Tacho Lycos
2017 NASA Student Launch Project
Student Launch Initiative 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 Whitmore 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 Whitmore has a level 3 certification with Tripoli.

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

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

1.1.2. High-Powered Rocketry Club

Established in 2009, the High-Powered Rocketry Club is an interdisciplinary student organization within the Mechanical and Aerospace Engineering department at North Carolina State University. The NCSU High-Powered 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. The team is led by a five-person senior design group who participate in the club as part of their senior project and receive a final grade corresponding to competition score.

1.2. Safety Officer

William Martz

William will act as the Safety Officer for the 2016-2017 North Carolina State University Student Launch Team. This is his fourth year with the NCSU High-Powered Rocketry Club. William is experienced on the safe operation of equipment used by the club including but not limited to: power tools, hand tools, and chemicals. He will be present for all aspects of construction to ensure the safety of team members and to help instruct/ train members on proper and safe usage of equipment.

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

1.3. Team Lead

Emily Gipson
Ejgipson@ncsu.edu
(704)-998-1053

Emily will act as the North Carolina State University 2016-2017 NASA Student Launch team lead. Emily is also team lead for the MAE Space Senior Design team which consists of other aerospace engineering seniors: Zachary Verbos, Landon Richardson, Robbie Buhrman, and Freddie Michaels. This is the fourth year that Emily has participated in High-Powered Rocketry Club.

1.4. Team Organizational Chart

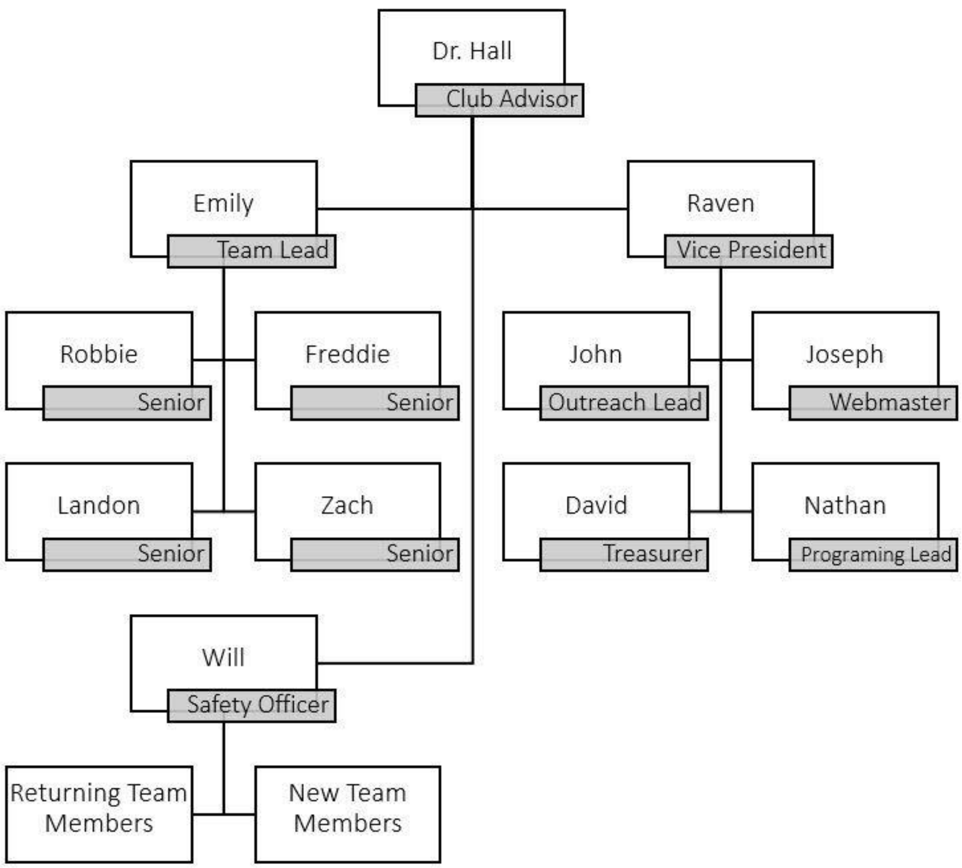

Figure 1: Team Organizational Chart

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. Dr. Hall and James Livingston are equally capable of supervising the use of these motors due to their TRA level 3 certifications.

1.5. Briefing

The entire club and senior design team meet together once per week to discuss club logistics and the rocket as well as document progress. These discussions include:

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

The club strives to provide an atmosphere that fosters learning as well as the passage of knowledge from veteran members to newcomers. Beyond weekly meetings, the rocketry lab is open for members to work on rockets, reports, and/or classwork as well as general fraternization. The senior design team meets throughout the week to discuss document and project progress and to resolve any current issues.

2. Facilities/Equipment

2.1. Description

The NCSU High-Powered Rocketry Club meets primarily in the MAE Student Fabrication Lab of Room 2003, Engineering Building III. The club members also have access to the Space and Aircraft Senior Design Labs.

In addition to the design labs, the club has access to a well-equipped machine shop on the first floor of Engineering Building 3. Gary Lofton is the supervisor for the mechanical senior design machine shop and is very helpful with design and part requests. Raven Lauer, club Vice President, is qualified to use the machine shop tools which will allow for faster part production. The structures lab will provide additional resources, including the Instron tensile and compression loading machine for materials testing. The club can also request access to the MAE Department’s laser cutter in Flight Research which is primarily run by graduate students.

2.2. Hours of Accessibility

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

2.3. Necessary Personnel

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

2.4. Equipment

Available equipment in room 2003 consists of the following:

- Craftsman 1.6 inch Variable Speed Scroll Saw
- Craftsman 12 inch Bench Drill Press with Laser
- Task Force 4" Belt & 6" Disc Sander
- 120 Volt 60 Hz Band Saw
- 16 Gallon 6.5 HP Shop Vac
- Dremel 400 XPR Rotary Tools
- Ryobi HG600 Heat Gun
- DeWalt 18V Hand Drill
- Drill Bit Case from 3/64" – ½" inch
- Ryobi Forstner 7 piece Drill Bit Set 1" - 2"
- Task Force Ratchet/Socket Kit
- Digital Micrometer
- SeeMyCNC Rostok Max V2 3D Printer
- SoftWorks 5lb Food Scale
- AWS 1 kg Digital Scale
- Wilton Bench Vice
- Vacuum hoses for wet layups

2.5. Supplies Required

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

- Fiberglass
- Epoxy
- Carbon fiber
- Safety equipment (fire extinguisher, First-Aid kit, gloves, goggles, masks, cleaning supplies)
- Black powder
- Servos/DC Motors
- Processors
- Barometric altimeters
- Linear Actuator
- Shock cord
- Hand tools (utility knives, hammers, screw drivers, and measuring equipment)
- Equipment from 2.2.4

- Simulation and modeling software (Microsoft Office Professional 2013, Solidworks 2016, OpenRocket 15.03, Abaqus 6.13, Matlab 2016b, Ansys 2015)
- BeagleBone Black computer
- Sensor board and DC controller
- Parachute
- Threaded Rod
- Cameras (2)

3. Safety

3.1. Safety Plan

3.1.1. NAR/TRA Personnel Procedures

3.1.1.1. NAR High Power Safety Code Requirements

High Power Rocket Safety Code

1. *Certification*. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
    a. With an L size motor, we stay within NAR Level 2 Certification. One of our club mentors is Alan Whitmore. Alan is Level 3 Certified with TRA.

2. *Materials*. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
    a. We are only using wood, fiberglass and foam in the construction of our Rocket and only the payload body is made of aluminum 6061-T6 for added compressive strength during payload operations.

3. *Motors*. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
    a. We are purchasing an Aerotech L1420R.

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

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

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

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

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

    a. The impulse of the L1420R is 4616 N-sec. At launch, our rocket will weigh about 42.8 lbs.

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

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

than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).

a. We will only launch at the Tripoli launch site in Bayboro, NC for testing and Huntsville, AL for the final competition launch.

