Worcester Polytechnic Institute

Project Goddard

Proposal

University Student Launch Initiative

2020

Acronym Definitions

3D: Three Dimension

ABS: Acrylonitrile Butadiene Styrene

AIAA: American Institute of Aeronautics and Astronautics

APCP: Ammonium Perchlorate Composite Propellant

BARC: Bridgeton Area Rocket Club

CMASS: Central Massachusetts Space Modeling Society

CRMRC: Champlain Region Model Rocket Club

CNC: Computer Numerical Control

ESC: Electronic Speed Controllers

E-bay: Electronics Bay

FAA: Federal Aviation Administration

FDM: Fused Deposition Modeling

GPS: Global Positioning System

LiPo: Lithium Polymer

LoRa: Long Range

LWHPR: Lake Winnipesaukee High Powered Rocketry

MMMSC: Maine Missile Math and Science Club

MSFC: Marshall Space Flight Center

NAR: National Association of Rocketry

NASA: National Aeronautics and Space Administration

NFPA: National Fire Protection Association

PC: Polycarbonate

PLA: Polylactic Acid

POP: Pre-Collegiate Outreach Programs

PPE: Personal protective equipment

RF: Radio Frequency

RSO: Range Safety Officer

SLI: Student Launch Initiative

STEM: Science, Technology, Engineering, and Math

TPU: Thermoplastic Polyurethane

TRA: Tripoli Rocketry Association

UAV: Unmanned Aerial Vehicle

URRG: Upstate Research Rocketry Group

USLI: University Student Launch Initiative

WOAA: Women of Aeronautics and Astronautics

WPI: Worcester Polytechnic Institute

Executive Summary

This document is the written proposal of Worcester Polytechnic Institute's (WPI) local American Institute of Aeronautics and Astronautics (AIAA) chapter for the National Aeronautics and Space Administration's (NASA) University Student Launch Initiative (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's 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 and complete a simulated lunar ice recovery mission. In order to achieve these requirements, the team has split into two divisions; a rocket team and a payload team each further splitting into smaller sub-teams working on individual components of the rocket or payload. Each division will collaborate and design compatible parts to launch and deploy in sequence, land and complete the outlined objectives. Upon test launches, minor changes will be made based on experimental data to ensure the success of our goals. All changes made will be reviewed by the team's mentor, NASA SLI representative and Range Safety Officer (RSO) to ensure that they comply with safety protocols outlined by the National Association of Rocketry (NAR) and the Federal Aviation Administration (FAA).

Mission Statement

Through competing in USLI, our team aims to help our members develop an understanding of teamwork, rocketry, robotics, and the engineering design processes and to share the knowledge we gain through this competition with our community to promote interest and excellence in Science, Technology, Engineering, and Math (STEM).

Section 1 General Information

Section 1.1 Adult Educators

Jason Nadeau

Lake Winnipesaukee High Powered Rocketry

Mentor

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John J. Blandino

Associate Professor, Mechanical Engineering

University Advisor

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Section 1.2 Team Leaders

Christian M. Schrader

Captain

BS Aerospace Engineering

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(781) 290-3098

Christian Maximilian Schrader is a Junior pursuing an Aerospace Engineering major and Computer Science minor. He currently has a level 1 high powered rocketry certification and is pursuing a level 2 certification. As Captain, his responsibilities include being a point of contact for the team, leading the Officer Board, and coordinating the team as a whole. This includes planning to ensure the team meets deadlines and ensuring the team follows competition regulations from NASA, WPI, and AIAA. His experience includes becoming an Eagle Scout, working as an Intern Group Lead at NASA Ames, and serving as the Safety Officer and Co-Founder on the team last year.

Sophie Balkind

Rocket Lead

BS Aerospace Engineering

sbalkind@wpi.edu

(978) 270-2900

Sophie Balkind is a Junior Aerospace Engineering major with concentrations in both aeronautics and astronautics. She is currently pursuing her level 1 certification in high powered rocketry. As Rocket Lead, Sophie's responsibilities are to facilitate the design, construction, and documentation of the Launch Vehicle. She will lead the design of the launch vehicle with input from the other officers and general team members. When time for construction Sophie will ensure that the team has adequate knowledge through workshops, organize construction times, and aid in the actual construction. She is also responsible for leading sub teams within the Rocket Division and communicating with the captain and payload lead. Sophie's background participating in Sailbot provided her with a technical and competitive background. Her participation in Real World Design Challenge in high school also provided her with experience writing extensive technical reports.

Thierry de Crespigny

Payload Lead

Worcester Polytechnic Institute

BS Aerospace Engineering

tldecrespigny@wpi.edu

(650) 515-0615

Thierry de Crespigny is a Junior Aerospace Engineering major with concentrations in both aeronautics and astronautics along with minoring in Robotics Engineering. He is currently pursuing his level 2 certification in high powered rocketry. As Payload Lead, Thierry's responsibilities are to facilitate the design, construction, and documentation of the payload. He will lead the design of the payload with input from the other officers and general team. During construction Thierry will ensure that the team has adequate knowledge through workshops, organize build and design times, and aid in the actual construction. He is also responsible for leading sub teams within the Payload Division and communicating with the captain and rocket lead. Thierry's background participating in Battle of the Rockets provided him with a technical and competitive background in designing and building payloads.

Section 1.3 Safety Officer

Veronika Karshina

Safety Officer

BS Aerospace Engineering

vkarshina@wpi.edu

Veronika Karshina is a Sophomore at WPI pursuing a Bachelor of Science in Aerospace Engineering with a minor in Computer Science. Currently pursuing her class 1 certification in high powered rocketry, Veronika has taken a principle of personal and social safety class in high school where part of the syllabus included safety procedures in case of dangerous chemicals release. Veronika has received a junior lifeguard training and was a counselor in training at a summer camp, where she got more training in first aid. Veronika Karshina was a member of WPI USLI team last year, where she was involved closely in the design, construction and launch of the rocket, learning safety principals along the way. All this training and skills gained from it make Veronika Karshina qualified to be Safety Officer of this team.

Section 1.3.1 Safety Officer Roles

The role of the Safety Officer is to ensure the wellbeing of all people, objects, and facilities affected by the inherently dangerous task of manufacturing and launching a class 2 launch vehicle. Our Safety Officer, Veronika Karshina, will supervise a group of safety personnel drawn from every sub team of the WPI USLI team. The Safety Officer will examine the potential risks of using various hazardous materials or procedures and create a risk mitigation plan for each such instance. WPI USLI defines risks as follows:

- potential for bodily harm
- potential for damage/destruction of personal property
- potential for damage/destruction of equipment
- potential for damage/destruction of facilities
- Any other potential risk that the Safety Officer or Safety Personnel deems critical

In addition to risk definition and management, the Safety Officer must have in depth knowledge of NAR High Powered Rocketry Code. It is the role of the Safety Officer to maintain compliance with this code as well as risk recognition and mitigation plans throughout the team. The Safety officer will complete this task by supervising a team of safety personnel that will be instructed in all relevant codes and plans. It will then be the safety personnel's' job to be present at all USLI event where potential risks could arise and ensure all codes/plans are followed during the duration of the event.

Lastly, it is the role of the Safety Officer to ensure that that all team members are versed in NAR High Powered Rocketry Code and with the safety procedures detailed above. This will be done through mandatory safety trainings, maintaining availability of safety personnel, written procedures/codes, and fostering a culture of asking clarifying questions regarding procedures, laws, regulations, or risks.

Section 1.4 General Officers

Adrianne Curtis

Philanthropy Officer

BS Aerospace Engineering

aecurtis@wpi.edu

(860)930-4257

The responsibilities of the philanthropy officer include:

- Creating a sponsorship package for potential sponsors
- Making connections with potential sponsors and gather sponsorship funds for the team
- Maintaining a positive relationship with sponsors

Jeremiah Valero

Documentation Officer

BS Aerospace Engineering

jwvaleroaraujo@wpi.edu

(774) 312-0138

The responsibilities of the documentations officer include:

- Compile all sections of the document
- Finalize all documents to NASA Student Launch Standards
- Ensure that documents are coherent, and the information contained is adequate

Connor Walsh

Outreach Officer

BS Aerospace Engineering

cwalsh@wpi.edu

(978) 846-5438

The responsibilities of the outreach officer include:

- Setting educational engagement goals for the team
- Contacting and working with organizations and programs around WPI focused on STEM engagement for children and the community around Worcester
- Creating educational engagement activities for events throughout the year

Chris Renfro

Social Media Officer

Worcester Polytechnic Institute

BS Aerospace Engineering

crenfro@wpi.edu

(508) 365-8470

The responsibilities of the social media officer include:

- Responsible for the team’s social media presence, merchandise, and the website

Kirsten Bowers

Treasurer

BS Aerospace Engineering / Minor in Electrical and Computer Engineering

kmbowers@wpi.edu

(716) 255-3417

The responsibilities of the treasurer include:

- Managing the budget and handling purchasing

Troy Otter

Logistics Officer

BS Aerospace Engineering

tmotter@wpi.edu

(508) 455-8828

The responsibilities of the logistics officer include:

- Coordinating transportation and lodging for the competition and test launches
- Facilitate spaces to store and build the launch vehicle

Section 1.5 Officer Structure

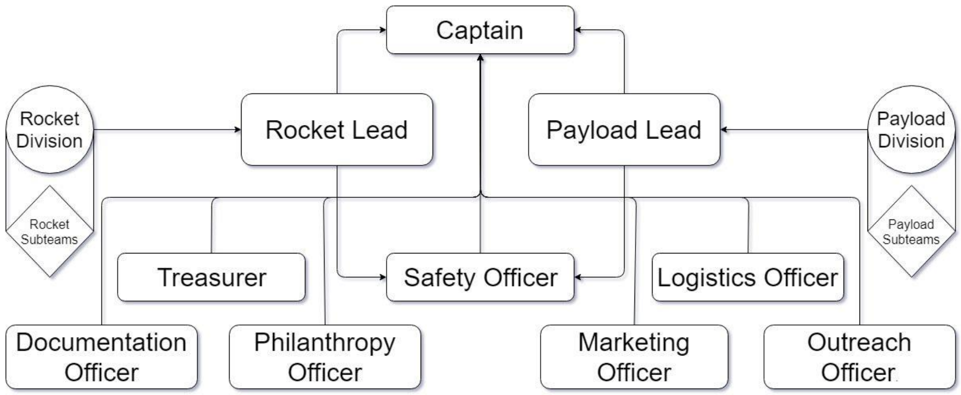


Figure 1.5.1

The above image shows the organization of the officer team, At the head is the captain who oversees all the officers in their duties. The rocket lead, payload lead, and captain form the executive board of the team which makes high level team decisions. Each lead is responsible for their respective division and ensuring that all of their respective aspects of the project are completed. They are also overseen by the safety officer who ensures all member are conducting their work in a safe manor. Below them are the officers for documentation, philanthropy, marketing, outreach, logistics, and treasury who report up to the captain.

Section 1.6 General Members

The rest of the team is made up of general members. Each one is part of a divisions. As of the time of submission, the team has 44 general members. Over the course of the year, this number is expected to fall slightly as a few members lose interest or realize the competition is not for them. This number has significantly increased from last year. In our previous proposal, we reported a team size of 20 general members. Thanks to this significant growth, the team expects to both decrease the workload per student and increase the quality of analysis, testing, and design.

Section 2 Facilities and Equipment

As students of WPI, we have access to many facilities on campus and the ability to use the various equipment with the proper certifications.

Section 2.1 Foisie Innovation Studio

WPI's Foisie Innovation Studio is a modern addition to the WPI campus and serves as a center for student design and engineering. The facility is open to all trained students to complete individual and classroom projects and will serve as the primary workspace for the payload division of our team. For the use of any/all equipment at the studio, there will be training sessions, so every team member is competent and safe when managing and using any of the equipment. The building hosts several conference rooms, lab spaces, tech suites, and a makerspace for students. The area also has a rapid prototyping lab which contains a LPKF ProtoLaser ST Printed Circuit Board machine, a Full Spectrum P-Series 48in x 36in laser cutter, 24 Fused Deposition Modeling (FDM) printers. Training is required to operate the laser cutter and three dimensional (3D) printers. 3D printer models include LulzBot Taz6, Ultimaker 3 and Ultimaker 3 Extended. There are 8 Taz6 printers, which have an 11" x 11" x 9.8" printing area and prints in Polylactic Acid (PLA) a standard material in the 3D printing world. There are 18 Ultimaker 3 printers, which have a print area of 7.75" x 8.4". The difference between the Ultimaker 3 and the Ultimaker 3 Extended is the print height; the normal Ultimaker has a height of 7.8in and the extended has a height of 11.8". The Ultimakers have the ability to print PLA, Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC), thermoplastic polyurethane (TPU), and Nylon. The laser cutter can cut materials such as wood and acrylic, up to ¾". These 3D printers and laser cutters will be used to produce much of the payload. Parts for the rocket and payload can be kept in storage lockers available in the Foisie makerspace until they are ready to be added to the full system. Foisie also houses basic and advanced hand tools available for rental at the front desk. Tool training is required to ensure a safe workspace. 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 2.2 Robotics Pit

The Robotics Pit is a space typically used for robotics competitions and their workspace in the first basement of the Sports and Recreation Center on WPI's campus. Our team is using this space to work on the launch vehicle and payload, as well as storage of the main assembly. There work surfaces provided in the robotics pit, however, no machines or tools are provided, therefore students have free access without the need of supervision or training. Students are permitted to use the Robotics pits whenever the Sports and Recreation Center is open, from 6:00 a.m. to 11:00 p.m. Monday through Friday, 8:00 a.m. to 11:00 p.m. on Saturday, and 10:00 a.m. to 11:00 p.m. on Sunday, apart from school breaks and certain campus events such as competitions and the career fair.

Section 2.3 Washburn Shops and Manufacturing Labs

The Washburn Shops and Manufacturing Labs are a series of WPI classrooms and lab spaces open to all students within WPI. These Labs contain larger equipment relative to the Foisie Studio and as such requires more supervision and a larger degree of training. To use the materials and equipment in the Washburn Shops, each user must complete a “Basic User Training.” This allows for access to the shops, as well as use of hand tools and the laser cutter. To gain access to all equipment, a user must go through the “Advanced User Training.”, during which you get certified on each machine individually. No matter if a user has advanced or basic training, he or she must check in with a “Lab Monitor,” before using the Washburn Shops, as well as work under the supervision of one. Washburn shops is supplied with equipment such as a Universal Laser VLS4.60 laser cutter, a MakerBot Replicator 2x 3D printer, a Prussa 3D Printer and a welding station. The shops are also equipped with a number of machines from HAAS including; an ST-30SSY computer numerical control (CNC) Lathe, a VM2 vertical mill, a ST10 CNC lathe, a Mill Drill Center, two SL10 CNC lathes, and three MiniMills. Each SL10 CNC lathe and MiniMill have their own computer workstation equipped with training materials, computer aided manufacturing software packages such as Esprit, MasterCam, and SurfCam, and all design and programming software supported on campus. The shop is also supplied with an array of manual tools such as; 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 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 unmanned aerial vehicle (UAV) payload systems.

Section 2.4 Higgins Laboratory

Higgins Laboratory is home to the Mechanical Engineering department, which, at WPI, Aerospace Engineering falls under. Higgins Labs serves as the location for many Aerospace classes, research, organizations, and projects. The building is accessible 24/7 for all students through key card access. For this competition, we will primarily utilize the Aerospace / Mechanical Lounge, classrooms, the Price Conference Room, the Project Laboratory, and Machine Shop. The Aerospace / Mechanical Lounge will primarily be used as a workspace for documentation in small groups. It is managed by AIAA. Classrooms are used for general team meetings and documentation and must be reserved ahead of time. The Price Conference Room, which can sit up to 40 people, is an ideal location to host teleconferences, as a projector and audio-visual system. The Project Laboratory is a space reserved for Major Qualifying Projects (senior projects), but in that space we have access to vacuum pumps and space to work with carbon fiber and accessed with key card access held by members of a Major Qualifying Project or through permission of Professor Blandino. With key card access members can access the Project Laboratory whenever they wish. Access to the Machine Shop in Higgins requires getting qualified through a head or qualifying lab monitor. Once you are qualified, you are free to use the Machine Shop whenever there is a lab monitor present. They have dedicated hours from 3:00 – 5:00 on weekdays. In the Machine Shop, there are two CNC Machine tools, a Haas Tool Room min and Haas Tool Room Lathe, there are two DoAll Mills and a DoAll Engine Lathe, as well as a drill press, two band saws, and assorted hand tools.

