USLI

WORCESTER POLYTECHNIC INSTITUTE

G.O.A.T.S.

September 19th, 2018

USLI OF AIAA
100 Institute Road
Worcester, MA 01609

Table of Contents

Acronym Definitions

This proposal uses a variety of acronyms. All acronyms used are defined below.

- 3D: Three Dimensional
- ABS: Acrylonitrile Butadiene Styrene (FDM Printer Filament)
- AGL: Above ground level
- AIAA: American Institute of Aeronautics and Astronautics
- APCP: Ammonium Perchlorate
- BS/MS: Bachelors/Masters
- CDR: Critical Design Review
- CFR: Code of Federal Regulations
- CG: Center of Gravity
- CMASS: Central Massachusetts Spacemodeling Society
- CNC: Computer Numerical Control
- CTI: Cesaroni Technology Incorporated
- CW: Clockwise
- CCW: Counterclockwise
- ESC: Electronic Speed Controller
- FAA: Federal Aviation Administration
- FDM: Fused Deposition Modelling
- FEA: Future Excursion Area
- FPV: First Person View
- FRR: Flight Readiness Review
- ft: Feet
- g: Grams
- G.O.A.T.S: Get Our Apogee to Space
- GSSS: Garden State Spacemodeling Society of New Jersey
- HIPS: High Impact Polystyrene (FDM Printer Filament)
- in: Inch

- lb: Pounds
- LPKF: Leiterplatten Kopier Fräsen (German Laser and Electronics Company)
- LiPo: Lithium Polymer
- LRR: Launch Readiness Review
- m: Meter
- ME: Maine
- mm: Millimeters
- MMMSC: Maine Missile Math and Science Club
- MPH: Miles per hour
- MSDS: Materials Safety Data Sheet
- MSFC: Marshall Space Flight Center
- N: Newtons
- NAR: National Association of Rocketry
- NASA: National Aeronautics and Space Administration
- NFPA: National Fire Protection Agency
- NJ: New Jersey
- Ns: Newton Seconds
- PDR: Preliminary Design Review
- PLA: Polylactic Acid (FDM Printer Filament)
- PLAR: Post-Launch Assessment Review
- POP: Pre-Collegiate Outreach Programs
- PPE: Personal Protective Equipment
- PVA: Polyvinyl Alcohol (FDM Printer Filament)
- RAS: Risk Assessment System
- RC: Remote Control
- RSO: Range Safety Officer
- s: Seconds
- SGA: Student Government Association
- SLI: Student Launch Initiative

- STEM: Science, Technology, Engineering, and Mathematics
- UAV: Unmanned Aerial Vehicle
- URL: Uniform Resource Locator
- USLI: University Student Launch Initiative
- WPI: Worcester Polytechnic Institute

Executive Summary

This is the written proposal of WPI's local AIAA chapter for NASA's USLI competition. The Academic Affairs Office at NASA Marshall Space Flight Center (MSFC) conducts the Student Launch Initiative (SLI) each year. The goal of WPI USLI team is to design a rocket and payload to complete the requirements outlined in the Student Launch Handbook. In summary, these goals are to launch a rocket containing a selected payload, which will (upon landing) deploy. In order to achieve these requirements, the team has split into two subteams; a rocket team and a payload team. Each team will collaborate and design compatible parts to launch and deploy in sequence, land and complete the objectives outlined in the handbook. Upon test launches, marginal changes will be made to ensure success of our goals. All changes and tests will be reviewed by a mentor or Range Safety Officer, as well as safety protocols outlined by NAR and the FAA.

Mission Statement

Our mission is to gain more knowledge in high powered rocketry along with other fields of engineering, and branch into the more competitive and challenging nature of NASA's University Student Launch Initiative competition. Additionally, through using NASA's design lifecycle we aim to gain real world experience about working in the field of engineering and encourage our members and team to excel through WPI's philosophy of collaborative learning. We want to in turn, spread our knowledge throughout the community to people of all ages, gender, and race to make a difference in the world around us.

Section 1. General Information

Section 1.1. Adult Educators

Robert Dehate
Team Mentor
President AMW/ProX
NAR L3CC 75918 TRA 9956
robert@amwprox.com
(603) 566-2904

Section 1.2. Safety Officer

Christian Maximilian Schrader
Worcester Polytechnic Institute
BS/MS Aerospace engineering, Computer Science Minor expected 2021
cmschrader@wpi.edu
(781) 290-3098

Christian Maximilian Schrader is a Sophomore at WPI pursuing a Bachelor of Science/Masters of Science in Aerospace Engineering with a minor in Computer Science. Currently pursuing his class 1 certification in high powered rocketry, Christian plans to immediately begin work on his class 2 certification at the start of the school year. Christian has previously worked as a lifeguard, and has achieved the highest rank of Eagle Scout, the highest rank available in the Boy Scouts of America. In order to achieve such an award, Christian proved strong his attributes in oath, law, service, and leadership while also earning 26 merit badges. A few of the badges he earned include first aid, lifesaving, aviation and space exploration badges, all directly applicable to the goals of the project. Ultimately, his Eagle Scout standing, skills, and attributes make him a valuable resource as the Safety Officer of this team.

Section 1.3. Team Leaders

Caroline Ann Kuhnle
Team Captain
Worcester Polytechnic Institute
BS/MS Aerospace Engineering, Astrophysics Minor expected 2021
cakuhnle@wpi.edu
(973) 919-3725

Caroline Ann Kuhnle is a Sophomore at WPI pursuing a BS/MS in Aerospace Engineering with a minor in Astrophysics. Currently pursuing her class 1 certification in high powered rocketry, Caroline plans to immediately begin work on her class 2 certification at the start of the school year. Caroline's role as a team leader is as Team Captain. Her responsibilities include, coordinating with the adult educators and mentors of WPI's USLI team and its members, ensuring coordination within the team to insure tasks are completed on time and that different subteams are collaborating efficiently, and to ensure the completion and quality of the deliverable documents described in the most recent revision of the NASA Student Launch Handbook and their submission. Caroline best represents this role through her experience in Girl Scouts where she earned the highest award in Girl Scouts, the Gold Award. Throughout her achievement of this award, Caroline demonstrated strong attributes in civic responsibility, promise and law. Caroline's journey towards her Gold Award demonstrates her strong leadership skills and value as the Team Captain.

Krystina Mychelle Waters
Director of System Integration
Worcester Polytechnic Institute
BS/MS Aerospace Engineering, Astrophysics Minor expected 2021
kmwaters@wpi.edu
(860) 501 1375

Krystina Mychelle Waters is a Sophomore at WPI pursuing a BS/MS in Aerospace Engineering with a minor in Astrophysics. Currently pursuing her class 1 certification in high powered rocketry, Krystina plans to immediately begin work on her class 2 certification at the start of the school year. Krystina's role as a team leader is the Director of Team Integration. Her responsibilities include encouraging and overseeing the flow of the USLI launch vehicle and payload subteams, ensuring subteams are supplied with the necessary resources to be successful in workshop and competition, and to communicate the progress of the subteams with the other student leads. Krystina best represents this role through her experience in mechanical engineering and computer science from her participation in FIRST Robotics Competition. Krystina was a valuable member of her team working as an essential mechanical member in the pits her senior year of high school. She has obtained the Society of Women Engineers Award for excellence in science and mathematics and has also volunteered as a mentor in educating elementary school students on the fields of science, technology, engineering, and mathematics (STEM). Through this she has gained skills in machining and programming making her a valuable asset as the team's Director of System Integration.

Section 1.4. Members and Key Managers

WPI's USLI team currently consists of approximately 20 active members split among two subgroups. These subgroups are designated as the launch vehicle and payload teams. Additionally, the team has a logistics officer and two educational engagement officers.

Krystina Mychelle Waters
Launch Vehicle Lead
Worcester Polytechnic Institute
BS/MS Aerospace Engineering, Astrophysics Minor expected 2021
kmwaters@wpi.edu
(860) 501 1375

The responsibilities of the launch vehicle lead include:

- Leading in the design, construction, and testing of the launch vehicle
- Responsible for abiding by all safety regulations throughout the course of build season
- Coordinates with the safety captain and team captain on reports needed for deadlines

Peter Jonathan Dentch
Payload Lead
Worcester Polytechnic Institute
BS/MS Robotics Engineering/Computer Science
pdentch@wpi.edu
(860) 333 4086

The responsibilities of the payload lead include:

- Leading in the design, construction, and testing of the selected payload option
- Responsible for abiding by all safety regulations throughout the course of build season
- Coordinates with the Safety Captain, Team Captain, and Director of System Integration on reports needed for deadlines

Jacob Koslow
Logistics Officer
Worcester Polytechnic Institute
BS/MS Aerospace Engineering
jkoslow@wpi.edu
(508) 596 7435

The responsibilities of the logistics officer include:

- Coordinate transportation and lodging for the competition
- Facilitate spaces to store and build the launch vehicle
- Manage travel related expenses while collaborating with the treasurer of AIAA

Christopher Renfro
Outreach Officer
Worcester Polytechnic Institute
BS Aerospace Engineering
crenfro@wpi.edu
(508) 365-8471

Ian Scott
Outreach Officer
Worcester Polytechnic Institute
BS Aerospace Engineering
iscott@wpi.edu
(612) 270-2236

The responsibilities for the Outreach Officers:

- To engage young students in STEM related activities
- Coordinating fundraising efforts to support the team
- To spread knowledge of rocketry throughout the local community through outreach

Section 1.5. NAR Section

The team intends to work with Maine Missile Math and Science Club (MMMSC) for test launches. Test launches may also be done with Garden State Spacemodeling Society of New Jersey (GSSS) in case of cancellations or other conflicts with MMMSC launches.

