Oregon State University

2020 NASA SL Team

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Corvallis, OR 97331

Proposal

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Acronym Dictionary

9DOF Nine Degree of Freedom. 31

AIAA American Institute of Aeronautics and Astronautics. 4, 14, 15, 94, 95

ATF Bureau of Alcohol, Tobacco, and Firearms. 24

BEAVS Blade Extending Apogee Variance System. 26, 29–32, 83

BP Black Powder. 20, 21, 24, 27, 35, 38, 39

CDR Critical Design Review. 17, 52, 56

CF Carbon Fiber. 13

CFD Computational Fluid Dynamics. 31

CFR Code of Federal Regulations. 22, 23

CNC Computer Numerical Control. 10

CO2 Carbon Dioxide. 19–21, 26, 27, 32, 35, 36, 38, 39, 67, 82, 83

EDM Electrical Discharge Machining. 10, 31

FAA Federal Aviation Administration. 18, 22–24, 77, 80

FDM Fused Deposition Modeling. 31

FMEA Failure Mode Effects Analysis. 18

FRR Flight Readiness Review. 17, 56, 59–61, 78

GHS Globally Harmonized System for Classifying Hazardous Chemicals. 4, 21, 22

GPS Global Positioning System. 27, 41

HDPE High-density polyethylene. 40

ICE Innovative Composite Engineering. 27

LRR Launch Readiness Review. 78

MIME Mechanical, Industrial, and Manufacturing Engineering. 4, 10, 12, 13, 16, 17

MPRL Machine Product and Realization Laboratory. 10

MSDS Material Safety Data Sheet. 19, 20, 79

NAR National Association of Rocketry. 8, 19, 24, 52, 77, 80

NASA National Aeronautics and Space Administration. 17, 24, 47–49, 52, 58, 61, 62, 75, 80

NEMA National Electrical Manufacturers Association. 31

NFPA National Fire Protection Agency. 21, 23, 24

OROC Oregon Rocketry. 8

OSGC Oregon Space Grant Consortium. 94

OSRT Oregon State Rocketry Team. 4, 7–10, 13–19, 21–24, 26, 28–32, 35, 39, 40, 46, 48, 65, 79, 85–91, 94, 95

OSU Oregon State University. 8, 10, 12–14, 16, 17, 85, 94, 95

PCB Printed Circuit Board. 31

PDR Preliminary Design Review. 17, 53

PID Proportional-Integral-Derivative. 32

PLA Polylactic Acid. 31

PPE Personal Protective Equipment. 8, 14, 19–21, 93

PTP Pre-Task Plan. 19, 21

PVC Polyvinyl Chloride. 40

RF Radio-Frequency. 27, 41

RPM Rotations per Minute. 41

RRC3 Rocket Recovery Controller 3. 39

RSO Range Safety Officer. 18, 19, 21, 23, 47, 48, 52, 53, 58, 62, 66, 77, 80

SO Safety Officer. 62, 66, 67, 78–80

STEM Science, Technology, Engineering and Mathematics. 8, 47, 48, 79, 85, 91, 93, 95

TRA Tripoli Rocketry Association, Inc.. 19, 24, 80

UAV Unmanned Aerial Vehicle. 36

USLI University Student Launch Initiative. 4, 18, 23, 24, 46, 87–90, 97

1 General Information

1.1 Leadership Overview

Table 1: Adult Educator Summary Chart

Name of Mentor	Dr. Nancy Squires	Joe Bevier
Professional Title	Senior Instructor	OROC TRA TAP
Academic Institution	Oregon State University	Oregon State University
Position within the OSRT	Team Advisor	Team Mentor
Contact	squiresn@engr.orst.edu (541) 740-9071	joebevier@gmail.com (503) 475-1589
TRA/NAR Number, **Certification Level**	TRA #15210 Level 3 NAR #97371 Level 3	TRA #12578 Level 3 NAR #87559 Level 3

Table 2: Team Leadership Chart

Name	Amy Caldwell	Wyatt Hougham
Administrative Role	Team Lead	Safety Officer
Contact	caldwamy@oregonstate.edu (503) 705-2981	houghamw@oregonstate.edu (541) 408-8655
TRA/NAR Number, **Certification Level**	TRA #16780 Level 1	NAR #221813 Level 1

The Oregon State Rocketry Team (OSRT) consists of eleven members pursuing a degree in Mechanical Engineering, six members pursuing an undergraduate degree in Electrical and Computer Engineering, three members pursuing a degree in Computer Science, and one member pursuing a degree in Human Developmental and Family Science. These members will be divided amongst three technical teams: Aerodynamics/Recovery, Payload, and Structures/Propulsion. A description of each technical team is below:

- ***Aerodynamics/Recovery*** – Aerodynamics/Recovery is responsible for the design and construction of the recovery system, including the parachutes, parachute retention system, parachute ejection system, and an autonomous altitude targeting system, along with creating and updating the flight simulations to calculate projected altitude and landing kinetic energy. Key requirements are to ensure a safe landing, monitor kinetic energy requirements, and fabricate electrical hardware to ensure aerodynamic flight.
- ***Payload*** – Payload is responsible for the design and fabrication of the payload, including the chassis, wheels, ice collection system, payload ejection and retention systems, and all required electronics to make these systems functional. Key responsibilities include meeting all customer requirements, designing a payload that reliably functions, and rigorously testing prior to final launch.

- ***Structures/Propulsion*** – Structures/Propulsion is responsible for the design and construction of the launch vehicle, including the nose cone, the fore and aft body sections, the fins, motor selection, the avionics bays, the motor retention system, and all interior structural components of the launch vehicle. Key responsibilities of this team include mass and stress analysis for altitude precision, understanding key propulsive features to ensure reliability, and monitoring of the effects of design improvements.

Each member will also have a second role as either a subteam lead, or in Budget and Finance, Safety, or Science, Technology, Engineering and Mathematics (STEM) Engagement.

- ***Budget and Finance*** – Budget and Finance is responsible for constructing the team budget and keeping it up to date at all times, along with being in charge of grant writing, fundraising, and ordering parts and supplies for the OSRT. Key requirements are to ensure that the OSRT has adequate funding to meet the needs of the teams within the OSRT, maintain good relations with sponsors and donors, and have necessary parts and supplies delivered to the OSRT in a timely manner.
- ***Safety*** – Safety is responsible for constructing all safety documents, identifying potential hazards, both personal and environmental, and creating all hazard analyses and mitigation plans, along with conducting pre-activity safety briefings, and ensuring that safe practices are both taught to and followed by all team members, regardless of activity and location. Key requirements are to ensure that the OSRT is operating in the safest manner possible at all times, record all safety actions and incidents, and ensure that adequate Personal Protective Equipment (PPE) is available for the OSRT's use.
- ***STEM Engagement*** – STEM Engagement is responsible for leading students in STEM-oriented activities ranging anywhere from building straw rockets and launching them to learn about rockets and physics to making slime to learn about chemistry. These students ranges in ages from Kindergarten through 12th grade, and a reached in a variety of locales, including traveling to students' classrooms, holding school-wide sessions, holding day camps on Oregon State University (OSU)'s campus, and attending community events.Key requirements are to ensure that the OSRT reaches out to as many schools in Oregon as possible, maintains good relations with schools and events we have already worked with, and provides high quality, engaging, and age-appropriate lessons for all students.

A chart of the team structure is shown in Figure 1.

The mentoring National Association of Rocketry (NAR) section who will be reviewing all of the OSRT's designs and documentation, and will be assisting the OSRT with our launches is Oregon Rocketry (OROC). Both of the OSRT team mentors are members of this NAR section.

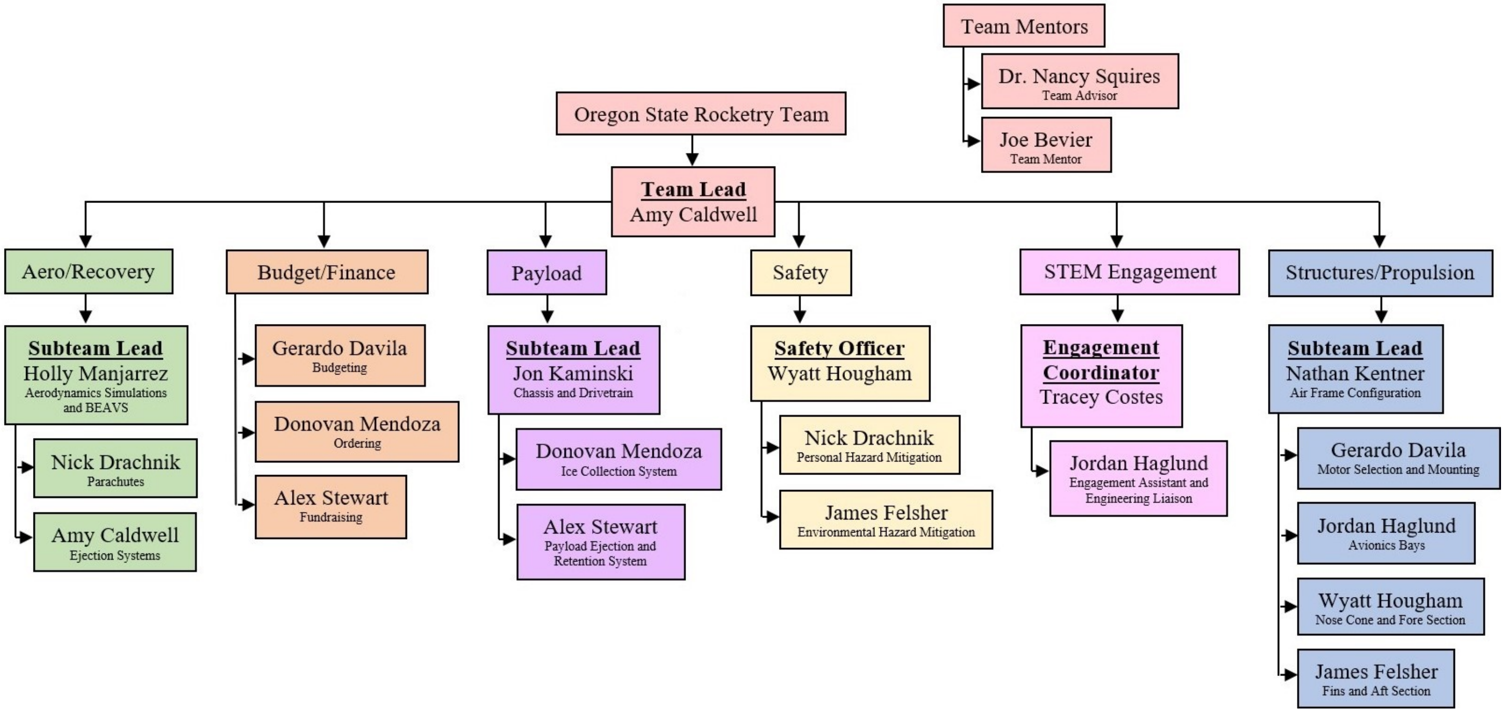

Figure 1: OSRT Team Structure

2 Facilities and Equipment

2.1 Accessible Equipment

The OSRT has access to eight work spaces on the OSU campus for research, prototyping, manufacturing, and testing purposes. First, the School of Mechanical, Industrial, and Manufacturing Engineering (MIME) Machine Product and Realization Laboratory (MPRL) offers the following to OSU students who have completed the MIME term-long machine shop course:

- 9 Engine Lathes
- 10 Vertical Milling Machines, shown in Figure 2
- 2 Computer Numerical Control (CNC) Turning (Lathe) Center
- 4 CNC Vertical Milling Machine Centers (three 3-axis, one 4-axis), shown in Figure 3
- 1 Electrical Discharge Machining (EDM) Burning Machine
- 1 Shielded Metal Arc Welder
- 1 Flux Core Arc Welder
- 1 Gas Tungsten Arc Welder
- 1 Spot Welder
- 1 Hydraulic Press
- 1 Steel Chop Saw
- 1 Press Brake
- 1 Sand Blasting Station
- 1 Steel Grinder
- 1 Belt Sander
- 1 Horizontal Band Saw, shown in Figure 4
- 1 Vertical Band Saw
- 1 Drafting Area, shown in Figure 5
- 2 Drill Presses

Figure 2: Vertical Milling Machines

Figure 3: Fadal VMC 3016 Milling Machine

Figure 4: Horizontal Band Saw, Press Brake, Welding Area, and Vertical Band Saw

Figure 5: Drafting Area

Second, not only does the School of MIME offer an area and machines made to manufacture metal parts, but it also offers a full wood shop, shown in Figures 6 and 7, which is accessible to any OSU student who has completed the free, 2-hour safety seminar and passed the safety test. The wood shop features:

- 1 Chop Saw
- 1 Table Saw
- 1 Vertical Band Saw
- 1 Drill Press
- A collection of power hand tools such as a jigsaw and circular saw
- A collection of manual hand tools such as files and saws
- A scrap wood pile that students can pull pieces from to use on projects

Figure 6: MIME Wood Shop (1/2)

Figure 7: MIME Wood Shop (2/2)

Third, the School of MIME also offers an area where students can work on electronics, shown in Figure 8, as well as ample space to work on manufacturing and constructing different projects with a wide variety of hand tools from Dremels and drills to hammers and screw drivers. This room also offers as assortment of nuts, bolts, and other supplies, shown in Figure 9, that students are allowed to use on educational projects for free.

Figure 8: MIME Assembly Room Electronics Station

Figure 9: MIME Assembly Room Work Space, Tools, and Supplies

Fourth, the School of MIME offers a MIME Rapid Prototyping Lab where are three additive manufacturing machines which allow OSU students the ability to rapidly prototype complex designs for a low cost. This lab includes the following machines, all depicted in Figure 10:

- Dimensions BST Rapid Prototyping Machine
- Fortus 4000mc Rapid Prototyping Machine
- Stratasys Objet 350 Connex2TM Rapid Prototyping Machine

Figure 10: Additive Manufacturing Machines

Fifth, the OSRT is also able to use the MIME composites lab, which is equipped to be able to handle the entire composite manufacturing process from cutting materials such as Carbon Fiber (CF) and fiberglass to baking the pieces to mold them. This space features:

- 1 Drill Press
- Various hand tools
- 1 Composite Oven
- 2 freezers for raw material storage
- 1 Polyethylene Cutter
- 1 Soldering Iron
- Oscilloscopes
- Pneumatic Cutting Tools
- Rapid Prototyping Capabilities
- 1 Chop Saw
- 1 Table Saw

Furthermore, sixth, the OSRT is partnered with the OSU student branch of American Institute of Aeronautics and Astronautics (AIAA), which works with six other rockets that fly to altitudes anywhere from 300 feet to 330,000 feet. Therefore, the OSRT able to use AIAA's lab space, shown in Figure 11, and their library of previous rocketry documentation in order to work with, learn from, and help other rocket teams. This lab underwent significant renovations over the summer, and therefore, the lab now has:

- Soldering stations
- Desktop computer stations
- Flammable storage cabinets
- A library of previous teams' work
- A collection of power hand tools, such as Dremels and drills
- A collection of manual hand tools such as Allen wrenches and files
- PPE such as latex gloves and safety glasses
- Storage space for smaller items

Figure 11: AIAA Lab

As part of the OSRT's affiliation with AIAA, the OSRT also has access to AIAA's Propulsion Lab, located on the edge of campus. This lab has a large field behind it, shown in Figure 12, where all of AIAA's deployment testing occurs. This is where the OSRT will be doing all deployment and ejection testing.

Figure 12: Energetics and Systems Testing Area

Finally, the OSRT has been provided specific space, shown in Figure 13, from the School of MIME where the OSRT can work on the launch vehicle, recovery system, and payload, and store all project-specific materials. This space is the OSRT's base for working on all portions of the project.

Figure 13: Graf Hall Work Space

2.2 Accessible Software

All members of the OSRT who are engineering or computer science students have access to on-campus engineering computer labs throughout the engineering buildings on the OSU campus. Many technical programs are available to us for use on this project, some of which are downloadable onto personal computers through license distribution from OSU, and all of which are available through the Citrix Receiver. Some available programs to the engineering and computer science students of the OSRT are:

- Abaqus
- Adobe Acrobat
- Adobe Illustrator 2015
- Adobe InDesign 2015
- Adobe Photoshop 2015
- ANSYS
- AutoCAD
- CES EduPack 2016
- Engineering Equation Solver
- LaTeX
- Mathematica
- MATLAB 2018

- Microsoft Office
- Minitab
- OpenRocket
- PTC Creo Parametric
- RASAero II
- Sketchup
- Solidworks 2019
- STAR-CCM+

Moreover, the OSRT members will use programming languages such as C, C++, Python, and Java, along with open-source software and other software that is available for use only by the computer science and electrical engineering students at OSU in order to develop and debug the necessary software for the recovery system and the payload, along with maintaining and updating the website. LaTeX will be used for technical documents, and all documentation will be stored on a Google Team Drive.

2.3 Communication

OSRT will be providing video conferencing capabilities such as speakers, projectors, microphones, cameras, and telephones in order to present the OSRT's Preliminary Design Review (PDR), Critical Design Review (CDR), and Flight Readiness Review (FRR) to a panel of National Aeronautics and Space Administration (NASA) personnel. Projectors and speakers will be provided by the School of MIME, as many of their classrooms and conference rooms have high quality projectors and speakers. Microphones, cameras, and telephones will be provided by the OSRT members.

3 SAFETY

3.1 Safety Team

The Safety Team for the OSRT is responsible for establishing safety standards in the construction and operation of the launch vehicles, ensuring compliance with regulations under the various involved organizations, and above all, the creation and maintenance of a safety-first culture and awareness within the OSRT, which includes fostering an atmosphere of self-policing, situational awareness, immediate reporting, and well-documented steps to move the entire OSRT toward a zero-incidents project completion. In order to accomplish this goal, hazards and other possible avenues of harm will be identified, catalogued, and assigned mitigation strategies in order to reduce both the severity and frequency of any events in accordance with established Failure Mode Effects Analysis (FMEA) practices.

The Safety Team is also responsible for additional documentation, checkoffs, and oversight required at any launch events, as specified in section 5.1 of the University Student Launch Initiative (USLI) handbook, which will ensure a rigorous chain of responsibility for the final safety check offs before each launch.

3.2 Risk Assessment

Major risks to the project that the Safety Team will focus on averting stem primarily from injuries or damage to persons or the work space that threaten the timing of the project, issues with legal compliance due to unsafe practices, designs that violate restrictions, or authorization failure from the Range Safety Officer (RSO) or other officials.

Any workplace incidents that occur during the project will inevitably cause delays. This may be something as simple as a cut or abrasion requiring minor medical attention, with delays less than an hour, but a serious injury and associated treatment, as well as cleanup of the accident site, could close a work space for the entire day or remove an important team member from their duties long enough to necessitate re-tasking of responsibilities. With an already tight project schedule, day-long delays due to safety incidents simply cannot be allowed to occur.

Absolute compliance to all laws and regulations set forth by the Federal Aviation Administration (FAA) and other organizations involved in the OSRT project must be upheld by the Safety Team. Failing to meet a particular safety threshold or design criteria, or a major certification shortfall like failing an RSO inspection will not simply delay the project, but stop it completely in its tracks for an unknown length until the situation is resolved. Depending on how deeply this safety matter is ingrained in a design choice, that could prove fatal for the success of the project as a whole. Thus, it is the duty of the Safety Team to not only ensure that existing standards are being adhered to in the build spaces, but also to look ahead towards the next inspection or certification milestone, and make sure all that requirements are met in the early planning phases to minimize the amount of reworking and lost time.

3.3 NAR Procedures/Personnel

Dr. Nancy Squires and Joe Bevier are our NAR/Tripoli Rocketry Association, Inc. (TRA) Level 3 certified mentors and they will be responsible for ensuring the team is in complete compliance with all NAR High Power Safety Code requirements. Nancy Squires and Joe Bevier will be responsible for storage, purchasing, use, and transportation of rocket motors and energetic devices. Furthermore, all Level 3 certified mentors will be present during all ground testing procedures and launches.

3.4 Hazard Recognition

Hazard information and recognition will be managed through the use of Material Safety Data Sheet (MSDS) records each time a new material is involved in a OSRT-affiliated work space. By maintaining a complete listing of potential material hazards and categorizing them by required PPE or additional observances (heat, handling, ventilation, etc.), anyone working with a material will have access to all relevant information in the event of accidental overexposure or uncertainty regarding which manufacturing processes are allowable at their current grade of PPE.

In the event that an undocumented hazard is located by either the Safety Team, a OSRT team member, mentor, or RSO, a form will be made available at all OSRT work spaces and launch events for reporting the hazard and determining mitigation strategies. This form will serve as a temporary addendum to policies and observances at that site until it can be formally added to team-wide training or posted hazard notifications.

Documentation of components that may be subject to stored energy hazards, specifically the Carbon Dioxide (CO_2) canisters anticipated for use in the parachute ejection systems will be maintained through a thorough record of each pressurization event, including the date and authorized technician responsible for inspection of the pressure vessel and the pressurizing and depressurizing where applicable.

All documentation, including MSDS, Pre-Task Plan (PTP), signed safety agreements, new addenda, and any other paperwork or printouts will be maintained in a binder and made available to the OSRT members who may have questions about a particular material or procedure, or wish to review their safety agreements.

