NC STATE UNIVERSITY

Tacho Lycos
2016 NASA Student Launch Project
Student Launch-MAV Proposal

High Powered Rocketry Team

911 Oval Drive

Raleigh NC, 27695

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1. General Information

1.1. Advisors

1.1.1. Academic

Dr. Charles Hall
chall@ncsu.edu
TRA Certification: 14134

Dr. Hall directs the Flight Research Group in the Mechanical and Aerospace Engineering Department at North Carolina State University. Dr. Hall is the current advisor for the High Powered Rocketry Club. He is also the professor in charge of the aerospace senior design project. Dr. Hall has level 3 certification with Tripoli Rocketry Association (TRA).

Alan Whitmore
acwhit@nc.rr.com
TRA Certification: 05945

In 2002, Alan was elected prefect of the East North Carolina chapter of TRA. In 2006, he was made a member of TRA's Technical Advisory Panel (TAP), a group that advises the TRA board of directors on technical aspects of propellants, construction material, recovery techniques, etc. and which supervises individual members during the process of designing, construction, and initial flight rockets used for TRA level 3 certification. Alan has a level 3 certification with Tripoli.

James Livingston
livingston@ec.rr.com
TRA Certification: 02204

In 1993, James joined Tripoli Rocketry Association and was certified level 3 in 1997. In 1998 James became a member of the Technical Advisor Panel, TAP committee. Since then, James has assisted over 20 Tripoli members in their level 3 certifications. James has also been involved in Tripoli research since 1997, and manufactures all the motors he uses (sizes I through N).

1.1.2. High Power Rocketry

Established in 2009, the NCSU High Power Rocketry Club is an interdisciplinary student organization within the Mechanical and Aerospace Engineering department at North Carolina State University. The NCSU High Power Rocketry Club gives undergraduate students the opportunity to gain real world design and construction experience through participation in the annual University Student Launch Project (SL) sponsored by the NASA Marshall Space Flight Center. Undergraduate student members, under the direction of undergraduate student officers, work with a faculty advisor and club mentor to research, design, construct, test, and launch high-powered rockets.

1.2. Safety Officer

Adam Tokonitz

Adam Tokonitz will act as the safety officer for the North Carolina State University 2015-2016 NASA Student Launch team. Adam has been an active High Power Rocketry Club member since 2014, and has sufficient experience in all aspects of rocketry safety, as well as general tool use safety. When present, he will oversee all activities conducted in the student fabrication lab as well as at the launch site. When unavailable, the responsibilities will be fulfilled by the highest ranking club officer present. Adam will also ensure new members undergo safety training before being allowed to use certain tools.

The active safety officer will provide the proper safety measures to all NCSU High Power Rocketry Club members and accompanying guests, the working environment, any construction, testing, and vehicle launches.

1.3. Team Lead

Andrew McKeon
amckeon@ncsu.edu
(610) 392-4896

Andrew will act as the North Carolina State University 2014-2015 NASA Student Launch team lead. Andrew is also the team lead for the MAE Space Senior Design team and will be partnering with his senior design team consisting of Will, Daniel, Nikola, Eric, and Stuart. This is Andrew's third year with the High-Powered Rocketry Club.

1.4. Team Outline Matrix

a. Officer Position: President
   i. Name: Andrew McKeon
   ii. Years in Club: 3
   iii. Prior Experience/Responsibilities: 2013-2015 Member
   iv. Qualities and Skills: Andrew is a senior in Aerospace Engineering and the Team Lead for the MAE Space Senior Design and was elected president after his involvement with the club during the last two years.

b. Officer Position: Vice-President of Electrical Endeavors
   i. Name: Daniel Mahinthakumar
   ii. Years in Club: 4
   iii. Prior Experience/Responsibilities: 2012-2015 Member
   iv. Qualities and Skills: Daniel is a senior in Computer Science and joined the club in the fall of 2012. He is knowledgeable in the electrical and programming aspect of rocket launching.

c. Officer Position: Vice-President of Mechanical Endeavors
   i. Name: William Martz

ii. Years in Club: 3
iii. Prior Experience/Responsibilities:2013-2015 Member
iv. Qualities and Skills: William is a senior in Aerospace Engineering and is experienced in design and construction of rockets and mechanical systems.

d. Officer Position: Coordination Leader
   i. Name: Raven Lauer
   ii. Years in Club: 4
   iii. Prior Experience/Responsibilities: 2012-2014 Member and 2014-2015 Coordination Leader
   iv. Qualities and Skills: Raven is a junior pursuing a double major in Aerospace Engineering and History. Raven was a valuable team member for Tacho Lycos during last year's competition and was elected to act as the coordination officer again this year. Raven's organization skills and passion for the club's success will make him a very useful member this year.

e. Officer Position: Webmaster
   i. Name: John Inness
   ii. Years in Club: 2
   iii. Prior Experience/Responsibilities: 2014-2015 Member
   iv. Qualities and Skills: John is a sophomore in Aerospace Engineering with a minor in music performance. John is a returning member to the club and obtained the webmaster to extend his knowledge base about computers and web design. In a previous year, John started and currently manages a social media page dedicated to one of the groups that he plays in.

f. Officer Position: Safety Officer
   v. Name: Adam Tokonitz
   vi. Years in Club: 2
   vii. Prior Experience/Responsibilities: 2014-2015 Member
   viii. Qualities and Skills: Adam is a returning member from last year, and is a sophomore in Electrical Engineering. Adam has experience with rocket construction techniques, as well as being a former Safety Captain for FIRST Robotics, and therefore has adequate knowledge of safety.

g. Officer Position: Treasurer
   i. Name: Emily Gipson
   ii. Years in Club: 3
   iii. Prior Experience/Responsibilities: 2013-2015 Member
   iv. Qualities and Skills: Emily is a returning member from last year and is a junior in Aerospace Engineering and Physics. She was an integral part of the fabrication team last year.

1.5. NAR/TRA Section

Alan Whitmore, current prefect of Tripoli East North Carolina, is the dedicated TRA mentor and responsible for the purchase and storage of the rocket motors. These motors are only purchased with his approval, and are stored according his specific requirements. Furthermore, the motors are only used with his approval and supervision.

1.6. Briefing

The entire club and senior design meets once a week to discuss club logistics as well as rocket and document progress. Club logistics include the following:

- Weekly updates
- Club outreach events
- Ongoing experiments
- Topics of special interest

The club strives to provide an atmosphere that fosters learning and the passing of knowledge from veteran members to newcomers. The senior design team meets an additional two times a week to discuss document and project requirements as well as to resolve any issues anyone might be having.

2. Facilities/Equipment

2.1. Description

The NCSU High Power Rocketry Club is located in the MAE Student Fabrication Lab, Room 2003, Engineering Building III. The club members also have access to the Space and Aircraft Senior Design Labs in Rooms 1224 and 1225.

In addition to the design labs, the club will have access to two machine shops on the first floor of Engineering Building 3. Gary Lofton is the supervisor for the machine shop located in Room 1205 and gladly helps with design and parts requests. The MAE department machine shop is in Room 1228 and is controlled by Steve Cameron. The structures lab in Room 2208 will provide additional resources including the Instron tensile and compression loading machine for materials testing.

2.2. Hours of Accessibility

Monday – Friday: 7AM – 10PM Undergraduate access
10PM – 7AM By graduate student or professor assisted entry
Saturday – Sunday: By graduate student or professor assisted entry

2.3. Necessary Personnel

Graduate student Christopher Buck, who completed Space Senior Design two years ago, is required for entry to the Fabrication lab after hours and on the weekend. Dr. James Kribs is required to approve access for testing in NCSU's subsonic wind tunnel, supersonic wind tunnel, and all testing machines.

2.4. Equipment

Available equipment in room 2003 consists of the following:

- Craftsman 1.6 inch Variable Speed Scroll Saw
- Craftsman 12 inch Bench Drill Press with Laser
- Task Force 4” Belt & 6” Disc Sander
- 120 Volt 60 Hz Band Saw
- 16 Gallon 6.5 HP Shop Vac
- Dremel 400 XPR Rotary Tools
- Ryobi HG600 Heat Gun
- DeWalt 18V Hand Drill
- Drill Bit Case from 3/64” – ½” inch
- Task Force Ratchet/Socket Kit
- Digital Micrometer
- SoftWorks 5lb Food Scale
- AWS 1 kg Digital Scale
- Wilton Bench Vice
- Vacuum hoses for wet layups

2.5. Supplies Required

A list of required materials includes, but is not limited to, the following:

- Fiberglass
- Epoxy
- Metal (80/20 railing)
- Carbon fiber
- Safety equipment (fire extinguisher, First-Aid kit, gloves, goggles, masks, cleaning supplies)
- Gloves
- Black powder
- Servos/DC Motors
- Processors
- Barometric altimeters
- Linear Actuator
- Shock cord
- Hand tools (utility knives, hammers, screw drivers, and measuring equipment)
- Equipment from 2.2.4
- Simulation and modeling software (Microsoft Office Professional 2013, Solidworks 2015, OpenRocket 14.11, Abaqus 6.13, Matlab 2015a, Ansys 2015)
- Beaglebone Black computer
- Sensor board and DC controller

3. Safety

3.1. Safety Plan

3.1.1. NAR/TRA Personnel Procedures

3.1.1.1. NAR High Power Safety Code Requirements

High Power Rocket Safety Code

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

a. With an L size motor we stay within NAR Level 2 Certification. One of our club mentors is Alan Whitmore. Alan is Level 3 Certified with TRA.

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.

a. We are only using wood, fiberglass and foam in the construction of our rocket.

3. *Motors*. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by

the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.

a. We are purchasing either an Aerotech L1150R or L850W.

4. *Ignition System*. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. If my rocket has onboard ignition systems for motors or recovery devices, these will have safety interlocks that interrupt the current path until the rocket is at the launch pad.

a. Our AGSE will insert the motor igniter only when the rocket has been raised to the launch inclination. Our launch system complies with the given requirements

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 no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table, and that a means is available to warn participants and spectators in the event of a problem. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable.

7. *Launcher*. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 if the rocket motor being launched uses titanium sponge in the propellant.

a. Our AGSE will raise the rocket to 85 degrees from the horizontal. When erected the blast deflector will be in place to prevent the motor exhaust from hitting the ground.

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.

a. The impulse of the L1150 is 3489 N-sec. The impulse of the L850W is 3695 N-sec. At liftoff our rocket ways 28 lbs.

9. *Flight Safety*. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site. 2

10. *Launch Site*. I will launch my rocket outdoors, in an open area where trees, power lines, 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.

a. We will only launch at the Bayboro Launch Site in Bayboro, NC and at Huntsville during competition.

11. *Launcher Location*. My launcher will be 1500 feet from any inhabited 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.

a. Our rocket has one drogue and two parachutes

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

3.1.1.2. Hazardous Material/Operations Performance Criteria

The following are the classifications of hazardous materials as determined by NCSU's Department of Environmental Health and Public Safety:

Class 1 – Explosives

Division 1.1	Explosives with a mass explosion hazard
Division 1.2	Explosives with a projection hazard
Division 1.3	Explosives with predominately a fire hazard
Division 1.4	Explosives with no significant blast hazard
Division 1.5	Very sensitive explosives; blasting agents
Division 1.6	Extremely insensitive detonating devices

Class 2 – Gases

Division 2.1	Flammable Gases
Division 2.2	Non-flammable, non-toxic compressed gases
Division 2.3	Gases toxic by inhalation

Class 3 – Flammable Liquids (and Combustible Liquids)

Flammable liquids – liquid with a flash point of 140°F or less
Combustible liquid – liquid with a flash point between 140°F and 200°F that does not meet any other hazard class definition.

