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NASA Student Launch PDR Report

Prepared for NASA by Boy Scout Troop 17 Student Launch Team

Boy Scout Troop 17
3022 Watercrest Drive
Charlottesville, VA 22911

Date	Revision	Remarks
Nov 1, 2021	1.0	Initial Document

TABLE OF CONTENTS

1 Summary of PDR Report

1.1 Team Summary

The name of our team is SLT17. We represent Troop 17 of the Boy Scouts of America.
SLT17
3022 Watercrest Drive
Charlottesville, VA 22911

The team's adult advisor is Steve Yates, NAR 28349 (NAR L1 certified), and team's assistant adult leader is Bill Brown. Tim Hoagland, an active Tripoli member in good standing and Tripoli L3 certified, is the team's high-powered rocketry mentor.

1.2 Launch Vehicle Summary

- Length: 85.4"
- Body Diameter: 4.025"
- Weight Without Motor: 12.8 lbs
- Weight With Motor: 16.2 lbs
- Predicted Altitude: 5200 ft AGL
- Motor Choice: Aero Tech K805

1.3 Payload Summary: Three-Axis Vibration Characterization of the Rocket During Flight

The purpose of the experiment is to research the vibrations in the rocket using 3-axis accelerometers. Our science payload will consist of an accelerometer connected to a Raspberry Pi Pico. The experiment will be placed in the nose cone to maximize vibrations, and our goal is to identify vibration patterns (magnitude, frequency spectrum, and time variance during various flight phases) during rocket flight to hopefully guide our experiment for next year.

The accelerometer will be connected to a Raspberry Pi Pico. As the Raspberry Pi has clock speeds of around 125 MHz, it should be more than fast enough to register the data the accelerometer is giving it. To reduce power consumption, the accelerometer will use an interrupt feature so that it only begins logging vibrations after the rocket accelerates to a certain level, indicating launch. We will have to keep the MicroSD card reader active at all times; any input delay at the beginning of the flight would cause us to lose valuable data. After the accelerometer triggers upon launch, the Pi will immediately translate its data and transfer it to the MicroSD card. After the rocket reaches its apogee, the accelerometer will once again use its interrupt to deactivate, further minimizing the possibility of data loss due to excessive battery consumption.

1.4 *Time Spent on PDR Phase*

SLT17 has spent a total of 334 hours on the PDR phase, including design alternative identification, analysis and selection; risk mitigation planning; requirements verification planning; STEM education planning; launch vehicle profile analysis and simulation; and budgeting and scheduling.

1.5 *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, since this document will be distributed publicly. Full team roster information has been provided to NASA directly in a private communication.

Name	Title	Email	Phone
Steve Yates	Troop 17 STEM Chair	steveyates@embarqmail.com	434-825-2850
Tim Hoagland	Tripoli/NAR Mentor	tim.hoagland@gmail.com	
Beau	SLT17 Team Leader		
Eoin	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/student-launch.

SLT17 will maintain an active and engaging social media presence, with emphasis on Facebook and Instagram. The team's Public Relations subteam already is busy establishing our new social media presence, and getting groundwork laid for these new sites.

1.6 Team Structure and Members

SLT17 currently consists of 12 team members, one adult advisor, an assistant adult advisor, and a Tripoli Level 3 mentor.

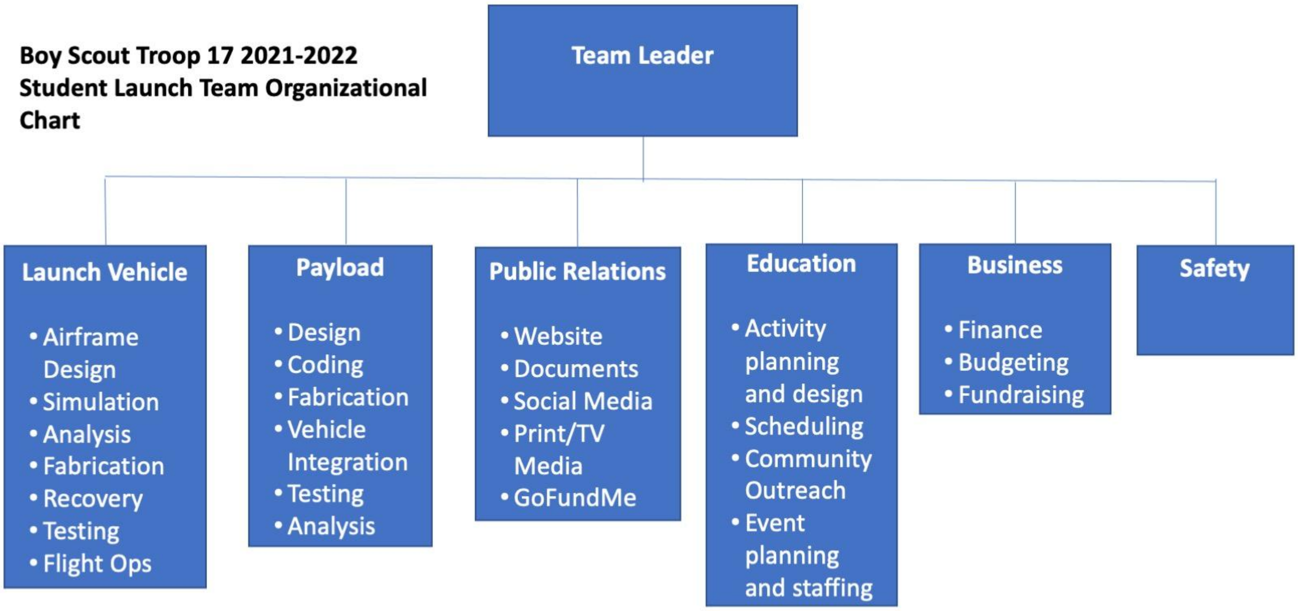
SLT17 is organized into six functional sub-teams: Rocket, Payload, Public Relations, Business, Education, and Safety. There were three lessons learned from prior years related to subteams on team structure, leadership, and day-to-day operations. First is that there needs to be a focus on subteams during day-to-day operations, document and report preparation, and regular team meetings. This year, the regular weekly team meetings will be subteam meetings instead of all-team meetings. Second is that due to our young team age (still mostly middle school) that we need a dedicated adult mentor assigned to each subteam. Third is to divide the subteams into "full time" and "part time" categories and have individual SLT17 members play a role on two subteams, one from each category. The reason is that some of the subteams have ongoing full-time duties, such as the Launch Vehicle, Public Relations, and Payload. In prior years, members of these subteams tended to stay more engaged and more satisfied with their SLI experience. But members of other subteams such as Business or Public Relations were part time, and the members of these teams were less engaged, had a harder time in the program, and were less satisfied with SLI. We feel these changes will help improve the SLI experience for our participants. We have made Public Relations a full-time subteam, due to our emphasis on social media and other public relations outlets.

Also each subteam has a designated youth leader and also has a designated adult mentor with experience in that area. In past years, the lack of subteam leaders and adult mentors meant that the subteams did not have clear leadership or subteam-level mentorship, which reduced the effectiveness and increased the workload on the all-team leadership to the point that it created difficulties. By delegating many of the leadership tasks and the step-by-step work planning into the subteams, the subteams are more independent and effective, and can work autonomously and be less dependent and less held up waiting for instructions from senior leadership.

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 independence and authority to truly create a culture of safety. We are very proud that we experienced no unmitigated safety issues during our prior two SLI seasons, and it is critically important to us to repeat that result this year.

The following table and organization chart provide details on team members, their roles, and team structure. Note that for clarity, only the primary subteam assignment is listed for each team member.

Name	Role	Team
Beau	Team Leader	
Eoin	Safety Officer	
	Team Member	Payload
Cole	Subteam Co-leader	Launch Vehicle
	Team Member	Business
Luke	Subteam Co-leader	Launch Vehicle
Brayden	Team Member	Launch Vehicle
Alex	Subteam Leader	Payload
Brayden	Team Member	Payload
Curtis	Subteam Leader	Public Relations
	Team Member	Education
Bryce	Rocket Art	Public Relations
Shrey	Subteam Leader	Business
	Team Member	Payload
Zachary	Team Member	Launch Vehicle
Cormac	Team Member	Payload



1.7 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 has an FAA waiver of 15,000 feet AGL. Troop 17's TARC team has conducted launches with Tripoli #25 for 14 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 SLI.

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 Changes Made Since the Proposal

Since SLT17 submitted its proposal, a number of changes have been made as we analyzed the design in more detail. These changes all serve to make improvements over the original proposal, either by simplifying the design, improving performance of the launch vehicle or payload, or reducing failure modes. The following is a listing and brief summary of the changes.

2.1 Relocated Payload Bay

The proposal showed the payload bay located in the booster section of the rocket, just forward of the fin can and motor mount. This was the same location as in our 2017-2019 SLI payloads, which required location near the motor so they could conduct experiments with heat generated by the motor during flight. But this year's payload characterizing vibrations requires no such proximity to the motor.

Relocating the accelerometer payload away from the motor in the nose cone in our view will improve the payload data. First, vibrations far away from the CP and CP, in the nose cone, are going to be more pronounced and more interesting. Second, putting the mass of the payload further forward will increase stability margin. Third, payloads are normally located in or near the nose cone in actual launch vehicles, so our data on vibrations and next year's payload either on energy harvesting or active vibration suppression will be more representative of situations faced by NASA and commercial industry, and therefore more useful.

2.2 Combined Payload and GPS Tracker Batteries; Payload Triggering Upon Launch

Since the payload and the GPS tracker will now share the same bay near the nose cone, we have decided to combine their previously separate LiPO batteries into a single larger battery. This eliminates a LiPO battery from the vehicle will improve safety, since there are fewer batteries that may potentially fail or sustain damage. Also eliminating a battery will simplify flight operations, since there are fewer batteries to charge, install in the rocket, and protect and label per SLI requirements for LiPO batteries this year.

2.3 Payload Triggering Upon Launch

SLT17 recognizes that the GPS tracker is an important function, so safeguards must prevent sharing a battery with the payload from impairing GPS operation. To prevent this, the payload now has a trigger function so that it is active in its full-power mode only during the flight after launch is detected. The energy consumed by the payload will therefore be minimal and GPS operation will not be at risk. Also, the combined battery is sized to accommodate the combined payload and GPS power needs.

2.4 Eliminated Ballast and Ballast Holder

Previously, we proposed the use of ballast and a holder for the ballast in the rocket as a means of altitude control. Our experience in past SLI years is that although we designed those rockets to accept ballast, we never actually used any. Our approach to altitude control this year has therefore changed from the proposed one based on ballast to a design-based approach where the altitude goal is met through launch vehicle design and assured by design analysis and flight testing, without any means of making adjustments to the as-built rocket.

This advantages of this approach are simplicity and elimination of potential failures caused by ballast coming loose or extra loads on recovery harnesses and other recovery components due to ballast. The disadvantages are that any deviations from the predicted masses of components of the rocket or building supplies such as epoxies or paint will throw off the design-based altitude prediction. SLT17 recognizes that it tends to “build heavy” with liberal use of epoxies to maximize strength and reduce chanc es of any structural failures. We have taken this into account in our design predictions and our altitude target declaration.

2.5 Revised Target Altitude

Based on the updated launch vehicle and payload designs and change in altitude control strategy, we have recomputed and revised our target altitude from 4800 feet AGL to 5200 feet AGL. This is within the altitude limits set by NASA and requires no additional design elements to achieve. Placing our target altitude at 5200’ also allows for our design-based altitude control methodology without serious risk of falling outside these limits.

2.6 Revised Payload Computer Selection

Further research and analysis has allowed us to select a payload computer. Previously in the proposal, this was an open question. Now, we feel comfortable stating that a Raspberry Pi Pico will be our payload computer. This has significantly higher performance than the Arduino Uno used in past years, but does not have the high power consumption of even faster Raspberry Pi models such as the RPi 4, which would require excessively large batteries.

