td><strong>Body tube</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 14 in</td>
<td>Mass: 1.11 lb</td>
</tr>
<tr>
<td><strong>Bulkhead</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 0.079 in</td>
<td>Mass: 0.093 lb</td>
</tr>
<tr>
<td><strong>Bulkhead</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 0.079 in</td>
<td>Mass: 0.093 lb</td>
</tr>
<tr>
<td><strong>Mass component</strong></td>
<td>Diam 3 in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Body tube</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 42 in</td>
<td>Mass: 3.34 lb</td>
</tr>
<tr>
<td><strong>Inner Tube</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 2.126 in</td>
<td>Length: 20 in</td>
<td>Mass: 0.793 lb</td>
</tr>
<tr>
<td><strong>Parachute</strong></td>
<td>Ripstop nylon ( (1.7 \text{ g/m}^2) )</td>
<td>Diam 35 in</td>
<td>Length: 2.5 in</td>
<td>Mass: 0.104 lb</td>
</tr>
<tr>
<td><strong>Shroud Lines</strong></td>
<td>Elastic cord ( (round 2 \text{ mm}, 1/16 \text{ in}) )</td>
<td>Lines: 6</td>
<td>Length: 11.811 in</td>
<td></td>
</tr>
<tr>
<td><strong>Shock cord</strong></td>
<td>Elastic cord ( (round 2 \text{ mm}, 1/16 \text{ in}) )</td>
<td></td>
<td>Length: 80 in</td>
<td>Mass: 0.008 lb</td>
</tr>
<tr>
<td><strong>Trapezoidal fin set (3)</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Thick: 0.125 in</td>
<td></td>
<td>Mass: 1.54 lb</td>
</tr>
<tr>
<td><strong>Engine block</strong></td>
<td>Carbon fiber ( (1.76 \text{ g/cm}^3) )</td>
<td>Diam 4.84 in</td>
<td>Length: 0.197 in</td>
<td>Mass: 0 lb</td>
</tr>
<tr>
<td>Centering ring</td>
<td>Carbon fiber (1.78 g/cm³)</td>
<td>Dia. 2.303 in</td>
<td>Len: 0.079 in</td>
<td>Mass: 0.072 lb</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------</td>
<td>---------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dia 4.34 in</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Centering ring</th>
<th>Carbon fiber (1.78 g/cm³)</th>
<th>Dia. 2.303 in</th>
<th>Len: 0.079 in</th>
<th>Mass: 0.072 lb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dia 4.34 in</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H: Functional Test Plan

USNA ROCKET PROPULSION PROGRAM

FUNCTIONAL TEST PLAN

USNA-TP-R001 20 AUG 2014

Approvals

_________________________________________              __________
Project Engineer                       Date
## RECORD OF CHANGES

<table>
<thead>
<tr>
<th>REVISION LETTER</th>
<th>DATE</th>
<th>TITLE OR BRIEF DESCRIPTION</th>
<th>ENTERED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20 SEP 14</td>
<td>Draft</td>
<td>TM</td>
</tr>
</tbody>
</table>
Introduction:
This Functional Test Plan describes the procedures used to operate the flow aerodynamic force test being performed on the University Student Launch Initiative (USLI) scale rocket in the Eiffel Wind Tunnel.

Pressure Variation on Symmetric rockets: The purpose of this experiment is to test a scale model rocket at a single incidence angle with varying Reynolds numbers. This test will allow Navy Rockets to determine the aerodynamic forces present on the rocket throughout the flight. Knowledge of the forces during flight will give way to more accurate analysis of rocket flight path trajectory, especially in comparison to rocket trajectory simulation software. This work will be presented to complement the Navy Rocket research and development as a part of the NASA USLI competition.

1.1 Philosophy of OPERATIONS
The scale model testing will take place inside the Eiffel Wind Tunnel in Rickover Hall. It will be mounted to the sting balance, with pressure ports longitudinally along the rockets keel. The model will be designed in SolidWorks and 3D printed to an exact scale. The pressure ports will be 3D printed into the scale model. The model will be ran at varying Reynolds numbers. The incidence angle of the scale model and the free-stream flow will not change.

1.2 Participation
Personnel responsible for the operations are listed in Table 1-1.

1.3 Flow Diagrams
The Additive Printing integration and test flow is shown in Figure 1-1.

![Flow Diagram](image)

**Figure 1-1. Additive Printing Integration and Test Flow**

Injector System Functional Test

2.1 Objectives
The objective of this experiment is to analyze the aerodynamic stability of the rocket used for the USLI competition.

2.2 Criteria for Success
The rocket shows static and dynamic stability at all Reynolds numbers tested at. Forces and moments will be taken into account when analyzing stability.

2.3 Facilities
The scale model testing will be performed using the Eiffel Wind Tunnel in Rickover hall at USNA.

2.4 Materials
A. 18 in scale model rocket
B. 6 sections surgical tubing - 3 ft – 1 cm diameter
C. 6 autonomous pressure gages

2.5 Test Overview
The test will involve turning the wind tunnel on while all pressure ports are connected.

TEST DATE: ______________________ TEST PERSON: _____________________

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Comment</th>
<th>Done? (Y/N)</th>
<th>Date</th>
<th>Initial</th>
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<tbody>
<tr>
<td>0</td>
<td>Attach pressure tube to each port through the inside of the rocket.</td>
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<td>1</td>
<td>Attach scale model aft section to the sting balance.</td>
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<td>2</td>
<td>Run surgical tube through the bottom of the wind tunnel out to the pressure gages.</td>
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<td>Ensure sting balance is properly attached through the bottom of the test section</td>
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<td>Run flow through test section to ensure all pressure ports and force measuring devices are securely fitted.</td>
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<td>5</td>
<td>Run program at initial test speed.</td>
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<td>6</td>
<td>When flow steadies tabulate data for given speed.</td>
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<td>Perform steps 5-6 as needed for each successive test speed.</td>
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<td>Once all data is taken, run again at initial test speed.</td>
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<td>9</td>
<td>Perform free-stream velocity sweep from initial to final test speeds, simultaneously tabulating data.</td>
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<td>10</td>
<td>When finished tabulating velocity sweep, move wind tunnel test speed down to 0%</td>
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<td>11</td>
<td>Shut down wind tunnel and wind tunnel software</td>
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<td>12</td>
<td>Detach the assembly in reverse order of attachment.</td>
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