Class 4– Flammable Solids; Spontaneously Combustible Materials; Dangerous when Wet Materials

Division 4.1 Flammable solids - wetted class 1 explosives, self-reactive materials or readily combustible solids
Division 4.2 Spontaneously combustible materials -pyrophoric or self-heating materials
Division 4.3 Dangerous when wet materials - gives off flammable or toxic gas or become spontaneously combustible on contact with water

Class 5 -- Oxidizers and Organic Peroxides

Division 5.1 Oxidizers - by yielding oxygen, causes or enhances the combustion of other materials
Division 5.2 Organic peroxides - organic compounds with the bivalent R-O-O-R structure where at least one R is a carbon chain, except for materials that meet class 1 (Explosive) definition, or are "*forbidden*" on the HMT.

Class 6 -- Toxic Materials and Infectious Substances

Division 6.1 Poisonous materials - a liquid with an LD50 oral not more than 500 mg/Kg, or a solid with an LD50 oral not more than 200 mg/Kg, or a compound with a LD50 dermal not more than 1000 mg/Kg, or a dust/mist with a LC50 or not more than 10 mg/L
Division 6.2 Infectious substances – Go to Guide to Shipping Biological Materials and Biological Materials Online Certification for more information.

Class 7 -- Radioactive Materials

Radioactives are any material with a specific activity greater than 0.002 microcuries per gram (mCi/g.) The specific activity of a nuclide means the activity of the nuclide per unit mass of that nuclide.

*** All Class 7 shipments must be coordinated through Radiation Safety 515-2894

Class 8 -- Corrosive Materials

Class 9 -- Miscellaneous Dangerous Goods

Materials that present a hazard during transport but do not meet other hazard class definitions. Examples are dry ice and lithium batteries.

3.1.2. Team Hazard Recognition, Accident Avoidance, and Pre-Launch Briefing Procedures

To ensure all hazards and accidents are avoided, the NCSU HPRC will follow the published Tripoli Pre-Flight Review Checklist:

a. General
   i. Is this member known to the TAP reviewer?
   ii. Does this member have the appropriate Certification Level or will this be a Certification Flight?
   iii. Does the proposed launch site and date have the appropriate recovery area and launch set-up for this flight?
   iv. Does the Prefect require TAP Review?

b. Rocket Review
   i. General
      1. Are there attachments to the Pre-Flight Data Capture?
      2. Drawings: airframe; structures; payloads, etc.
      3. Schematics: avionics, ignition systems, payloads, etc.
      4. Performance calculations: Center of Pressure; Center of Gravity, motor type, altitude, velocity, etc.

   ii. Airframe
      1. Is the design generally suitable for the application?
      2. Is the airframe material suitable for this rocket?
      3. Is the fin material/attachment sound?
      4. Is the motor mount sound?
      5. Is the nosecone suitable?
      6. What are the most probable airframe faults and corrective actions?
      7. What are the safety implications of an airframe failure?
      8. Are there any design change recommendations?

   iii. Recovery System
      1. Is the recovery system attachment secure/suitable?
      2. Does the recovery system have sufficient capacity for a safe descent?
      3. What is the deployment system?

4. What are the most probable deployment system faults and corrective actions?
5. What are the safety implications of a recovery system failure?
6. Are there any design change recommendations?

iv. Avionics Description

1. Commercial or unique design?
2. What are the functions of the avionics components?
3. Are the avionics appropriate to the application?
4. Do the avionics have flight safety implications?
5. Can the avionics and inhibits be accessible from outside the vehicle?
6. Are there safing/arming indicators?
7. Are any of the systems redundant?
8. What are the most probable avionics system faults and corrective actions?
9. What are the safety implications of an avionics system failure?
10. Are there any design change recommendations?

ii. Motor

1. Is the motor suitable for the rocket?
2. Is the motor Tripoli Certified?
3. Is the motor ignition suitable?
4. What are the most probable motor faults and corrective actions?
5. What are the safety implications of a motor failure?
6. Are there any design change recommendations?

iii. Launcher

1. Is the launcher suitable for the rocket?
2. Is the launch lug, or rail guide suitable for the rocket?
3. What will the launch angle be?
4. Are there any special launch control requirements?
5. What are the most probable faults with the launcher?
6. What are the safety implications of a launcher failure?
7. Are there any design change recommendations?

iv. Performance

1. How were the performance calculations done?
2. Were the calculations done manually?
3. Are the algorithms used correct?
4. Were the calculations accomplished correctly?
5. Was a computer used?
6. What is the source of the software?
7. Is the software suitable for this rocket?
8. Are there printouts?
9. Should the calculations be independently run?
10. What are the safety implications of poor performance data?
11. Are there any changes or recommendations?

v. Operations
   1. Is there a pre-flight checklist?
   2. Which operations does it cover?
   3. Are each the operations sufficiently documented?
   4. Are hazardous operations flagged?
   5. What are the safety implications of poor checklists?
   6. Are there any changes or recommendations?

3.1.3. Cautionary Statements, Procedures, SOP's, MSDS and PPE

a. General
   i. Always ask if unsure about equipment, tools or a procedure.
   ii. Only handle certain materials if you have the proper permit.
   iii. Always wear the appropriate safety materials and clothing
      1. These items include safety glasses, gloves, long paints, and closed-toe shoes
   iv. Always secure long hair and clothing
   v. Always properly secure machinery, and never leave it unattended when in operation

b. Chemicals (e.g. adhesives, solvents, and paint) and Black Powder
   i. Risks include:
      1. Irritation from skin contact, eye contact and inhalation of hazardous fumes.
      2. Flammable and/or explosive chemicals/substances.
   ii. Ways to prevent these risks:
      1. Be familiar with relevant MSDS sheets
      2. Wearing appropriate safety gear. Some examples are goggles and gloves
      3. Be aware of locations of nearest first-aid kit, fire extinguisher, and eye wash station
      4. Keep chemicals away from open flames.
      5. Clean work stations.
      6. Keep construction and test rooms well ventilated.
      7. Wear cotton clothing.

c. Risks from Tools
   i. Cutting from sharp tools, burning from hot tools, etc.
   ii. Injury from mishandling of heavy equipment
   iii. Ways to prevent these risks:
      1. Wear closed-toed shoes
      2. Seek advice if unsure about the operation of equipment
      3. Wear goggles and gloves when necessary

d. Procedures for Cleaning Up
   i. After using drill press or cutters

1. Ensure that the power is disconnected and the switch is in the off position
2. Remove the bit and replace the safety if available
3. Clean up all spare chips/shavings with either a shop vac or dedicated brush, whichever is more appropriate
4. Replace safety goggles and gloves in an easily accessible place for the next user

ii. After using epoxy
1. Clean up any excess epoxy that may have spilled during its use
2. Properly dispose of the epoxy in the proper receptacle
3. Store epoxy in the flame cabinet for others to use

3.1.4. Federal and Local Law Compliance

The team is aware of the federal and local safety regulations and agrees to comply with their stipulations. The club will follow all safety issues as directed by the NAR/TRA member and club safety officer who will be present at all of our launches. Some of the key safety regulations include:

a. Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C. This involves use of airspace.
b. NFPA 1127. Code for High Power Rocketry. This involves fire prevention regulations for high power rockets.

3.1.5. Energetic Device Acquisition, Storage, and Transport

All black powder will remain in the provided manufacturer's sealable container for both storage and transport until black powder charges are needed. When charges are necessary, the proper amount of black powder will be determined by the formula

$$CD^2L = \text{grams of black powder}$$

C: Desired pressure dependent constant
D: Compartment diameter
L: Compartment length

All purchased motors will remain separate of the other rocket sections at all times. Motor insertion will only be completed for determining proper fitting and for launch operations. These high powered motors will only be purchased, stored, and transported with the guidance of our club TRA mentor.

3.1.6. Team Member Safety Compliance Statement

3.1.6.1. Range Safety Inspection

Launch Systems

The RSO shall familiarize themselves with the types of launch pads available ensuring that they do not approve any flight for which there isn't a sufficient pad.

The RSO shall make a cursory examination of the Range area to ensure that the pads available have been placed appropriately according to the Safety Code.
The RSO should become familiar with the launch control systems and ensure that sufficient safety interlocks are in place to prevent accidental ignitions.

Emergency

The RSO shall confirm that adequate safety equipment is on site including a portable fire extinguisher, first aid kit, and cellular communications.
The RSO shall have available to them contact numbers for local fire departments, police, emergency medical, and power authority personnel.

Flight Operations

The RSO is to perform a Flight Safety Review (FSR) of all rockets intended for launch. Upon completion of the FSR the RSO will make a flight readiness decision. If the flight is approved this should be indicated by the RSO initialing the flight card. If minor modifications will bring the rocket to flight ready status the flyer should be informed of the required modifications and asked to return only after taking appropriate corrective actions. If a situation arises that the RSO is unfamiliar with and/or feels uncomfortable making a judgment call on, it is their obligation the find one or more experienced Tripoli members on the field to consult with. As always, the final decision rests with the Certificate of Waiver Holder.

Flight Safety Review

Safety First –

At all times prior to a safe firing position on the rod, rail, tower, or other suitable ground support facility, the igniter **shall not** be inside the motor, and all ejection charge related **electronics must be off**!

Flyer –

By asking to see a current membership card:
Verify that the individual flying the rocket is a current member in good standing of Tripoli Rocketry Association or the National Association or Rocketry.
Verify the certification level of the individual and that they are flying within their certification level or attempting a new certification level.
Observe that the individual does not appear impaired by the use of drugs or alcohol. Under no circumstances should someone who has participated in the consumption of alcoholic beverages be allowed to enter the range or launch a rocket.

Flight Card –

Verify that an applicable flight card exists, is filled out in a legible manner, and indicates all of the pertinent flight data including but not limited to flyer name and TRA number, physical vehicle parameters, motor configuration, and recovery systems.
Special attention should be given to flights that are indicated as Heads-up or Certification. In the case of a Level 3 certification attempt, verify the presence of associated TAP member.

History –

Ask the flyer if they have flown this particular rocket and motor combination. If they have, ask for the results of that flight. If not, ask if they have flown a similar rocket/motor combination and the outcome.

Use the results of this line of questioning to determine into how much detail the remainder of the FSR will go.

IMPORTANT: By no means does a response of "I've flown it just like this perfectly before" exempt the flyer from the remainder of the FSR.

Propulsion –

Verify that the motor used is a currently certified motor or that it is on the consumer list.

Verify that the total installed power does not exceed the limitations of the field.

Verify, as best possible, that the vehicle is capable of withstanding the forward thrust that will be produced by the motor.

Verify that the initial thrust of the motor chosen will provide at least a 5:1 thrust-to-weight ratio. This can be done by one of three ways:

1. The flyer can provide documentation that shows the initial thrust produced by the motor. This can then be compared to the GLOW (Gross Lift Off Weight) of the rocket as presented.
2. The peak thrust of the motor can be assumed to be at least equal to the average thrust as indicated in the motor designation. In this case, the average Newtons produced by the motor should be converted to pounds and compared to the GLOW of the rocket as presented.
3. A printout from a flight prediction software package can be presented. In this case the prediction output should indicate the thrust-to-weight of > 5, the initial acceleration of > 5 g's, or the velocity of the rocket at the end of the rod/rail/tower > 45 f/s. The motor installed and the weight of the rocket must also be indicated and shall be verified to match the presented rocket. Verify that a suitable means of aft retention is used to keep the motor in place during the flight and recovery.

Construction –

Check the structural integrity of the vehicle including the body tubes, nose cone, and fins to ensure that they are adequate to withstand the forces anticipated during the flight and recovery.

Verify the fit of the nose cone. Whenever possible hang the rocket by the nose cone. The vehicle should stay in place. With agitation however, the nose should come free or begin to come free. *Exception*: When shear pins are being employed ask the flyer to explain how they determined the number, size, and type of shear pins to use and what special provisions have been taken in regards to calculation of ejection charges.