Section 2. Facilities and Equipment

Section 2.1. Robotics Pit

The Robotics Pit is a large area primarily used for robotics competitions. The USLI team has been allotted a space in the Robotics Pit that will be used as the main space to assemble and store the launch vehicle and parts of the payload. Provided in the Robotics Pit are fold-up tables and basic tools that will be used during the final stages of assembly. Launch vehicle and payload parts will be stored between the Robotics Pit and Foisie lockers until they are ready to be attached to the main launch vehicle body. This facility is open from 6:00am to 11:00pm Monday through Friday, 8:00am to 11:00pm on Saturday, and 10:00am to 11:00pm on Sunday. Students have access to the Robotics Pit without any authorized personnel since no heavy machining will occur there.

Section 2.2. Foisie Innovation Studios

The Foisie Innovation Studio Makerspace serves as a hub for design and engineering at WPI. The building has a common workspace as well as several conference rooms that will serve as the team's primary workspace for the payload. The building has a prototyping lab that includes a LPKF ProtoLaser S Printed Circuit Board machine, a Full Spectrum P-Series 48in x 36in laser cutter, 15 Fused Deposition Modeling (FDM) printers, Juki DU-1181 industrial sewing machines, and several soldering stations. Among the 3D printers are multiple LulzBot TAZ 6's each equipped with an 11in x 11in x 9.8in printing area and the ability to print using ABS, PLA, HIPS, PVA, and many more materials. The LulzBot will be used to make many of the team's payload parts. These parts will be stored in the various storage lockers available in Foisie until they are ready to be incorporated into the main launch vehicle body. The Studio also has basic and advanced tools available for rental at the front desk when a desk manager is present. Training on tools is required to ensure a safe workspace, however, no supervision is required for using the Prototyping Lab. The makerspace is open from 7:30am to 12:00am Monday through Thursday, 7:30am to 2:00am on Friday, and 8:00am to 1:00am on Saturday and Sunday. The Prototyping Lab is open from 10:00am to 11:00pm Sunday through Thursday and 10:00am to 1:00am on Friday and Saturday.

Section 2.3. Washburn Shops and Manufacturing Labs

The Washburn Shops house the manufacturing labs which serve as a center for manufacturing at WPI. These labs are equipped with machines such as a Universal Laser VLS4.60 laser cutter, a MakerBot Replicator 2x 3D printer, a Prussa 3D Printer, and welding stations. There are several machines made by Haas which include a ST-30SSY CNC Lathe, a VM2 vertical mill, two SL10 CNC lathes, a ST10 CNC lathe, a Mill Drill Center, and three MiniMills. The shop is also supplied with an array of manual tools available to students that have completed the prerequisite safety training. Among these are two vertical band saws, one horizontal band saw, one sheet metal shear, two drill presses, one belt sander, one grinder, and one polishing wheel. The Haas SL10's and MiniMills each have their own computer workstation equipped with training materials, computer aided manufacturing software packages such as Esprit, MasterCam, and SurfCam, and all the design and programming software supported on campus. In addition to these computer stations, the facility has two computer classrooms which hold eight to twelve computer workstations, conference tables, whiteboards, and a ceiling mounted projector. The team will be using these machines as needed in the creation of the launch vehicle and UAV payload systems. Washburn Shops is open from 9:00am to 5:00pm Monday through Friday and is accessible after hours to students who have card access to the building. The manufacturing labs are open 24 hours a day as long as an authorized lab monitor is present.

Section 2.4. Higgins Laboratories

Higgins Laboratories houses many state-of-the-art facilities available to students. The Price Conference Room in Higgins will be used to host video teleconferences and has a large conference table, 40 chairs, high speed internet, and a projection system with an input for an external laptop. Among the other facilities in Higgins is an aerodynamics testing facility equipped with pressure, temperature, velocity sensors and advanced optical instrumentation. A low-speed, closed-return wind tunnel has a test section of 2ft x 2ft x 8ft and continuously variable speed of up to 180ft/s. In addition, a vacuum test facility containing a 50in diameter, 72in long stainless steel vacuum chamber is available for student use. Higgins also has multiple fluid and plasma dynamics laboratories for both graduate and undergraduate students as well as a machine shop. Housed in the machine shop is a Haas TM1 vertical mill, a Haas Toolroom Mill, two DoAll manual mills, a DoAll engine lathe, two vertical band saws, a drill press, a belt sander, a surface grinder, a horizontal band saw, and assorted hand tools. The machine shop is managed by a machinist and undergraduate peer learning assistants. All the other facilities in Higgins require oversight by an aerospace faculty member. The facility is open from 8:00am to 5:00pm Monday through Friday and is available after hours to students who have card access.

Section 3. Safety

Safety is the top priority of the team. This section describes the measures that will be taken to protect the wellbeing of members, bystanders, and facilities. It goes into detail on the dangers associated with the various workspaces, tools, and materials that will be used by members. Students are required to follow the rules described herein and must sign a waiver indicating their understanding prior to participation.

Section 3.1. Safety Plan and Risk Assessment

Rocketry is inherently risky and our team has an active safety program designed to reduce both the likelihood and consequences associated with failures and accidents. The team has evaluated safety risks using the U.S. Geological Survey Risk Assessment System (RAS) and developed methods for mitigation. This matrix is located in Appendix A.

Section 3.1.1 Materials

The team will consider safety when selecting the materials used for the construction of the launch vehicle. Heavy or dense metals will be entirely avoided and light and ductile metals will only be used sparingly when absolutely necessary for structural integrity. Any materials used will be evaluated to ensure they can withstand the forces they are expected to experience in flight. Before a material is used, the associated Materials Safety Data Sheet (MSDS) will be consulted to identify any additional safety precautions that must be taken.

Section 3.1.2. Facility Safety

The Robotics Pit will be the team's main workspace for the launch vehicle. It will provide space to store the launch vehicle but not any energetics or hazardous chemicals. There will be enough space for the team to work comfortably. Tables and tools will be available for use. The team will need to bring Personal Protective Equipment (PPE) and tools as the room does not have a supply. The Robotics Pit will only be used for assembly and small cutting operations.

To access basic tools and the FDM printers queue at Foise, an online safety course must be completed. In order to have access to advanced tools and direct access to the prototyping lab equipment, additional training must be completed in the lab. The makerspace has tools that are available when a desk manager is present. The Prototyping Lab is open only when a Prototyping Lab monitor is present.

In order to use tools in Washburn Shops, WPI students are required to get a certification. Students can become basic users by reading the shop safety policy and completing a quiz. They are granted access to basic tools including hand tools, the laser cutter, and 3D printers. Students may become advanced users through additional training and can use any tool in the shop they have received formal training on. The labs are only open for use when a trained lab monitor is present. A minimum of two authorized users are required to be present when work is being done in the lab. The maximum time a user can work in the manufacturing labs is 12 hours in any 24 hour period. Users who work for periods longer than 8 hours are required to take a 10 hour break.

There are no certifications required to use the facilities in Higgins Laboratories, however they are only available to students with an aerospace faculty member. A machinist must be present in the machine shop when it is in use.

Section 3.1.3. Student Responsibility

Team members will be held responsible for upholding all safety practices and regulations followed by the team. This includes the use of proper PPE such as safety glasses or respiratory masks. They are required to attend a safety briefing and must sign a statement of Member Understanding. Violation of safety protocol is grounds for the removal from the team, especially in cases where negligence could lead to serious injury or death.

Section 3.2. NAR Compliance

The team agrees to abide by all NAR High Power Rocketry safety codes and instructions from the acting Range Safety Officer (RSO) at launch events. All tests are projected to occur at our primary launch site operated by MMMSC in Berwick, ME. The team may use the GSSS launch site in Somerville, NJ if MMMSC is unable to start launches early enough in 2019 for us to test our full-scale launch vehicle. All sites are operated by RSOs with level 3 high power rocketry certifications and have FAA waivers for 10,000ft.

Section 3.2.1. High Power Safety Code

3.2.1.1. Certification

High powered launch vehicle operators will only fly high power launch vehicles or possess high power launch vehicle motors that are within the scope of their certification and required licensing. The team mentor will transport and handle all motors before and during launches.

3.2.1.2. Materials

Operators will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass or, when necessary, ductile metal, for the construction of the launch vehicle.

3.2.1.3. Motors

Operators will be required to only use certified, commercially made launch vehicle motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. Operators must ensure there is no smoking, open flames, nor heat sources within 25ft of the launch vehicle motors.

3.2.1.4. Arming Energetics and Launch Vehicle Motors

The team will turn on the altimeter and wait for a successful continuity check in the energetics before attempting to insert the motor igniter. Once complete, an electrical motor igniter will be installed by the RSO. The number of people at the launch pad during this phase will be kept to a minimum.

3.2.1.5 Motor Ignition

The RSO will utilize a switch wired in series with the igniter to initiate the launch.

3.2.1.6. Ignition Failure

If the team's launch vehicle does not launch when electrically triggered, the RSO will remove the launcher's safety interlock or disconnect its battery. The team will then wait 60 seconds after the last launch attempt before requesting permission from the RSO to approach the launch vehicle. Members will follow all directions given by the RSO.

3.2.1.7. Pre-Launch Checks

Team members will work in pairs to pack the parachutes and the rocket lead will check to ensure all of the systems are ready for flight. All energetics will be handled by the team mentor. The team will determine the launch vehicle's stability and thrust-to-weight ratio using OpenRocket, a software tool for designing and simulating launch vehicles. An RSO will verify the launch vehicle is stable and has a thrust-to-weight ratio greater than 3:1 before allowing the launch vehicle on the launch pad. This ensures the launch vehicle will not succumb to weather cocking and will leave the launch rail at a speed great enough to make it aerodynamically stable.

