NC STATE UNIVERSITY

Tacho Lycos
2015 NASA Student Launch Project
MAXI-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

Jamie Region

Jamie Region will act as the safety officer for the North Carolina State University 2014-2015 NASA Student Launch team. Jamie has been an active High Power Rocketry Club member since 2012 and has sufficient experience in all aspects of rocketry safety. When present, she will oversee all activities conducted in the student fabrication lab as well as at the launch site. When Jamie is unavailable, the responsibilities will be fulfilled by the highest ranking club officer present.

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

Chris Celestino
ccelest@ncsu.edu
(830) 515-8060

Chris will act as the North Carolina State University 2014-2015 NASA Student Launch team lead. Chris is also the team lead for the MAE Space Senior Design team and will be partnering with his senior design team consisting of Collin Bolton, Mitchell Plyler, Conor Benson, and Joshua Pickles. This is Chris' second year with the High Power Rocketry Club, but has had plenty of leadership experience in the past. From September 2003 to December 2010 Chris served as a crew chief on the AH-64D Apache Helicopter. This time included multiple year-long tours to Iraq where he served as a shift leader. Chris has also gained fabrication knowledge from working with Dr. Mark Pankow in the BLAST Lab at NCSU on multiple research projects.

1.4. Team Outline Matrix

a. Officer Position: President
   i. Name: Chris Celestino
   ii. Years in Club: 2
   iii. Prior Experience/Responsibilities: 2013-2014 Member
   iv. Qualities and Skills: Chris 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 last year.

b. Officer Position: Vice-President
   i. Name: Collin Bolton
   ii. Years in Club: 3
   iii. Prior Experience/Responsibilities: 2013-2014 Safety Officer, 2012-2013 Member

iv. Qualities and Skills: Collin is a senior in Aerospace Engineering and joined the club in the spring of 2012. He is knowledgeable in both the Student Launch documentation and related processes and construction of rockets.

c. Officer Position: Coordination Leader
   i. Name: Raven Lauer
   ii. Years in Club: 3
   iii. Prior Experience/Responsibilities: 2012-2014 Member
   iv. Qualities and Skills: Raven is a sophomore 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.

d. Officer Position: Safety Officer
   i. Name: Jamie Region
   ii. Years in Club: 3
   iii. Prior Experience/Responsibilities: 2012-2014 Member
   iv. Qualities and Skills: Jamie is a returning member from last year and is a junior in Aerospace Engineering. Jamie has experience with rocket construction techniques which makes her very knowledgeable about safety.

e. Officer Position: Treasurer
   i. Name: Emily Gipson
   ii. Years in Club: 2
   iii. Prior Experience/Responsibilities: 2013-2014 Member
   iv. Qualities and Skills: Emily is a returning member from last year and is a sophomore in Aerospace Engineering and Physics. She was an integral part of the fabrication team last year.

f. Officer Position: Treasurer
   i. Name: Matthew Bruce
   ii. Years in Club: 3
   iii. Prior Experience/Responsibilities: 2012-2014 Member
   iv. Qualities and Skills: Matt is a returning member from the club and has contributed more every year with fabrication and knowledge.

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.

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 students Christopher Buck or Jacob Reedy, who both completed Space Senior Design last year, are 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
- 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
- BlueTube 2.0
- Epoxy
- Metal (Bosch railing)
- Carbon fiber
- Safety equipment (fire extinguisher, First-Aid kit, gloves, goggles, masks, cleaning supplies)
- Gloves
- Black powder
- Servos/DC Motors
- Processors
- Barometric altimeters
- 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 2014, OpenRocket 14.06, Abaqus 6.13, Matlab 2014a)
- Raspberry Pi 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

<u>High Power Rocket Safety Code</u>

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

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

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

4. *Ignition System*. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the

launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. 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.

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.

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

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

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.

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. Is it a clustered motor rocket?
7. What are the most probable airframe faults and corrective actions?
8. What are the safety implications of an airframe failure?
9. 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 safeing/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?

v. Motor

1. Is the motor (or motors) suitable for the rocket?
2. Are the motors 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?

vi. 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?

vii. 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?

viii. 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. Wearing closed-toed shoes
      2. Seeking 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

e. 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).

f. 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.

g. 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

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MATERIAL SAFETY DATA SHEET
Klean-Strip Denatured Alcohol

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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.

h. 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.

i. 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.

j. 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.

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**!
Exception: Igniters used in the initiation of upper stages and those of complex clusters may be inserted early but must be shunted to avoid accidental ignition.

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, or motors, in place during the flight and recovery. This is of particular importance in parallel staged cluster flights. In such cases, special attention should be given to providing a positive form of retention that will not allow motors to become dislodged during initial acceleration forces.

