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NASA Student Launch Proposal

Prepared for NASA by Boy Scout Troop 17 Student Launch Team

Date	Revision	Remarks
Sept 21, 2017	1.0	Initial Proposal

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1 General Information

1.1 Introduction

Boy Scout Troop 17 is very excited to have the opportunity to submit a proposal for NASA Student Launch (SL). Having participated in Team America Rocketry Challenge (TARC) since 2007 and qualified for the National Finals three times, we have large interest in and experience with hobby rocketry. We placed 11th in TARC for the 2016-2017 season, and we are honored to be invited by NASA to submit a proposal for SL. We feel this is a great next step for our rocketry program.

STEM education has long been an important but often under-recognized part of Boy Scouting. Even at the beginning of Boy Scouting in the early 1900's, almost one-third of the original 53 merit badges were STEM-related. The focus on STEM has increased since then, and 90% of merit badges introduced since 2009 have a STEM component. In 2012, BSA National introduced the STEM/Nova program as a focused STEM program. And in 2014, Troop 17 became one of the only Troops in Virginia to offer this program at the Troop level (in most areas, STEM/Nova is only offered at the Council level).

Rocketry fits into the Troop's STEM program in multiple ways:

- It serves as a challenging STEM event that fulfills BSA STEM/Nova requirements to earn the Supernova Medals (the highest awards in STEM/Nova).
- It allows us to offer STEM-related education and outreach within the Boy Scouts, including Scouts in our own Troop as well as Boy Scouts and Cub Scouts in other units. For example, we use the Rocketry program to teach merit badges including Space Exploration, Aviation, Electronics, Computer Programming, and others. We also use it as a way to reach younger youth in Cub Scouting.
- It also gives us an opportunity to promote STEM education and outreach within the community at large, including local schools and other community groups.
- It helps to create hands-on experience and passion for STEM that is very well aligned to the natural interests and talents of our youth.

Student Launch Team, Troop 17 (SLT17) was formed over the Summer of 2017 after receiving the invitation to participate in SL and after our Mentor, Steve Yates, attended the ARW in Huntsville in July. Interest in SLT17 is large, and we have 12 youth who have joined the team. We have been conducting frequent meetings to organize, plan, and get the groundwork in place so we are ready for the RFP. With the skills, experience, and passion of our team members, the full commitment and support of our Troop's adult leadership, and the support of sponsors, we feel that SLT17 is strongly positioned for success in the 2018 NASA Student Launch.

1.2 Team Contacts

The following is contact information for SLT17 youth and adult leadership. To comply with BSA Youth Protection and Online Safety requirements, youth are referred to in this document (and all other public documents) by first name only and youth contact information is not provided here, but will be provided to NASA directly in a private communication.

Name	Title	Email	Phone
Steve Yates	Troop 17 STEM Chair	steveyates@embarqmail.com	434-825-2850
Hunter	SLT17 Team Leader		
Roman	SLT17 Safety Officer		

All deliverables during the period of performance for the program, other than this proposal, will be delivered to NASA and made publicly available via the team's website, which will be a new section of the existing Troop 17 website: http://www.troop17bsa.org. The SLT17 section of the Troop's website is under development and while it is not yet publicly accessible, it will be quickly brought online assuming NASA accepts our proposal.

1.3 Team Structure and Members

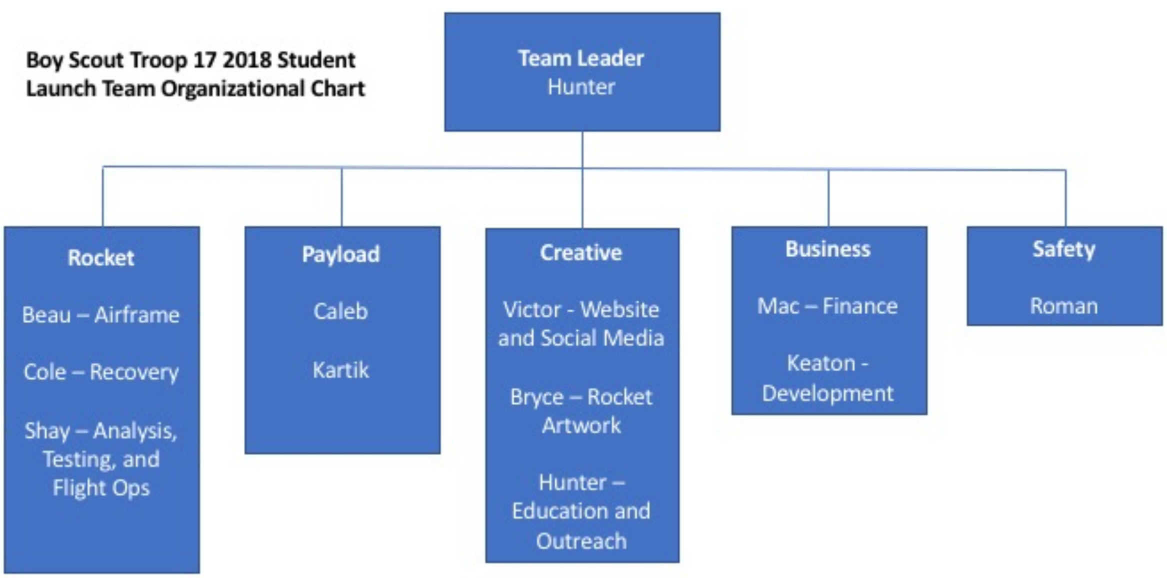
SLT17 currently consists of 12 team members, one adult advisor, and a Tripoli Level 3 mentor. There was a focused recruiting effort over the summer of 2017, including multiple presentations to the Troop about SL, along with informational meetings and Q&A sessions with prospective members. While the recruiting effort is never totally closed and the team would welcome any additional members, it is unlikely that more would join for the 2017-2018 event at this point.

SLT17 is organized into five functional sub-teams: Rocket, Payload, Creative, Business, and Safety. Within each sub-team, there is some specialization of functions, and this level of specialization will continue to evolve as we progress and collect feedback from NASA. For example, today we have specialists within the Rocket Team for airframe, recovery, and flight operations. However, there is not currently any specialization within the Payload team. We expect to specialize more within Payload, for example possibly with Hardware and Coding specialists.

In order to maintain independence and full authority of Safety within SLT17, Safety is a separate functional team reporting directly to the Team Leader. Safety is discussed in more detail later, but we feel that structuring SLT17 so that Safety is an independent function stresses the importance of safety, while giving the Safety Officer the necessary position and authority to truly create a culture of safety.

The following table and organization chart provide details on team members, their roles, and team structure.

