Gator Locator

NASA Student Launch 2022 Proposal

University of Florida
Swamp Launch Rocket Team
939 Center Dr, Gainesville, FL 32611
MAE-A 324
September 20th, 2021

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1. General Information

1.1 Adult Educators

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1.2 Student Team Leader

Project Manager:
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1.3 Safety Officer

Primary:
Jason Rosenblum
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Secondary:
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1.4 Student Leaders

Joel Perez
Swamp Launch President
4th year Mechanical and Aerospace Engineering

Mikaela De Gracia
Vice President – External
3rd year Mechanical and Aerospace Engineering

Bryce Behm
Vice President – Internal
4th year Mechanical Engineering

Ireland Brown
Treasurer
4th year Mechanical and Aerospace Engineering

Megan Wnek
Project Manager
3rd year Aerospace Engineering

Jason Rosenblum
Safety Officer
3rd year Mechanical and Aerospace Engineering

Raymond Pace
Safety Officer
4th year Industrial and Systems Engineering

Margaret Wielatz
Structures Lead
3rd year Mechanical and Aerospace Engineering

Collin Larke
Avionics and Recovery Lead
3rd year Aerospace Engineering

Brida Gibbons
Testing Lead
3rd year Aerospace Engineering

Krusha Patel
Flight Dynamics Lead
3rd year Mechanical and Aerospace Engineering

Gabriella Peburn
Educational Engagement
2nd year Mechanical and Aerospace Engineering

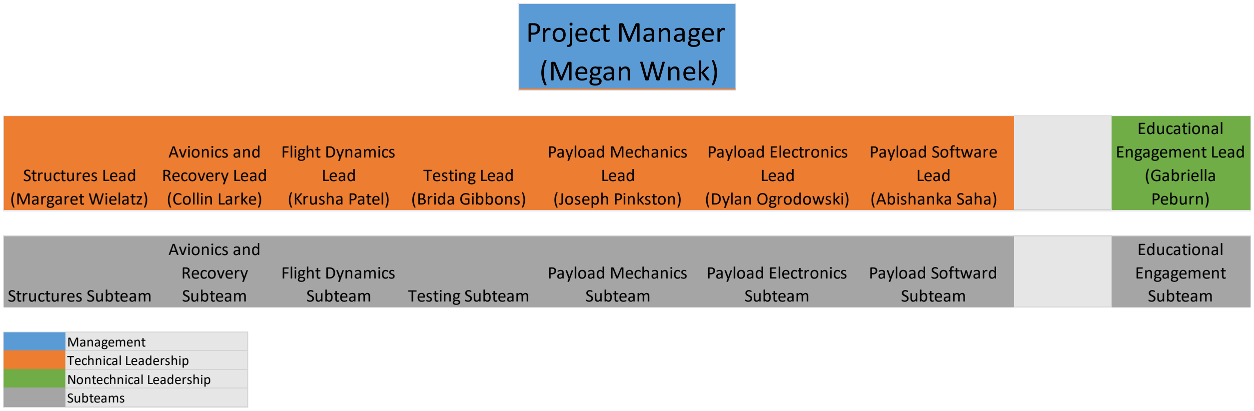
Joseph Pinkston
Payload Mechanics Lead
3rd year Mechanical and Aerospace Engineering

Dylan Ogrodowski
Payload Electronics Lead
3rd year Electrical Engineering

Abishanka Saha
Payload Software Lead
2nd year Computer Science and Economics

1.5 Project Organization

Swamp Launch Rocket Team is organized into 7 technical subteams plus a nontechnical team committed to educational engagement (Figure 1). The subteams are each overseen by a technical Lead, and are designated as follows: Structures, Avionics and Recovery, Flight Dynamics, Testing, Payload Mechanics, Payload Electronics, and Payload Software. The team of technical and nontechnical Leads is overseen by the Project Manager. Swamp Launch estimates that approximately 5 members per subteam will be actively committed to the completion of the project, resulting in a total of approximately 50 students.



Project Manager (Megan Wnek)

Structures Lead (Margaret Wielatz)	Avionics and Recovery Lead (Collin Larke)	Flight Dynamics Lead (Krusha Patel)	Testing Lead (Brida Gibbons)	Payload Mechanics Lead (Joseph Pinkston)	Payload Electronics Lead (Dylan Ogrodowski)	Payload Software Lead (Abishanka Saha)		Educational Engagement Lead (Gabriella Peburn)
Structures Subteam	Avionics and Recovery Subteam	Flight Dynamics Subteam	Testing Subteam	Payload Mechanics Subteam	Payload Electronics Subteam	Payload Softward Subteam		Educational Engagement Subteam

🟦	Management
🟧	Technical Leadership
🟩	Nontechnical Leadership
▨	Subteams

Figure 1: Swamp Launch team structure

1.6 NAR/TRA Section and Mentor

The Tampa Tripoli Rocketry Association (TRA #17) is a launch site in Tampa Bay, Florida that hosts monthly launches within 150 miles of the University of the Florida. This launch site will serve as the primary launch site for completing all Project Milestones. As a backup launch site, Tripoli Fort Myers (TRA #19) is an additional launch site that provides launches on alternate dates and is still within a reasonable distance from the University in LaBelle, FL. Finally, the Spaceport Rocketry Association (NAR #342, Tripoli #73) in

Palm Bay, FL is available as a launch site if weather conditions at the previous two launch sites are not acceptable for safe flight.

The team mentor will be Jimmy Yawn. Mr. Yawn is a Level 3 certified NAR member and will provide launch assistance for the team on site, as well as oversee the design.

1.7 Hours

Approximately 293.5 hours were spent on the design, planning, writing, and editing of the submitted proposal (Table 1).

Proposal hours: 8/18-9/20				
Subteam	**Design/Planning Hours**	**Meeting Hours**	**Writing Hours**	**Total**
Project Management	4	14.5	14	**32.5**
Structures	7	3	10	**20**
Avionics and Recovery	3	5	7	**15**
Flight Dynamics	14	3	4	**21**
Payloads - Mechanical	10	8	8	**26**
Payloads - Electrical	12	8.5	13	**33.5**
Payloads - Software	10	7.5	4	**21.5**
Testing	4.5	10	7	**21.5**
Safety	3	2	10	**15**
Educational Engagement	0.5	3	1.5	**5**
Treasury	0	2	2	**82.5**
Total	**68**	**66.5**	**80.5**	**293.5**

Table 1: Proposal hours

2. Facilities and Equipment

2.1 Student Design Center

The Student Design Center (SDC) will be the team's primary manufacturing facility. The SDC consists of the team's designated work area, storage space, and manufacturing tools (Figure 2). The team has access to a roll-in bandsaw, drill press, and vertical bandsaw (Figure 3). One of the team's safety officers must be present for any use of the machines in the SDC. Apart from this accessibility restriction, the SDC is available to students with keycard access at any time.

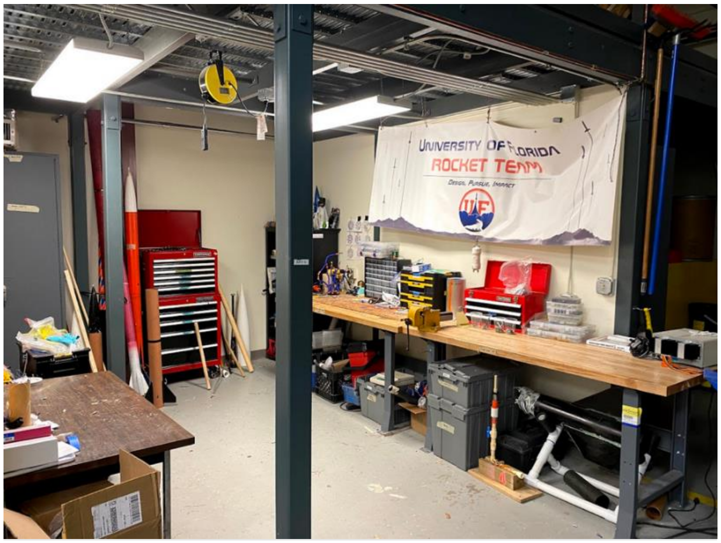


Figure 2: Student Design Center Bay 5

Figure 3: Machines in the SDC

2.2. University of Florida Mechanical and Aerospace Engineering Building C

2.2.1 Mechanical Design Lab

The Mechanical Design Lab will act as a second workshop and meeting area (Figure 4). The lab provides the team access to milling machines, engine lathes, 3D printers, and an assortment of power tools.

The team has access to the Mechanical Design Lab on weekdays after 6:30 pm. The presence of a lab teaching assistant is required in order to use the machines.

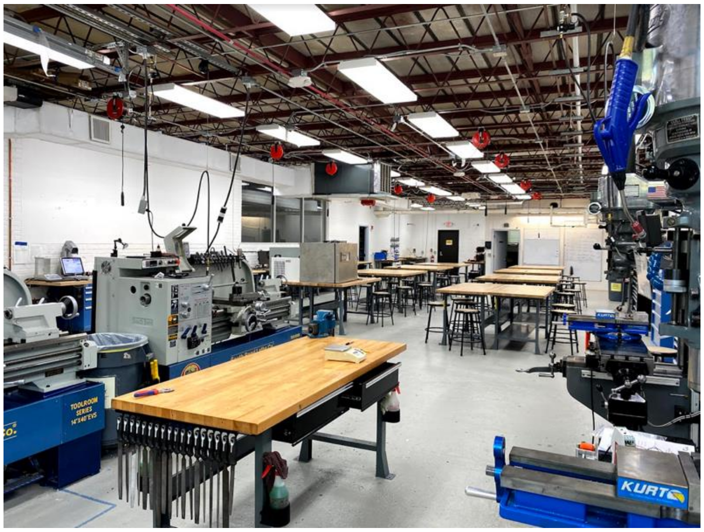


Figure 4: MAEC-010

2.2.2 Student Shop

The Student Shop provides the team access to a variety of machines including bandsaws, milling machines, and a water jet (Figure 5). The team has access to the Student Shop on Tuesdays and Thursdays from 8:30 am to 6:00 pm. The presence of a design lab teaching assistant is required when using any of the machines.

Figure 5: Abrasive water jet room

2.3 Additional Equipment

In addition to the equipment highlighted above, the team will also have access to additional equipment and supplies necessary for manufacturing the launch vehicle. Equipment the team knows will be utilized is outlined below (Table 2). Additional smaller tools will also be required and are available in the team's facilities.

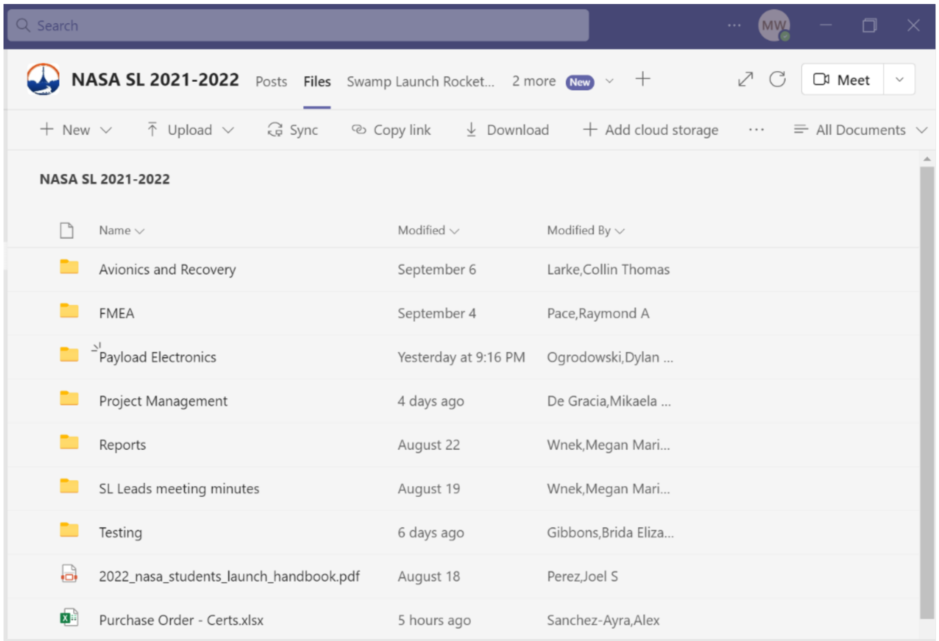
Required Equipment	Purpose	Accessibility
Power drills	Body tube manufacturing	Available in the SDC and MAE-C
Dremel	Body tube and fin manufacturing	Available in MAE-C
Assorted screwdrivers	Launch vehicle and payload manufacturing	Available in the SDC and MAE-C
Soldering iron	Payload manufacturing	Available in the SDC
Sandpaper	Launch vehicle manufacturing	Available in the SDC

Table 2: Required Equipment

2.4 Virtual Collaboration Platforms

2.4.1 Microsoft Teams

Microsoft Teams is a communication and file sharing platform (Figure 6). The team will utilize Microsoft Teams for budgeting, scheduling, and collaborating on Project Milestones. All participating team members will have access to Microsoft Teams through the University of Florida and will be able to request access to the team's channel. Channel requests will be approved by the Project Manager and Leads team.



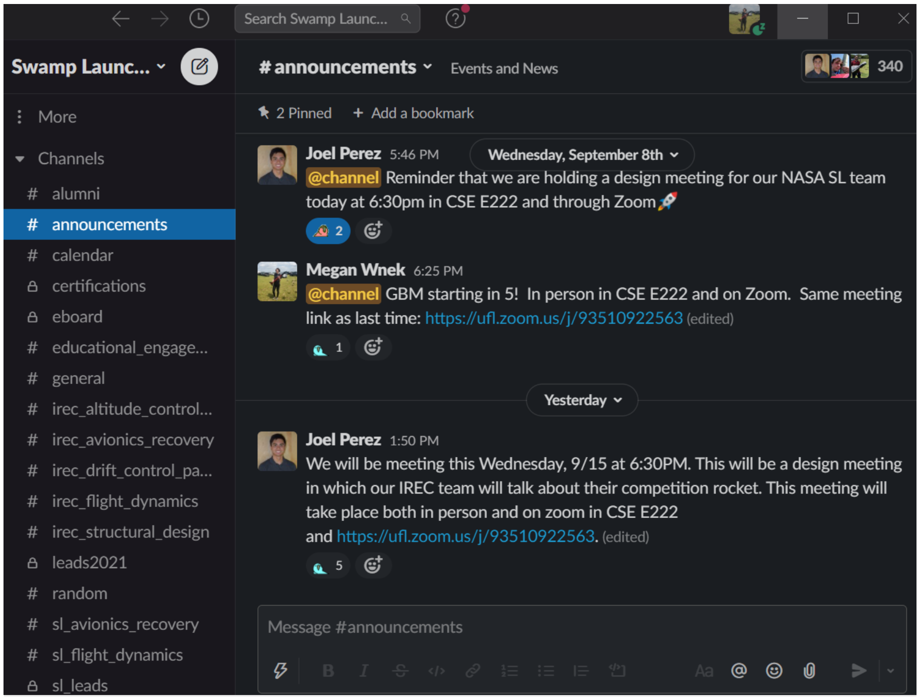
NASA SL 2021-2022

Name	Modified	Modified By
Avionics and Recovery	September 6	Larke,Collin Thomas
FMEA	September 4	Pace,Raymond A
Payload Electronics	Yesterday at 9:16 PM	Ogrodowski,Dylan ...
Project Management	4 days ago	De Gracia,Mikaela ...
Reports	August 22	Wnek,Megan Mari...
SL Leads meeting minutes	August 19	Wnek,Megan Mari...
Testing	6 days ago	Gibbons,Brida Eliza...
2022_nasa_students_launch_handbook.pdf	August 18	Perez,Joel S
Purchase Order - Certs.xlsx	5 hours ago	Sanchez-Ayra,Alex

Figure 6: Microsoft Teams

2.4.2 Slack

Slack is a communication platform that allows participants to be organized into designated channels (Figure 7). The team will utilize Slack for all communication across the entire project, including announcing General Body Meetings and Educational Engagement events. It will also serve as the primary method of communication between the Project Manager and the Leads team, as well as the subteam Leads and their designated members.