Section 3 Safety

It is important to have well-defined procedures and information available to members to ensure safety for all participants. High powered model rocketry has inherent risks, and our team takes great measures to limit them. Students are required to follow the rules laid out here in order to protect both their safety and that of others around them.

Section 3.1 Robotics Pits

The Robotics Pits is an indoor construction space that will be the primary assembly and cutting area for the team. The space is large enough that the entire team can work comfortably on multiple projects simultaneously. Inside the robotics pits the team will not do any heavy machining or assembly using materials with inhalation risks as there is no dedicated ventilation system or tools present. If heavy machining needs to be accomplished; the team will go to Washburn Shops. If materials that are hazardous to inhale are needed, the team will exit the robotics pits through the loading dock and conduct the work outside with proper ventilation and PPE.

Section 3.1.1 Dremel

Hazards	Causes	Effects	Mitigation Plan
Laceration injury	Appendage caught by slipping Dremel	Up to and including severe lacerations or amputations.	Participants will be trained in proper use of Dremel. Gloves will always be worn by operator
Clothing/Jewelry damage/destruction	Loose clothing/jewelry stuck in rotating blade	Up to and including destruction of stuck material and increased potential for laceration injury.	Participants will be instructed to not wear loose clothing/jewelry when using a Dremel
Inhalation injury	Dust particles inhaled by user or bystanders	Throat/Lung irritation. Potential for Fibrosis	Participants will be instructed to wear a safety mask while using or around someone using a Dremel.
Eye injury	Eyes struck by flying objects created by Dremel	Up to and including severe eye injury and partial or total loss of site in affected eye.	Participants will be instructed to always wear safety glasses when using or around someone using a Dremel.

Section 3.1.2 Angle Grinder

Hazards	Causes	Effects	Mitigation Plan
Laceration injury	Appendage caught by slipping or kickback from Angle Cutter.	Up to and including severe lacerations or amputations.	Participants will be trained in proper use of Angle Cutter. Gloves will always be worn by operator
Clothing/Jewelry damage/destruction	Loose clothing/jewelry stuck in rotating blade.	Up to and including destruction of stuck material and increased potential for laceration injury.	Participants will be instructed to not wear loose clothing/jewelry when using an Angle Cutter.
Inhalation injury	Dust particles inhaled by user or bystanders.	Throat/Lung irritation. Potential for Fibrosis.	Participants will be instructed to wear a safety mask while using or around someone using an Angle Cutter.
Eye injury	Eyes struck by flying objects created by Angle Cutter.	Up to and including severe eye injury and partial or total loss of site in affected eye.	Participants will be instructed to always wear safety glasses when using or around someone using an Angle Cutter.

Section 3.2 Foisie Innovation Studio Maker Space

Foisie Innovation Studio will be used for requesting FDM 3D prints. In order to be active in the Foisie Maker Space and to request the prints, participants will fill out a safety quiz on proper attire and conduct for the labs.

Section 3.2.1 FDM Printers

Participants will not be using the FDM printers for USLI projects. They will place a print request into the Foise printer queue and will handle only the finished prints. The actual printing will be handled by prototype lab staff.

Section 3.3 Washburn Shops

The team will utilize Washburn Shops to conduct heavy machining, cutting, and manufacturing of rocket parts that cannot be completed in the Robotics Pits. In order to use tools in Washburn Shops, WPI students are required to get certified via an online quiz. Upon completion, they will be granted a Basic User Certificate granting them access to basic tools including hand tools and the laser cutter. 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.

Section 3.3.1 Haas ST30 SSY CNC Lathe

Hazards	Causes	Effects	Mitigation Plan
Blunt force trauma	Improperly securing rotor and subsequent ejection.	Up to and including death due to massive blunt force trauma	Participants must be trained on proper usage of CNC Lathe before any work is done with it. All safety procedures supplied by Washburn Shops will be followed.
Avulsion/ amputation	An appendage stuck in the Lathe due to improper use or attire	Up to and including amputation of appendage caught in lathe	Participants must be trained on proper usage of CNC Lathe before any work is done with it. All safety procedures supplied by Washburn Shops will be followed.
Clothing/Jewelry/Hair damage/destruction	Loose clothing, jewelry, hair or gloves caught in the rotating Lathe	Up to and including complete destruction of material caught. Greatly increased risk of avulsion and amputation.	Participants will not be permitted to use the CNC Lathe when wearing loose clothing, jewelry, or have long hair that is not contained by hat, hairnet, or similar means.

Eye injury	Eyes struck by flying objects created by improper use of Lathe.	Up to and including severe eye injury and partial or total loss of site in affected eye.	Participants will not be permitted near the CNC Lathe without safety glasses.
Hearing Injury	High decibel noises caused by Lathe.	Up to and including hearing loss.	Participants must wear hearing protection when near the CNC Lathe.
Foot Injury	Heavy materials falling out of Lathe landing on foot.	Up to and including bruising and crushing injuries to affected foot.	Participants must wear closed toed shoes when using the CNC Lathe.

Section 3.3.2 Laser Cutter

Hazards	Causes	Effects	Mitigation Plan
Eye Injury	High energy laser beam not contained by glass doors.	Up to and including blindness and severe burns.	Participants will not be permitted to use laser cutter without proper training. They must use safety glasses when around laser cutter. They will be instructed not to look at cutter when in operation.
Burns and other Fire Injuries	High energy laser beam not contained by glass doors. Fire caused by improper use of laser cutter settings.	Up to and including severe burns on any body part in contact with fire or the laser beam. Potential destruction of laser cutter, material being cut, and surrounding area.	Participants will not be permitted to use laser cutter without proper training. Participants must wear gloves when operating the laser cutter.
Inhalation Injury	Inhalation of fumes released by laser cutter. Improper use of ventilation system. Cutting materials not cleared for the laser cutter.	Up to and including severe sickness and death caused by inhalation of toxic fumes.	Participants will not be permitted to use laser cutter without proper training. Participants will be instructed to shut down the laser cutter if ventilation system fails.

Section 3.3.3 Haas MDC vertical mill

Hazards	Causes	Effects	Mitigation Plan
Avulsion/ amputation	An appendage stuck in the Mill due to improper use or attire.	Up to and including amputation of appendage caught in Mill.	Participants must be trained on proper usage of Vertical Mill before any work is done with it. All safety procedures supplied by Washburn Shops will be followed.
Clothing/Jewelry/Hair damage/destruction	Loose clothing, jewelry, hair or gloves caught in the rotating Vertical Mill.	Up to and including complete destruction of material caught. Greatly increased risk of avulsion and amputation.	Participants will not be permitted to use the Vertical Mill when wearing loose clothing, jewelry, or have long hair that is not contained by hat, hairnet, or similar means.
Eye injury	Eyes struck by flying objects created by improper use of Mill.	Up to and including severe eye injury and partial or total loss of site in affected eye.	Participants will not be permitted near the Vertical Mill without safety glasses.
Hearing Injury	High decibels caused by Mill.	Up to and including hearing loss.	Participants must wear hearing protection when near the Vertical Mill.
Foot Injury	Heavy materials falling out of Mill land on foot.	Up to and including bruising and crushing injuries to affected foot.	Participants must wear closed toed shoes when using the Vertical Mill.

Section 3.3.4 Minimill

Hazards	Causes	Effects	Mitigation Plan
Avulsion/ amputation	An appendage stuck in the Mill due to improper use or attire.	Up to and including amputation of appendage caught in Mill.	Participants must be trained on proper usage of Minimill before any work is done with it. All safety procedures supplied by Washburn Shops will be followed.
Clothing/Jewelry/Hair damage/destruction	Loose clothing, jewelry, hair or gloves caught in the rotating Minimill.	Up to and including complete destruction of material caught. Greatly increased risk of avulsion and amputation.	Participants will not be permitted to use the Minimill when wearing loose clothing, jewelry, or have long hair that is not contained by hat, hairnet, or similar means.
Eye injury	Eyes struck by flying objects created by improper use of Mill.	Up to and including severe eye injury and partial or total loss of site in affected eye.	Participants will not be permitted near the Minimill without safety glasses.
Hearing Injury	High decibels caused by Mill.	Up to and including hearing loss.	Participants must wear hearing protection when near the Minimill.
Foot Injury	Heavy materials falling out of Mill land on foot.	Up to and including bruising and crushing injuries to affected foot.	Participants must wear closed toed shoes when using the Minimill.

Section 3.4 Materials

During the construction part of the competition, team members will be exposed to potentially hazardous materials. Since safety is the number one priority of our team, no member will be allowed to use such materials without a safety briefing from the safety officer, in which they will go over Personal Protective Equipment (PPE), potential hazards, first aid and other things that will ensure everyone's safety. We will make sure that each member has access to the necessary PPE if they will be working with or coming in to contact with potentially dangerous materials. Such materials are, but not limited to the following list:

Section 3.4.1 Carbon Fiber

Use	Hazards	Mitigation
Fins, Bulkheads, Body	Can cause eye, skin and upper respiratory track irritation; vapor or fumes may cause eye and respiratory tract irritation; fibers and dust are electrically conductive and may create electrical short-circuits.	Will be stored sealed in a cool, dry place. When working with the material members will wear safety goggles, gloves, long pants and long sleeve shirts to avoid eye and skin irritation. The material will not be heated to avoid hazardous fumes and vapor. We will be working with carbon fiber in well-ventilated spaces to control dust levels

Section 3.4.2 Aluminum

Use	Hazards	Mitigation
Bulkheads, fasteners, coatings, shielding	Dust or fumes can cause eye, skin and respiratory track irritation; chips and dust react violently and/or explosively with water, steam or moisture; air sensitive.	Will be stored in a cold, dry, well-ventilated place, away from ignition sources and materials that can cause a reaction. When working with the material members will wear safety goggles, gloves, long pants and long sleeve shirts to avoid eye and skin irritation. Will be used in adequately ventilated spaces.

Section 3.4.3 NylonX

Use	Hazards	Mitigation
3D printing parts	Solid or dust may cause eye irritation; when heated can cause thermal burns on the skin, vapors can cause eye irritation; burning can produce toxic fumes.	Will be stored in a cool, dry area with no direct sunlight. Members will wear safety goggles when machining the material. Gloves will be worn for thermal or mechanical protection if needed. Will not be used or stored near flames, sparks and heat generators.

Section 3.4.4 PLA

Use	Hazards	Mitigation
3D printing parts	Can cause eye and skin irritation; burning can produce obnoxious and toxic fumes; dry powders can build static electricity charges.	Will be stored in a cool, dry, well-ventilated area. Members will wear safety goggles, gloves, long pants and long sleeve shirts when machining the material to avoid eye and skin contact. Will be machined in ventilated places to avoid dust accumulation. Will not be used or stored near flames, sparks and heat generators.

Section 3.4.5 Epoxy

Use	Hazards	Mitigation
Conjoining parts of the rocket, filling holes	Can cause eye and skin irritation; prolonged and reputative skin contact can cause chemical burns; burning releases toxic fumes; when cured in big quantities can cause ignition of surrounding material.	Will be stored in a cool, dry place in a tightly sealed container, far from heating or ignition sources. When working with epoxy members will wear safety goggles, gloves, clothes that protect the skin from coming in contact with the material. Proper mixing and curing technics will be used to avoid ignition.

Section 3.4.6 LiPo Battery

Use	Hazards	Mitigation
Payload component	Can cause chemical burns if contacts skin or eyes; heating can cause fire.	Will not be dismantled. Will be stored in a cool, dry place in a tightly sealed container, far from heating or ignition sources. When handling members will wear safety goggles, gloves, long pants and long sleeve shorts to avoid contact with skin and eyes. Will be handled carefully, not heated, shook or short-circuited.

Section 3.4.7 Black Powder

Use	Hazards	Mitigation
Used to separate sections of the airframe and to release the retention system from the airframe.	Explosive; highly flammable; fire, blast or projection hazard; can cause serious eye irritation, an allergic skin reaction; can cause damage to organs through prolonged and repetitive exposure.	Will be stored in a tightly closed original container in a cool, dry, well-ventilated place away from all sources of ignition, heat, incompatible materials. Will not be subjected to mechanical shock. Only people who are trained in working with black powder will be allowed to handle it. They will wear safety goggles, gloves and protective clothing to minimize risk of contact with skin and eyes. Clothing that has black powder on it will be washed in special conditions.

Section 3.4.8 Ammonium Perchlorate Composite Propellant (APCP)

Use	Hazards	Mitigation
Used in the rocket motor	Flammable; explosive; can cause eye irritation, in the form we are using it is a low hazard for skin.	Will only be purchased as part of a commercial solid rocket motor. Will never be removed from a motor and will be stored in a cool, dry place away from sources of heat or ignition. Safety goggles, protective clothing will be worn by members to avoid contact with skin or eyes.

Section 3.4.9 Igniter Pyrogen

Use	Hazards	Mitigation
Used for ignition	Flammable; explosive; can cause eye irritation, in the form we are using it is a low hazard for skin.	Will be stored in the original container in a cool, dry place away from sources of heat or ignition. Safety goggles, protective clothing will be worn by members to avoid contact with skin or eyes.

Section 3.4.10 General Materials Rules

Even when concepts seem obvious, it is often important to acknowledge them as rules. These rules are:

- Members will not consume, or inhale materials, fumes, or vapors created by them.
- If a potentially dangerous material contacts eyes or skin, safety procedures will be conducted to avoid injuries and irritations.
- If fumes or vapor of a potentially dangerous material are inhaled, safety procedures will be conducted to avoid injuries and irritation.
- In case of a fire or if a member's health is in danger an appropriate safety agency will be contacted immediately.

Section 3.5 Compliance with NAR

NAR and Tripoli Rocketry Association (TRA) personnel will follow all NAR High Power Safety Code requirements (see 3.2.1. for a full list). The team agrees to comply with all NAR High Power Safety Code requirements and follow RSO's instructions at launch sites.

Section 3.5.1 High Power Safety Code

3.5.1.1 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.

3.5.1.2 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.

3.5.1.3 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.

3.5.1.4 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.

3.5.1.5 Motor Ignition

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

3.5.1.6 Misfire

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.

3.5.1.7 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.

3.5.1.8 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. The RSO will place the safety tape at a distance stated in the minimal distance table in the NAR High Power Safety Code. Further, the team will wait to launch the launch vehicle if the wind speed exceeds 20mph.

3.5.1.9 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. The RSO will ensure any flammable foliage has been removed from the surrounding area.

3.5.1.10 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. The RSO will set up the launch rail at least 1500ft from any occupied building or public highway.

3.5.1.11 Flight

The team will not launch the launch vehicle at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site and will not put any flammable or explosive payload in the launch vehicle.

3.5.1.12 Recovery

Our launch vehicle will utilize a dual deployment recovery system, with a drogue parachute deploying at apogee and a main parachute deploying at 550ft. 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.

3.5.1.13 Recovery Safety

The team will not attempt to catch the launch vehicle as it's coming down or recover any part of the launch vehicle from power lines, tall trees, or other dangerous places.

Section 3.5.2 Launch Site

For subscale model launches, the team intends to launch with the Central Massachusetts Space Modeling Society (CMASS) in Amesbury Massachusetts. CMASS is a NAR Section #464 site, where WPI USLI team members have launched from on multiple occasions, for individual NAR level one certifications. A backup location is White's Field, used by CATO (lacking an official acronym) Rocketry Club NAR #581 in Durham Connecticut. Both primary and backup sites have a FAA waiver for launches up to at least 2,000 ft., which will satisfy the requirements of our sub-scale test vehicle.

Test launches of our competition vehicle will take place primarily at the Lake Winnipesaukee High Power Rocketry (LWHPR) Club on Lake Winnipesaukee in New Hampshire (NAR #834) which has an FAA waiver up to 16,000 ft. WPI has worked with the President, Jason Nadeau in the past, and test launched the 2019 competition rocket from this site. The launch site is limited by the weather, as it does not become operational until the ice on the lake has frozen sufficiently, usually opening in January. Since it would be beneficial for us to launch our full-scale rocket prior to January, additional launch sites were selected for earlier launches. Earlier launches may take place at the Champlain Region Model Rocket Club (CRMRC), Bridgeton Area Rocket Club (BARC), or the Upstate Research Rocketry Group (URRG).

URRG (NAR #765) has an FAA waiver of 18,000 ft and is located in Youngstown, NY. CRMRC (NAR #635) has a FAA waiver of 10,000 ft and is located in St. Albans, VT. BARC (NAR #775) has a base FAA waiver of 5500ft with special clearance up to 8000ft and is located in Bridgeton NJ. URRG, CRMRC, and BARC will only be considered if all other sites are unavailable, as they are farthest from WPI.

