Purdue University

Project Grissom

107 MacArthur Drive
Room #150
West Lafayette, Indiana 47906

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1. General Information

1.1. Adult Educator(s)

Name	Barlow, Victor M.
Title	Faculty Mentor
Contact Information	vmbarlow@purdue.edu 765-494-4546

1.2. Safety Officer

Name	Repella III, Michael V.
Title	Safety Officer
Contact Information	mrepella@purdue.edu 330-495-1270

1.3. Team Leader

Name	Hazzard, Mason R.
Title	Project Manager
Contact Information	mhazzard@purdue.edu 860-847-1469

1.4. Student Participants

The Purdue University Team competing in this year's USLI competition will have roughly 15 participants. Some key technical personnel include Jordan (Payload Specialist), Sean (Outreach Director), Marc (Construction Lead), and Chris (Manufacturing Lead). If Purdue is accepted to participate in this year's USLI Competition, then it is our hope to expand the team to roughly twice the current size in order to distribute workload and improve collaborative efforts.

1.5. NAR/TRA Section Affiliations

Name	Indiana Rocketry
Registration	Prefecture #132 (TRA), Section #711 (NAR)
Website	http://www.indianarocketry.org/

2. Facilities And Equipment

2.1. Description of Facilities

2.1.1. Zucrow Propulsion Labs

Zucrow Propulsion Labs is a facility with various research capabilities that encompass many disciplines within aeronautical and astronautical engineering. We will be utilizing this facility, and more specifically the High Pressure Labs within Zucrow, to store hazmat materials such as the rocket motor or other energetic devices (black powder, CO2 canisters, ignition supplies, etc.). We will also be using the area to conduct deployment charge ground tests to ensure proper separation of the vehicle components at apogee and main parachute deployments. Our contact for the site is Professor Scott Meyer, who is the Zucrow Managing Director, and is the only required personnel for the building. As a safety precaution to limit liability to team personnel, he will be the sole person with access into the secure areas where supplies will be stored in a safe and controlled environment. He will be available between 7 A.M. and 5 P.M.

Hours of Operation	7 A.M. - 5 P.M. or by appointment
Required Personnel	Scott Meyer
Necessary Equipment	High Energy Devices (motor, compressed gas, ignitors, black powder, etc.)
Safety Precaution	Limited access through Scott Meyer, climate controlled environment, and secured areas
General Use	Storage of potentially dangerous materials

2.1.2. Aerospace Science Labs

The Aerospace Science Labs (henceforth referred to as ASL) is an annex attached to the Purdue University Airport that specializes in manufacturing and wind tunnel testing. It is also where Purdue SEDS has their storage area. Although the building is only publicly open between the hours of 7 A.M. and 5 P.M., we will have full access around the clock thanks to Chris who is an Executive Board Member for SEDS and has a key to the locked doors. We will use this area for general assembly as it is where our building supplies and tools will be stored. We will be utilizing basic manufacturing equipment such as drill presses, table saws, rotary tools, and vertical bandsaws. The team will also have access to construction equipment including adhesives, abrasives, craft knives, and common hand tools (pliers, screwdrivers, wrenches, taps, etc.).

Hours of Operation	Around the clock access with Key
Required Personnel	Chris, Safety Officer
Necessary Equipment	Drill presses, table saws, vertical bandsaws, adhesives, abrasives, and common hand tools
Safety Precaution	Safety Officer must be present at all times within the facility
General Use	Vehicle assembly, light manufacturing

2.1.3. Artisan And Fabrication Labs

Underneath Armstrong Hall Of Engineering is the Artisan and Fabrication Lab (henceforth referred to as AFL), which is a student run machine shop with additional dirty rooms that can be used for sanding or painting. All students who enter the shop must take a series of online quizzes for each type of tool or machine they wish to use, and will be paired with an undergraduate teaching assistant or Purdue employed machinist for the duration of their project. The AFL is only open from 9 A.M. to 5 P.M. during the business week since a trained professional must always be present to minimize safety hazards. The team will use equipment such as sandblasters, mills, CNC’s, paint booths, laser cutters, belt sanders, routers, and similar manufacturing machines at this facility for fabrication of custom or complex parts.

Hours of Operation	9 A.M. - 5 P.M.
Required Personnel	UGTA supervisor, Purdue employed machinist
Necessary Equipment	Sandblasters, mills, CNC’s, paint booths, laser cutters, belt sanders, routers, etc.
Safety Precaution	UGTA and employee must always be present, team members must take quizzes and undergo training before using machines
General Use	Fabrication of custom or complex parts

2.1.4. Purdue BoilerMAKER Lab

The Purdue BoilerMAKER Lab specializes in additive manufacturing and we will be using their lab space and equipment in order to rapid prototype parts. This can be done for testing tolerances and function, creating tool guides or jig assemblies, or creating mounting surfaces for the payload and electronics systems. The makerspace operates between the hours of 10 A.M. to 7 P.M. from Monday through Thursday and 10 A.M. to

4 P.M. on Friday, and is closed for the weekends. Due to the high temperatures associated with 3D printing, we will be letting the lab assistants and technicians handle the machinery and parts as they are being produced. The team member who designed the part will then be responsible for going and retrieving the part from the lab

Hours of Operation	10 A.M. - 7 P.M. M-Th, 10 A.M. - 4 P.M. Fr
Required Personnel	Lab assistants, part designer
Necessary Equipment	3D Printer, various types of plastic filament, CAD software, computer station
Safety Precaution	Lab assistants will handle the machinery and parts during production to avoid burns to the team members
General Use	Rapid prototyping and development

3. Safety

3.1. Safety Officer

The Safety Officer for the Purdue SL Team participating in the 2018 competition will be Michael Repella. As Safety Officer, this team member is responsible for the safety and well being of all personnel throughout the course of the competition. This involves ensuring that everybody is constantly aware of the safety plans and emergency procedures, as well as all necessary precautions and personal protective equipment (PPE) required. Once procedures and plans are set by the team, any amendments to them must be authorized by the Safety Officer. Michael will be required to be present at all meetings when fabrication, testing, or assembly is planned to occur. It will also be required of the Safety Officer to have a working knowledge of all facility, equipment, and organizational rules set outside the realm of the team and personnel. This includes adherence to the NAR and TRA high power rocketry safety codes, NFPA 1127, and Federal Aviation Regulations 14 CFR. The Safety Officer will be responsible for the following:

- Creating and maintaining risk analysis matrices to be used throughout the competition
- Creating preflight and postflight checklists to be carried out
- Enforcing all safety plans and procedures set by the team
- Ensuring that all team members are properly trained and supervised to be carrying out their current task
- Ensuring that all team members are wearing appropriate PPE for the task they are conducting
- Ensuring that all team members are following proper operating procedures for using facilities and equipment
- Enforcing all laws and regulations set for the team by authorities and governing bodies
- Attending all build sessions and launches
- Attending all educational opportunities or events where legal minors are expected to be present

3.2. NAR/TRA Personnel Procedures

Victor Barlow, the NAR mentor currently working with the team, will be responsible for the handling and loading of the rocket motors used during launches. He will also be responsible for the purchase, safe storage, and transportation of these motors when necessary. Professor Barlow will be on location whenever the rocket is being launched to serve as Range Safety Officer, will work with the Safety Officer to ensure that all team members follow the NAR High Power Rocket Safety Code during all launches, and will prepare motors and ejection charges during full-scale flights as needed, even though other team members have certification for such tasks.

3.3. Risk Assessment Matrix

The seriousness of a risk will be evaluated by two criteria: the likelihood of an event to occur and the impact of the event should it happen or fail to be prevented.

Likelihood Of Event

Category	Value	Guage
Remote	1	Less than 1% chance of occurrence.
Unlikely	2	Less than 20% chance of occurrence.
Possible	3	Less than 50% chance of occurrence.
Likely	4	Less than 85% chance of occurrence.
Very Likely	5	Greater than 85% chance of occurrence.

Impact of Event

Category	Value	Guage
Negligible	1	Minimal injury, damage to equipment or facility, or environmental effects. Flight continues as normal.
Minor	2	Minor injuries, major reversible damage to equipment or facility, and minor environmental impact. Flight proceeds with caution.
Moderate	3	Moderate injuries, reversible failure, and reversible environmental impact. Flight is put on hold until effects are reversed.
Major	4	Potentially serious injuries, partial failure, and serious reversible environmental effects. Flight is scrubbed or put on hold until system is removed.
Disastrous	5	Potentially life threatening injury, total failure, and serious irreversible environmental damage. Flight is scrubbed or completely destroyed

By cross examining the likelihood of an event with the impact it would have if it occurred, a new table is created that yields a total risk for our safety matrix.

Category	**Negligible**	**Minor**	**Moderate**	**Major**	**Disastrous**
Remote	1	2	3	4	5
Unlikely	2	4	6	8	10
Possible	3	6	9	12	15
Likely	4	8	12	16	20
Very Likely	5	10	15	20	25

Personnel Hazards

Hazard	**Likelihood (Cause)**	**Severity (Effect)**	**Risk**	**Mitigation**
Power Tool Injury	3 (Carelessness)	4 (Possible Hospitalization)	12, Medium	Secure loose hair, clothing, and jewelry; wear appropriate PPE
Dust Inhalation	3 (Airborne Particulate Debris)	3 (Short To Long Term Respiratory Damage)	9, Medium	Wear appropriate PPE or respirator, work in well ventilated area
Eye Irritation	3 (Airborne Particulate Debris)	2 (Temporary Eye Irritation)	6, Low	Wear appropriate PPE or protective eyewear, wash with water
Epoxy Contact	3 (Resin Spill)	3 (Exposure to Irritant)	9, Medium	Wear appropriate PPE such as gloves or lab coats, wash with water
Workplace Fire	1 (Ignition Of Flammable Substance)	5 (Severe Burns, Loss Of Workspace, Irreversible Damage)	5, Low	Have fire suppression systems nearby, prohibit open flames, and store

				energetic devices in Type 4 magazines
Hearing Damage	2 (Close Proximity To Loud Noises)	4 (Long Term Hearing Loss)	8, Medium	Wear appropriate PPE such as ear muffs when using power tools
Burns From Motor Exhaust	1 (Proximity To Launch Pad)	3 (Mild To Moderate Burns)	3, Low	Maintain minimum safe launch distances
Injury from Ballistic Trajectory	3 (Recovery System Failure)	5 (Severe Injury, Death)	15, High	Keep all eyes on the rocket and call “heads up” if needed
Premature Ignition	2 (Short Circuit)	2 (Mild Burns)	4, Low	Prepare energetic devices only immediately prior to flight
Launch Pad Fire	2 (Dry Launch Area)	3 (Moderate Burns)	6, Low	Have fire suppression systems nearby and use a protective ground tarp
Recovery Related Injury	2 (Uneven Ground, Poisonous Plants, Fast Moving Water)	4 (Broken Bones, Infections, Drowning, Etc.)	8, Medium	Do not attempt to recover from atypically dangerous areas
Power Lines	2 (Rocket Becomes Entangled In Lines)	5 (Death Via Electrocution)	10, Medium	Call the power company and stand clear until proper personnel arrive

Failure Modes

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation
Failure To Launch	2 (Lack of continuity)	1 (Recycle launch pad)	2, Minimal	Check for continuity prior to attempted launch
CATO	1 (Motor defect, assembly error)	5 (Partial or total destruction of vehicle)	5, Low	Inspect motor prior to assembly and closely follow assembly instructions
Instability	1 (Stability margin of less than 1.00)	5 (Potentially dangerous flight path and loss of vehicle)	5, Low	Measure physical center of gravity and compare to calculated center of pressure
Motor Expulsion	1 (Improper retention methods)	5 (Risk of recovery failure and low apogee)	5, Low	Use positive retention method to secure motor
Premature Ejection	1 (Altimeter programming, poor venting)	5 (Zippering)	5, Low	Check altimeter settings prior to flight and use appropriate vent holes
Loss of Fins	1 (Poor construction or improper materials used)	5 (Partial or total destruction of vehicle)	5, Low	Use appropriate materials and high powered building techniques
Ejection Charge Failure	4 (Not enough power, electrical failure)	5 (Ballistic trajectory, destruction of vehicle)	20, High	Ground test charge sizes at least once before flight
Altimeter Failure	3 (Loss of connection or improper programming)	5 (Ballistic trajectory, destruction of vehicle)	15, High	Secure all components to their mounts and check settings

