OREGON STATE UNIVERSITY

2019 NASA SL TEAM

104 KERR ADMIN BLDG. # 1011

CORVALLIS, OR 97331

Proposal

September 19, 2018

Contents

List of Tables

List of Figures

Acronym Dictionary

9DOF Nine Degree of Freedom. 27

AGL Above Ground Level. 11, 28, 31, 35, 51

AIAA American Institute of Aeronautics and Astronautics. 7, 11, 68, 69

APCP Ammonium Perchlorate Composite Propellant. 52

ARRD Advanced Retention and Release Device. 42, 44

ATI Allegheny Technologies Incorporated. 68

BEAVS Blade Extending Apogee Variance System. 20, 24–28, 62

CAR Canadian Association of Rocketry. 52

CDR Critical Design Review. 12, 53

CFD Computational Fluid Dynamics. 27

CNC Computer Numerical Control. 9, 26

DC Direct Current. 46

EARS Ejection and Retention System. 43, 44

EDM Electrical Discharge Machining. 9

FAA Federal Aviation Administration. 17, 52

FDM Fused Deposition Modeling. 26

FMEA Failure Mode Effects Analysis. 18

FRR Flight Readiness Review. 12, 53

GPS Global Positioning System. 36

HDPE High-density polyethylene. 43–45

JHA Job Hazard Analysis. 16, 18, 19

LED Light Emitting Diode. 19

LiPo Lithium Polymer. 18, 48

MIME Mechanical, Industrial, and Manufacturing Engineering. 9, 10, 12

MPRL Machine Product and Realization Laboratory. 9, 18

MSDS Material Safety Data Sheet. 14, 16

NAR National Association of Rocketry. 17, 18, 52

NASA National Aeronautics and Space Administration. 52, 53, 57

NEMA National Electrical Manufacturers Association. 26

NFPA National Fire Protection Agency. 17

OROC Oregon Rocketry. 17

OSGC Oregon Space Grant Consortium. 68

OSRT Oregon State Rocket Team. 7, 9–13, 17, 21, 24–29, 34, 38, 51, 55, 57, 68, 69

OSSEP Oregon Space Science Education Program. 57

OSU Oregon State University. 18, 57, 69

PCB Printed Circuit Board. 27

PDR Preliminary Design Review. 12, 51

PID Proportional-Integral-Derivative. 27, 28

PLA Polylactic Acid. 26

PPE Personal Protective Equipment. 13, 14, 16, 19

ROS Robot Operating System. 12

RRC3 Rocket Recovery Controller 3. 29, 36

RSO Range Safety Officer. 13, 35, 52

SO Safety Officer. 13, 16, 18

STEM Science, Technology, Engineering and Mathematics. 57, 69

STP Standard Temperature and Pressure. 33

TRA Tripoli Rocketry Association, Inc.. 17, 18, 52

USLI University Student Launch Initiative. 13, 26, 41

1 General Information

1.1 Leadership Overview

Table 1: Adult Educator Summary Chart

Name of Mentor	Nancy Squires	Joe Bevier
Professional Title	Senior Instructor	OROC TRA TAP
Academic Institution	Oregon State University	Oregon State University
Position within 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	Trevor Rose	Jon Verbiest
Administrative Role	Team Lead	Safety Officer
Contact	rosetr@oregonstate.edu (541) 231-9320	verbiesj@oregonstate.edu (971) 322-4668
TRA/NAR Number, Certification Level	NAR #104620	NAR #219448

1.2 Team Structure and Organization

The Oregon State Rocket Team (OSRT) consists of twelve members pursuing an undergraduate degree in Mechanical Engineering, six members pursuing an undergraduate degree in Electrical and Computer Engineering, and three members pursuing an undergraduate degree in Computer Science. A breakdown of the team structure can be seen in Figure 1. The team will also involve members of the campus American Institute of Aeronautics and Astronautics (AIAA) chapter. The team has been broken up into three sub-teams according to the technical requirements of the challenge.

- ***Structures*** – Responsible for designing and fabricating the airframe, electronics bays, and all internal components necessary for a successful launch and payload recovery. This team will also be in charge of implementing a proper motor while considering safety and handling before and after each launch. Key responsibilities include mass and stress analysis for altitude precision, understanding key propulsive features to ensure reliability, and monitoring of the effects of design improvements.

- ***Aerodynamics-Recovery*** – Responsible for the simulations behind aerodynamic stability, all recovery systems, and design of stability measures. Key requirements are to ensure a safe landing, monitor kinetic energy requirements, fabricate electrical and mechanical hardware to ensure aerodynamic flight, and develop a system to accurately reach target altitude.
- ***Payload*** – Responsible for the design, fabrication, and testing of a rover capable of being autonomously deployed from the internal structure of the launch vehicle once it has landed safely on the ground and collected a minimum soil sample of 10 millimeters. Additionally responsible for integrating an ejection and retention system for the rover. Key responsibilities include meeting all customer requirements, designing a payload that reliably functions, and rigorously testing prior to final launch.

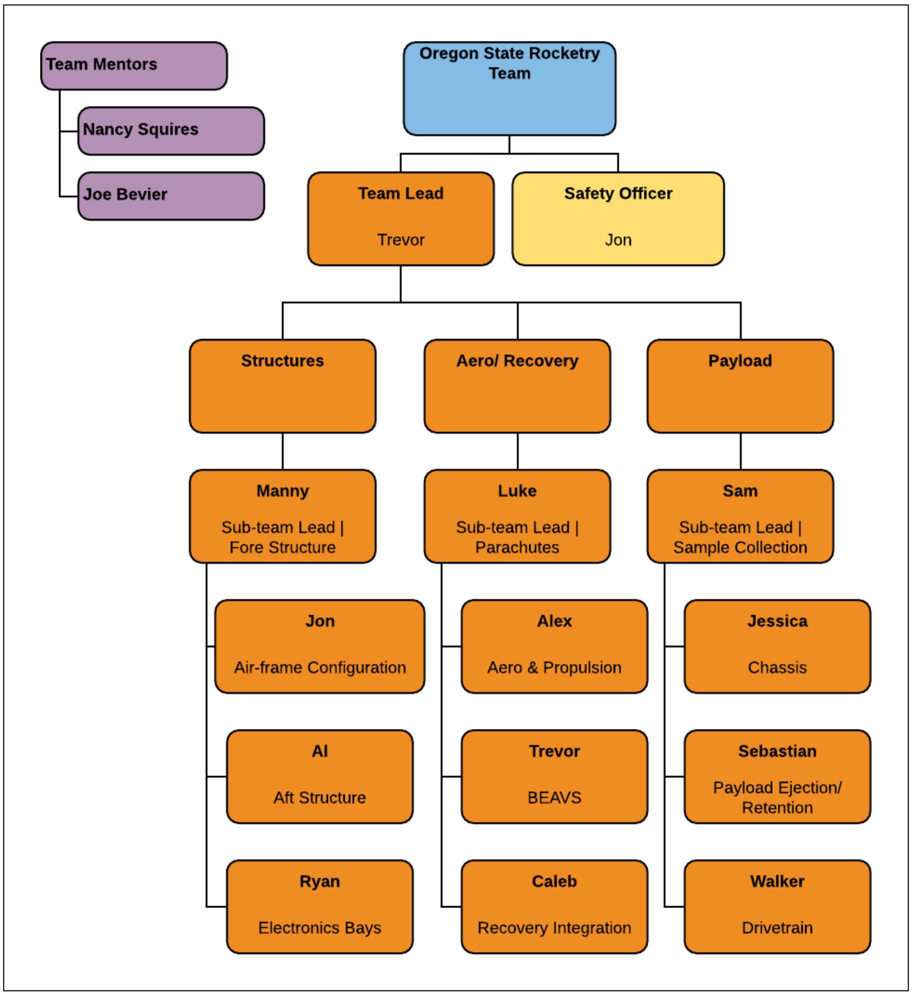

Figure 1: Team Organization

2 Facilities and Equipment

2.1 Accessible Equipment

The OSRT has access to multiple highly optimized work spaces for research, prototyping, and manufacturing purposes. The school of Mechanical, Industrial, and Manufacturing Engineering (MIME) Machine Product and Realization Laboratory (MPRL) offers the following to Oregon State students, including a Fadal VMC 3016 shown in Figure 2:

- 9 Engine Lathes
- 10 Vertical Milling Machines
- 2 Computer Numerical Control (CNC) Turning (Lathe) Center
- 4 CNC Vertical Milling Machine Centers (three 3-axis, one 4-axis)
- Electrical Discharge Machining (EDM) Burning Machine
- Shielded Metal Arc Welder
- Flux Core Arc Welder
- Gas Tungsten Arc Welder
- Sheet Metal Fabrication Tooling
- Dimensions BST Rapid Prototyping Machine
- Fortus 4000mc Rapid Prototyping Machine
- Wood Sawing and Shaping Tools
- Press Brake
- Sand Blasting Station
- Stratasys Objet 350 Connex2TM Rapid Prototyping Machine

Figure 2: Fadal VMC 3016 Milling Machine

This shop is open to Oregon State students who have completed an introductory machining course at any time upon request and provides OSRT students with a space to work and store all the components of their projects. Some of this work and storage space is shown in Figure 3.

Figure 3: Graf Hall Work Space

In the MIME Rapid Prototyping Lab are three additive manufacturing machines (a Stratasys Objet Connex2TM, a Fortus 400mc, and a Dimension BST 1200es) along with a fully furnished wood shop. This allows OSRT students rapid prototyping abilities and are shown in Figures 4 and 5.

Figure 4: Additive Manufacturing Machines

Figure 5: MIME Wood Shop

The OSRT also has access to a composites lab equipped with a polyethylene cutter and an oven capable of all baking steps required for molding. In addition to these resources, the OSRT is partnered with the local chapter of AIAA and has access to their lab space and technical knowledge which has covered the creation and fabrication of multiple rockets designed to reach altitudes of 30K and 100K feet Above Ground Level (AGL).

This lab space is shown in Figure 6. The entirety of tools available include the following:

- Drill Press
- Various hand Tools
- Composite Oven
- Polyethylene Cutter
- Soldering Iron
- Oscilloscopes
- Pneumatic Cutting Tools
- Rapid Prototyping Capabilities
- Chop Saw
- Table Saw

Figure 6: AIAA Lab

2.2 Accessible Software

All members of the OSRT have access to on-campus engineering computer labs with locations throughout the Oregon State campus. As students at Oregon State, we also have access to download the same technical programs on to our personal computer or run the programs through Citrix Receiver. The applications available to the OSRT include the following:

- Abaqus
- Adobe Acrobat
- Adobe Illustrator 2015

- Adobe InDesign 2015
- Adobe Photoshop 2015
- ANSYS
- CES EduPack 2016
- Engineering Equation Solver
- LaTeX
- Mathematica
- MATLAB
- Microsoft Office
- Minitab
- OpenRocket
- RASAero II
- Sketchup
- Solidworks 2018
- STAR-CCM+

Additionally, OSRT members will utilize standard programming languages (ex. C, C++, Python) and open source software packages (ex. Git, Robot Operating System (ROS)) in the development of the software systems necessary for launch vehicle operation. Similar resources will be utilized for logistic and documentation projects such as the team website and technical documents. Team members studying computer science or electrical engineering at Oregon State have access to university hosted servers that will streamline the process of developing, debugging, and deploying all necessary software deliverables.

2.3 Communication

The OSRT will be expected to provide video conferencing capabilities in order to present its Preliminary Design Review (PDR), Critical Design Review (CDR), and Flight Readiness Review (FRR) to a panel of NASA employees. All the equipment needed to conduct a successful video teleconference will be provided by the OSRT and Oregon State Department of MIME. The facilities provided by Oregon State University include designated rooms equipped with high quality speakers, projectors, and cameras. Also provided by the University is in room support, which handle all the electronics, to ensure the teleconferences run smoothly.

3 Safety

3.1 Safety Agreement

All members of the OSRT have read and will comply with the following safety agreement:

Oregon State Rocketry Team Safety Agreement

I, ________, have read, understood, and will abide by all laws and regulations set forth by the National Association of Rocketry, 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. This includes being properly certified and wearing all required Personal Protective Equipment (PPE) when appropriate. I understand that these laws and regulations are for my safety and the safety of others. I will use my best judgment in University Student Launch Initiative (USLI) matters to keep myself and others safe and I will follow guidelines and procedures set by the Safety Officer (SO). The Range Safety Officer (RSO) will inspect the rocket before any launch to ensure the rocket meets all range safety requirements and I understand that the RSO has the final say on the status of any launch. I understand that any launches unapproved by the RSO are strictly prohibited. I understand that any violation of the above is grounds for removal from the team or further action if offense warrants.

Signature: ________________ *Date:* _______

3.2 Risk Assessment

Shown in Table 3 is an analysis of risks to the mission and personnel and how these risks are being mitigated by OSRT.

Table 3: Risk Assessment

Risk	Cause	Chance (1-10)	Severity (1-10)	Mitigation
Injury From Composite Materials	Improper handling of composite materials during rocket build.	**7**	**2**	Proper PPE (Mask, Goggles, Gloves) and a safety brief. Awareness and caution will be utilized.
Injury From Chemical Usage (Adhesives, Cleaners)	Inhaling or physical contact with substances.	**6**	**2-8**	All chemical usage will take place in well-ventilated areas. Proper PPE will be used based on the Material Safety Data Sheet (MSDS) of the chemical and a safety brief prior to dealing with chemicals. All surfaces will be cleaned after chemical use. Awareness and caution will be utilized.
Injury From Cutting Tool (Mill, Lathe, Drill)	Improper use or preparation of the tool.	**3**	**7**	All tool users must pass Machine Shop Safety Class and wear appropriate PPE (Eye Protection, Gloves, etc.).
Injury From Sanding Tool	Improper use or preparation of the tool.	**5**	**4**	All tool users must pass Machine Shop Safety Class and wear appropriate PPE (Eye Protection, for example).
Injury From Electric Shock	Touching or working with payload and avionics components or tools attached to live power.	**3**	**5**	All electric systems will be powered down before alteration. Only personnel directly involved with electric systems will modify said systems.
Burns From Heated Equipment (Soldering Irons)	Disturbing heated tools or components that are prepped for use or interacting with said tools when unaware they are in use.	**5**	**1**	All heated tools will be kept separate and away from the general workspace. All heated tools will be turned off when not currently in use. Hot tools will be placed in a safe area while they cool.
Injury From Catastrophic Failure Of Motor	Defect in the motor or improper handling in preparation of motor.	**2**	**10**	The motor will be purchased from a certified vendor. The motor will be handled and prepared by designated personnel and all non-essential personnel will be moved away from the launch pad during igniter installation. Caution and awareness will be utilized.