Section 3.6 Launch Briefings and Aerospace Compliance Plans

Prelaunch safety briefings will be conducted by the Safety Officer at each general body meeting prior to a launch event. Safety personnel will conduct additionally prelaunch safety briefings at the launch site prior to vehicle handling. Briefings will include launch hazard recognition and risk mitigation procedures. During each pre-launch briefing Safety Personnel will also review Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets and any other local laws regarding use of airspace. Lastly, Safety Personnel present at launches will be vigilant to maintain all procedures, regulations, and laws are followed by team members.

Section 3.7 Motor Safety and Handling

Launch vehicle motors are classified as hazardous materials in the United States. Because of this, we will not be able to fly or ship the launch vehicle motors to launch sites. In order to comply with these regulations, the team will purchase the motor at the launch site. NAR/TRA-certified mentor and team members will be responsible for the purchase, storage, and handling of all launch vehicle motors and other energetics such as black powder. Individuals handling energetics will be briefed on by the Safety Officer and comply with Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, National Fire Protection Association (NFPA) 1127 "Code for High Power Rocket Motors", and any local laws regarding launch vehicle motors or other energetics.

Section 3.8 Written Safety Agreement of USLI Club Members

- I recognize that fabrication and launch of High-Power Rockets is a potentially dangerous activity, and that I have a responsibility to myself and to my teammates to actively ensure that best practice is used at all times to minimize risk associated with these activities.

- I will not use tools or perform operations for which I do not have an appropriate working knowledge and will complete all required training steps prior to using dangerous tools.

- In the event of uncertainty regarding safety or correct procedure, I will consult with the team's Safety Officer before proceeding.

- I will employ appropriate Personal protective equipment (PPE) as required while performing machining operations, using hand/power tools, or handling hazardous materials.

- I will familiarize myself with the material safety data sheets relevant to any potentially hazardous materials I work with, along with the hazard mitigation techniques documented by our team.

- I understand that I have not just a responsibility to personally perform operations safely but also to actively contribute to a culture of safe practice within our team, and to actively intervene should I observe a team member failing to follow the terms of this safety agreement, reporting any violations to the team Safety Officer and WPI-appointed Lab Monitor on duty. Throughout my activities within the team, I will seek to continuously educate myself on hazard identification, mitigation, and safe practice, and to promote an environment where my teammates may learn from my example.

- I agree to follow all policies and procedures set forth by WPI regarding access and safe use of laboratory facilities. I understand that the team's Safety Officer and WPI Lab Monitors may intervene with any action judged to pose a potential safety hazard, and that failure to correct my actions to meet their standards will result in the loss of privileges to engage in fabrication or launch activities with the team.
- I understand that at NAR/TRA sanctioned events, instructions from or decisions made by the Range Safety Officer are final and must be followed, including in cases where such decisions run counter to information provided by USLI personnel or our team's Safety Officers.

- I have read and understand the NAR High Power Rocket Safety code and agree not to perform any launch activities in violation of the code, or in violation of FAA regulations, NFPA 1127, or any other applicable local, state, or federal laws and regulations.

- I have read and agree to the following safety regulations included in the 2019-2020 USLI Student Handbook:

1.6.1. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.

1.6.2. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.

1.6.3. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team will not fly a rocket until the mentor has reviewed the design, examined the build and is satisfied the rocket meets established amateur rocketry design and safety guidelines.

1.6.4. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

By signing this document, I agree to all of the above, and that failure to comply with the requirements may result in loss of shop privileges or membership standing within USLI.

Section 4 Technical Design

As with all engineering proposals, the purpose is to describe the basic form of the project. It is important not only to effectively communicate the ideas presented but coherently explain the concepts behind them. No detail should be overlooked or have no logical reasoning and it is understood that this will most likely not be the final design.

Figure 4.1 Diagram Showing the side view of the launch vehicle

Section 4.1 Nose Cone

A nosecone constructed of fiberglass was chosen due to the high strength and relatively low weight. Additionally, the chosen fiberglass nosecone was also used in last year's competition and it not only worked well but returned safely, further proving its durability in flight and in recovery. Reusing the nose cone will further decrease the cost to build the launch vehicle. The chosen nosecone is 31 in long, has a shoulder length of 7.13 in, tangent ogive (shape parameter = 1) in shape and is constructed of fiberglass with an aluminum tip. The increased weight of an aluminum tipped fiberglass nosecone is beneficial to both stability and structural integrity. The replaceable aluminum tip is designed to both take the impact forces of a nose-down descent, protecting the more brittle fiberglass in case of a high kinetic energy landing, as well as raising the center of mass higher up the body of the rocket. Shifting the center of mass of the rocket higher up effects the stability of the rocket, helping us obtain a desired stability ratio. We simulated launch vehicle models using nosecones of different materials and found that due to cost and availability, along with the structural benefits, fiberglass was the best available nosecone material for our needs. The proposed payload retention system will be integrated with the nosecone. The retention system will actively retain the nosecone with the use of a threaded drive rod. The drive rod will be used to push forward the nosecone in order to release the payload from the upper airframe.

Section 4.2 Airframe

The design process of the launch vehicle was done through OpenRocket version 15.03. The launch vehicle airframe will be divided into three sections: upper airframe, middle airframe, and lower airframe. These sections will be 26 in, 30 in, and 26 in respectively, and each will have an outer diameter of 6.079 in. The diameter of the airframe will provide the payload team more room to work with while designing the selected payload. The diameter also provides space for larger parachutes to be used without packing them too tightly, resulting in a smoother, more reliable recovery system.

The upper airframe of the launch vehicle will house the selected payload and will also act as a retention system.

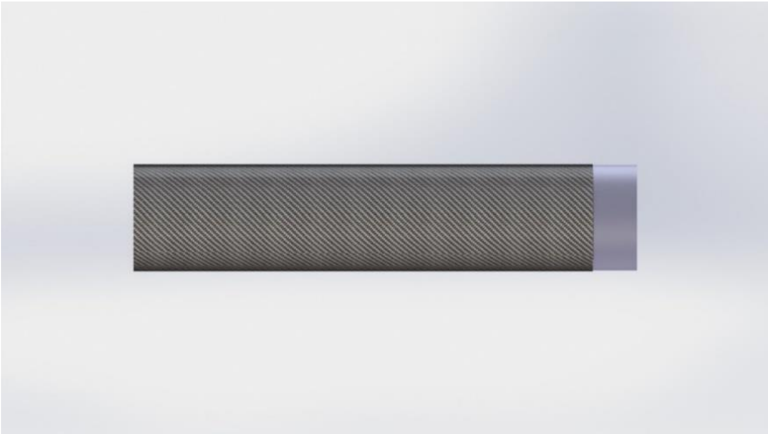


Figure 4.2.1 Diagram Showing the Upper Airframe

The middle airframe of the launch vehicle will house the three parachutes associated with the recovery system. The parachutes will be made of ripstop nylon, connected to their corresponding components by nylon shock cord. The coupler connecting the middle and lower airframe components will be used to house the electronics bay.

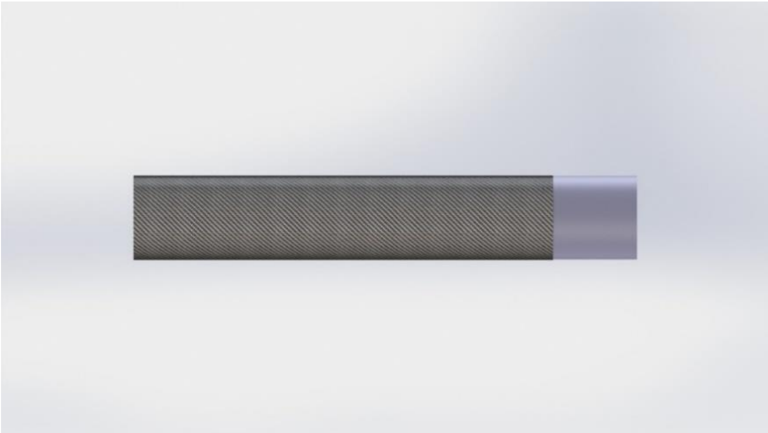


Figure 4.2.2 Diagram Showing the Middle Airframe

The lower airframe of the launch vehicle will house a 25 in long inner tube of 2.15 in outer diameter and 2.11 in inner diameter to house the selected motor. The inner tube will be constructed out of Blue Tube. The lower airframe will also hold the attachments for the fin can.

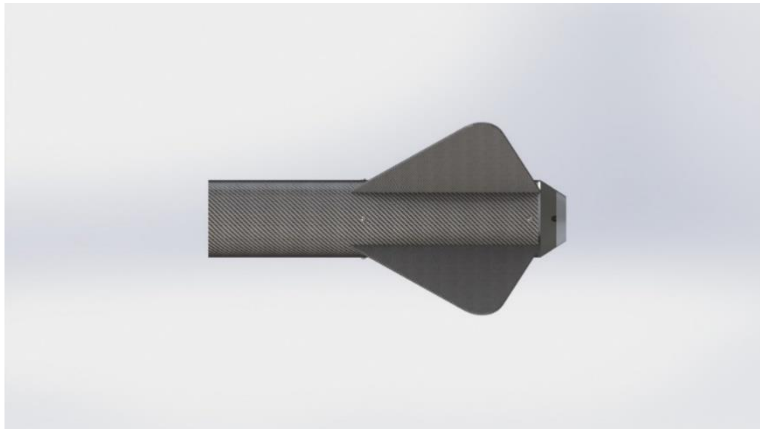


Figure 4.2.3 Diagram Showing the Lower Airframe

Carbon fiber was selected as a potential material because it is considerably stronger than alternatives such as Blue Tube, phenolic, and fiberglass. This adds longevity to the rocket in the case of any difficulties during mid-launch or landing. The major disadvantage of carbon fiber is its cost which our team cannot afford given our budget.

Ideally, Ramar-Hall, a precision machining and assembly company, will sponsor our team and supply the carbon fiber needed to construct our airframe, thus eliminating the issue of cost, which is the largest downside of using carbon fiber. However, should this sponsorship agreement not be made, Blue Tube will be used to construct the airframe of our launch vehicle.

Blue Tube was chosen as an alternative material because of its resistance to abrasion, cracking, toughness and other forms of damage that can be expect from the launch/landing of the launch vehicle. This makes Blue Tube an adequate alternative to phenolic. Blue Tube's availability in varying diameters, makes it a good alternative to carbon fiber. It is also a considerably lighter material than fiberglass making it far more useful for the purpose of the launch. Due to its durability, it is commonly used by WPI's AIAA chapter.

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

Section 4.3 Payload Retention System

During flight, the payload is secured to a 10 in long sled supported by circular 5.85 in diameter structural plates, allowing for rotation within the airframe. The UAV will be secured to a launch platform inside of the sled by two clamps contacting opposite sides of its chassis.

Figure 4.3.1 Diagram Showing the Retention System

Once the upper airframe has landed and clearance has been received by the RSO to release the payload, the UAV must be oriented upwards to ensure proper deployment. To accomplish this, an active control system will be designed using a servo to rotate the payload sled within the airframe. Data from an Adafruit LIS3DH Triple-Axis Accelerometer will be used to drive the servo and achieve the correct vertical orientation. At both ends of the payload sled, a bearing track will run between the sled and the airframe to facilitate smooth rotation and translation. This active control system will not be active during flight in order to hold the payload in a secure position.

After being oriented for deployment, the nosecone and payload sled will be driven out of the upper airframe by an internally stored lead screw with a projected length of 20 in and a projected diameter of 3/8 in. The lead screw will have one end fixed to the nosecone, and the other end attached to the 1000:1 Micro Metal Gearmotor HP 6V drive motor which is fixed to the rotating orientation plate. Once given the command, the drive motor will engage and start translating the oriented sled, kept straight by a guide rail

After the nosecone and sled have fully translated out of the airframe, the bed the UAV is resting on will be raised by a scissor lift so that its arms can unfold outwards into their flight position without contacting the nosecone or upper airframe. This scissor lift will be driven by a pair of linear actuators on either side of the leadscrew.

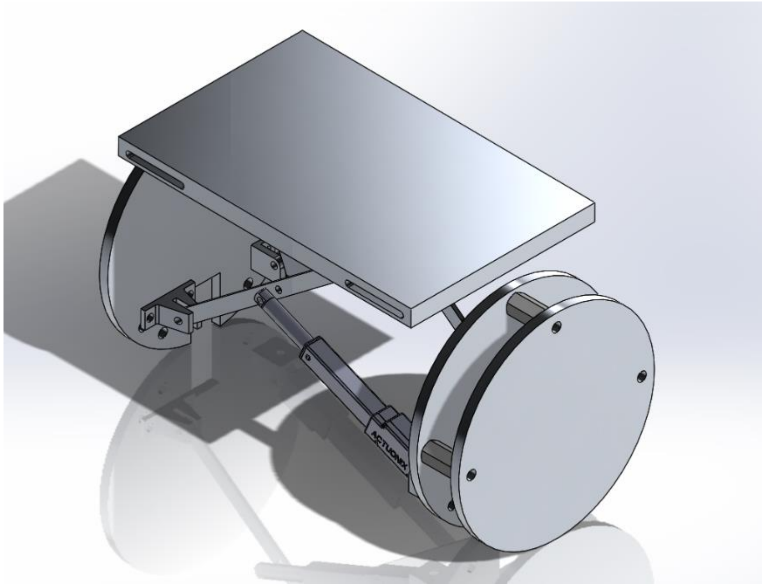


Figure 4.3.2 Diagram Showing the Fully Deployed Retention System

The clamps securing the UAV to the launch platform will be rotated open via a mounted servo motor, allowing its spring-loaded arms to unfold. The UAV then will take off from the platform.

Section 4.4 Payload UAV

The objective of this payload is to travel to one of five soil sample locations, collect at least 10 mL of target material and then transport the sample a minimum of 10 ft away. A quadcopter UAV was chosen over a ground-based system due to its high mobility, avoidance of ground obstacles, and reliable operation. Our team decided on using a quadcopter UAV as our primary payload.

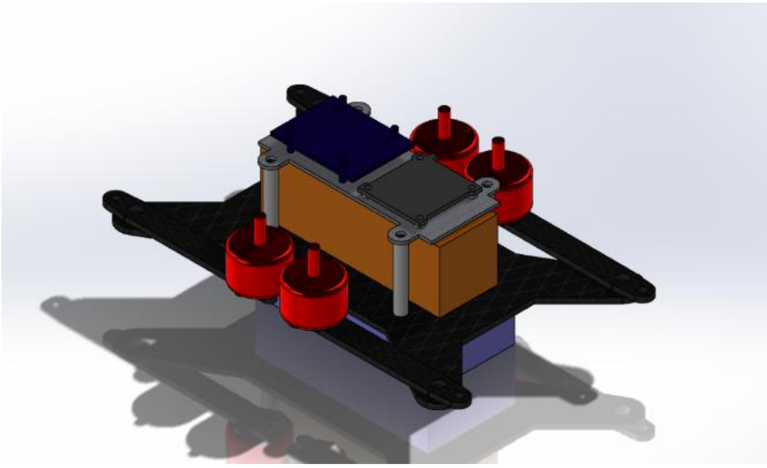


Figure 4.4.1 Diagram showing the unmanned aerial vehicle when folded

Section 4.4.1 Body Frame

The dimensions of the UAV when it's retained in the rocket are height of 2 in, width of 4.5 in, vertical length of 10 in. All major structural components on the drone are made from 1/8 - 3/16 in foam core carbon fiber panels. The arms of the drone will include joints that are attached to the UAV main body that allow them to fold inwards while the drone is stowed in the payload retention system. Both the front and back arms will fold horizontally inward towards the drone body. This means the front arms rotate backwards towards the main body, and the rear arms will rotate forwards towards the body. These arms are spring loaded to deploy once the payload retention system has reached takeoff position. A brushless motor is mounted at the end of each arm, directly driving one prop each. Horizontal arm rotation was chosen for several reasons. It is easy to implement, compared to vertically folding arms. Additionally, horizontal deployment enhances structural rigidity in the vertical direction. If deployment is not completely successful, a partially deployed arm can still operate and provide thrust in vertical direction. Folding horizontally also allows the drone to be stowed in a very compact form, saving space in the payload compartment for the payload retention system.