Name	Role	Team
Hunter	Team Leader	
Beau	Airframe	Rocket
Cole	Recovery	Rocket
Seamus	Flight ops, Analysis, Testing	Rocket
Caleb	TBD	Payload
Kartik	TBD	Payload
Victor	Website/ Social Media	Creative
Bryce	Rocket Artwork	Creative
Hunter	Education and Outreach	Creative
Mac	Finance	Business
Keaton	Development	Business
Roman	Safety Officer	Safety



1.4 Tripoli and NAR Assistance

Tripoli Central Virginia #25 has graciously offered its assistance to SLT17. This Tripoli prefecture is located very close to us, and is providing assistance including an expert mentor, design and documentation review, and what is probably the best high-power launch site in Virginia which is located near Culpeper, VA and typically has an FAA waiver of 15,000 feet AGL. Tripoli #25 is experienced working with SL teams, and they are also supplying a mentor and similar assistance to Boy Scout Troop 295, a fellow TARC finalist located in Woodbridge, VA that is also submitting a proposal for SL this year. Troop 17's TARC team has conducted launches with Tripoli #25 for 10 years. The prefecture also sponsors the "Battle of the Rockets" which is a well-established college-level rocketry challenge that is similar in some ways to SL.

We also will be working with the Northern Virginia Association of Rocketry (NOVAAR), NAR Section 205. NOVAAR is the sponsoring NAR section for the TARC finals, and they offer a wealth of mentoring as well as a backup launch site near Warrenton, VA with a 5,000 foot AGL FAA waiver (suitable for the subscale flight, if our primary site is unavailable).

Lastly, the Valley Aerospace Team (VAST) operates our second backup launch site near Monterey, VA, which typically has a 10,000 foot AGL FAA waiver.

2 Safety

2.1 Introduction

Priority one for SLT17 is safety. Priorities 2 and 3 are also safety. Safety is not a separate function, or something to be added after the fact.

SLT17 is firmly committed to the fact that safety is the foundation of everything we do, and safety is THE primary mission goal that's even more important than the science or flight objectives. Without safety, there can be no science, so safety is the cornerstone of the team.

As previously discussed, we have structured the team to highlight this founding principle.

2.2 Compliance with Boy Scout Safety Regulations

Since we are a part of a Boy Scouts of America unit, SLT17 is committed to fully complying with all safety regulations and guidelines as set forth by the Boy Scouts of America National Council. These BSA regulations include the following:

- Youth Protection (http://www.scouting.org/Training/YouthProtection.aspx)
- Cyber Protection (http://www.scouting.org/cyberchip.aspx)
- Youth use of power tools (http://www.scouting.org/filestore/healthsafety/pdf/680-028.pdf). This regulation states that youth under the age 14 cannot use power tools at all. Youth between 14 and 18 can only use small handheld sanders, drills, electric screwdrivers, and similar handheld tools. Only adults 18 and older can use power saws.
- Transportation (http://www.scouting.org/scoutsource/HealthandSafety/GSS/gss11.aspx)
- Use of chemicals (http://www.scouting.org/scoutsource/HealthandSafety/GSS/gss06.aspx)
- Adult leader training requirements applicable to SLT17's activities

We feel that the BSA safety guidelines are an advantage to SLT17, as they address many underlying issues of personal safety, online safety, and youth protection in a clear and coherent fashion. This contributes to our culture of safety.

The team's designated Safety Officer will oversee that all rules and regulations are followed at all times by all members of the team. The Safety Officer will brief all team members on the procedures outlined in the Safety Plan. Also, the NAR/TRA mentor and Safety Officer shall oversee launch operations and motor handling. The NAR/TRA mentor will be the official owner of the rocket for insurance purposes, and they will be the purchaser and user of rocket motors and black powder ejection charges for compliance with relevant laws and regulations.

Safety briefings conducted by the Safety Officer will utilize Safety Data Sheets and will come before every activity that requires tools and/or hazardous materials, as well as before all launches. Team members that are late will have to be briefed before they are allowed to begin work on the project. On launch days Flight, Post-Flight checklist and Safety Data Sheets will be handed out and reviewed to ensure the safety of the team members as well the general public. All team members will follow instructions given by NAR/TRA mentor, team leader and/or safety officer. All launches will be conducted in full compliance with all NAR and TRA Safety Code requirements.

The main facility that the team will utilize when fabricating the rocket is space at ADI Engineering building in Charlottesville Virginia. All members of the team will have to follow the BSA Guidelines that all youth under the age of 14 cannot use power tools (see section 1.4.1). Scouts over the age 14 will be assigned with the cutting and modify of the rocket.

2.3 Safety Briefings

The Safety Officer will be responsible for briefing the team of any possible risks that could occur throughout designing/build process, as well as before each launch. During the briefing, the Safety Officer will inform the team of all necessary procedures to avoid risks or hazards. The Safety Officer will regularly brief team members about these risks in order to create a safe environment. The Safety Officer will also be responsible for informing the team of any laws and regulations that may apply set by the NAR/TRA, including NFPA 1122 (code for Model rocketry) and NFPA 1127 (code for high power rocketry).

2.4 NAR/TRA Mentor

Ben Russell has agreed to mentor our team and accompany our team to all launches and Launch Week in Huntsville in April 2018. He is a certified Level 3 with the TRA and NAR. His duties will include the purchase, storage, transportation and installation of rocket motors and black powder for ejection charges. Mr. Russell is already actively engaged, and has helped the team tremendously already during the proposal stage.

Mr. Russell will be advising the team during design and construction, and during the handling of hazardous or restricted materials. He will also brief the team on launch safety and protocol prior to launch.

2.5 Procedures for Team Mentor to Perform

The team mentor shall maintain the proper certification required for the motor impulse used in the launch vehicle. The mentor shall have completed at least two flights in the proper flight class prior to PDR. The TRA certified mentor will purchase, store, and transport rocket motors, black powder, and electric matches. The mentor will be the owner of record for the rocket for TRA/NAR insurance purposes. The Safety Officer and mentor will work together to choose a location where the motor will not be damaged and is at least 25 feet away from any heat sources or flammable liquids. The motor shall be transported separately from the rest of the rocket. During transportation the motor will be protected to prevent any damage.

2.6 Procedures for TRA/NAR Personnel to Perform

The Safety Officer will work in conjunction with TRA/NAR personnel and the mentor to ensure that the team complies with the TRA/NAR High Power Safety Codes. The Safety Officer, mentor, and TRA/NAR personnel shall ensure that before launch all conditions are met for a safe launch. The Range Safety Officer (RSO) shall arm the launch system, and will ensure all members and spectators are not within 100 feet of the rocket. The RSO shall count down from five before launch; if the vehicle does not launch, the RSO shall disarm the system and wait 60 seconds before investigating. TRA/NAR personnel along with the safety officer shall ensure no one attempts to catch the rocket on return or remove it from a dangerous location such as a power line.