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Table 3 – continued from previous page

Risk	Cause	Chance (1-10)	Severity (1-10)	Mitigation
Injury From Rocket Test	Rocket falls during launch setup.	**2**	**8**	A safety briefing will be performed before all launches. Personnel handling the rocket launch will have gone through safety procedures. Caution and awareness will be utilized.
Injury From Rocket Debris	The recovery system of the rocket fails (parachute does not open or body separation fails).	**3**	**10**	All systems will be simulated and tested prior to launch. Proper drill for rocket set up will be undertaken to ensure all recovery systems are loaded and armed properly. Caution and awareness will be utilized. NAR rules will be reviewed prior to launch.
Unable To Meet Project Deadlines	Design or build-time overrun or miscommunication between sub-teams.	**2**	**3**	Weekly meetings to coordinate sub-teams and overall team goals. Setting internal deadlines to have all deliverables finished before the actual deadlines.
Unable to Launch On Launch Day	Destruction of airframe during testing or transportation. Failure of electronics in testing or transportation.	**4**	**2**	Tools and repair supplies will be brought to the launch site.

3.3 Safety Briefings

Proper PPE will be provided to all team members during fabrication, assembly, testing, and operation of the launch vehicle and payload. During test launches and competition, all team members will follow the provided instructions and stand a safe distance away from the launch vehicle.

Before any construction of the launch vehicle or fabrication of any components, all members taking part must attend a safety briefing led by the SO to provide all pertinent warnings for the tools and materials that will be used. This is to ensure that all team members have a complete understanding of the potential hazards and the best ways to mitigate them. Members will also be briefed on when to fill out a Job Hazard Analysis (JHA). Completing a JHA will allow team members to consider all potential hazards associated with a task and determine the safest way to proceed. If any safety concerns arise from the JHA which cannot be mitigated to provide a safe work environment, those concerns will be brought to the SO or team mentor in order to develop different method to complete the task. This alternative method may require a new JHA.

The SO will hold briefings before all launches to provide an overview and refresher on all safety procedures and launch site regulations. During this briefing, launch checklists will be distributed to all members to determine that all members understand the plan for the launch and their assigned roles. The distribution of launch checklists allows for all team members to be observant for deviations from the predetermined plan that could potentially be dangerous.

3.4 Caution Statements

In addition to safety briefings, caution statements will be placed in work instructions and additional safety information will be placed in working areas. The caution statements will include possible hazards for the portion of the build process and the appropriate PPE to mitigate those hazards. Statements will include a header which describes the potential penalty for failure to adhere to protocol. 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 —

Attempting to catch a landing launch vehicle can result in injury or death.

All work areas will have signs listing the appropriate PPE for the area and for any tools to be used in that area. Additionally, all work areas will have easy access to MSDS for all materials that may be use in said areas and all PPE that would be required to use such materials.

3.5 Rocket Motor Handling

Rocket motors will be purchased only by an National Association of Rocketry (NAR)/Tripoli Rocketry Association, Inc. (TRA) certified instructor. Motors and ejection charges will be stored away from ignition and heat sources, isolated in specified containers. In addition, NAR/TRA certified instructors will prepare all motors and ejection charges. Transportation of the rocket motors will be the responsibility of a NAR/TRA certified mentor. Motors will be purchased on site or transported by car to the launch site.

3.6 NAR Procedures/ Personnel

Our NAR/TRA Level 3 certificatied mentors will be responsible for ensuring the team is in complete compliance with all NAR High Power Safety Code requirements. Joe Bevier will be responsible for purchase, storage and transport, and use of rocket motors and energetic devices. Additionally, Joe Bevier will be present during all ground testing procedures and all launches.

3.7 Law Compliance

OSRT is fully committed to following all laws and regulations pertaining to the building and launching of high powered rockets. This includes specific attention to Federal Aviation Administration (FAA) regulations pertaining to the use of airspace for rocket launches and launch sites and the National Fire Protection Agency (NFPA) codes that govern the use of high powered rocketry (NFPA 1127) to prevent fire caused by rocket use. For all rocket launches, OSRT will work with Oregon Rocketry (OROC) to obtain the appropriate waiver for the OROC launch facility in Brothers, OR. All launch activities will be suspended if said waiver is not issued until the waiver can be obtained.

3.8 Safety Verification Matrix

Shown in Table 4 is a breakdown of safety requirements, a brief description of how OSRT is verifying these requirements will be completed, and the current status of the verification implementation.

Table 4: Safety Verification Matrix

Safety Requirement	Verification Plan	Status
All team members that use the manufacturing and machining facilities at Oregon State University (OSU) will have appropriate certification.	All team members who need to use the OSU MPRL, the woodshop, or the composites manufacturing lab will get appropriate certification from the administrator of said lab before use.	In Progress - Necessary certifications will be obtained as they are required.
Additional team members to assist the SO in explicitly promoting team safety and the preparation of safety documents.	Two additional safety officers, a Launch Vehicle Safety Officer and a Payload Safety Officer will assist the Team Safety Officer. JHA form developed for internal use when completing hazardous tasks.	Completed - Two team members volunteered for Launch Vehicle Safety Officer and Payload Safety Officer.
The team will secure all hazardous material so only certified personnel can access them.	Hazardous materials will be kept in a separate area of the team workspace secured with a lock. Only team leaders, SO, and team mentors will have access to the hazardous materials.	Completed - Hazardous materials have been locked away in cabinets.
The team will follow all safety rules and guidelines set by the NAR, TRA and OSU.	The SO will understand both NAR/TRA safety regulations, OSU safety codes and will ensure team members abide by all rules. Team members are also expected to be familiar with all safety regulations.	In Progress - All team members have followed all safety regulations so far.
The team will have written checklists with instructions on how to safely assemble the rover, recovery systems, and launch vehicle.	Each team member or sub-team responsible for designing a part on any assembly pertaining to the launch vehicle or payload will write a formal checklist to ensure that any team member can assemble the part without the presence of the designer of the part. All checklists will be verified by assembler, inspector, and safety officer.	Incomplete - Will be implemented when assembly processes are developed.
The team will create a comprehensive list of Failure Mode Effects Analysis (FMEA)s for each subsystem of the project, to mitigate as many of the failure modes as the team can.	Each team member will write a FMEA for each and every part of the project they are working on. These will be organized by sub-team and subsystem so they can be easily referenced.	Incomplete - Will be implemented when team reaches that point.
The team will charge all Lithium Polymer (LiPo) batteries with a smart charger to prevent nonuniform or over charging of the batteries	The team will agree to only buy smart chargers, so that non-smart chargers are never used for charging the batteries.	Incomplete - Will be implemented when team buys chargers.
		Continued on next page

Table 4 – continued from previous page

Safety Requirement	Verification Plan	Status
The team will not short circuit any of the batteries while installing them into systems requiring batteries.	A formal procedure will be written with instructions explaining how to safely install the batteries into the rover.	Incomplete - Will be implemented when team reaches that point.
The team will use appropriate PPE when handling and machining composite materials.	Safety briefings will be conducted, JHAs will be filled out as necessary.	Incomplete - Will be implemented when team reaches that point.
There shall be no sharp edges on the payload.	Any sharp edges on payload will be machined off or will be completely encased in a safe container. See section 4.5.4 for auger encasing.	Incomplete - Will be implemented when team reaches that point.
There will be a light to indicate the payload ejection charges are armed.	Blinking Light Emitting Diode (LED) indicator will be installed, connected to payload ejection controller. LED blinking will be visible upon arming vehicle.	Incomplete - Will be implemented when team reaches that point.
The payload ejection controller will have an arming switch.	Turn the switch to verify the LED is blinking to indicate armed status.	Incomplete - Will be implemented when team reaches that point.
The Mentor and Educational Advisor will have a final say in safety decisions on all activities and designs.	If the safety of an event or activity is disputed, whatever the Mentor or Advisor decides will be the final decision.	Complete - All team members have agreed to follow this rule should this issue arise.
All team members must remain attentive and at safe distances from the launch area during subscale and full scale launches.	Each team member will be responsible for having awareness of their surroundings during all launch related activities. All three safety officers will oversee team members' safety.	Incomplete - Will be implemented at first launch event and maintained through all future launches.

4 Technical Design

4.1 Vehicle Specifications

Nine main sections within the body make up the airframe: The nose cone, fore recovery bays, fore electronics bay, the payload bay, aft recovery bay, aft electronics bay, Blade Extending Apogee Variance System (BEAVS) bay, and the motor bay. This is shown in Figure 7. The nose cone and upper fore section will hold the fore electronics bay and the fore recovery bays. Inside the electronics bay are the altimeters and a tracking device. The fore parachutes are contained in the fore recovery bays. The payload bay will house the payload and its deployment system.

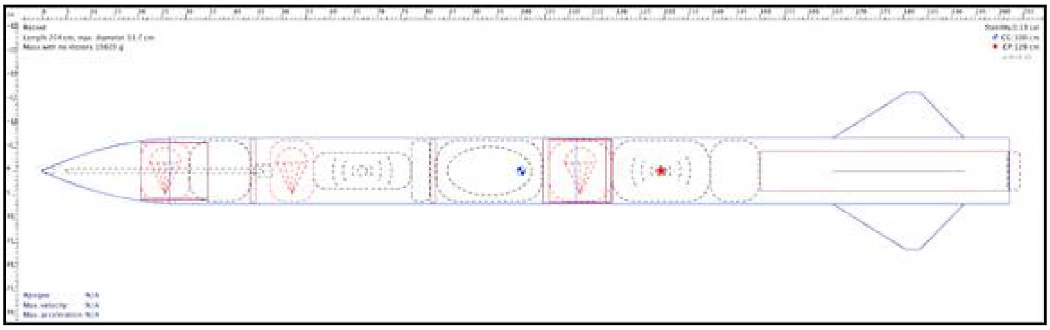

Figure 7: Launch Vehicle Equipment Layout

The aft recovery bay will be home to the chutes (drogue and main). The aft electronics bay holds the the electronics controlling the BEAVS, two altimeters, and a tracking device. All altimeters will be located in a separate compartment from the other electronics, and they are shielded from any on-board electronics. The BEAVS bay contains the system in charge of adjusting the altitude of the launch vehicle. Lastly, the motor bay will contain the rocket motor, which is a L1520-PS. The body is made up of eight different components: the airframe (aft), the airframe (fore), the nose cone, the couplers, the fins, the motor mounting, and the bulkheads and attachment hardware. The body will mostly be made of carbon fiber, made by Innovative Composite Engineering. The body features seamless transitions to fiberglass for certain components to allow for RF transparency. The Aft section will be made from carbon fiber and fiberglass. It has a length of 42.25″ and an inner diameter of 5.2″. This inner diameter is larger than the initial design for last year's rocket to allow for more room to work with. The airframe wall thickness will be 0.0825″. The Fore section will consist of solely carbon fiber and is a little longer than the Aft at 43.75″ while keeping the inner diameter and airframe wall thickness the same; 5.2″ and 0.0825″ respectively. The nose cone will be made of fiberglass and tipped with aluminum. It uses a 4:1 Ogive shape and will be 16.5″ in length. There will be an 10.4″ coupler to attach to the Fore section to the nose cone. Like the main body sections, the couplers will be made of carbon fiber. The main body coupler length will be 13″ and the inner diameter and wall thickness will be 5.075″ and 0.0715″ respectively. The fins consist of both carbon fiber and fiberglass. The fin shape will be

Clipped Delta and there will be four of them. The design for the motor mounting consists of three centering rings. The motor mounting tube and aft retainer will secure the motor within the Aft. The bulkheads will be made of plywood with a thickness of 0.4605″. The outer diameter will be 5.2″ and there will be a 0.5″ hole drilled directly through the center of the bulkhead. Lastly, the attachment hardware consists of a locknut, eye nut, and a washer. This component is for parachute quick links. These materials were chosen for specific components because they have shown to be sufficient in other OSRT endeavors, including the 2017-2018 OSRT launch vehicle.

The stability of the launch vehicle was determined using OpenRocket to simulate a launch. It was found to be 2.13 calibers and is shown on Table 5. The OpenRocket simulation results are shown in Figure 8. The stability of the launch vehicle will change throughout the design process. As the design develops, the stability will be recalculated through this method.

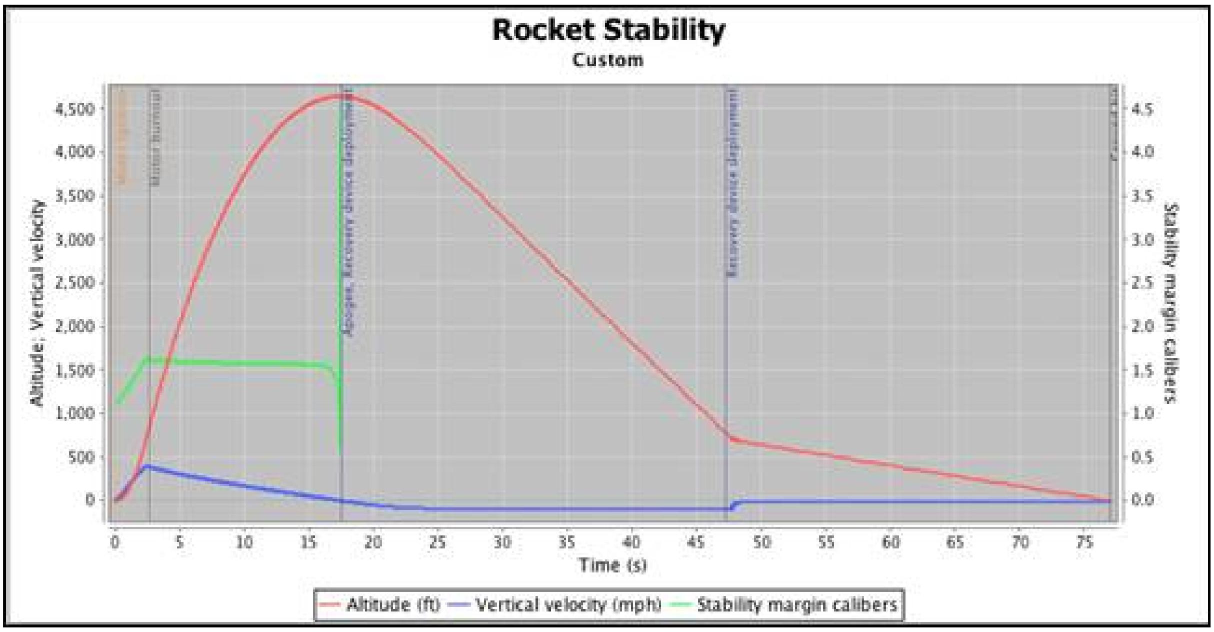

Figure 8: OpenRocket Simulation

Table 5 shows key characteristics of the launch vehicle used in the OpenRocket simulation.

Table 5: Launch Vehicle Specifications

Diameter	**Total Length**	**Loaded Weight**	**Stability**
5.2″	104″	39.55	2.13 Cal

Shown in Table 6 is a breakdown of launch vehicle requirements, a brief description of how OSRT is verifying these requirements will be completed, and the current status of the verification implementation.

