NORTH CAROLINA STATE UNIVERSITY

# NASA USLI PROPOSAL

Tacho Lycos

Submitted by: North Carolina State University High Powered Rocket Club

22 November 2013

This document is in response to the NASA USLI request for proposals for the 2013/2014 competition year. The North Carolina State University High Powered Rocket Club, Tacho Lycos, is proposing to design, build and safely recover a launch vehicle that will fly to an altitude greater than one mile with an array of scientific devices to measure various flight characteristics.

# Contents

# I. General Information

## 1. School/Organization Information

a. School/Organization:
North Carolina State University
High Powered Rocket Club – Team Tacho Lycos

b. Mailing Address:
911 Oval Drive, EB III
Raleigh, NC 27607

c. Project Title:
University Student Launch Initiative: design, build and safely recover a launch vehicle that will fly to an altitude greater than one mile with an array of onboard scientific devices to measure various flight characteristics.

## 2. Team Official

a. Name:
Dr. Charles Hall

b. Title:
Professor of Mechanical and Aerospace Engineering, Flight Research

c. Contact Information:
chall@ncsu.edu
(919) 522-5768

d. Bio:
Dr. Hall has been teaching at North Carolina State University since July 1990 with the Mechanical and Aerospace Engineering Department. He first became exposed to model rockets at age nine, completed his first successful flight of a guided model rocket in 1983, and has received his NAR Level 3 certification. After receiving his Ph.D. from Ohio State University in 1986, he worked on several missiles including the Patriot at Redstone Arsenal in Huntsville, Alabama, while serving active duty in the Army.

## 3. Safety Officer

a. Name:
Collin Bolton (See Item 5)

## 4. Student Team Leader

a. Name:
Raven

b. Title:
Coordination Officer

c. Contact Information:
relauer@ncsu.edu

(919) 414-4950

# 5. Outline of Leadership Positions and Sub Teams

a. Officer Position: President
   i. Name: Chris
   ii. Years in Club: 1
   iii. Prior Experience/Responsibilities: 2012-2013 Member
   iv. Qualities and Skills: Chris is a senior in Aerospace Engineering and was elected president after his involvement with the club during last year. Chris is also part of the Flight Research Senior Design Team leading HPRC.

b. Officer Position: Vice-President
   i. Name: Stephen
   ii. Years in Club: 1st year
   iii. Prior Experience/Responsibilities: New Member
   iv. Qualities and Skills: Stephen is a senior in Aerospace Engineering and joined the club at the start of the year as part of the Flight Research Senior Design Team charged with leading HPRC this year.

c. Officer Position: Vice-President
   i. Name: Jess
   ii. Years in Club: 1st year
   iii. Prior Experience/Responsibilities: New Member
   iv. Qualities and Skills: Jess is a senior in Aerospace Engineering and joined the club at the start of the year as part of the Flight Research Senior Design Team charged with leading HPRC this year.

d. Officer Position: Coordination Leader
   i. Name: Raven
   ii. Years in Club: 1
   iii. Prior Experience/Responsibilities: 2012-2013 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 during this year. Raven's organization skills and passion for the club's success will make him a very useful member this year.

e. Officer Position: Safety Officer
   i. Name: Collin
   ii. Years in Club: 1
   iii. Prior Experience/Responsibilities: 2012-2013 Member
   iv. Qualities and Skills: Collin is a returning member from last year and is a junior in Aerospace Engineering. Collin has experience with rocket construction techniques which makes him very knowledgeable about safety in the fabrication lab.

f. Officer Position: Treasurer
   i. Name: Azariah
   ii. Years in Club: 1
   iii. Prior Experience/Responsibilities: 2012-2013 Member

iv. Qualities and Skills: Azariah is a senior in Aerospace Engineering and is very interested in propulsion techniques, applications of open-sourced technologies, and 3D printing.

g. Sub Teams

With over 14 active members, all individuals will be divided up among the below sub teams under the guidance of an experienced team leader based upon each person's interests and experience levels.

i. Excitation System: This team is led by Raven and is responsible for designing, testing, and implementing an excitation system meant to perturb the rocket's flight to measure the stability of the vehicle during vertical flight. The team will incorporate their design and data in design review presentations and reports.

ii. Payload Development and Design: This team is led by Cody and is responsible for all selections and design of the onboard scientific experiments and logistics of data collection.

iii. Recovery: The recovery team is led by Jamie and is responsible for ensuring that the launch vehicle falls and is recovered safely. This team will use various measurements to choose the needed parachutes and will teach the rest of the club common procedure to properly handle, fold, and pack parachutes in the rocket.

iv. Structures:

v. Propulsion: This team is led by Azariah and is responsible for the safe, consistent, and controlled burn-out of the rocket. The team is in charge of motor selection, controlled motor testing, calibrating the load cell, and measuring the effect of the motor on other structural areas of the rocket.

## 6. TRA/NAR Partners

NAR Section 608 Rocketry of Central Carolina
NAR Section 648 Rocketry Organization of South Carolina at Orangeburg
Tripoli Section 60 Tripoli South Carolina
Tripoli Section 65 Tripoli Eastern North Carolina
Tripoli Section 66 Tripoli Charlotte

# II. Facilities

## 1. Mechanical and Aerospace Engineering (MAE) Department North Carolina State University

The MAE department has authorized the members of Tacho Lycos with access cards to Engineering Building III (EB III), Centennial Campus every day from 7am until 10pm.

a. EB III EOS Computer Lab – EB III 2108

This lab has 68 computer workstations providing the students and faculty access to all software and network capabilities offered by North Carolina State University. The lab also has three network printers, a scanner, and a copier. Authorized students have access to this lab 7 days a week from 7:00 am to 10:00 pm.

b. MAE Student Fabrication Shop – EB III 2003A
This lab will primarily be used for construction of the rocket components, the rocket, and the scientific payload. This workspace is accessible 5 days a week from 7:00am to 10:00pm to authorized students. Department consent is required to access the Fabrication shop on Saturdays and Sundays. Available equipment is listed in the equipment section.

c. Flight Research Material Storage Locker — EBIII High Bay
Accessible 24 hours a day, 7 days a week by authorized students. Locker will be used to store flammable and dangerous materials such as solid motors.

d. MAE Machine Lab
Students do not have access to this lab, but parts can be machined by request through the department. Machine lab will be used for large scale machine work. Lab contains equipment such as lathes, a CNC Machine, and a Laser Cutter.

e. MAE Aircraft Senior Design Lab – EB III Room 1225
Accessible from 7:00 am until 10:00 pm, 7 days a week to authorized students. Lab will be used for construction of composite components. Vacuum system, manufacturing equipment, and safety equipment are present.

## 2. Bayboro, North Carolina, Test Launch Location

Facility is accessible during scheduled launch events, as described at: http://www.colonialvirginiahpr.org/bb2010sch.htm.
Field will be used for large scale testing of rocket and its components. It is located at Paul's Farm Road, Bayboro, NC.

