University of Massachusetts Lowell

Project: Peregrine Explorer

220 Pawtucket St, Suite #220

Lowell, MA 01851

NASA University Student Launch Initiative Proposal

September 10, 2024

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Acronyms

AGL = Above Ground Level

ACS = Altitude Control System

APCP = Ammonium Perchlorate Composite Propellant

CDR = Critical Design Review

CFR = Code of Federal Regulations

CG = Center of Gravity

CMASS = Central Massachusetts Spacemodeling Society

COTS = Commercial Off the Shelf

CP = Center of Pressure

DDIR = Dual Dissimilar Independent Redundancy

DOT = Department of Transportation

FAA = Federal Aviation Administration

FFF = Fused Filament Fabrication

FMEA = Failure Modes and Analysis

FN = Foreign National

FOV = Field of View

FRR = Flight Readiness Review

GPS = Global Positioning System

HPR = High Power Rocket

LCO = Launch Control Officer

LMS = Lawrence Lin Makerspace

LRR = Launch Readiness Review

MSDS = Material Safety Data Sheet

MSFC = Marshall Space Flight Center

MSL = Mean Sea Level

NAR = National Association of Rocketry

NFPA = National Fire Prevention Agency

PCB = Printed Circuit Board

PDF = Portable Document Format

PDR = Preliminary Design Review

PERR = Passive Electronic Recovery Reporter

PLAR = Post Launch Assessment Review

PPE = Personal Protective Equipment

RF = Radio Frequency

RFP = Request for Proposal

RSO = Range Safety Officer

SL = Student Launch

SLA = Stereolithography

SME = Subject Matter Expert

SOW = Statement of Work

SRAD = Student Researched And Designed

STEM = Science Technology Engineering and Math

TRA = Tripoli Rocket Association

UML = University of Massachusetts Lowell

UMLRC = University of Massachusetts Lowell Rocketry Club

USLI = University Student Launch Initiative

VDF = Vehicle Demonstration Flight

1 General Information

1.1 Contact information

Mailing information: UMass Lowell Rocketry Club. 220 Pawtucket Street Suite #220. Lowell, MA 01851-3095

Digital Contact Information: UMLRocketry@gmail.com

1.2 Team Member Information

UMLRC-Student Launch (SL) is comprised of 19 members, but we are still expanding and our goal is to carry 25 members for the 2025 competition year. The current breakdown of our 19 members can be seen below:

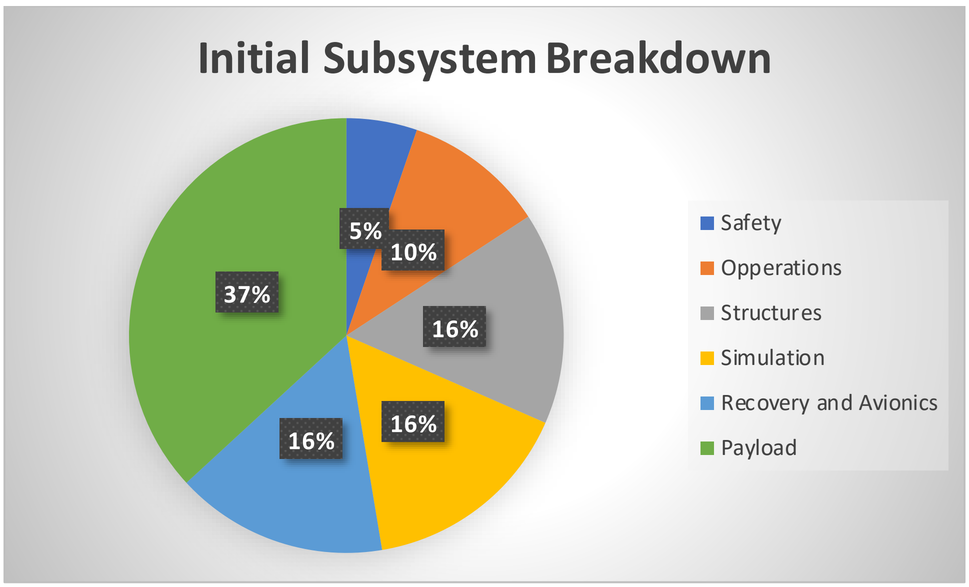


Figure 1.1 Breakdown of Subsystem Composition

1.2.1 Team Structure

Subsystem	Description
Project Team Lead	Managing the communication between each subsystem and monitoring the completion of mission objectives
Design and Manufacturing	Designing, fabricating, and validating the airframe and passive aerodynamics of the rocket
Aerodynamics and Simulation	Using computer modeling to predict flight path, aerodynamic properties and loads, and simulating the structure to ensure the vehicle is safe.
Recovery and Avionics	Designing and assembling the COTS Avionics Bay and the vehicle recovery system.
Payload	Planning, designing, and creating the payload to complete mission criteria set by NASA in the 2025 USLI RFP
Safety and Operations	Ensures the safety of our members, spectators, and property. Working with all other subsystems to ensure all work is progressing and works with others. Creates and manages project plans.

Table 1.1: List and Descriptions of Subsystems

1.2.2 Team Leadership

Position	Member	Email
Team Lead	Ethan Norton	Ethan_Norton@student.uml.edu
Design & Manufacturing Team Lead	Alinna Hanna	Alinna_Hanna@student.uml.edu
Aerodynamics & Simulation Team Lead	Zachary Muniz	Zachary_Muniz@student.uml.edu
Recovery and Avionics Team Lead	Andrew Bonczek	Andrew_Bonczek@student.uml.edu
Payload Team Lead	Charles Perrow	Charles_Perrow@student.uml.edu
Safety Officer	Joshua Barosin	Joshua_Barosin@student.uml.edu

Table 1.2: List of Team Leads

1.2.3 Mentors

1.2.3.1 Faculty Advisor – Jonathan Perez de Alderete

Email: jonathan_perezdealderete@uml.edu

Phone: 978-934-2959

1.2.3.2 Team Mentor – Howard Greenblatt – NAR HPR L2 Certification

Email: h.greenblatt@comcast.net

Phone: 617-797-1426

NAR#: 84058 Expires 4/30/2025

1.2.4 Total Proposal Hours

The team has tracked all hours working on the 2025 Proposal for Peregrine Explorer. Hours are being tracked using a self-reporting tracking sheet and taking attendance during meetings. In total, the team has spent approximately 200 hours creating the proposal and the design described.

1.3 NAR Section

UMLRC is registered as NAR section #932, but also works closely with Central MAssachusetts Spacemodeling Society (CMASS), NAR section #464, in Amesbury, MA. Their launch site, which they call “Amesbury”, is located at Woodsom Farm on Lions Mouth Road in Amesbury, Massachusetts. Amesbury has a standing FAA waiver for all weekends annually, granting HPR flights to 5000ft MSL (4900ft AGL). Our Team Mentor, Howard is one of the two members of CMASS eligible to activate the waiver. While launches at Amesbury do not occur from November 3rd, 2024 to April 19th, 2025, UMLRC can Co-Host a launch with CMASS during this period as long as the field can be reserved with the town of Amesbury, MA.

2 Facilities & Equipment

2.1 Shop Access

2.1.1 Lawrence Lin Makerspace (LMS)

The Lin Makerspace is open to UMass Lowell students for project space. LMS hosts UMass Lowell's Rocketry Club, Machining Club, Drone Club, and AIAA-DBF club. LMS facilities include a CNC lab, 3D printing lab, and woodshop. Moveable whiteboards/Touchscreen TVs, workstations, hand tools, and power tools are also provided.

Vehicle construction and team meetings will occur during normal operating hours. However, UMass Lowell Rocketry has a standing agreement with the LMS allowing access after-hours to retrieve equipment for launches and testing.

Hours:

- Monday through Thursday: 8 am – 8 pm
- Friday: 8 am – 5 pm
- Saturday: 9 am - 5 pm
- Sunday: Closed

2.1.1.1 3D lab

Students may gain access to the 3D printing lab following training on the equipment provided. Students with access may use 6 UltiMaker S3s, an UltiMaker S5, and an UltiMaker S7, 100W Fiber/CO_2 and 60W laser cutters with an optional 4th Axis to cut cylindrical patterns. Students also may request services from 2 Formlabs SLA 3D printers and a poster printer through makerspace staff.

2.1.1.2 CNC Lab

The CNC Lab is not open to students for general use. However, services may be requested of Makerspace staff or UML Machining Club members who are properly trained in the operation of the relevant equipment. The space houses 3 CNC Lathes, 3 CNC Mills, a bandsaw, several conventional 3-axis mills, and a FabLight metal laser cutter.

2.1.1.3 Woodshop

The Woodshop is a smaller lab with various advanced power tools (band saws, compound saws, skill saws, routers, and drill presses) for clubs to use on request.

2.1.1.4 VR Lab

The VR lab is a classroom-style space containing a Large TV and a whiteboard wall where students can host meetings and brainstorm ideas.

2.1.1.5 LMS Loading Dock

The loading dock in the rear of the Lin Makerspace also functions as a location for the use of VOC or other processes that require ventilation, such as sanding of fiber-reinforced composites, spray painting, cutting of composite materials without the use of cutting fluids (e.g. Dremel, dry sanding). The Loading dock be configured to be fully closed or open-air so that adequate ventilation is provided.