Table 6: Launch Vehicle Verification Matrix

Requirement	Verification Plan	Status
All components will be able to withstand the heat and pressure from ejection charges.	All designs will be tested through ejection tests using standard bulkheads. Designs will be hanged if they do not pass.	Completed in design - has been accounted for in all designs and will be included in any future designs.
Rocket will not be over stable or susceptible to weathercocking.	Stability will be limited to maximum of 3.5 at rail exit.	Completed in design - has been accounted for in all designs and will be included in any future designs.
Launch vehicle will be able to be stowed in a 4′x4′x2′ container for shipping.	Launch vehicle will be able to disassemble into sections no longer than 4 feet and no wider than 2 feet to fit into container.	Completed in design - has been accounted for in all designs and will be included in any future designs.
The launch vehicle shall be recoverable and reusable.	The launch vehicle will be using the recovery system in place to minimize any damage upon landing. Once the launch vehicle is recovered, an inspection will be done to determine its structural integrity. The inspector will be looking for any signs of tearing, deformation, and any other visual indicators of wear. If there are any visual indicators of damage, then appropriate actions will be taken to repair the body. If there are no indicators of damage to the body, then the launch vehicle will be deemed capable of launching again.	Completed in design - has been accounted for in all designs and will be included in any future designs.
Motor shall provide required thrust to launch vehicle.	Using OpenRocket simulations we will be able to test the thrust output of the motor acting on the launch vehicle. Using this information to make the best decisions about the vehicle design and motor selection, the actual thrust will be measured during the first full scale launch. Proper installation protocols will be followed to ensure the integrity of the test. If thrust does not meet the requirement and all installation protocols were followed, then vehicle aerodynamics designs will have to change to compensate for lack of thrust or the selection of the motor will have to change.	Completed in design - has been accounted for in all designs and will be included in any future designs.

Continued on next page

Table 6 – continued from previous page

Requirement	Verification Plan	Status
The launch vehicle shall accommodate the payload and avionics systems.	Launch vehicle will have specific areas to accommodate the payload and avionics system in the payload bay and avionics bay, respectively. Both the payload and avionics system will be designed within the constraints of the interior dimensions or their respective bay. The payload and avionics system will be verified upon assembly of full scale launch vehicle.	Completed in design - has been accounted for in all designs and will be included in any future designs.
The launch vehicle shall be able to be rapidly integrated for launch.	Launch vehicle assembly integration will be practiced and require less than 2 hours.	Completed in design - has been accounted for in all designs and will be included in any future designs.
MATLAB scripts will be used in conjunction with all OpenRocket simulations.	Descent velocities, descent trajectory, landing energy, and an estimated apogee will be calculated using MATLAB scripts. All simulations will be checked to ensure no values disagree by more than 15%.	In progress - MATLAB code has been developed for necessary calculations thus far.
Bulkheads will have a factor of safety of 2.0 with respect to the maximum pressure forces experienced during separation.	Maximum pressure forces and stress on the bulkheads and at the bulkhead/airframe bond will be calculated and compared to the epoxy's bond strength.	Incomplete - will be accounted for and completed in final design.
Threaded rods will have a minimum tensile safety factor of 5.0 during recovery.	Simulations will determine maximum forces on the recovery harness, which will be compared to the tensile strength of selected threaded rod.	Incomplete - will be accounted for and completed in final design.
All threaded attachments have a length greater than 1.5 times the minimum shear length of the selected threads.	All purchased threaded components will be compliant, all manufactured components will be compliant.	Incomplete - will be accounted for and completed in final design.

4.2 Projected Altitude

An OpenRocket simulation was performed to calculate a projected altitude of the OSRT launch vehicle. Simulations were performed for different cross wind speeds, with a maximum projected altitude of 4,639 feet with no cross winds. With 5 mph wind speeds projected altitude is 4,637 feet. At 10 mph, the projected altitude of the launch vehicle is 4,635 feet, and decreases to 4,612 feet with a wind speed of 15 mph. The maximum simulation wind speed was 20 mph, giving a projected altitude of 4,530 feet. The projected altitudes assume there is no ballast and no changes to the drag profile of the rocket during flight. The projected altitudes were calculated at an angle of launch at zero degrees. Factoring in a launch angle can greatly decrease the projected altitudes but also may decrease horizontal distance traveled on decent due to cross-winds. The data collected in the OpenRocket simulation will be verified in subscale test launches, prior to the full scale launch day. Additional aerodynamic analysis will be performed using RASAero II to verify the OpenRocket simulation. Wind speeds will be monitored as launch day approaches. OSRT has decided to target 4,500 feet as a desired apogee altitude.

4.2.1 Projected Altitude Adjustment

The BEAVS will be used to control the exact apogee altitude of the launch vehicle despite variances in launch day conditions such as wind. This system uses two different subsystems to control apogee altitude: a passive and an active system. The passive BEAVS system is a coupled pair of ballast bays. These ballast bays are separated into the fore and aft sections, one below and one above the center of gravity. The mass contained within these ballast bays can be easily adjusted which will result in a consistent center of gravity location. A consistent center of gravity location is beneficial because it will allow for the launch vehicle to maintain the same stability while changing the amount of ballast. The active system will adjust the drag profile of the launch vehicle during flight to achieve the desired apogee altitude. OSRT plans to use the BEAVS to target an altitude within 50 feet of the planned target altitude.

This system will include blades which remain inside of the launch vehicle during motor burn, as shown in Figure 9. Upon motor burnout, blades which are perpendicular to the airframe can be deployed simultaneously, increasing the drag force on the launch vehicle. After motor burnout, drag and gravity are the only forces present on the launch vehicle. The BEAVS can accurately determine the position, velocity, acceleration, and angle of attack of the launch vehicle during flight, known as the current state. Based on the current state, BEAVS will then estimate apogee altitude by using these characteristics in a numerical method with a small time step. Based on the drag coefficient with blades extended and the calculated apogee altitude, the BEAVS can calculate the duration the blades should be extended from the airframe to achieve a desired apogee altitude. After the blades are retracted into the airframe, the BEAVS will calculate the new expected apogee altitude, and determine the error between the newly calculated apogee altitude and the desired apogee altitude. This value will be used to modify the drag coefficient of the launch vehicle for future blade actuation during flight. The BEAVS will make use of a varying set point during flight to perform a self optimization routine which allows for small error in the estimated drag coefficients.

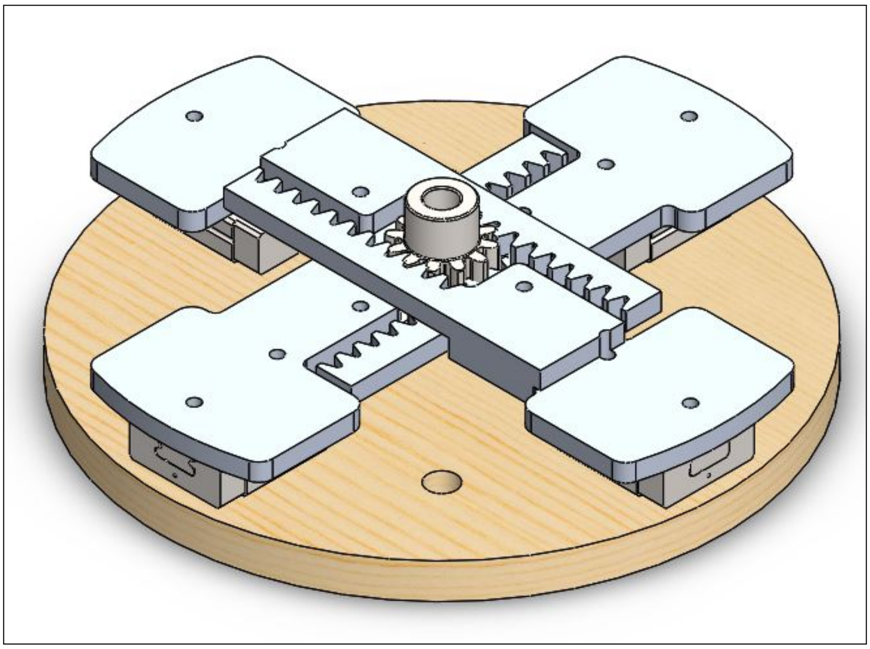

Figure 9: BEAVS design displaying bladed system.

The BEAVS will be placed as the furthest aft component excluding the motor. This location will be aft of the center of pressure. When the blades deploy, the center of pressure will be lowered, increasing stability. The increase in stability assures that in the event of system failure the launch vehicle will not pose a safety risk.

The BEAVS is not critical to successful completion of the mission; however the BEAVS will increase accuracy of the intended flight path to allow OSRT to deliver a reliable flight independent of launch day conditions. A system which actively controls the apogee altitude during flight increases the risk of failure to achieve the desired altitude if the system does not perform nominally. Therefore OSRT has decided to combine both a passive and active system which will mitigate the increased risk of failure of the active system, while maintaining the benefit of desired mission accuracy due to the active system.

4.2.1.1 Testing

Despite the BEAVS being a self optimizing system during flight, OSRT will validate the concept of BEAVS through a series of tests. The initial testing phase will be the most rigorous. If the BEAVS is unable to pass the testing phase with the desired accuracy from the active system, the BEAVS will be simplified to only include the passive system for mission assurance.

The testing will take place on a Mad Dog DD fiberglass airframe which has 4″ body diameter. This airframe was selected due to its availability to the OSRT: it was used as the 2017-2018 OSRT subscale launch vehicle. Some modifications to the airframe will be required to prepare it for testing of the BEAVS. It will, however, allow OSRT to begin testing the system as early as possible. OSRT plans to test the BEAVS on at least 3 flights in the Mad Dog DD launch vehicle before the active system is integrated into the full scale launch vehicle. Once integrated into the full scale launch vehicle, the BEAVS will undergo additional testing to ensure it maintains performance in the new airframe. The rigorous and continuous testing of the BEAVS will allow OSRT to provide an additional level of mission assurance by proving reliability of the active portion of the BEAVS.

In addition to the testing of the active portion of the BEAVS, the passive portion of the BEAVS must be tested in all potential ballasted conditions prior to launch at the USLI competition. The BEAVS will be tested with at minimum 3 ballast configurations, sized for wind conditions of 0 mph, 10 mph, and 20 mph. The ballast will be a modular stack of steel weights in each bay which are secured through the use of 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. While the modularity is beneficial for testing purposes, OSRT notes that the exact ballast configuration used at competition must be successfully tested previously.

4.2.1.2 Mechanical System

The BEAVS will extend 4 blades through slots cut into the airframe. The blades will be manufactured from $^1/_8$″ aluminum plate using a CNC mill. The blades will attach to a linear bearing on a 7 millimeter guide rail with three M2 fasteners. The blades will have a set of teeth which create a rack and pinion system with 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, and will be the compartment which stores the aft ballast weights of the BEAVS. The fore ballast bay will be located on the fore section hard point.

The blades were designed to account for a 32.0% increase cross sectional area of the test launch vehicle. Due to the self optimizing control scheme, the 32.0% increase in the cross sectional area was used to approximate a drag coefficient of the launch vehicle by acting as a direct multiplier of the drag coefficient before deployment. The test launch vehicle being flown has a drag coefficient of approximately 0.51 according to OpenRocket simulations, therefore when the blades are fully deployed it is estimated that the drag coefficient is 0.67. This is expected to be a conservative estimate, due to fluid flow separation effects when the blades are extended from the airframe. OSRT is currently developing a Computational Fluid Dynamics (CFD) simulation in STAR-CCM+ which will provide a more 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.

4.2.1.3 Electrical System

The BEAVS will consist of a Printed Circuit Board (PCB) which is designed by OSRT and consists of a Nine Degree of Freedom (9DOF) accelerometer, a barometric pressure sensor, a motor driver, and a microcontroller. The software for the BEAVS will be written in C/C++ to control the sensor data acquisition and filter the data. The data will be filtered using a Kalman filter to reduce the effects of noise in the measurements. The filtered data will then be used to predict apogee altitude based on current flight characteristics. Based off of 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.

4.2.1.4 Control System

The BEAVS will have a control scheme which is reliant on a varying set point to provide in-flight optimization. The control system has been reduced to a 1 degree of freedom control system, where the control variable is apogee altitude. The control system has only two possible states: blades retracted or blades deployed (note: this assumes blades deploy quickly enough to be negligible). With the blades deployed, the drag coefficient of the launch vehicle is increased, which lowers the expected apogee altitude. With blades retracted, the expected apogee altitude does not change. Therefore, the only output of the control system is to lower the expected apogee altitude. This presents a problem that if the control scheme overshoots the desired apogee altitude, there is no way to recover from that error to reach the desired apogee altitude. OSRT broke this problem down into two different ways which the problem could be solved.

The first solution is the more traditional control method which OSRT was familiar with, designing a Proportional-Integral-Derivative (PID) control loop and optimizing the parameters through testing in order to find PID coefficients such that the system is critically damped. This method presented a large flaw: the best way to test these parameters is to fly the launch vehicle and analyze the results of the test numerous times. This is expensive per test, and may require more test flights than OSRT can reasonably conduct before the competition.

The next option which OSRT looked at was to 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 a number of steps that gradually approach the overall desired apogee altitude value. After each blade deployment cycle, the PID parameters are updated based on the error between the set point and the expected apogee altitude. This method drastically reduces the number of tests required to dial in the PID parameters of the control system. The self optimizing control scheme will utilize only proportional control during initial testing of the BEAVS for simplicity. If it is determined to be necessary to achieve desired accuracy, integral and derivative control can be added in at a later date.

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. Based on the 2017-2018 OSRT flight data, BEAVS should have at least 10 duty cycles to be completed during flight.

4.3 Recovery System

4.3.1 Separation Events and Descent

The recovery system will consist of two dual deployment systems. At apogee, two ejection charges containing a predetermined amount of black powder will be ignited with electronic matches. One of the charges, located centrally in the launch vehicle, will separate the launch vehicle into two independent sections: fore and aft. The other charge, located in the fore section, will separate the fore section of the airframe from the nose cone. Immediately following the apogee separation event, a drogue parachute is released from each independent section of the launch vehicle. The drogue parachutes will control the descent velocity and provide stability to the launch vehicle. At 600 feet AGL, both main parachutes will be released, allowing all sections to land under the required 75 foot pounds of kinetic energy. The projected flight is seen in Figure 10.

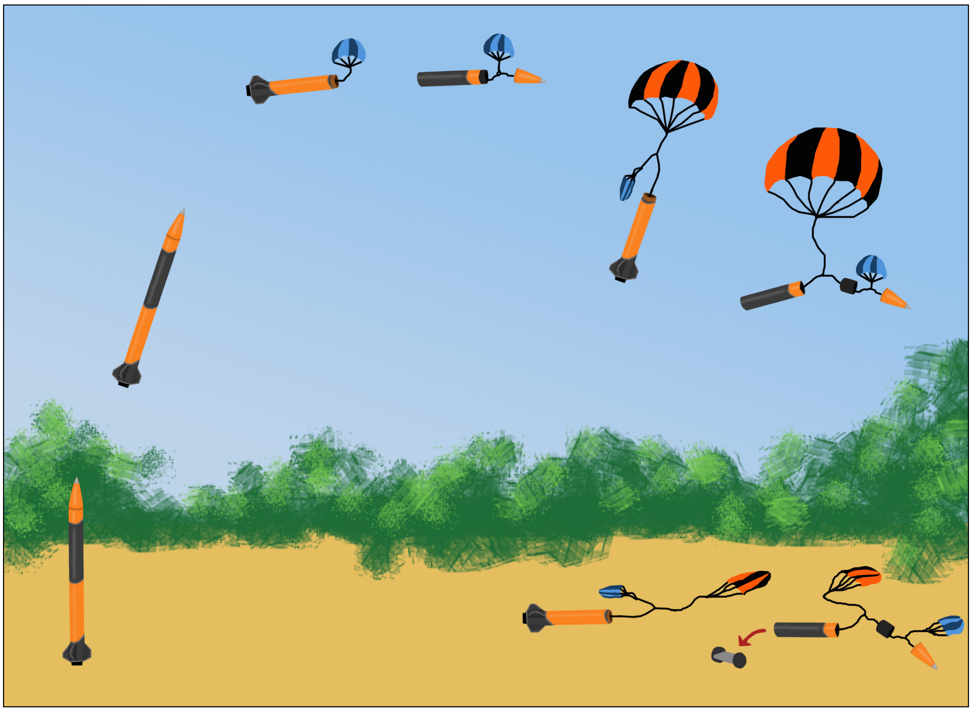

Figure 10: Launch Vehicle Flight (not drawn to scale).