3.5 Anticipated Hazards

The primary hazards recognized in the construction and operation of the launch vehicle are stored-energy, reactivity, handling, and exposure hazards.

Stored-energy hazards include both the stored force in CO_2 canisters, compressed springs, electric potential stored in batteries, and any tension or compression in the payload retention and ejection mechanisms. In these situations, the hazards stem from both the unintended release of stored forces via mechanical failure or operator error, as well as requiring elevated care when disarming or de-energizing these systems once the test is complete.

Reactivity hazards are almost entirely related to the volatility of the motor fuel, but the Black Powder (BP) charges that might be employed in the parachute ejection design also present a significant potential for unintentional detonation via accumulated static charge or exposed ignition sources.

Handling hazards primarily refer to any injuries or damage that could be sustained while moving, manipulating, or securing subcomponents that might have sharp edges, protruding fasteners, pinch points, or temporarily elevated temperatures following cutting, joining, or other fabrication processes, and may necessitate elevated PPE use on a case-by-case basis. Minimizing the amount of materials that exhibit these properties, such as sharp edges on metals, as well as favoring design with flush components and well-fitted parts will help reduce the rate that these particular hazards arise.

Exposure hazards reference any categories of materials that can be damaging to exposed persons, either in their expected state or as a result of manufacturing processes. Nearly all materials involved in the construction and operation of the launch vehicle will have some amount of exposure hazard, as detailed in their MSDS, typically only reaching unsafe levels in certain situations that should be monitored (such as poorly ventilated spaces). Strong solvents like acetone create exposure hazards from fumes and vapor emitted during use, as indicated in the associated MSDS, and adhesives like epoxies create exposure hazards from coming into contact with skin. Another subcategory of exposure hazards will be particulate contamination, namely from materials likely to give off large amounts of dust or other loose material when processed. Fiberglass and carbon fiber components will be the primary culprits, both in contact with exposed skin, potentially leading to dermatitis, as well as irritation in the eyes, but especially with regards to accidental inhalation of these sorts of non-degrading irritants which can cause significant, well-documented long-term health complications.

Even the more commonly materials anticipated for use like laminated plywood or aluminum may still have exposure, handling, or reactivity hazards. The sawdust generated by cutting and sanding plywood is a combustion vector as well as an eye irritant, and aluminum swarf[1] might damage tools or cut exposed skin if allowed to build up.

1. Debris or waste resulting from subtractive machining processes

3.6 Caution Statements

All team members of the OSRT will receive briefings on expected behavior, potential hazards, and approved methods of mitigation at each launch event, both prior to arrival on the site and again once an area of operation has been established. This briefing must, at minimum, include a basic identification of movement restrictions such as range closure by the RSO, activity restriction such as open flames near working areas, and an identification of the RSO, present members of the Safety Team, and any other personnel relevant to the chain of incident reporting. Further briefing on local hazards such as weather conditions, wildlife, or terrain may be made at the discretion of the briefing Safety Officer.

Teams operating with materials, tools, or in work spaces that may have working hazards or other risks present will require a PTP to be created and signed by the working team, which serves as a means of identifying hazards associated with the working steps and a method of mitigation for these hazards. A physical record of each PTP will be retained for the duration of the project in an accessible binder.

Teams that are expected to encounter additional conditions or dangers which require stronger measures for active mitigation will receive briefings on both the steps for recognition of the hazards as well as steps to mitigate the hazards where possible, or will be provided a well-maintained chain of contact where mitigation of a hazard may require specialized training or certification. Hazards associated with these supplementary briefings may range from exotic material fires and correct extinguisher recognition to handling energized circuits and correct lockout-tagout procedure, and could cover other areas with more potential for personal or paired mitigation such as heat stroke, dehydration, or hypothermia where teams are expected to take an active role in watching for signs of these emergent hazards in their fellow teammates and practice communal mitigation techniques.

In the event that a material hazard, stored-energy hazard, or other potential risk vector is located but cannot be entirely mitigated by design or alternatives, such as the energized launch circuits, volatile combustibles of the motor, or stored CO2 cartridges and BP charges, standardized warning labeling and notifications will be applied to subcomponents as necessary following National Fire Protection Agency (NFPA) and Globally Harmonized System for Classifying Hazardous Chemicals (GHS) standards, shown in Figure 14, for unambiguous communication of hazards and preventative measures to team members, RSO inspectors, launch site staff, and bystanders with non-technical backgrounds who may inadvertently come into contact with launch vehicle systems. Any warning labels that are damaged or illegible must be replaced immediately, followed by a review to determine if the damage to a critical warning insignia is a repeatable event due to design or conditions at that location.

Caution statements will also be placed in work instructions and procedures. The caution statements will include possible hazards for the portion of the build process and the appropriate PPE to mitigate those

Figure 14: GHS Hazard Labels

hazards. These statements will not only detail what hazards are presents, but what the results will be if the hazards are not mitigated. Examples are shown below.

— CAUTION: Hazard to Equipment —

Attempting to remove logic board while still secured can cause damage and dislodge components.

— CAUTION: Hazard to Personnel —

Wearing loose clothing while using a lathe can result in injury or death.

3.7 Law Compliance

Per Section 5.5 of the handbook, the OSRT will practice strict adherence to the FAA regulations regarding visibility, duration, expected altitude, time, and other restrictions of both General Operating Limitations defined in 101.23 as well as Class-2 launch vehicle rules (defined in 14 Code of Federal Regulations

(CFR) 101.22), such as advance notification, the involvement of certified RSO oversight, and launches being conducted in clear spaces, defined as at least a quarter of expected altitude in all directions per the FAA, or 2,500 ft. from launch specified in 3.10 of the USLI 2020 handbook. Additional constraints come from the rigidly defined visibility requirements to minimize danger to the surroundings, including lighting conditions and current cloud coverage. The Certificate of Wavier or Authorization issued by the FAA described in 14 CFR 101.25 must be present at all launch sites used for subscale tests and final operation of the launch vehicle, and it is the duty of the Safety Team to ensure this document is present and displayed in accordance with all federal and local rulings, and that parameters such as altitude limits specific to that wavier are acceptable for the expected results of the launch event.

As noted in the USLI handbook in Section 1.4, compliance with NFPA Section 1127 is also required. Especially relevant Sections of NFPA 1127 are: Sections 4.5 through 4.7 which prohibit the use of various materials, prohibit modification of standard motors, requirements for hazard labeling, and the general expectation of durability and structural integrity with regard to expected aerodynamic forces; Section 4.8, detailing the requirements for stability both in documentation of pressure and mass centers as well as the duties of the RSO in making a final determination of stability before authorization of launch; Section 4.9 detailing the weight and power limitations for the launch vehicle, of which 4.9.1 is the primary concern; 4.10 which places restrictions and requirements on the manner of recovery; and 4.12-4.14 which provides extensive information on the manner of launch, standards for launch ignition sources and the timing or location of ignition installation and system arming/disarming, and legal requirements for the zoning and waivers of a launch site approved for high power rocketry. A checklist of all relevant NFPA requirements will be maintained by the safety team, and must be passed as part of the pre-launch checklists prior to seeking RSO approval. Other NFPA matters that deal with stages of launch vehicle testing not directly related to design, such as 4.10 recovery procedures, will be addressed in each pre-launch briefing to ensure full compliance from the entire OSRT team.

Handling of all volatile materials such as rocket motors will be performed exclusively by those certified to possess and handle such materials, and their proof of certification will be present at all transaction and relocation of the aforementioned material.

Coordination with a RSO at each FAA-approved launch site will ensure that no components of the proposed launch vehicle, nor any aspects of its intended flight plan violate the wavier for a particular launch site, keeping in mind that the RSO has final authority on the ability to launch any and all vehicles at the site they oversee.

3.8 Launch Vehicle Motor Handling

Launch vehicle motors will be purchased only by an NAR/TRA certified mentor. Any activated material such as BP charges, ignition charges, and motors, will be stored away from any sources of flame or heat in isolated, resealable containers in accordance with NFPA 1127 Section 4.19.2.5. All motors and ejection charges will be prepared by NAR/TRA certified instructors. All motor transportation and handling will be done by NAR/TRA certified personnel. Motors will be purchased on site or transported to location by car in NFPA and Bureau of Alcohol, Tobacco, and Firearms (ATF) compliant containers with attention paid to all shock, static, and heat conditions that may need mitigating. ATF regulations regarding explosives outlined in Part 55 - Commerce In Explosives, as well as all other relevant federal, state, and local laws will be followed, and compliance assured by the safety team in advance of any travel or relocation to a jurisdiction which might have separate or additional requirements for safe handling and transportation of high power rocket motors.

3.9 Safety Agreement

As specified by USLI handbook Section 1.6, all members of the OSRT will read and sign the following safety agreement assuring that they are in compliance with NAR/TRA launch guidelines, NASA safety regulations, and required FAA observances:

Safety Agreement

I, ______________, have read, understood, and will abide by all laws and regulations set forth by the National Association of Rocketry, the Tripoli Rocketry Association, the National Aeronautics and Space Administration, the Federal Aviation Administration, the National Fire Protection Association, and Oregon State University while handling, working on, or when in the presence of high powered rockets or their active components. This includes being properly certified and wearing all required Personal Protective Equipment (PPE) when appropriate, as well as understanding potential hazards and the steps for mitigating these risks for myself and others. I understand that these laws and regulations are for my safety and the safety of others. I will use my best judgment in Oregon State Rocketry Team (OSRT) and University Student Launch Initiative (USLI) activities to keep myself and others safe and I will follow guidelines and procedures set by the Safety Officer (SO). I have a responsibility to actively ensure a safe working environment, including reporting of incidents and identification of unsafe conditions or emergent hazards. I understand that, in accordance with USLI handbook Sections 1.6.1 through 1.6.4, The Range Safety Officer (RSO) will inspect the launch vehicle before any active tests to ensure it meets all range safety requirements, and has the final say on the status of any launch. I understand that any launches unapproved by the RSO are strictly prohibited, that a launch may be prohibited for any reason, and that the absolute safety and lawful conduct of the OSRT team supersedes any and all vehicle launch goals or deadlines.

I understand that any violation of the rules indicated above or in the handbook, or other actions found to endanger myself, others, or property of OSU and associated organizations may be grounds for removal from the team or further action if offense warrants.

Signature: ____________________

Date: __________

4 Technical Design

4.1 Vehicle Specifications

4.1.1 Vehicle Overview

The purpose behind the launch vehicle is to fly to an apogee of 4,000 ft while carrying a payload of a robotic rover, then delivering the rover safely to the ground to allow it to complete its mission. The vehicle will do this without damage to the rover, and adhering to certain standards to ensure the safety of the ground crew and bystanders. To accomplish this, the launch vehicle will be separated into three main sections: the nose cone, the fore section, which contains the payload, and the aft section, which contains the motor. These sections perform the tasks of delivering the payload to the desired altitude, then returning both the launch vehicle and payload safely back to the ground without damage.

The fore and aft sections will both house drogue and main parachutes for recovery, along with several CO2 ejection systems and altimeters to determine proper deployment altitudes. The nose cone will house the avionics module for the fore section, along with space for ballast. The fore section which is 44” long, will also contain the rover and its deployment hardware. The aft section will house the vehicle’s propulsion system, along with the Blade Extending Apogee Variance System (BEAVS), which is the active system and aft ballast system. The aft section will be 50” long and be designed slightly larger in diameter at 6.26” ID, rather then the payload sections 6.25” OD, allowing the fore section to slide inside it, held by a ridge inside the aft section and outside the fore section at least 6.5" in length. This will negate the need for a traditional coupler between the two sections and enable the the rover to travel a shorter distance down the airframe tube in order to deploy. This will need further testing to determine the structural stability of the coupling, and to determine the best manufacturing method in which to implement it. While this would be the first option however, in the event that manufacturing this proves to be impractical, or structurally unsound, the OSRT will revert the design to a more traditional coupler and tube configuration. In this configuration both the fore and aft tubes would remain the same diameter, with a coupler at each break in the launch vehicle extending at least 6.5” into both the aft and fore sections and at least 3.5" into the nose cone. The fore coupler will attach the nosecone to the fore section of the airframe. This coupler will be permanently fixed to the nosecone, and will fit snugly within the airframe. The aft coupler will attach the fore section of the airframe to the aft section of the airframe. This coupler will be permanently fixed to the aft section of the airframe, while it will fit snugly within the fore section. To prevent early section separation due to ejection forces in other sections of the launch vehicle or drag, 2-56 x 1/4 -inch shear pins will be used to ensure that the launch vehicle will stay assembled until its intended time of separation. These pins are made of nylon, and will shear when a strong force is applied to them, as a result of a parachute ejection charge being activated. In order to ensure that the shear pins will not prevent the deployment of the parachutes from the launch vehicle, regardless of the type of ejection charge, a minimum of five ground tests will be conducted with both BP ejection charges and CO2 ejection charges.

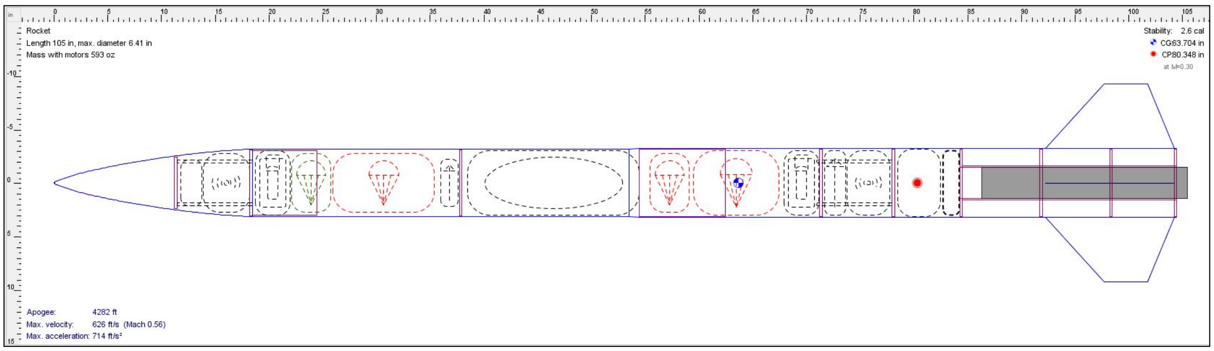

Figure 15: Launch Vehicle Layout

A student-designed avionics bay will act as an active tracking system for the launch vehicle. Global Positioning System (GPS) data will be transmitted in real time to a ground station monitored by the team to ensure the launch vehicle does not get lost, even if line of sight is broken. Location and altitude will also be logged along with timestamps to allow for flight data to be plotted and assessed post flight.

In order to allow the avionics bay to communicate with the ground station the nose cone will be made out of fiberglass to enable Radio-Frequency (RF) signals to pass through. It will be shaped in a Von Karman style with a 3:1 fineness ratio. Housing the avionics bay in the nose cone negates the need for creating another fiberglass section in the fore section of the vehicle, as the nose cone does not need to be bonded with the payload section tube, which reduces possible failure points. The payload section will be constructed of a carbon fiber tube, for strength and reduced weight, with plywood bulkheads. The strength of the carbon fiber tube will aid in the safe deployment of the rover, which is the heaviest system in the vehicle, and will support it from launch through landing. Depending on the method for deployment, the payload section may need a fiberglass section as well to allow for RF signals to pass through. This fiberglass section will be implemented in the same manner as in the aft section of the vehicle. Since there will be a tracker in the aft section as well, the electronics bay in the aft section will be made from fiberglass instead of carbon fiber to maintain RF transparency. This section will manufactured by Innovative Composite Engineering (ICE) to ensure tube strength in the joints between materials.

Fins on the aft section are in a trapezoidal configuration to help decrease drag over other fin configurations and increase stability. This configuration was also chosen because their design enables the launch vehicle to touchdown tube first due to the slanted aft section of the fin. This will reduce the possibility of breaking a fin in case the launch vehicle experiences a landing with a large kinetic energy. These will pass through the aft airframe tube and be secured to the motor mounting tube as well as the aft airframe tube to increase rigidity in the booster section. The motor tube will be secured with 3 centering rings and a solid bulkhead. These rings will have a 3.03″ ID and a 6.25″ OD. The fins will be constructed of formed carbon fiber to decrease weight and increase rigidity and strength of the airframe. Carbon fiber also allows for molding around a desired airfoil profile, aiding in the creation of different types of fins that will have the desired strength and rigidity. Research into composite manufacturing and testing will be conducted to determine the optimal way to lay the fibers in order to gain rigidity from air resistance and lift forces, but greater flexibility when the vehicle touches down further decreasing the chances of breaking a fin.

All joints in the launch vehicle will be epoxied in place using an aerospace grade epoxy with fillets on all critical components. The carbon fiber tubes and nose cone will be purchased from suppliers that the OSRT has worked with in the past, such as Innovative Composite Engineering. The fins and bulkheads will be made in house using wood shop equipment for the bulkheads, carbon fiber molds and an oven for the fins.

A subscale model will be designed and built to launch and test systems of the full sized launch vehicle. This will be created as close to the actual design of the full scale as possible in 2/3rds scale, with the exception of the size of electrical components such as altimeters. The motor used will be chosen to mirror the motor for the full scale, by its burn and force characteristics. The payload bay will be loaded with an appropriate amount of weight to approximate the scale version of the rover that the full scale will be carrying.

Using OpenRocket the launch vehicle and its stability was simulated. The stability was calculated to be 2.6 calibers. This will be adjusted as the vehicle and payload design evolve, however a minimum caliber requirement of 2 will be maintained through ballast and mounting adjustments of hardware thought the year. The current vehicles general dimensions are listed in the table below.

Table 3: Launch Vehicle Specifications

Diameter	**Total Length**	**Loaded Weight**	**Stability**
6.25″	105″	37.1 lb	2.6 Cal

4.2 Projected Altitude

The OSRT is naming our target apogee altitude as 4,000 ft. Our launch vehicle comes weighing in at 37.1 lb, with a 105 inch length and 6.25 inch diameter (see Table 3). With a Cesaroni 3300-L3200-VM motor, OpenRocket simulations have given the following unballasted results for apogee altitudes with cross wind speeds up from 0 - 20 mph. The simulations also had a launch angle of 0 degrees. The projected altitudes can be seen in Table 4.

Table 4: OpenRocket Unballasted Apogee Altitudes with Varying Wind Speeds

Wind Speeds (mph)	Apogee Altitude (ft)
0	4346
5	4339
10	4330
15	4312
20	4290

With a ballasted system (0 lbs in forward ballast and 2.8 lbs in aft ballast), OpenRocket simulations result in the following apogee altitudes seen in Table 5

Table 5: OpenRocket Ballasted Apogee Altitudes with Varying Wind Speeds

Wind Speeds (mph)	Apogee Altitude (ft)
0	4006
5	4001
10	3991
15	3976
20	3956

It is acknowledged that this launch vehicle and its components will go through various design changes from now until competition day, unavoidably altering the center of gravity and weight. The intention is to adjust the weight and drag on the body with an active and passive system to achieve our named target altitude, despite these design changes.

4.2.1 Altitude Accuracy Assistance

Competition rules require teams to be capable of launching in wind speeds up to 20 mph. In order to combat potential launch day conditions and reach the projected apogee altitude of 4,000 feet, the OSRT is implementing an apogee variance system (BEAVS). BEAVS has two subsystems: a passive subsystem which consists of a coupled pair of ballast bays, and an active subsystem that can adjust the drag force on the launch vehicle body during flight. For this system to work, the motor selected must project our launch vehicle above desired apogee because BEAVS can only adjust the projected altitude by lowering it with weight and drag.

The ballast bays will be separated, with one located forward of the center of gravity (towards the nose cone), and one located after the center of gravity (towards the fins). These locations will allow for the mass of the launch vehicle to be adjusted while the center of gravity will remain the same. Keeping a consistent center of gravity will ensure stability of the launch vehicle.

For the active system, four blades will be centered around a motor and actuated during flight in order to increase the launch vehicle's drag coefficient. The blades sit in the airframe on a bulkhead and extend out perpendicular to the frame, increasing surface area, thus increasing drag force. Software will be utilized to predict the apogee altitude of the trajectory to assess the "current state" of the launch vehicle after motor burnout, which is determined by the current position, velocity, acceleration, and angle of attack. BEAVS can also determine how long the blades must be extended in order to achieve the desired altitude. This timing will be attained using a numerical method approximation with a small timestep, iterating each of the current state conditions to fine tune the drag during flight. In order to reduce error in the drag coefficient approximations, a varying set point will be used to perform self-optimization within BEAVS.

The active BEAVS system will be located just forward of the motor so that if the blades are deployed, the center of pressure is lowered, therefore stability is not compromised.

4.2.2 Testing and Development

BEAVS will require rigorous testing to ensure the accuracy of the approximations required can be achieved. Both physical testing during test launches and software simulations will be required to prepare the active system for competition. The passive BEAVS system must also be tested for wind speeds of up to 20 mph, to pre-set ballast configurations for launch conditions.

The ballast will be a stack of steel weights in each bay which are secured with two 1/4-20 fasteners, allowing for the exact weight to be modified on test launch days. The aft ballast bay will be located fore of the active system. The fore ballast bay will be located at the hard point on the fore section of the airframe. The purpose of this testing is for preparedness to have the exact ballast configuration to be used at competition.