2.2 Software and Communication Resources

The team will primarily utilize Autodesk Fusion for CAD software through a student license. Project planning will occur through Microsoft Planner in the club's Microsoft Teams channel, which will also be used for general file management. UML students are also eligible for MATLAB, SOLIDWORKS, and Microsoft Office licenses through university IT. Flight simulation is carried out using OpenRocket. All club members are recommended to install and have a basic understanding of utilizing the software. UMLRC uses its discord as a primary form of communication, with university-affiliated student emails serving as a secondary form.

2.3 Online Presence

UMLRC has an active Twitter, Instagram, Discord, LinkedIn, and website. Weekly progress updates will be made on the club's Instagram. A monthly newsletter will be posted on the UMLRC website for team sponsors.

- Twitter: @rhrocketry
- Instagram: @RiverhawkRocketry
- LinkedIn: https://www.linkedin.com/company/uml-rocketry
- Website: https://umass-lowell-rocketry-club-44052636.hubspotpagebuilder.com/

3 Regulations, Written Safety Plan, and FMEA

3.1 Safety Officer Identification, Responsibilities, and Alternates

The safety officer for UMLRC Student Launch will be Joshua Barosin who holds a level 2 HPR Certification with NAR. The primary role of the Safety Officer is to ensure all members are following procedures, wearing required PPE, and are aware of emergency procedures and safety plans. All safety plans must be authorized by the safety officer, including any amendments that may be created after authorization. The safety officer must have a working knowledge of the facility, equipment, and external organizational rules. This includes 14 CFR 101 Part C, NFPA 1127, state laws, and the NAR/TRA High Power Rocketry safety codes.

The safety officer is responsible for the following:

I. Creating and updating risk analysis used throughout the competition
II. Approving and enforcing checklists to be carried out before major milestones leading to flight and post-flight procedures
III. Enforcing the Team's procedures, PPE usage, operating procedures, and Safety Plan
IV. Enforcing all laws and regulations set by authorities and governing bodies
V. Attending all Launches and testing events
VI. Attending all educational opportunities or events where legal minors are present

3.1.1 Safety Officer Alternates

In addition to the safety officer, the team lead and sub-system leads are expected to be aware of the rules and assist in monitoring the team's use of PPE and safe practices. Additional members, including the safety officer in training, can also give instructions to team members but can be overruled by the safety officer if such instruction is unnecessary or contradictory.

If the safety officer is not present, the responsibilities fall to the team lead, then the next most experienced officer (team leads, sub-system leads) of the club. If no club member with experience is present for activities requiring a safety officer, then activities must cease until the safety officer, or an eligible alternate is present. Safety officer alternates are only allowed for build sessions; ground testing and all launches must have the Lead Safety Officer, Josh Barosin, present for activities.

3.2 Written Safety Plan

Mission safety is a critical component to any engineering project. UMLRC's utmost priority is to ensure team and public safety while constructing, testing, and launching a high-powered rocket. The following section will outline the team's safety plan and lay the groundwork for creating a safe working environment for the team.

3.2.1 Material Safety

Non-energetic hazardous materials (e.g. epoxy, solvents) will have Material Safety Data Sheets (MSDS) stored in the LMS folder and in a folder inside the UMLRC locker. Team members working with hazardous materials will only be allowed to do so after a safety briefing and demonstration of sufficient knowledge of how to handle the materials required to perform manufacturing operations.

3.2.2 Energetic Materials Handling Protocol

Energetic materials (e.g. black powder, Ammonium Perchlorate Composite Propellant (APCP)) will be handled and stored with the team's mentor, Howard Greenblatt. Propellant reloads will be ordered from UMass Lowell and will be shipped directly to Howard.

Lithium-Polymer (Li-Po) and Lithium-Ion (Li-Ion) batteries are an exception to energetic materials storage and can be stored in the UMLRC locker on campus. Li-Po and Li-Ion batteries will be stored in battery isolation bags and in military-grade ammunition cans that will have an insulating coating placed on the inside to prevent any risk of accidental electrical short circuits. Like any regular hazardous material, team members must demonstrate a sufficient knowledge of the hazards and procedures with lithium-based batteries before being able to handle them.

3.2.3 Manufacturing Safety

Documentation outlining the safe operation of power tools will be provided for any new tool the club acquires and provides to members, that exceeds the tools available through the General Safety Lab training provided by the LMS. Additional safety documents on working with Li-Po batteries and any hazardous material the club may use will be provided. Club members are required to pass 3D Lab training provided by the LMS to use Ultimaker 3D Printers and Epilog Laser Cutters.

3.2.4 Operational Safety

Before operations that may pose a risk to the safety or well-being of the team, facility, or vehicle, a list of safety instructions and procedures will be written. The procedures and responsibilities of team members will be understood and followed by all student members wishing to participate in the previously mentioned operations.

3.3 Federal, State, Local, & NAR Regulations

3.3.1 Federal Regulations

Hobby and amateur rocketry in the United States is operated under the regulation of the DOT/FAA. The federal regulations describing hobby and amateur rocketry are §14 CFR 101.21-23,25,27,29. These regulations outline: the definition of Class 1 Model, Class 2 High Power, and Class 3 High Power Rockets; General Operating Limitations; Class 2 and Class 3 Operating Limitations; ATC notification and Information Requirements.

UMLRC will work with our team mentor Howard Greenblatt, who is an operator for the CMASS "Amesbury" waiver that is eligible for all weekends during the day and allows for flights to 4900 feet AGL. In the situation we fly at another field or during a weekday at "Amesbury" we will file FAA Form 7711-2 (6-23) at least 45 days in advance.

3.3.2 State Regulations & NFPA 1127

Massachusetts State General Laws Part 1 Section XX Chapter 148 defines laws regarding fire prevention. Section 9A dictates that rocketry in Massachusetts must follow the regulations set forth by the relevant National Fire Prevention Agency (NFPA) codes, which are NFPA 1122, 1125, and 1127. These rules will be provided for team members to read, but the codes will also be emphasized during safety briefings.

3.3.3 National Association of Rocketry – High Power Safety Code

All team members are expected to abide by the operational procedures outlined in the High-Power Safety Code from the National Association of Rocketry. During safety briefings, the safety team will emphasize these codes and ensure compliance.

See Appendix A for the NAR High Power Safety Code

3.4 Failure Modes and Effect Analysis

3.4.1 Failure Occurrence Likelihood

Level	Category	Definition
0	Rare	Failure mode is Extremely Unlikely to happen
1	Unlikely	Failure mode is unlikely to occur
2	Plausible	Failure mode has average odds to occur
3	Likely	Failure mode is likely to occur
4	Common	Failure Mode has happened before and/or is very likely to happen

Table 3.1: Risk Likelihood Table

3.4.2 Failure Effect Severity

Level	Category	Health and Safety	Equipment	Environment	Project
A	Negligible	No First aid required	Cosmetic Damage	No risk or damage to environment	No impact to Project timeline or goals
B	Minor	First aid was provided. Less than 1 day recovery time.	Damage is noted but can continue to operate with little to no detriment to the machine.	Slight damage to the environment, no clean up or action needed	Less than 1 day delay, no long-term impact
C	Moderate	First Aid Provided. Gause or other large bandage, Recovery time over 1 day	Reversible machine failure, requiring near-immediate repairs.	Damage to the environment that requires team intervention, but no long-term effects or reporting needed.	Delay of up to 1 week, may impact testing / flight schedule, no effect of deadlines
D	Major	Serious Injury requiring hospitalization, no long-term effects.	Total machine failure requiring repairs before continuing usage	Severe damage to the environment, immediate team intervention required, reporting to relevant agency	Delay of over 1 week, testing/ test flights will slip. Risk of missing deadline
F	Catastrophic	Life Threatening injury or serious injury that results in long-term injury/disability	Total irreversible failure of equipment requiring replacement	Extreme damage to the environment requiring immediate government intervention	Delay of over 1-month, high risk of missing deadline, retirement from competition.