Compare the fin material, stiffness, size and attachment method to the projected flight velocity and acceleration to avoid the potential for excessive fin flutter and any structural failures. If a questionable situation arises, consider assigning the flyer to a pad that is further away than the minimum setback.

Verify that a suitable launch guidance system is employed. Take into consideration the overall dimensions of the vehicle, the total weight of the vehicle, the predicted acceleration, and the current wind conditions. In the case of launch lugs or rail guides, ensure that mounting of the lug or button is sufficient to withstand the loads.

In the case of a two-stage vehicle, check the strength of the inter-stage connection. Verify that is will not buckle under the acceleration loads, and that it will separate as intended.

Stability –
Verify that the rocket is of a stable design.

1. If it has flown in the current configuration with a similar motor and was stable it will likely remain stable.
2. If the design employs unusually small fins be extra careful with the stability verification.
3. Providing the Cp (center of pressure) calculation by Barrowman or other suitable calculation method should be compared to the Cg(center of gravity) as found on the flight ready vehicle. If stability calculations indicate a Cg, its accuracy should always be verified.
4. If no calculations are available or it is an untested design, use past experiences and call upon the expertise of others at the launch in coming to consensus about stability. If the stability is uncertain on an unusual design, ask for proof of stability. Any marginally stable rockets should be treated with extra concern and additional launch safety precautions should be taken.

Recovery –
Verify that the parachutes selected for recovery are rated for the weight of the vehicle and the expected conditions at deployment. Confirm that the parachutes intended for the final descent phase to the ground will not allow a decent rate of >30f/s.

Verify that there is an adequate system in place to contain all of the separable parts of the rocket and parachutes at the forces anticipated during deployment. This includes adequate length of retaining cord, strength of retaining cord, and hard points for recovery system attachment.

Ensure that adequate protection is in place to prevent the hot ejection gases from causing burn damage to retaining cords, parachutes, and other vital components.

If electronics are being used to activate the recovery system, verify that an externally controllable method is being used to turn electronics on and that a known good battery is in use.

3.1.6.2. RSO Clearance Policy

Range Operations

The RSO/LSO is responsible for determining the status of range operations. Before any launch begins, or in the event of a breech, the following criteria must be assessed. If not met, it is up to the RSO/LSO to halt any further launches until a safe condition is returned.

Site

The RSO shall make a cursory examination of the Range area to ensure that adequate barriers, markings, and safety measures exist to prevent unauthorized person from entering into the range and alert authorized person as to any hazardous situations.

The RSO shall make themselves aware of the largest motor that can be supported by the site area given the table in the High Power Rocketry Safety Code.

The RSO has the authority to open and close the range to any and all personnel

Airspace

Where applicable (i.e. when entering controlled airspace):

1. The RSO must have knowledge that a current Certificate of Waiver issued by the U.S. Department of Transportation is in force and applies to the sections of the Federal Aviation Regulations that will be bypassed.
2. The RSO should have knowledge of the Special Provisions of the Certificate of Waiver and that they are being adhered to.
3. The RSO must have knowledge that a Notice to Airman has been issued for the date and times of the launch.
4. The RSO must not allow launches when aircraft are within a three-mile radius of the projected flight path.

Weather

The RSO must have clear and convincing evidence that the following constraints are not violated.

1. Do not launch if ground level winds exceed 20 mph.
2. Do not launch if the planned flight path will carry the vehicle through any clouds
3. Do not launch if any type of lightning is detected within 10 miles of the launch site

Time Interval Determination Method

- Visual conformation of lightning flash
- Count number of seconds until you hear thunder
- Divide the result by five (5)
- Result is in miles

GOOD SENSE RULE: Even when constraints are not violated, if any other hazardous weather conditions exist, the RSO may hold at any time based on the instability of the weather.

NC STATE UNIVERSITY

3.1.6.3. Team Compliance Policy

By signing below, I agree that I have read, understand, and will follow all parts of the Safety Agreement shown above.

1. *Print Name:* Andrew McKeon
   Signature: [signature]
   Date: 9/10/2015
2. *Print Name:* Frederick Morrow
   Signature: [signature]
   Date: 9/10/15
3. *Print Name:* William Martz
   Signature: [signature]
   Date: 9/10/15
4. *Print Name:* Nikola Milisav
   Signature: [signature]
   Date: 9.10.15
5. *Print Name:* Daniel Mahinthakumar
   Signature: [signature]
   Date: 9/10/15
6. *Print Name:* Stuart Philpott
   Signature: [signature]
   Date: 9/10/15
7. *Print Name:* John Inness
   Signature: [signature]
   Date: 9/10/15
8. *Print Name:* Chris Celestino
   Signature: [signature]
   Date: 9-10-15
9. *Print Name:* [signature]
   Signature: Adam Tokonitz
   Date: 9/10/15
10. *Print Name:* Matthew Bruce
    Signature: [signature]
    Date: 9-10-15

TachoLycos
NORTH CAROLINA STATE UNIVERSITY

11. Print Name: Jacob Sebastian
Signature: [signature]
Date: 09-10-15

12. Print Name: Corey White
Signature: Corey White
Date: 9/10/15

13. Print Name: Jamie Region
Signature: [signature]
Date: 9/10/15

14. Print Name: EMILY GIPSON
Signature: [signature]
Date: 09-10-15

15. Print Name: Evan Li
Signature: [signature]
Date: 9/10/15

16. Print Name: Alex Bartell
Signature: [signature]
Date: 9/10/15

17. Print Name: Bryan Nelson
Signature: [signature]
Date: 9/10/15

18. Print Name: Christopher R Buck
Signature: [signature]
Date: 9/10/15

19. Print Name: Raven Lauer
Signature: [signature]
Date: 09/10/2015

20. Print Name: Andrew Wallace
Signature: Andrew Wallace
Date: 9/10/15

4. Technical Design

4.1. Proposed Rocket and Payload Design

4.1.1. General Vehicle Design

4.1.1.1. Dimensions

The launch vehicle is proposed to be 100 inches long with a constant body diameter of 5.5 inches. It will have a four piece trapezoidal fin set; these fins will have a root chord of 12 inches, a tip chord of 4.25 inches, and a sweep angle of 50 degrees. The rocket will have a 3:1 ogival nose cone, which was picked due to its slightly increased drag compared to ellipsoid nose cones. With the motor loaded, the rocket will weigh approximately 28 pounds.

4.1.1.2. Design Aspects

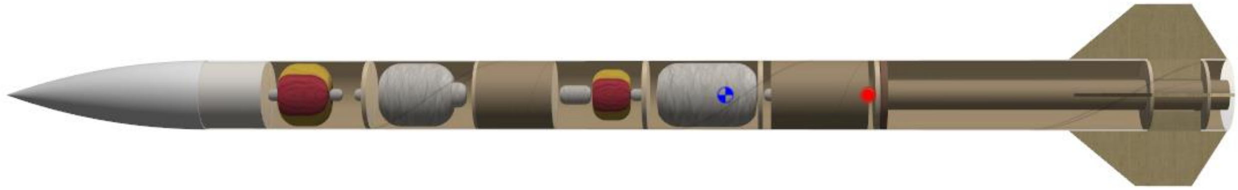

Figure 1 Open Rocket Model of Full Scale Rocket

The design of the rocket can be seen above in ***Figure 1***; it can be divided up into four sections: an upper section, two middle sections (upper and lower) and a fin can. These sections will be separated by bulkheads and couplers. The upper section will be 16.5 inches long, the upper-mid section will be 25 inches long, the lower-mid section will be 24 inches long, and the fin can will be 34.5 inches long.

The upper section will contain the nose cone and a bulkhead that attaches to the upper main parachute. The upper-mid section will contain a bulkhead to attach to the upper main parachute, the payload bay and payload bay door mechanism, the upper avionics bay as well as a coupler that contains the telemetry bay. The coupler will have two bulkheads, the forward bulkhead will be 0.25 inches thick and will utilize foil to keep the telemetry bay's signals from interfering with the altimeters (StratoLogger 100 and Entacore AIM) in the avionics bay. The aft bulkhead will have the ARRD, which attaches to the drogue parachute. The lower-mid section will contain a bulkhead that attaches to the drogue parachute, the lower avionics section, the airbrake system, and a bulkhead that attaches to the lower main parachute. The fin can will contain a coupler that connects the lower-mid section and the fin can, a bulkhead that attaches to the lower main parachute, the an inner fiberglass tube (54 or 75mm in diameter, depending on final motor selection) held in place with two 0.375 inch thick centering rings and a 0.5 thick engine block, fins, the motor casing, and the motor.

The payload retention system will consist of polyurethane foam, cut into slits. The robotic arm from the AGSE will place the payload into the foam, deforming it into a form fitting mold, retaining the payload. This foam will be 3.5 inches deep, and will form fit within the body tube. The door that closes the payload section will also have foam to ensure that the payload is snugly secured. The door will be attached to the rocket body-tube with two hinges and will secure itself to the rocket body using magnets.

To ensure that the rocket does not over shoot the desired altitude of 5280 feet (as each foot over is a 2 point deduction, while each foot under is only a 1 point deduction), the rocket will be equipped an airbrake system that will be servo actuated and controlled by an Arduino Mega. This system is located aft of the center of gravity (after the motor has completed its burn). The airbrake system, is the reason that our chosen motors overshoot the desired apogee. In addition to the airbrake system, an ogival nosecone was chosen because initial research indicated that this shape will create more drag at subsonic speeds than would comparable elliptical or hyperbolic shaped nosecones.

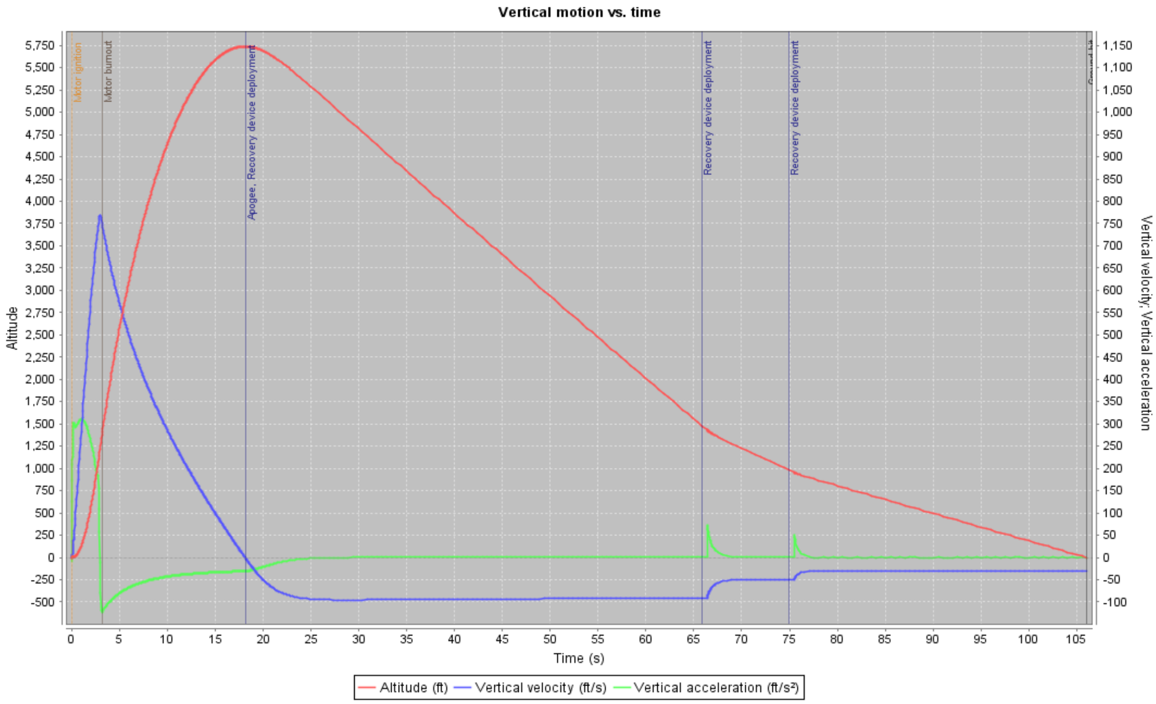

Figure 2 Open Rocket Performance Simulation

4.1.1.3. Material Selection and Justification

Based off preliminary estimates of the rocket's top speed, it was determined that supersonic velocities would not be encountered. The payload bay and telemetry are located well aft of the nose cone and impose no constraints on the geometry of the nose cone. A filament wound ogival nose cone was selected due to its higher friction drag characteristics and availability from vendors. The diameter of the nose cone is 5.5 inches and the length is 16.5 inches.