A similar system was attempted previously, by the 2018-2019 OSRT. The system was never successfully implemented and tested on a flight. The primary reason for the failure in 2018-2019 was due to lack of resources devoted to the system. The mechanical systems were built and launched, however no electronics were successfully completed due to a lack of electrical engineering support. In 2019-2020, a renewed effort to developing the system will include more dedicated support from electrical engineers on the project, which will allow for full testing of the system during vehicle demonstration flights. In addition to more dedicated support, several team members who worked directly on this system will be working on it again. This will reduce the likelihood of the same mistakes being repeated in 2019-2020.

4.2.3 Mechanical System

As introduced last year, a rack and pinion system will be utilized to extend four blades from the interior of the airframe. The blades will be manufactured from an 1/8″ aluminum plate using a wire EDM. The blades will attach to a linear bearing on a 7-millimeter guide rail with three M2 fasteners. The rack and pinion system will have a central drive gear. The central drive gear will operate all four fins simultaneously. The linear bearings will be mounted to a removable bulkhead made of 1/2″ aerospace grade plywood. The bulkhead will be just fore of the motor casing and will provide the structure for how the system is retained within the launch vehicle. Four 8-32 threaded rods will extend through the bulkhead towards the fore section of the launch vehicle. These four threaded rods will tie into a bulkhead on the fore side of BEAVS with nylon lock nuts, which will serve as the attachment point for the aft electronics bay. A National Electrical Manufacturers Association (NEMA) 23 stepper motor will be directly attached to the central drive gear. Fore of the NEMA 23 stepper motor will be a custom designed and Fused Deposition Modeling (FDM) 3D printed compartment out of Polylactic Acid (PLA) for the electronic systems used to control the stepper motor. This compartment will also store the aft ballast weights of the BEAVS. The fore ballast bay will be located on the fore section hard point. The blades are designed to account for an increase in cross-sectional area of the test launch vehicle. The OSRT is currently developing a Computational Fluid Dynamics (CFD) simulation in STAR-CCM+ which will provide an accurate result for the drag coefficient with and without blade deployment. Due to the self-optimizing nature of the BEAVS control system, there is allowable error within the drag coefficient to still achieve desired performance of the system. [8]

4.2.4 Electrical System

The BEAVS electronics will be arranged on a Printed Circuit Board (PCB) designed by the OSRT and consisting of:

- 1 Nine Degree of Freedom (9DOF) accelerometer
- 1 Barometric pressure sensor
- 1 Motor driver
- 1 Microcontroller

The software for the BEAVS will be written in C/C++ and will be able to control the sensor data acquisition and filter the data. A Kalman filter will be used to filter the data and to reduce the effects of noise in the measurements. Once filtered, the data will then be used to predict apogee altitude based on current flight characteristics. Based off the predicted apogee altitude, the PCB will send a signal to a motor driver which will be used to control the exact position of the blades during flight.

4.2.5 Control System

The BEAVS control scheme is reliant on a varying set point to provide in-flight optimization. The control system is a 1 degree of freedom control system, with the control variable being apogee altitude. The control system will only vary between blades retracted or blades deployed, with no state between. Once the blades are deployed, the drag coefficient of the launch vehicle is increased, and the apogee altitude is decreased. The expected apogee altitude does not change with retracted blades. This presents a problem of the control scheme overshooting the desired apogee altitude. There is no way to recover from this type of error to reach the desired apogee altitude.

To combat this issue, the OSRT will use a varying set point control scheme. In this control scheme, the desired apogee altitude value after blade deployment changes during flight. The set point is to be reduced through several steps that gradually approach the overall desired apogee altitude value. After each blade deployment cycle, the Proportional-Integral-Derivative (PID) parameters are updated based on the error between the set point and the expected apogee altitude. With this method, the number of tests required to optimize the PID parameters of the control system will be minimized. The self-optimizing control scheme will utilize only proportional control during initial testing of the BEAVS for simplicity. To achieve desired accuracy, integral and derivative control can be added in later, however this is not within the current scope of the proposed system.

The proportional control will be achieved through duty cycle adjustment. A duty cycle of 1 second will be utilized, with the blade deployment time required to reach the set point being a percentage of the duty cycle. The percentage of the duty cycle will be multiplied by the proportional control parameter to determine actual blade deployment time.

4.3 Recovery System

4.3.1 Separation and Descent

The launch vehicle will have two points of separation. At apogee two CO2 systems will activate causing the separations. One will be from the fore and aft section and the other will be from the nose cone and fore section. Once these sections separate the fore and aft will each release a drogue parachute to control descent velocity and stability. Then at a 600 ft reading from the altimeter, the main chute will deploy for each section, this chute will allow the vehicle to land within 90 s and less than or equal to 75 ft-lbf of kinetic energy.

A single pole double throw switch will be used as the arming switch for each of the altimeters present in the launch vehicle. When in the off position, the power input of the altimeter will be pulled to ground, shorting the system and shunting the circuit. When the altimeter arming switch is in the on position, power will be supplied to the altimeter, arming the system. The altimeter arming switches will be accessible from the exterior of the launch vehicle, satisfying competition requirement 3.6.

4.3.2 Parachute Location and Control

There will be a total of 4 parachutes in the launch vehicle. There will be one drogue and one main parachute in the fore section of the vehicle, located between the nose cone and body. There will also be one drogue parachute and one main parachute located in the aft section of the vehicle.

4.3.3 Fore and Aft Parachutes

The fore parachutes will have a nylon shock cord that attaches in two places to the airframe. The nosecone will have eye nut on a bulkhead, which is attached to the nosecone via a threaded rod to the nosecone tip. The fore section will have a bulkhead which will also have eye nuts to attach the shock cord. The bulk heads will be made of 1/2 in. aerospace grade plywood. On the threaded rods there will be an eye nut and locking nut to secure the drogue chute and main chute to the airframe. There will be a nylon shock cord attaching from the nose cone to the fore section, keeping the body connected throughout its descent. The drogue chute will be connected to the same shock cord. The main chute will be retained by two Tender Descenders in parallel, which will be released simultaneously with two altimeters for redundancy.

The aft section parachutes will be attached to a nylon shock cord, which is attached to an eye nut. The eye nut is secured to a threaded rod, extending from the motor casing. The main and drogue parachute will both be stored in the same bay, but the main parachute will be retained until 600 ft by two Tender Descenders in parallel, which will be released simultaneously with two altimeters for redundancy.

4.3.4 Protection and parachute Bag Deployment

The drogue and main parachutes will be protected using Nomex blankets and bags respectively. The bags are wrapped around the chute and secured with a pin and lace. When the cord reaches full length and tension is applied, the pin is pulled allowing the bag to unfurl and the main parachutes to deploy. For this deployment bag, we will have metal clasps secured with a pin as the friction generated by the lace will be too much as seen in Figure 16 [1].

Figure 16: Example Parachute Pin Design [1]

4.3.5 Parachute Sizes and Rates of Descent

The initial weight of the vehicle will be 37.1 lbs. Once the fuel is burned and the vehicle reaches apogee the launch vehicle will separate into the fore and aft sections. The fore section will weight 20.2 lbs and the aft section will weigh 16.9 lbs. Using the equation shown in Equation 1 the speeds of the fore and aft were calculated to ensure that below the 75 ft-lbf of impact energy.

$$KE = F_{impact} = \frac{1}{2}mv^2 \tag{1}$$

In Equation 1, KE is kinetic energy in $ft - lbf$, m is in slugs, and v is in ft/s. From the NASA website [2] we can calulate drag using Equation 2

$$D = \frac{1}{2}C_d \rho_{air} v^2 A_r \tag{2}$$

In Equation 2, D is drag of the parachute in $lbft$, C_d is the coefficient of drag on the parachute dependent upon its shape. These calculations assume the use of toroidal parachutes for the main and cruciform chutes for the drogue. ρ_{air} is the density of the air in Huntsville, Alabama, v is the velocity in ft/s, A_r is the area of the parachute canopy in ft^2, and W_{lv} is the weight of the launch vehicle in lbf.

Expanding Equation 1 into Equation 2 results in

$$D = W_{lv} = \frac{1}{2}C_d \rho_{air} v^2 A_r \tag{3}$$

A_r can be calculated from Equation 4

$$A_r = \frac{1}{4}\pi(d_o^2 - d_i^2) \tag{4}$$

For a torodial parachute, there is an inner and outer diameter defined. Using the Fruity Chutes website, the ratio between the two is 5:1 [5]. Equation 5 the simplified equation of area with this ratio.

$$A_r = \frac{6}{25}\pi d_o^2 \tag{5}$$

Combining Equation 3 with Equation 5 results in Equation 6

$$d_o = \sqrt{\frac{25W_{lv}}{3\pi C_d \rho_{air} v^2}} \tag{6}$$

Based on the calculations, the fore and aft must stay at a speeds slower than 15.46 $^{ft}/_{s}$ and 16.9 $^{ft}/_{s}$ respectively. With these weights, the fore section a parachute diameter of 7 ft is needed and the aft chute diameter of 6 ft is needed. This will result in the decent speeds of the fore being 15.03 $^{ft}/_{s}$ and the aft being 16.0 $^{ft}/_{s}$. The impact forces t the fore and aft section would be 70.8 ft-lbf and 67.5 ft-lbf. The drogue chutes from the below calculations result in 2.3 ft diameter parachutes. With a coefficient of drag of .9 the speeds fore and aft result in 67.8 $^{ft}/_{s}$ and 63.9 $^{ft}/_{s}$, respectively.

4.3.6 Parachute Ejection Charges

Historically, the OSRT has used BP ejection charges to separate sections of the launch vehicle and deploy the parachutes. While these kinds of charges are dependable, they are also quite dangerous as they are prone to early detonation due to static electricity. This can cause serious damage to the recovery system and serious injury or death to the operator who is installing the charge. Because of this, the OSRT will be deploying the parachutes by designed and manufactured ejection system that solely uses CO2. These ejection systems will be loosely based on the designs for the Peregrine and RAPTOR CO2 ejection systems.

While retail organizations have created CO2 ejection systems that do not use energetics or pyro-consumables, these systems are sold for about $450 each, before purchasing the CO2 canisters. The OSRT can build CO2 ejection system that does not use energetics of any sort for roughly $50, including a canister, before electronics.

To create this system, the OSRT designed three different methods. The first, shown in Figure 17, is based heavily on the Peregrine design, except, instead of the CO2 canister being blown forward into the opening pin by a small BP charge, the opening pin is pushed into the CO2 canister via a spring that is released by a servo, and then is pushed out of the canister by springs in a track [7]. The gas vents out into the parachute bay around the opening pin.

The second design is a combination design of a BB gun and a standard CO2 parachute ejection system. A standard BB gun's firing system is depicted in Figure 18, and shows how a slender tube with a hole in it by the base of the piston system is pushed forward by a piston with a spring, which gives the ball bearing its

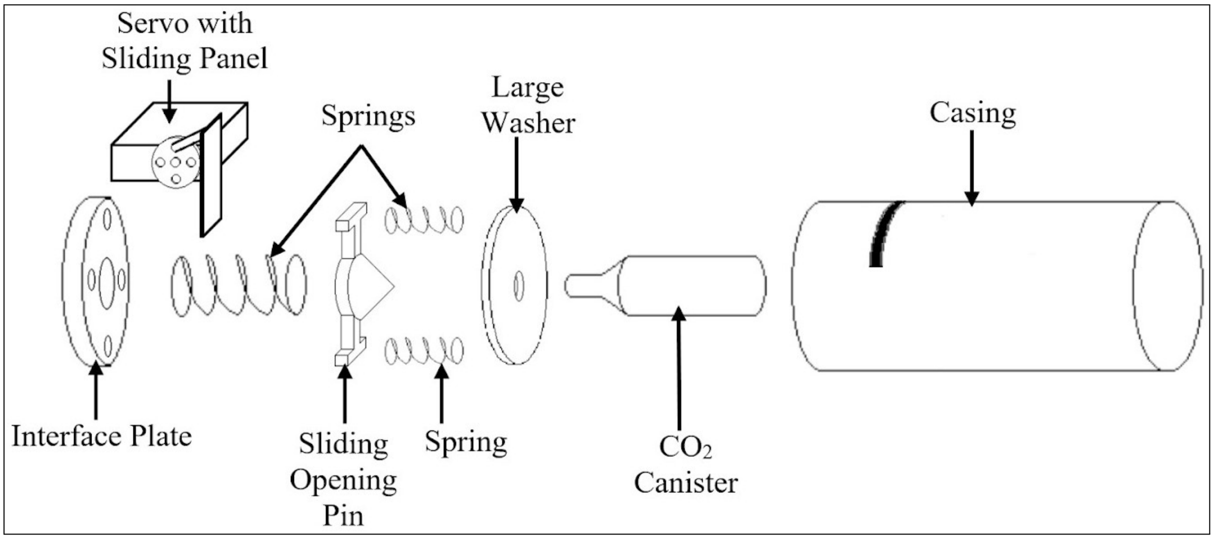

Figure 17: Peregrine-Based Design

initial speed. Then, once the piston and spring are fully extended, the hole at the base of the tube allows the CO2 from the cartridge to vent through the tube, giving the ball bearing the rest of the speed it needs [6].

Similarly, the second design, shown in Figure 19, is a needle-shaped tube with two holes in it, one toward the tip, and one toward the base, which is driven by a spring released by a servo into the CO2 canister, which will vent through the tube and into the parachute bay.

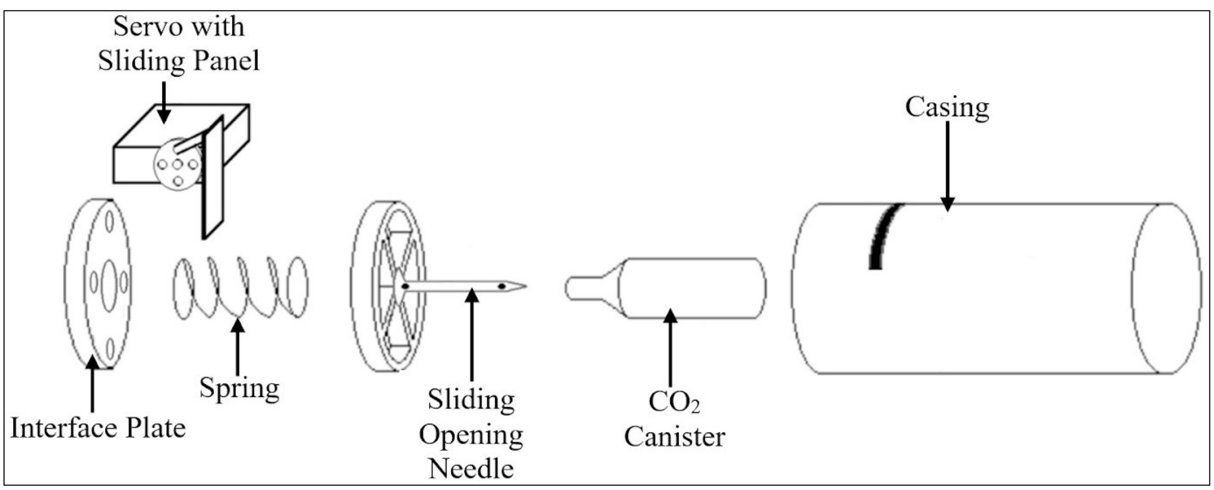

Figure 19: BB Gun-Based Design

The third design uses a drilling method to release the gas, as shown in Figures 20 and 21. [3] A stiff spring pushes the canister into the drill bit, which is attached to a small Unmanned Aerial Vehicle (UAV) motor via

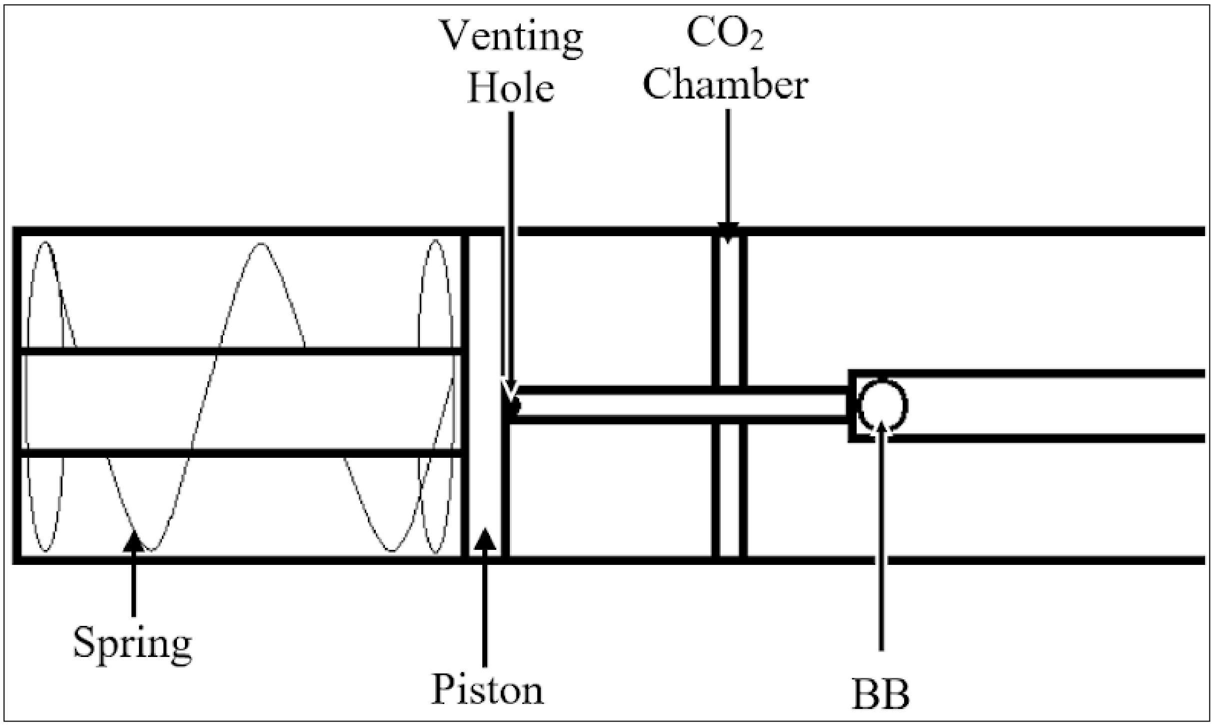

Figure 18: Diagram of How a BB Gun is Structured

a small drill chuck. When it is time to deploy the parachutes, the motor will turn the drill bit as the canister is pushed into it and prevented from rotating via a square interface piece. The gas will vent out around the drill bit, and around the motor, into the parachute bay.

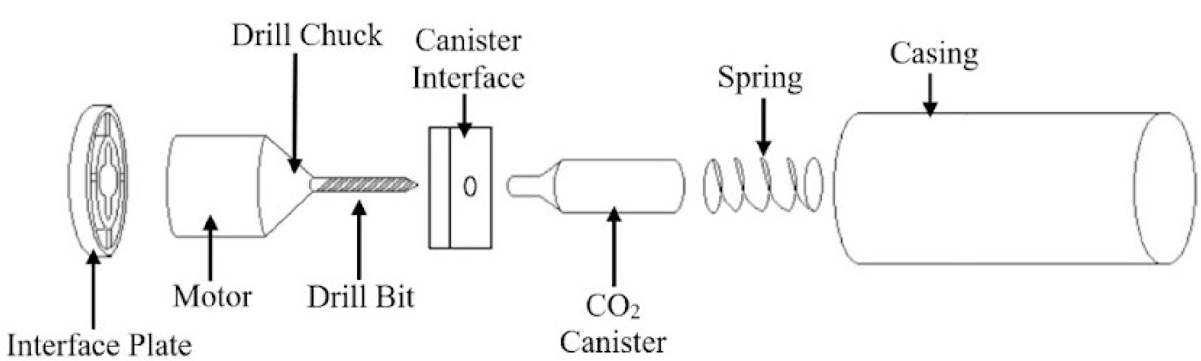

Figure 20: Expanded Design of Drilling Method

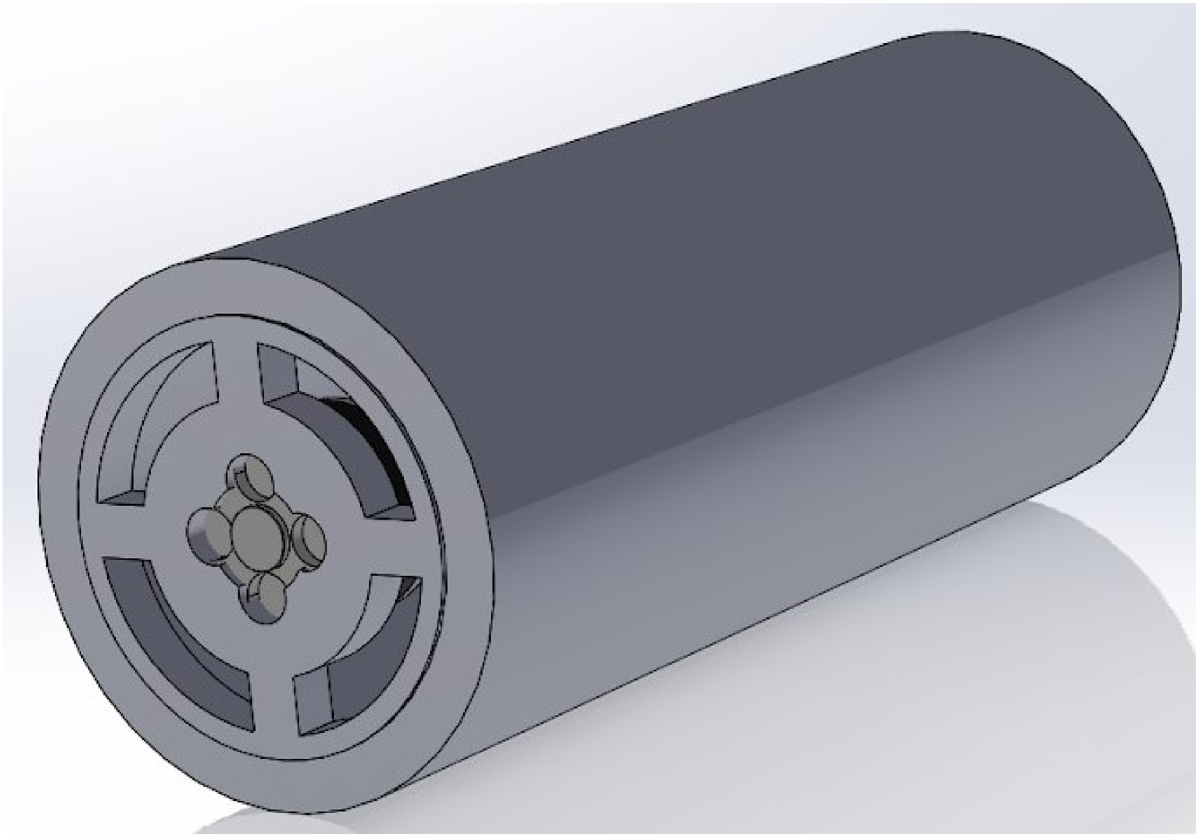

Figure 21: Drilling Method Design Assembled

Based on how students will be manufacturing these systems, the Drilling Method will be explored further, because it will be the easiest to manufacture and appears to have a high rate of success. The BB Gun-Based Method will be used as the back-up design. The material for the casing will be first determined through material stress ratings available on McMaster-Carr and through simulations available in SolidWorks. Then, the casing will be manufactured and used for testing the ejection system. The motor will be determined based on criteria such as shaft diameter, can diameter, and overall length. The spring will be selected based on its spring constant. As a place to start for determining the correct CO2 canister size, the amount of BP necessary to blow the parachutes out of the bay in pounds of force will be found through testing, and then multiplied by 5. This method is based on a method found on the Tinder Rocketry website, in the instruction manual for the Peregrine system [7]. After a number is calculated, canisters both at the calculated size, and the next available size larger will be bought and tested to ensure that the parachutes can be deployed.