# III. Equipment

## 1. Manufacturing Equipment

a. Band Saw
b. Drill Press
c. Soldering Equipment
d. Composite Layup Board & Vacuum/Compressor
e. Belt Sander
f. Hand tools (utility knives, hammers, screw drivers, and measuring equipment)

## 2. Safety Equipment

a. Fire Extinguisher
b. First-Aid Kit
c. Gloves, Goggles, Masks
d. Cleaning supplies
e. Campus Emergency Response – Dial (919) 515-3000
f. Campus Health Services – Dial (919) 515-2563
g. Non-Emergency Lab Accident – Contact Dr. Hall at (919) 515-5299

## 3. Computer Hardware

Every team member has access to a personal computer for email communications, in addition to lab computers. Lab computer specifications include:

a. Processor: Intel Core 2 Duo E8400 3 GHz & 2.99 GHz
b. RAM: 4 GB
c. Graphics: NVIDIA GeForce 9300 GE
d. Campus Broadband Connections

## 4. Software

The team will use the following software licensed to North Carolina State University:

a. Microsoft Office Professional 2010: Planning and document development
b. Solidworks 2013-2014: Rocket component and payload design
c. OpenRocket 1.1.9: Rocket design
d. Ansys 14.5 Workbench: Structural analysis of rocket and/or payload
e. Google Chrome version 31.0

## 5. Video Conference Equipment – EB III

Conference rooms are available for student reservation. They currently do not support video conferencing. However, a request has been submitted for one of the conference rooms to include the necessary equipment. The following WebEx compatible equipment is being purchased by the Mechanical and Aerospace Engineering Department:

a. LCD Monitor
b. USB Webcam
c. Speakers
d. Microphone
e. Projector

## 6. Information Technology Contact

Mr. Lance Mangum – EB III Room 3264
(919) 515-5685
mangum@eos.ncsu.edu

## 7. Team Official Contact for Daily Communication

Raven Lauer – Coordination Officer
relauer@ncsu.edu
(919) 414-4950

## 8. Accessibility Standards

All team members have read and comply with the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility (36 CFR Part 1194) and Subpart B-Technical Standards, as described at the provided website.

# IV. Safety

## 1. Certified Mentor

Alan Whitmore is the mentor for our rocketry team this year. He began making and flying high-power rockets in 1998 and joined Tripoli Rocketry Association (TRA) in 1997. In 2000, he began making his own homemade propellant and motors, and in 2001 he initiated a propellant characterization program to gather data on thrust and combustion chamber pressure produced by various propellant formulas under different conditions. This testing program continues today and has resulted in the publication "Performance Evaluation of Experimental Rocket Propellants," which is in its 3rd edition. 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.

Work Phone: (919) 966-4026
Home Phone: (919) 929-5552
Home Email Address: acwhit@nc.rr.com

His role in the team will include the following responsibilities:

a. To ensure compliance with the NAR high power rocketry code requirements [http://nar.org/NARhpsc.html].
b. To ensure the safe handling and execution of all hazardous materials and operations.
c. Purchasing and safely handling motor reloads.
d. Traveling with the team to the USLI launch.

## 2. Ensuring Team Safety and Awareness

All team members will be made aware of the federal, state, and local laws regarding unmanned rocket launches and motor handling. Safety measures involving the proper use of airspace and the regulations involving the launching of different classes of rockets will be discussed with the team. The handling and use of low-explosives will be explained to all team members. The following steps will be taken in order to ensure that the entire team is cognizant of the safety issues and risk mitigation techniques of this project:

a. Assigning a safety officer. This year's safety officer is Collin. He is ultimately responsible for the safety of the entire project.
b. A presentation was given to all team members including the above safety information before rocket construction and material handling had begun. Also included in this presentation were ways in which these safety risks can be mitigated and prevented as well as proper pre-launch procedure.
c. All of the pertinent safety documents from the FAA and other sources (and including our safety/risk mitigation presentation) will be available on the team's website for ease of reference.

d. Copies of MSDS sheets and other important material information will be kept in the lab used for rocket construction and on the team website so that all team members are aware of its location. Copies of this information will also be taken with the rocket during test launches.
e. First-Aid kits are located in the rocket construction lab and will also be taken to test launches.
f. Each team member is required to understand and agree by the safety information in Parts I and II of the Student Safety Agreement. The first section of this agreement is the official NAR safety code for high power rocketry which can be found on the NAR homepage. The second section of the safety agreement includes some key USLI safety regulations.

g. The team is to be aware of the following key safety related regulations:
    i. Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C. This involves use of airspace.
    ii. NFPA 1127. Code for High Power Rocketry. This involves fire prevention regulations for high power rockets.
    iii. The handling of low-explosives such as APCP, black powder, igniters and E-Matches.

# 3. Safe Purchasing and Handling of Rocket Materials

The student members of the team will purchase the reload casing. The rocket motor reloads themselves will be purchased by our Level 3 Tripoli certified mentor, Alan Whitmore. He will also be responsible for the safe storage of the rocket motors and transportation of the rocket motors when necessary. Alan will also be on location whenever the rocket is being launched.

Alan Whitmore will be responsible for the safe handling of the rocket motor that we choose to purchase. He will be in charge of the transportation of the motor in appropriate container when taking it to the test locations, or the final launch location. The motor reloads will only be accessible by him during transportation and use.

# 4. Student Safety Agreement – Part I
# NAR High Power Rocket Safety Code

a. 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.
b. 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.
c. Motors
I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purpose except those recommended by the

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

d. 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 to 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.

e. 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.

f. 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 unless it is determined to be stable.

g. 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.

h. 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.

i. Flight Safety
I will not launch my rocket at targets, into clouds, near airplanes, nor on launch 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, if applicable at that launch site.

j. 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.

k. 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.

l. 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.

m. 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 area or outside the launch site, nor attempt to catch it as it approaches the ground. Note: A complex rocket is one that is multi-staged or that is propelled by two or more rocket motors.

# 5. Student Safety Agreement – Part II

## General USLI Safety Regulations

a. Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection.
b. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
c. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