If a cluster of motors is being used, the possible failure modes should be explored. If any of the possible scenarios create an extra hazardous situation, additional precautions should be taken.
Verify that a suitable means of ignition has been chosen and will provide a safe and reliable motor ignition. All igniters should be shorted until just prior to connection to launch control equipment. In the event of a hang-fire (failure of the igniter to light the motor), the rocket should not be approached for a minimum of two minutes.

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. Special consideration should be given the flights that are predicted to exceed Mach 1.

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 canards or 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 motor delay is used to actuate recovery system, verify that the delay length was properly selected for the motor/rocket system. Do not allow the rocket to fly if the flyer does not know the reason why they have chosen the installed delay.

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.

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: Chris Celestino
   Signature: [illegible]
   Date: 10/4/14
2. Print Name: Andrew McKeon
   Signature: [illegible]
   Date: 10/4/2014
3. Print Name: MITCHELL PLYLER
   Signature: Mitchell Plyler
   Date: 10/4/2014
4. Print Name: Joshua Pickles
   Signature: Joshua Pickles
   Date: 10/4/14
5. Print Name: Conor Benson
   Signature: Conor Benson
   Date: 10/4/14
6. Print Name: Eli Meyer
   Signature: Eli meyer
   Date: 10/4/14
7. Print Name: Raven Lauer
   Signature: Raven Lauer
   Date: 10/04/2014
8. Print Name: Stuart Philpott
   Signature: Stuart Philpott
   Date: 10/4/2014
9. Print Name: Daniel Mahinthakumar
   Signature: D Mahinthakumar
   Date: 10/4/14
10. Print Name: William Mertz
    Signature: William Mertz
    Date: 10/4/14

11. Print Name: Adam Tokonitz
Signature: Adam Tokonitz
Date: 10/5/14

12. Print Name: Thomas Manzo
Signature: Thomas Manzo
Date: 10/5/14

13. Print Name: Collin Bolton
Signature: Collin Bolton
Date: 10/5/14

14. Print Name: Ben Adamcik
Signature: 10/6/14
Date: Ben Adamcik

15. Print Name: EMILY GIPSON
Signature: Emily
Date: 10/6/14

16. Print Name: Jamie Region
Signature: Jamie Region
Date: 10/6/14

17. Print Name: Matthew Bruce
Signature: Matthew Bruce
Date: 10/6/14

18. Print Name: Christopher R. Buck
Signature: CRBuck
Date: 10/6/14

19. Print Name: Jacob Reedy
Signature: Jacob Reedy
Date: 10/6/14

20. Print Name: Braeden Earp
Signature: Braeden Earp
Date: 10/6/14

4. Technical Design

4.1. Proposed Rocket and Payload Design

4.1.1. General Vehicle Design

4.1.1.1. Dimensions

The proposed vehicle will be 78 inches in length with a 5.5 inch constant diameter body tube. The nose cone will be a 5.5 inch blunt elliptical shape to reduce friction drag in the subsonic region. Fins will be a trapezoidal shape with a sweep angle of 45 degrees. The root chord will be 12 inches with the tip chord being 5 inches. The fins will be layered with birch aircraft plywood and strengthened with carbon fiber to reduce weight.