Table 3.2: Failure Effect Table

3.4.3 Risk Analysis

By cross-examining the likelihood of a failure with the effect of the impact, a total risk can be determined. This is shown in the table below:

		Severity				
		A - Negligible	B - Minor	C – Moderate	D – Major	F - Catastrophic
Likelihood	1 – Rare	1A	1B	1C	1D	1F
	2 – Unlikely	2A	2B	2C	2D	2F
	3 – Possible	3A	3B	3C	3D	3F
	4 – Likely	4A	4B	4C	4D	4F
	5 – Very Likely	5A	5B	5C	5D	5F

Table 3.3: Risk Analysis Matrix

3.3.4 Failure Modes and Analysis

Hazard	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Fastener Failure	2 (Excessive Force)	F (Irreversible Damage to vehicle, Dangerous flight path to personnel and surroundings, Falling debris)	2F, Moderate	Increase the number of simulations and increase safety factor of flight critical components to 2+	Physical Testing to confirm manufacturer specifications	1F, Enhanced
Thrust Structure Failure	2 (Poor Construction, Motor Overperformance causing excessive force)	F (Irreversible damage to vehicle, Falling debris)	2F, Moderate	Increase number of simulations and increase safety factor of flight critical components to 2+	Physical testing of motor mount assembly to 200% the expected force of boost	1F, Enhanced
Recovery System Failure: Drogue Stage	2(Bad product control on ejection charge ignitors, airframe shoulders having high friction, drogue parachute failure)	F (failure to prevent ballistic trajectory, high energy non-ballistic descent)	2F, Moderate	Implement checks for ignitors to ensure continuity, Size primary and backup ejection charges to be at least 130% the required force to deploy the system, ensure	Ground testing and maintenance of the airframe to prevent binding	1D, Slight

				both parachute and protector are intact before use		
Recovery System Failure: Main Stage	4 (Bad product control on ejection charge ignitors, airframe shoulders having high friction, Main parachute failure, failure to fully deploy from parachute bay)	D (High energy non-ballistic landing)	4D, Moderate	Implement checks for ignitors to ensure continuity, Size primary and backup ejection charges to be at least 130% the required force to deploy the system, ensure both parachute and protector are intact before use	Ground testing and maintenance of the airframe to prevent binding	1D, Slight
Recovery System Failure: Tether, Riser, or shock cord failure	3 (Excessive force, Burn through from ejection charge deployment)	F (Falling debris, High-Energy non-ballistic landing)	3F, Moderate	Use high quality materials, fire resistant materials / coverings, use tethers that are 200% the strength of the expected loading	Ground testing and inspections between testing and flights. During assembly, multiple engineers verify that connections are torqued to spec	1F, Enhanced

Structural failure of Bulkheads	2 (poor construction, faulty modeling/simulation)	F (Falling debris)	2F, Moderate	Design components to a safety factor of 2	Testing of bulkheads to validate computer modeling	1F, Enhanced
Damaged Nose Cone, Payload Compartment	2 (Poor, Construction, Flight/transportation damage)	D (instability, Damage to payload, Dangerous flight path to personal and surroundings)	2D, Enhanced	Ensure that the descent rate of section is below damaging levels, provide protective packing when transporting	Inspect material between launches	1C, Slight
Component Misalignment: Motor mount tube / Assembly	2 (Poor Construction, bad manufacturing plan, bad product control of construction components)	D (Launch vehicle does not follow flight path, Severe Instability)	2D, Enhanced	Use tools from the CNC Lab to measure all components to verify eccentricity and location	Have multiple engineers verify measurements	1D, Slight
Commercial Rocket Motor failure	2 (Faulty motor preparation, manufacturer defect)	F (Destruction of vehicle section, Falling Debris)	2F, Moderate	Purchase propellant from reliable sources, only team mentor is allowed to handle and assemble motor	Safety officer will observe motor preparation and integration.	1F, Enhanced
Recovery and Tracking	3 (Faulty wiring, design not resistant to flight forces)	F (Recovery device may not	3F, Moderate	Test avionics bay assembly to investigate its	Continuity and "pull tests" will be performed	1F, Enhanced

Avionics Power Failure		deploy, Ballistic Landing)		reaction to flight forces, observe set up before and after test flights to validate data	during avionics bay integration to test wire connectivity and attachment	
Onboard vehicle fire	1 (Electronic fire, Fire spread due to motor failure)	F (Falling debris, un-planned vehicle separation, ground/brush fire)	1F, Enhanced	Creation of "Fire Compartments" that separate critical hardware from each-other to reduce or prevent spread of fire	Cover exposed wire with insulators, install heat insulation if needed	1F, Enhanced

3.3.5 Personal Hazards

Hazard	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Contact with airborne chemical/debris	3 (airborne particulates made during manufacturing)	B (Minor burns, Abrasions)	3B, Slight	Wear proper PPE. Such as: Gloves, eye protection, lab coats, rinse with water if contact	Safety team, subsystem leads, will enforce PPE usage, safety procedures	1B, Marginal
Contact with Hazardous Chemicals	3 (Chemical spills, improper chemical usage)	C (Burns, abrasions)	3C, Enhanced	Wearing appropriate PPE: Gloves, lab coat, and eyewear. Wash with water. Dispose in proper containers	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1C, Slight
Dust/Chemical Inhalation	3 (Particulate debris)	C (short-term respiratory damage)	3C, Enhanced	Wearing Appropriate PPE: N95, eyewear, lab coat (optional). Working in well-ventilated area. Wash with water.	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1C, Slight
Electrocution	3 (Work with custom PCBs, LiPo Batteries)	C (Short Term Nerve Damage, Electrical burns)	3C, Enhanced	Ensure team is working with proper PPE, treating all	Oversight by team officers	2C, Slight

				electronic circuitry as if it is live		
Dehydration/Heat Exhaustion	4(Hot sunny days, working in warm labs)	B (Fatigue, risk of passing out)	4B, Slight	Reminding members to drink water and wear hot weather clothes, if signs of dehydration or heat exhaustion are present, members are forced to take a break and drink water.	Oversight by team officers	3B, Slight
Entanglement with Machinery	1 (Working with manual machines)	F (Loss of body part, serious injury requiring hospitalization)	1F, Enhanced	Members only allowed to use machinery are trained properly, use of buddy system in labs	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1D, Slight
Epoxy Contact	3 (Assembling components on vehicle, small repairs, fabricating test samples)	B (Skin Irritation)	3B, Slight,	Wear appropriate PPE: gloves, N95, glasses optional	Call out before use to make sure team members are informed about hazards.	1B, Marginal

					Oversight by team officers	
Eye Irritation	3 (airborne particulate, debris, smoke)	B(Temporary eye irritant)	3B, Slight	Wear proper PPE including protective eyewear. Wash eyes if contact is made.	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1C, Slight
Hearing damage	4(proximity loud noises, high pitched noises)	D (Long term hearing damage	4D, Moderate	Ensure team is wearing hearing protection if around loud or high-pitched noises for longer than 10 minutes	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1D, Slight
Contact with heat sources	3 (working with cutting tools, curing epoxy)	B (Slight burn, skin irritation)	3B, Slight	Ensure that members are wearing the proper PPE, letting items cool down after working them	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1B, Marginal
Contact with falling equipment	1 (Dropped items, falling items)	C (Bruising, cuts, hospitalization in worst case scenario)	1C, Slight	Secure items that are heavy to worktables, use carts to carry	Call out before use to make sure team members are informed about	1C, Slight

				heavy/bulky items	hazards. Oversight by team officers	
Power tool cuts, lacerations, and injuries	3 (cuts from drill bits, rotary tools, exact-o blades / box cutters)	D (lacerations, avulsions, hospitalization plausible)	3D, Moderate	Secure loose hair, clothing, and jewelry. Wearing appropriate PPE	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1D, Slight
Tripping Hazards	3 (Equipment not put away, wires on ground)	C (upper body injury from fall, bruising from walking into heavy object)	3C, Enhanced	Brief team on picking up equipment on floor, clear common walking paths	Enforce clean up procedure at the end of meetings	1C, Slight
Fire in workshop	2 (Damage to LiPo Batteries, sparking equipment, epoxy overheating, improper disposal of wash rags)	F (Loss of workspace, severe burns to personal)	2F, Moderate	Know where Fire prevention equipment is stored, store hazardous materials in proper storage containers	Make sure all members are informed on fire safety protocols.	1F, Enhanced

3.4.6 Environmental Hazards

Hazard	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Landscape	3 (Trees, streams, Rocks)	D (Unable to recovery rocket, water damage to components or electronics, Physical damage)	3D, Moderate	Scout out launch-field for hazards and aim away from them, use weather forecast to determine wind to help aid aiming.	Inspect launch site before launch to verify mitigation.	2C, Slight
Humidity	4 (Humid Climate)	C (Condensation creating electrical shorts, humidity affecting adhesives or construction materials)	4C, Enhanced	Construction and storage of construction materials and motors in Climate Controlled rooms, electronic boards given conformal coating to give them resistance to shorting across traces	Check weather forecasts	2B, Marginal
Winds	4 (High winds preventing launch, Winds	D (Scrubbing launch, rocket	4D, Moderate	Weather forecasting and scheduling in	Check weather forecasts and creating a	1D, Slight

	blowing in unsafe direction)	landing outside of launch site)		back-up launch dates to allow for weather delays	launch weather criteria list to allow us to safely launch at our range	
Rain/Weather	4 (Can not launch in rain, cloud cover)	D (scrubbing launch, delay of 1 day to 1 week)	4D, Moderate	Weather forecasting and scheduling back-up launch windows to allow for weather delays	Check weather forecasts and creating a launch weather criteria list to allow us to safely launch at our range	1D, Slight
Visibility	3 (Exceeding operating limitations of 14 CFR 101.25)	D (scrubbing launch, delay of 1 day to 1 week)	3D, Moderate	Weather forecasting and scheduling back-up launch windows to allow for weather delays	Check weather forecasts and creating a launch weather criteria list to allow us to safely launch at our range	1D, Slight
High temperature	2 (Hot weather in Huntsville, abnormally hot day in winter)	C (On-board and ground support batteries getting damaged, Heat Exhaustion/stroke)	2C, Slight	Observing weather forecast and temperatures above 80F classified as hot weather, and above 90F classified as Extreme heat.	Ensure team members are prepared for extreme heat. If necessary, running a car with AC to provide cool environment for	1C, Slight