4.3.2 Altimeters

MissileWorks Rocket Recovery Controller 3 (RRC3) and PerfectFlite StratoLogger CF altimeters will be used to set off ejection charges and record the altitude. Both of these altimeters have excellent reliability. These altimeters also have an excellent track record at Oregon State, as they have been used previously by OSRT and have had minimal issues. Both brands of altimeters calculate altitude and apogee using barometric sensors. The main altimeters will be RRC3, and the secondary altimeters will be StratoLogger CF. Two of each will be used: one of each in the fore and aft sections. The reason to have two different altimeters is for redundancy. If one fails due to a defect, having a backup of a different brand will eliminate the chances of total failure due to a batch defect.

4.3.2.1 Accurate Pressure Readings

In order for a barometric altimeter to work correctly, it must be vented to the outside air. Static port holes will be located so there are no obstructions forward of them, and they will also be placed on the altimeter bays. Additionally, on the fore altimeter bay, the static port holes will be placed as far aft of the nose cone as possible while still being located on the bay. Following MissileWorks recommendations for port hole sizing, the altimeter bay volume in inches cubed divided by 400 equals the port hole diameter in inches. If the port hole diameter ends up being relatively large, such as larger than 3/4", three static port holes of one third the diameter will be used for each altimeter bay.

4.3.2.2 Number of Static Port Holes

Sizing of the altimeter bays will be very important - having static port holes which are too large or too small can cause early or late deployment of parachutes, respectively. The proposed launch vehicle diameter is 5.2 inches. If the maximum diameter chosen for static port holes were to be .75 inches, then the altimeter bays would need to be shorter than 14.1 inches. If the bays were longer than 14.1 inches, more than one static port hole should be used.

4.3.2.3 Backup Charges

Ejection charges are used to separate the nose cone from the fore section, the fore altimeter bay from the fore section, and the fore section from the aft section. For each separation event, two charges will be used. For the release of the aft main parachute, two Tender Descenders will be connected in series. Each Tender Descender will have one charge inside of it. Every altimeter will ignite two charges: the fore altimeters are in charge of the separation events, while the aft are in charge of separation and release of Tender Descenders. Backup separation charges will be ignited one second after primary charges in order to stay within the two second maximum delay at apogee, assuming the first charges fail, and to avoid overpressurization of the launch vehicle due to simultaneous ignition.

4.3.3 Parachutes and Retention

Both aft parachutes are located centrally in the launch vehicle, and both fore parachutes are located between the upper body tube and the nose cone.

4.3.3.1 Fore Parachutes

The fore parachutes will be secured to one bulkhead and one end of the fore altimeter bay each. One bulkhead is located in the nose cone and one is located in the fore section. The fore bulkhead will have one short, threaded rod ran through it. The end the main parachute is secured to will have an eye nut threaded onto the rod, as well as a locking nut, to ensure the eye nut does not twist off. The opposite end will have a standard nut, securing the rod in place. The nose cone bulkhead will have one threaded rod with an eye nut and regular nut threaded onto it in the same fashion as the fore bulkhead. The fore altimeter bay will have an eye bolt on both sides. The drogue parachute will be harnessed to the nylon shock cord, which is connected to the nose cone and the fore end of the altimeter bay. The shock cord will be attached to the eye nut with a quick link. The main parachute will have two attachment points: the eye nut in the fore bulkhead and the eye bolt connected to the aft end of the altimeter bay. Both will have a long section of nylon shock cord attached to quick links, which are attached to the eye nuts in the bulkheads. The charges separating the fore altimeter bay from the fore section are ignited at 600 feet AGL, allowing the main parachute to be pulled out. Each harness and shock cord attached to an eye nut or bolt will have a quick link between them. All quick links will be rated at 880 pounds for static load. Each section of shock cord attached to a parachute will have the same quick links used everywhere else, as well as a swivel, rated at 1000 pounds static load, to allow the parachutes to rotate freely.

4.3.3.2 Aft Parachutes

The aft parachutes will be secured to one bulkhead, which is located in the aft section coupler. The aft bulkhead will have two eye nuts secured to it the same way as the eye nuts in the fore bulkheads. The drogue parachute will be harnessed to a nylon shock cord which is connected to the main parachute. The main parachute will have two more attachment points: the eye nuts in the aft bulkhead. One will have a long section of nylon shock cord, while the other will have a short harness attached to two Tender Descenders, seen in Figure 11, connected in series. The Tender Descenders will be released at 600 feet AGL, allowing the drogue parachute to pull the main parachute out.

Figure 11: Tender Descender

Each section of shock cord attached to an eye nut will also be attached to a quick link rated at 880 pounds static load. Each section of shock cord attached to a parachute will have the same quick links used at the eye nuts, as well as a swivel rated at 1000 pounds static load. All parachutes will be protected with a fire resistant Nomex blanket or bag attached to the nylon shock cord.

4.3.4 Shock Cord Material

All shock cords and shroud lines will be rip-stop nylon. Rip-stop nylon is superior to Kevlar due to its higher elasticity. If nylon is subjected to high loads, it stretches and deforms, while Kevlar snaps. In the event of extreme snatch loads, Kevlar could fail, while nylon would stretch, helping dissipate the load. The nylon will be $9/16$ inches in width to avoid zippering of the airframe. The length of the main parachute shock cords will be three times the length of their respective body sections, while the drogue shock cords will be at least two times the length of their respective body sections.

4.3.5 Parachute Shielding

Every parachute will be shielded from heat. The main parachutes will be wrapped in a deployment bag. These deployment bags will be held shut with laces and a pin, depicted in Figure 12 (Deployment Bag from Rick Newland's paper *Parachute Recovery System Design for Large Rockets*, 2014, digital copy, accessed 10 September, 2018). When the nylon shock cord reaches its full length, the pin will be pulled from the laces. This opens the bag, allowing the parachute to unfurl. Each bag will also be attached to its respective shock cord with quick links so it is not lost during recovery. The reason a heat resistant deployment bag is used instead of a heat resistant Nomex blanket for the main parachutes is to reduce the snatch load. The drogue parachutes will be wrapped in fire resistant Nomex blankets that are attached to their respective harness with quick links. The Nomex blanket will be 9 inches in width and octagonally shaped.

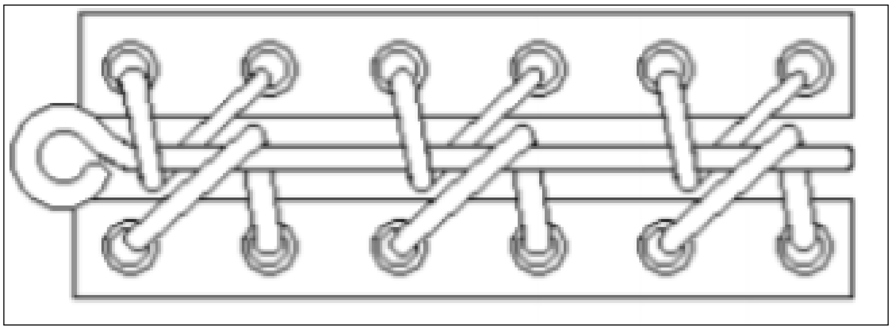

Figure 12: Deployment Bag Closure

4.3.6 Descent Rates and Parachute Sizes

The proposed launch vehicle weight is 39.55 pounds without ballast. After separation at apogee, the fore section will weigh 18.29 pounds and the aft section will weigh 17.26 pounds after the fuel has been burned. The aft section will be split into three section. The weight of each is: fore body tube equals 13.64 pounds, fore avionics bay equals 2.97 pounds, and the nose cone equals 1.68 pounds. In order for every section to stay under 75 foot pounds of kinetic energy upon landing, the maximum allowable descent rate under the main parachutes are 16.73 ft/s and 18.82 ft/s for aft and fore sections respectively. It has been determined that the main parachute diameters need to be 7 feet for aft and and 6 feet for fore. Under these size parachutes, the aft section will fall at 15.44 ft/s and the fore section will fall at 16.67 ft/s. The resulting kinetic energies of each section are as follows: aft equals 63.9 foot pounds, fore airframe equals 58.89 foot pounds, fore avionics bay equals 12.82 foot pounds, and the nose cone equals 7.25 foot pounds. The shape used for the main parachutes will be toroidal, because of the increased drag the shape offers. This allows for smaller parachutes and smaller packing volume with the same descent rate as an elliptical parachute would offer. Below is the process followed to solve for the listed values. The values used for the coefficient of drag for the toroidal parachutes and air density in Huntsville, Alabama are as shown in Table 7

Table 7: Values for Coefficient of Drag and Air Density

Variable	Value
C_d	2.2
ρ_{air}	.0022 $slug/ft^3$

According to FruityChutes, their toroidal parachutes produce a coefficient of drag of at least 2.2, and in some cases over 3. 2.2 was used, as it would give the safest results, keeping the kinetic energy upon landing within requirements.

The value for air density chosen was the value at Standard Temperature and Pressure (STP) multiplied by the percentage of air density in Huntsville, Alabama, which is 92.75 percent. This will likely not be the same value as launch day conditions, but the diameters chosen for the main parachutes account for any differences in air density.

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

KE is kinetic energy in $ft - lbf$, where m is mass in $slugs$, and v is velocity of the system in ft/s.

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

D is drag around the parachute in lbf, where C_d is the coefficient of drag of the parachute, ρ_{air} is the density of air in $slugs/ft^3$, v is the velocity of the system in ft/s, A_r is the reference area of the parachute in ft^2, which is the cross sectional area, and W_{lv} is the weight of the launch vehicle in lbf.

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

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

The reference area can be defined in terms of the outer and inner diameters of the toroidal parachute, where d_o is the outer diameter and d_i is the inner diameter. Typically, the ratio between outer and inner diameters for this shape of parachute is 5:1. Using this, the reference area equation becomes:

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

Plugging equation 5 into equation 2 and solving for the outer diameter gives:

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

The drogue parachutes chosen are cruciform shape. The diameter of the parachutes are 2.33 ft. With a coefficient of drag of about 0.9, the fore and aft sections will fall at 72.87 $^{ft}/_{s}$ and 70.79 $^{ft}/_{s}$ respectively.

4.3.7 Couplers and Shear Pins

The launch vehicle will contain two couplers: one attaching the nose cone to the fore section, and one attaching the fore section to the aft section. The fore coupler will be permanently fixed to the nose cone, and it will fit snugly inside the fore section of the launch vehicle. The aft coupler will be permanently fixed to the aft section, and it will fit snugly inside the fore section. The aft coupler will be 2.5 times the diameter of the launch vehicle in length, which is 13 inches, and the fore coupler will be two times the launch vehicle length, which is 10.4 inches. In order to keep the pieces of the launch vehicle intact during the ascent, nylon 2-56 x $^1/_4{}''$ shear pins will be used to temporarily hold each section together. These pins will shear when under too much pressure. In order to ensure separation, a slight excess of black powder will be used in each ejection charge. Ground testing will be done to ensure at least three complete separations of sections after ignition of ejection charges.

4.3.8 Recovery System Verification Matrix

Shown in Table 8 is a breakdown of recovery system requirements, a brief description of how OSRT is verifying these requirements will be completed, and the current status of the verification implementation.

Table 8: Recovery System Verification Matrix

Requirement	Verification Method	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.	At apogee, an ejection charge will separate the fore from the aft, and another will separate the fore from the nose cone. The ejection charge in the middle of the launch vehicle will separate the aft from the fore section, as well as push the drogue out of the aft section. An ejection charge located in the upper fore section will separate the nose cone from the fore section. At 600 feet AGL, the main fore parachute will be pulled out by the fore avionics bay, after another charge has been ignited, and the aft main parachute is pulled out by the drogue parachute after a Tender Descender releases it.	Completed in design - has been accounted for and will be incorporated in any future designs.
3.1.1 The main parachute shall be deployed no lower than 500 feet.	Barometric altimeters will sense the altitude AGL, and they will tell the parachutes to deploy at 600 ft. AGL.	Completed in design - has been accounted for and will be incorporated in any future designs.
3.1.2 The apogee event may contain a delay of no more than 2 seconds.	When the barometric altimeters sense apogee, the delay for the primary ejection charges will be set to less than a second, and the backup charges delay will be set one second later, less than two seconds after apogee is sensed.	Incomplete - will be completed once altimeters are purchased and programmed.
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.	Ground ejection tests will be performed prior to all launches, subscale and full scale, to ensure all parachutes are ejected properly during the launch.	Incomplete - will be completed prior to all launches.
3.3 At landing, each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.	Appropriate main parachute sizes have been chosen in order to keep each independent section under 75 ft-lbf of kinetic energy upon landing.	Completed in design - the kinetic energy requirements upon landing has been accounted for in design with parachute sizing.
3.4 The recovery system electrical circuits will be completely independent of any payload electrical circuits.	All recovery and payload circuits will be independent of each other.	Completed in design - has been accounted for completely independent circuits for payload and recovery.
3.5 All recovery electronics will be powered by commercially available batteries.	All batteries will be purchased from a vendor determined to have batteries which meet all required needs.	In progress - all batteries will be purchased through reputable vendors.

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Table 8 – continued from previous page

Requirement	Verification Method	Status
3.6 The recovery system will contain redundant, commercially available altimeters. The term ”altimeters” includes both simple altimeters and more sophisticated flight computers.	The launch vehicle will contain four altimeters, two primary and two secondary. The primary will be MissileWorks RRC3, and the secondary will be PerfectFlite StratoLogger CF.	Completed in design - has accounted for redundant, commercially available altimeters.
3.7 Motor ejection is not a permissible form of primary or secondary deployment.	The motor will not be ejected from the launch vehicle during primary or secondary deployment.	Completed in design - has accounted for no motor ejection.
3.8 Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Nylon shear pins will be used for all parachute compartments to ensure the launch vehicle’s sections are fixed together until ejection charges are fired.	Completed in design - all couplers have included shear pins.
3.9 Recovery area will be limited to a 2,500 ft. radius from the launch pads.	Each independent section will fall quickly and controlled under drogue parachutes. The main parachutes will deploy, and the launch vehicle sections will fall as quickly as possible while staying under the kinetic energy requirement to limit drift.	Completed in design - has accounted for appropriate descent rates to land within the recovery radius.
3.10 Descent time will be limited to 90 seconds (apogee to touch down).	To limit descent time spent under the main parachutes, the launch vehicle has been split into two independent sections. This allows for safer descent rates under the drogue parachutes while still staying under the required 90 seconds.	Completed in design - has accounted for appropriate parachute sizes to stay within the limited descent time.
3.11 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 launch vehicle will contain two Global Positioning System (GPS)s: one in the fore section and one in the aft section.	Completed in design - has accounted for the inclusion of tracking systems.
3.11.1 Any launch vehicle section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	The fore and aft sections will land independently of each other. Both will contain a GPS in their respective avionics bays.	Completed in design - has accounted for a tracking system in each independent section.
3.11.2 The electronic tracking device(s) will be fully functional during the official flight on launch day.	All tracking systems will be tested on launch day to ensure they are working correctly.	Incomplete - will be completed the morning of all launches.
3.12 The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	All recovery systems needing protection will have proper protection, eliminating any adverse reactions.	Completed in design - has accounted for appropriate shielding and protection of electronics.