The body tube of the flight vehicle will be constructed of 5.5" diameter filament wound fiberglass tubing. Fiberglass offers a greater strength than Blue Tube or unreinforced cardboard. Fiberglass also has superior water resistance compared to Blue Tube. Internally, the fiberglass body tube will be reinforced by a number of bulkheads and centering rings constructed of 3/8-inch birch aircraft plywood.

4.1.2. Altitude Projections/Calculations

As shown in ***Figure 2***, OpenRocket was used to predict the altitude of the proposed rocket. The vehicle modeled was 28 pounds and 100 inches in length. The parachutes, couplers, bulkheads, and payload were modeled within OpenRocket and are the main contributors to the specified weight. Using an Aerotech L1150R motor, with a specific impulse of 790.6 lbf-s, the rocket is projected to reach an altitude of 5739 feet. With an Aerotech L850W-O motor, with a specific impulse of 819.6 lbf-s, the rocket reached a height of 6177 feet above ground level. The final rocket will likely be heavier than the 28 pounds specified, both due to payload and unaccounted excess weight in epoxy due to the manufacturing process. The parachutes will also weigh differently than the values in

OpenRocket. However, these extra weights will be beneficial as they will cause the rocket to reach apogee at an altitude closer to the required 5280 feet. A final altitude projection and motor selection will be made once the rocket weight is finalized.

4.1.3. Parachute/Recovery System

The current plan is to have the vehicle ultimately come down in two independent sections. At apogee, a one and a half foot drogue parachute will deploy. This will separate the fin can and body section from the sample section and nose cone. The drogue will be attached to a bulkhead on the body tube and to an Advanced Retention Release Device (ARRD) on the sample section. At 1000 feet, the ARRD will separate the combined sample section and nosecone from the lower body section. Shortly after, the sample section and nose cone will separate, releasing a five foot main parachute. In order to decrease the drift range, a seven foot main parachute will deploy at 700 feet between the body tube and fin can. In summary, the sample section and nose cone will come down on a main parachute, and the body tube and fin can will come down on a main parachute and drogue. All parachutes will be purchased by Fruity Chutes. ***3*** below shows the general setup of the parachutes and where they will be located.

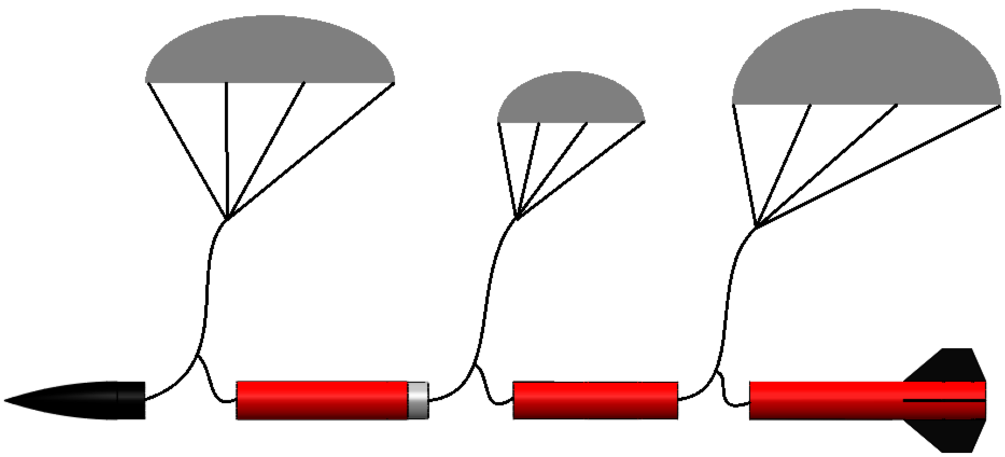

Figure 3 Parachute Setup

The main parachute between the fin-can and lower mid-section body tube will be packed in the body tube inside the coupler connecting the two sections. The coupler will be 7.5 inches long, with 4 inches inside the body tube 3.5 inches inside the fin can. Once the fin can is blown off, it will pull the main parachute out of the body tube. Similarly, the drogue chute will be packed inside of the other end of the body tube, forward of the fore lower mid-section bulkhead and connected to it. The drogue chute's other end will be connected to the aft telemetry bay bulkhead located in the upper mid-section body tube. The sample section will have a bulkhead on both ends, in order to seal the container. The sample container will be used to pull out the main parachute packed inside of the nose cone. The parachutes will be attached to the bulk heads via D-links on Kevlar shock cord. For a given shock cord, the parachute will be attached to a center loop, with different lengths of shock cord on either side. These different lengths ensure that the sections of the vehicle attached to the shock cord do not hit each other during descent. Twelve-inch square Kevlar sheets will also be used to protect the parachutes from the black powder charges.

In order to keep track of the sections, the sample container and body tube will be fitted with a GPS. Furthermore, these two sections will also contain two altimeters each, one to set off the black powder charges, and the other for backup. The backup black powder charges will be made slightly larger than the main charges, in order to ensure that the parachutes fully deploy. They will also be set on a delay after the main charges: The delay at apogee will be 1 second after apogee, and the backup charge to deploy the main parachute between the nose cone and sample section will be set at around 900 feet. Because the altimeter in the sample section is only connected to a main parachute, the drogue output in the altimeter will be connected to the ARRD. These two charges will be set to go off at the same time (1000 feet). The primary altimeter in the body tube will be used as the competition altimeter.

4.1.4. Propulsion System

With the current estimation of 28 pounds for the weight of the rocket, an L-class motor is required to reach the 5280 feet mark. Two motors are currently in consideration for the final design, the choice of which being dependent on the final weight and the airbrake system of the vehicle. The first motor is an AeroTech L1150R motor. This motor has a specific impulse of 790.6 lbf-s and a burn time of 3.1 seconds. At 20.87 inches long and 2.95 inches in diameter, this motor will cost $180. A simulation in OpenRocket (see *Figure 2*) shows that this motor will send 28 pound rocket approximately 5739 feet above ground level. The other motor being considered is an AeroTech L850W motor. This rocket features similar dimensions to the L1150R but has a greater specific impulse of 819.6 lbf-s and longer burn time of 4.4 seconds. Because of those factors, the L850W will send the same rocket to 6177 feet. This motor also costs $180, the same price as the L1150R. Although both motors will send the rocket higher than the specified altitude, more weight and the airbrake system will reduce the apogee to 5280 feet. The unaccounted weight increase is due the manufacturing processes and other factors like excess epoxy and extra ballast added. By aiming to overshoot the 5280 foot mark, the airbrake system in conjunction with the excess weight will bring the rocket closer to the desired altitude. Both motors in consideration provide a maximum approximate velocity of 760 ft/s.

4.1.5. Proposed AGSE

Figure 4 Proposed AGSE Assembly

Launch Rail Raising System

Given the success of the raising mechanism last year, the team considered using the same geared motor system as last year. This system included a ratcheting stop that acted as a failsafe during erection to prevent the launch rail from falling in the event of power loss, motor failure, or gear slippage. As an alternative to that, this year the team has elected to use a linear actuator. The launch rail and rocket is projected to weigh approximately 40 lbs. Based on the point where the raising force is being applied to the launch rail for erection, it was determined that a minimum force ratio of 3:1 would be required to raise the rocket. As such, the team selected a linear actuator that could generate at least 120 lbs of force.

Sample Retrieval System

To pick up the sample and place it in the rocket, the AGSE will use a robotic arm. The arm will have 5 degrees-of-freedom that allow a gripper to reach the sample. The shoulder of the arm, the base, will have one step motor that controls the pitch of the entire arm and a servo that spins the arm. The elbow will have one degree of freedom, one servo, to pitch the forearm. The wrist of the mechanical arm will have two degrees-of-freedom, two servos, where one servo controls the pitch of the wrist. Attached to the pitching servo, will be a spinning servo that controls the spin of the wrist. The wrist hosts the gripper that will have one servo controlling two contracting pincers that will grapple the sample.

In order to control the robotic arm, the component will be connected via USB connection to a Beaglebone Black as shown in the diagram below. "Regulator" indicates a series of regulators that we will construct to supply different voltages of power to each device. Since the Beaglebone only has 1 USB Port, we will hook up a USB hub to increase the number of USB connections it can have. By definition, most Linux computer systems will support a maximum of 127 USB devices.

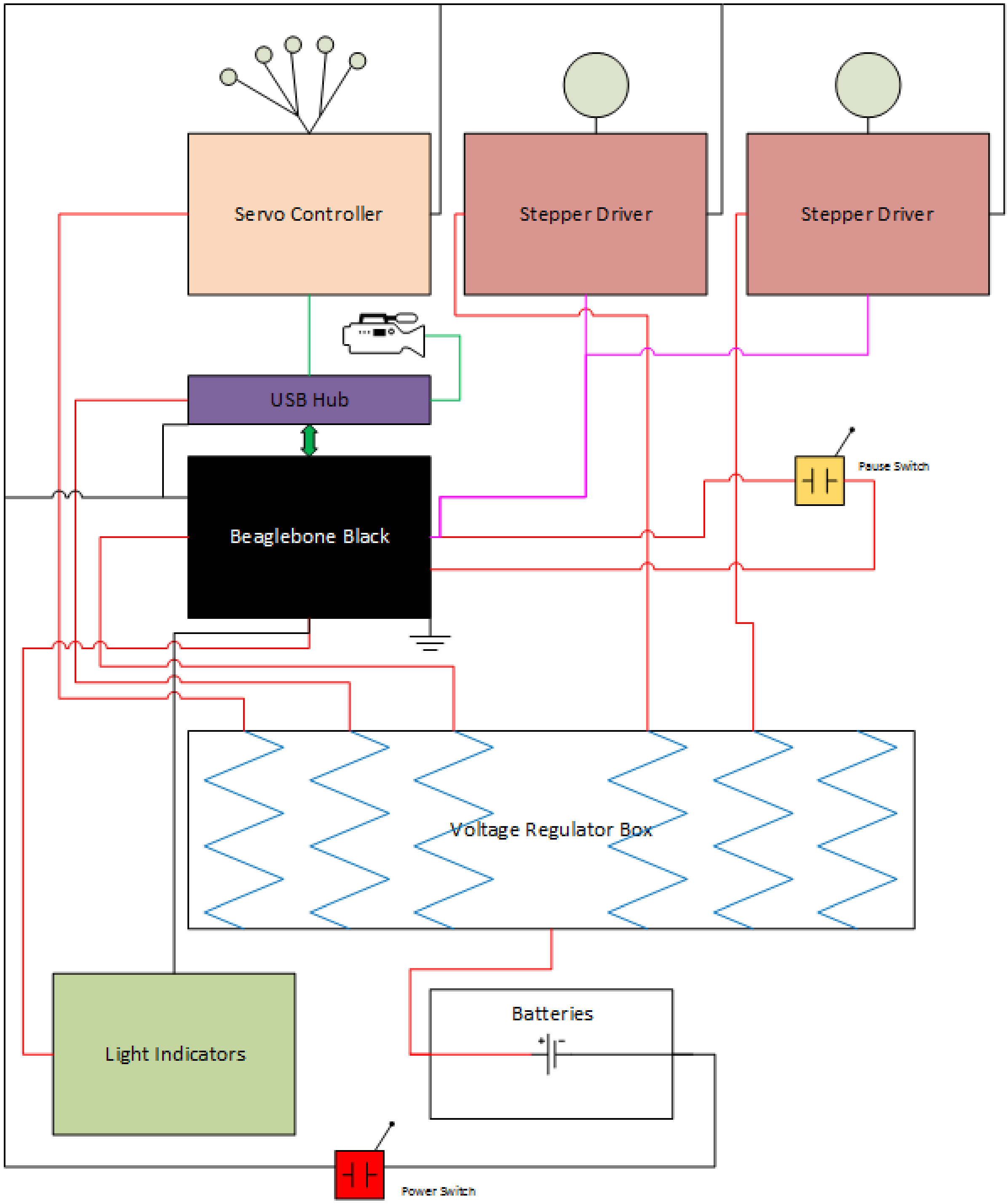

Figure 5 AGSE Schematic

The servo controller will be able to control 30 servo motors. The Beaglebone has about 1.2 GHz of processing power. The team believes that this will be a sufficient amount for handling all of the controllers.