Payload Failure	3 (Electrical failure, program error, dead battery)	4 (Disqualified, objectives not met)	12, Medium	Test payload prior to flight, check batteries and connections
Heat Damaged Recovery System	2 (Insufficient protection from ejection charge)	4 (Excessive landing velocity)	8, Medium	Use appropriate protection methods, such as Kevlar blankets
Broken Fastener	1 (Excessive force)	5 (Ballistic trajectory)	5, Low	Use fasteners with a breaking strength safety factor of 2
Destruction Due To Drag Forces	1 (Poor construction or improper materials used)	5 (Partial or total destruction of vehicle)	5, Low	Use appropriate materials and high powered building techniques
Airframe Zipper	2 (Excessive deployment velocity)	5 (Partial destruction of vehicle)	10	Properly time ejection charges and use an appropriately long tether
GPS Lock Failure	2 (Interference or dead battery)	5 (Loss of vehicle)	10	Ensure proper GPS lock and battery charge before flight
Excessive Landing Speed	3 (Parachute damage or entanglement, improper load)	5 (Partial or total destruction of vehicle)	15, High	Properly size, pack, and protect parachute

Environmental Hazards

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation
Drag	2 (High air pressure, low temperature and humidity	4 (Premature drag separation)	8, Medium	Use appropriate amount of shear pins and vent holes
Landscape	3 (Trees, brush, water, power lines, wildlife)	5 (Inability to recover rocket)	15, High	Angle rocket into wind as necessary to reduce drift
Humidity	3 (Climate, poor forecast)	1 (Rust on metallic components)	3, Low	Use as little metal as possible, store indoors
Winds	3 (Poor forecast)	4 (Inability to launch, excessive drift)	12, Medium	Angle into wind as necessary and abort if wind exceeds 20 mph
Temp.	3 (Poor forecast)	3 (Heat related injury)	9, Medium	Ensure team is protected against the sun and stays hydrated
Pollution From Exhaust	5 (Combustion of APCP motors)	1 (Small amounts of greenhouse gasses emitted)	5, Low	None
Pollution From Vehicle	2 (Loss of components from vehicle)	4 (Materials degrade extremely slowly)	8, Medium	Properly fasten all components

Project Hazards

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation
Improper Funding	3 (Lack of revenue)	5 (Inability to purchase parts)	15, High	Create and execute detailed funding plan properly
Failure To Receive Parts	2 (Shipping delays, out of stock orders)	5 (Cannot construct and fly vehicle)	10, Medium	Order parts while in stock well in advance of needed date
Loss Of Work Area	1 (Construction, building hazards, loss of lab privilege)	4 (Temporary inability to construct vehicle)	4, Low	Follow work area regulations and have secondary spaces available
Design Flaw	2 (Program logic error, improper data entry, oversight)	5 (Inability to complete objectives or construct vehicle)	10, Medium	Collaborate and share design files for peer evaluation
Inactivity	2 (Members are unable or unwilling to work)	5 (Loss of team member and labor force, inability to construct vehicle)	10, Medium	Train all members to work in all areas necessary
Injury	2 (Members are unable to work)	3 (Temporary loss of team member and labor force)	6, Low	Keep first aid kit on hand at all times and train all members to follow procedures
Damage By Non-Team Members	1 (Accidental damage of other workspace users)	4 (Extensive repairs necessary, delay in construction)	4, Low	Separate all components from other areas of the workspace as necessary
Damage During Transit	2 (Mishandling)	5 (Inability to fly rocket)	10, Medium	Protect all components during transit
Calendar	3 (Overlap with	4 (Inability of	12,	Inform professors

Conflicts	classes)	team members to travel)	medium	and concerned persons about overlap ahead of time

3.4. Plan For Compliance With Laws

The project team will follow regulations listed in NFPA 1127 and CFR 27 Part 55 and will store all motors, black powder, and other flammable materials in a Type 4 Magazine. These materials will only be removed immediately prior to flight. All launches will be conducted in an area with an active FAA waiver that extends beyond 5,623 feet, the projected altitude of the launch vehicle. All team members present at these launches will closely follow the NAR High Power Rocket Safety Code and the safety agreement in section 3.6.

3.5. Plan To Purchase, Store, Transport, And Use Hazardous Materials

Hazardous materials which will be used on this project include: black powder, ammonium perchlorate composite propellant, pre-made rocket motor igniters, and potentially compressed carbon dioxide. Hazardous materials will be stored off-site, within the Zucrow Labs research facilities adjacent to the Purdue University Airport. Certain members of the team working on project Goddard currently hold a Low Explosives User Permit (LEUP), and these are the members who will handle the acquisition, transportation, and storage of the hazardous materials involved in this project. All team members will be given a briefing on the plan to properly purchase, store, transport, and use hazardous materials by the safety officer. This safety brief will provide knowledge of and access to Material Safety Data Sheets (MSDS) for all potentially hazardous substances which will be used on the project and will ensure the use of proper PPE when handling hazardous materials.

3.6. Team Safety Statement

The following statement will be printed out for all team members to sign:

As a member of Purdue SEDS Rocket Team, I agree to:

1. Adhere to any and all relevant local, state, and federal laws and regulations.
2. Adhere to the NAR High Power Rocket Safety Code.
3. Comply with all instructions given to me by the Safety Officer and by the Range Safety Officer.
4. Wear appropriate personal protective equipment whenever constructing or operating the launch vehicle.
5. Understand the hazards of each material or machine I plan to use or operate.
6. Never misuse the materials or equipment I will work with in this project for any reason.
7. Acknowledge that the Range Safety Officer will inspect the launch vehicle prior to all flights.
8. Acknowledge that the Range Safety Officer reserves the right to approve or deny the flight of the launch vehicle for any relevant reason.
9. Acknowledge that my team will not be allowed to fly if we do not comply with each of the aforementioned safety regulations.

My signature confirms that I have read and understood the aforementioned agreements. I recognize that any violation of these agreements may result in being unable to participate in Project Grissom or the NASA SL program.