Continued on next page

Table 8 – continued from previous page

Requirement	Verification Method	Status
3.12.1 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.	All electronics producing radio frequency or magnetic waves will be located in separate compartments from all altimeters and recovery electronics.	Completed in design - has accounted for appropriate shielding and protection of electronics.
3.12.2 The recovery system electronics will be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.	All recovery system electronics will have proper protection, shielding from transmitting devices, ensuring charges are not ignited early.	Completed in design - has accounted for appropriate shielding and protection of electronics.
3.12.3 The recovery system electronics will be shielded from all on-board devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	The recovery system electronics will be shielded from all magnetic waves produced by any device onboard the launch vehicle to avoid inadvertent excitation of the recovery system.	Completed in design - has accounted for appropriate shielding and protection of electronics.
3.12.4 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 recovery system will be appropriately shielded from all devices which may have any adverse effect on the recovery system electronics.	Completed in design - has accounted for appropriate shielding and protection of electronics.

4.4 Propulsion

The OSRT will use the AeroTech L1520-PS75mm high power rocket motor with specifications shown in Table 9. This decision was based on the high average and max thrust for the propellant type and relatively small size.

Table 9: Motor Specifications

Total Impulse	Burn Time	Max Thrust	Average Thrust	Loaded Weight	Propellant Weight	Propellant Type
3716 N-sec	2.4 sec	1765 N	1568N	8 lbs	4 lbs	Blue Thunder

4.5 Launch Vehicle Technical Challenges

Table 11 displays a breakdown of some of the major technical challenges and the solutions which OSRT have developed for the launch vehicle.

Table 11: Launch Vehicle Technical Challenges

Technical Challenge	**Solution**	**Launch Vehicle Section**
Zippering of the airframe with the shock cords.	Wide shock cords, 9/16 inches in width, will be used to minimize the chance of zippering the airframe.	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
Ensuring each individual section lands under 75 ft-lbf of kinetic energy.	Calculations have been run to correctly size parachutes, allowing individual sections to land under the kinetic energy requirements.	Recovery
Ensuring proper deployment of drogue parachutes.	Ejection charges will be placed in specific locations to ensure that the drogues are pushed out at the same time the launch vehicle components are separated.	Recovery
Ensuring proper deployment of main parachutes	The tangling of shroud lines will be minimized to ensure that charges and Tender Descenders function properly.	Recovery
Ensuring the launch vehicle does not go ballistic.	The launch vehicle will contain redundant altimeters and backup ejection charges to ensure the separation of sections.	Recovery
Launch vehicle must reach predetermined altitude.	A motor will be accurately selected to accommodate the mass of the launch vehicle and the payload to reach apogee	Launch Vehicle
Launch vehicle sections will separate and deploy parachutes with black powder charges	The appropriate amount of black powder charges will be used to ensure the sections separate without causing harm to launch vehicle or the operators. Safety procedures will be implemented to increase safety.	Launch Vehicle
Bulkheads should withstand section ejection and parachute chord forces	Epoxy fillets or fasteners will be used to secure bulkheads in place, which will be made from durable material	Launch Vehicle
Wind conditions affect apogee altitude.	Utilize BEAVS to adjust expected apogee altitude during flight.	BEAVS
Active portion of the BEAVS deploys at undesired time.	Blade actuation will be aft of the center of pressure to maintain safety in the event of undesired actuation. System will be tested rigorously to ensure reliable performance.	BEAVS

Continued on next page

Table 11 – continued from previous page

Technical Challenge	**Solution**	**Launch Vehicle Section**
Active portion of the BEAVS does not deploy blades during flight.	Ballast will be configured in passive portion of BEAVS to provide accuracy in the event of system failure. BEAVS will be tested rigorously to ensure reliable performance.	BEAVS
Motor unable to actuate blades.	Blades will extend perpendicular to the airframe, reducing required torque from the motor. Linear bearings will be used to minimize friction in the system.	BEAVS
Control system does not converge to desired apogee altitude.	System will be self optimizing through modification of PID coefficients during flight with a varying set point.	BEAVS
BEAVS does not accurately determine position, velocity, acceleration, and angle of attack of launch vehicle during flight.	A Kalman filter will be used in order to reduce noise.	BEAVS

4.6 Payload - Deployable Rover

4.6.1 Payload Overview

The team will pursue the USLI deployable rover payload challenge. The rover's purpose is to travel a distance of at least ten feet from the landing site, collect a soil sample, and securely store it. An extra soil analysis component may be included in the design; the team is considering options based on feasibility and scientific value added to the mission. The requirements for this payload option, and the team's plans to meet them, are summarized in Table 12.

Table 12: Rover Payload Requirements.

Requirement	Verification Plan	Status
4.3.1 The team's custom rover must deploy from the internal structure of its launch vehicle.	The rover will be situated within the fore section of the launch vehicle until landing.	Complete - Ejection and retention system will hold payload throughout launch and flight, and will deploy once safely landed.
4.3.2 The team's launch vehicle will feature a fail-safe active retention system to maintain control of the payload, even under atypical flight forces.	The retention system will feature an Advanced Retention and Release Device (ARRD) and two Tender Descenders for redundancy and retention under atypical conditions.	Complete - Retention devices to be used will still retain the payload even in electrical and mechanical failures.
4.3.3 Once on the ground, the team's rover must be deployed remotely.	The payload will be ejected by way of a properly sized black powder charge.	Complete - Charge will be ignited remotely once given approval.
4.3.4 The team's rover must travel at least 10 feet from its launch vehicle before collecting a soil sample.	The rover will drive itself away from its starting location for a duration long enough to guarantee more than 10 feet of covered ground.	Complete - Rover is designed to autonomously travel further than 10 feet away from launch vehicle with avoidance detection.
4.3.5 The collected sample must be greater than or equal to 10 milliliters in volume.	The sample collection mechanism will empty itself into a storage compartment several times to guarantee more than 10 milliliters of soil.	Complete - Auger design and collection plan will guaranty sufficient collection volume.
4.3.6 The soil sample must be stored in a compartment that can be closed to prevent contamination.	The storage compartment will feature a spring-assisted cover.	Complete - Design includes closing storage compartment to seal collected sample.
4.3.7 All rover batteries must be protected from impact with the ground.	Battery module will be contained within the chassis.	Complete - Chassis is designed to be very durable, and surrounds the battery module
4.3.8 All rover batteries must be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other rover parts.	Battery module(s) will be marked with colored electrical tape.	In Progress - Batteries will be marked once purchased.

The team intends to build a dual wheel rover with a roughly cylindrical form factor. Its chassis will be a truss with carbon fiber rods and aluminum couplers. Mounted to its chassis, at its midpoint, will be an auger-type tool for sample collection. The rover will be retained as described below in the Ejection and Retention System (EARS), which is situated lengthwise in the payload bay in the 5.2" inner diameter airframe.

The payload's sequence of events is as follows:

1) The rover and EARS are packed within the payload bay in the fore section of the launch vehicle at launch.
2) During flight, the payload bay will separate from the aft section of the launch vehicle leaving the end of the payload bay open, and with the help of the fore drogue and main chute, come to rest on the ground.
3) Shortly after landing, under supervision of the Remote Deployment Officer, the team will remotely ignite the retention devices holding the rover in the payload bay, and then ignite a black powder charge that will eject the rover from the fore section of the launch vehicle.
4) The dual wheel design combined with a stabilizing tail will allow the rover to simply and autonomously orient itself into the position necessary to carry out the mission–that is, with its auger pointed toward the ground.
5) The rover will travel more than 10 feet from its starting position, using object avoidance in order to navigate away from airframe components and other ground obstacles.
6) The rover will extend its auger, drill into the soil, and collect a sample, repeating several times in several locations to ensure the sample exceeds the 10 milliliter requirement. The mission is complete.

4.6.2 Payload Ejection and Retention System

The payload EARS will be fully removable from the airframe to ensure all energetic charges are not loaded or wired until assembly at the launch site. The system is all mounted and spaced on a threaded rod prior to insertion in the airframe. The components mounted along the rod are listed below, and can be seen numbered in Figure 13:

1) Removable High-density polyethylene (HDPE) tip
2) Threaded rod
3) Fore spacer bulkhead
4) Electronics bay for ejection and retention charges
5) Aft Spacer Bulkhead
6) Retention devices and ejection charges
7) Payload spacer on end of threaded rod
8) Wrapped payload assembly.

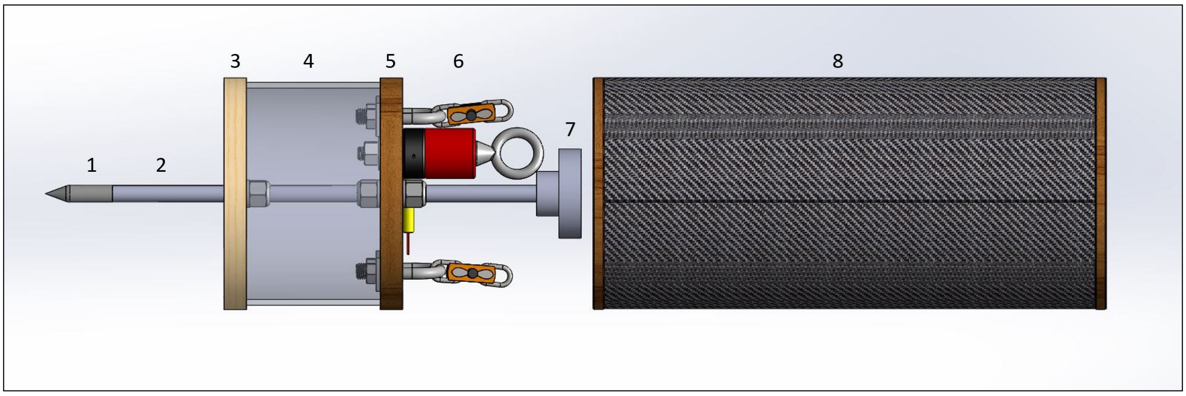

Figure 13: EARS Assembly Prior to Airframe Insertion

The wrapped payload assembly consists of a Kevlar harness which holds two bulkheads against the wheels of the payload with attachment rings to the retention devices, and a carbon fiber wrap which encases the payload and harness. The retention devices to be used are a single ARRD and two Tender Descenders. While two devices are needed to hold the payload during flight and landing forces, an additional device will be added for ensured retention if abnormal forces are experienced. An ARRD was chosen over a third Tender Descender to add another layer of safety achieved by having redundant devices from a different manufacturer than the main devices.

Once the wrapped payload is attached to the retention devices and the electronic matches are tested and attached to the retention devices and ejection charge, the whole assembly will be placed into the fore section of the airframe. This is done by sliding assembly into the open end of the fore section of the airframe. The threaded rod will pass through the fore hard point which separates the fore recovery system from the payload system. This hard point consists of a plywood bulkhead and HDPE bulkhead with a countersunk funnel to aid the threaded rod in going through the bulkhead. The assembly can be seen in Figure 14. This design will make assembly very simple as slight cocking issues while sliding the payload assembly into the airframe will be corrected by the HDPE rod tip finding the center position via the HDPE funnel. Once fully inserted, from the other end of the airframe the rod tip can be removed, and a washer and nut can be added to fully retain the EARS within the airframe.

During flight, the retention devices will hold the payload in place against the spacer at the end of the threaded rod. Should any sort of electrical failure happen within the EARS, the retention devices will not fail and will keep the payload fully secured within the airframe. After a safe landing, the retention devices will be blown, untethering the wrapped payload from the airframe. Finally a black powder charge located in the same location as the retention devices will be ignited. The wrapped payload will act as a pressure seal against the airframe, so when the charge is ignited the wrapped payload will be ejected from the open end of the fore airframe. Once clear of the airframe, the wrap and bulkheads will fall away, the rover will

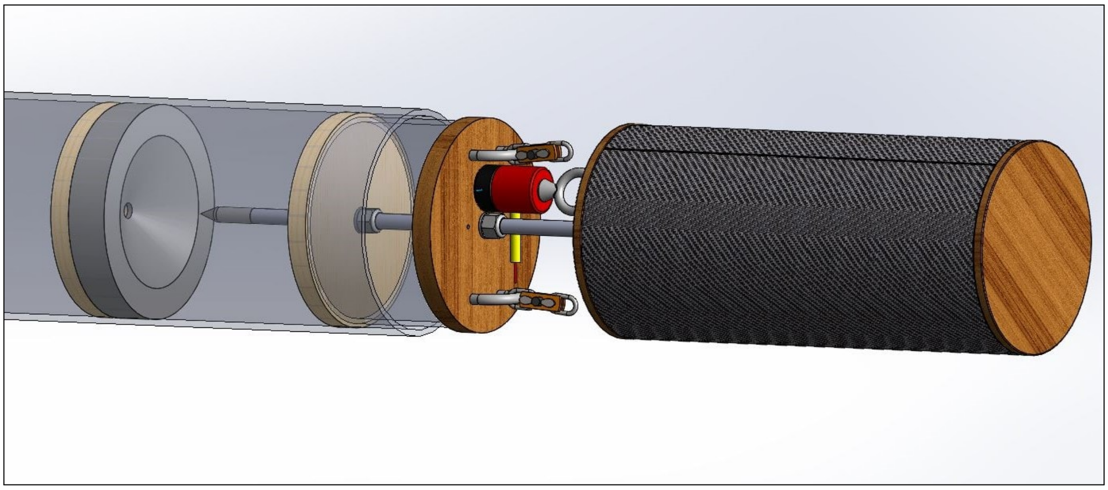

Figure 14: EARS Assembly into Airframe

land in any oriention, self-right, and be ready to drive away to collect and analyze a soil sample. While the EARS is simple, there were some technical challenges that needed to be addressed as can be seen in Table 13.

Table 13: EARS Technical Challenges and Solutions

Technical Challenge	Solution
Difficult EARS assembly into airframe	HDPE funnel bulkhead will aid threaded rod through fore hard point by centering rod regardless of system cocking.
Pressure seal on between payload and airframe	Foam tires on rover wheels will allow rover to be compressed in carbon fiber wrap and inserted into the airframe. The foam tires will then expand until the wrap is sealed to the ID of the airframe.