Programming:

All programming will be done in C since the electronics being used require low level communication. The Beaglebone will utilize multiple programs and scripts that will be written to autonomously control all electrical components on the AGSE. Physical controls on the AGSE will be included to pause and resume the system with a switch.

Launch platform

The AGSE will be on a 3-footed platform, with two legs on the back and one on the front. This setup provides the AGSE stability during the launch of the vehicle. The vehicle itself will be already on the launch rail, in the horizontal position approximately 1 foot above the platform of the AGSE. The launch rail itself will be made out of 1515 Aluminum 80/20 railing. In order to support the rocket as it is being raised and to prevent it from falling back down, a guide rail on the bottom of the launch rail will be attached to a low friction linear slider which is attached to a linear actuator. As the rocket is raised, the linear actuator pulls the slider backward which raises the launch rail. Once the actuator is fully retracted, the launch rail will be at the 5 degree from vertical angle. Linear actuators have a built in failsafe which causes the piston to lock in place in the event of a power loss. This safety feature is the reason the electric linear actuator was chosen over hydraulics or pneumatics, which will fall when depressurized.

Igniter Insertion

The igniter will be on a vertical rod behind the tail of the rocket which extends approximately 4 inches below the bottom of the AGSE. As the rocket is raised, it will center itself over the igniter. Once the rocket is in the launch position, rollers will guide the rod into the motor and secure it in place with a plug.

4.1.6. Requirements

4.1.6.1. Vehicle

According to the Request for Proposal (RFP) the vehicle is not to exceed 5280 feet (above ground level apogee) and must be reusable. In order to record this altitude, a barometric altimeter must be used. Although there can be multiple altimeters within the vehicle, one must be designated before launch to be the competition altimeter used for scoring. Every foot above 5280 feet is a two point deduction in the altitude score and every foot below is a one point deduction, with going above 5600 feet resulting in an automatic zero points. The vehicle is also to be a maximum of four independent sections, each independent, untethered section requiring its own tracking device (i.e. GPS or radio transmitter). The motor is limited to an L-class, single stage motor, and the rocket must remain in a launch-ready position on the pad for a minimum of 1 hour.

4.1.6.2. Recovery System

The vehicle must contain a drogue parachute that deploys at apogee and a main parachute that deploys at a lower altitude. Each section is to have a maximum kinetic energy of 75 ft-lbf and its own tracking device. Redundant altimeters must be used and must be able to be armed via switches that can be locked on the ON position. Furthermore, all electronics must be insulated from interference so as to prevent accidental firing of the recovery system. The usage of shear pins in the main and drogue parachute compartments are also required.

4.1.6.3. AGSE

In general, the Autonomous Ground Support Equipment (AGSE) is defined to be any system(s) not a part of the vehicle. The AGSE must be fully autonomous with no human intervention. Once the master switch is activated, all processes must be completed within 10 minutes. Exceeding this time results in disqualification. There must also be a pause switch to allow for the arming of the altimeters and as a safety precaution. In order to represent the conditions on Mars, several systems are prohibited to be used on the AGSE. These systems include: magnetic field sensors, ultrasonic sensors, open circuit pneumatics, and air breathing systems. The AGSE must also have a safety light that shows when the unit is powered on and when it is receiving power but is paused. The light will be solid when the unit is paused, and flashing when the AGSE is in the process of completing its tasks.

4.1.7. Technical Challenges/Solutions

One of the biggest technical challenges that will be faced is the design and application of the airbrakes. The airbrakes need to be located behind the center of gravity of the rocket and close to the fins. The size of the motor prevents it from being placed within two feet of the tail end of the rocket. Another challenge with the airbrakes is that upon deployment, they need to be designed so that they do not interrupt the air flow around the fins. This has the potential to severely reduce the stability of the rocket. They also might force a premature drogue parachute deployment because the altimeter might be affected by the sharp drop in speed of the rocket and reread an altitude to that it thinks it is at the apogee of flight. To reduce the possibility of premature drogue deployment through incorrect determination of apogee, the air brakes should be deployed in a gradual sweep as opposed to full deployment in a single move. The diagram below explains the electrical components that we are planning to include in the airbrake system.

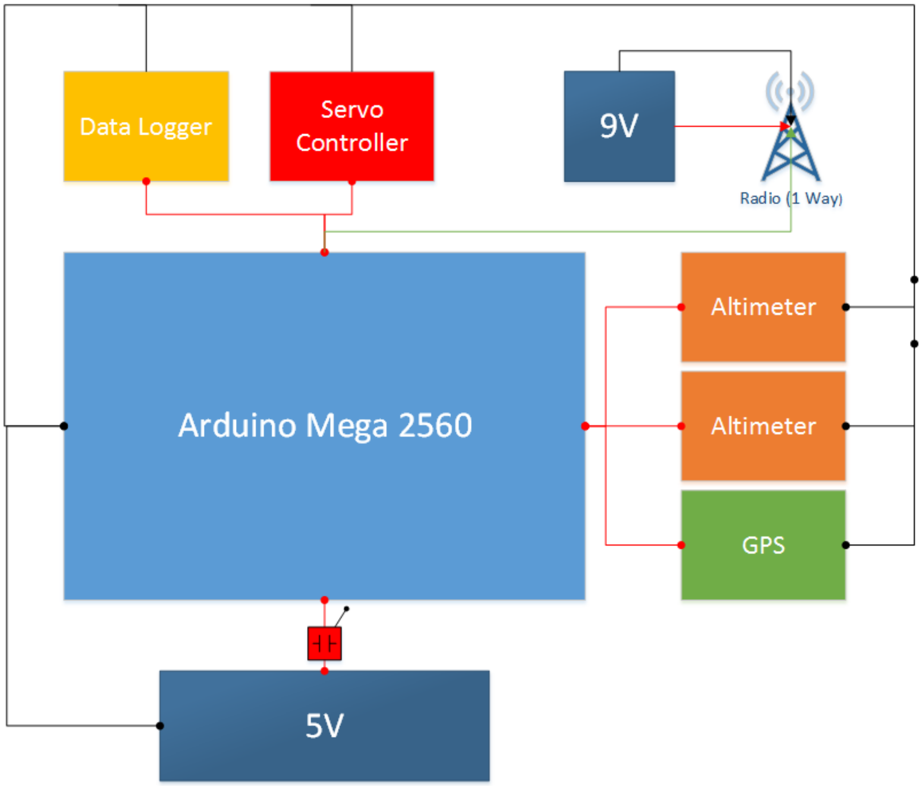

Figure 6 Airbrake and Telemetry System

This system will be controlled by an Arduino Mega 2560. Two Adafruit BMP180 altimeters will be used to accurately measure the rockets altitude. Experiments will be conducted to ensure that these altimeters give the same results as the ones used for parachute ejection sequences on the rocket. On September 26, 2015, the experiment will be conducted to see how well the system measures altitude compared with the main altimeters (SL100 and Entacore) using one of our older high powered rockets. We will develop an algorithm that will relate the altimeter measurements to the movement of the servo that will control the flaps. In addition to the airbrakes, this system will also send back live telemetry data to a ground station using a Digi XTend 900 MHz radio. Data includes altimeter readings, servo positions, and GPS coordinates (Adafruit 60Hz GPS). Data will also be logged onboard in case the data link gets interrupted. Precautions will be taken to ensure that the radio transmissions do not interfere with the altimeters that control the parachute ejection sequences.

Another challenge is securing the payload in the rocket without using gravity. One method that was discussed involves placing strips of polyurethane foam in the payload bay. Polyurethane foam is flexible enough to deform around the payload without requiring too much force from the robotic arm during insertion. The foam will also act like a cushion for the payload, damping any forces that are put on the payload bay through the erection, launch and recovery of the rocket.

After payload insertion the payload bay opening must be sealed securely before the rocket can be erected. Our preliminary design just had the robotic arm push a hatch closed and magnets located on the hatch edges kept it in place. However, we felt that this design, while simple, could be construed as a gravity assisted method. A way to exclude gravitational assistance would be to rotate the opening hatch of the payload bay by 90 degrees so that the robotic arm has to close the hatch entirely. The magnetic hatch edges would still be the same design, but the arm no longer just tips the hatch and then gravity closes it.

The challenges are not limited to these three items, but as a team we felt that we have needed to discuss these three in particular more in depth to get a strong grasp on what we needed to accomplish.

5. Educational Engagement

NC State Hosted Family STEM night

The NCSU High Powered Rocketry Club plans to help host Family STEM Nights at Brentwood Elementary and Zebulon Elementary. These events will be set up like a fair with different STEM groups from NC State running activities and explaining basic engineering concepts to the students and their parents. Each event should have about 100 students and their parents. It is sponsored by the NC State Engineering Ambassadors program.

Location: Brentwood Elementary School 3426 Ingram Dr. Raleigh, NC 27604
Time: October 15th, 4pm-8pm
Location: Zebulon Elementary School 700 Proctor St, Zebulon, NC 27597
Time: October 21st, 4pm-8pm

First Robotics THOR Offseason Competition
Several members of the NCSU High Powered Rocketry Club are planning on volunteering at the First Robotics THOR Offseason Competition. The event is a friendly competition for teams to prepare for in between the regular competition season. The event takes place all day on Saturday at Reidsville High School. 24 teams attended last year's event. Team members will have the opportunity to help officiate the competition and mentor students at the event.

Location: Reidsville High School 3426 Ingram Dr. Raleigh, NC 27604
Time: October 10th, 9am-5pm

Thales Academy Rocket Unit Kick-Off
A couple of members from the High Powered Rocketry Club will be going out to two Thales Academy high schools in Rolesville and Apex later this autumn. The members will discuss rocketry and basic aerospace engineering concepts such as thrust, drag, stability, and recovery systems. After this, the members will have the students design and build water bottle rockets while offering up any assistance that teams need for the design or build. The specifics of time and date will be determined with the Thales Academy Director of Development.

Locations: Thales Academy 1201 Granite Falls Blvd, Rolesville, NC 2757
Thales Academy 1177 Ambergate Station, Apex, NC 27502
Time: TBD

YMCA Kite and Rocket Day

The High Powered Rocketry Club is planning on continuing the tradition of being a part of the YMCA Kite and Rocket Day in the spring of 2016. The Club plans to set up an informational booth at Carter Finley Stadium to assist young rocketeers with assembling and launching model rockets. Last year's event had over 200 kids attend the Kit and Rocket Day and we expect many more this year. The details will be available as the event gets closer in the spring.