3.2.1.7. Launch Procedures

The launch coordinator must use a 5 second countdown before launch. They will use a loudspeaker to broadcast the launch countdown and any problems to participants. The team will remain behind the safety tape while a launch vehicle is being launched to ensure their personal safety. MMMSC places the safety tape in accordance with the distances found on the table in Appendix B. Further, the team will wait to launch the launch vehicle if the wind speed exceeds 20mph.

3.2.1.8. Launch Pad

The launch vehicle will be launched from a launch rail that provides rigid guidance until the launch vehicle has attained a speed of at least 52ft/s that ensures stable flight. It will be pointed to within 20 degrees of vertical and feature a blast deflector to prevent the motor's exhaust from hitting the ground. MMMSC will ensure any flammable foliage has been removed from the surrounding area.

3.2.1.9. Launch Site

The launch site's smallest dimension must be at least one-half the maximum altitude on the FAA waiver or 1500ft, whichever is greater. In our case, this means the launch site must be at least 5,000ft by 5,000ft. MMMSC members will set up the launch rail at least 1500ft from any occupied building or public highway.

3.2.1.10. Flight

The team will not launch the 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 the rocket.

3.2.1.11. Recovery

Our launch vehicle will utilize a dual deployment recovery system, with a drogue parachute deploying at apogee and a main parachute deploying at 700ft AGL. The drogue parachute allows the launch vehicle to descend quickly and avoid getting blown downrange by wind, and the main parachute slows the launch vehicle to a safe landing speed. The parachutes will be protected from the energetics by Nomex blankets tied to shock cord.

Team members will not attempt to catch the launch vehicle as it lands and will not try to retrieve it from power lines, tall trees, or other dangerous places. The team will seek assistance from MMMSC and the property owner in the case of an extraordinary recovery.

Section 3.2.2. Handling and Operating Hazardous Materials

The motor and any other energetic devices will only be purchased and handled by a mentor who has a Class 2 High Powered Rocketry certification. Only commercially available solid launch vehicle motors will be used. They will not be tampered with or used for any purposes other than what is described by the manufacturer. Open flames and heat sources will be kept at least 25ft away from the launch vehicle motors. The motor will be ignited using an electrical igniter that will only be installed when the launch vehicle is at the launch pad or in a designated preparation area. The function of onboard energetics and firing circuits will be inhibited until they are on the launch pad. If the launch vehicle does not fire when electrically triggered, the team will follow proper misfire procedures and the direction of the RSO.

Materials that create microparticles, dust, or chemical fumes require extra safety considerations. If working with these materials is required, it will only be done in areas with proper ventilation and while wearing proper PPE. Hazardous chemicals and energetics will be stored securely and locked.

Section 3.3. Member Safety Briefing

A mandatory safety briefing will be given prior to all building or launch activities. The briefing will cover proper practices for working in the lab safely, proper safety practices including wearing necessary PPE, and emergency procedures for the building. It will also cover federal, state, local, FAA, and NAR safety regulations. Following the briefing, members will be required to sign a waiver indicating their understanding of these safety regulations and their critical importance. Members will not be allowed to participate in any building, launch, or testing activities until they have signed the waiver. Prior to any launch or testing activities, members will be instructed on proper safety practices for model rockets. Importantly, the briefing will cover the operating procedures of the range.

Section 3.4. Cautionary Statements

Every member will be informed of the importance of PPE as well as tool and machine safety. Around the workspace, signs will be posted reminding members of required safety measures that should be taken. Additionally, safety data sheets will be available for the needed lab and workspace procedures.

Section 3.5. Plan for Compliance with Laws

The team will abide by all laws, at every level, that regulate any part of the process of constructing, transporting or launching a launch vehicle. These include, but are not limited to Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C: Amateur launch vehicles, Code of Federal Regulation 27 Part 55: Commerce in Explosives, and NFPA 1127: Code for High Power Rocket Motors. This will be accomplished by working with team mentors and other safety organizations to ensure that the team is in compliance with all laws and regulations.

Section 3.6. Plan for Transportation of Motors and Energetic Devices

The U.S Department of Transportation classifies launch vehicle motors as hazardous materials. This means the motors are not allowed to fly on a passenger carrying aircraft or be shipped using a postal service or a shipping company. In order to comply with these regulations, the team will purchase the motor at the launch site.

Section 3.7. Written Statement of Member Understanding

Only students who have signed the safety waiver may attend launch and building activities. The waiver indicates their recognition that strict adherence to the safety rules is required for membership. In the case that a student misses the briefing, they must meet with the safety officer to discuss the safety rules and sign the waiver. The waiver covers the following points.

- Before flight, rockets will have a range safety inspection. The team must comply with the verdict or be removed from the program.
- The RSO has the final say in all rocket safety matters and has the right to deny launch to any rocket for safety reasons.
- The team mentor is responsible for the safe flight and recovery of the team's rocket. It will not fly until the mentor has reviewed the design and has verified that it satisfies all safety guidelines.
- Compliance with all safety requirements is mandatory for the team to be allowed to launch their rocket.

Section 4. Technical Design

Section 4.1. General Design and Construction

The design process of the launch vehicle was done using OpenRocket version 15.03. OpenRocket is an open source program purposed for the design, calculation, and simulation of everything needed to construct launch vehicles before beginning the building and testing stages of design. The launch vehicle will be divided into three main sections that consist of the nose cone, upper airframe, and lower airframe as can be seen in Figure 4.1.2. Approximately 116 inches in length, the launch vehicle will have a diameter of six inches enabling the payload team more space to work with while designing the selected payload. Additionally, this extra space will be useful for ensuring larger parachutes are not packed too tightly while also enabling a smoother and more reliable recovery system.

Figure 4.1.1. Simulation of proposed launch vehicle

The launch vehicle main body upper airframe and lower airframe will be constructed out of 6in x 0.074in x 72in Blue Tube that will be cut down to 42 inches a piece. Although more expensive than some other materials used to construct high powered launch vehicle bodies, Blue Tube was selected as the material of choice because it is highly resistant to abrasion, cracking, and other forms of damage making it a durable alternative to phenolic and carbon fiber. It is also a far lighter material than fiberglass. Due to its durability, it is commonly used by WPI's AIAA chapter.

The upper and lower airframes will be connected by a Blue Tube tube coupler that will house the altimeter and electronics bay of the launch vehicle. The tube coupler serves not only as a form of extra protection for the instruments contained inside but also as a simpler way to access the launch vehicle's electrical components. The electronics bay houses a Raven 3 altimeter that will be wired to an external switch on the main body of the launch vehicle. When switched to the on position the altimeter will beep to ensure the continuity of the charges within the launch vehicle. The altimeter along with the launch vehicle's chosen Turnigy Graphene 65C LiPo battery will be secured using a 3D-printed mounting plate, screws, and washers.

The nose cone will be 31 inches in length, conical, and comprised of fiberglass. Although fiberglass nose cones are heavier than plastic they are extremely durable. Given the complexities of the competition and the fact that the nose cone is a part of the launch vehicle that experiences a lot of forces, fiberglass was selected as the best option to minimize the damage done to the nose cone by these forces.

The upper airframe of the launch vehicle will house the selected payload along with three parachutes associated with the recovery system. Pictured in Figure 4.1.1 from left to right there is the nose cone parachute, the payload parachute, and the main parachute. The parachutes will be made out of ripstop nylon and connected to their corresponding components by nylon shock cord.

The lower airframe of the launch vehicle will house the drogue parachute and a 25.5in inner tube made from blue tube for the selected motor. Additionally, the lower airframe is where the fin slots will be cut in relation to the tabs of the fins and centering rings will be used in stabilizing the motor tube within the launch vehicle. The launch vehicle will have four fins and four centering rings that will be made using quarter inch plywood sheets and cut using the laser cutter in Washburn Shops.

Epoxy will be used as the main adhesive and sealant for all parts of the launch vehicle. This is because it is a cheap but strong and reliable material. Epoxy is made from polymerizing a mixture of resin and hardener. Epoxy is also slightly heat resistant and will be available for use by the team in the Robotics Pit.

The entirety of the launch vehicle's construction will take place on the campus of Worcester Polytechnic Institute within Foisie Innovation Studio, Washburn Shops, Higgins Laboratories, and the Robotics Pit. Proper safety measures will always be taken to ensure the safety of the members during the launch vehicle's construction.