A back-up BP ejection system will also be created and utilized until the CO2 ejection system works consistently to ensure that the parachutes will deploy during every launch and keep both spectators and the launch vehicle and payload safe. At the same time, the BP ejection system will also aid in the creation of the CO2 ejection system, as it will be necessary to find the amount of BP that is necessary to eject the parachute from the parachute bay to calculate the theoretical size of the CO2 canister. The BP charges will be built with surgical tubing, cable ties, rubber plugs, and electronic matches. The theoretical amount of BP needed to eject the parachutes will be calculated with from Equation 7.

$$BP = 0.0000132 * l_{compartment} d^2_{compartment} \tag{7}$$

The compartment diameter and length are both measured in inches, and the BP is measured in pounds of force. [4] After the theoretical amount is calculated, charges will be made both with the theoretical amount of BP and with larger amounts of black powder and they will be ground tested to determine what size of a black powder charge would be best to eject the parachutes.

Both the BP and CO2 ejection systems will be actuated by altimeters such as the MissileWorks Rocket Recovery Controller 3 (RRC3) and PerfectFlite StratoLogger CF altimeters, however, in order to actuate the motor, a motor controller will also be used.

4.4 Propulsion

The OSRT will use a Cesaroni Technology L3200 for the launch vehicles source of propulsion with specifications shown below. This motor was chosen based off of a desirable amount of power to propel the launch vehicle to the desired apogee while maintaining adherence to the fuel and motor size regulations. It also has the benefit of being smaller than other solutions.

Table 6: Motor Specifications

Total Impulse	Burn Time	Max Thrust	Average Thrust	Loaded Weight	Propellant Weight	Propellant Type
3300.3 N-sec	1.0 sec	3723.0 N	3209.4N	7.2 lbs	3.8 lbs	Vmax

4.5 Payload

4.5.1 Payload Overview

The payload mission has a series of objectives that must be addressed in our design. The payload must navigate to a predefined sample recovery area, collect a lunar ice sample of at least 10 mL, store that sample, and move at least 10 linear feet away from the sample recovery area. The real life application of this competition is to simulate a lunar rover collecting ice samples from The Moon and bringing them to a location for analysis. In order to complete these tasks, the launch vehicle will need a system dedicated to detaching the payload from the launch vehicle after it has been recovered safely. Once the payload has been separated from the launch vehicle, it must navigate through unknown terrain to an ice sample, and collect that sample. The plans to meet these objectives are discussed in detail below.

4.5.2 Ejection System

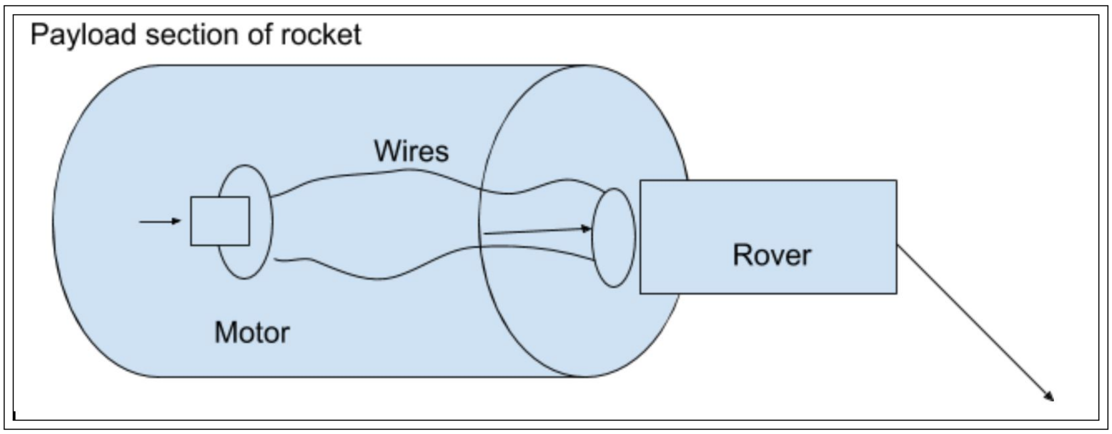

Figure 22: Rover Ejection System

As pictured, the rover is ejected by a small motor used to turn a screw with a pusher, pushing the rover out the side of the tube, through a slip fitted housing cap. Wires connect to the rover power system and control the motor. After the rover has fully pushed itself out of the launch vehicle housing, it is able to disconnect itself from the stationary motor and drive towards the sample recovery zones. The rover frees itself by driving its crawling arms forward, which will pull apart the connection to the housing .

4.5.3 Structure System

The chassis of the rover must fulfill multiple requirements for proper testing and performance of the rover. Chassis design must be easily accessible to allow constant modification and adjustment of the rover's internal systems prior to the competition. During the competition, the chassis must be able to withstand the impact forces when landing, while also fitting within the launch vehicle's payload section. Once on the ground the chassis must be resistant to dirt and moisture.

To maximize space for electronics, OSRT is pursuing a cylindrical geometry for the chassis. Along with maximizing space for electronics, this shapes tubing comes readily available in a variety of materials and sizes. This will aid in the manufacturing of necessary components. The chassis needs to be made out of lightweight materials. For this purpose we have decided to use polymers. Polymers like High-density polyethylene (HDPE), Polyvinyl Chloride (PVC), and Acrylic are readily available and easy to work with. Plastics can also be very forgiving when subjected to impact and bending, while maintaining rigidity.

Polymers are also cheap and can be welded using solvents, making it possible to easily assemble prototypes and affordable to make spare parts. In Figures 23 and 24 the rover design is shown. The collection system has not yet been integrated into the system. As we add components, the dimensions of the rover are subject to change.

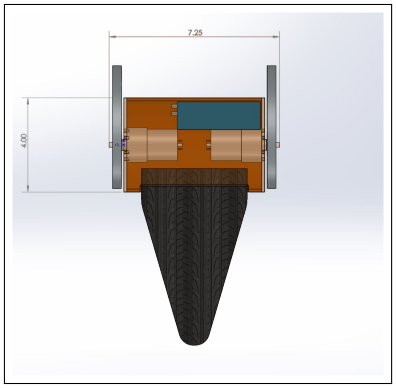

Figure 23: Rover, General Structure

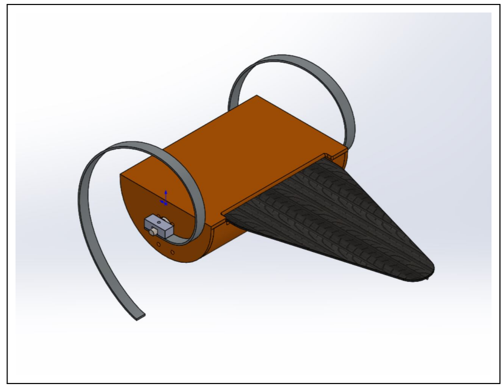

Figure 24: Rover, Isometric Structure

4.5.4 Propulsion System

The drive-train of the rover consists of two claws, powered by separate dc motors that function similarly to wheels (see Figures 23 and 24). These claws drag the sled shaped rover across any terrain. Each arm will have its own motor to allow for independent control. This allows us to turn the rover by running the claws asymmetrically. The danger of this design is timing between motor rotation, and arm position. When both motors run independently they will also run at different speeds. We plan to control this by using motors with lower Rotations per Minute (RPM), and using cameras to monitor the rover. This drive-train was selected to explore new possibilities on rovers, specifically exploring unique designs that can replace the wheels typically seen on rovers.

The control electronics aboard the rover will be housed on a custom designed control board. The control board will contain motor driver circuits for each of the drive motors. The control board will also contain a GPS module and a magnetometer which, in conjunction with a microcontroller, will allow for the nearest target location to be determined and a heading towards that location to be calculated. The microcontroller will also communicate with a RF module to allow for communication with a remote control module, operated by a team member. All rover electronics will be powered by a battery with sufficient capacity to operate all rover electronics for the duration of the mission under worst case current draw. The control board will also contain motor driver circuits to operate the soil collection motor.

4.5.5 Collection System

The collection system includes a small motor with a custom steel drill bit attached linearly. Both of these components will be encased in a small plastic pipe to ensure the motor does not move with the drill bit as to prevent the wires from getting tangled and to produce the required torque to drill through the dirt. This will also ensure that the dirt and samples drilled will be gathered up through the tube. The sample will travel up through the tube to a slot near the motor where the dirt and samples will drop into the final component, a large box with a cut out for the tube. The box will retain the samples. The system will either be lowered to the ground level, in order to drill and collect the dirt and sample mixture, by the use of the drive system. The drive system will include crawling arms which may be positioned in order to give the collection system proper proximity to the ground. The attachment of the collection system is to be determined. It will most likely be placed on the bottom of the main body or, possibly, on the back flap.

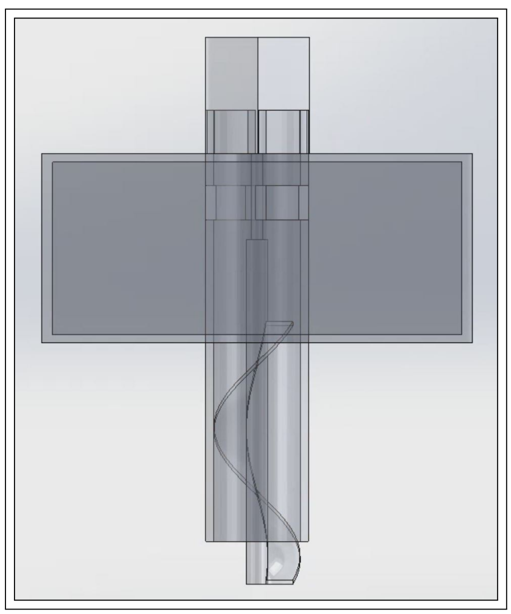

Figure 25: Rover Collection System CAD

4.5.6 Structure System

The chassis of the rover must fulfill multiple requirements for proper testing and performance of the rover. Chassis design must be easily accessible to allow constant modification and adjustment of the rover's internal systems prior to the competition. During the competition the chassis must be able to withstand the impact forces when landing, while also fitting within the launch vehicle's payload section. Once on the ground the chassis must be resistant to dirt and moisture.

To maximize space for electronics we are pursuing a cylindrical geometry for the chassis. Another benefit of this shape is tubing comes readily available in a variety of materials and sizes. This will aid in the manufacture of necessary components. The chassis needs to be made out of lightweight materials. For this purpose we have decided to use polymers. Polymers like HDPE, PVC, and Acrylic are readily available and easy to work with. Plastics can also be very forgiving when subjected to impact and bending, while maintaining rigidity. Polymers are also cheap and can be welded using solvents, making it possible to easily assembly prototypes and affordable to make spare parts.

4.5.7 Design Justification

This design was chosen to explore new design space within rovers that moves away from the typical wheels and treads seen on existing rovers. This “crawling arm” form of locomotion has never been used on an extraterrestrial lander and deserves closer inspection for feasibility. Even if this rover is less successful than a more traditionally wheeled lander, the team is interested in researching a less known field, because the potential could be there. The expected terrain will consist of large clumps of clay, simulating a rough lunar surface where the rover will need to navigate over obstacles similar in size to the rover itself. The arms will be easily collapsible, and uncoil when released from the launch vehicle. Once released, the arms will have a much farther reach than any expandable wheel. Making it possible for the rover to easily traverse a rough terrain.

4.5.8 Rover Test Plan

Initial testing of rover designs will be done to prove design concepts and identify areas of improvement. These tests will be done with representative prototypes, presenting features relevant to functionality. The rover’s locomotion will need to be tested on terrain similar to what is expected at the launch site, which will require a terrain test bed to be constructed. This test bed will be used to simulate a variety of launch day conditions, including rain, varying levels of moisture in the soil, obstacles, and small hills or bumps. Additionally, the rover’s internal systems will need to be tested to find values such as battery life, wireless range, shock absorption, and waterproofing. The rover’s characteristics such as top speed, turning radius, reverse speed, and maximum climbable incline will all be vital to understanding our payload’s capabilities. Individual tests will be done for the following components:

1) Rover wheels/claw locomotion (turning, forward, reverse)
2) Rover ejection system
3) Rover Retention system
4) Rover communication/control
5) Rover batteries
6) Rover camera

7) Rover soil collection system
8) Rover sample storage system
9) Rover stabilization
10) Structure stability
11) Rover structure

Table 7: Rover Test Plan

Test	Test Procedure
Terrain Travel	A design with representative features will be made with on hand components to test wheel design. This will then be tested in multiple terrains (tilled clay, grass, tarp, etc.).
Rover Deployment	A test fixture will be developed to hold the deployment mechanism and rover. This will allow us to test the system before the launch vehicle is ready for a launch.
Control System Communication	The robot controls will be tested to establish the maximum operational distance of the rover.
Auger Soil Collection	Initial testing will be done by hand to establish auger designs with the best functionality. If proven feasible further testing will be done with a a fixture representative of rover.
Rover agility	A pro-type will be made with similar geometry to the designed rover. This will then be used to test rovers ability to turn, and move in reverse, in a variety of terrains
Battery life	Motors will be ran using specified batteries, on a representative prototype. Motors will be run till they loose functionality.
Structure and component rigidity	Rover structure will be subjected to drop tests to ensure structure stability and identify failure points. Components will then be fastened to structure, the test will be repeated to identify weak connections.
Rover orientation	A prototype will be tested in an array of orientations that could result from ejection from the launch vehicle. Then using the tail, and claws the rover will attempt to achieve proper orientation.
Camera	Camera will be tested to establish maximum operating distance.
Retention system	Retention system will be subjected to atypical loading and drop tests.
Retention system deployment	Retention system and fail-safes will be tested to ensure functionality.

4.6 Project Requirements

Shown in Tables 8-13 is a breakdown of all USLI competition requirements outlined in the handbook, a brief description of how OSRT plans to verify these requirements will be completed, and the current status of the verification implementation.

4.6.1 General Requirements

Table 8: General Requirement Verification Matrix

Requirement	Verification Plan	Status
1.1.1 Students on the team will do all of the work on the project, except when it comes to assembling motors and handling black powder or any other kind of ejection charge.	Individuals who are not students on the team will be prohibited from doing work on the project at any point in time, unless it is for motor assembly or ejection charge purposes, and only team members will be granted access to the team's shared drive and LaTeX documents.	In progress - This will be a daily practice starting from the time the handbook is released to when the Post-Launch Assessment Review is submitted, and is included in the timeline, as everything in the timeline is student work.
1.1.2 The team will submit new work.	The team will not copy and paste large sections of material from previous documents into new documents without significantly modifying that which is copied.	In progress - This will be completed at each each deliverable submission, and is included in the timeline, with ample time to write, compile, and edit all deliverables before submission.

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Table 8 – continued from previous page

Requirement	Verification Plan	Status
1.2 The team will provide and maintain a project plan, including project milestones, budget and community support, checklists, personnel assignments, STEM Engagement events, and risks and mitigations.	The Team Lead will maintain the project plan, monitor the work of the team done by project milestones, and keep track of personnel assignments, while Budget and Finance keeps the budget up-to-date and works to maintain community support, STEM Engagement will keep track of all STEM Engagement activities and record and report the outcome of each activity to NASA via the STEM Engagement Activity Report, and Safety will be responsible for keeping risks and mitigations up-to-date. All aforementioned subteams will update these respective pieces of information in each deliverable submitted to RSO	In progress - A project plan with the milestones, budget and community support, checklists, personnel assignments, STEM Engagement events, and risks and mitigations will be repeatedly updated and submitted to NASA personnel up to and including to when the Post-Launch Assessment Review is submitted. This is included in the timeline in the compiling and editing phase of each deliverable.
1.3 Foreign National team members must be identified by the Preliminary Design Review.	Team members will be required to report to the Team Lead that they are a Foreign National before the Preliminary Design Review submission deadline.	In progress - All team member's nationalities will be collected by the Preliminary Design Review submission deadline, and this collection is accounted for in the timeline in the compiling and editing schedule of the Preliminary Design Review.
1.4 The team must identify all team members attending launch week activities by the Critical Design Review.	The Team Lead will collect a list of members and one mentor who will be attending launch week activities and submit it by the Critical Design Review submission deadline.	Not complete - This will be completed closer to the Critical Design Review submission deadline, and is accounted for in the timeline in the editing and compiling schedule of the Critical Design Review.

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Table 8 – continued from previous page

Requirement	Verification Plan	Status
1.5 The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and math activities, as defined by the STEM Engagement activity report between project acceptance and FRR.	The team will keep a tally of how many students participate in each educational activity, and will submit this number, along with the STEM Engagement Activity Report, within two weeks of the STEM Engagement activity to RSO	In progress - The OSRT has started working on STEM Engagement projects and reaching out to schools and activities, and will continue to do so throughout the project. This is accounted for in the timeline under all of the STEM Engagement events and lesson plans.
1.6 The team will establish a social media presence to inform the public about team activities.	The team will create a Snapchat and Instagram account, and will post on these platforms regularly to keep followers up-to-date on team activities.	Complete - Snapchat and Instagram accounts have been created.
1.7 Teams will e-mail all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone either by e-mailing the file directly, or, if the file is too big, by including a link to download the file.	The team will send all deliverables to the NASA project management team, and then will screenshot the sent e-mail with a timestamp and keep the screenshots in a file on the team's shared drive.	In progress - This will be completed at each deliverable submission and is accounted for in the timeline on the day of deliverable deadlines.
1.8 All deliverables must be in PDF format.	All deliverables submitted to NASA will be saved in PDF format, and one copy of each deliverable will be saved to the team's shared drive.	In progress - This will be completed at each deliverable submission and is accounted for in the timeline on the day of the deliverable deadlines.
1.9 In every report, the team will provide a table of contents with major sections and their respective sub-sections.	A table of contents will be submitted within each deliverable that details the deliverable's sections and sub-sections.	In progress - This will be completed at each deliverable submission and is accounted for in the timeline in the compiling and editing schedule of each deliverable.
1.10 In every report, the team will include a page number at the bottom of each page.	A page number will be included at the bottom of each page in every deliverable.	In progress - This will be completed at each deliverable submission and is accounted for in the timeline in the compiling and editing schedule of each deliverable.

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Table 8 – continued from previous page

Requirement	Verification Plan	Status
1.11 The team will provide any computer equipment necessary to perform a video teleconference with the review panel.	The team will reserve a conference room on the Oregon State University campus for the duration of the video teleconference that has a speaker and projector system. The team members will provide a camera, a microphone, and a telephone.	Not complete - This will be completed before each video teleconference, and is accounted for in the timeline in the video teleconference schedule of each deliverable.
1.12 The team will use a launch pad provided by Student Launch's launch services provider.	The team will only use Student Launch's launch services provider's launch pad, and will design the launch vehicle so that it is compatible with either 8-foot 1010 or 12-foot 1515 rails.	In progress - This will be incorporated into the launch vehicle designs, and is accounted for in the timeline with the launch vehicle design schedule, but will officially be completed at the competition launch.
1.13 The team will identify a "mentor".	The team will identify their mentor and report their mentor to the NASA project management team by the time the Proposal is submitted.	Completed - The team's mentor is Joe Bevier and the team's advisor is Dr. Nancy Squires.