Location: Carter Finley Stadium, 4600 Trinity Rd. Raleigh, NC 27607
Time: TBD

Sigma Gamma Tau Boy Scout Merit Badge Event

The club is also planning on partnering with NCSU's chapter of Sigma Gamma Tau to host their annual Boy Scout Merit Badge Event in the spring of 2016. On the morning of this event, the club launches a model rocket for the enjoyment of the Boy Scouts and their families. Sigma Gamma Tau then gives a presentation for those attending before the Space Exploration badges are awarded. This even takes place on NCSU's campus and involves around 30-40 Boy Scouts and their families. The details of this event will be finalized in spring 2016.

Location: North Carolina State University's campus, Raleigh, NC 27695
Time: TBD

6. Project Plan

6.1. Development Schedule/Timeline

Event/Task	Start Date	Finish Date
Request for Proposal (RFP) is Released	8/7/2015	8/7/2015
RFP Writing/Editing	8/7/2015	9/11/2015
Completed RFP Submission	9/11/2015	9/11/2015
Airbrake Altimeter Test (4.1.7)	9/15/2015	9/26/2015
Awarded Proposals Announced	10/2/2015	10/2/2015
Team Web Presence Established	10/23/2015	10/23/2015
Preliminary Design Review (PDR) Writing	10/2/2015	11/6/2015
First Robotics THOR Offseason Competition	10/10/15	10/10/15
NC State Hosted Family STEM night	10/15/15	10/15/15
NC State Hosted Family STEM night	10/21/15	10/21/15
Completed PDR Submission	11/6/2015	11/6/2015
PDR Team Teleconference (Tentative)	11/9/2015	11/22/2015
Critical Design Review (CDR) Writing	11/7/2015	12/15/2015
Subscale Launch	11/21/2015	11/22/2015
NCSU Winter Break (no building access)	12/17/2015	1/5/2016
CDR Writing	1/6/2016	1/15/2016

Completed CDR Submission	1/15/2016	1/15/2016
CDR Team Teleconference (Tentative)	1/19/2016	1/29/2016
Flight Readiness Review (FRR) Writing	1/16/2016	3/14/2016
Fullscale Launch (Tentative)	2/1/2016	2/29/2016
Completed FRR Submission	3/14/2016	3/14/2016
FRR Team Teleconference (Tentative)	3/17/2016	3/30/2016
Team Travel to Huntsville, Alabama	4/13/2016	4/13/2016
Launch Readiness Review (LRR)	4/13/2016	4/14/2016
NASA Safety Briefing	4/14/2016	4/14/2016
Rocket Fair and Tours of MSFC	4/15/2016	4/15/2016
Launch Day	4/16/2016	4/16/2016
Backup Launch Day	4/17/2016	4/17/2016
Post-Launch Assessment Review	4/29/2016	4/29/2016
Winning Team Announced by NASA	5/11/2016	5/11/2016

6.2. Budget

The current budget accounts for, but is not limited to the following:

	Item	Amount	Total Price
AGSE	Beaglebone Black	1	$50
	Phidgets Stepper Motor Controller	1	$95
	Phidgets Servo Controller	1	$50
	Phidgets Sensor Board	1	$90
	Phidgets Servo Motor	8	$95
	Strain gage	10	$180
	USB hub	1	$10
	12-20 V DC Power Supply	1	$125
	Aluminum Railing (ft)	30	$950
	Brackets	15	$80
	Aluminum sheet (for arm) (ft)	2x4	$80
	Miscellaneous hardware (nuts/bolts/washers)	--	$100
	Phidgits DC Controller	1	$120
	Phidgets DC motor	2	$80
	Mini Slide Rail	1	$126
	Rod Actuator	1	$250
Rocket	ARR Standard Coupler 4”(3.9” , 98mm) x .062 wall x 8”	1	$15

	ARR Standard Coupler 5.5" x .077 wall x 12"	1	$20
	ARR Airframe 5.5" x .077 wall x 48" Airframe/MMT	1	$60
	ARR Airframe 5.5" x .077 wall x 72" Airframe	1	$90
	ARR Airframe 4"(3.9" , 98mm) x .062 wall x 48" Airframe/MMT	1	$40
	Fiberglass 3k, 2 x 2 Twill Weave Carbon Fiber Fabric (1 yard), 50'' wide, .012" Thick	1	$60
	Aircraft Spruce Domestic Birch Plywood ¼" x 4 x 4	1	$120
	Aircraft Spruce Domestic Birch Plywood⅜" x 4 x 4	1	$140
	Epoxy and hardener	1	$50
	Paint	--	$30
	Rail buttons	4	$10
	StratoLogger Altimeter	4	$320
	GPS Bee	3	$95
	L motor (full scale)	2	$360
	I motor (subscale)	2	$100
	Wires	--	$30
	Connectors	--	$20
	Nose cone (full scale)	1	$115
	Nose cone (subscale)	1	$65

	Motor casing (full scale)	1	$65
	Motor casing (subscale)	1	$65
	Kevlar shock cord (ft)	60	$60
	Parachute materials	--	$500
	Black powder (lb)	1	$20
	RATTworks ARRD	1	$95
Other	Travel expenses (hotel, rental car, gas) (# people)	20	$3,000
	incidentals (replacement tools, hardware, safety equipment)	--	$1,000
	Shipping costs		$750
Subtotal	--	--	$9,776

6.3. Funding Plan

The current budget for the 2015-2016 is largely based off of NASA SL requirements from the previous year and previous awards from various sources. The budget is projected to be $10,000 for the building of the full scale competition rocket and AGSE. The club received $2,000 from the Engineering Technology Fee Fund from the Mechanical and Aerospace Department at North Carolina State University for the 2014-2015 academic year and the same is expected for the 2015-2016 academic year. The Engineering Council at North Carolina State University granted the club $3,000 for the 2014-2015 academic year. The club plans to request $4,500 for fall of 2015 from the Engineering Council through a proposal, presentation, and appeals presentation and interview. If the budget for the Engineering Council remains the same, the request of $4,500 will be made for spring of 2016. The Student Government Appropriations committee awarded the club $1,000 for spring of 2015. The club plans to request $2,000 for fall of 2015 through a budget plan, interview process, and presentation. The club received $7,000 from the North Carolina Space Grant for competition and senior design for the 2014-2015 academic year. The club must submit two separate proposals to NC Space Grant for the 2015-2016 academic year and expects to receive the same amount of $7,000. The total amount requested is $20,000, however this is based on an expectation of maximum funding. The projected amount to be received is much lower as requests do not have to be awarded in full.

6.4. Community Support

The High Powered Rocketry Club is largely self-sufficient, having all of the machines and materials needed on-site. If outside help is needed, the club can direct them to its hosted events and its website to spark interest in its mission. The club also hopes that its outreach events will promote its good standing in the community.

6.5. Project Local Sustainability Plan

The club plans to sustain itself by continuing to host its outreach events. These events promote others to participate in the club and provide its newest members a chance to experience what it is like to be in the rocketry club. That way, they can teach others and promote the club in the years ahead. The club also does not discriminate against new members, giving everyone an equal chance to help and join the club. The club does not limit the members to a certain degree, but instead welcomes anyone with an interest in rocketry. The club believes that diversity is the key to success.

7. Appendices

7.1 MSDS Information

a. GOEX Black Powder MSDS

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

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

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

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

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).

b. Rust-oleum MSDS sheet

*** Emergency Overview ***: Harmful if inhaled. May affect the brain or nervous system causing dizziness, headache or nausea. Contents Under Pressure. Vapors may cause flash fire or explosion. Extremely flammable liquid and vapor. Harmful if swallowed.

Effects Of Overexposure - Eye Contact: Causes eye irritation.

7733830, 7740830, 7794830, 7721830, 7722830, 7723830, 7724830, 7727830, 7729830, ... Page 2 of 7

Effects Of Overexposure - Skin Contact: May be harmful if absorbed through skin. Prolonged or repeated contact may cause skin irritation. Substance may cause slight skin irritation.

Effects Of Overexposure - Inhalation: High vapor concentrations are irritating to the eyes, nose, throat and lungs. Avoid breathing vapors or mists. High gas, vapor, mist or dust concentrations may be harmful if inhaled. Harmful if inhaled.

Effects Of Overexposure - Ingestion: Aspiration hazard if swallowed; can enter lungs and cause damage. Substance may be harmful if swallowed.

Effects Of Overexposure - Chronic Hazards: IARC lists Ethylbenzene as a possible human carcinogen (group 2B). May cause central nervous system disorder (e,g.,narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. Overexposure to xylene in laboratory animals has been associated with liver abnormalities, kidney, lung, spleen, eye and blood damage as well as reproductive disorders. Effects in humans, due to chronic overexposure, have included liver, cardiac abnormalities and nervous system damage. Overexposure to toluene in laboratory animals has been associated with liver abnormalities, kidney, lung and spleen damage. Effects in humans have included liver and cardiac abnormalities.
Contains carbon black. Chronic inflammation, lung fibrosis, and lung tumors have been observed in some rats experimentally exposed for long periods of time to excessive concentrations of carbon black and several insoluble fine dust particles. Tumors have not been observed in other animal species (i.e., mouse and hampster) under similar circumstances and study conditions. Epidemiological studies of North American workers show no evidence of clinically significant adverse health effects due to occupational exposure to carbon black.
Carbon black is listed as a Group 2B-"Possibly carcinogenic to humans" by IARC and is proposed to be listed as A4- "not classified as a human carcinogen" by the American Conference of Govermental Industrial Hygienists. Significant exposure is not anticipated during brush application or drying. Risk of overexposure depends on duration and level of exposure to dust from repeated sanding of surfaces or spray mist and the actual concentration of carbon black in the formula.

Primary Route(s) Of Entry: Skin Contact, Skin Absorption, Inhalation, Eye Contact

Section 4 - First Aid Measures

First Aid - Eye Contact: Hold eyelids apart and flush with plenty of water for at least 15 minutes. Get medical attention.

First Aid - Skin Contact: Wash with soap and water. Get medical attention if irritation develops or persists.

First Aid - Inhalation: If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately.

First Aid - Ingestion: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention.

Section 5 - Fire Fighting Measures

Flash Point: -156 F (Setaflash)

LOWER EXPLOSIVE LIMIT: 1.0 %
UPPER EXPLOSIVE LIMIT : 9.5 %

Extinguishing Media: Dry Chemical, Foam, Water Fog

Unusual Fire And Explosion Hazards: Vapors can travel to a source of ignition and flash back. Vapors may form explosive mixtures with air. Closed containers may explode when exposed to extreme heat. Water spray may be

ineffective. FLASH POINT IS LESS THAN 20 °. F. - EXTREMELY FLAMMABLE LIQUID AND VAPOR! Perforation of the pressurized container may cause bursting of the can. Isolate from heat, electrical equipment, sparks and open flame. Keep containers tightly closed.

Special Firefighting Procedures: Evacuate area and fight fire from a safe distance.

Section 6 - Accidental Release Measures

Steps To Be Taken If Material Is Released Or Spilled: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers.

Section 7 - Handling And Storage

Handling: Wash thoroughly after handling. Wash hands before eating. Use only in a well -ventilated area. Follow all MSDS/label precautions even after container is emptied because it may retain product residues. Avoid breathing vapor or mist.

Storage: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Do not store above 120 ° F. Store large quantities in buildings designed and protected for storage of NFPA Class I flammable liquids. Contents under pressure. Do not expose to heat or store above 120 ° F.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Use explosion-proof ventilation equipment. Prevent build -up of vapors by opening all doors and windows to achieve cross-ventilation. Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits.

Respiratory Protection: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with an organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, exposure levels are not known, or any other circumstances where air purifying respirators may not provide adequate protection.

Skin Protection: Use impervious gloves to prevent skin contact and absorption of this material through the skin. Nitrile or Neoprene gloves may afford adequate skin protection.

Eye Protection: Use safety eyewear designed to protect against splash of liquids.

Other protective equipment: Refer to safety supervisor or industrial hygienist for further information regarding personal protective equipment and its application.