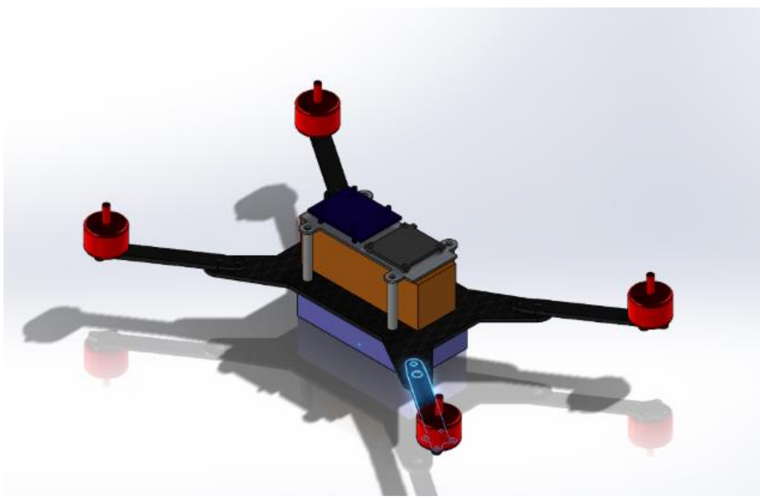


Figure 4.4.1.1 Diagram showing the unmanned aerial vehicle when unfolded

Section 4.4.2 Propulsion System

The primary propulsion system for the UAV are four electric brushless motors with folding propellers fixed directly to the motor rotors. The selected motors are Racerstar 2306 Fire Editions 2400Kv, chosen for their Kv rating, stator size, and efficiency. Attached to the motors are DJI Spark folding propellers, which are capable of stowing in a folded configuration, and automatically deploying during initial motor spin up.

Section 4.4.3 Sampling Collector

Our team choose to use a rotating auger as our sample extraction mechanism. This auger will physically collect and store our sample. It is composed of a tube that terminates in a special drill head for collecting material. It will have an inner diameter of approximately 0.8 in, and when active will slowly rotate as it is pressed into the soil. The drill's geometry is designed to feed material into the tube and prevent it from falling out while in flight. Different drill heads can be used depending on the material being sampled, achieving the best performance for a given material. The auger will be driven by a high torque, low speed gearmotor, and mounted on a spring-loaded slide to ensure that the auger is engaged with the sample material. We selected an auger because of its simplicity and stability. Additionally, an auger would impart the smallest moment on the fuselage of the drone while active.

Section 4.4.4 Flight Controller and Power Systems

The flight controller is a Diatone Mamba F722S Stack quadcopter flight controller which we chose for its combination of built in components and small form factor. The attributes of this flight controller we value are its F7 architecture processing chip, ample physical connectors, connectivity to desired flight programs, and an integrated Electronic Speed Controllers (ESC) with a high continuous current. The UAV will be powered by Turnigy 2200mAh 4S 40C LiPo battery giving the UAV an approximate max flight time of 4 minutes under full load.

Section 4.5 Fins

Fins provide the launch vehicle stability as it flies by affecting the locations of the center of pressure of the rocket. Basic, stable rocket flight requires that the center of pressure be behind the center of gravity along the axis running through the rocket from top to bottom. The location of the center of pressure is related to the surface area of the rocket and adding fins to the rear lowers the midpoint in the surface area. The greater the distance between the center of gravity and center of pressure, the more stable the rocket flight will be. However, If the rocket is too stable, it can turn into the wind, causing a change in flight direction (e.g. flying horizontally) that could be dangerous to others in the surrounding area.

Our launch vehicle will have four fins that are mounted in the fin-can using bolts to secure them as shown in *Figure 4.5.1* The root of the fin will be 15in in length, with a 12.5in tab that will protrude into the body so it can be secured to the fin-can. Within the tabs will be 4 staggered holes for ¼ in bolts.

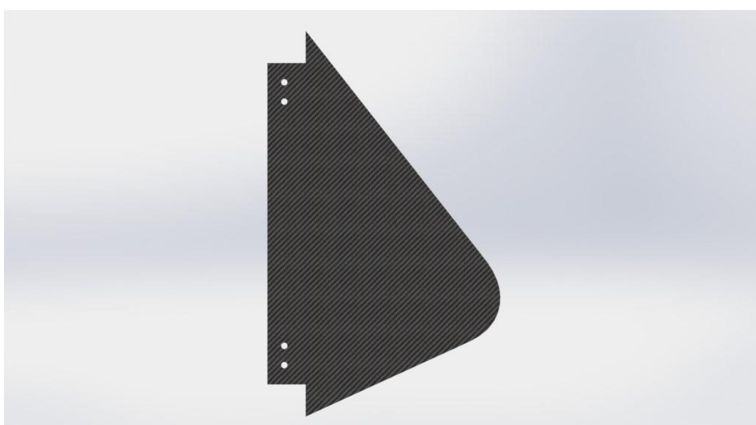


Figure 4.5.1 Diagram Showing One of Four Fins

The fins of the launch vehicle will be a modified clipped shape. The trailing edge with be brought to a sharp edge and while sweeping the trailing edge up towards the nose cone, furthermore, we will be chamfering the forward outer edge of the fin. The edges are done this way since we will be traveling at a subsonic speed. This fin shape was chosen to give the rocket the most aerodynamic design while allowing enough surface area to achieve the desired stability.

The shape of the fine will be manufactured in either of two methods. In the primary method, the fins will be constructed of a carbon fiber exterior molded around a foam interior and a leading edge created of 3D printed material. The choice of a carbon fiber exterior provides the rocket fins the strength to absorb the impact of landing. The purpose of the interior foam and 3D printed interior are to provide structural support for the carbon fiber to be molded around as well as to make the fin lighter and cheaper. The fully constructed fins will be ¼ in thick. We are currently in an experimental stage with this construction method. Our secondary method is to buy carbon fiber sheets of 1/8 in and have them cut to shape using a high-pressure water jet.

Section 4.6 Technical Fin-Can

In order to facilitate easy transport and maintenance of the rocket while maintaining adequate structural stability, the lower airframe will contain a removeable fin can assembly, consisting of a removable motor tube section, removable fins, and a tail cone assembly (*Figure 4.6.1*). This also makes any potential fin repairs easier and allows for easy testing of different fin designs. Additionally, the modular design reduces the amount of epoxy needed, making the assembly lighter, and the construction easier. The fin can will accommodate a section of 2.953 in blue tube as the motor tube around which the construction will be based (*Figure 4.6.2*).

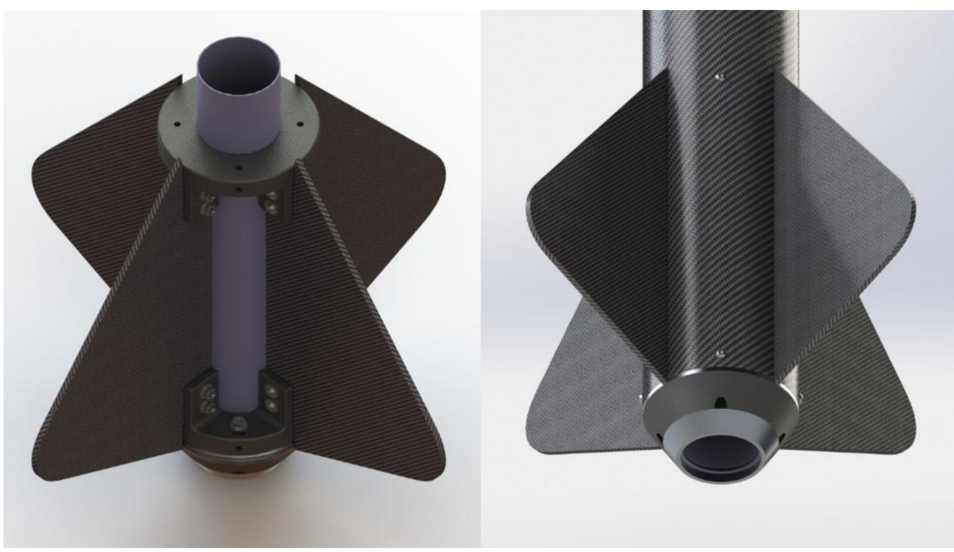


Figure 4.6.1 & 4.6.2 Diagram Showing the Fin-Can with the Carbon Fiber Body Off (Left) and On (Right)

The primary design uses two 3D printed fin brackets to hold the fins (*Figure 4.5.3*). The bracket will be printed out of MatterHackers NylonX filament, a very strong and lightweight carbon fiber reinforced nylon filament. The fins will be bolted into place, each using four ¼-20 bolts. The fin brackets will be epoxied to the motor tube and will have four captive ¼-20 hex nuts each to attach the bracket and motor tube to the lower airframe body tube when not under thrust. The motor tube and fin brackets will slide into and out of the lower airframe as one unit, allowing for easy access and modularity.

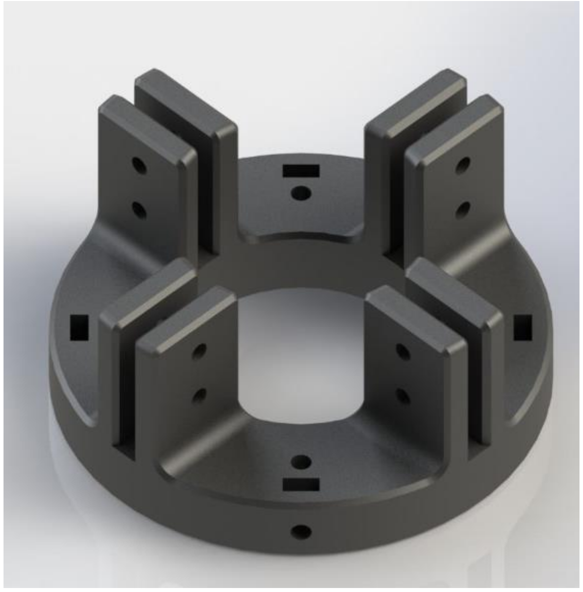


Figure 4.6.3 Diagram Showing one of the Fin-Can's Brackets (Two are Shown in Figure 4.6.1)

In the case that the primary design becomes unfeasible, our secondary design replaces the 3D printed fin brackets with aluminum L-channel epoxied to the motor tube and body tube (*Figure 4.6.4*). Each fin bolts between four L-channel sections, two on the motor tube and two on the body tube, using ¼-20 bolts, providing two-point support of the fins, reducing the chance of deflection due to aerodynamic forces. Again, the motor tube will slide into and out of the lower airframe for easy access and modularity.

Figure 4.6.4 Diagram Showing the Back-Up Fin-Can Retention Design

Adequate retention of the fin can and motor within the rocket under the heavy accelerations and shock loading events of launch and recovery deployment is a key concern. While the motor is firing, a custom manufactured thrust plate attached to the bottom fin bracket with four ¼-20 bolts will transfer the load directly onto the body tube of the rocket, without the shear forces associated with epoxied centering rings. The thrust plate will be made from ½ in 6061 aluminum alloy to withstand the force from the motor. Stress analysis was performed with an expected maximum thrust of 244.16 lbf, with a resulting minimum safety factor of 3.6 (*Figure 4.6.5*).

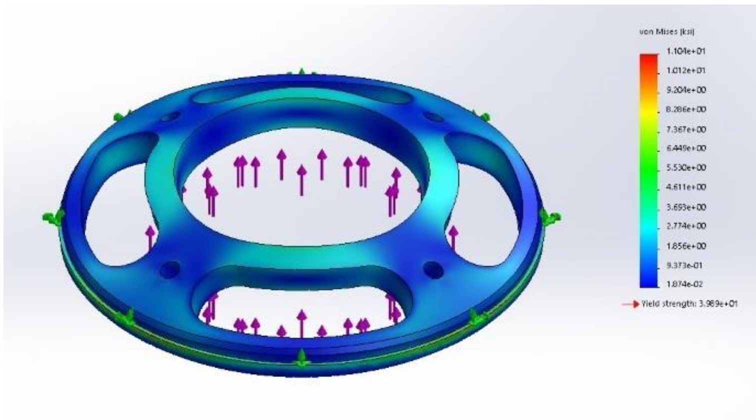


Figure 4.6.5 Diagram Showing Stress Analysis Performed on Back-Up Retention Design

The retainer will be based off an Aeropack RA75 motor retention system, which features a two-piece machined aluminum construction. A threaded base is permanently fixtured to the base of the motor mount, via a ribbed sleeve which bonds to the outside of the mount via high temperature epoxy. A matching flanged retention cap will then be threaded over the motor's aft closure, firmly securing the Cesaroni Pro75 reload case inside the rocket. The threaded profile and retention cap flange will match the off-the-shelf Aeropack design but be custom machined from 6061-T6 aluminum alloy with a modified exterior profile, to integrate the retention system with a truncated conical aerodynamic tail cone. Stress analysis was performed on the retention sleeve as shown in *Figure 4.6.6* with an expected max thrust of 244.16 lbf, resulting in a minimum safety factor of 68, an order of magnitude above any danger of structural failure.

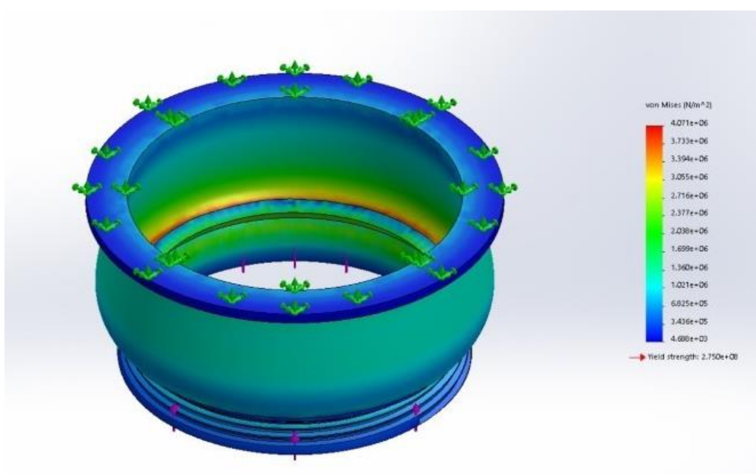


Figure 4.6.6 Stress Analysis of the Retention Sleeve

The tail cone serves to shield obtrusive retention components from the flow of air over the rocket body and reduce drag. The upper section of the tail cone will be 3d printed from MatterHackers NylonX filament and will bolt to the bottom of the thrust plate. The lower section, as discussed, will be part of the machined 6061 aluminum alloy cap flange to better withstand the heat of the motor. The tail cone will be designed to handle the impact of landing in the case that the airframe section lands on the tail, protecting the reloadable motor hardware.

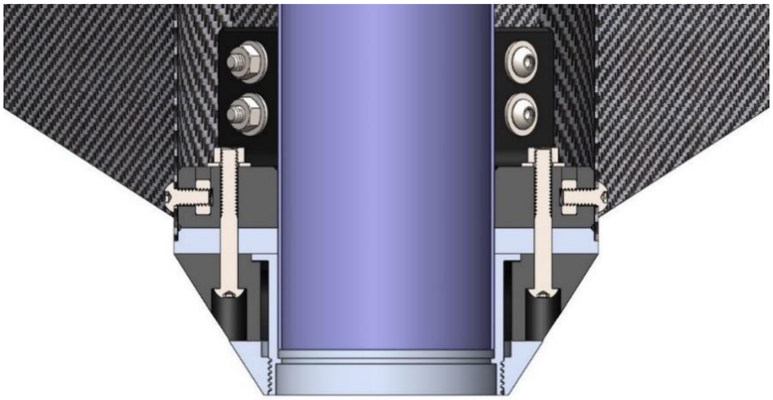


Figure 4.6.7 Diagram Showing a Cutaway View of the Tail Cone Assembly

Section 4.7 Projected Motors

The L910-P is an L class 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 2.95 in. As can be seen in Table 4.7.1 and Figure 4.7.1 the L910 has a total impulse of 2856 Ns ensuring a higher chance of success with the competitions one mile Above Ground Level (AGL) target altitude.