2.7 Handling of Hazardous Materials

Some of the materials to be used will require extreme caution and care. Team members will be reminded of the safety rules based on which portion of the project they are working on by Safety Data Sheets.

The materials include but are not limited to fiberglass, black powder, epoxies and other adhesives, powdered aerogel, and rocket motors. The Safety Officer will be tasked with designing protocols for handling, storing, and disposing of these materials. The Safety Officer will be engaged before the purchase of any materials, to make certain that the existing Safety Plan is adequate to address any new safety issues, to proactively identify and acquire any Personal Protective Equipment (PPE) needed, and to collect and maintain all MSDS's and other safety information.

Also, the Safety Officer will be responsible for briefing all team members on protocols and regulations for the use of all materials. As fiberglass will be a primary hazard all team members that are working with this airframe material will be required to properly use PPE such as safety goggles and dust masks at all time when sanding, cutting, and painting to prevent dust from get into their eyes or lungs. Since we are using Aerogel in a power form as part of the payload, team members will be required to wear the proper PPE. Also, the proper clothing will be worn, including long sleeve shirt, jeans and gloves, to prevent injury to the legs or arms from sharp objects.

The Safety Officer shall brief team members on any other hazards associated with materials used in the rocket or the science payload. The Team will follow all of the BSA regulations as well those stated in the "Policy on the Storage, Handling, and Use of Chemical Fuels and Equipment."

2.8 Compliance with the Law

A mandatory team briefing will be done by the Safety Officer along with NAR/TRA mentor reviewing all guidelines and regulations upon proposal acceptance by NASA. BSA regulations will be followed at all times. Other relevant laws and regulations that the Safety Officer will educate all team members on that the team will be required to follows at all times are Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, NFPA 1127 "Code for High Power Rocket Motors."

2.9 Safety Regulations Links:

- BSA Safety Guide: http://www.scouting.org/filestore/pdf/34416.pdf
- BSA Age Guidelines For Tools : http://www.scouting.org/filestore/healthsafety/pdf/680-028.pdf
- BSA Policy on the Storage, Handling, and Use of Chemical Fuels and Equipment":
- http://www.scouting.org/filestore/pdf/680-013WB.pdf
- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C:
- https://www.law.cornell.edu/cfr/text/14/part-101
- Amateur Rockets, Code of Federal Regulation 27 Part 55 Commerce in Explosives:
- https://www.law.cornell.edu/cfr/text/27/555.141
- NFPA 1127 Code for High Power Rocket Motors:
- http://www.nar.org/safety-information/high-power-rocket-safety-code/
- MSDS for the Aerogels: http://www.buyaerogel.com/wp-content/uploads/2014/02/NGFPA-NA-EN.pdf\
- MSDS for Rocketpoxy: https://www.apogeerockets.com/downloads/MSDS/ROCKETPOXY_MSDS.pdf
- MSDS for Acetone: http://www.sciencelab.com/msds.php?msdsId=9927062

2.10 Team Member Agreement to Comply with Safety Rules

After a mandatory safety briefing, all team members will sign a Safety Agreement to abide by the regulations discussed as well as the following safety regulations:

- Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.

- 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.
- Any team that does not comply with the safety requirements will not be allowed to launch their rocket. The Safety Agreement will also state that any violation of safety protocols can result with dismissal from the Team with no warnings.

Project Risks

Risk	Probability	Effect	Prevention
Team members dropping out	Moderate	Team will have to work hard and pull double rolls	Ensuring all members are able to commit time to the team. Making sure all roles can be filled by someone else if needed by cross training.
Funding shortages	Moderate	Inability to purchase the necessary items to complete the project	We are soliciting funding pledges mainly from corporate donors, and we will also get some funds from the Troop. Should funding be inadequate, we may have to cut back on the amount of people who can go to Huntsville. Camping in Huntsville is always an option because we are Boy Scouts.
Falling behind schedule	Moderate	Inability to complete required tasks, causing time constraints and leading to suboptimal work or missed deadlines	Having enough team members to make sure work gets done, even if some members are short on time due to other commitments
Launches cancelled	Moderate	Missing a full or sub-scale test launch	Launches will be at Battle Park in Culpeper VA but if a launch is cancelled we will go to VAST in Monterey VA or Great Meadow in The Plains VA. If necessary, the team will go to other high-power launches throughout NC, MD, DE, or VA.
Motors in limited supply due to demand or production problem	Moderate	Inability to acquire needed motors for qualification or competition flights	Have backup motors from multiple manufacturers identified so that we are not dependent on a sole source motor manufacturer

Safety Risks

Risk	**Probability**	**Effect**	**Prevention**
Injury during fabrication	Low	Minor to serious injuries including cuts and burns	Receiving training in the safe use of all equipment, require PPE to be used at all times, follow BSA safety requirements, and make sure a first aid kit is always present during all team functions.
Injury during rocket launch	Low	Minor to serious injury	Following all launch safety procedures, such as staying the proper distance away and inspecting launch guide, motor casing, and other parts beforehand, and following all NAR/TRA safety code requirements. Also follow all BSA safety requirements, and make sure a first aid kit is always present during all team functions.
Accidental ignition or detonation of material	Low	Possible burns	Following safety procedures for the handling of explosive material; ensuring everyone is in a safe location in case of detonation on launch pad.
Injury during rocket recovery	Low	Minor burns	Follow all recovery safety procedures
Motor mount failure	Low	Damage to rocket and potentially observers	Testing the motor mount in simulations, static fire tests, and experimental flights. Inspecting as specified by pre-launch checklist

3 Facilities and Equipment

SLT17 will have access to necessary workspace and tools required to successfully and safety complete all aspects of the SL program, from launch vehicle design, payload design, rocket and payload fabrication, ground and flight testing, team meetings, videoconferences with NASA SL personnel, and post-flight data analysis.

3.1 ADI Engineering Office and Production Space

SLT17's main facility is the Troop's long-established TARC meeting and production space in the top floor of the ADI Engineering facilities in Charlottesville, VA. The top floor (approximately 2000 square feet) of the ADI facility is a currently unoccupied, unfinished space that is being used for Troop STEM activities, including SL. In addition, the ADI facility has four conference rooms that are used for all-team and individual functional sub-team meetings, and which can readily be used for videoconferences.

The top floor is available without any time restrictions, 7 days a week, 24 hours a day. It is a separate locked and access controlled space. One of the conference rooms is in this top floor, so we also have meeting and videoconference access 24/7.

The ADI facility also has the equipment to manufacture and assemble the structural and electrical components of the rocket. The facility offers a full complement of work benches, small hand and power tools, and support equipment for fabricating in wood, metal, or fiberglass. It also has a fully equipped electronics lab that can be used to fabricate, integrate, test and if necessary debug the Arduino-based hardware and software.