4.6.3 Payload Details

The rover's drivetrain will employ two 4.8" diameter circular wheels cut from 0.75" HDPE, which is known for its impact resistance and strength relative to weight. This material also has negligible thermal expansion up to 130 °C, which is important for safe and predictable ejection from the airframe. The interior disk of the wheels will be solid to mitigate the risk of debris entering the drivetrain mechanism.

The wheels must be able to grip the ground surface once deployed; failure to do so may leave the rover stuck on an obstacle or slick surface with its wheels spinning. To avoid this, the team will apply a length of memory foam to the tread of each wheel which matches its width and circumference. This will give a better friction coefficient. A secondary benefit of this foam "tire" is that it can be compressed while within the wrapped payload. The increase in radius that occurs when the foam decompresses gives the rover's chassis more clearance with the ground. Various types of foams will be tested for maximum expansion and durability.

If a dual wheel rover has wheels that cannot be controlled independently, then it can only travel along a single, straight path. Though there is a benefit here in simpler design, the risk of becoming stuck on an obstacle with no way to avoid it is too severe to ignore. This is particularly important since the ground surface at the launch location is unpredictable. The rover will need to be capable of turning, so the team will utilize two Direct Current (DC) motors which vary the rotational speed of each wheel independently to turn as needed.

The team previously found success with a similar rover using a pair of GHM-04 spur gear motors; they offer plenty of torque for their size and weight. The same motors, whose specifications are provided in table 14, will drive this rover.

Table 14: GHM-04 Motor Specifications.

Nominal Voltage	7.2 V
Rated RPM	146 rpm
Rated Torque	13.9 oz-in
Stall Torque	125 oz-in

The core of the drivetrain is a pair of 0.25" diameter steel shafts, which transmit power to the wheels using an aluminum assembly. The assembly consists of a 0.25" bore clamping hub that presses against one of two discs on the exterior of the wheel. Another disc sits in a recess on the interior side of the wheel and the entire assembly is held together with four 6-32 hex screws and nuts. The intention is to distribute the shaft's forces more evenly across the wheel.

The drive shafts are joined with the motors using 6 millimeter flexible aluminum couplings and the assembly is fixed to the nearest member of the truss chassis using a three-piece aluminum assembly. Two countersunk top pieces secure the drive shaft to the member without needing to disassemble the chassis. The proposed drivetrain design is shown in exploded view in Figure 15. The design will be mirrored for the other wheel, and a radial bearing will be added to the aluminum assembly for smooth operation.

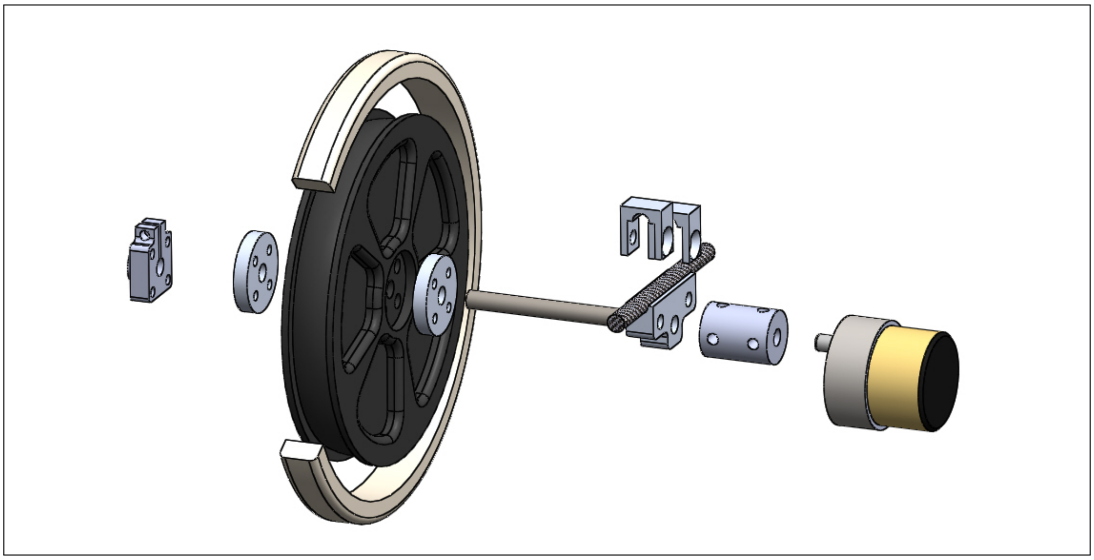

Figure 15: Rover Drivetrain

4.6.3.1 Soil Collection

Soil collection will be accomplished by the device shown in Figure 16, using an auger-type tool which will be 3D printed out of a carbon fiber infused filament. This material was selected for its beneficial strength, lightweight characteristics, and its ability to be 3D printed. The auger will be deployed from the internal structure of the truss chassis between the two wheel motors at a 45°angle toward the front of the rover. The placement of the auger will ensure a stable structure when soil collection is engaged.

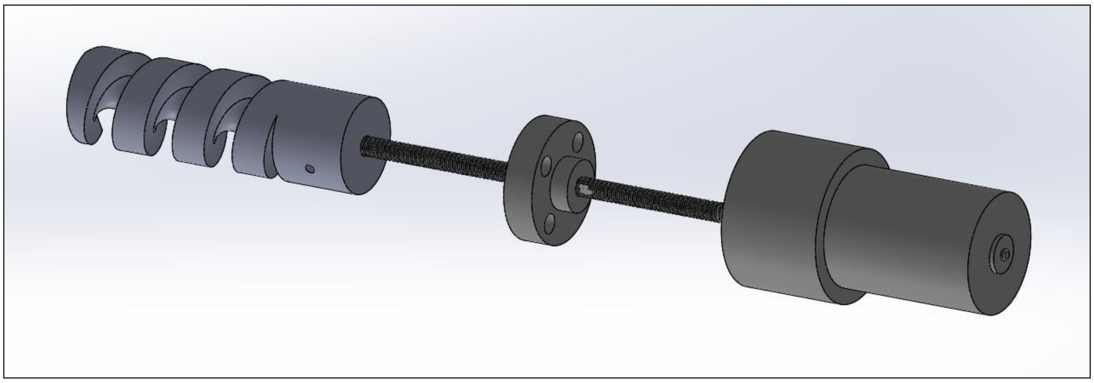

Figure 16: Soil Collection Device

The auger will be rotated using a brushless motor connected by a threaded rod. A flanged nut will be threaded through the rod and bolted onto the frame of the rover, preventing the nut from moving. When the motor rotates the rod, the flange causes the auger to feed into the soil. A circular tube will encase the auger, which will be used to retain the soil during transportation from the ground to the soil container. Once the soil reaches the top of the auger, it will fall downward by gravity into the soil storage container. The soil storage container will use spring-assisted doors to seal a sample of at least 10 milliliter. When the soil falls onto the container doors, the weight will cause the spring-assisted doors to open into the container, allowing soil to fall. When there is no longer soil contacting the doors, they will close to seal the container. Multiple samples may need to be collected to fulfill the 10 milliliter sample requirement.

One motor will be needed for the soil collection operation. A high-torque/low-speed motor will be used for the auger rotation/feed. A Planetary Gear Motor PGHM-03 will be used. The specification of this motor are listed in Table 15 below.

Table 15: PGHM-01 Motor Specifications.

Nominal Voltage	12.0 V
Rated RPM	14 rpm
Rated Torque	208.31 oz-in
Stall Torque	499.95 oz-in

4.6.3.2 Electrical Design

The rover will use MB7360 HRXL-MaxSonar-WR sensors placed in the front to determine distance traveled as well as identify upcoming terrain hazards where an open-loop control system will reroute the rover to avoid the hazard. A Raspberry Pi will control the function of the rover. LiPo batteries will be used due to their small size and high current delivery capabilities.

4.6.4 Rover-Related Technical Challenges and Solutions

Table 16: Rover Technical Challenges and Solutions

Technical Challenge	Solution
Topsoil is hard-packed and difficult to manipulate.	Sample collection auger will be sharpened, but encased for safety when not in use; ballast may be added to rover to aid auger's penetration.
Rover stabilizer does not deploy properly.	The torsion spring will be properly sized to actuate the stabilizer in all orientations.
Rover encounters an obstacle.	Dual motors allow the rover to maneuver onto a more favorable path. Sonar sensors will be used to detect obstacles prior to collision.
High impact landing could damage rover.	The rover is contained in protective housing and constructed of impact-resistant materials.
Electronics in rover could sustain damage due to high launch and landing forces.	The important electronics will be vibrationally isolated from the structural body.
Rover fails to gain traction on soil surface.	Higher-friction memory foam will be applied to wheel surfaces.

Shown in Table 17 is a summary of tests which have been developed to test the payload performance.

4.6.5 Rover Test Plan

Table 17: Rover Test Plan

Test	Test Procedure
Terrain Travel	The rover will be tested in different terrains, such as dry dirt, rocky terrain, and mud, to determine if the motors, sensors, tires, and control systems are functioning properly.
Rover Retention	Individual retention devices, the ARRD and Tender Descenders, will be tested separately from the launch vehicle. Full system retention will be tested on the ground along with rover deployment testing. The full assembly will then be launch tested in the Vehicle Demonstration Flight.
Rover Deployment.	A rover deployment test apparatus will be developed, along with an airframe, that can be adjusted to simulate multiple landing angles. This system can be used to test both rover deployment as well as rover retention.
Control System Communication	The control system will be tested to determine the operational range of the wireless system.
Auger Soil Collection	The functionality of the auger will be tested at various locations with different soil densities and moistness levels. Auger length, angle of operation, applied force to the ground, rotation speed, and motor torque will also be tested to determine the optimal soil collection process.
Auger Soil Container	The container spring-assisted sealing method will be tested using different soil types and auger orientations to determine the optimal location, shape, size, and motor specifications to meet the mission criteria. Spring stiffness will also be analyzed.

4.7 Project Requirements

Shown in Table 18 is a breakdown of vehicle requirements, a brief description of how OSRT is verifying these requirements will be completed, and the current status of the verification implementation.

Table 18: Vehicle Requirement Verification Matrix

Requirement	Verification Plan	Status
2.1. The vehicle will deliver the payload to an apogee altitude between 4,000 and 5,500 feet AGL. Teams flying below 3,500 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.	The motor selection is based on OpenRocket simulation to reach the required AGL range. This will be determined as the team refines the design and determines a definite weight.	Completed - launch vehicle has been designed to meet requirements.
2.2. Teams shall identify their target altitude goal at the PDR milestone.	The target AGL goal will be declared on the PDR.	In Progress - target altitude has been set to 4500 feet for current design. This altitude is subject to change during preliminary design phase.
2.3. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner.	The launch vehicle will contain a commercially available barometric altimeter.	Completed in design - multiple commercially available altimeters have been selected in current design.
2.4. 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 location of the altimeter housing will allow for each altimeter arming switch to be activated from the exterior of the launch vehicle.	Completed in design - arming switches will be accessible from exterior of launch vehicle.
2.5. Each altimeter will have a dedicated power supply.	All altimeters will have their own dedicated power supply.	Completed in design - each altimeter in design has dedicated power supply.
2.6. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	All arming switches will have a mechanical locking system.	Completed in design - arming switches are armed through use of hex key which maintains ON position throughout flight.

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Table 18 – continued from previous page

Requirement	Verification Plan	Status
2.7. The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	The launch vehicle will be designed to survive launch and recovery without needing repairs or modifications prior to an additional same day launch.	Completed in design - launch vehicle has been designed to be reusable.
2.8. The launch vehicle will have a maximum of four (4) independent sections.	The launch vehicle will have no more than four independent sections.	Completed in design - launch vehicle has 4 sections.
2.9. The launch vehicle will be limited to a single stage.	The propulsion system will consist of only one motor.	Completed - only one motor will be used.
2.10. The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the FAA flight waiver opens.	The team will perform preparation drills to practice assembling and readying the launch vehicle within two hours.	In Progress - design for assembly is being emphasized. Testing and practice will be implemented to ensure assembly process is less than two hours.
2.11. The launch vehicle will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components.	The team will perform testing for leakage current in order to optimize energy usage of all electrical systems.	Completed in design - all batteries were chosen to be capable of maintaining functionality for more than 2 hours.
2.12. The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the National Aeronautics and Space Administration (NASA)-designated launch services provider.	The launch vehicle will have a separate launch system that is powered by an external 12-volt system.	Completed in design - motor firing system is planned to be a 12-volt direct current firing system.
2.13. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch.	All electrical systems will run autonomously and wait for launch, internally. Acceleration sensors will inform the control systems of launch.	Completed - no external circuitry will be used.
2.14. 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 NAR, TRA, and/or the Canadian Association of Rocketry (CAR).	The launch vehicle will be designed to use a commercially available motor that is approved and certified by the NAR, TRA, and/or the CAR.	Completed - motor has been selected to meet these requirements.
2.15. Pressure vessels on the vehicle will be approved by the RSO and will meet the provided criteria.	Pressure vessels will not be integrated into the launch vehicle.	Completed - no pressure vessels used.

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Table 18 – continued from previous page

Requirement	Verification Plan	Status
2.16. The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class). The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).	The motor selection will be limited to using a L-class or lower as to not exceed 5,120 Newton-seconds of impulse.	Completed - motor selected meets requirement.
2.17. The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	The current design has a static stability of 2.13 at the rail exit.	Completed - static stability has been determined and will be adjusted as design progresses.
2.18. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	The rail will be built to allow the launch vehicle to reach at least 52 fps at the exit of the rail.	Completed - minimum rail exit velocity is above 52 fps.
2.19. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets.	The team will successfully create, launch, and recover a subscale launch vehicle prior to submitting the CDR.	Incomplete - a subscale model will be launched prior to CDR.
2.20. All teams will complete demonstration flights as outlined below.	The team will launch a subscale and full scale launch vehicle with retained payload included in the full scale, eliminating the need of a simulation mass. Both vehicles will be built with resources available at Oregon State institution, fully equipped with chutes and avionics. Information recovered from the flight will reported on the FRR. The launch vehicle will not be modified at this point. If re-flight is necessary, proper documentation will be filed for an extension which would be done before the FRR deadline.	Incomplete - will be completed by each of the specified deadlines.
2.21. 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 the team fails to complete a Payload Demonstration Flight prior to the FRR Report, the team will follow the proper procedure for Re-Launch.	Incomplete - will be completed by specified deadline if necessary.
2.22. Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	Any structural protuberances will be located behind the burnout center of gravity.	Complete - designed to meet requirement.

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Table 18 – continued from previous page

Requirement	Verification Plan	Status
2.23. 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.	There will be sufficient and obvious contact information on each section of the launch vehicle.	Incomplete - contact information will be labeled during manufacture of the launch vehicle.

4.7.1 Vehicle Prohibitions

Shown in Table 19 is a breakdown prohibited aspects of the vehicle, a brief description of how OSRT is verifying these requirements will be completed, and the current status of the verification implementation.