3 Launch Vehicle Criteria

3.1 Overview

Recognizing that SLT17 is composed of middle and high school students, our approach is to de-risk the rocket design and construction to the greatest extent possible., while still fully following the high-level SLI program goals and objectives of youth doing all work. 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 also helps to 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 tasks. 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 already been flight tested (though we are not reducing our testing or analysis). One risk this year is that MadCow has discontinued the Formula 75, and thus far we have been unable to locate a Formula 75 kit still left in stock at distributors. However, we have found a distributor who is willing to sell us individual components as a sort of de-facto kit that overcomes the discontinuance of the Formula 75 by MadCow. This is on order and will allow us to proceed with the subscale build on schedule.

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 are not limited to: protective eyewear, 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, isopropyl alcohol), epoxies, and paints.

3.2 Mission Statement

The Troop 17 Student Launch team will build a rocket capable of reaching an altitude of 5200 feet above ground level while carrying the payload. The rocket will be recovered using a redundant dual deployment system, and will transmit its position both before and after the flight to the ground station via a GPS tracking system.

3.3 Mission Success Criteria

Our mission will be successful if the flight is safe, the science experiment returns useful data, and the launch vehicle attains an altitude close to the 5200 feet AGL goal. Finally, the rocket's recovery system must operate correctly and successfully bring the rocket safely to the ground. Our threshold for "safe landing" is one where all sections of the rocket stay tethered as intended, drift is within NASA limits, and contact the ground is made with kinetic energy under the maximum limits set by NASA. All aspects of the flight must also be deemed safe by the RSO and other applicable flight range staff.

3.4 Design Alternative Evaluation

3.4.1 Profiles

As the rocket is being designed, it is critical to consider alternatives for the profile of the rocket, the number of sections from the body, and the nosecone.

There are two types of profiles: Standard and nonstandard. A standard profile is where the entire body of the rocket has the same diameter, whereas a non-standard one has sections that are of different diameters.

Profile	Pros	Cons
Standard	Is easy to design, model, and build, and has normal aerodynamics	None
Non-standard	Possibly lower weight and more interior space	Harder to build design and model for simulation. Requires diameter transition pieces. Higher drag.

The body sections are the separable parts of the body

Number of sections	Advantages	Disadvantages
Less than 3	Less places for the rocket to accidentally separate	Not enough sections to hold both parachutes without additional work required on the recovery system
3	No extra work required for the recovery system	Takes more effort to construct the body
More than 3	none	Requires even more effort to construct the body

There are different types of nose cones: Ogive, which has a profile like a parabola but ends in a steep point, parabolic, which is like a regular cone but has a profile of a parabola with a more rounded end, and cone, which is simply a cone.

Nose Cone Type	Advantages	Disadvantages
Ogive	Commercially available for our body tube size and is the cone type used in our kit	Slightly higher drag
Parabolic	Slightly lower drag	Not available for use with our body tube and kit
Cone	Lower drag when encountering higher speeds	Not available for use with our body tube and kit

3.4.2 Altitude Control

Three different techniques of altitude control are possible - active, passive (ballast), and design assurance. Active techniques would use some form of aerobraking deployment (parachutes, flaps, etc.) under the control of an on-board computer to stop the rocket's ascent at the declared target altitude. Passive ballasting adjusts the final mass of the rocket to achieve the target altitude. Design assurance techniques simply make the overall mass and drag profile of the rocket without any means of adjustment so that the rocket achieves the declared target altitude without any other control mechanisms.

Altitude Control	**Advantages**	**Disadvantages**
Active	• Precise control of vehicle's altitude • Can compensate for motor manufacturing variations or changing launch conditions	• Expensive • Need electronic controls • Difficult to manufacture and install • Adds additional failure modes that would be safety critical to the rocket's flight
Passive Ballast	• Easier to manufacture • Not as expensive • Can compensate for unexpected mass deviations in as-built rocket	• Not as precise control of altitude • Ballast increases masses of rocket sections, creating extra stresses in recovery components
Design Assurance	• Easiest to manufacture • Least expensive • Least stress on recovery system and other structures	• Least precise altitude control • No means for adjustment in as-built rocket if unexpected mass deviations occur

3.4.3 Compartmentalization

Due to the black powder charges for separation of the launch vehicle, we need bulkheads to protect areas of the rocket that are more sensitive like the electronics and experiment. Some of the bulkheads will also be used to mount onto the recovery harness. There are different materials to use for the bulkheads; plywood, fiberglass, and aluminum.

Material	**Advantages**	**Disadvantages**
Plywood	• Lighter • Cheaper • Easier to cut than either materials	• Not as durable as the other materials
Fiberglass	• Easier to use than aluminum • Stronger than Plywood • Lighter than aluminum	• Not as strong as aluminum • More expensive than plywood • Harder to cut
Aluminum	Stronger than either material	• Very difficult to work with • Much more expensive than either material • Harder to bond to than other materials

3.4.4 Flight Stability

Two main points that will determine the launch vehicle's stability are the center of gravity and the center of pressure. The center of pressure is where aerodynamic forces are centered and is determined by the design and location of the fins. The center of gravity location is the balance point of the rocket and is determined by the placement and weight distribution of all of the components making up the launch vehicle. Obviously, the center of gravity location will vary during flight based on the lightening of the motor due to propellant combustion.

Fin design options that will determine our launch vehicle's stability include the shape, size, placement, number, and material.

Fin Shape	**Advantages**	**Disadvantages**
Elliptical	Produce less drag	Difficult to manufacture
Trapezoidal	Easy to design, manufacture, and attach	Higher drag than elliptical fins

Number of Fins	**Advantages**	**Disadvantages**

3	• Less weight and drag • Less likely to be made unstable by high winds • Less time spent into manufacturing and attachment of fins	None
4	None	• More weight and drag • More time spent on manufacturing and attachment of fins
4+	Looks cool	• More weight and drag • More time spent on manufacturing and attachment of fins

Mounting of Fins	**Advantages**	**Disadvantages**
Through The Wall	Strong attachment of fins and strengthens the motor mount too.	More difficult to attach
Exterior Attachment	Easy to attach	Not strong, can shear off easily, does not reinforce motor mount like TTW

Fin Material	**Advantages**	**Disadvantages**
Plywood	• Cheaper than Fiberglass or Carbon fiber • Light weight • Stronger than balsa wood	Not very strong
Balsa Wood	• Cheapest • Lightest in terms of weight	Very Weak, not suitable for high power rockets
Fiberglass	• Stronger than both types of woods listed • Cheaper than Carbon Fiber	More expensive and harder to work with than wood
Carbon Fiber	Strongest material listed	Most expensive and hardest to work with

3.4.5 Launch Stability

The initial launch stability is determined by the rail system, and depends on whether sufficient speed can be attained at rail exit for sufficient aerodynamic forces to keep the rocket stable. We will discuss the exit velocity under section 4.3.

Attachment type	Advantages	Disadvantages
Rail Buttons	• Attached better • More aerodynamic	None
Launch Guides	None	• More weakly attached • Less aerodynamic

3.4.6 Motor Retention

The motor retention system will include 2 parts which will keep the motor securely in the rocket during all phases of flight, which is required for a safe flight.

Motor Retention	Advantages	Disadvantages
Plate Retainer	None	Not commercially available in correct size
Screw-on Retainer (Aeropak)	Commercially Available in correct size for engine	Cost
Engine Hook	None	Not commercially available in correct size

3.4.7 Tracking

For the tracking system, it is important to decide whether to use a commercially available, custom tracking system, or GPS.

Type of Tracking	Advantages	Disadvantages
Commercially available tracking	Easy to use and setup reliable	• Limited by the data it is designed to sent
Custom tracking	Can transmit more data than just the position of the rocket Probably less expensive	• Less reliable • More work involved in setting up • Weighs more • Has a greater chance of inter-system interference
GPS	More accurate	Requires an GPS receiver on the rocket plus a transmitter and a ground-based receiver.

3.4.8 Leading Design Alternatives

System	Subsystem	Choice	Reason(s)
Airframe	Profile	Single	Simplicity, performance
	Body Sections	Three	Simplicity
	Nose Cone	Ogive	Commercial availability
Altitude Challenge		Design Assurance	Simplicity, reduced complexity, safety
Compartmentalization	Bulkhead Material	Metal	Strength
Flight Stability	Fin Shape	Trapezoidal	Ease of fabrication
	Number of Fins	3	Reduced drag
	Mounting of Fins	TTW	Strength
	Fin Material	Fiberglass	Commercial availability, strength, ease of construction
Launch Stability	Rail Attachment	Buttons, 1515	Commercial availability, strength
Motor Retention	Motor Retention	Screw-On Retainer (Aeropak)	Commercial availability, strength, ease of use
	Centering Rings	Fiberglass	Commercial availability, strength
	Centering Rings Material	Fiberglass	Commercial availability, strength
Tracking	Commercial or Custom Tracking	Commercial	Accuracy of tracking
	Position Detection	GPS	Accuracy of tracking

3.5 Recovery Subsystem

3.5.1 Components and Alternatives

The primary components to the recovery system are the main and drogue parachutes, the recovery harnesses, and the avionics.

Parachute Material	Pros	Cons
Ripstop Nylon	Strong Common within the hobby UV resistant Commercially available Has a high CD	Sensitive to heat
Kevlar	Significantly stronger than Nylon. Does not melt or burn. Abrasion resistant. Has a low CD	Abrasive material to handle.

Recovery Harness Material	Pros	Cons
Nylon	Moderate strength Commonly available for purchase	Low heat tolerance
Kevlar	Stronger than Nylon Does not melt or burn Abrasion resistant	Abrasive material to handle

Mounting Points	Pros	Cons
Forged Eye Bolts	Only require one hole in centering rings or bulkheads	Weaker attachment Can be detached by a spinning section
U-bolts	Stronger attachment Cannot be detached by a spinning section	Require two holes in centering rings or bulkheads

Recovery Harness Attachment	Pros	Cons
Permanent	Minimizes points of failure	Rocket cannot be separated into sections
Quick links	The rocket can be separated into sections	Forgetting to install or tighten then can lead to unsafe landing

Avionics	**Pros**	**Cons**
Barometric altimeter	Proven technology Easy to configure Less expensive than a flight computer	Vent holes must be sized correctly.
Flight computer	Proven technology Better data collection	Complicated which can lead to configuration errors More expensive.

Ejection Method	**Pros**	**Cons**
4F Black powder	Proven technology Less expensive.	Must be contained Must be handled with care Requires the recovery gear to be protected from hot ejection gases.
CO2	Proven technology Less dangerous. Doesn't require protecting the recovery harness and chutes from hot eject gases.	More complex to use Higher weight. Larger. More points of failure. Expensive

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3.5.2 Parachutes

Based on the current design, it is estimated that a 20 in Sky Angle Classic drogue parachute and a 60 inch Sky Angle Classic main parachute will support a safe descent. Using these recovery chutes, the highest kinetic energy of any section of the launch vehicle at landing is under 55 ft-lbs.

3.5.2.1 Leading Design

System	Choice(s)	Reason(s)
Parachute material	Ripstop Nylon	Ripstop Nylon parachutes are readily available.
Recovery harness material	Kevlar	Kevlar is strong enough to endure the forces involved with the recovery system with enough of a safety margin.
Mounting points	U-bolts	Two points of attachment for each U-bolt provides makes them less likely to separate, which makes the recovery system safer.
Recovery harness attachment	Quick links and swivels	Quick links will be used to attach the recovery harnesses to the launch vehicle so that the sections of the launch vehicle can be separated for transport. Swivels will be used to attach the recovery harnesses to the parachutes to prevent tangling the shroud lines.
Avionics	Barometric altimeter	At least one of the altimeters in the rocket is required to be barometric, and it will be simpler to use a barometric altimeter as the secondary one as well.
Ejection method	Black powder	Black powder will be simpler to use than CO2.

