Purdue University
Project Walker

500 Allison Road
West Lafayette, Indiana 47906

September 19, 2018

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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	Lyons, Jory C.
Title	Safety Officer
Contact Information	lyons41@purdue.edu 219-252-2816

1.3. Team Leader

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

1.4. Student Participants

The Purdue University Team competing in this year's SL competition will have roughly 30 participants as part of the Purdue Space Program (PSP) Student Launch. Some key personnel other than the ones listed above include Luke Perrin (Assistant Project Manager), Wes O'Dell (Payload Officer), Sean Heapy (Funding Officer), Zach Carroll (Construction Officer), Harith Kolaganti (Social Officer), and Reni Patel (Avionics Officer).

1.5. NAR/TRA Section Affiliations

Name	Indiana Rocketry

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

1.6. Project Dedication

This project is named after Charles D. Walker, who received a Bachelors of Science in Aeronautical and Astronautical Engineering at Purdue University in 1971. While an employee of the McDonnell Douglas Corp., Charles Walker was confirmed by NASA in 1983 as the first industrial payload specialist. He accompanied the McDonnell Douglas continuous-flow electrophoresis (CFES) equipment as a crew member on space shuttle missions 41D, 51D and 61B, accumulating 20 days of experience in space and traveling 8.2 million miles. This information was retrieved from https://www.purdue.edu/space/astronauts.php#charlesWalker.

2. Facilities And Equipment

2.1. Zucrow Propulsion Labs

Zucrow Propulsion Labs is a facility with various research capabilities that encompass many disciplines within aeronautical and astronautical engineering. The team will be utilizing this facility, and more specifically the High Pressure Labs within Zucrow, to store hazmat materials such as the motors or other energetic devices (black powder, CO2 canisters, ignition supplies, etc.). The team 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. The team's 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, igniters, black powder, etc.)
Safety Precaution	Limited access through Scott Meyer, climate controlled environment, and secured areas
General Use	Storage of potentially dangerous materials

2.2. 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., the team will have full access around the clock thanks to Chris Nilsen who is president of the Purdue SEDS Executive Board and has a key to the locked doors. The team will use this area for general assembly as it is where the majority of the team's parts, building supplies, and tools will be stored. The team 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 use of key
Required Personnel	Chris Nilsen for access, Jory Lyons as safety officer
Necessary Equipment	Drill presses, table saws, vertical bandsaws, adhesives, abrasives, and common hand tools
Safety Precaution	Team Officers or the Safety Officer must be available at all times
General Use	vehicle assembly, light manufacturing

2.3. Bechtel Innovation Design Center

The Bechtel Innovation Design Center (BIDC) is an advanced prototyping facility and machine shop which is located on campus and is available to all Purdue students. 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 a teaching assistant or Purdue employed machinist for the duration of their project. The BIDC 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	TA supervisor or Purdue employed machinist
Necessary Equipment	Sandblasters, mills, CNC's, paint booths, laser cutters, belt sanders, routers, etc.
Safety Precaution	TAs or employed machinists must always be present when using machines, team members must take quizzes and undergo training before using machines
General Use	Fabrication of custom or complex parts

2.4. Purdue BoilerMAKER Lab

The Purdue BoilerMAKER Lab specializes in additive manufacturing and the team will be using their lab space and equipment in order to rapidly prototype parts. This can be done for testing tolerances and function, creating tool guides and 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, the team 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 and will oversee the machines to ensure no problems arise
General Use	Rapid prototyping and development

3. Safety

3.1. Safety Officer

The Safety Officer for the Purdue SL Team participating in the 2019 competition will be Jory Lyons. 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, emergency procedures, necessary precautions, and personal protective equipment (PPE) required to perform project activities. Once procedures and plans are set by the team, any amendments to them must be authorized by the Safety Officer. The Safety Officer 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, flight, and postflight checklists to be carried out
- Creating and enforcing the team's safety plans and procedures
- 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 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 launch vehicle 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. Briefings on Hazard Recognition/Avoidance and Launch Procedures

Prior to the first construction meeting, the team will hold a short briefing on basic launch vehicle construction safety, in which all team members will be instructed on fundamental safety procedures (e.g. wearing protective eyewear during construction), as well as how to use lab equipment and recognize any potential hazards associated with it. In addition, the team will compose a checklist prior to all launches detailing the exact procedures that must be performed in order to ensure success and maximize launch safety, and all inexperienced flyers will receive an additional briefing about basic launch safety (e.g., not standing immediately next to the launch pad as the launch control officer prepares to ignite the propellant situated on top of it).

Briefings will be carried out before major events and launches. A dedicated seminar during a team meeting will initially be provided to students on hazard recognition and accident avoidance to promote safety and keep students aware of the potential threats that exist. Historical and fictional examples will be generated to exemplify potential hazards and avoidance. Students will be required to sign a form acknowledging the potential threats as described at the seminar. Students must sign the form to ensure that safety is met and understood. The briefings and seminar will be made available through the group so that all members have permanent access. Dedicated pre-launch briefings will be presented and required to be acknowledged to attend a launch. Additional briefings and seminars will similarly be posted and required to ensure problems or concerns are addressed.

Briefings will cover the following topics and more:

- Lawful launch procedures which comply with FAA regulations, federal laws, and Purdue University policies
- What to do if the launch vehicle poses a threat at the time of launch
- What to do if the launch vehicle poses a threat during the flight
- What to do if the launch vehicle causes injury to a student or personnel
- What to do if the launch vehicle veers off the calculated course
- What to do in the case of unpredicted weather on the day of the launch

3.4. Caution Statements and Personal Protective Equipment Advisories

The safety officer will deliver a briefing on how to properly use the Personal Protective Equipment (PPE) this project necessitates. These necessary caution statements will be included before documented plans and procedures as to maintain a reminder of potential threats or concerns. All lab equipment will be labeled with the basic safety protocols associated with its use, including any PPE required to operate it, and all hazardous materials will be stored in labeled containers.

The current established procedures for PPE, which will be updated throughout the course of the project, are as follows:

- All team members must secure loose hair and clothing and remove jewelry before participating in construction and fabrication processes or launches and before handling hazardous materials. Apparel should be metal-free and non-static producing.
- ANSI Z87.1-certified protective eyewear must be worn at all times during construction and fabrication processes, when handling hazardous materials, and during launches. Any safety glasses used must include a side shield.
- Thermal protection such as leather or canvas gloves must be used when working with hot objects. Such objects include, but are not limited to, recently-fired launch vehicle motors or objects which are being heated for construction or fabrication purposes. Team members must at the least wear cotton clothing for thermal protection.
- Proper NIOSH/MSHA-approved respiratory equipment must be worn in situations where airborne particle debris will be present as the result of a construction or fabrication process with limited ventilation.
- Measures must be taken to cover exposed skin when working with materials that are hazardous on contact such as epoxy. Nitrile rubber gloves and a lab coat or apron must be worn when working with these types of materials. Shoes that cover the entire foot must also be worn. In the case of a large spill or prolonged contact, boots must be worn. If clothing is soiled or contaminated, it should be removed ASAP.
- Ear protection must be worn when using equipment which creates a noise 85 decibels or louder. Earplugs or earmuffs should always be worn when operating power tools which create loud noises.
- Closed-toe shoes should be worn during all construction and fabrication processes.

