Project Casper Proposal

Purdue University 2020

500 Allison Road
West Lafayette, IN 47906

Purdue Space Program

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Acronyms and Abbreviations

Acronym / Abbreviation	Definition
PSP	Purdue Space Program
SL	Student Launch
ASAP	As Soon As Possible
ASL	Aerospace Science Laboratory
CDR	Critical Design Review
FAA	Federal Aviation Administration
FRR	Flight Readiness Review
LRR	Launch Readiness Review
NAR	National Association of Rocketry
NASA	National Aeronautics and Space Agency
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
TRA	Tripoli Rocket Association

1. Proposal Report Summary

The information in the following sections summarizes who PSP-SL is as a team and provides information about our mentor, general launch vehicle details, and various other basic statistics.

1.1. Team Summary

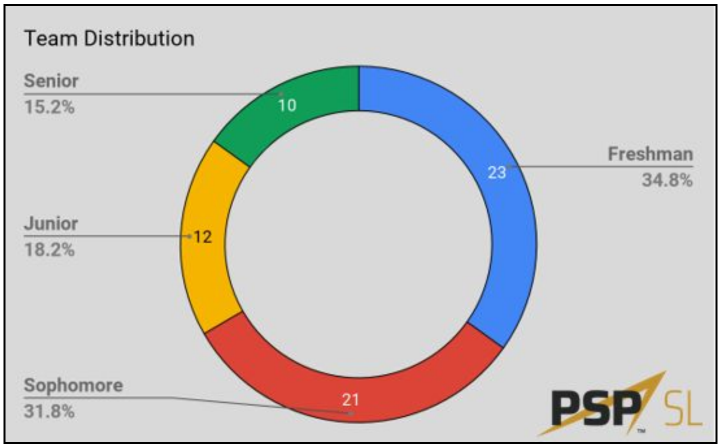
Team Name	PSP-SL (Purdue Space Program - Student Launch)
Mailing Address	2604 Bristlecone Dr., West Lafayette, IN 47906
2020 Mentor Name	Victor Barlow
2020 Mentor Contact Information	vmbarlow@purdue.edu | (765) 414-2848 (Cell)
2020 Mentor TRA / NAR Certifications	NAR 88988, TRA 6839 TAP, Level 3 Certified
2020 TRA / NAR Sections of Choice	NAR 88988, TRA 6839

1.2. PSP-SL 2020 Executive Board

Position	Name	Email
Project Manager	Luke Perrin	lperrin@purdue.edu
Assistant Project Manager	Michael Repella	mrepella@purdue.edu
Safety Team Lead	Noah Stover	nstover@purdue.edu
Payload Co-Team Lead	Josh Binion	binionj@purdue.edu
Payload Co-Team Lead	Hicham Belhseine	hbelhsei@purdue.edu
Avionics & Recovery Team Lead	Katelin Zichittella	kzichitt@purdue.edu
Business Team Lead	Natalie Keefer	nkeefer@purdue.edu
Social & Outreach Team Lead	Skyler Harlow	sharlow@purdue.edu
Construction Team Lead	Lauren Smith	smit3204@purdue.edu
Construction Team Mentor	Zach Carroll	carrollz@purdue.edu

1.3. Student Participants

The PSP-SL team currently consists of 65 students for this year's competition, each ready to show what makes Purdue University one of the best engineering schools in the nation. The breakdown of these student participants by PSP-SL academic year is as follows:



1.4. Access to Facilities

Listed below are the facilities the team intends to utilize throughout the rocket manufacturing process, as well as a brief description of the facility, the team's primary contacts, the extent of the facility's intended use and equipment to be used, and any safety precautions specified by the facility.

1.4.1. Aerospace Science Laboratory

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 the Purdue Space Program organization 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. 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 keypad
Required Personnel	A member of the PSP-SL exec board for access, Safety Officer for safety
Necessary Equipment	Drill presses, table saws, vertical bandsaws, adhesives, abrasives, and common hand tools
Safety Precaution	Team members must be briefed on proper safety precautions for using the ASL's equipment by the safety officer before being allowed to use

	the building's resources. PPE in the form of earplugs and safety glasses is available on-site
General Use	Vehicle assembly, light manufacturing

1.4.2. Zucrow Propulsion Laboratory

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	Professor Scott Meyer for access, Safety Officer for safety
Necessary Equipment	Equipment specified by Scott Meyer and on-site instructions
Safety Precaution	Limited access through Scott Meyer, climate controlled environment, and secured areas
General Use	Storage of potentially dangerous materials, such as high energy devices (motor, compressed gas, igniters, black powder, etc.)

1.4.3. BIDC

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. These rules, safety concerns, and safety protocols will be applied to all machining and safety for every location used by the team (Zucrow, ASL, etc.) to where all must be briefed before working with construction or operations. 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. All proper PPE will be worn in addition to the machinery having emergency protocols with emergency stop buttons and guards.

Hours of Operation	9 A.M. - 5 P.M. M-F
Required Personnel	Teaching assistant 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

1.4.4. Purdue BoilerMAKER Lab

The Purdue BoilerMAKER Lab specializes in additive manufacturing. 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 on 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 designs a 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

1.5. Access to Equipment and Supplies

As the Purdue Space Program Student Launch team has participated in the NASA Student Launch competition for multiple years, the vast majority of the required equipment necessary for safety constructing a launch vehicle and payload is already on hand. Some exceptions include additions to the required quantity of per-person equipment, such as safety glasses and earplugs, due to an increase in total number of members on the team this year. Additional equipment may be needed for the payload since the team has not yet designed a quadcopter; the added cost of such equipment is described in Section 5.2.4.

Supplies required for this project are similar to those from past years but have not yet been acquired. The main supplies needed are the components required for construction of the sub-scale and full-scale launch vehicles and the additional materials needed to put them together, such as epoxy. More information on what additional supplies need to be acquired can be found in Section 5.2.

2. Safety

2.1. Preliminary Safety Plan

Integral to any successful mission is safety. To ensure a safe working environment, both when manufacturing and launching a rocket, carefully considered guidelines should be laid out ahead of time, governing operations such as construction, material handling and transportation, and launch procedures. The following pages will outline the team's safety plan and lay the groundwork for creating a safe working environment for all team members.

2.2. Safety Officer

The Safety Officer for the Purdue SL Team participating in the 2019 competition will be Noah Stover. 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 all members are 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

2.3. Material Safety

Hazardous materials which will be used on this project may include: black powder, ammonium perchlorate composite propellant, pre-made motor igniters, and irritants such as fiberglass and carbon fiber. 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 prior to any such operation. 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.

2.4. Facility Safety

Each facility used by the team maintains operational safety documents governing requirements for training, PPE, facility usage, and personnel activities. Any team member participating in a relevant capacity in any of these facilities will have a working knowledge of that facility's safety doctrine and will abide by such regulations. For a more complete list of facility safety requirements, see Section 1.4.