4.6.2 Vehicle Requirements

Table 9: Vehicle Requirement Verification Matrix

Requirement	Verification Plan	Status
2.1 The launch vehicle will deliver the payload to an apogee between 3,500 feet and 5,000 feet above ground level.	The Aerodynamics/Recovery and Structures/Propulsion Teams will maintain altitude simulations as the launch vehicle is constructed in order to accurately select a motor that will deliver the launch vehicle into the given altitude window. Aerodynamics/Recovery will also develop an altitude control system to hone in on our declared altitude during flight.	In progress - A projected altitude is defined in the projected altitude section, but will be officially declared by the Preliminary Design Review submission deadline, and this is accounted for in the timeline in the compiling and editing schedule of the Preliminary Design Review.

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Table 9 – continued from previous page

Requirement	Verification Plan	Status
2.2 Teams shall identify their target altitude goal at the Preliminary Design Review milestone.	The team will report our target altitude on our submission for the Preliminary Design Review.	In progress - A projected altitude is defined in the projected altitude section, but will be officially declared by the Preliminary Design Review submission deadline, and this is accounted for in the timeline in the compiling and editing schedule of the Preliminary Design Review.
2.3 The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner.	The team will select a commercially available barometric altimeter for implementation into the recovery system by the Preliminary Design Review submission deadline.	In progress - Altimeter research has been conducted, such as in the parachute ejection section, but this will officially defined by the Preliminary Design Review submission and is accounted for in the timeline in the design schedule for recovery.
2.4 The launch vehicle will be designed to be recoverable and reusable.	The launch vehicle will be designed so that it has a recovery system that allows the launch vehicle to land softly, and an interchangeable motor and ejection charges that allow for the launch vehicle to relaunch within a reasonable time frame.	In progress - The initial design is complete, as detailed in the launch vehicle section, but is yet to be finalized, and this requirement will be completed when the launch vehicle design is complete. This is accounted for in the timeline in the launch vehicle design schedule.
2.5 The launch vehicle will have a maximum of four (4) independent sections.	The launch vehicle will be designed to have three (3) independent sections.	Complete - The launch vehicle will have three (3) independent sections, the nose cone, the fore body section, and the aft body section.

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Table 9 – continued from previous page

Requirement	Verification Plan	Status
2.5.1 Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.	The team will design the airframe shoulders to be at least 6.25 inches in length.	Complete - The airframe shoulders are designed to be 6.5 inches in length on both the fore and the aft breaks of the launch vehicle.
2.5.2 Nose cone shoulders which are located at in-flight separation points will be at least 1/2 body diameter in length.	The team will design the airframe nose cone shoulders to be at least 3.125 inches long.	Complete - The nose cone shoulders are designed to be 3.5 inches long.
2.6 The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	The team will arrive to the launch site at least two hours before the flight waiver opens, and will practice integration of all of the systems into the launch vehicle no later than 1 day in advance of the launch day in order to ensure that the assembly of the launch vehicle takes no longer than 2 hours.	Not completed - This will be completed when the subscale systems are completed and is accounted for in the timeline in each launch's integration schedule.
2.7 The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components.	The team will design all on-board electronics to last a minimum of 10 hours, and the payload to last a minimum of 18 hours.	In progress - The initial design has been outlined in the launch vehicle and payload sections, but both are yet to be finalized. This requirement will be completed when the design of launch vehicle and payload electronics are complete, and is accounted for in the timeline in launch vehicle and payload design schedule.
2.8 The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system.	The team will use a standard, commercially available motor and will ensure that it will be able to be ignited with a standard 12-volt direct current firing system by launching it at least once with a 12-volt direct current firing system.	Not complete - This will be completed when the motor has been integrated and successfully launched with a standard 12-volt direct current firing system, and is accounted for on the timeline in the integration and launch schedules.

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Table 9 – continued from previous page

Requirement	Verification Plan	Status
2.9 The launch vehicle will require no extraneous external circuitry or special ground support equipment to initiate launch.	The team will use a standard, commercially-available motor, will not make any modifications to it, and will ensure that the motor can be launched without extraneous external circuitry by launching an identical motor at least once.	Not complete - This will be completed when the motor has been integrated and launched once without extraneous external circuitry which is accounted for on the timeline in the integration and launch schedules.
2.10 The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	The team will only select a motor that uses ammonium perchlorate composite propellant that is approved and certified by NAR, and will have the team mentor approve of the purchase as a representative of NAR before purchase of the motor.	In progress - A motor has been selected, as shown in the propulsion section, however, this will be completed when the motor is purchased after approval of a NAR mentor, and is accounted for in the section for ordering launch vehicle components schedule.
2.10.1 Final motor choices will be declared by the CDR milestone.	The team will include their declaration of their final motor by the team's Critical Design Review deliverable submission.	In progress - A motor has been selected, as shown in the propulsion section, however, it will be officially declared after a scaled-down motor is purchased after approval of a NAR mentor, and flown successfully before the Critical Design Review deliverable submission, which is accounted for in ordering launch vehicle components, integration, and launch schedules.
2.10.2 Any motor change after CDR must be approved by the NASA RSO.	The team will not change their motor after their Critical Design Review deliverable submission unless it is absolutely necessary, in which case, the team will seek approval from the NASA RSO before finalizing any motor changes.	Not completed - This will be completed when the launch vehicle is launched at competition, but if needed, is incorporated on the timeline in the modifying/repairing the launch vehicle section.

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Table 9 – continued from previous page

Requirement	Verification Plan	Status
2.11 The launch vehicle will be limited to a single stage.	The launch vehicle will be designed to only hold one motor in the aft section of the launch vehicle.	In progress - A single-staged launch vehicle has been designed in the launch vehicle, and this requirement will be complete when the design for the launch vehicle as been finalized, which is accounted for on the timeline in the design of the launch vehicle.
2.12 The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).	The team will not select a motor larger than an L-class for implementation into the launch vehicle, and will keep the launch vehicle and rover weight low enough that an L-class motor or smaller can carry the launch vehicle to the predetermined altitude.	Complete - The team has selected a Cesaroni Technology L3200 with a total impulse of 3300.3 N-sec.
2.13 Pressure vessels on the vehicle will be approved by the RSO	The team will have all checklists that involve pressure vessels require a signature from the RSO after the RSO approves the vessel in order for the checklist to be complete.	In progress - The checklists will be completed while doing design and preparing for construction of the system and will be, and has been accounted for in the timeline during the design and early construction schedules of the recovery system.
2.13.1 The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	The team will ensure that all pressure vessels have a minimum factor of safety of 4:1, and will supply updated calculations in each deliverable to demonstrate that the factor of safety remains at least 4:1.	In progress - This will be completed at each deliverable submission starting with PDRand is accounted for in the timeline in the compiling and editing schedule of each deliverable.
2.13.2 Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.	The team will incorporate a pressure relief valve into all pressure vessels, and test it to ensure that the valve can withstand the maximum pressure and flow rate of the vessel.	In progress - This will be complete when pressure relief valves are incorporated into the parachute ejection charge design, which is accounted for in the timeline in the recovery design section.

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Table 9 – continued from previous page

Requirement	Verification Plan	Status
2.13.3 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 the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	The team will keep a log explicitly for each tank used, and will record the number of pressure cycles and the dates of pressurization/depressurization, along with requiring the signature of the individual who administered each pressure event. This documentation, along with the description of the application for which the tank was designed will be included in all deliverables.	In progress - This will be complete when the tanks are incorporated into the parachute ejection charge system and go through testing, which is accounted for in the timeline in the recovery design, manufacturing, and testing schedules.
2.14 The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit.	The team will ensure that the static stability margin of the launch vehicle will at least be 2.0, and the updated calculations will be included in each deliverable submitted.	In progress - This will be completed at each deliverable submission and is accounted for in the timeline in the compiling and editing schedule of each deliverable.
2.15 Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	The burnout center of gravity will be calculated twice: first, prior to finishing the design of the launch vehicle to ensure that all protuberances are designed to be aft of the burnout center of gravity, and second, after finishing the design of the launch vehicle to ensure that the protuberances are still aft of the burnout center of gravity after their addition.	In progress - The launch vehicle has been designed without any protuberances thus far, but this will be completed when the launch vehicle design is finalized, and is accounted for in the timeline in the launch vehicle design schedule.
2.16 The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	Simulations will be conducted in OpenRocket throughout the development of the launch vehicle, recovery system, and payload to ensure that the launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit. If it cannot, the motor will either be increased, or the weight of the overall launch vehicle will be decreased.	Not completed - This will be completed when the manufacturing and testing of the launch vehicle, recovery system, and payload are completed, and is accounted for in the timeline in the launch vehicle, recovery, and payload manufacturing and testing schedule.

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Requirement	Verification Plan	Status
2.17 All teams will successfully launch and recover a subscale model of their rocket prior to CDR.	The team will have three subscale launches to test the launch vehicle and recovery system designs, which will all be photographed and signed off by two members in every checklist leading up to the launch, one on Saturday, November 9th, another on Saturday, November 30th, and a third on Sunday, December 15th.	Not completed - This will be completed by the final subscale launch day, Sunday, December 15th.
2.17.1 The subscale model should resemble and perform as similarly as possible to the full-scale model.	The subscale model will be designed to be 2/3rds scale replica of the full-scale rocket.	In progress - The design of the subscale model is detailed in the launch vehicle section but this will be complete when the subscale launch vehicle and recovery system and full-scale launch vehicle and recovery system are designed, and this is accounted for in the design and launching of the subscale model and the design of the full-scale model schedules.
2.17.2 The subscale model will carry an altimeter capable of recording the model's apogee altitude.	The subscale model will use the same altimeters as the full-scale model.	In progress - Altimeters have been explored, such as in the parachute ejection section, but this will be complete when the altimeters are selected for the full-scale launch vehicle, and implemented in the subscale launch vehicle, all of which is accounted for in the timeline for purchasing both launch vehicle and recovery components, ground testing the recovery system, and building the subscale schedules.

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Requirement	Verification Plan	Status
2.17.3 The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	The launch vehicle and recovery system will be constructed from all-new materials, ensuring that these systems are built specifically for this year's project.	Not completed - This will be completed when materials for the subscale launch vehicle and recovery system are ordered and when both systems are built, all of which is accounted for in the timeline.
2.17.4 Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	Altimeter data and photos of the launch day, including of the launch and of the recovery, will be provided as proof of a successful flight.	Not completed - This will be completed when a successful flight is completed and the proof is submitted in the Critical Design Review deliverable, which is accounted for in the timeline under launch and compiling and editing the Critical Design Review deliverable.
2.18.1.1 All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration.	The team has scheduled two launch days to do a successful launch and recovery of the launch vehicle and recovery system, which will all be photographed and signed off by two members in every checklist leading up to the launch, one on Saturday, February 1st and another on Saturday, February 22nd.	Not completed - This will be completed upon successfully launching and recovering the launch vehicle and recovery system in February, which is accounted for in the timeline with scheduled full-scale launches.
2.18.1.2 The rocket flown must be the same rocket to be flown on launch day.	The team will not change the launch vehicle or recovery system between its final flight before FRR and its flight on launch day, and will use the same checklists as will be used on launch day to ensure this.	Not completed - This will be completed between the final launch before the Flight Readiness Review and launch day, where no technical modifications will be made to the launch vehicle or recovery system between the two flights, and has been accounted for in the timeline with a scheduled launch vehicle repair time, but not a launch vehicle modification time.

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Requirement	Verification Plan	Status
2.18.1.3 The vehicle and recovery system will have functioned as designed.	The vehicle will meet all speed and energy requirements, will separate at the correct times, and the recovery system will deploy and inflate its parachutes at the correct times to ensure that the vehicle lands under the energy requirements as well.	Not completed - This will be completed at full-scale launches in February, and has been accounted for in the timeline in the scheduled launch and, if needed, the modify/repair schedules as well.
2.18.1.4 The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	The launch vehicle and recovery system will be constructed from all-new materials, ensuring that these systems are built specifically for this year's project.	Not completed - This will be completed when the full-scale launch vehicle and recovery system are built and is accounted for in the timeline both in material and components purchasing for the launch vehicle and recovery system, and in both of their manufacturing schedules as well.
2.18.1.5 If the payload is not flown, mass simulators will be used to simulate the payload mass, and will be located in approximately the same location as where the payload would be.	If the Payload Team is not ready to fly to payload, they will manufacture a mass that is the same size and basic shape of the payload, and can be retained by the same retention and ejection system in the launch vehicle.	Not complete - This will be completed when the Payload Team manufactures a mass representative of the payload that is flown in a full-scale flight, which is accounted for in the timeline in the manufacturing schedule of a full-scale payload.
2.18.1.6 If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	The team will activate all payload features that change the external surface of the launch vehicle and/or manage the total energy of the vehicle, and will have two team members sign off on the checklist for this system, along with photos taken of the system, to verify its actuation later.	Not completed - This will be completed when Payload actuates these features before a full-scale launch, which is accounted for in the timeline in both the integration schedule and the February launch days' schedules.

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Table 9 – continued from previous page

Requirement	Verification Plan	Status
2.18.1.7 Teams shall fly the launch day motor for the Vehicle Demonstration Flight.	The team will fly the launch day motor at both full-scale launches and will have two people sign off on its checklist for this feature, along with photos taken of this system, to be able to verify this later if need be.	Not completed - This will not be completed until both full-scale launches are completed and is accounted for in the timeline in the ordering schedule for launch vehicle components, the integration schedule the day before launch, and the February launch days' schedules.
2.18.1.8 The vehicle must be flown in its fully ballasted configuration during the full-scale test flight.	The team will fly the vehicle in its fully ballasted configuration, and will have two people sign off on its checklist for this feature, along with photos taken of this system, to be able to verify this later if need be, and if it is necessary to change the ballasted configuration after the second full-scale flight, a third full-scale flight will be conducted to ensure that the final ballasted configuration is flown before the Flight Readiness Review.	Not completed - This will be completed when the vehicle has a fully ballasted full-scale flight in February, which has been accounted for in the timeline in the integration schedule and the February launch days' schedules.
2.18.1.9 After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA RSO.	The team will not modify any portion of the launch vehicle and its components without a signature or written consent of the NASA RSO	Not completed - If necessary, this will be completed when the NASA RSO either sends a letter of approval in the form of an e-mail or letter, or signs a form stating their approval, and has been accounted for in the timeline in the modify/repair schedules between the two February launches should the first launch be successful, or in the repair schedules should the second launch be successful.

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Requirement	Verification Plan	Status
2.18.1.10 Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.	Altimeter data and photos of the launch day, including of the launch and of the recovery, will be provided as proof of a successful flight.	Not completed - This will be completed when a successful flight is completed and the proof is submitted in the Flight Readiness Review report, and has been accounted for in the timeline in the February launch days' schedules and in the compiling and editing schedule for the Flight Readiness Review deliverable.
2.18.1.11 Vehicle Demonstration flights must be completed by the FRR submission deadline.	The team will have two full-scale vehicle demonstration flights which will all be photographed and signed off by two members in every checklist leading up to the launch, the first on Saturday, February 1st and the second on Saturday, February 22nd.	Not completed - This will be completed when both launches are completed before the FRR submission deadline, which is accounted for in the timeline in the two scheduled February launch days and their respective integration days.
2.18.2.1 All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline.	The team will launch and recover the full-scale launch vehicle with the payload twice while the launch vehicle and recovery system meet all requirements, and will photograph the payload's flight during launch, after landing before payload deployment, after payload deployment, and after payload actuation.	Not completed - This will be completed when the payload is flown and documented in February, and is accounted for in the timeline in the two scheduled February launch days and their respective integration days.

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Requirement	Verification Plan	Status
2.18.2.2 The rocket flown must be the same rocket to be flown on launch day.	The team will not change the launch vehicle or recovery system between its final flight before FRR and its flight on launch day, and will use the same checklists as will be used on launch day to ensure this.	Not completed - This will be completed between the final launch before the Flight Readiness Review and launch day, where no technical modifications will be made to the launch vehicle or recovery system between the two flights, and has been accounted for in the timeline with a scheduled launch vehicle repair time, but not a launch vehicle modification time.
2.18.2.3 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 requiring repair.	The team will design and test the retention system before flying it in the launch vehicle it ensure the robustness of this system.	In progress - The Payload team has worked on designing a payload retention and ejection system, which is demonstrated in the ejection system subsection of the Payload section. This requirement will be completed once the Payload team finishes the design, and has manufactured and tested their retention system, all of which has been accounted for in the timeline in the designing, ordering, manufacturing, and testing schedules for the payload.

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Requirement	Verification Plan	Status
2.18.2.4 The payload flown must be the final, active version.	The team will fly the payload in its final, active state, with photographs being taken, along with two people signing off on all of the payload checklist leading up to the flight to be able to ensure that the payload was flown in its final and active state.	Not completed - This will be completed between the final launch before the Flight Readiness Review and launch day, where no technical modifications will be made to the payload between the two flights, and has been accounted for in the timeline with a scheduled payload repair and testing time, but not a payload modification time.
2.18.2.5 Payload Demonstration Flights must be completed by the FRR Addendum deadline.	The team will complete two Payload Demonstration Flights which will all be photographed and signed off by two members in every checklist leading up to the launch, the first on Saturday, February 1st and the second on Saturday, February 22nd.	Not completed - This will be completed when both launches are completed before the FRR Submission deadline and therefore, will also be completed before the FRR Addendum deadline, which is accounted for in the timeline in the two scheduled February launch days and their respective integration days.
2.19 An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.	If an FRR Addendum is necessary to submit to NASA project management, the team will complete the addendum and submit it by the due date of March 23rd, 2020.	Not completed - This will be completed when it the FRR Addendum is submitted to NASA project management, and time will be allotted, if necessary, to ensure that the FRR Addendum is completed by the time it is due.

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Requirement	Verification Plan	Status
2.19.1 Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week.	If it is necessary to petition the NASA RSO for permission to fly the payload, the team will petition the NASA RSO no later than March 25th, 2020 with a letter from the team and a detailed report of what caused the Payload Demonstration Flight failure, and what the team has done to fix those causes.	Not completed - This will be completed when the team sends the letter and report to the NASA RSO, and time will be allotted, if necessary, to ensure that the letter and report are sent to the NASA RSO no later than March 25th, 2020.
2.20 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. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	The team will place a label detailing the team's name and the launch day contact information of the team lead to the outside of the fore and aft sections of the launch vehicle, and on the underside of the payload in an area that is clearly visible.	Not completed - This will be completed when the launch vehicle and payload are built, and has been accounted for in the timeline in the launch vehicle manufacturing schedule.
2.21 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 team will develop a uniform method of brightly coloring and clearly labeling all Lithium Polymer batteries so that they are easily distinguished from other electronics components and payload hardware. This method will be turned into a checklist, which, once completed, will need to be signed by the person in charge of the system, the team Safety Officer (SO), and the Team Lead.	Not completed - This will be completed when a uniform method of clearly marking the Lithium Polymer batteries is developed and properly executed, and is accounted for in the design, order, and manufacturing of the launch vehicle.

Table 10: Vehicle Prohibition Verification Matrix

Requirement	Verification Plan	Status
2.22.1. The launch vehicle will not utilize forward canards. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	The launch vehicle will be designed without the need for forward canards excluding camera housings.	In progress - Completed in current designs, all future design iterations will not include forward canards. This requirement will be completed when manufacturing of the full scale launch vehicle is complete.
2.22.2. The launch vehicle will not utilize forward firing motors.	The launch vehicle will be designed without the need for forward firing motors, using drag characteristics to slow down instead.	In progress - Completed in current design, all future design iterations will not include forward firing motors. This requirement will be completed when manufacturing of the full scale launch vehicle is complete.
2.22.3. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, Metal- Storm, etc.)	The launch vehicle will be designed without utilizing motors that expel sponges.	In progress - Completed in current design, all future design iterations will not include motors that expel titanium sponges. This requirement will be completed at CDR, when the final competition motor is selected.
2.22.4. The launch vehicle will not utilize hybrid motors.	The launch vehicle will be designed without the need for hybrid motors.	In progress - Completed in current design, all future design iterations will not include hybrid motors. This requirement will be completed upon manufacturing of the full scale launch vehicle.

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Requirement	Verification Plan	Status
2.22.5. The launch vehicle will not utilize a cluster of motors.	The launch vehicle will be designed without the need for cluster of motors.	In progress - Completed in current design, all future design iterations will not include clusters of motors. This requirement will be completed upon manufacturing of the full scale launch vehicle.
2.22.6. The launch vehicle will not utilize friction fitting for motors.	The launch vehicle will be designed without using friction fitting for motor retention.	In progress - Completed in current design, all future design iterations will not utilize friction fitting for motors. This requirement will be completed upon manufacturing of the full scale launch vehicle.
2.22.7. The launch vehicle will not exceed Mach 1 at any point during flight.	The launch vehicle will use a motor with a long enough burn time and low enough thrust to stay below Mach 1 but reach apogee.	In progress - OpenRocket simulations verify the vehicle will not exceed Mach 1 at any point during flight. Flight data from the Vehicle Demonstration Flight will be used to ensure the vehicle does not exceed Mach 1.
2.22.8. Vehicle ballast will not exceed 10 percent of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	The launch vehicle will have its fully fueled weight measured prior to flight to determine the max ballast available to use.	In progress - Completed in current design, less than 10 percent ballast is required for all planned launch conditions. All future design iterations will utilize less than 10 percent ballast for all flight conditions.
2.22.9. Transmissions from onboard transmitters will not exceed 250 mW of power (per transmitter).	The launch vehicle will be designed without transmitters that use more than 250 mW of power	In progress - Completed in current design, the transmitters selected do not transmit more than 250 mW of power. Any future changes to the transmitters will require no more than 250 mW of power.