3.5. Risk Assessment Matrices

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. Categories of likelihoods and impacts are discussed below:

3.5.1. Likelihood Of Event

Category	**Value**	**Gauge**
Remote	1	Less than 1% chance of occurrence.
Unlikely	2	Less than 20% chance of occurrence.
Possible	3	Less than 40% chance of occurrence.
Likely	4	Less than 80% chance of occurrence.
Very Likely	5	Greater than 80% chance of occurrence.

3.5.2. Impact of Event

Category	**Value**	**Gauge**
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 total risk can be calculated which is detailed in the table below. The color code displayed is as follows:

- Green: Minimal risk
- Yellow: Low risk
- Orange: Medium risk
- Light red: High risk
- Dark red: Very high risk

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

3.5.3. Personnel Hazards

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation
Burns From Motor Exhaust	1 (Proximity To Launch Pad)	3 (Mild To Moderate Burns)	3, Low	Maintain minimum safe launch distances
Contact with Airborne Chemical Debris	3 (Airborne particulate debris)	2 (Minor burns, abrasions)	6, Low	Wear appropriate PPE such as gloves or lab coats, wash with water
Dehydratio n	3 (Failure to drink adequate amounts of water)	3 (Exhaustion and possible hospitalization)	9, Medium	Ensure all members have access to water at launch
Direct	3 (Chemical spills,	3 (Moderate	9, Medium	Wear appropriate

Contact with Hazardous Chemicals	improper use of chemicals)	burns, abrasions)		PPE such as gloves or lab coats, wash with water
Dust or Chemical Inhalation	3 (Airborne particulate debris)	3 (Short to long-term respiratory damage)	9, Medium	Wear appropriate PPE or respirator, work in well ventilated area
Electrocution	3 (Improper use of equipment, static build-up)	4 (Possible explosion, destruction of electrical tools or components, possible severe harm to personnel)	12, Medium	Give labels to all high voltage equipment warning of their danger; ground oneself when working with high-voltage equipment
Entanglement with Construction Machines	3 (Loose hair, clothing, or jewelry)	5 (Severe injury, death)	15, High	Secure loose hair, clothing, and jewelry; wear appropriate PPE
Epoxy Contact	3 (Resin Spill)	3 (Exposure to Irritant)	9, Medium	Wear appropriate PPE such as gloves or lab coats, wash with water
Eye Irritation	3 (Airborne particulate debris)	2 (Temporary eye irritation)	6, Low	Wear appropriate PPE or protective eyewear, wash with water
Falling Hazards	3 (Improper use of ladders, attempting to climb unstable objects)	4 (Bruising, abrasions, possible severe harm if falling into construction equipment)	12, Medium	Do not climb objects which are not ladders, when using ladders have another person present to stabilize the ladder
Heatstroke	3 (High	3 (Exhaustion and	9, Medium	Wear clothing

	temperatures on launch day)	possible hospitalization)		appropriate to the weather, ensure all members have access to water at launch
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
Hypothermia	3 (Low temperatures on launch day)	3 (Sickness and possible hospitalization)	9, Medium	Wear clothing appropriate to the weather, ensure all members have access to a warm area to rest at launch
Kinetic Damage to Personnel	1 (Failure to take appropriate care around unburned fuel, post-landing launch vehicle explosion)	5 (Possible severe kinetic damage to personnel)	5, Low	Extinguish any fires before recovering, wait for motors to burn fully before recovering, wear appropriate PPE when recovering
Launch Pad Fire	2 (Dry Launch Area)	3 (Moderate Burns)	6, Low	Have fire suppression systems nearby and use a protective ground tarp
Injury from Ballistic Trajectory	3 (Recovery System Failure)	5 (Severe Injury, Death)	15, High	Keep all eyes on the launch vehicle and call “heads up” if needed
Injury from Falling Components	3 (Failure to keep all components securely attached to the launch vehicle; result of	5 (Severe injury, death)	15, High	Keep eyes on the launch vehicle at all times; make sure all team members who

	improper staging constraints, part failure, or excessive vibration)			cannot watch the launch vehicle have spotters nearby; alert others if the launch vehicle enters a ballistic trajectory.
Injury from Navigating Difficult Terrain	2 (Uneven ground, poisonous plants, fast-moving water)	4 (Broken bones, infections, drowning, etc.)	8, Medium	Do not attempt to recover the launch vehicle from atypically dangerous areas
Injury from Projectiles Caused by Jetblast	1 (Failure to properly clean launchpad, failure to wear proper PPE, failure to stand an appropriate distance from the launch vehicle during launch)	3 (Moderate injury to personnel)	3, Low	Clean the launchpad before use, ensure all members are wearing proper PPE for launch, ensure all team members are an appropriate distance from the launch vehicle when launching
Physical Contact With Heat Sources	3 (Contact with launch vehicle parts which were recently worked with, improper use of soldering iron or other construction tools)	3 (Moderate to severe burns)	9, Medium	Wear appropriate PPE, turn off all construction tools when not in use, be aware of the safety hazard that parts which were recently worked with present)
Physical Contact with Falling Construction Tools or Materials	3 (Materials which were not returned to a safe location after use)	5 (Bruising, cuts, lacerations, possible severe physical injury)	15, High	Brief personnel on proper clean-up procedures, wear shoes that cover the toes

Premature Ignition	2 (Short Circuit)	2 (Mild Burns)	4, Low	Prepare energetic devices only immediately prior to flight
Power Lines	2 (Launch vehicle Becomes Entangled In Lines)	5 (Fatal Electrocution)	10, Medium	Call the power company and stand clear until proper personnel arrive
Power Tool Cuts, Lacerations, and Injuries	3 (Carelessness)	4 (Possible Hospitalization)	12, Medium	Secure loose hair, clothing, and jewelry; wear appropriate PPE; brief personnel on proper construction procedures
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
Tripping Hazards	3 (Materials which were not returned to a safe location after use, loose cords on or above the ground during construction processes)	4 (Bruising, abrasions, possible severe harm if tripping into construction equipment)	12, Medium	Brief personnel on proper clean-up procedures, tape loose cords or wires to the ground if they must cross a path which is used by personnel
Unintended Black Powder Ignition	3 (Accidental exposure to flame or sufficient electric charge)	5 (Possible severe hearing damage or other personal injury)	15, High	Label containers storing black powder, one may only handle the black powder if he/she possesses a low-explosives user permit

Workplace Fire	2 (Unplanned ignition of flammable substance, through an overheated workplace, improper use or supervision of heating elements, or improper wiring)	5 (Severe burns, loss of workspace, irreversible damage to project)	10, Medium	Have fire suppression systems nearby, prohibit open flames, and store energetic devices in Type 4 magazines