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

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

    a. Our rocket has one drogue and one main parachute with another main parachute installed on the payload.

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 device

Class 2 – Gases

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

Class 3 – Flammable Liquids (and Combustible Liquids)

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

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

Division 4.1 Flammable solids - wetted class 1 explosives, self-reactive materials or readily combustible solids

Division 4.2 Spontaneously combustible materials -pyrophoric or self-heating materials

Division 4.3 Dangerous when wet materials - gives off flammable or toxic gas or become spontaneously combustible on contact with water

Class 5 – Oxidizers and Organic Peroxides

Division 5.1 Oxidizers - by yielding oxygen, causes or enhances the combustion of other materials

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

Class 6 – Toxic Materials and Infectious Substances

Division 6.1 Poisonous materials - a liquid with an LD50 oral not more than 500 mg/Kg, or a solid with an LD50 oral not more than 200 mg/Kg, or a compound with a LD50 dermal not more than 1000 mg/Kg, or a dust/mist with a LC50 or not more than 10 mg/L

Division 6.2 Infectious substances – Go to Guide to Shipping Biological Materials and Biological Materials Online Certification for more information.

Class 7 – Radioactive Materials

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

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

Class 8 – Corrosive Materials

Class 9 – Miscellaneous Dangerous Goods

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

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

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

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

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

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

   iii. Recovery System
      1. Is the recovery system attachment secure/suitable?
      2. Does the recovery system have sufficient capacity for a safe descent?
      3. What is the deployment system?
      4. What are the most probable deployment system faults and corrective actions?
      5. What are the safety implications of a recovery system failure?
      6. Are there any design change recommendations?

   iv. Avionics Description
      1. Commercial or unique design?
      2. What are the functions of the avionics components?
      3. Are the avionics appropriate to the application?

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

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

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

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

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

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

a. General
   i. Always ask if unsure about equipment, tools, or a procedure.
   ii. Only handle certain materials if you have the proper permit.
   iii. Always wear the appropriate safety materials and clothing
      1. These items include safety glasses, gloves, long pants, 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, chemical shower, and eye wash station
      4. Keep chemicals away from open flames.
      5. Clean work stations.
      6. Keep construction and test rooms well ventilated.
      7. Wear cotton clothing.

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

d. Procedures for Cleaning Up
   i. After using drill press or cutters
      1. Ensure to remove power and that the switch is in the off position
      2. Remove the bit and replace the safety if available
      3. Clean up all spare chips/shavings with either a shop vac or dedicated brush, whichever is more appropriate
      4. Replace safety goggles and gloves in an easily accessible place for the next user

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

3.1.4. Federal and Local Law Compliance

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

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

3.1.5. Energetic Device Acquisition, Storage, and Transport

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

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

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

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

3.1.6. Team Member Safety Compliance Statement

3.1.6.1. Range Safety Inspection

A. 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.

B. 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.

C. 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.

3.1.6.2. Flight Safety Review

A. 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**!

B. 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.

C. 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.

D. 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.

E. Propulsion

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

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

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

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

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

F. Construction

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

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

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

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

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

G. Stability

Verify that the rocket is of a stable design.

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

H. Recovery

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

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

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

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

3.1.6.3. RSO Clearance Policy

A. 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.

B. 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

C. 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.

D. 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.

<u>Time Interval Determination Method</u>

- 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.

3.1.6.4. 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: Landon Richardson
   Signature: [signature]
   Date: 9/24/2016
2. Print Name: Frederick Michaels
   Signature: [signature]
   Date: 9/24/2016
3. Print Name: Robert Buhrman
   Signature: [signature]
   Date: 9/29/2016
4. Print Name: Zachary F. Verbos
   Signature: [signature]
   Date: 9/29/16
5. Print Name: John Inness
   Signature: [signature]
   Date: 9/24/2016
6. Print Name: William Martz
   Signature: [signature]
   Date: 9/29/16
7. Print Name: Joseph Taylor
   Signature: [signature]
   Date: 9/29/16
8. Print Name: Ashlee Bracewell
   Signature: [signature]
   Date: 9/29/16
9. Print Name: Michael Andrew McDonald
   Signature: [signature]
   Date: 9/29/16

10. Print Name: Jacob A. Weinberg
Signature: [signature]
Date: 29 Sept 16
11. Print Name: Zhuowei Xu
Signature: [signature]
Date: 9/29/16
12. Print Name: Jayesh Patel
Signature: Jayesh Patel
Date: 9/29/16
13. Print Name: Adam Phillips
Signature: [signature]
Date: 9-29-16
14. Print Name: Devin Stafford
Signature: [signature]
Date: 9-26-16
15. Print Name: Annette Gray
Signature: [signature]
Date: 9/29/16
16. Print Name: Nathan Courie
Signature: [signature]
Date: 9-29-16
17. Print Name: Mercedes McCarthy
Signature: [signature]
Date: 09/28/16
18. Print Name: Trevor Hinshaw
Signature: Trevor Hinshaw
Date: 9-29-16
19. Print Name: Ashby Scruggs
Signature: [signature]

20. Print Name: Emily J. Gipson

Signature: [illegible]

Date: 9-29-16

21. Print Name: Raven Lauer

Signature: [illegible]

Date: 9/29/16

22. Print Name: Cade Brinkley

Signature: [illegible]

Date: 9-29-16

23. Print Name: Tim Dzwill

Signature: Timothy Dzwill

Date: 9-29-16

24. Print Name: Nathan Cox

Signature: [illegible]

Date: 9-29-16

25. Print Name:

Signature:

Date:

4. Technical Design

4.1. Proposed Rocket and Payload Design

4.1.1. General Vehicle Design

4.1.1.1. Dimensions

The launch vehicle is proposed to be 111 inches long with a constant body diameter of 6.188 inches. It will have a four-piece trapezoidal fin set; these fins will have a root chord of 11 inches, a tip chord of 5 inches, and a sweep angle of 40.0 degrees. With the motor loaded, the rocket will weigh approximately 42.8 lbs.

4.1.1.2. Design Aspects

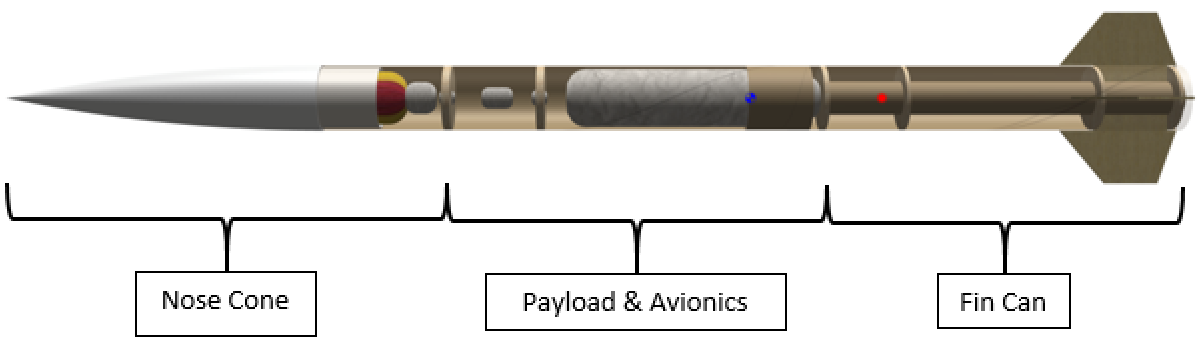

Figure 2: Open Rocket Model of Full Scale Rocket

The rocket can be divided into three sections: an upper nosecone section, a middle payload and avionics section, and a lower fin can section. These sections will be separated by bulkheads and couplers. The upper section will be 30 inches long, the mid-section will be 44 inches long, and the fin can will be 37 inches long.

The projected pre-burn CG (blue point on Fig. 2) of the fully loaded rocket is 70 inches aft of the nose and the CP (red point on Fig. 2) is 83 inches aft of the nose (pre-burn). The OpenRocket calculation of these values gives a static stability of 2.0 cal. This will be discussed further in §4.1.3.