Joel Perez 5:46 PM
@channel Reminder that we are holding a design meeting for our NASA SL team today at 6:30pm in CSE E222 and through Zoom 🚀

Megan Wnek 6:25 PM
@channel GBM starting in 5! In person in CSE E222 and on Zoom. Same meeting link as last time: https://ufl.zoom.us/j/93510922563 (edited)

Joel Perez 1:50 PM
We will be meeting this Wednesday, 9/15 at 6:30PM. This will be a design meeting in which our IREC team will talk about their competition rocket. This meeting will take place both in person and on zoom in CSE E222 and https://ufl.zoom.us/j/93510922563. (edited)

Figure 7: Swamp Launch Rocket Team Slack Channel

2.4.3 Zoom

Zoom Cloud Meetings is a video teleconferencing program. The team will utilize Zoom to meet virtually when working on Project Milestones or other aspects of the project that do not require meeting face-to-face in the facilities. Additionally, Zoom meetings will be provided as an alternative method for attending most General Body, Leads, and subteam meetings to allow the maximum number of members to participate while maintaining a safe environment.

2.4.4 SolidWorks Product Data Management (PDM)

SolidWorks PDM is a file management system that allows the team to share and collaborate on SolidWorks part, drawing, and assembly files. SolidWorks PDM will be utilized across the entire project and within subteams. SolidWorks PDM will be available to all members through the University of Florida.

2.5 Software

2.5.1 OpenRocket

OpenRocket is a model rocket simulator (Figure 8). OpenRocket will be used to model the complete launch vehicle including all materials and masses. Additionally, simulations will be utilized to select the motor and recover methods. OpenRocket is available for free and will be accessible to all team members.

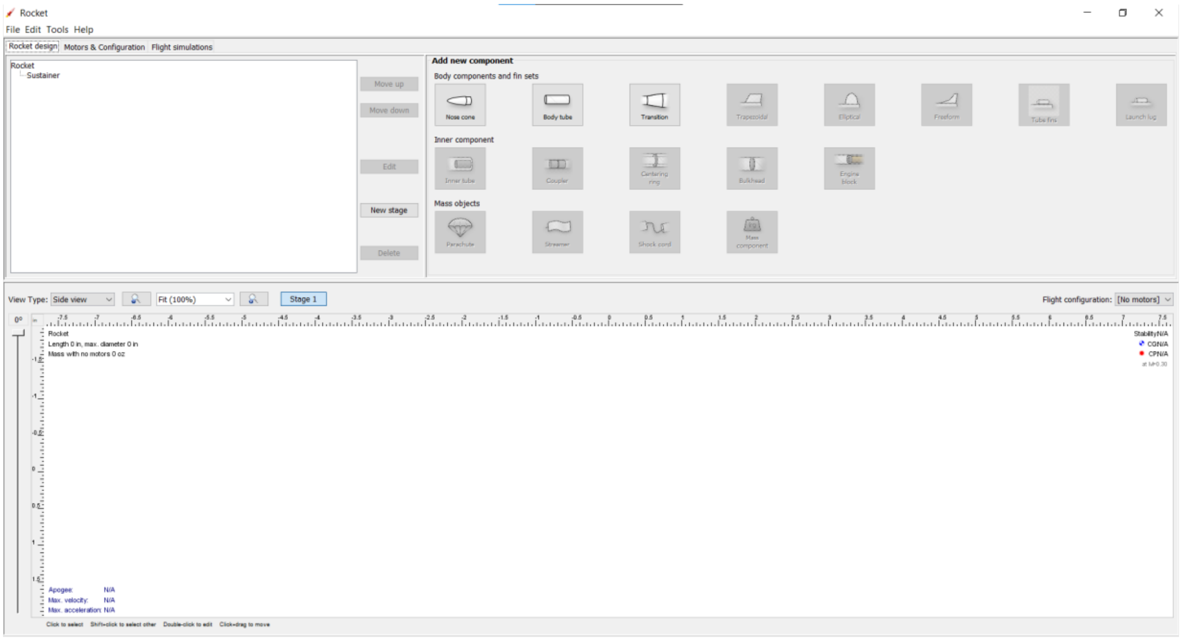


Figure 8: OpenRocket Interface

2.5.2 SolidWorks 2021

SolidWorks 2021 is the latest version of SolidWorks, a computer aided 3D design system (Figure 9). SolidWorks will be utilized for modeling all structural components of the project. Additionally, SolidWorks drawings will be utilized to create references for manufacturing. SolidWorks 2021 will be available to all members through the University of Florida.

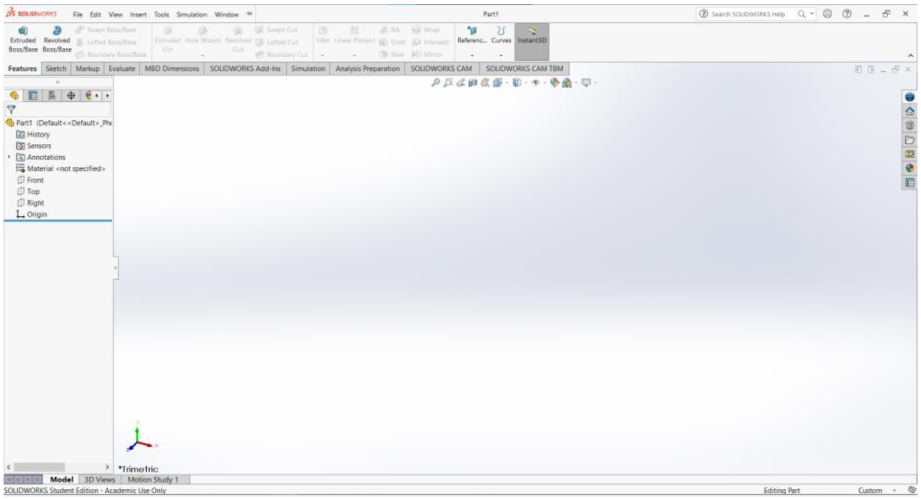
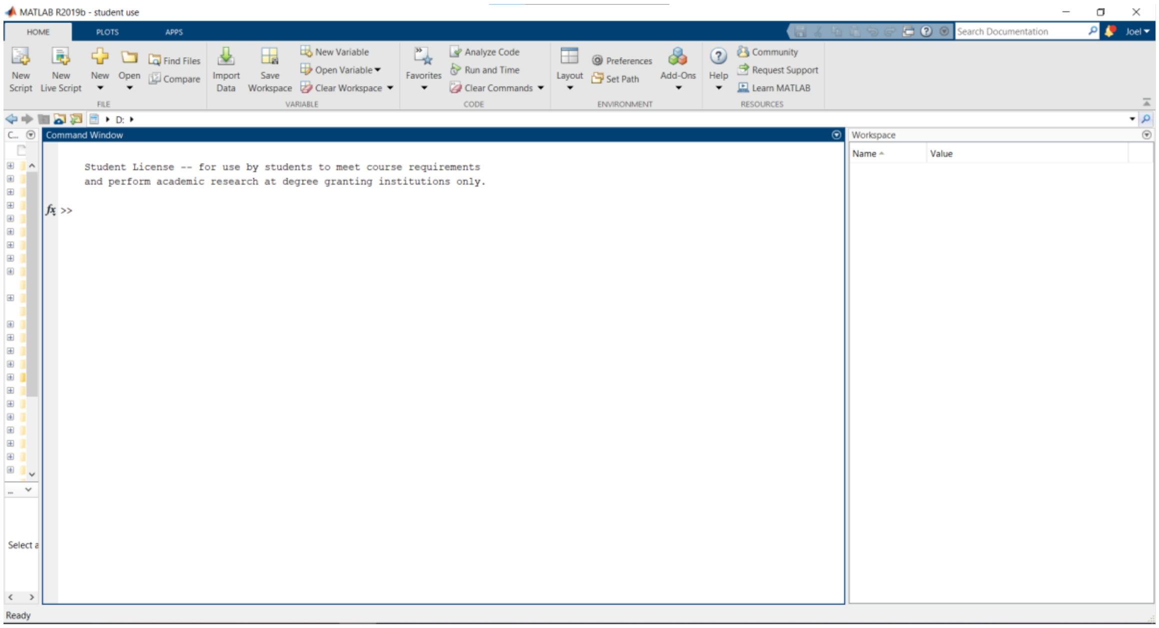


Figure 9: SolidWorks Interface

2.5.3 MATLAB

MATLAB is a programming and computing environment (Figure 10). MATLAB will be used primarily by the Flight Dynamics subteam to form simulations and analyze data. MATLAB is available to all team members through the University of Florida.



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Student License -- for use by students to meet course requirements
and perform academic research at degree granting institutions only.

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Figure 10: MATLAB Interface

3. Safety

The team will prioritize safety throughout the competition. There are inherent risks due to the nature of this project. This section details the measures the team has put in place to ensure that every team member takes an active part in mitigating risk and is aware of potential hazards.

A safety plan has been developed that covers all aspects of project activities, including design, assembly and manufacturing, testing, and launch attempts. The safety plan also outlines the responsibilities of the Safety Officers and Safety Stewards. The entire team has been briefed on the current safety plan through meetings hosted by the Leads. Any updates to the safety plan will be communicated via the team Slack channel and through additional meetings hosted by the Leads or the Safety Officers.

3.1 Safety Team Responsibilities

The safety team is led by Safety Officers Jason Rosenblum and Raymond Pace. It will also be comprised of Safety Stewards certified by the University of Florida Mechanical and Aerospace Engineering (MAE) department.

3.1.1 Safety Officer Responsibilities

The Safety Officers will 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 they will use the role to fulfill this responsibility. The Safety Officers have 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 Officers 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
        i. Enforce adherence to machine and tool standard operating procedures
    c. Supervision of launch vehicle and payload assembly
        i. Enforce proper launch-day assembly procedure
    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
        iii. NAR/TRA mentor shall also supervise launch day procedure
    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
        iii. NAR/TRA mentor shall also supervise launch day procedure
    h. Supervision of recovery activities after launch attempt
        i. Close observation of launch vehicle descent and landing
        ii. Enforcement of 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 Officers shall verify the team has developed procedures for actively mitigating potential hazards. The Officers shall also enforce the implementation of the procedures.
3. The Safety Officers 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 Officers 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 will assist the Safety Officers with the supervision of team members during work in the Student Design Center. This will 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 a Safety Officer, but at least two Safety Officers or Safety Stewards will always perform supervision together. New Safety Stewards with less experience supervising relevant processes will be aided by a Safety Officer. Additionally, the Safety Stewards will have multiple methods of quick communication with the Safety Officers, such as phone or Slack direct message. The official responsibilities of the Safety Stewards have been provided by the MAE Facilities Operations Specialist, Daniel Preston.

1. Safety Stewards shall enforce all protocols outlined in the SDC's 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. Safety Stewards must have a strong understanding of each machine at the SDC.
3. Safety Stewards shall train students on machines, administer knowledge quizzes, and sign authorization sheets to allow future supervised equipment use.
4. Safety Stewards shall verify students are trained and authorized on each machine they use.
5. Safety Stewards shall set up each approved equipment each time a user works on a new part.
6. Safety Stewards shall keep watch of powered machinery as it is being used.
7. Safety Stewards shall manage access to common-use tools via the Material & Tool Use List.
8. Safety Stewards shall ensure students clean machines after each use and accept responsibility for stations not up to SDC cleaning standards.
9. Safety Stewards shall ensure students keep the team's bay neat and clean.

3.2 NAR/TRA Safety Procedures

The following measures will be taken as a team to ensure compliance with the NAR High Power Rocket Safety Code

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 25-foot rule will be followed at all times, meaning the launch vehicle motor will be kept at least 25 ft. away from any smoke, flames, or other open heat sources.
4. The launch vehicle will use an electrical launch system
    a. Electrical motor igniters will be installed in the motor after setup on launch pad
    b. Launch system will use a 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 beyond 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. A longer rail will be used 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 minimum 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 individuals not participating in launch activities. On its smallest dimension, the launch site will be at least as large as one-half of the maximum altitude to which rockets are allowed to be flown at that site

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 a minimum of 1500 ft. away from occupied buildings or public highways with traffic flow exceeding 10 vehicles per hour.
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. The recovery system will be designed with backup separation charges to deploy the parachutes in case of primary charge failure.
13. The Safety Officers 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.

3.3 Hazard Recognition and Accident Avoidance

3.3.1 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 hazards analysis, failure mode and effects analysis, and environmental hazards analyses. The assessment will be updated and amended with more hazards and mitigation strategies based on project developments. A testing plan has been established to mitigate hazards to the team (Appendix A, Table 30-Table 31).

3.3.1.1 Personnel Hazards Analysis

The personnel hazards analysis evaluates 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 ‘I’ of each risk by its likelihood value ‘L’ (Table 3Table 4).

	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 3: 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 4: RAC score chart

3.3.1.1.1 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 SDC (Table 5).

Hazard	Cause	Effect	I	L	Score	Mitigation Strategy
Cleaning agent contacts eyes	Cleaning agent sprayed into eyes	Eye irritation or blindness	4	4	16	Use of proper PPE per MSDS 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, blindness	7	1	7	Use of proper PPE per MSDS Keep lid closed when not in use
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	Use of proper PPE per MSDS 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	Use of proper PPE per MSDS Use in well-ventilated area
Grease contacts eyes	Spills, touching substance then face	Eye irritation, blindness	5	1	5	Use of proper PPE per MSDS
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
Spray paint contacts skin/eyes	Sprayed into eyes	Eye irritation, blindness	5	5	25	Use of proper PPE per MSDS
	Sprayed onto skin	Skin irritation	2	5	10	Use of proper PPE per MSDS
Spray paint inhalation	Prolonged exposure to toxic fumes	Dizziness	4	4	16	Use of proper PPE per MSDS Use in well-ventilated area
		Respiratory irritation	4	4	16	Use of proper PPE per MSDS Use in well-ventilated area
Epoxy contacts skin	Spilled, handled without PPE	Skin irritation	5	6	30	Use of proper PPE per MSDS

Table 5: Chemical hazard analysis

3.3.1.1.2 Physical Hazards

Physical hazards are posed by team activities such as manufacturing processes (Table 6), launch preparation, and launches (Table 7).

3.3.1.1.2.1 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 and hits person	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
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 6: Manufacturing hazard analysis

3.3.1.1.2.2 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 failed launch attempt	Hearing damage or burns	8	1	8	RSO removes safety interlock switch, team waits 60 seconds to approach launch vehicle on launchpad
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
	Recovery harness 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 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
	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
Ballistic launch vehicle hits person	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 trajectory mid-flight	Severe impact injury	9	4	36	Verify launch vehicle design is sufficiently stable before launch Maintain proper stand-off distance 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 dispel electric charge by contact with metal post/shelf prior to handling black powder
	Ejection charge prematurely ignites during testing	Skin laceration and severe burns	7	3	21	Verify proper wiring of charges and altimeters Remove voltage source until team members are safe distance away
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 7: Launch hazard analysis

3.3.1.1.3 Biological Hazards

Biological hazards are posed by living organisms, such as bacteria and wildlife (Table 8).