3.5.4. Failure Modes and Effects Analysis (FMEA)

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	1 (Poor	5 (Partial or total	5, Low	Use appropriate

Fins	construction or improper materials used)	destruction of vehicle)		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

3.5.5. 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 launch vehicle)	15, High	Angle launch vehicle 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

3.5.6. 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 a detailed funding plan properly, minimize excessive spending by having multiple members check the necessity of purchases
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
Damage to or Loss of Parts	2 (Failure during testing, improper part care during construction, transportation, or launch)	5 (Cannot construct or fly vehicle without spare parts)	10, Medium	Have extra parts on hand in case parts need to be replaced, follow all safety procedures for transportation, launch, and construction
Rushed Work	2 (Rapidly approaching deadlines, unreasonable schedule expectations)	4 (Threats of failure during testing or the final launch due to a lower quality of construction and less attention paid to test data)	8, Medium	Set deadlines which both keep the project moving at a reasonable pace and leave room for unforeseen circumstances
Major Testing Failure	2 (Improper construction of the rocket, insufficient data used before creating the rocket's design)	5 (Damage to vehicle parts, possible disqualification from the project due to a lack of subscale flight data, an increase in budget for buying new	10, Medium	Only include reliable elements in the design which have been confirmed to work through prior designs or extensive mathematical and physical analysis

		materials, delay in project completion)		
Unavailable Test Launch Area	2 (Failure to locate a proper area to launch subscale rockets for testing, failure to receive an FAA waiver for the test launch)	5 (Disqualification from the project due to a lack of subscale flight data)	10, Medium	Secure a reliable test launch area and FAA waiver well in advance of the dates on which test launch data is required
Loss or Unavailability 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
Failure in Construction Equipment	1 (Improper long-term maintenance of construction equipment, improper use or storage of equipment)	3 (Possible long-term delay in construction)	3, Low	Ensure proper maintenance and use of construction equipment and have backup equipment which can be used in case of an equipment breakdown
Insufficient Transportation	1 (Insufficient funding or space available to bring all project members to launch sites or workplace)	3 (Loss of labor force, team members lose knowledge of what is happening with the project, low attendance to the final launch)	3, Low	Organize and budget for transportation early and keep track of dates on which large amount of transportation are needed

3.6. 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 4,360 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 3.8.

3.7. 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 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 currently hold a Low Explosives User Permit (LEUP), and these team members may assist the team's faculty mentor in handling 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. The MSDS must be read before working with the respective substances.

3.8. Team Safety Statement

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

As a member of the Purdue Space Program Student Launch (PSP-SL) 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 it does 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 Walker or the PSP-SL program.

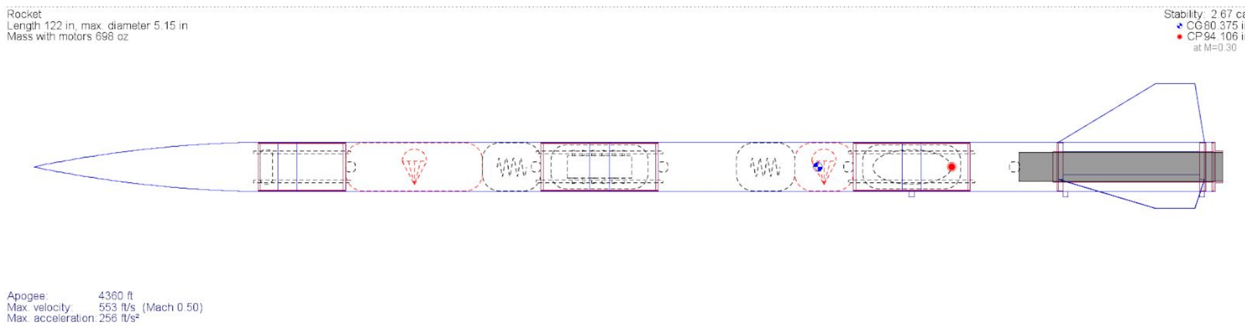
Name____

Signature____ Date_______________

4. Technical Design

4.1. Proposed Approach To Design

4.1.1. General Dimensions, Materials, And Construction



The team's proposed full scale launch vehicle is 5.15" in diameter, 122" tall, and made entirely out of filament wound fiberglass composite materials. It features a main tube, a drogue tube, and a bottom tube, all 30'' in length. The group chose to build the vehicle out of this material for various reasons. FWFG is available from multiple distributors, allowing ease to receive spare parts and ease to cut, drill, sand, and paint components. 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.

Two breakpoints will be utilized to break the launch vehicle up into three sections during descent, as a regular launch vehicle would if flying the standard dual deployment configuration. At apogee, the launch vehicle 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 nose cone 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 six 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, the team will also be utilizing a thrust plate at the rear of the launch vehicle 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

The projected altitude for the full scale launch vehicle that is planned to be competed with was calculated by using OpenRocket, a publicly available launch vehicle design program. The simulation was run 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 the current vehicle design will reach an apogee of 4,360’ above ground level. This gives us a buffer of 860’ over the minimum height before disqualification of 3,500’, which is approximately a 25% margin of error. This model is acceptable to us currently as it does not include weights associated with construction or add-ons such as epoxy, paint, shear pins, or rivets. Additionally, the payload weight was overestimated to allow for flexibility in design. Once construction of the launch vehicle 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 4,360’ above ground level, and the physical model will be weighted appropriately to match the computer data.

4.1.3. Projected Recovery System Design

The 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 launch vehicle. The drogue parachute the team will be using is likely to be a Skyangle Cert 3 24” drogue parachute with a drag coefficient of 1.16 and a total surface area of 6.3 ft^2. The parachute weighs a total of 6.0 oz and is made of zero porosity 1.9 oz/yd^2 silicone coated balloon cloth. It is connected to a nickel-plated 1,500 lbs rated swivel via four canopy shroud lines that are ⅝” mil-spec tubular nylon rated for 2,250 lbs. The tether that will connect the two separate sections will likely be made of ½” tubular kevlar with a tensile strength of 7,200 lbs. Both ends of the tether will be sewn shut to allow quick disconnection to the launch vehicle 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 launch vehicle 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 nose cone. The main parachute will likely be a Skyangle Cert 3 XL parachute with a drag coefficient of 2.59 and a total surface area of 89.0 ft^2. It is constructed in an identical fashion to the proposed drogue parachute, and will use the same shock cord for the main tether as is used in the drogue tether of the launch vehicle. 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 nose cone 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 FFFFg 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 in^2

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.

