PROJECT GATORLAND

NASA Student Launch 2021 Proposal

University of Florida
Swamp Launch Rocket Team
3525 SW 20th Ave, Gainesville, FL 32607
MAE-A 324

September 21st, 2020

Table of Contents

Table of Figures

Table of Tables

1. General Information

1.1 Educator Information

Dr. Richard Lind
University of Florida
Department of Mechanical & Aerospace Engineering
Associate Professor
ricklind@ufl.edu
(352) 392-6745

1.2 Student Team Leader

Dylan Ogrodowski
Project Manager
2nd Year Electrical Engineering
dylanogrodowski@ufl.edu
(954) 205-6792

1.3 Safety Officer

Charles Wilson
Safety Officer
5th Year Aerospace Engineering

1.4 Design and Management Leaders

Julian Rodriguez
Swamp Launch President / Integration Lead
5th Year Aerospace Engineering

Ireland Brown
Swamp Launch Treasurer
3rd Year Aerospace and Mechanical Engineering

Maggie Wielatz
Educational Engagement Lead
2nd Year Mechanical Engineering

Joel Perez
VP External / Structures Lead
3rd Year Aerospace Engineering

Matthew Estenoz
Flight Dynamics Lead
3rd Year Aerospace Engineering

Alexander Krestan
Payloads Lead
4th Year Aerospace Engineering

Collin Larke
Avionics and Recovery Lead
2nd Year Aerospace Engineering

Megan Wnek
Testing Lead
2nd Year Aerospace Engineering

1.5 Project Organization

The team is organized into seven subteams: structures, flight dynamics, payloads, avionics and recovery, testing, integration, and educational engagement. Each subteam consists of one student leader and three to ten additional student participants. A project manager oversees the seven subteams and guides project development (Figure 1). Approximately ten student leaders and thirty-five additional participants will be committed to the project.

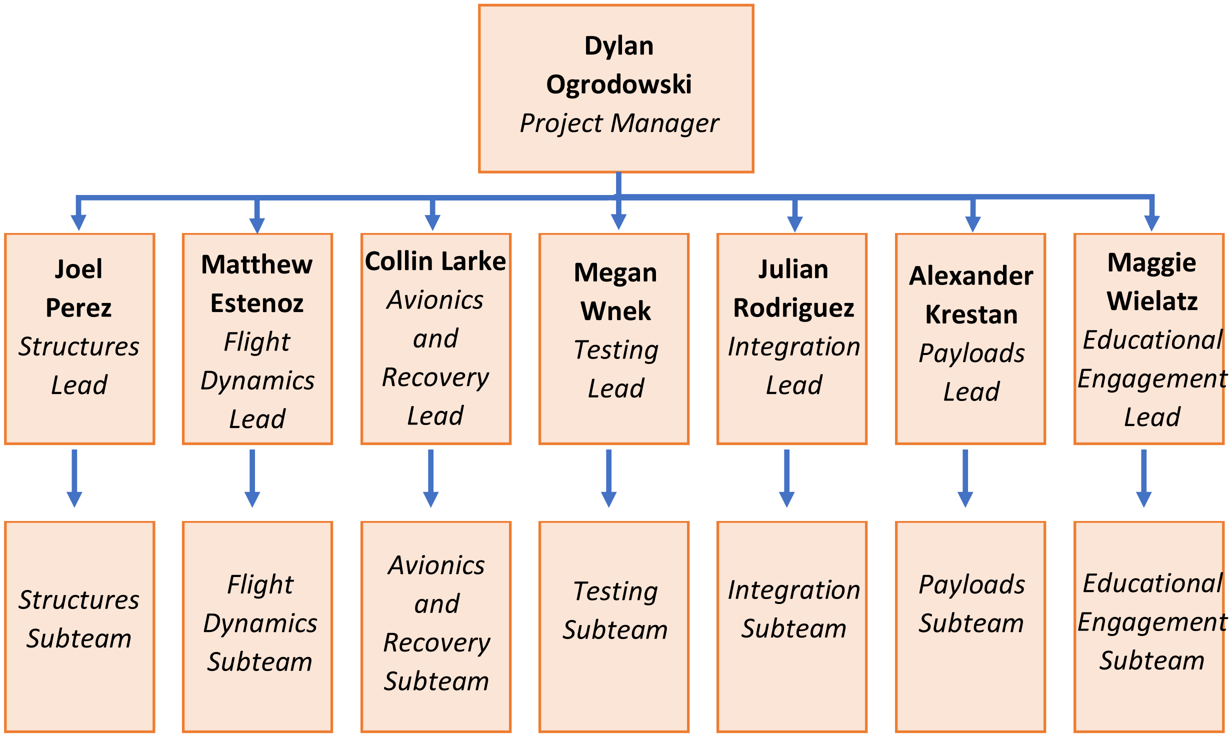

Figure 1 Project Organization Diagram

1.6 NAR/TRA Sections

The team will work with the Spaceport Rocketry Association (NAR #342, Tripoli #73) for launch assistance. This association provides a launch site that is within 200 miles of the University of Florida campus and supports launches of up to 13,500 feet. The team will receive mentorship from Jimmy Yawn, a level 3 certified NAR member.

1.7 Development Time

Subteam	Design/Plan Hours	Meeting Hours	Writing Hours	Total
Project Management	3	9	13.5	**25.5**
Structures	9	3	6	**18**
Avionics and Recovery	7	3	2	**12**
Flight Dynamics	11	5	4.3	**20.3**
Payloads	15	3	2	**20**
Testing	1	3	12	**16**
Integration	0	3	0	**3**
Safety	0	3	17.9	**20.9**
Educational Engagement	4	3	3.5	**10.5**
Treasury	0	5	5	**10**
Total	**50**	**40**	**66.2**	**156.2**

Table 1 Hours spent on development

The team has recorded all hours spent working on the project proposal, displayed in Table 1. Development time was separated by subteam and type of task performed. A total of 156.2 hours was logged in the creation of the proposal document.

2. Facilities and Equipment

2.1 Summary of Facilities

The team will have access to three facilities for manufacturing: the Student Design Center, Student Machine Shop, and DCP Fabrication Lab (Table 2).

Facility	Hours of Accessibility	Necessary Personnel
Student Design Center	Daily, 8:00 am – 10:00 pm Reservation Only	Chas Wilson – *Safety Officer*
Student Machine Shop	Weekdays, 7:30 am – 3:30 pm	Todd Prox – *Facility Manager* Brian Smith – *Engineer*
DCP Fabrication Lab	Weekdays, 10:00 am – 5:00 pm	Juan Griego – *Director* Breanne Schenk – *Assistant Director*

Table 2 Facilities, Hours of Accessibility, and Necessary Personnel

2.1.1 Student Design Center

The University of Florida's Student Design Center (SDC) will serve as the team's primary manufacturing and storage facility. This facility contains the worktables, storage space, and tools necessary for manufacturing. The tools available at the SDC include a bandsaw (Figure 3), roll-in bandsaw, and drill press (Figure 2). The team's safety officer, Chas Wilson, is required for all use of machinery at this facility.

Figure 3 Band saw in use at the SDC

Figure 2 Drill press in use at the SDC

The team will have access to this facility by reservation only. This restriction is in place to ensure the presence of the team's safety officer and to limit the number of students present in the facility. Limitations on the facility's student capacity are in place to satisfy the University of Florida's COVID-19 social distancing policies.

2.1.2 Student Machine Shop

The Student Machine Shop is a fabrication and assembly facility (Figure 4). This facility will serve as the team's secondary manufacturing location and houses several machines, including:

- Monarch EE Lathe
- LeBlonde Engine Lathe
- Bridgeport Milling Machine
- South Bend Drill Press
- Vertical Band Saw
- Small Horizontal Band Saw
- Various Hand Tools and Measuring Instruments

The team will have access to the Student Machine Shop weekdays from 7:30 am to 3:30 pm. The presence of the facility's manager, Todd Prox, or engineer, Brian Smith, is required for use of this facility.

Figure 4 Student Machine Shop

2.1.3 DCP Fabrication Lab

The DCP Fabrication Lab will be the team's tertiary manufacturing facility and contains a waterjet cutter, CNC router, CO2 laser cutter, and several 3D printers. This facility will be utilized for the manufacturing of fins, bulkheads, centering rings, and other components. The team will have access to this facility every weekday from 10 am to 5 pm. The presence of the facility's director, Juan Griego, or assistant director, Breanne Schenk, is required for use of this facility.

2.2 Equipment and Supplies

Machine	Purpose	Availability
Drill press	• Drilling of rivet and shear pin holes • Fabrication of bulkheads and centering rings	Available at the SDC and Student Machine Shop
Bandsaw	• Airframe cutting • Avionics sled manufacturing	Available at the SDC and Student Machine Shop

3D Printer	• Fabrication of custom components such as avionics sled mounts	Available at the DCP Fabrication Lab
Dremel	• Cutting threaded rods	Available for lending at the Marston Science Library
Sheet Metal Cutters	• Payload manufacturing	Available at the SDC
Soldering Iron	• Payload manufacturing • Avionics manufacturing	Available at the SDC
120-grit Sandpaper	• Rough sanding	To be acquired
220-grit Sandpaper	• Fine sanding	To be acquired

Table 3 Required tools

The team will need access to a drill press, bandsaw, 3D printer, Dremel, sheet metal cutters, soldering iron, 120-grit sandpaper, and 220-grit sandpaper for launch vehicle and payload manufacturing (Table 3). Each of these tools are currently available at the SDC, Student Machine Shop, or DCP Fabrication lab with the exception of 120-grit sandpaper and 220-grit sandpaper.

2.3 Required Software

2.3.1 OpenRocket

OpenRocket is an open source rocket design and simulation program (Figure 5). The team will use OpenRocket for all initial design drafting, descent rate determination, altitude simulation, and static stability margin calculation. All OpenRocket simulation data will be verified through comparison to a MATLAB flight simulation program developed by the team. All team members have free access to the OpenRocket software.

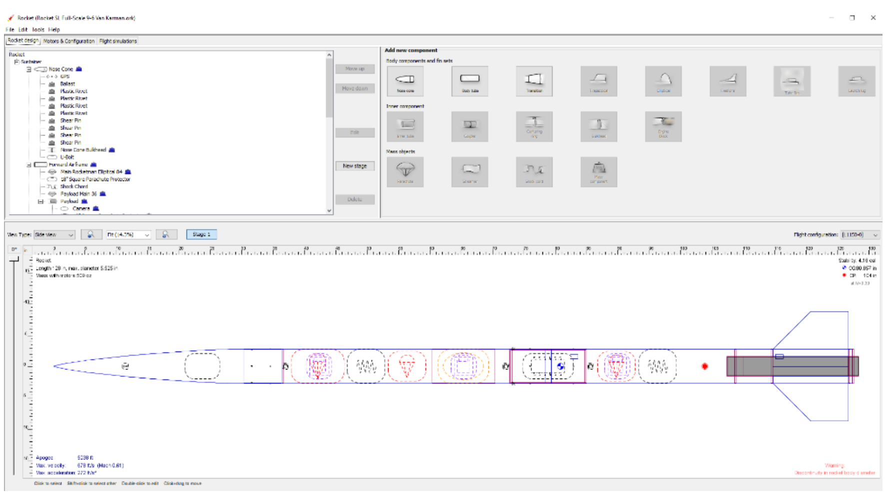

Figure 5 OpenRocket Simulation Software

2.3.2 SOLIDWORKS 2020

SOLIDWORKS 2020 is a 3D-modelling and simulation software (Figure 6). The team will use SOLIDWORKS for launch vehicle and payload design. All manufacturing drawings and printouts will be generated using SOLIDWORKS. All team members have access to SOLIDWORKS through the University of Florida's Mechanical and Aerospace Engineering Department.

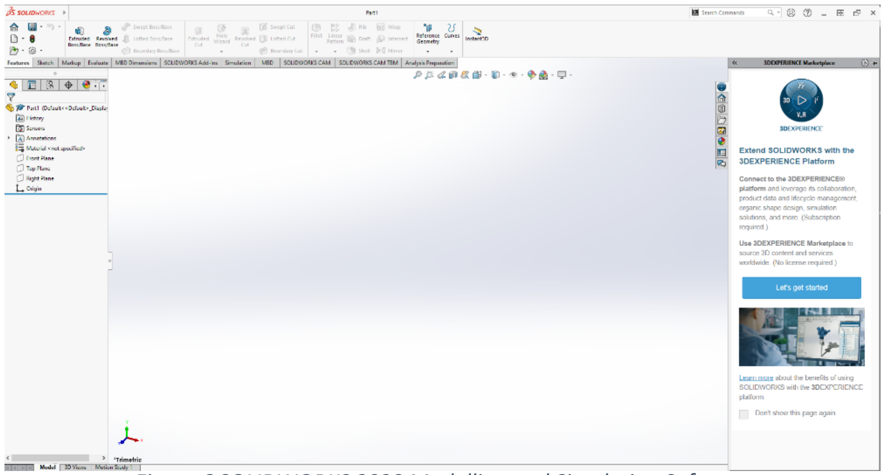

Figure 6 SOLIDWORKS 2020 Modelling and Simulation Software

2.3.3 SOLIDWORKS Project Data Management

SOLIDWORKS Project Data Management is a data sharing and management software. This program will be used for the storage of all SOLIDWORKS and OpenRocket files to facilitate development and editing from multiple contributors. All team members will have access to SOLIDWORKS Project Data Management through the University of Florida's Mechanical and Aerospace Engineering Department.

2.3.4 Microsoft Teams

Microsoft Teams is a file management and communication software. The team will use Microsoft Teams for the creation of all milestone review, budgeting, and scheduling documents. All team members will have access to Microsoft Teams through the University of Florida.

2.3.5 Slack

Slack is a business communication platform and will be the primary method of communication between team members. Slack will be used to coordinate all subteam and lead meetings and announce educational engagement events.

2.3.6 Zoom

Zoom is a video conferencing platform. All subteam and lead design meetings will be conducted virtually over Zoom.

2.3.7 MATLAB

MATLAB is a programming environment with the capability to directly perform matrix and array computations. The team will use MATLAB to perform simulations with six degrees of freedom and for data analysis.

3. Safety

The highest priority of the team is member safety. A safety plan has been developed that covers all aspects of project activities, including design, assembly and manufacturing, testing, and launch attempts. The entire team has been briefed on the current safety plan through meetings hosted by the lead engineers. Any updates to the safety will be communicate via the team Slack channel, and through additional meetings hosted by the lead engineers or the safety officer.

3.1 Safety Plan

3.1.1 Safety Officer Responsibilities

The safety officer shall be responsible for ensuring the safety of the team from all project hazards. A list of the safety officer's specific duties outlines the plan for how (s)he will use the role to fulfill this responsibility. The safety officer has been identified in team general body meetings, and team members have been informed of all available methods of contact. These include email, phone, and direct message through the team Slack channel.

1. The safety officer will monitor team activities to emphasize safe practices and hazard mitigation.
    a. Safety-related feedback on launch vehicle and payload design choices
    b. Supervision of manufacturing activities in the MAE Student Design Center
        i. Enforce adherence to machine and tool standard operating procedures
        ii. Safety stewards shall assist with supervision
    c. Supervision of launch vehicle and payload assembly
        i. Safety stewards shall assist for maximum coverage of activities
    d. Supervision of ground testing
        i. NAR/TRA mentor shall also supervise ground tests
    e. Supervision of subscale launch testing
        i. Enforce adherence to launch preparation procedure
        ii. Ensure all checks are carried out and redundancies are in place
    f. Supervision of full-scale launch testing
        i. Enforce adherence to launch preparation procedure
        ii. Ensure all checks are carried out and redundancies are in place
    g. Supervision of team activities on Launch Day
        i. Hazard recognition around team launch vehicle and vehicles of others
        ii. Compliance with NAR/TRA policies
    h. Supervision of recovery activities after launch attempt
        i. Close observation of launch vehicle descent and landing
        ii. Enforcement of extreme caution around launch vehicle debris
    i. Verification of hazard mitigation strategies in place for STEM engagement
        i. Supervision if active hazard mitigation is required
2. The Safety Officer shall verify the team has developed procedures for actively mitigating potential hazards. The Officer shall also enforce the implementation of the procedures.
3. The Safety Officer shall manage and maintain current revisions of the team's safety documentation.
    a. Personal Hazard Analysis
    b. Failure Mode Effect Analysis

    c. Environmental Hazard Analysis
    d. Material Safety Data Sheets
    e. Standard Operating Procedures
4. The Safety Officer shall assist in the writing and development of the team's new safety documentation.
    a. Revisions or updates to hazard analyses
    b. Failure mode analyses for the updated payload and launch vehicle designs
    c. Launch procedures for the updated payload and launch vehicle designs
    d. Updated material safety data sheets for new materials

3.1.2 Safety Steward Responsibilities

Safety stewards shall assist the safety officer with supervision of team members during work in the team's manufacturing facility, the Student Design Center. Constant supervision from the safety team shall ensure hazard mitigation strategies are being followed. A certified and experienced safety steward is qualified to supervise a team manufacturing process without the presence of the safety officer, but at least two members of the safety team will always perform supervision together and more will be present when the need requires. New safety stewards shall be aided by the safety officer when they have not supervised a certain relevant process. Additionally, the safety stewards have multiple methods of quick communication with the safety officer, such as by phone or Slack direct message. The official responsibilities of the safety stewards have been provided by the SDC facilities manager Daniel Preston.

1. Enforce all protocols outlined in the Rules for Facility Use document. This includes policies for personal safety; equipment uses; facility cleanliness, organization, and respect; proper language; use of the Material & Tool List and Broken / Lost Tooling List; and all other miscellaneous policies.
2. Have a strong understanding of each machine at the SDC. Stewards cannot effectively train students in proper equipment use unless they possess a solid understanding of each machine and process. They will also be ineffective at proactively identifying and preventing mistakes that cause injury or damage.
3. Train students on machines, administer knowledge quizzes, and sign authorization sheets. If a student requests machine training, it is the stewards responsibility to train him/her to the standard expected and outlined in the safety protocols. After training, administer the knowledge quiz to assess their understanding of the safety protocols for the specific machine. If the student passes the quiz, add their name to the approved list of users for that machine so (s)he can use the machine with steward supervision in the future.
4. Verify students are trained and authorized on each machine they use. The steward's primary responsibility is to ensure students are trained and authorized on each machine they use by referencing the lists of authorized users located by each machine. Students using machines on which they are not authorized lose facility use privileges, effective immediately.
5. Setup each approved equipment user each time (s)he works on a new part. Two trained users should catch more mistakes, so always setup team members each time they use facility equipment. For example, if a team member wishes to use a bandsaw to cut a piece of 4130 alloy steel tubing, check its hardness with a file to ensure it is soft enough to cut with a bandsaw, select the appropriate bandsaw, change the blade so its pitch matches the material thickness, and watch the student make the first cut. If the following day another student desires to cut a

piece of steel flat bar, the same checks need to be made with a safety steward. Even if the same student desires to cut more 4130 alloy tubing another day, the same checks will need to be made, which require the presence of safety steward.

6. Keep watch of powered machinery as it is being used. Accidents can happen to the best trained users. Therefore, even though all users of powered machinery must be trained to be allowed to use them, safety stewards should keep a watchful eye to make sure that machinery is being used safely and correctly. Do not hesitate to interject if a student is making a mistake on the machines.
7. Manage common use tools access. Common use facility tools like sanders and grinders can be checked out using the Material & Tool Use List and must be returned after use each work session so all users have equal access to them. During checkout, a student must ask a safety steward to retrieve the item from its storage location. Upon return, a safety steward must check that the tool has been respectfully cleaned by the user and that it functions properly prior to returning it to its storage location. Users who fail to clean and return tools each session will lose use privileges.
8. Ensure students clean machines after each use and accept responsibility for stations not up to SDC cleaning standards. Machine stations should always be left cleaner than they are found. Holding students to this expectation helps keep the SDC an efficient facility by preventing premature deterioration of machines, floors, and work surfaces. If a student cannot clean their workstation(s) properly, facility use privileges should be revoked. That said, safety stewards will also be held accountable for dirty stations, so ensure users properly clean each station immediately after use (not at the end of each work session, at which time cleaning will be easily or conveniently forgotten).
9. Ensure students keep bays neat and clean. A clean SDC communicates professionalism and appreciation. Teams should adhere to the cleanliness policies outlined in the Rules for Facility Use document and your job is to ensure they do. This includes spills, general trash, the strict no-food policy, as well as general tidiness. Balance being respectful yet stern.
10. Safety stewards are never required to assist other student groups. This might sound odd at first, but safety stewards are never required to assist other student groups using the facility. The first reason is accountability: if a mistake occurs it is more difficult to assign responsibility. The second reason is that each group using the facility should care enough to put forth responsible members from their team for training who have completed EML2322L instead of burdening other groups' safety stewards. That said, please feel free to help other student groups on occasion if they do not have their own steward present, but it is asked that stewards do not make a habit of doing so for the reasons mentioned.
11. Report concerns, problems, or suggestions for improvement to the lab manager (prestond@ufl.edu) in an e-mail with SDC in the subject line.