Available equipment includes the following:

- Basic hand tools (e.g., saws, screwdrivers, hammers, etc.)
- Basic power tools (e.g., drills, Dremel, sanders, router, etc.)
- Small power saws (can be used only by adults per BSA regulations)
- Electronics assembly equipment (soldering irons, heat guns, microscopes)
- Electronics test equipment (digital multi-meters, oscilloscopes, benchtop power supplies)
- Thermal test chamber (-40 to +100C range) for use in ground tests of aerogel films

With our strategy of modifying a commercial off the shelf (COTS) high power rocket kit, we do not anticipate the need for use of power saws (table saws, band saws). Avoidance of need for power tools that youth are prohibited from using under BSA regulations is a major reason we have adopted a strategy of basing the rocket on a COTS kit. Should cutting airframe tubes or other operations requiring the use of prohibited tool become required, SLT17 will attempt to outsource this to the commercial vendor supplying the parts. As a last result, it is possible an adult affiliated with the team will have to perform those operations, but we will keep it to a minimum and notify NASA if it becomes necessary (because the goal is for the youth team members to do everything).

3.2 Required Supplies

To complete the various elements of the project, the following supplies will be required. All of these supplies are commercially and readily available. Some will be donated directly by sponsors, and the rest will be purchased through the team budget.

- Fiberglass body tubes, sheets, and nosecone for the primary rocket and subscale, available as a kit to allow off-the-shelf purchasing.
- Recovery harnesses and equipment, including main and drogue parachutes.
- Electronic components including altimeters, flight computers, sensors, and microcontrollers such as Arduino.
- Tracking devices
- Mid and high-power rocket motors.
- Assorted hardware, wiring, adhesives (including epoxy, cyanoacrylate / super glue, and wood glue), and finishing materials such as primer, paint, topcoat, and sanding supplies.

3.3 Technical Tools

The following software and technical tools will be used by the team to facilitate collaboration, technical design/development, communication, and project management.

3.3.1 Google Drive

Google Drive is an online document sharing system that allows easy access to the files needed by the team. The team uses it to organize and compile documents in a central location as well as share important links and information such as meeting notes and agendas. We are using a folder within the Troop's Google Drive account.

3.3.2 Arduino IDE

The Arduino IDE is a free software program that is used to program the Arduino microcontroller. An Arduino will be used as our temperature logger, so software must be developed and tested to perform the functions of reading temperatures from all sensors and storing this data on the SD card.

3.3.3 Open Rocket

Open Rocket is a free, open source rocket design and simulation program that is being used by the team to help design the rocket, analyze static stability margin, and predict rocket flight performance: apogee, velocity upon rail exit, max velocity, speed and therefore kinetic energy during descent, motor selection, ballast sizing, etc. Open Rocket was selected as our main rocket design and simulation software because it is freely available, and all team members who are interested can download and use it without paying any fees.

3.3.4 RockSim

RockSim is a commercial rocket design and simulation program that SLT17 already owns through our participation in TARC. However, we only have one license, and to prevent the expense of purchasing additional licenses, we are not using RockSim as our primary rocket software. Our plan is to use RockSim to validate the simulation results produced by Open Rocket before we fabricate or order rocket kits, parts, or motors.

3.3.5 Slack

SLT17 is using Slack as our primary team collaboration and communications platform through which members can send messages, post files, and pose questions, and brainstorm ideas. Especially in the case of SLT17, our team is spread across multiple different schools, so an efficient and accessible online team collaboration tool is critical to discuss issues and brainstorm and then analyze and implement solutions. Slack has already proved to be invaluable in the proposal phase.

Our Slack account is organized by functional teams, and there is a Slack channel for every team: Safety, Rocket, Payload, Business, and Creative.

3.3.6 Teleconference Facilities

The ADI Engineering facilities have videoconference equipment available for team use. The facility has a guest Wi-Fi network throughout and 250Mbps broadband service. These facilities will be available to the team for the required reviews with NASA.

4 Preliminary Launch Vehicle Design

Recognizing that SLT17 is composed mainly of middle school students, our approach is to de-risk the rocket design and construction to the greatest extent possible. This allows us to maximize safety and our chances of success. Our approach to doing this is to base our launch vehicle on a commercially-available high-power rocket kit and modify it to carry the science payload and to meet other SL requirements (like 2.0 calibers of static margin). Basing the launch vehicle on a kit provides an example of a successful dual deployment high power rocket, and it also helps avoid possible issues with parts availability since the parts all come together.

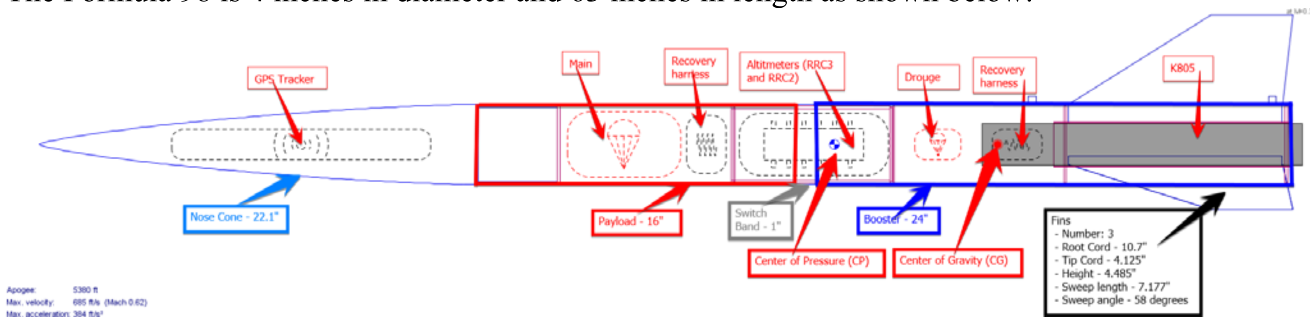
We feel our approach even follows NASA's example of re-using existing technology for new missions, where possible. This approach is followed extensively in SLS, with the re-use of many designs and technologies developed for the Space Shuttle, adapting them as necessary.

We recognize that basing our design on a modified commercial off-the-shelf (modified COTS) kit does not reduce the need for design simulation, analysis, testing, or safety actives. We will undertake all these activities just like we had a scratch-designed rocket.

The projected launch vehicle is based on a modified Mad Cow Formula 98 with dual deployment. One advantage of this kit is that Mad Cow sells a subscale version that we can use as our sub-scale rocket: the fiberglass Mad Cow Formula 75. These kits were selected because they meet all of our mission requirements as shown in preliminary Open Rocket simulations and because they can be modified to carry our payload. Specific factors include: they are easy to build, they are strong, and they have been already been flight tested (though we are not reducing our testing or analysis).