Force on Bolt at Fail = Area of Bolt * Shear Strength of Nylon
Force on Bolt at Fail = 0.00502 in^2 * 10,000 PSI
Force on Bolt at Fail = 50.2 lb
3x Force on Bolt at Fail = 150.6 lb

Bulkhead Area = Pi * $Radius^2$
Bulkhead Area = 3.14 * 3^2
Bulkhead Area = 28.27 in^2

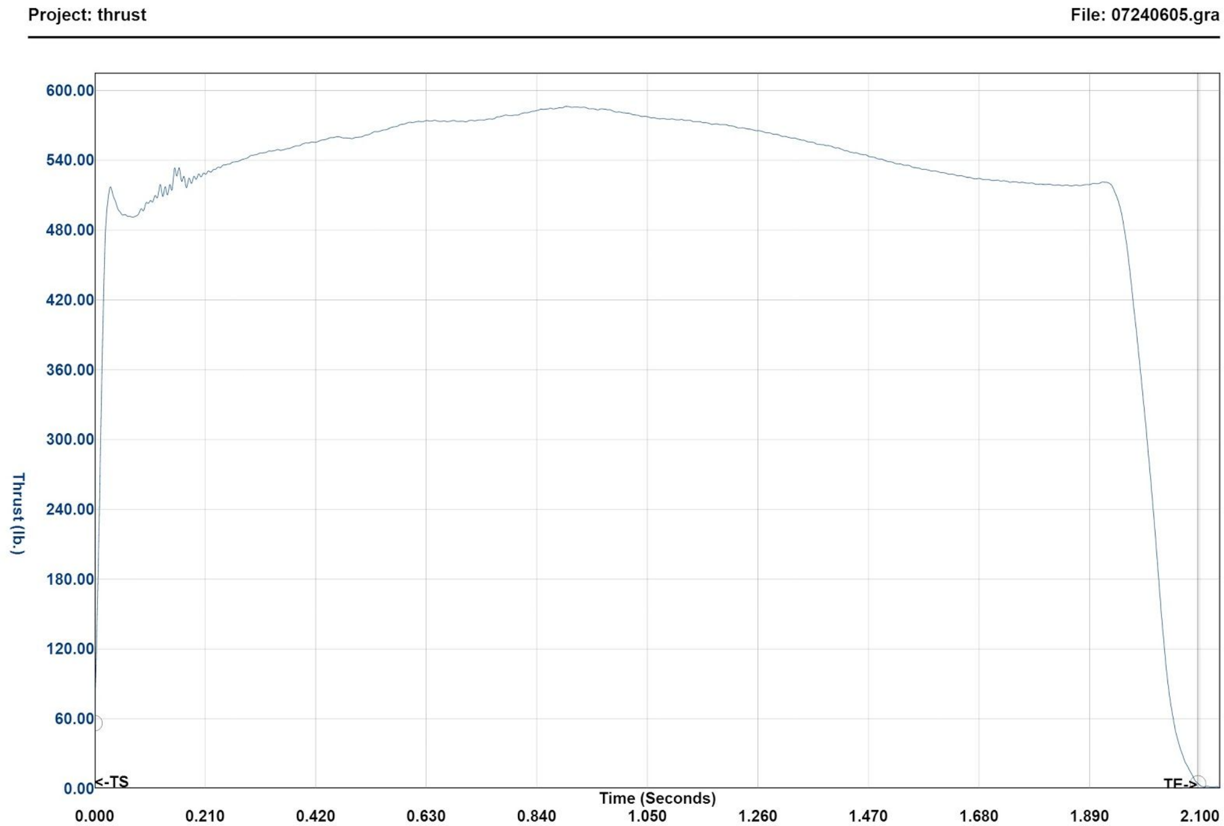
$$\text{Bulkhead Pressure} = 3x \text{ Force on Bolt at Fail} / \text{Bulkhead Area}$$
$$\text{Bulkhead Pressure} = 150.6 \text{ lb} / 28.27 \text{ in}^2$$
$$\text{Bulkhead Pressure} = 5.32 \text{ PSI}$$

By using the equation $0.004 * D^2 * L = G$ (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), the amount of black powder needed to sufficiently shear all of the nylon bolts can be calculated, and a safety factor of 1.2 can be added to the that amount via multiplication.

$$G = 0.004 * 5.15^2 * 30 * 1.2$$
$$G = 3.81924 \text{ g of black powder}$$

4.1.4. Projected Motor Brand And Designation

The motor proposed for use in the full scale launch vehicle 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, delivering a maximum thrust of 629 pounds. This will propel the full scale launch vehicle 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 system that will deploy a rover upon landing. This system will be able to detect that the rocket has landed safely and be remotely triggered to deploy from the payload bay. This rover will autonomously exit the payload bay and maneuver a distance of at least ten feet from all parts of the rocket. After reaching this distance and ensuring that it is far enough from the rocket, a process will be triggered on the rover to collect a ten milliliter soil sample from the ground. This sample will be contained so that it can be tamper-proof and safely retrieved manually.

Retention and Deployment Systems:
The design will consist of a payload bay located aft of the avionics bay. The payload bay will hold a fairing capsule with the rover inside. The capsule will be weighted on one side, and it will rotate freely, allowing the rover to stay upright within the launch vehicle during flight and landing. This will be necessary should the rover design change. The inside of the capsule will be padded to secure the rover and protect it from damage during takeoff and landing. The capsule will consist of two halves connected by a spring loaded hinge at the rear. The sides of the launch vehicle will hold the capsule closed

during flight. Upon landing, the capsule will be launched from the launch vehicle via black powder charge, and the two halves will spring open, releasing the rover. The capsule will be made from a lightweight plastic using a 3D printer. This design was selected because it effectively protects the rover, is very lightweight, keeps the rover upright, and has minimal need for electronics and a power source.

Physical Rover Specifications:
The rover will consist of two wheels, a digging mechanism, a sample storage bay, and an arduino microcontroller. The rover will be powered by Lithium-Polymer(LiPo) batteries that will be incorporated in the center of the chassis. The two wheels will be larger than the chassis, allowing the rover to function regardless of orientation and to rotate the digging system to optimal position. The digging system will be able to collect the desired 10 mL sample and store it in the storage bay underneath the chassis.
The wheels will be acquired from a hobby-RC car to prevent possible traction issues. Each wheel will be independently controlled and powered by a brushless DC motor for quick maneuverability and acceleration.

Soil Sampling:
Several concepts have been developed for the rover's soil sample collection. The primary control factor for the designs mandated that the rover fit the specifications of the 5.15'' diameter launch vehicle, and from this arose other constraints. The concern became that the rover would not be able to generate enough counter-torque for digging due to its light-weight structure. These issues had to be addressed in the soil collection systems.

- Chosen Method:
  This method has three steps. First, loosen the soil - preferably with no grass nearby. Next, collect the required amount of soil. Finally, contain it on-board the rover. Several strategies were developed to accomplish these steps. The first, and by far the simplest, is to attach a container (a prism or cylinder) to the belly of the rover. The container will have a spade-like (or scoop) edge nearest the ground. The rover will the drive back and forth in a single area while loosening the soil underneath with the "shovel." The container, via a small actuator, will scoop up a sample and a flap will fall over the collection aperture, thereby containing the soil in the rover.