The nose cone is the most forward component that houses the main parachute. At 30 inches long, the nose come will have ample room to house the main parachute. Moving aft, the middle section of the rocket is the payload and avionics body tube. This is the longest of the three sections at 44 inches. All of the electronics for decoupling and payload deployment will be controlled from this section. Likewise, the payload is also housed within this section as a self-contained unit that will take up 14 inches. Finally, the most aft section of the rocket is the fin can that houses the engine components. This section is 37 inches total with 26 inches devoted to the engine. Each component is discussed in further detail later in §4.

The upper section is made up of the nose cone and the forward most bulkhead that attaches to the main parachute. The mid-section houses a bulkhead to attach the main parachute and the drogue chute. The mid-section also contains the avionics bay with the two altimeters--one Stratalogger and one Entacore--for the decoupling of the rocket and deployment of the parachutes, as well as the payload that will be deployed when the rocket reaches apogee. The fin can will house a bulkhead attaching to the drogue chute, an inner fiberglass tube containing the motor, and the motor block and fins.

The payload section of the rocket is explained in further detail in §4.1.2.

The rocket is currently modelled to reach approximately 5400 feet in order to allow for increased weight of the payload design as it becomes more refined and manufacturing processes and other factors like excess epoxy and ballast added. Once the payload weight is determined minor adjustments can be made to the overall rocket weight in order to achieve the desired apogee of 5280 feet.

4.1.1.3. Material Selection and Justification

Based off preliminary estimates of the rocket's top speed, it was determined that supersonic velocities would not be encountered. The payload bay and telemetry are located well aft of the nose cone and impose no constraints on the geometry of the nose cone. A filament wound ogive-shaped nose cone was selected due to its higher friction drag characteristics and availability from vendors. The diameter of the nose cone is 6.188 inches and the length is 30 inches.

The body tube of the flight vehicle will be constructed of 6.188 inch diameter filament wound fiberglass tubing. Fiberglass offers a greater strength than Blue Tube or unreinforced cardboard. Fiberglass also has superior water resistance compared to Blue Tube. Internally, the fiberglass body tube will be reinforced by a number of bulkheads and centering rings constructed of 0.375 inch and 0.75 inch birch aircraft plywood. The majority of the bulkheads and all the centering rings are to be constructed of 0.375 inch birch aircraft plywood while the bulkheads surrounding the avionics bay will be 0.75 inch birch plywood to allow an access hatch to be used for the avionics.

The fins will be constructed of aircraft grade plywood capable of withstanding the estimated applied forces during flight and recovery.

4.1.2. Payload Design

4.1.2.1. Dimensions

The proposed payload body is cylindrical with a constant diameter of 4 inches and height of 14 inches, including the parachute recovery system. The upright landing system will increase the effective diameter of the payload to 5 inches. This will leave 0.5 inches of clearance between the effective payload diameter and the rocket inner diameter. The payload weight is estimated to be 5 lbs.

It should be noted that the rail system (§4.4) will not interfere with the effective payload diameter but instead the payload body diameter; that is to say the rail system will be radially offset from the upright landing system (§4.2.5.2).

4.1.2.2. Design Aspects

The cylindrical design was decided upon after considering payloads of variable diameter. A constant diameter allows for more inner payload volume with the same height. Furthermore, a conical design with a maximum outer diameter of 4.00 inches would not leave an appreciable volume to contain the parachute recovery system and the electronics would have been mounted on the inner wall of the payload body. A cross section of the cylindrical payload can be seen below in Figure 3.

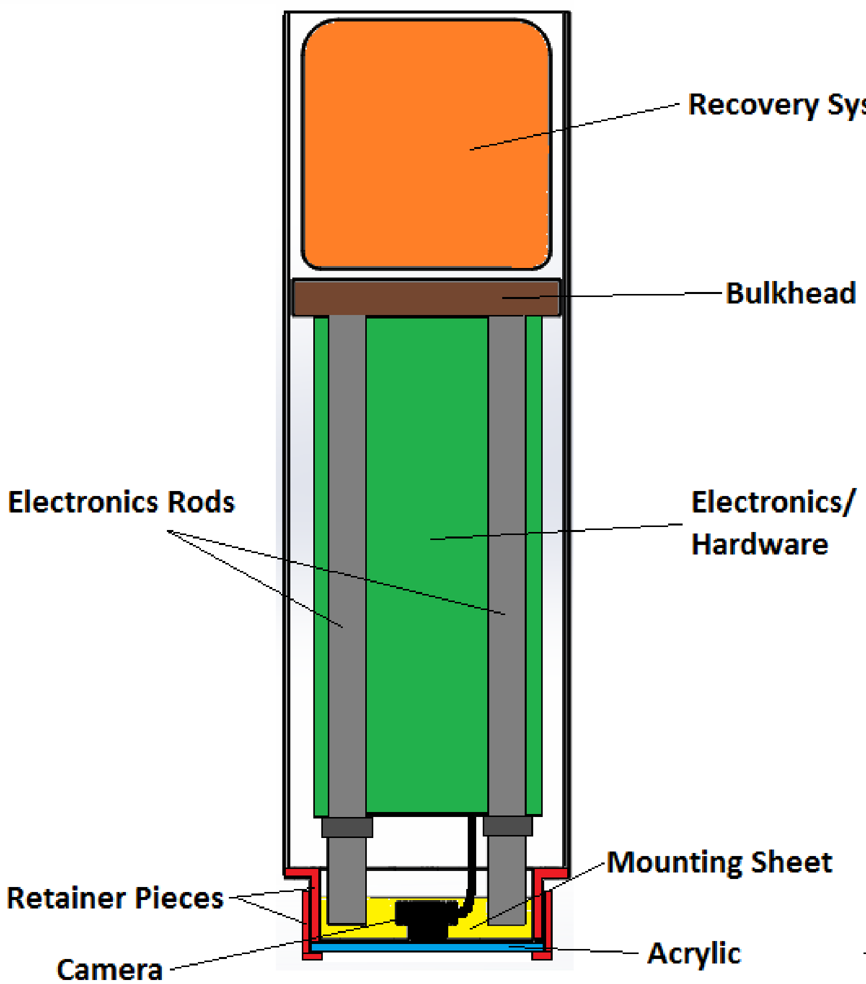

Figure 3: Cross Sectional View of Cylindrical Payload

The payload can be broken up into three sections: viewing surface, payload body, and recovery system. The recovery system will be discussed in §4.2.5.

The main subassembly in the viewing surface is a repurposed Aero Pack 75mm Retainer (Flanged), which is comprised of an inner (body) and outer (cap) piece. The retainer body will be connected to the payload body by twelve socket head screws. The Aero Pack 75mm Retainer was chosen for the viewing surface retainer because the inner and outer pieces can be screwed together. This allows for ease of access to the payload internals while maintaining fastening integrity.

The retainer cap will surround a 0.125 inch thick circular acrylic grazing sheet. The acrylic sheet will protect the camera lenses from any in-air or ground impacts while not obstructing the cameras' functionality. Directly forward of the acrylic sheet will be a 3D-printed ABS plastic sheet (subsequently referred to as the "mounting sheet") of similar shape to the acrylic sheet and will fit inside a change in cross-section within the retainer cap. The mounting sheet will have cutouts for the camera lenses as well as provide a mounting surface for securing the cameras. The mounting sheet will also have two holes which will connect it to the electronics rods in order to eliminate the possibility of the mounting sheet rotating during flight. The viewing surface has one plane of symmetry coincident across the diameter of the acrylic sheet.

The payload body will be a cylindrical aluminum 6061-T6 tube of wall thickness 0.065 inches with an inner radial flange on the aft face of thickness 0.125 inches. This flange will connect the retainer body to the payload body through the predrilled holes in the retainer body. Between the payload body and the retainer body connection, the main attachments for the upright landing system will use eight of the twelve socket head screws. Spacers will be placed on the unused holes to create a full ring. One spacer section will employ a shear pin system to connect it to the rocket drogue chute (§4.4). This system will be explained in §4.2.5.2.