Hazard	Cause	Effect	I	L	Score	Mitigation Strategy
Spread of COVID-19	Not wearing a facemask	Member infected with COVID-19	7	8	56	Follow university policy regarding facemask use
	Not maintaining 6 feet of distance	Member infected with COVID-19	7	8	56	Limit number of members in SDC
	Not sanitizing hands frequently	Member infected with COVID-19	7	5	35	Provide accessible sources of hand sanitizer

Table 8: Biological hazard analysis

3.3.1.2 Failure Mode and Effects Analysis

Failure mode and effects analysis (FMEA) evaluates the impact of component failure on the launch vehicle and its ability to complete the mission. The completed FMEAs include: Structures (Table 9), Payloads (Table 10Table 12Table 12), Avionics and Recovery (Table 13), and Flight Dynamics (Table 14). Three ratings are given to each failure mode to quantify the significance of the failure: severity, occurrence, and detection. Severity is rated from 1 to 10 where a rating of 1 means that the failure has no effect while a rating of 10 is a catastrophic failure. Occurrence is rated from 1 to 10 where a rating of 1 means that the failure has little to no chance of occurring while a 10 indicated it is incredibly likely to occur. Detection is rated from 1 to 10 where a 1 is a failure that has a high likelihood of detection while a 10 is a failure that has an extremely low likelihood of detection. A risk priority number (RPN) is calculated as the product of the ratings and will be used to inform the team where mitigation strategies are needed.

3.3.1.2.1 Structures

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					
Airframe and coupler	Contains the payload and vehicle hardware	Breaks	Manufacturing defect or poor transportation	Fails to contain payload and other internal components	Launch vehicle assembly fails	Launch vehicle is unrecoverable	10	3	3	90	Inspect launch vehicle before and after each launch
Fin Fillets	Epoxy keeps the fins attached to the aft airframe and motor tube assembly	Epoxy fails	Improper application	Launch vehicle loses stability	Uncontrolled flight	Launch vehicle drifts or moves uncontrollably, posing a hazard	8	2	4	64	Follow proper procedures for applying epoxy to fins
Centering ring	Keeps the motor centered within the airframe	Epoxy fails	Improper application	Launch vehicle loses stability	Uncontrolled flight	Launch vehicle drifts or moves uncontrollably	10	2	5	100	Inspect launch vehicle before and after each launch

Centering ring	Keeps the motor centered within the airframe	Breaks	Manufacturing defects	Launch vehicle loses stability	Uncontrolled flight	Launch vehicle drifts or moves uncontrollably	10	2	3	60	Inspect component for defects immediately after manufacturing
Bulkhead	Seals the ends of the couplers and protects internal components	Epoxy fails	Improper application	Fails to maintain sufficient seal	Ejection charges fail to separate vehicle	Parachutes are not deployed properly, or internal components are damaged	8	2	2	32	Inspect component for defects immediately after manufacturing
Bulkhead	Seals the ends of the couplers and protects internal components	Breaks	Manufacturing defects	Fails to maintain sufficient seal	Ejection charges fail to separate vehicle	Parachutes are not deployed properly, or internal components are damaged	8	2	2	32	Inspect launch vehicle before and after each launch
Shear pins	Keeps components connected before separation events	Early shearing	Excessive pressure from other events or excessive force from poor packing	Airframe and couplers separate	Premature parachute deployment	Reduced altitude, failure to complete payload mission	8	3	8	192	Test ejection charges and ensure that design adequately houses internal components so shear pins do not break prematurely (Tests #11, #12)
Shear pins	Keeps components connected before separation events	Do not shear	Insufficient ejection charge during separation event	Parachutes do not deploy	Rapid descent of launch vehicle	Launch vehicle impacts ground with high velocity	8	4	8	256	Test ejection charges to find sufficient amount of black powder for separation (Test #15)

Table 9: Structures FMEA

3.3.1.2.2 Payloads

3.3.1.2.2.1 Payload Mechanical

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					
3D Printed Sled	Protect and hold all electronics on the payload	Fracture	Stresses and vibrations	Cracking/breaking of plastic	Damaged electronics on payload	Loss of payload functionality	7	2	4	56	Extensive vibrations and stress tests to ensure structural integrity (Test #16)
Rail System	Secure payload in rocket	Fracture	Stresses and shearing	Cracking or shearing from payload	Payload comes loose during flight	Extensive damage to payload	8	3	2	48	Test for payload compatibility and flight performance (Test #16)

Table 10: Payload mechanical FMEA

3.3.1.2.2.2 Payload Electronics

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					
Lithium Battery	Provides power to electronic payload components.	Short circuit	Unintended connection between the positive and negative battery terminals.	High current flow within the battery, generating excessive heat.	Fire within the launch vehicle.	Loss of the payload and vehicle.	9	2	2	36	Ensure no loose or exposed metallic objects are present in the payload bay. Ensure power terminals are fully insulated.
Radio Transceiver	Provides communication between the payload and ground station.	Radio interference	Two or more transmitters transmitting on the same frequency simultaneously.	Data received by the ground station is altered.	The ground station is unable to correctly receive the vehicle’s landing location.	The ground station is unable to display the vehicle’s landing location.	1	1	1	1	Report all radio frequencies used to NASA officials to avoid overlap with other teams.
Radio Transceiver	Provides communication between the payload and ground station.	Loss of signal between transmitter and receiver.	Significant physical obstructions or great distance between the two devices.	The payload is unable to send or receive pings with the ground station.	The payload is unable to determine its distance from the ground station.	The payload is unable to determine or report its current grid location.	1	1	1	1	Ensure the antenna used has a sufficient range rating.
Digital signal processor	Controls payload peripherals and calculates vehicle’s grid location.	Momentary power loss	Poor connection between the battery terminals and control board and/or vehicle vibrations.	The microcontroller reboots and data stored in SRAM is lost.	Information regarding the vehicle’s flight state and position is lost.	The payload is unable to determine its current grid location.	1	2	6	12	Use power connectors with strong mechanical latches and include software power-loss recovery mechanisms.

Table 11: Payload electronics FMEA

3.3.1.2.2.3 Payload Software

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					
Digital signal processor	Controls payload peripherals and calculates vehicle’s grid location.	Software debug error	Unaccounted edge case in software, causing system to crash	The microcontroller reboots. Data may be lost or overwritten	Information regarding the vehicle’s flight state and position is lost.	The payload is unable to determine its current grid location.	1	4	6	24	Run testcases preflight, by simulating effect at different altitude and terrain

Table 12: Payload software FMEA

3.3.1.2.3 Avionics and Recovery

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					
Altimeter	Track and record the altitude of the rocket in order to accurately set off ejection charges to cause separation and parachute deployment for both main and drogue parachutes.	Instant detonation of ejection charges when powered on	Polarity of battery reversed due to improper installation.	Ejection charges detonating on the launch pad	Hot gasses and heavy rocket components moving near team member responsible for arming altimeter	Unable to launch, potential for burns and other injuries	10	3	1	30	Test wiring of altimeters before placing in rocket and attaching ejection charges (Test #10).
Altimeter	Track and record the altitude of the rocket in order to accurately set off ejection charges to cause separation and parachute deployment for both main and drogue parachutes.	Sudden power loss	Disconnection of battery due to inflight motion	Tracking and recording of altitude halts	Ejection charges do not go off, separation does not occur, and parachutes are not deployed.	The launch vehicle goes ballistic and descends uncontrolled	10	1	5	50	Altimeters and their power sources will be secured in the avionics bay. The secondary altimeter will have its own power source.
Altimeter	Track and record the altitude of the rocket in order to accurately set off ejection charges to cause separation and parachute deployment for both main and drogue parachutes.	Reverse wiring of ejection charges, (main ejection plugged into drogue terminal)	Mislabeling of terminals or improper programing of altimeter	Early deployment of main parachute	Main parachute is deployed at Apogee	Launch vehicle drifts out of launch field, potential for launch vehicle to be lost	5	2	3	30	Proper labeling of ejection charges and altimeter terminals.

Recovery Harness	The recovery harness tethers the separated sections of the launch vehicle together during descent.	Tearing of recovery harness	Melting of the harness due to ejection charge gasses, insufficient strength of recovery harness	The launch vehicle becomes two or more untethered sections	Sections disconnected from the parachutes will descend significantly faster than designed for	Partial damage to the launch vehicle	6	1	5	30	Protect the recovery harness from ejection gasses using the parachute protector, ensure the recovery harness is strong enough for the mission during design and testing.
Parachute Protector	Protects the parachute and recovery harness from hot ejection charge gasses during separation	Holes or tears in the parachute protector	Excessive use and age	Ejection gasses burn the parachute	Holes form or parts of the parachute are melted together	Faster than anticipated descent rate leading to damage to the launch vehicle	7	2	1	14	Inspection of the parachute protector before use
Main parachute	Slows the launch vehicle to an acceptable landing velocity	Tangled lines	Improper storage or packing of the parachute	Parachute does not fully inflate on descent	Faster than anticipated descent rate	Minimal to mild damage to the launch vehicle or payload	4	5	1	20	Inspection of parachute pre-packing and safety officer or avionics recovery lead pack the parachute for launch.
Main parachute	Slows the launch vehicle to an acceptable landing velocity	Holes or tears in parachute	Parachute protector failure or exposure to sharp edges	Holes or tears could increase in size and reduce the effectiveness of the parachute	Faster than anticipated descent rate	Damage to the launch vehicle or payload	6	2	1	12	Inspection of parachute before selecting it for use. Perform regular maintenance on parachutes
Drogue Parachute	Deploys at apogee to slow the initial descent of the launch vehicle	Failure of the drogue parachute to deploy and slow the initial descent	Holes in drogue, failure to deploy due to insufficient ejection charges, failed altimeter, torn recovery harness	Launch vehicle descends much faster initially until deployment of main parachute	Launch vehicle zippers or other components are damaged during main parachute deployment	Damage to the launch vehicle or payload	4	1	4	16	Properly pack the drogue parachute and follow mitigation strategies for other potential causes of failure

Table 13: Avionics and recovery FMEA

3.3.1.2.4 Flight Dynamics

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					
Propellant	Generate appropriate thrust to propel the rocket.	Propellant Failure	Improper storage of motor.	Improper propellant burnout or incomplete propellant ignition.	Changes the propellant burn distribution creating	Overpressure risks, unpredictable trajectory/flight, or rocket does not take off.	9	3	4	108	Ensure the structural integrity of the propellant by visually ensuring defects, or moisture is not present. Motors need to be

					abrupt changes in thrust.						contained in a Climate Regulated room, and ensure they are handled carefully.
Nozzle	Controls the mass flow rate of the propellant	Nozzle Deformation	Structural failure of nozzle.	Nozzle exit area, nozzle exhaust pressure, propellant flow rate change.	Abrupt changes in the thrust vector.	Altered trajectory of the rocket creating potential danger to bystanders.	9	3	5	135	Always handle nozzle carefully, and visually inspect ensuring defects are not present.
Motor Case (including forward and aft closures)	Enclose solid propellant to protect the body from ignited propellant.	Case Defect	Defect or structural failure of the motor case including the forward and aft enclosures.	Propellant burns through motor case interacting with the rocket body.	Motor assembly gets damaged.	Structural integrity of motor tube and body tube are compromised.	7	2	8	112	Always handle motor case carefully, and visually inspect ensuring defects are not present. Always have a protective cover over the casing until launch.
Motor Tube	Encloses the motor assembly in the correct position.	Motor Tube Fails or Dislodges	Defect or structural failure of the motor tube	Motor case is not held in correct position.	Improperly aligned thrust vector	Altered flight trajectory and potential damage to other components.	6	3	6	108	Always handle motor tube carefully, and visually inspect ensuring defects are not present.
Motor Mount	Retains the motor inside the rocket	Motor Mount Fails	Structural failure of mount or screws improperly fastened	Motor case moves forward in the rocket	Damage to forward rocket components	Rocket integrity is compromised, and function is lost.	7	4	7	196	Visually inspect ensuring defects are not present and tighten screws.
Thrust Plate	Transfers thrust from centering rings to airframe	Thrust Plate Fails	Structural failure of thrust plate or screws improperly fastened	Structural integrity of centering ring becomes compromised	Improperly aligned thrust vector	Altered flight trajectory and potential damage to other components.	5	4	7	140	Visually inspect ensuring defects are not present and tighten screws.

Table 14: Flight dynamics FMEA

3.3.1.3 Environmental Hazards Analysis

Environmental hazard analyses are hazards posed by environment to the launch vehicle (Table 15), or vice versa (Table 16).

3.3.1.3.1 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
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 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
Wind	Launch vehicle drifts during descent	Launch vehicle drifts far, into potentially unsafe retrieval area	5	5	25	Angle launch rail into wind Scrub launch if wind reaches unsafe speed determined by wind speed gauge at site
	Launch vehicle changes flight trajectory	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	Performance of electronics 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
Fog/Low Visibility	Launch vehicle descent out of view	Launch vehicle retrieval after descent difficult	7	3	28	Launch delayed until visibility improves, or launch canceled

Table 15: Effects of environment on launch vehicle hazard analysis

3.3.1.3.2 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	Ensure black powder is separated from electronics and any ignition sources during prep
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 16: Effects of launch vehicle on environment hazard analysis

3.4 Safety Briefings

3.4.1 Safety Orientation

The safety orientation 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.

1. The Safety Officers and Safety Stewards shall meet with small groups of team members at the MAE Student Design Center
2. Standard operating procedures for each machine and tool used during the project shall be explained to the groups
3. Potential hazards and their respective mitigation strategies shall be explicitly stated to the team members by the Safety Officers and Stewards
4. Live demonstrations of machine and tool use shall supplement verbal instruction
5. Team members should ask questions and gain experience with using project relevant tools and machinery under close supervision from the Safety Officers and Safety Stewards
6. Meetings shall take place throughout the competition period to ensure each member can operate in the SDC and avoid manufacturing accidents
7. No team member will be exempt from attending an orientation.

3.4.2 Testing Briefings

The Testing Lead, Brida Gibbons, will oversee testing procedures and shall conduct the hazard recognition and accident avoidance briefing during a meeting with her team members prior to the test. The Safety Officers 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 Swamp Launch Rocket Team, the responsibilities of the Safety Officers and NAR/TRA mentor shall fall to that organization.

3.4.3 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 including, but not limited to, the rules of the private property and NAR/TRA safety policies.

The Project Manager, Safety Officers, and Leads will conduct the meeting prior to the scheduled launch. Attendance will be mandatory for team members to be present at the launch site.

3.5 Caution Statements

3.5.1 Formatting Text

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.

Caution 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.

3.5.2 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 (Figure 11Figure 11Figure 19). 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.