Hygienic Practices: Wash thoroughly with soap and water before eating, drinking or smoking.

c. Klean Strip Denatured Alcohol MSDS

3. Hazards Identification

Emergency Overview

Danger! Flammable! Keep away from heat, sparks, flame, and all other sources of ignition. Do not smoke. Extinguish all flames and pilot lights, and turn off stoves, heaters, electric motors and all other sources of ignition during use and until all vapors are gone. Beware of static electricity that mat be generated by synthetic clothing and other sources.

OSHA Regulatory Status: This material is classified as hazardous under OSHA regulations.

Health Hazards (Acute and Chronic)

Inhalation Acute Exposure Effects:
Vapor harmful. May cause dizziness, headache, watering of eyes, irritation of respiratory tract, irritation to the eyes, drowsiness, nausea, other central nervous system effects, spotted vision, dilation of pupils, and convulsions.

Skin Contact Acute Exposure Effects:
May cause irritation, drying of skin, redness, and dermatitis. May cause symptoms listed under inhalation. May be absorbed through damaged skin.

Eye Contact Acute Exposure Effects:
May cause irritation.

Ingestion Acute Exposure Effects:
Poison. Cannot be made non-poisonous. May be fatal or cause blindness. May produce fluid in the lungs and pulmonary edema. May cause dizziness, headache, nausea, drowsiness, loss of coordination, stupor, reddening of face and or neck, liver, kidney and heart damage, coma, and death. May produce symptoms listed under

inhalation.

Chronic Exposure Effects:
May cause symptoms listed under inhalation, dizziness, fatigue, tremors, permanent central nervous system changes, blindness, pancreatic damage, and death.

Signs and Symptoms Of Exposure

No data available.

Medical Conditions Generally Aggravated By Exposure

Diseases of the liver.

OSHA Hazard Classes:

HEALTH HAZARDS : N/E
PHYSICAL HAZARDS : N/E
TARGET ORGANS & EFFECTS: N/E

4. First Aid Measures

Emergency and First Aid Procedures

Inhalation:
If user experiences breathing difficulty, move to air free of vapors. Administer oxygen or artificial respiration until medical assistance can be rendered.

Skin Contact:
Wash with soap and water.

Eye Contact:
Flush with large quantities of water for at least 15 minutes. If irritation from contact persists, get medical attention.

Ingestion:
Call your poison control center, hospital emergency room or physician immediately for instructions to induce vomiting.

Note to Physician

Poison. This product contains methanol. Methanol is metabolized to formaldehyde and formic acid. These metabolites may cause metabolic acidosis, visual disturbances and blindness. Since metabolism is required for these toxic symptoms, their onset may be delayed from 6 to 30 hours following ingestion. Ethanol competes for the same metabolic pathway and has been used as an antidote. Methanol is effectively removed by hemodialysis. Call your local poison control center for further instructions.

5. Fire Fighting Measures

Flammability Classification:	OSHA Class IB
Flash Pt:	45.00 F Method Used: SCC
Explosive Limits:	LEL: 1.00 UEL: No data.
Autoignition Pt:	No data.

Special Fire Fighting Procedures

Self-contained respiratory protection should be provided for fire fighters fighting fires in buildings or confined area. Storage containers exposed to fire should be kept cool with water spray to prevent pressure build-up. Stay away from heads of containers that have been exposed to intense heat or flame.

Unusual Fire and Explosion Hazards

No data available.

Extinguishing Media

Use carbon dioxide, dry powder, or foam.

Unsuitable Extinguishing Media

No data available.

6. Accidental Release Measures

Steps To Be Taken In Case Material Is Released Or Spilled

Clean-up:

Keep unnecessary people away; isolate hazard area and deny entry. Stay upwind, out of low areas, and ventilate closed spaces before entering. Shut off ignition sources, keep flares, smoking or flames out of hazard area.

Small spills:

Take up liquid with sand, earth or other noncombustible absorbent material and place in a plastic container where applicable.

Large spills:

Dike far ahead of spill for later disposal.

7. Handling and Storage

Precautions To Be Taken in Handling

Read carefully all cautions and directions on product label before use. Since empty container retains residue, follow all label warnings even after container is empty. Dispose of empty container according to all regulations. Do not reuse this container.

Precautions To Be Taken in Storing

Keep container tightly closed when not in use. Store in a cool, dry place. Do not store near flames or at elevated temperatures.

8. Exposure Controls/Personal Protection

Respiratory Equipment (Specify Type)

For OSHA controlled work place and other regular users. Use only with adequate ventilation under engineered air control systems designed to prevent exceeding appropriate TLV. For occasional use, where engineered air control is not feasible, use properly maintained and properly fitted NIOSH approved respirator for organic solvent vapors. A dust mask does not provide protection against vapors.

Eye Protection

Safety glasses, chemical goggles or face shields are recommended to safeguard against potential eye contact, irritation, or injury. Contact lenses should not be worn while working with chemicals.

Protective Gloves

Wear impermeable gloves. Gloves contaminated with product should be discarded. Promptly remove clothing that becomes soiled with product.

Other Protective Clothing

Various application methods can dictate the use of additional protective safety equipment, such as impermeable aprons, etc., to minimize exposure. A source of clean water should be available in the work area for flushing eyes and skin. Do not eat, drink, or smoke in the work area. Wash hands thoroughly after use. Before reuse, thoroughly clean any clothing or protective equipment that has been contaminated by prior use. Discard any clothing or other protective equipment that cannot be decontaminated, such as gloves or shoes.

Ventilation

Use only with adequate ventilation to prevent build-up of vapors. Open all windows and doors. Use only with a cross ventilation of moving fresh air across the work area. If strong odor is noticed or you experience slight dizziness, headache, nausea, or eye-watering -- Stop -- ventilation is inadequate. Leave area immediately.

d. Klean Strip Acetone MSDS

3. Hazards Identification

Emergency Overview

Danger! Extremely Flammable. Keep away from heat, sparks, flame and all other sources of ignition. Vapors may cause flash fire or ignite explosively. Vapors may travel long distances to other areas and rooms away from the work site. Do not smoke. Extinguish all flames and pilot lights, and turn off stoves, heaters, electric motors and all other sources of ignition anywhere in the structure, dwelling, or building during use and until all vapors are gone from the work site. Keep away from electrical outlets and switches. Beware of static electricity that may be generated by synthetic clothing and other sources.

OSHA Regulatory Status:

This material is classified as hazardous under OSHA regulations.

Potential Health Effects (Acute and Chronic)

Inhalation Acute Exposure Effects:
Vapor harmful. May cause dizziness, headache, watering of eyes, irritation of respiratory tract, drowsiness, nausea, and numbness in fingers, arms and legs.

Skin Contact Acute Exposure Effects:
May cause drying of skin, and numbness in fingers and arms. Liquid is absorbed readily.

Eye Contact Acute Exposure Effects:
This material is an eye irritant.

Ingestion Acute Exposure Effects:
Harmful if swallowed. May cause dizziness, headache, nausea, and irritation of the mouth, throat, and stomach.

Chronic Exposure Effects:
Reports have associated repeated and prolonged overexposure to solvents with neurological and other

physiological damage. May cause weakness, fatigue, skin irritation, and numbness in hands and feet.

Signs and Symptoms Of Exposure

Primary Routes of Exposure:
Inhalation, ingestion, and dermal.

Medical Conditions Generally Aggravated By Exposure

Skin, eye, lung (asthma-like conditions)

4. First Aid Measures

Emergency and First Aid Procedures

Inhalation:

If user experiences breathing difficulty, move to air free of vapors. Administer oxygen or artificial respiration until medical assistance can be reached.

Skin Contact:

Wash with soap and water.

Eye Contact:

Flush with large quantities of water for at least 15 minutes and seek immediate medical attention.

Ingestion:

Call your poison control center, hospital emergency room, or physician immediately for instructions.

Note to Physician

Call your local poison control center for further instructions.

6. Accidental Release Measures

Steps To Be Taken In Case Material Is Released Or Spilled

Clean Up:

Keep unnecessary people away; isolate hazard area and deny entry. Stay upwind, out of low areas, and ventilate closed spaces before entering. Shut off ignition sources; keep flares, smoking or flames out of hazard area. For small spills, take up liquid with sand, earth, or other noncombustible absorbent material and place in a container for disposal. For large spills, dike far ahead of spill and use sand, earth, or other noncombustible absorbent material and then place material in a container for disposal.

Waste Disposal:

Dispose in accordance with applicable local, state, and federal regulations.

7. Handling and Storage

Precautions To Be Taken in Handling

Read carefully all cautions and directions on product label before use. Since empty container retains residue, follow all label warnings even after container is empty. Dispose of empty container according to all regulations. Do not reuse the container.

Precautions To Be Taken in Storing

Keep container tightly closed when not in use. Store in a cool, dry place. Do not store near flames or at elevated temperatures.

8. Exposure Controls/Personal Protection

Respiratory Equipment (Specify Type)

For OSHA controlled work place and other regular users. Use only with adequate ventilation under engineered air control systems designed to prevent exceeding appropriate TLV. For occasional use, where engineered air control is not feasible, use properly maintained and properly fitted NIOSH approved respirator for organic solvent vapors. A dust mask does not provide protection against vapors.

Eye Protection

Safety glasses, chemical goggles or face shields are recommended to safeguard against potential eye contact, irritation, or injury. Contact lenses should not be worn while working with chemicals.

Protective Gloves

Wear chemical resistant gloves suited for use with acetone. Gloves contaminated with product should be discarded. Promptly remove clothing that becomes soiled with product.

Other Protective Clothing

Various application methods can dictate use of additional protective safety equipment, such as impermeable aprons, etc., to minimize exposure.

Engineering Controls (Ventilation etc.)

Use only with adequate ventilation to prevent build-up of vapors. Open all windows and doors. Use only with a cross ventilation of moving fresh air across the work area. If strong odor is noticed or your experience slight dizziness, headache, nausea, or eye-watering - STOP - ventilation is inadequate. Leave area immediately.

Work/Hygienic/Maintenance Practices

A source of clean water should be available in the work area for flushing eyes and skin.
Do not eat, drink, or smoke in the work area.
Wash hands thoroughly after use.
Before reuse, thoroughly clean any clothing or protective equipment that has been contaminated by prior use.
Discard any clothing or other protective equipment that cannot be decontaminated, such as gloves or shoes.

e. West System 105 Epoxy Resin MSDS

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

HMIS Hazard Rating: Health - 2 Flammability - 1 Physical Hazards - 0

WARNING! May cause allergic skin response in certain individuals. May cause moderate irritation to the skin. Clear to light yellow liquid with mild odor.

PRIMARY ROUTE(S) OF ENTRY:.................... Skin contact.

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION:.................... Not likely to cause acute effects unless heated to high temperatures. If product is heated, vapors generated can cause headache, nausea, dizziness and possible respiratory irritation if inhaled in high concentrations.

CHRONIC INHALATION: .... Not likely to cause chronic effects. Repeated exposure to high vapor concentrations may cause irritation of pre-existing lung allergies and increase the chance of developing allergy symptoms to this product.

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

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

EYE CONTACT: .... May cause irritation.

INGESTION:.................... Low acute oral toxicity.

SYMPTOMS OF OVEREXPOSURE: .... Possible sensitization and subsequent allergic reactions usually seen as redness and rashes. Repeated exposure is not likely to cause other adverse health effects.

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

4. FIRST AID MEASURES

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

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

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

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

6. ACCIDENTAL RELEASE MEASURES

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

7. HANDLING AND STORAGE

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

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

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

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

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

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

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

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

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

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

f. West System 206 Hardener MSDS

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. Can cause allergic reaction. Aspiration hazard. Clear liquid with ammonia odor.

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

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION: .... Excessive exposure to vapor or mist is irritating to the upper respiratory tract, causing nasal discharge, coughing, and discomfort in eyes, nose, throat and chest. Severe cases may cause difficult breathing and lung damage.