- Alternative Method 1:
  Another method was proposed to loosen the dirt via the wheels. If the wheels have large grousers that could dig themselves into the dirt, the rover could potentially hang a scooping container aft of the rear wheels - perhaps a bar, like some tractors do when they sow a field. This would require some testing to see if the rover would not get stuck.

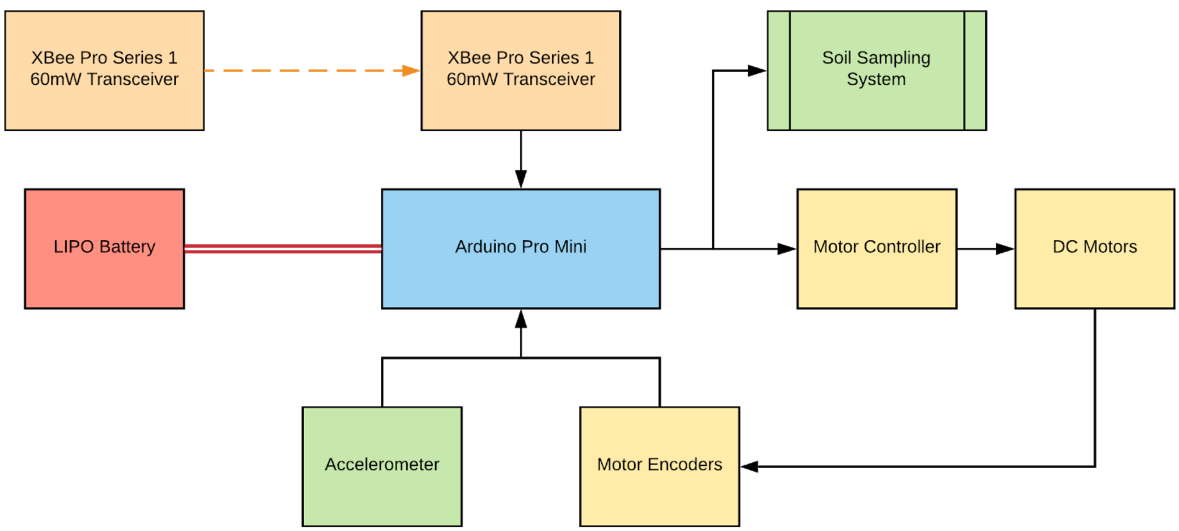
- Alternative Method 2:
  This method involved drilling via an auger or drill bit into the ground and

extracting a sample. Seeing as there is no requirement for depth over sheet mining, this method is likely unfeasible especially since there exists the concern of the rover's ability to counter the digging force. This method was tossed aside on account of its complexity, which would likely cause size restriction. However, this method would be beneficial for the future should requirements change.

- Alternative Method 3:
  This method involved using a quasi clam-shell system to grab a sample from a predetermined location around the rover. This would require multiple actuators to control the height of the arm and the motion of one shell, so it was also not chosen due to its complexity. However, this method could be useful depending on what type of environment the rocket lands in.

Onboard Electronics and Logic

A general electronics architecture has been outlined for the control of the rover hardware as well as the general logic of its operation.



As seen in the above diagram, the preliminary payload design utilizes an Arduino Pro Mini microcontroller for control of the inputs and outputs of the system. The Arduino Pro Mini has a number of design features that make it ideal for this application. First, it has a very small footprint. Weighing only 56 grams and taking up roughly 600 mm^2 of space, its size will yield flexibility in the placement of it inside the vehicle. Secondly, the Arduino platform has extensive support documentation and a multitude of readily available software libraries that can be utilized when working with the other electronics on the rover. Finally, the Arduino Pro Mini meets the projected electrical and software needs of the vehicle. The device can operate on low power and has a sufficient number of inputs and outputs to interface with the rest of the rover.

Another integral piece of the overall electronics architecture for the rover is the communication link between the rover and the team at the launch site. The preliminary payload design uses two XBee Pro Series 1 60mW wireless communication modules to handle this communication. This system must be dependable, as the rover's chance at a successful mission is predicated on successful deployment from the launch vehicle. With an effective range of 1 mile, automatic serial linking, and low-power functionality, the XBee system will provide assurance that the remote execution of the rover's deployment will go smoothly.

Finally, to power the rover's electronics, the preliminary design relies on lithium polymer (LiPo) battery technology. LiPo batteries provide higher current draw and higher capacities than other types of batteries, such as nickel metal hydride (NiMH), that were researched. Additionally, LiPo batteries are generally very lightweight and can be manufactured in a variety of shapes and sizes. One drawback of LiPo battery technology, however, is the potential safety hazard associated with it. Care must be taken by the team in the handling, charging, and discharging of the batteries so as not to cause a fire.

Path-Planning

Path-planning of the rover involves determining a continuous trajectory in free space, assuming one exists, from a starting location to an end goal. In order to complete the necessary mission requirements relevant to rover navigation and guidance, a sufficient and robust path-planning system is necessary. The capabilities describing the minimum success criteria for the path-planning of the rover is the ability to avoid collision with the launch vehicle body, the ability to avoid collisions with environmental objects, and the ability to move a distance of at least 10 feet from the closest launch vehicle component. Capabilities that are secondary to these minimum success criteria may be determination of a final configuration suitable for optimal soil extraction, determination of a minimum length and safe path, accurate mapping and localization of the rover, and collection and storage of sensor information.

Upon deployment from the payload bay, the rover must be capable of calculating a path from its starting point to its final configuration such that no collision takes place between the rover and the obstacles present within the environment. Calculation of a collision free path requires knowledge of the structure of the environment, placement and configuration of those obstacles, as well as the physical dimensions and capabilities of the robot. Since the environment and placement of several launch vehicle sections will be random, it will be impossible to have prior knowledge of the rover's environment and therefore an on-line algorithm must be used to discreetly map and remap the environment. In order to map the environment of the rover as well as determine its relative position, on-board sensors that can recognize obstacles and measure rover movement will be necessary.

The on-board sensors that will be used on the rover will be non-visual due to the limited computational capabilities of the microcontroller. Visual sensors, such as cameras, are computationally expensive since they involve high use and frequency of I/O as well as continuous manipulation and interpretation of large sets of data, both of which are not feasible for a microcontroller. Non-visual sensors, in comparison, provide much less data making it easier both handle and interpret sensor data, all the while being sufficient enough to handle pose estimation, pose maintenance, and map construction. Call frequencies, number and location of sensors, and types of sensors used will depend on constraints of the rover and its environment.

The algorithms, sensors used, and mapping and localization capabilities will depend on several constraints involving the microcontroller, physical rover construction (i.e. weight, dimensions, etc.), environment of the rover, mission requirements, and rover and environmental uncertainties. The computational speed of the microcontroller will limit the speed and effectiveness of mapping and localization, meaning limits on sensor call-frequency, number of sensors and accuracy must be made to optimize performance. The physical construction of the rover will also have a hand in determining the number of sensors, and the placement of sensors. The environment will determine the most effective sensors that will be used for obstacle recognition and measurement of rover movement. The mission requirements will place constraints on the operational range of the range-finding sensors since the requirements call for the rover to move a certain distance away from the launch vehicle.