				Bringing pop-up tents to provide shade for the team and equipment, in addition to bringing water for the entire team.	personal and equipment	
Low Temperature	4 (Cold Plunge in New England, temperatures below 40F)	D (damage to propellant reload, Hypothermia and Frostbite, reduced battery performance)	4D, Moderate	Bring heaters, handwarmers, and insulating equipment under 40F. Activities limited or suspended under 10F.	Check weather forecasts. If Necessary suspension of outside activities may be called at any time, providing a running car with heat on.	2D, Enhanced
Pollution from Motor Exhaust	5 (Combustion by-products from firing commercial rocket motor)	A (small quantities of greenhouse gas, Hydrochloric acid, NO_x / SO_x Compounds)	5A, Slight	Use rocket motors approved by NAR / TRA.	Motors used to launch test vehicles and competition flight will be inspected by Safety Officer to ensure compliance	5A, Slight
Pollution from Vehicle	3 (Debris from vehicle from an in-air failure or	C (Small pieces of debris left from vehicle that pose	3C, Enhanced	If a failure is noticed, the team will form a	Initial inspection of the vehicle at	1C, Slight

	damage during landing)	minimal effect to the environment)		"Police line" and search the field for debris. The landing site will always be investigated for debris	the landing zone and prep area to determine if any items have been dislodged or removed from the vehicle.	
Pollution from Team	3 (wrappers from motor reloads, trash from vehicle integration, snack-wrappers)	C (Small pieces of debris from team)	3C, Enhanced	The team will conduct a "police line" search after pack down to clear prep and ground control areas from any trash left behind	Instilling Pack-in / Pack-out mentality in team. "Leave the field better than we found it"	1B, Marginal
Collisions with structures	1 (Vehicle veering off course)	D (Damage to vehicle, damage to structure, unable to recovery rocket.	1D, Slight	Weather forecasting winds at the surface and at altitudes to visualize wind shear. Aiming rocket away from structures.	Doing simulations with different wind scenarios to find the furthest distance a rocket will drift down/cross range.	1D, Slight
Contact with wildlife	1 (wildlife interacting with	C (animal interacting with residue from	1C, Slight	Installing deterrents on the vehicle to	Safety briefing talking about what hazards	1C, Slight

	vehicle after landing)	flight, damaging vehicle)		scare off wildlife such as buzzers.	may be present, educating members on how to interact with wildlife	
Battery Leakage	2 (damage to battery from flight)	D (fire, chemical residue from combustion of hazardous materials)	2D, Enhanced	Protecting battery from flight forces and landing forces	Safety briefing talking about what hazards may be present, inspect batteries between flights for damage	1D, Slight
Fire	2 (Motor Failure near ground, on-board fire continuing to landing)	F (Fire on ground, pollution from	1F, Enhanced	Using ground protector next to the launch pad, bringing Fire suppression equipment	Safety briefing talking about what hazards may be present	1F, Enhanced
Unstable Ground	2 (Loose rocks, Loose dirt, Mud)	B (Personal or equipment falling)	2B, Marginal	Inspect area for launch pad and prep-area for ground hazards	Safety briefing talking about what hazards may be present	1B, Marginal

3.4.7 Project Hazards

Hazard	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Lack of Funding	5 (Recovering from COVID, First Year Attempting NASA USLI, No Current Corporate Sponsorships)	D (Unable to afford Equipment, Unable to Attend Launch in Huntsville)	5D, High	Aggressive Fundraising Campaigns, Recruitment of Business Team	The Business Team Lead will work with the Student Launch Team lead to ensure the club is raising enough money for the competition	3B, Slight
Failure to Receive parts	2 (ordering from unreliable sellers)	C (Multiple day delays from shipping, ordering new parts)	2C, Slight	Order parts from verified sellers and legitimate websites	Verifying links and auditing purchase orders	1C, Slight
Damage or Loss of Parts/gear	3 (improper part care during construction, testing, or launch)	C (cannot construct vehicle or continue testing)	3C, Enhanced	Creation of multiple replacement parts when applicable, owning spare sets of equipment	Extra parts ordered for all needed systems	2C, Slight
Rushed/bad workmanship	3 (Approaching deadlines, unreasonable schedule expectations)	D (Testing failures & launch failures due to low-quality construction)	3D, Moderate	Built-in schedule buffers so deadlines aren't stressing	Pre-flight inspection and following tolerances	2C, Slight

Unavailable Launch Area for Test Flights	3 (Unhappy neighbors, fields not in condition to fly, no-waiver to fly)	F (delay of multiple weeks to get to flight, disqualification from the project due to no subscale & vehicle demonstration flight data)	3F, Moderate	Being in contact with multiple NAR sections near us, like St. Albans, VT CRMRC. Attempting launches early in the period to allow for scheduling issues	The Safety officer will work with team mentor to secure fields for testing at least 45 days in advance.	1F, Enhanced
Testing failure	3 (bad design, unforeseen mechanisms leading to failure, commercial component failure)	D (Damage to vehicle, failure of subscale or vehicle demonstration flight)	3D, Moderate	Following standard practice as set by team's mentor, designing critical systems to be redundant	Safety officer will ensure that all sub-systems are being designed with a proper safety factor and considerations	1D, Slight
Loss of work area	2 (Fire, loss of lab privileges)	F (Inability to construct vehicle)	2F, Moderate	Follow regulations and rules set by team and workspace occupied	Team Officers will ensure that the team will be utilizing each space we occupy correctly and follow the rules set in place by the safety agreement	1D, Slight

Failure in construction equipment	2(Improper maintenance, improper use)	D (Long-term delay in project for replacement)	2D, Enhanced	Ensure members using tools and equipment are trained properly, owning back-up equipment that can be used in the event of a failure	Each member will be responsible for maintaining equipment following the team safety agreement	1D, Slight
Insufficient Transportation	4 (lack of funding or space to bring available members to off-campus testing, launches, or workplaces)	C (Loss of sufficient labor, loss of transfer of knowledge to new members, loss of work efficiency)	4C, Enhanced	Organize and budget for transportation early and plan expenses in advance	Project management and team leads will be responsible for communicating when activities are being held and plan transportation to the events	2C, Slight

3.5 Team Safety Agreement

3.5.1 Safety Agreement Statement

The following will either be printed or put into an electronic form for all members of UMLRC Student Launch to sign:

As a member of the UMass Lowell Rocketry Club - Student Launch (UMLRC-SL) team, I agree to:

1. Always Follow the Umass Lowell Code of Conduct, on or off campus
    a. All members must abide by the rules of the governing space (i.e. if in the Lawrence Lin Makerspace, all club members must follow the rules of said space)
2. Follow the rules set forward by the FAA under 14 CFR §101 subpart C, NFPA codes 1122 & 1127, and the National Association of Rocketry
3. Wear appropriate PPE when constructing or operating the vehicle
4. Understand the hazards and operating standards of each material, tool, or machine I plan to use
5. Adhere to the guidelines set by the team's mentor
6. Recognize that the team is expected to comply with established amateur and hobby rocketry design as determined by the team's mentor
7. Acknowledge that any rocket will not be allowed to fly until the team’s mentor has reviewed and approved the design
8. Comply with all instructions given by the team mentor, team safety officer, and Range Safety Officer (RSO)
9. Acknowledge that the team mentor, Safety officer, and any Range Safety officer reserve the right to deny flight of the launch vehicle for any relevant reason.
10. Acknowledge that failure to comply with any of the listed safety regulations is cause for suspension or removal from the team

My signature Confirms that I have read and understood the rules listed above. I recognize any violation of these agreements may result in being unable to participate in UMass Lowell Rocketry, including for credit.

Name: ____

Signature: ____ Date: ________________

3.6 Team Safety Briefings

Team safety briefings will be conducted before all major events and Launches. Additional safety briefings before construction of the vehicle begins and other similar scenarios. Briefings will be a dedicated seminar during a team meeting and will initially be provided on hazard recognition and accident avoidance to promote safety. Later briefings that occur in the L-3-day period before a major test or launch will be a separate event isolated from a meeting. Each briefing will have a short agreement for each member to sign to ensure that safety standards are met and understood.

Examples of briefing topics:

I. Lawful procedures that comply with regulating agencies
II. What if scenarios:
    a. Launch vehicle poses a threat at the time of launch
    b. A team member gets injured
    c. Launch vehicle veers off course
    d. Ejection charge failure
    e. Major motor failure
    f. Premature motor ignition
    g. Premature Parachute deployment
    h. Spectator intrusion into restricted area
    i. Structural failure mid-flight
    j. Unpredicted weather / Severe weather
    k. Animal or wildlife interference

4 Technical Design

4.1 Overview of Design

External Diameter	4.02 in / 10.2 cm
Overall Length	6 ft 9.5 in / 207.01 cm
Nose cone length	10 in / 25.4 cm (4 in / 10.2 cm Shoulder)
Main Parachute Bay Length	24 in / 60.96 cm
Avionics Bay Length	10 in / 25.4 cm internal, 2 in / 5.4 cm external
Drogue Bay Length	45.15 in / 115 cm
Altitude Control System Bay Length	9 in / 22.9 cm internal, 3 in / 7.5 cm external
Booster Length	27 in / 68.6 cm
Stability Caliber	wet: 2.86 body calibers. dry: 4.78 body calibers

Table 4.1: Overall Vehicle Information

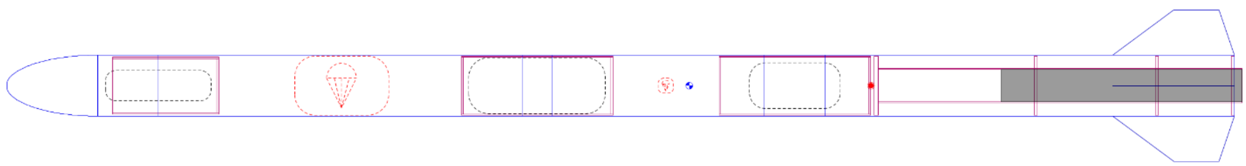


Figure 4.1: Open Rocket Simulation of Peregrine Explorer

The overall design of the launch vehicle Splits the vehicle into 6 bays that are fixed into 3 sections for flight. The bays, from tip to tail, are: Payload Bay (Nosecone), Main Parachute Bay, Avionics Bay, Drogue Parachute Bay, Altitude Control System (ACS) Bay, and the Booster.