Section 4.2. Projected Altitude and Flight

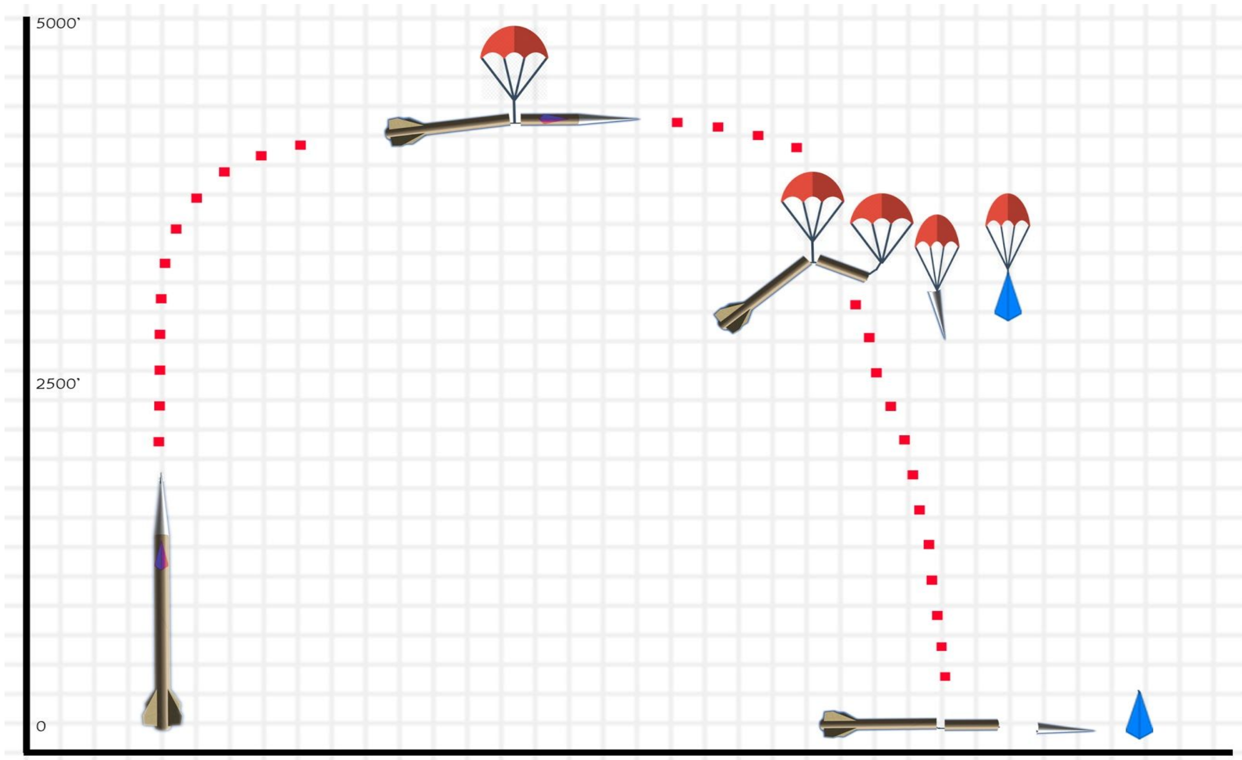

Figure 4.2.1. Conceptual flight plan and stages of proposed launch vehicle

The stability of the proposed launch vehicle is 2.59cal and its apogee is 5,472ft. This will occur approximately 16.8 seconds into flight. Just after apogee, the launch vehicle will split into two sections and deploy a drogue parachute to stabilize its initial descent. Then at approximately 700ft the main parachute will deploy along with the nose cone and nose cone parachute. The payload will be housed within a capsule made from blue tube, and will be released simultaneously from within the launch vehicle body, descending using its own parachute. Using OpenRocket, it is predicted the launch vehicle will reach a max speed of 807.1ft/s and max acceleration of 485.6ft/s^2 over the course of its flight. At landing, the launch vehicle will be falling at approximately 21.4ft/s. In Figure 4.2.1. an OpenRocket simulation of the launch vehicle's flight can be seen. The graph represents vertical motion and position with time with reference to altitude (ft), vertical velocity (ft/s), and vertical acceleration.

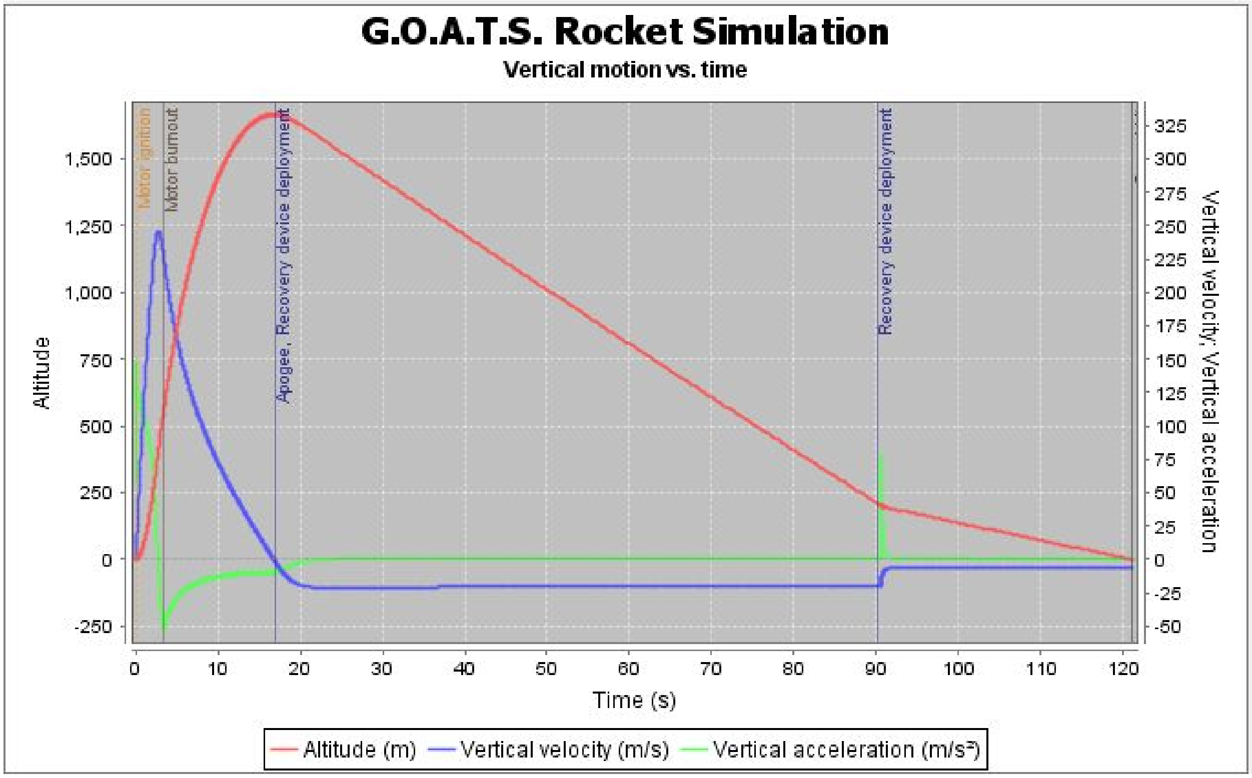

Figure 4.2.2. OpenRocket vehicle flight Simulation

Section 4.3. Projected Parachute System

The projected parachute system will include three parachutes purposed towards assisting in slowing the launch vehicle down for recovery, in addition to one parachute attached and designated to the selected payload. The first to deploy will be the drogue parachute located just forward of the motor and motor tube in the lower airframe. The drogue parachute will deploy when the launch vehicle hits apogee at 5,472ft causing the lower airframe to disconnect from the upper airframe. The purpose of the drogue parachute is to slow the initial descent of the launch vehicle. The drogue parachute will consist of six shroud lines, each 11.811in in length, and will consist of elastic cord (round 2mm, 1/16in)(1.8g/m). The canopy will have a diameter of 30in of ripstop nylon ($1.372*10^{-2}$lb/ft^2).

At approximately 700ft the main parachute, located centrally on the launch vehicle, will deploy. This parachute will consist of a canopy 84in in diameter. It is also at this lower altitude that the nose cone detaches and the payload capsule is released. The payload capsule will have a parachute with canopy 54in in diameter. The detached nose cone will also have its own parachute that will have a canopy 36in in diameter. All these parachutes will have a canopy consisting of ripstop nylon (67g/m^2), and six shroud lines that will be 11.811in in length and consisting of elastic cord (round $7.874*10^{-2}$in, 1/16in)($1.210*10^{-3}$lb/ft).

Section 4.4. Projected Motor

The L935-IM-0 is an L class 2 motor, manufactured by Cesaroni technology, and the chosen main launch vehicle motor for the launch vehicle. The motor uses an E-match igniter and has a diameter of 2.15in. As can be seen in Table 4.4.1 and Figure 4.4.1 the L935-IM-0 has a total impulse of 3,076.45Ns ensuring a higher chance of success with the competitions one mile AGL target altitude.

Average Thrust	932.2580 N
Class	20% L
Delays	Plugged Seconds
Designation	L935-IM
Diameter	54.0 mm
Igniter	E-Match
Length	649.0 mm
Letter	L
Manufacturer	CTI
Name	L935
Peak Thrust	1,582.74 N
Propellant	APCP
Propellant Weight	1,734.7 g
Thrust Duration	3.3 s
Total Impulse	3,076.45 Ns
Total Weight	2,542 g
Type	Reloadable

Table 4.4.1. Main Motor Data (L925-IM-0)