The electronics rods will support the electronics board in the payload body and be connected to the bulkhead further forward of the electronics board. The electronics board is a 3D-printed ABS plastic prism (with two thru-holes for the electronics rods) on which all of the electronic components will be mounted in the payload. Since the payload has two completely redundant camera systems the electronics board will be symmetric across the plane formed by the electronics rods. One hex nut on each threaded electronics rod will secure the electronics board flush with the bulkhead separating the electronics from the parachute recovery system

On the exterior of the payload body will be two rail buttons for the payload deployment system (§4.1.3). The upright landing system will also be held against the exterior of the payload body while in collapsed position.

Forward of the electronics board is the bulkhead which separates the electronics from the parachute recovery system (§4.2.5.1). The electronics rods are connected to the payload bulkhead. On the recovery system side of the bulkhead there is a U-bolt which attaches the bulkhead and payload body to the parachute recovery system. The bulkhead will be held in place by two-to-four metal tabs held in place by screws through the payload body on either side of the bulkhead. This will enable removal of the bulkhead, thus allowing access to the payload internals from above if needed.

A solid model of the payload, excluding the upright landing system, can be seen below in Figure 4.

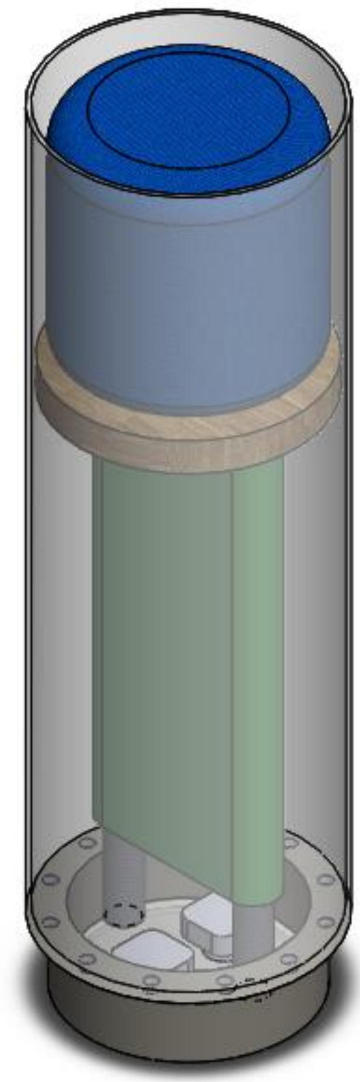

Figure 4: Solid Model of Payload – Isometric View

4.1.2.3. Material Selection and Justification

The Aero Pack 75mm Retainer is constructed from aircraft-grade aluminum and anodized to a black color. It is provided by Apogee Components in this configuration.

The acrylic grazing sheet was chosen for the viewing surface because it is much less brittle than glass but is not noticeably more opaque than glass. It is also easy to cut circular windows from acrylic grazing sheet than to cut from glass. Acrylic grazing sheet will greatly increase the safety of the system when compared to conventional glass while not impairing the cameras' ability to capture images for target identification.

The payload body is an aluminum 6061-T6 tube with outer diameter 4 inches and wall thickness 0.065 inches. 6061-T6 aluminum was chosen because it is an aluminum alloy commonly used in the aerospace industry and will withstand the rail system deployment. Furthermore, drilling holes in brittle composite materials introduces stress concentrations which can lead to cracks in the payload. Attaching the rail buttons and potentially securing the bulkhead using metal tabs will introduce holes in the payload body relatively close to one another—this may lead to brittle material failure if exposed to an applied load. Quantum Composites QC-2150LD NT 25% Fiberglass Reinforced Phenolic SMC (used in rocket bodies) has a tensile strength of 10,900 psi [1] compared to 6061-T6 aluminum's ultimate tensile strength of 45,000 psi [2]. While these ultimate strengths are much outside the magnitude of any anticipated load on the body, aluminum is estimated to be more receptive to screw insertion/removal cycling: if access to the payload internals is needed at any time the metal tabs will have to be unscrewed and refastened when the job has been completed. It is expected that this may occur at least once to perform checks on the internal components of the payload when the retainer cap is completely connected to the body.

The difference in weight between the 6061-T6 aluminum payload body and QC-2150LD payload body is on the order of 0.2 lbs when comparing identically sized tubes on vendor websites. [3][4] Additionally, the thinnest fiberglass tube wall thickness found online was 0.125 inches, which is almost double the thickness of the aluminum body tube. A wall thickness of 0.125 inches would solicit a redesign of the payload system because the screws that fasten the retainer body to the payload body would be bored into the payload wall through the flange; of which would need to be fiberglass if a fiberglass body was used. This would greatly increase the stress concentrations around a critical section of the payload body and is not desirable. If the outer diameter of the payload was increased, a larger retainer system would be needed. A fiberglass flange with twelve holes going through it susceptible to applied loads would still not be desirable—any impact to the retainer system would translate directly to the fiberglass flange and the corner connecting it to the fiberglass body. Welding a 6061-T6 flange onto the payload body is much more feasible.

The electronics board and mounting surface are made from ABS plastic because it is easily formable and is commonly used in 3D-printing. The aluminum electronics rods will be purchased pre-threaded to fit with carbon steel hex nuts. The rail buttons are purchased from Apogee Components. The bulkhead is made out of 4 layers of 0.125 inch birch plywood and epoxy totaling to 0.5 inches.

4.1.2.4. Target Identification System

4.1.2.4.1. Software

The target recognition system will begin its image analysis process upon they payload's descent to a predetermined altitude after its release from the launch vehicle. At a frequency of approximately once per second, the system will read telemetry data from a barometric altimeter and an absolute orientation sensor, take a photo from the attached USB camera, analyze that photo to detect the presence and locations of the three targets, then calculate the position of each target relative to the payload. The software will use the altitude above ground level and the position of each target within the camera's field of view to calculate the location of the target relative to the payload descent vehicle. The orientation measurements supplied by the BNO055 Absolute Orientation Sensor will be used to correct for any variation in the payload's orientation during the descent.

4.1.2.4.2. Electronics & Hardware

The independently redundant system will require two of each hardware component listed below. It includes, but is not limited to:

- BeagleBone Black Single-Board Computer
- USB accessible HD camera
- Adafruit BMP180 Barometric Altimeter
- Adafruit BNO055 Absolute Orientation Sensor
- 7.1V Lithium Polymer Batteries
- GPS Module(s)
- One-Way Radio Transmitters

The two BeagleBone single-board Linux computers will operate the software to control the cameras, process the image data, retrieve telemetry data from the altimeters and orientation sensors, and use that information to calculate each target's position relative to the descent vehicle. At a certain altitude and orientation (determined after preliminary testing), the computers will begin capturing images of the ground. The computer will not be programmed to take images until the payload is oriented so the targets will be within viewing range of the cameras. Images will only be captured at a maximum frequency of 1Hz. The Adafruit BNO055 Absolute Orientation Sensor is a nine degree-of-freedom orientation sensor that internally processes data from its accelerometers, gyroscopes, and magnetometers in order to produce accurate measurement of the sensors position in three-dimensional space. Data from an experiment carried on an upcoming launch will be used to evaluate the reliability of the BNO055 in the conditions of a rockets flight. The Adafruit BMP180 is a barometric altimeter with an accuracy of three feet and measurement frequency of 20 Hz. In previous years, the team has found it to be a reliable altimeter. A 7.1V Lithium Polymer rechargeable battery will be sufficient to power each computer/camera system installed. At least one GPS unit will be installed on the payload to track its location.

4.1.2.4.3. Configuration

A high-level circuit diagram for the configuration of the Target Identification System can be seen below in Figure 5.