3.1.3 Risks and Mitigations Assessment

A risk assessment was conducted to evaluate the level of risk associated with project activities. The assessment consists of preliminary personnel hazard analyses, failure mode effect analyses, and environmental hazard analyses. The current revisions of each hazard analysis, from the previous project year, were consulted and relevant hazards based on the 2020-21 project plans were incorporated. The assessment will be updated with more hazards and mitigation strategies, as well as amendments to current hazards based on project changes in the future.

	Impact (I)	Likelihood (L)
1	No effect on flight/no injury obtained/no risk of mission loss	Extremely Unlikely
2	Slight impact on flight or launch vehicle /very minor injury/mission obstructed	Unlikely/low probability
3		
4	Moderate impact on flight/significant effect on launch vehicle /minor injury	
5		Likely
6	Severe flight impact/extensive repair/partial mission loss or entire mission at risk/moderate injury risk	
7		Highly likely/high probability
8		
9	Total loss of vehicle function/moderate to severe injury	
10	Complete loss of vehicle/major injury or death of personnel	Extremely likely/almost certain

Table 4 Risk Assessment Chart (RAC)

	Likelihood										
Impact		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	1	1	2	3	4	5	6	7	8	9	10
	2	2	4	6	8	10	12	14	16	18	20
	3	3	6	9	12	15	18	21	24	27	30
	4	4	8	12	16	20	24	28	32	36	40
	5	5	10	15	20	25	30	35	40	45	50
	6	6	12	18	24	30	36	42	48	54	60
	7	7	14	21	28	35	42	49	56	63	70
	8	8	16	24	32	40	48	56	64	72	80
	9	9	18	27	36	45	54	63	72	81	90
	10	10	20	30	40	50	60	70	80	90	100

Table 5 RAC Score Chart

3.1.3.1 Personnel Hazard Analyses

The personnel hazard analyses evaluate the level of risk to the personal health and safety of team members, as well as the strategies used to mitigate that risk. The score is calculated by multiplying the impact value of each risk by its likelihood value.

3.1.3.1.1 Chemical Hazards

Chemical hazards are hazards posed by the team's chemical inventory. The hazards and proposed mitigations are identified by the material safety data sheets in the MAE SDC.

Hazard	Cause	Effect	I	L	Score	Mitigation Strategy
Cleaning agent contacts eyes	Cleaning agent sprayed into eyes	Eye irritation	4	4	16	Safety glasses and gloves Spray down and away from persons

Paint thinner ignites	Flammable liquid exposed to heat source	Burns, smoke inhalation	8	2	16	Cool, well-ventilated storage Keep away from ignition sources/oxidizers
Paint thinner contacts eyes	Spilled, person touches substance then face	Eye irritation	7	1	7	Keep lid closed when not in use Safety glasses and gloves
Floor coating contacts skin/eyes	Applying coating with unprotected hands	Skin irritation	2	1	2	Safety glasses and gloves
	Spilled, touching substance then face	Eye irritation	4	1	4	Keep lid closed when not in use Safety glasses and gloves
Gelcoat compound ignites	Flammable liquid exposed to heat source	Burns, smoke inhalation	8	2	16	Cool, well-ventilated storage Keep away from ignition sources/oxidizers
Gelcoat fume inhalation	Prolonged exposure to toxic fumes	Dizziness	4	1	4	Mask, safety glasses and gloves Use in well-ventilated area
All-purpose cement ignites	Flammable liquid exposed to heat source	Burns, smoke inhalation	8	2	16	Cool, well-ventilated storage Keep away from ignition sources/oxidizers
All-purpose cement ingestion	Exposure to fumes, accidental consumption	Dizziness	5	1	5	Mask, safety glasses and gloves Use in well-ventilated area
Grease contacts eyes	Spills, touching substance then face	Eye irritation	5	1	5	Safety glasses and gloves
Spray paint ignites	Flammable aerosol exposed to heat source	Burns, smoke inhalation	9	4	36	Cool, well-ventilated storage Keep away from ignition sources/oxidizers
Spray paint can explodes	Compressed gas exposed to heat source	Hearing damage, Blast debris	9	1	9	Cool, well ventilated storage Keep away from ignition sources/oxidizers
	Sprayed into eyes	Eye irritation	5	5	25	Mask, safety glasses and gloves

Spray paint contacts skin/eyes	Sprayed onto skin	Skin irritation	2	5	10	Mask, safety glasses and gloves
Spray paint inhalation	Prolonged exposure to toxic fumes	Dizziness	4	4	16	Mask, safety glasses and gloves Use in well-ventilated area
		Respiratory irritation	4	4	16	Mask, safety glasses and gloves Use in well-ventilated area
Epoxy contacts skin	Spilled, handled without PPE	Skin irritation	5	6	30	Gloves, protective clothes
Oxidizer contacts skin/eyes	Spilled	Skin irritation	7	3	21	Handle in area with no draft or wind
	Spilled	Eye irritation	7	3	21	Safety glasses
Oxidizer ignites	Flammable solid exposed to heat source	Burns	9	4	36	Ground everything touched by oxidizer Keep away from ignition sources Well-ventilated storage

Table 6 Chemical Hazard Analysis

3.1.3.1.2 Physical Hazards

Physical hazards are posed by team activities such as manufacturing processes (Table 7), launch preparation, and launches themselves (Table 8).

3.1.3.1.2.1 Manufacturing Hazards

Hazard	Cause	Effect	I	L	Score	Mitigation
Bandsaw blade touches person	Hand in blade path while cutting material	Skin laceration	9	1	9	Keeping hands out of blade plane
	Small workpiece limits space between hands and blade	Skin laceration	9	2	18	Using a piece of material as a buffer when cutting small workpiece
Spinning drill touches member	Hand brought too close to cut zone	Skin laceration	9	1	9	Keep hands 6 inches away while machining
Sharp tool cuts person	Holding sharp tool with bare hand	Skin laceration	6	5	30	Use a rag to carry sharp tools
Hands sucked into drill press cutting zone	Wearing safety gloves while machining	Skin laceration	9	1	9	No gloves on when machining
Workpiece flies out of cutting zone	Workpiece not properly clamped in drill press vise	Skin laceration or impact injury	6	3	18	At least two clamps used on workpiece when mounting to drill press

and hits person						
Harmful fiberglass debris	Dust and fumes from sanded fiberglass	Skin irritation and inhalation hazard	6	4	24	Use respirator while cutting, perform cutting in well-ventilated area and alert other personnel of operation
Vise pinches person	Hands not kept out of work area	Pinching or skin laceration	4	1	4	Keep hands out of work zone when operating machinery
Soldering injury	Exposure to melted solder or hot soldering iron	Skin irritation or burns	5	2	10	Proper use of equipment, space between soldering zone and body parts
Hammer injury	Hammer impacts person's body	Pinching, contusion, or skin laceration	5	2	10	Body parts clear of hammer work area, no excessive force used
Exposure to battery acid	Batteries dropped or abused	Chemical hazard or skin irritation	6	2	12	Proper battery storage, safe handling
Loud manufacturing process	Long duration of operation	Hearing damage	4	8	32	Wear ear protection
Sudden and excessively loud operation	Person startled by operation while in proximity to sharp tools	Skin lacerations or physical trauma	4	2	8	Verbal warning before any loud and sudden operation is performed
Material debris in workspace	Cutting material causes chips or dust	Eye irritation or skin laceration	3	10	30	Wear safety glasses always, debris cleared with air or rag

Table 7 Manufacturing Hazard Analysis

3.1.3.1.2.2 Launch Hazards

Hazard	Cause	Effect	I	L	Score	Mitigation
Motor ignites near person	People close to launchpad during ignition	Hearing damage or burns	8	1	8	Abide by NAR minimum distance code
	Ignition during motor loading	Hearing damage or burns	8	2	16	Ground motor loading area, no member in fire-line of energetic
	Delayed motor ignition after	Hearing damage or burns	8	1	8	RSO removes safety interlock switch, team waits 60 seconds to approach launch vehicle on launchpad

	failed launch attempt					
Falling debris	Parachutes come untied	Impact injury or skin laceration	7	3	21	Verify correct knots used to tie parachutes (Test 7) Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Shock cord fails	Impact injury or skin laceration	7	2	14	Examine cords used for frayed portions Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Main parachute does not deploy	Impact injury or skin laceration	7	4	28	Redundant altimeters and blast charges (Tests 2/7) Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Drogue chute does not deploy	Impact injury or skin laceration	7	4	28	Redundant altimeters and blast charges (Tests 2/7) Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Spectator attempts to catch descending launch vehicle	Impact injury or skin laceration	6	2	12	Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Fins break off launch vehicle body during flight	Impact injury or skin laceration	6	2	12	Multiple points of contact for adhesive and sufficiently strong fin material selected (Tests 1/4) Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Main Parachute does not open after ejecting	Impact injury or skin laceration	7	4	28	Verify no interference between shroud lines and parachute protector
	Drogue chute does not open after ejecting	Impact injury or skin laceration	7	4	28	Verify no interference between shroud lines and parachute protector
	No separation events after apogee	Severe impact injury or death	10	3	30	Redundant altimeters and ejection charges, test E-charges (Test 2) Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Launch vehicle changes	Severe impact injury	9	4	36	Verify launch vehicle design is sufficiently stable before launch Maintain proper stand-off distance

Ballistic launch vehicle hits person	trajectory mid-flight					Aim launch vehicle away from crowds/personnel
	Launch vehicle exits too slowly off launch rail	Severe impact injury	9	2	18	Verify safe exit velocity achievable with motor and provided launch rail length Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
	Ignition during motor loading	Severe impact injury	10	2	20	Launch vehicle pointed away from spectators, members do not stand behind fuselage Maintain proper stand-off distance Aim launch vehicle away from crowds/personnel
Black powder ignites near person	Static electricity ignites black powder	Skin laceration and severe burns	7	3	21	Members handling black powder ground themselves
Electrical shock/thermal burns from component wiring	Live wire from electrical component exposed	Burns and minor electrocution	4	2	8	All component wiring complete before applying power supply

Table 8 Launch Hazard Analysis

3.1.3.1.3 Biological Hazards

Biological hazards are posed by living organisms, such as bacteria and wildlife (Table 9).

Hazard	Cause	Effect	I	L	Score	Mitigation Strategy
Spread of COVID-19	Not wearing a facemask	Member infected with COVID-19	7	8	56	Strictly enforcing face mask rule in SDC
	Not maintaining 6 feet of distance	Member infected with COVID-19	7	8	56	Limit capacity of members in SDC
	Not sanitizing hands frequently	Member infected with COVID-19	7	5	56	Provide accessible sources of hand sanitizer

Table 9 Biological Hazard Analysis

3.1.3.2 Failure Mode Effect Analyses

Failure mode effect analysis evaluates the impact of component failure on the launch vehicle and its ability to complete the mission.

3.1.3.2.1 Structures

Id.	Component	Function	Failure Mode	Failure Cause	Failure Effects			S[1]	O[2]	D[3]	RPN[4]	Corrective Actions
					Local Effects	Next Higher Level	System Effects					
1.2.3.4	Nosecone rivets	Keeps the nosecone attached to the forward airframe	Rivets are sheared off	The nosecone and forward airframe get pulled apart by the recovery harness, shearing the rivets due to insufficient number of shear pins	Nosecone falls off during descent	Launch Vehicle Assembly connection between the nosecone and forward airframe	Reduced altitude; premature deployment of payload and main parachute	8	3	5	120	Perform ejection charge testing of other sections to ensure rivets in the nosecone are not affected
	Airframe shear pins	Keep sections connected prior to midair separation events	Shear pins do not shear	Insufficient ejection charge during separation event	Airframe does not separates from couplers	Launch Vehicle Assembly connection points between the nosecone and forward airframe, and the avionics bay and aft airframe	Reduced altitude, premature deployment of payload and parachutes	8	3	8	192	Test ejection charges to find the amount sufficient for separation, then include a percentage more for safety
	Airframe shear pins	Keep sections connected prior to midair separation events	Shear pins break early	Too much pressure from other events causes or poor packing causes the pins to experience too much force	Events do not deploy parachutes as designed; main parachute and payload deploys at apogee	Launch Vehicle Assembly and payload	Launch Vehicle and payload drifts further than expected	8	4	8	256	Perform ejection test charges and properly design the rocket such hat premature shear pin breakage won't occur
	Body tube and Coupler	Contains launch vehicle hardware and payload	Breaks propagates along fracture cracks	Manufacturing defect, poor transportation	Body tube fails to contain internal components	Launch Vehicle Assembly	Launch vehicle is not recoverable/reusable	10	3	3	90	Inspect launch vehicle before and after every launch
	Fin fillets	Keeps the fins attached to the aft airframe	Epoxy Fails	Improper application	Rocket loses stability during ascent	Launch Vehicle Assembly	Launch vehicle drifts or spirals out of control	8	2	4	64	Ensure fins are stable and completely attached
	Centering ring	Keeps the motor tube aligned with the fuselage	Epoxy Fails	Improper applications	Rocket loses stability during ascent	Launch Vehicle Assembly	Launch vehicle drifts or spirals out of control	10	2	5	100	Inspect launch vehicle before and after every launch
	Centering ring	Keeps the motor tube aligned with the fuselage	Breaks	Manufacturing defect	Rocket loses stability during ascent	Launch Vehicle Assembly	Launch vehicle drifts or spirals out of control	10	2	3	60	Inspect launch vehicle before and after every launch
	Bulkhead	Closes off the end of couples to separate and protect components	Epoxy Fails	Improper applications	Bulkheads are unable to maintain proper seal to allow for ejection charges to	Launch Vehicle Assembly	Events do not properly deploy parachutes or destroy internal components	8	2	2	32	Inspect launch vehicle before and after every launch

					separate vehicle							
	Bulkhead	Closes off the end of couples to separate and protect components	Breaks	Manufacturing defect	Bulkheads are unable to maintain proper seal to allow for ejection charges to separate vehicle	Launch Vehicle Assembly	Events do not properly deploy parachutes or destroy internal components	8	2	2	32	Inspect launch vehicle before and after every launch

Table 10 Structures Failure Analysis

3.1.3.2.2 Payloads

Id.	Component	Function	Failure Mode	Failure Cause	Failure Effects			S[1]	O[2]	D[3]	RPN[4]	Corrective Actions
					Local Effects	Next Higher Level	System Effects					
1.1.1	Payload Case	Structure for payload	Impact of ground at higher than expected speeds	Failure to deploy from rocket or parachute problems	Failure to support payload electronics	Wires snap and PCB boards break	Loss of effectiveness of electronics to carry out mission	9	2	6	108	Parachute packing verified and tested before electronics, testing on prototype for strength
1.1.2	Legs	Support for payload	Impact with ground	Parachute problems	Failure to stabilize payload	Unable to orientate properly	Mission failure as unable to go vertical	9	2	4	72	Testing with leg strength
1.2.1	Raspberry Pi	Computer controller for payload	Breaks or loses power	Wire disconnected or payload hits ground too hard with faulty mounting	Servos and camera do not function properly	Cannot correctly orientate payload or take 360 pictures	Failure to make mission requirements	9	2	2	36	Wiring and soldering will be checked before launch
1.2.2	GPS Module	Sends location of payload	Loss of power or breaks	Wire disconnected or payload hits ground too hard with faulty mounting	No location data	Failure to report location after launch	Difficulty finding payload	2	2	2	8	Wiring and soldering will be checked before launch
1.2.3	Gyroscope and accelerometer	Reporting orientation of payload	Loss of power or breaks	Wire disconnected or payload hits ground to hard with faulty mounting	No orientation data	Servos and control software will malfunction and not be able to perform effectively	Payload will not orientate effectively, and camera will not function	9	2	2	36	Wiring and soldering will be checked before launch
1.2.4	Camera Module	Takes 360-degree picture	Loss of power or breaks	Wire disconnected or payload hits ground to hard with faulty mounting	Picture unable to be taken	Picture will not be able to send to command module	Loss of challenge	9	2	2	36	Wiring and soldering will be checked before launch
1.2.5	Xbee	Wireless communication	Out of range or faulty wiring	Wire disconnects, antenna breaks, or payload out of range	Picture will not be able to be sent or location data	Corrupted picture or no picture received	Loss of challenge	9	5	5	90	Wiring checked, testing with subscale to make sure range does not become an issue.

1.2.6	Servos	Moves legs for orientation	Loss of power, leverage, or breaks	Wire disconnects, strips gear heads, or motor begs	Servos do not orientate payload properly	Payload is not in proper orientation for picture	Loss of challenge	9	2	7	126	Testing before launc h to confirm orientation and servos are powerful enough for orientation
1.2.7	Batteries	Powers electronic system	Wire failure or runs out of power early.	Launch does not take off at scheduled time or too rough of a landing	Power is not delivered to componen ts	All other systems will not be able to function	Loss of challenge as no communication or picture could be taken.	9	2	2	36	Testing before launch and power calculations to determine adequate battery size.

Table 11 Payloads Failure Analysis

3.1.3.2.3 Avionics and Recovery

Id.	Component	Function	Failure Mode	Failure Cause	Failure Effects			S[1]	O[2]	D[3]	RPN[4]	Corrective Actions
					Local Effects	Next Higher Level	System Effects					
1	Altimeter	Measure the speed and altitude of the launch vehicle in order to accurately deploy parachutes.	Loss of power	Old or damaged battery, faulty wiring	Failure to sense apogee and other target altitudes	Black powder charges do not detonate, and parachutes are not deployed.	High velocity impact with the ground damaging the launch vehicle and payload.	9	2	5	90	Incorporate a separate back up system that has its own wiring, power, and black powder charges.
	Altimeter	Measure the speed and altitude of the launch vehicle in order to accurately deploy parachutes.	Premature deployment	Incorrect wiring or programming	The altimeter is wired or programmed incorrectly to cause premature deployment of the main parachute.	The main parachute is deployed at apogee instead of, or with, the drogue.	The launch vehicle drifts very far away from the launch site.	1	5	2	10	The wiring and programming of the altimeter will be checked before being loaded into the avionics bay.
2	Black powder charges	Detonates to provide force necessary to separate pieces of the airframe.	Doesn't detonate or insufficient detonation to cause separation	Faulty altimeter, bad wiring, bad electric match, not enough powder loaded into charges.	Detonation does not occur and airframe does not separate.	Parachutes do not deploy at target altitudes.	High velocity impact with the ground damaging the launch vehicle and payload.	9	1	4	36	Include a secondary system that is completely separate from the primary system. Separation will be ground tested the day of the flight using long leads connected to charges similar in weight to planned.
3	Main parachute	Slow the launch vehicle to an	Burn holes, torn shroud lines, tearing	Heat damage from black powder,	Damaged parachute.	Parachute fails to slow launch vehicle sufficiently.	High velocity impact	8	2	2	32	Fire protective blankets will

		acceptable ground hit velocity.	of the parachute	deployed at very high speed			with the ground damaging the launch vehicle.					be used to protect the parachutes when the blackpowder charges detonate. The parachute will also be inspected before being packed.
4	Drogue parachute	Slow the launch vehicle for deployment of main parachute	Burn holes	Heat damage from black powder	Drogue parachute is less effective.	Main parachute is deployed at a higher speed potentially damaging it or other recovery system components.	High impact velocity with the ground damaging the launch vehicle.	8	1	2	16	The drogue will be protected by a fire protective blanket.
5	Fire protective blanket	Protect parachutes from black powder	Wrapping around parachutes stopping successful deployment.	Poor packing	Fire protective blanket encases parachutes during deployment.	Main and drogue parachutes do not inflate or inflate later then planned.	High impact velocity with the ground damaging the launch vehicle and payload.	9	4	8	288	Fire protective blankets will be secured to the recovery harness at least the length of the blanket away from the parachute when packed to ensure successful parachute deployment.
6	Recovery Harness	Secure separated sections of the launch vehicle to the drogue and main parachutes.	Tearing of the air frame	High velocity deployment of parachutes.	Damage of bulkheads or even the airframe of the launch vehicle.	Could cause damage to the payload or electronic systems on board.	Damage could cause the launch vehicle to not be re-flyable.	7	3	6	126	The plan to avoid structural damage to the airframe during parachute deployment is to use washers to disperse the load across a wider area of the bulkheads.
	Recovery Harness	Secure separated sections of the launch vehicle to the drogue and main parachutes.	tangling	Poor packing of the parachutes and recovery harness	Tangles the lead lines, parachute, and recovery harness together.	Could cause failure to deploy main or drogue parachute.	High velocity impact with the ground damaging the launch vehicle and potentially payload.	9	5	1	45	Packing of the parachutes and recovery harness will be done carefully so as to avoid tangling the separate pieces.