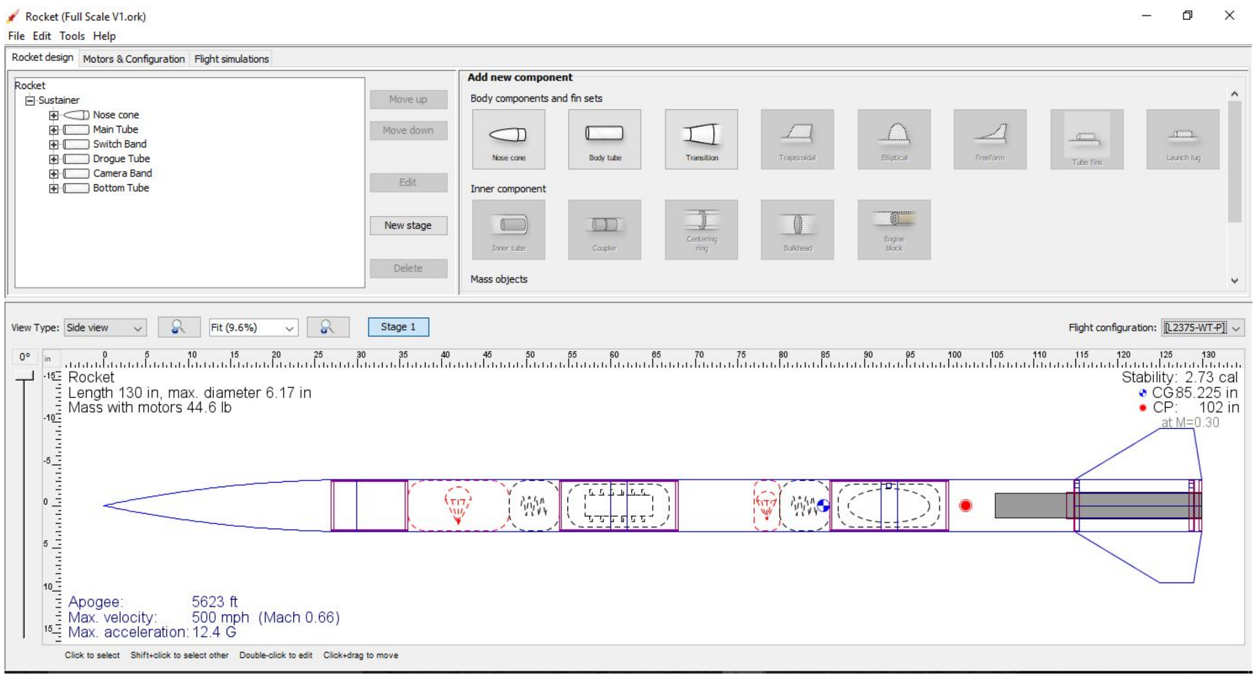
Name____
Signature____ Date_______________

4. Technical Design

4.1. Proposed Approach To Design

4.1.1. General Dimensions, Materials, And Construction

Full Scale Rocket



Our team's proposed full scale rocket is 6" in diameter, 130" tall, and made entirely out of filament wound fiberglass composite materials. The group chose to build the vehicle out of this material for various reasons. FWFG is available from multiple distributors, making access to spare parts easy. It is also to cut, drill, sand, and paint. Most importantly, though, fiberglass is one of the strongest standard construction materials available to high power rocketry due to its quasi-isotropic material properties. The major drawbacks of composite construction, though, is weight and safety. Fiberglass is nearly three times as heavy as cardboard, and the dust particles and splintering can be health hazards.These will be taken into special consideration during the entirety of the construction phase.

We will be utilizing two break points to break the rocket up into three sections during descent, as a regular rocket would if flying the standard dual deployment configuration. At apogee, the rocket will split at the avionics bay switch band to deploy the drogue parachute for rapid controlled descent. The nosecone, main tube, and avionics bay coupler will remain attached to the drogue tube, camera bay coupler, and motor section via 40' of ½" tubular Kevlar. At a predetermined altitude, in this case 700' AGL, the nosecone will split from the main tube and avionics bay coupler to deploy the main parachute in order to achieve a soft touchdown. All sections will be held together at the appropriate breaking points by use of 3x #2-56 nylon shear pins, and all couplers will be secured into their respective airframes by use of 6x ¼” plastic rivets.

All structural joints will be bonded, not mechanical, and will use G5000 Rocket Epoxy as the main adhesive. This two part epoxy was chosen due to its excellent tensile and shear strength, as well as its widely accepted use in nearly all areas of modern high power rocketry. In order to minimize the amount of stress placed on bonded joints, we will also be utilizing a thrust plate at the rear of the rocket in order to transfer axial loading to the entire airframe rather than the motor assembly, centering rings, and through the wall fin tabs. In addition to the epoxy fillets, each fin will also be supported by notched centering rings to minimize rotational moments and prevent them from breaking at the motor mount joint. The fins themselves will be CNC cut from 3/16” G10 fiberglass panels, and the bulkheads will be made from ⅛” stock of the same material and doubled to make a step that fits inside of the coupler tubing.

4.1.2. Projected Altitude And Calculation

Our projected altitude for the full scale rocket we plan to be competing with was calculated by using OpenRocket, a publicly available rocket design program. We chose to run the simulator using the extended barrowman equations with six degrees of freedom and a 4th order Runge-Kutta scheme, as well as choosing the “spherical approximation” option for processing geodetic calculations. This combination of settings simulates that our current vehicle design will reach a maximum altitude of 5,623’ above ground level without adding any ballast. This gives us a buffer of roughly 340’, or slightly over a 6% margin of error. This model is acceptable to us currently as it does not include weights associated with construction or finishing such as epoxy, paint, shear pins, or rivets. Once construction of the rocket is complete it will be weighed, and the simulation will be adjusted using the “override mass” function. Ballast will then be simulated until the predicted apogee is exactly 5,280’ above ground level, and the physical model will be weighted appropriately to match the computer data.

4.1.3. Projected Parachute System Design

Our team plans on using a typical dual deployment configuration for the recovery phase of the flight. This involves deployment of a drogue parachute at apogee to create a controlled rapid descent of two tethered sections of the rocket. The drogue parachute we will be using is a Skyangle Cert 3 24” drogue parachute with a drag coefficient of 1.26 and a total surface area of 6.3 square feet. The parachute weighs a total of six ounces and is made of zero porosity 1.9 ounce per square yard silicone coated balloon cloth. It is connected to a nickel plated 1,500 pound rated swivel via four canopy shroud lines that are ⅝” tubular nylon rated for 2,250 pounds. The tether that will be connecting the two separate sections will be made of 1/” tubular kevlar with a tensile strength of 7,200 pounds. Both ends of the tether will be sewn shut to allow quick disconnection to the rocket through the use of ¼” quick links, which will in turn be connected to ¼” u-bolts mounted through the bulkhead. The drogue parachute will also be attached to the quick link located at the bottom avionics bay.