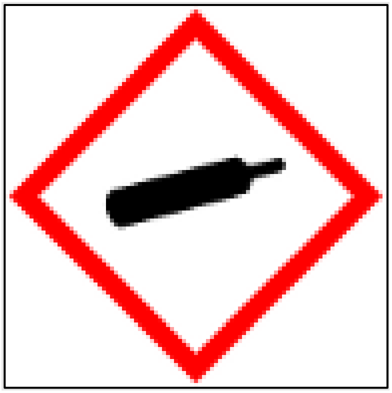

Figure 11: Gas under compression warning

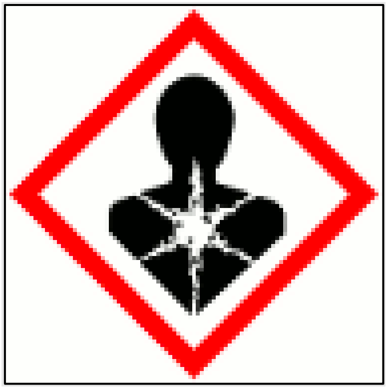

Figure 12: Serious health hazard warning

Figure 13: Health hazard/Irritant

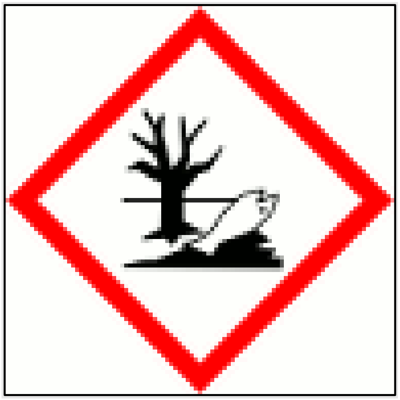

Figure 14: Environmental hazard warning

Figure 15: Acute toxicity hazard

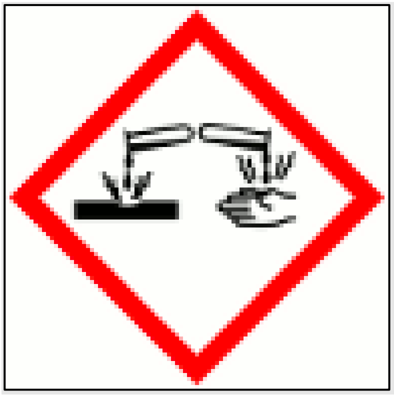

Figure 16: Corrosion warning

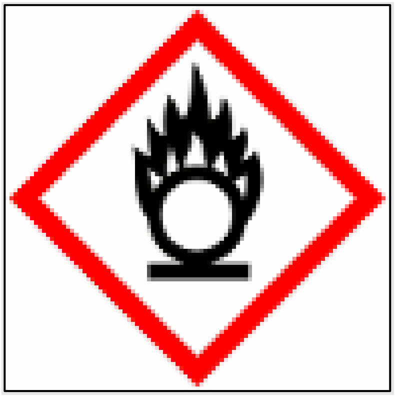

Figure 17: Oxidizer warning

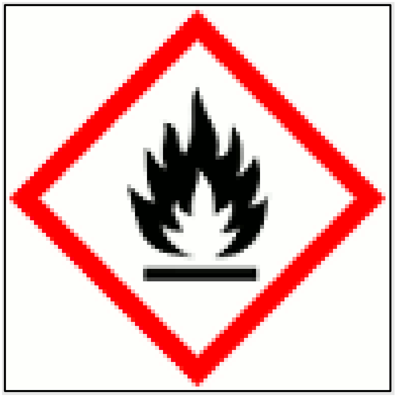

Figure 18: Flammable warning

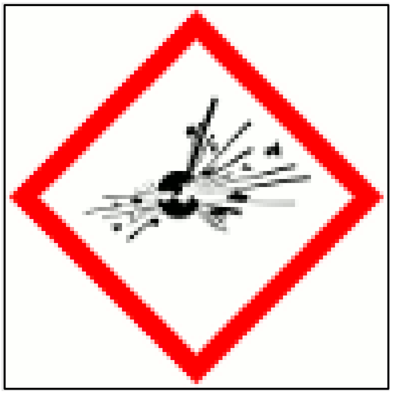

Figure 19: Explosive warning

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 20-Figure 20Figure 25Figure 25).

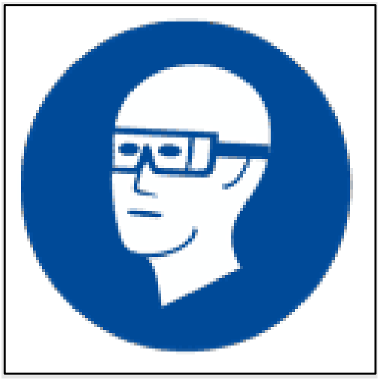

Figure 20: Safety glasses

Figure 21: Hearing protection

Figure 22: Gloves

Figure 23: Safety shoes

Figure 24: Respirator

Figure 25: Face mask

3.6 Federal, State, and Local Law Compliance

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

3.6.1 Federal

3.6.1.1 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 N·s 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 closer than a quarter of the maximum expected altitude away or closer than 1500 ft. away
- h. A launch site where there is no person at least eighteen years old, who has final authority on initiating high-powered launch activity, overseeing 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.

3.6.1.2 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 ft. away from inhabited buildings, 75 ft. from public railroads and highways, and 50 ft. 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 lbs. in case multiple magazines are required for storage in the SDC. The magazines will be fire-resistant.

3.6.2 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 2021.

3.6.2.1 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.

3.6.2.2 Title XLVI Chapter 790.001

(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 rocket is designed to deliver a payload with no intent to be used as a weapon and, by definition, is not a "destructive device". The team will utilize quantities of black powder below the legal limit that would qualify as an "explosive."

3.6.3 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.

3.6.3.1 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 mechanisms, launch site layout, and personnel safety statutes.

3.7 Rocket Motor 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-foot rule, as well as performing any tests or procedures that generate excessive heat or sparks completely outside the SDC building. While travelling to Huntsville for competition, the high-powered motor will always be stored in the magazine and kept inside the car. A 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-foot rule will be enforced for the entirety of the trip.

3.8 Written Statement

The team has read and understood the following safety regulations and will be compliant with them throughout the duration 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 Information

The proposal launch vehicle was modeled in OpenRocket (Figure 26) and SolidWorks 2021 (Figure 27).

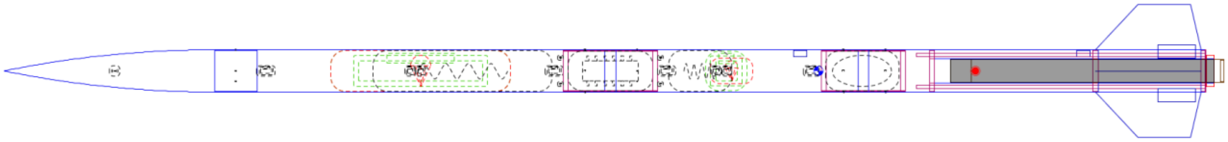

Figure 26: Launch Vehicle OpenRocket Model

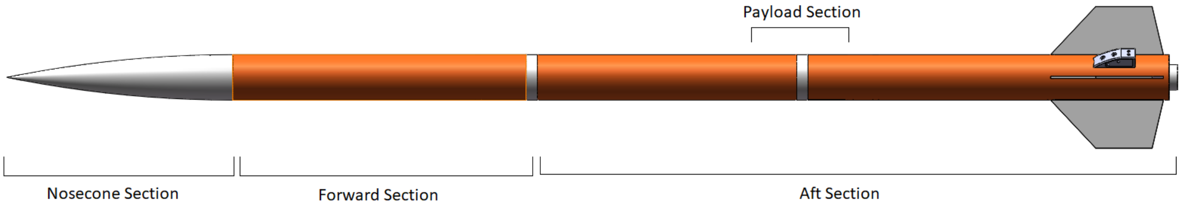

Figure 27: Launch Vehicle SolidWorks Model

4.1.1 Vehicle Dimensions

Section	Exterior Length (in.)
Nosecone	20
Forward Section	38
Aft Section	55
Total	**113**

Table 17: Vehicle section lengths.

Nosecone Section		
Subteam	**Component**	**Mass (oz)**
Structures	Nosecone	20
Avionics and Recovery	GPS	8.0
Structures	Nosecone bulkhead	2.2
Structures	U-bolt	1
Total		31.2
Forward Section		
Subteam	**Component**	**Mass (oz)**
Structures	Airframe	32
Avionics and Recovery	Parachute protector	5.0
Avionics and Recovery	Main parachute	30
Avionics and Recovery	Recovery harness	16
Structures	Coupler and switchband	9.9
Avionics and Recovery	Threaded rods	6.1

Avionics and Recovery	Altimeters	0.80
Avionics and Recovery	U-bolts	2.0
Avionics and Recovery	Electronics sled	4.0
Avionics and Recovery	9-V batteries	2.4
Total		108.2
Aft Section		
Subteam	**Component**	**Mass (oz)**
Structures	Airframe	48
Structures	Rail Buttons	0.68
Avionics and Recovery	Drogue parachute	1.1
Avionics and Recovery	Parachute protector	1.0
Avionics and Recovery	Recovery harness	16
Payloads	Wire tubes	0.60
Structures	Epoxy*	22
Structures	Motor tube	9.8
Structures	Centering rings	4.4
Structures	Motor casing	17
Structures	Thrust plate	4.8
Structures	Motor retainer	2.3
Flight Dynamics	Motor	80
Structures	Fins	33
Payloads	Cameras	3.9
Structures	Coupler and switchband	8.9
Structures	Payload	4.4
Structures	Bulkheads	4.4
Payloads	Hardware	20
Payloads	U-bolt	1.0
Total		283.3
Overall Total		422.7

Table 18: Mass estimate for the entire launch vehicle.

*Epoxy mass estimated through Test #17 (Table 30, Appendix A)

The launch vehicle has a nominal outer fuselage diameter of 4 in., a total length of 113 in. (Table 17), and mass of about 423 oz with the motor and 342 oz without the motor (Table 18). It will be comprised of 3 sections: nosecone, forward section, and aft section. The nosecone, forward section, and aft section will be tethered together and connected to a dual deploy recovery system comprised of two parachutes: an 84-in. main parachute and a 24 in. drogue parachute.

The nosecone is a 5 to 1 Ogive shape with an outer diameter of 4 in. that can be purchased off the shelf from certified rocketry vendors. It has an outer length of 20 in. and a separate shoulder length of 4 in. The nosecone will be connected to the forward section with 3 shear pins. 3 shear pins are sufficiently strong enough to keep the nosecone and forward section connected before separation occurs. The nosecone shoulder will fully slide into the forward section and will have a bulkhead on the aftmost end with an eyebolt to connect to the recovery harness. It will also house the launch vehicle's GPS which is utilized when recovering the launch vehicle.

The forward section will be 38 in. in length. The forward will contain an 84-in. main parachute. The forward airframe connects to the avionics bay with 3 plastic rivets. The forward and aft end of the avionics bay will be capped by bulkheads. Eyebolts will be mounted to the bulkheads to connect to the recovery harnesses. The aft end of the avionics bay will couple to the aft section with 3 shear pins.

The aft section will be 55-in. in length. It will contain a 24-in. drogue parachute, payload, motor assembly, and four fins. The aft section will consist of two sections of airframe and a removeable payload bay. The switchband in the aft is present to increase the ease of removal and assembly of the payload. The payload bay is coupled between each section of the aft airframe with three rivets on each side of the coupler. The payload remains contained throughout the entirety of flight. Three centering rings will be used to maintain alignment between the 2.13-in. diameter motor tube and aft airframe. The centering rings will also be used to help secure the fins. A fin guide will be used to align the fins into proper position. The aftmost centering ring will be used to mount a thrust plate. The motor retainer will then connect to the thrust plate for motor retention.

4.1.2 Material Selection and Justification

The airframe and couplers will be made of 0.06 in. thick G12 fiberglass. G12 fiberglass was selected because of its high strength, resistance to water, and resistance to forces from impact. As a result, fiberglass has the advantage of being an incredibly durable material for longer use operations. Durability in airframe material is desired to ensure the launch vehicle is recoverable and reusable. Although fiberglass presents some difficulties with manufacturing, the equipment, and resources available to students will mitigate this issue.

Centering rings and bulkheads will be made of 0.5 in. thick plywood. Plywood is being used instead of fiberglass because of its increased machinability and appropriate strength. The aftmost centering ring will be reinforced with an aluminum thrust plate. The thrust plate will reduce the shear stress on each centering ring, allowing them to be made of a slightly weaker material like plywood. Plywood has the advantage of being easily manufacturable and is a less expensive material.

The nosecone will be made of 0.08-in. thick G12 fiberglass, reinforced with a metal tip. A fiberglass nosecone was selected due to its high strength. The tip is reinforced with metal to provide extra support because it is the first point of contact upon impact and therefore experiences the greatest force. In addition to being more durable than plastic, fiberglass has the added benefit of being much heavier, which moves the center of gravity forward and increases the stability of the launch vehicle.

The motor tube will be made of 3/16-in. G12 fiberglass due to its durability and resistance to heat. The motor casing will be located inside the motor tube and secured in place with a thrust plate and a 2.13-in flanged motor retainer (Figure 28). The thrust plate transfers the force from the motor to the rocket and the motor retainer secures the motor in the aft. An aluminum thrust plate will be mounted to the aftmost centering ring. The metal motor retainer will connect to the thrust plate to keep the motor contained within the rocket. A metal flanged thrust plate will be used because it is reusable and is more durable than other materials.

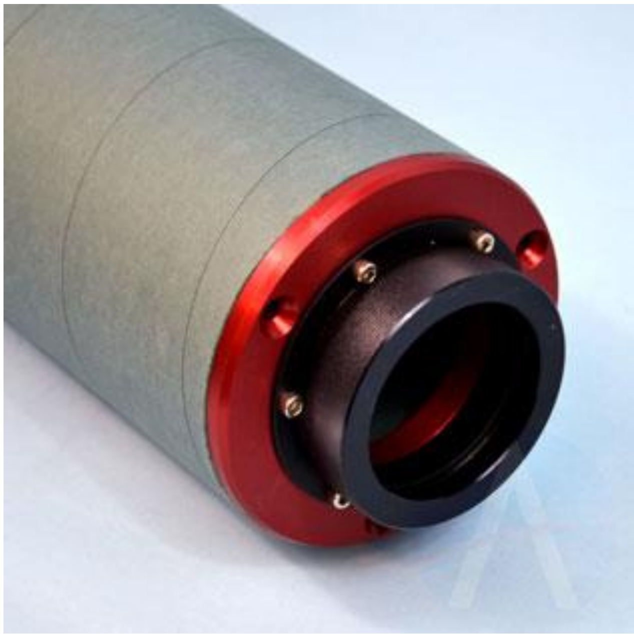

Figure 28: Motor retainer and thrust plate assembly from Apogee Components

4.1.3 Construction

Manufacturing will take place in the SDC, Student Shop, and Mechanical Design Lab. Safety guidelines will be followed (Table 6).

Models and detailed design drawings will be made in SolidWorks before any manufacturing takes place. Instructions will be created for manufacturing each part. Drawings and instructions will be reviewed by Safety Officers to verify the manufacturability given the machines available. All manufacturing will be supervised by a Safety Officer and any additional personnel for the chosen facility. During manufacturing, all parts will be checked for tolerance.

4.2 Projected Altitude and Calculation Method

The projected altitude was calculated using an OpenRocket Simulation for the design proposed. The expected apogee is approximately 4682 ft, within the given range of 4,000-6,000 ft. The simulation assumes the flight conditions are in Huntsville, Alabama, 12 ft. launch rails, 20 ft/s wind, and a 5° rail cant. The lengths, diameters, and shapes of all components were chosen to accommodate the weights and sizes of the payload and avionics bay while reducing drag. Given the launch conditions, the velocity at launch exit is 90.2 ft/s. With this configuration, the motor was altered to ensure the simulation remained in altitude range and met the minimum stability requirement of 2.0 and minimum velocity requirement of 52 ft/s outlined in this proposal. To illustrate, the altitude of the launch vehicle was plotted as function of time, given the launch conditions (Figure 29).

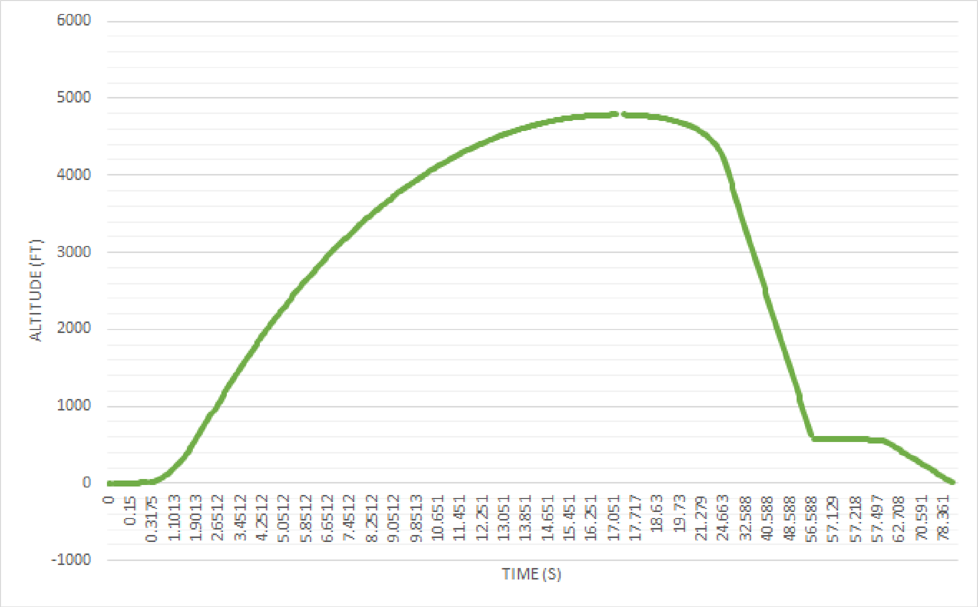

Figure 29: Altitude of Launch Vehicle given 12 ft launch rails, 20 ft/s wind, and 5° rail cant

4.3 Recovery System

The proposed recovery system will use a dual deploy system. Altimeters will be used to control the separation events to deploy the main and drogue parachutes. The launch vehicle and parachutes will be tethered with two 0.5 in. wide and 19 ft. long tubular Kevlar recovery harnesses. The parachutes will be attached to the recovery harness using a D-link and swivel. The forward sections will be attached to the recovery harness with U-bolts on the nosecone and avionics bay bulkheads (Figure 32). The aft section will be tethered to the avionics bay with a U-bolt on the avionics bay bulkhead and an eye-bolt on the payload bulkhead (Figure 34). The main parachute for the proposed rocket is the Skyangle Large Cert-3 parachute. The drogue parachute for the proposed rocket is a 24-inch parachute from Spherachute (Table 19).