Currently, the path-planning system plans to utilize ultrasonic range-finding sensors for obstacle detection and an inertial measurement unit (IMU) to determine pose. The future decision of the actual path-planning algorithm will rely on the on-line algorithms used for mapping and localization, which are further dependent on limitations of the sensors (such as call-frequency and accuracy) and computational speed of the microcontroller.

4.1.6. Outline of Project Requirements

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).

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.

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.

1.4. The team must identify all team members attending 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.

1.5. The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the STEM Engagement Activity Report, by FRR. To satisfy this requirement, all events must occur between project acceptance and the FRR due date and the STEM Engagement Activity Report must be submitted via email within two weeks of the completion of the event. A sample of the STEM Engagement Activity Report can be found on page 33 of the handbook.

1.6. The team will establish a social media presence to inform the public about team activities.

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.

1.8. All deliverables must be in PDF format.

1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections.

1.10. In every report, the team will include the page number at the bottom of the page.

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. All teams will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted on the launch field. Eight foot 1010 rails and 12 foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on launch day. The exact cant will depend on launch day wind 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 certification, 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 launch vehicle 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.

2. vehicle Requirements

2.1. The vehicle will deliver the payload to an apogee altitude between 4,000 and

5,500 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.

2.2. Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score during Launch Week.

2.3. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner. The Altitude Award will be given to the team with the smallest difference between their measured apogee and their official target altitude on launch day.

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

2.5. Each altimeter will have a dedicated power supply.

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

2.7. 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.

2.8. 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.

2.8.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.

2.8.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.

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

2.10. 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.

2.11. The launch vehicle 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.

2.12. 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.

2.13. 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).

2.14. 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

2.19. All teams will successfully launch and recover a subscale model of their launch vehicle prior to CDR. Subscales are not required to be high power launch vehicles.

2.19.1. 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.

2.19.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude.

2.19.3. The subscale launch vehicle must be a newly constructed launch vehicle, designed and built specifically for this year's project.

2.19.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.

2.20. All teams will complete demonstration flights as outlined below.

2.20.1. vehicle Demonstration Flight - All teams will successfully launch and recover their full-scale launch vehicle prior to FRR in its final flight configuration. The launch vehicle flown must be the same launch vehicle to be flown on launch day. The purpose of the vehicle Demonstration Flight is to validate 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 the intended lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:

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

2.20.1.2 The full-scale launch vehicle must be a newly constructed launch vehicle, designed and built specifically for this year's project.

2.20.1.3. The payload does not have to be flown during the full-scale vehicle Demonstration Flight. The following requirements still apply:

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

2.20.1.3.2. The mass simulators will be located in the same approximate location on the launch vehicle as the missing payload mass.

2.20.1.4. If the payload changes the external surfaces of the launch vehicle (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 vehicle Demonstration Flight.

2.20.1.5. Teams shall fly the launch day motor for the vehicle Demonstration Flight. The RSO may approve use of an alternative motor if the home launch field cannot support the full impulse of the launch day motor or in other extenuating circumstances.

2.20.1.6. 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.

2.20.1.7. 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).

2.20.1.8. Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.

2.20.1.9. vehicle Demonstration flights must be completed by the FRR submission deadline. 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 must submit an FRR Addendum by the FRR Addendum deadline.

2.20.2. Payload Demonstration Flight - All teams will successfully launch and recover their full-scale launch vehicle containing the completed payload prior to the Payload Demonstration Flight deadline. The launch vehicle flown must be the same launch vehicle to be flown on launch day. 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 launch vehicle experiences stable ascent, the payload is fully retained during ascent and descent, and the payload is safely deployed on the ground. The following criteria must be met during the Payload Demonstration Flight:

2.20.2.1. The payload must be fully retained throughout the entirety of the flight, all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair.

2.20.2.2. The payload flown must be the final, active version.

2.20.2.3. If the above criteria is 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.

2.20.2.4.Payload Demonstration Flights must be completed by the FRR Addendum deadline. No extensions will be granted.

2.21. 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.

2.21.1. 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 the vehicle at launch week.

2.21.2. 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 the payload at launch week.

2.21.3. 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.

2.22. Any structural protuberance on the launch vehicle will be located aft of the burnout center of gravity.

2.23. The team's name and launch day contact information shall be in or on the launch vehicle 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.

2.24. vehicle Prohibitions

2.24.1. The launch vehicle will not utilize forward canards. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.

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

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

2.24.4. The launch vehicle will not utilize hybrid motors.

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

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

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

2.24.8. vehicle ballast will not exceed 10% of the total unballasted weight of the launch vehicle as it would sit on the pad (i.e. a launch vehicle with and unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).

2.24.9. Transmissions from onboard transmitters will not exceed 250 mW of power.

2.24.10. Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.

3. 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.

3.1.1. 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.

3.2. 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 section 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 2,500 ft. radius from the launch pads.

3.10. Descent time will be limited to 90 seconds (apogee to touch down).

3.11. 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.

3.11.1. Any launch vehicle section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.

3.11.2. The electronic tracking device(s) will be fully functional during the official flight on launch day.

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

3.12.1. 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.

3.12.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.

3.12.3. 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.

3.12.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

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 one of the College/University Division experiment options.

4.2. College/University Division – Each team will choose one experiment option from the following list.

4.2.1. An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring.

4.2.2. 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.

Option 1 - Deployable Rover/Soil Sample Recovery

Option 2 - Deployable UAV/Beacon Delivery

4.3. Deployable Rover / Soil Sample Recovery Requirements

4.3.1. Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.

4.3.2. The rover will be retained within the vehicle utilizing a fail-safe active retention system. The retention system will be robust enough to retain the rover if atypical flight forces are experienced.

4.3.3. At landing, and under the supervision of the Remote Deployment Officer, the team will remotely activate a trigger to deploy the rover from the rocket.

4.3.4. After deployment, the rover will autonomously move at least 10 ft. (in any direction) from the launch vehicle. Once the rover has reached its final destination, it will recover a soil sample.

4.3.5. The soil sample will be a minimum of 10 milliliters (mL).

4.3.6. The soil sample will be contained in an onboard container or compartment. The container or compartment will be closed or sealed to protect the sample after collection.

4.3.7. Teams will ensure the rover's batteries are sufficiently protected from impact with the ground.

4.3.8. The batteries powering the rover will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other rover parts

4.4. Deployable Unmanned Aerial vehicle (UAV) / Beacon Delivery Requirements

4.4.1. Teams will design a custom UAV that will deploy from the internal structure of the launch vehicle.

4.4.2. The UAV will be powered off until the launch vehicle has safely landed on the ground and is capable of being powered on remotely after landing.