Once the rocket has descended to an altitude of 700’ above ground level, the main parachute and recovery harness will be expelled from the main tube and remain tethered to the nosecone. Our main parachute is a Skyangle Cert 3 XL parachute with a drag coefficient of 2.59 and a total surface area of 89 square feet. It is constructed in an identical fashion to our drogue parachute, and will be using the same shock cord for the main tether as we used in the drogue tether of the rocket. It will be connected at both ends using the same methods as the drogue harness, and the main canopy will be attached to the uppermost quick link connected to the nosecone as well.

Both parachutes will be deployed via use of black powder pyrotechnic charges initiated by redundant onboard flight computers. The primary apogee charge will ignite at apogee with backup at apogee plus two seconds, and the primary main charge will ignite at 700’ above ground level with backup at 500’ above ground level. All 4 charges will contain 5.2g of FFFF black powder. By calculating the cross sectional area of a single pin and multiplying it by the shear strength of nylon, it is possible to calculate the force necessary to shear a single bolt.

Bolt Area = Pi * Radius^2
Bolt Area = 3.14 * 0.04^2
Bolt Area = 0.00502 inches squared

From there, one can determine how much force is required to shear three bolts and use that to calculate how much pressure is necessary on a 6” diameter bulkhead to sufficiently shear all three pins.

Bolt Shear Strength = Area * Shear Strength
Bolt Shear Strength = 0.00502 inches squared * 10,000 pounds
Bolt Shear Strength = 50.2 PSI
3x Bolt Shear Strength = 150.6 PSI

Bulkhead Area = Pi * Radius^2
Bulkhead Area = 3.14 * 3^2

Bulkhead Area = 28.27 inches squared

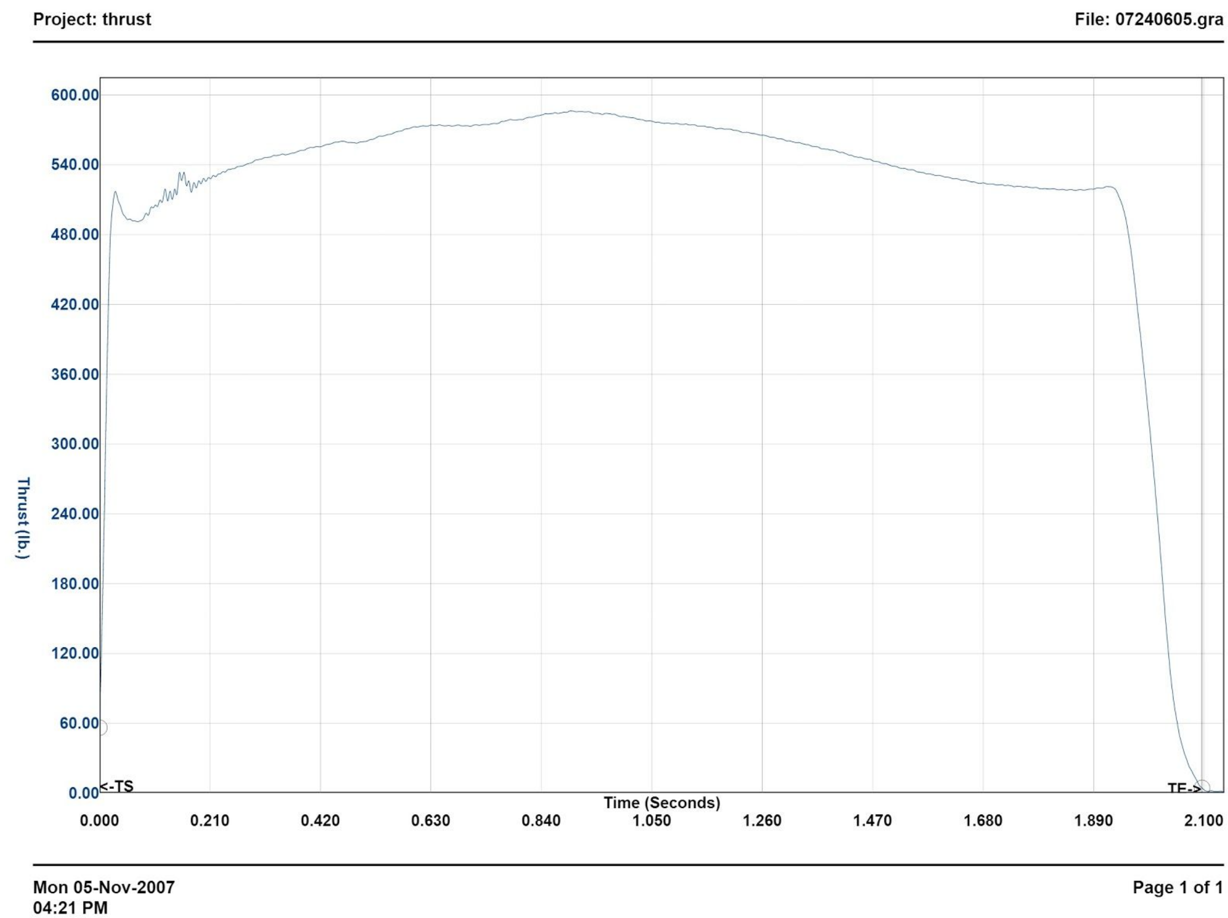
Bulkhead Pressure = 3x Bolt Shear Strength / Bulkhead Area
Bulkhead Pressure = 150.6 PSI / 28.27 inches squared
Bulkhead Pressure = 5.32 P

By using the equation 0.004 * D * D *L = G (where 0.004 is the pressure coefficient, D is the diameter of the airframe, L is the length of the airframe section, and G is grams of black powder), we can calculate the amount of black powder needed to sufficiently shear all of the nylon bolts, as well as add a safety factor of 1.2.