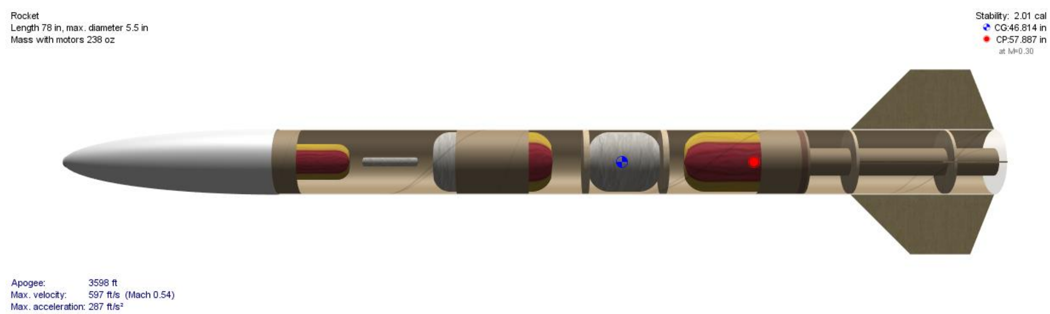

Figure 1 Open Rocket Model of Full Scale Rocket

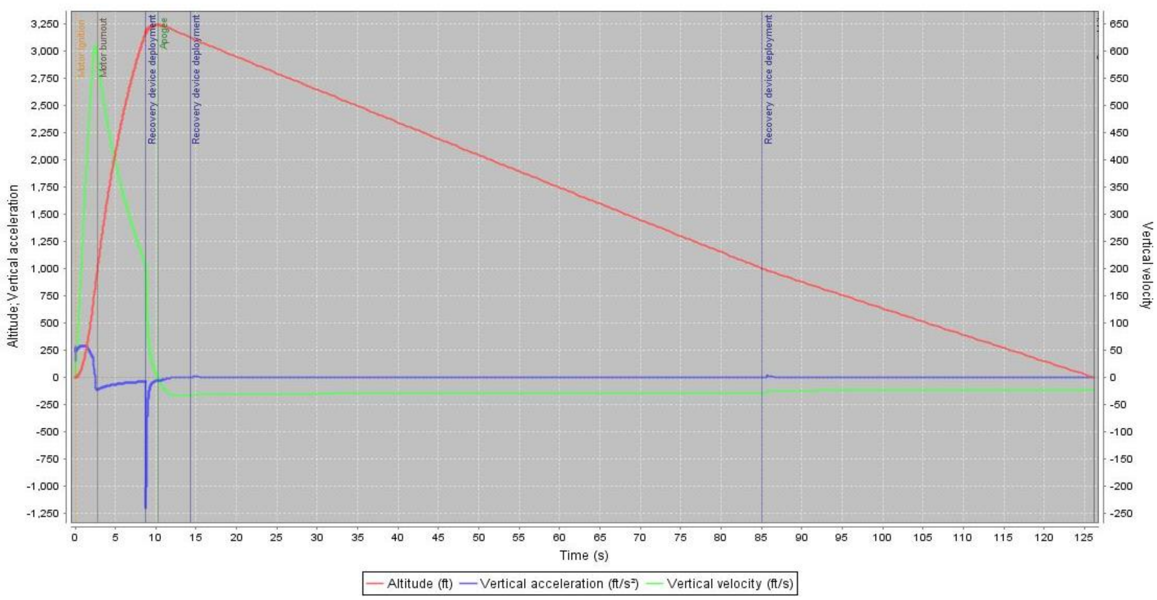

Figure 2 Open Rocket Performance Simulation

As our rocket will be flying at low subsonic speeds, friction drag will play a larger role in the performance of the rocket than pressure drag. This is due to the fact that friction drag has a linear relationship with velocity whereas pressure drag relates to the square of the velocity. As such, we have elected to use a nose cone in a long elliptical shape.

Our research compared long elliptical, parabolic, long cone, short elliptical, ogive, short cone, solid cylinder, vented cupped cylinder, and cupped cylinder shapes to evaluate their respective drag at low speeds. Friction drag is lowest on shapes that follow a shape in the manner of a continuous function. Therefore, cylindrical and pointed conical shapes, including ogive, typically resulted in greater friction drag forces than the round tipped elliptical and parabolic shapes. The elliptical is superior to the parabolic as it has a smoother transition from the streamlined nose cone shape to the straight shaft of the body of the rocket. That is to say, ellipses have an instantaneous slope of zero at the points of the minor axis while parabolic shapes become infinitely wider. Longer shapes are more streamlined than squatter shapes, which is why a longer elliptical shape has lower friction drag than a shorter elliptical shape. The elliptical nose cone will be purchased from a professional manufacturer to make for a more cost and time efficient operation.

As it can be seen in ***Figure 1***, the rocket will have multiple aircraft birch bulkheads. The bulkheads are planned to be 3/8 inches to 1/2 thick with carbon fiber reinforcements to reduce weight and size. Further structural testing will be done to decide the exact thickness needed to withstand the forces exerted on the bulkheads by the parachute deployment. U-bolts that have been bolted to the bulkheads will hold the shock cords to keep the rocket connected at the sections that will separate.

Bulkheads will be constructed using epoxy and a vacuum seal. A large, clean surface that is free of any debris will be covered with a plastic lining that is sized to accommodate the amount of bulkheads needed. The size of the lining will be such that the desired amount of bulkheads take up half of the sheets size. This is so the lining can be folded in half over itself. Prior to placing the lining, thin strips of plumbers putty will be placed along the entire outer perimeter of the lining. The bulkheads will then have the epoxy applied and the carbon fiber reinforcements positioned. The bulkheads will be carefully placed on the lining and sheets of peel ply will be cut to cover each bulkhead with approximately two inches of overhang along the entire edge. Breather will then be cut to the same size as the peel ply and placed directly over the peel ply. Strips of breather will be bridged from bulkhead to bulkhead all the way to the location of the vacuum tubing. This will ensure no air pockets remain trapped and an even pressure is applied at all points. Plumbers putty will then be placed adjacent to and along the entire previous putty lining on the inside edge, except for a one inch gap at the open end of the plastic lining fold. The vacuum tubing will then be inserted in this location and additional putty will be applied around the tubing to keep an airtight seal. The vacuum will then be applied to a pressure of -20 inHg for 8-12 hours minimum.