These rockets will be built using the RocketPoxy structural epoxy. All appropriate PPE will be used during the construction of the rockets. These include but not limited to: protective eye wear, protective outer clothing, vented space, and the use of nitrile gloves. Additionally, dust masks will be used during any sanding. Good ventilation will be used when using solvents (acetone), epoxies, and paints.

The Formula 98 is 4 inches in diameter and 63 inches in length as shown below:



The projected motor is an Aerotech 54mm K805. Open Rocket was used to compare multiple motors and from that analysis, we have preliminarily selected the K805. This motor achieves the projected flight performance as detailed in the table below.

Motor	Velocity off Rail	Apogee	Max. Velocity	Max. Acceleration	Time to Apogee	Flight time	Landing velocity
Aerotech K805	78 ft/sec	5149 ft	681 ft/sec	385 ft/sec	17.3 sec	72.3 sec	18.3 ft/sec

The preliminary deployment and altitude recording altimeters are the Missile Works:

- RRC3 as the primary
- RRC2 as the back up

We propose to use two different models of altimeters to control the two fully redundant recovery deployment systems. The advantage of this is that a common issue in the rocket or altimeter design, construction, altimeter software bug, or altimeter configuration or usage problem will be also avoided. Redundant deployment systems built with the same hardware meet NASA requirements, but we feel that it is better to have different altimeters to avoid common issues that may impact both.

Each of the altimeters will have their own power source and black powder charges. For apogee deployment, our preliminary plan is for the RRC3 altimeter to be set to deploy the drogue at apogee and the RRC2 will be set to deploy 1 second after apogee. For main deployment, the RRC3 will be set to deploy the main at 700' and the RRC2 will be set to deploy at 500'. The exact altitudes and times are subject to change, but offsetting the firing of charges also eliminates the possibility of structural failure (and possible separate and uncontrolled recovery) of the rocket due to overpressure caused by simultaneous firing of both charges. If the first charge successfully deploys the chute, then the second charge will harmlessly fire out of the already open airframe tube. But if the primary charge fails for any reason, the backup provides critical safety redundancy, to greatly reduce the chances of an unsafe ballistic recovery.

A separate altitude scoring altimeter will also be used: the Perfect Flight P-Nut. Our interpretation of the SL requirements is that the deployment altimeters cannot be used for altitude scoring, and that a separate scoring altimeter is needed. If we can use the Missile Works altimeters for altitude scoring, then the P-Nut will be eliminated.

Note that redundancy is neither required nor provided for the science payload or scoring altimeter. Since failure of these devices cannot result in an unsafe flight, it is not deemed necessary to make them redundant.

The Missile Works RTx Navigator will be used for tracking. Since all parts of our rocket remain tethered during recovery, only one tracking device is required per the NASA SL requirements. The RTx provides GPS tracking over the 900MHz unlicensed radio frequency band, with more than sufficient range in comparison with the SL flight objectives (5280' AGL altitude, 2500' maximum wind drive) and it will be placed in the nose cone. Our mentor already owns a suitable receiver so we will not need to purchase one.

For recovery of the vehicle, the Sky Angle Classic II has been selected as our main parachute and the Sky Angle 12" for the drogue. The drogue will be deployed at apogee to control the decent of the rocket in a orderly and safe manner while keeping wind drift within the maximum specified by NASA. The main will be deployed at 500'. The main and drogue deployment charges will be ground tested to determine the charge sizes for deployment. We will also analyze the descent and landing kinetic energies to assure they comply with the limits set by NASA.

The major technical challenges and the primary mitigation strategy for each includes the following:

- Motor not available – select another motor
- Primary launch site availability – use one of two back ups
- Not enough space in the booster section for the payload – extend the booster section with an avionics bay to hold the Arduino.
- The size of the main chute doesn't meet the required landing forces – select a larger chute which will pack in the same space.

5 Preliminary Science Payload Design

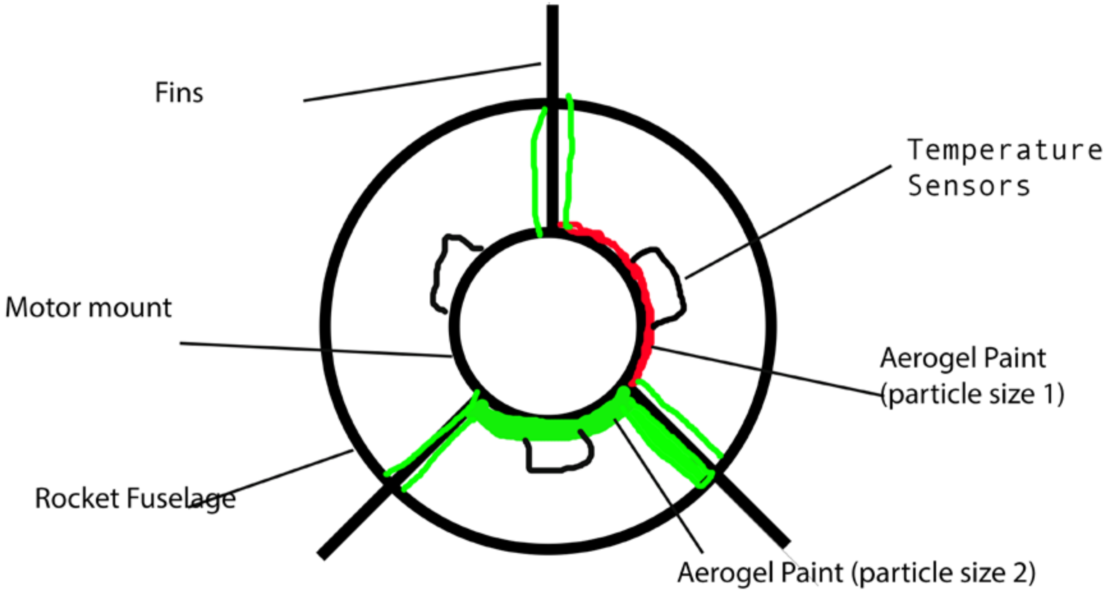
5.1 Overview

The purpose of the experiment is to research the insulation properties of aerogel thin films. Lightweight, easily applied thin film thermal insulation is of great value in space missions, and our experiment will gather data and analyze the effectiveness of aerogel thin films during actual flight conditions.

Our science payload will consist of three chambers around the motor mount which are separated by the fins. The heat generated by the motor during flight will be the heat source, and the goal is to measure the effectiveness of an aerogel thin film insulation consisting of finely powdered aerogel mixed into paint in isolating the heat generated by the motor during flight.