2.5. Operational Safety

Prior to any operations which may present a risk to the safety or well being of any team member, facility, or the environment, a comprehensive list of safety instructions, procedures, and requirements will be written. These requirements will be understood and followed by all students wishing to participate in the aforementioned operations, including but not limited to testing, construction, and launching.

Safety documents will outline requirements for power tool and machine usage, hazardous material handling, and personal protective equipment use. Safety documents will also outline safety procedures when dealing with high voltage or explosive components, and will be written in compliance with any relevant state, local, and federal laws, as well as applicable workplace safety standards.

2.6. Risk Assessment

The seriousness of a risk will be evaluated by two criteria: the likelihood of an event to occur and the severity of the event should it happen or fail to be prevented. Categories of likelihoods and impacts are discussed below:

2.6.1. Likelihood Of Event

Category	Value	Gauge
Remote	1	Less than 10% chance of event
Unlikely	2	10-20% chance of event.
Possible	3	20-40% chance of event.
Likely	4	40-80% chance of event.
Very Likely	5	Greater than 80% chance of event.

2.6.2. Severity of Event

Category	Value	Health and Personal Safety	Equipment	Environment	Flight Readiness
Negligible	1	Minor and negligible injury	Minimal and negligible damage to equipment or facility	Negligible damage	No flight readiness disruption
Minor	2	Minor injury	Minor damage	Minor environmental impact	Flight proceeds with caution
Moderate	3	Moderate injury	Reversible equipment failure	Reversible environmental damage	Flight delayed until effects are reversed
Major	4	Serious injury	Partially irreversible failure	Serious but reversible environmental damage	Flight on hold until system is removed
Disastrous	5	Life threatening or debilitating injury	Irreversible failure	Serious irreversible environmental damage	Flight scrubbed or completely destroyed

2.6.3. Risk Analysis Methods

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

2.6.4. 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
Dehydration	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 Contact with Hazardous Chemicals	3 (Chemical spills, improper use of chemicals)	3 (Moderate burns, abrasions)	9, Medium	Wear appropriate 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
Heatstroke	3 (High temperatures on launch day)	3 (Exhaustion and possible hospitalization)	9, Medium	Wear clothing 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 improper staging constraints, part failure, or excessive vibration)	5 (Severe injury, death)	15, High	Keep eyes on the launch vehicle at all times; make sure all team members who 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 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,	3 (Carelessness)	4 (Possible Hospitalization)	12, Medium	Secure loose hair, clothing, and jewelry; wear

Lacerations, and Injuries				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

2.6.5. 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 Fins	1 (Poor construction or improper materials used)	5 (Partial or total destruction of vehicle)	5, Low	Use appropriate materials and high powered building techniques
Ejection Charge Failure	4 (Not enough power, electrical failure)	5 (Ballistic trajectory, destruction of vehicle)	20, High	Ground test charge sizes at least once before flight
Altimeter Failure	3 (Loss of connection or improper programming)	5 (Ballistic trajectory, destruction of vehicle)	15, High	Secure all components to their mounts and check settings
Payload Failure	3 (Electrical failure, program error, dead battery)	4 (Disqualified, objectives not met)	12, Medium	Test payload prior to flight, check batteries and connections
Heat Damaged Recovery System	2 (Insufficient protection from ejection charge)	4 (Excessive landing velocity)	8, Medium	Use appropriate protection methods, such as Kevlar blankets
Broken	1 (Excessive force)	5 (Ballistic	5, Low	Use fasteners with a

Fastener		trajectory)		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, Medium	Properly time ejection charges and use an appropriately long tether
GPS Lock Failure	2 (Interference or dead battery)	5 (Loss of vehicle)	10, Medium	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

2.6.6. 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

2.6.7. 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 materials, delay in project completion)	10, Medium	Only include reliable elements in the design which have been confirmed to work through prior designs or extensive mathematical and physical analysis
Unavailable Test Launch Area	2 (Failure to locate a proper area to launch subscale rockets for testing, failure to receive an	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

	FAA waiver for the test launch)			
Loss or Unavailability of Work Area	1 (Construction, building hazards, loss of lab privileges)	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

2.7. NAR / TRA Personnel Procedures

All team members are expected to abide by the operational procedures outlined by the NAR/TRA. These rules include governing procedures regarding but not limited to material usage, ignition operations, launch procedures, and rocket size. A complete list of NAR/TRA safety regulations can be found at the following locations:

NAR Safety Code:
https://www.nar.org/safety-information/high-power-rocket-safety-code/

Tripoli Safety Code:
http://www.tripoli.org/Portals/1/Documents/Safety%20Code/HighPowerSafetyCode%20-%202017.pdf

2.8. Safety Briefings

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. All inexperienced flyers will receive an additional briefing about basic launch safety (e.g. not

standing 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 standards are met and understood. The briefings and seminar will be made available throughout 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

2.9. Cautionary Statements

The safety officer will deliver briefings 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 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. 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 must be worn during all construction and fabrication processes.
- If using a machine with an instructor or teaching assistant, follow all instructions given both by this aide and the machine manual as to what PPE to use.

2.10. 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 (an "army type' structure designated for the storage of such materials as outlined in CFR 27 part 55). 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 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 2.12.

2.11. Handling Rocket Motors and Energetic Devices

All motor and energetic device purchasing, assembly, handling, and transport will be performed by NAR/TRA certified personnel/team members, including but not limited to motors and ignition devices. In addition to the regulations set forth by the NAR/TRA, all state, local, and federal laws will be followed. The team's mentor, Victor Barlow, or other certified individuals/facilities (including but not limited to Purdue's ASL or Zucrow Labs) will maintain possession and provide transportation for any such regulated devices to launch activities/demonstrations.

2.12. 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 team mentor, the Safety Officer, and by any Range Safety Officers.
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 team will not be permitted to fly a rocket until the team mentor has reviewed the design.
8. Recognize that the team is expected to comply with established amateur rocketry design and safety guidelines as determined by the team's mentor.
9. Acknowledge that the team mentor, the Safety Officer, and any Range Safety Officers reserve the right to approve or deny the flight of the launch vehicle for any relevant reason.
10. Acknowledge that failure to comply with any of the aforementioned safety regulations is cause for removal from the team.

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 Casper or the PSP-SL program.