Average Thrust	907.1 N
Class	11.6% L
Delays	Plugged Seconds
Designation	L910-P
Diameter	75.0 mm
Igniter	E-Match
Length	350.0 mm
Letter	L

Manufacturer	CTI
Name	L910
Peak Thrust	1086.1 N
Propellant	APCP
Propellant Weight	1270 g
Thrust Duration	3.15 s
Total Impulse	2856.1 Ns
Total Weight	2,615.8 g
Type	Reloadable

Table 4.7.1 L910-P Specifications

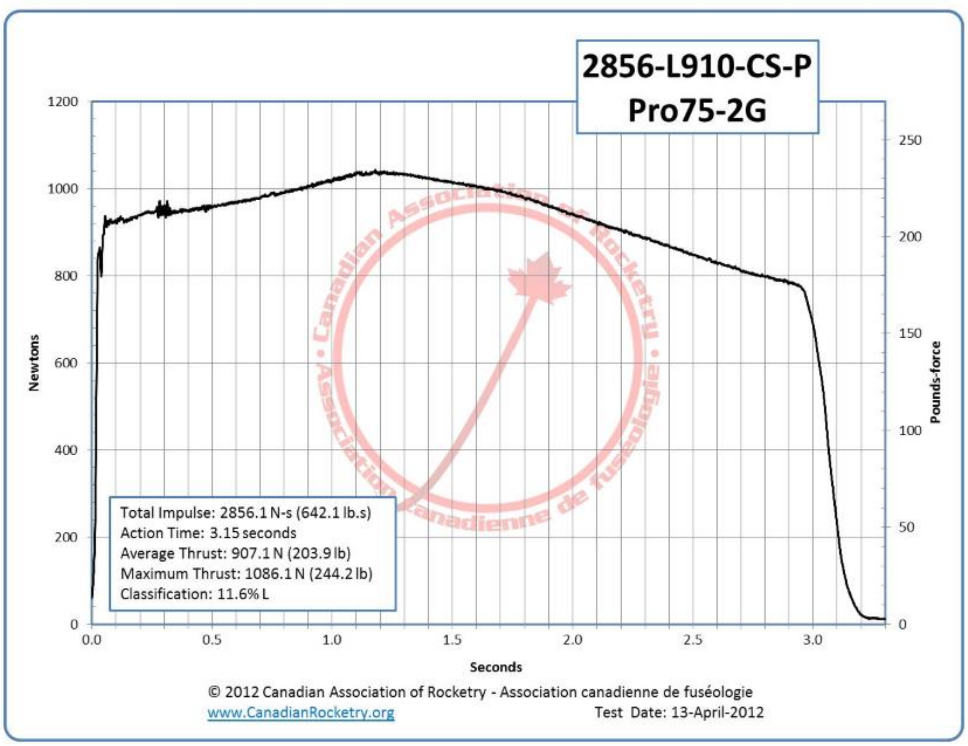


Figure 4.7.1 L910-P Thrust Over Time

The L645-P is an L class 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 2.95in. As can be seen in Table 4.7.2 and Figure 4.7.2 the L645-P has a total impulse of 3419 Ns. 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	644.8 N
Class	33.6% L
Delays	Plugged Seconds
Designation	L9645-P
Diameter	75.0 mm
Igniter	E-Match
Length	486.0 mm
Letter	L
Manufacturer	CTI
Name	L9645
Peak Thrust	776.6 N
Propellant	APCP
Propellant Weight	2072 g
Thrust Duration	5.3 s
Total Impulse	3419.8 Ns
Total Weight	3751.8 g
Type	Reloadable

Table 4.7.2 L645-P Specifications

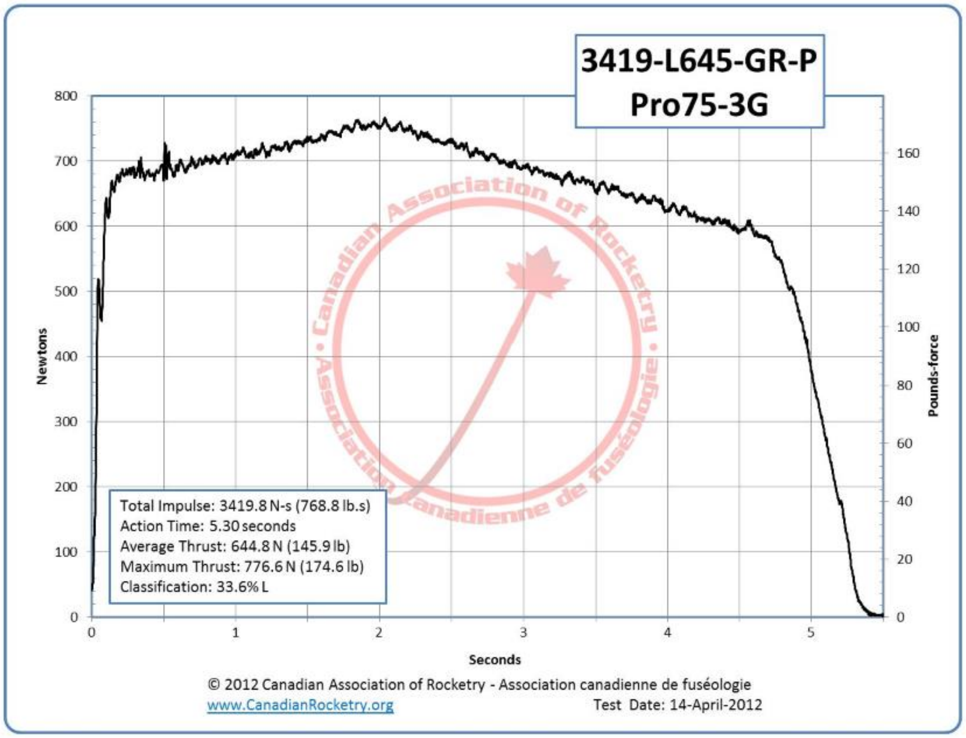


Figure 4.7.2 L645-P Thrust Over Time

Section 4.8 Projected Electronics Bay

The electronics bay will house the StratoLogger altimeters 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 perform a specific set of beeps to communicate the continuity of the charges and confirm proper orientation within the launch vehicle. The StratoLogger is a robust and accurate altimeter with a simple cost-effective design that is sufficient for our purposes. It is designed for the intent of use in rockets that use a dual-deploy system, while collecting the data needed precisely while also being easy to use. The Stratologger does not have an accelerometer, but we deemed this unnecessary for the data collection needed. Since when the rocket reaches its maximum height and begins its descent in a curved motion, the accelerometer data may become inaccurate due to the accelerometer measuring the altitude as it is only moving in a straight line and doesn’t take into consideration the curve of the descent. The Stratologgers will be shielded to decrease the effect of charges upon air pressure data.

A one or two cell lithium polymer (LiPo) battery will be used this year as opposed to the previously used 9-volt batteries. These LiPo batteries have the highest energy density per weight and are very compact. LiPos are better at handling the forces of launch so they can be reliably reused while 9-volt batteries get less reliable after every launch due to the forces and power draw from pyro ignitions. LiPos are much more resistant to the cold and will be used since our test launches will be done in the northern winter months making it more reliable. The LiPos will be physically shielded due to probable high temperatures, forces and pressure during flight.

The components used within the electronic bay this year have been improved or stayed in use from the previous year. The global positioning system (GPS) NEO-6MV2 is chosen due to its compact design and excellent cost effectiveness. In addition, the MPU-6050 will be used as a gyroscope, it combines a 3-axis gyroscope and a 3-axis accelerometer. Even though it requires careful calibration, it's small size and low latency performance make it the most desirable choice. The Arduino Nano microcontroller board is selected due to its compact small size, low mass, and ease of use. The Arduino Nano will efficiently receive data from our GPS and transmit it to our radio frequency (RF) transceiver. The breakout board will be used for receiving an input and output of data easily through the electrical components. Furthermore, the Adafruit RFM95W Long Range (LoRa) 915MHz Radio Transceiver performs well with the Arduino. High speed data transfer and long-range coverage make it the ideal choice for this build.

The altimeters and batteries, along with the launch vehicle's chosen components, will be secured using a 3D printed mounting plate, screws, and washers to a sled. A custom 3D printed sled is being developed for the efficient organization of our components. The sled will be printed with PLA filament with a 50% infill for structural stability and cost effectiveness. The physical layout of the electronic bay will adopt a more modular style, with divots sized for each of our components to protect and allow for easy removal of our components. The main and secondary LiPos will fit tightly in 3D printed containers which will slide and screw into the sled. The sled design is an I-beam with two threaded rods running laterally through it. The sled will organize the components of the electronics bay using channels for wires and individual depressed slots. For ease of access and efficient use of space the components will be on both sides of the sled, with the batteries, altimeters, and pyros on one side, with trackers and antennas on the reverse side with the circuit board. Both the rocket tracker and the Stratologgers will be shielded from the other electronics with a metal plate on the I-Beam. This will prevent the charges from effecting the static air pressure data. This modular design will improve ease of access on both moving components and the sled itself.

Section 4.9 Recovery System

The recovery system will consist of three parachutes to slow down the launch vehicle. All parachutes will be stored in the top of the middle airframe. The drogue parachute will deploy at apogee and be stored in between the main parachutes in the middle airframe. The purpose of the drogue parachute is to slow the descent of the launch vehicle until the main parachutes are deployed so the main parachutes do not experience a high impulse upon deployment.

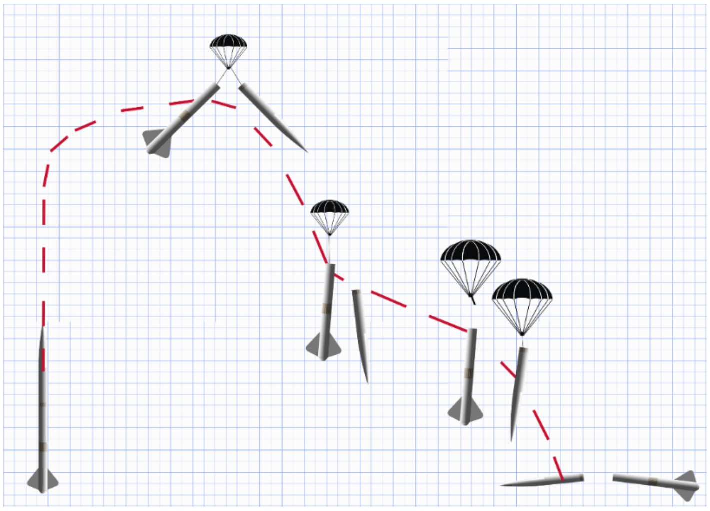


Figure 4.9.1 Recovery Profile

Once the drogue parachute is deployed, a drag force upwards will begin to slow the launch vehicle down until it reaches a terminal velocity, which is slower than the terminal velocity if there was not a drogue parachute. Once the system reaches terminal velocity the weight of the system will be equal to the drag of the system. At this point the vehicle is no longer accelerating. The weight is equal to the mass of the launch vehicle and the parachute multiplied by acceleration due to gravity. In order to determine the radius of the parachute needed, we can use the equation to calculate drag and rearrange it to solve for the radius.

Though there are many resources online to calculate the radius necessary for a parachute, it is important to understand the process. The University of Idaho walks through the process of calculating this in their "Sizing a Parachute" article online. When the launch vehicle starts from rest at apogee, it will accelerate to a terminal velocity at which point it will have no acceleration and therefore a net force of zero. At that point, the weight (W) will be equal to the drag force (D).

$$W = D \tag{1}$$

The equation for weight, in general form, is mass (m) multiplied by acceleration (a). In this case, we know the acceleration is just the force of gravity on the system.

$$W = ma = mg \tag{2}$$

The drag force is calculated using the coefficient of drag (C_d) of the parachute, the area of the parachute (A_p), density of the fluid (ρ), in this case air, and relative velocity of the fluid (v).

$$D = \frac{1}{2} C_d A_p \rho v^2 \tag{3}$$

Knowing the equation for area of a circle, we can equate the equations for weight (2) and drag (3) and solve for the radius of the parachute.

$$r = \sqrt{\frac{2mg}{C_d A_p v^2}} \tag{4}$$

Through this process, and confirmed through online resources, we have decided on tentative radii for the three parachutes we will be using. The drogue parachute will have a canopy diameter of 24in, an upper main of 40in, and a lower main of 48in. These numbers are subject to change due to change in weight of the launch vehicle design. All the parachutes will have a canopy made of ripstop nylon (67g/m^2). The parachutes will be attached to the airframe sections using 1 in width tubular nylon shock cord with a total length of 250 in.

Section 4.9.1 Projected Flight Plan

The projected flight plan of our launch vehicle was simulated using OpenRocket. The launch vehicle will reach an apogee of 5015 ft at 17.2s, a maximum acceleration of 271 ft/s^2 at approximately

2.5 s, a max velocity of 685 ft/2 at approximately 3s. The main parachutes are deployed at 550 ft at approximately 17s while moving at a downward velocity 88.1 ft/s.

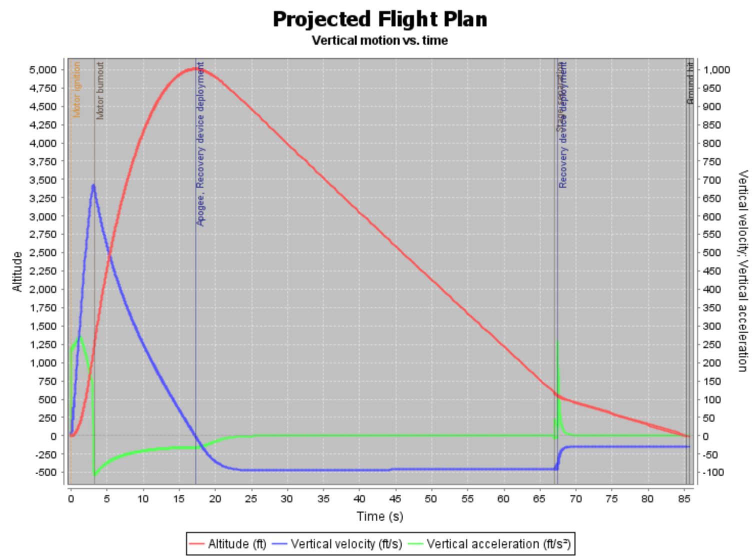


Figure 4.9.1.1 Diagram showing the projected flight plan over altitude, vertical velocity and vertical acceleration

The graph below shows the stability of the launch vehicle over time. The stability of the launch vehicle on real exit is 2.155cal and the maximum stability of approximately 3.5 cal at just over 3 s.

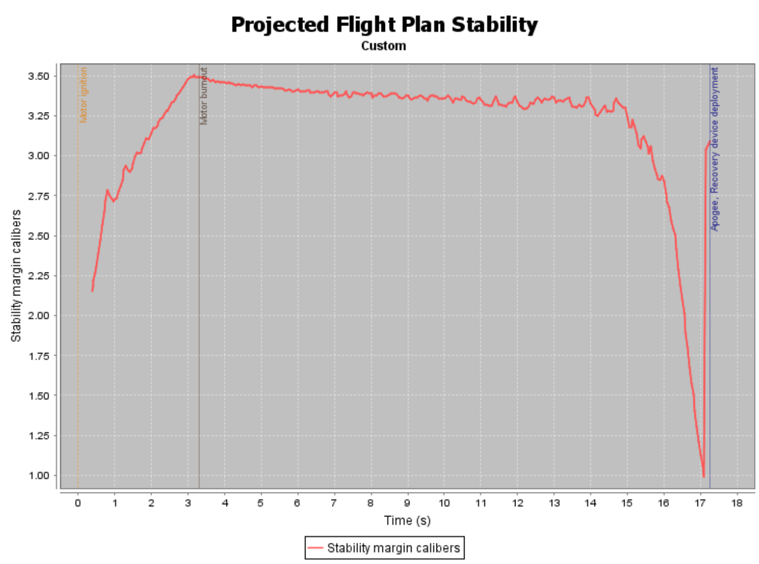


Figure 4.9.1.2 Diagram showing the Stability of the rocket over the project flight plan

Section 4.10 Subscale

A rocket subscale will be used to show proof of concept of our rocket. The subscale will provide an opportunity to assess various aspects of our design and to observe any areas where improvements are needed before scaling up to the full-sized model. We have chosen to make our subscale a two-thirds scale which should give ample room to test the electronics and recovery system.

Section 4.10.1 Nose cone

Our rocket subscale will be using a smaller nosecone made from plastic instead of fiberglass and will still be ogive in shape. The subscale nosecone will be approximately 21 inches in length with a shoulder length of approximately 4.75 in. Additionally, the nosecone will not have an aluminum tip.

Section 4.10.2 Airframe

The airframe of our subscale will use a 4 in diameter Blue Tube or a carbon-fiber reinforced phenolic. We are waiting to hear back from a company who would provide us with a service sponsorship of making our carbon fiber airframe for the full-scale launch vehicle. If we are not able to acquire carbon fiber tubes, we would use Blue Tube.