Aerogel powder of varying particle sizes will be mixed with paint, and applied to the outside motor mount. A different formulation of aerogel+paint will be applied to each of the three chambers to study the performance of the different formulations. Each chamber will have a temperature sensor inside it, and the sensors will be connected to the analog inputs of an Arduino Uno, which will serve as a multi-channel temperature logging unit. The Arduino will also be expanded using an SD card shield board to provide non-volatile flash memory storage that can retain the flight data and also allow it to be uploaded to a computer for post-flight data analysis. The advantage of using SD versus volatile memory is that even if power is lost (for example, if rocket recovery takes longer than planned), the loss of battery power for the Arduino will not result in the loss of fight data.

Of the three chambers, one will be a control, with no aerogel paint at all, in order to collect data for the insulated case. One chamber will have small particle sizes, and the last chamber will have large particle sizes. Temperatures will be samples as close in time as possible, and the temperature data will be stored by the Arduino on the SD During post-flight data analysis, we will observe any differences in the temperatures and draw conclusions from that.



5.2 Aerogel Coating

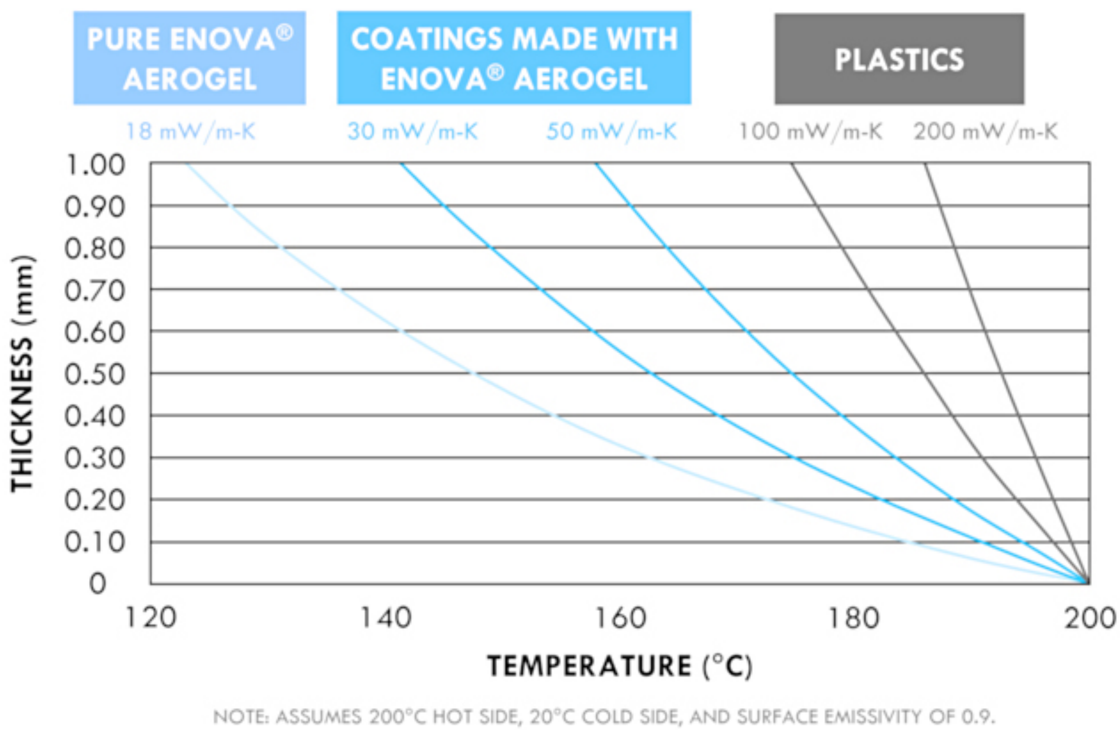
The objective is to test the difference of the insulation properties between large and small particles of aerogel when mixed with paint. In order to make sure the flight tests will produce meaningful data, we will run an insulation experiment with the aerogel on the ground first to determine the right mixture, particle size, film thickness, and proportions of aerogel and paint to use before attempting it in the rocket. This ground test does not need to use a rocket motor, any heat source would work. We propose to use an electrically generated heat source, such as a heat gun.

The aerogel powders we propose to use are readily available from BuyAerogel.com, available as Enova aerogel in the following grades:

- **IC3100**, which consists of ultrafine particles with diameters ranging from 2 to 40 µm. 1-L bottle is $68.
- **IC3110**, which consists of fine particles with diameters ranging from 100-700 µm (0.1-0.7 mm). 1-L bottle is $68.

The aerogel mixed with paint is expected to provide some degree of thermal insulation between the rocket motor and the exterior of the motor mount. The diagram below provides some data on coatings made from Enova aerogel and indicates the anticipated thermal conductivity should be between 30 and 50 mW/m·K. Since most of the heat produced by the rocket motor will be propelled out the back of the rocket, it is difficult to estimate the temperature increase inside the rocket. Therefore, we will use the three chambers surrounding the motor mount to realize three different experiments. One will be a control chamber that will be coated with plain paint. The other two chambers will be coated with a mixture of paint and one of the two grades of aerogel mentioned above: IC3100 or IC3110:

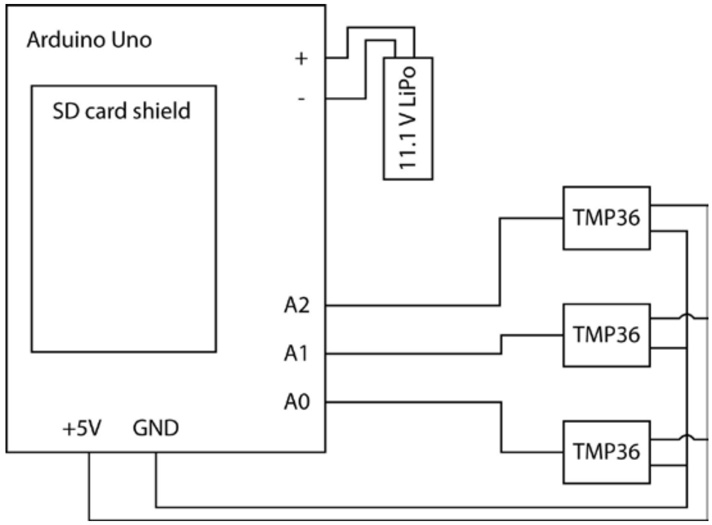
> *Need to review safety concerns of handling aerogel particles:*
> *Aerogel particles and blankets may generate nuisance dust when handled and so appropriate protective gear such as safety glasses, gloves, and a dust mask are recommended when handling these types of products. For non-silica aerogel materials, the aerogel form is, in general, as safe as the material(s) upon which the aerogel is based, keeping in mind that particulate forms of any material can potentially present respiratory hazards. For more information about a particular aerogel product, please consult the materials safety data sheet (MSDS).*



5.3 Measurement System

In order to quantify the difference between the insulation properties of large and small particle aerogels when mixed with paint, temperature sensors will be used to measure the local temperature within the motor mount chambers. Preliminary system components:

- TMP36 temperature sensors (x3) (5V, 50 μA each)
- Arduino Uno microcontroller (7-12 V, ~46 mA, 25 g)
- SD card shield board (3.3V, X mA, 22 g)
- LiPo battery (11.1 V, 650 mAhr, 59 g)



The Arduino will need a battery that can power it for at least an hour. Based on the estimated power consumption of the Arduino Uno, the minimum battery size is 50 mAhr. A 650 mAhr LiPo battery weighing 59 g will power the measurement system for approximately 13 hrs.