Component	Description	Dimensions/Values
Altimeter	Entacore AIM	2 programmable outputs
Recovery harness	Tubular Kevlar	1/2in wide, 19 ft long
Main parachute	Skyangle Large Cert-3	*84in diameter, 1.2 Cd
Drogue parachute	Spherachute	24in diameter, 0.75 Cd

Table 19: Recovery Components

*84 inches is not provided by the manufacturer, value calculated with use of manufacturer provided descent rate calculator to use in open rocket simulation

With a simulated apogee of 4682 ft., the descent rates the team will be targeting are 81 ft/s for the drogue parachute and 18 ft/s for the main parachute. The parachutes used to achieve these values in the simulation are a Skyangle Large Cert-3 parachute for the main parachute and a 24-inch Spherachute parachute for the drogue. Each parachute will have a parachute protector that will be folded in to protect it from ejection gasses during deployment. These descent rates provide a total descent time of 83.7 seconds and a drift of 2456 ft. with wind speeds of 20 mph (Table).

Description	Value
Apogee	4682 ft
Drogue parachute descent rate	81 ft/s
Main parachute descent rate	*18 ft/s
Descent time from apogee	83.7 s
Drift with 20 mph winds	2456 ft

Table 20: Descent values

*Descent rate found from manufacturer provided calculator

The proposed recovery system will utilize two Entacore AIM altimeters. One will be the primary altimeter and the other will be the secondary altimeter. Each altimeter will be powered and wired independently of the other (Figure 30). Each altimeter will have its own keylock switch accessible from the outside of the launch vehicle. The altimeters will be located in the avionics bay, which will be sealed at either end with a bulkhead.

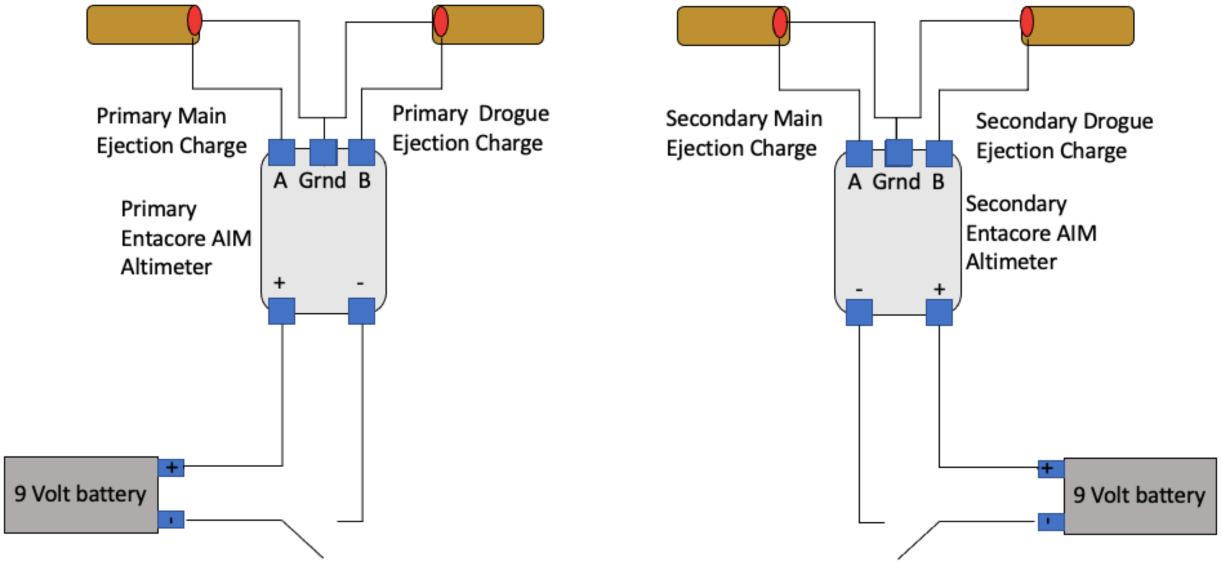

Figure 30: Altimeter diagram

Separation will be caused by the detonation of black powder charges. The black powder will be packed with an e-match and wadding. The backup charges will be 25% larger than the primary charges and on a delay from the primary charges to ensure separation occurs (Table 21). The backup drogue ejection charge will be delayed by 1 second. The backup main ejection charge will be delayed by 50 feet in altitude. The separation events will be tested on the ground in accordance with Test #11 and Test #12 (Table 31, Appendix A).

Charge	Mass (g)
Primary main parachute	2.0
Backup main parachute	2.5
Primary drogue parachute	1.5
Backup drogue parachute	1.875

Table 21: Ejection charge masses

The ejection charges will be located to help push the parachutes out of the launch vehicle. The forward separation point was chosen to allow the main parachute to fall out of the airframe if it is not pushed out by the ejection charge. The aft separation point was chosen to limit the number of bulkheads the wires for the ejection charge must pass through to make it easier to assemble (Figure 31).

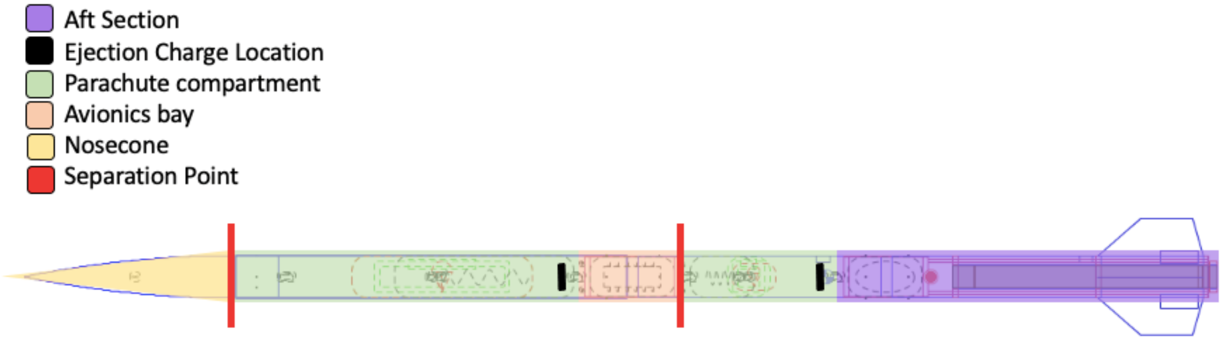

Figure 31: Separation points and ejection charge locations

The drogue parachute will deploy first, with primary deployment occurring at apogee and secondary deployment occurring one second after apogee to ensure separation occurs. The drogue parachute will deploy from the aft compartment. The separation point for this deployment will be the aft airframe separating from the avionics bay (Figure 32).

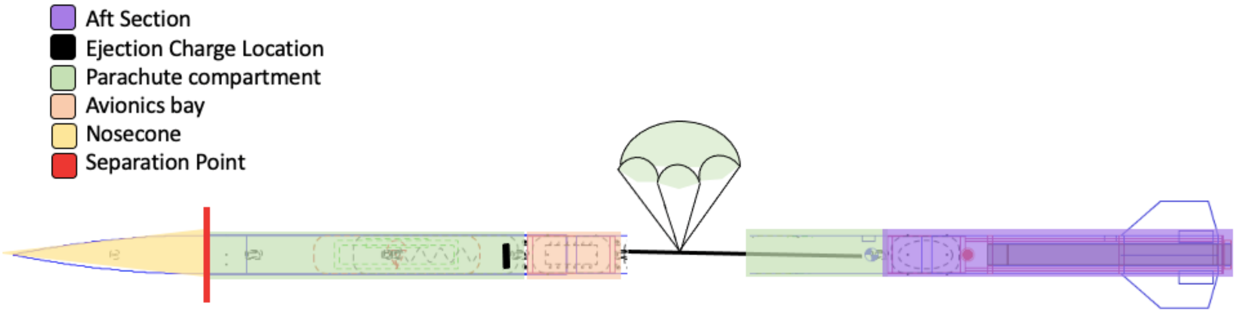

*Figure 32: First Separation Event**

*Not drawn to scale

During Drogue descent, the drogue parachute will be positioned such that the hanging sections of the launch vehicle will be less likely to collide. The drogue parachute will be located closer to the avionics bay than the motor section. This positioning will also allow for the main parachute to pass fewer objects in the air during the main parachute deployment. This will help mitigate the risk of the two parachutes tangling (Figure 33).

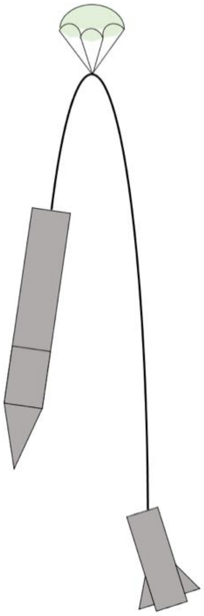

*Figure 33: Drogue Parachute Location**

*Not drawn to scale

The main parachute will deploy second, with primary deployment occurring at 600 ft. and secondary deployment occurring at 550 ft. The main parachute will deploy from the compartment forward of the avionics bay and aft of the nosecone. The separation point will be the forward airframe from the nosecone (Figure 34). This separation point location would allow for the parachute to fall out of the launch vehicle if the separation is less energetic than anticipated (Figure 34, Figure 35).

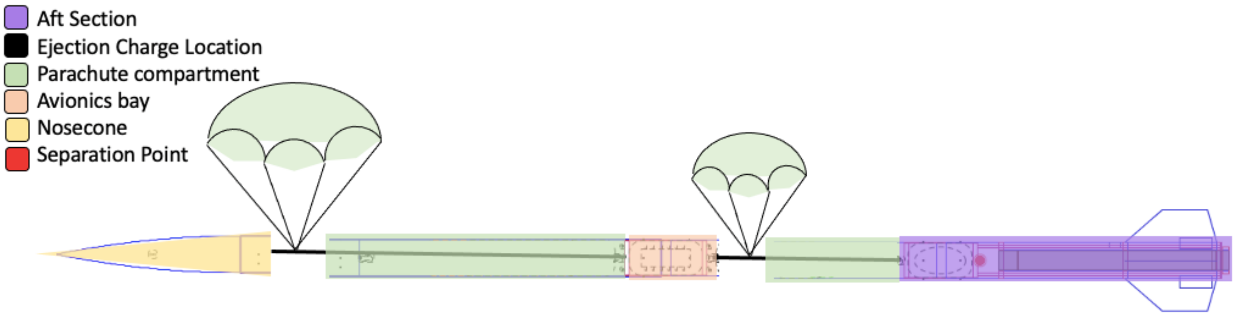

*Figure 34: Second Separation Event**

*Not drawn to scale

The main parachute will be located closer to the nosecone section than to the avionics bay. This location will be able to utilize the momentum of the nosecone during the separation event to assist in pulling the main parachute out of the forward airframe (Figure 35).

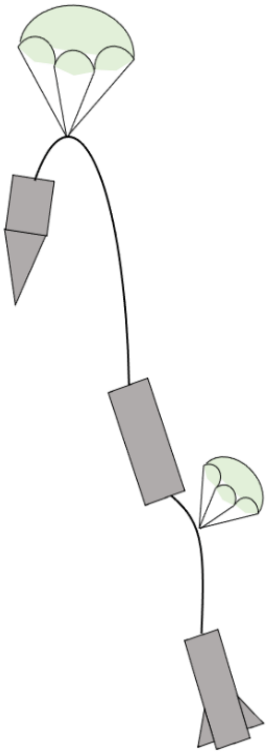

*Figure 35: Main Parachute Location**

*Not drawn to scale

4.4 Motor Designation

The aft section of the Gator Locator Rocket will house the Aerotech K1050W-PS motor and its accompanying retention system. The motor was chosen in order to ensure the project would stay within the altitude range of 4,000 ft- 6,000 ft. Additionally, it ensured stability was at least a caliber of 2.0. The simulation predicted the motor would produce a velocity of 90.2 ft/s at rail exit, attain a maximum velocity at 616 ft/s, and attain a maximum acceleration of 361 ft/s.

The reloadable Aerotech K1050W-PS has a total impulse of 2426 N*s, and a maximum thrust of 2171 N. The motor has a burn time of 2.1 sec in which it will burn 2203 g of propellant. Overall, the thrust to weight ratio is 8:1 (Figure 36).

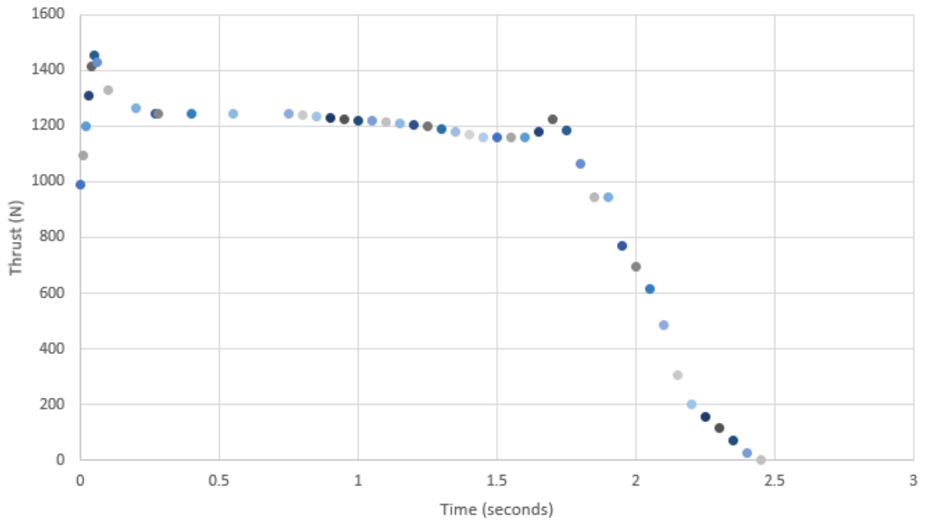

Figure 36: Thrust Curve for Aerotech K1050W-PS Motor

4.4.1 Stability Margin

Moreover, the launch vehicle and motor configuration have a stability margin at the rail exit of 2.2. After launch rail clearance, stability remains above the minimum requirement of 2.0. The projected stability margin over time from the rail exit to apogee was plotted (Figure 37).