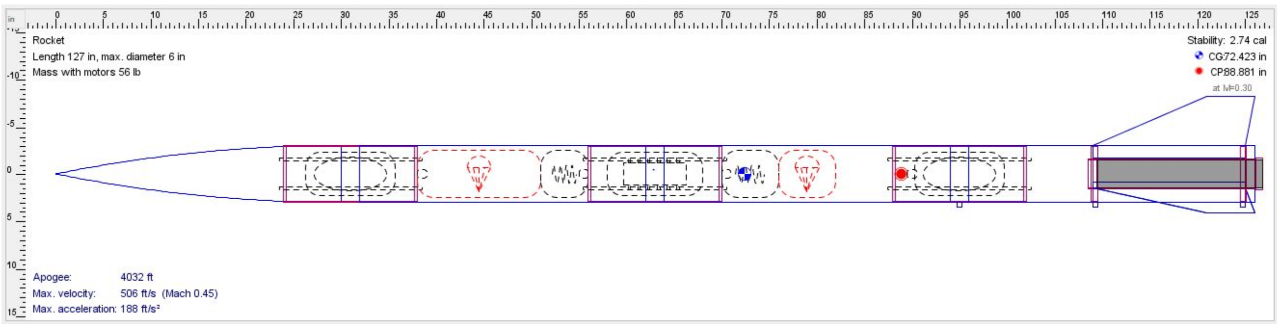
Name____

Signature____ Date_______________

3. Technical Design

3.1. General Dimensions, Materials, and Construction

The overall dimensions, weight, and stability of the current proposed launch vehicle are displayed below. The proposed design will have a body tube made from fiberglass.



Rocket Length [in]	127
Rocket Diameter [in]	6
Dry Weight [lbm]	56
GLOW [lbm]	56
Stability [Cal]	2.74

3.2. Projected Motor Brand and Designation

There are a few different motors under consideration for the 2020 competition. The top choice at this time is the Cesaroni Technology Inc. L1115. The L1115 is a 75mm, approximately 2ft long motor. It is capable of providing 5015 N*s of impulse, making it one of the most powerful motors under the L-class designation. The motor will burn for approximately 4.5 seconds, expelling approximately 5.5 lbm of propellant. An L1115 motor starts at about 9.75 lbm and therefore ends at approximately 4.25 lbm after expelling all the propellant.

The reasoning behind picking the L1115 motor is mainly due to the high impulse. This allows the team a wider range of apogees to aim for. Since the team has until PDR to decide the apogee, picking a high power motor will allow the team to examine a larger variety of weight combinations without worrying about going too low and being disqualified; the last PSP-SL team had issues with weight estimation and ended up too heavy. Having a strong motor will allow the most flexibility in weight. If the team chooses a lower altitude, then a lower motor can be used. If the team models their altitude off the most powerful motor, the team knows they cannot go higher than that if the rocket comes in overweight again.

3.3. Projected Altitude and Calculation

The projected altitude for the planned full scale launch vehicle 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 4,280 feet above ground level using an Aerotech L1365M motor. This gives us a buffer of 780' over the minimum height before disqualification at 3,500', which is approximately a 22% 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 4,280' above ground level (or, alternatively, the chosen altitude goal from PDR), and the physical model will be weighted appropriately to match the computer data.

3.4. Projected Avionics and Recovery System Design

3.4.1. Drogue Parachute

The team plans on using a typical dual deployment configuration for the recovery phase of the flight. This involves the 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 24" Fruity Chutes Classic Elliptical parachute with a drag coefficient of between 1.5 and 1.6 and a total surface area of 6.3 ft^2. The parachute weighs a total of 2.2 oz and is made of 1.1 oz/yd^2 mil-spec calendered ripstop nylon. It is connected to a 1,000 lb. rated swivel via four nylon canopy shroud lines rated to 220 lbs. This parachute was chosen for this year because it scored highly in a decision matrix among several other drogue parachutes considering factors such as size, weight, packing volume, carrying capacity, drag coefficient, and price. 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, with an additional swivel in between (rated to 1500 lbs.) in order to prevent the shroud lines from tangling if the launch vehicle begins to twist on descent. This additional swivel is new for the 2020 competition.

3.4.2. Main Parachute

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 made of zero porosity 1.9 oz/yd^2 silicone coated balloon cloth and is connected to a nickel-plated 1,500 lb.-rated swivel via four canopy shroud lines that are ⅝" mil-spec tubular nylon rated to 2,250 lbs. This parachute was chosen again for this year because it scored the highest in a decision matrix among several other main parachutes considering factors such as size, weight, packing volume, carrying capacity, drag coefficient, and price. The main parachute 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. The main canopy will be attached to the uppermost quick link connected to the nose cone as well, with another swivel in between (rated to 1500 lbs.) in order to prevent the shroud lines from tangling if the launch vehicle begins to twist on descent. This additional swivel is new for the 2020 competition.

3.4.3. Deployment Charges and Calculations

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 one second, and the primary main charge will ignite at 700' above ground level with backup at 500' above ground level. All 4 charges will contain 4g 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.

$$Area_{Bolt} = \pi R^2$$

$$Area_{Bolt} = 3.1415 * (0.04\ in)^2 = 0.00503\ in^2$$

$$Force_{Bolt,Failure} = Area_{Bolt} * \tau_{Nylon}$$

$$Force_{Bolt,Failure} = 0.00503\ in^2 * 10,000\ psi = 50.3\ lbf$$

$$3 * Force_{Bolt,Failure} = 150.9\ lbf$$

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.

$$Area_{Bulkhead} = \pi R^2$$

$$Area_{Bulkhead} = 3.1415 * (3\ in)^2 = 28.27\ in^2$$

$$P_{Bulkhead} = \frac{3*F_{Bolt,Failure}}{Area_{Bulkhead}} = \frac{150.9\ lbf}{28.27\ in^2} = 5.34\ psi$$

By using the equation below (where 0.002 is the pressure coefficient corresponding to a desired pressure on the bulkhead of 5.34 psi, 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. Here a safety factor of 1.2 is added to that amount.

$$G = Mass_{BP} = C_P * D^2 * L * 1.2$$

$$G = Mass_{BP} = 0.002 * (6\ in)^2 * 30\ in * 1.2 = 2.592\ grams \approx 3\ grams\ of\ black\ powder$$

3.4.4. Avionics Bay Design

The avionics bay will consist of a 14” long coupler located between the upper and mid airframe of the launch vehicle, including a 2” wide switch band located around the middle of the bay. The switch band and the bay walls will be 0.15” thick, the outer diameter of the switch band will be 6”, and the outer diameter of the avionics bay will be 5.85”. Several shear pins will secure the bay to the airframe on either side of the switch band. The team will be incorporating a switch band into the avionics bay design this year, rather than a simple switch hole located between the upper and mid airframe sections, in order to prevent the shear pins on the upper side of the bay (the main parachute side) from shearing when the drogue parachute deploys. The team has had problems with this in past years.