The fins will also be constructed from a combination of birch aircraft plywood and carbon fiber in an effort to keep weight low. We chose carbon fiber over a fiberglass laminate to increase strength and decrease weight. The fins will be created in the exact same process as the bulkheads using the combination of West Systems epoxy and vacuum application. If the combined production amount of bulkheads and fins can be accommodated into one layup, both will be created at the same time. The fins will pass through the outer body tube and will be attached to the motor mount inner tube with epoxy. On the outside of the vehicle body the fins will have a tip to tip layer of carbon fiber or fiberglass to reduce any warping of the fins which could cause a constant roll during flight. Due to shape complexity of the fin section, the layup will mainly air dry with partial heat gun application if needed.

The sample containment section will have a hatch on the side of the rocket. This hatch will remain open during the course of the AGSE's actions. As the rocket is erected, a door on the inside of the rocket will slide down under its own weight, sealing the compartment. The door will be latched shut as it slides down, similar to how a standard door closes. In order to prevent the door from sliding shut too early as the rocket is erected, a spring latch will act as a stop for the door. Once the rocket reaches an angle steep enough for the door to close completely, the stop will release and allow the door to close.

In order to contain the sample within the rocket, a sled with two kick panel clamps, as seen in ***Figure 3***, will secure the sample container. The arm will place the container within the clamps, and the clamps will prevent the sample from shifting during flight. Because this system does not require any electrical input or moving parts, its simplicity will decrease the number of modes of failure in the design.

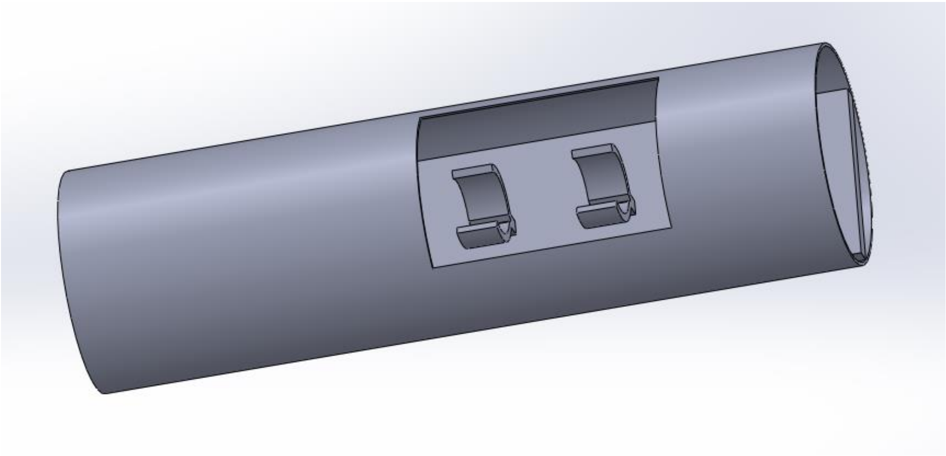

Figure 3 Sample Containment Device

4.1.1.2. 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 was located well aft of the nose cone and imposed no constraints on the geometry of the nose cone. A filament wound blunt elliptical nose cone was selected due to its low friction drag characteristics and availability from vendors. The diameter of the nose cone is 5.5 inches and the length is 18 inches.

The body tube of the flight vehicle will be constructed of 5.5” diameter Blue Tube. Blue Tube offers greater strength than unreinforced cardboard while maintaining a lower weight than standard filament wound fiberglass tubing. Internally, Blue Tube will be reinforced by a number of bulkheads and centering rings constructed of 3/8-inch birch aircraft plywood. The epoxy for bulkheads closest to the motor will be reinforced with cotton flock for additional strength.

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 16 pounds and 72 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 K1499N-P motor, with a specific impulse of 1320 Ns, the rocket is projected to reach an altitude of 3100 feet. With an Aerotech K185W-0 motor, with a specific impulse of 1379 Ns, the rocket reached a height of 3400 feet above ground level. The final rocket will likely be heavier than the 16 pounds specified, both due to payload and unaccounted for 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 3000 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 (3000 feet), a two 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 three feet main parachute. In order to decrease the drift range, a four feet 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 made out of rip-stop nylon and will be manufactured by the club. ***Figure 4*** below shows the general setup of the parachutes and where they will be located.