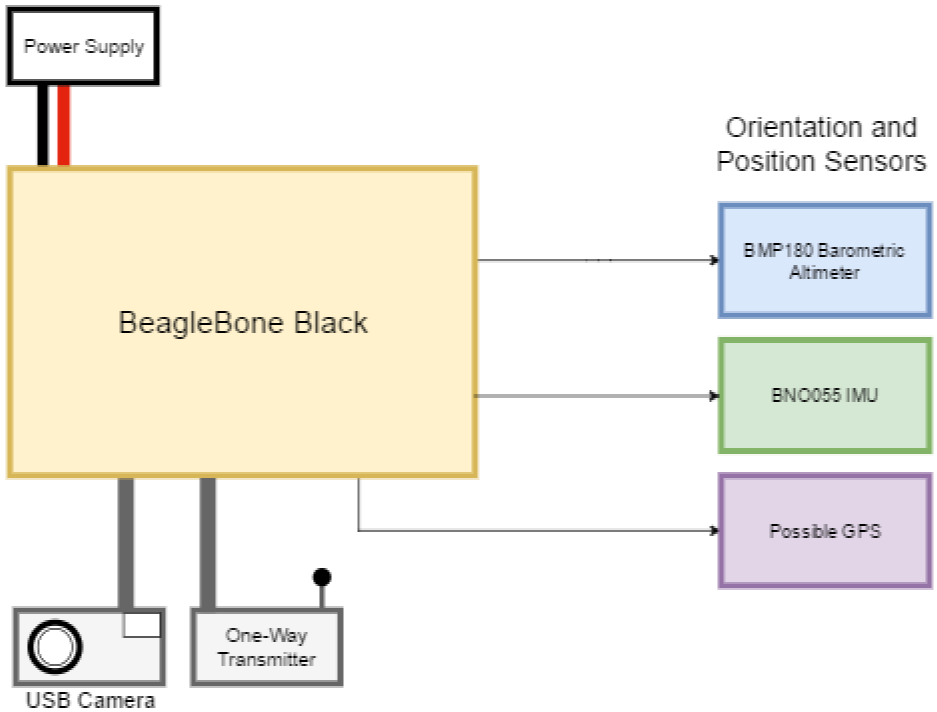

Figure 5: Target Identification System Hardware Circuit Diagram

4.1.2.5. Recovery System

4.1.2.5.1. Parachute System

The payload will utilize both a streamer and main chute for recovery. The streamer will passively unfurl upon payload deployment from the rocket body. This streamer will provide some drag to slow the payload as well as stabilize it for higher altitude image capture.

At a set altitude a Jolly Logic chute release will deploy the payload main chute. This chute will be housed directly above the payload cylinder as to mitigate any tendencies for the chute to tangle with any rocket components. The payload will have plenty of air time for photo collection and data retrieval.

All of the descending components must have a kinetic energy of less than 75 ft-lb. Sizing the parachute is based upon the payload mass. The payload will weight approximately 5 lbs. Calculations indicate that a main parachute of 46 in diameter will suffice.

4.1.2.5.2. Upright Landing System

The upright landing system will consist of four metallic spring loaded legs acting as the first point of contact with the ground. Once the main chute deploys the cylindrical payload will be oriented vertically. When the payload fully deploys from the rail system (the payload deployment system will be discussed in §4.4) the legs will automatically extend outward and act as a shock absorber for the payload upon landing and secure it in an upright orientation. The upright landing system in both configurations is shown below in Figure 6.

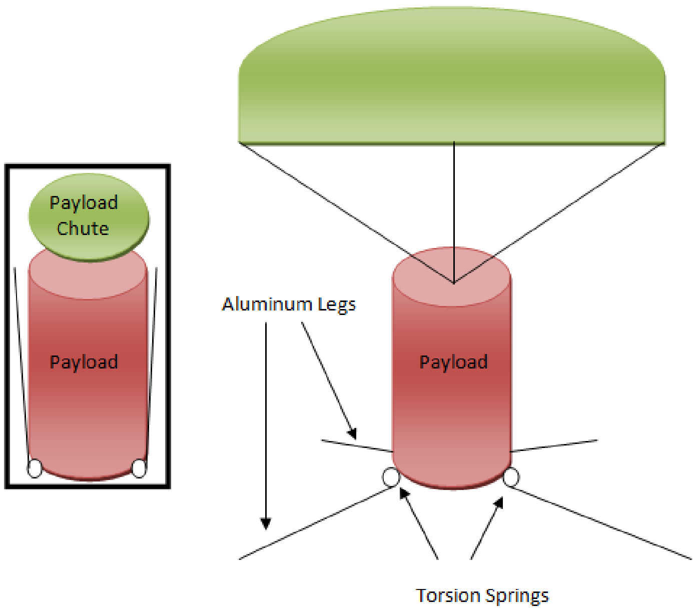

Figure 6: Upright Landing System

The four legs will be attached via the same screws that attach the retainer body and payload body. Each leg will be mounted through two screws with one empty screw hole between each leg. A torsional spring will connect the leg mount to the leg at the corner of the payload body. The torsional spring's resting orientation will place the leg 5°-10° below the lowest horizontal plane of the viewing surface. This is to ensure the legs will impact the ground before the payload regardless of whether the payload lands on a flat or inclined surface.

The legs will run the full length of the payload, twelve inches long. This will be done to provide the largest reaction moment possible to counteract tipping at ground impact. The landing legs will have a 90° U-shaped cross section in order to allow torsional springs to be placed inside them at the base and to increase rigidity. Having springs inside the legs will ensure proper locking position and allow for some give on uneven surfaces.

4.1.3. Altitude Projections/Calculations

As shown below in Figure 7, OpenRocket was used to predict the altitude of the proposed rocket. The vehicle modeled was 42.8 lbs inches and 111 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 L1420R motor, with a specific impulse of 183.8 s, the rocket is projected to reach an altitude of 5421 feet. The final rocket will likely be heavier than the 42.8 lbs specified, due to unaccounted excess weight in epoxy, fasteners, avionics, and payload. The parachutes will also weigh differently than the values in OpenRocket. However, these extra weights will be beneficial as they will cause the rocket to reach apogee at an altitude closer to the required 5280 ft. A final altitude projection and motor selection will be made once the rocket weight is finalized.

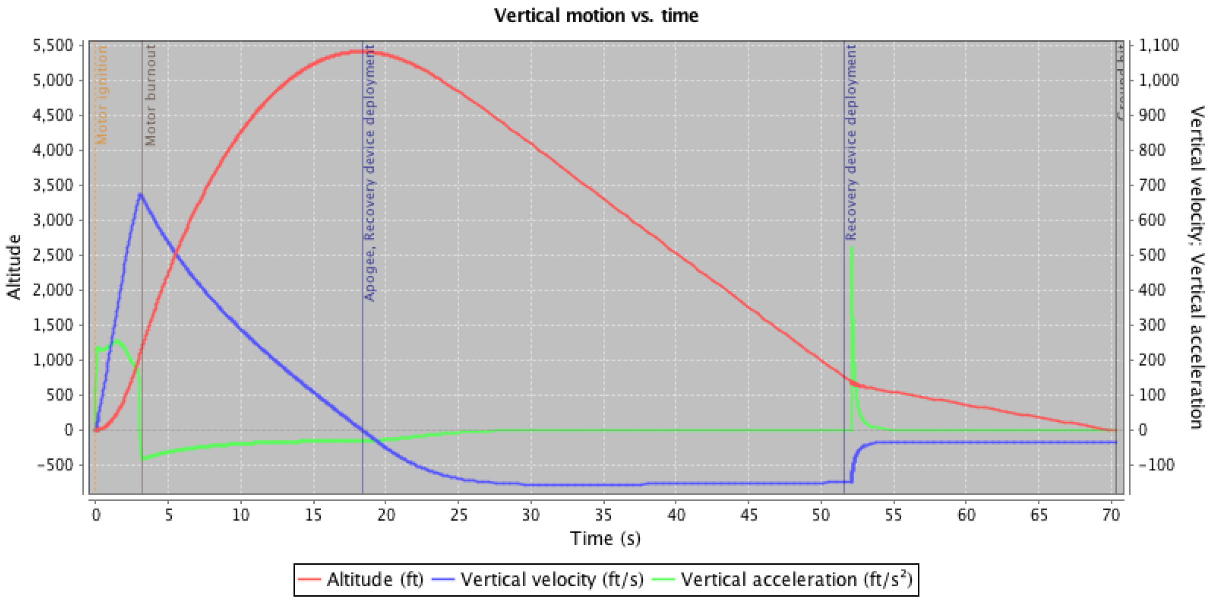

Figure 7: Open Rocket Performance Simulation

4.1.4. Parachute/Recovery System

The rocket will descend as a single unit tethered together by Kevlar shock cords capable of withstanding the decoupling forces. At apogee an appropriately sized drogue parachute will deploy by black powder ejection charges. This will separate the fin can and middle section of the rocket with the payload being ejected simultaneously. The main chute will be attached to the middle section and nosecone section and will deploy by black powder ejection charges at approximately 700 ft altitude. Kevlar sheets will wrap both parachutes protecting them from the ejection charges.