The two ends of the avionics bay will be sealed with fiberglass bulkheads. Attached to the outside of each bulkhead will be the main and secondary black powder canisters, the main and secondary terminal blocks, nuts to secure the two threaded rods running through the length of the bay, and a U-bolt to provide an attachment point between the respective parachute and the end of the bay. Inside the avionics bay will be the two aforementioned threaded rods, a 3D printed sled that will slide onto the rods and be secured into place using bolts on either end, and wiring to connect the altimeters to the terminal blocks on the outside of the bay. The sled will hold the main (Telemetrum) and backup (RRC3+ Sport) altimeters and their respective batteries. Finally, there will be static portholes through the avionics bay and airframe above each altimeter so outside air pressure and therefore altitude can be accurately determined.

3.5. Projected Payload Design: UAV for Lunar Ice Sampling

3.5.1. Payload System Overview

PSP-SL’s payload subteam has decided to design build and fly a fully-autonomous Unmanned Aerial Vehicle (UAV) with ice mining capabilities on this year’s rocket. The UAV will be safely stored inside the rocket just below the nose cone. Upon successful landing of the launch vehicle and payload, the UAV is planned to be autonomously deployed and will reorient itself prior to egressing the vehicle through the nose cone or a door built into the payload bay. Once the UAV is in a flight-ready position, it will begin to take off from the payload bay. In the air, the UAV shall locate the target area then navigate to the mining location. Upon reaching the target area, the UAV shall extract and store at least 10ml of sample material autonomously. Once it has stored and sealed the sample material, the UAV will navigate to its final destination with the sealed sample. In addition to the base requirements laid out by NASA, the team may impose additional design challenges that include an extensive onboard computer vision system or a UAV equipped with a surveying payload.

3.5.2. Mission Profile

The payload’s mission can be broken down into five distinct phases, each posing unique challenges and design requirements. The first phase of the mission profile begins with ignition of the launch vehicle and ends with the touchdown of the rocket via the recovery system. Through this phase, the payload must be safely contained in the payload bay of the rocket via a mechanical retention system. The second phase of the mission is the deployment phase, in which the UAV payload, upon receiving the deployment signal, is released from the rocket and placed in a configuration in which it can fly. Phase three of the mission profile is comprised of the flight of the UAV toward one of the ice mining recovery locations. This phase includes any autonomous search algorithms that may be run on the UAV to locate the lunar ice. During this phase the UAV also needs to abide by FAA and NAR rules and regulations. The fourth phase of the mission profile is the procurement of the lunar ice. In this phase, the payload must successfully land at one of the recovery locations and collect a sample of the material. The sample procured needs to contain at least 10 millimeters of lunar ice. Finally, the fifth phase of the mission profile sees the UAV travel away from the recovery area with the collected sample, landing a minimum of 10 feet away.

3.6. UAV Design

The UAV will be required to remain confined within the payload bay from the point of insertion all the way up until the time of deployment on the ground. Therefore, the vehicle will be constrained by the inner wall of the payload bay and will need to maintain a constrained state for a minimum of two hours. Once deployed, the UAV and its lift-producing units must be able to operate normally, likely requiring the UAV lift units to separate away from each other and become fixed in an operational arrangement. Once configured, the UAV will be able to take flight and perform its desired set of operations.

Early concepts of the UAV include multiple folding pylons that will connect the lift units to a central multi-layered airframe. These pylons will be actively held in place and then released by field signal. Once released, the arms will lock into their final operational position, allowing the UAV to take off. The central chassis will support multiple subsystems and structurally connect the lift pylons to these centralized systems. The central chassis will house control-type systems on its dorsal side, while an ice sampling apparatus and an array of sensors will find their place on the ventral side.

While in flight, the UAV should have the ability to lift and lower itself, translate about the horizontal plane, pitch itself in its direction of motion, and yaw itself in order to determine direction of motion. This will require a design capable of sufficient lift, stability, and orientation authority.

It is planned that the UAV lift units will utilize the rotating force of electric motors, each with a propeller. At the current time, a count of four propellers is projected to operate and perform the aforementioned maneuvers according to team members’ prior experience. The UAV will also hover sufficiently high in order to utilize on-board navigation sensors. These sensors combined with control code will be developed to navigate the UAV to the sampling location and land. Once present at the sampling site, the ventral procurement system will be in the optimal location to complete the mission objective of collecting ice samples.

3.6.1. Ice Procurement

The lunar ice recovery is the final part of the launch mission. There will be five recovery areas on the launch field, and each recovery site will be at least 3 feet in diameter and extend 2 inches below the surface. Ice procurement must be conducted on any of the recovery areas, and amount of the required sample material recovery must be at least 10ml. Although the ice mining mission will be conducted by the UAV, the team has yet to decide what method will be used to recover the granular material. Currently, the team is analyzing the possible advantages and disadvantages of three general methods for ice mining: an impact extraction method, a method used to extract trees, and a drill method. To recover the granular material, the team is considering ideas such as an auger, scoop, claw, or (if the granules are rather large) an adhesive pad. The UAV will then fly at least 10 feet away from the recovery area.

3.6.2. Retention and Deployment

The retention and deployment of the payload may be one of the most complicated design aspects of the payload section. The payload must be held secure inside the rocket throughout flight, but then be able to be deployed after landing. The team decided that deploying a UAV in-flight would present more technical challenges than a ground based deployment, while having no additional value in completing the experiment. The team is therefore currently considering two general ground-deployment designs which will each enable the payload to properly orient itself then release itself from the payload bay. The first uses a free-rotating weighted swing which will naturally reorient itself once the rocket has landed. This reoriented swing will then be ejected out of the end of the launch vehicle with a leadscrew, after which the UAV will fly. The other design involves a rotating payload bay. The entire payload bay will rotate on bearings using two external servo motors (for redundancy) to orient payload doors upright. These doors will open and the UAV can deploy.

3.6.3. Technical Challenges

Technical Challenges start with creating a UAV capable of fitting inside of our payload bay. We must design and create a way for our UAV to fold or compress together in a way that will not hinder the structural integrity of the UAV or Payload bay. The next technical challenge is securing the payload into the body of the rocket. Design specifications says that a mechanical retention system must be used to hold the payload. Two proposed retention ideas involve the payload being able to rotate inside the payload bay. In order for this to work the design needs to allow the UAV to freely move, and that rotation is limited so it won't affect the movement of the rocket during flight. These challenges continue into deployment where we will need to design a way for our UAV to be safely and effectively deployed from the payload bay. After deployment the UAV will have to navigate towards one of the ice spots. This is a challenge for the software side of the payload. The UAV will require sensors to know its flight position and to locate the ice. The UAV will require an efficient flight planning software that searches for recovery areas possibly using a computer-vision imaging system to recognize where to go. Technical challenges for the lunar ice recovery mission include the method of harvesting the ice, the method of storing the ice, and the method used for the UAV to leave the zone. For harvesting the ice there are currently many different ideas which each gives its own set of challenges. The weight, placement, and the size of the harvesting device needs to be considered as the UAV needs to be within its allotted weight range and be able to fly. The method of storing the ice needs to be well thought out because it could affect the UAV's ability to stay stable in flight if the ice changes its center of gravity.