7	Avionics bay	Holds all electronic systems that are used to deploy the parachutes.	Opening or coming a part in a way that exposes the electronics to damage.	Stripping of the metal rods or nuts used to hold the bulkheads in place on the avionics bay.	Nuts on metal rods securing the removable bulk heads strip out or loosen during flight.	Avionics bay is open to the elements during descent and may be separated from the recovery harness.	Loss of electronics kept inside of the avionics bay.	3	3	5	45	This will be avoided by using two nuts on either end of the rods to ensure they are locked in place.

Table 12 Avionics and Recovery Failure Analysis

3.1.3.2.4 Flight Dynamics

ID.	Component	Function	Failure Mode	Failure Cause	Failure Effects			S[1]	O[2]	D[3]	RPN[4]	Corrective Actions
					Local Effects	Next Higher Level	System Effects					
1	Motor Nozzle	Generate thrust vector	Deformation	Physical impact to nozzle	Ignited propellant cannot escape	Motor pressure rupture	Damage to aft section of rocket	9	2	4	72	Handle motor nozzle carefully at all times
1	Motor Nozzle	Generate thrust vector	Deformation	Physical impact to nozzle	Ignited propellant released in an undesirable direction	Motor propels rocket at undesirable thrust vector direction	Rocket trajectory altered	4	3	6	72	Handle motor nozzle carefully at all times
2	Propellant	Fuel for rocket	Wetting	Improper storage of propellant	Propellant does not ignite	Motor cannot propel rocket	Rocket does not take off	9	2	4	72	Store propellant in a dry location
3	Motor Casing	Protect rocket body from ignited propellant	Breach of casing wall	Physical impact to casing	Ignited propellant escapes from casing	Motor tube damage	Structural integrity of motor mounting assembly compromised	7	2	8	112	Handle motor casing carefully at all times
4	Motor Forward Enclosure	Protect rocket body from ignited propellant	Breach in enclosure	Physical impact to enclosure	Ignited propellant escapes from enclosure	Damage to forward rocket components	Loss of rocket integrity /function	8	1	8	64	Handle motor forward enclosure carefully at all times
5	Motor Retainer	Hold motor assembly in position	Detachment from assembly	Screws unfastened	Motor assembly allowed to move forward in rocket	Damage to forward rocket components	Loss of rocket integrity /function	7	4	7	196	Fasten screws securely
6	Thrust Plate	Transfer thrust force from centering rings to airframe	Detachment from assembly	Screws unfastened	Centering ring structural integrity compromised	Motor becomes misaligned and thrust vector altered	Rocket trajectory altered	5	4	5	100	Fasten screws securely

Table 13 Flight Dynamic Failure Analysis

3.1.3.3 Environmental Hazard Analyses

Environmental hazard analyses are hazards posed by environment to the launch vehicle, or vice versa (Table 14).

3.1.3.3.1 Effects of Environment on Launch Vehicle

Hazard	Cause	Effect	I	L	Score	Mitigation
Precipitation soaks launch vehicle	Weather change at launch site	Ruined electronics	7	5	35	Bring canopy for prep area and waterproof storage for electronics
	Weather change at launch site	Warped airframe shape	7	5	35	Bring canopy for prep area and waterproof storage for electronics
Descent into body of water	Launch vehicle drifts too far	Ruined electronics	7	2	14	Minimize drift with drogue, angle launch rail into wind
	Launch vehicle drifts too far	Warped airframe shape	8	2	16	Minimize drift with drogue, angle launch rail into wind
Launch vehicle caught in tree or power line	Launch vehicle drifts too far	Difficulty retrieving	6	4	24	Verify launch site is away from obstacles
Launch vehicle flies into cloud	Liftoff occurs without waiting for clear sky	Launch vehicle collision with unseen aircraft	9	2	18	Delay launch until sky is clear Verify that present cloud cover is not located below expected apogee
High winds	Launch vehicle drifts during descent	Difficulty retrieving	5	5	25	Angle launch rail into wind
	Launch vehicle changes flight trajectory	Ballistic launch vehicle crashes at high speed	9	3	18	Launch does not occur in high wind, verify launch vehicle is not over stable
Dryness	Brittle adhesive at critical joint locations	Fins, centering rings, or bulkheads come loose or break off	7	3	21	Adhesive with longer curing time used at design critical joints for improved resistance to environment
Humidity	Moisture affects electrical components	Recovery system or payload malfunction	5	7	35	Altimeter performance tested on site to verify functionality

High Temperatures	Electrical components overheat	Recovery system or payload malfunction	7	6	42	Canopy brought to launch site to keep launch prep area out of sunlight, quick retrieval after launch vehicle landing
Fog/Low Visibility	Launch vehicle descent out of view	Launch vehicle retrieval after descent difficult	7	4	28	Launch delayed until visibility improves, or launch canceled

Table 14 Effects of Environment of Launch Vehicle Hazard Analysis

3.1.3.3.2 Effects of Launch Vehicle on Environment

Hazard	Cause	Effect	I	L	Score	Mitigation
Fire around launchpad	Motor ignition sets grass on fire	Fire damage to private property	7	2	14	NAR minimum distance code, remove dry grass from launch pad area
Fire at launch prep site	Black powder spilled and ignited	Fire damage to private property	8	3	24	Pour water on black powder to reduce likelihood of ignition
Litter	Components or trash left behind	Pollution of land	3	4	12	Post-launch clean-up enforced by SO
Chemical leaks	Battery acid from ruptured battery case	Harms vegetation or wildlife	5	2	10	Batteries with quality casing selected, proper disposal into designated waste bins
Launch vehicle Debris	Ballistic launch vehicle impact scatters debris	Pollution of land	5	2	10	Redundancies used in recovery system to prevent ballistic descent

Table 15 Effects of Environment on Launch Vehicle Hazard Analysis

3.1.3.4 Test Reference List

Test Reference Number	Name of Test	Basic Test Procedure	List of Supplies	Corresponding Requirement Number and/or Purpose of Test
#1	Airframe Material Compressive Test	Use an Instron machine to put compressive force onto the airframe material and record the resulting data.	Blue tube, Instron Machine	2.4 – to ensure that the airframe will be both recoverable and reusable after multiple uses.
#2	Avionics Bay Transmission Test	Run altimeters at different orientations and record signal strength and any notable concerns.	Altimeters	3.4 – to ensure that the altimeters work correctly and will effectively record and transmit.

#3	Black Powder Charge Ejection Test	For both subscale and full-scale rockets. With altimeters set to appropriate altitude, ignite black powder charges to initiation ejection.	Subscale rocket prototype and full-scale final rocket launch vehicles, black powder, electric match, copper wires, test stand, remote igniter, altimeter, shear pins	3.2 – to determine the appropriate amount of black powder needed to conduct separation tests before the subscale and full-scale test launches.
#4	Shear Pin Strength Test	Exert a force similar to that which would occur at engine burn out or apogee and observe how shear pins perform.	Shear pins, fuselage sections of subscale and full-scale launch vehicles	3.9 – to validate the performance of the required shear pins for the parachute compartments.
#5	Thrust Test	Fire motor on a thrust stand in order to obtain a thrust curve that can then be used in simulation.	Thrust stand, motor	2.1 – to determine the thrust curve of the motor and ensure it will be sufficient to deliver the rocket to the designated apogee.
#6	Battery Life Test	Allow battery to run for a minimum of 2 hours.	Battery	2.7 – to ensure that the launch vehicle will be able to remain launch ready for at least 2 hours.
#7	Airframe shock Resistance Drop Test	Drop portion of airframe from an appropriate height to simulate impact similar to what would be experienced by the launch vehicle when landing after launch. Assess how structure behaves.	Blue tube, test parachute	2.4 – to ensure that the airframe will be both recoverable and reusable.
#8	Bulkhead Shock Resistance Drop Test	Drop bulkhead from an appropriate height to simulate force bulkhead will experience and assess the resulting reactions.	Plywood bulkhead, test parachute	2.4 – to ensure that the bulkheads are both recoverable and reusable.
#9	Separation/	For subscale and full-scale launch vehicles. Use black powder	Subscale and full-scale launch	3.1.1 – to ensure that the main parachute deploys smoothly.

	Main Parachute Deployment Test	charges to verify the ability to separate sections to the appropriate amount of clearance for parachute and payload deployment.	vehicles, test main parachute black powder, electric match, copper wires, test stand, remote igniter, altimeter	
#10	Main Parachute Packing Test	Experiment with packing parachute in different configurations.	Blue tube, test main parachute	3.1.1 – to ensure that the main parachute deploys smoothly and at the appropriate altitude.
#11	Shock Cord Strength Test	Introduce a sudden force on the shock cord in order to observe the strength of the retention system	Shock cord, subscale and full-scale launch vehicle fuselage sections	2.4 – to ensure the retention system of the launch vehicle will be recoverable and reusable.
#12	Payload Parachute Deployment Test	Eject payload parachute (by itself and following main) and record how parachutes behave together.	Subscale and full-scale launch vehicle, black powder, electric match, copper wires, test payload parachute, test stand, remote igniter, altimeter	4.3.1 – to ensure that the payload will be able to be jettisoned and land at the designated altitude between 500 and 1000 ft. above ground level.
#13	Payload Parachute Packing Test	Experiment with packing payload parachute in different configurations.	Subscale and full-scale launch vehicles, test payload parachute	4.3.1 – to ensure that deployment of the payload occurs smoothly and effectively.
#14	Payload System Landing and Alignment Test	Using a payload prototype and parachute, simulate the landing of the vehicle by dropping from an appropriate height and observing how the structure's alignment is affected during landing.	Payload prototype, test payload parachute	4.3.3 – to ensure that the landing system will self-level to within 5 degrees from vertical.

#15	Payload Stability Test	Simulate a similar landing experience to Test #12. Observe how the structure affects the stability during descent.	Payload prototype, test payload parachute	4.3.2 – to ensure that the landing system remains stable enough in descent in order to land in an upright position.
#16	Payload Photo Transmission Test	Take photographs on the payload cameras. Transmit and read to obtain picture.	Payload prototype, test payload parachute	4.3.4 – to ensure that payload can produce and transmit a 360-degree image.
#17	GPS Range and Transmission Tests	Test GPS transmission ability up to the necessary distance the vehicle could drift.	GPS/tracker	3.12 – to ensure the GPS system is capable of tracking and transmitting the location up to at least 1/2 mile.
#18	On/Off Avionics Test	Assemble the avionics bay design to launch configuration and turn the avionics systems on and off	Complete avionics bay design and electronics	To ensure that avionics systems can be easily accessed when in pre-launch configuration
#19	Payload Electronics Test	Test that servo motors are capable of righting the landing system to an upright position.	Payload prototype, servo motors, test payload parachute	4.3.3 – to ensure that the landing system is capable of reorienting itself into an upright position, 5-degree tolerance from vertical.
#20	Interference Test	Run all electrical components through airframe material to ensure that there is no blockage or interference from the different subsystems.	Blue tube airframe, complete avionics bay electronic configuration, complete payload electronic configuration	3.13 – to ensure that recovery system electronics are not negatively affected by any other on-board electronics, and vice versa.
#21	Epoxy Fin Connection Test	Exert force a force on connections of fins to body in order to measure the stress the connections can withstand before disconnecting.	Epoxy, blue tube, fiberglass fins	2.4 – to ensure that the entire system will remain recoverable and reusable following launch, decent, and impact.
#22	Wind Tunnel Nosecone Drag Test	Place a subscale prototype of the rocket in the wind tunnel and measure the drag	Subscale prototype, wind tunnel	2.1 – to measure the drag of the nosecone and ensure the launch

		resulting from the nosecone		vehicles ability to reach the intended apogee.
#23	Wind Tunnel Fins Drag Test	Place a subscale prototype of the rocket in the wind tunnel and measure the drag resulting from given fin configurations.	Subscale prototype, wind tunnel	2.1 – to measure the drag induced by the fins and ensure the launch vehicle's ability to reach the intended apogee.
#24	Wind Tunnel Fins Center of Pressure Test	Place a subscale prototype of the rocket in the wind tunnel and measure the center of pressure of the fins	Subscale prototype, wind tunnel	2.4 – to ensure that the entire system will be recoverable and reusable, and the location of center of pressure is able to withstand the resulting forces.
#25	Center of Gravity Test	Balance both the subscale and full-scale systems across an appropriate surface in order to measure the center of gravity.	Subscale and full-scale rockets in their final configurations	To determine the true center of gravity and compare with the center of gravity determined by modeling and simulation.
#26	Subscale Demonstration Test Launch	Launch and recover a subscale model of the rocket design.	Subscale rocket in its final configuration	2.17 – to successfully launch and recover a subscale launch vehicle. Data to be included in CDR.
#27	Vehicle Demonstration Test Flight	Launch the full-scale launch vehicle in its final configuration.	Full-scale rocket in its final configuration	2.18.1 – to successfully launch and recover the full-scale launch vehicle. Data to be included in FRR.
#28	Payload Demonstration Flight	Launch the full-scale launch vehicle including the payload. All components will be in their final configuration.	Full-scale launch vehicle and payload	2.18.2 – to successfully launch, jettison, and recover the payload lander system.
#29	Launch Rehearsal	Assemble full scale rocket to launch readiness.	Full-scale rocket and all its components in their final configurations	To ensure that the team can assemble the final rocket to launch-ready configuration in an appropriate amount of time on launch day.

Table 16 Testing Plans and Reference List

3.1.3.5 Testing Safety by Reference Number

Test Reference Number	Safety Precautions (if applicable)
#1	Instron Machine will be operated by appropriate personnel. Team members will remain at a safe distance from experiment.
#2	Not applicable. Negligible risk.
#3	Black powder will be kept away from flammable substances. The test will be set up on a nonflammable stand. Team members will remain grounded at a safe distance from test.
#4	Motor will be handled by appropriate personnel. Team members will remain at a safe distance from experiment.
#5	Team members will remain at a safe distance from experiment and/or designated landing area.
#6	Not applicable. Negligible risk.
#7	Team members will remain at a safe distance from the designated landing area.
#8	Team members will remain at a safe distance from the designated landing area.
#9	Black powder will be kept away from flammable substances. The test will be set up on a nonflammable stand. Team members will remain grounded at a safe distance from test. Altimeter data will not be manipulated prior to the test.
#10	Not applicable. Negligible risk.
#11	Team members will remain at a safe distance from experiment.
#12	Black powder will be kept away from flammable substances. The test will be set up on a nonflammable stand. Team members will remain grounded at a safe distance from test. Altimeter data will not be manipulated prior to the test.
#13	Not applicable. Negligible risk.
#14	Team members will remain at a safe distance from the designated landing area.
#15	Team members will remain at a safe distance from the designated landing area.
#16	Not applicable. Negligible risk.
#17	Not applicable. Negligible risk.
#18	Not applicable. Negligible risk.
#19	Electronics will be handled safely in a dry, nonflammable environment.
#20	Electronics will be handled safely in a dry, nonflammable environment.
#21	Team members will remain at a safe distance to avoid any inhaling of fiberglass. If necessary, team members will wear appropriate respiratory face coverings.
#22	Wind tunnel will be operated by appropriate personnel.
#23	Wind tunnel will be operated by appropriate personnel.
#24	Wind tunnel will be operated by appropriate personnel.
#25	Not applicable. Negligible risk.
#26	Team members will follow all safety precautions set forth by NAR/Tripoli Range Safety Officer.
#27	Team members will follow all safety precautions set forth by NAR/Tripoli Range Safety Officer.
#28	Team members will follow all safety precautions set forth by NAR/Tripoli Range Safety Officer.
#29	Not applicable. Negligible risk.

Table 17 Testing Hazard Analysis

3.1.4 NAR/TRA Procedures

3.1.4.1 NAR High Power Rocket Safety Code Compliance

1. The team will have a member with a level 2 certification or higher perform handling and installation of the launch vehicle motor.

2. Lightweight material will be used to construct the launch vehicle.

3. The team will use a certified, commercially made rocket motor for the launch vehicle. The motor will only be used for the purpose intended by the manufacturer and will not alter any of the motor components. The launch vehicle motor will also be kept at least 25 feet away from any smoke, flames, or other open heat sources.

4. The launch vehicle will use an electrical launch system
    a. Electrical motor igniters be installed in the motor after setup on launch pad
    b. Launch system will use safety interlock switch in series with launch switch
        i. Launch switch will not be installed until launch pad setup is complete
        ii. Launch switch will return to "off" position when released
    c. The launch vehicle motor and separation charges will be inhibited until after launch pad setup

5. The launch site range safety officer (RSO) will remove the safety interlock or disconnect the battery in the case of a launch vehicle misfire. The team will wait a minimum of 60 seconds, or until the RSO gives approval, before approaching the misfired vehicle to troubleshoot the problem.

6. The RSO will initiate a 5-second countdown before launching the rocket. Only the required certified team members will be present at the launch pad to arm the vehicle's electrical firing system and altimeters. During launch, all team members will stand behind the RSO at the minimum personnel distance, according to the NAR Safety Code. Additionally, all team members will observe the launch to check for falling debris over spectators.

7. The stability of the vehicle will be confirmed to be an acceptable value by the team before arriving at the launch site. The team will confirm that the project vehicle can reach a safe rail-exit velocity when loaded with the selected motor, and that a launch rail of enough length is available at the launch site, or a longer rail if the windspeed exceeds 5 mph. The vehicle will sit on the launchpad angled within 20 degrees of vertical. A blast deflector will be used, and dry grass will be cleared according to the mini mum cleared area required from the NAR Safety Code.

8. The project vehicle will not contain a motor or combination of motors with a total impulse totaling more than 40,960 N-sec (9208 pound-seconds). The vehicle will also not weigh more than one-third of the certified average thrust of the selected high-powered motor at liftoff.

9. The flight dynamics lead and assisting team members will verify that the planned trajectory of the vehicle will keep it within the boundaries of the launch site and not directly above the spectators. The vehicle trajectory will also avoid high-altitude hazards such as clouds and airplanes. The team will follow the Federal Aviation Administration regulations regarding the launch site altitude limit, and a certified member will scrub the launch if the windspeed exceeds 20 mph. The team will design the vehicle payload such that it has no explosive or flammable components.

10. The team will only perform launches at sites where there is wide open space away from trees, power lines, occupied buildings, or people not participating in launch activities. The launch site will be at least a half-mile wide on its smallest dimension.

11. The launchpad of the vehicle will be located at least the minimum personnel distance away from any launch site boundary. The launcher will also be at least 1500 feet away from occupied buildings or public highways with traffic flow exceeding 10 mph.