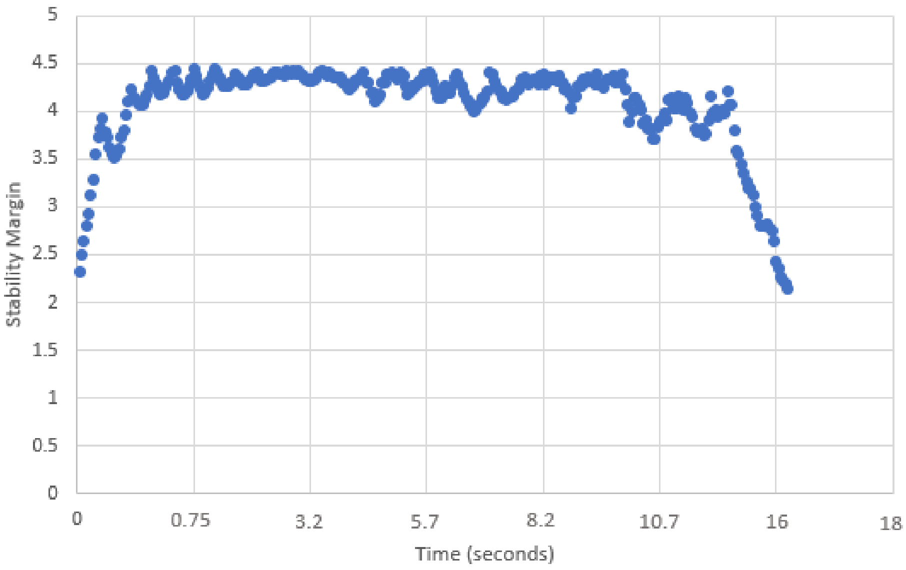

Figure 37: Projected Stability Margin as a function of time

4.5 Payload Design

4.5.1 System Overview

The payload system will identify the vehicle’s landing location through the use of camera pose estimation and image localization in conjunction with Inertial Measurement Unit (IMU) data. Throughout the flight, cameras onboard the vehicle will capture images of the launch field's terrain. These images will then be compared to pre-uploaded satellite images of the launch field to identify landmarks in the surrounding views that will then be used as reference locations.

The payload will continuously track its position using the identified landmarks until these landmarks are no longer visible to the onboard cameras. Once this occurs, the payload will save its last known location (as identified via camera pose estimation) and track its displacement from that position with an IMU. The final vehicle location will be stored as two characters, a row and column label. This result will be transmitted to a ground station via XBee radio transceivers, where they will be output to an LCD screen and recorded onto an SD card (Figure 38).

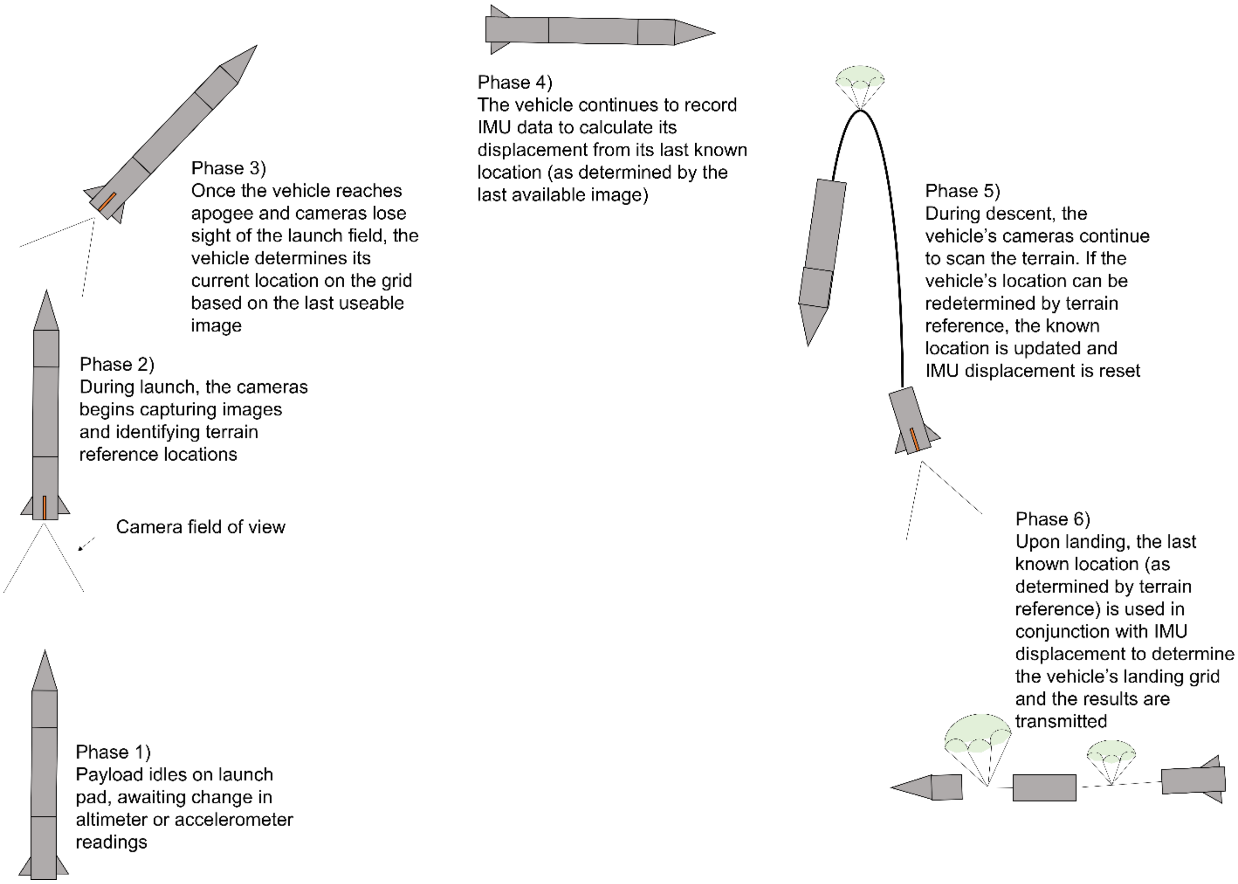

Figure 38: Payload flight sequence diagram

To adjust for the camera's angle relative to the ground, the camera's orientation and altitude will be captured by the IMU and altimeter respectively at the time of each picture. This data will then be used to rectify the image and then calculate where the vehicle is located on each captured image relative to the camera's principle focus point on the image. This approach was selected because it does not require the deployment of any external camera device, greatly reducing the system's mechanical complexity.

The payload mounting system is comprised of a payload sled, a rail system, and two downward facing camera shrouds. The payload sled and rail system will be located in the aft section of the launch vehicle, in their own coupler to isolate them from any ejection gases. The cameras will be bolted to the exterior of the launch vehicles airframe, towards the aft of the rocket near the fins to avoid any obstructions. These cameras will be secured in their respective 3D printed camera mounts. To power these cameras, wires will run along the interior of the aft section through the centering rings to each of the cameras through two small cardboard cylindrical tubes. This cylindrical tube will be attached to the interior of the aft section by epoxy, to ensure it does not experience violent movements during flight. This tube will be the connection between the electronics on the payload and the cameras and ensure isolated protection of the wires from any gases or vibrations. These cameras will be the ones that capture the images of the launch field during ascent and descent, allowing the payload to utilize the image processing software and IMU data to locate the launch vehicle's location.

4.5.2 Payload Electronics

The payload will include two cameras, a digital signal processor, an inertial measurement unit, an altimeter, an XBee radio transceiver, an SD card, a SRAM chip, and a lithium-ion battery (Figure 39). All components, with the exception of batteries and external cameras, will be integrated onto a printed circuit board designed by the team.

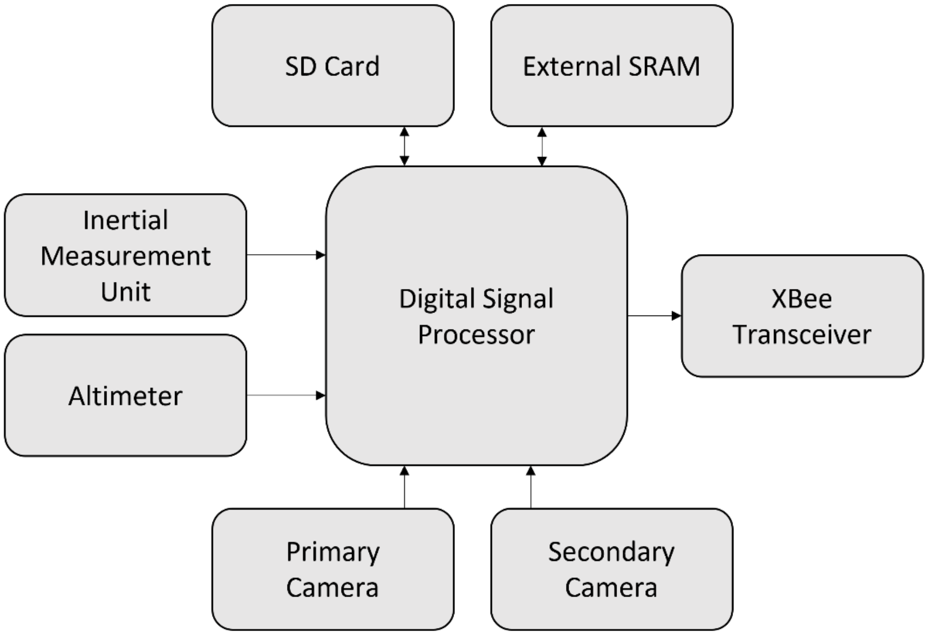

Figure 39: Block diagram of payload electronics

4.5.2.1 Camera Specifications

Two OV5640 cameras will be fixed to the vehicle’s aft to capture images of the terrain during the vehicle’s flight. The cameras’ attachment location at the aftmost point of the aft airframe allows each camera to capture a clear view of the launch field without obstructions by the launch vehicle. The OV5640 camera captures a 100° field of view with a resolution of 1080p at 30 frames per second. This field of view will allow the cameras to observe the entire launch field at apogee with minimum distortion.

4.5.2.2 Processor Specifications

A Texas Instruments AM5728 digital signal processor (DSP) will perform all camera pose estimation computations, control sensor sampling, and initiate radio communications. A dedicated digital signal processor is optimized for high-speed floating-point computations and can perform the necessary feature detection. The AM5728 provides native support for image processing libraries such as OpenCV, greatly reducing the development time and complexity required for software development.

4.5.2.3 Inertial Measurement Unit Specifications

The payload will continuously sample a Bosch BNI088 Inertial Measurement Unit (IMU) to track the vehicle's acceleration throughout the flight. This acceleration data will be integrated to determine the vehicle's velocity over time. After the vehicle has descended to an altitude in which reference landmarks are no longer visible, the payload will begin using this IMU data to calculate its displacement from its last identified position. The displacement error, S, of an inertial measurement unit can be expressed as a function of accuracy, a, and time, t (Equation 1).

$$S = \frac{a \cdot t^2}{2} \tag{1}$$

To ensure the error induced by the inertial measurement unit remains under 50 ft, assuming a total vehicle flight time of 90 s, the IMU must have an accuracy of greater than 0.00038 g and a range of at least 16 g (as determined by the vehicle's maximum expected acceleration). This error will be further reduced through the application of Kalman filtering.

The IMU will record the camera's orientation at the time of each image capture. This orientation data, along with altimeter data, will be used to calculate which pixel the rocket is located above on each captured image.

4.5.2.4 Altimeter Specifications

The payload will contain an altimeter for launch detection and to assist with camera pose calculations. The vehicle's altitude will be sampled and recorded alongside each image capture to adjust for the camera's angle relative to terrain**.** The payload altimeter will be used solely for camera pose calculations and will be independent of the launch vehicle avionics and recover system.

4.5.2.5 Radio Specifications

A 900 MHz XBee transceiver module will be used to transmit the landing location to the ground station. This module supports an outdoor line-of-sight range of up to 9 miles with a maximum transmitting power of 250 mW.

4.5.2.6 Memory Specifications

The payload will use a 16 MB external SRAM chip and a 16 GB SD card for data storage. The SD card allows for storage of a larger quantity of data, while the external SRAM chip allows for fast access and manipulation of image data. As the cameras capture each new image, the image data will immediately be transferred to the SD card for bulk storage. While processing, the digital signal processor will then sequentially load each image from the SD card into SRAM. This approach allows for data to be collected and processed asynchronously, which in turn allows for more data to be collected while the vehicle is in flight.

4.5.3 Payload Software

The software for the electronics on board the payload and on the ground-station will be developed in-house.

The TI DSP will be running on TI-RTOS. OpenCV library will be utilized for analyzing images and performing image localization and distance calculation because of the better performance and native compatibility with TI ARM Processors.

4.5.3.1 Payload Onboard Software

The software on board will be performing image localization using a convolutional neural network (CNN) model and OpenCV on the TI DSP. This will be done by getting pictures from the camera, storing them in the SD card, and then analyzing them against pre-uploaded images of the launch field. The machine learning model will be trained for recognizing reference points in satellite Images, with multiple datasets including Spacenet. In addition, the team will also conduct supervised learning by creating a dataset of 100 sets of images, with each set consisting of 1 satellite images and 9 aerial images. The final model will undergo supervised training on the satellite image of the launch field with the unique reference points (lakes, trees, buildings etc.) pre-segmented and used as parameters. Each reference point will be further segmented according to the gridded dimensions (every grid box is 250 ft. x 250 ft.) so that the payload is able to identify the position even if the entire reference point is not in camera view (Figure 40), (Figure 41Figure).

The analysis will be done by calculating the distance from the principal point of the camera to the bounding box of the reference object. The altimeter will then be used to get the current altitude and scale the distance accordingly. The known location of the reference object on the gridded map will be used to estimate the location of the rocket on the gridded map. For images taken at a tilted angle, a gyroscope will be used to account for the tilt to rectify the image, and then the position will be calculated as described before.

Once the vehicle's final landing location is determined, the result will be transmitted to the ground station via the XBee radio transceiver.

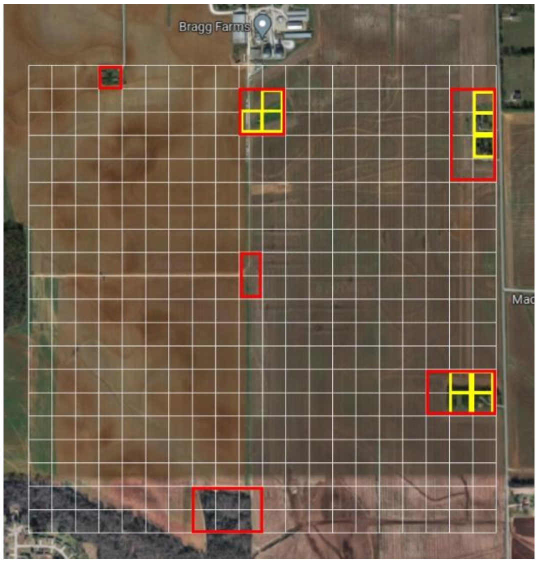

Figure 40: Rough estimate of reference point bounding boxes

Figure 41: Example of how image will be segmented for training

4.5.4 Payload Ground Station

The ground station is responsible for receiving, saving, and displaying the vehicle landing location as determined by the payload. The ground station will consist of an Arduino microcontroller, XBee radio transceiver, SD card interface module, and LCD screen (Figure). The ground station will receive radio signals consisting of 2 characters – a letter and a number – which will correspond to the grid co-ordinates of the rocket.

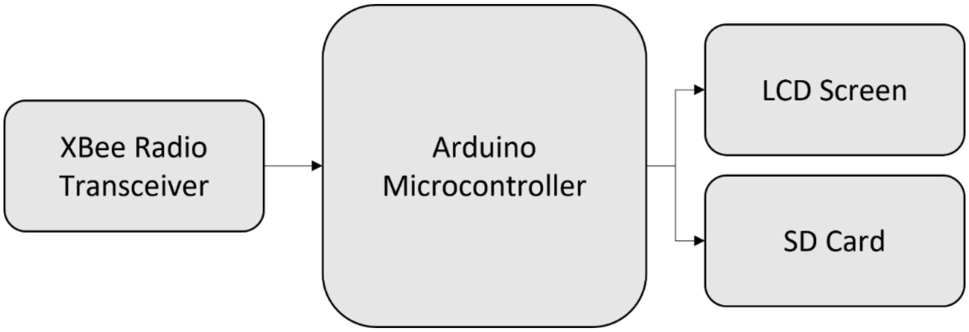

Figure 42: Payload ground station block diagram

4.5.4 Payload Mechanics

The structure of the payload consists of one 3D printed sled, and two 3D printed camera mounts on the exterior of the launch vehicles air frame. The 3D printed sled will be located in the aft of the launch vehicle, providing the necessary electronic and computing power for the images and processing of the images. The structure of the sled and the rail system of the payload allows for easy detachment from the launch vehicles airframe, allowing the removal of the sled from the launch vehicle possible. This enables the team to change components on the PCB as well as perform constant tests on the different electrical components.