Section 4.10.3 Electronics Bay

The electronics bay (E-bay) of the subscale will contain fewer components than the full-scale rocket. The subscale E-bay will only house two altimeters, a GPS, two black power charges, and two 9-volt batteries. The altimeter will track the rocket's height and deploy a parachute at apogee, with the black powder charge to separate the air frame. The GPS will be used for tracking and recovering the subscale. These electronic components will be fitted into a custom designed sled that will be easily accessible and removable from the subscale. One alterative design that may be used is a parachute bag which would require a third altimeter also located in the electronics sled.

Section 4.10.4 Fins and Fin Can

The fins of the will be a 2/3 scale of the final fin design. The fins for the subscale will either be made of a carbon fiber exterior with a foam interior or be cut out of carbon plates, as in the full-scale. The subscale test should prove the reliability of our construction method. We are also going to use a fin can in the subscale as a proof of concept of our design, as this would be the team's first time using one.

Section 4.10.5 Recovery System

The recovery system for our subscale will be similar to the full scale. We will have our drogue deploy at apogee like in the full scale, but we will only have one main parachute deploying at approximately 550ft, adjusting to replicate full scale conditions. Because will are not going to have the detachment for the main parachutes, we will likely need a larger single parachute than either of the individual parachutes. In the subscale test, we want to ensure that the parachutes have no problem being deployed at the velocity the launch vehicle we reach by that altitude.

The calculations for the parachute sizes has not been finalized at this time. If the parachutes are scaled linearly by the 2/3 ratio, the drogue parachute will have a diameter of 16 in and the main parachute will have a diameter of 32 in.

Section 4.11 Technical Challenges

One major technical challenge faced by our team was designing the recovery system in such a way that allowed the vehicle to remain within the 90 second descent time limit, while not exceeding safe opening speeds for the main parachutes. To find a balance, our team utilized OpenRocket Simulation software to test a variety of different parachute configurations and deployment altitudes. Our team also investigated and decided on using a Tender Descender, a main parachute release device allowing for dual deployment from the same canister. The Tender Descender allows for a separation of the rocket into 2 separate, unconnected components just before main chute deployment, allowing for both smaller, and therefore cheaper, main parachutes, and aiding in keeping the descent time under 90 seconds.

Another technical challenge faced was the development of a removable fin can system, allowing for component modularity and repair and simplified/reduced cost shipping. While an epoxied motor mount and fins are mechanically simpler than a fin can, the loss in precision, ease of component repair, and modularity are major downsides, along with its increased weight. To solve the problem, our team designed an innovative system incorporating 3D printed fin brackets, a thrust plate, tail cone, and a custom motor retention system inspired by an Aeropack RA75 retention system integrated into the tail cone. This allows for the desired modularity, with only one component requiring any epoxy at all, while incorporating a tail cone design as an added benefit.

Following the difficulties encountered with the payload retention system in our previous year's rocket, this year the team set out to design a radically different system for payload retention. Changing from the unfolding petal design of last year, the team designed a fully mechanical payload sled that is actively deployed with the nosecone of the rocket upon landing and raises up to give the UAV room to maneuver. The system is mechanically oriented upon landing to prepare the UAV for liftoff, accounting for all possible landing orientations.

Section 4.12 Technical 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.

Section 4.12.1 Launch Vehicle Requirements

- The launch vehicle must deliver the payload to an apogee altitude between 3,500 ft and 5,500 ft
- Identify target altitude by PDR milestone
- The launch vehicle must carry one barometric altimeter for determining official altitude
- The launch vehicle will be recoverable and reusable
- The launch vehicle will have a maximum of 4 independent sections

- Couplers/airframe shoulders located at in-flight separation points will be at least 1 body diameter in length
- Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length
- Launch vehicle capable of being assembled in 2 hours
- Launch vehicle capable of sitting on launch pad for a minimum of 2 hours
- Launch vehicle capable of being launched by a standard 12-volt direct current firing system
- The launch vehicle will require no external circuitry or special ground support equipment to initiate launch
- The launch vehicle will use a commercially available motor propulsion system using APCP which is approved and certified by the NAR, TRA, or CAR
- Final motor choices will be declared by the CDR milestone
- Any motor change after CDR must be approved by NASA RSO
- The launch vehicle will be a single stage
- The total impulse will not exceed 5,120 Newton-seconds (L-class)
- Pressure vessels will be approved by RSO
- The minimum factor of safety will be 4:1 with supporting design documentations included in all milestone documents
- Each pressure vessel will include a pressure relief valve capable of withstanding the maximum pressure and flow rate of the tank
- The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include number of pressure cycles, dates of pressurization, and name of person administering each pressure event
- The launch vehicle will have a minimum static stability margin of 2.0 cal at the point of rail exit.
- Any protuberance on the rocket will be located aft of the burnout center of gravity
- The launch vehicle will accelerate to a minimum velocity of 52 ft/s at rail exit
- All teams will successfully launch a subscale model of their rocket prior to the CDR milestone.
- The subscale should resemble and perform as similarly as possible to the full-scale model
- The subscale will carry an altimeter capable of recording the model's apogee altitude
- The subscale must be a newly constructed rocket
- Proof of subscale flight will be supplied in the CDR. Altimeter data may be used to meet this requirement
- Launch vehicle that will be used for the final launch will be the one reused from previous launch tests.
- Launch vehicle recovery system will function as designed
- The full-scale launch vehicle is a newly designed rocket from last year's competition
- Payload does not need to launch with the final launch vehicle
- If payload is not used, a simulated mass will be used in its place at the approximate same location
- If the payload changes 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
- Teams shall fly the launch day motor for Vehicle Demonstration Flight
- The vehicle must be flown in its fully ballasted configuration during the full-scale test flight.
- Launch vehicle will not be modified after test flight
- Proof of successful flight will be supplied in the FRR document. Altimeter data is required.
- Vehicle Demonstration Flight must be completed by FRR

- All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the FRR deadline.
- The payload must be fully retained until the intended point of deployment, all retention mechanisms must function as designed, and the retention mechanism must not sustain damage.
- The payload must be flown in the final active version
- The team’s name and launch day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe
- All Lithium Polymer batteries will 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.
- The launch vehicle forward canards. Camera housings will be exempted, provided the team can prove the cause minimal aerodynamic effect on the rocket's stability.
- The launch vehicle will not utilize forward firing motors
- The launch vehicle will not utilize motors that expel titanium sponges
- The launch vehicle will not utilize hybrid motors
- The launch vehicle will not utilize a cluster of motors
- The launch vehicle will not utilize friction fit for motor retention
- Transmissions from onboard transmitters will not exceed 250 mW of power per transmitter
- Transmitters will not create excessive interference
- Excessive and/or dense metal will not be utilized in the construction of the launch vehicle

Section 4.12.2 Recovery System Requirements

- 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
- 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 cal 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 rocket

Section 4.12.3 Payload Requirements

- 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 be deployed upon the ground after clearance from the RSO
- The payload will utilize a mechanical retention system.
- The UAV will extract a soil sample no less that 10mL
- The UAV will transport the collected soil sample at least 10ft away from the collection area

Section 5 Educational Engagement

Educational outreach is one of the most vital aspects of the entire WPI USLI project. As the competition within itself is a learning experience one of our goals is to share this learning with others, specifically younger students interested in Science, Technology, Engineering, and Mathematics (STEM) fields. Our current endeavors in the scientific community are for the purpose of creating a better future, younger children and students are a part of this future, so it is important to us that we get them as involved as possible in exploration and science. Our goal through this outreach process is to inspire as many young people as we can to pursue a career in STEM and make their learning experience as entertaining and engaging as it possibly can be.

Throughout the 2019-20 school year, our team is planning middle-school outreach events to engage students in STEM. To meet these goals, each of our team members are required to fill an outreach quota per semester. Members will partake in special events such as middle school field trips to WPI's campus for STEM activities, off-campus mentoring for children in surrounding grade schools, and other after school programs.

Section 5.1 Plan for Educational Engagement Activities

1. Pre-Collegiate Outreach Programs (POP) collaboration: The WPI POP hosts STEM Saturdays several times throughout the year. These are day long events that connect with middle schoolers and their parents. The team plans to continue running activities such as egg drops, and rocket launches through this program this school year.
2. Women of Aeronautics and Astronautics (WOAA) collaboration: Like USLI, WOAA is a subcommittee of the WPI 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.
3. Introduce A Girl to Engineering Day: Introduce a Girl to Engineering day is a half-day workshop run by POP 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.
4. STEM Week Big Brothers Big Sisters: This year our team will be volunteering at Big Brothers Big Sisters' STEM week. We will be sending groups of members to two elementary schools near WPI to complete activities themed around environmental stewardship with children and their mentors.
5. Bigs (mentors): Through Big Brothers Big Sisters: This year members have the opportunity to become bigs and are matched with a child from Elm Park Elementary School which is close to WPI. They meet once a week with their matched child to set goals, play some games, chat, and generally hang-out. Bigs are meant to be guides and resources.

Section 5.2 Evaluation Criteria for Engagement Activities

The success of each event will be determined by the number of youths reached, as well by the amount of new knowledge and skills kids gained during the event. Our teams' main goal is to make each activity spark kids' interest in STEM. Our secondary goal is to provide a platform and materials accessible to everyone who wants to learn more about space, rocket flight and other areas of STEM.

Based on knowledge gained by the 2018-19 USLI team, we created a system to make sure that outreach events run successfully and every member on the team is able to make a meaningful contribution. The parameters of the system are as follows:

1. WPI has a four-term schedule, with three terms before the USLI competition and for the second and third term each team member must complete a minimum requirement of participating in two outreach events.
2. All events prior to the second term count towards bonus attendance points, those points are needed in order to attend the event in Huntsville.
3. Members who are participating in the Big Brothers Big Sisters program fulfil their engagement requirement, since being a Big is a large commitment.

We hope that it will help us to ensure a smooth run of events, since we will always have enough members attending. It will also bring diversity into events, since every member will be attending them, not only people who know they are good at doing them.

Section 6 Project Plan

Section 6.1 Timeline

Table 6.1.1 shows the major milestones of the project and what key tasks must be completed to meet their deadlines. To supplement this, a Gantt chart is available in Appendix Section A which shows a more granular view of the competition plan. As the project goes on, the Gantt chart will be continually updated.

Timeline		
Milestone	**Requirements**	**Due Date**
Preparation for Competition	Host team workshops Set up subteams	10/3/19
Preliminary Design Review (PDR)	Create initial full CAD models for rocket and payload. Narrow down design choices for rocket and payload. Perform analysis, including simulation, calculation, and testing, of choices. Declare Target Altitude Create preliminary Personal Hazard Analysis, Failure Modes and Effects Analysis, and Environmental Risk Analysis. Create team derived requirements. Begin prototyping of rocket and payload subsystems. Write and prepare presentation and report.	11/1/19
Critical Design Review (CDR)	Construct and Launch Subscale Finalize design of rocket and payload. Perform more in-depth analysis and testing of the finalized design and its subsystems to determine possible failure modes and improve designs. Create assembly and launch procedures. Create requirements verification plan for both NASA and team derived requirements. Update Personal Hazard Analysis, Failure Modes and Effects Analysis, and Environmental Risk Analysis. Create flysheet	1/10/20

	Write and prepare presentation and report.	
Flight Readiness Review (FRR)	Execute requirements verification plan. Finalize Personal Hazard Analysis, Failure Modes and Effects Analysis, and Environmental Risk Analysis. Make final design modifications Construct final Payload and Rocket. Complete full-scale test flight. Write and prepare presentation and report.	3/2/20
Launch Readiness Review (LRR)	Simulate and Calculate final predictions for flight path, drift, center of pressure, and center of gravity. Review flight procedures and safety checklists and present them. Inspect rocket and payload to ensure readiness for final flight. Write and prepare and report and pass inspection.	4/1/20
Post-Launch Assessment Review (PLAR)	Analyze flight data. Assess mission performance and whether or not the team met mission success criteria. Create a lessons learned document to be passed on to next year's officer board. Write and prepare and report.	4/27/20

Table 6.1.1 Timeline

Section 6.2 Budget

This is our estimated budget for the USLI Competition year of 2019 – 2020. Our USLI Subcommittee was allocated a budget of $4,100.00 through our AIAA Chapter. We understand that this budget may not be enough for all the components listed below or will be needed in the future. We plan to submit additional funding requests to our Student Government Association, gain sponsors, and fundraise.

Section 6.2.1 Full Scale and Subscale Rocket Components

Full Scale						
Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Nose Cone	6" Fiberglass Nose Cone	0	$139.00	$0.00	AMW Pro-X	Already Owned
Nose Cone	Metal Tip for DX3 Massive	1	$20.00	$20.00	MadCow Rocketry	
Parachute Deployment	Tender Descender	1	$129.00	$129.00	Tinder Rocketry	
Parachute Deployment	Chute Release	2	$129.95	$259.90	Jolly Logic	
Main Tube	Blue Tube 2.0 6"x0.074"x48"	2	$66.95	$133.90	Always Ready Rocketry	Airframe
Centering Rings	Plywood ½"x2'x4'	4	$15.50	$62.00	Home Depot	
Fins	Luminier 3k Carbon Fiber Sheet 5mm Thick 400mm x 500mm	1	$159.99	$159.99	Get FPV	Cheaper options being considered
Motor Tube	Blue Tube 2.0 54mm x .062"x48"	2	$23.95	$47.90	Always Ready Rocketry	Airframe
Inner Tube	Blue Tube 2.0 6'x0.077"x 48"	1	$66.95	$66.95	Always Ready Rocketry	
Motor Case	CTI 75-3 Grain Case	1	$201.99	$201.99	CSRocketry	
Flight Computer	StratoLogger CF	3	$61.06	$183.18	Apogee Rockets	
Arming Switch	Mini On/Off Push-Button Switch	4	$.95	$3.80	Adafruit	
Wiring	Wiring	0	$5.00	$0.00	WPI	Already Owned
Main Engine	Cesaroni L910 C-Star Rocket Motor	3	$157.99	$437.97	CSRocketry	-
Backup Engine	Cesaroni L645 Green3 Rocket Motor	0	$224.99	$0.00	CSRocketry	Will buy as needed

Separation Charges	Black Powder Charges	0	$0.00	$0.00	WPI	Already Owned
Shear Pins	2-56x1/2” Nylon Screws	0	$10.64	$0.00	McMaster-Carr	Already Have (100)
Rail Buttons	Large Airfoiled Rail Buttons (fits 1.5” rail – 1515)	2	$11.17	$22.34	Apogee Rockets	
Nomex Blankets	Sunward 18in Nomex Blanket	2	$10.91	$21.82	Apogee Rockets	
Igniter	Full Scale Igniter	0	$0.00	$0.00	WPI	Already Owned
Parachutes	24” Drogue	1	$19.00	$19.00	Spherachutes	
Parachutes	40” Upper	1	$44.00	$44.00	Spherachutes	
Parachutes	48” Lower	1	$50.00	$50.00	Spherachutes	
Shock Cord	BlueWater 1" Climb-Spec Tubular Webbing - 30 ft.	1	$13.50	$13.50	REI	
U-Bolt	U-Bolts	0	$0.00	$0.00	WPI	Already Owned
Drop Cover	10 ft. x 25 ft. Clear 3.5 mil Plastic Sheeting (2-Pack)	1	$17.98	$17.98	Home Deopt	
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 Painters Tape	ScotchBlue 1.88” x60yds	0	$6.58	$0.00	Home Depot	Already Owned
Gorilla Tape	Gorilla 1-7/8x35yds	0	$8.98	$0.00	Home Depot	Already Owned
Organizer	15-Compartment Interlocking Small Parts	1	$11.97	$12.72	Home Depot	2 pack

	Organizer in Black					
TOTAL				$1907.94		
Subscale						
Main Tube	4”x0.062”x48”	2	$38.95	$77.90	Always Ready Rocketry	
Nose Cone	Fiberglass 4" Filament Wound 5:1 Ogive	1	$79.95	$79.95	Madcow Rocketry	
Motor Tube	1.15”x.062”x24”	1	$6.25	$6.25	Always Ready Rocketry	Estimated from last year - TBD
Inner Tube	2.15”x0.062”x8”	1	$8.95	$8.95	Always Ready Rocketry	Estimated from last year - TBD
Motor Casing	CTI 38mm 6xl-grain case	1	$76.56	$76.56	Apogee Rockets	
Subscale	4" Dia. Braided Carbon Fiber Sleeve (5ft)	2	$73.75	$147.50	ACPScales	
Subscale	4" Phenolic Tube 36" long	2	$20.99	$41.98	Rocketarium	
Wiring	Wiring	0	$0.00	$0.00	WPI	Already Owned
Parachutes	18” Drogue	1	$15.00	$15.00	Spherachutes	Approx
Parachutes	24” Upper	1	$19.00	$19.00	Spherachutes	Approx
Parachutes	30” Lower	1	$27.00	$27.00	Spherachutes	Approx
Motor	CTI P38-6XLG SMOKY SAM (J580)	1	$93.76	$93.76	Apogee rockets	
Separation Charges	Black Powder Charges	0	$0.00	$0.00	WPI	Already Owned
Overhead	Miscellaneous Bits	1	$100.00	$100.00	Various	
TOTAL				$693.85		