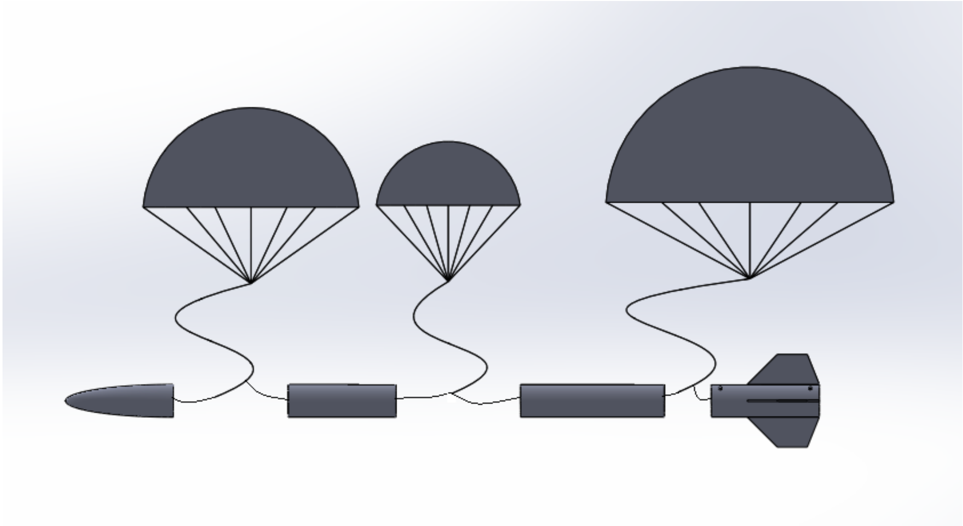

Figure 4 Parachute Setup

The main parachute between the fin-can and body tube will be packed in the body tube inside the coupler connecting the two sections. The coupler will be 12 inches long, with 6 inches inside each of the body tube and 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 other bulkhead. The sample section will have a bulkhead on both ends, in order to seal the container and provide a place to hook up the shock cord. The sample container will be used to pull out the drogue in the body tube and 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 around 4 seconds 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

Given the current estimation of 16 pounds for the weight of the rocket, a K-class motor is required to reach the 3000 feet mark. Two motors are being considered for the final design, the choice of which being determined by the final weight of the vehicle. The first is an Aerotech K1499N-P motor. This motor features 1320 Ns specific impulse and has a burn time of 0.88 seconds. At 10.2 inches long and 2.95 inches in diameter, this motor also costs $130. A simulation in OpenRocket (see ***Figure 2***) shows that this motor would send a 16 pound rocket approximately 3100 feet above ground level. The other motor being considered is an Aerotech K185W-0. This motor is slightly longer than the first (17.2 in), but has a smaller diameter of 2.13 inches. This motor also has slightly more thrust than the K1499N-P, sending the same rocket 3400 feet with 1379 Ns specific impulse. However, the K185W-0 is only $91.99. Although both motors send the rocket higher than the desired altitude, more weight can be added to the vehicle to decrease the apogee to 3000 ft. There is also going to be some unaccounted weight due to excess epoxy and the manufacturing process. By overshooting the 3000 foot mark, this extra weight will help guide the rocket closer to the desired altitude. Both motors in consideration provide a maximum velocity of 600 ft/s.