3.7. Project Requirements and Verifications

Subteam	Requirement	Verification Method	Verification Process / Description
General	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).	Inspection	Verification of this requirement occurs constantly throughout the project - if any team member sees another member outsourcing work that should be done by the team, it should be reported to project management.
General	The team will provide and maintain a project plan that includes, but is not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	Demonstration	Verification of this requirement occurs when providing each milestone report to NASA. Each delivered report should have these sections in it.
General	The team will identify Foreign National (FN) team members by the Preliminary Design Review (PDR).	Demonstration	Verification of this requirement occurs when the required information is delivered on time to the student launch team for review.
General	The team will identify all members attending launch week activities by the Critical Design Review (CDR).	Demonstration	Verification of this requirement occurs when the required information is delivered on time to the student launch team for review.
General	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 the Flight Readiness Review (FRR), and will report these activities appropriately to the student launch team.	Demonstration	Verification of this requirement occurs when the required information is delivered on time to the student launch team for review.

General	The team will establish a social media presence to inform the public about team activities.	Demonstration	Verification of this requirement occurs constantly as team members check that the website contains up-to-date information in a professional and presentable manner.
General	The team will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone.	Demonstration	Verification of this requirement occurs when the required information is delivered on time to the student launch team for review.
General	All deliverables will be in PDF format.	Demonstration	Verification of this requirement occurs by double-checking that all attachments are in PDF format before emailing them to the student launch team.
General	In every report, the team will provide a table of contents including major sections and their respective sub-sections.	Inspection	Verification of this requirement occurs when each report is given its final review, as the reviewer will be checking to ensure a table of contents is included.
General	In every report, the team will include the page number at the bottom of the page.	Inspection	Verification of this requirement occurs when each report is given its final review, as the reviewer will be checking to ensure page numbers are included and are at the bottom of the page.
General	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.	Testing	Verification of this requirement will occur during the preparatory Q&A sessions and before presentations for each milestone to ensure the team can properly use the required technology.

General	The team will use the launch pads provided by Student Launch's launch services provider.	Inspection	Verification of this requirement occurs when the team observes the launch pad it uses in Huntsville and confirms that it has been provided by the launch services provider.
General	The team will identify a "mentor", 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 will have maintained a current certification, and will 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 will 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 will be designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week.	Inspection	Verification of this requirement occurs when the team double-checks that the mentor position has been filled and that the chosen mentor satisfies all requirements listed above.
Vehicle	The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL).	Testing and Analysis	Verification for this requirement includes constant retesting and analysis in simulation programs, including OpenRocket and RASAero II.
Vehicle	The team will identify its target altitude goal at the PDR milestone.	Demonstration	Verification of this requirement occurs when the PDR report is given its final review, as the reviewer will be checking to ensure altitude goal information is included.
Vehicle	The vehicle will carry one commercially available, barometric altimeter for recording its official altitude used by the student launch team to determine the altitude award winner.	Inspection	Verification for this requirement includes inspecting rocket components before flight to ensure at least one altimeter is being used.

Vehicle	Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Inspection and Testing	Verification for this requirement includes testing altimeter continuity and inspection of proper electrical connections.
Vehicle	Each altimeter will have a dedicated power supply.	Inspection	Verification for this requirement includes inspection of proper electrical connections and separate electrical systems.
Vehicle	Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	Demonstration	Verification of this requirement includes designing the arming switch such that it can be locked in the ON position.
Vehicle	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.	Inspection and Testing	Verification for this requirement will include the subscale and full scale test flights and inspection of all parts to ensure there is no critical damage, structural issues, or missing parts.
Vehicle	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.	Demonstration	Verification for this requirement will be done by inspection prior to all launches to confirm that at most four sections have been used.
Vehicle	Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.	Demonstration	Verification will be achieved by inspecting the rocket prior to all launches to ensure the shoulders at in-flight separation points are sufficiently long.
Vehicle	Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	Inspection	Verification will be achieved by inspecting the rocket prior to all launches to ensure the shoulders at in-flight separation points are sufficiently long.

Vehicle	The launch vehicle will be limited to a single stage.	Demonstration and Inspection	Verification will be achieved upon inspection prior to launches, proving that the rocket is only one stage.
Vehicle	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.	Testing and Demonstration	Verification will include testing the team's ability to prepare the rocket in time both in-house and prior to all launches.
Vehicle	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.	Testing	Verification will include designing and testing the rocket's capability to stay launch-ready on the pad.
Vehicle	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.	Demonstration and Testing	Verification will be done by inspection of the rocket upon final flight configuration and through prior launches including subscale and full scale.
Vehicle	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).	Demonstration	Verification will be done by inspection of the rocket in final flight configuration.
Vehicle	The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	Demonstration and Testing	Verification will include all launches which use these motors and demonstration during the official competition.
Vehicle	Final motor choices will be declared by the Critical Design Review (CDR) milestone.	Demonstration	Verification will be achieved by checking the CDR document and ensuring the motor choice does not change between CDR, FRR and PLAR.
Vehicle	Any motor change after CDR will be approved by the NASA Range Safety Officer (RSO).	Demonstration	Verification will be achieved via double-checking that the

			RSO has been notified in the case of any motor changes.
Vehicle	All pressure vessels on the vehicle will be approved by the NASA RSO.	Demonstration	Verification will be demonstrated during the official competition.
Vehicle	The minimum factor of safety for any pressure vessels on the vehicle (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	Analysis	Verification will be achieved using simulation programs such as Solidworks.
Vehicle	Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.	Analysis and Testing	Verification will be achieved using simulation programs such as Solidworks and testing at maximum expected pressure.
Vehicle	Full pedigree of any pressure vessel tanks used will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.	Demonstration	Verification will be done by inspection of the reports and ensuring that the proper pressure vessel information is displayed.
Vehicle	The total impulse provided by the launch vehicle will not exceed 5,120 Newton-seconds (L-class).	Demonstration	Verification will include inspection of the launch vehicle at all launches to ensure that the motor being used is L-class or lower.
Vehicle	The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	Analysis	Verification will include using simulation programming, specifically OpenRocket and RASAero II.
Vehicle	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	Analysis	Verification will include using simulation programming, specifically OpenRocket and RASAero II.
Vehicle	A subscale model of the final vehicle will be successfully launched and recovered prior to CDR.	Testing and Demonstration	Verification will include demonstration of subscale results from a test launch and demonstration after it has been completed by the team.