Table 19: Vehicle Prohibition Verification Matrix

Requirement	**Verification Plan**	**Status**
2.24.1. 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 design does not include forward canards.	Completed - design meets the requirement.
2.24.2. The launch vehicle will not utilize forward firing motors.	The launch vehicle will have a single, rear firing, motor.	Completed - design meets the requirement.
2.24.3. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	The selected motor for the launch vehicle will not expel any titanium sponges.	Completed - design meets the requirement.
2.24.4. The launch vehicle will not utilize hybrid motors.	The selected motor will not be a hybrid motor.	Completed - design meets the requirement.
2.24.5. The launch vehicle will not utilize a cluster of motors.	The launch vehicle will have a single, rear firing, motor.	Completed - design meets the requirement.
2.24.6. The launch vehicle will not utilize friction fitting for motors.	The motor will be attached in a housing that uses a screw on engine retainer to hold the motor.	Completed - design meets the requirement.
2.24.7. The launch vehicle will not exceed Mach 1 at any point during flight.	The motor selection will be constrained to keep the maximum velocity under Mach 0.80.	Completed - design meets the requirement.
2.24.8. Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with and unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	The launch vehicle is designed to not utilize ballast and fin design will be used to adjust drag and stability.	In progress - ballast configurations will be tested. A maximum of 10% ballast will be used.
2.24.9. Transmissions from onboard transmitters will not exceed 250 mW of power.	The team will find energy efficient onboard transmitters that will not exceed 250mW of power.	Completed - design meets the requirement.
2.24.10. Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	The launch vehicle design will utilize a structurally necessary amount of carbon fiber and G10 fiberglass.	Completed - design meets the requirement.

5 STEM ENGAGEMENT

Oregon State University is very supportive in increasing young students' Science, Technology, Engineering and Mathematics (STEM) exposure. Our hope is to increase the amount that Oregon students get hands-on experience with rocketry and space sciences. Oregon is a distance from NASA centers and as a result pre-college students' exposure to space sciences is limited. Most of the exposure falls on dedicated teachers and museum trips. We hope to establish connections that extend beyond to timelines of the competition and create recurring events with schools. We also gain the opportunity to practice important science communication skills that will be necessary in our careers.

We have connected with both schools in the surrounding area and the OSU Pre-College Program. The Pre-College Program hosts events throughout the year from various age groups of students. They promote hands on learning and communicating opportunities that students can pursue in college or as careers. We began working with them after the 2018 competition and reached 1,500 students this past summer. The program hosts an event in the fall called Discovery Days, which invites elementary students from the surrounding areas to come and participate in hands-on experiments. We presented at a previous event in the summer and will be continuing to participate in future Discovery Days.

Members of the OSRT will work together to coordinate events and create lesson plans for varying subjects. Our goal is to have a library of lesson plans to fit into teachers' lesson plans and are specific to different age groups. We fortunately have a variety of backgrounds on the team and can confidently deliver lectures to students on engineering, physics, biology, chemistry, and mathematics. Many of the schools that we visit and educate do not have the financial funding to perform their own hands-on activities and it is important for us to provide the best learning experience that we can for each school.

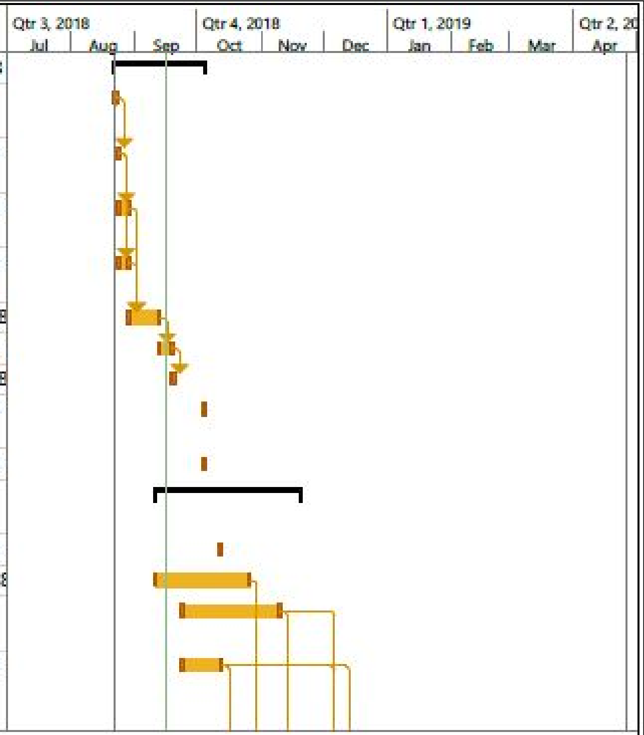
Currently, we are working with local organizations to set up educational events. Oregon Space Science Education Program (OSSEP) is an organization that specializes in bringing past and current NASA research to classrooms. They are interested in creating a partnership to also educate students about college opportunities. We are also planning to set up events with the Evergreen Aviation and Space Museum in McMinnville, Oregon and the Oregon Museum of Science and Industry in Portland, Oregon in addition to visiting several local schools for outreach events.

6 PROJECT PLAN

6.1 Schedule

A comprehensive schedule has been developed for the 2018-2019 year. This schedule is displayed in Figures 17-19.

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Proposal Phase**	**32 days**	**Wed 8/22/18**	**Thu 10/4/18**
2			Competition Rules Released	1 day	Wed 8/22/18	Wed 8/22/18
3			Team Decisions and Kickoff Meeting	1 day	Thu 8/23/18	Thu 8/23/18
4			Launch Vehicle Concept	3 days	Fri 8/24/18	Tue 8/28/18
5			Payload Concept Development	3 days	Fri 8/24/18	Tue 8/28/18
6			Compile Proposal	11 days	Wed 8/29/18	Wed 9/12/18
7			Edit Proposal	4 days	Thu 9/13/18	Tue 9/18/18
8			Submit Proposal	1 day	Wed 9/19/18	Wed 9/19/18
9			Proposal Awards Announced	1 day	Thu 10/4/18	Thu 10/4/18
10			AIAA Presentation	1 day	Thu 10/4/18	Thu 10/4/18
11			**Preliminary Design Phase**	**50 days**	**Tue 9/11/18**	**Mon 11/19/18**
12			Kickoff and PDR Q&A	1 day	Fri 10/12/18	Fri 10/12/18
13			Compile PDR	33 days	Tue 9/11/18	Thu 10/25/18
14			Manufacture Subscale	35 days	Mon 9/24/18	Fri 11/9/18
15			Manufacture BEAVS Prototype and Test Airframe	15 days	Mon 9/24/18	Fri 10/12/18



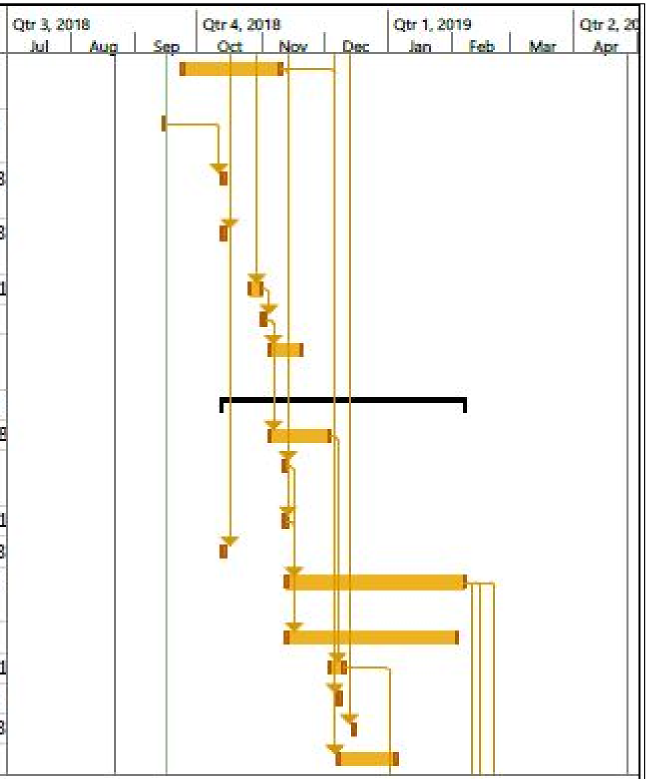
Project: Proposal Schedule.mpp
Date: Sun 9/16/18

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

Page 1

Figure 17: OSRT's Schedule for 2018-2019 USLI (1/3)

ID		Task Mode	Task Name	Duration	Start	Finish
16			Manufacture Payload Test Prototype	35 days	Mon 9/24/18	Fri 11/9/18
17			Build L1/L2 Certification Rockets	1 day	Sat 9/15/18	Sat 9/15/18
18			Certification Rocket Launch Day	1 day	Sat 10/13/18	Sat 10/13/18
19			BEAVS Test Launch	1 day	Sat 10/13/18	Sat 10/13/18
20			Edit PDR	4 days	Fri 10/26/18	Wed 10/31/1
21			Submit PDR	2 days	Thu 11/1/18	Fri 11/2/18
22			PDR Video Teleconferences	11 days	Mon 11/5/18	Mon 11/19/18
23			**Critical Design Phase**	**83 days**	**Sat 10/13/18**	**Wed 2/6/19**
24			Compile CDR	21 days	Mon 11/5/18	Mon 12/3/18
25			Payload Prototype Testing	1 day	Mon 11/12/18	Mon 11/12/18
26			Subscale Launch	1 day	Mon 11/12/1	Mon 11/12/1
27			BEAVS Test Launch	1 day	Sat 10/13/18	Sat 10/13/18
28			Manufacture Full Scale Launch Vehicle	62 days	Tue 11/13/18	Wed 2/6/19
29			Manufacture Payload	60 days	Tue 11/13/1	Sat 2/2/19
30			Edit CDR	5 days	Tue 12/4/18	Mon 12/10/1
31			BEAVS Test Launch	1 day	Sat 12/8/18	Sat 12/8/18
32			BEAVS Test Launch	1 day	Sat 12/15/18	Sat 12/15/18
33			Performance Testing	21 days	Sat 12/8/18	Fri 1/4/19



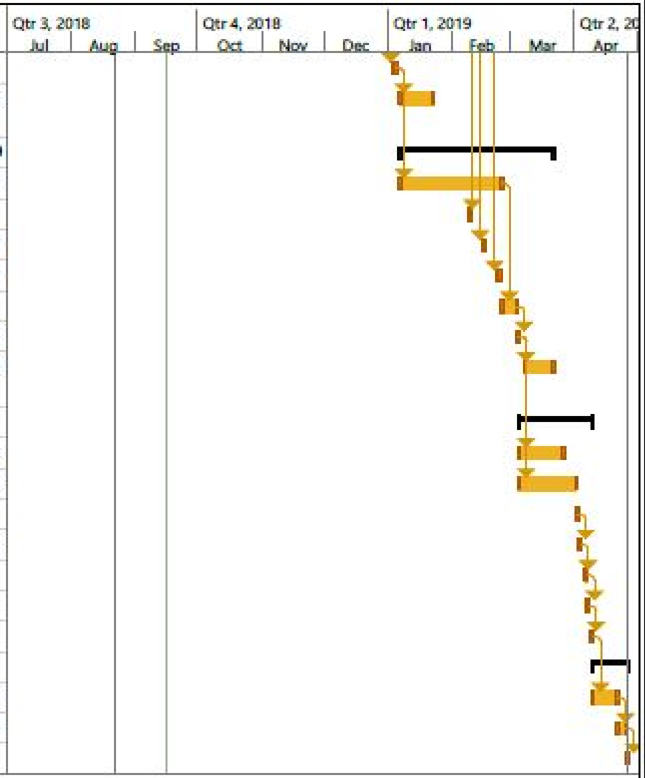
Project: Proposal Schedule.mpp
Date: Sun 9/16/18

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

Page 2

Figure 18: OSRT's Schedule for 2018-2019 USLI (2/3)

ID	Task Mode	Task Name	Duration	Start	Finish
34		Submit CDR	1 day	Fri 1/4/19	Fri 1/4/19
35		CDR Video Teleconferences	12 days	Mon 1/7/19	Tue 1/22/19
36		**Final Readiness Phase**	**54 days**	**Mon 1/7/19**	**Thu 3/21/19**
37		Compile FRR	36 days	Mon 1/7/19	Sun 2/24/19
38		Full Scale Launch	1 day	Sat 2/9/19	Sat 2/9/19
39		Full Scale Launch	1 day	Sat 2/16/19	Sat 2/16/19
40		Full Scale Launch	1 day	Sat 2/23/19	Sat 2/23/19
41		Edit FRR	6 days	Mon 2/25/19	Sun 3/3/19
42		Submit FRR	1 day	Mon 3/4/19	Mon 3/4/19
43		FRR Video Teleconferences	10 days	Fri 3/8/19	Thu 3/21/19
44		**Competition Phase**	**26 days**	**Tue 3/5/19**	**Tue 4/9/19**
45		Paint Rocket	16 days	Tue 3/5/19	Tue 3/26/19
46		Develop Displays	20 days	Tue 3/5/19	Mon 4/1/19
47		Arrive in Huntsville	1 day	Tue 4/2/19	Tue 4/2/19
48		LRR	1 day	Wed 4/3/19	Wed 4/3/19
49		Launch Day	1 day	Sat 4/6/19	Sat 4/6/19
50		Backup Launch Day	1 day	Sun 4/7/19	Sun 4/7/19
51		Depart from Huntsvill	1 day	Tue 4/9/19	Tue 4/9/19
52		**Post Launch Phase**	**13 days**	**Wed 4/10/1**	**Fri 4/26/19**
53		Compile PLAR	9 days	Wed 4/10/19	Sun 4/21/19
54		Edit PLAR	4 days	Mon 4/22/19	Thu 4/25/19
55		Submit PLAR	1 day	Fri 4/26/19	Fri 4/26/19



Project: Proposal Schedule.mpp
Date: Sun 9/16/18

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

Page 3

Figure 19: OSRT's Schedule for 2018-2019 USLI (3/3)

6.2 Budget

What follows is a full budget for the proposed project design. It includes a bill of materials for each subteam (Structures in Table 21, Aerodynamics/Recovery in Table 22, and Payload in Table 23) and an estimate of anticipated travel costs for the competition in Table 24.

Each of the launch vehicle sections has an accompanying section code, 01-10, listed in Table 20. Each section has a set of assemblies, which are numbered starting at 01. Finally, each assembly has a set of parts, which are numbered starting at 001. Concatenating these numbers will give each part a unique identifier. For instance, the drivetrain coupling has the identifier 05-03-008.

Table 20: Section codes for use in budget tables.

Section Code	Section Name
01	Motor
02	Blade Extending Apogee Variance System (BEAVS)
03	Aft Avionics/Ejection Bay
04	Aft Chutes
05	Payload
06	Fore Hard Point
07	Fore Avionics Bay
08	Fore Main Chute
09	Fore Ejections Bay
10	Fore Drogue Chute

Shown in Table 21 is a breakdown of the expected costs for the Structures team.