4.4.3. The UAV will be retained within the vehicle utilizing a fail-safe active retention system. The retention system will be robust enough to retain the UAV if atypical flight forces are experienced.

4.4.4. At landing, and under the supervision of the Remote Deployment Officer, the team will remotely activate a trigger to deploy the UAV from the rocket.

4.4.5. After deployment and from a position on the ground, the UAV will take off and fly to a NASA specified location, called the Future Excursion Area (FEA). Both autonomous and piloted flight are permissible but all reorientation or unpacking maneuvers must be autonomous.

4.4.6. The FEA will be approximately 10 ft. x 10 ft. and constructed of a color which stands out against the ground.

4.4.7. One or more FEA's will be located in the recovery area of the launch field. FEA samples will be provided to teams upon acceptance and prior to PDR.

4.4.8. Once the UAV has reached the FEA, it will place or drop a simulated navigational beacon on the target area.

4.4.9. The simulated navigational beacon will be designed and built by each team and will be a minimum of 1 in W x 1 in H x 1 in D. The school name must be located on the external surface of the beacon.

4.4.10. Teams will ensure the UAV's batteries are sufficiently protected from impact with the ground.

4.4.11. The batteries powering the UAV will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other UAV parts.

4.4.12. The team 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).

4.4.13. Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.

4.5. Team-Designed Payload Requirements (High School/Middle School Division)

4.5.1. Team-designed payloads must be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.

4.5.2. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.

4.5.3. The experiment must be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.

4.5.4. Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.

4.5.5. Unmanned aerial vehicle (UAV) 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 UAV.

4.5.6. Teams flying UAVs 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).

4.5.7. Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.

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.

5.2. Each team must identify a student safety officer who will be responsible for all items in section 5.3.

5.3. The role and responsibilities of each 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

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. Launch day

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.

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.

5.5. Teams will abide by all rules set forth by the FAA.

4.1.7. Major Technical Challenges and Solutions

There are a few concerns for the design of the deployable rover. The first major technical challenge will be to actually deploy the rover from the payload bay. Since the bay will be made to be durable and able to safely deliver the rover, this will also make it difficult to open up upon landing. To overcome this the team will use a black powder charge that has been calculated to shoot out a capsule containing but not damaging the rover. This will be tested multiple times to ensure the rover is ejected in a manner which is safe for the launch vehicle, the rover, and the surrounding area. Another major technical challenge will be maneuvering the rover a distance of ten feet away from each part of the rocket. Since there is a certain degree of variability in where each one of the pieces will be located, the team will need to have some sort of proximity sensors on the rover that can ping distances from the rover to the pieces of the rocket. The computer system will be able to calculate the path of travel based on this data. The last major technical challenge will be retrieving and storing a soil sample from the ground. The soil will not necessarily be loose already, so the rover will need to have a means of digging into the ground, potentially through grass as well. The rover will first be able to loosen the dirt, and then be able to drive back over the loosened dirt and collect it.

5. Educational Engagement

5.1. Plans And Evaluation Criteria For Educational Engagement

To engage and raise interest in space exploration and rocketry, the team will hold several educational involvement events during Purdue's 2018-2019 school year. The team will have a booth at Purdue Space Day to reach children attending the event and will have team members volunteer as group and activity leaders. The team is also going to hold live demonstrations at the Imagination Station Mini Makers Faire involving the team's subscale rocket. The team is also planning on visiting local schools to show how its rockets work and to allow students to safely help in the construction of hobby rockets to increase their interest in rocketry. The team is also going to hold various 3D printing classes at locations around campus to teach students how to use CAD and other tools. The team is also planning various cookouts to increase social engagement around the campus and teach students about rocket science and other STEM subjects.

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
08/31-09/03/2018	AIRFest 24 @ Argonia, Kansas Rocket Pasture
09/02/2018	Purdue SL general meeting
09/03/2018	LABOR DAY
09/09/2018	Indiana Rocketry Launch
09/09/2018	Purdue SL general meeting
09/16/2018	Purdue SL general meeting
09/19/2018	Proposal due to project office by 3PM CDT
09/23/2018	Purdue SL general meeting
09/29-09/30/2018	ROCI HPR Sport Launch @ AMA Aeromodeling Center in Muncie
09/30/2018	Purdue SL general meeting
10/04/2018	Awarded proposals announced
10/07/2018	Purdue SL general meeting
10/08-10/09/2018	OCTOBER BREAK
10/12/2018	Kickoff, PDR Q&A
10/13/2018	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville
10/14/2018	Purdue SL general meeting
10/14/2018	Indiana Rocketry Launch
10/20/2018	ROCI HPR Sport Launch @ AMA Aeromodeling Center in Muncie
10/21/2018	Purdue SL general meeting
10/26/2018	Web presence established, URLs sent to project office by 8AM CDT
10/27/2018	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville
10/28/2018	Purdue SL general meeting
10/28/2018	Chipotle Fundraiser
11/01-11/03/2018	SEDS SpaceVision @ San Diego
11/02/2018	PDR reports, slides, and flysheet posted online by 8AM CDT
11/02-11/04/2018	Midwest Power Launch

11/04/2018	Purdue SL general meeting
11/05/2018	PDR video teleconferences start
11/10/2018	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville
11/11/2018	Purdue SL general meeting
11/11/2018	Indiana Rocketry Launch
11/18/2018	Purdue SL general meeting
11/19/2018	PDR video teleconferences end
11/21-11/24/2018	THANKSGIVING BREAK
11/24/2018	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville
11/25/2018	Purdue SL general meeting
11/27/2018	CDR Q&A
12/2/2018	Purdue SL general meeting
12/08/2018	Quad Cities Rocket Society (QCRS) Launch
12/09/2018	Purdue SL general meeting
12/09/2018	Indiana Rocketry Launch
12/15-01/06/2019	WINTER BREAK
01/03/2019	Final day for subscale launch
01/03/2019	Final motor choice made for launch
01/04/2019	CDR reports, slides, and flysheet posted online by 8AM CDT
01/06/2019	Possible Purdue SL general meeting
01/07/2019	CDR video teleconferences start
01/13/2019	Purdue SL general meeting
01/13/2018	Indiana Rocketry Launch (?)
01/20/2019	Purdue SL general meeting
01/21/2019	MLK JR. DAY
01/22/2019	CDR video teleconferences end
01/25/2019	FRR Q&A
01/27/2019	Purdue SL general meeting
02/03/2019	Purdue SL general meeting
02/10/2019	Purdue SL general meeting
02/10/2019	Indiana Rocketry Launch (?)
02/17/2019	Purdue SL general meeting
02/24/2019	Purdue SL general meeting
03/03/2019	Purdue SL general meeting