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Requirement	Verification Plan	Status
2.22.10 Transmitters will not create excessive interference. Teams will utilize unique frequencies, hand-shake/passcode systems, or other means to mitigate interference caused to or received from other teams.	The launch vehicles transmitters will not create excessive interference and will use frequency unique to OSRT.	In progress - Completed in current design, OSRT tracking systems have implemented this previously, similar methods will be utilized this year. Any changes to the systems will have means to mitigate interference.
2.22.11. Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of light- weight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	The launch vehicle will be designed mainly using composites, wood, plastics. Use of metals will be minimized to critical components which cannot be manufactured from other materials.	In progress - Completed in current design, all future designs will be made with the intent to minimize metal usage.

4.6.3 Recovery System Requirements

Table 11: Recovery System Requirement Verification Matrix

Requirement	Verification Plan	Status
3.1. The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO	The team has designed the recovery system to deploy its drogue parachute at apogee and its main parachutes at 600 feet in altitude, which is what the system will be set to for all of the launches, which will be completed by checklists which will be signed by the team member in charge of this system, the Team SO, and the Recovery Team Lead. Video from the ground will be taken for verification that the parachutes ejected at the appropriate time and altitude.	In progress - The recovery system has been designed and is detailed in the recovery system subsection. This requirement will be completed when recovery system's design is finalized, and the system is manufactured and implemented into the subscale and full-scale launch vehicles, which will both launch and complete their recovery sequences at the correct altitudes. All of this has been accounted for in the timeline in the design, ordering, manufacturing, and testing schedule of the recovery system, as well as in the integration and launch schedules for the subscale and full-scale launches.

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Requirement	Verification Plan	Status
3.1.1. The main parachute shall be deployed no lower than 500 feet.	The team has decided to deploy the parachute at 600 feet, and that is what the system will be set to while it is being assembled, which will be completed by checklists which will be signed by the team member in charge of this system, the Team SO, and the Recovery Team Lead, and the process will be photographed as well in the event that the team needs to reexamine the parachute set-up.	In progress - The initial recovery system is detailed in the recovery system section, however, for this requirement to be completed, the recovery system will be finalized, manufactured, and implemented into the subscale and full-scale launch vehicles, which will complete their recovery sequences at the correct altitudes. This is accounted for in the timeline in the recovery system design, ordering, manufacturing, and testing schedules, along with the integration and launch schedules of both the subscale and full-scale launch vehicles.
3.1.2. The apogee event may contain a delay of no more than 2 seconds.	The team will set the apogee event to contain as little to no delay as possible during the subscale launches in order to allow for both a CO2 and BP charge to fire. The CO2 will fire first, as that is what the team is trying to perfect, but, until it is perfected, a back-up black powder charge will be ignited 2 seconds later to ensure that the drogue parachute is deployed. This is what the system will be set to while it is being assembled, which will be completed by checklists which will be signed by the team member in charge of this system, the Team SO, and the Recovery Team Lead, and the process will be photographed as well in the event that the team needs to reexamine the parachute ejection charge set-up.	Not completed - This will be completed when the subscale and full-scale launches complete their apogee events within the first two seconds of reaching apogee. This is accounted for in the timeline in the integration and launch day schedules of the subscale and full-scale launch vehicles.

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Requirement	Verification Plan	Status
3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.	The team will design the motor retention system to ensure that the motor will not fall out either during or directly after launch, and will test their system at the first subscale launch for verification that it securely holds the motor in place.	In progress - A motor rentention system has been initially designed, as seen in the vehicle specifications section, however, this requirement will be completed when the motor retention system's design is further developed and finalized, the system is built, and has successfully completed one subscale launch. All of this is accounted for in the timeline in the launch vehicle design, component ordering, and manufacturing schedules, as well as in the integration and launch day schedules.
3.2. Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.	The team will conduct at least 5 ground ejection tests for both the drogue and the main parachutes in order to ensure that both the parachute and ejection system work, and that the operators receive enough practice to minimize the chance of making a careless error that could cause the recovery system to fail when it comes time to actually to deploy the parachutes during a launch. These tests will be photographed, and a summary of what was done and what was happened will be written no later than 3 days after the testing took place.	Not completed - This will be completed when the parachutes and their ejection systems' designs are finalized, and are constructed to the point that they can be tested.
3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	The team will run simulations in OpenRocket in order to determine the correct size and shape of the parachutes, as well as when they need to deploy, to determine how to land with a maximum kinetic energy equal to or less than 75 ft-lbf.	Complete - For the full-scale launch, the drogue will open at apogee, and

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Requirement	Verification Plan	Status
3.4. The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	The team will purchase and install at least four different altimeters, one for each ejection charge and one for each back up ejection charge.	Not completed - This requirement will be complete when altimeters are purchased, tested, and installed. This is accounted for in the timeline in the recovery system design, ordering, manufacturing, testing, and launch vehicle integration schedules.
3.5. Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	The team will ensure that each altimeter has its own battery, and will select a battery that can be purchased either online or from local hobby stores.	Not completed - This requirement will be completed when a battery has been selected and purchased for each altimeter and installed. If these batteries are Lithium Polymer batteries, this will be completed when the battery is also properly marked and labeled. This has been accounted for in the timeline in the recovery system design, ordering, manufacturing, and testing schedules
3.6. Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	The team will design each avionics bay so that the mechanical arming switch is easily accessible from the exterior of the launch vehicle and the altimeters can be armed within 10 seconds of needing to arm them.	Not completed - This requirement will be complete when the avionics bays are laid out, built, and tested to ensure that the arming switches are easy to find and turn on. This has been accounted for in the timeline in the recovery and launch vehicle designs, ordering, manufacturing, and testing schedules.

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Requirement	Verification Plan	Status
3.7. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	The team will ground test the arming switches to ensure that the switches cannot be disarmed by flight forces.	Not completed - This requirement will be completed when arming switches are selected, purchased, and tested. This has been accounted for in the timeline in the recovery design, ordering, manufacturing, and testing.
3.8. The recovery system electrical circuits will be completely independent of any payload electrical circuits.	The team will design the payload and recovery system electrical circuits will be independently designed and built by separate member on the team as to not depend on each other electrically in any way.	Not completed - This requirement will be complete when the payload and recovery system electrical circuits are designed and manufactured so that the recovery electrical system does not rely on the payload electrical system. This has been accounted for in recovery system design, ordering, and manufacturing schedules.
3.9. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	The team will use 2-56 1/4-inch nylon shear pins to fix the nose cone to the fore section of the launch vehicle, and the fore section of the vehicle to the aft section of the vehicle.	In progress - While shear pins have been selected, this requirement Will be complete when shear pins have been purchased, tested, and installed in the launch vehicle. This has been accounted for in the timeline in the recovery system ordering and testing schedules, and integration schedules of the launch vehicle.

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Requirement	Verification Plan	Status
3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads.	The team will deploy the main parachutes as low as possible in order to minimize the mount of drift while still keeping the landing kinetic energy less than or equal to 52 fps.	In progress - The altitude at which the main parachutes deploy has been selected, as shown in the recovery system section, Therefore, this requirement Will be complete when the recovery system components are purchased and assembled to deploy at 600 feet. This has been accounted for in the timeline in the recovery system design, ordering, and manufacturing schedules.
3.11. Descent time will be limited to 90 seconds (apogee to touch down).	The team will deploy the main parachutes as low as possible in order to minimize the mount of time it takes the launch vehicle to go from apogee to landing while still keeping the landing kinetic energy less than or equal to 52 fps.	In progress - The altitude at which the main parachutes deploy has been selected, Therefore, this requirement Will be complete when the recovery system components are purchased and assembled to deploy at 600 feet. This has been accounted for in the timeline in the recovery system design, ordering, and manufacturing schedules.

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Requirement	Verification Plan	Status
3.12. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	The team will install an active electronic tracking device in the aft section of the airframe, and either in the fore section of the airframe or in the nose cone, and will have a life of at least 18 hours to ensure that the active tracking is still functional by the time it is launched, even if the launch vehicle waits for several hours on the launch pad.	In progress - the size of the recovery system is already determined through initial recovery system designs, however, this requirement will be completed when the active electronic tracking devices are purchased and installed. This has been accounted for in the timeline in the recovery system's design, ordering, manufacturing, and testing schedules, and the team's integration system.
3.12.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	The team will install an active electronic tracking device in the aft section of the airframe, and either in the fore section of the airframe or in the nose cone, and will have a life of at least 18 hours to ensure that the active tracking is still functional by the time it is launched, even if the launch vehicle waits for several hours on the launch pad.	In progress - the size of the recovery system is already determined through initial recovery system designs, however, this requirement will be completed when the active electronic tracking devices are purchased and installed. This has been accounted for in the timeline in the recovery system's design, ordering, manufacturing, and testing schedules, and the team's integration system.

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Requirement	Verification Plan	Status
3.12.2. The electronic tracking device(s) will be fully functional during the official flight on launch day.	The team will test extensively electronic tracking devices before launch day and will record what tests they conducted and the results of those tests within 3 days after conducting the tests.	In progress - the type of electronic tracking device has already determined through initial recovery system designs, however, this requirement will be completed when the active electronic tracking devices are purchased and installed. This has been accounted for in the timeline in the recovery system's design, ordering, manufacturing, and testing schedules, and the team's integration system.
3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	The team will design a shield that can be easily placed and secured around the recovery system electronics to prevent them from being adversely affected by other on-board electronic devices during flight.	Not completed - This requirement will be complete when the shielding system is designed, finalized, manufactured, and tested. This is accounted for in the timeline in the recovery system design, ordering, manufacturing, and testing schedules.
3.13.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	The team will design the sections of the launch vehicle to allow space to for the recovery system altimeters to be separated from other radio frequency transmitting device.	In progress - The initial designs of the recovery system and launch vehicle have been completed, but, the requirement will be complete when the avionics and parachute bays' designs are finalized. This is accounted for in the timeline in both recovery and launch vehicle design.

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Requirement	Verification Plan	Status
3.13.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	The team will design a shield that can be easily placed and secured around the recovery system electronics to prevent the early excitation of the recovery system due to transmitting devices.	Not completed - This requirement will be complete when the shielding system is designed, finalized, manufactured, and tested. This is accounted for in the timeline in the recovery system design, ordering, manufacturing, and testing schedules.
3.13.3. The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	The team will design a shield that can be easily placed and secured around the recovery system electronics to prevent the early excitation of the recovery system due to magnetic waves.	Not completed - This requirement will be complete when the shielding system is designed, finalized, manufactured, and tested. This is accounted for in the timeline in the recovery system design, ordering, manufacturing, and testing schedules.
3.13.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	The team will design a shield that can be easily placed and secured around the recovery system electronics to prevent the early excitation of the recovery system due to all other sources other than transmitting devices and magnetic waves.	Not completed - This requirement will be complete when the shielding system is designed, finalized, manufactured, and tested. This is accounted for in the timeline in the recovery system design, ordering, manufacturing, and testing schedules.

4.6.4 Payload Requirements

Table 12: Payload Experiment Requirement Verification Matrix

Requirement	Verification Plan	Status
4.2 Teams will design a system capable of being launched in a high power rocket, landing safely, and recover simulated lunar ice from one of several locations on the surface of the launch field.	The team will design, build, and test a payload that can fit within the airframe of the launch vehicle and sustain launch forces, and, once the launch vehicle has landed, can be deployed and navigate to one of the predetermined locations to retrieve a lunar ice sample and carry the sample away from the location from which it was taken.	In progress - The initial payload design is small enough to be launched inside a launch vehicle, however, this requirement will be completed when the payload design is finalized, and it is built and tested. All of this has been accounted for in the timeline in the payload design, ordering, manufacturing, and testing schedules.
4.3.1. The launch vehicle will be launched from the NASA-designated launch area using the provided Launch pad. All hardware utilized at the recovery site must launch on or within the launch vehicle.	The launch vehicle will entirely contain the payload within the airframe that will be able to deploy from the launch vehicle once it has landed, and navigate to one of the predetermined collection areas to collect a lunar ice sample without any exterior hardware.	In progress - The initial payload design, as depicted in the payload section, is small enough to fit all required hardware for operation into the airframe of the launch vehicle, however, this requirement will be completed when the payload design is finalized and built, and has been integrated with the launch vehicle. This is accounted for in the payload design, ordering, manufacturing, and testing schedules.

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Requirement	Verification Plan	Status
4.3.2. Five recovery areas will be located on the surface of the launch field. Teams may recover a sample from any of the recovery areas. Each recovery site will be at least 3 feet in diameter and contain sample material extending from ground level to at least 2 inches below the surface.	The team will design, build, and test a payload that can navigate to the recovery site, and dig down three inches below the surface in order to access an ice sample.	In progress - The initial payload design has been completed, and is depicted in the payload section, however, this requirement will be completed when the payload design is finalized and built, the payload test bed is designed and built, and the payload navigation and digging capabilities are tested. This has been accounted for in the proposed timeline in the payload design, ordering, manufacturing, and testing schedules.
4.3.3. The recovered ice sample will be a minimum of 10 milliliters (mL).	The team will design a payload that has an ice sample storage capacity of at least 15 milliliters to ensure that it can collect and store the required amount of ice.	In progress - The ice collection system has an initial design, as depicted in the ice collection system section, but this requirement will be completed when the ice collection system design is finalized, built, and its storage capacity is tested. All of this is accounted for in the proposed timeline in the payload design, ordering, manufacturing, and testing schedules.
4.3.4. Once the sample is recovered, it must be stored and transported at least 10 linear feet from the recovery area.	The team will design the payload to have a storage system with the capability to securely hold the ice sample and will have the capability to drive at least 20 linear feet from the recovery area to ensure that it makes it far enough from the recovery area.	In progress - The design has been worked on, but needs to be finalized, and the payload needs to be built and tested. All of this has been accounted for in the proposed timeline.

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Requirement	Verification Plan	Status
4.3.5. Teams must abide by all FAA and NAR rules and regulations.	The team will familiarize itself with FAA and NAR rules and regulations and design a system that does not violate any rules or regulations from the FAA and NAR.	In progress - The payload is still being designed to FAA and NAR standards. This design time has been accounted for in the proposed timeline.
4.3.6. Black Powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Any ground deployments must utilize mechanical systems.	The team will design, build, and test a mechanical payload deployment system that uses a motor to turn a threaded rod which will contact a metal cylinder that pushes the payload out of the airframe.	In progress - The design needs to be finalized, built, and tested. All of this has been accounted for in the proposed timeline.
4.3.7. Any part of the payload or vehicle that is designed to be deployed, whether on the ground or in the air, must be fully retained until it is deployed as designed.	The team will design, build, and test a payload retention system that will retain the payload until it is intended to be deployed.	In progress - The payload retention system design needs to be finalized, built, and tested. All of this has been accounted for in the proposed timeline.
4.3.7.1. A mechanical retention system will be designed to prohibit premature deployment.	The team will avoid using any sort of energetics for the retention of the payload, as to avoid any sort of premature ignitions, and will only be able to be actuated upon the RSO's approval, and will be actuated by the push of a button.	In progress - The payload retention system design needs to be finalized, built, and tested. All of this has been accounted for in the proposed timeline.
4.3.7.2. The retention system will be robust enough to successfully endure flight forces experienced during both typical and atypical flights.	Once the retention system is designed, the team will put it through rigorous testing to ensure that it can withstand anything from launch forces to ballistic impact forces.	Not completed - the payload retention system needs to finished being designed and built before it can be tested. Testing is accounted for in the proposed timeline.

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Requirement	Verification Plan	Status
4.3.7.3. The designed system will be fail-safe.	The team will design the retention system so that, if the system loses power before the launch vehicle lands, the rover will still be secured inside the airframe, and not pose a safety threat to spectators.	In progress - The payload retention system design needs to be finalized, built, and tested. All of this has been accounted for in the proposed timeline.

4.6.5 Safety Requirements

Table 13: Safety Requirement Verification Matrix

Requirement	Verification Plan	Status
5.1. Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	The team will develop a launch and safety checklist for each system that is designed and implemented into the launch vehicle, the recovery system, and/or the payload.	In progress - Checklists will be developed and finalized with the designs. This portion of the design process has been accounted for in the proposed timeline.
5.2. Each team must identify a student SO who will be responsible for all items in section 5.3.	The team will identify a student SO by September 14th, 2019.	Completed - The team student SO is Wyatt Hougham

Continued on next page

Table 13 – continued from previous page

Requirement	Verification Plan	Status
5.3. The role and responsibilities of the SO will include, but are not limited to: Monitor team activities with an emphasis on safety during: Design of vehicle and payload, Construction of vehicle and payload components, Assembly of vehicle and payload, Ground testing of vehicle and payload, Subscale launch test(s), Full-scale launch test(s), Launch day, Recovery activities, and STEM Engagement Activities.	The team SO will approve final designs before orders are placed, the SO and their safety team will help subteams draft safety documents for the construction process of their respective system, and either the SO, or a member of the team appointed and trained by the SO, will be present at all construction and assemblies of systems, as well as at all ground tests, launches, recovery activities, and STEM Engagement activities.	In progress - the designs will be approved as they are finalized, the safety team is working on drafting up documents to help the subteams complete them more efficiently and effectively, and the SO is working on training members of the safety team, and members of the team in general, so that they can act as SO in the event that the SO is unable to.
5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	The Safety team will work alongside the subteams to develop procedures that are both safe and effective for construction, assembly, launch, and recovery activities.	Not completed - This will start after the designs are finalized, and is accounted for in the construction time for each portion of this project.
5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	The Safety team will maintain a binder that will be stored in OSRT's main work space in an easily accessible area. This binder will hold all of the team's current hazard analyses, failure modes and analyses, procedures, and MSDS/chemical inventory data, and will be updated weekly.	In progress - Hazard analyses have been started, and the rest of the binder will be created as subteams' designs become finalized and as they create construction plans, and has been included in the timeline.

Continued on next page

Table 13 – continued from previous page

Requirement	Verification Plan	Status
5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	The Safety team will assist the subteams with writing and developing their hazard analyses, failure modes and analyses, and procedures throughout the duration of the project.	In progress - Hazard analyses have been started, and failure modes and analyses and procedures will be created as the designs are finalized and construction procedures are created. The construction of these safety documents is included in the design and construction phases of the timeline.
5.4. During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	The SO and Team Lead will work together to contact the local club's President of Prefect and RSO at least a week before attending any NAR or TRA launch.	Not completed - This will be completed as needed, and therefore, will not be included in the timeline.
5.5. Teams will abide by all rules set forth by the RSO	The SO and Safety team will familiarize themselves with the FAA rules regarding rocketry, and help the rest of the team familiarize themselves with the FAA rules. The Safety team will be responsible for holding the entire team to the FAA rules.	In progress - The Safety team is in the process of familiarizing themselves with the FAA rules and is included on the timeline as looking over last years documentation, and working on research and design of the launch vehicle, recovery system, and payload.