# 6. Risk Prevention and Safety Presentation

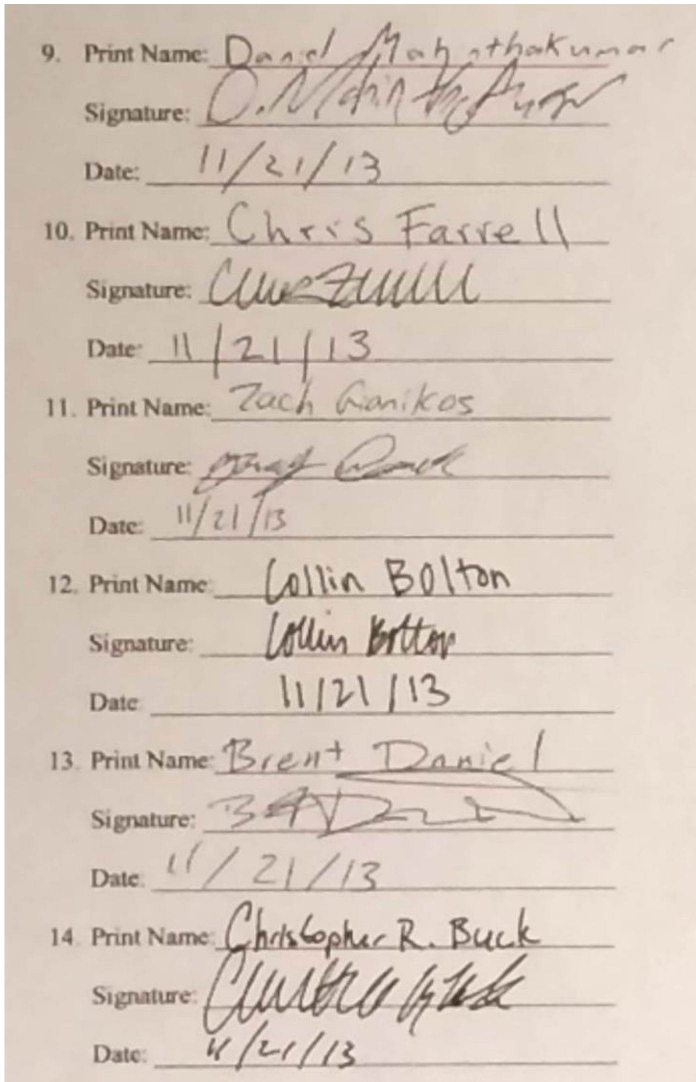
a. General
   i. Always ask if unsure about equipment, tools or a procedure.
   ii. Only handle certain materials if you have the proper permit.
b. Chemicals (e.g. adhesives, solvents, and paint) and Black Powder
   i. Risks include:
      a. Irritation from skin contact, eye contact and inhalation of hazardous fumes.
      b. Flammable and/or explosive chemicals/substances.
   ii. Ways to prevent these risks:
      a. Be familiar with relevant MSDS sheets
      b. Wearing appropriate safety gear. Some examples are goggles and gloves
      c. Be aware of locations of nearest first-aid kit, fire extinguisher, and eye wash station.
      d. Keep chemicals away from open flames.
      e. Clean work stations.
      f. Keep construction and test rooms well ventilated.
      g. 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:
        a. Wearing closed-toed shoes.
        b. Seeking advice if unsure about the operation of equipment.
        c. Wear goggles and gloves when necessary.

d. Safety Agreement Signature Sheets:
**See Next 2 Pages**

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

1. Print Name: Jamie Kegion
   Signature: Jamie Christine Kegion
   Date: Nov 21st 2013
2. Print Name: Raven Lauer
   Signature: Raven Lauer
   Date: 11-21-2013
3. Print Name: Braden Epp
   Signature: Braden Epp
   Date: 11-21-13
4. Print Name: William Martz
   Signature: William Martz
   Date: 11/21/13
5. Print Name: Suleyman Barthe-Sukhera
   Signature: Suleyman Barthe-Sukhera
   Date: 11/21/13
6. Print Name: Matthew Bruce
   Signature: Matthew Bruce
   Date: 11/21/13
7. Print Name: Chris Celestine
   Signature: [illegible]
   Date: 11/21/13
8. Print Name: Stephen West
   Signature: [illegible]
   Date: 11/21/13



9. Print Name: Daniel Mahanthakumar
Signature: [illegible]
Date: 11/21/13

10. Print Name: Chris Farrell
Signature: [illegible]
Date: 11/21/13

11. Print Name: Zach Ganikos
Signature: [illegible]
Date: 11/21/13

12. Print Name: Collin Bolton
Signature: Collin Bolton
Date: 11/21/13

13. Print Name: Brent Daniel
Signature: [illegible]
Date: 11/21/13

14. Print Name: Christopher R. Buck
Signature: [illegible]
Date: 11/21/13

# V. Technical Design

## 1. Airframe Design

a. Nose Cone:

A Von-Karman nose cone has been selected for the vehicle. With the vehicle's top speed expected (and predicted by preliminary simulation) to be in the transonic regime (~Mach 0.7), an ogive type nose cone was selected based on its low drag coefficient at transonic velocities (Stroick, 12). The Von-Karman, in particular, was selected as the tangent ogive with the lowest drag coefficient in the transonic regime (Fisher). In order to avoid excessive labor in the fabrication of the nose cone, a geometry was selected that is readily available from a reputable suppliers. The available Von-Karman nose cones are constructed from filament wound fiberglass and include an aluminum replaceable tip. A bulkhead will be fitted in the nose cone to permit attachment of a shock cord between the airframe and the nose cone. After burnout and main parachute deployment separation, the nose cone will descend under a separate parachute. This design will allow for the nose cone parachute to help facilitate main parachute deployment.

b. Structure:

In order to accommodate the specified payload diameter of 5 inches, as well as to utilize material sizes that are readily available, a 5.5-inch diameter Blue Tube was selected as the main structural component of the airframe. Blue Tube offers greater strength than unreinforced cardboard while maintaining a lower weight than standard filament wound fiberglass tubing. Some of the high strength attributes of fiberglass can be imparted on the Blue Tube airframe by wrapping the fuselage with a single layer of fiberglass. This can be easily accomplished by enveloping each body tube section in a fiberglass sleeve which also permits smoother finishing capabilities reducing skin friction.

Internally, the fiberglass wrapped Blue Tube will be reinforced by a number of bulkheads and centering rings constructed of 3/8-inch birch aircraft grade plywood. The bulkheads nearest to the motor will be fiberglass reinforced for additional strength. The motor itself will interface to the vehicle via a minimum diameter motor retainer affixed to a load cell securely mounted to a bulkhead in the aft section of the rocket. A fiberglass sleeve will surround the motor casing, providing additional strength as well as insulation to reducing the heat transfer from the motor casing to other portions of the fin can assembly.

The body tube of the rocket is split in two locations. The farthest aft split, located forward of the engine bulkhead, will be secured by nylon shear pins and will allow for easy deployment of the drogue parachute at apogee. The second split is located near the middle of the body tube and is not designed to separate in flight. A coupler that doubles as the payload bay will hold the upper and lower body tubes together. Disassembly of the rocket at this joint will provide convenient access to the payload bay for installation, servicing, and preflight checks. During preparations for launch, a hatch covering, an opening through the body tube, will provide access to the avionics bay, separate from the engineering payload.

c. Fin Configuration:

The fin configuration is the primary factor in the location of the center of pressure, or neutral point. The location of the center of pressure and the center of gravity each need to be found in order to calculate the rocket's static margin determining its stability. The standard in rocketry is to have a rocket with 1 caliber stability (Nakka). However, with heavier rockets, a stability between 1 to 2 caliber is acceptable. A caliber refers to the diameter of the main body of the rocket. The goal of the design is to have a static margin near a value of 1.25 caliber which will increase as the propellant is expelled, reducing the weight of the motor housing in the aft portion of the vehicle, thus shifting the center of gravity forward. In short, the rocket will become more stable as the flight progresses.