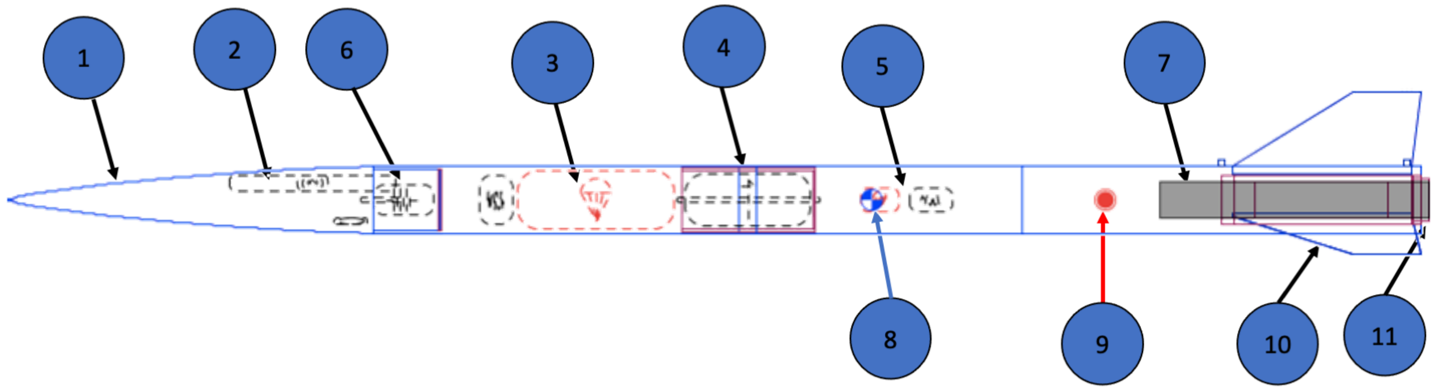
The recovery system has an avionics bay in the central section of the rocket which will house the altimeters, ejection canisters and attachment points for the recovery harnesses. The Kevlar recovery harnesses are 25 ft. long with a loop at each end for attachment to the recovery U-bolts via the quick-links. The apogee recovery harness is attached to the booster and fin can assembly The main recovery harness is attached to the payload bay and the nose cone.

3.5.2.2 Plan for Redundancy

The avionics bay will contain two completely independent altimeters, each of which will have its own battery and be connected to its own pair of ejection canisters, thereby eliminating the risk of being unable to deploy recovery systems because of an electronics failure. The Marsa Systems MARSA33LHD is the primary altimeter and the Missile Works RRC3 is the backup altimeter. The primary MARSA33LHD will fire at apogee followed by the backup RRC3 firing its apogee charge one second after apogee. The primary MARSA33LHD will fire the main charge at 600 feet followed by the backup RRC3 backup charge at 500 feet. The apogee and main back up charges will be 50% larger than the apogee and main charges, so that in case any unexpected binding occurs between the couplers and body tubes at the separation interfaces, the larger backup charges will have extra energy to overcome that.

3.6 Updated Vehicle Design

The following diagram shows the updated launch vehicle design, with the forward combined bay housing the RTX tracker and payload together, and elimination of the aft payload bay.



Component Number	Description
1	5:1 Von Karman filament wound nosecone
2	Missile Works RTx Navigator for GPS tracking
3	Main Recovery - SkyAngle Classic II 60” chute with 25’ kevlar harness
4	Electronic bay - Marsa Systems MARSA33LHD + Missile Works RRC3 flight computers with independent LiPO batteries and redundant black powder charges
5	Apogee Recovery - SkyAngle 12” drouge with 25’ kevlar recovery harness
6	Science experiment data acquisition and logging unit including a Raspberry Pi Pico, three-axis accelerometer, MicroSD card data storage system, single LiPO battery to power payload + RTx tracker
7	Aerotech K805 motor
8	Center of Gravity (CG) - 52” from tip of nose cone
9	Center of Pressure (CP) - 66” from tip of nose cone
10	Fins - 3 G10 fiberglass ⅛” thick
11	Aeropak 54mm motor retainer

3.7 *Mission Performance Predictions*

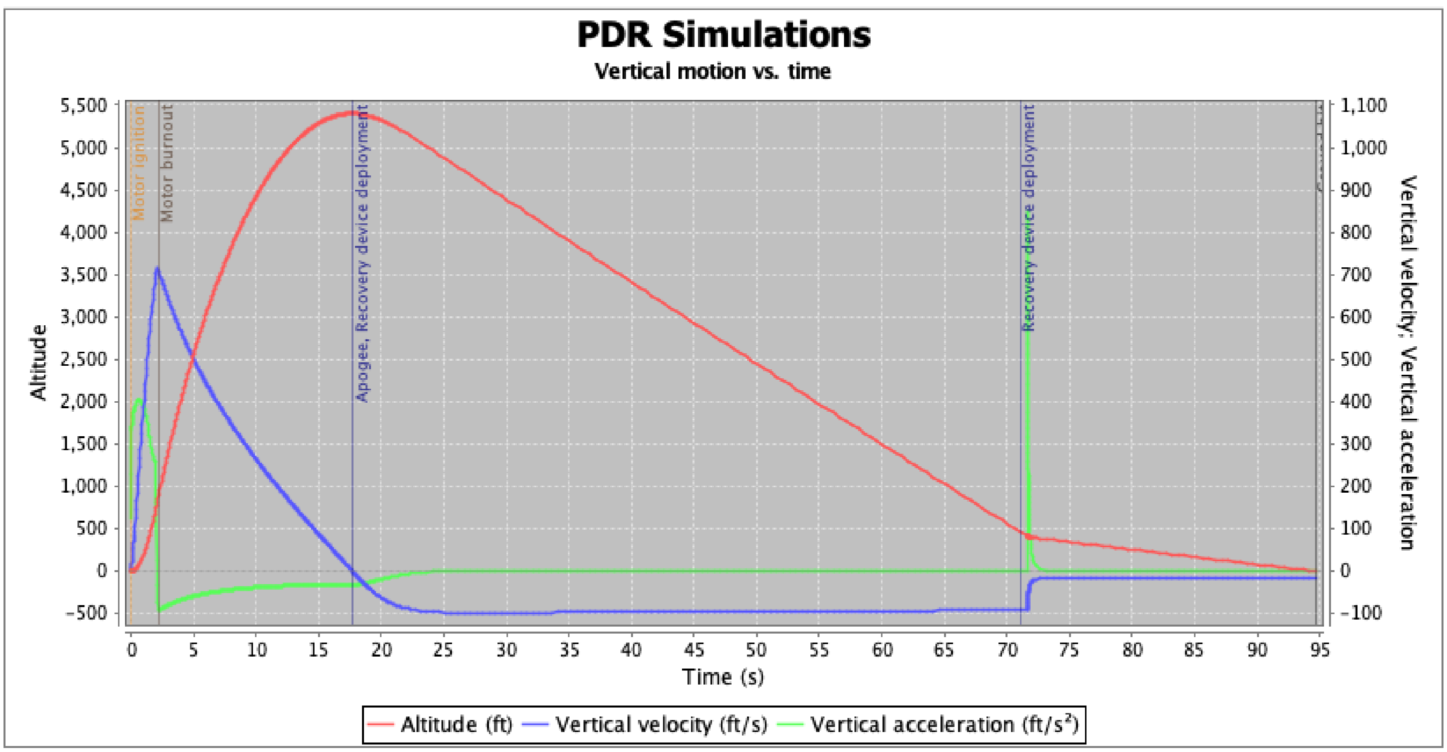
The mission performance predictions were made by creating a model of the current design of the rocket by running simulations in OpenRocket.

3.7.1 Flight Profile Simulations and Altitude Predictions

Conditions were chosen to reflect the anticipated conditions of the launch site at Huntsville.

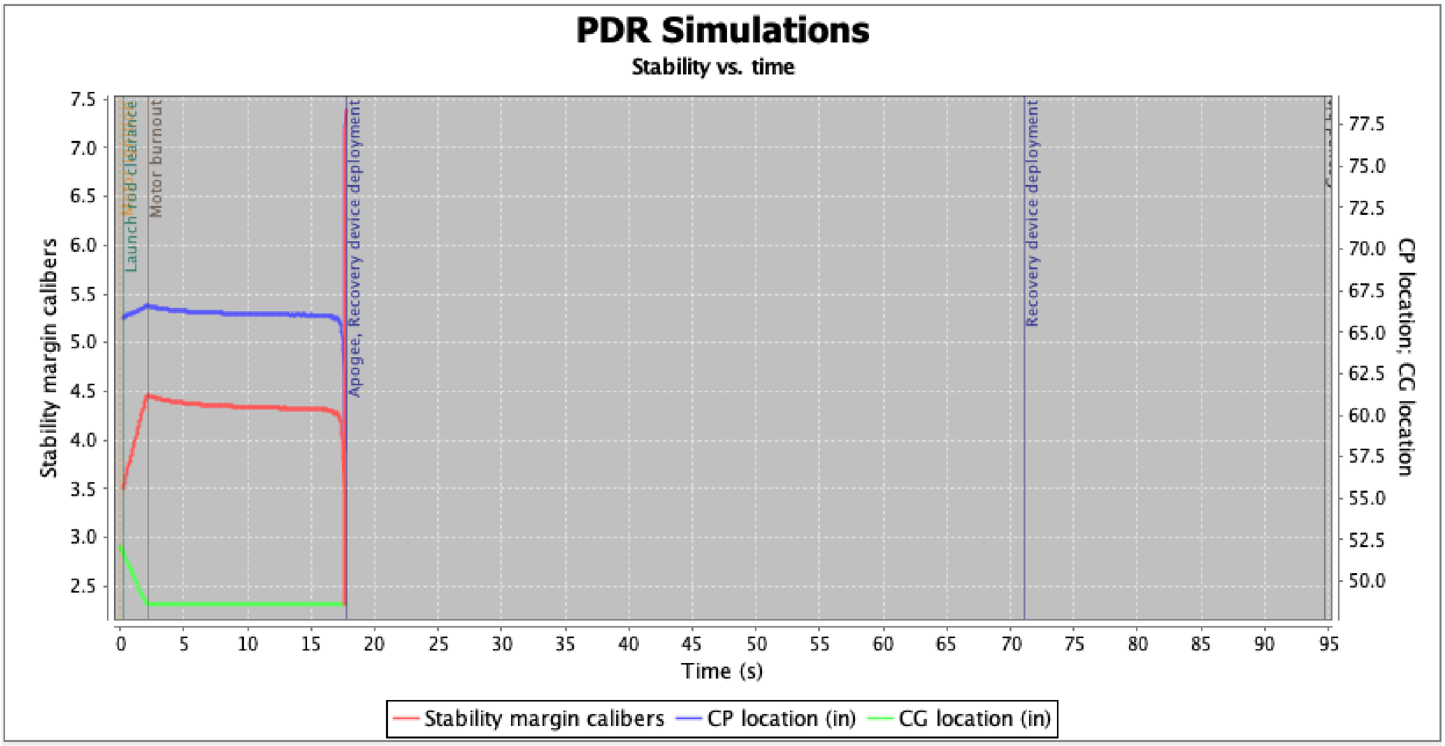
Condition	Value
Altitude above sea level	680 feet
Latitude, Longitude	34.7 degrees, -86.7 degrees
Temperature	70 degrees Fahrenheit
Wind Speed	5.0 – 7.0 mph
Pressure	1.013 bar
Launch angle	5 degrees

The charts below show the results of our simulations for the K805. The rocket leaves the rail with a velocity of 78.1 ft/sec reaching an apogee of 5300ft. At apogee the primary MARSA33LHD fires the drogue chute. At 600 ft, the primary MARSA33LHD fires the main charge deploying the main chute. The rocket lands with a landing speed of 18.7 ft/sec. The descent time from apogee to landing is 77 seconds, well under the NASA limit of 95 seconds.