4.1.5. Proposed AGSE

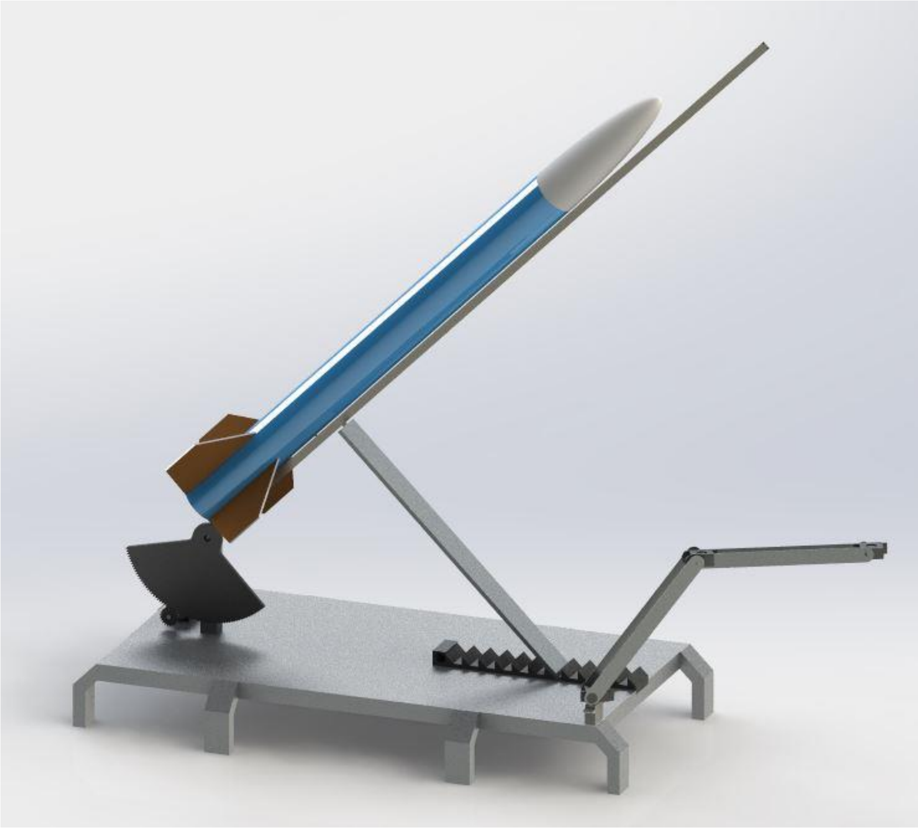

Figure 5 Proposed AGSE Assembly

Launch Rail Raising System

The team considered several different designs when choosing how to raise the rocket from a horizontal to a vertical orientation. One of the designs was a winch and pulley system. This would feature an elevated pulley built onto the structure of the launch platform with a winch at the base which would pull the launch rail into a vertical position. The higher the placement of the pulley, the lower the maximum tension in the cable due to the trigonometry of the setup. The cable would need to be placed in such a way that it would not interfere with the rocket when it came time for the launch. Another design was a gear system with a set of gears at the base of the launch rail. The launch rail itself would be attached to a large gear. Both of those designs would be powered by a step motor. The other design considered was a pneumatic linear actuator located under the launch rail. This actuator would extend via a compressed air tank. All three of these designs would feature a secondary system to support the launch rail during raising and hold it vertical during launch. After reviewing the options, the team has decided on the geared system for its simplicity and robustness and is researching stepper motors with sufficient torque to counter the rocket and launch rail moments. With preliminary values for the combined rocket and launch rail weight of 30 lb, a moment arm of 40", a launch rail gear radius of 10", and a motor gear radius of 1", it was determined that a motor with 120 in-lb of torque would be required to lift the launch rail vertical.

Sample Location System

The AGSE will use a simple webcam to locate the sample on the ground. The team will place the sample within range of the robotic arm and perpendicular to the camera's vision. This placement allows the base of the AGSE to be stationary and the only reach of the system comes from the arm. The sample's perpendicular orientation gives the digital image processing the best chance to find the sample.

The digital image processing, DIP, will be built using tools from OpenCV due to the fact that it has a Java API. The webcam will take a picture and feed it to the DIP. The DIP will then pick out the sample from the background. The aspect ratio of the sample in the picture will be measured by counting the pixels along its height and width. This aspect ratio will be fed into a calibration curve that relates it to distance between the sample and the object. The calibration curve will require many constants including: the camera, the sample orientation. The pixel count between the center of the sample and the center of the image relates the horizontal displacement of the actual sample from the camera. Once the distance from the camera to the sample is known, this information can be related to the distance from the camera to the robotic arm gripper. The robotic arm is then able to move to the sample and fetch.

An ideal sample location system could find the sample at any reasonable distance, orientation, and on various terrains. This system can only find the sample within a short distance from the camera and only at one orientation, and it will most likely struggle on terrain with significant grade.

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.

The webcam will be mounted on the wrist pitching servo bracket. This gives more precise measurement readings from the DIP as the camera moves closer to the sample. The drawbacks of a wrist mounted camera are added arm weight and increased complexity in the system. The added reliability and precision of the gripper system with an arm mounted camera justify added servo and computing loads.

In order to control the robotic arm, the components will be connected via USB connection to the Raspberry Pi as shown in the diagram below. “Regulator” indicates a regulator that we will construct to supply different voltages of power to each device. Since the Raspberry Pi only has 2 USB Ports, 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 (which is much more than we need).