Table 21: Structures Budget

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
03			Pyrodex	1	$ 24.99	$ 24.99	Cabela's		current
03			MissileWorks RRC3 Sport Altimeter	2	$ 69.95	$ 139.90	MissileWorks		current
03			PerfectFlite StratoLogger CF	2	$ 57.50	$ 115.00	PerfectFlite		current
07			MissileWorks RRC3 Sport Altimeter	2	$ 69.95	$ 139.90	MissileWorks		current
07			PerfectFlite StratoLogger CF	2	$ 57.50	$ 115.00	PerfectFlite		current
09			MissileWorks RRC3 Sport Altimeter	2	$ 69.95	$ 139.90	MissileWorks		current
09			PerfectFlite StratoLogger CF	2	$ 57.50	$ 115.00	PerfectFlite		current
			Structures Subtotal			$ 789.69			
			10 % Contingency			$ 78.97			
			STRUCTURES TOTAL			**$ 868.64**			

Shown in Table 22 is a breakdown of the expected costs of the Aerodynamics and Recovery team.

Table 22: Aerodynamics and Recovery Budget

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
02	Mechanical BEAVS	02-01-001	1/8″ aluminum plate (2″x 24″ Bar)	1	$ 11.08	$ 11.08	McMaster-Carr		current
02	Mechanical BEAVS	02-01-002	1/4-20 Fasteners	4	$ 0.19	$ 0.78	McMaster-Carr		current
02	Mechanical BEAVS	02-01-003	8-32 Threaded Rod (4 in)	4	$ 1.67	$ 6.68	McMaster-Carr		current
02	Mechanical BEAVS	02-01-004	1/2″ Aerospace Grade Plywood Bulkhead	21.24 (in2)	$ -	$ 1.53	Wicks		current
02	Mechanical BEAVS	02-01-005	PLA 3D Printer Filament (1 kg)	1	$ 19.99	$ 19.99	Amazon		current
02	Mechanical BEAVS	02-01-006	M2 Fasteners (Qty 100)	0.25	$ 13.26	$ 3.32	McMaster-Carr		current
02	Mechanical BEAVS	02-01-007	7mm Linear Guide Block	4	$ 65.47	$ 261.88	McMaster-Carr		current
02	Mechanical BEAVS	02-01-008	7mm Linear Rail (172 mm)	4	$ 21.06	$ 84.24	McMaster-Carr		current
02	Mechanical BEAVS	02-01-009	10 GA Steel Plate	10	$ 2.37	$ 23.70	JCI		current
02	Electrical BEAVS	02-02-001	SparkFun Venus GPS	1	$ 49.95	$ 49.95	SparkFun		current
02	Electrical BEAVS	02-02-002	Teensy 3.6	1	$ 31.25	$ 31.25	DigiKey		current

Continued on next page

Table 22 – continued from previous page

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
02	Electrical BEAVS	02-02-003	MPL3115 Barometer	1	$ 4.87	$ 4.87	Mouser		current
02	Electrical BEAVS	02-02-004	BNO055 9DOF IMU	1	$ 34.95	$ 34.95	Adafruit		current
02	Electrical BEAVS	02-02-005	Turnigy 2200mah LiPo	1	$ 10.99	$ 10.99	HobbyKing		current
02	Electrical BEAVS	02-02-006	OSRT Designed PCB	1	$ 92.90	$ 92.90	DFRobot		current
02	Electrical BEAVS	02-02-007	Xbee Pro 900hp	1	$ 39.00	$ 39.00	DigiKey		current
02	Electrical BEAVS	02-02-008	7 in RPSMA whip antenna	1	$ 4.29	$ 4.29	Amazon		current
04			Main Parachute (Toroidal, 7′ diameter)	1	$ 276.00	$ 276.00	FruityChutes		current
04			Drogue parachute (Cruciform, silk body with nylon shroud lines, 28″ diameter, 500 in2)	1	$ 19.99	$ 19.99	AerospaceEducation		current
04			Eye nuts (5/8-11 drop forged)	4	$ 8.60	$ 34.40	Grainger - Ken Forging		current
04			Nuts		$ -	$ -			current
04			Nylon shock cord (9/16″, 10 yd)	1	$ 29.00	$ 29.00	FruityChutes		current
04			Quick links		$ -	$ -			current
04			Swivel		$ -	$ -			current
04			Nylon harness (1/2″ harness, 5 ft)	1	$ 42.00	$ 42.00	FruityChutes		current
04			Deployment bag (4 x 12″)	1	$ 45.00	$ 45.00	FruityChutes		current
04			Nomex blanket (9″)	1	$ 13.00	$ 13.00	FruityChutes		current
08			Main Parachute (Toroidal, 6′ diameter)	1	$ 210.00	$ 210.00	FruityChutes		current
08			Eye nuts (5/8-11 drop forged)	2	$ 8.60	$ 17.20	Grainger - Ken Forging		current
08			Nuts		$ -	$ -			current
08			Nylon shock cord (9/16″, 10 yd)	1	$ 29.00	$ 29.00	FruityChutes		current
08			Quick links		$ -	$ -			current
08			Swivel		$ -	$ -			current
08			Nylon harness (1/2″ harness, 5 ft)	1	$ 42.00	$ 42.00	FruityChutes		current
08			Deployment bag (4 x 15″)	1	$ 47.00	$ 47.00	FruityChutes		current

Continued on next page

Table 22 – continued from previous page

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
10			Drogue parachute (Cruciform, silk body with nylon shroud lines, 28" diameter, 500 in2)	1	$ 19.99	$ 19.99	AerospaceEducation		current
10			Nomex blanket (9")	1	$ 13.00	$ 13.00			current
			Aero/ Recovery Subtotal		$ 1,518.97				
			10 % Contingency		$ 151.90				
			AERO/ RECOVERY TOTAL		**$ 1,670.87**				

Shown in Table 23 is a breakdown of the expected costs for the Payload team.

Table 23: Payload Budget

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
05	EARS	05-01-001	HDPE Rod Tip - fore	1	$ 1.46	$ 1.46	McMaster-Carr		current
05	EARS	05-01-002	Threaded Rod	1	$ 5.56	$ 5.56	McMaster-Carr		current
05	EARS	05-01-003	Fore EARS Bulkhead - Loose	1	$ 0.35	$ 0.35	Home Depot		current
05	EARS	05-01-004	Electronics	1	$ 35.00	$ 35.00	Various estimates		current
05	EARS	05-01-005	Aft EARS Bulkhead - Loose	1	$ 0.35	$ 0.35	Home Depot		current
05	EARS	05-01-006	HDPE Rod Cap - Spacer	1	$ 3.54	$ 3.54	McMaster-Carr		current
05	EARS	05-01-007	Fore Payload Bulkhead	1	$ 0.35	$ 0.35	Home Depot		current
05	EARS	05-01-008	Aft Payload Bulkhead	1	$ 0.35	$ 0.35	Home Depot		current
05	EARS	05-01-009	Kevlar Harness	1	$ 10.00	$ 10.00	Dutch Ware		current
05	EARS	05-01-010	Carbon Fiber Wrap	1	$ 43.63	$ 43.63	Fibre Glast		current
05	EARS	05-01-011	ARRD	1	$ 119.00	$ 119.00	RATTworks		current
05	EARS	05-01-012	Tender Decender	2	$ 79.00	$ 158.00	Apogee Rockets		current
05	EARS	05-01-013	Misc. Hardware	1	$ 6.00	$ 6.00	Home Depot		current
05	Soil Collection	05-02-001	3D Printed Auger	1	$ 5.00	$ 5.00	3D Print (OSU)		current
05	Soil Collection	05-02-002	Auger Circular Tube	1	$ 10.00	$ 10.00	Possibly 3D Print (OSU)		current

Continued on next page

Table 23 – continued from previous page

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
05	Soil Collection	05-02-003	Planetary Gear Motor PGHM-03	2	$ 39.95	$ 79.90	Various vendors (Robotshop.com)		current
05	Soil Collection	05-02-004	Metal Gear - 14-1/4 Degree Pressure Angle	1	$ 17.53	$ 17.53	McMaster-Carr		current
05	Soil Collection	05-02-005	Roller Track Frame	1	$ 10.00	$ 10.00	3D Print (OSU)		current
05	Soil Collection	05-02-006	Threaded Track Rollers	4	$ 17.46	$ 69.84	McMaster-Carr / Home Depot		current
05	Soil Collection	05-02-007	Misc. Hardware	1	$ 6.00	$ 6.00	McMaster-Carr		current
05	Drivetrain	05-03-001	GHM-04 Spur Gear Motor	2	$ 21.95	$ 43.90	RobotShop		current
05	Drivetrain	05-03-002	HDPE Plate (6x12x0.75″)	2	$ 15.76	$ 31.52	McMaster-Carr	8619K791	current
05	Drivetrain	05-03-003	4140 Chamfered Steel Rod (24″)	1	$ 3.23	$ 3.23	McMaster-Carr	8927K18	current
05	Drivetrain	05-03-004	6061 Aluminum Bar (0.5x1x12″)	1	$ 4.91	$ 4.91	McMaster-Carr		current
05	Drivetrain	05-03-005	6061 Aluminum Bar (1x1x12″)	1	$ 8.29	$ 8.29	McMaster-Carr		current
05	Drivetrain	05-03-006	6061 Aluminum Bar (1x1.5x12″)	1	$ 3.68	$ 3.68	McMaster-Carr	8975K518	current
05	Drivetrain	05-03-007	Steel Round Head Screws (6-32, 1.5″, 100 ct.)	1	$ 3.65	$ 3.65	McMaster-Carr	90276A157	current
05	Drivetrain	05-03-008	Aluminum Shaft Coupling (6mm)	4	$ 1.82	$ 7.28	Banggood	994356	current
05	Drivetrain	05-03-009	Clamping Hub (0.770″ pattern, 0.25″ bore)	2	$ 5.99	$ 11.98	ServoCity		current
05	Drivetrain	05-03-010	6-32 Brass Hex Nuts (6-32, 100 ct.)	1	$ 4.50	$ 4.50	Bolt Depot		current
05	Electronics	05-04-001	Raspberry Pi	1	$ 40.00	$ 40.00	Digikey		current
05	Electronics	05-04-002	MB7360 HRXL-MaxSonar-WR sensors	2	$ 99.95	$ 199.90	Karlsson Robots		current
05	Electronics	05-04-003	Turnigy Graphene 950 mAh LiPo Battery Pack	9	$ 10.55	$ 94.95	Newegg		current
06		06-01-001	Fore Plywood Bulkhead	1	$ 0.35	$ 0.35			current
06		06-01-002	Fore HDPE Funnel	1	$ 13.90	$ 13.90			current

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Table 23 – continued from previous page

Section	Assembly	Identifier	Description	Quantity	Unit Cost	Cost	Vendor/ Source	SKU	Status
10			Drogue parachute (Cruciform, silk body with nylon shroud lines, 28” diameter, 500 in2)	1	$ 19.99	$ 19.99	AerospaceEducation		current
10			Nomex blanket (9”)	1	$ 13.00	$ 13.00			current
			Payload Subtotal			$ 837.31			
			10 % Contingency			$ 83.73			
			PAYLOAD TOTAL			**$ 917.74**			

Shown in Table 24 is a breakdown of expected travel costs.

Table 24: Projected Travel Expenses

Expense	Quantity	Subquantity	Unit Cost Estimate	Cost	Cost Estimate Source*likely to vary
Rental Vehicle	4 cars	10 days	$44.35/car/day	$1,774.00	2018 Corporate Travel Index
Fuel	125 gallons	4 cars	$2.51/gallon/car	$1,275.00	GasBuddy (Huntsville, AL)
Lodging	4 rooms	4 nights	$108.95/room/night	$1,743.20	Hilton Embassy Suites (Huntsville, AL)
Lunch	15 people	5 lunches	$25.42/person/lunch	$1,906.50	2018 Corporate Travel Index
Dinner	15 people	5 dinners	$55.52/person/dinner	$4,164.00	2018 Corporate Travel Index
TOTAL	-	-	-	**$10,862.70**	-

6.3 Funding

OSRT will seek external project assistance by way of grants, mentorship, and donations of parts and services. The team hopes to secure its main body of funding through the Oregon Space Grant Consortium (OSGC). OSGC is a program which emerged in 1988 and has developed to establish a national network of universities with interest and capabilities in aeronautics, space, and related fields. Its call for proposals begins September 21st. The maximum contribution from OSGC to a single team is $12,000, however 150% of this award must be matched with other sources.

Therefore, to supplement any contribution received from OSGC, the team is reaching out to corporate partners in pursuit of monetary donations, educational mentorship, and rocket components. Team members are currently speaking with two potential new partners, namely Allegheny Technologies Incorporated (ATI) Cast Products and Concept Systems Incorporated. Both companies have roots in nearby Albany, Oregon. The Oregon State University AIAA team also has existing corporate sponsors, the bulk of which are listed in Figure 20. Donations from these organizations will be graciously accepted and split among project teams according to need.

AIAA	The Boeing Company	Garmin
CadSoft	Binder Design	Wildman Rocketry
Lancair International, Inc.	Oregon NASA Space Grant	AeroRocket
Oregon Powder Coating	Advanced Circuits	A-1 Coupling
GetFPV.com	Oregon State University College of Engineering	American Sensor Technologies

Figure 20: AIAA and its Current Partnership Network

6.4 Sustainability

The OSRT competition is a new team at Oregon State, with only one previous entrance to the competition last year in 2017-2018. However, OSRT has developed a strong connection with the community, the school, and the local AIAA chapter throughout the competition last year and during the off season. This development is critical to the long term success of OSRT.

The OSRT is a team which is composed of two primary groups of members: senior capstone members and student volunteers. The capstone team members are participating in the project for course credit in senior design courses while student volunteers participate in the program on their own time. Despite only having one year to recruit volunteers, many of the capstone members in 2018-2019 previously participated as a student volunteer in the 2017-2018 competition. OSRT is developing this as a tradition through emphasis on getting student volunteers engaged in the project. The OSRT looks primarily to engage students from the OSU AIAA chapter, as well as students enrolled in OSU's aerospace engineering minor. The capstone members will have student volunteers shadow capstone team members and have put together numerous projects that will be lead by student volunteers. These two opportunities were developed through direct feedback from student volunteers who participated previously. OSRT looks to continuously recruit students from all disciplines at OSU through continuous improvement of the way in which student volunteers are given responsibilities which interest them. Student volunteer contributions to the project will make up portions of the future capstone team, so ensuring their involvement is crucial for sustainability of OSRT beyond the work they are able to contribute to the current year's success.

The OSRT also strives to engage and interest the community in rocketry, aerospace, and STEM year round. In the 2017-2018 competition, OSRT was able to teach lessons to over 900 students K-12 and develop connections which can provide success for future engagement within the community. This success was demonstrated throughout the off-season, when OSRT was given the opportunity to teach an additional 1500 K-12 students about rocketry, aerospace, and STEM. This provided a great opportunity to develop interest within the community about the project and about what we do as a part of OSRT. Throughout 2018-2019, OSRT looks to continue to develop connections within the community which will provide additional opportunities in the future for OSRT to engage the community.

Another important aspect of long-term success of OSRT is external sponsorship from the community and industry partners. The OSRT is committed to developing beneficial relationships with sponsors throughout the community. Sponsors for OSRT are acknowledged on the OSRT website and on the full scale launch vehicle. Additionally, sponsors will receive team pictures and can be kept informed through our OSRT social media profiles. The OSRT is committed to maintaining relationships with current industry partners and developing new relationships for the long term success of OSRT.