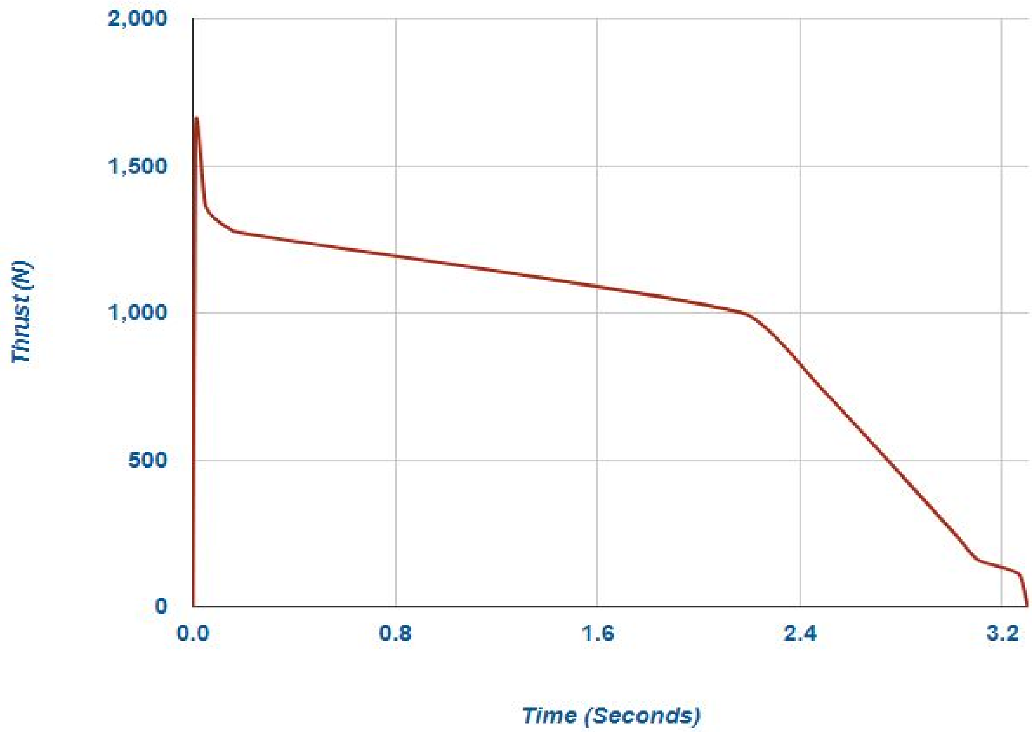

Figure 4.4.1. Main Motor Thrust/Time curve (L925-IM-0)

The L1030-RL is an L class 2 motor, manufactured by Cesaroni technology, and the chosen backup motor for the launch vehicle. The motor uses an E-match igniter and has a diameter of 2.15in. As can be seen in Table 4.4.2 and Figure 4.4.2 the L1030-RL has a total impulse of 2,781Ns. Using OpenRocket the launch vehicle's flight was simulated with the backup motor in addition to the main motor to ensure its reliability in relation to the success of the launch vehicle in competition.

Average Thrust	1,028.5500 N
Class	9% L
Delays	Plugged Seconds
Designation	L1030-RL
Diameter	54.0 mm
Igniter	E-Match
Length	649.0 mm
Letter	L

Manufacturer	CTI
Name	L1030
Peak Thrust	1,539.44 N
Propellant	APCP
Propellant Weight	1,520 g
Thrust Duration	2.7040 s
Total Impulse	2781.2100 Ns
Total Weight	2,338.0 g
Type	Reloadable

Table 4.4.2. Back-up Motor Data (L925-IM-0)

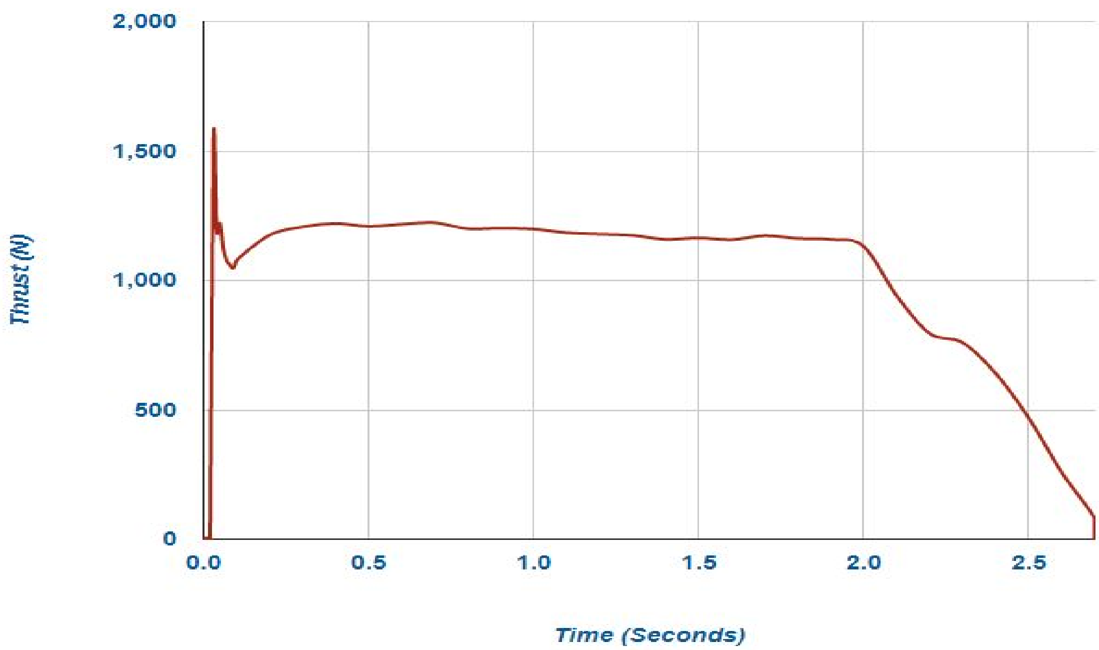

Figure 4.4.1. Back-up Motor Thrust/Time curve (L925-IM-0)

Section 4.5. Description of Projected Payload

The payload option selected by our team is the deployable UAV/beacon delivery system. The design chosen by our team consists of a quadrotor UAV housed within a pyramid-like structure whose triangular "petals" unfold to allow for the deployment of the UAV as well as ensure it's properly oriented for takeoff from any landing position. Based off of the popular tetrahedron orientation and deployment design used by NASA in past Mars missions such as Pathfinder and the Mars Exploration Rover mission's Spirit and Opportunity, this system is mechanically simple and has long proven its reliability, making it our favored design. The choice of a multirotor UAV, specifically a quadcopter, was due to their mechanical simplicity and the convenience of how it would fit within the pyramid housing system. This is done by allowing the arms of the quadcopter to fold upwards to fit within the pyramid, a feature our team quickly discovered would be necessary given the size constraint of a width slightly less than the diameter of the launch vehicle body. The pyramid capsule will be fitted with sensors and a control system to detect when it has landed and begin to autonomously actuate to orient the quadcopter for deployment. It will also have a transceiver for telemetry and a system for powering on the quadcopter once receiving a signal to do so from the ground station after being given permission. The quadcopter will be operated using a standard RC aircraft transmitter as well as an FPV camera to aid in locating a Future Excursion Area. The beacon will be a 3D printed small cube greater than or equal to the minimum dimensions specified in the launch handbook and will be released from the quadcopter using a small linear servo.

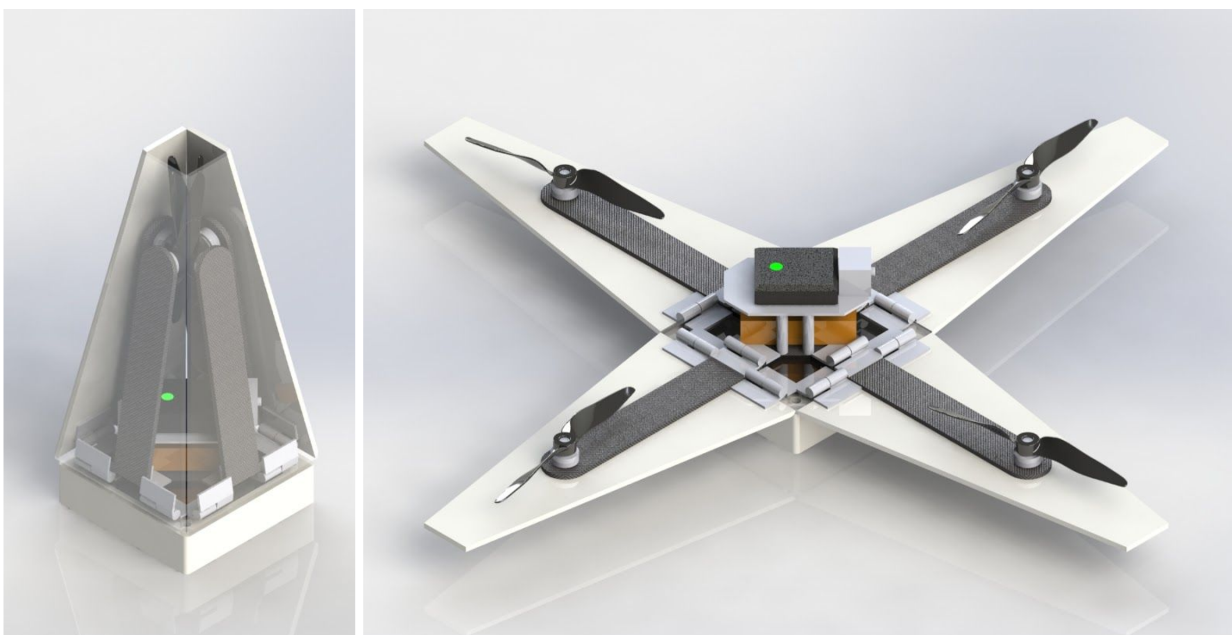

Figure 4.5.1. Conceptual CAD model of the payload

Section 4.6. Vehicle, Recovery System, and Payload Requirements

Listed below are the criteria for the launch vehicle, recovery system and payload requirements sent out by NASA with regulations that must be followed in order to compete safely and successfully in the competition.