12. The team will design and assemble the launch vehicle with a recovery system consisting of a main parachute and drogue parachute to safely return all components to the ground undamaged. The parachutes will ensure the landing speed is low enough to protect all vehicle components. Only flame-resistant or fireproof wadding will be inserted into the recovery system. Th recovery system will be designed with backup separation charges to deploy the parachutes in case of primary charge failure.

13. The Safety Officer and other certified members will ensure that no team member attempts to recover the vehicle from a dangerous place such as in a tree or tangled in a power line. If the vehicle is likely to recover in spectator populated areas or outside the boundaries of the launch site, then the launch will be scrubbed, or the risk will be mitigated. No team member will attempt to recover the vehicle by catching it before it touches the ground.

3.1.5 Safety Briefings

All members of the team shall share the responsibility of recognizing hazards present when working in the manufacturing facility, conducting tests on launch vehicle systems, and executing launch procedures. The responsibility of briefing the team on how to identify potential hazards and avoid accidents shall fall to the Safety Officer. A plan has been created to outline how hazard briefing and accident avoidance will occur over the course of the project duration.

3.1.5.1 Hazard Recognition

MAE Student Design Center Safety Orientation

The safety orientation at the SDC shall be the formal hazard recognition and accident avoidance briefings for manufacturing work on the project. The orientation shall educate new members and refresh the knowledge of returning members on the team's established mitigation strategies.

- The Safety Officer and safety stewards shall meet with small groups of team members at the MAE Student Design Center

- Standard operating procedures for each machine and tool used during the project shall be explained to the groups
- Potential hazards and their respective mitigation strategies will be explicitly stated to the team members by the Safety Officer and stewards
- Live demonstrations of machine and tool use shall supplement verbal instruction
- Team members should ask questions and gain experience with using project relevant tools and machinery under close supervision from the Safety Officer and safety stewards
- Meetings shall take place in the period between proposal acceptance and PDR submission to ensure each member can operate in the SDC and avoid manufacturing accidents
- Group meetings shall be limited in size to abide by COVID-19 safety guidelines while still communicating hazard recognition and accident avoidance effectively
- No team member that has not received University-sanctioned safety certification will be exempt from attending the orientation.

3.1.5.2 COVID-19 Safety Guidelines Briefing

The team shall abide by the University of Florida's safety guidelines to prevent the spread of COVID-19 to individuals internal and external to the team. Enforcement of COVID-19 prevention mitigation strategies shall be the responsibility of the project leadership, including the executive board, the subsystem leads, and safety team. The entire team shall be briefed on the mitigation plan at the first general body meeting by the Safety Officer, with additional reminders during later meetings and via Slack.

3.1.5.3 Testing Briefings

The lead engineer in charge of a testing procedure shall conduct the hazard recognition and accident avoidance briefing during a meeting with their team members prior to the test. The Safety Officer and NAR/TRA mentor shall ensure the testing procedure implements established mitigation strategies. They shall also supervise the conducting of the test. When a test procedure requires the use of equipment operated by a university organization external to the Swamp Launch Rocket Team, the responsibilities of the Safety Officer and NAR/TRA mentor shall fall to the that organization.

3.1.5.4 Pre-launch Briefings

A formal pre-launch meeting shall serve as the hazard recognition and accident avoidance briefing for launch and recovery procedures. The meeting shall also serve as a briefing for proper conduct on the launch site, with respect to both the rules of the private property and NAR/TRA safety policies. The Project Manager, Safety Officer, and lead engineers will conduct the meeting prior to the scheduled launch date. Attendance shall be mandatory for team members to be present at the launch site.

3.1.6 Caution Statements

The team shall take measures to alert members of potential hazards through caution and warning statements written in project documentation. Several methods will be utilized to communicate hazards in a way that will lead to successfully carried out mitigation strategies.

3.1.6.1 Text Formatting

Working documentation used by the team, such as standard operating procedures and safety plans, shall alert team members to cautions and warnings through distinct text formatting.

Cautions statements will advise careful and attentive action from team members. The successful application of a caution statement in practice will prevent minor personal injury, project setbacks, or both.

Caution: A caution statement will be bolded in working documentation.

Warning statements will inform team members of a high risk of danger. The successful application of a warning statement in practice will prevent serious injuries, major project failures, or both.

WARNING: A WARNING STATEMENT WILL BE COMPLETELY CAPITALIZED AND LARGER THAN SURROUNDING TEXT.

3.1.6.2 Hazard and PPE Symbols

Caution and warning statements in the team's working documentation shall include symbols indicating the types of hazards presented by a process. The symbols will serve as a visual reference to supplement written hazard warnings or remind members to consult the team's hazard mitigation strategies before proceeding with a certain operation.

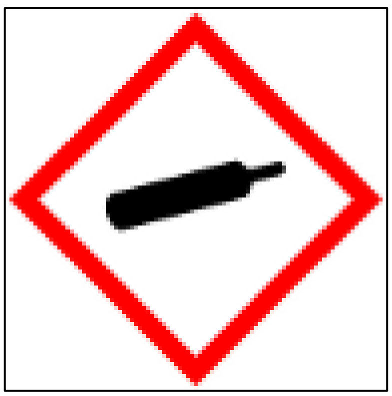

Figure 7 Gas under compression warning

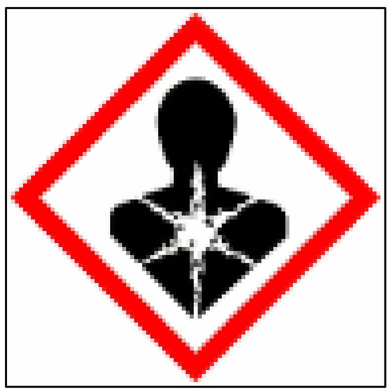

Figure 8 Serious health hazard warning

Figure 9 Health hazard/irritant

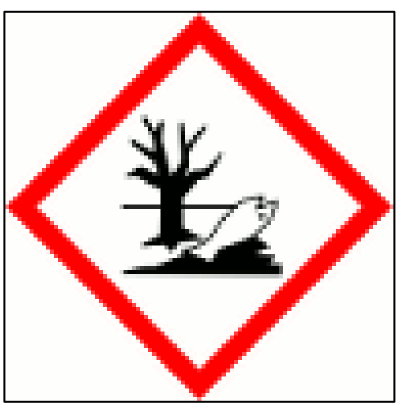

Figure 10 Environmental hazard warning

Figure 11 Acute toxicity hazard

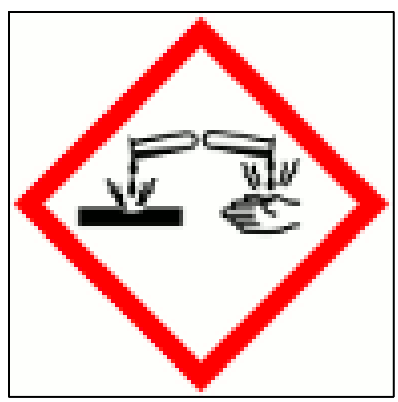

Figure 12 Corrosion warning

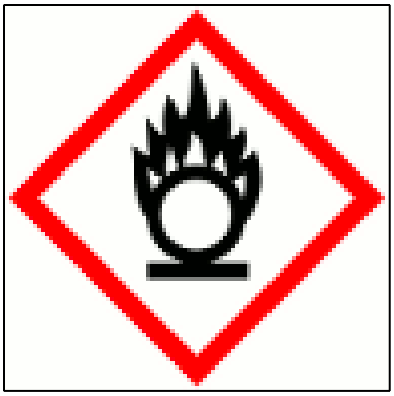

Figure 13 Oxidizer warning

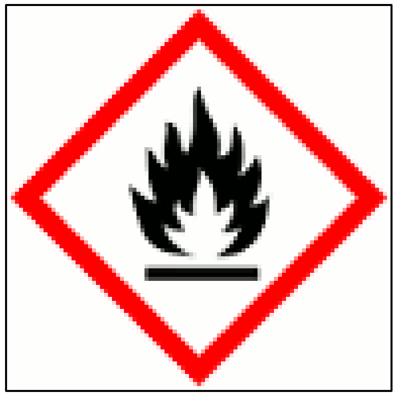

Figure 14 Flammable warning

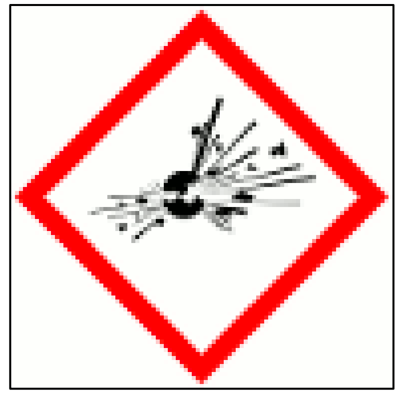

Figure 15 Explosive warning

Certain processes that require the use of personal protective equipment will have PPE symbols included alongside the steps for that process in a procedure document.

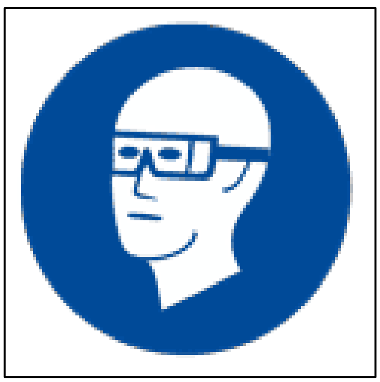

Figure 16 Safety glasses

Figure 17 Hearing protection

Figure 18 Gloves

Figure 19 Safety Shoes

Figure 20 Respirator

Figure 21 Face mask

3.1.7 Legal Compliance Plan

The team has created a plan to ensure compliance with all federal, state, and local laws regarding unmanned rocket launches and motor handling.

3.1.7.1 Federal

3.1.7.1.1 Federal Aviation Regulations, 14 CFR, Subchapter F, Part 101

101.22 - The team will design a launch vehicle that meets the definition of a class 2 amateur high-power rocket. A single motor will be selected with a confirmed total impulse under 40,960 Newton-seconds to ensure compliance with the high-power rocket definition.

101.23 - The launch vehicle will be designed for a mission with a suborbital trajectory. OpenRocket simulations will be conducted to confirm the target apogee of the launch vehicle is less than 62 miles high, or the suborbital limit for aircraft. The launch vehicle trajectory will not cross outside the borders of the United States into a foreign country. The team will adhere to NAR/TRA safety protocol requiring launches to occur within the boundaries of a NAR/TRA launch site, which will be located entirely within the United States borders. The team's launch vehicle will be unmanned and will not create a hazard to any persons, property, or other aircraft. Personnel hazard prevention compliance will be fulfilled by following the team safety plan, including the launch procedures which will mitigate all launch preparation and mission-related hazards. Property and other aircraft will be protected from hazard by complying with the launch site safety protocols and other rules put in place by the NAR/TRA and the property owners.

101.25 - The team will not operate the launch vehicle in certain environmental conditions:

A) An altitude where clouds or other obscuring phenomena cover five-tenths of the area

B) An altitude with horizontal visibility of less than five miles

C) Any cloud's interior

D) At a time not between sunrise and sunset

E) Within 9.26 km of any airport boundary, unless the launch site has FAA authorization

F) A controlled airspace, unless the launch site has FAA authorization

G) An area where any persons or property unassociated with the launch are more than a quarter of the maximum expected altitude away or 1500 feet away, whichever distance is greater

H) A launch site where a person at least eighteen years old, who has final authority on initiating high-powered launch activity, oversees launch safety

I) An area where reasonable precautions to report and control a fire caused by rocket activities are not provided

The team will ensure no launch vehicle operation occurs in areas that meet any of these criteria by performing launches at FAA authorized NAR/TRA launch sites that have protocols already in place to mitigate the conditions.

3.1.7.1.2 Code of Federal Regulation 27 Part 55: Commerce in Explosives

55.203 - The team will use Type 4 magazines to store low explosives used for testing procedures and launches.

55.206 - Outdoor low explosive magazines will be used for storage on launch sites. These magazines will be kept 75 feet away from inhabited buildings, 75 feet from public railroads and highways, and 50 feet from other above ground explosive storage magazines

55.210 - The team will use type 4 magazines constructed from fabricated metal to store low explosives. The total amount by weight of low explosives stored by the team will never exceed 50 pounds in case multiple magazines are required for storage in the SDC. The magazines will be fire-resistant.

3.1.7.2 State

The following statutes were obtained from the Florida Senate archive of state laws and regulations. All information has been confirmed as up to date in 2020.

3.1.7.2.1 Title XXXIII Chapter 552.12

No person shall transport any explosive into this state or within the boundaries of this state over the highways, on navigable waters or by air, unless such person is possessed of a license or permit; provided, there is excepted from the effects of this sentence common, contract and private carriers, as mentioned in the next succeeding sentence. Common carriers by air, highway, railroad, or water transporting explosives into this state, or within the boundaries of this state (including ocean-plying vessels loading or unloading explosives in Florida ports), and contract or private carriers by motor vehicle transporting explosives on highways into this state, or within the boundaries of this state, and which contract or private carriers are engaged in such business pursuant to certificate or permit by whatever name issued to them by any federal or state officer, agency, bureau, commission or department, shall be fully subject to the provisions of this chapter; provided, that in any instance where the Federal Government, acting through the Interstate Commerce Commission or other federal officer, agency, bureau, commission or department, by virtue of federal laws or rules or regulations promulgated pursuant thereto, has preempted the field of regulation in relation to any activity of any such common, contract or private carrier sought to be regulated by this chapter, such activity of such a carrier is excepted from the provisions of this chapter.

Compliance – The team will use solid propellant motors not classified as explosives to permit transport from the SDC to launch sites.

3.1.7.2.2 Title XLVI Chapter 790.001 Subsection 4

“Destructive device” means any bomb, grenade, mine, rocket, missile, pipe bomb, or similar device containing an explosive, incendiary, or poison gas and includes any frangible container filled with an explosive, incendiary, explosive gas, or expanding gas, which is designed or so constructed as to explode by such filler and is capable of causing bodily harm or property damage; any combination of parts either designed or intended for use in converting any device into a destructive device and from which a destructive device may be readily assembled; any device declared a destructive device by the Bureau of Alcohol, Tobacco, and Firearms; any type of weapon which will, is designed to, or may readily be converted to expel a projectile by the action of any explosive and which has a barrel with a bore of one-half inch or more in diameter; and ammunition for such destructive devices, but not including shotgun shells or any other ammunition designed for use in a firearm other than a destructive device. “Destructive device” does not include:

(a) A device which is not designed, redesigned, used, or intended for use as a weapon;

(b) Any device, although originally designed as a weapon, which is redesigned so that it may be used solely as a signaling, line-throwing, safety, or similar device;

(c) Any shotgun other than a short-barreled shotgun;

(d) Any nonautomatic rifle (other than a short-barreled rifle) generally recognized or particularly suitable for use for the hunting of big game.

(5) “Explosive” means any chemical compound or mixture that has the property of yielding readily to combustion or oxidation upon application of heat, flame, or shock, including but not limited to dynamite, nitroglycerin, trinitrotoluene, or ammonium nitrate when combined with other ingredients to form an explosive mixture, blasting caps, and detonators; but not including:

(a) Shotgun shells, cartridges, or ammunition for firearms;

(b) Fireworks as defined in s.791.01;

(c) Smokeless propellant powder or small arms ammunition primers, if possessed, purchased, sold, transported, or used in compliance with s.552.241;

(d) Black powder in quantities not to exceed that authorized by chapter 552, or by any rules adopted thereunder by the Department of Financial Services, when used for, or intended to be used for, the manufacture of target and sporting ammunition or for use in muzzle-loading flint or percussion weapons.

Compliance – The team will utilize quantities of black powder below the legal limit qualifying the substance as a “destructive device”.

3.1.7.3 Local

The National Fire Protection Association 1127 “Code for High Power Rocket Motors” is the accepted fire prevention code for the local NAR/TRA launch sites used by the team. Any statutes not explicitly mentioned in the NFPA 1127 code section are included in other safety codes in the proposal and the team’s plan of compliance is stated in those sections.

3.1.7.3.1 NFPA 1127 Code for High Power Rocket Motors

4.1 - The team will comply with the commands and instructions of NAR/TRA range safety officers present at launch sites. This compliance also extends to individuals delegated authority by the RSO.

4.2 - Only certified high-power rocket members will launch the vehicle.

4.3 - The team will abide by the statutes of NFPA 1127, as well as those of 14 CFR Part 101 from section 3.1.5.1 in this proposal and any other federal, state, or local ordinances.

4.4 - The team will submit the launch vehicle to a pre-flight inspection by the RSO and will abide by the RSO decision to either launch or abort the mission over safety concerns.

4.5 - The team will comply with the motor use and motor handling requirements of the NFPA 1127 code:

4.5.1 - Only certified motors, reloading kits, or components will be used in the launch vehicle

4.5.2 - Single-use motors will not be dismantled or altered

4.5.3 - Single-use motors will be used only for the purpose intended by the manufacturer while following all manufacturer provided instructions.

4.5.7 - A reloadable motor kit intended for use in the launch vehicle will not be removed from its packaging until the motor installation step in the launch preparation procedure.

4.6 - The launch vehicle will be designed to withstand all operating stresses and retain structural integrity under flight conditions.

4.7 - Lightweight materials will be used to construct the launch vehicle.

4.8 - Launch vehicle stability will be verified using OpenRocket with up-to-date weight and dimensional measurements. The verification will occur on the launch site immediately prior to launch during the RSO inspection.

4.10 - The team will design the launch vehicle with a recovery system that will return all components to the ground safely at a non-hazardous landing speed.

4.10.1- The team will design an electronically actuated recovery system for both its primary and backup recovery systems.

4.10.2 - The team will use flame-resistant wadding to mitigate flame-related recovery system hazards.

4.11 - The launch vehicle payload will not have any flammable or explosive components.

4.11.2 - The payload will not contain a vertebrate animal.

4.12-4.19 - The team will perform launches at NAR/TRA sites that are in accordance with the NFPA 1127, which will ensure compliance with all launching mechanism, launch site layout, and personnel safety statutes.

3.1.8 NAR/TRA Mentor Purchase, Storage, Transportation, and Use of Motors and Energetics

The Team Mentor, Jimmy Yawn, who is an active NAR member with a Level 3 certification, will purchase the selected high-powered rocket motor for the team. The motor, once purchased, will be kept in a Type 4 magazine which is painted red with “EXPLOSIVE, KEEP FIRE AWAY” written in white, 3-inch-tall letters. The magazine will be stored in the MAE Student Design Center and kept away from any heat sources, open flames, or smoke in accordance with the NAR High Power Rocketry Safety Code. This safety rule will be enforced by informing other design teams who share the SDC space of the 25-meter rule, as well as performing any tests or procedures that generate excessive heat or sparks completely outside the SDC building. While travelling to Huntsville, the high-powered motor will always be stored in the magazine and kept inside the car. A kingpin locking system will be used to constrain the magazine when the car is left unattended. The magazine will be in the trunk of the automobile, constrained to the body of the car using duct tape. Nothing will be permitted to be stored on top of the magazine. The 25-meter rule will be enforced for the entirety of the trip.

3.1.9 Written Statement of Compliance for Safety Regulations

The team has read and understood the following safety regulations and will be compliant with them through the life of the project.

1. The team agrees to have the project vehicle submitted for a range safety inspection conducted by the RSO. The team will also comply with the determination of the safety inspection.
2. The team agrees that the RSO has the final word on all safety issues associated with the project vehicle. The team therefore acknowledges the right of the RSO to deny permission to launch due to safety concerns.
3. The team agrees that the Team Mentor is ultimately responsible for the safe flight and recovery of the project vehicle. The team accepts that the Mentor will conduct a review of the project vehicle design and assembled build. The team will not launch the vehicle until the Team Mentor conducts this review and is satisfied that it meets the safety guidelines.
4. The team agrees that if it does not comply with safety requirements, it will not be allowed to launch the vehicle.