The payload will be housed in the same bay as the drogue parachute. The drogue chute will be attached to the avionics bay bulkhead and the fin can bulkhead by a shock cord. The drogue will be packed forward of the payload with the payload resting on a shelf attached to the fin can bulkhead. The drogue chute will be contained in a bowl shaped PVC canister which is attached to the shock cord. This canister will transfer the force from the ejection charge through the payload and into the fin can to break the shear pins attached to the coupler.

Two equally spaced rails will be attached to the walls of the rocket body for the payload to slide along as it exits the rocket. The rails will be 1" x 0.5" T-slotted aluminum and fit on rods that are attached to the avionics bulkhead. A centering ring will attach to the aft end of both rails to increase rigidity in separation. Rail buttons will be mounted on the payload to guide the payload along the rails.

The shock cord will be routed from the avionics bay bulkhead through the chute canister, around the payload, through the shelf, and connected to the fin can bulkhead. The chute canister will only have enough shock cord to reach the exit of the bay. In order to avoid the payload traveling with the fin can until the entire shock cord is taught, a shear pin will attach the chute canister and the payload. This shear pin will break at payload clearance of the bay and will decelerate and impart a moment to turn the payload away from the fin case.

The legs of the upright landing system will be touching the inner diameter of the rocket body upon deployment of the payload. Once the payload is fully deployed the upright landing system will automatically deploy.

Figure 8 below shows the general deployment of the different sections of the rocket.

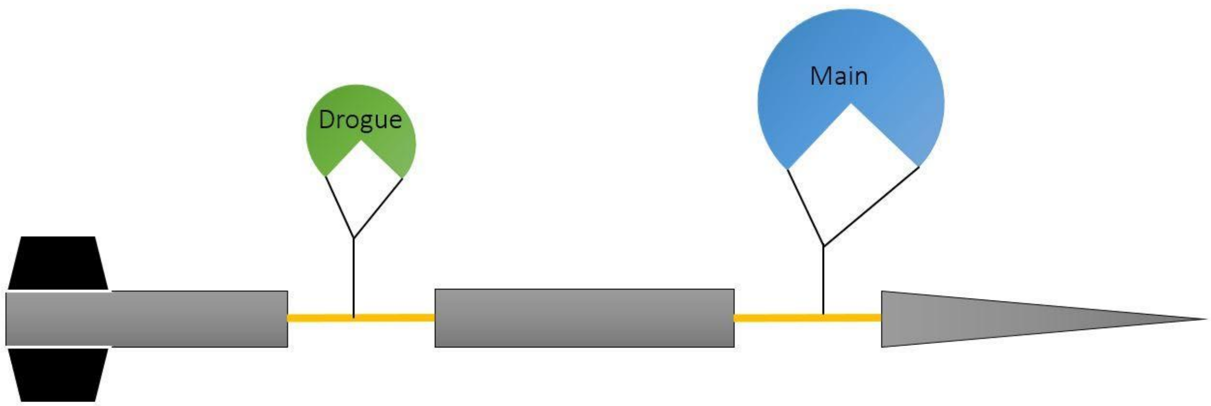

Figure 8: Parachute Setup (Not to Scale)

The middle section will contain one avionics bay to control both the drogue and main chute deployment. Altimeters will control the ejection charges to deploy the parachutes for the rocket. A GPS tracker will be housed in the avionics bay along with the altimeters. Both sets of ejection charges and altimeters will be independently redundant.

4.1.5. Propulsion System

With the current estimation of 42.8 lbs with the motor included for the weight of the rocket, an L-class motor is required to reach the 5280 ft mark. Using the OpenRocket design and simulation, the AeroTech L1420R motor has the required thrust and impulse needed to reach the required apogee height. This motor has a specific impulse of 1034.8 lbf-s and a burn time of 3.2 s. This motor is 26.18 inches long and 2.95 inches in diameter. A simulation in OpenRocket (see Figure 7) shows that this motor will send the weighted rocket approximately 5400 ft. The model shows the rocket will experience a maximum acceleration of 250 ft/s^2 and a maximum velocity of 675 ft/s, which translates to a Mach number of 0.61.

The apogee is higher than required by mission specifications to account for an increase in rocket weight, which is anticipated to come from manufacturing processes and other factors like excess epoxy and ballast added. The excess weight will bring the rocket closer to the desired altitude and apogee precision will be improved through minor adjustments thereafter.

4.1.6. Requirements

4.1.6.1. Vehicle Requirements

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

4.1.6.2. Recovery System

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

4.1.6.3. Payload

The payload is tasked with targeting 3 randomly placed targets via an onboard camera system. It must identify and differentiate between all three targets that will be located within 300 ft of the launch pad. The payload housing the camera must process the data real time by a custom designed on-board software package and then land upright upon touchdown proving a successfully controlled descent.

4.1.7. Technical Challenges/Solutions

Two major technical challenges were identified within the mission proposal. The first major issue is designing the payload so that it will eject with as many passive systems as possible while still maintaining functionality after it leaves the rocket. Including too many electronics increases risks of failure in a single component that is required to operate in a step by step order. Failure in a critical electronic component early in the launch may prohibit the payload from being released and could damage in the internal electronics or the rocket itself. Therefore, special consideration needs to be given towards the release mechanisms controlling the payload ejection.

The current solution is to have a mechanical rail system that operates as a guide for the payload upon apogee decoupling. Using rail buttons on the payload and two rails inside the rocket body tube no electronics are needed to eject the payload, excluding the altimeter controlled black powder charges. The payload can act as a self-contained unit and once deployed will no longer interact with the rocket in its descent.

The second major challenge also involves the payload. Because it is cylindrical in shape a designated upright landing system needed to be created to ensure mission success.

A passive system is more desirable to reduce relying solely on electronics to engage the landing system. A mechanical system of four spring loaded legs will be used to land the payload upright acting as not only a stabilizer upon touchdown, but also a cushion for the landing to reduce risk of damage to the internal components. Further testing will be carried out to determine if a fully passive system will be viable or if some sort of latching mechanism will need to be constructed to extend the lander legs.

Both of these design challenges will encourage further research and data collection. Testing these proposed designs will allow further improvements to be made before the competition launch. The challenges are not limited to these items, but the two aforementioned challenges have been discussed much more in-depth than any other challenge thus far.

5. Educational Engagement

NC State Hosted Family STEM night

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

Location: Brentwood Elementary School 3426 Ingram Dr. Raleigh, NC 27604
Time: October 14th, 4pm-8pm
Location: Zebulon Elementary School 700 Proctor St, Zebulon, NC 27597
Time: October 21st, 4pm-8pm

First Robotics THOR Offseason Competition
Several members of the NCSU High Powered Rocketry Club are planning on volunteering at the First Robotics THOR Offseason Competition. The event is a friendly competition for teams to prepare for in between the regular competition season. The

event takes place all day on Saturday at Reidsville High School. 24 teams attended last year's event. Team members will have the opportunity to help officiate the competition and mentor students at the event.

Location: Reidsville High School 3426 Ingram Dr. Raleigh, NC 27604
Time: October 15th, 9am-5pm

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

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

YMCA Kite and Rocket Day
The High Powered Rocketry Club is planning on continuing the tradition of being a part of the YMCA Kite and Rocket Day in the Spring of 2017. 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 2017. 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 event takes place on NCSU's campus and involves around 30-40 Boy Scouts and their families. The details of this event will be finalized in early Spring 2017.