3.7.2 Center of Pressure and Center of Gravity

The Center of Pressure (CP), Center of Gravity (CG), and stability margin were determined using OpenRocket. The CG with the motor is 52.0 in from the tip of the nose cone. The CP is 66.1 in from the tip of the nose cone. The static stability with the motor installed at rail exit is 3.5 calibers. The static stability margin just prior to burnout is 4.3 calibers.



3.7.3 Landing Predictions

The kinetic energy was calculated using Equation 3.1 where m is the mass of the rocket and v is its velocity. All landing kinetic energies come in well under the NASA limit of 75 ft-lbf.

$$KE = \frac{1}{2} M * V^2 \tag{3.1}$$

Section	Velocity (ft/s)	Weight (lbs)	Kinetic Energy (ft-lbf)
Booster	17.6	5.1	24.6
Avionics	17.6	1.4	6.7
Forward Bay	17.6	6.3	30.3

Energy at Landing

3.7.4 Drift Predictions

Wind Speed	Lateral Drift (ft)
0	1010.0
20	1954.0

3.8 Target Apogee Altitude Declaration

SLT17 declares 5200' AGL as our target apogee altitude. This is based on simulations of the rocket using Open Rocket along with experience gained in last year's program. We also have taken into account the 5-10 degree cant during launch and realistic build weight (epoxy and paint) not directly accounted for in the simulations.

4 Safety

4.1 Introduction

The main priority 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.

4.2 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, in addition to requirements set by NASA.. 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 the Lightstorm Research facility 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. Scouts over the age 14 will be assigned with the cutting and modification of rocket components.

4.3 Safety Briefings

The Safety Officer will be responsible for briefing the team of any possible risks that could occur throughout the design/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).

4.4 NAR/TRA Mentor

Tim Hoagland has agreed to mentor our team and accompany our team to all launches and Launch Week in Huntsville in April 2022. Our mentor from prior years, Ben Russell, has agreed to be a backup on-site mentor in case Mr. Hoagland cannot attend. Mr. Russell is part of the NAR range crew at launch week, so he will be on-site in Huntsville, and he is familiar with SLT17. Both Mr. Hoagland and Mr. Russell have active Level 3 certifications and are in good standing with the TRA and NAR. Their duties will include the purchase, storage, transportation and installation of rocket motors and black powder for ejection charges. Mr. Hoagland is already actively engaged, and has helped the team tremendously already during the proposal stage.

Mr. Hoagland 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.

4.5 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.

4.6 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 countdown 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.

4.7 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 timse 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 a 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."

4.8 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."

4.9 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

4.10 Team Member Agreement to Comply with Safety Rules

All team members have signed 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.

4.11 Preliminary Check Lists

SLT17 will utilize checklists during final assembly and flight of our rocket. This will assure we consistently apply best practices and consistent safety controls during flight operations every time. The following is our preliminary checklist, which will be updated and finalized prior to FRR.

4.11.1 Final Assembly

- ❑ Check airframe for damage
- ❑ Check payload
    - ❑ Wiring properly in place
    - ❑ No damage
    - ❑ LiPO properly padded, labeled, plugged in, and secured
- ❑ Check motor casing for damage
- ❑ Check motor mount
- ❑ Check recovery system
    - ❑ Recovery harness connected to drogue chute
    - ❑ Recovery harness connected to main parachute
    - ❑ Recovery harness between lower section and central section
    - ❑ Recovery harness between upper section and central section
    - ❑ Avionics bay
        - ❑ Altimeters in place and secured
        - ❑ Batteries in place, plugged in, padded, labeled, and secured
        - ❑ Ejection charges in place and secured
        - ❑ Electric matches threaded to ejection charges, in place, secured, have continuity
    - ❑ Parachute protectors between ejection charges and parachutes in place
    - ❑ Main parachute checked for damage/imperfections

- ❑ Drogue parachute checked for damage/imperfections
- ❑ Main parachute properly folded and in place
- ❑ Drogue parachute properly folded in place

❑ Attach rocket components with proper fasteners (bolts or shear pins)

❑ Check all connections again

❑ Insert motor into motor casing

________________________ ________________________

Safety Officer Range Safety Officer

4.11.2 Launch Procedures

❑ Ensure all unnecessary personnel are in a safe location for launch

❑ Place rocket on launch rails

❑ Have qualified personnel place electronic igniter

❑ Have all personnel move to launch positions

❑ Check with range safety officer to ensure range is all clear and ready for launch

________________________ ________________________

Safety Officer Range Safety Officer

4.12 Risk Definitions

The severities and likelihoods of the various risks are given in the Risk Assessment Code (RAC) format from the Student Launch Handbook. The possible values for severity are:

- 1 – Catastrophic
- 2 – Critical
- 3 – Marginal
- 4 – Negligible

The possible values for likelihood are:

- A – Frequent
- B – Probable
- C – Occasional
- D – Remote
- E – Improbable

The risks in the following analysis have both a Pre-RAC value and a Post-RAC value. Pre-RAC refers to the combined severity and likelihood before mitigations are put in place, and Post-RAC is after the mitigations have been put in place. It is required that all Catastrophic and Critical risks have Post-RAC probabilities of either Remote or Improbable.

4.13 Preliminary Personnel Hazard Analysis

Our primary risk concern will always be the safety of all personnel involved with the project. The risk team members and the public can take place during both fabrication, launch and flight of the rocket. The secondary component for a successful project completion will be the meeting of deadlines.

Risk	Probability	Severity: Effect	Prevention
Injury during fabrication	Low	High: 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	High: Minor to serious injury or property damage	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	High: 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	High: Minor burns	Follow all recovery safety procedures
Motor mount failure	Low	High: 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

Hazard	Effect	Cause	Mitigation	Pre-RAC	Post-RAC

Accidental black powder ignition	Moderate injury (burns).	Improper handling or storage of black powder.	Black powder will be properly stored and handled only by our mentor.	2D	2E
Power tools	Minor to severe injury.	Improper use. Distractions	All team members involved in the fabrication of the rocket will be briefed on how to safely use all power tools. We will follow BSA regulations on power tool usage.	2D	2E
Fiberglass	Minor to moderate injury.	Fiberglass dust on skin, in eyes or in lungs.	Gloves and masks will be worn when working with fiberglass. Any dust will be cleaned up.	3C	3E

4.14 Preliminary Launch Vehicle Failure Modes and Effects Analysis

4.14.1 Ignition

Failure	**Potential Effects**	**Causes**	**Mitigations**	**Pre-RAC**	**Post-RAC**
Engine fails to ignite	Recycle or delay of launch	Bad igniter	None	4C	4C
Engine “chuffs” prior to launch	Lower than nominal altitude	Improper igniter installation Improper motor storage	Assure igniter installed in full accordance with manufacturer instructions Assure motor stored in original sealed packaging in cool dry area until ready for assembly and use	3C	4E

4.14.2 Stable Powered Flight

Failure	**Potential Effects**	**Causes**	**Mitigations**	**Pre-RAC**	**Post-RAC**
Rocket goes off course	Failure to reach desired altitude.	Launch rail is not vertical.	Check launch rail direction with post level before launch.	1C	1E
	Vehicle flies into crowd.	Incorrectly aligned fins or insufficient velocity at rail exit.	Use ground based and in-flight test to ensure the fins are aligned, assure sufficient rail exit velocity.		
	Rocket lands in the wrong place.	Offset CG.	Verify CG during design and also by measuring as-built rocket		
	Failure to reach sufficient altitude for recovery system.	Misaligned engine/engine mount.	Purchase pre-cut components (using laser cutter) for motor mount.		

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
Internal damage	Damage to rocket. Experiment failure. Recovery system failure.	High acceleration, insufficient build strength, motor failure	Ensure all points of failure are strong enough to withstand the maximum expected acceleration with a margin of safety. Use liberal epoxy fillets on fins and motor mount.	2D	2E
Engine ejects from rocket	Falling debris.	Insufficient motor retention or thrust ring.	Use metal screw-type motor retainer.	1D	1F
	Damage to rocket. Engine flies into crowd.	Engine mount fails.	Ensure the engine mount is strong enough to withstand the force from the engine.		

4.14.3 Recovery - Drogue Deployment

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
Recovery harness breaks	Falling debris.	Too much black powder.	Repeated tests of the ejection system on the ground.	1D	1E
	Destruction of rocket.	Damaged recovery harness. Rocket is moving too fast at deployment.	Inspect the recovery harness before launch. Choose the engine and ballast and program the recovery electronics such that the rocket is moving at a safe velocity when the parachute deploys.		

Ejection charge doesn't ignite	Drogue chute doesn't deploy - see below.	Bad igniter. Altimeters not turned on. Altimeters not programmed correctly. Batteries not charged. Wires come loose. Batteries come loose. Black powder not properly secured before launch.	Redundant igniters and ejection cups. Follow pre-launch checklist. Have the mentor, RSO, and safety officer inspect the ejection system before launch.	1C	1E
Ejection charge fires but drogue chute doesn't deploy	Rocket is moving too fast for main chute to deploy.	Not enough black powder.	Repeated tests of the ejection system on the ground.	1D	1E
	Falling debris.	Too much friction.	Repeated tests of the ejection system on the ground.		

4.14.4 Recovery - Main Deployment

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
Recovery harness breaks.	Falling debris.	Too much black powder. Harness too short. Harness insufficiently strong.	Repeated tests of the ejection system on the ground.	1D	1E
	Destruction of rocket.	Damaged recovery harness.	Inspect the recovery harness before launch.		
		Rocket is moving too fast.	Choose the size of the drogue chute such that the rocket is moving at a safe velocity when the main parachute deploys.		
Ejection charge doesn't ignite	Parachute doesn't deploy - see below.	Bad igniter. Altimeters not turned on. Altimeters not programmed correctly. Batteries not charged. Wires come loose.	Redundant igniters and ejection cups. Follow pre-launch checklist.	1C	1E

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
		Batteries come loose. Black powder not properly secured before launch.	Have the mentor, RSO, and safety officer inspect the ejection system before launch.		
Ejection charge fires but parachute doesn't deploy	Destruction of rocket.	Not enough black powder.	Repeated tests of the ejection system on the ground.	1D	1E
	Falling debris.	Too much friction.	Repeated tests of the ejection system on the ground.		

4.14.5 Landing

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
Rocket hits the ground too hard	Damage to rocket or injury to people.	Parachute is too small.	Run simulations to ensure the parachute is the correct size for the rocket.	2D	2E
Rocket lands in undesirable	Rocket falls on people.	Wind.	Don't launch when wind speed high,	2C	2D

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
place (e.g. on people, on a car, on a road, in a pond, etc.)			angle the launch rail to account for wind.		
	Damage to cars, etc.	Bad launch angle.	Check launch rail angle before launch.		
	Damage to rocket.	Drogue chute too big.	Use the smallest possible drogue that will allow safe deployment of the main chute.		
	Electronics destroyed and data lost (rocket lands in pond)	Hazards at launch site.	Choose suitable launch sites for rocket size.		

4.14.6 Payload Electronics

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
Data collection failure (Raspberry Pi data logger)	Payload fails to meet experiment criteria.	Programming error.	The payload program will be tested on the ground and in test flights; every part of the program will be reviewed by multiple people.	3C	3E

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
	Tracking system failure.	Programming failure. Rocket too far from receiver. Interference.	Ground and in-flight tests will ensure the transmitter and receiver have sufficient range.		