Vehicle	The subscale model will resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.	Demonstration	Verification will include displaying subscale information listing the scale of the model.
Vehicle	The subscale model will carry an altimeter capable of recording the model's apogee altitude.	Testing and Demonstration	Verification will include retrieving altimeter data from a test launch and demonstration that the rocket has flown.
Vehicle	The subscale rocket will be a newly constructed rocket, designed and built specifically for this year's project.	Demonstration	Verification will include demonstration that the rocket is unique to this year's competition.
Vehicle	Proof of a successful subscale flight will be supplied in the CDR report.	Testing and Demonstration	Verification will include subscale results from a test launch and demonstration that the rocket has flown.
Vehicle	The team will successfully launch and recover its full-scale rocket prior to FRR in its final flight configuration. The rocket flown will be the same rocket to be flown on launch day. A successful flight is defined as a launch in which all hardware is functioning properly. For this flight, the following must be true: ● The vehicle and recovery system will have functioned as designed. ● The full-scale rocket will be a newly constructed rocket, designed and built specifically for this year's project. ● If the payload is not flown, mass simulators will be used to simulate the payload mass. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass. ● If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight. ● The team 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	Testing and Demonstration	Verification will be done by flying the rocket and demonstrating the rocket is the same. Flight results will be provided in the FRR document.

	the launch day motor or in other extenuating circumstances. ● The vehicle will 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 will not be added without a re-flight of the full scale launch vehicle. ● 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). ● Proof of a successful flight shall be supplied in the FRR report using altimeter data. ● Vehicle Demonstration flights must be completed by the FRR submission deadline unless a Vehicle Demonstration Re-flight is deemed necessary. ● If completing a Vehicle Demonstration Re-flight, an FRR Addendum will be submitted by the FRR Addendum deadline.		
Vehicle	The team will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown must be the same rocket to be flown on launch day. A successful flight is defined as a launch in which the rocket experiences stable ascent, the payload is fully retained during ascent and descent, and the payload is safely deployed on the ground. For this flight, the following must be true: ● 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. ● The payload flown must be the final, active version ● 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.	Testing and Demonstration	Verification will be done by flying the rocket with the payload and demonstrating the rocket is the same as the final flight configuration.

	• Payload Demonstration Flights must be completed by the FRR Addendum deadline. No extensions will be granted.		
Vehicle	Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	Demonstration	Verification will be achieved by inspecting the rocket prior to all launches.
Vehicle	The team's name and launch day contact information will be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information will be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	Demonstration	Verification will be done by inspection of the rocket prior to launch.
Vehicle	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.	Demonstration	Verification will be done by inspection of the rocket.
Vehicle	The launch vehicle will not utilize forward firing motors, motors that expel titanium sponges, hybrid motors, a cluster of motors, or motors fitted using friction.	Demonstration	Verification will be done by inspection of the rocket.
Vehicle	The launch vehicle will not exceed Mach 1 at any point during flight.	Analysis and Demonstration	Verification will be done using software programs such as OpenRocket and RASAero II.
Vehicle	Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad.	Demonstration	Verification will be achieved by inspecting the rocket prior to all launches.
Vehicle	Transmissions from onboard transmitters will not exceed 250 mW of power.	Demonstration and Testing	Verification will be achieved by inspecting the rocket prior to all launches and using results from previous launches using the same transmitters.
Vehicle	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	Demonstration	Verification will be done by inspection of the rocket.

	necessary to ensure structural integrity of the airframe under the expected operating stresses.		
Recovery	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. ● The main parachute shall be deployed no lower than 500 feet. ● The apogee event may contain a delay of no more than 2 seconds.	Demonstration	Verification for this requirement will be completed via ejection charge demonstration at simulated altitudes and via the subscale and full-scale flights.
Recovery	The 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.	Demonstration	Verification for this requirement will be completed via successful deployment of drogue and main parachutes before first flight.
Recovery	At launch vehicle landing, each individual component of the launch vehicle must have a maximum kinetic energy of 75 ft-lb.	Analysis	Verification for this requirement will be completed via OpenRocket simulation.
Recovery	The recovery system electrical circuits will be completely independent of any payload electrical circuits.	Inspection	Verification for this requirement will be completed via inspection of avionics bay.
Recovery	All recovery system electronics will be powered by commercially available batteries.	Inspection	Verification for this requirement will be completed via inspection of avionics bay.
Recovery	The recovery system will contain redundant, commercially available altimeters.	Inspection	Verification for this requirement will be completed via inspection of the avionics bay.
Recovery	Motor ejection will not be used as a form of primary or secondary deployment.	Inspection	Verification for this requirement will be completed via inspection of the flight vehicle.

Recovery	Removable shear pins will be used for both the main parachute compartment as well as the drogue parachute compartment.	Inspection	Verification for this requirement will be completed via inspection of the flight vehicle.
Recovery	The launch vehicle recovery area will be limited to a 2,500 ft radius from the launch pads.	Analysis	Verification for this requirement will be completed via OpenRocket simulation.
Recovery	Descent time, from apogee to touchdown, shall be limited to 90 seconds.	Analysis	Verification for this requirement will be completed via OpenRocket simulation.
Recovery	An electronics tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent vehicle component to a ground receiver. ● Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device. ● The electronic tracking devices will be fully functional during the official flight on launch day.	Inspection	Verification for this requirement will be completed via inspection of the flight vehicle.
Recovery	The recovery system electronics will not adversely affected by any other on-board electronic devices during flight. ● The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting and/or magnetic wave producing device. ● The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves to avoid inadvertent excitation of the recovery system. ● The recovery system electronics will be shielded from any other onboard devices that may adversely affect the proper operation of the recovery system.	Inspection	Verification for this requirement will be completed via inspection of the avionics bay.
Payload	The team will design a custom rover that will deploy from the internal structure of the launch vehicle.	Demonstration	Verification for this requirement will consist of a test which places the launch vehicle in a touchdown

			configuration and deploys the rover and of the full-scale launch test with the custom payload installed.
Payload	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.	Testing	Verification of this requirement will consist of the full-scale launch test with the custom payload installed and possible drop testing with the retention system and payload installed in the launch vehicle.
Payload	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.	Testing	Verification for this requirement will be achieved by placing the assembled launch vehicle in a touchdown configurations and remotely triggering rover deployment.
Payload	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.	Demonstration	Verification for this requirement will be achieved by placing the launch vehicle in a touchdown configuration and deploying the rover to ensure it starts its autonomous navigation and collects the required soil sample.
Payload	The soil sample will be a minimum of 10 milliliters (mL).	Demonstration	Verification for this requirement will be achieved by doing a test run on the rover in a terrain similar to Alabama red clay, such as harvested farmland, in which the soil collection system collects and stores a sample fulfilling this requirement.
Payload	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.	Demonstration	Verification for this requirement can be accomplished by sealing soil in the soil compartment and