4. Technical Design

4.1 General Vehicle Description

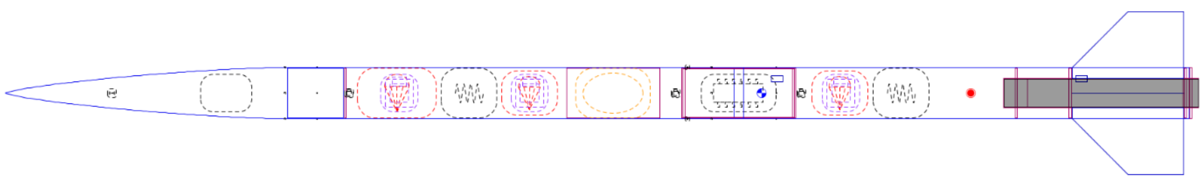

Figure 22 OpenRocket Model of Proposal Rocket

Figure 23 - SolidWorks Model of Proposal Rocket

4.1.1 Vehicle Dimensions

Section	Exterior Length (in)
Nosecone	31
Forward Section	49
Payload	0
Aft Section	48
Total	**128**

Table 18 Table of Vehicle Dimensions

The rocket has a nominal outer fuselage diameter of 5.5 inches, a total length of 128 inches, and mass of 509 ounces. It will be comprised of 4 sections; nosecone, forward section, payload, aft section. The nosecone, forward section, and aft section will be tethered together and connected to a set of two parachutes: a 72-inch main parachute and a 24 inch drogue parachute. The payload will reside within the forward section but deploy during descent and separate from the launch vehicle assembly with a 36 inch parachute.

The nosecone has an outer diameter of 5.5 inches and is Von Karman in design. It has an outer length of 31 inches and a separate shoulder length of 9-10 inches depending on manufacturer. The nosecone will attach to the nosecone coupler with four plastic rivets. The nosecone coupler will slide about 4 inches nosecone body, leaving about 5-6 inches to allow for the forward section airframe to couple to the nosecone. The nosecone coupler will have a bulkhead on the aftmost end with a U-bolt to connect to the recovery harness. It will also house the launch vehicle's GPS.

The forward airframe will be 48 inches in length. It will contain a 72-inch Rocketman Elliptical main parachute, payload, and 36-inch payload parachute. The forward airframe also connects to the avionics bay with 4 plastic rivets. The forward and aft end of the avionics bay will be capped by bulkheads. They will have U-bolts mounted to them to connect to recovery harnesses. The aft end of the avionics bay will couple to the aft section with 4 shear pins.

The aft airframe will be 48 inches in length. Within the aft airframe will be a 24-inch drogue parachute, motor assembly, and four fins. Three centering rings will be used to maintain alignment between the 75mm motor tube and aft airframe. The centering rings will also be used to help secure the fins. The aftmost centering ring will be used to mount a thrust plate. The thrust plate will then connect to a motor mount for motor retention.

4.1.2 Material Selection and Justification

The airframe will be made out of Blue Tube 2.0 which has a thickness of 0. 077 inches. Blue Tube 2.0 is being used because of its strength and ease of manufacturing. G12 fiberglass, while being stronger and more resistant to water and other external forces than blue tube, is difficult to manufacture with given the equipment available to students. Blue Tube 2.0 is cheaper and lighter than other materials commercially available to the team. While it may be more vulnerable to water damage, this can be mitigated by sanding and coating the outer surface with sealer.

Centering rings and bulkheads will be made of plywood. Plywood is being used instead of fiberglass because of its increased machinability. The rearmost centering ring will be reinforced with an aluminum thrust plate. This will reduce the shear stress on each centering ring, meaning that they do not need to be made from stronger materials.

The Nosecone will be made out of fiberglass and will feature a metal tip. A fiberglass nosecone was chosen over a plastic nosecone because the shoulder is a separate removable piece. This allows for parts to be stored inside the nosecone behind a bulkhead on the coupler. The increased weight of a fiberglass nosecone also moves the center of gravity forward which makes it easier to design fins to achieve a desired stability margin.

The motor tube will be made out of Blue Tube 2.0. An aluminum thrust plate will mount to the aftmost centering ring and will connect to a metal motor retainer. A metallic flanged thrust plate will be used because it is reusable and also because it can sustain more wear and tear than other materials.

4.1.3 Construction Methods

All manufacturing will take place in either the Student Machine Shop or in DCP Lab spaces. All safety guidelines will be followed. The Abrasive Water Jet, 3D Prototyping Lab, and DCP Fab Lab may also be used to request specially made parts that cannot be produced by traditional manufacturing methods.

All parts and assemblies will be designed in SOLIDWORKS with an accompanying design drawing. Drawings will be reviewed by safety stewards to verify manufacturability. Then instructions will be generated for manufacturing the parts with available machinery. Any work in the Student Design Center must be under the supervision of a safety steward. The produced instructions and safety guidelines will be then used to manufacture the part from stock material. Parts will then be measured and compared against design drawing. Parts that are different will either have the design updated or will be remanufactured. Parts will be checked for tolerances to ensure they fit together prior to complete assembly.

4.2 Projected Altitude and Calculation Method

The projected rocket altitude has been calculated using an OpenRocket simulation for our proposal design, with apogee at approximately 4931 ft. The altitude over time throughout the flight is displayed in Figure 24. The simulation accounts for the longitude, latitude, and altitude of the launch site in Huntsville, Alabama, in order to better approximate actual flight conditions. The simulation also assumes 12 ft launch rails, which will be provided at the actual launch, and a 5° rail cant, which is the lower end of the possible range for the launch. Design parameters for the simulation include a vehicle length of 128 in, an airframe diameter of 5.5 in, a mass of 38.1 lbs, a center of gravity 81 in from the tip of the nose cone, and a center of pressure 104 in from the tip of the nose cone. While a minimal airframe length and diameter is desirable to reduce drag, this optimization is constrained by the size required for the payload bay. Given this configuration, the optimal motor selected for the simulation was the L1150.

The key parameter that was altered while running simulations was the motor. Other parameters that were used, and may still be used, for fine-tuning the simulation results include fin number and geometry, ballast weight, and nose cone geometry.

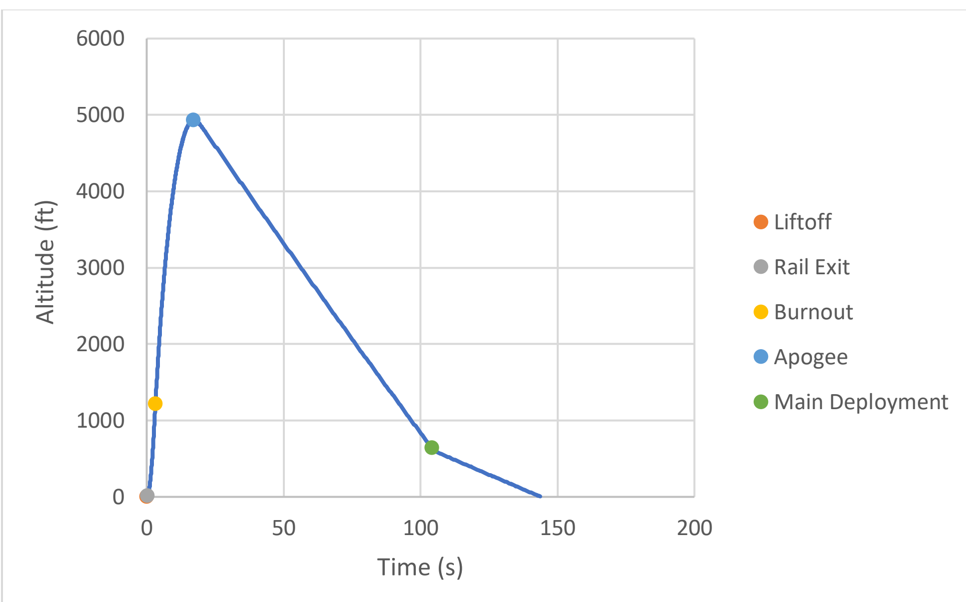

Figure 24 Altitude of rocket with respect to time

4.3 Projected Recovery System Design

The current plan for the recovery system is to deploy a 24-inch standard Rocketman parachute as the drogue, a 36-inch elliptical parachute from the same company will be used to recover the payload, and a 72-inch elliptical parachute from the same company as the main. These parachutes were chosen based off of current mass estimates, and how effectively they limit kinetic energy on descent while still meeting recovery requirements. A StratologgerCF will be used to measure altitude and accurately execute each event. A diagram of the wiring for the primary and backup system is shown in Figure 25. The drogue parachute will deploy at apogee, the payload at 1000 feet, and the current plan is to deploy the main parachute around 600 feet. The main will be held in the same compartment as the payload, but deployment will be delayed using a Jolly Logic Chute Release device. These events are shown in figures 26 through 28.

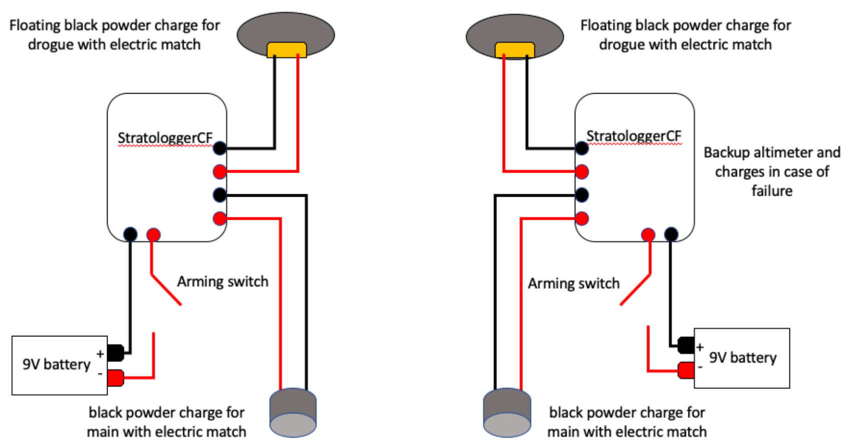

Figure 25 Circuit Diagram

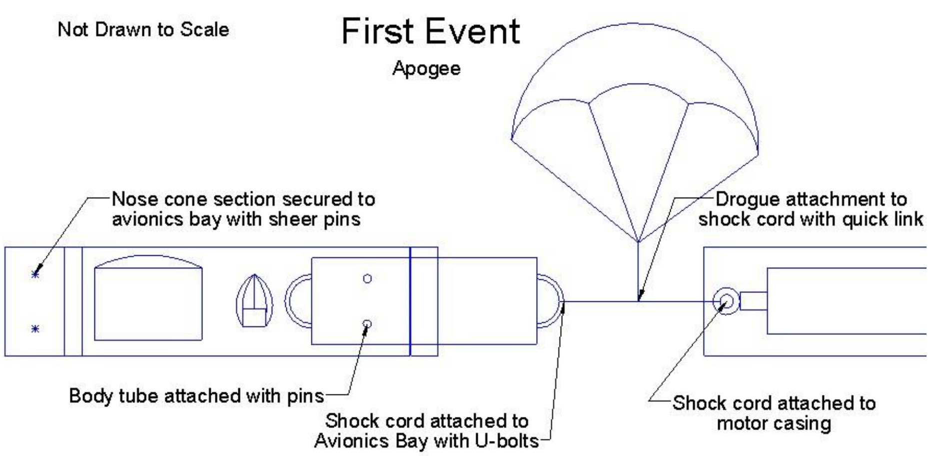

Figure 26 First Event

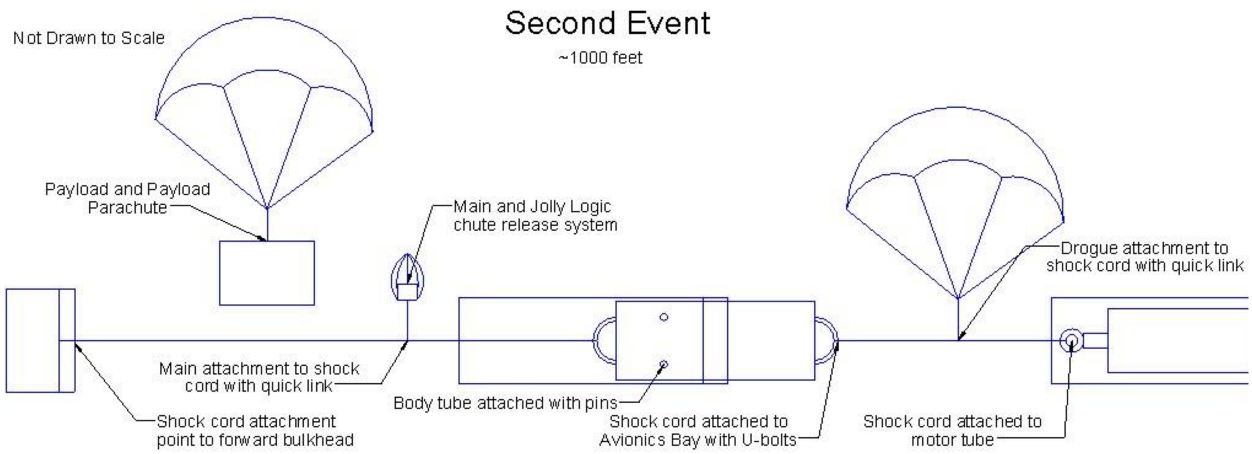

Figure 27 Second Event

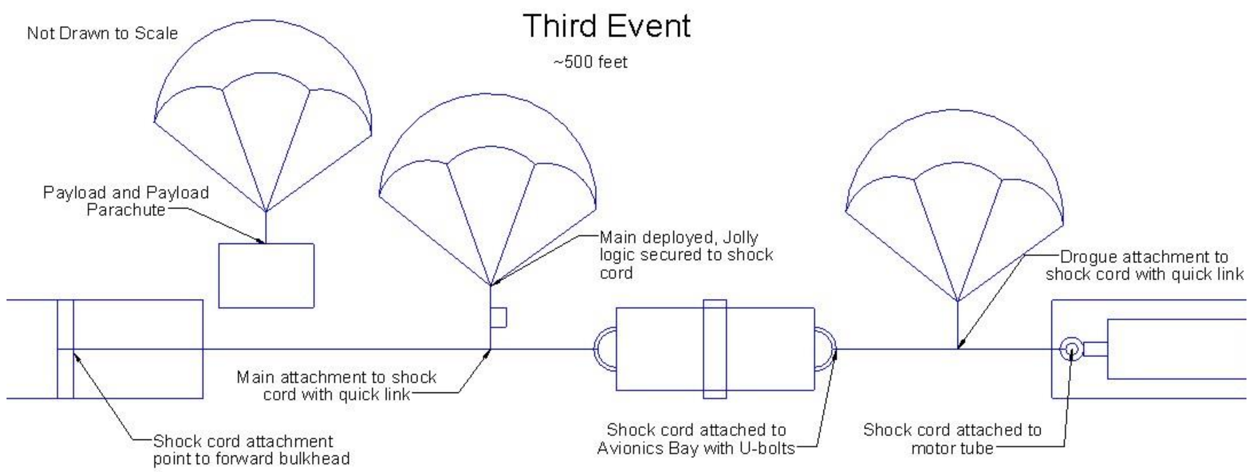

Figure 28 Third Event

The drogue will be deployed from the aft section of the launch vehicle using a floating black powder charge to pressurize the airframe and break the shear pins. The charges will be floating so that they may be positioned to push the drogue out of the separated airframe. The drogue will be secured to the recovery harness using quick links. The recovery harness will be attached to the motor casing using an eyebolt and attached to the avionics bay using a U-bolt. The plan is to deploy the payload at 1000 feet from the forward section of the launch vehicle. The airframe will be separated from the nose cone section using charge wells attached to the avionics bay bulkhead. The main parachute will be located in the same compartment but will be kept folded using a Jolly Logic Chute Release device. The main parachute will be released at around 600 feet to adequately slow the rocket and minimize drift. The two separate deployment altitudes will allow for the payload to move away from the launch vehicle and avoid tangling with the main parachute.

An avionics bay will be used to contain the recovery electronics. The bay will have a 1-inch switch band and will be contained inside of a coupler tube. The electronics will be secured to a ¼-inch thick plywood board. On either end of the coupler section electronics will be protected by bulkheads that are currently planned to be secured using two ¼ inch – 20 threaded rods running the length of the avionics bay. These rods will be secured using two hex nuts on either end to ensure they do not loosen. Charge wells will be located on the forward section of the avionics bay, while floating charges will be utilized to separate the aft section. A model of the bay can be seen in Figures 29 and 30.

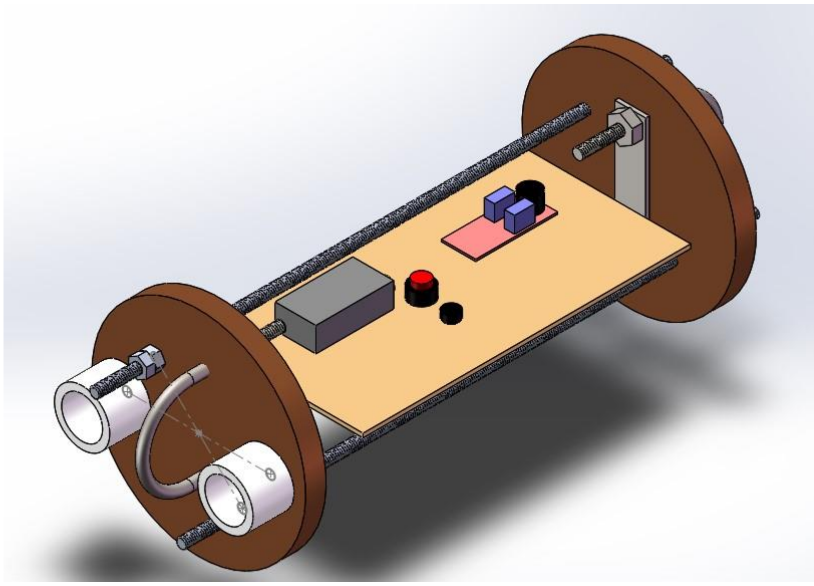

Figure 29 Avionics Bay Interior

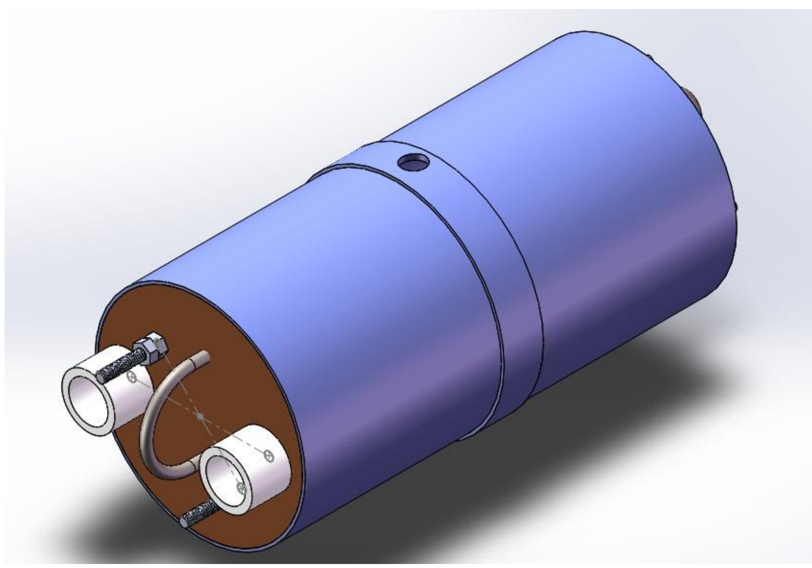

Figure 30 Avionics Bay Exterior

4.4 Projected Motor Brand and Designation

The team plans to utilize an AeroTech L1150 Redline Rocket Motor to propel the launch vehicle. Using OpenRocket simulations, the team tested several motors with different impulses to fine-tune the apogee altitude. Starting with more powerful motors like the L1390G and L1040DM, the team found that it was overshooting its desired altitude of 4500 ft. However, scaling down to a K-class motor would cause its altitude to drop significantly lower than the desired altitude. Because the weight of the payload may become greater as the design matures, the 4931 ft apogee L1150 is the team's current choice as it is within 500 ft of their current target with a margin of safety for this weight uncertainty.