G = 0.004 * 6 * 6 * 30 * 1.2
G = 5.184 grams of black powder

4.1.4. Projected Motor Brand And Designation

The motor proposed for use in the full scale rocket for the competition flight is the Cesaroni Technology Pro75 4 Grain L2375 White thunder. This particular motor has a total impulse of 4,878 Newton Seconds, classifying it as a 92% L class motor. The motor will weigh 9.2 pounds fully loaded and will burn 5.1 pounds of ammonium perchlorate composite propellant during its 1.9 seconds burn time. During combustion, delivering a maximum thrust of 629 pounds. This will propel the full scale rocket to a velocity of approximately 95 feet per second by the time it clears the launch rail, meeting the minimum requirement of 52 feet per second. It will also have a static margin of stability of roughly 2.1 calibers. During ascent, the maximum speed experienced by the vehicle will be 500 miles per hour.



4.1.5. Projected Payload Description

Objective:

In addition to reaching the altitude requirements of the mission, the payload will contain a target detection system. The system will identify three 40’ x 40’ colored targets on the ground in real time during the rocket flight. The current objective is to build a minimum fidelity system which will meet the requirements of processing the data on board the rocket. After recovery, the data will then be retrieved from the payload and displayed on a portable computer. Once the minimum fidelity system has proved successful performance aboard the sub-scale rocket, a high fidelity version of the system will be produced. The high fidelity system will have the capability to relay the data being processed aboard the rocket in real time to a computer on the ground via wireless connection.

Image feed:

The design will consist of a payload section located aft of the avionics bay. The payload will carry two cameras pointed downward and rotated 180 degrees from one another. One camera will take continuous flight video while the other will take still photos at momentary increments. Their opposing positions are intended to balance aerodynamics effects. The cameras will be mounted to harnesses on the inner wall of the payload section. In order to minimize drag and effects on flight performance, only the lens of the cameras will be protruding the exterior of the rocket. The lenses will be protected by a carbon fiber shroud to aid in pressure recovery. Currently the Mobius Action Cam and LiquidFyre Shrouds are being considered to accomplish these tasks. This camera was selected for its video quality, light weight design, and fact that it contains a built in battery.

Computer & Power supply:
The video and camera images will be relayed from the cameras to an on board computing source. This computing source will be a Raspberry Pi, chosen for its low cost and easy programmability. The Raspberry Pi will be mounted to an electronics sled similar to one used in a typical avionics bay. It will be powered via a battery supply. The battery power supply can be made use of from any commercially available portable power pack used for charging phones and common hand held electronic devices. Once the image processing program has been developed and calculations have been performed to predict the power needs of the computing system, the correct battery supply will be selected which optimizes the inverse relationship between size/weight and power storage.

Processing & Theory:
In this preliminary design phase of the design cycle, the exact program languages to be used for the image processing have yet to be decided. However, it is likely that either Matlab or OpenCV-Python will serve as the target detection operation platform. The target detection program will start by uploading the still frame images taken by one of the cameras. Each image received will be evaluated as a grid of 1280x720 pixels. As an image file, every pixel will be evaluated based on the color intensity and assigned a numerical value corresponding to a color value. Every pixel will then be analyzed to determine if their color value matches any of the three values (red, blue, green) assigned by NASA. As a table of true and false values are created, the program will then be able to identify the three ground targets. The targets are going to be against a "noisy" background, so the program will identify the regions with the highest frequency of true values to avoid falsely identifying any targets. The program will visually represent the targets on the image by either highlighting the region or assigning some sort target indicator. In order to optimize computing efficiency the program will make use of machine learning and optimize algorithms such as robust feature analysis and corner detection.

4.1.6. Requirements for Vehicle, Recovery, and Payload

Vehicle Requirements

2.1. The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).

2.2. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points (5,280) if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude.

2.3. Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.

2.4. Each altimeter will have a dedicated power supply.

2.5. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).

2.6. 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.

2.7. 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.

2.8. The launch vehicle will be limited to a single stage.

2.9. The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.

2.10. The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components.

2.11. 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 Range Services Provider.

2.12. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).

2.13. The launch vehicle will use a commercially available solid motor propulsion system using 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).

2.13.1. Final motor choices must be made by the Critical Design Review (CDR).

2.13.2. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.

2.14. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:

2.14.1. 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.

2.14.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the valve that is capable of withstanding the maximum pressure and flow rate of the tank.

2.14.3. Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.

2.15. The total impulse provided by a College and/or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).

2.16. 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.

2.17. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.

2.18. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets.

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 reporting the model's apogee altitude.

2.19. All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability 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 a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:

2.19.1. The vehicle and recovery system will have functioned as designed.

2.19.2. The payload does not have to be flown during the full-scale test flight. The following requirements still apply:

2.19.2.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.

2.19.2.1.1. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.

2.19.3. If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration flight.

2.19.4. The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulates, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight.

2.19.5. The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.

2.19.6. 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).

2.19.7. Full scale flights must be completed by the start of FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first-time flights.

2.20. Any structural protuberance on the rocket will be located aft of the burnout center of gravity.

2.21. Vehicle Prohibitions

2.21.1. The launch vehicle will not utilize forward canards.

2.21.2. The launch vehicle will not utilize forward firing motors.

2.21.3. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark,MetalStorm, etc.)

2.21.4. The launch vehicle will not utilize hybrid motors.

2.21.5. The launch vehicle will not utilize a cluster of motors.

2.21.6. The launch vehicle will not utilize friction fitting for motors.

2.21.7. The launch vehicle will not exceed Mach 1 at any point during flight.

2.21.8. Vehicle ballast will not exceed 10% of the total weight of the rocket.

Recovery System Requirements

3.1. The 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.

3.2. Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.

3.3. At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.

3.4. The recovery system electrical circuits will be completely independent of any payload electrical circuits.
3.5. All recovery electronics will be powered by commercially available batteries.
3.6. The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.
3.7. Motor ejection is not a permissible form of primary or secondary deployment.
3.8. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.
3.9. Recovery area will be limited to a 2500 ft. radius from the launch pads.
3.10. 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.

- 3.10.1. Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device.
- 3.10.2. The electronic tracking device will be fully functional during the official flight on launch day.

3.11. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).