A trapezoidal fin design was selected for the rocket. The trapezoidal geometry allows for reduced drag on the leading edge of the fin and a reduced probability of damage to the fins during landing. A four fin configuration will be used in order to simplify the construction process. The ease of construction for a four fin design justifies the slight increase in interference drag that accompanies the closer proximity of each fin to one another versus a three fin design. The fins will be attached to the rocket by cutting slots out of the main body and attaching them directly to the motor block. Epoxy mixed with flocks will be used to attach and reinforce the structure between the fins, body tube, and motor block. The fins will be constructed of 3/8-inch birch aircraft grade plywood and will be layered with "tip-to-tip" woven fiberglass to provide additional strength.

Figure 1 shows an Open Rocket model which was used during the design of the shape of the fins. Using Open Rocket, the dimensions and placement of the fins was determined in order to position the center of pressure in the correct position in relation to the center of gravity.

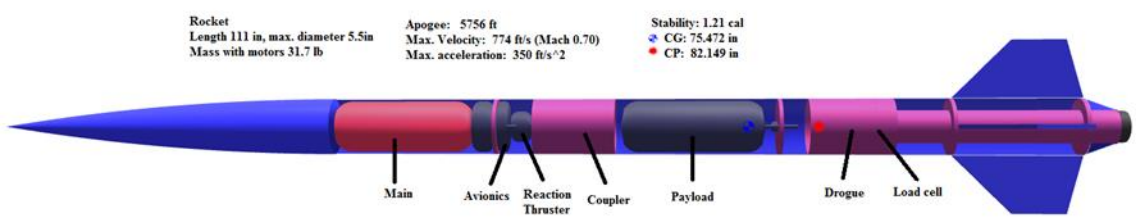



*Figure 1: Open Rocket Model with Supplementary Data*

For the fins, the root and tip chords will measure 12 and 5 inches, respectively. The height of each fin is 5.5 inches with a sweep angle of 45 degrees. From Open Rocket, a static margin of 1.21 caliber was calculated for the modeled rocket. It is vital to rocket performance that each of the four fins are geometrically identical as to allow for the generation of equal amounts of drag distributed symmetrically around the base of the rocket. Also, fin alignment is vital to flight vehicle stability. In order to ensure even and uniform placement of the fins, a specially designed "fin-jig," made of ¼-inch birch plywood as to keep prices down, will be used. The laser cut jig will allow the fins to be attached, at the proper angle, with respect to the motor block and body tube section. The general fin design, excluding fin tabs which will protrude into the body tube and attaching to the fiberglass motor sleeve can be seen in Figure 2.

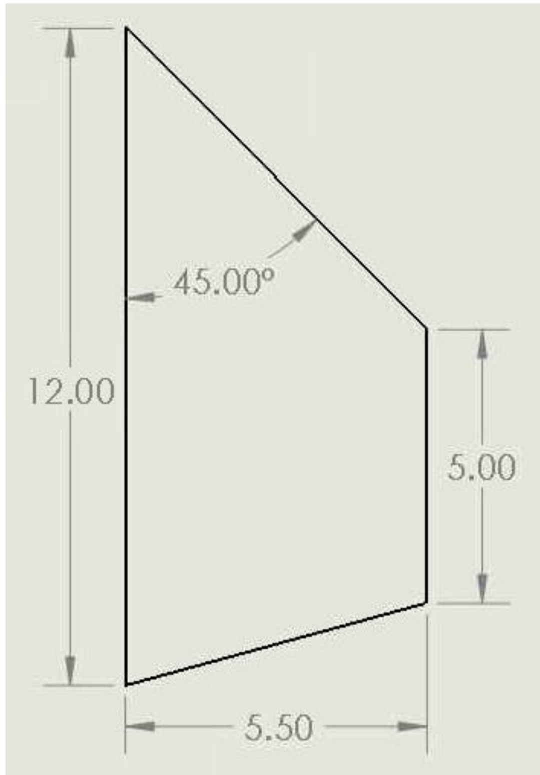



*Figure 2: Preliminary Fin design*

a. Motor Selection

The current motor selected for the rocket is the L1390G-P. This motor was chosen after a full model of the rocket was made in Open Rocket. Open Rocket calculated a rough estimate of the mass of the rocket and a motor was paired that would propel it nearly 500 feet above the 1 SM goal. The 500 foot margin will allow for an additional 5 pounds to be added to the rocket during construction. These 5 pounds will account for the small items that have been omitted from the model including epoxy, resin, wires, ballasts, etc. Additional weight can also be added if the full 5 pounds is not met from additional items.

The total impulse of the L1390G-P motor is 3946 Ns. The average thrust is 1374 N with a maximum thrust of 1650 N. The burn time is expected to be 2.87 seconds. The launch mass of the rocket motor is 8.55 lb with an empty mass of 4.2 lb. This means that 4.35 lb of propellant is burned off during flight and should be accounted for when determining main and drogue chute sizes. The maximum velocity from Open Rocket is 774 ft/s (M=0.7) with a maximum acceleration of 350 ft/s2. A graph of the altitude, vertical acceleration, and vertical velocity is plotted against time in Figure 3.