4.7 Technical challenges

Table 14: Launch Vehicle Technical Challenges

Technical Challenge	Solution	Impacted Section
Ensuring bulkheads of parachute compartment do not fail on parachute deployment.	A factor of safety will be maintained with the calculated strength of epoxy joints in the airframe construction.	Recovery
The failure of any shock cord, eye-nut, and epoxy due to high snatch loads.	The snatch load experienced by shock cords, eye-nuts, and epoxy at the bulkheads will be minimized by having a high safety factor at each component, and by placing main parachutes in deployment bags.	Recovery
Bulkheads do not fit.	Machining will be precise and proper adhesives and materials will be selected.	Launch Vehicle
Launch vehicle must reach desired apogee altitude.	Launch vehicle weight will be calculated and computer simulated launches will be conducted prior to flight, with current motor, to ensure proper apogee altitude.	Launch Vehicle
Rover will fit in launch vehicle payload.	Vehicle and Rover will be designed to fit inside a 6.25 in. diameter airframe.	Launch Vehicle
Ensuring vehicle can withstand landing forces.	Vehicle will be designed with a factor of safety to withstand calculated landing forces.	Recovery
Ensuring shock cord is not tangled inside launch vehicle.	Structures will include no rough or sharp points that protrude from the vehicle.	Recovery
Ensuring proper motor ignition, with no igniter misfires.	Motor will be loaded according to manufacturer's instructions by a properly certified person. Igniters will be properly stored and handled, only being installed as vehicle is vertical on the launch stand.	Launch Vehicle
Reaches predetermined altitude.	Motor will be selected to accommodate the mass of the launch vehicle and likely weather condition.	Launch Vehicle

Table 15: Recovery System Technical Challenges

Technical Challenge	Solution	Impacted Section
Motor becomes disconnected from power supply during launch.	Connect motor to power supply with electrical tape so that it can become disconnected after launch, but will not disconnect itself due to launch vibrations.	Parachute Ejection
The motor is actuated too early.	Ground test the altimeters to ensure that they will not send faulty readings to the ejection motor and ensure that the static port holes are drilled correctly to allow for proper pressure readings.	Parachute Ejection
The CO_2 canister is punctured too early.	Test the ejection system with different springs to make sure that the spring can give enough force to the canister so that it will be punctured when the drill bit starts turning, but not so much that the canister will puncture due to vibrations during flight .	Parachute Ejection
Drill bit breaks during flight.	Test the system with varying sizes of drill bits to find a drill bit small enough to puncture the canister, but large enough to not break due to any extraneous forces.	Parachute Ejection
Canister becomes misaligned during flight.	Manufacture the casing so that it fits snugly around the canister and that the channel which holds the canister interface is long enough that when the canister is punctured, it doesn't slide out to ensure that the canister will not be misaligned during flight .	Parachute Ejection
Canister unscrews from the Canister Interface during flight.	Use Locktite on the threads before placing the Canister and interface into the casing.	Parachute Ejection
Spring becomes misaligned during flight.	Manufacture the casing so that it fits snugly around the spring and adhere the bottom of the spring to the back of the canister using epoxy.	Parachute Ejection
The motor falls out of the casing.	Create several holes in the casing and notches in the motor interface to use screws to hold the motor in place.	Parachute Ejection
The compressed CO_2 gas makes all metal parts brittle due to extreme cold.	Replace the drill bit after every ejection, either paint all exposed surfaces in the inside of and immediately around the canister with thermally insulating paint or cover them with thermally insulating tape.	Parachute Ejection

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Table 15 – continued from previous page

Technical Challenge	Solution	Impacted Section
The metal casing bulges or bursts due to the pressure of the gas released from the canister.	Cut more vents into the casing to allow for the pressure to escape more quickly.	Parachute Ejection
The shear pins break before intend parachute ejection.	Add more shear pins.	Parachute Ejection
The shear pins do not break at intended point of ejection.	Ground test the system to ensure that the CO_2 canister is the right size to offer the right amount of pressure to shear the pins.	Parachute Ejection
The entire ejection system becomes dislodged in the launch vehicle.	Either drill holes in the casing so that screws can be put through the casing and into the bulkhead, or use two u-bolts to bolt the casing down, place a bolt behind the casing to stop the system from sliding out of the u-bolts due to the force of the gas escaping.	Parachute Ejection
BEAVS active system fails to correct apogee prior to launch day.	Scrap the active system and rely solely on the coupled ballast system to reach predicted apogee with highest accuracy possible.	BEAVS
BEAVS blades have unwarranted deployment during flight.	BEAVS is located aft the center of pressure so stability is not compromised.	BEAVS
BEAVS blades do not deploy at all during flight.	Apogee altitude control will be mainly combated on launch day with ballast weights so that minimal amounts of correction rely on the active system. Failure of blades to deploy will not endanger the launch.	BEAVS
BEAVS miscalculates/misreads current state conditions due to noise.	A Kalman Filter will be used to filter out noise effects.	BEAVS
Parachutes get tangled after ejection.	Parachute folding on launch days will be supervised by at least one other to ensure there are no missteps in the process.	Parachutes
Parachutes are not ejected at proper altitudes	Strictly commercially available altimeters will be used, with back up altimeters to ensure proper ejection. Recovery system will have test ejections before test launches to verify system.	Parachutes
The air frame zippers	A wide nylon shock cord will be used and parachutes will be taped into sections to disperse the energy from ejection.	Parachutes
Parachutes do not deploy at all	There will be back up charges and altimeters in the system. Multiple ground test ejections will be performed to ensure parachutes are repeatably being deployed with no issues.	Parachutes

Table 16: Payload Technical Challenges

Technical Challenge	**Solution**	**Impacted Section**
Rover encounters obstacles/rough terrain.	Combination of claw reach, and design allows them to reach past, and pull robot past obstacles.	Drivetrain
Terrain is clay based, and presents challenges for sample collection. It is both hard to dig into, and will stick to any collection system used.	Drill will be sharpened and outer diameter will be reduced to aid with initial penetration of soil.	Ice Collection System
Rover must move in reverse due to unforeseen circumstance.	Claw design makes it difficult to achieve motion backwards. To combat this we will pursue testing of different designs to ensure robot can move in reverse if needed.	Drivetrain
Claw design will require extra torque, and power than conventional wheels.	By keeping rover weight down, and investing in high torque motors, and high capacity batteries we will ensure rover battery will last for the duration of the mission.	Payload Electronics
Rover deploys upside down or on its side.	Incorporating a stabilizing tail to the rover will help position the rover in the correct orientation.Testing will be done to ensure rover can orient itself correctly.	Chassis

5 STEM Engagement

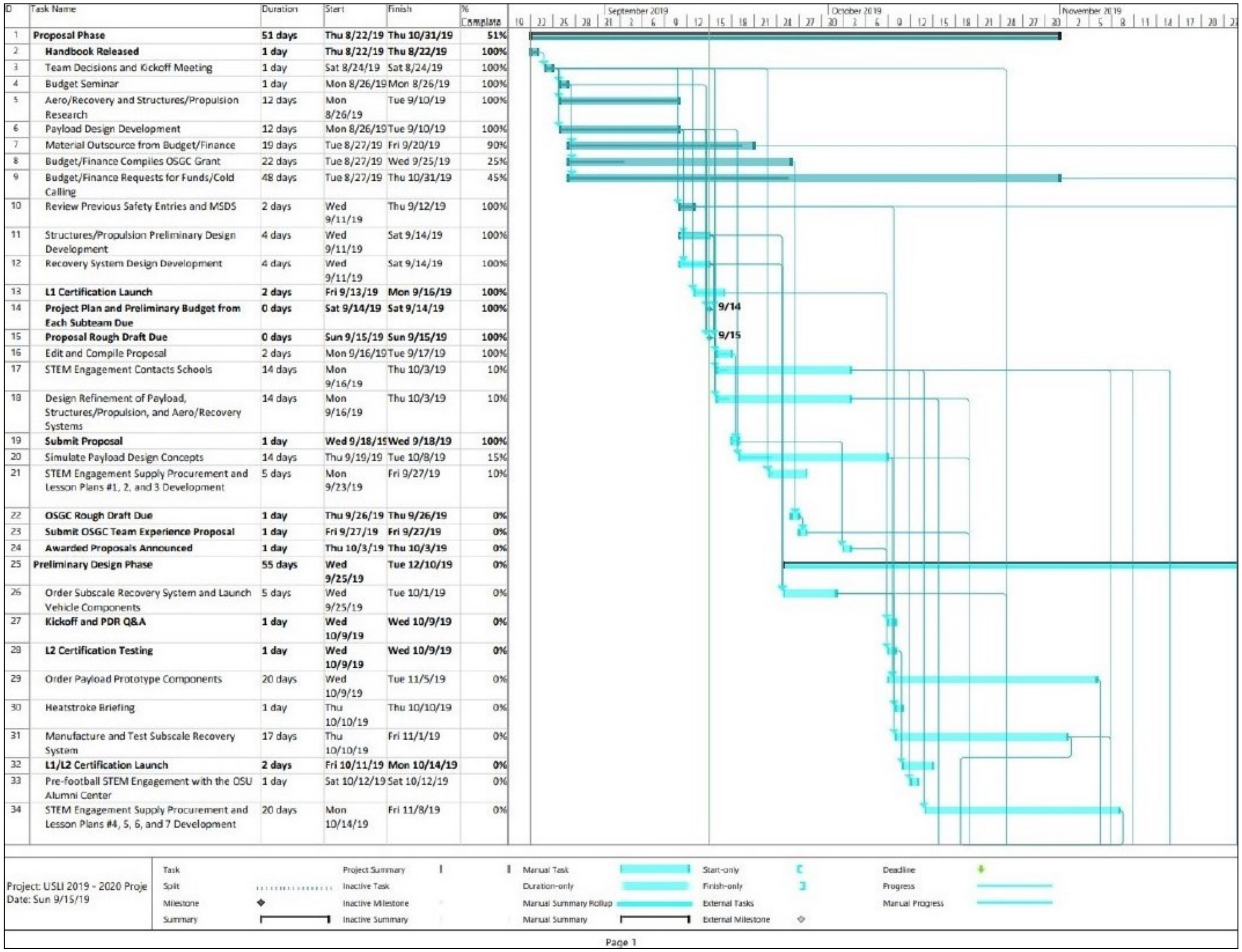
OSRT is committed to bringing STEM engagement to various schools around Oregon. Our members joined this team because they are very passionate about rocketry, and we are excited to share that passion with the next generation. We will engage with students in many different ways. OSRT will have a table available before OSU home football games where we will provide a fun and interesting engineering activity for young students to get an introduction to STEM. Our team has connections to many schools and teachers throughout Oregon. In as many schools as possible, our team will spark the curiosity of students in a lesson plan intended to get students from kindergarten through high school engaged in the various STEM topics and to help teachers bring even more STEM into their classrooms. Students are going to learn that STEM can be applied in almost every aspect of life, even ones they would not have previously thought. For example, young students may not realize that cooking involves a lot of science, as it involves many small chemical reactions and uses predictions in knowing how much of an ingredient is necessary to produce a desired reaction.

We are prepared to seize every possible opportunity for educational outreach leading up to launch week. This year, OSRT has a STEM engagement coordinator who has the specific job of being available to help the team research events and keep in contact with schools where we will be able to engage with students. Tracey, this year's STEM engagement coordinator, has the background to create lesson plans that will be applicable to the students while also increasing their knowledge of STEM topics because she is familiar with creating lesson plans and implementing them with groups of students. By having a sub-team lead for STEM engagement we hope to have created the opportunity to reach more students than before. Students are going to be inspired and given every opportunity possible because the team will be relentless in contacting schools. The STEM engagement team will contact every school that they can find and devote as much time as they can to finding and reaching out to schools and students. We want every student to feel that they have what it takes to achieve their dreams, whatever they may be and to literally reach for the stars. The OSRT team is looking forward to continuing to improve our educational outreach efforts.

6 PROJECT PLAN

6.1 Timeline

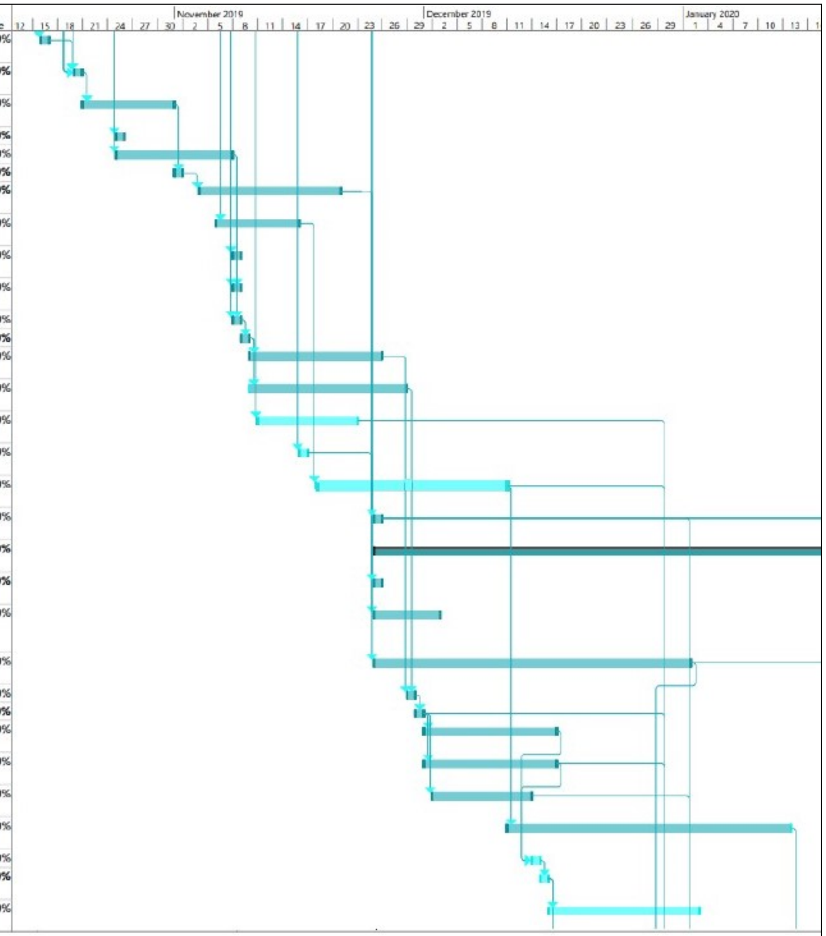
OSRT has developed a comprehensive Project Plan and Timeline for the 2019 - 2020 competition season, which is shown in Figures 26, 27, 28, and 29.



ID	Task Name	Duration	Start	Finish	% Complete
1	**Proposal Phase**	**51 days**	**Thu 8/22/19**	**Thu 10/31/19**	**51%**
2	**Handbook Released**	**1 day**	**Thu 8/22/19**	**Thu 8/22/19**	**100%**
3	Team Decisions and Kickoff Meeting	1 day	Sat 8/24/19	Sat 8/24/19	100%
4	Budget Seminar	1 day	Mon 8/26/19	Mon 8/26/19	100%
5	Aero/Recovery and Structures/Propulsion Research	12 days	Mon 8/26/19	Tue 9/10/19	100%
6	Payload Design Development	12 days	Mon 8/26/19	Tue 9/10/19	100%
7	Material Outsource from Budget/Finance	19 days	Tue 8/27/19	Fri 9/20/19	90%
8	Budget/Finance Compiles OSGC Grant	22 days	Tue 8/27/19	Wed 9/25/19	25%
9	Budget/Finance Requests for Funds/Cold Calling	48 days	Tue 8/27/19	Thu 10/31/19	45%
10	Review Previous Safety Entries and MSDS	2 days	Wed 9/11/19	Thu 9/12/19	100%
11	Structures/Propulsion Preliminary Design Development	4 days	Wed 9/11/19	Sat 9/14/19	100%
12	Recovery System Design Development	4 days	Wed 9/11/19	Sat 9/14/19	100%
13	**L1 Certification Launch**	**2 days**	**Fri 9/13/19**	**Mon 9/16/19**	**100%**
14	**Project Plan and Preliminary Budget from Each Subteam Due**	**0 days**	**Sat 9/14/19**	**Sat 9/14/19**	**100%**
15	**Proposal Rough Draft Due**	**0 days**	**Sun 9/15/19**	**Sun 9/15/19**	**100%**
16	Edit and Compile Proposal	2 days	Mon 9/16/19	Tue 9/17/19	100%
17	STEM Engagement Contacts Schools	14 days	Mon 9/16/19	Thu 10/3/19	10%
18	Design Refinement of Payload, Structures/Propulsion, and Aero/Recovery Systems	14 days	Mon 9/16/19	Thu 10/3/19	10%
19	**Submit Proposal**	**1 day**	**Wed 9/18/19**	**Wed 9/18/19**	**100%**
20	Simulate Payload Design Concepts	14 days	Thu 9/19/19	Tue 10/8/19	15%
21	STEM Engagement Supply Procurement and Lesson Plans #1, 2, and 3 Development	5 days	Mon 9/23/19	Fri 9/27/19	10%
22	**OSGC Rough Draft Due**	**1 day**	**Thu 9/26/19**	**Thu 9/26/19**	**0%**
23	**Submit OSGC Team Experience Proposal**	**1 day**	**Fri 9/27/19**	**Fri 9/27/19**	**0%**
24	**Awarded Proposals Announced**	**1 day**	**Thu 10/3/19**	**Thu 10/3/19**	**0%**
25	**Preliminary Design Phase**	**55 days**	**Wed 9/25/19**	**Tue 12/10/19**	**0%**
26	Order Subscale Recovery System and Launch Vehicle Components	5 days	Wed 9/25/19	Tue 10/1/19	0%
27	**Kickoff and PDR Q&A**	**1 day**	**Wed 10/9/19**	**Wed 10/9/19**	**0%**
28	**L2 Certification Testing**	**1 day**	**Wed 10/9/19**	**Wed 10/9/19**	**0%**
29	Order Payload Prototype Components	20 days	Wed 10/9/19	Tue 11/5/19	0%
30	Heatstroke Briefing	1 day	Thu 10/10/19	Thu 10/10/19	0%
31	Manufacture and Test Subscale Recovery System	17 days	Thu 10/10/19	Fri 11/1/19	0%
32	**L1/L2 Certification Launch**	**2 days**	**Fri 10/11/19**	**Mon 10/14/19**	**0%**
33	Pre-football STEM Engagement with the OSU Alumni Center	1 day	Sat 10/12/19	Sat 10/12/19	0%
34	STEM Engagement Supply Procurement and Lesson Plans #4, 5, 6, and 7 Development	20 days	Mon 10/14/19	Fri 11/8/19	0%

Figure 26: OSRT Schedule for 2019-2020 USLI Competition (1/4)

ID	Task Name	Duration	Start	Finish	% Complete
35	Finalize Altitude Calculations	1 day	Wed 10/16/19	Wed 10/16/19	0%
36	**PDR Rough Draft Due**	**1 day**	**Sun 10/20/19**	**Sun 10/20/19**	**0%**
37	Edit and Compile PDR	9 days	Mon 10/21/19	Thu 10/31/19	0%
38	**Social Media Presence Due**	**1 day**	**Fri 10/25/19**	**Fri 10/25/19**	**0%**
39	Manufacture Subscale Launch Vehicle	10 days	Fri 10/25/19	Thu 11/7/19	0%
40	**Submit PDR**	**1 day**	**Fri 11/1/19**	**Fri 11/1/19**	**0%**
41	**PDR Video Teleconfrences**	**13 days**	**Mon 11/4/19**	**Wed 11/20/19**	**0%**
42	Manufacture and Test Payload Prototype	8 days	Wed 11/6/19	Fri 11/15/19	0%
43	Pre-football STEM Engagement with the OSU Alumni Center	1 day	Fri 11/8/19	Fri 11/8/19	0%
44	Distribute PTPs and Full-Team Safety Brief	1 day	Fri 11/8/19	Fri 11/8/19	0%
45	Subscale Integration	1 day	Fri 11/8/19	Fri 11/8/19	0%
46	**Subscale Launch #1**	**1 day**	**Sat 11/9/19**	**Sat 11/9/19**	**0%**
47	Modify/Repair Subscale Launch Vehicle and Design	12 days	Sun 11/10/19	Mon 11/25/19	0%
48	Modify/Repair Subscale Recovery System and Design	15 days	Sun 11/10/19	Thu 11/28/19	0%
49	STEM Engagement Supply Procurement and Lesson Plans #8 and 9 Development	10 days	Mon 11/11/19	Fri 11/22/19	0%
50	Pre-football STEM Engagement with the OSU Alumni Center	1 day	Sat 11/16/19	Sat 11/16/19	0%
51	Modify Payload Prototype and Design	17 days	Mon 11/18/19	Tue 12/10/19	0%
52	STEM Engagement Evaluation	1 day	Mon 11/25/19	Mon 11/25/19	0%
53	**Critical Design Phase**	**52 days**	**Mon 11/25/19**	**Tue 2/4/20**	**0%**
54	**CDR Q&A**	**1 day**	**Mon 11/25/19**	**Mon 11/25/19**	**0%**
55	Determine Manufacturing Company for Outsourced Materials for Full Scale Launch Vehicle	6 days	Mon 11/25/19	Mon 12/2/19	0%
56	Budget/Finance Cold Calls and Follows Leads	28 days	Mon 11/25/19	Wed 1/1/20	0%
57	Subscale Integration	1 day	Fri 11/29/19	Fri 11/29/19	0%
58	**Subscale Launch #2**	**1 day**	**Sat 11/30/19**	**Sat 11/30/19**	**0%**
59	Modify/Repair Subscale Recovery System and Design	12 days	Sun 12/1/19	Mon 12/16/19	0%
60	Modify/Repair Subscale Launch Vehicle and Design	12 days	Sun 12/1/19	Mon 12/16/19	0%
61	Order Full Scale Launch Vehicle Components	10 days	Mon 12/2/19	Fri 12/13/19	0%
62	Order Full Scale Payload Components	24 days	Wed 12/11/19	Mon 1/13/20	0%
63	Subscale Integration	1 day	Sat 12/14/19	Sat 12/14/19	0%
64	**Subscale Launch #3**	**1 day**	**Sun 12/15/19**	**Sun 12/15/19**	**0%**
65	Order Full Scale Recovery System Components	14 days	Mon 12/16/19	Thu 1/2/20	0%