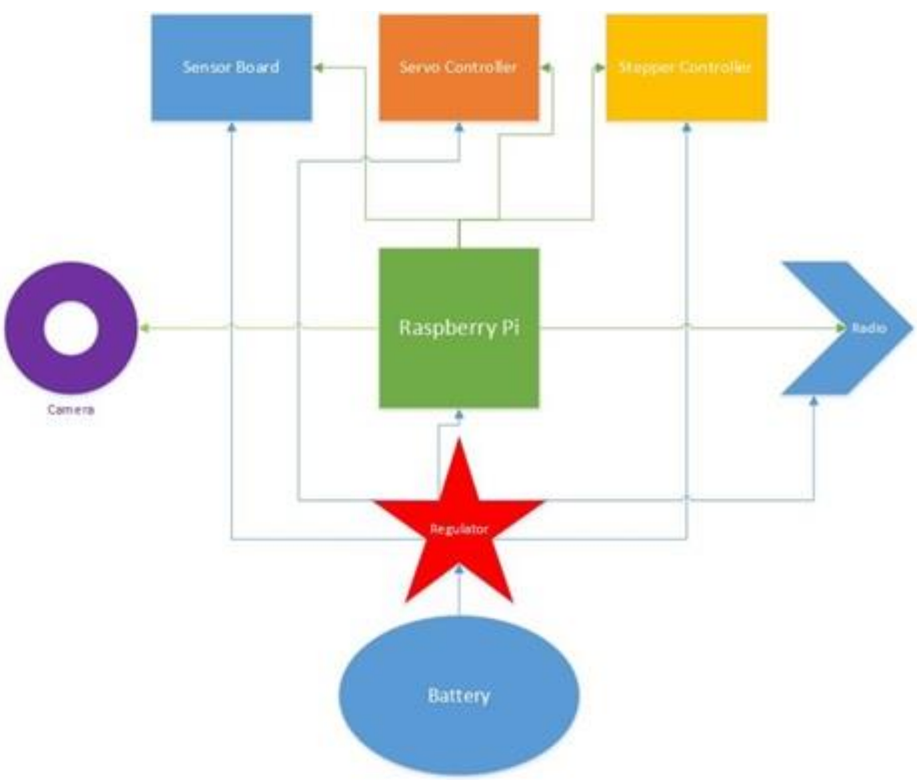

Figure 6 Arm Controller Setup

The sensor board will be able to read 8 sensors, the servo controller will be able to control 8 servo motors, and the stepper controller will be able to control 1 high-torque stepper motor. The Raspberry Pi has about 800 MHz of processing power. We believe that this will be a sufficient amount for handling all of the controllers, as well as processing images from the camera. The Xtend Radio can both transmit and receive data on an encrypted 900 MHz signal. We will not send signals to the AGSE except for pausing and emergencies. Data received from the AGSE include live video, sensor values, servo positions, stepper position, battery life, system calls, and various serial data.

Programming:

We will be programming in java due to the large amount of libraries available, and easy User Interface (UI) building. The Raspberry Pi will utilize multiple classes that we will be writing to autonomously control all electrical components on the AGSE. All sensor and vehicle data will be transmitted over the radio to a ground station where we can view all diagnostics. We will be designing an interface (in java) to view all sensor and system data. The interface will include a pause button, a resume button, and an emergency termination button.

Launch platform

The AGSE will be on a 8-footed platform, with two legs on each side and two each on the front and back. 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 approximately 1-in square Aluminum Bosch railing. In order the 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 fit into several teeth location on the platform of the AGSE. As the rocket is raised, the supporting arm will fit into the teeth, prevent the launch rail from falling back down. The concept is similar to how the backs of pool chairs work. The last tooth will have a hook so as to prevent the rocket from moving past the desired angle for launch.

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 too exceed 3000 ft (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 or below 3000 ft is a one point deduction in the altitude score, with going above 5000 ft resulting in an automatic zero points. The vehicle is also to be a maximum of four independent sections, each independent 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. During the descent, the sample section must be jettisoned at 1000 ft.

4.1.6.2. Recovery System

The vehicle must contain a drogue chute 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 ASGE 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 is identifying the sample once it has been placed. The system must be able to differentiate between the sample on the ground and its surroundings. Once the sample has been identified, the distance from the AGSE to the sample must also be determined. This problem relies heavily on calibrating the camera and arm to ensure that they are in synch. As described above, the number of pixels that the object occupies in the picture can be used to find the distance given a calibration curve made during testing. In order to identify the sample, the processor can try to identify the whitest parts of the image for example.

Another challenge that must be overcome is lifting the rocket and launch rail. We have gone through multiple iterations of a few design ideas from a pneumatic actuated arm, a folding scissor arm, and a gearing system. The problem we have encountered is the size and power required to lift a rocket and launch rail to almost vertical without going past vertical. We can always find a motor or server or actuator with enough power, but we are looking to decrease the weight of the AGSE if possible. To stop the vehicle from going past vertical we are implementing a series of ratcheting stops on the AGSE that is attached to a stability arm. These ratcheting stops will allow the actuated arm to fail without the entire rocket falling back to the horizontal position for safety. The end of the ratcheting stops will have a latch to stop the rocket from coming back down or going past vertical once the vehicle has been raised to its launch position. Completing this task will be one of the more fabrication intensive parts of this project.

Closing the sample door and sealing the door for aerodynamic and stability purposes is another challenge that has been discussed in detail by the club. The consensus of the club has been to try to reduce the number of electrical systems that can fail. Using that, we have decided to attempt a door system that will let gravity and door latches do the work. When the vehicle is raised to the launch position, the door will fall, on tracks, into the correct location which will have push door locks to lock the door into place. Manufacturing the sliding door will be difficult and presents another challenge to the team.

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

Tripoli Summer Low-Mid Power Launches
During the summer, NCSU High Powered Rocketry Club attended Tripoli-hosted low-mid power rocket launches on May 24th, June 28th, July 26th, and August 16th. During these launches the club members Chris Celestino, Emily Gipson, Jamie Region, Josh Pickles, and Will Martz assisted the Tripoli organization with setting up and taking down the launch site in Butner, NC, setting up an information table for kids and adults to learn about High Powered Rocketry, launching our subscale demonstrators from previous years, and helping to recover rockets. There were between 50-150 people attended each of these launches.