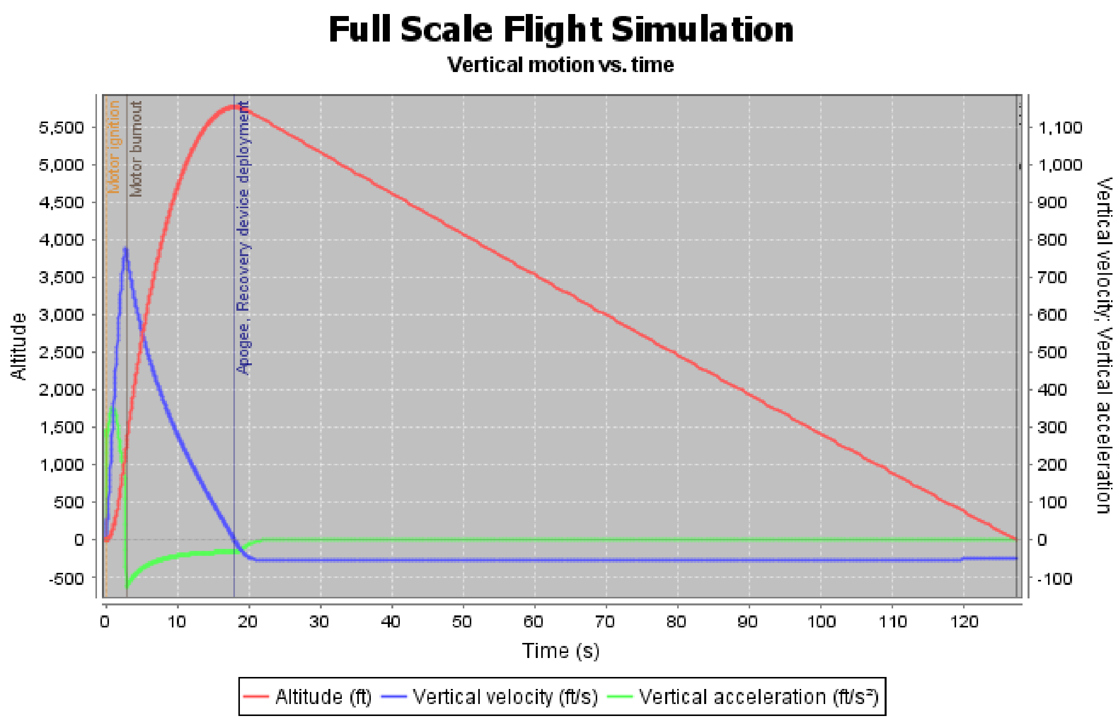



*Figure 3: Open Rocket Simulation of Full Scale Performance*

d. Recovery System

The recovery system will be a dual deploy system with redundant altimeters and black powder charges. Redundant black powder charges will be connected to the Perfectflight SL100 Stratologger and Entacore AIM 3.0 Altimeters. One charge will deploy the drogue, at apogee, and one will deploy the main parachute, at ~1000-ft AGL. Drogue parachutes are used to allow the rocket to descend at an elevated rate from the main parachute's descent rate as to reduce drift from launch area due to upper level winds experienced during descent. The drogue will be deployed once the altimeter stops sensing an increase in altitude, i.e. at apogee. The drogue will be 24 inches in diameter and will slow the rocket's descent to ~100 ft/s which is adequate for main parachute deployment without the risk of damage to the main parachute. The main parachute will be placed in a deployment bag to decrease the chance of deployment failure. A Sky Angle Model C3 size large will be used for the main parachute. This parachute has a surface area of 57 square feet and is rated to support a launch vehicle of 25-40 pounds. Deployment will be after the burn time and will not include the mass of the propellant thus reducing the returning weight of the vehicle from ~31.7 ±3 lbs. to ~27.35 ±3 lbs. Both altimeters will be set to deploy the main parachute at 1000 ft. AGL increasing the overall pressure increase in the main parachute compartment. Staggering charge ignitions could be done if structural strength was a concern, but, with the Blue Tube's high strength and the addition of the fiberglass sock, the body tube's strength is believed to be more than adequate to accommodate the high pressures which will be experienced. Tensile testing of the final product will be performed to quantify the actual strength and ensure that this is a reasonable assumption.

## 2. Payload

The proposed payload, including avionics, for the flight vehicle serves three functions. The flight vehicle avionics includes the redundant altimeters responsible for igniting the black powder charges deploying the main and drogue parachutes, ensuring safe damage free recovery. This system will be mounted in a separate bay from the 5-inch diameter, 14-inch length experimental payload bay. As a primary vehicle system, the altimeters will be included on every flight, including those carrying the proposed payload. (It should be noted that the payload included in this proposal has been designed to be easily replaceable with alternate payloads, weighing 4 ± 1 lbs., for future experiments. This capability allows the customer/team to reduce operational costs by having the ability to test new payload systems, within dimensional and weight limits, without constructing an additional flight vehicle.)

The second payload function will be accomplished by hardware carried in lieu of the customer's payload, on the development flights. Primarily, this payload will gather engineering data. This data will be gathered from components included in the proposed payload bay along with peripheral instruments located throughout the flight vehicle. The components, their task, and specifications proposed are as follows:

At the heart of the engineering data being gathered is attitude and position information. An ADIS16448AMLZ inertial measurement unit (IMU), provided by Analog Devices®, will record pitch, roll, and yaw rates via a three axes gyroscopes, sensitivity of 0.1 - 1200 degrees/sec, acceleration in three axes via a three axes accelerometers, sensitivity of 0.01 – 2000 g's and 10,000 g max limit, and magnetic fields in three axes, sensitivity of 0 - 1.2 MGauss. The sampling rate capabilities of the Analog Devices® IMU are upwards of 9,000 Hz. The full sampling rate of this component is not expected to be needed but is adjustable. A sampling rate, closer to the capabilities of the other electronic components will be used to reduce the signal noise inherent in these devices.

For location correction, a GPS receiver, 3DR UBLOX, will be utilized. By combining attitude and location information from the GPS receiver, the vehicle's flight path can be recorded and plotted with a higher degree of accuracy.

In addition to flight path, via the IMU and GPS systems, the payload data collection will include motor thrust, via a team designed load cell, ANSYS® strain analysis can be seen in Figure 4.

The load cell will be located in the fin can. The motor casing will be mounted directly to it and it will be mounted to a bulkhead just behind it. The cell is designed so that the outer ring has a thickness of 5/8-inch and the arms and center ring of thickness ½-inch centered about the outer ring's thickness. This spacing allows the load cell room to flex in both directions and will incorporate the bulkhead forward of the load cell and the fiberglass motor sleeve aft of the load cell as stops. These stops will ensure that the load cell is not allowed to plastically deform thus reducing the risk of separation of the center of the load cell, and motor casing, from the fin can assembly.

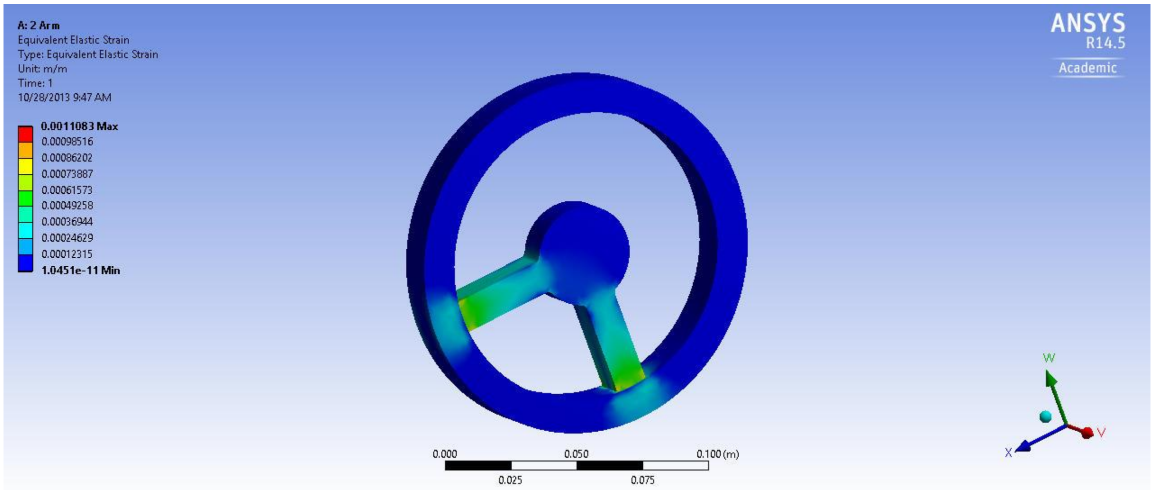



*Figure 4: ANSYS Analysis of Load Cell*

The load cell will be located in the fin can, Figure 5. The motor casing will be mounted directly to it and it will be mounted to a bulkhead just behind it. The cell is designed so that the outer ring has a thickness of 5/8-inch and the arms and center ring of thickness ½-inch centered about the outer ring's thickness. This spacing allows the load cell room to flex in both directions and will incorporate the bulkhead forward of the load cell and the fiberglass motor sleeve aft of the load cell as stops. These stops will ensure that the load cell is not allowed to plastically deform thus reducing the risk of separation of the center of the load cell, and motor casing, from the fin can assembly.