Failure	Potential Effects	Causes	Mitigations	Pre-RAC	Post-RAC
Physical failure	All other payload electronics failures.	Batteries come loose. Wires come loose. Batteries not charged	Perform ground tests to find out how long the batteries will last; keep track of how long each battery has been used	2D	2E

4.15 Environmental Risks

4.15.1 Environmental Impacts on Rocket

Hazard	Effect	Mitigation	Pre-RAC	Post-RAC

Direct sunlight/high temperatures	Overheating of electronic components, affecting efficiency. Possible distortion of airframe.	Assemble and store rocket in shaded area.	3D	3E
Humidity	Swelling of airframe components. Wet rocket and electrical components	Inspect rocket before launch for airframe swelling. Electronics should be sealed to protect from water	3D	3E

Hazard	**Effect**	**Mitigation**	**Pre-RAC**	**Post-RAC**
Wind	Rocket potentially flies off trajectory. Drifts farther after parachute deployment.	Check simulations and flights for stability. Minimize time on main parachute to ensure minimal drift while maintaining safe landing speed.	2C	2E

4.15.2 Rocket's Impacts on Environment

Risk	**Cause**	**Effect**	**Mitigation**	**Pre-RAC**	**Post-RAC**
Grass fire	Rocket crashes while motor is still burning.	Burnt vegetation. Potential injury.	Fire extinguishers shall be ready during launch.	3D	3E

Scattered rocket components	Rocket breaks during flight. Recovery system fails.	Harmful chemicals and materials released into the environment. Negative impacts to wildlife and vegetation.	See Preliminary Failure Modes and Effects Analysis above.	2D	2E

Risk	Cause	Effect	Mitigation	Pre-RAC	Post-RAC
Harming wildlife	Animals wander onto the launch field.	Potential injury.	Inspect launch field for potential wildlife.	2D	2E

4.16 Project Risks

Risk	**Likelihood**	**Impact**	**Mitigation**
Late completion of reports and presentations	Low	High	Set early deadlines and have multiple people working on sections in order to ensure completion.
Team members dropping out	Medium	High	Ensuring all members are able to commit time to the team. Making sure all roles can be filled by someone else if needed.
Funding shortages	Medium	Medium	Ensure that budget is spent wisely and find sponsors and individual donors to help close gaps.

Rocket destroyed during transport, fabrication, or launch.	Low	High	Take proper precautions to reduce risk, including proper storage. Follow all checklists for inspection of rocket and launch procedure.

Risk	Likelihood	Impact	Mitigation
Failure to complete experiment requirement	Low	High	Experimental flights with proof-of-concept rocket as well as scaling of experiment to subscale and final rockets to ensure design works.

5 Payload Criteria

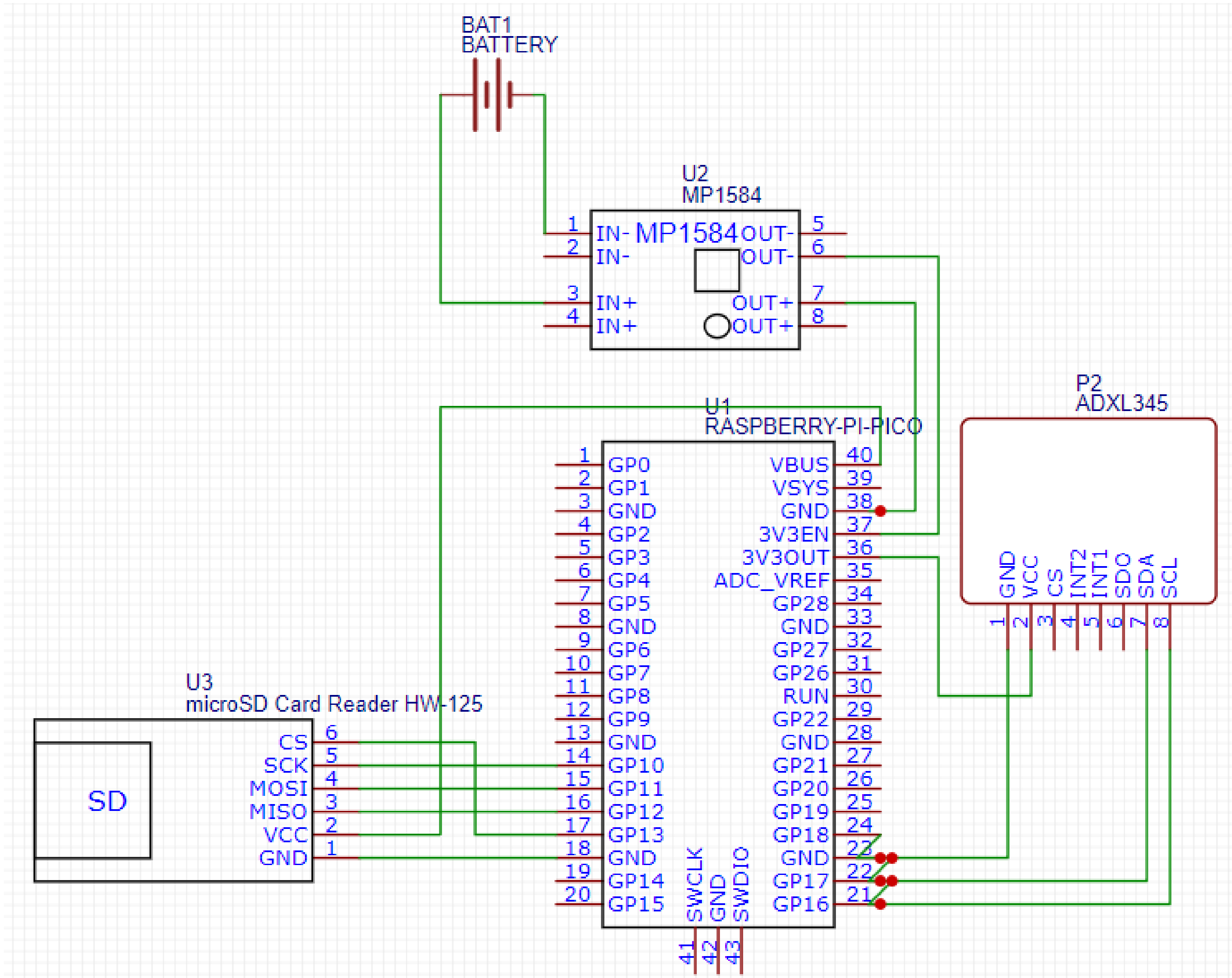
5.1 Overview

Our goal for the science payload is to capture and read the vibrations given off by the rocket at different points during flight. To read this information, we will use a 3-Axis accelerometer connected to a Raspberry Pi Pico. When vibrations are detected, the Raspberry Pi will send the data received from the accelerometer to a MicroSD pre-installed into the system.

This technology could be used in conjunction with the second part of our experiment to either generate electricity using piezoelectric generators, or to suppress vibrations within the rocket as a means of payload protection. The data we collect will help us determine the systems required to perform either of our next experiments next year. The vibration data can be used to sync with piezoelectric generators, or to create opposite vibrations within the rocket, therefore reducing the payload vibration during ascent. If we decide to use piezoelectric generators to harvest electrical energy, the applications for larger scale rockets could be used to improve many systems within the rocket. While we do not expect a large amount of energy from these generators, it may be enough to power a small circuit. For larger rockets, we expect vibrations to be higher, therefore having more kinetic energy that we can convert to electrical energy. This energy could be used as another way to divert excess energy from the rocket into its subsystems. If we decide to reduce vibrations in the rocket, it could be used to minimize damage to internal rocket parts or payloads, reduce dynamic loads on rocket components, and possibly to minimize drag. During ascent, when the rocket is accelerating, the vibrations could be damaging internal rocket systems and payloads. If these vibrations are reduced or removed entirely, these systems may not end up damaged. In addition, less vibrations could minimize drag for the rocket.

This experiment also builds on our successful 2018-2019 SLI payload, where we generated small amounts of electricity using thermo-electric generators. We measured the electricity generated from these generators and logged it to an Arduino. This year's experiment will build on the knowledge of reducing wasted energy during the rocket flight.

A diagram of the electronics of our experiment is below.



5.2 *Measurement System*

In order to quantify the vibrations from this experiment, we will attach our accelerometer to a Raspberry Pi Pico and place it in the nose cone of the rocket, the farthest point from the center of gravity, therefore maximizing vibrations from the rocket. Preliminary system components:

- ADXL345 3-axis accelerometer (2.5V, 23 μA in use, 0.1 μA standby, 9g)
- Raspberry Pi Pico microcontroller (3.3V, ~100 mA, 9 g)
- MicroSD Card reader HW-125 (3.3V, X mA, ~11 g)

- LiPo battery (3.7 V, 2000 mAhr, 34 g)
- MP1584 buck dc-dc converter (17g)

The Raspberry Pi will need a battery that can power it for up to 3 hours depending on wait time before launch. Based on the estimated power consumption of the Raspberry Pi Pico, the minimum battery size must be around 375 mAh. A 2000 mAhr LiPo battery weighing 34g will power the measurement system, and should be able to power the system for over 16 hours. The Raspberry Pi along with the rest of the experiment will be housed in a 3d printed part contained in the nose cone. While the Raspberry Pi will be in the bottom of the nose cone, the accelerometer will be placed at the top, both to maximize vibrations and to reduce possible disconnection and misreading of data.

5.3 Payload Design Alternatives

Component	**Pros**	**Cons**
Wire		
Teflon Wires	-Well insulated -Heat resistant	Expensive
PVC Wires	-Less Expensive	-Low melting point
Connection		
Solder	-Accessible	
Screw Terminals		-Not Easily Accessible
Controller		
Arduino	-Less Expensive -Lower power consumption	-Low Performance
RaspberryPi	-High Performance -Simple -Necessary performance to sample accelerometers at required 3.2 kHz rate	-Higher power consumption
Accelerometer		
ADXL345	-Very inexpensive -Simple -Small -Has a configurable interrupt to use for launch detection	-No gyroscope
MPU6050	-Small -Has a gyroscope	-More Expensive -No interrupt

6 Project Plan

6.1 Requirements Compliance

6.1.1 Minimum Verification Plans

Requirement	Verification Plan	Test(s) If needed
1. General Requirements		
1.1. Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). Teams will submit new work. Excessive use of past work will merit penalties.	Students will do all of the work needed to complete the project with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches which will be done by the team mentor.	N/A
1.2. The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	The team will maintain a project plan and budget.	N/A
1.3. Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during Launch Week due to security restrictions. In addition, FN's may be separated from their team during certain activities on site at Marshall Space Flight Center.	SLT17 has no FN team members.	N/A
1.4. The team must identify all team members who plan to attend Launch Week activities by the Critical Design Review (CDR). Team members will include: 1.4.1 Students actively engaged in the project throughout the entire year. 1.4.2 One mentor (see requirement 1.13). 1.4.3 No more than two adult educators.	• We will identify all team members who will be attending launch week by the CDR. • Tim Hoagland is our mentor and he will be attending launch week. • There will not be more than two adult educators on the team.	N/A

1.5. The team will engage a minimum of 250 participants in direct educational, hands-on science, technology, engineering, and mathematics (STEM) activities. These activities can be conducted in-person or virtually. To satisfy this requirement, all events must occur between project acceptance and the FRR due date. A template of the STEM Engagement Activity Report can be found on pages 129-132 of the NASA handbook.	All of our STEM events and support will occur between project acceptance and the FRR due date. We will engage at least 250 participants and submit the required documentation.	N/A
1.6. The team will establish and maintain a social media presence to inform the public about team activities.	The team has already established and is regularly updating Twitter, Instagram, and Facebook, as well as the website.	N/A
1.7. Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient. Late submissions of milestone documents will be accepted up to 72 hours after the submission deadline. Late submissions will incur an overall penalty. No milestone documents will be accepted beyond the 72-hour window. Teams that fail to submit milestone documents will be eliminated from the project.	The team will email all deliverables to the NASA project management team by the deadline specified in the handbook.	N/A
1.8. All deliverables must be in PDF format.	All deliverables will be in PDF format.	N/A
1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections	A table of contents will be provided for all sections and subsections.	N/A
1.10. In every report, the team will include the page number at the bottom of the page.	Page numbers will be included at the bottom of every report.	N/A

1.11. The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort. 1.12. Teams will track and report the number of hours spent working on each milestone.	The team will provide the necessary equipment needed to support the teleconference. On launch day, the team will use the launch pad and rail provided by the SLI provider. The team acknowledges that the pads will be canted 5 to 10 degrees away from the crowd. The exact cant will be determined on launch day by range personnel.	Run flight simulations and conduct full scale test flight using the 5-10 degree cant that will be used on launch day, so that vehicle performance can be determined under actual launch day conditions.
1.13. Each team must identify a “mentor.” A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certifica- tion, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to Launch Week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend Launch Week in April.	SLT17’s mentor is Tim Hoagland, who meets all requirements of 1.13.	N/A
1.14. Teams will track and report the number of hours spent working on each milestone.	SLT17 is logging hours spent working on each milestone	N/A
2. Vehicle Requirements 2.1. The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on their competition launch will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.	An apogee altitude target of 5200’ AGL is hereby declared by SLT17.	Simulations and full scale test flight will be used to test how close to the altitude goal the rocket gets.