Project: USLI 2019 - 2020 Proje
Date: Sun 9/15/19

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Progress · Manual Progress

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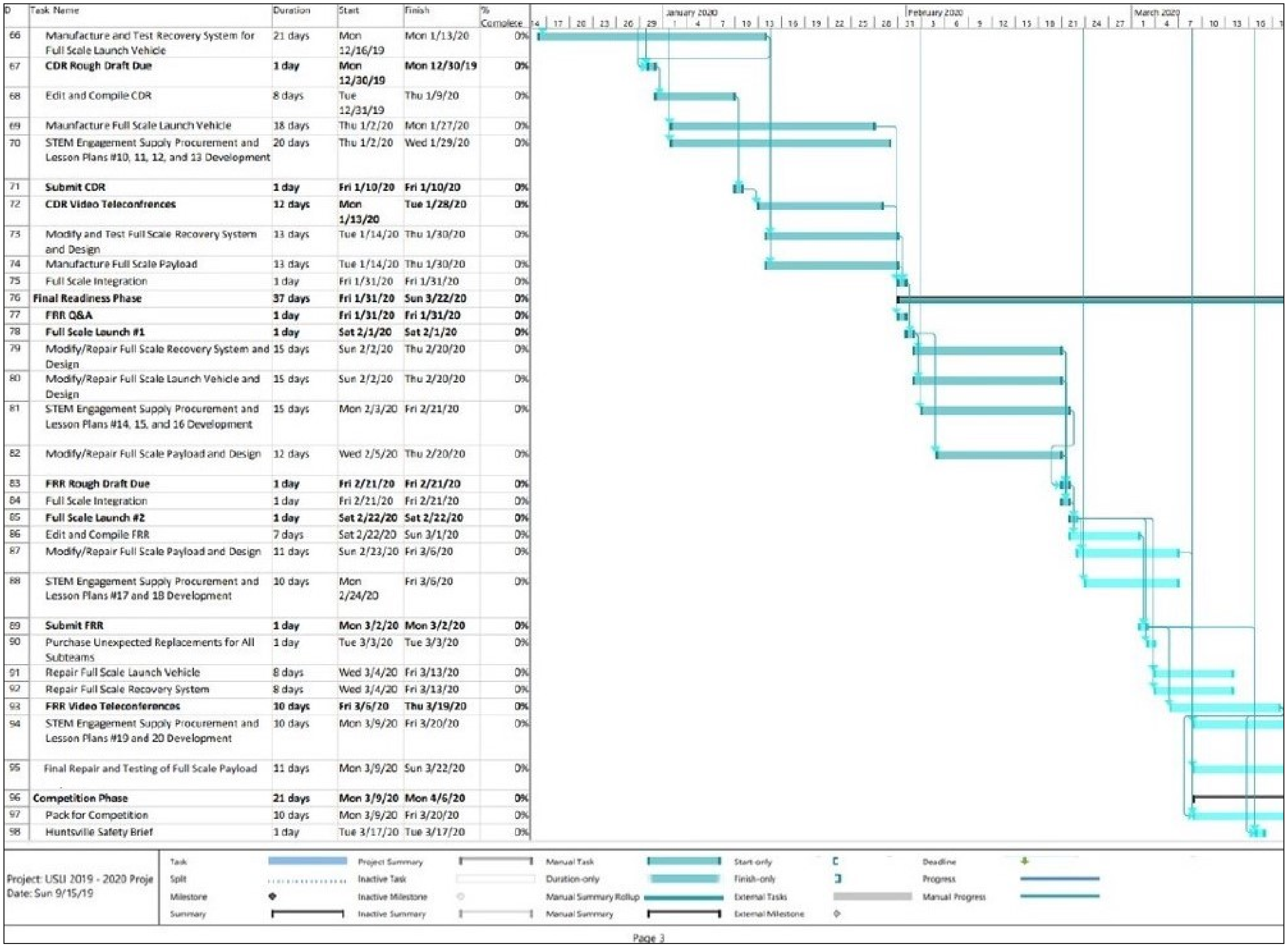
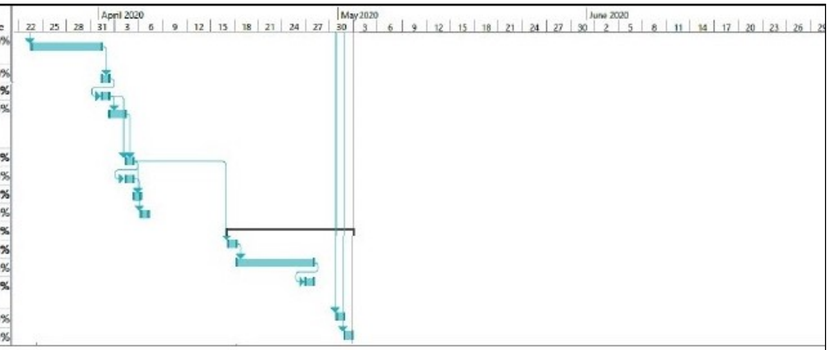
Figure 27: OSRT Schedule for 2019-2020 USLI Competition (2/4)



ID	Task Name	Duration	Start	Finish	% Complete
66	Manufacture and Test Recovery System for Full Scale Launch Vehicle	21 days	Mon 12/16/19	Mon 1/13/20	0%
67	**CDR Rough Draft Due**	**1 day**	**Mon 12/30/19**	**Mon 12/30/19**	**0%**
68	Edit and Compile CDR	8 days	Tue 12/31/19	Thu 1/9/20	0%
69	Maunfacture Full Scale Launch Vehicle	18 days	Thu 1/2/20	Mon 1/27/20	0%
70	STEM Engagement Supply Procurement and Lesson Plans #10, 11, 12, and 13 Development	20 days	Thu 1/2/20	Wed 1/29/20	0%
71	**Submit CDR**	**1 day**	**Fri 1/10/20**	**Fri 1/10/20**	**0%**
72	**CDR Video Teleconfrences**	**12 days**	**Mon 1/13/20**	**Tue 1/28/20**	**0%**
73	Modify and Test Full Scale Recovery System and Design	13 days	Tue 1/14/20	Thu 1/30/20	0%
74	Manufacture Full Scale Payload	13 days	Tue 1/14/20	Thu 1/30/20	0%
75	Full Scale Integration	1 day	Fri 1/31/20	Fri 1/31/20	0%
76	**Final Readiness Phase**	**37 days**	**Fri 1/31/20**	**Sun 3/22/20**	**0%**
77	**FRR Q&A**	**1 day**	**Fri 1/31/20**	**Fri 1/31/20**	**0%**
78	**Full Scale Launch #1**	**1 day**	**Sat 2/1/20**	**Sat 2/1/20**	**0%**
79	Modify/Repair Full Scale Recovery System and Design	15 days	Sun 2/2/20	Thu 2/20/20	0%
80	Modify/Repair Full Scale Launch Vehicle and Design	15 days	Sun 2/2/20	Thu 2/20/20	0%
81	STEM Engagement Supply Procurement and Lesson Plans #14, 15, and 16 Development	15 days	Mon 2/3/20	Fri 2/21/20	0%
82	Modify/Repair Full Scale Payload and Design	12 days	Wed 2/5/20	Thu 2/20/20	0%
83	**FRR Rough Draft Due**	**1 day**	**Fri 2/21/20**	**Fri 2/21/20**	**0%**
84	Full Scale Integration	1 day	Fri 2/21/20	Fri 2/21/20	0%
85	**Full Scale Launch #2**	**1 day**	**Sat 2/22/20**	**Sat 2/22/20**	**0%**
86	Edit and Compile FRR	7 days	Sat 2/22/20	Sun 3/1/20	0%
87	Modify/Repair Full Scale Payload and Design	11 days	Sun 2/23/20	Fri 3/6/20	0%
88	STEM Engagement Supply Procurement and Lesson Plans #17 and 18 Development	10 days	Mon 2/24/20	Fri 3/6/20	0%
89	**Submit FRR**	**1 day**	**Mon 3/2/20**	**Mon 3/2/20**	**0%**
90	Purchase Unexpected Replacements for All Subteams	1 day	Tue 3/3/20	Tue 3/3/20	0%
91	Repair Full Scale Launch Vehicle	8 days	Wed 3/4/20	Fri 3/13/20	0%
92	Repair Full Scale Recovery System	8 days	Wed 3/4/20	Fri 3/13/20	0%
93	**FRR Video Teleconferences**	**10 days**	**Fri 3/6/20**	**Thu 3/19/20**	**0%**
94	STEM Engagement Supply Procurement and Lesson Plans #19 and 20 Development	10 days	Mon 3/9/20	Fri 3/20/20	0%
95	Final Repair and Testing of Full Scale Payload	11 days	Mon 3/9/20	Sun 3/22/20	0%
96	**Competition Phase**	**21 days**	**Mon 3/9/20**	**Mon 4/6/20**	**0%**
97	Pack for Competition	10 days	Mon 3/9/20	Fri 3/20/20	0%
98	Huntsville Safety Brief	1 day	Tue 3/17/20	Tue 3/17/20	0%

Figure 28: OSRT Schedule for 2019-2020 USLI Competition (3/4)

ID	Task Name	Duration	Start	Finish	% Complete
99	Drive to Huntsville	7 days	Mon 3/23/20	Tue 3/31/20	0%
100	Arrive in Huntsville	1 day	Wed 4/1/20	Wed 4/1/20	0%
101	**LRR**	**1 day**	**Wed 4/1/20**	**Wed 4/1/20**	**0%**
102	Meet with RSO/Launch Safety Preparation and Oversight Implementation	2 days	Thu 4/2/20	Fri 4/3/20	0%
103	**Launch Day**	**1 day**	**Sat 4/4/20**	**Sat 4/4/20**	**0%**
104	Award Ceremony	1 day	Sat 4/4/20	Sat 4/4/20	0%
105	**Backup Launch Day**	**1 day**	**Sun 4/5/20**	**Sun 4/5/20**	**0%**
106	Leave Hunsville	1 day	Mon 4/6/20	Mon 4/6/20	0%
107	**Post Launch Phase**	**11 days**	**Fri 4/17/20**	**Sat 5/2/20**	**0%**
108	**PLAR Rough Draft Due**	**1 day**	**Fri 4/17/20**	**Fri 4/17/20**	**0%**
109	Edit and Compile PLAR	7 days	Sat 4/18/20	Mon 4/27/20	0%
110	**Submit PLAR**	**1 day**	**Mon 4/27/20**	**Mon 4/27/20**	**0%**
111	Thank you Letters to Donors	1 day	Fri 5/1/20	Fri 5/1/20	0%
112	Catalogue Materials for Future Teams	1 day	Sat 5/2/20	Sat 5/2/20	0%



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Date: Sun 9/15/19

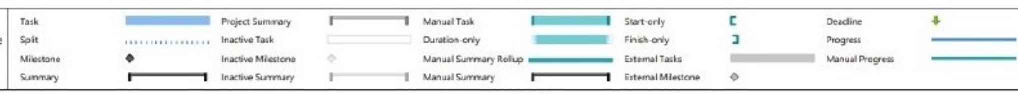

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Figure 29: OSRT Schedule for 2019-2020 USLI Competition (4/4)

6.2 Budget

The expenses for OSRT were estimated by developing a preliminary itemized cost breakdown for all elements of the project. Shown in Tables 17-19 are the itemized cost breakdowns for the Aerodynamics and Recovery subteam, the Payload subteam, and the Structures and Propulsion subteam. Additional costs are anticipated in several different areas: safety, STEM engagement, travel, and miscellaneous costs. These additional costs are displayed in Table 20 and 21.

Table 17: Aerodynamics and Recovery Budget

Quantity	Item	Unit Cost	Full Cost	Vendor/Source
		Parachutes		
2	8ft main chute	$348.15	$696.30	Fruity Chutes
2	7ft main chute	$296.96	$593.92	Fruity Chutes
8	Drogue chute	$55.97	$447.76	Fruity Chutes
10	Shock Cord (per yard)	$23.13	$231.30	Fruity Chutes
6	Shear Pins	$5.50	$33.00	Home depot
4	Nomex Fire Proof Blankets	$27.00	$108.00	Fruity Chutes
15	Quick Release Hooks	$4.10	$61.50	Apogee components
6	Descenders	$81.43	$488.58	Apogee components
2	6ft chute	$225.75	$451.50	Fruity Chutes
2	5ft chute	$193.50	$387.00	Fruity Chutes
1	8ft deployment bag	$74.18	$74.18	Fruity Chutes
1	7ft deployment bag	$46.23	$46.23	Fruity Chutes
1	6ft deployment bag	$46.23	$46.23	Fruity Chutes
		BEAVS		
1	MPL3115 Barometer	$4.87	$4.87	Mouser
1	BNO055 9DOF IMU	$34.95	$34.95	Adafruit
1	Turnigy 2200mah LiPo	$10.99	$10.99	HobbyKing
1	OSRT Designed PCB	$92.90	$92.90	DFRobot
1	Xbee Pro 900hp	$39.00	$39.00	DigiKey
1	7 in RPSMA whip antenna	$4.29	$4.29	Amazon
1	1/8” aluminum plate (2” x 24” bar)	$11.08	$11.08	McMaster-Carr
4	1/4-20 fasteners	$0.78	$0.78	McMaster-Carr
4	8-32 Threaded Rod	$1.67	$6.68	McMaster-Carr
21.24	1/2" Aerospace Grade Plywood Bulkhead	$1.53	$1.53	Wicks
1	PLA 3D Printer Filament (1 kg)	$19.99	$19.99	Amazon
0.25	M2 Fasteners (100)	$13.26	$3.32	McMaster-Carr
4	7mm Linear Guide Block	$65.47	$261.88	McMaster-Carr
4	7mm Linear Rail (172mm)	$21.06	$84.24	McMaster-Carr
10	10 GA Steel Plate	$2.37	$23.70	JCI
1	SparkFun Venus GPS	$49.95	$49.95	SparkFun
1	Teensy	$31.25	$31.25	DigiKey
		Parachute Ejection		
				Continued on next page

Table 17 – continued from previous page

Quantity	Item	Unit Cost	Full Cost	Vendor/Source
1	Yakamoz 14pcs 0.5-3mm Small Electric Drill Bit Collet Micro Twist Drill Chuck Set with Allen wrench	$8.99	$8.99	Amazon
3	Turnigy D1104-4000kv 5.5g Brushless Motor	$7.09	$21.27	HobbyKing
1	Hobbywing Quicrun 60A 2S-3S Waterproof Brushed ESC for 1/10	$20.99	$20.99	HobbyKing
2	Turnigy 1700mAh 2S 20C Lipo Pack (Suits 1/16th Monster Beatle, SCT & Buggy)	$8.82	$17.64	HobbyKing
1	Turnigy 12v 2-3S Basic Balance Charger	$5.10	$5.10	HobbyKing
1	Turnigy TGY-i6 AFHDS Transmitter and 6CH Receiver (Mode 1)	$57.80	$57.80	HobbyKing
1	2" x 2" x 3′ Aluminum Stock	$78.72	$78.72	McMaster-Carr
1	INTOO Mini Drill Bit Set 60 Pcs+12 Pcs Free High Speed Steel HSS Titanium Micro Drill Bits For Metal, Plastic,Wood 3/64"-1/8" Small drill bit	$11.99	$11.99	Amazon
5	12gm CO2 Cartridge (each)	$4.50	$22.50	Tinder Rocketry
1	NYLON SHEAR PINS - 20 PACK	$3.22	$3.22	Apogee Components
1	Fantasycart Fiberglass Cloth Plain zWeave 4.12 Oz 39"wide in 16.6 yards long	$36.99	$36.99	Amazon
1	3M 20124 All Purpose Fiberglass Resin, 1 Gallon	$57.40	$57.40	Amazon
6	1′ of 1/2" ID Surgical Tubing	$1.78	$10.68	McMaster-Carr
2	Pack of 24 E-Matches	$15.60	$31.20	MJG Technologies
4	1′ of 1/2" OD Silicone Rubber Rod	$7.45	$29.80	McMaster-Carr
1	1lb. of GOEX FFFFg Black Powder	$17.95	$17.95	Powder Valley Inc.
1	8 In. Black Cable Ties 100 Pk.	$1.99	$1.99	Harbor Freight
1	Hornady G2-1500 Digital Powder Scale 1500 Grain Capacity	$39.49	$39.49	Midway USA
			Total	**$ 4,866.85**

Table 18: Payload Budget

Quantity	Item	Cost per unit	Full Cost	Vendor/Source
		Rover Parts		
2	Driver Motors	$40.00	$80.00	TBD
1	Battery Charger	$35.00	$35.00	TBD
2	Battery	$80.00	$160.00	TBD
1	RC Remote/Receiver	$150	$150	TBD
#	Structural Material	$100.00	$100.00	Self-Machined
1	Camera/Receiver	$50.00	$50.00	TBD
#	Wire/Assorted Bits	$30.00	$30.00	On-Campus Resistore
		Testing Accessories		
1	Terrain Bed Material	$30.00	$30.00	Self-Built

Rocket Ejection				
1	Ejection Motor	$40.00	$40.00	TBD
1	Ejector	$20.00	$20.00	TBD
#	Composite Ejection Material	$60.00	$60.00	Self Machined
			Total:	**$695.00**

Table 19: Structures/Propulsion Budget

Quantity	Item	Cost per unit	Full Cost	Vendor
Structure				
3	Tubes(fore,aft,motor)	$200	$600	Innovative Composite Engineering
1	Epoxy	$81	$81	ApogeeRockets
1	Epoxy Resin	$59	$59.00	Fiberglass Supply Depot
1	4′ X 8′ Carbon Sheet	$395.00	$395.00	Tim McAmis Performance Parts
4	Fiberglass sheets	$6.50	$26.00	Fiberglass Supply Depot
1	Plywood	$43.50	$43.50	Aircraft Spruce & Specialty Co
Propulsion				
1	Cesaroni L3200 Reload	$189.95	$189.95	Cesaroni Tech
1	75 mm Casing	$388.42	$388.42	Apogee
Devices				
4	Altimeter	$69.95	$279.80	MissileWorks
			Total:	**$2,252.62**

Table 20: Additional Expected Costs

Item	Anticipated Cost
PPE, Hazard Labels, Locks	$200.00
STEM Engagement	$500.00
Misc (Fuel, Office Supplies)	$200.00

Table 21: Projected Travel Expenses

Expense	Quantity	Subquantity	Unit Cost Estimate	Cost	Cost Estimate Source (subject to change)
Rental Vehicle	4 cars	10	$45/car/day	$1,800.00	Corporate Travel Index
Fuel	125 gallons	4	$2.39/gallon/day	$1,195.00	GasBuddy
Lodging	4 rooms	4 nights	$114	$1,824.00	Hilton Embassy Suites
Lunch	16 members	5	$25/person/lunch	$2,000.00	-
Dinner	16 members	5	$40/person/dinner	$3,200.00	-
			Total:	**$10,019.00**	

6.3 Funding Plan

OSRT's project will be supported by grants, mentorship, and donations of materials and services by reaching out to corporate partners of AIAA, and local companies who have previously donated. Our budget members are currently calling companies to ask for donations which will be graciously accepted.

Main support for donation will likely be secured by Oregon Space Grant Consortium (OSGC). OSGC is a program which emerged in 1988 and has developed a national network of universities with interest and capabilities in aeronautics, space, and related fields. The OSRT's grant proposal is currently in progress by our budget team. Partnership network of AIAA is seen in figure 30, where donations among these sponsors will be split among the AIAA teams here at OSU.

Figure 30: AIAA Partnership Network

6.4 Sustainability

In order to regularly engage younger students in this program, and ensure that this program continues for years to come, OSRT will create multiple projects that will be completely volunteer lead and completed, while OSRT's members will offer mentorship and guidance. To encourage more majors than technical ones to join OSRT, projects that volunteers will be able to work on include everything from the design and construction of test beds that will be crucial to the success of the technical aspects of this project, to the design of the team mission patch, which will be crucial for team branding and cohesiveness. This way, students across majors and interests can fit in on the team no matter where their strengths may lie. This lets volunteers have ownership of their projects, to encourage the feeling of having an important impact on the team because they are having an incredibly important impact on the team as a whole. OSRT does not discriminate based on knowledge and experience, so if a younger student comes to the team and either does not know where they want to work, or has no experience working in the area in which they are interested, OSRT is willing to teach these students whatever they need to know in order to find something within this project that the younger students really enjoy working on.

Once students finish their projects, they will be reassigned to other volunteer projects in order to keep them both engaged with and contributing to the project in ways that they enjoy in order to retain their membership and keep them interested with the project.

For recruitment, OSRT will work with OSU's AIAA student branch to reach out to students in lower grades and other departments through presentations and booths at various events to offer them the ability to join the project. For example, OSRT will be giving presentations in October (along with AIAA) in several freshman-level engineering classes to increase student interest in both OSRT and similar teams. OSRT's wide variety of volunteer projects will also encourage student recruitment, as OSRT will offer projects that appeal to students from a variety of majors and that are realistic for students with either little to no experience with rocketry, or extensive experience.

Keeping in touch with the STEM engagement lead from the 2018-2019 competition year has left this years OSRT team with a head start in planning engagement events. The previous members are able to pass down connections and supplies to the current members, and are also able to answer any questions to work out road bumps that the current members may have with any engagement events, as there are many specifics that must be addressed when it comes to traveling across the state to present at schools and such.

To increase the teams continued financial life in years to come, it will be important to ensure a continued relationship with the businesses and contacts which have donated thus far. This will be achieved by sending them occasional updates showcasing our progress and how their generosity has been vital to our success. Example "thank you cards" style updates we could send to them could include a team photo in front of the part which was supplied or funded by their donation and a short paragraph about how the part is used on the rocket. These follow ups will positively reinforce the business's donations and make it more likely that they will be willing to donate again next year.

At the same time, it will be important not to over-stress any connections we have made by repeatedly asking for donations from the same business or contact. After receiving a donation from a sponsor, unless they specifically tell us otherwise, we will not contact them for a second donation within the same year.

Over time, the goal will be to create connections which we are able to contact on a yearly basis, and who will be expecting our call with positive emotions. To achieve this goal, "thank you card" style updates will be vital to making sure our contacts think of the team positively, and understand that we value the connection with them as more than just a source to receive funds, but as a partner to the project.

7 References

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