			ensuring that no soil, under its own weight, can exit the soil compartment at any rover orientation.
Payload	The team will ensure that the rover's batteries are sufficiently protected from impact with the ground.	Demonstration	Verification for this requirement can be accomplished by placing the rover in any configuration in the vehicle and driving the rover over various terrain and ensuring the battery does not make any unexpected contact and is sufficiently protected.
Payload	The batteries powering the rover will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other rover parts.	Inspection	Verification for this requirement can be accomplished by double-checking that the rover's batteries are in a clearly-marked and distinguishable location on the rover and stand out in coloration.
Safety	The team will use a launch and safety checklist. The final checklist will be included in the FRR report and used during the LRR and any launch day operations.	Inspection and Demonstration	Verification for this requirement can be accomplished by ensuring that the team safety officer, project manager, and assistant project manager have copies of checklists and are present on for launch days.
Safety	The team must identify a student safety officer who will be responsible for all of the following items: ● Monitor team activities with an emphasis on safety during: ○ Design of vehicle and payload ○ Construction of vehicle and payload ○ Assembly of vehicle and payload ○ Ground testing of vehicle and payload ○ Subscale launch tests ○ Full-scale launch tests	Inspection and Demonstration	Verification for this requirement will be completed with the team identifying a student safety officer who will be responsible for the above items that will be completed similarly by verification by inspection.

	○ Launch day ○ Recovery activities ○ STEM Engagement Activities ● Implement procedures developed by the team for construction, assembly, launch, and recovery activities. ● Manage and maintain current revision of the team's revision hazard analyses, failure mode analyses, and recovery activities. ● Assist in the writing and development of the team's hazard analyses, failure mode analyses, and procedures.		
Safety	During test flights, the team 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 the team to fly these vehicle configurations and/or payloads at other club launches. The team will communicate their intentions to the local club's President or Prefect and RSO before attending and NAR or TRA launch.	Demonstration and Inspection	Verification for this requirement will be that both safety officer and project manager will read local regulations prior to test flights, bring copies with them to test flights, and brief team members on those test flights.
Safety	The team will abide by all rules and regulations set forth by the FAA.	Demonstration	Verification for this requirement will be that both safety officer and project manager will read local and future FAA regulations prior to all flights, bring copies with them to flights, and brief team members on those test flights. As well as obtain proper clearance for flight.

4. STEM Engagement

4.1. Planned Engagement Activities

To engage and raise interest in space exploration and rocketry, the team will hold several educational involvement events during Purdue's 2019-2020 school year. The team plans to do the following:

- Run a station at Purdue Space Day to reach children attending the event. Team members will volunteer as group and activity leaders.
- Give live demonstrations and educational activities at the Imagination Station Mini Makers Faire.
- Visit local schools to show how the team's rockets work and to allow students to safely help in the construction of rockets and learn about STEM related fields.
- Host educational events on campus during the school year for university students.
- Work with College Mentors for Kids as a way to engage more students of lower income in rocketry and engineering.

4.2. Evaluation of Engagement Activity Success

In order to evaluate the success of activities the team will gauge the involvement of the people we reach and track team member participation. For successful events to occur, many students should be reached in an impactful way that will teach them about rocketry and engineering in general. Another way that the team can measure success is through team member involvement in the planned activities. More team members at each activity means each student will have more of an opportunity to learn from one-on-one interactions with team members.

5. Project Plan

5.1. Timeline

The PSP-SL team will follow the timeline below - however, items are subject to change. The timeline outlines events such as general team meetings, meetings or teleconferences with NASA officials, launch opportunities, deadlines, and miscellaneous events.

Date	Event	Date	Event
08/22/2019	NASA Released 2020 Student Launch Handbook	01/03/2020	Final day for subscale launch
08/31/2019-09/03/2019	AIRFest 24 @ Argonia, Kansas Rocket Pasture	01/03/2020	Final motor choice made for launch
09/01/2019	Purdue SL general meeting	01/04/2020	CDR reports, slides, and flysheet posted online by 8AM CDT
09/03/2019	LABOR DAY	01/05/2020	Purdue SL general meeting
09/09/2019	Indiana Rocketry Launch	01/07/2020	CDR video teleconferences start
09/08/2019	Purdue SL general meeting	01/12/2020	Purdue SL general meeting
09/15/2019	Purdue SL general meeting	01/13/2020	Indiana Rocketry Launch (?)
09/19/2019	Proposal due to project office by 3PM CDT	01/19/2020	Purdue SL general meeting
09/22/2019	Purdue SL general meeting	01/21/2020	MLK JR. DAY
09/29-09/30 /2019	ROCI HPR Sport Launch @ AMA Aeromodeling Center in Muncie	01/22/2020	CDR video teleconferences end
09/29/2019	Purdue SL general meeting	01/25/2020	FRR Q&A
10/04/2019	Awarded proposals announced	01/26/2020	Purdue SL general meeting
10/06/2019	Purdue SL general meeting	02/02/2020	Purdue SL general meeting
10/08-10/09 /2019	OCTOBER BREAK	02/09/2020	Purdue SL general meeting
10/12/2019	Kickoff, PDR Q&A	02/10/2020	Indiana Rocketry Launch (?)
10/13/2019	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville	02/16/2020	Purdue SL general meeting
10/13/2019	Purdue SL general meeting	02/23/2020	Purdue SL general meeting
10/14/2019	Indiana Rocketry Launch	03/01/2020	Purdue SL general meeting
10/20/2019	ROCI HPR Sport Launch @ AMA Aeromodeling Center in Muncie	03/03/2020	Final day for full scale launch/Vehicle Demonstration Flight
10/20/2019	Purdue SL general meeting	03/04/2020	Vehicle Demonstration Flight data reported to NASA