Table 6.2.1.1 Full Scale and Subscale Rocket Components

Section 6.2.2 Payload Components and Total

Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Processor	Arduino Nano	3	$22.00	$66.00	Arduino	
UAV Battery	Turnigy 2200mAh 4S 40C Lipo Pack	1	$24.94	$24.94	Hobby King	
Payload LiPo Battery	ZIPPY Compact 1000mAh 3S 35C Lipo Pack	1	$7.47	$7.47	Hobby King	
Retention System Board	Adafruit Precision NXP 9-DOF Breakout Board - FXOS8700 + FXAS21002	1	$14.95	$14.95	Adafruit	
Retention Motor	1000:1 Micro Metal Gearmotor HP 6V	1	$22.95	$22.95	Pololu	
Motor	4X Racerstar 2306 BR2306S Fire Edition 2400KV 2-4S Brushless Motor For 210 220 250 300 RC Drone FPV Racing	1	$38.50	$38.50	Banggood	
Flight comp	Diatone Mamba F722S Stack - 506 50A Dshot1200 6S ESC	1	$79.99	$79.99	GetFPV	

High Gauge Wire	22AWG colored wire	1	$15.99	$15.99	Amazon	
Transceiver	NRF24L01	4	$5.00	$20.00	Amazon	
FPV Camera	FX798T micro FPV camera	1	$30.00	$30.00	GetFPV	Possible option
FPV Monitor	4.3” LM403 LCD FPV Monitor	1	$70.00	$70.00	GetFPV	Possible option
Controller & Receiver	Flysky FS-i6X	1	$54.00	$54.00	Amazon	Possible option
3D Printer Filament	Nylon X	1	$70.00	$70.00	-	
3D Printer Filament	PLA	2	$30.00	$60.00	-	
Propellers	DJI Spark - Quick-Release Folding Propellers (Part2)	4	$9.00	$36.00	Hobby King	
Overhead	Carbon	1	$100.00	$100.00		
TOTAL				$710.79		

6.2.2.1 Payload Components and Totals

Section 6.2.3 Component Budget Totals

Totals	
Full Scale Rocket	$1907.94
Subscale Rocket	$693.85
Payload	$710.79
Logistics	$4000
Total	$7312.58

Table 6.2.3.1 Component Budget Totals

Section 6.3 Funding

A large portion of this year's funding for the 2019-2020 USLI rocketry team will come from corporate sponsors. In addition to this, other modes of funding may come from on campus fundraisers the team holds throughout the year, organized by the philanthropy officer. The Philanthropy Officer is responsible for gathering funds from corporate sponsors and communicating with the Philanthropy Department of WPI to ensure all proper transfer of funds is being done so appropriately.

A campaign is being organized to present corporate sponsorships to companies mainly in the local Worcester area. Each sponsor interested in funding our team will be provided with the selection of several packages. In order of increasing value, Bronze, Silver, Gold and Platinum. Each package is aligned with the amount of money the sponsor decides to fund the team. One of the team's primary goals in funding this year is to create strong and lasting relationships with these sponsors so they will be interested in working with us again in the following competition years. This corporate sponsorship package is approved by the Philanthropy department on WPI's campus before it is presented to our potential sponsors. Through this funding process if the team receives any extra funding this money will roll over to be used in the next competition year in 2020-2021.

In addition to gathering corporate sponsorships WPI's USLI team will also be receiving funds from the AIAA chapter on campus. They receive this money from the Student Government Association (SGA) on campus which is responsible for governing undergraduate organizations on campus. This year, USLI will be the only competitive rocketry team in AIAA so all the funding for high powered rocketry competitions will be going to the USLI team. Any additional funds will have a request submitted to the Student Government Association. SGA is unable to pay for airfare of the team members so the corporate sponsorship funds will be applied to minimize travel expenses.

Section 6.4 Logistics

Team members will be flying to the competition from Boston Logan International Airport to Huntsville International Airport on Wednesday, April 1st, and returning on Sunday, April 5th, accounting for time for a launch date delay to Sunday.

The team has budgeted $4000 dollars towards logistics. The budget includes costs for 24 members to attend the competition and plans to use $3720 of the budget to pay for the hotel rooms. Shipping costs for the rocket make up the remaining budget, of $230. Flight costs and transportation to and from Logan will be paid for by sponsors or, if necessary, students.

Subscale and full-scale test launches will be coordinated under the logistics officer. See section 1.5.2 for a list of launch sites.

Section 6.5 Sustainability

As a Subcommittee of the WPI Student AIAA chapter, the WPI Student Launch team enjoys many benefits that increase the sustainability of the program. The WPI AIAA has a strong presence on campus, being one of the largest clubs. It provides a large audience of students with experience and interest in robotics and aerospace, many of which join AIAA specifically for rocketry. This provides a reliably large recruitment source from which the majority of our members are from. Additional recruitment is done by creating posters to post across campus and via word of mouth. AIAA also provides many opportunities that help members to more actively participate in the team. They provide funding and mentorship to students looking to get level 1 and 2 NAR HPR certifications and run a variety of workshops throughout the year.

Although many changes had to be made to the operating procedures and team structure, the team has a better idea of what to expect going into this year's competition. This has allowed the team's Operating Document to become much more refined. Similar to last year, the team will consist of a Rocket Division and a Payload Division, each lead by a Division Lead. Unlike last year, each division will be further divided into Sub teams, which will focus on a specific task or subsystem in the division. This is expected to improve the distribution of work throughout the team. Every week the team will host one General Team Meeting and at least one meeting for each division. The number of meetings will be increased as necessary to meet deadlines. There is will also be a weekly meeting of the Officer Board open to all members. The team now has much more explicit operational procedures which will reduce ambiguity when making team decisions.

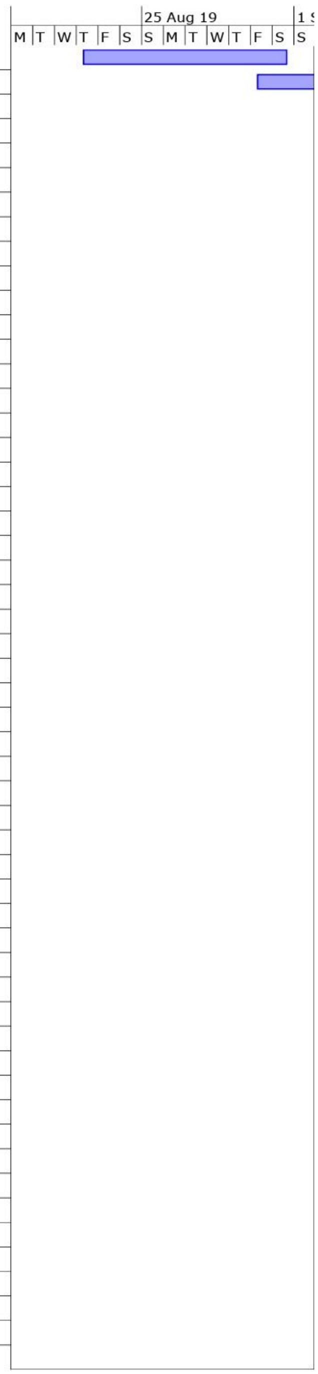
This year we hope to have increased member participation in STEM engagement activities with our partners at Friendly House, Big Brothers Big Sisters, the AIAA and educational engagement programs through WPI. These partnerships allow us as a team to engage with our community and help to inspire the next generation of scientists and engineers. We achieve this through mentorship programs, STEM presentations, events activities focused on core STEM topics and by creating lasting connections between our team and the next generation. Each year we hope to continue and expand our STEM engagement activities so we can sustain a strong connection between our community, the next generation and our team.

Another benefit of being associated not only with the AIAA but the institution of Worcester Polytechnic Institute itself is the multiple resources for the funding of this club. We are the only rocket competition club on campus, and the funding from AIAA has expanded from that of the previous year. The Student Government Association (SGA) allows all clubs to apply for funding requests to make sure sufficient funds are provided for the club's operation. The only thing SGA will not provide funds for is airfare, which we will supplement with sponsorship funds that we are currently searching for. Funding requests applied for this year can also be requested to be included in the budget for next year. Between the given budget from the AIAA, help from the SGA, in addition with sponsorship and fundraising, we believe Worcester Polytechnic Institute's USLI team will be able to sustain this and future competition projects.

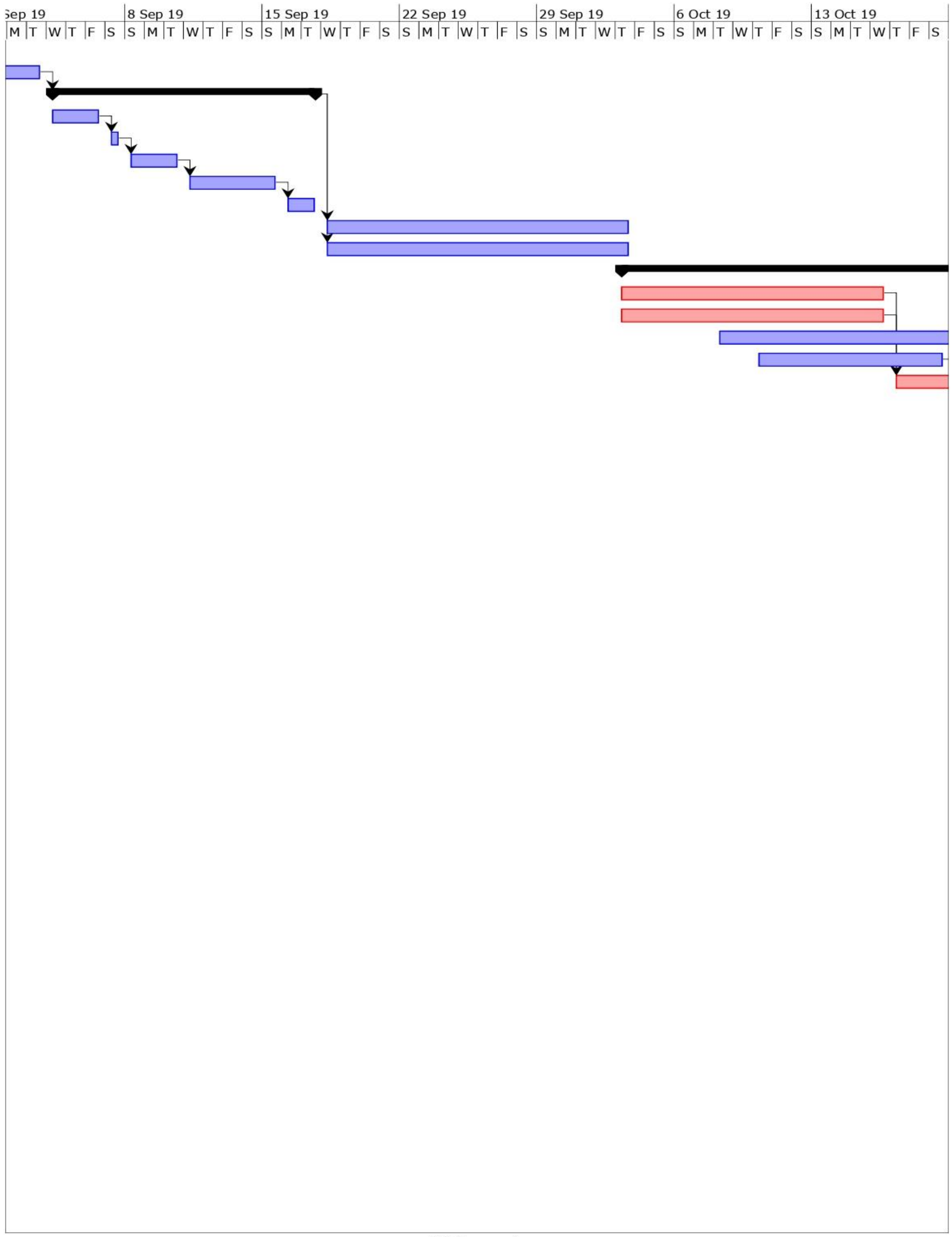
Appendix

Section A

	Name	Duration	Start	Finish
1	Recruiting	10 days	8/22/19 8:00 AM	8/31/19 5:00 PM
2	Orientation	5 days	8/30/19 8:00 AM	9/3/19 5:00 PM
3	**⊟Proposal**	**14 days?**	**9/4/19 8:00 AM**	**9/17/19 5:00 PM**
4	Brainstor...	3 days	9/4/19 8:00 AM	9/6/19 5:00 PM
5	Concept ...	1 day	9/7/19 8:00 AM	9/7/19 5:00 PM
6	Outline	3 days	9/8/19 8:00 AM	9/10/19 5:00 PM
7	Proposal ...	5 days?	9/11/19 8:00 AM	9/15/19 5:00 PM
8	Revision	2 days?	9/16/19 8:00 AM	9/17/19 5:00 PM
9	Workshops	16 days?	9/18/19 8:00 AM	10/3/19 5:00 PM
10	Team Socia...	16 days?	9/18/19 8:00 AM	10/3/19 5:00 PM
11	**⊟PDR**	**28 days?**	**10/3/19 8:00 AM**	**10/30/19 5:00 PM**
12	Rocket D...	14 days?	10/3/19 8:00 AM	10/16/19 5:00 PM
13	Payload ...	14 days?	10/3/19 8:00 AM	10/16/19 5:00 PM
14	Safety D...	18 days?	10/8/19 8:00 AM	10/25/19 5:00 PM
15	Project Pl...	10 days?	10/10/19 8:00 AM	10/19/19 5:00 PM
16	Outline	5 days?	10/17/19 8:00 AM	10/21/19 5:00 PM
17	PDR Writing	7 days?	10/22/19 8:00 AM	10/28/19 5:00 PM
18	Revision	2 days?	10/29/19 8:00 AM	10/30/19 5:00 PM
19	**⊟CDR**	**43.875 day...**	**11/1/19 9:00 AM**	**12/14/19 5:00 PM**
20	Rocket D...	19.875 days?	11/1/19 9:00 AM	11/20/19 5:00 PM
21	Payload ...	19.875 days?	11/1/19 9:00 AM	11/20/19 5:00 PM
22	Safety A...	7 days	11/21/19 8:00 AM	11/27/19 5:00 PM
23	Write Pro...	6.875 days?	11/21/19 9:00 AM	11/27/19 5:00 PM
24	Outline	6 days?	11/28/19 8:00 AM	12/3/19 5:00 PM
25	CDR Writing	9 days?	12/4/19 8:00 AM	12/12/19 5:00 PM
26	Revision	2 days	12/13/19 8:00 AM	12/14/19 5:00 PM
27	Subscale C...	12.875 days?	10/28/19 9:00 AM	11/9/19 5:00 PM
28	Winter Break	31.875 days?	12/15/19 8:00 AM	1/15/20 4:00 PM
29	**⊟FRR**	**47 days?**	**1/15/20 4:00 PM**	**3/2/20 4:00 PM**
30	Rocket R...	13 days	1/15/20 4:00 PM	1/28/20 4:00 PM
31	Payload ...	13 days	1/15/20 4:00 PM	1/28/20 4:00 PM
32	Requirem...	30 days	1/29/20 9:00 AM	2/28/20 9:00 AM
33	Rocket C...	15 days	1/28/20 4:00 PM	2/12/20 4:00 PM
34	Payload ...	15 days	1/28/20 4:00 PM	2/12/20 4:00 PM
35	Full-Scale...	1 day	2/12/20 4:00 PM	2/13/20 4:00 PM
36	Final Desi...	5 days	2/13/20 4:00 PM	2/18/20 4:00 PM
37	Full-Scale...	1 day?	2/18/20 4:00 PM	2/19/20 4:00 PM
38	Outline	3 days	2/18/20 4:00 PM	2/21/20 4:00 PM
39	FRR Writing	8 days	2/21/20 4:00 PM	2/29/20 4:00 PM
40	Revision	2 days	2/29/20 4:00 PM	3/2/20 4:00 PM
41	**⊟LRR**	**31 days**	**3/2/20 9:00 AM**	**4/2/20 9:00 AM**
42	Final Pre...	15 days	3/2/20 9:00 AM	3/17/20 9:00 AM
43	Final Pre...	15 days	3/2/20 9:00 AM	3/17/20 9:00 AM
44	Final Anal...	5 days	3/17/20 9:00 AM	3/22/20 9:00 AM
45	Outline	4 days	3/22/20 9:00 AM	3/26/20 9:00 AM
46	LRR Writing	5 days	3/26/20 9:00 AM	3/31/20 9:00 AM
47	Revision	2 days	3/31/20 9:00 AM	4/2/20 9:00 AM
48	Competition	4.875 days?	4/1/20 9:00 AM	4/5/20 5:00 PM
49	**⊟PLAR**	**22 days?**	**4/6/20 8:00 AM**	**4/27/20 5:00 PM**
50	Analysis ...	10 days?	4/6/20 8:00 AM	4/15/20 5:00 PM
51	Lessons L...	3 days	4/16/20 8:00 AM	4/18/20 5:00 PM
52	Outline	3 days	4/19/20 8:00 AM	4/21/20 5:00 PM
53	PLAR Wri...	5 days	4/22/20 8:00 AM	4/26/20 5:00 PM
54	Revision	1 day	4/27/20 8:00 AM	4/27/20 5:00 PM