For flight, the Main Parachute Bay and Avionics bays are fixed together to create the Upper Section. The Drogue Parachute Bay, ACS Bay, and Booster are fixed together to create the Lower Section. The Upper Section and Lower Section are tethered together and will be recovered using the Recovery system described in 4.3. The Payload Bay is not tethered to the main vehicle, and will descend under its own parachute, described in section 4.4.1.

4.1.1 Airframe Material Overview

Component	Material
Airframe Body, coupler, motor mount sections	G12 Fiberglass
Motor Thrust Plate, ACS Bay Bulkheads	¼ in 6061 Aluminum
Motor Centering rings, Avionics Bay Bulkheads	¼ in Pure bond Plywood
Payload Bay, Fins, Avionics mounting plates	Segmented 3D Printed Polycarbonate

Table 4.2: Overview of Materials

4.1.2 Construction of the Booster

The Booster for the vehicle is defined as the section directly aft of the ACS and includes the Motor Mount and Fin Section. The thrust structure of Peregrine Explorer will be a modular design, coming with 3 Main parts, the Airframe, Motor mount, and Fins.

4.1.2.1 Airframe

The airframe will be constructed using G12 fiberglass from Wildman Rocketry. There will be radial attachment points for the motor mount, and slots to the rear for the fins to fasten to both the airframe and motor mount.

4.1.2.2 Motor Mount

The motor mount will be constructed using 54mm airframe from Wildman Rocketry, (G12 Fiberglass.) Adhered to the motor mount will be 2 thrust plates made from ¼-in aluminum, and 2 centering rings made from ¼-in purebond plywood. The thrust plates will use radial mounting holes to attach to the airframe, the aft mounting plate will also include 3 threaded holds to screw in the motor retainer.

4.1.2.3 Fins

The fins will be FFF 3D-printed out of Polycarbonate thermoplastic. 3D printing the fins will allow UMLRC to quickly produce multiple fins for the airframe with an airfoil cross-section. The fins will be attached to the booster using a dovetail slot system and will be retained with 2 fasteners.

4.2 Projected Altitude

4.2.1 Motor Specifications

Manufacturer	Engine code	Diameter (mm)	Length (mm)	Burn time (s)	Total Impulse (N-s)	Avg. Thrust (N)
Cessaroni	2114K780-15A	54	489	2.72	2114	778

Table 4.3: Motor Specifications

The chosen motor would propel the vehicle to an estimated 5835 ft (1778m) with a maximum velocity of 0.743 Mach (823 ft/s or 250 m/s) and a lift-off thrust-to-weight ratio of 12.2:1 when the vehicle leaves the launch rail.

4.2.2 Open Rocket Simulation

Figure 4.2 shows the data on the Open Rocket simulation with the chosen motor. The graph plots altitude, vertical acceleration, and vertical velocity versus time. The times of motor ignition, motor burnout, apogee, and recovery device deployments are shown. The apogee occurs at 18.28 seconds, at an altitude of 5835 ft. The drogue parachute deploys 1 second after apogee, with a backup deployment 2 seconds after apogee. Main parachute deployment is commanded at 650ft, with redundant deployment at 550ft.

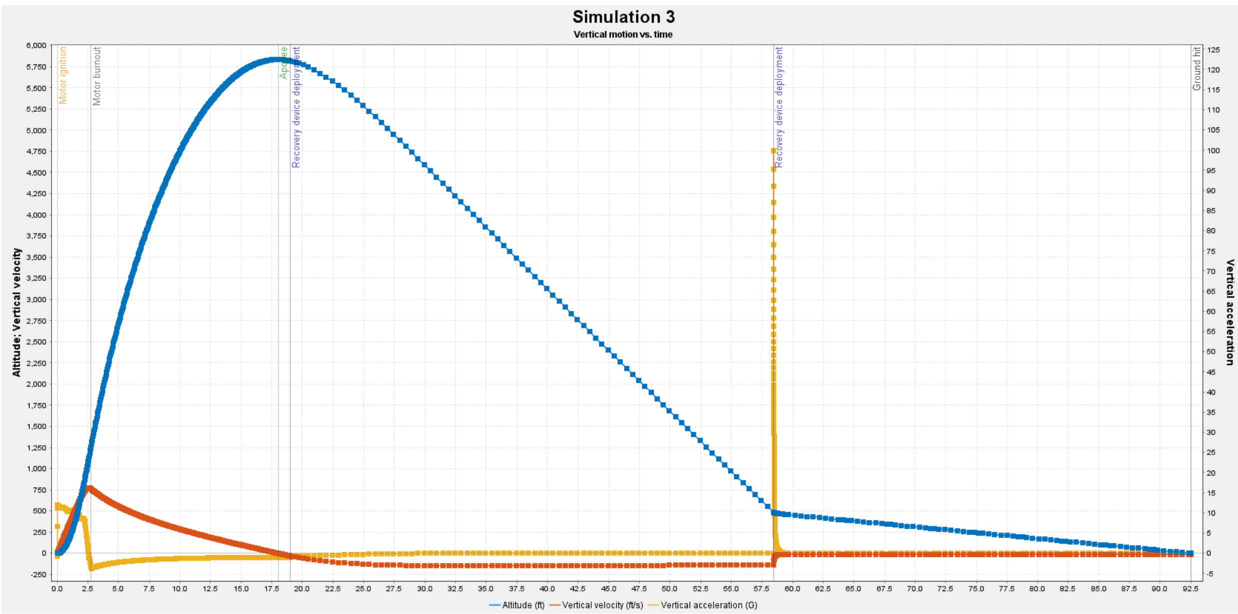


Figure 4.2: Open Rocket Simulation Data – CTI K780

4.2.3 Target Altitude

The current proposed target altitude for the project is 5500ft, which will be achieved by the Altitude Control System (ACS). The target altitude was determined from the “worst-case” flight scenario, which is: 10% underperformance of the flight motor, a 10-degree from vertical launch rail, and flying into 20 mph winds.

4.3 Avionics and Recovery Design

4.3.1 Recovery System Overview

The recovery system utilizes commercial, off-the-shelf flight computers for active vehicle tracking, deployment of recovery systems, and redundant flight data collection. Additionally, the bay will contain on-board cameras to visualize fight performance, which is analyzed after landing.

The avionics bay is isolated in a coupling-bulkhead package near the geometric center of the rocket fuselage. The recovery system uses an Altus Metrum Telemetrum V4 as the primary flight computer and a Featherweight Blue Raven as the redundant flight computer.

These COTS computers were chosen for their successful implementation in prior team rockets. The Altus Metrum Telemetrum V4 has HAM radio telemetry and GPS capabilities. The Featherweight Blue Raven offers complete data redundancy with Telemetrum V4, alongside additional 3-axis gyro capability. The Blue Raven does not offer live telemetry capability.

4.3.2 Avionics Bay Design

The avionics bay design follows a Dual Dissimilar Independent Redundancy (DDIR) mentality. The design will be centered around simplicity, avoiding the use of complex solutions to solve simple problems.

The Avionics Bay will reside inside a 10-inch fiberglass coupler tube, held in place by a bulkhead on either side. Both bulkheads will be removable for avionics bay servicing. The forward shoulder is fastened to the main parachute bay along a shoulder 4in long. The switch-band is 2in in length and features the power switches. The aft shoulder is at an in-flight separation point for the drogue parachute and is 4in long. All fiberglass tubing for avionics componentry will be COTS from Wildman Rocketry.

The avionics bay's internal structure will consist of metal, plywood, and FFF 3D-printed polycarbonate components. The load-bearing structure will be supported using stainless steel ¼-20 threaded rod, nuts, and washers. Multiple layers of laser-cut ¼-in plywood will be used to construct the fore and aft bulkheads. 3D-printed panels will form a triangular sled inside of the bay. On-board computers, batteries, and safety equipment will be mounted to the 3D-printed panels.

The On-board cameras will be mounted to view out of the switch-band. One camera will look upwards, one camera will look downwards. An additional, third camera will be mounted looking outwards and have a large FOV to gather flight footage for the team public relations and promotional posts.

In addition, the avionics bay switch-band will house a small power switch box. This box will contain multi-purpose USB-C ports alongside dedicated screw switches to provide access to programming flight computers and charging flight batteries while the Avionics Bay is integrated.