Launch Vehicle

- The launch vehicle must deliver the payload to an apogee altitude between 4,000ft and 5,500ft
- The launch vehicle must carry one barometric altimeter for determining official altitude
- The launch vehicle's mechanical arming switch must be accessible from its exterior and must be capable of being locked in the ON position
- The altimeter will have its own dedicated power supply
- The launch vehicle will be recoverable and reusable
- The launch vehicle will have a maximum of 4 independent sections
- The launch vehicle will be single stage only
- Total impulse shall not exceed 5,120Ns
- The launch vehicle must have a stability of at least 2.0 at the point of rail exit
- The launch vehicle will not utilize forward canards
- The launch vehicle will not utilize forward firing motors
- The launch vehicle will not utilize titanium sponge motors
- The launch vehicle will not utilize hybrid motors
- The launch vehicle will not utilize friction fitting motors
- The launch vehicle will not exceed Mach 1 at any point during flight
- Vehicle ballast will not exceed 10% of the total unballasted weight of the launch vehicle

Recovery System

- The drogue parachute will be deployed at apogee
- The main parachute will be deployed no lower than 500ft
- A successful ground ejection test for the drogue and main parachutes will be performed
- Recovery system circuitry must be separate from payload circuitry
- All recovery electronics will be powered by commercially available batteries
- The recovery system will contain redundant commercially available altimeters
- Recovery area is limited to a 2,500ft radius from the launch pads
- Descent time will be limited to 90s
- An electronic tracking device will be installed in launch vehicle and any component which lands untethered to the main airframe
- Recovery system electronics will not be affected by any other on-board electronic devices
- Recovery system electronics will be shielded from any other onboard devices to prevent interference

Payload Experiment

- Must deploy from the internal structure of the launch vehicle
- The UAV will be powered off until the launch vehicle has safely landed

- The UAV must be capable of being powered on after landing
- The UAV must be retained in the launch vehicle using a fail-safe active retention system
- All reorientation and or unpacking maneuvers must be autonomous
- The UAV will place a simulated navigational beacon on the target area
- The UAV must be no greater than 10% of the total mass of the launch vehicle

Section 4.7. Major Technical Challenges and Solutions

One major technical challenge encountered by our team was the design of an active retention system which could reliably contain the UAV during the launch and orient it for takeoff upon landing. Our team began the process for choosing the design of this system by first reviewing previously successful designs used by our university's AIAA teams as well as some used in actual spacecraft missions. In addition to these concepts, original ideas were discussed and evaluated with high regard to feasibility, reliability, mechanical simplicity, and compliance with the regulations defined in the student launch handbook to bring us to our final design choice. The unfolding pyramid was selected for its satisfaction of these requirements, specifically its proven reliability from numerous use in NASA Mars missions. Despite the actual design used being an equilateral tetrahedron, prior testing showed the pyramid model to be equally successful, as this design was used in the past by our university's AIAA chapter for another competition.

Another challenge was the choice of the type of UAV to be used and how it would fit within the retention system. Though different models such as a helicopter or tricopter were discussed, a quadcopter was selected as they are mechanically simple and can be easily modified to fold up their arms to efficiently fit within a pyramid-shaped capsule. Though heavier than a tricopter, the addition of a fourth rotor arm adds greater stability and ease of maneuverability and is the reason for the use of a pyramid-shaped retention capsule as opposed to the original tetrahedron into which a tricopter would better fit. The use of a traditional helicopter was also dismissed despite their inherent stability compared to other multirotor designs as this is a result of their mechanical complexity, a system which would most likely be heavy, subject to damage during launch, and difficult to easily fit within our choice of retention system.

Section 5. Educational Engagement

One of the main goals of the WPI USLI team is to educate others about what is going on in the world of STEM. Our plan is to spark curiosity in young adults and children, and help grow their sense of exploration in the ever-expanding technical age we live in today. Without public interest, humanity's reach into this universe will cease to continue and grow. Each member of the WPI USLI team is passionate about science, and knows that the future is in the children of this world. It is our job as young adults to instill in them the desire to learn and explore.

Throughout the Fall 2018 semester, our team is planning middle-school outreach events through WPI's preexisting STEM Saturday program, local school outreach sessions that include fun and educational experiments (including but not limited to: rocket launches, egg drop, and plane design and building) and outreach events on-campus.

Section 5.1. Plan for Educational Engagement Activities

Listed below are the events currently being planned by the team:

1. Pre-Collegiate Outreach Programs (POP) collaboration: The WPI Pre-Collegiate Outreach Department hosts STEM Saturdays several times throughout the year. These are day long events that connect with middle schoolers and their parents. The team plans on running activities such as egg drops and rocket launches through this program on January 12, February 9, and March 16.
2. UAV Club collaboration: The UAV Club is a subcommittee of AIAA, the same parent organization of the USLI team. The team plans on co-hosting UAV fly and race days for pre-collegiate kids on a currently unspecified date.
3. Women in Aerospace Engineering collaboration: Like the UAV Club, Women in Aerospace Engineering is a subcommittee of the AIAA. They are a professional group for WPI women in the Aerospace Engineering field. The team hopes to co-host an event to introduce middle school girls to STEM.
4. Introduce A Girl To Engineering event: Introduce a girl to Engineering day is a half-day workshop run by the WPI Pre-Collegiate Outreach Program department for girls from 3rd to 5th grade. The team plans on joining POP in this event to supplement their activities with one of our own. This will be happening on a yet to be determined date in February.
5. Geek is Glam booth: Geek is Glam is a one day event on October 13th for Girl Scouts. The team plans on having a booth at this event to show off our teams' rocket as well other smaller demonstrations.

Section 5.2. Evaluation Criteria for Engagement Activities

Successful educational outreach will be evaluated in terms of both the number of people reached, as well as the caliber of the content provided at the outreach events. Each activity will be categorically successful if a small number of criteria is met. The main goal is to get kids excited and curious about STEM. A common goal of USLI is to increase public interest in things such as space travel and STEM in general. Secondary goals are to provide an easily accessible platform for people of all ages to learn about and explore STEM organizations and projects. Additionally, the team hopes to educate on the basic principles of rocket flight and other aerial vehicles.

Ideally, the team hopes to have an outreach impact that exceeds the requirements stated by NASA in the Student Launch Handbook requirements. The team hopes to strengthen ongoing activities funded by WPI as well as launch new programs to be repeated. A successful outreach event will combine aspects of STEM learning, fond memories, team building activities, and fun.

Section 6. Project Plan

This is WPI's first year participating in the NASA Student Launch competition. The team is excited to compete and has prepared as much as possible. The team has already planned out when to go to launches for this year and has come up with a detailed schedule of how deadlines can be met and our mission statement fulfilled. The team has also created a budget of all of the supplies needed to build the whole launch vehicle/payload system and have made sure that funding required for mission success is obtained. The team is dedicated to ensuring our plan will be sustainable and replicable for the years to come.

Section 6.1 Timeline

Table 6.1.1. demonstrates the team's designated milestones of this year's competition and all of the requirements for each one. In addition to this, a Gantt chart has been created which can be found in Appendix C. The Gantt chart is a more in depth look at all the steps that must be taken for a successful mission.

Timeline		
Milestones	**Requirements**	**Due dates**
Proposal	● Create a safety plan ● Create a detailed design ○ Launch vehicle ○ Payload ● Create a plan for educational engagement activities ● Create a detailed ○ Budget ○ Timeline ○ Funding plan ○ Sustainability plan	September 19th
Preliminary Design Review (PDR)	● Come up with designs and pick one ○ Launch Vehicle ○ Recovery System ○ Payload ● Come up with simulations, calculations, and predictions for the missions performance ● Declare target altitude. ● Create preliminary Personnel Hazard Analysis, Failure Modes, and Effect Analysis, and come up with environmental concerns and risks. ● Create requirements for missions success in	November 2nd

	○ Vehicle ○ Payload ○ Recovery ○ Safety ○ General ● Create presentation	
Critical Design Review (CDR)	● Create a subscale model of vehicle ○ Do ground charge ejection test ○ Launch model ○ Analyze data collected ● Finalize design of: ○ Launch Vehicle ○ Recovery System ○ Payload ● Perform final simulations, calculations, and predictions for the missions performance ● Submit assembly and launch procedures ● Update Personnel Hazard Analysis, Failure Modes, and Effect Analysis, and come up with environmental concerns and risks. ● Test designs and edit them to better complete the task ● Create a verification plan and team requirements for ○ Vehicle ○ Payload ○ Recovery ○ Safety ○ General ● Generate CDR presentation package	January 4th
Flight Readiness Review (FRR)	● Create full scale model of launch vehicle ○ Do ground charge ejection test ○ Launch model ○ Analyze data collected ● Complete Launch and Safety checklist ● Finish simulations, calculations, data collection and analysis ● Update Personnel Hazard Analysis, Failure Modes, and Effect Analysis, and come up with environmental concerns and risks. ● Edit final designs as necessary ○ Launch Vehicle ○ Recovery System	March 4th

	○ Payload ● Finalize ● verification plan and team requirements for ○ Vehicle ○ Payload ○ Recovery ○ Safety ○ General ● Update ○ Budget plans ● Generate FRR presentation package	
Launch Readiness Reviews (LRR)	● Must Present ○ Anchored flight predictions ○ Anchored drift prediction ○ Procedures and Checklists ○ Center of pressure and center of gravity ● Must have ○ Airframe ready for flight ○ Data on previous flight ○ Flight anomalies ○ Changes to airframe ○ Flight simulations ○ Pre-flight checklist and Fly Sheet	April 3th
Post-Launch Assessment Review (PLAR)	● Write up assessment of system in-fight performance ○ Summary of ■ Vehicle ■ Payload ■ Educational Engagement ■ Budget ○ Dimension, data analysis, and results ○ Conclusion	April 26th