The simulations have also predicted that the motor will produce a velocity of 79 fps at rail exit, which has a 1.5 safety factor over the 52 fps requirement. Furthermore, the current configuration has a stability margin at rail exit of 2.6 cal, exceeding the minimum required stability of 2.0. The projected stability margin over time is displayed in Figure 31, from rail exit to apogee. With the L1150, our rocket is projected to attain a maximum velocity of 679 fps and a maximum acceleration of 274 fps^2. The projected velocity over time throughout the flight is displayed in Figure 32. This particular motor has a documented burn time of 3.04 s, throughout which it will burn approximately 4.555 lbs of propellant. With a total impulse of 3489 Ns, the motor will provide an average of 258 lbs of thrust and reach a maximum thrust of 294 lbs. A more complete thrust curve for the motor is displayed in Figure 33, from liftoff to burnout.

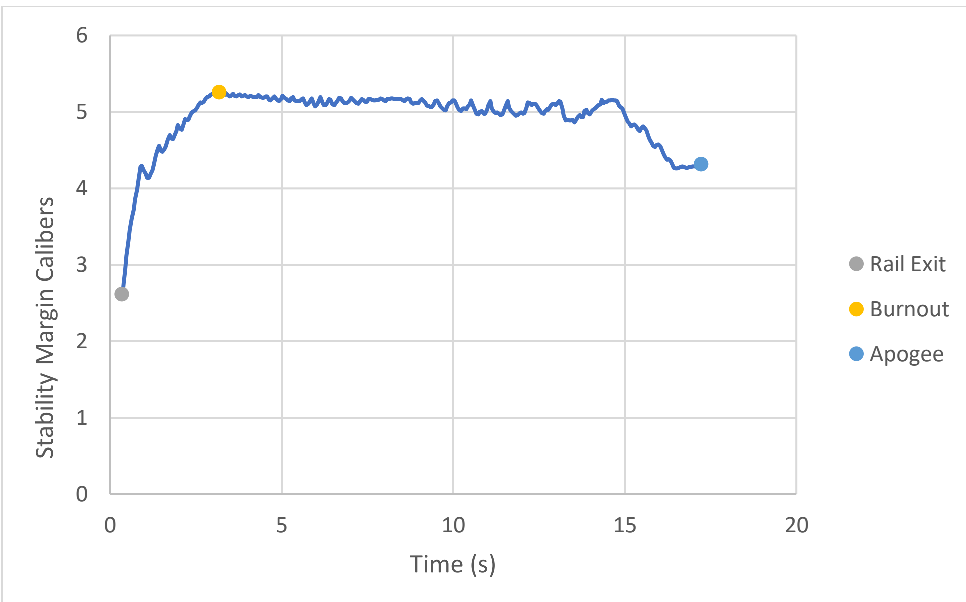

Figure 31 Stability margin calibers with respect to time.

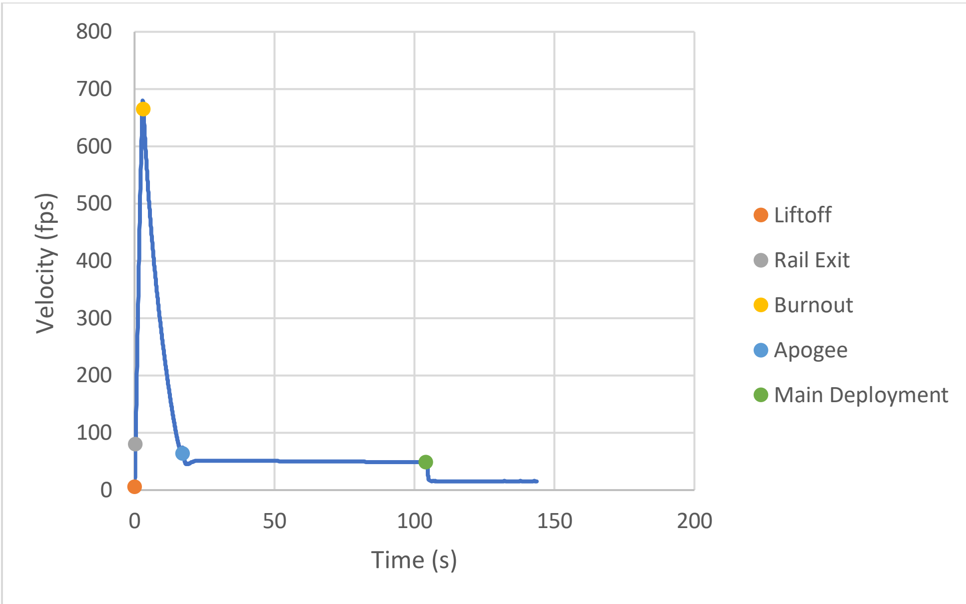

Figure 32 Velocity of rocket with respect to time.

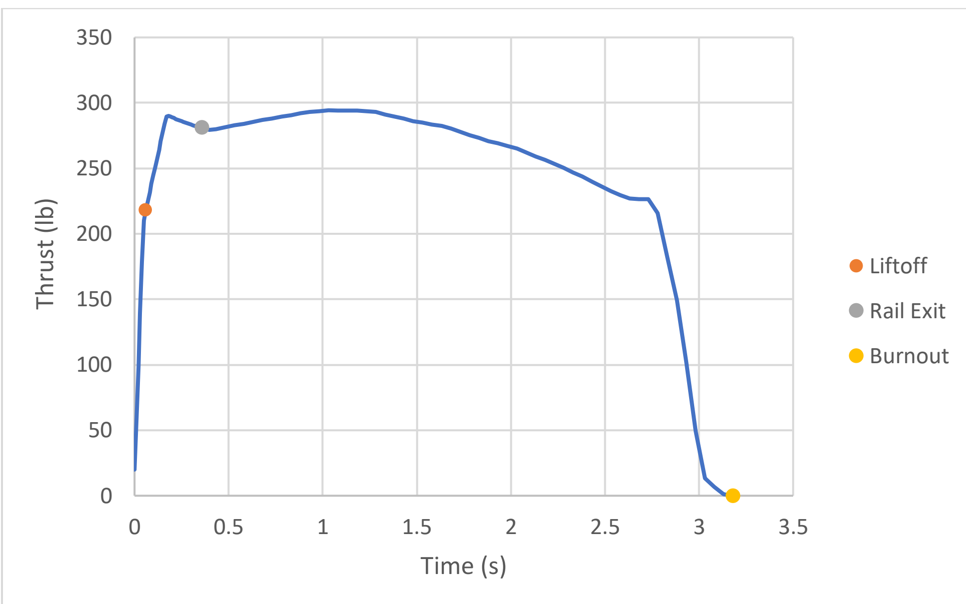

Figure 33 Thrust curve for AeroTech L1150 motor.

4.5 Project Payload Detailed Description

The planetary lander will be a 4.1-inch diameter cylindrical tube made up of 3 tiers to allow for stacking of different electronic components with legs closed that is 9.2 inches. It is to weigh approximately 4 pounds. It is designed to land upright on its legs via parachute with attachment points on top. Although the payload is designed to land upright, the legs will allow for the planetary lander to correct its vertical position to guarantee the mission requirement of being 5 degrees from vertical.

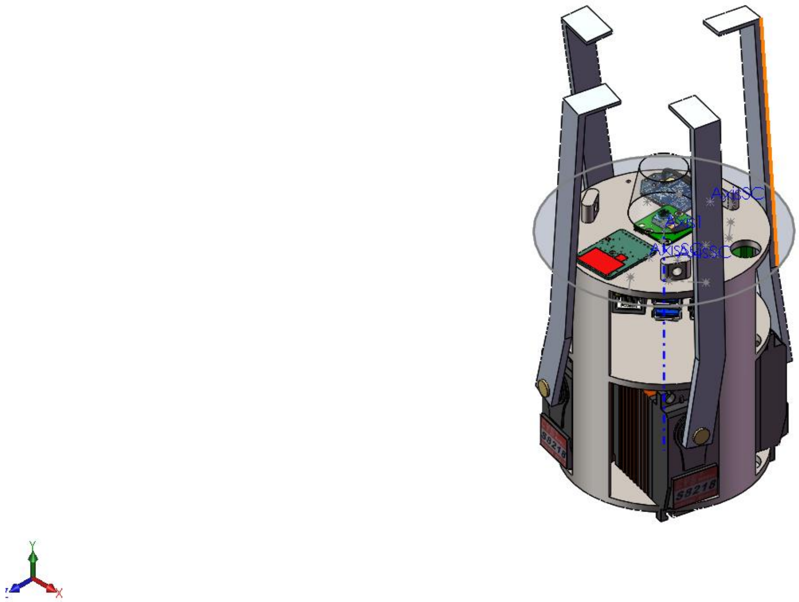

Figure 34 Planetary Lander Angled View

Figure 35 Planetary Lander Side View

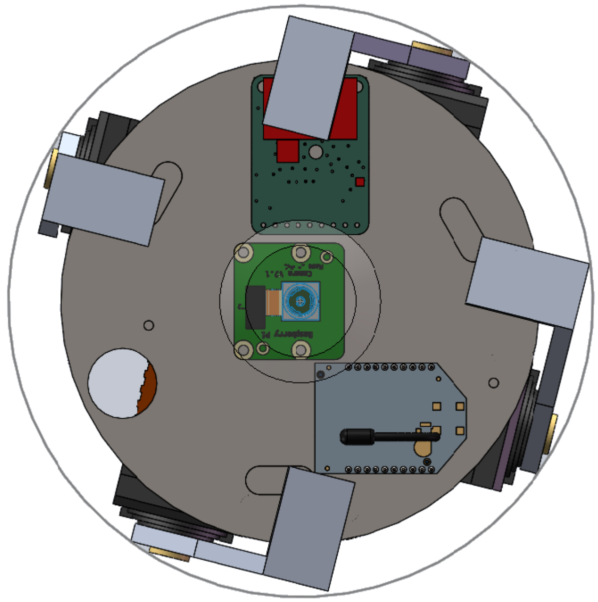

Figure 36 Planetary Lander Top View

The planetary lander's casing is designed to be a robust lander that can withstand the forced of launch and landing. The cylindrical tube is made of 5/32" steel sheet metal with a diameter of 5". This design choice was determined with past failures of payloads made of 3D printed parts when withstanding hard impacts and rocket landings as well as the size of the payload casing. Steel was chosen over aluminum due to manufacturing concerns with the difficulty to weld aluminum. Holes are to be drilled through the different layers to pass wire through the layers of the payload.

The servos on bottom tier of the payload are CYS-S8212 servos. These servos were chosen for their superior torque outputs compared to other servos. This torque was needed in the case of a severe failure of the planetary lander when touchdown occurs. If the planetary lander is to be tipped over these servos must be able to output adequate torque to the legs of the lander to make the planetary lander upright. It is these servos that drive the diameter of the planetary lander as they are the biggest components. The servos are located at the bottom to allow for the legs of the lander to be longer and to allow more precise movements with the servos when landing to allow the legs to be at shallower angles with respect to the planetary lander. In addition, the metal gear of the servos will also allow for higher landing speeds without damage to the servos.

The middle tier of the planetary lander is designed to house the sensitive electronics including the batteries, the raspberry pi, and the gyroscope. The raspberry pi is designed to be in the middle so that it has access to the servos on the bottom without excessive wiring and to the electronics on the top. In addition, this is the safest part of the payload from the environment. The batteries are with the raspberry pi as this was the most open part of the planetary lander but is also the safest to prevent damage to the batteries. The gyroscope location was chosen as it does not need to be on top of the payload as it does not a clear line of sight, so it is the safest in the middle.

The top tier of the planetary lander houses the Xbee Pro 3, the PI360 cam and the GPS. These three devices are all placed on top as they require clear line of sight to function as intentioned. The PI360 cam will be along the central axis of the planetary lander so that it is less sensitive to the tolerance of 5 degrees from vertical as it would be on the outside of the lander. The PI360 cam takes a 360-degree image in the JPEG image format. The Xbee Pro 3 and the GPS both do not matter where on top of the planetary lander they are if they have access to line of sight. The Xbee Pro 3 was chosen over a different Xbee due to the range that the rocket can land away from the receiving Xbee. This Xbee has a range of at least 2 Km which will allow for adequate range to receive the image.

The raspberry pi was chosen as the main computer for both its price and performance as well as the number of GPIO pins. There are 4 pins that support hardware PWM for the servos on pins 12,13,18, and 19. The Xbee pro 3 will use the serial data connectors on the raspberry pi on pins 14 and 15. The GPS will be connected using the USB connector as it is easiest to interface with and would require the same pins as the XBee pro 3. The gyroscope/ accelerometer only requires the SDA and SCL pins which are pins 3 and 5.

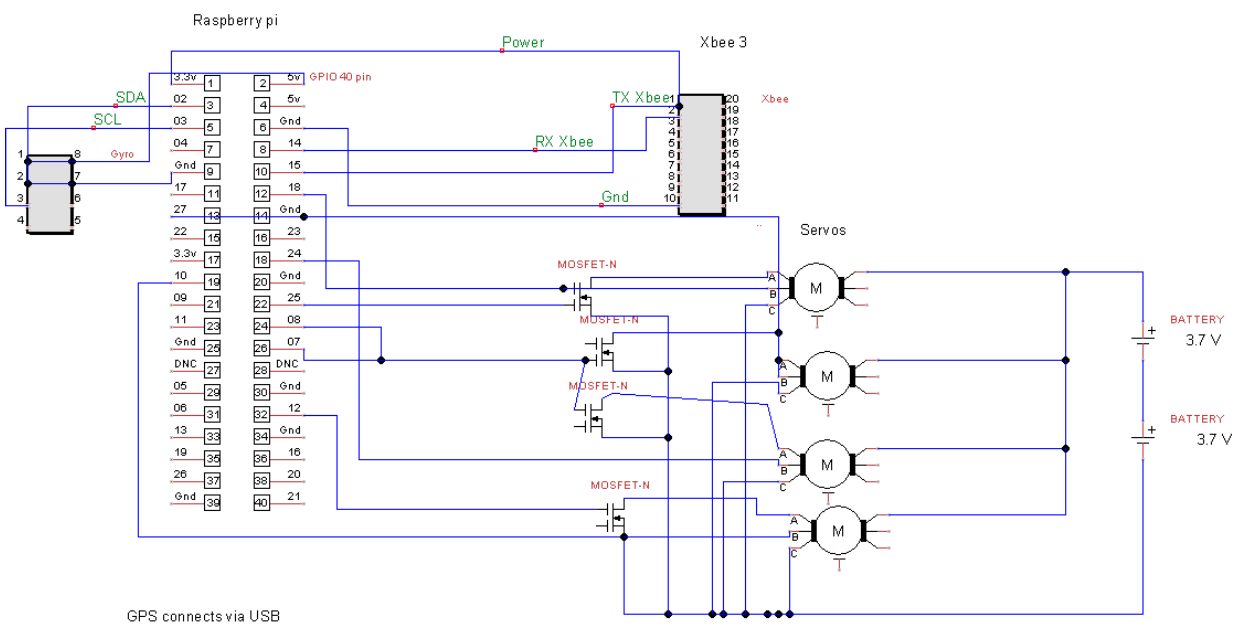

Figure 37 Planetary Lander Wiring Diagram

The mission plan is for the planetary lander to deploy with the main parachute of the rocket so that it can deploy at the correct altitude without its own altimeter. The parachute would then deploy to slow down the lander. From the accelerometer and GPS, the raspberry pi will then determine it is close enough to the ground to deploy the legs wide. This will allow for a soft landing. Once the planetary lander has come to a stop determined by the accelerometer the gyroscope will determine its relative vertical position making sure it is within 5 degrees from vertical. If the payload is not control software will position the legs to make the payload within 5 degrees from vertical. Once the planetary lander determines it is within tolerance of the vertical the raspberry pi will make the PI360 cam take a picture.

This will then be sent to a receiver Xbee Pro 3 connected to a computer within the designated area for the team.

Due to the autonomous requirements programming will be required throughout the project. Control software for the servos is planned to be written in MATLAB and loaded onto the raspberry pi as that is the software that most engineers on the team are most comfortable with. The software for the camera and Xbee will either be written in Python or C++ depending on the ease of using both with the defined components. Additionally, due to the limitations of the XBee Pro 3 the image must be sent in but format and then decoded by the host computer. This can easily be done with publicly available software in multiple languages.

4.6 Requirements and Implementation Plans

The team will meet all general, vehicle, recovery, payload, and safety requirements outlined in the handbook. The team's implementation strategies for each of these requirements are described in Tables 18-22.

4.6.1 General Requirements

Requirement	Implementation Plan
1.1. Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). Teams will submit new work. Excessive use of past work will merit penalties.	All design, writing, and manufacturing will be done completely by students. The team will create a new launch vehicle design and new documentation.
1.2. The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	The team's project schedule, budget, community support plan, personnel assignments, STEM engagement event plans, and risks and mitigation plans are included in this document. Updates to these plans will be provided with each milestone report.
1.3. Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during Launch Week due to security restrictions. In addition, FN's may be separated from their team during certain activities on site at Marshall Space Flight Center.	Each subteam leader will identify all foreign nationals on his or her subteam and forward this information to the team's project manager. The team's project manager will be responsible for compiling a list of all foreign national members for submission prior to the PDR.
1.4. The team must identify all team members who plan to attend Launch Week activities by the Critical Design Review (CDR). Team members will include: 1.4.1. Students actively engaged in the project throughout the entire year. 1.4.2. One mentor (see requirement 1.13).	Each subteam leader will identify actively engaged students who plan to attend launch week activities in his or her subteam and submit this information to the team's project manager. The team's project manager will be responsible for compiling a list of active members, adult educators, and a mentor who plan to attend

1.4.3. No more than two adult educators.	launch week activities prior to the submission of the CDR.
1.5. The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities. These activities can be conducted in-person or virtually. To satisfy this requirement, all events must occur between project acceptance and the FRR due date. The STEM Engagement Activity Report must be submitted via email within two weeks of the completion of each event. A template of the STEM Engagement Activity Report can be found on pages 36-38.	The team is partnering with Alachua County Public Schools to bring STEM engagement events to elementary and middle school students virtually.
1.6. The team will establish a social media presence to inform the public about team activities.	The team has established and will maintain a social media presence on Instagram (@SwampLaunch), Twitter (@SwampLaunch), and Facebook (@SwampLaunch).
1.7. Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient. Late submissions of milestone documents will be accepted up to 72 hours after the submission deadline. Late submissions will incur an overall penalty. No milestone documents will be accepted beyond the 72-hour window. Teams that fail to submit milestone documents will be eliminated from the project.	The team's project manager will be responsible for the submission of all milestone documents prior to each deadline. The team will abide by internal deadlines displayed in Figure 38 to ensure early completion and submission of each milestone document.
1.8. All deliverables must be in PDF format.	The team's project manager will be responsible for ensuring each submitted document is in PDF format.
1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections.	The team include a table of contents in each milestone report. The team's project manager will be responsible for ensuring this table is added and updated.
1.10. In every report, the team will include the page number at the bottom of the page.	The team will include a page number at the bottom of each page for each milestone review document.
1.11. The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones	Each team member will supply his or her own video teleconference equipment.

should be used for speakerphone capability only as a last resort.	
1.12. All teams attending Launch Week will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted at the NASA Launch Complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on Launch Day. The exact cant will depend on Launch Day wind conditions.	The team will use standard 1515 rail buttons to ensure compatibility with NASA-provided launch pads. The launch pad angle will be measured and adjusted during rocket installation to ensure it is canted 5 to 10 degrees away from the crowd.
1.13. Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to Launch Week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend Launch Week in April.	The team will receive mentorship from Jimmy Yawn, a level 3 certified NAR member. The team's NAR mentor is in good standing with the National Association of Rocketry and meets the successful launch requirement.
1.14 Teams will track and report the number of hours spent working on each milestone.	The team will maintain a detailed log of hours spent working on each milestone. This time log will be separated by subteam and type of task performed. The team will update this log a minimum of once per week to maintain accuracy. See section 1.7 for the proposal time report.