A physical arming pin will be integrated into the avionics bay as well. This pin will contact four internal switches that will toggle the electrical connection to all parachute ejection charges. Removal of the arming pin will be included in the pre-launch procedure while on the pad.

4.3.3 Drogue and Main Parachute

The Main parachute is a fruity chute IFC-72, which is an elliptical parachute with a 72in diameter. The Main parachute will be commanded to deploy at 650ft AGL, with the backup computer commanding deployment at 550ft AGL. Fruity Chutes rates the parachute for 20fps descent rate for a 28lbs load. During descent, Peregrine Explorer will only weigh 12lbs. The expected descent rate is 14 fps.

The drogue parachute will be a 12-inch hexagonal parachute from Apogee Components, deploying at apogee + 1s, and our backup computer commanding at apogee + 2s. The descent velocity under drogue is simulated at 140fps.

4.3.4 Ejection Configuration

The ejection charges will be mounted to the forward and aft bulkheads of the avionics bay. The Charges will use FFFFg black powder and will be stored in brass ejection charge wells. Each charge will have its own charge well. The charges will be sized relative to the volume of the bay. The primary charge will contain 110% of the minimum calculated black powder necessary for ejection and the redundant charge will contain 190%.

As these charges pose a large safety risk to personnel, a set of physically redundant safety measures will be implemented to ensure the charges do not detonate when not intended. The power switch box will contain screw switches for controlling power to all computers. Peregrine Explorer will also utilize an arming pin that physically disconnects the ejection charge leads from the flight computers. The arming pin is removed when the vehicle is ready for launch and before the motor is armed.

The mechanism used to eject the main parachute is a piston ejection system. This arrangement uses a floating bulkhead on the inside of the fuselage to push the parachute out of the vehicle without exposing the parachutes directly to hot ejection charge gasses. The Drogue parachute will use a fire-resistant parachute protector instead of this system.

4.3.5 Vehicle Tracking

For avionics, vehicle tracking is achieved through the Telemetrum V4 integrated HAM telemetry and GPS. All recovery systems will be adequately shielded from all potential devices that could have adverse effects on recovery systems. An RF inhibitor (such as aluminum foil and/or carbon paper) may be used with other methods to protect the recovery systems from such RF interference/exposure.

4.4 Payload Design

4.4.1 Passive Electronic Recovery Reporting – Capsule (PERR - C)

UMass Lowell Rocketry will be building a STEMCRaFT. The capsule will be the nose cone of the vehicle. Upon landing, it will automatically start transmitting data about the flight and landing via 2-M Radio back to NASA at the flight line.

4.4.1.1 Overview

UMLRC's Payload team will have two primary missions for the 2025 competition, the Passive Electronic Recovery Reporting – Capsule (PERR-C). PERR-C will satisfy NASA's payload requirements. These requirements present many new obstacles, primarily consisting of collecting multiple different data points about the STEMnauts' status upon landing and being able to successfully transmit the data back to NASA-owned receivers whilst controlling when data is measured and transmitted. The nosecone of the vehicle will serve as the capsule's primary structural element. The capsule, PERR-C, will hold the STEMnauts and the transmitting computer.

4.4.1.2 STEMnaut Capsule Criteria

The STEMnaut capsule, PERR-C, will be reporting all 8 pieces of data to the NASA receiver that we have been directed to choose from. These are as follows:

- Temperature of landing site
- Apogee reached
- Battery check/power status
- Orientation of on-board STEMnauts
- Time of landing
- Maximum velocity
- Landing velocity, G-forces sustained
- Calculated STEMnauts crew survivability

PERR-C will be held within the nosecone of the rocket, and will not have any protrusions from the vehicle prior to apogee beyond a quarter inch of the rocket

PERR-C shall transmit on the 2-M band, with a maximum of 5W, and transmissions shall not occur prior to landing

4.4.1.3 PERR-C Design

The Passive Electronic Recovery Reporting – Capsule (PERR-C) will utilize FFF 3D-printed techniques to produce a partially transparent thermoplastic nosecone. Within the nosecone will be the PERR-C computer on a single threaded-rod sled, atop which a base will sit that safely holds the four STEMnauts, modeled after "Rowdy" the River Hawk. The PERR-C computer system will attempt to transmit all eight data points about the landing site and STEMnaut conditions to the NASA receiver.

PERR-C will deploy simultaneously with the Main Parachute. As it is untethered, PERR-C will have a commercial tracking system separate from the payload to satisfy the requirements of the competition. After Ejection, PERR-C's parachute will deploy, and the riser, which is attached near the nose, will re-orient the capsule so that the shoulder is facing towards the ground.

4.4.1.4 Payload Electronics Package (PEP)

The payload recovery computer will be a Student Researched And Designed (SRAD) computer. UMLRC's payload electronics team has chosen components because of their high precision, ease of use and assembly, availability, and price. Components will be selected from commercially verified vendors, such as Adafruit, allowing the use of C++ libraries. It will utilize a Teensy 4.1, BMP-388 Barometer, ADXL345-Accelerometer, ICM-20948-Gyro, and 144mhz (2m) Radio.

To fulfill NASA requirements for payload data transmission, the PEP system will be capable of:

I. Detecting launch and landing
II. Sampling, recording, and calculating flight data
III. Transmitting data over 2m radio once landing is detected

4.4.2 Altitude Control System (ACS)

4.4.2.1 Overview of System

The Altitude Control System (ACS) consists of two primary subsystems: a computer and a mechanical system. The computer will be a PEP board, the SRAD computer built for our STEMCRaFT payload, with an additional board for expanded capability. This design approach not only saves development time but also helps reduce costs.

Once the target speed and altitude are achieved, the computer sends signals to a motor that controls the mechanical component of the ACS. The mechanical subsystem then adjusts the airbrake deployment angle, allowing precise control over the vehicle's drag. This fine-tuning enables accurate control of the rocket's apogee. The primary goal of the ACS is to ensure the rocket reaches the target altitude.

4.4.2.2 PEP Extension for ACS (PEP-ACS)

PEP- ACS system is a derivative of the PEP and is tasked with autonomous control over the airbrakes to achieve the target altitude. The ACS extension will be based on an external board that will connect to a PEP board through a multi-pin connector. The expansion PCB will use an off-the-shelf 900 MHz transceiver, a GPS receiver, and output for electric motor control. The 900 MHz radio will be transmitting the entire flight and will act as a redundant GPS transmitter for the main vehicle.

The code for the ACS will also be an addition to the code developed for PERR-C, adding the Live radio telemetry, GPS positioning, and Airbrake Guidance and Control

PEP-ACS will be able to:

I. Transmit flight data and tracking information to team-made ground station
II. Processing real-time telemetry to control the deployment of airbrake, ensuring Peregrine Escape reaches the target altitude
III. Controlling deployment of Airbrakes autonomously

4.4.2.3 ACS Mechanical Design

The mechanical design of the ACS prioritizes simplicity and efficiency. A central lead screw and nut function as a linear actuator that pushes on four linkages to extend 4 control surfaces. The airbrake will be hinged from the top of the surface and will get pushed out to an angle of 65 degrees from the airframe. This system will be beneficial in the event of a mechanical failure of the system, the aerodynamics will force the airbrakes into a naturally closed state. The lead screw and motor will also allow the system to be “throttled” in which a lower angle of deployment can be deployed for fine-tuning the flight profile.

4.5 Project Requirements

Vehicle and Project requirements are listed in Appendix C.

4.6 Major Technical Challenges

4.6.1 Payload Electronic Package design

Regarding the electronics on board the vehicle, while the team has made development systems in the past, we have never made a full-fledged flight computer, let alone multiple systems that can communicate with each other. While we believe the task is doable, it will be a challenge throughout the NASA Student Launch Competition. The team has a general idea of how to make a flight computer but needs to put the pieces together: Designing a Printed Circuit Board (PCB), building the code, and testing the system.

4.6.2 Structural Design and Construction of the Booster

UMLRC is working with a new design for the thrust structure for our rockets, utilizing a modular motor mount and fin system to facilitate ease of repair for our rocket in the event of a failure during testing or damage received in transport. The biggest challenge we face is designing a system tolerant enough to work across multiple airframes, motor mounts, and fins, while being of a tight enough tolerance to facilitate stable and structurally sound flight.

5 Project Plan

5.1 Timeline

Project timeline is listed in Appendix B.

5.2 Educational Engagement

Educational engagement will be managed by the UMass Lowell Finance, Public Relations, and Media (FPRM) team, with support from team leads and other club members in organizing STEM outreach events. These events will feature challenges designed to foster teamwork and creative problem-solving, benefiting the local community. Planned challenges include activities such as egg drops, water rockets, and low-power hobby rockets with more being developed. Such events aim to guide participants, especially children, in thinking innovatively and devising creative solutions for each challenge.

Current Ideas for projects to Engage students with:
1. Model Rocket Building with a small high school group or Cub Scout group (multi-day)
2. Larger High School Group building water rockets (single day)
3. Space Exploration and Other STEM Merit Badges with Scout BSA Troops (Multi-Day)
4. Elementary – Middle School Egg Drop Competition (Multi-Day)

5.2.2 Requirements for Outreach

1. Minimum of 250 students
2. Only K-12 Students participating will qualify
3. Only direct STEM engagement will count for the 250 Students. Direct STEM engagements are described as an activity where students learn about a STEM concept through active participation.