03/03/2019	Final day for full scale launch/vehicle Demonstration Flight
03/04/2019	vehicle Demonstration Flight data reported to NASA
03/04/2019	FRR reports, slides, and flysheet posted online by 8AM CDT
03/08/2019	FRR video teleconferences start
03/10/2019	Purdue SL general meeting
03/10/2019	Indiana Rocketry Launch (?)
03/11-03/16/2019	SPRING BREAK
03/17/2019	Possible Purdue SL general meeting
03/21/2019	FRR video teleconferences end
03/24/2019	Purdue SL general meeting
03/25/2019	Payload Demo Flight/vehicle Demonstration Re-flight deadlines
03/25/2019	FRR Addendum submitted to NASA by 8:00AM CDT (if needed)
03/31/2019	Purdue SL general meeting
04/03/2019	Travel to Huntsville, Alabama
04/03/2019	OPTIONAL – LRR for teams arriving early
04/04/2019	Launch week kickoff and activities
04/04/2019	Official LRRs if not done on 04/03
04/05/2019	Launch week activities
04/06/2019	Launch day
04/06/2019	Awards Ceremony
04/07/2019	Backup launch day
04/07/2019	Possible Purdue SL general meeting
04/14/2019	Purdue SL general meeting
04/21/2019	Purdue SL general meeting
04/26/2019	PLAR posted online by 8AM CDT

6.2. Detailed Budget

Full Scale Rocket

Rocket Parts	Unit Cost	Quantity	Total
5:1 5" Von Karman FWFG Nosecone	108.95	1	108.95
5" Stepped AL Avionics bay lids	16	6	96
5" FWFG Airframe, 30" long	85	3	255
Custom Airframe Slotting, 3/16" wide, 15" long	6	3	18
5" FWFG Switch Band, 2" long	7	2	14

5" FWFG Coupler, 12" long	53	2	106
3" FWFG Motor Tube, 30" long	50	1	50
1/8" G10 FG Centering Ring	9	2	18
1/2" Plywood Centering	5	2	10
3/16" G10 FG Fins 6" tall, 15" root, 4" tip, 10" sweep	20	3	60
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
5"/75mm SC Precision Thrust Plate	55.59	1	55.59
Aerotech 75mm 3G Hardware Set	450	1	450
Aerotech 75mm 3G L1520-T Reload	199	2	398
Total Cost			2066.89

The above parts for the full scale rocket have already been purchased and financed by last year's competition budget, so the amount above is not included in the overall budget this year.

Sub Scale Rocket

The subscale rocket will be a non-high-power rocket. Anticipated overall cost for sub-scale parts is around $100 based on costs from previous years in the competition. Many team members have the parts required to build a rocket of this scale already, so the $100 is a safeguard to the project in case the team finds that no members have a specific part required to build the subscale.

Avionics
Avionics parts are currently being provided by the team's parent organization, the Students for the Exploration and Development of Space (SEDS), with the exception of 3D printed parts and connectors. Expected costs for unpurchased/unprovided parts will be around $150.

Payload
Necessary payload parts will be determined once rover design is finalized. For now, $500 will be allocated towards the payload parts.

Travel

Item	Unit Cost	Quantity	Total
Hotel Room	240	5	1200
Gas	40	18	720
			1920

Total Projected Cost: $6,390
When the total projected cost is given a 10% buffer it amounts to $7,029. This buffer accounts for costs that the team does not currently have a value for or does not know, including potential full scale parts that require replacement and other products the team does not currently have the price for.

6.3. Funding Plan

Assuming that the team requires around $7000, there will be three primary ways funds will be made to support the NASA SL project:

1. Skip-a-meals and Campus Fundraisers: Skip-a-meals are social events where individuals can mention PSP-SL 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. The team currently has two skip-a-meals scheduled for later in the semester - one is currently scheduled for October 28th.

2. Non-profit and Educational Grants: Although they can easily fund a large chunk of the team's expected budget, 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 from which the team has taken its members (eg. College of Engineering), so that the team 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). Currently the team

plans to approach INSGC (Indiana Space Grant Consortium), whose grant can pay for its travel expenses.

3. Honors College Grants: Certain students on the team are making their work on this team part of class through the honors college. Part of this contract is a $1,000 grant attached to their participation. The team anticipates one or two students will be awarded this money to put towards the team.

4. GoFundMe: The team plans to run a GoFundMe page for external donations to the project. This page will be made live in a few weeks.

The team's current goal is to have almost all the money needed available before the end of the fall semester. Grants can take a while to process. Doing them in advance, especially if the team needs the money to be able to manufacture the rocket, is going to be very important. The team has 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 to do skip-a-meals with, and make decisions on which the team will approach. The sign-up process usually only takes a week or two
- Figure out if the team going to do any other types of campus fundraising or hold any social events from which the team benefits financially
- Begin catering the website to purposes related to outreach

October:
- Finish website sufficiently enough to present it to the public (mid-October at the latest)
- Send out emails to school departments
- Hold at least one skip-a-meal/public event to gain a rough understanding of how much money the team can acquire from that
- Begin applying for grants and talking to companies for sponsorships

November:
- Have a few grants that the team can use
- Build a more accurate budget
- Website should be regularly updated at this point, whether it be for documentation purposes or for giving the team an active image

December:

- Continue applications. At this point the team will ideally have most of the money it needs. If not, the team will have another two months to continue searching for ways to make the remainder of the money.

Fund Source	**Funds Generated**
SEDS Treasury	$2000
Restaurant Socials (3 throughout year)	$600 ($200 each)
Grants	$3000 (across multiple grants)
GoFundMe	$1400 (will pay for travel mostly)
TOTAL:	$7000

6.4. Project Sustainability

On campus the team will be regularly scheduling booths where it can present the work that it has accomplished to students on campus. The team also intends to have representatives at local rocketry competitions and launches in order to raise awareness for the team. The PSP-SL website will be updated fairly regularly, documenting the work done on the 2018-2019 project so that others may see. Individuals and organizations/companies that donate to the project will be updated on how their donation is being used in the project.

The sustainability of the Purdue Space Program Student Launch team founded under SEDS is dependent on multiple factors, primarily funding. By following the team's funding plan, the team hopes to generate enough revenue to continue its 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 the 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 the team's hope that projects such as these continue to be held past the completion of the 2018 competition and well into the future.

Appendix A

A1. High Power Rocketry Safety Code

1. Certification. I will only fly high power rockets or possess high power launch vehicle 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 launch vehicle 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 launch vehicle 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 launch vehicle 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 launch vehicle is in the launching position.

5. Misfires. If my launch vehicle 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 launch vehicle 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 launch vehicle I will observe the additional requirements of NFPA 1127.

7. Launcher. I will launch my launch vehicle from a stable device that provides rigid guidance until the launch vehicle 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 launch vehicle 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 launch vehicle motor being launched uses titanium sponge in the propellant.

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

9. Flight Safety. I will not launch my launch vehicle 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 launch vehicle will not exceed any applicable altitude limit in effect at that launch site.

10. Launch Site. I will launch my launch vehicle 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 launch vehicle so that all parts of my launch vehicle 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 launch vehicle 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.

A2. 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 launch vehicle is one that is multi-staged or that is propelled by two or more launch vehicle motors