Table 19 General Requirement Implementation Plans

4.6.2 Vehicle Requirements

Requirement	Implementation Plan
2.1. The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on Launch Day will receive zero altitude points towards their overall	The team will utilize OpenRocket simulation software to ensure predicted altitude lies between 3,500 and 5,500 feet AGL. OpenRocket simulations will be conducted with as-built weight and stability prior to each launch.

project score and will not be eligible for the Altitude Award	
2.2. Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score.	A finalized target altitude will be declared in the PDR milestone document, but the team is currently designing for an altitude around 4,500 ft.
2.3. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner. The Altitude Award will be given to the team with the smallest difference between their measured apogee and their official target altitude on Launch Day. This altimeter may also be used for deployment purposes (see Requirement 3.4)	The team's primary StratologgerCF altimeter will be used for official altitude determination. The primary altimeter will be visibly distinguished from the secondary altimeter to assist in identification.The StratologgerCF is a commercially available barometric altimeter.
2.4. 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 so as to ensure that the kinetic energy on impact does not cause damage that would require repairs or modifications to enable for the launch vehicle to be reused.
2.5. The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	The launch vehicle will have four independent sections. These sections will include a nosecone assembly, forward assembly, aft assembly, and payload.
2.5.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.	Each coupler shoulder will extend at least 5.5 inches into each joined airframe.
2.5.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	The nosecone shoulder will extend 5 inches into the forward airframe.
2.6. The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	The team will engage in a launch rehearsal as outlined in Test #20 to ensure that the vehicle can be made flight-ready in less than 2 hours.
2.7 The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.	The recovery system electronics and the redudant electronics will be powered by separate 9-volt batteries. This should ensure that the launch vehicle can remain in launch ready configuration for a minimum of 2 hours.
2.8. 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 NASA-designated launch services provider.	The motors under our evaluation throughout the design process will utilize an igniter that is compatible with this firing system.

2.9. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	The motors under our evaluation throughout the design process will utilize an igniter that does not require external circuitry or special ground support equipment to initiate launch.
2.10. The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	The motor used will be an Aerotech L1150, which is commercially available and certified.
2.10.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone.	Motor choice will be evaluated at each stage of design until CDR.
2.10.2. Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment will not be approved. A penalty against the team’s overall score will be incurred when a motor change is made after the CDR milestone, regardless of the reason.	Simulations for the CDR design will be sufficient to make a final motor choice at that time. If such a change is required, the team will immediately notify NASA for approval.
2.11. The launch vehicle will be limited to a single stage.	The launch vehicle will have a single motor.
2.12. 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 projected total impulse provided by our University launch vehicle will be 3,489 Ns (L-class).

2.13. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: 2.13.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews. 2.13.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank. 2.13.3. The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	The launch vehicle will not utilize any pressure vessels.
2.14. 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.	At each stage of design, the team will perform OpenRocket simulations to verify the projected stability margin at rail exit.
2.15. Any structural protuberance on the rocket will be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	The rocket will not feature any structural protuberances.
2.16. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	At each stage of design, the team will perform OpenRocket simulations to verify the projected velocity at rail exit.
2.17. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data will be reported at the CDR milestone. Subscales are not required to be high power rockets.	The team will both launch and recover a subscale test rocket after the proposal is awarded and before the deadline for the Critical Design Review. The timeframe of this launch is displayed in the project schedule in section 6.1. Data from the launch will be recorded in the previously mentioned report.
2.17.1. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.	The team will construct a subscale launch vehicle for this test launch. The materials for the airframe and bulkheads will be constant with the final design in order to obtain relevant data but will be resized proportionally. This launch vehicle will be completely independent from the final, full-scale rocket.

2.17.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude.	The subscale will carry two StratologgerCF's, one as a primary and the other as a backup. These are both capable of recording the apogee altitude.
2.17.3. The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	The team will design and construct a subscale rocket. The complete design and construction of this system will be unique specifically to this year's project.
2.17.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	The subscale rocket will utilize an altimeter. This data will be read and supplied within the CDR report.
2.18. All teams will complete demonstration flights as outlined below	See below.
2.18.1. Vehicle Demonstration Flight - All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown must be the same rocket to be flown on Launch Day. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:	The team will perform a full-scale test launch of the final rocket including all hardware before the Flight Readiness Review deadline. The rocket will be launched at this time will be the same rocket prepared for Launch Day. The team will analyze the results of the launch in order to validate the stated criteria.
2.18.1.1. The vehicle and recovery system will have functioned as designed.	The recovery system will utilize backup charges and altimeter that will be wired separately from the primary system. Either systems will be able to cause separation in case of failure.
2.18.1.2. The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	The full-scale rocket design is new and specifically created for this year's project. Newly purchased materials will be used to manufacture the designed rocket.
2.18.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:	In the event that the payload is not flown, the team will abide by the plans listed for 2.18.1.3.1-2.18.1.3.4.
2.18.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.	In the event that the payload is not flown in the vehicle demonstration flight, a mass simulator will be used.
2.18.1.3.2. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.	In the event that the payload is not flown in the vehicle demonstration flight, the mass simulator will be stored in the forward airframe where the payload would otherwise be kept.
2.18.1.4. If the payload changes the external surfaces of the rocket (such as camera housings	The payload does not change the external surface of the rocket.

or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	
2.18.1.5. Teams shall fly the Launch Day motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the Launch Day motor or in other extenuating circumstances.	The team's home launch field can support L-class motors.
2.18.1.6. The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the Launch Day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.	The team will prepare the launch vehicle for the test flight exactly as it will be flown on Launch Day. This will include being in its fully ballasted configuration. Additional ballast will not be added unless absolutely necessary, upon which a re-flight will be conducted.
2.18.1.7. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO).	The launch vehicle and its components will be safely recovered and will not need to be modified for any reason.
2.18.1.8. Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.	The full-scale rocket will be equipped with a StratologgerCF altimeter. The altimeter data will be read and recorded in the FRR report.
2.18.1.9. Vehicle Demonstration flights must be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.	The team will begin building the full-scale launch vehicle at the start of the spring semester, giving enough time for all components to be completed so that the Vehicle Demonstration Flight requirements may be fulfilled before the FRR deadline. In the case of a re-flight, an Addendum will be made to the FRR submission.
2.18.2. Payload Demonstration Flight - All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown must be the same rocket to be flown on Launch Day. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria	As the team is working to construct the full-scale launch vehicle during the spring semester, work will also be done to construct the payload design. With these two designs completed, the team will then launch and recover both the launch vehicle and the payload. The flight will be completed successfully before the deadline for the Payload Demonstration Flight.

must be met during the Payload Demonstration Flight:	
2.18.2.1. The payload must be fully retained until the intended point of deployment (if applicable), all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair	The payload will be retained in the forward airframe through the use of shear pins.
2.18.2.2. The payload flown must be the final, active version.	The payload will be active and will not be changed following the payload demonstration flight.
2.18.2.3. If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.	The team will submit an FRR addendum only if a separate payload demonstration flight is required.
2.18.2.4. Payload Demonstration Flights must be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	If a separate payload demonstration flight is required, it will be conducted prior to March 29th, 2021.
2.19. An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.	The team will submit an FRR addendum prior to March 29th, 2021 if a vehicle demonstration re-flight or payload demonstration flight is required.
2.19.1. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch.	In the event that a Vehicle Demonstration Re-Flight is necessary, the team will strive to complete the flight as soon as possible in order to ensure that an FRR Addendum can be submitted before the deadline.
2.19.2. Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly a final competition launch.	The team will complete a payload demonstration flight if the payload is not successfully flown in the vehicle demonstration flight.
2.19.3. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.	The team will petition the NASA RSO for permission to fly the payload at launch week if the payload demonstration flight is unsuccessful.
2.20. The team's name and Launch Day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	The team's name and project manager's contact information will be displayed on the exterior of the avionics switch band.

2.21. All Lithium Polymer batteries will be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	All Lithium Polymer batteries will be wrapped in brightly colored tape and labeled with a “FIRE HAZARD” indicator.
2.22.1. The launch vehicle will not utilize forward firing motors	Forward firing motors will not be featured on the launch vehicle.
2.22.2. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	Motors that expel titanium sponges will not be utilized. The proposed launch vehicle will use an AeroTech L1150.
2.22.3. The launch vehicle will not utilize hybrid motors.	The team will design a launch vehicle that uses a solid fuel motor.
2.22.4. The launch vehicle will not utilize a cluster of motors.	The proposed launch vehicle will use a single AeroTech L1150.
2.22.5. The launch vehicle will not utilize friction fitting for motors.	A motor retainer will be used to secure the motor to the launch vehicle.
2.22.6. The launch vehicle will not exceed Mach 1 at any point during flight.	At each stage of design, the team will perform OpenRocket simulations to verify the max velocity results in a Mach Number below 1.
2.22.7. 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 an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	At each stage of design, the team will perform OpenRocket simulations to verify the vehicle performs nominally with the appropriate ballast.
2.22.8. Transmissions from onboard transmitters, which are active at any point prior to landing, will not exceed 250 mW of power (per transmitter).	The BRB900 GPS uses 250 mW of power.
2.22.9. Transmitters will not create excessive interference. Teams will utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.	Transmitters will not create excessive interference. Testing will be planned to ensure that excessive interference is not created. The BRB900 GPS has a unique destination address associated with its receiver. This address is unique to the device, and is necessary to decode messages from the transmitter.
2.22.10. 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 nosecone will be primarily fiberglass with a metal tip. No other metals will be used in vehicle construction.

Table 20 Vehicle Requirement Implementation Plans

4.6.3 Recovery System Requirements

Requirement	Implementation Plan
3.1. The full scale launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO.	The team is planning on using a 24 inch diameter Rocketman parachute as our drogue parachute to be deployed at apogee from the aft section of the launch vehicle. The current plan is to deploy the main parachute, a 72 inch diameter elliptical Rocketman parachute at an altitude of 600 feet. The kinetic energy during drogue stage descent will be reevaluated as the launch vehicle develops, and the masses of independent sections are finalized. This will be done to ensure that it is kept at a reasonable value, by changing the drogue parachute if necessary.
3.1.1. The main parachute shall be deployed no lower than 500 feet.	The team is planning on using a 72 inch elliptical parachute as our main parachute, and the deployment is planned to occur at 600 feet using a Jolly Logic release device.
3.1.2. The apogee event may contain a delay of no more than 2 seconds.	There will be a delay put on the back up black powder charges of no more than 2 seconds. The primary charges will not have a delay so that the airframe is not excessively pressurized by the detonation of two charges at the same time.
3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.	Parachute deployment will occur by causing separation of the airframe with electronically detonated black powder charges.
3.2. Each team will perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full scale vehicles.	The team will perform the indicated ground ejection tests before each flight, as outlined in the testing plan.
3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	The team's current estimates indicate that no independent section of the launch vehicle will have a kinetic energy of 75 ft-lbf or greater. This will be reevaluated as the launch vehicle and payload change over the course of the project to ensure that the kinetic energy of each section does not exceed 75 ft-lbf at landing.
3.4. The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	The redundant system will include a StratologgerCF altimeter with an independent power source and independent charges.
3.5. Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	The primary and backup systems will be powered by separate commercially available 9-volt batteries.
3.6. Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the	The altimeters will be armed using a push button accessible through a small hole in the switch band of the avionics bay.

rocket is in the launch configuration on the launch pad.	
3.7. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	Each arming switch will be capable of being locked in the on position for launch. The pushbuttons will be protected by the avionics bay, and secured to the board holding the recovery electronics to ensure there are no accidental power failures. Tests will be done to ensure that the arming switches will not be affected by in flight forces.
3.8. The recovery system electrical circuits will be completely independent of any payload electrical circuits.	The recovery electrical systems will be completely independent from payload electrical circuits. The recovery electronics will be housed in a separate compartment from the payload, and will not be connected in any way.
3.9. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Removable sheer pins will be used for both main and drogue parachute compartments.
3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads.	The current estimated recovery area, if 20 mph winds are encountered at launch, is 2473 feet. This will be reevaluated as the design for the launch vehicle and payload progress to their final forms. At the minimum it will be reevaluated for the PDR and CDR.
3.11. Descent time of the launch vehicle will be limited to 90 seconds (apogee to touch down). The jettisoned payload (planetary lander) is not subject to this constraint.	The current estimate for time between apogee and touch down is 84.3 seconds. This will be reevaluated as the launch vehicle's design progresses. This will also be reevaluated for the PDR and CDR.
3.12. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver	A GPS will be installed in the nose cone section of the rocket and will transmit its position to a handheld ground station.
3.12.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	The payload lander will have a separate GPS unit that transmits it location to a payload ground station.
3.12.2. The electronic tracking device(s) will be fully functional during the official flight on Launch Day.	Each GPS tracking unit will be tested for functionality prior to the official flight on Launch Day. Each GPS tracking unit will be fully active during the official flight.
3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	The recovery system electronics will be located inside the avionics bay protected by bulkheads on either side to shield it from the black powder charges and landing.
3.13.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency	The GPS will be in the nosecone section, and the payload is in its own separate section from the avionics bay.

transmitting device and/or magnetic wave producing device.	
3.13.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	Aluminum foil will be used to shield the electronics from all onboard transmitting devices. It will be placed along the inside of the forward bulkhead of the avionics bay to shield it from the GPS on-board the launch vehicle and the transmitter on the payload.
3.13.3. The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves by using aluminum foil.
3.13.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	The recovery system electronics will be housed inside the avionics bay. The wires and lead attachment points will be insulated to avoid short circuiting. They will be shielded from other transmitting devices with aluminum foil.

Table 21 Recovery Requirement Implementation Plans

4.6.4 Payload Experiment Requirements

Requirement	Implementation Plan
4. Payload Experiment Requirements All payload designs must be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.	Proposal will be submitted to NASA such that any issues or concerns can be addressed by the appropriate review panel.
4.1. High School/Middle School Division – Teams may design their own science or engineering experiment or may choose to complete the College/University Division mission. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	Payload proposal will be to accomplish the mission requirements set out by NASA for the college division and this requirement does not apply.
4.2. College/University Division – Teams will design a planetary landing system to be launched in a high-power rocket. The lander system will be capable of being jettisoned from the rocket during descent, landing in an upright configuration or autonomously uprighting after landing. The system will self-level within a five-degree tolerance from vertical. After autonomously uprighting and self-leveling, it will take a 360-degree panoramic photo of the landing site and transmit the photo to the team. The method(s)/design(s) utilized to complete the payload mission will be at the teams' discretion	The payload will be self-leveling to within 5 degrees using servo-controlled legs working in conjunction with a gyroscope and accelerometer such that it would be autonomous. The payload will then have use a spherical lens with a regular camera and Open CV to make the spherical picture into a 360-degree panoramic photo and wirelessly transmitted to the team through the use of an Xbee 3. FAA regulations and FCC requirements will be checked and met prior to any testing and building to remain in compliance.

and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety.	
4.3.1. The landing system will be completely jettisoned from the rocket at an altitude between 500 and 1,000 ft. AGL. The landing system will not be subject to the maximum descent time requirement (Requirement 3.11) but must land within the external borders of the launch field. The landing system will not be tethered to the launch vehicle upon landing.	The payload will be jettisoned with the main parachute of the launch vehicle. The main parachute will receive data from the StratologgerCF altimeter to deploy at a determined height between 500 and 1000 ft. This will ensure landing close to the launch vehicle and within the external boarders of the launch field.
4.3.2. The landing system will land in an upright orientation or will be capable of reorienting itself to an upright configuration after landing. Any system designed to reorient the lander must be completely autonomous.	The payload is designed to land upright with a parachute centered on the payload and legs deployed as wide as possible to make sure payload lends upright. In the event reorientation is necessary the gyroscope will be used with control software on a raspberry pi to correctly orientate the payload using the legs attached the servos.
4.3.3. The landing system will self-level to within a five-degree tolerance from vertical.	The gyroscope system on the payload will be used in conjunction with the Raspberry Pi to control the servos of the lander to achieve vertical within 5 degrees of tolerance using control software on the Raspberry Pi
4.3.3.1. Any system designed to level the lander must be completely autonomous.	The control system will be a custom control software written and executed on the Raspberry Pi to allow for self-leveling of the system.
4.3.3.2. The landing system must record the initial angle after landing, relative to vertical, as well as the final angle, after reorientation and self-levelling. This data should be reported in the Post Launch Assessment Report (PLAR).	The gyroscope will send initial angle data and corrected angle data to the raspberry pi that will record the data to the SD card and transmit the data via the Xbee to the team computer to ensure data is not lost.
4.3.4. Upon completion of reorientation and self-levelling, the lander will produce a 360-degree panoramic image of the landing site and transmit it to the team.	After confirmation from the gyroscope that the payload is withing 5 degrees of vertical the raspberry Pi will take, save, and transmit the image back to the team using dual XBee's for transmission
4.3.4.1. The hardware receiving the image must be located within the team's assigned prep area or the designated viewing area.	The XBee on the payload is rated to have a 2-mile range such that data can be received from within the assigned prep area or designated viewing area.

4.3.4.2. Only transmitters that were onboard the vehicle during launch will be permitted to operate outside of the viewing or prep areas.	No extra transmitters will be used.
4.3.4.3. Onboard payload transmitters are limited to 250 mW of RF power while onboard the launch vehicle but may operate at a higher RF power after landing on the planetary surface. Transmitters operating at higher power must be approved by NASA during the design process.	Xbee 3 max transmit power is about 79 mW of RF power.
4.3.4.4. The image should be included in your PLAR.	Images will be saved onboard the computer and received via wirelss transmission on the host computer so that images may be included in the PLAR
4.4.1. Black Powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations.	No black powder or energetics are used in any surface operations with the lander.
4.4.2. Teams must abide by all FAA and NAR rules and regulations.	All FAA and NAR rules will be followed and checked by appropriate members of the design team such that no rules or regulations will be broken.
4.4.3. Any experiment element that is jettisoned, except for planetary lander experiments, during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.	The planetary lander experiment will be the only element jettisoned from the launch vehicle.
4.4.4. Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS.	The team will not utilize an unmanned aircraft system payload.
4.4.5. Teams flying UASs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	The team will not utilize an unmanned aircraft system payload.
4.4.6. Any UAS weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	The team will not utilize an unmanned aircraft system payload.

Table 22 Payload Requirement Implementation Plans

4.6.5 Safety Requirements

Requirement	Implementation Plan
5.1. Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.	The team will develop a launch and safety checklist based on the launch requirements derived from the final payload design and other constraints. The safety officer will enforce completion of the checklist on launch days, and

	the team leads will take charge of checklist tasks related to their subsystems.
5.2. Each team must identify a student safety officer who will be responsible for all items in section 5.3.	Chas Wilson was appointed as the team safety officer for the 20-21 school year and will assume responsibility for items in Section 5.3.
5.3. The role and responsibilities of the safety officer will include, but are not limited to: 5.3.1. Monitor team activities with an emphasis on safety during: 5.3.1.1. Design of vehicle and payload 5.3.1.2. Construction of vehicle and payload components 5.3.1.3. Assembly of vehicle and payload 5.3.1.4. Ground testing of vehicle and payload 5.3.1.5. Subscale launch test(s) 5.3.1.6. Full-scale launch test(s) 5.3.1.7. Launch Day 5.3.1.8. Recovery activities 5.3.1.9. STEM Engagement Activities	The safety officer will review design choices and offer feedback safety-related feedback. The safety officer will supervise the manufacturing and assembly activities of the team with assistance from the safety stewards. The safety officer and NAR/TRA mentor will supervise ground testing of the vehicle and payload. The safety officer will be present on Launch Day to enforce adherence to NAR/TRA safety protocols and the team's hazard mitigation strategies. The safety officer will oversee and enforce the completion of the team's launch procedure for both the subscale and full-scale tests. The safety officer will enforce caution and careful observation during launch vehicle recovery after launch. The safety officer will supervise STEM engagement in the circumstance that active hazard mitigation is required.
5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	A manufacturing plan will be developed prior to construction of the subscale launch vehicle to serve as a reference for all team members for all relevant manufacturing processes. The plan will be reviewed by the safety officer to verify compliance with the team's hazard analyses. The manufacturing lead and safety team will enforce compliance with the plan for the rest of the project.
5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	All current revisions of the hazard analyses, failure mode analyses, and procedures are accessible to the team via the team's google drive and Microsoft Teams account. Physical copies of the MSDS/chemical inventory data are located in the MAE SDC, with digital backups on Microsoft Teams and Google Drive.
5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	The safety officer will assist the team leads with the development/writing of the hazard analyses, failure mode analyses and procedures.
5.4. During test flights, teams will abide by the rules and guidance of the local rocketry club's	Team members will follow all rules, guidelines, and safety procedure set forth by the safety

RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	officer, and will establish communication as necessary prior to attending any NAR or TRA launch.
5.5. Teams will abide by all rules set forth by the FAA.	The team has reviewed FAA regulations and developed a long-term plan to design a launch vehicle that complies with all requirements. Regulations involving launch sites and launching protocols are complied with through the team's collaboration with NAR/TRA, who have adopted the FAA regulations into their own safety policies.