The Arduino Uno with SD card shield and LiPo battery will need to be housed in a small enclosure mounted in the bottom part (booster) of the rocket. The Arduino cannot reside in the avionics bay with the flight computers and scoring altimeter, because the temperature sensors must be wired to the Arduino. Therefore, a special housing will protect it from ejection gasses. Our current thought is that the enclosure will mount inside the booster body tube, however this also creates complications because in that location, the enclosure will be exposed to ejection gasses during drogue deployment. For that reason, we may decide to add a new body tube section to the booster and create a dedicated avionics bay for the Arduino right above the fin can.

6 Educational Engagement

6.1 Cub Scout Packs

Our main strategy for educational engagement is to use resources and contacts within the Boy Scouting organization to reach younger elementary and middle school youth. This is also aligned well with our other BSA STEM/Nova program goals, which include STEM education for younger Scouts in other units locally.

Our main educational engagement activity will be to attend local Cub Scout Pack or Den meetings to conduct a STEM learning activity at the meeting.

Approaches that are currently being considered with Cub Scouts include:

- Contact local Cub Scout Packs and schedule a STEM program that we conduct at a Pack or Den meeting. To generate maximum attendance, we would lead the Cub Scouts in their Adventure in Science elective, using NASA SL and rocketry as the main theme. This would likely be a hands-on activity involving model rocketry, such as a rocket build/fly session.
- Setup a display and hands-on activity at the Council Cub Scout day at the upcoming Apple Harvest camporee, which attracts many hundreds of Scouts from all across Central Virginia. Teach the basic principles of rocketry and allow Scouts to launch model or water rockets.

6.2 Boy's Life Magazine

Troop 17 already has the commitment from Boy's Life magazine to publish an educational article on how to build and fly a model rocket. We obtained this commitment from Boy's Life over the late Spring of 2017 but we and they decided to defer the article until the SL program was underway, to preserve the opportunity to make this part of our educational engagement program, and to help publicize SL to the Boy Scouting community.

We have also discussed with Troop 295 the general idea of both being featured jointly in this article, and both troops are in agreement to pursue a joint article.

We are not sure if this article could count toward an educational activity for NASA SL. Our goal would be to teach something about rocketry in the article, so that it was educational in nature. Even if the article does not count toward our educational outreach requirements, it is still something we are going to do, because it helps promote some of the activities Troop 17 is undertaking and it helps to reinforce even more the STEM initiatives within Boy Scouting.

6.3 Charlottesville Mini Maker Faire

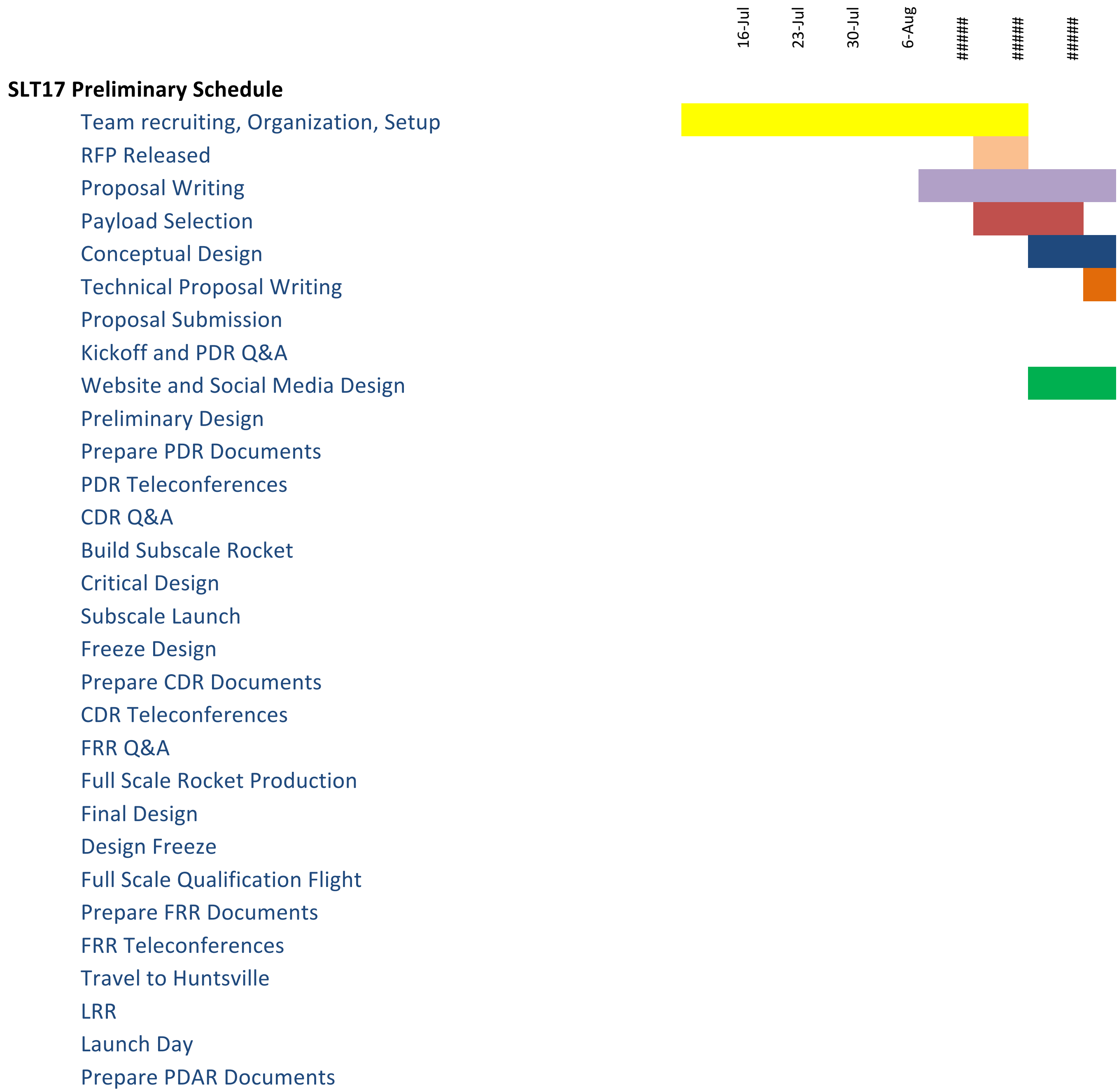
This local maker faire is attracts many youths who are interested in STEM. Our plan is to have a display and conduct and educational activity teaching fundamentals of rockets. This is also an excellent opportunity to collaborate with the Piedmont Student Launch Team, who also plans on being there.