Table 6.1.1. Timeline

Section 6.2. Budget

Full Scale and Subscale Rocket Components

Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Nose Cone	6" Fiberglass Nose Cone	0	$139.00	$0.00	AMW Pro-X	Already Owned
Main Tube	Blue Tube 2.0 6"x0.074"x72"	2	$105.95	$211.90	Always Ready Rocketry	Airframe
Centering Rings	Plywood ½"x2'x4'	4	$15.50	$62.00	Home Depot	-
Fins	Plywood ¼"x2'x4'	6	$14.00	$84.00	Home Depot	-
Motor Tube	Blue Tube 2.0 54mmx.062"x48"	2	$23.95	$47.90	Always Ready Rocketry	Airframe
Inner Tube	Blue Tube 2.0 6'x0.077"x48"	1	$66.95	$66.95	Always Ready Rocketry	Coupler
Motor Case	Aluminum Motor Casing	0	Free	Free	WPI	Already Owned
Flight Computer	Raven 3 Altimeter	0	$155.00	$0.00	Feather weight Altimeters	Already Owned
Full Scale Battery	Turnigy Graphene 65C Lipo	1	$15.69	$15.69	Hobby King	-
Arming Switch	Full Scale Rocket Arming Switch	1	$9.93	$9.93	Apogee Components	-
Wiring	Wiring	0	$5.00	$0.00	WPI	Already Owned
Main Engine	L935IM	2	$200.00	$400.00	AMW ProX	-
Backup Engine	L1030 RL	0	$175.00	$0.00	AMW ProX	Will buy as needed
Separation Charges	Black Powder Charges	0	Free	Free	WPI	Already Owned

Shear Pins	2-56x1/2" Nylon Screws	0	$10.64	$0.00	McMaster-Carr	Package of 100
Rail Buttons	1515 Rail Buttons	2	$6.00	$12.00	AMW ProX	-
Nomex Blankets	Sunward 18in Nomex Blanket	0	$10.49	$0.00	Apogee Rockets	Already Owned
Igniter	Full Scale Igniter	0	Free	Free	WPI	Already Owned
Parachutes	30" Drogue	0	$32.00	$0.00	Spherachutes	Already Owned
Parachutes	84" Hemisphere	0	$120.00	$0.00	Spherachutes	Already Owned
Parachutes	36" Hemisphere	0	$30.00	$0.00	Spherachutes	Already Owned
Shock Cord	BlueWater 1" Tubular Webbing	0	$58.50	$0.00	REI	130 in, $0.45/in, 4000 lb breakforce
U-Bolts	U-Bolts	0	Free	Free	WPI	Already Owned
Motor Retention	Hanger Wire	0	Free	Free	WPI	Already Owned
Quick Links	316 Stainless Steel Quick Link	0	$5.08	$0.00	McMaster-Carr	Already Owned
Swivel Mounts	Swivel 12/0 1500 lb	0	$4.00	$0.00	AMW ProX	Already Owned
Nuts/Bolts/ Washers	Assorted	0	$15.00	$0.00	McMaster-Carr	Already Owned
Blue Tape	ScotchBlue 1.88"x60yds	1	$6.58	$6.58	Home Depot	Already Owned
Gorilla Tape	Gorilla 1-7/8x35yds	1	$8.98	$8.98	Home Depot	Already Owned
Main Tube	2.15"x0.062"x48"	2	$23.99	$47.90	Always Ready Rocketry	Airframe

Nose Cone	54mm Plastic Nose Cone	1	$14.80	$14.80	Apogee Components	Nose Cone
Motor Tube	1.15”x.062”x24”	1	$6.25	$6.25	Always Ready Rocketry	Motor Tube
Inner Tube	2.15”x0.062”x8”	1	$8.95	$8.95	Always Ready Rocketry	Inner Tube
Motor Casing	Pro-29 4G	1	$26.00	$26.00	AMW ProX	Motor Casing
Flight Computer	Raven 3 Altimeter	0	$155.00	$0.00	Feather weight Altimeters	Already Owned
Battery	9V Battery	0	$11.55	$0.00	Amazon	Already Owned
Arming Switch	Sub Scale Arming Switch	1	$9.93	$9.93	Apogee Components	-
Wiring	Wiring	1	$5.00	$5.00	WPI	-
Parachutes	30” Hemisphere	1	$26.75	$26.75	Spherachutes	Already Owned
Parachutes	18” Hemisphere	1	$14.00	$14.00	Spherachutes	Already Owned
Parachutes	18”Drogue	1	$21.50	$21.50	Spherachutes	Already Owned
Main Engine	H118CL	0	Free	Free	AMW ProX	Already Owned
Separation Charges	Black Powder Charges	0	Free	Free	WPI	Already Owned

Payload Components

Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Processor	Arduino Nano	3	$22.00	$66.00	Arduino	Capsule Processor
Processor	Pix Hawk Mini	1	$134.95	$134.95	Amazon	UAV Processor
LiPo Battery	3.7v 2000mAh	4	$12.50	$62.00	Adafruit	-
ESCs	Lumenier 30A BLHeli_S OPTO	4	$13.00	$54.00	GetFPV	-
Brushless Motor	RotorX RX1404B	4	$15.00	$60.00	GetFPV	-
High Gauge Wire	22AWG colored wire	1	$15.99	$15.99	Amazon	-
Servos	1.8 gram linear servo	2	$12.00	$24.00	Spektrum	-
More Servos	SG90 9g micro servo	1	$18.00	$18.00	Amazon	Pack of 10
Transceiver	NRF24L01	4	$5.00	$20.00	Amazon	-
FPV Camera	FX798T micro FPV camera	1	$30.00	$30.00	GetFPV	-
FPV Monitor	4.3" LM403 LCD FPV Monitor	1	$70.00	$70.00	GetFPV	-
Controller & Receiver	Flysky FS-i6X	1	$54.00	$54.00	Amazon	-
3D Printer Filament	Nylon X	1	$70.00	$70.00	-	-
3D Printer Filament	PLA	2	$30.00	$60.00	-	-
Carbon Fiber	1ftx1ft sheet	1	$27.03	$27.03	Hobby King	-

Propellers	Carbon fiber 5in	4	$4.75	$19.00	Hobby King	1 order is two props, one CW, one CCW
Overhead	Cover for additional components	1	$50.00	$50.00	-	-

Logistical Pricing

Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Test Launch	Participation Fee	10	$5.00	$50.00	MMMSC	-
Certifications	Level 1 and 2	4	$25.00	$100.00	MMMSC	-
Hotel Rooms	(4 nights) 2 Double Beds	4	$62.00	$992.00	La Quinta Inn	4870 University Dr NW, Huntsville, AL, 35816 (6.8 miles from the space center)
Flights	Flight Tickets	12	$326	N/A	-	Flights will be paid for by students or sponsors

Grand Total	$3,083.98
Total with shipping/tax	$3,700.776

Table 6.2.1. Budget

Section 6.3. Funding

Our USLI team is run under WPI's branch of the AIAA chapter. The majority of the funding for our organization will come from our school's Student Government Association (SGA). They are the main source of funding for undergraduate student organizations at WPI. Last year, a request for funding for the 2018-2019 school year was submitted through the AIAA. Half of the money that was allotted to AIAA for high powered rocketry competitions will go towards our USLI team. If additional funds are required, a request for another round of funding can be submitted to the SGA.

Additional funding requests will be made to WPI's Foundation & Corporate Philanthropy Department. The Foundation & Corporate Philanthropy Department coordinates with WPI's Office of Sponsored Programs, Academic & Corporate Engagement departments and more.

Teaming with the Philanthropy department will help pair our financial needs with sponsorships whose goals align with that of the WPI USLI team.

Corporate sponsorships will be pursued through local outreach to STEM companies in the area. A presentation or campaign will be organized to present to potential corporate sponsors. Ideally, a sponsorship deal with a local corporation will pave the way to begin a long lasting relationship between WPI and the corporation involved. External funding will mainly be devoted to team travel as WPI's SGA does not pay for travel by flight. Additionally, this money may also be used for other unforeseen expenses compounded during the build process.

Section 6.4. Website

After submitting documents to NASA, the team will make them freely available on the internet. The team will post these on the USLI page on the website of WPI's AIAA chapter. The URL is "aiaa.wpi.edu". The website will also include a description of the team and the competition.

Section 6.5. Sustainability

WPI's AIAA chapter has always been a strong member of the campus community. The AIAA is involved in a variety of activities relating to the pursuit of learning high powered rocketry. AIAA members have the option to work towards their Class One and Two certifications through the NAR while also being given the opportunity to compete in high powered rocketry competitions such as USLI. The team plans to get the majority of our members through the AIAA. Additionally, the team plans to recruit new members through WPI's yearly activities fair at the end of freshman orientation. This way, the team can welcome new members with no previous experience in rocketry with an interest in learning more about it. The USLI team is open and welcoming to all WPI students. This ensures an easier transfer of leadership roles to the next generation and allows the program to prosper throughout the years. Also, informational posters with meeting times will be hung around campus. These will be used to grasp the attention of other WPI students outside the AIAA and Aerospace Engineering community. Having a wide array of majors and students leads to a well-rounded team.

The majority of members will choose to work on the vehicle and/or the payload. The team will be separated into two different subteams and will have at least two two-hour meetings per week. This approach has been used successfully in the past for similar AIAA rocketry competitions. In addition to these meetings, short biweekly meetings will be held in which the subteams will come together to discuss their progress. Full team meetings encourage communication between the sub-teams and are a great time for all the members to gain a respect for their teammates. Additional meetings will be planned as needed to meet competition deadlines.

The majority of the funding for the competition will be acquired through the SGA. The SGA has helped fund the AIAA and will continue to fund us as the organization continues to prosper. In addition to this, our team is also searching to expand ways of funding to other sources such as sponsors in order to create long lasting relationships between companies and our team.