5.2.3 Local groups

- Lowell Public Schools
- Dracut Public Schools
- Chelmsford Public Schools
- Boy Scout Troop 81, Topsfield, Ma.
- Boy Scout Troop 7, Lowell Ma.
- Boy Scout Troop 80, Dracut Ma.
- Boy Scout Troop 46, Tyngsborough Ma.
- Boy Scout Troop 49, Tewksbury Ma.

5.3 Budget

The budget below details the expected expenditures of UMLRC – SL for the 2025 Competition. Included in the budget is spare hardware and materials that will be needed to construct almost 2 full-scale vehicles and survive multiple Avionic Failures with replacements available without needing to place an order.

Items	Cost	% Total
Fiberglass	$580	3.75
Non-Fiberglass Airframe components	$740	4.79
Recovery Electronics	$250	1.62
Parachutes	$300	1.94
Payload & Secondary Electronics	$700	4.53
Motors & Expendables	$900	5.82
Lodging	$2500	16.17
Travel	$6500	42.03
Shipping (Hazmat, vehicle to Huntsville)	500	3.23
Budget Emergency Buffer	$2494	16.13
Total (without Buffer)	12470	
Total	16464	

Table 5.2: List of Subsection Budget Projections

5.4 Funding Plan

UMass Lowell Rocketry currently has $3,504.38 in the club account. To supplement the budget this year, donations are sought from internal sources at the university, club members, and corporate sponsorships. Every year, UMLRC receives donations from the Francis College of Engineering Dean's Office (FCOE) and the Department of Mechanical and Industrial Engineering (MIE), the club is also eligible to apply for a Student Government Association (SGA) Grant through UML Student Activities. In total, these 3 internal sources at UMass Lowell can provide up to $6500, with $5000 guaranteed from the FCOE and MIE, and another $1500 from SGA, though this amount is rarely given out. This will bring the budget total to at least $8,500 by the end of November.

For external sources this year, all members of the UMass Lowell Rocketry Club will be asked to assist in a crowd-sourcing campaign. Each team member will be given a donation link with instructions on how to distribute it to as many donors as possible. Additionally, the FPRM team will work on gaining 2-5 corporate sponsorships and lining up engineers from space or related fields to visit UML as guest speakers.

5.5 Team Sustainability

5.5.1 Membership and Knowledge Sustainability

UMass Lowell Rockery Club has multiple teams and is likely to retain over 40 active members for the entire academic year, something our club has not attained before. Like sports in high school, we consider our NASA USLI team to be our "Varsity" team, primarily consisting of Seniors and Juniors. However, first-year students and sophomores who have demonstrated a commitment to the club and a working knowledge of a system can be "called up" to the USLI team. Additionally, Project leads (Team and Sub-system) are urged to pick an assistant so that they have a replacement for when they graduate.

In addition to the USLI team, UMLRC offers a pathway for members to get their Level 1 and soon, level 2 HPR Certifications, as well as other teams that can demonstrate new vehicle design techniques or advanced building techniques such as Multi-stage, or Clustered High-Powered rockets. These teams are in place to teach underclassmen how to build rockets in a non-competitive situation, where there is less stress to meet deadlines.

5.5.2 STEM Engagement Sustainability

The plan for STEM Engagement is to target 8-10th graders in the Greater Lowell Area: Lowell, Dracut, Tewksbury, Chelmsford, Billerica, Dunstable, Pepperell, and Westford. As well as Boy Scouts from the surrounding BSA Councils: Spirit of America, Heart of New England, and the southern districts of Daniel Webster Council which covers all of NH.

5.5.3 Funding Sustainability

For the foreseeable future, Umass Lowell Rocketry will always receive at least $6000 from the University, through donations from the FCOE and MIE department, and yearly budgets and grants from Student Activities through SGA. Additional departments like the Electrical and Computer Engineering Department and Physics and Astrophysics Department may also donate to the club if more students from those degrees filter into the club.

Crowd-source funding also appears to be sustainable, with other university teams competing in NASA USLI attaining $2000-$5000 yearly from crowdsourcing. These two sources alone will allow UMLRC- student launch to participate in NASA USLI every year indefinitely, granted from a field in New England and not at Huntsville, AL.

Appendix A – NAR High Powered Rocket Safety Code

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

than one-third of the certified average thrust of the high-power rocket motor(s) intended to be ignited at launch.

9. **Flight Safety**. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 24 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 20 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. **Launcher Location**. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
12. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE

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

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

Table A.1: Minimum Personnel Distance Table

Appendix B – Gantt Chart/Timeline

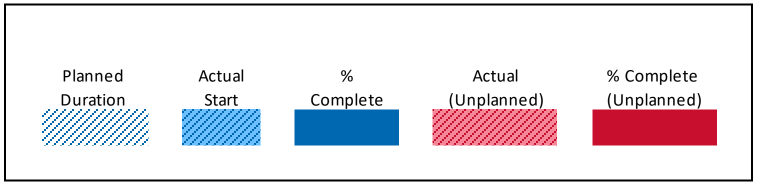
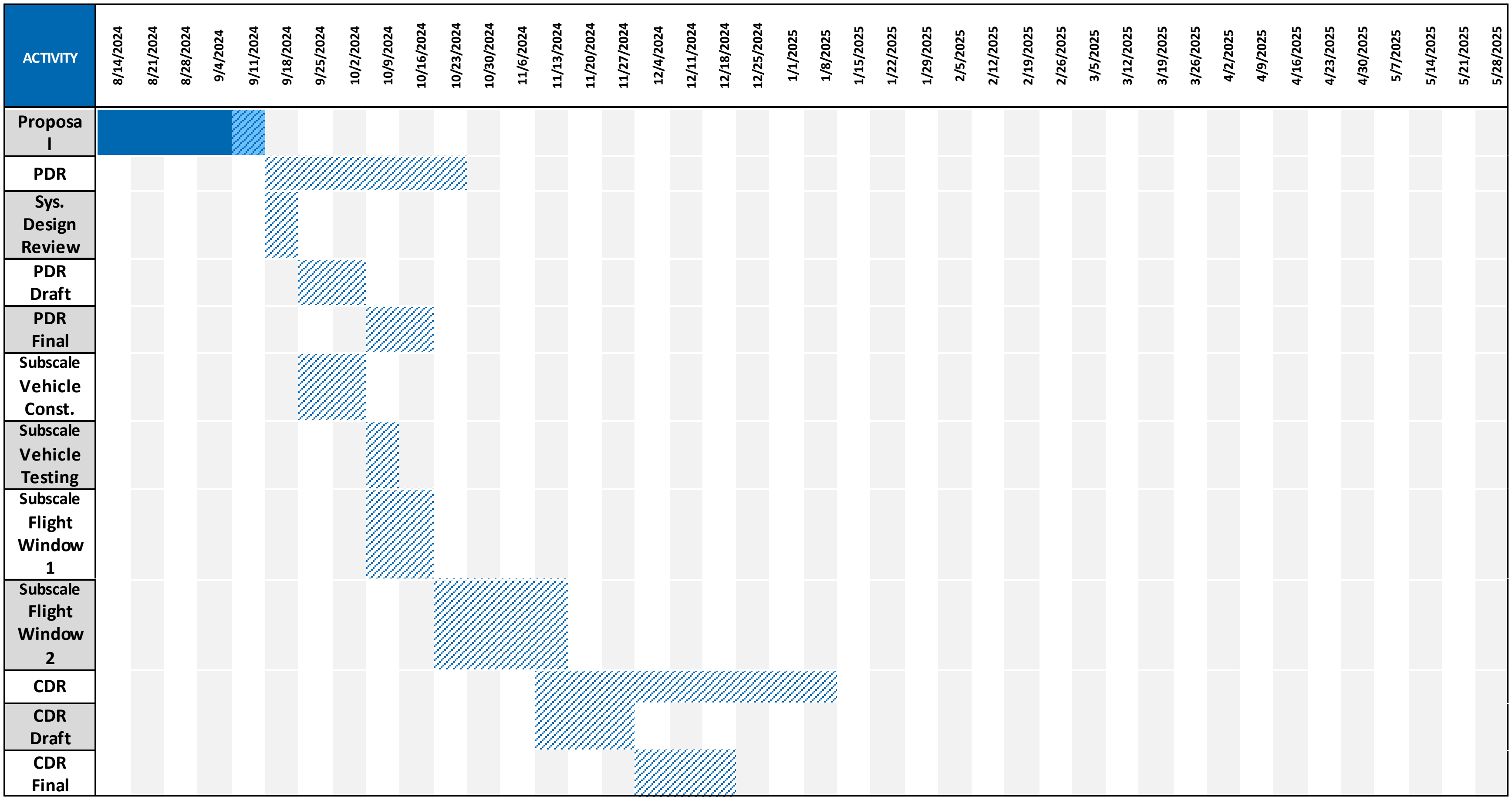