2.2. Teams shall identify their target altitude goal at the PDR milestone.	The team has identified their target altitude of 5200' AGL in this document and in the PDR Flysheet.	Target altitude based on Open Rocket simulations, and will also be validated by test flights of the rocket.
2.3. The vehicle will carry, at a minimum, two commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events (see Requirement 3.4). An altimeter will be marked as the official scoring altitude used in determining the Altitude Award winner. The Altitude Award winner will be given to the team with the smallest difference between the measured apogee and their official target altitude for their competition launch.	SLT17 is using two altimeters meeting requirements of 2.13. The team will identify which altimeter will be used for the recording of the official altitude.	The selected altimeter will read out the official altitude.
2.4. The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	Each altimeter will have its own screw switch for arming the altimeter. The switch will be accessible from the exterior of the rocket in the launch configuration on the pad.	The design of the rocket will provide external switch access via the switch band.
2.5. The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute. 2.5.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length. 2.5.2. Nosecone shoulders which are located at in-flight separation points will be at least 1⁄2 body diameter in length.	The team's launch vehicle will have 3 sections: Nose cone, payload and booster. The sections will be tethered together and will not be recovered separately. The coupler/air frame shoulders are 2 body tube diameters in length. The nose cone shoulder is 1 body tube diameter in length. Each altimeter will have its own dedicated battery power supply.	N/A
2.6. The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.		N/A

2.7. The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a **minimum** of 2 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.	All batteries will be sized to provide at least 2 hours run time with the avionics fully active. The launch vehicle has been designed with sufficient strength and durability to be recoverable and reusable. The launch vehicle will use a drogue and parachute system to return.	N/A
2.8. The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated launch services provider.	The launch vehicle is capable of being launched with a standard 12-volt system. Manufacturer supplied initiators will be used.	N/A
2.9. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).		N/A
2.10.The launch vehicle will use a commercially available solid motor propulsion ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR). 2.10.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone. 2.10.2. Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment will not be approved. A penalty against the team's overall score will be incurred when a motor change is made after the CDR milestone, regardless of the reason.	Only commercially available APCP motors which have been certified by NAR or TRA will be used. The final motor choice will be declared at the CDR milestone. Any motor changes after CDR must be approved and will only be done for safety reasons. Changing the motor after CDR, will incur a penalty.	N/A
2.11. The launch vehicle will be limited to a single stage.	Only a single stage rocket will be designed and flown.	N/A
2.12. The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).	Our motor will be a K-class. Only manufacturer supplied initiators will be used.	N/A

2.13. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: 2.13.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews. 2.13.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank. 2.13.3. The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	Our vehicle has no pressure vessels	N/A
2.14. The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.		N/A
2.15. The launch vehicle will have a minimum thrust to weight ratio of 5.0 : 1.0.	The rocket is being designed and the motor is being selected to have a thrust-to-weight ratio of greater than 5.0 : 1.0	Verify through computations using estimated rocket weight (before construction) and as-built weight (after construction) along with official NAR thrust data for selected motor.
2.16. Any structural protuberance on the rocket will be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	Our rocket has no protuberances	N/A
2.17. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	The launch vehicle is being designed and the motor is being selected to provide velocity of at least 52 fps at rail exit.	Verify using Open Rocket simulations.

2.18. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data will be reported at the CDR milestone. Subscales are required to use a minimum motor impulse class of E (Mid Power motor). 2.18.1. The subscale model should resemble and perform as similarly as possible to the full-scale model; however, the full-scale will not be used as the subscale model. 2.18.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude. 2.18.3. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project. 2.18.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter flight profile graph(s) OR a quality video showing successful launch and recovery events as deemed by the NASA management panel are acceptable methods of proof. 2.18.5. The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter 100" length rocket your subscale shall not exceed 3" diameter and 75" in length.	The team will build and successfully launch a subscale model of the rocket before the CDR. The subscale will resemble and perform like the full scale. The subscale will have at least one recording altimeter to record the model's apogee. The subscale will be newly constructed rocket designed and built for this year's project; Altimeter flight data from the subscale flight will be included with the CDR as proof of flight.	Conduct subscale test flight, compare measured flight performance parameters against predicted values.

2.19. All teams will complete demonstration flights as outlined below. 2.19.1. Vehicle Demonstration Flight - All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown shall be the same rocket to be flown as their competition launch. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's abil- ity to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.). The following criteria shall be met during the full- scale demonstration flight: 2.19.1.1. The vehicle and recovery system will have functioned as designed. 2.19.1.2. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project. 2.19.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply: 2.19.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass. 2.19.1.3.2. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass. 2.19.1.4. If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight. 2.19.1.5. Teams shall fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances. 2.19.1.6. The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the competition launch flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.	We will comply with all of 2.19 requirements.	Conduct the flights as specified within the allowed timeframe.

2.19.1.7. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO). 2.19.1.8. Proof of a successful flight shall be supplied in the FRR report. Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. 2.19.1.9. Vehicle Demonstration flights shall be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight shall submit an FRR Addendum by the FRR Addendum deadline. 2.19.2. Payload Demonstration Flight - All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown shall be the same rocket to be flown as their competition launch. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria shall be met during the Payload Demonstration Flight: 2.19.2.1. The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair. 2.19.2.2. The payload flown shall be the final, active version. 2.19.2.3. If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required. 2.19.2.4. Payload Demonstration Flights shall be completed by the FRR Addendum deadline		

NO EXTENSIONS WILL BE GRANTED		
2.20. An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report. 2.20.1. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch. 2.20.2. Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly a final competition launch. 2.20.3. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.	The full scale rocket will be successfully launched in its final configuration and successfully recovered before the FRR. The following criteria will be met for a successful flight ● Recovery system must have functioned ● Must be a newly designed and built rocket for this year's project. ● The payload doesn't have to flown. If the payload isn't flown, its mass must be included and at the same location as the payload. ● Our payload does not change any of the external surfaces. ● The flight must be flown with the launch day motor. However, if the field doesn't support it, another motor may be used. ● After a successful flight, the vehicle will not be modified. ● Proof of the flight will be included in the FFR report. ● Demonstration flight will be completed before the FFR.	Conduct and analyze test lights as specified without the allowed timeframes.
2.21. The team's name and Launch Day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	The team's name and launch day contact information will on the rocket airframe on launch day	

2.22. All Lithium Polymer batteries will be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	We will properly protect, make brightly colored, and mark as a fire hazard all LiPO batteries.	N/A
2.23. Vehicle Prohibitions 2.23.1. The launch vehicle will not utilize forward firing motors. 2.23.2. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, Metal-Storm, etc.) 2.23.3. The launch vehicle will not utilize hybrid motors. 2.23.4. The launch vehicle will not utilize a cluster of motors. 2.23.5. The launch vehicle will not utilize friction fitting for motors. 2.23.6. The launch vehicle will not exceed Mach 1 at any point during flight. 2.23.7. Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast). 2.23.8. Transmissions from onboard transmitters, which are active at any point prior to landing, will not exceed 250 mW of power (per transmitter). 2.23.9. Transmitters will not create excessive interference. Teams will utilize unique frequencies, hand- shake/passcode systems, or other means to mitigate interference caused to or received from other teams. 2.23.10.Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of light- weight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	We fully comply with all requirements in 2.23 by design	N/A
3. Recovery System Requirements		

3.1. The full scale launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO. 3.1.1. The main parachute shall be deployed no lower than 500 feet. 3.1.2. The apogee event may contain a delay of no more than 2 seconds. 3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.	The rocket will be designed with dual deployment recovery. The drogue will be released at apogee and the main at 600 feet. The back up apogee event will be 1 second after apogee and backp main event will be at 500 feet. We will not use motor ejection.	N/A
3.2. Each team will perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full scale vehicles.	All deployment charges will be ground tested prior to the subscale and full scale flights.	Ground ejection tests will be performed using the selected charge sizes.
3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	The rocket's recovery system will be designed such that no section will have a kinetic energy greater than 75 ft-lbf.	Calculate the maximum laning kinetic energy of each section.
3.4. The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	The rocket's recovery altimeters will be completely independent of any payload electrical circuits,	N/A
3.5. Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	The rocket will have dedicated and independent power supplies for both recovery altimeters. The batteries will be commercially-available LiPO types.	N/A
3.6. Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Once the screw on the screw switch has been fully turned down, it is locked in the On position for launch.	N/A
3.7. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	The arming switches are locking and cannot be disarmed due to flight forces.	N/A

3.8. The recovery system electrical circuits will be completely independent of any payload electrical circuits.	The recovery system circuits will be completely independent of all payload circuits.	N/A
3.9. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Removable shear pins will be used for the main and drogue parachute compartments.	Maximum drift computations will ensure that drift stays below 2500’.
3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads.	The recovery system has been designed to land the rocket within a 2,500 foot radius of the launch pad.	Maximum descent time will be computed to ensure compliance with this requirement.
3.11. Descent time of the launch vehicle will be limited to 90 seconds (apogee to touch down).	The recovery system has been designed to land within 90 seconds of apogee.	N/A
3.12. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver. 3.12.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device. 3.12.2. The electronic tracking device(s) will be fully functional during the official competition launch.	The electronic tracking device will be located in the nose cone. Only one device is required as the pieces of the rocket are tethered The electronic tracking device will be fully functional on launch day.	