Location: Perkins Field, Butner, NC 27509
Time: 9:00 - 3:00PM

GE Aviation – Manufacturing Day

Chris Celestino and Collin Bolton attended GE Aviation's Manufacturing day at the GE Aviation plant in Durham, NC. This event was open to a number of students from the surrounding area and had approximately 80 high school students from 4 different high schools (including early college STEM school at NC State) and another 25 students from the NC State Career Development Center. These students made up a majority of the audience, but adults participated as well. Roughly 150 people were in attendance.

NC State's High Power Rocketry Club hosted a display table for an info fair to provide some "next step" ideas for students who are interested in aerospace manufacturing. The members engaged participants about NC State Aerospace Engineering, Rocketry, and the High Power Rocketry Club with a table top booth/display, hands-on and interactive elements, and hand-out information about the club and NC State's Aerospace program.

Location: GE Aviation 3701 S. Miami Boulevard, Durham, NC 27703
Time: Friday, October 3rd 10:00 – 1:00PM

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 2015. 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 2015. 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 at NCSU's campus and involves around 30-40 Boy Scouts and their families. The details of this event will be finalized in spring 2015.

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	9/11/2014	9/11/2014
RFP Writing/Editing	9/11/2014	10/5/2014
GE Aviation Manufacturing Day Outreach Event	10/3/2014	10/3/2014
Completed RFP Submission	10/6/2014	10/6/2014
Awarded Proposals Announced	10/17/2014	10/17/2014
Team Web Presence Established	10/31/2014	10/31/2014
Preliminary Design Review (PDR) Writing	10/18/2014	11/4/2014
Completed PDR Submission	11/5/2014	11/5/2014
PDR Team Teleconference (Tentative)	11/7/2014	11/21/2014
Critical Design Review (CDR) Writing	11/6/2014	12/15/2015
Subscale Launch	11/22/2014	11/23/2014
NCSU Winter Break (no building access)	12/16/2014	1/6/2015
CDR Writing	1/7/2015	1/15/2015
Completed CDR Submission	1/16/2015	1/16/2015
CDR Team Teleconference (Tentative)	1/21/2015	2/4/2015
Flight Readiness Review (FRR) Writing	1/17/2015	3/15/2015
Fullscale Launch (Tentative)	2/1/2015	2/28/2015

Completed FRR Submission	3/16/2015	3/16/2015
FRR Team Teleconference (Tentative)	3/18/2015	3/27/2015
Team Travel to Huntsville, Alabama	4/7/2015	4/7/2015
Launch Readiness Review (LRR)	4/7/2015	4/7/2015
NASA Safety Briefing	4/8/2015	4/8/2015
Rocket Fair and Tours of MSFC	4/9/2015	4/9/2015
Launch Day	4/10/2015	4/10/2015
Backup Launch Day	4/12/2015	4/12/2015
Post-Launch Assessment Review	4/29/2015	4/29/2015
Winning Team Announced by NASA	5/11/2015	5/11/2015

6.2. Budget

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

	Item	Amount	Total Price
AGSE	Raspberry Pi	1	$40
	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
	Xtend Radio Units	2	$600
	Camera	1	$100
	Aluminum Railing (ft)	30	$100
	Brackets	15	$80
	Aluminum sheet (for arm) (ft)	2x4	$80
	Aluminum square beam (for ratcheting stops) (ft)	4	$10
	Miscellaneous hardware (nuts/bolts/washers)	--	$100
	Phidgits DC Controller	1	$120
	Phidgets DC motor	2	$80

	Sensors for touch and image processing software	--	$1,000
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
	Fiberglast 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

	K motor (full scale)	2	$200
	J motor (subscale)	2	$100
	Wires	--	$30
	Connectors	--	$20
	Nose cone (full scale)	1	$60
	Nose cone (subscale)	1	$35
	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	--	--	$10,005

6.3. Funding Plan

The plan to receive the $14,000 budget we need for this project has been started. The club received $2,000 from the Engineering Technology Fee Fund from the Mechanical and Aerospace Department at North Carolina State University. The Engineering Council at NCSU has also granted the club $1,500 for the fall semester through a proposal, a presentation, and an appeals presentation. The club is looking to receive another $1,500 in the spring semester from the Engineering Council. The Student Government Appropriations committee has also received a proposal for the spring semester and interviewed various members of the club in order to give $2,000 to the club in the spring semester. Two proposals, for competition and for senior design, have been submitted to the NC Space Grant. NC Space Grant is offering $5,000 for the competition and $2,000 for senior design that we are expecting to receive.

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 users 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 new users, 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.