4.5.4.1 Sled Specifications

The electronics and PCB will be housed and retained within the 3D printed sled. The sled will be manufactured by the Prusa 3D printers available in the MAE-C facility. The sled will have outer walls that contain a small cutout on both sides that will allow the PCB to slide in without any interference (Figure 43). The depth of the cutouts will be 0.1 in. larger than the thickness of the selected PCB, roughly 0.7 in, enabling the PCB to slide into the sled. Rubber seals will then be placed on the ends of these cutouts to ensure the PCB doesn't slide out, and to help absorb any vibrations the sled endures during flight and descent. The overall dimensions of the sled are 7.00 in. x 3.75 in. x 2.00 in., ensuring the sled will have clearance inside of the launch vehicles airframe. Towards the rear of the sled behind the PCB cutouts is where the battery compartments will be located. Each compartment will be capable of securing a lithium-ion battery that will be used to power the electronics on the sled. These compartments will have two small slits on the sides, 0.5 in x 0.15 in to allow a strap to be attached around the batteries ensuring the batteries are tightly secured.

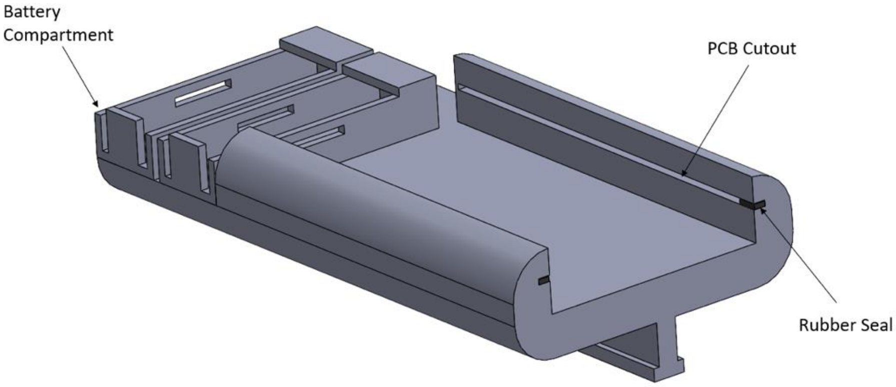

Figure 43: Payload Sled

4.5.4.2 Rail System Specifications

The rail system of the payload is what secures the payload to the launch vehicles airframe, while also allowing the sled to be easily removed for any modifications or tests. The rail system will also be 3D printed using PETG filament, lowering manufacturing costs and complexity. The rail system utilizes a beam cutout that matches the one located on the bottom of the payload to ensure a smooth connection (Figure 44Figure). The rails length will be slightly shorter than the sled at 6.75 in. The width of the rail system is 2.0 in, with a height of 1.0 in. The rail system will be permanently attached to the removable coupler of the payload section with epoxy on the underside.

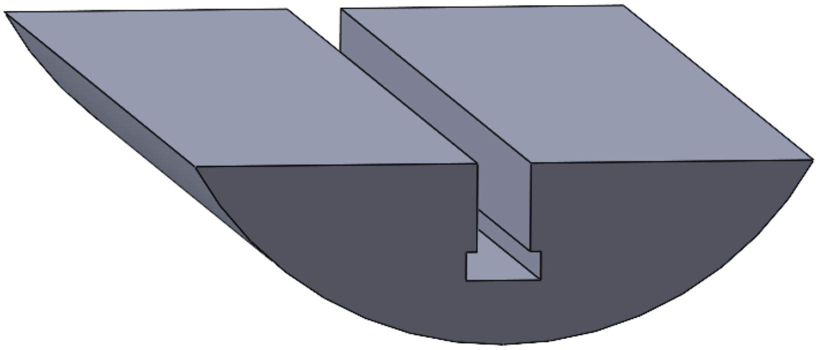

Figure 44: Rail system

4.5.4.3 Payload Assembly

The payload assembly consists of one 3D printed sled and one 3D printed rail system. The sled will slide onto the rail system, allowing the sled to be removed from the launch vehicle whenever needed (Figure 45). Rubber seals will also be placed at the end of the rail system to ensure the payload does not slide out of the rail during flight. The rubber seal will also help absorb vibrations the payload assembly will experience during flight. The payload assembly is concentric with the 4.0 in diameter airframe, ensuring there is no interference between the payload and the airframe (Figure 46).

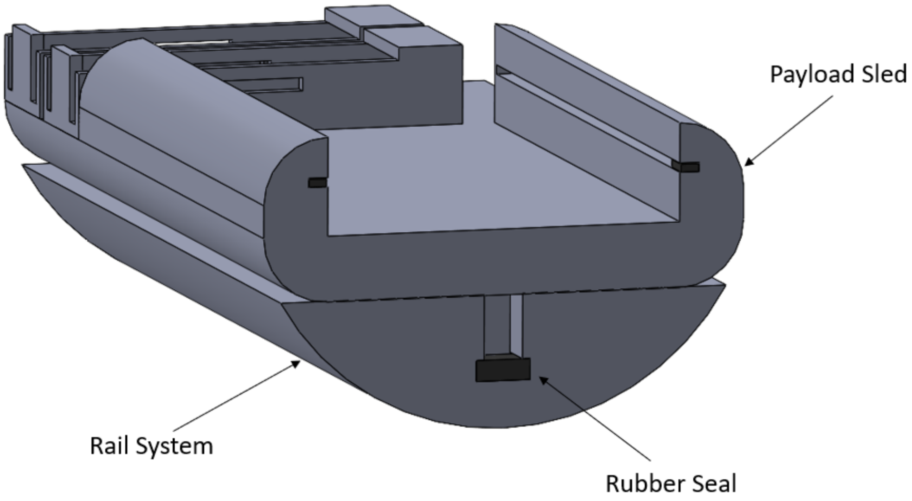

Figure 45: Payload Assembly

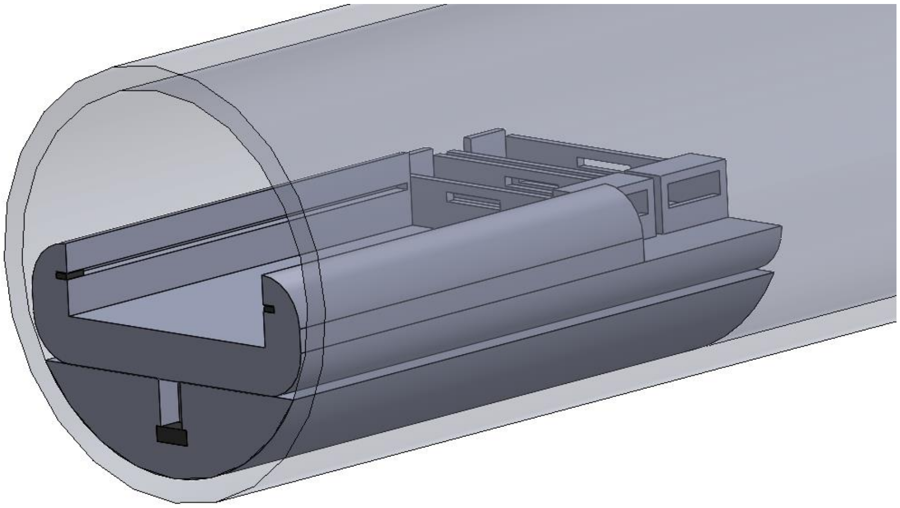

Figure 46: Payload Assembly in Airframe

4.5.4.4 Camera Mount

The cameras will be located on the exterior of the launch vehicles airframe, to enable a series of aerial images for the image processing software (Figure 50, Figure 51). These cameras will be mounted using a 3D printed casing designed to hold the cameras steady during flight (Figure 47). The camera mount is secured to the launch vehicles airframe using two ¼-20 fasteners, along with their corresponding ¼-20 well-nuts (Figure 48). The camera mount will have a small hole in the camera housing compartment to allow the wires from the payload access to the camera. A cover is placed on the side of the camera mount housing to protect the wiring and camera (Figure 49). This cover is attached to the camera mount housing through two ¼-20 fasteners and their corresponding hex-nuts. The wiring that attaches to the camera will be connected from the payload via a 0.25 in diameter cardboard tube. This cardboard tube will travel along the interior of the launch vehicles airframe from the payload to the cameras, passing through the centering rings. The centering rings will have a drilled hole to enable the tube to pass through them, and the tube will be epoxied to the interior of the launch vehicles airframe.

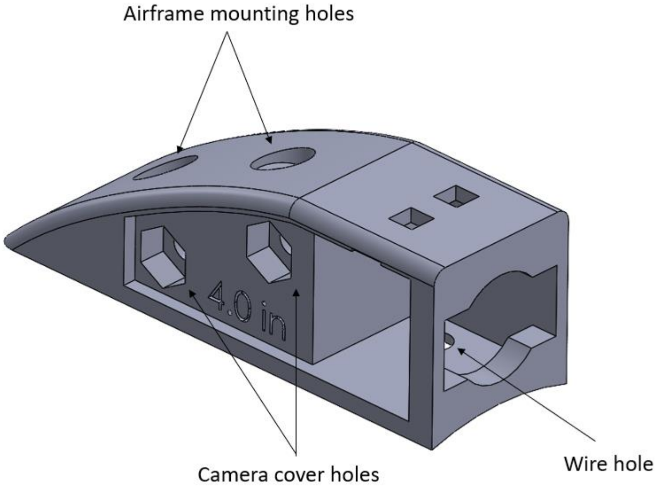

Figure 47: Camera Mount Housing

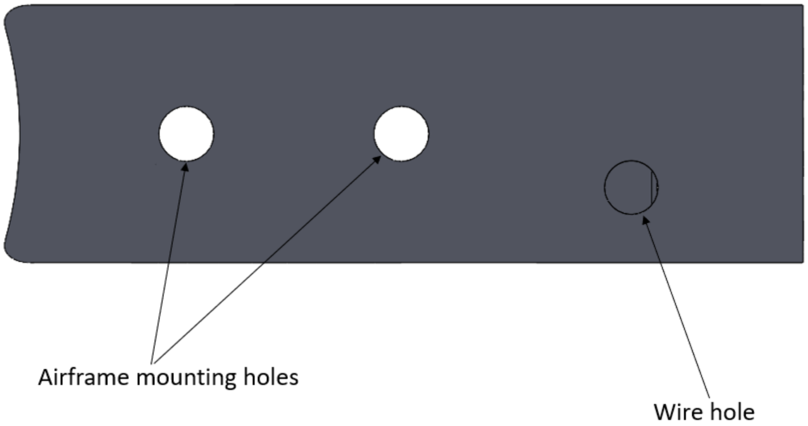

Figure 48: Camera Attachment Holes

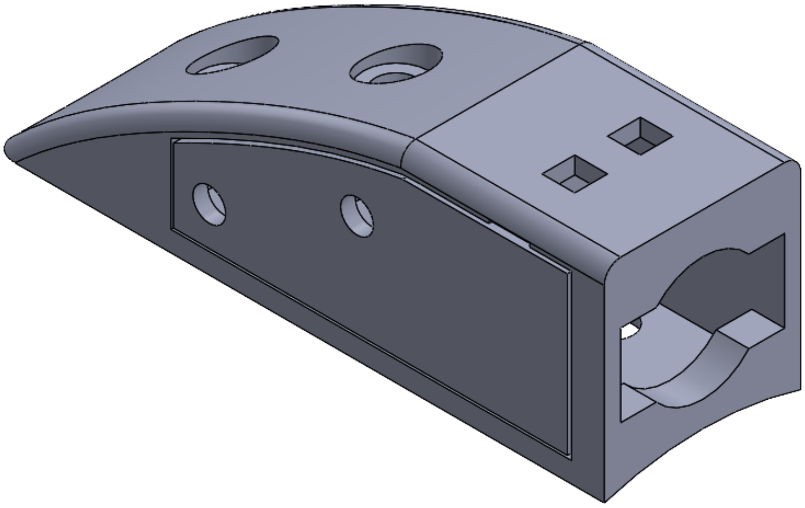

Figure 49: Camera Mount Assembly

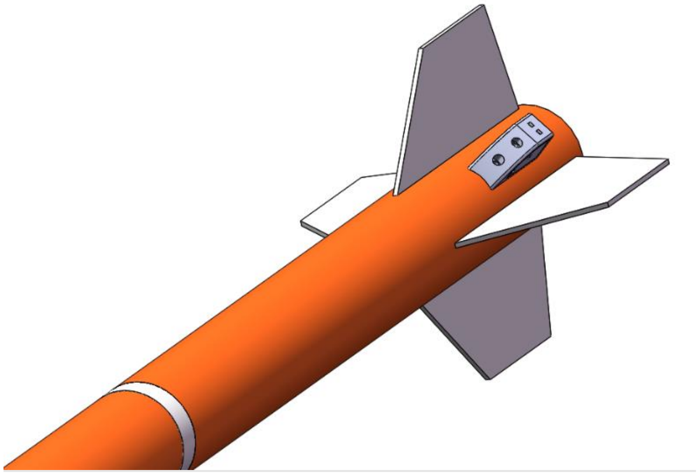

Figure 50: Camera mount attached to the launch vehicle

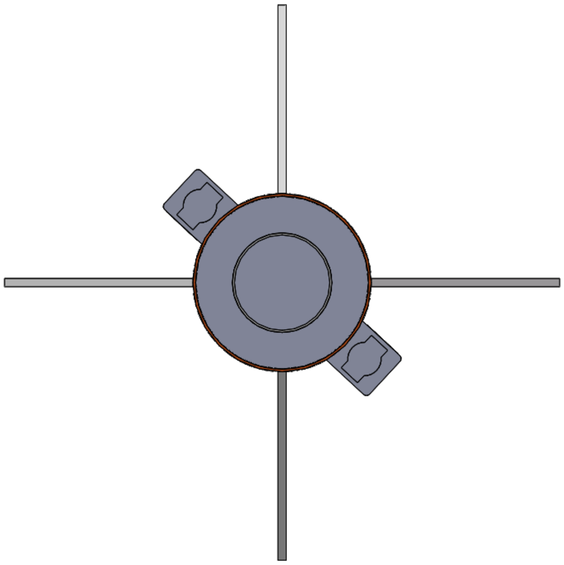

Figure 51: Camera mounts attached to the launch vehicle as viewed from the aft.

4.6 Requirements

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.	The entirety of the launch vehicle and payload will be designed, manufactured, and prepared by the students on the team. All reports will be written by the students and the work will not be plagiarized or recycled.
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 will create an outline that includes project milestones, a budget, community support, checklists, personnel assignments, STEM engagement events, risks, and mitigations. This document will be updated when new reports are generated.
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.	Due to security restrictions, FN team members must be identified by the subteam leaders. A compiled list of all FN members will be submitted prior to PDR and may or may not have access to certain activities or be separated from their team during Launch Week at Marshall Space Flight Center.
1.4. The team must identify all team members who plan to attend Launch Week activities by the	Team members who will attend Launch Week activities will be members with consistent engagement, a selected mentor, and a limit of 2

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). 1.4.3. No more than two adult educators	adult educators. A list of these active members that plan to attend will be compiled prior to CDR.
1.5. The team will engage a minimum of 250 participants in direct 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. A template of the STEM Engagement Activity Report can be found on pages 40-43.	At least 250 participants will engage in direct educational STEM activities offered by the team in-person or online during the time between project acceptance and the FRR due date. This requirement will be satisfied through the partnership with Alachua County Public Schools to engage with elementary and middle school students.
1.6. The team will establish and maintain a social media presence to inform the public about team activities.	An active and engaging social media presence has been established and will be maintained to publicize team activities on Instagram (@SwampLaunch), Twitter (@SwampLaunch), and Facebook (@Swamp Launch Rocket Team).
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.	All email deliverable materials will be sent by the team's project manager by the deadline specified in the handbook. In the event that materials are sent in late, the team will only be allowed 72 hours after the specified deadline to send the deliverables with a penalty. There are no acceptations beyond this deadline.
1.8. All deliverables must be in PDF format.	All email deliverable materials will be in PDF format.
1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections.	All reports will include a table of contents outlining important sections and their sub-sections.
1.10. In every report, the team will include the page number at the bottom of the page.	All reports will include page numbers at the bottom of each page.
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 should be used for speakerphone capability only as a last resort.	In the event of a teleconference with the review panel, all video teleconference equipment (camera, microphone, computer, Internet connection) will be provided by the team.