3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing). 3.13.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device. 3.13.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics. 3.13.3. The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system. 3.13.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics	The recovery electronics will be located in a seperate section from the tracking electronics.	N/A
4. Payload Experiment Requirements 4.1. High School/Middle School Division – Teams may design their own science or engineering experiment or may choose to complete the College/University Division mission stated below. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	We are a High School/Middle School team and have chosen to do our own payload.	N/A
4.2. College/University Challenge – Teams shall design a payload capable of autonomously locating the launch vehicle upon landing by identifying the launch vehicle's grid position on an aerial image of the launch site without the use of a global positioning system (GPS). The method(s)/design(s) utilized to complete the payload mission will be at the teams' discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety.	Sections 4.2 - 4.3 do not apply to us.	N/A

4.3. Launch Vehicle Landing Zone Mission Requirements 4.3.1. The dimensions of the gridded launch field shall not extend beyond 2,500 feet in any direction; i.e., the dimensions of your gridded launch field shall not exceed 5,000 feet by 5,000 feet. 4.3.1.1. Your launch vehicle and any jettisoned components must land within the external borders of the launch field. 4.3.2. A legible gridded image with a scale shall be provided to the NASA management panel for approval at the CDR milestone. 4.3.2.1 The dimensions of each grid box shall not exceed 250 feet by 250 feet. 4.3.2.2 The entire launch field, not to exceed 5000 feet by 5000 feet, shall be gridded. 4.3.2.3 Each grid box shall be square in shape. 4.3.2.4 Each grid box shall be equal in size, it is permissible for grid boxes occurring on the perimeter of your launch field to fall outside the dimensions of the launch field. Do not alter the shape of a grid box to fit the dimension or shape of your launch field. 4.3.2.5 Each grid box shall be numbered 4.3.2.6 The identified launch vehicle's grid box, upon landing, will be transmitted to your team's ground station. 4.3.3. GPS shall not be used to aid in any part of the payload mission. 4.3.3.1. GPS coordinates of the launch vehicles landing location shall be known and used solely for the purpose of verification of payload functionality and mission success. 4.3.3.2. GPS verification data shall be included in your team's PLAR. 4.3.4. The gridded image shall be of high quality, as deemed by the NASA management team, that comes from an aerial photograph or satellite image of your competition launch field. 4.3.4.1. The location of your launch pad shall be depicted on your image and confirmed by either the NASA management panel for those flying in Huntsville or your local club's RSO. (GPS coordinates are allowed for determining your launch pad location).	Section 4.3 does not apply to us	N/A

4.3.5. No external hardware or software is permitted outside the team's prep area or the launch vehicle itself prior to launch.		
4.4. General Payload Requirements 4.4.1. Black Powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations. 4.4.2. Teams shall abide by all FAA and NAR rules and regulations. 4.4.3. Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement at the CDR milestone by NASA. 4.4.4. Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS. 4.4.5. Teams flying UASs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs). 4.4.6. Any UAS weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	We fully comply by 4.4 by design	N/A
5. Safety Requirements		
5.1. Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	The team will develop and use a safety checklist. The final checklist will be included with the FFR and used at any launch.	The checklist will be used for our subscale and full scale test flights. Any problems noted will be fixed prior to flight week.

5.2. Each team must identify a student safety officer who will be responsible for all items in section 5.3.	The team has identified the safety officer.	N/A
5.3. The role and responsibilities of the safety officer will include, but are not limited to: 5.3.1. Monitor team activities with an emphasis on safety during: 5.3.1.1 Design of vehicle and payload 5.3.1.2 Construction of vehicle and payload components 5.3.1.3 Assembly of vehicle and payload 5.3.1.4 Ground testing of vehicle and payload 5.3.1.5 Subscale launch test(s) 5.3.1.6 Full-scale launch test(s) 5.3.1.7 Competition Launch 5.3.1.8 Recovery activities 5.3.1.9 STEM Engagement Activities 5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities. 5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data. 5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	The safety officer(s) will meet or exceed all of the roles and activities listed in 5.3 - 5.3.4.	N/A
5.4. During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	The team will abide by all of the rules and guidance of the local rocketry club's RSO. The team will contact the local club to discuss their flight test requirements.	N/A
5.5. Teams will abide by all rules set forth by the FAA.	The team will abide by all of the FAA rules which govern this contest..	The checklist and safety briefings will be structured to achieve

		compliance with all applicable FAA rules. We will also only fly at sites with valid FAA waivers.

7 Educational Engagement

7.1 NASA's Mission

The NASA Student Launch is a research-based, competitive and experiential exploration project that provides relevant and cost-effective research and development to support the Space Launch System, or SLS. The project involves reaching a broad audience of colleges and universities across the nation in an eight-month commitment to design, build, and fly payloads or vehicle components that support SLS. Participation is limited to U.S. Institutions. The project is built around a NASA mission, not textbook knowledge. NASA through the education outreach component is looking to ensure that an awareness about STEM and Rocket missions is created and an ongoing interest is generated and sustained.

As per the requirement of the student NASA SL education outreach, we need to engage a minimum of 250 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement Activity Report, by FRR (Flight Readiness Review). An educational engagement activity report needs to be completed and submitted within two weeks after completion of each event. The educational engagement activity report template is provided in the NASA SL handbook. All the events need must occur between project acceptance and the FRR due date.

Educational Engagement Award: Awarded to the team that is determined to have best inspired the study of rocketry and other science, technology, engineering, and math (STEM) related topics in their community. This team not only presented a high number of activities to many people, but also delivered quality activities to a wide range of audiences.

7.2 SLT17 Mission

Boys Scouts of America (BSA) introduced the STEM/NOVA Program in 2012 as a focused program to create STEM awareness and outreach. In 2014, Troop 17 became one of the first troops in Virginia to offer this program and rocketry challenges fit very well within the BSA and Troop 17's overall STEM mission.

Troop 17 will design, generate and conduct STEM related education workshops and sessions to promote awareness about STEM activities and with specific focus on our NASA Student Launch project, rocket and the STEM principles associated with it.

The STEM Education outreach will be conducted through workshops, hands on activities, educational articles and other appropriate mediums.

The target audience will be the community at large with focus on Local - Scouting Organization, Schools, Faire, Library and National – STEM & Rocket related topics on Social Media. We plan to target age groups from

Elementary grades to High School, Under- Privileged students, Educators, Parents and Women to create an inclusive outreach in the community.

High Level design of the education outreach is being aligned to NASA's categorization of the outreach. We will design our outreach program based on the Education and Outreach from a direct and indirect interactions perspective.

7.3 Educational Engagement Plan

Troop 17 has laid out the initial engagement plan based on the key design parameters to ensure a successful education outreach.

- ✓ Types and medium of Education and Outreach Interactions
- ✓ Target Audience – Age, Gender, Community – Local & National
- ✓ STEM, Rocket, Troop 17's NASA SL Project
- ✓ Ability to timely execute the education activities
- ✓ Generate Sustainable STEM interest

Troop 17 has done an initial design and laid out the following activities as part of the Educational outreach based on the pros / cons, risks, and feasibility of conducting and executing the educational events/activities. This has been done keeping in focus our key design parameters.

- ✓ Identification of the Target Audience
- ✓ Categorization of the events based on the interactions.
- ✓ Age appropriate education topics
- ✓ Event appropriate education topics

Initial Interaction Categorization of Events and target audience is laid out below. This will be firmed up as we move forward.

Education		**Outreach**	
Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
Troop 17	Cub Scouts	Women's ESteam group	Boys' Life Magazine
Local BSA Troops	Girl Scouts	Middle & High School	
Girl Scouts Middle & High School High School	Local Library Elementary School	High School KidVention Science Event at Discovery Museum	Social Media

Here are the List of the Possible topics that will be covered. This is an initial list which will undergo modification.

- Troop 17's NASA SL Project overview and details
- Principles of Rocketry
- Explaining parts of the rocket (age appropriate)

- STEM related Science Experiment
- Materials & Component involved in the manufacturing of a rocket
- Overall processes of executing a similar project – Rocketry Design, Payload, Creative, Education and Business.

7.4 Education/Direct Interactions

7.4.1 Discovery Museum of Virginia Kid*Vention

7.4.2 Local BSA Units

Boy Scouts is the main part of the BSA Organization. Boy Scouting is a strong leadership, STEM and Fun focused program based on the age range from 11- 18 years of age.

Below is the initial list of local Boy Scouts troops that are being considered for the outreach.

Boy Scout	Contact	Number of Scouts	Status
		TBF	Open
		TBF	Open
		TBF	Open
		TBF	Open
		TBF	Open

The following activities will be undertaken. (This list needs to be completed)

Activities	Completion Date	Status
	TBD	Open
	TBD	Open
	TBD	Open
	TBD	Open
	TBD	Open
Measurement of the Outreach – Survey to measure the effectiveness	TBD	Open
Complete and Submit Educational Engagement Activity Report	Within 2 weeks of event	Open

7.4.3 Middle & High Schools in Charlottesville

Below is the initial list of middle and high schools that are being considered for the outreach based on the schools represented by the Troop 17 SLI Team members. We will plan to include other schools based on the availability of time and outreach needed.

School	Contact Coordinator	Number of Students	Status
Covenant School	Beau	TBF	Open
St. Anne's-Belfield	Alex	TBF	Open

The following activities will be undertaken.

Activities	Completion Date	Status
Contact school and get commitment for the events	9th Nov 2021	Open
Content identification and content preparation	TBD	Open
Conduct workshops/Session	TBD	Open
	TBD	Open
	TBD	Open
Measurement of the Outreach – Survey to measure the effectiveness	TBD	Open
Complete and Submit Educational Engagement Activity Report	Within 2 weeks of event	Open

7.4.4 Collaborative Educational Events with Other Nearby SL Teams

We have already been in contact with both the Piedmont Virginia Community College Student Launch Team (PSLT), which has 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. Possible events are participation in monthly sessions of Girls Geek Day sponsored by Charlottesville Women in Technology and in the PVCC's Family Space Exploration Day early next year. We will be working on the collaboration details and the nature of the engagements.

7.5 Education/Indirect Interactions

7.5.1 Cub Scouts

Cub Scouts is the foundation of the BSA Organization. Cub Scouting is an affirmative and fun focused program for youth grades 1-5 focused on character development, fun, and building an understanding of scouting to get ready to become a Boy Scout.

One of Troop 17's BSA STEM/Nova goals is to create awareness and provide STEM education for younger Scouts in the Charlottesville and nearby regions.

Troop 17 will be leveraging the resources and contacts within the local boys scouting organization to reach younger elementary school youth. The target audience for the educational outreach will be the local Cub Scout Pack/ Den Scouting youth.

Below is the initial list of local Cub Scouts packs that are being considered for the outreach.

Cub Scout	Contact	Number of Scouts	Status
Pack 222		TBF	Open
Pack 206	Kevin Bivins	TBF	Open

The following activities will be undertaken.

Activities	Completion Date	Status
Contact Cub Scout Pack Leader and share the education outreach initiative and get commitment for having their cub scout exposed to the STEM education (NASA SL Rocketry)	15th Nov'21	Open
Finalize the training structure relevant for Cub Scouts.	TBD	Open
Finalize the Schedule for Training – One Vs Multiple	TBD	Open
Plan for the Outreach	TBD	Open
Measurement of the Outreach – Number of Cub Scout Pack and Cub Scouts	TBD	Open
Measurement of the Outreach – Survey to measure the effectiveness	TBD	Open
Complete and Submit Educational Engagement Activity Report	Within 2 weeks of the event	Open

7.5.2 Local Girl Scouts

Girls Scout is a preeminent leadership development organization for girls with programs from coast to coast and across the globe. Girl Scouts offers every girl a chance to practice a lifetime of leadership, adventure, and success.

Troop 17 plans create STEM awareness and interest in the community of girls and help with the STEM mission of the Girls scout.

Below is the initial list of local Girls Scouts Troop that is being considered for the outreach. (The list needs to be prepared)

Girls Scout	Contact	Number of Scouts	Status
		TBF	Open
		TBF	Open
		TBF	Open
		TBF	Open
		TBF	Open

The following activities will be undertaken. (This list needs to be completed)

Activities	Completion Date	Status
	TBD	Open
	TBD	Open
	TBD	Open
	TBD	Open
	TBD	Open
Measurement of the Outreach – Survey to measure the effectiveness	TBD	Open

Complete and Submit Educational Engagement Activity Report	Within 2 weeks of event	Open

7.5.3 Local Boys & Girls Club of Central Virginia

The Boys & Girls Clubs of Central Virginia enables all young people, especially those who need us most, to realize their full potential as productive, responsible, and caring citizens.