USLI - page1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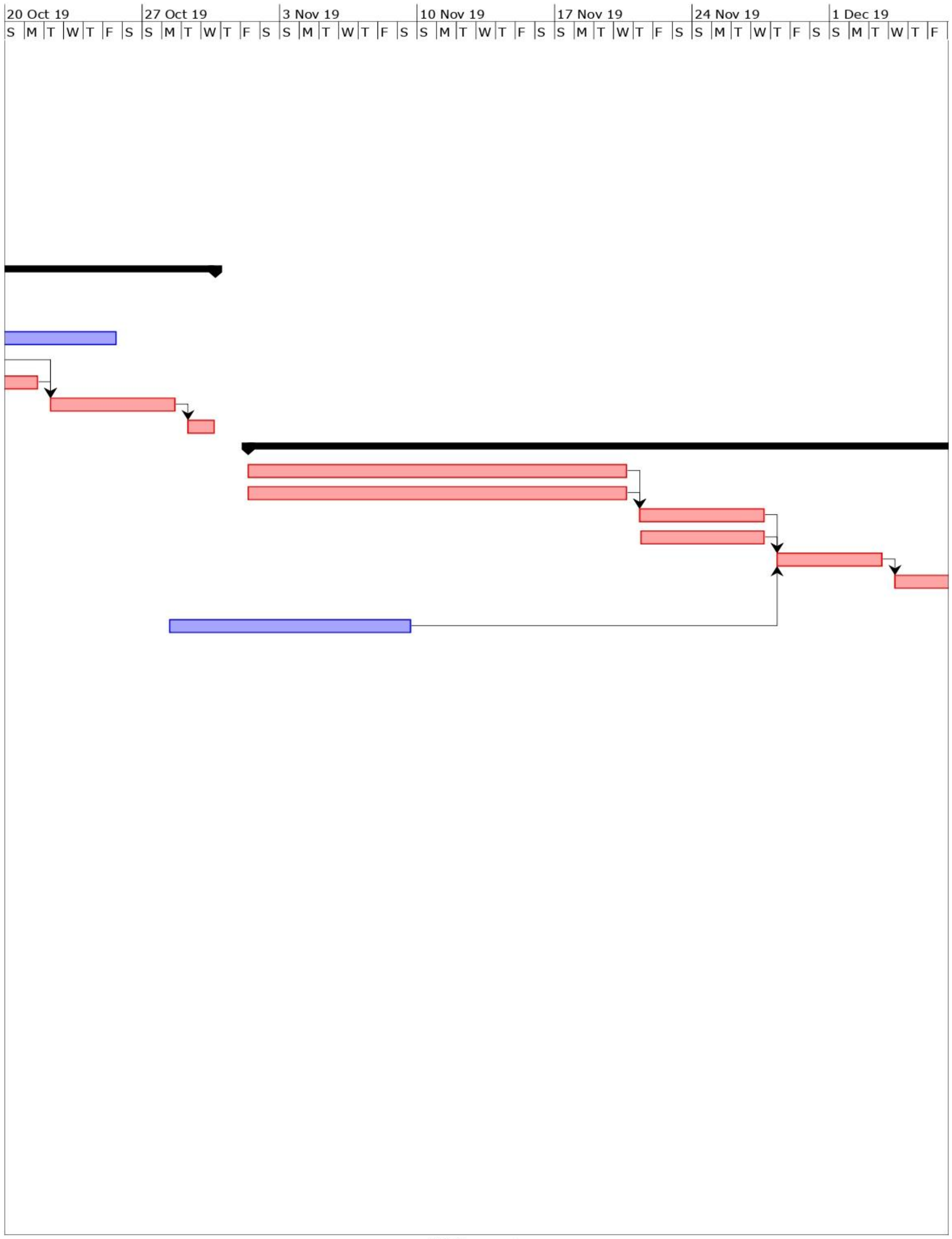

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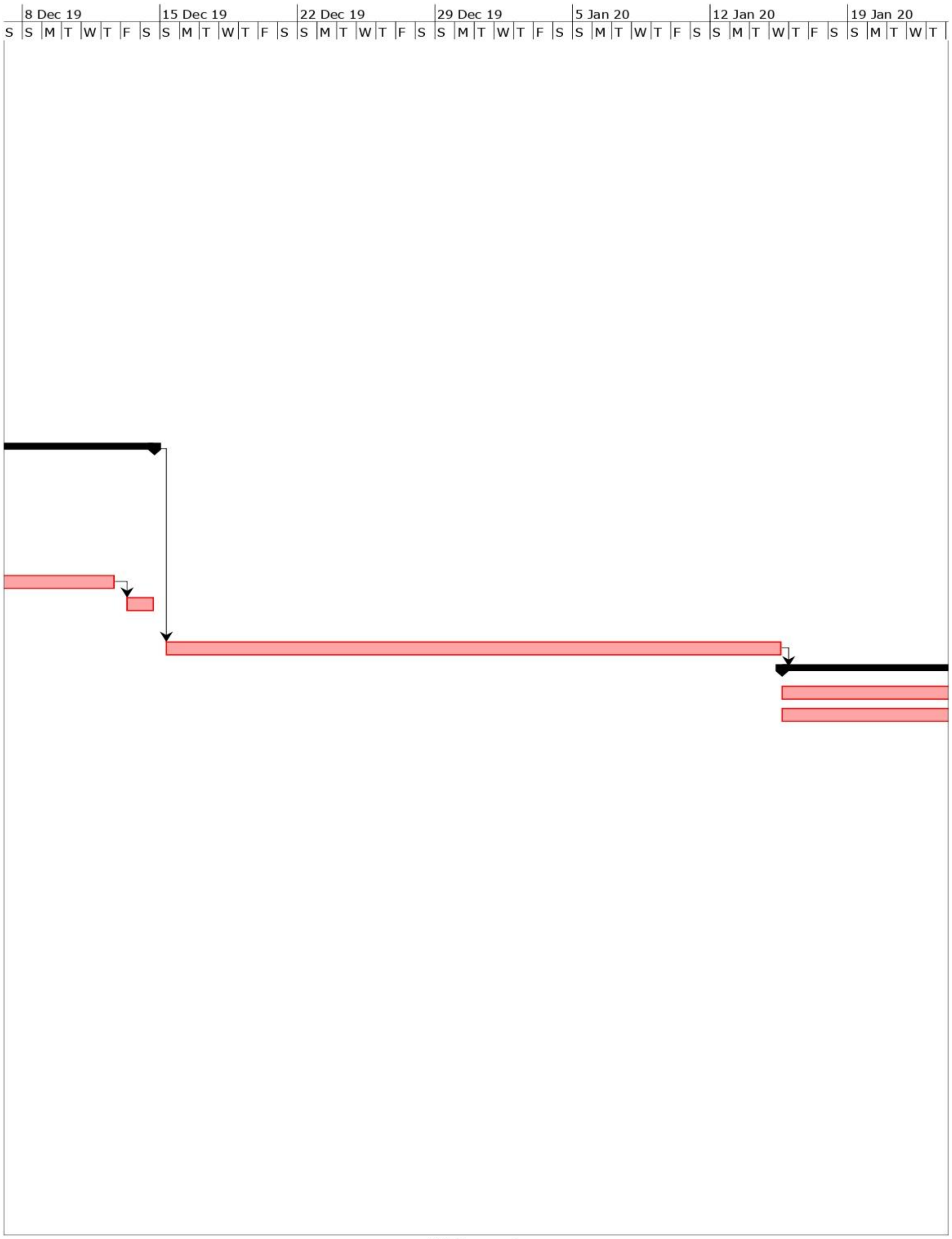
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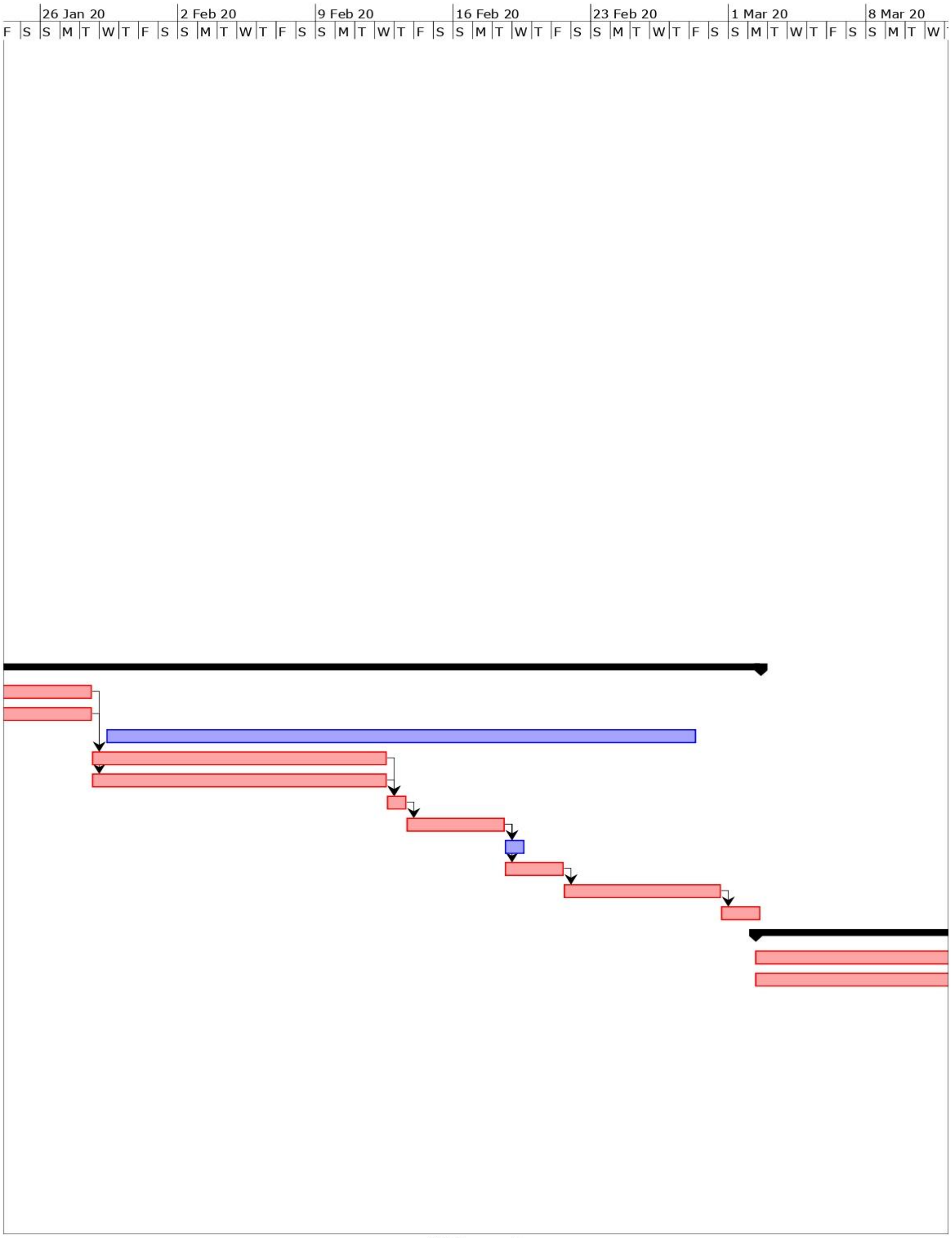
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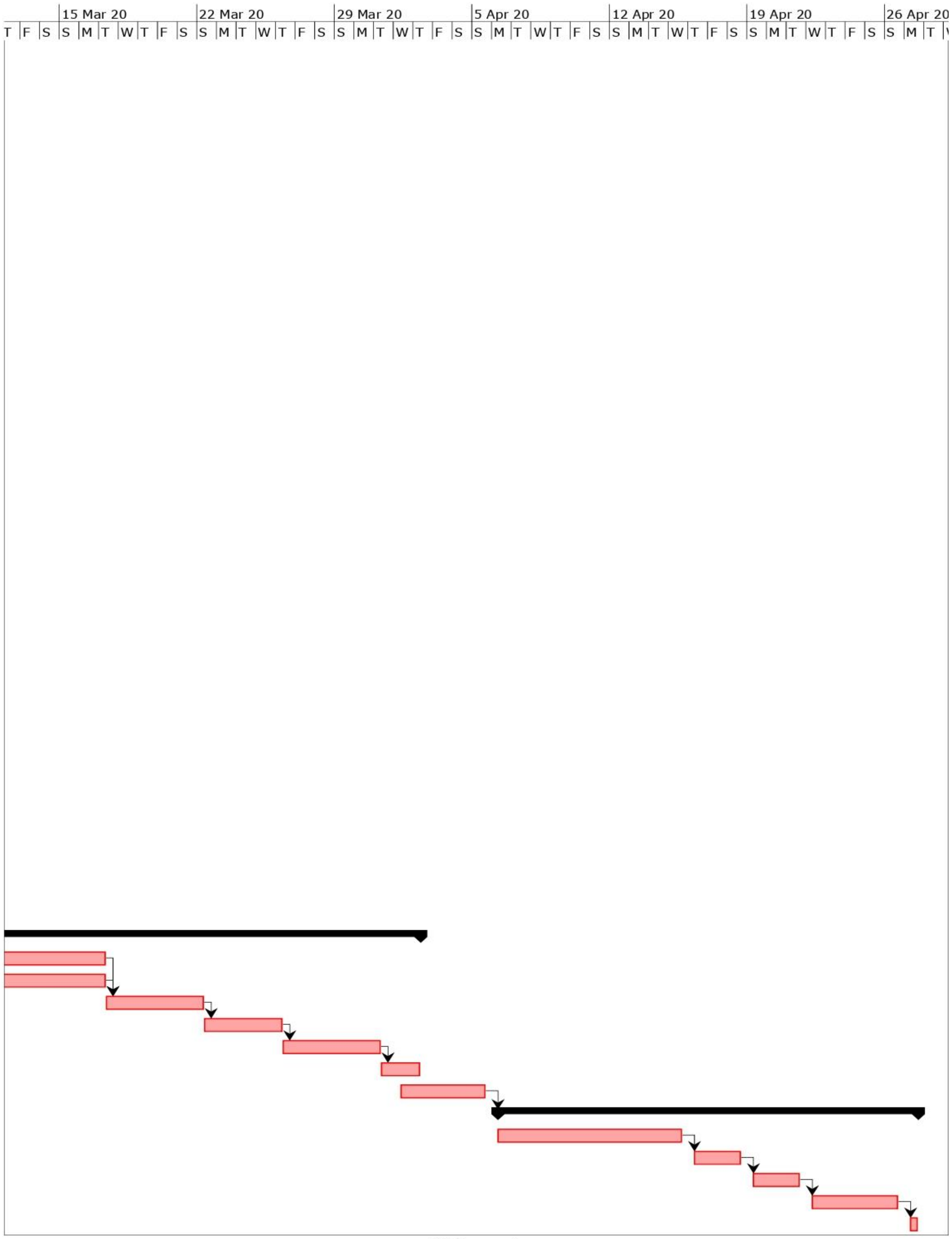
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