10/26/2019	Web presence established, URLs sent to project office by 8AM CDT	03/04/2020	FRR reports, slides, and flysheet posted online by 8AM CDT
10/27/2019	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville	03/08/2020	FRR video teleconferences start
10/27/2019	Purdue SL general meeting	03/08/2020	Purdue SL general meeting
11/01-11/03 /2019	SEDS SpaceVision @ San Diego	03/10/2020	Indiana Rocketry Launch (?)
11/02/2019	PDR reports, slides, and flysheet posted online by 8AM CDT	03/11-03/16/ 2020	SPRING BREAK
11/02-11/04 /2019	Midwest Power Launch	03/15/2020	Possible Purdue SL general meeting
11/03/2019	Purdue SL general meeting	03/21/2020	FRR video teleconferences end
11/05/2019	PDR video teleconferences start	03/22/2020	Purdue SL general meeting
11/10/2019	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville	03/25/2020	Payload Demo Flight/Vehicle Demonstration Re-flight deadlines
11/10/2019	Purdue SL general meeting	03/25/2020	FRR Addendum submitted to NASA by 8:00 AM CDT (if needed)
11/11/2019	Indiana Rocketry Launch	03/29/2020	Purdue SL general meeting
11/17/2019	Purdue SL general meeting	04/03/2020	Travel to Huntsville, Alabama
11/19/2019	PDR video teleconferences end	04/03/2020	OPTIONAL – LRR for teams arriving early
11/21-11/24 /2019	THANKSGIVING BREAK	04/04/2020	Launch week kickoff and activities
11/24/2019	ROCI HPR Sport Launch @ Federal Rd. Field in Cedarville	04/04/2020	Official LRRs if not done on 04/03
11/24/2019	Purdue SL general meeting	04/05/2020	Launch week activities
11/27/2019	CDR Q&A	04/06/2020	Launch day
12/01/2019	Purdue SL general meeting	04/06/2020	Awards Ceremony
12/08/2019	Quad Cities Rocket Society (QCRS) Launch	04/07/2020	Backup launch day
12/08/2019	Purdue SL general meeting	04/05/2020	Possible Purdue SL general meeting
12/09/2019	Indiana Rocketry Launch	04/12/2020	Purdue SL general meeting
12/15-01/06 /2020	WINTER BREAK	04/19/2020	Purdue SL general meeting
		04/24/2020	PLAR posted online by 8AM CDT

5.2. Line Item Budget

5.2.1. Full Scale Budget

There is currently a purposefully-overestimated full scale budget of $3000. This is based off our expenses from last year and the needs of the team. Very few known costs currently exist (as shown below), but as more become available, the line item budget will be adjusted.

Item	Unit Cost	Quantity	Total (including shipping)
24" Fruity Chutes Classic Elliptical Parachute	$75.05	1	$75.05
Skyangle Cert 3 XL Parachute	$189.00	1	$189.00

5.2.2. Sub Scale Budget

The subscale budget is currently set at $250. This value is based off the team's values from last year as well as expected changes from this year. Many team members have access to the parts needed for the subscale, so the $250 is a safeguard in case something goes wrong.

5.2.3. Avionics and Recovery Budget

Our current budget for avionics and recovery is $900. We have increased this value significantly since last year, as the team no longer has access to the same amount of funding and materials through our parent organization, PSP. Due to our increased knowledge of the competition, we have decided to improve our rocket and buy higher quality materials. For this reason, we increased the budget by $750.

Item	Unit Cost	Quantity	Total (including shipping)
TeleMetrum - Altus Metrum Altimeter	$300.00	1	$300.00
TeleDongle - Altus Metrum	$100.00	1	$100.00
RRC3+ Sport - Missile Works Altimeter	$70.00	1	$70.00
Electronic Match	$1.00	50	$50.00
Jolly Logic AltimeterOne Altimeter	$58.19	1	$58.19
Altimeter Mounting Posts	$3.68	2	$7.36
6g Charge Well	$8.50	2	$17.00
Missile Works USB Interface Module	$32.95	1	$32.95
Pair Programming / Debug Cable	$5.00	1	$5.00
9V Battery Clip	$1	1	$1
9V Battery - Duracell	$6.00	4	$24.00
9V Battery Holder	$2.50	1	$2.50

Dual Altimeter Wiring Kit - Binder Design	$20.00	1	$20.00
3/4" Panel-Mount Key Switch - McMaster-Carr	$14.10	2	$28.20
National Hardware 1 Count 1/4-in to 20 x 2.5-in Stainless Steel Plain Eye Bolt with Hex Nut	$1.00	4	$4.00
Hillman 0.375-in x 36-in Standard (SAE) Threaded Rod	$2.90	2	$5.80
900mAh LiPo Battery Pack	$16.29	1	$16.29
Terminal Block	$7.10	2	$11.85
8g Charge Well	$8.95	4	$45.25
Solid Plywood Block (¼"X2'X4')	$16.99	1	$16.99
Acrylic Sheet	$22.98	1	$22.98
Polyseamseal Sealant	$4.06	2	$8.12
1500lbs Rated Swivel	$12.41	2	$24.82
Various Materials Required for Testing	$35.00	1	$35.00
			$883.30

5.2.4. Payload Budget

Our current payload budget is $2000. In previous years, we did less complex payloads, but due to our current payload plan, the budget had to be increased for higher quality materials.

Item	Unit Cost	Quantity	Total (including shipping)
Pixhawk 4 - Flight Computer	$250.00	1	$250.00
ESC	$25.00	6	$150.00
Motor	$25.00	6	$150.00
Pixhawk Telemetery - Radio for GCS 918MHz	$40.00	1	$40.00
BEC - 5/12v DC power for telemetry	$10.00	2	$20.00
Camera - Onboard digital camera	$50.00	1	$50.00
RC Radio Tx	$100.00	1	$100.00
RC Rx	$20.00	1	$20.00
Li-Ion Battery	$40.00	2	$80.00
Propellers - 4+ pack of propellers	$10.00	4	$40.00
Airframe	$200.00	1	$200.00
PCBs - Custom order circuit boards	$200.00	1	$200.00
UAV Deployment - Retention and deployment	$300.00	1	$300.00
UAV Ice Mining	$150.00	1	$150.00
			$1750.00

5.2.5. Branding Budget

We have set aside $550 for team branding. This is for items such as t-shirts to wear that ensure we are presentable at our STEM outreach events as well as a way for us to promote our team throughout Purdue's campus.

5.2.6. Travel Budget

We have a current travel budget of $4000. This value is based on our expenses from last year. We spent around $2000 last year and this year we want to be able to bring more team members. Additionally, we have not provided meals to team members in the past, and that is something we are looking to do going forward.

5.2.7. Budget Justification

This budget has been estimated based on previous years' experience and inflated slightly to plan for unexpected issues. In the past, our team was frozen in progress due to a delay in acquiring funds; this is why our team has tried to secure a good deal of our budget before its official start. Our budget is flexible in the event that an unexpected change occurs, which is a likely probability for a project of this scale.

5.3. Plan for Continued Funding & Project Sustainability

Currently, we have three main methods to obtain our full budget, crowdfunding, grant applications, and Purdue department aid. We have obtained nearly 60% of our budget, and are far ahead of our projected budgeting timeline. We hope to be at 100% of our budget by December to ensure that our project can be fully funded and sustainable. Additionally, our team will continue to interact with our major sponsors to ensure a dynamic relationship and help secure future financial aid.

6. Appendix A

6.1. NAR High Power Rocket Safety Code

- Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
- 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.
- Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
- Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
- Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
- Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
- Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
- Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
- Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace

regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

- Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
- 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.
- Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
- Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

6.2. NAR Minimum Distance Table

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

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