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) Released	**8/15/2016**	**8/15/2016**
RFP Writing/Editing	8/15/2016	9/30/2016
Completed RFP Submission	**9/30/2016**	**9/30/2016**
Awarded Proposals Announced	**10/12/2016**	**10/12/2016**
Team Web Presence Established	**10/31/2016**	**10/31/2016**
Preliminary Design Review (PDR) Writing	10/12/2016	10/31/2016
First Robotics THOR Offseason Competition	10/10/16	10/10/16
NC State Hosted Family STEM night	10/15/16	10/15/16
NC State Hosted Family STEM night	10/21/16	10/21/16
Completed PDR Submission	**10/31/2016**	**10/31/2016**
PDR Team Teleconference (Tentative)	11/2/2016	11/18/2016
Critical Design Review (CDR) Writing	11/2/2016	12/16/2016
Subscale Launch	**11/21/2016**	**11/22/2016**
NCSU Winter Break (no building access)	12/16/2016	1/9/2017

Event/Task	Start Date	Finish Date
CDR Writing	1/9/2017	1/13/2017
Completed CDR Submission	**1/13/2017**	**1/13/2017**
CDR Team Teleconference (Tentative)	1/17/2017	1/31/2017
Flight Readiness Review (FRR) Writing	1/16/2017	3/6/2017
Full-scale Launch (Tentative)	2/1/2017	2/29/2017
Completed FRR Submission	**3/6/2017**	**3/6/2017**
FRR Team Teleconference (Tentative)	3/8/2017	3/24/2017
Team Travel to Huntsville, Alabama	4/5/2017	4/5/2017
Launch Readiness Review (LRR)	**4/5/2017**	**4/5/2017**
NASA Safety Briefing	4/6/2017	4/6/2017
Rocket Fair and Tours of MSFC	4/7/2017	4/7/2017
Launch Day	**4/8/2017**	**4/8/2017**
Backup Launch Day	4/9/2017	4/9/2017
Post-Launch Assessment Review	**4/24/2017**	**4/24/2017**
Winning Team Announced by NASA	**5/12/2017**	**5/12/2017**

6.2. Budget

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

North Carolina State University 2016 Proposed Budget

	Item	**Amount**	**Total Price**
Experiment Payload	Beaglebone Black	2	$90
	Aero Pack 75 mm Retainer (Flanged)	1	$53.50
	.125 " Acrylic Grazing Sheet	1	$10
	12" Drawn Alum. Bare Tubing 6061 T6	1	$45.48
	12"x12" Alum. Bare Sheet 6061 T6	1	15.35
	Standard Airfoil Rail Buttons (for 1010 rail)	1	$7
	.5" X 72" #13 Threaded Alum. 6061 2-pack	1	$33.39
	Carbon Steel Hex Nut with 1/2"-13 Dia./Thread Size; PK25		$5.45
	USB accessible HD camera	2	$90.00

NC STATE UNIVERSITY

	BMP180 Altimeters	4	$39.80
	BNO055 Orientation Sensors	2	$70
	7.2V 2000mAh Lithium Polymer Batteries	2	$81.50
	GPS Module	2	$79.90
	5V 1.5A Linear Voltage Regulator - 7805 TO-220	2	$1.50
	TO-220 Clip-On Heatsink		$0.15
	10uF 50V Electrolytic Capacitors - Pack of 10	1	$1.95
	Jolly Logic Parachute System	1	$130.00
	Aluminum Legs	4	$100
	Torsional Spring	4	16.68
Rocket	ARR Standard Coupler 4” (3.9” , 98mm) x .062 wall x 8”	1	$15 ($26.55)
	ARR Standard Coupler 5.5” x .077 wall x 12”	1	$20 ($63.70)
	ARR Airframe 75mm (3") x .077 wall x 48” MMT	1	$60 ($79)
	ARR Airframe 5.5” x .077 wall x 72” Airframe	1	$90 ($167 for 60")
	ARR Airframe 4” (3.9” , 98mm) x .062 wall x 48” Airframe/MMT	1	$40
	Fiberglass 3k, 2 x 2 Twill Weave Carbon Fiber Fabric (1 yard), 50'' wide, .012'' Thick	1	$60
	Aircraft Spruce Domestic Birch Plywood ¼” x 4 x 4	1	$120
	Aircraft Spruce Domestic Birch Plywood⅜” x 4 x 4	1	$140
	Epoxy and hardener	1	$50
	Paint	--	$30
	Rail buttons	4	$10
	StratoLogger Altimeter	4	$320
	GPS Bee	3	$95
	L motor (full scale)	2	$360
	I motor (subscale)	2	$100
	Wires	--	$30
	Connectors	--	$20
	Nose cone (full scale)	1	$115
	Nose cone (subscale)	1	$65
	Motor casing (full scale)	1	$65
	Motor casing (subscale)	1	$65
	Kevlar shock cord (ft)	60	$60

	Parachute materials	--	$500
	Black powder (lb)	1	$20
	Travel expenses (hotel, rental car, gas) (# people)	20	$3,000
Other	Incidentals (replacement tools, hardware, safety equipment)	--	$1,000
	Shipping costs		$750
Subtotal	--	--	$8,161

6.3. Funding Plan

The current budget for the 2016-2017 school year is largely based off of NASA SL requirements from the previous year and previous awards from various sources. The budget is projected to be $6,000 for the building of the full scale competition rocket and payload. The club received $2,000 from the Engineering Technology Fee Fund from the Mechanical and Aerospace Department at North Carolina State University for the 2016-2017 academic year and the same is expected for the 2016-2017 academic year. The Engineering Council at North Carolina State University granted the club $3,000 for the 2014-2015 academic year. The club has received $2,850 for fall of 2016 from the Engineering Council through a proposal, presentation, and appeals presentation and interview. If the budget for the Engineering Council remains the same, the request of $4,500 will be made for spring of 2017. The club has received $1,600 for fall of 2016 through a budget plan, interview process, and presentation. The club received $7,000 from the North Carolina Space Grant for competition and senior design for the 2015-2016 academic year. The club must submit two separate proposals to NC Space Grant for the 2016-2017 academic year and expects to receive the same amount of $7,000. The total amount requested is $20,000, however this is based on an expectation of maximum funding. The projected amount to be received is much lower as requests do not have to be awarded in full.

6.4. Community Support

The High-Powered Rocketry Club is largely self-sufficient, having all of the machines and materials needed on-site whether in the rocketry lab or machine shops. If outside help is needed, we will communicate with local high power rocketry enthusiasts and/or leaders. To maintain a good standing within the local community and build networking relationships, the Club participates in several outreach events at local schools, museums, and/or businesses.

6.5. Project Local Sustainability Plan

The club plans to sustain itself by continuing to host its outreach events. These events promote others to participate in the club and provide its newest members a chance to experience what it is like to be in the rocketry club. That way they can teach others and promote the club in the years ahead. The club also does not discriminate against new members, and welcomes anyone with an interest in rocketry to participate and contribute to the club.

7. References

[1] "Aluminum 6061-T6; 6061-T651," MatWeb Material Property Data, http://www.matweb.com/search/DataSheet.aspx?MatGUID=16bda8c8d9b24a54ade5de2ebe5fb082 [retrieved 23 September 2016].

[2] "Quantum Composites QC-2150LD NT 25% Fiberglass Reinforced Phenolic SMC," MatWeb Material Property Data, http://www.matweb.com/search/DataSheet.aspx?MatGUID=1b8c06d0ca7c456694c7777d9e10be5b&ckck=1 [retrieved 23 September 2016].

[3] "DRAWN ALUMINUM BARE TUBE 6061 T6," Online Metals, http://www.onlinemetals.com/merchant.cfm?pid=4744 [retrieved September 25, 2016].