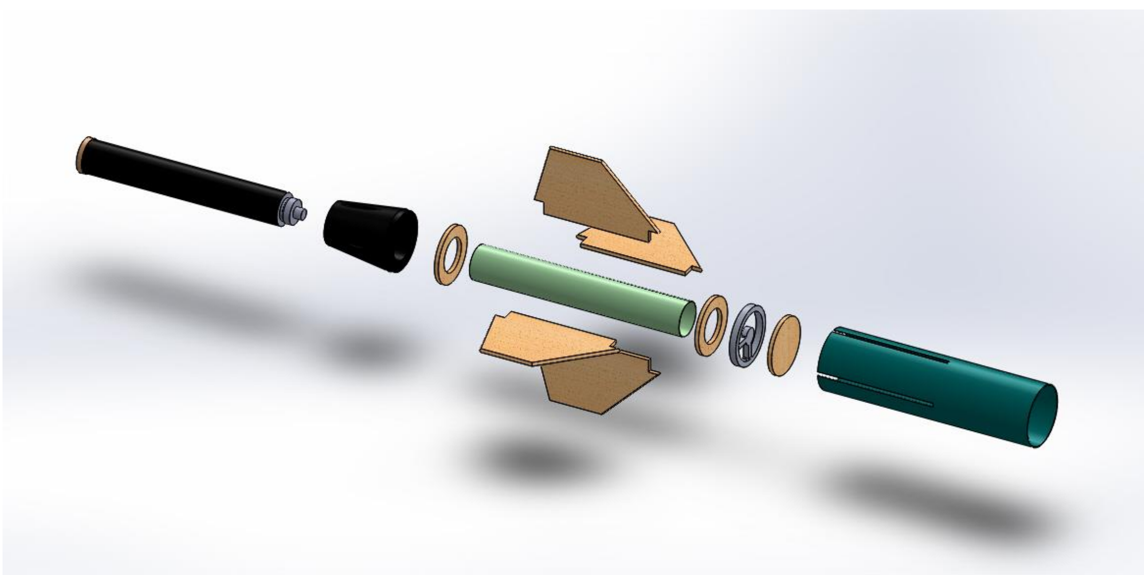


*Figure 6: Fin Can Exploded View*

The load cell will gather the force exerted by the motor via two half Wheatstone bridge, which will accommodate temperature variations, strain gage configurations attached to each arm of the load cell. This data will have to be processed to account for the fact that the vehicle is not static but dynamic. This processing will be done using MATLAB® and will be compared against the published values from Aerotech and the IMU data.

A Pitot tube, as seen in Figure 6 protruding from the tip of the nose, will be used to gather total pressure. This total pressure will be used in conjunction with static pressure, recorded elsewhere, to determine airspeed. The airspeed calculations made here will then be compared to the IMU, GPS, and load cell data to determine the actual airspeed with which the flight vehicle experiences.

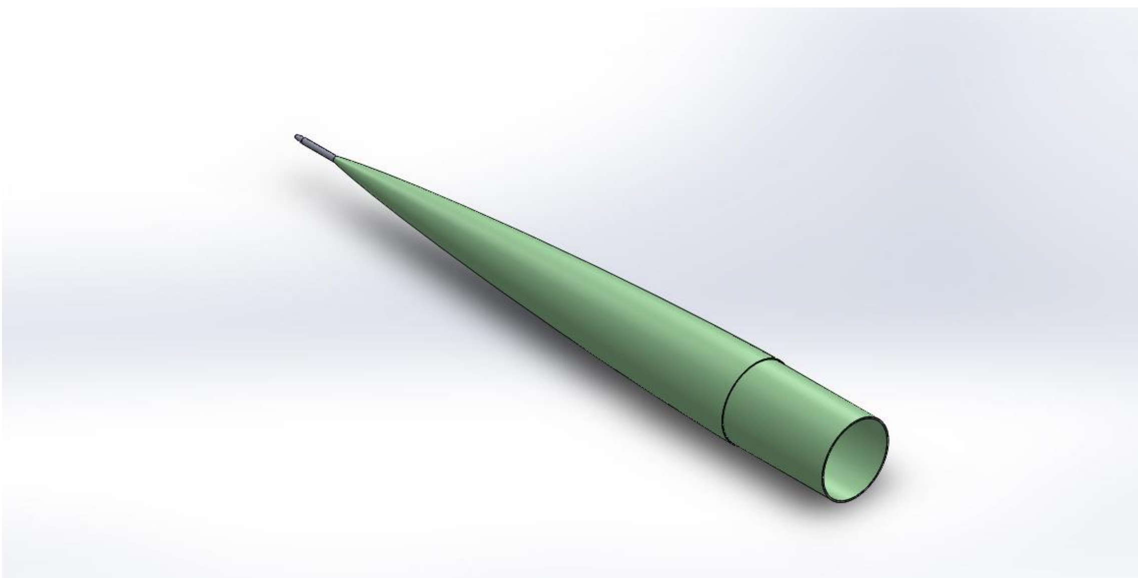


*Figure 6: Nose Cone with Pitot Tube*

Mounting the Pitot tube away from the payload bay raises a concern that is also encountered by the thrust load cell. Namely, any connections, electrical or otherwise, run to sensors mounted away from the payload bay must either have some provision for separation during parachute deployment or sufficient slack in the wiring to extend the full length of the shock cord. Clearly, the latter solution is problematic at best. It will be necessary to devise a quick disconnect device that prevents two fuselage sections from remaining attached imparting undue stress on connections after parachute deployment.

In a similar fashion, the strain gage for measuring structural stress can be mounted away from the payload bay provided a quick disconnect is also installed on its lead. The exact location of the strain gage has yet to be determined pending more detailed analysis of the loads acting on the vehicle. The strain gage will be placed at a location that bears a high concentration of stress either in flight, during parachute deployment, or during landing. If multiple high stress areas merit investigation, multiple strain gage installations will be considered.

The final function of the development vehicle's payload is to validate that the rocket can gather atmospheric data. A pressure transducer and a thermocouple measuring atmospheric pressure and temperature (respectively) will accomplish this function. The atmospheric data along with all other data collected will be recorded by a microprocessor for local storage. At this juncture, an Arduino Due™ has been selected for this function. Due to its substantial processing power, the Arduino imposes fewer limitations on sampling rate and is easier to program than other microcontrollers considered, ie Raspberry Pi, Arduino Uno. When coupled with a Digi XT09-DK 900 MHz RF transmitter with a 40 km range, the Arduino will supply the needed data to support the custom GUI In real time. This portion of the team's goal is by far the most challenging of the payload design. Real-time processing of the data received from the rocket will require extensive program development and testing.