Figure B.1: Gantt Chart Legend



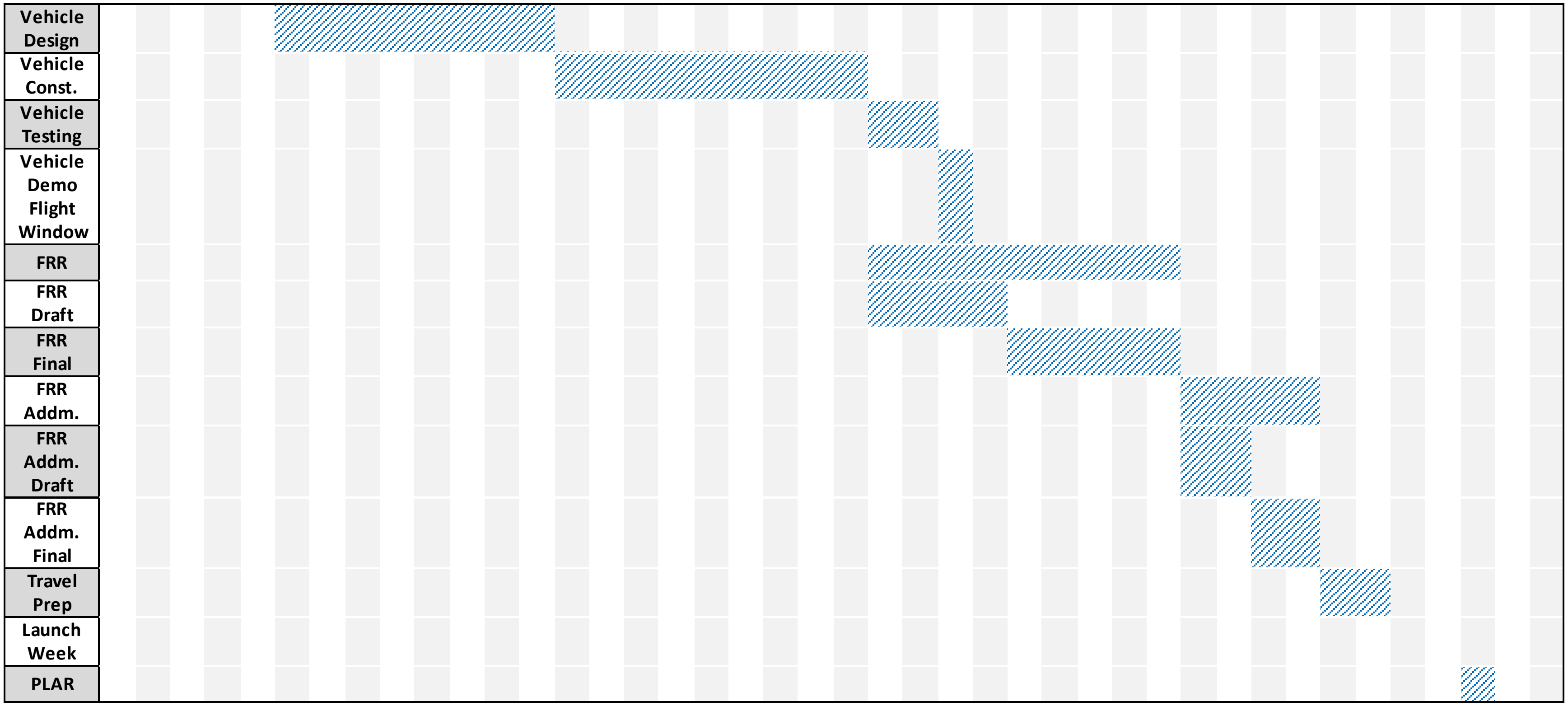


Figure B.: Project Timeline

Appendix C – Vehicle and Recovery Requirements

C.1 Vehicle Requirements

1. The vehicle shall deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL).
2. Teams shall declare their target altitude goal at the CDR milestone. The declared target altitude shall be used to determine the team's altitude score
3. The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.
4. The launch vehicle shall 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.
    a. Coupler/airframe shoulders which are located at in-flight separation points shall be at least two airframe diameters in length.
    b. Coupler/airframe shoulders which are located at non-in-flight separation points shall be at least 1.5 airframe diameters in length.
    c. Nosecone shoulders which are located at in-flight separation points shall be at least ½ body diameter in length.
5. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.
6. The launch vehicle and payload shall be capable of remaining in launch-ready configuration on the pad for a minimum of 3 hours without losing the functionality of any critical on-board components.
7. The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system. The firing system shall be provided by the NASA-designated launch services provider.
8. The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).
9. Each team shall use commercially available ematches or igniters. Hand-dipped igniters shall not be permitted.
10. The launch vehicle shall 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).
    a. Final motor choice shall be declared by the Preliminary Design Review (PDR) milestone.
    b. Any motor change after PDR shall be approved by the NASA management team or NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment shall not be approved. A scoring adjustment against the team's

overall score shall be incurred when a motor change is made after the PDR milestone. The only exception is teams switching to their secondary motor choice provided the primary motor choice is unavailable due to a motor shortage.

11. The launch vehicle shall be limited to a single motor propulsion system.
12. The total impulse provided by a College or University launch vehicle shall not exeed 5,120 Newtonseconds (L-class).
13. Pressure vessels on the vehicle must be approved by the RSO and shall meet the following criteria:
    a. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.
    b. Each pressure vessel shall 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.
    c. The full pedigree of the tank shall be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.
14. The launch vehicle shall 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.
15. The launch vehicle shall have a minimum thrust to weight ratio of 5.0:1.0.
16. Any structural protuberance on the rocket shall be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.
17. The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.
18. All teams shall successfully launch and recover a subscale model of their rocket. Success of the subscale is at the sole discretion of the NASA review panel. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data shall be reported in the CDR report and presentation at the CDR milestone. Subscales are required to use a minimum motor impulse class of E (Mid Power motor).
    a. The subscale model should resemble and perform as similarly as possible to the full-scale model; however, the full-scale shall not be used as the subscale model.
    b. The subscale model shall carry an altimeter capable of recording the model's apogee altitude.
    c. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.

   d. Proof of a successful flight shall be supplied in the CDR report with altimeter flight profile, quality flight video, and pictures of the landed configuration of all sections of the launch vehicle.
   e. The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket.

19. All teams shall complete demonstration flights as outlined below
    a. Vehicle Demonstration Flight— All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown shall be the same rocket to be flown for their competition launch. A successful flight is defined as a launch in which all hardware is functioning properly (drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.).
       i. The vehicle and recovery system shall have functioned as designed.
       ii. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.
       iii. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:
          1. If the payload is not flown, mass simulators shall be used to simulate the payload mass.
          2. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.
       iv. If the payload changes the external surfaces of the rocket or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.
       v. Teams shall fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances.
       vi. The vehicle will be flown in its fully ballasted configuration during the full-scale test flight.
       vii. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA management team or Range Safety Officer (RSO).
       viii. Proof of a successful flight shall be supplied in the FRR report with altimeter flight profile, quality flight video, and pictures of the landed configuration of all sections of the launch vehicle.
       ix. Vehicle Demonstration flights shall be completed by the FRR submission deadline. No exceptions will be made.

   b. Payload Demonstration Flight— All teams shall successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline.
      i. The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.
      ii. The payload flown shall be the final, active version.
      iii. If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.
      iv. Payload Demonstration Flights shall be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.
20. An FRR Addendum shall be required for any team completing a Payload Demonstration Flight or NASArequired Vehicle Demonstration Re-flight after the submission of the FRR Report.
   a. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch.
   b. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload during launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.
21. The team's name and Launch Day contact information shall be in every section of the vehicle
22. All Lithium Polymer batteries shall be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.
23. Vehicle Prohibitions:
   a. The launch vehicle shall not utilize forward firing motors
   b. The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)
   c. The launch vehicle shall not utilize hybrid motors.
   d. The launch vehicle shall not utilize a cluster of motors.
   e. The launch vehicle shall not utilize friction fitting for motors.
   f. The launch vehicle shall not exceed Mach 1 at any point during flight.
   g. Vehicle ballast shall not exceed 10% of the total un-ballasted weight of the rocket, as it would sit on the pad (i.e., a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).

h. Transmissions from on-board transmitters, which are active at any point prior to landing, shall not exceed 250 mW of power (per transmitter).
i. Transmitters shall not create excessive interference. Teams shall utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.
j. Excessive and/or dense metal shall not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.

C.2 Recovery Requirements

1. The full-scale launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO.
   a. Main parachute shall deploy over 500ft AGL
   b. Apogee Delay shall not exceed 2 seconds
   c. Motor Ejection is not allowed
2. Each team shall perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles.
3. Each independent section shall not have a kinetic energy exceeding 75 ft-lbf at landing
4. Recovery system must use redundant, commercially available barometric deployment altimeters.
5. Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries.
6. Each altimeter shall 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 and can be locked into the **ON** position
7. The recovery system, GPS and altimeters, and electrical circuits shall be completely independent of any payload electrical circuits.
8. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.
9. Bent eyebolts shall not be permitted in the recovery subsystem.
10. The recovery area shall be limited to a 2,500 ft. radius from the launch pads.
11. Descent time shall not exceed 90s from apogee to landing
12. An electronic GPS tracking device shall be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver

13. The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).
    a. The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.
    b. The recovery system electronics shall be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.
    c. The recovery system electronics shall be shielded from all on-board devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.
    d. The recovery system electronics shall be shielded from any other on-board devices which may adversely affect the proper operation of the recovery system electronics.