[4] "4" G12 FIBERGLASS FILAMENT WOUND TUBE 48" LONG," Apogee Components, https://www.apogeerockets.com/Building_Supplies/Body_Tubes/Fiberglass_Tubes/4in_G12_Fiberglass_Filament_Wound_Tube_48in_Long?cPath=42_43_285& [retrieved September 25, 2016].

8. Appendices

8.1. MSDS Information

GOEX Black Powder
Klean-Strip Acetone
West System 105 Epoxy Resin
West System 206 Slow Hardener
Fiberglass Fabric
Batteries
Electronic Matches
Cotton Floc
Baby Wipes
Igniter
Liquid Nails
Glass Microspheres
Turtle Wax
WD-40

8.2 FMECA

Structures

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

		Loads beyond design specification			2	Maintain operations within design specifications
		Improper Maintenance			2	Pre/post launch inspections
	Non-compromising cracks	Poor Design	Potential for future damage	No system level safety effect	4	FEA of bulkhead stress
		Manufacturing Defect			4	QC of manufacturing process
		Loads beyond design specification			4	Maintain operations within design specifications
		Damaged during handling			4	Adhere to proper handling procedure
		Improper maintenance			4	Pre/post launch inspections
Fins	Damage from impact	Poor design	Loss of future fin use	Possible damage to other components	2	FEA
		Manufacturing defect			2	QC of manufacturing process
		Damaged during handling			2	Adhere to proper handling procedure
		Loads beyond design specification			2	Maintain operations within design specifications
		Improper maintenance			2	Pre/post launch inspections
Shear Pins	Breaking before	Manufacturing	Loose	Separation of	3	QC of parts received

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

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

		Improper maintenance			1	Pre/post launch inspections

Recovery

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

	coding	defect		Large drift from early ejection	4	Test two altimeters for redundancy
Bulkhead and U-bolt	U-bolt failure	Improper attachment	Separation of rocket section from parachute	Rocket is not safely recovered	1	Make sure components are adequately constructed
	Bulkhead failure	Improper attachment			1	
Parachute deployment	Parachutes (3) fail to deploy correctly	Parachute tangling	Parachutes do not correctly deploy	Rocket is not safely recovered	1	Ensure that parachutes and shock cord are folded correctly
		Remote sensor of rocket section from parachutes			3	Construct the rocket so the wires are out of the way
		Parachute bags do not fully open			1	Fold bags correctly and make sure nothing can snag the parachutes
		Shock cord connections come loose			1	Check all shock cord
	Premature detonation	Improper wiring/attachment	Premature separation of connections between lower and middle airframe	Large drifting distance of lower airframe	3	Make sure components are adequately constructed
		RF interference			3	Complete testing of electronic devices

Aerodynamics

Function / Component	Failure Mode	Causal Factors	Failure Effects: Subsystem	Failure Effects: System	Hazard	Recommendations
Fins	Fins layout cause unexpected trajectory	Fins are not attached at the correct angle	Aerodynamic forces from fins are not the same from each fin	Trajectory is different than expected	3	Use fin jig to ensure angles are correct
		Fins are not symmetric			4	Shape fins to specifications before installation
Nosecone	Nosecone imperfections lead to altered trajectory	Manufacture defect	Aerodynamic forces are greater on one side of the nosecone	Trajectory is different than expected	4	Inspect nosecone and sand to correct shape
Rocket Sections	Rocket sections separate before charges ignite	Deceleration of the rocket	Sections separate early	High velocity separation	1	Make sure shear pins and screws can hold
				Premature parachute deployment at high altitudes	4	

Propulsion

<table>
<tr><th rowspan="2">Function / Component</th><th rowspan="2">Failure Mode</th><th rowspan="2">Causal Factors</th><th colspan="2">Failure Effects</th><th rowspan="2">Hazard</th><th rowspan="2">Recommendations</th></tr>
<tr><th>Subsystem</th><th>System</th></tr>
<tr><td>Bulkhead</td><td>Motor breaks through bulkhead</td><td>Material or construction flaws</td><td>Motor system is compromised</td><td>Motor damages rocket frame or contents</td><td>1</td><td>Inspect bulkhead prior to launch</td></tr>
<tr><td rowspan="3">Motor Casing</td><td rowspan="3">Damage to motor casing</td><td>Superficial damage</td><td rowspan="3">Motor is not safe if major damage occurs</td><td rowspan="3">Rocket is not safe to launch if damage is major</td><td>4</td><td rowspan="3">Check motor casing before launch, remove foreign objects from motor area</td></tr>
<tr><td>Motor inoperable</td><td>2</td></tr>
<tr><td>Motor casing fracture</td><td>1</td></tr>
<tr><td rowspan="3">Fuel</td><td rowspan="3">Contamination of fuel</td><td>Rocket fails to launch</td><td rowspan="3">Reduced performance of rocket motor</td><td rowspan="3">Rocket does not launch or perform as expected</td><td>2</td><td rowspan="3">Store and maintain motor fuel properly and in isolation / order from reputable source</td></tr>
<tr><td>Over-oxidized reaction</td><td>2</td></tr>
<tr><td>Reduced fuel efficiency</td><td>3</td></tr>
<tr><td rowspan="2">Construction</td><td rowspan="2">Motor misalignment</td><td>Construction or measurement error</td><td rowspan="2">Thrust is not in expected direction</td><td rowspan="2">Unpredicted trajectory</td><td>1</td><td rowspan="2">Check motor alignment during construction</td></tr>
<tr><td>Rocket frame fracture</td><td>1</td></tr>
<tr><td rowspan="2">Launch</td><td rowspan="2">Launch interference from foreign object</td><td>Unpredictable rocket trajectory</td><td rowspan="2" colspan="2">Launch when clear</td><td>3</td><td rowspan="2">Launch in an open area, wait for clear airspace before launch</td></tr>
<tr><td>Rocket frame fracture</td><td>2</td></tr>
</table>

Stability

Function / Component	Failure Mode	Causal Factors	Failure Effects		Hazard	Recommendations
			Subsystem	System		
CG	Expected numbers are different from actual	Error in calculations and measurements	Stability characteristics are different than projected	Flight path and characteristics in jeopardy	1	Physically measure the location of the center of gravity
CP						Use Barrowman's method/OpenRocket to determine location of center of pressure
Static Margin						Calculate by using the locations of the center of gravity and pressure
Weight Shift	Weight shift causes center of gravity shift	Large acceleration or deceleration forces an object to shift	Static margin change due to shift in center of gravity		1	Ensure all rocket components are secure during construction process

Payload

Function / Component	Failure Mode	Causal Factors	Failure Effects: Subsystem	Failure Effects: System	Hazard	Recommendations
Parachute Recovery System	Doesn’t Deploy	Improper Folding	Cameras cannot perform effectively	Payload has no means to decrease descent velocity.	1	Careful packing of parachute recovery system.
	Streamer Doesn't Deploy	Excessive Rotation Upon Jettison	Effectiveness of cameras decreased	Parachute Recovery System deployed at higher than expected velocity	3	Evaluation during black powder charge testing.
		Damaged by Rail System Upon Jettison			3	Evaluation of Rail System hazards during sub-scale rocket testing.
Electronics/ Hardware	Rail Button Sheared Off Upon Payload Jettison	Excessive loading	Structural defects encountered	Possible damage to other components	4	Testing during build and pre-flight checklist.
	Shear Pin Malfunction	Manufacturing Defect				
	Electrical Short in Circuit	Circuitry is Disrupted/ Damaged	Payload hardware experiences catastrophic failure	Mission requirements not met	3	Hardware system thoroughly tested.
	Cameras Damaged during Payload Ejection	Excessive force applied to Payload during Jettison				
Upright Landing System (ULS)	Payload Doesn't Eject Properly	Excessive Radial Force Caused by Legs Against Inner Rocket Body		Mission requirements not met	2	Run experiments and simulations that ensure that proper payload deployment will occur.
	Legs Do Not Deploy	Poor selection in design process	Payload doesn’t land upright		2	Testing during build and pre-flight checklist.
	Legs Fall Off					