In addition to the complications of program development, interference from the RF transmitter with other electronics, specifically the altimeters, can be detrimental to a successful flight. This issue has been considered, extensively, as a major safety issue during prelaunch checks. In order to ensure proper operation of all the electronics onboard the rocket, extensive testing will be conducted and RF shielding will be applied to areas containing electronics that are found to be sensitive to such signals. The safety of the team, and success of the flight, is a key priority to everyone involved.

## 3. Excitation System

The purpose of the exciter system is to excite the dynamic models of the rocket during the unpowered "coast" phase of flight between burnout and drogue deployment. Instead of a flap or fin, the team has chosen a reaction type thruster to accomplish this task. In addition to having a lower total weight, a reaction type thruster will have fewer individual failure points than a comparable fin or flap. The conceptual design of the reaction thruster system is based off threaded N2 cartridges typically used by bikers to refill their tires after an incident resulting in a flat. The cartridges maintain the gas under high pressure (~850 psi) and have a low individual weight (~16 g). The proposed thruster design includes several of these cartridges mounted together with a common actuation mechanism. When actuated, the cartridges will release the high-pressure gas, through a C-D nozzle to impart a disturbance force on to the rocket. The distance between the thruster and the center of gravity will determine the disturbance needed to excite the dynamic modes of the rocket. The current concept for the thruster is mounted in the payload bay at the farthest point from the center of gravity while still remaining within the payload bay. Depending on the results of the experiments conducted to validate the thruster design, it may be necessary to move the thruster farther away from the center of gravity in order to achieve the desired disturbance.

One of the challenges presented by this unique design is the need for simultaneous actuation. As of yet, a valve capable of operating under the high pressures required, while still fitting in the limited space of the payload bay, has not been identified. Additionally, the thruster will require extensive experimentation to determine its performance so that it can be appropriately located to provide a known and desired disturbance to the flight vehicle. Though an excitation thruster may appear to be more complex and require extra time in the development phase, versus a conventional flap setup, the benefits of reduced failure modes, and overall simplicity after said development phase, out-weigh the risks involved in using an unconventional excitation method.

### 4. Subscale Design

The subscale flight vehicle is to be a 1:2.149 scale model of the full-scale rocket. This scaling factor yields a 2.56 in. diameter rocket which is to be 4.3 ft. in length. This scale model is to be flown in two flights to demonstrate the stability of the full-scale rocket and to demonstrate the team's ability to successfully launch with a dual deploy system. Customer requirements detail that these two demonstrations must be done using the same vehicle and the stability demonstration requires a total weight of less than 3.3 lbs. The proposed subscale rocket is estimated to be 2.43 lbs. well within this requirement. Given the excess weight available for use in this flight, the team has opted to include a single altimeter during this flight. The team is also planning to attempt to match the static margin in the dual deploy demonstration to ensure the full-scale models stability with two subscale flights. Ballasts may be required to accurately place the flight vehicle's center of gravity in its appropriate location.

## VI. Educational Engagement

Over the course of the past years, the NCSU HPRC has engaged in rocketry outreach to local schools, which has allowed for many great partnerships with local schools to form. The opportunities presented to the club because of these partnerships are very important and facilitates the expanded goals of the NCSU HPRC's 2013-2014 educational engagement program.

### 1. Outreach

As in previous years, we will also engage in regular outreach programs to local middle schools and youth organizations. These serve to educate middle school age individuals about the basic principles of rocket propulsion and stability, as well as encourage youngsters to become involved in the STEM field. These events will include presentations about our particular rocket, as well as demonstrate both water and solid motor powered rockets. As required in the USLI handbook, these will reach at least 100 students; however, our goal is to surpass this significantly. Following events, feedback forms will be sent to the educators involved in order to improve our presentations in the future. We are currently planning two events – one with a local elementary school and another with a local YMCA.

## VII. Project Plan

### 1. Timeline

All club events and schedules will be based on both the USLI-generated schedule as well as the Senior Design timeline set for the club by the Flight Research advisors on campus.

## 2. All Aspects of the Proposed Budget

a. Subscale Budget:

| System | Supplier | Qty | Cost(ea) | Description | Total cost |
|---|---|---|---|---|---|
| Airframe | Apogee | 1 | $26.95 | 48" by 2.56" dia Body Tube, High Density, High Strength | $26.95 |
| | Apogee | 1 | $28.95 | 48" by 2.56" dia Coupler, High Density, High Strength Paper | $28.95 |
| | Apogee | 1 | $14.65 | 9" x 2.63"Nose Cone PNC-2.56" Polly Propylene Nose cone | $14.65 |
| | Soller Composites | 8 | $2.59 | Fiberglass bi-axial sleeves | $20.72 |
| | Apogee | 1 | $7.00 | Standard Airfoiled Rail Buttons (2 ea) | $7.00 |
| Propulsion | Apogee | 2 | $5.80 | Centering rings for 2.56" dia | $11.60 |
| | Apogee | 1 | $22.47 | Motor Retainer Subscale | $22.47 |
| | redarrowhobbies | 1 | $20.39 | Motor for Stability Demonstrition | $20.39 |
| | redarrowhobbies | 1 | $49.99 | Motor for Dual deply Demonstration | $49.99 |
| | Rocketry Warehouse | 1 | $28.00 | Fiberglass tubing motor sleeve, 24" length | $28.00 |
| Recovery | Sky Lite | 1 | $99.00 | 4.4-9.5 lbs | $99.00 |
| | | | | **Subscale Estimated Budget:** | **$329.72** |
| | | | | **Items Acquired From HPRC:** | **$99.00** |
| | | | | **Remaining Balance of Items to be Purchased:** | **$230.72** |

b. Full Scale Budget:

| System | Supplier | Qty | Cost(ea) | Description | Total cost |
|---|---|---|---|---|---|
| **Airframe** | Apogee | 3 | $56.95 | 48" by 5.5" Body Tube, High Density, High Strength Paper | $170.85 |
| | Apogee | 1 | $55.95 | 48" by 5.5" Coupler, High Density, High Strength Paper | $55.95 |
| | Rocketry Warehouse | 1 | $129.00 | Filament wound 5:1 ratio von Karman Nose Cone | $129.00 |
| | Soller Composites | 16 | $4.69 | Fiberglass bi-axial sleeves | $75.04 |
| | Apogee | 1 | $10.00 | Large Airfoiled Rail Buttons (2 ea) | $10.00 |
| **Propulsion** | Red Arrow Hobbies | 1 | $145.90 | Full Scale Motor | $145.90 |
| | Apogee | 2 | $7.00 | Center rings for 5.5" dia | $14.00 |
| | Apogee | 1 | $42.80 | Engine retainer plug mount | $42.80 |
| | Rocketry Warehouse | 1 | $85.00 | Fiberglass tubing motor sleeve, 48" length | $85.00 |
| **Engineering Payload** | Allied Electronics | 1 | $35.00 | 700 MHz Processor | $35.00 |
| | Digi | 1 | $499.00 | Xtend Development kit | $499.00 |
| | Cooking Hacks | 1 | $54.33 | Arduino Adapter | $54.33 |
| | Undecided | 1 | $25.00 | LiPo Battery For Payload | $25.00 |
| | Undecided | 1 | $8.00 | Battery Adapter for Payload | $8.00 |
| | Amazon | 30 | $0.99 | Mosa 16g Threaded CO2 Cartridges | $29.55 |