6.4 Collaborative Educational Events with Other Nearby SL Teams

We have already been in contact with both the Piedmont Student Launch Team (PSLT) and Boy Scout Troop 295 Team, and both have expressed interest in collaborative educational activities, to increase the interest and impact of these activities. Our idea is that by teaming, we have greater resources to undertake bigger and more impactful activities. While the collaboration is not yet defined in detail, we will look to collaborate with other SL teams whenever possible.

7 Project Schedule

7.1 Schedule



8 Project Budget

8.1 Overview

The total cost for this project is estimated at an upper limit of $14,289. This includes two primary expense categories: rocket-related, and travel.

8.2 Rocket Expense

The rocket-based expenses are based on costs researched by team members online. It includes rocket kits, motors, computers and payload for a full-sized F-98 rocket ($1,629), and a scale-model F-75 rocket ($615). We have imputed $500 expenses for safety, though we have no basis for this projection. We've also imputed an estimated $100 for promotion to cover paper, ink and other related costs to raise funds for this project.

8.3 Travel Expense

The largest cost category by far is travel-related expenses. We have included an estimate of $11,946 for travel. This includes the following items:

- Transportation: $4,536 - It is 1,200 miles round trip to Huntsville, AL. from Charlottesville, VA. Based on the number of team members, we estimate seven personal vehicles making the trip at $0.54 per mile (IRS estimates)
- Lodging: $3,000 - We estimate 6 rooms with at 3 or more people in each room, at $100 per night, for five nights in Huntsville.
- Food $4,410 - We estimate a per diem of $30/day for 7 days for 21 people.

The plan is to apply funds raised first to rocket and payload and related equipment, and second to travel-related costs. That way, if there is a fundraising shortfall, the science and flight objectives are not impacted and we can compensate by reducing travel expenses.

Possibilities for covering travel expenses include the following:

- Renting or hiring small buses to transport the team to and from Huntsville, and/or sending the team to Huntsville by train. This may reduce the transportation cost. However, once the team arrives in Huntsville, we would have to rent one or two vans to shuttle the team between the hotel and the NASA launch, making this option less appealing.
- There is also a possibility that parents will absorb and share some or all of travel costs. This will require a team decision to be made closer to the time of the travel and on the basis of how much money has been raised.
- Depending upon fundraising success, Boy Scout Troop 17 may be willing to contribute in some funding to support the trip.
- The total cost per person for food, lodging, and transportation, is nearly $570. This may be more expensive than many will find possible to fund. So the number of Scouts attending may decline, but the ultimate cost per person would remain the same.

8.4 Budget Detail

In total, we will need $14,289 to cover all expenses. So we will need to do a lot of fundraising and hopefully get gracious sponsors.

	No. of units	**Cost / Unit**	**Rocket #1**	**Rocket #2**	**Total**	**Risks**
Sources of Funds						
Uses of Funds						
Total Uses	_	_	**13,675**	**615**	**14,289**	The biggest costs are travel-related. We have excluded $2,520 for meals costs, as we expect people will cover their own
Rocket	_	_	**1,629**	**615**	**2,243**	
Kits 4" Fiberglass Formula98	1	190	190		190	
Kits 3" Fiberglass Formula75	1	119		119	119	
Motors - 4" rocket ($150 each)	4	150	600		600	
Motors - 3" rocket ($75 each)	3	75		225	225	
Motor Hardware - Formula98	1	150	150	150	300	
Motor Hardware - Formula75	1	50	50	50	100	
Arduino Uno	3	22	66	66	132	
Sensors -			0	0	0	
TMP36 + high temperature cable	3	2	5	5	9	
Aerogel - 1 litre	1	68	68	0	68	
Safety	1	500	500	0	500	Estimates for PPE and supplies
			0	0	0	
			0	0	0	
			0	0	0	

Promotion	-	-	100	0	100	
Website			0	0	0	
Troop 17 website			0	0	0	
Fundraising promotion	**1**	**100**	100	0	100	General costs of material for promotional activities
Design		**1**	0	0	0	
			0	0	0	
			0	0	0	
Travel	-	-	11,946	0	11,946	$568.86 per person
Rooms 6 rooms @ $100/night; 5 nights	**30**	**100**	3,000	0	3,000	See itemization for rooms estimate below
Travel: 600 miles each way x $0.54/mi x 7 vehicles	**8,400**	**0.54**	4,536	0	4,536	21 people could be making the trip; assume 3/car, means 7 cars; we may wish to hire a bus, but will have to clear and estimate the costs later
Food ($30/day x 7 days x 21 people)	**147**	**30**	4,410	0	4,410	I presume everyone will pick up their own meal costs, but I've calculated it here,
			0	0	0	
			0	0	0	
		Rooms	Total	Adults	Youth	
		1.0	3	1	2	allen
		0.5	2	1	1	barker
		0.5	2	1	1	romanko
		1.0	4	1	3	yates
		0.5	2	1	1	gamble
		0.5	2	1	1	orejudos
		0.5	2	1	1	Scindia
		0.5	2	1	1	Shray

		1.0	2	1	1	Smith
		6.0	21	9	12	

8.5 Fundraising Plan

The SLT17 funding will come from several locations and sources. These include corporate sponsors, private donations, online sources, and fundraisers.

- The fundraisers we would do include: yard work, car washes, bake sales. BSA has strict policies and procedures on fundraisers that we must comply with, and fundraisers must be pre-approved by the local council (http://www.scouting.org/filestore/financeimpact/pdf/CFD-Manuals/Policies_and_Procedures.pdf)
- We will contact local stores and businesses to see if they would be willing to give us some percentage of their earnings or to sponsor us. ADI Engineering, who has sponsored our TARC team in the past, has also committed to supporting the SL team. There has also been preliminary interest in donations expressed by some leading aerospace and defense companies, and we intend to secure this funding right away assuming NASA accepts our proposal.
- Online fundraising (for example, a "Donate Here" button on our website) is heavily regulated by BSA National and we must comply with all requirements.
- Private donations could come from family members and friends or even possibly somebody that is willing to support us.