Table 23 Safety Requirement Implementation Plans

4.7 Major Technical Challenges and Solutions

The team is anticipating challenges in manufacturing, payload electronics, and payload deployment. The team's responses to these challenges are outlined in sections 4.7.1, 4.7.2, and 4.7.3.

4.7.1 Manufacturing Challenges

Challenges the team will face when manufacturing includes teaching new members property safety procedures in the lab and when operating machines. New members often lack the experience to operate machinery that is learned through upper level classes. Safety stewards and approved teaching assistants must supervise and teach new members when using machinery and equipment.

Use of manufacturing spaces will also present a challenge. New health and safety guidelines as set out by the University restricts the number of students that can be inside the Student Design Center or in Manufacturing Labs. Reservations must be made ahead of time. Strict manufacturing deadlines must be adhered else the team will be unable to manufacture all the necessary parts.

4.7.2 Payload Challenges

The largest anticipated challenge is manufacturing and testing. Due to social distancing protocols, a limited number of team members will be able to manufacture and test the payload at any given time. To allow for sufficient manufacturing and testing time under these circumstances, the team will begin payload manufacturing process early on November 13th.

The other challenge is the autonomous programming the payload must have. Without being able to control the payload multiple contingencies must be thought of in advance to prepare for unexpected scenarios. In addition, the control software must be robust enough to allow for all configurations that the payload can land in so that the payload may right itself.

The last challenge that the payload will face is the wireless communication. Because the launch vehicle may drift up to 2,500 feet from the launch point, the wireless communication equipment therefore must be robust enough to allow proper transmission of the 360-degree image at maximum range with minimal data packet loss.

4.7.3 Recovery Challenges

A difficulty that will be faced with the recovery of the launch vehicle and payload is entanglement. The payload is being housed in the same compartment as the main parachute, and will have the recovery harness going past it. This can be seen in Figure 26 and 28. This could cause the recovery harness and payload parachute to become tangled. This could damage the payload, affect its deployment on the ground, or affect the eventual deployment of the main parachute and landing of the launch vehicle. The current plan to avoid this is to ensure the recovery harness easily fits past the payload during packing, and to pack the payload with care. The payload will also be packed to be pushed out before the recovery harness and main parachute by the black powder in the charge wells. The initial separation should deploy the payload, but the main parachute will be kept folded by a Jolly Logic Chute Release device. The delay on the deployment of the main parachute will allow for the payload to move away from the launch vehicle and help avoid entanglement with the main parachute.

A potential hazard to the safe recovery of all sections of the rocket is the tangling of the parachutes with the fire protective blanket. This could cause a higher than expected ground hit velocity and damage the launch vehicle and payload. This will be avoided by securing the fire protective blanket a distance away from the connection point of the parachutes.

Another recovery challenge is ensuring that the airframe is undamaged by the sudden deployment of the parachutes. The plan to avoid damaging the airframe is to use U-bolts with mounting plates to disperse the force put on the bulkheads by the recovery harness. The recovery harness will also be significantly longer then the launch vehicle so that independent sections do not collide during descent.

5. STEM Engagement

Education in science, technology, engineering, and math (STEM) is vital to the development of a better understanding of the way the world works. It is important for STEM knowledge to develop among all different kinds of people. The Swamp Launch Rocket Team aims to educate students in the community on rocketry and encourage them to further develop their knowledge of STEM topics.

5.1 Engagement at Local Schools

The Swamp Launch Rocket Team works with Alachua County Public Schools in order to engage with students and provide opportunities to advance STEM learning in the community. The team aims to provide lessons on physics and engineering in an accessible way in addition to hands-on activities that reinforce understanding and promote creativity and engagement.

In both virtual and in-person events, the younger students will accomplish similar activities. The activities for younger students, ages 5-8, will include arts and crafts activities like designing a rocket or a constellation-related project. Students will individually work to design a rocket that is able to withstand a set of provided conditions. They will be able to draw or glue on the different parts of their rocket with the supplies on hand. Students will be able to receive feedback on their design from Swamp Launch Rocket Team members before presenting their designs and explaining their design choices. The activity will help advance their creativity and their understanding of engineering design.

During virtual events, the older students, ages 8-18, will engage in a space simulator in order to learn some of the more advanced details of rocketry and space. Due to the online format, simulations are the best option for explaining rocketry and space topics in a more in-depth manner. In addition, the use of a simulation will engage the students as they are able to learn through trial and error. This activity will promote a better understanding of rocketry and engineering.

In the event of in-person events, the older students will design and build bottle rockets. Before the activity, the lecture component of the event will be used to teach students about rocketry and provide background information on the design of bottle rockets. The students will work to construct their own bottle rockets with the assistance of Swamp Launch Rocket Team members. The hands-on nature of this activity will help strengthen their understanding of the information presented during the lecture. After the students finish building their rockets, they will be launched outside using a pump that will increase the pressure within the bottle in order to provide thrust for the rocket. Their rockets will be evaluated overall based on factors like their maximum height and flight time. This project provides the students with the opportunity to apply their knowledge from the lecture to engineering design and accomplish a specific goal.

5.2 Engagement at the University of Florida

The Swamp Launch Rocket Team will promote engagement within the University of Florida by working with other organizations and by hosting regular General Body Meetings.

The team plans to use joint events with other organizations to give presentations on rocketry and promote a better understanding among interested students. For example, the team will collaborate with the American Institute of Aeronautics and Astronautics (AIAA) at functions in order to teach students about engineering and rocketry. In addition to providing general information on rocketry, the Rocket Team will provide relevant examples in the form of past rockets built by the team.

The General Body Meetings (GBMs) are regularly scheduled technical meetings that the Rocket Team will use as an opportunity to educate members on different aspects of rocketry while also providing updates on the team’s overall progress. Furthermore, the GBMs will allow members to ask questions and advance their knowledge and of rocketry.

6. Project Plan

6.1 Development Timeline

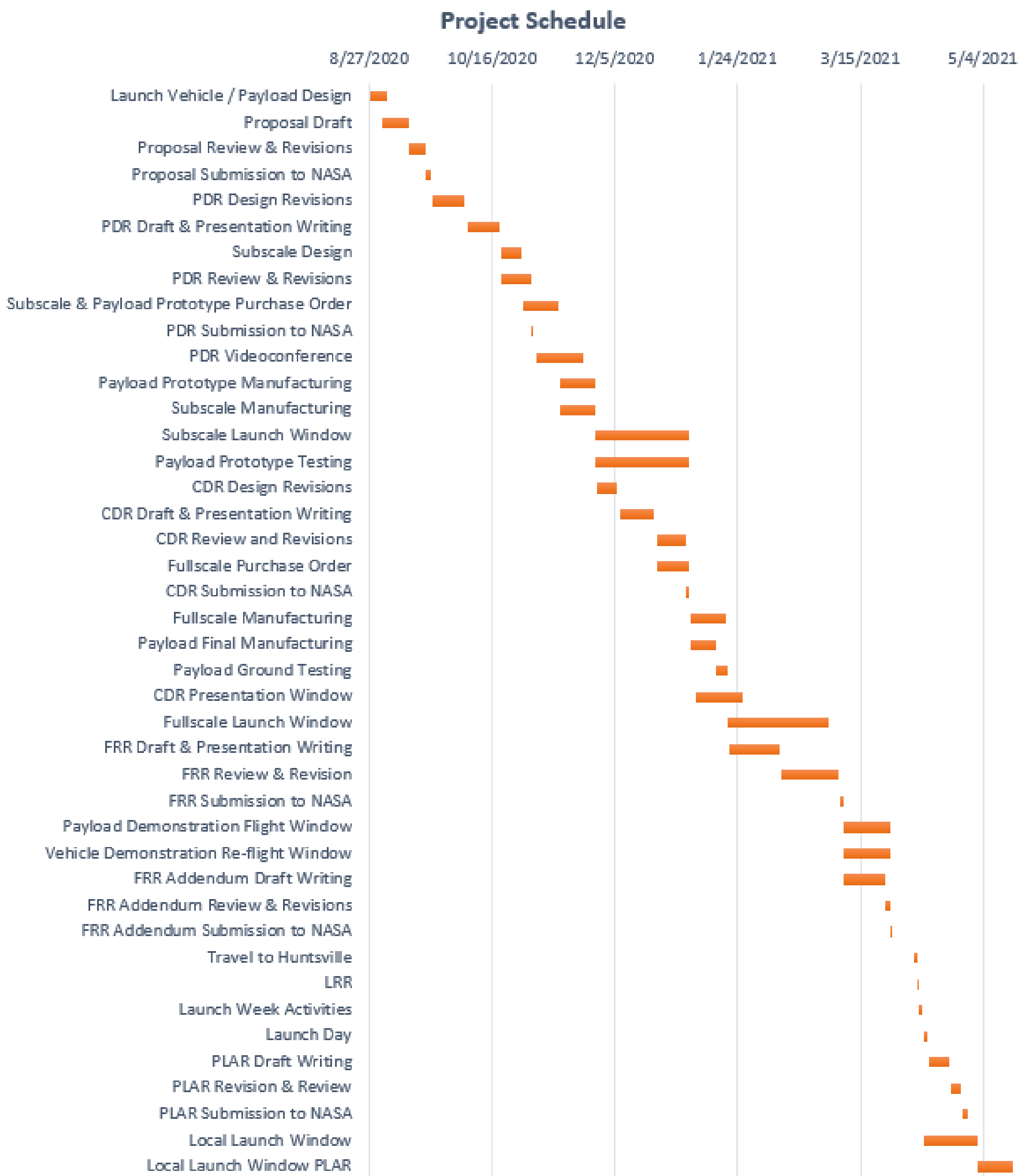

Figure 38 Project Schedule Gantt Chart

The team will adhere to the timeline displayed in Figure 38. Each project development period is divided approximately evenly into three phases: design revision, report drafting, and report review and revision.

The manufacturing of a prototype payload will begin on November 13th, 2020 to allow time for testing and associated modifications prior to the submission of the critical design review.

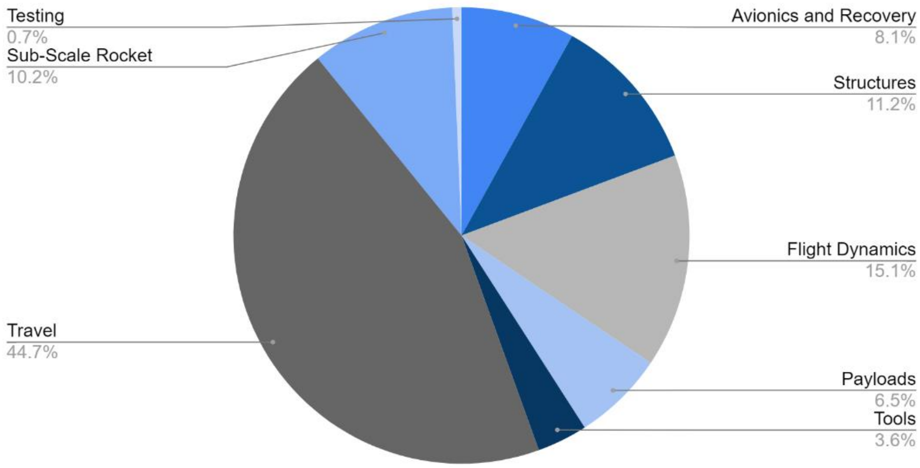

Figure 32 Project Budget Breakdown

6.2 Detailed Budget

The team's expected budget for the 2020-2021 season is approximately $9,000 as seen in Table 23. This budget is based off of a total of all estimated component and travel costs, including components needed for the full-scale rocket design and the subscale rocket build. It also accounts for changes that may occur from any necessary changes and testing or unexpected damages. The components are broken down by rocket subgroup (as seen in Table 24) and listed in Tables 25-30. Travel costs are also included in the budget accounting for road travel and hotel stays for the competition and launches, although this amount may be deemed unnecessary and will be adjusted as needed (given the current pandemic).

Category	Total Cost ($)
Full-Scale Rocket	3,665.24
Travel	4000.00
Subscale	913.69
Testing	59.13
Tools	320.40
Total:	8,958.46

Table 24 Total Project Cost

Subgroup	Total Cost ($)
Structures	1,006.67
Avionics and Recovery	721.87
Flight Dynamics	1,356.31
Payloads	580.39
Total:	3,665.24

Table 25 Full-scale Budget Breakdown and Total

Component	Quantity	Unit Cost ($)	Total Cost ($)
JB Weld (10oz)	4	13.95	55.80
Rocketpoxy (2 qt)	2	65.00	130.00
Shear Pins	4	3.22	12.88
Plastic Rivets	3	3.86	11.58
Bluetube Airframe	3	56.95	170.85
Bluetube Coupler	2	55.95	111.90
Sandpaper (120 grit)	2	4.98	9.96
Sandpaper (220 grit)	2	4.98	33.98
Sealer	1	33.98	33.98
Fin Slots – CNC Custom Service	1	16.00	16.00
CNC Plywood Coupler Bulkhead	5	7.50	37.50
Plywood (1/2" and 1/4")	Inventory	0.00	0.00
CNC Cut Plywood Centering Ring	5	7.50	37.50
Bluetube Motor Tube	1	29.95	29.95
Fiberglass Metal Tipped Nosecone	1	111.96	111.96
Spray Paint and Primer	4	15.00	60.00
Rail Buttons	2	11.17	22.34
G10 Fiberglass Sheet (3/16 - 24" x24")	3	48.17	144.51
Total:			1,006.67

Table 26 Structures Component Estimates

Category	Quantity	Unit Cost ($)	Total Cost ($)
Main Parachute	1	135.00	135.00
Payload Parachute	2	70.00	140.00
Recovery Harness	2	39.00	78.00
Altimeter	2	69.95	139.90
U-Bolt	4	0.96	3.84
Eyebolt	Inventory	0.00	0.00
Threaded rod	2	0.75	1.50
Charge Well	2	1.00	2.00
Main Parachute Protector	1	11.50	11.50
Drogue Parachute Protector	1	7.35	7.35
Payload Parachute Protector	1	7.35	7.35
Snap Swivel	3	3.00	9.00
Quick Link	5	1.35	6.75
Keylock Switch	2	1.35	2.70
9V Battery Connector	2	1.00	2.00
9V Battery	1	7.98	7.98
Altimeter Programming Board	1	29.95	29.95
Ejection Charge Terminals	2	3.55	7.10
Jolly Logic Chute Release	1	129.95	129.95
Total:			721.87

Table 27 Avionics and Recovery Component Estimates

Category	Quantity	Unit Cost ($)	Total Cost ($)
Motor	3	224.99	674.97

Motor Retainer	1	72.22	72.22
Motor Forward Enclosure	1	111.82	111.82
Motor Casing	1	429.61	429.61
Thrust Plate	1	59.22	59.22
Ballast Clay	1	8.47	8.47
Total:			1,356.31

Table 28 Flight Dynamics Component Estimate

Category	**Quantity**	**Unit Cost ($)**	**Total Cost ($)**
Raspberry Pi	1	45.51	45.51
PiCam360 Panoramic Camera	1	75.00	75.00
Accelerometer/Altimeter	1	35.00	35.00
Servo	4	42.98	171.92
Servo PWM	Inventory	0.00	0.00
USB Connector	1	10.00	10.00
Battery	1	22.99	22.99
Battery Balancer/Charger	1	22.99	22.99
Dupont Wires	1	7.00	7.00
Xbee Radio	2	29.99	59.98
GPS Unit	1	40.00	40.00
Steel Sheet Metal	1	78.00	78.00
Aluminum for legs	1	12.00	12.00
Ground Station Processor	Inventory	0.00	0.00
Parachute Attachment Hardware u/eye bolts	Inventory	0.00	0.00
Steel or Aluminum Rod for leg reinforcements	Inventory	0.00	0.00
Spherical Lens	Inventory	0.00	0.00
Total:			580.39

Table 29 Payload Component Estimate

Component	**Quantity**	**Unit Cost ($)**	**Total Cost ($)**
Dremel Set and Attachments	1	99.00	99.00
Drill Set	1	49.00	49.00
Jigsaw	1	62.98	62.98
X-Acto Knife	2	5.10	10.20
Precision Screwdriver Set	1	9.99	9.99
Jig Saw Blade for Cutting Ceramic	2	6.97	13.94
HSS End Mill – 2 Flute, 1/8" Mill D, 3/16" Shank D	1	19.67	19.67
HSS End Mill – 2 Flute, 1/8" Mill D, 3/16" Shank D	1	19.67	19.67
Frog Tape	1	24.97	24.97
Heat Shrink Tubing	1	10.98	10.98
Total:			320.40

Table 30 Tool List Estimates

Category	Quantity	Unit Cost ($)	Total Cost ($)
Spray Paint and Primer	2	15.00	30.00
U-Bolt	4	0.96	3.84
Threaded Rod	2	0.75	1.50

Charge Well	2	1.00	2.00
Snap Swivel	3	3.00	9.00
Quick Link	5	1.35	6.75
Ejection Charge Igniter	2	17.95	35.90
Aerotech 38mm HP SU DMS Motor-J270W-14A	1	86.00	86.00
Arming Switch	2	1.35	2.70
Recovery Harness	2	39.00	78.00
9V Battery	2	7.98	15.96
Motor Retainer	1	34.44	34.44
Quick Link	5	1.35	6.75
Total:			913.69

Table 31 Subscale Component List

6.3 Funding Plan

This project is primarily funded by the University of Florida's Department of Mechanical and Aerospace Engineering. The team is also being sponsored by Nuclear Propulsion Officer Candidate Program as well as ANCORP, and is actively seeking more corporate sponsorships by having weekly meetings specifically dedicated to reaching out to potential sponsors. The sponsorships range from $250 to $1,000. Funding will first be received by our advisors Dr. Lind and Dr. Niemi and will be allocated to our group. The team will also be starting an alumni program to stay in touch with dedicated members who have graduated and encourage them to stay involved and support the future of the group.

6.4 Sustainability

Funding will be provided primarily by the University of Florida's Department of Mechanical and Aerospace Engineering Department, which has reliably provided funding over the past several years. Additional funding will be provided by the University of Florida's Student Government, as well as corporate sponsorships. The team will continue to seek out corporate sponsorships throughout the year.

The team will maintain relationships with local schools and businesses. Online zoom meetings will be organized with students and teachers in Alachua County Public Schools. When acceptable, live presentations and activities may be held to further educate students about model rocketry. Presentations and sponsor packets will be prepared to create and maintain relationships with local businesses. A YouTube channel will also be created to record and post updates of the team for students and businesses to observe what Swamp Launch is capable of.

Team members will be recruited through the posting of virtual flyers advertising the team. Flyers will include meetings and links for the team's social media where updates are regularly posted. Social media will be used to promote events and general body meetings. Swamp Launch will further extend its reach by presenting for various technical societies including the American Institute of Aeronautics and Astronautics (AIAA). Updates will be sent out biweekly to students within the Wertheim College of Engineering through the Benton Engineering Council (BEC) and a team hosted Newsletter. Updates will also be posted on the UF Canvas page for all MAE students through MAE Undergrad Advising.

7. Conclusion

The team is confident that it is capable of completing all challenges outlined in the NASA Student Launch 2021 handbook. The team has retained access to all key manufacturing facilities and is fully able to conduct all design and report work virtually. The team will continue to develop its payload system and launch vehicle design throughout the project to overcome any technical challenges and ensure mission success.