| | | | | | |
|---|---|---|---|---|---|
| | Palmer-pursuit | 3 | $15.00 | Adapter for CO2 cartridges | $45.00 |
| | Grainger | 1 | $10.17 | 50 ft roll of 1/8" nylon tubing | $10.17 |
| | Palmer-pursuit | 1 | $40.00 | Solenoid valve for exciter activation | $40.00 |
| | Palmer-pursuit | 1 | $109.00 | CO2 Pressure regulator | $109.00 |
| | Solutions Direct | 2 | $61.74 | Dwyer Pitot Tube, Stainless, 1/8" | $123.48 |
| | Omega | 30 | $5.00 | Strain gages | $150.00 |
| | Hobby King | 1 | $150.00 | GPS receiver for Arduino | $150.00 |
| | MSC Industrial | 1 | $151.93 | Aluminum Bar for Load Cell, 5/8"x6"x12" | $151.93 |
| | Analog Devices | 2 | $624.00 | IMU Sensor | $1,248.00 |
| | Analog Devices | 1 | $819.00 | Evaluation board for Prototyping with IMU | $819.00 |
| **Recovery** | Sky Lite | 1 | $139.00 | 25-40 lbs | $139.00 |
| | Loc Precesion | 1 | $35.00 | Deployment Free Bag for Parachute | $35.00 |
| | Apogee | 3 | $85.55 | PerfectFlite StratoLogger Altimeter | $256.65 |
| | Hobby King | 30 | Unavailable | E-Matches | $50.00 |
| | | | | **Full Scale Estimated Budget:** | **$4,706.65** |
| | | | | **Items Acquired From HPRC:** | **$2,206.00** |
| | | | | **Remaining Balance of Items to be Purchased:** | **$2,500.65** |

c. Shared Subscale and Full Scale Costs:

| System | Supplier | Qty | Cost(ea) | Description | Total cost |
|---|---|---|---|---|---|
| Misc. | balsausa | 2 | $18.94 | 12"x48" Plywood for Fins | $37.88 |
| | Rocketry Warehouse | 1 | $63.48 | Fiber Glass sheet 36"x24" | $63.48 |
| | Apogee | 1 | $42.95 | Fiberglass cloth 26"x25yds 6 oz/yd | $42.95 |
| | West Systems | 1 | $100.00 | Epoxy Resin 1 gallon | $100.00 |
| | West Systems | 1 | $45.00 | Epoxy Hardner | $45.00 |
| | Lowes | 1 | $50.00 | Supplies to Build Stand | $50.00 |
| | Lowes | 1 | $100.00 | Dremel Tool | $100.00 |
| | Lowes | 1 | $150.00 | Misc Hardware(nuts, bolts, etc) | $150.00 |
| | | | | **Shared Items Estimated Budget:** | **$589.31** |
| | | | | **Items Acquired From HPRC:** | **$0.00** |
| | | | | **Remaining Balance of Items to be Purchased:** | **$589.31** |

## 3. Funding Plan

The project will be funded through multiple sources all from within the university. The NC State Engineering Council will be funding the subscale launches and the rest of the money is provided through other on-campus organizations.

## 4. Major Pragmatic Challenges and Solutions

The problems that existed during last year's competition for the team include accountability, time management, participation, and an overall failure to lead. These challenges were all major setbacks for the team and resulted in the team having every launch end in failure along with the visual reminder of a destroyed rocket before the launch in Huntsville, Alabama. After last year's competition, the team mentor's decided the best course of action to keep the club alive and the decision was made to give Aerospace Engineering seniors the option to participate in the club as part of their mandatory Senior

Design Project. This has allowed for team leaders to dedicate themselves to the success of the club with full intentions to create a "foundation" for the rest of the team once the seniors graduate and leave the club. All officers from last year's competition have since left the club and has allowed the entire team to perform a "redo" from last year. This system of leadership is already showing great success as all team members have worked with the seniors teaching them about rocketry as well as the USLI competition while the undergrad team members learn valuable techniques for technical writing, experiment planning, and design implementation. The club is also under heavy review from the team's mentor who is much more involved with the club than last year. The team's faculty advisor is also the mentor for the Flight Design Senior Project program and acts as both an advisor and grader for the seniors in the club.

Though the seniors involved with the club have shown to be more than effective in leading the club and producing great results from the undergrad members (who have collectively shown that they are on par with writing technical documents as the seniors, now), some challenges have appeared as a part of their involvement. The seniors are set to more strict design regulations for the Senior Project and must comply with a must stricter timeline which forces all members to give much more effort to the club than ever before. This extra commitment has proven too much for many members and the club now sits at a solid 15 active members compared to the 38 that were present just a month ago. The students who have stuck with the club have shown great interest in the team's success and have been able to learn many new skills from the seniors.

# 5. Project Sustainability

North Carolina State University is participating in USLI for the fifth consecutive year. This year's team is unique in that after a large restructuring of the club following last year's failures, the team will be led by a Senior Design team. This was done to facilitate the natural spread of rocketry knowledge from both seniors to new members and old members to the seniors. This has allowed a solid "foundation" for the club to form as all members of the team are involved with every aspect of the design and construction of the rocket.

Some educational engagements being planned by the team include presentations at which we will provide exciting demonstrations on the basics of rocketry. By design, this investment of our time will increase early interest and awareness of rocket and space related fields, ultimately providing long-term team benefits in the form of increased future membership.

Initial recruitment for subsequent years will begin in the spring semester. This will allow inexperienced students time to develop various ideas as well as familiarize themselves with the general processes and applications of high-powered rockets. The combination of spring recruits and returning members should provide a solid team foundation. However, because first and second year students are critical to the sustainability of the team and it is typical for these initial members to be comprised primarily of upperclassman. It is vital that recruitment continue at the start of the fall semester. The Outreach Coordinator should organize team participation in the various events at which student organizations are provided with exposure. This includes, but is not limited to, the various events held during the week of "Welcome Back Pack" and developing a relationship with the Student

Organization Resource Center. In a continued effort to maintain club awareness, internet presence should be maintained throughout the entirety of the year, allowing relevant information to be easily accessible at all times. Additionally, student interest and team progress could be monitored with the development and use of a club blog.

Through these established methods coupled with a solid team “foundation” once the Senior Design team students leave, the Tacho Lycos team will continue to operate and compete for the indefinite future.