- 3.11.1. 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.
- 3.11.2. The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.
- 3.11.3. 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.
- 3.11.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

Experiment Requirements

4.1. Each team will choose one design experiment option from the following list.
4.2. Additional experiments (limit of 1) are allowed, and may be flown, but they will not contribute to scoring.
4.3. If the team chooses to fly additional experiments, they will provide the appropriate documentation in all design reports, so experiments may be reviewed for flight safety.
4.4. Target detection

4.4.1. Teams will design an onboard camera system capable of identifying and differentiating between 3 randomly placed targets.

4.4.1.1. Each target will be represented by a different colored ground tarp located on the field.

4.4.1.2. Target samples and RGB values will be provided to teams upon acceptance and prior to PDR.

4.4.1.3. All targets will be approximately 40’X40’ in size.

4.4.1.4. The three targets will be adjacent to each other, and that group will be within 600 ft. of the launch pads.

4.4.2. Data from the camera system will be analyzed in real time by a custom designed on-board software package that shall identify, and differentiate between the three targets.

4.4.3. Teams will not be required to land on any of the targets.

4.1.7. Major Technical Challenges and Solutions

The primary concern of the design for the target detection system is the clarity of the images being processed by the on board cameras. There is a reality that during flight the rocket may be spinning quickly and that the images will be too blurry to identify the targets. The level of concern of this uncertainty will not be determined until the minimum fidelity design is loaded aboard the sub scale model and tested in an actual flight. In the case where rocket spin becomes an unavoidable issue preventing target detection success, the contingency plan is to make a deployable payload. The payload would be deployed at apogee and be recovered on an independent parachute system. The program would then process the image feed during the payloads decent where the aerodynamic forces are much less extreme and the issue of image blurriness is mitigated.

5. Educational Engagement

5.1. Plans And Evaluation Criteria For Educational Engagement

We will hold a small number of educational involvement events throughout the fall and spring semesters. The events will either be booths and activities at local events based on educating children and the Purdue community about rocketry and our team (eg. Purdue Space Day), or they will be planned visits to local schools where we will give a presentation or demonstrate the work that our team has completed up to that point. School visits will be coordinated through and between our team's and SEDS' outreach directors. Booths can be coordinated to both provide educational engagement and advertise our organization by handing out fliers for restaurants that will give a portion of our proceeds to the team for individual who purchase food at the restaurant. These events will also tie into local sustainability by offering students who visit our booth the opportunity to join the team.

6. Project Plan

6.1. Development Timeline

The Purdue SL team will be following the timeline listed below. This outlines events such as general team meetings, meetings or teleconferences with NASA officials, launch opportunities, deadlines, and miscellaneous events.

Date	Event
09/09/2017	Purdue SL general meeting
09/16/2017	Purdue SL general meeting
09/20/2017	Proposal due to project office by 5PM CDT
09/22/2017	Purdue SL general meeting
09/30/2017	Purdue SL general meeting
10/06/2017	Awarded proposals announced
10/07/2017	Purdue SL general meeting
10/08/2017	Indiana Rocketry Launch
10/12/2017	Kickoff, PDR Q&A
10/14/2017	Purdue SL general meeting
10/21/2017	Purdue SL general meeting
10/28/2017	Purdue SL general meeting
11/03/2017	Web presence established, URL sent to project office
11/03/2017	PDR reports, slides, and flysheet posted online by 8AM CDT
11/03/2017	Midwest Power Launch
11/04/2017	Purdue SL general meeting
11/04/2017	Midwest Power Launch
11/05/2017	Midwest Power Launch
11/06/2017	PDR video teleconferences start
11/11/2017	Purdue SL general meeting
11/18/2017	Purdue SL general meeting
11/25/2017	Purdue SL general meeting
11/29/2017	PDR video teleconferences end
12/2/2017	Purdue SL general meeting
12/06/2017	CDR Q&A
12/09/2017	QCRS Launch
12/09/2017	Purdue SL general meeting

12/16/2017	Purdue SL general meeting
12/23/2017	Purdue SL general meeting
12/30/2017	Purdue SL general meeting
01/06/2018	Purdue SL general meeting
01/11/2018	Final day for subscale launch
01/11/2018	Final motor choice made for launch
01/12/2018	CDR reports, slides, and flysheet posted online by 8AM CDT
01/13/2018	Purdue SL general meeting
01/16/2018	CDR video teleconferences start
01/20/2018	Purdue SL general meeting
01/27/2018	Purdue SL general meeting
01/31/2018	CDR video teleconferences end
02/03/2017	Purdue SL general meeting
02/07/2018	FRR Q&A
02/10/2018	Purdue SL general meeting
02/17/2018	Purdue SL general meeting
02/24/2018	Purdue SL general meeting
03/03/2018	Purdue SL general meeting
03/04/2018	Final day for full scale launch
03/05/2018	FRR reports, slides, and flysheet posted online by 8AM CDT
03/06/2018	FRR video teleconferences start
03/10/2018	Purdue SL general meeting
03/17/2018	Purdue SL general meeting
03/22/2018	FRR video teleconferences end
03/24/2018	Purdue SL general meeting
03/31/2018	Purdue SL general meeting
04/04/2018	Travel to Huntsville, Alabama
04/04/2018	LRR
04/05/2018	Launch week kickoff and activities
04/06/2018	Launch week activities
04/07/2018	Launch day
04/07/2018	Banquet
04/08/2018	Backup launch day
04/27/2018	PLAR posted online by 8AM CDT

6.2. Detailed Budget

Full Scale Rocket

Item	Unit Cost	Quantity	Total
5:1 6" Ogive FWFG Nosecone	124.95	1	124.95
6" G10 FG Coupler Bulkhead	9	6	54
6" G10 FG Airframe Bulkplate	9	6	54
6" FWFG Airframe, 60" long	228	1	228
6" FWFG Airframe, 30" long	114	1	114
Custom Airframe Cutting to 36" length	8	1	8
Custom Airframe Slotting, 3/16" wide, 15" long	6	4	24
6" FWFG Switch Band, 2" long	9	2	18
6" FWFG Coupler, 14" long	69	2	138
3" FWFG Motor Tube, 30" long	50	1	50
1/8" G10 FG Centering Ring	10	2	20
1/2" Plywood Centering	5	2	10
3/16" G10 FG Fins	20	4	80
Skyangle Cert 3 XL Parachute	189	1	189
Skyangle Cert 3 Drogue Parachute	27.5	1	27.5
18" x 18" Nomex Parachute Protector	10.95	2	21.9
40' Long Double Looped Kevlar Tether	61	2	122
Large Rivet Package	4.5	2	9
1515 Series Rail Button Package of 4	7.95	1	7.95
75mm AeroPac Flanged Motor Retainer	50	1	50
6"/75mm SC Precision Thrust Plate	65.05	1	65.05
CTI 75mm 4G Hardware Set	341	1	341
CTI 75mm Closure Wrench	46.2	1	46.2
CTI 75mm 4G L2375 WT Reload	271.7	2	543.4
			2345.95