Troop 17 plans create STEM awareness and interest among the community of boys & girls who need help and support. The following activities will be undertaken. (This list needs to be completed)

Activities	Completion Date	Status
	TBD	Open
	TBD	Open
	TBD	Open
	TBD	Open
	TBD	Open
Measurement of the Outreach – Survey to measure the effectiveness	TBD	Open
Complete and Submit Educational Engagement Activity Report	Within 2 weeks of event	Open

7.5.4 Library

Troop 17 will also look at the possibility of using the Local or surrounding area Libraries as a channel to carry out the educational outreach. We will reach out to the Libraries and plan the events.

7.6 Outreach/Indirect Interactions

7.6.1 Social Media

Social media is a great way to connect with current & future students, parents, faculty & staff, business & community partners, and the community at large.

Troop 17 will focus on leveraging the power of Social media to promote STEM awareness keeping in mind the safety aspects of online media as there are youths in our SL team. The key thought process is to deliver at least One (1) STEM or Rocket related topics through social media to increase the outreach locally and at a larger level.

The relevant age appropriate topics will be finalized, and contents prepared for the outreach.

We will have Facebook, Twitter, and Instagram accounts to deliver the outreach. It will also let other people know when and where the events will be taking place.

7.7 Educational Engagement Activity Reporting

7.7.1 Reporting Template

Troop 17 will complete and submit the Educational Engagement Activity report each time we conduct an educational engagement event which is needed as per the NASA's guidelines. This will be done within 2 weeks of the completion of the event.
School/Organization name:
Date(s) of event:
Location of event:
Instructions for participant count:
Education/Direct Interactions: A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket.
Education/Indirect Interactions: A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation**.**
Outreach/Direct Interaction: A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.
Outreach/Indirect Interaction: A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants:

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4				
5-9				
10-12				
12+				
Educators (5-9)				
Educators (Others)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)? Y N If yes, what group/organization?

7.7.2 Education Activity Recording

Troop 17 will create a process to record the attendance and all the aspects of the sessions conducted including the lessons learnt which will be applied to the future events/sessions.

7.7.3 Education Activity Survey

Troop 17 will create a process to carry out survey to measure the effectiveness of the educational activity.

7.8 Risk & Mitigation Plan

Troop 17 based on its experience has identified the risks associated with the education outreach and the mitigation plans.

Risks	Mitigation Plan	Risk Probability
Troop 17 SL Teams time availability	Focus on Weekend, After School Hours and Coordination with School management	High
Need for funding	Create a detailed funding plan	Medium
Lack of Attendance (Low Turnout)	✓ Have the management teams of the Groups being targeted to ensure attendance. ✓ Tie the workshops to requirements that a group must complete in scouting or other organizations	Medium
Kidvention event cannot take place before next summer because of possible indoor COVID restrictions	This is a well-attended annual event that was cancelled last year because of COVID and might not be able to take place in winter 2022 because of possible indoor COVID restrictions for large gatherings this coming year. We will fill in with other events as necessary	Medium to High

7.9 Additional Consideration points

These are some of the points Troop 17 has considered which will be incorporated as part of our program and as we continue to further strengthen our plan for the education there is a possibility of further points that will be included and executed on.

- Safety consideration for educational activities at all locations and processes.
- Detailed Project Plan for the Educational engagement
- Submission of the Educational Activity report.
- Electronic copies of the Educational Engagement form(s) and any lessons learned submitted prior to FRR and within two weeks of the educational engagement event

7.10 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.

7.10.1 Collaborative Educational Events with Other Nearby SL Teams

We have already been in contact with both the Piedmont Student Launch Team (PSLT) and they 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.

7.11 Project Schedule

The following is SLT17's schedule that demonstrates the feasibility of our plans and our ability to complete the deliverables on time. Note that the subscale and full scale qualification flights will take place by the dates shown below assuming that we have to resort to backup launch sites and dates, so they are worst case dates. Do not interpret this schedule as indicating that our first launch attempt will be on the dates shown.

Task / Milestone	**Start**	**End**
Team recruiting, Organization and Setup	16-July-2021	15-September-2021
RFP Released		18-August-2021
Proposal Writing	18-August-2021	20-September-2021
Payload Selection	22-August-2021	12-September-2021
Conceptual Design	29-August-2021	12-September-2021
Technical Proposal Writing	22-August-2021	20-September-2011
Proposal Submission		20-September-2021
Kickoff and PDR Q&A		07-October-2021

Website and Social Media Presence Established; Handle sent to NASA		21-October-2021
Preliminary Design	07-October-2021	25-October-2021
Prepare PDR Documents	18-October-2021	01-November-2021
PDR Report, Presentation, Flysheet Submission		01-November 2021
PDR Video Teleconferences	02-November-2021	23-November-2021
CDR Q&A		30-November-2021
Critical Design	23-November-2021	04-January-2022
Build Subscale	19-November-2021	02-January-2022
Subscale Launch		02-January-2022
Prepare CDR Documents	09-December-2021	03-January-2022
CDR report, Presentation, Flysheet Submission		03-January-2022
Freeze Design of Full Scale		03-January-2022
CDR Video Teleconferences	06-January-2022	26-January-2022
FRR Q&A		27-January-2022
Final Design of Full Scale	27-January-2022	8-February-2022
Full Scale Design Freeze		8-February-2022
Full Scale Rocket Production	25-January-2019	04-March-2022
Vehicle Demonstration Flight and Payload Demonstration Flight (may combine into a single flight pending NASA approval)		05-March-2022
Prepare FRR Documents	18-January-2022	07-March-2022
FRR Report, Presentation, Flysheet Submission		07-March-2022
FRR Video Teleconferences	09-March-2022	28-March-2022
Travel to Huntsville		20-April-2022
Launch Day		23-April-2022
Backup Launch Day		24-April-2022

Prepare PLAR Documents	25-April-2022	09-May-2022
Submit PLAR Documents		09-May-2022

8 Project Budget

8.1 Overview

The total cost for this project is estimated at an upper limit of $13,644. 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 Formula 98 rocket ($1158), and the subscale Formula 75 rocket ($290). We have estimated $100 expenses for a budget safety margin, based on prior years actual expenses and the fact that we expect fewer contingencies this year. We've also estimated an estimated $100 for miscellaneous rocket expenses.

Our budget for rocket expenses is based on the fact that we can re-use the GPS tracker and receiver used in previous years. However, we will need to purchase a new payload computer, payload sensors and other components, and potentially payload batteries, and these expenses are included in our budget. Also, some other items such as the MARSA33LHD primary altimeter, RRC3 backup altimeter, and LiPO batteries for the altimeters used in the past are in excellent shape and can be re-used this year.

8.3 Travel Expense

The largest cost category for SLT17 by far is travel-related expenses. We have included an estimate of $11,996 for travel. This includes the following items:

- Transportation: $5,376 - 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 $0.56 per mile (IRS estimates).
- Lodging: $3,200 - We estimate 8 rooms with at 3 or more people in each room, at $100 per night, for four nights in Huntsville.
- Food $3,420 - We estimate a per diem of $30/day for 6 days for 19 people (including team members and accompanying parents).

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.

Note that our transportation and lodging costs are relatively high because our team is composed of minors who require greater levels of adult supervision since they are under 18. This also is required to comply with BSA youth protection rules requiring two-deep leadership at all Scouting events. Our approach is to solve this by asking all team members to travel with at least one parent to accompany them. We will deal with situations where team members must travel without parents to Huntsville as special cases.

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 $631. 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 $13,644 to cover all expenses. So we will need to do a lot of fundraising and hopefully get gracious sponsors.

	No. of units	Cost / Unit				
Sources of Funds						
Uses of Funds						**Comments**
Total Uses			**13,354**	**290**	**13,644**	The biggest costs are travel-related
			Full Scale	**Sub Scale**	**Total**	
Rocket			**1,158**	**290**	**1,448**	
Full scale Formula 98	1	250	250		250	
Sub scale Formula 75	1	145		145	145	
Full scale reload - K805	3	115	345		345	
Sub scale reload - I600	2	50		100	100	
Full scale motor hardware - K805	1	179	179		179	
Sub scale motor hardware - I600	1	45		45	45	
Flight Computer - Marsa 33	1	199	199		199	Replace RCC2 with Marsa 33; works for both rockets
New Arduino	1	35	35		35	
Accelerometers and cables	1	50	50		50	
Safety Margin	1	100	100	0	100	Reduced from $500 estimated last year
			0	0	0	
Education			**200**	**0**	**200**	
Website			0	0	0	
Troop 17 website			0	0	0	

Educational Materials	1	200	200	0	200	General costs of material for educational activities
Design		1	0	0	0	
			0	0	0	
Travel			**11,996**	**0**	**11,996**	
Rooms 8 rooms @ $100/nt; 4 nights	32	100	3,200	0	3,200	Assume 8 families make it, for 3 nights (could be 4 nights)
Travel: 600 miles each way x $0.56/mi x 8 vehicles	**9,600**	**0.56**	5,376	0	5,376	19 people could be making the trip; assume 1 car/family, means 8 cars; we considered a bus, but determined the cost and lack of mobility was a problem; each family covered own travel costs
Food ($30/day x 6 days x 19 people)	114	30	3,720	0	3,720	
			0	0	0	
		Rooms	**Total**	**Adults**	**Youth**	
		1.0	2	1	1	Allen
		1.0	3	1	2	Brown
		1.0	2	1	1	Sanusi
		1.0	3	1	2	Yates
		1.0	2	1	1	Carter
		1.0	2	1	1	Smith
		1.0	2	1	1	Panicker
		1.0	3	1	2	O'Malley
		8.0	19	8	11	

8.5 Fundraising Plan

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

- First, we are contacting sponsors from previous years to see if they are willing to support us again this year.
- The Virginia Space Grant Consortium has indicated they might be willing to donate, and we are contacting them to try and secure their potential sponsorship.
- We are also contacting individuals who contributed in the past to try to obtain their support again this year.

- We may do other fundraisers, time and COVID permitting, such as yard work, car washes, and bake sales.
- Note that the 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. In the past, some fast food restaurants such as Bojangles donated a portion of their sales on certain days to us. We will pursue similar opportunities this year.
- There has also been preliminary interest in donations expressed by some leading aerospace and defense companies, and we are attempting to secure this funding.

9 Social Media and Public Relations

9.1 Overview

Social media is a great way to connect with current & future scouts, parents, business & community partners, and the community at large. Troop 17 will focus on leveraging the power of Social media to promote STEM awareness, keeping in mind the safety aspects of online media as there are youths in our SL team.

9.2 Social Media Platforms and Automation Tools

This year, the team started an Instagram and Twitter account, as well as updating the Facebook page. The team researched ways to streamline posting to these social media sites. There were several social media management tools, such as Social Pilot, TweetDeck, and HootSuite. Our priorities for using a social media management tool were the ability to upload (and schedule) posts to Instagram, Facebook and Twitter, as well as low or no cost and ease of use. Social Pilot, while giving the ability to post to all three, no longer has a no cost option. TweetDeck only manages Twitter accounts. We chose HootSuite because it gave us the ability to schedule and post to all three accounts, with a free option. \

9.3 Posting Frequency

The key thought process is to deliver original posts at least once per week to give updates on our team's progress. In addition, the team plans to post on Throwback Thursday an interest item from last year's team. Our team is also closely following NASA events and other SLT events and will post about those items to promote these efforts to our followers in the community at large. The team will also use these social media channels to advertise education events.

9.4 Website

The Student Launch Team website is housed with the Troop 17 website (troop17bsa.org). The team documents are posted on the website, as well as updates. Facebook, Twitter and Instagram links are in several places as well. The team is exploring the use of a Twitter Plugin. Wordpress is the platform for our website, and the team is looking at options to have the Twitter feed automatically update through the plugin.

9.5 Social Media Handles

Social media handles for SLT17 are as follows:

- Facebook: @troop17studentlaunch
- Twitter: @17launch
- Instagram: @troop_17_launch