CHRONIC INHALATION: .... May cause lung damage. May cause respiratory sensitization in susceptible individuals. Repeated exposures may cause internal organ damage.

ACUTE SKIN CONTACT: .... Corrosive. Prolonged contact may cause skin damage with burns and blistering. Wide spread contact may result in material being absorbed in harmful amounts.

CHRONIC SKIN CONTACT: .... May cause persistent irritation or dermatitis. Repeated contact may cause allergic reaction/sensitization and possible tissue destruction. Can be absorbed through the skin in amounts that can cause internal organ damage.

EYE CONTACT: .... Corrosive. May cause blurred vision. May cause irritation with corneal injury resulting in permanent vision impairment or even blindness.

INGESTION: .... Moderately toxic. May cause gastrointestinal irritation or ulceration. May cause burns of the mouth and throat. Aspiration hazard.

SYMPTOMS OF OVEREXPOSURE: .... Skin irritation, burns and blistering. Irritation of the nose and throat, possible headache. Eye irritation and blurred vision.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: .... Existing respiratory conditions, such as asthma and bronchitis. Existing skin conditions.

4. FIRST AID MEASURES

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

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

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

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

6. ACCIDENTAL RELEASE MEASURES

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

7. HANDLING AND STORAGE

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

STORAGE:.. Store in cool, dry place with adequate ventilation.

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

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION GUIDELINES:... Chemical splash goggles, full-face shield or full-face respirator.

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

RESPIRATORY/VENTILATION GUIDELINES: .... General mechanical or local exhaust ventilation. With inadequate ventilation, use a NIOSH/MSHA approved air purifying respirator with an organic vapor cartridge.

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 (amines) were either so low that they were not detected at all or they were well below OSHA's permissible exposure levels.

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

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

7.2 FMECA

Structures

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
FiberglassAirframe	Cracks or breaks	Manufacturing defect	Individual sections structural integrity at risk	Unintended launch vehicle separation	1	Visual inspection prior to use
		Loads beyond design specification			1	Maintain vehicle within design specifications
		Damaged during handling			1	Adhere to proper handling procedure
		Improper maintenance			1	Pre/post launch inspections
Bulkheads	Separation of bulkhead from other structural members	Poor design	Unable to transfer loads	Increased loads on other structural members	2	FEA of bulkhead fixed support
		Manufacturing defect			2	QC of manufacturing process
		Loads beyond design specification			2	Maintain vehicle within design specifications
		Damaged during handling			2	Ensure analysis includes handling loads/adhere to proper handling procedure
		Improper maintenance			2	Pre/post launch inspections
	Damage/separation from parachute deployment	Poor design	Unable to support loads of chute deployment	Loss of safe and effective recovery system	2	FEA of bulkhead stress
		Manufacturing defect			2	QC of manufacturing process

		Loads beyond design specification			2	Maintain operations within design specifications
		Improper Maintenance			2	Pre/post launch inspections
		Poor Design			4	FEA of bulkhead stress
		Manufacturing Defect			4	QC of manufacturing process
	Non-compromising cracks	Loads beyond design specification	Potential for future damage	No system level safety effect	4	Maintain operations within design specifications
		Damaged during handling			4	Adhere to proper handling procedure
		Improper maintenance			4	Pre/post launch inspections
		Poor design			2	FEA
		Manufacturing defect			2	QC of manufacturing process
		Damaged during handling			2	Adhere to proper handling procedure
Fins	Damage from impact		Loss of future fin use	Possible damage to other components		
		Loads beyond design specification			2	Maintain operations within design specifications
		Improper maintenance			2	Pre/post launch inspections

Shear Pins	Breaking before charge detonation	Manufacturing defect	Loose assembly of compartment	Separation of vehicle compartments	3	QC of parts received
		Loads beyond design specification			3	Maintain vehicle within design specifications
		Improper maintenance			3	Use of new pins after each launch
Avionics Bays	Detaches from secured position	Poor design	Damage to/loose wiring of avionics components	Loss of recovery system initiation	3	Design to ensure secure sled with redundancy
		Manufacturing defect			3	QC of manufacturing process
		Damaged during handling			3	Adhere to proper handling procedure
		Loads beyond design specification			3	Maintain operations within design specifications
		Improper maintenance			3	Pre/post launch inspections
Nosecone	Non-compromising cracks	Manufacturing defect	Potential for future damage	No system level safety effect	4	QC of part received
		Damaged during handling			4	Adhere to proper handling procedure
		Loads beyond design specification			4	Maintain vehicle within design specifications

		Improper maintenance			4	Pre/post launch inspections
	Damage from impact	Manufacturing defect	Loss of future nosecone use	No system level safety effect	3	QC of part received
		Damaged during handling			3	Adhere to proper handling procedure
		Loads beyond design specification			3	Maintain vehicle within design specifications
		Improper maintenance			3	Pre/post launch inspections
	Pre-mature	Damaged during	Potential for	Loss of	1	Adhere to proper

	separation from other structural members	handling	structural damage	controlled and stabilized flight	1	handling procedure
		Improper maintenance			1	Pre/post launch inspections

Recovery

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
Black Powder Charges	Deployment failure	Charge is too small	Unsuccessful parachute deployment	Rocket is not safely recovered	1	Complete experimental testing to ensure proper charge sizing
	Violent ejection causes accidental separation	Charge is too big			1	
Avionics	No power to avionics or igniters	Dead battery	No ejections	Rocket is not safely recovered	1	Use new batteries for each launch
	Interference from RF	Improper design	No ejections	Damage from	2	Complete testing of

	transmitter		or mistimed ejections	high velocity ejection		electronic devices
	Bug in altimeter coding	Manufacturer defect		Large drift from early ejection	4	Test two altimeters for redundancy
Bulkhead and U-bolt	U-bolt failure	Improper attachment	Separation of rocket section from parachute	Rocket is not safely recovered	1	Make sure components are adequately constructed
	Bulkhead failure	Improper attachment			1	
Parachute deployment	Parachutes (3) fail to deploy correctly	Parachute tangling	Parachutes do not correctly deploy	Rocket is not safely recovered	1	Ensure that parachutes and shock cord are folded correctly
		Remote sensor of rocket section from parachutes			3	Construct the rocket so the wires are out of the way
		Parachute bags do not fully open			1	Fold bags correctly and make sure nothing can snag the parachutes
		Shock cord connections come loose			1	Check all shock cord

Exploding Eyebolt (ARRD)	Eyebolt fails to detonate	Improper wiring/attachment	Upper and middle airframes do not separate	Rocket is not safely recovered	1	Make sure components are adequately constructed
		Manufacturer defect			4	Test two eyebolts for redundancy
	Premature detonation	Improper wiring/attachment	Premature separation of connections between lower and middle airframe	Large drifting distance of lower airframe	3	Make sure components are adequately constructed
		RF interference			3	Complete testing of electronic devices

Aerodynamics

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
Fins	Fins layout cause unexpected trajectory	Fins are not attached at the correct angle	Aerodynamic forces from fins are not the same from each fin	Trajectory is different than expected	3	Use fin jig to ensure angles are correct
		Fins are not symmetric			4	Shape fins to specifications before installation
Nosecone	Nosecone imperfections lead to altered trajectory	Manufacture defect	Aerodynamic forces are greater on one side of the nosecone	Trajectory is different than expected	4	Inspect nosecone and sand to correct shape

Air Brakes	Airbrakes don't deploy correctly leading to altered trajectory	Servo Malfunction	Aerodynamic forces from airbrake system is not the same from each airbrake	Trajectory is different than expected	3	Ensure that Arduino coding for servo is correct and that power connection is secure
		Component Failure			4	Make sure that each component can withstand the aerodynamic loads that it will experience
	Airbrakes cause unstable flight	Center of Gravity of rocket is lower than expected	Airbrake system is higher than center of gravity		1	Run experiments and simulations that ensure that proper airbrake deployment won't create unstable flight
Rocket Sections	Rocket sections separate before charges ignite	Deceleration of the rocket	Sections separate early	High velocity separation	1	Make sure shear pins and screws can hold
				Premature parachute deployment at high altitudes	4	

Propulsion

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
Bulkhead	Motor breaks through bulkhead	Material or construction flaws	Motor system is compromised	Motor damages rocket frame or contents	1	Inspect bulkhead prior to launch
Motor Casing	Damage to motor casing	Superficial damage	Motor is not safe if major	Rocket is not safe to launch	4	Check motor casing before launch,

		Motor inoperable	damage occurs	if damage is major	2	remove foreign objects from motor area
		Motor casing fracture			1	
Fuel	Contamination of fuel	Rocket fails to launch	Reduced performance of rocket motor	Rocket does not launch or perform as expected	2	Store and maintain motor fuel properly and in isolation / order from reputable source
		Over-oxidized reaction			2	
		Reduced fuel efficiency			3	
Construction	Motor misalignment	Construction or measurement error	Thrust is not in expected direction	Unpredicted trajectory	1	Check motor alignment during construction
		Rocket frame fracture			1	
Launch	Launch interference from foreign object	Unpredictable rocket trajectory	Launch when clear		3	Launch in an open area, wait for clear airspace before launch
		Rocket frame fracture			2	

Stability

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
Cg	Expected numbers are different from actual	Error in calculations and measurements	Stability characteristics are different than projected	Flight path and characteristics in jeopardy	1	Physically measure the location of the center of gravity
Cp						Use Barrowman's method/OpenRocket to determine location of center of pressure

Static Margin						Calculate by using the locations of the center of gravity and pressure
Weight Shift	Weight shift causes center of gravity shift	Large acceleration or deceleration forces an object to shift	Static margin change due to shift in center of gravity		1	Ensure all rocket components are secure during construction process

Sample Compartment

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
Door	Magnets do not connect	Bracket misalignment	Door doesn't shut securely	Rocket is not ready to Launch. Door could open during flight and cause instability.	1	Careful inspection as part of pre-flight checklist.
					1	Inspection as part of pre-flight checklist.
	Hinges Fail	Excessive arm pressure			1	Tests during build process to ensure the arm behaves correctly.
		Manufacturing defect			1	Inspection and tests during build.
PE Foam	Breaks	Excessive loading	Sample free to move and at risk of damage	Mission requirements not met	2	Build to withstand max force of arm.

	Doesn't hold sample securely	Misalignment of mold			3	Inspection during pre-flight checklist.
		Sample cut out improperly sized			3	Verified during build and pre-flight checklist.
Clamps	Breaks	Excessive loading by arm			3	Visualization design needs to register proper location of clamp.
	Insufficient/excessive gripping force	Poor selection in design process			3	Testing during build and pre-flight checklist.

AGSE

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
Robotic Arm	Pivot points seize	Debris	Arm cannot move to retrieve sample	Failure of mission requirements	2	Inspection during pre-flight checklist.
		Binding of gears			2	Inspection during pre-flight checklist.
	Arm will not move	Rust			2	Inspection during pre-flight checklist.
		Power failure			2	Power backup as part of design.

	Unwanted movement	Signal interference			2	EMF Shielding for servo controller.
	Cannot grab with claw	Gearing slips			2	Testing during build and pre-flight checklist.
Igniter insertion system	Does not insert all the way	Igniter falls off rail	Failure to activate propulsion system	System requires human intervention to launch.	2	Testing during build. Monitor during competition.
		Rollers stop			2	Testing during build. Monitor during competition.
	Falls out	Cap not completely inserted			2	Inspection during pre-flight checklist.
	No ignition	Bad igniter			2	Inspection during pre-flight checklist.
		Short in wiring			2	Inspection during pre-flight checklist.
Launch rail raising system	Seizure of components	Lack of lubrication	Launch rail fails to raise	Failure of mission components	2	Inspection during pre-flight checklist
		Loss of power				Ensure that all power connections are secure during pre-flight checklist