Sub Scale Rocket

Item	Unit Cost	Quantity	Total
5:1 3" Ogive Standard Wall FWFG Nosecone	58.95	1	58.95
3" G10 FG Coupler Bulkhead	5	6	30
3" G10 FG Airframe Bulkplate	5	6	30

3" FWFG Standard Wall Airframe, 60" long	100	1	100
Custom Airframe Slotting, 3/32" wide, 7.5" long	5	4	20
3" FWFG Switch Band, 1" long	4	2	8
3" FWFG Coupler, 6" long	15	2	30
38mm FWFG Standard Wall Motor Tube, 30" long	32	1	32
1/8" G10 FG Centering Ring	6	2	12
1/4" Plywood Centering	3.55	2	7.1
3/32" G10 FG Fins	10	4	40
Top Flite 50" Main Parachute	26.95	1	26.95
Top Flite 15" Drogue Parachute	6.95	1	6.95
9" x 9" Nomex Parachute Protector	6.95	2	13.9
20' Long Double Looped 5/16" Kevlar Tether	26.99	2	53.98
Medium Rivet Package	3.5	2	7
1010 Series Rail Button Package of 4	6.95	1	6.95
38mm AeroPac Motor Retainer	25	1	25
CTI 38mm 5G Casing	57.2	1	57.2
CTI 38mm 5G J357 BS Reload	61.6	1	61.6
			627.58

Travel

Item	Unit Cost	Quantity	Total
Hotel Room	200	16	3200
Gas	40	16	640
			3840

Total Projected Cost: $6,935.53
Total Projected Cost with 20% buffer: $8,322.64, rounded up to the nearest $500 is $8,500. This buffer accounts for costs that we do not currently have a value for or do not know, such as electronics that are yet to be determined or miscellaneous pieces of hardware.

6.3. Funding Plan

Assuming that the team requires around $10000, there will be three primary ways funds will be made to support the NASA USLI project:

1. Skip-a-meals and Campus Fundraisers: Skip-a-meals are social events where individuals can mention the name of our organization at a designated food establishment and a percentage (usually half) of money they spend at the establishment will be given to the team. These events usually last for a whole afternoon.

2. Non-profit and Educational Grants: Although they can easily fund a large chunk of our expected required budget, experiences have shown me that finding private grants that specifically meet the criteria of a student organization can sometimes be hard to find. The team will consult both private companies and school departments here on campus for this. SEDS will need a list of purdue departments we have a student involved in (eg. College of engineering), so that we can send out formal emails asking about current school grants/scholarships and potential alumni bases to look for donations from (which has proved successful in the past). Granted, our group will need to have a likeable image, and that starts with a good website.

3. Company Sponsorship and Donations: Are very much dependent on personal outreach and social image. The team will need to create a website that details the work of our members and is easily accessible and understandable so that any individual that is referred to our site can easily make a donation, or at least consider doing so.

Our current goal is to have almost all the money needed available before the end of the fall semester. If we are looking at getting grants, they can take a while to process. Doing them in advance, especially if we need the money to be able to manufacture the rocket, is going to be very important.We have not created a chart for how much money will be made in each of these three categories, as the amounts can vary significantly. It is also important that everyone on the team reaches out to anyone they know who may have leverage to have a company sponsor us, or better yet, make a personal donation.

Basic Tentative Schedule (end of each month)

September:

- Come up with a list of campus restaurants we can do skip-a-meals with, and make decisions on which we will do. Sign up process usually only takes a week or two
- Figure out if we are going to do any other types of campus fundraising, or hold any social events
- Begin building the website, for purposes related to outreach

October:

- Finish site sufficiently enough to present it to the public (mid-october at the latest)
- Send out emails to school departments

- Hold at least on skip-a-meal/public event, get a rough idea of how much money we can get from that
- Begin applying for grants and talking to companies for sponsorships

November:
- Solidify company/companies who can sponsor us.
- Have a few grants that we can use
- Build a budget
- Website should be regularly updated at this point, whether it be for documentation purposes or for giving ourselves an active image

December:
- Continue applications, at this point ideally we will have most of the money we need. If not then we will have another two months to continue searching for ways to make the remainder of the money.

Fund Source	**Funds Generated**
SEDS Treasury	$500
Restaurant Socials (4 throughout year)	$800 ($200 each)
Federal and Private Grants	$5700 (across multiple grants)
Company Sponsorship	$3000 (in materials)
TOTAL:	$10000

6.4. Local Sustainability

On campus we will be regularly scheduling booths where we can present the work that we have accomplished to student on campus. The team also intends to have representatives at local rocketry competitions and launches in order to raise awareness for our team. Our website will be updated fairly regularly, documenting the work on our project for others to see, and individuals or organizations/companies that donate to the project will be updated on how their donation is being used in the project.

Appendix A

High Power Rocketry Safety Code

1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket

to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
13. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

High Power Rocketry Distance Index

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Appendix B

Plan for Sustainability

Purdue SL Team Sustainability

The sustainability of the Purdue NASA SL team founded under SEDS is dependent on multiple factors, primarily funding. By following our funding plan, we hope to generate enough revenue to continue our involvement with the competition not only this year, but in the future as well. This involves applications for grants, reaching out to companies for sponsorships and donations, hosting local events, and simply getting positive publicity in our local area. In addition to funding, though, teams for this project and others like it require the manpower and labor force to stay active and competitive. Without creating and maintaining relationships with groups such as students, local NAR and TRA clubs, or faculty members, the amount of interest generated will dwindle until projects become unsustainable. Both require outreach on the part of the team through the university and SEDS to establish professional relationships with others who are willing to help and join us. It is our team's hope that projects such as these continue to be held past the completion of the 2018 competition, and well into the future.