Educational engagement will be planned in collaboration with WPI's Pre-Collegiate Outreach Programs. Together both groups plan to reach out to children to expand their interest in STEM. Some annual events that our team is planning to partake in are *Geek is Glam*, an activity for Girl Scouts, and *Introduce a Girl to Engineering*, both of which are events aimed at encouraging the increase of women in STEM. In addition, the team plans to participate in STEM Saturdays which WPI hosts in order to appeal towards students' love of STEM with many fun STEM related activities. As more opportunities arise additional outreach events will be planned. Due to the nature of the events listed above and the nature of our relationship with these partnerships, it will not be hard to continue on engaging children of all ages in STEM.

Appendix

Appendix A. Risk Assessment Matrix

Risk Assessment				
Phase	**Risk**	**Description**	**Severity-Probability**	**Mitigation**
Building	Cuts or Lacerations	Cutting tools such as dremels and saws can cause serious injuries if safe practices are not followed.	CII	Members will be instructed on the proper use of cutting tools and how to use them safely. Appropriate PPE will be worn. No members shall cut towards themselves or another person.
	Epoxy	Fumes can be dangerous if inhaled frequently and can be toxic if ingested. Can cause skin irritation or chemical burns if in contact for long periods of time.	CIV	Members will be instructed on the proper methods of mixing and using the epoxy. Appropriate PPE will be worn.
	Splinters	Materials like wood, carbon fiber, and fiberglass may cause splinters if handled improperly.	CIV	Members will be instructed on proper techniques to handle all materials used by the team. Appropriate PPE will be worn. All edges on building materials will be filed after use.

	Burns	Tools, materials, and circuitry that must be heated up to use can cause burns if handled improperly.	CII	Members will be instructed on the heat tolerances of materials used. In cases when members handle directly heated items PPE will be used. High temperatures will be avoided unless it is necessary.
	Fires	A fire can start if flammable materials are put into contact with heat.	DI	All open flame or heating will be closely regulated by mentors. Only members certified in working with materials and tools that can cause extreme heat will be allowed to do so. Fire protection equipment will be easily accessible in the workspace and clearly marked.
	Detonation of Energetics	A motor or separation charge detonation could cause burns, severe burns, amputation, or death.	CI	Only the Mentor will handle energetics. Motor and charges will only be prepared on the launch pad or in the designated area.
	Inhalation of dust or microparticles	Dust and microparticles naturally arise when working with some materials. Inhalation of such particles can cause lung damage.	BIII	When cutting materials, PPE will be used. Materials that produce especially dangerous microparticles, like fiberglass, will not be cut without proper ventilation and tools. Workspaces will be regularly cleaned to

				reduce the risk of lingering dust and microparticles.
	Inhalation of Chemical Fumes	Reactive materials can release chemical fumes that can easily be inhaled if not regulated.	CIII	All materials that have a risk of emitting fumes will only be used in well-ventilated spaces. PPE will be worn by the members handling such materials.
	Chemical Burns	Reactive materials can also react with skin if not carefully handled and regulated.	CII	When working with materials that have the possibility of reaction with skin, heavy duty PPE will be worn. Only trained personnel will work with such materials in a well-insulated area.
	Combustion of Lithium-Ion Batteries	High-density energy storage batteries can combust if they are punctured or exposed to temperature ranges outside of their design parameters, which can cause severe burns, amputations, or death.	CI	Batteries will be securely fastened to the fuselage such that they may not break free. The rocket motor and batteries will be placed in different sections of the rocket. The batteries will be installed without the use of sharp objects. No sharp protrusions will be allowed near the batteries.

Launch	Motor Misfire	If the motor is improperly inhibited, damaged, or an improper electrical charge is applied to the ignition system the motor will not ignite at a safe time and result in severe burns if operators are too close to motor, or destruction of the rocket.	CII	New ignitors and motor propellants will be used. The igniters will be correctly installed by a certified mentor.
	Premature Motor Ignition	If the motor is damaged or accidentally fired this can result in severe burns or destruction of the rocket.	DI	New ignitors and motor propellants will be used. The motor will be correctly installed by a certified mentor and ignited by the RSO.
	Motor Ejected from Rocket	If the motor is not secured properly, it can go into freefall or, if still on the launchpad, it can cause severe burns or destruction of the rocket.	CI	The motor will be correctly installed by a certified mentor. The motor retention system will be inspected prior to launch.
	Parachute Failure	If parachutes are not correctly packed it may prevent their deployment. If they are not properly protected from the motor and other energetics, they may be damaged leading to insufficient drag.	CI	Parachutes will be installed correctly and properly protected from other rocket components.
	Unpredictable Flight Path	In flight, wind changes or instabilities in thrust can cause the rocket to veer off of the predicted course.	DI	The rocket will not be flown in unsafe weather such as in a strong crosswind. The mass of the rocket and its fins will be designed with stability in mind. Before

				construction, the results will be verified by simulation.
	Drogue Chute not Deployed at Apogee	If the drogue chute is not deployed close to apogee, the rocket will be damaged or destroyed by aerodynamic forces.	CI	Drogue chute will have multiple redundancy systems capable of deploying it.
	Airframe Failure	If structural integrity is severely compromised for any reason, the airframe of the rocket will break apart, sending pieces into freefall	DI	Structural integrity will be kept in mind during the construction of the rocket in terms of the load it will bear and any forces it may experience. Will be properly packaged during transportation to prevent damage.
	Shock Cord is Severed	If the shock cord is not properly secured or is not protected from the motor and other energetics, it could be severed.	CI	The shock cord will be properly installed and protected from other components of the rocket. It will be visually inspected before launch.
	Vehicle Flys Over or Lands Close to Spectators	In the case where there is an unpredictable flight path, the rocket may veer towards spectators.	DI	The rocket will be launched at a safe distance from any persons and only in safe conditions, keeping wind direction in mind.

Appendix B. Minimum Distance Table

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

Revision of August 2012

Appendix C. WPI USLI Gantt Chart 2018-2019

Task	Start	Duration	Aug. 22	Sep. 5	Sep. 19	Oct. 3	Oct. 17	Oct. 31	Nov. 14	Nov. 28	Dec. 12	Dec. 26	Jan. 9	Jan. 23	Feb. 6	Feb. 20	Mar. 6	Mar. 20	Apr. 3	Apr. 17
Request for Proposal	Aug. 23	N/A																		
Team Interest Meeting	Aug. 28	1 Meeting																		
Discussion of the Proposal	Aug. 31	1 Meeting																		
Design Launch Vehicle and Payload	Sep. 5	1 Meeting																		
Write up Proposal	Sep. 7	1 Meeting																		
Revise Proposal	Sep. 11	2 Meetings																		
Design Subscale Launch Vehicle	Sep. 13	1 Meeting																		
Submit Proposal	Sep. 19	N/A																		
Proposal Submission Celebration	Sep. 20	1 Meeting																		
Supply Order	Sep. 21	1 Meeting																		
Begin Working on PDR	Sep. 24	2 Meetings																		
Payload Prototyping Begins	Sep. 25	4 Meetings																		
Create Subscale Rocket	Sep. 26	4 Meetings																		
Finish PDR Rough Draft	Oct 1	2 Meetings																		
Awarded Proposals Announced	Oct. 4	N/A																		
Payload Design Testing	Oct. 9	5 Meetings																		
Fall Break	Oct. 12 to Oct. 22	N/A																		
Do Ground Ejection Test for Subscale R	Oct. 19	1 Meeting																		
Launch Subscale Rocket	Oct.20	1 Meeting																		
Revise Rough Draft	Oct. 24	2 Meetings																		
PDR (report, presentation, and flysheet	Nov. 2	N/A																		
PDR video teleconferences	Nov. 5 to Nov. 19	1 Meeting																		
Post PDR Review	Nov. 20	1 Meeting																		
Continue Payload Design	Nov. 22	2 Meeing																		
Finalize Launch Vechicle Full Scale Desi	Nov. 23	1 Meeting																		
Finalize Payload Design	Nov. 26	1 Meeting																		
CDR Q&A	Nov. 27	N/A																		
CDR Rough Draft	Nov. 29	3 Meeting																		
Begin Launch Vechicle Full Scale Build	Nov. 30	3 Meetings																		
Begin Payload Construction	Nov. 30	3 Meetings																		
Finalize CDR	Dec.7	2 Meetings																		
Winter Break	Dec. 15 to Jan. 8	N/A																		
CDR (report, presentation, and flysheet	Jan. 4	N/A																		
CDR video teleconference	Jan. 7 to Jan.22	1 Meeting																		
Post CDR review	Jan. 23	1 Meeting																		
Finish Launch Vechicle Full Scale	Jan. 24	2 Meeting																		
Finish Payload	Jan. 24	2 Meeting																		
FRR Q&A	Jan. 25	N/A																		
FRR Rough Draft	Jan. 25	2 Meeting																		
Spring Break	Feb.2 to Feb. 10	N/A																		
Full Scale ground ejection test	Feb. 15	1 Meeting																		
Launch Vechicle Full Scale Launch	Feb. 16	1 Meeting																		
Finalize FRR	Feb. 24	3 Meeting																		
Vehicle Demonstration Flight Deadline	Mar. 4	N/A																		
FRR (report, presentation, and flysheet	Mar. 4	N/A																		
FRR video teleconference	Mar. 8 to Mar. 21	1 Meeting																		
Prepare for Competition	Mar. 23	3 Meetings																		
Travels to Huntsville, AL	Apr. 3	N/A																		
Launch Readiness Reviews (LRR)	Apr. 3	N/A																		
Launch Day	Apr. 6	N/A																		
Award Ceremony	Apr. 6	N/A																		
Backup Launch Day	Apr. 7	N/A																		
Post-Launch Assessment Review (PLAR	Apr. 26	N/A																		
End of the Year Celebration	Apr. 30	1 Meeting																		

Due dates
Meetings
On Break