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.	At Launch Week, the team will utilize the 8-foot 1010 rails or the 12-foot 1515 rails canted 5 to 10 degrees away from the crowd provided by the launch services provider. These are the only launch pads the team will utilize.
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's mentor is Jimmy Yawn, a level 3 certified NAR member. The team's mentor is in good standing with the NAR and has launched the required number of flights. Mr. Yawn is the designated owner of the rocket and will be traveling with the team.
1.14 Teams will track and report the number of hours spent working on each milestone.	All progress will be recorded and reported with specifications on hours spent and goals met. Each subteam will record their progress once per week.

4.6.2 Vehicle Requirements

Requirements	Implementation Plan
2.1. The vehicle will deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL). Teams flying below 4,000 feet or above 6,000 feet on their competition launch will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.	An altitude between 4,000 and 6,000 feet AGL must be met for the team's vehicle to be considered for the Altitude Award or to obtain altitude points towards overall project score. The team's current altitude estimate is 4682 ft.
2.2. Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude	A target altitude goal will be decided at the PDR milestone which will be used to determine the team's altitude score.

will be used to determine the team’s altitude score.	
2.3. The vehicle will carry, at a minimum, two commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events (see Requirement 3.4). An altimeter will be marked as the official scoring altitude used in determining the Altitude Award winner. The Altitude Award winner will be given to the team with the smallest difference between the measured apogee and their official target altitude for their competition launch.	In order to measure the altitude, the team's vehicle will carry at least 2 barometric altimeters specially for rocketry recovery. This measured altitude from the barometric altimeter will be utilized to determine the team's altitude points and consideration for the Altitude Award.
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 team’s launch vehicle will be built to be able to launch again without significant modifications within the same day.
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. 2.5.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length. 2.5.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	The team’s launch vehicle will have 3 sections, including the nosecone section, the forward section, and the aft section. In-flight separation points will have coupler shoulders that will be at least 4 in. in length and nosecone shoulders that will be 4 in. length.
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's launch vehicle will be made ready for flight within 2 hours as outlined by Test #24.
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.	Without losing any vital functionality or components, the launch vehicle will be able to withstand a launch ready position for at least 2 hours. This will be achieved by Test #28 and #30.
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 team's launch vehicle will utilize a motor that is compatible with a 12-volt direct current firing system offered by NASA launch services.
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 team’s chosen motor will be capable of initiating launch without external circuitry or specific ground support.

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). 2.10.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone. 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.	The team's launch vehicle will use an NAR, TRA, or CAR certified APCP motor propulsion system. Additionally, the choice of motor will be finalized before the CDR deadline. The chosen motor is an AeroTech K1050W-PS, which satisfies the motor requirements. If changing motors is necessary after the CDR deadline, the team will be sure to attain approval from the NASA Range Safety Officer. It is understood that a penalty will be given to the team if a motor change is necessary.
2.11. The launch vehicle will be limited to a single stage.	The team will utilize one motor.
2.12. The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).	The team's chosen motor will not exceed L-class. The chosen motor is an AeroTech K1050W-PS (K-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 team will not utilize pressure vessels in the launch vehicle.
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.	The team's launch vehicle will have a static stability margin of at least 2.0. This will be ensured through OpenRocket simulations to determine the stability margin.
2.15. The launch vehicle will have a minimum thrust to weight ratio of 5.0:1.0.	A minimum thrust ratio of 5.0:1.0 will be enforced on the launch vehicle.

2.16. 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 include external camera mounts that will not provide substantial aerodynamic effect.
2.17. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	The team's launch vehicle will reach 90.2 ft/s at the rail exit. This will be ensured through OpenRocket simulations to determine the velocity.
2.18. 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 required to use a minimum motor impulse class of E (Mid Power motor).	The teams will launch and recover a subscale model of the rocket after the Proposal and prior to the CDR submission deadline. Section 6.1 outlines the planned schedule including this launch.
2.18.1. 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's subscale model will be of utmost similarity to the full-scale model in order to obtain data for the full-scale model. The team will not use the full-scale model as the subscale model.
2.18.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude.	The team's subscale model will carry an Entacore AIM altimeter to record the model's apogee altitude.
2.18.3. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.	The team's subscale rocket will be designed and built for this year's project.
2.18.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter flight profile graph(s) OR a quality video showing successful launch and recovery events as deemed by the NASA management panel are acceptable methods of proof.	The team will provide successful flight data in the CDR report from altimeter flight profile graphs or a sufficient video showing all parts of launch and recovery.
2.18.5. The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter 100" length rocket your subscale shall not exceed 3" diameter and 75" in length.	The team's subscale model will not be larger than 75% of the full-scale model's dimensions.
2.19. All teams will complete demonstration flights as outlined below.	See the guidelines specified below.
2.19.1. 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 shall be the same rocket to be flown for their competition launch. The purpose of the Vehicle Demonstration Flight is to validate the	The teams rocket will demonstrate a successful flight and recovery prior to FRR with the same rocket intended for the competition. The rocket's success will be defined by its stability, minimal changes in structure, proper recovery systems,

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 shall be met during the full-scale demonstration flight:	proper preparation, and functionality of hardware.
2.19.1.1. The vehicle and recovery system will have functioned as designed.	During the full-scale flight demonstration, the team’s rocket will function as intended through either the primary or redundant systems.
2.19.1.2. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year’s project.	The team's rocket will be designed and built specifically for this year’s project.
2.19.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:	The following requirements apply during the full-scale Vehicle Demonstration Flight:
2.19.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.	If the payload is not flown, the mass of the payload will be simulated by mass simulators.
2.19.1.3.2. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.	The mass simulators will be placed in the aft section, approximately the same location as the payload.
2.19.1.4. If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	Since external camera housings are intended for the design, these features will be included in the Vehicle Demonstration Flight.
2.19.1.5. Teams shall fly the competition launch 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 competition launch motor or in other extenuating circumstances.	Teams must use the competition launch motor for the Vehicle Demonstration Flight since the team’s home launch field is capable of supporting its motor.
2.19.1.6. The vehicle shall 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 competition launch flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.	At the full-scale test flight, the team’s rocket will be prepared in a fully ballasted configuration to test how the flight will be on Launch Day.
2.19.1.7. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified	The launch vehicle or its components will not be changed without the agreement of the NASA Range Safety Officer after a successful full-scale demonstration flight.

without the concurrence of the NASA Range Safety Officer (RSO).	
2.19.1.8. Proof of a successful flight shall be supplied in the FRR report. Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement.	The FRR report will contain proof of a successful flight. This will include altimeter flight profile data output with accompanying altitude and velocity versus time plots.
2.19.1.9. Vehicle Demonstration flights shall 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 shall submit an FRR Addendum by the FRR Addendum deadline. 11 General and Proposal Requirements	Vehicle Demonstration flights must be made by the FRR submission deadline. An extension may be allowed if a Vehicle Demonstration Re-flight is necessary as determined by the Student Launch office. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.
2.19.2. 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 shall be the same rocket to be flown as their competition launch. 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 shall be met during the Payload Demonstration Flight:	The team must launch their full-scale rocket, including the payload, successfully by the Payload Demonstration Flight deadline. The payload will be launched in the rocket intended for competition. The payload must be fully retained, and the rocket will experience a stable ascent.
2.19.2.1. The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.	The team's design outlines that payload will not jettison and will be retained properly within the launch vehicle.
2.19.2.2. The payload flown shall be the final, active version.	The payload will be completed and flown in its final version.
2.19.2.3. 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.	If the payload is successfully flown at the Vehicle Demonstration Flight, the Payload Demonstration Flight is not required.
2.19.2.4. Payload Demonstration Flights shall be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	The Payload Demonstration Flight must be completed by the submission deadline of the FRR Addendum with no exceptions.

2.20. An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.	If the Payload Demonstration Flight or Vehicle Demonstration Flight is completed after the submission of the FRR report, an FRR Addendum must be completed by the team.
2.20.1. 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.	If the team requires a Vehicle Demonstration Re-flight, the team must submit the FRR Addendum or will be banned from the final launch.
2.20.2. 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 must have a successful launch for both the Vehicle Demonstration Flight and the Payload Demonstration Flight.
2.20.3. 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.	If the Payload Demonstration Flight is not successful, the team may request to fly the payload during launch week, only with permission from the NASA RSO.
2.21. 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 must include their name and contact information on each section of the launch vehicle that is not tethered to the main airframe.
2.22. 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.	Lithium Polymer batteries must be appropriately protected and marked using orange tape.
2.23. Vehicle Prohibitions:	See Vehicle Prohibitions below.
2.23.1. The launch vehicle will not utilize forward firing motors.	The launch vehicle will use rear-firing motors.
2.23.2. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	The launch vehicle will use an AeroTech K1050W-PS motor that does not release titanium sponges.
2.23.3. The launch vehicle will not utilize hybrid motors.	The motor chosen for the launch vehicle is not a hybrid motor.
2.23.4. The launch vehicle will not utilize a cluster of motors.	A single motor is chosen for the launch vehicle.
2.23.5. The launch vehicle will not utilize friction fitting for motors.	The chosen motor will use centering rings and a thrust plate for motor retention.
2.23.6. The launch vehicle will not exceed Mach 1 at any point during flight.	The rocket will not exceed Mach 1 during flight, ensured through utilizing OpenRocket simulations to determine the launch vehicle's velocity.

2.23.7. 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)	Any vehicle ballast utilized will not weigh more than 10% of the rocket's total unballasted weight.
2.23.8. Transmissions from onboard transmitters, which are active at any point prior to landing, will not exceed 250 mW of power (per transmitter).	Each transmitter must not exceed 250 mW of power.
2.23.9. 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.	Each transmitter will be equipped appropriately to minimize interference.
2.23.10. 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 team's design will only include minimal lightweight metal primarily in the tip of the nosecone.

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 full-scale launch vehicle will use a dual deploy system. A drogue will be deployed within 1 second of apogee, and a main parachute will deploy at 600 feet.
3.1.1. The main parachute shall be deployed no lower than 500 feet.	The main parachute will be deployed at 600 feet.
3.1.2. The apogee event may contain a delay of no more than 2 seconds.	The primary charge for the drogue deployment will not have a delay for drogue deployment.
3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.	Motor ejection will not be used as a form of parachute deployment.
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 testing lead and safety officers will perform ejection tests for all electronic recovery events for both the subscale and full-scale launch vehicles prior to their first flights.
3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	It will be ensured that no section of the launch vehicle has a kinetic energy that equals or exceeds 75 ft-lbf at landing. This will be done using OpenRocket simulations and the current maximum kinetic energy is estimated to be 61 ft-lbf.

3.4. The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	The design will include a redundant Entacore AIM altimeter.
3.5. Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	Each altimeter implemented will have an independent fully-charged 9-volt battery power source.
3.6. Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	The altimeters will have the ability to be armed through a key switch on the switch band of the avionics bay.
3.7. Each arming switch will be capable of being locked in the ON position for launch (i.e., cannot be disarmed due to flight forces).	The arming switches will be locked in the “On” position during launch.
3.8. The recovery system electrical circuits will be completely independent of any payload electrical circuits.	The electronics included in the payload and the recovery system will be separate and will be located in separate sections of the launch vehicle.
3.9. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	The launch vehicle will be secured together through the use of shear pins at any section that will separate and rivets at any section that does not separate.
3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads.	The rocket will not drift farther than 2,500 ft from the launch pad when landing. The current estimated recovery area is 2485 ft. This value will be re-estimated throughout the project process.
3.11. Descent time of the launch vehicle will be limited to 90 seconds (apogee to touch down).	The time from apogee to touch down will not exceed 90 seconds. The current estimated landing time is 84.7 sec.
3.12. An electronic GPS 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 placed in the nosecone of the launch vehicle and will have the ability to communicate with the ground station.
3.12.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic GPS tracking device.	There will not be any untethered sections of the launch vehicle or payload.
3.12.2. The electronic GPS tracking device(s) will be fully functional during the official competition launch.	The testing Lead will be responsible for ensuring the proper functionality of the GPS devices prior to launch.
3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	Any electronic devices involved in the launch vehicle will not interfere with the recovery system electronic capabilities.
3.13.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency	The recovery system altimeters will be located in the avionics bay, away from the devices implemented in the payload that will be located in the aft section.

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.	The recovery system electronics will be shielded using aluminum foil from interference with any other transmitting devices.
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 using aluminum foil from magnetic waves with any other transmitting devices.
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 shielded using aluminum foil from other devices that may negatively affect the recovery system by being placed in the avionics bay.

4.6.4 Payload Experiment Requirements

Requirement	**Implementation Plan**
4. All payload designs shall 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.	The team's payload design must be approved by NASA and may be changed by NASA if necessary.
4.1. College/University Division – Teams shall design a payload capable of autonomously locating the launch vehicle upon landing by identifying the launch vehicle's grid position on an aerial image of the launch site without the use of a global positioning system (GPS). The method(s)/design(s) utilized to complete the payload mission will be at the teams' discretion 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.	The team's payload design will implement cameras placed on the exterior of the airframe and will be utilized to identify reference points found on the ground in order to locate the launch vehicle upon landing.
4.2.1. The dimensions of the gridded launch field shall not extend beyond 2,500 feet in any direction; i.e., the dimensions of your gridded launch field shall not exceed 5,000 feet by 5,000 feet.	The gridded launch field dimensions are 5,000 ft by 5,000 ft.

4.2.1.1. Your launch vehicle and any jettisoned components must land within the external borders of the launch field.	The entirety of the launch vehicle and its components will land within the 2,500 ft radius since the estimated drift range is 2490 ft.
4.2.2. A legible gridded image with a scale shall be provided to the NASA management panel for approval at the CDR milestone. 4.2.2.1. The dimensions of each grid box shall not exceed 250 feet by 250 feet. 4.2.2.2. The entire launch field, not to exceed 5,000 feet by 5,000 feet, shall be gridded. 4.2.2.3. Each grid box shall be square in shape. 4.2.2.4. Each grid box shall be equal in size, it is permissible for grid boxes occurring on the perimeter of your launch field to fall outside the dimensions of the launch field. Do not alter the shape of a grid box to fit the dimension or shape of your launch field. 4.2.2.5. Each grid box shall be numbered 4.2.2.6. The identified launch vehicle's grid box, upon landing, will be transmitted to your team's ground station.	A gridded image of the launch field with an appropriate scale has been created and will be submitted at the CDR deadline. Each square grid is 250 ft by 250 ft and the grid box that the launch vehicle lands in will be communicated to the ground station.
4.2.3. GPS shall not be used to aid in any part of the payload mission. 4.2.3.1. GPS coordinates of the launch vehicles landing location shall be known and used solely for the purpose of verification of payload functionality and mission success. 4.2.3.2. GPS verification data shall be included in your team's PLAR.	A GPS is not included in the payload design. The GPS located in the nosecone will be used only for verification of the payload's results.
4.2.4. The gridded image shall be of high quality, as deemed by the NASA management team, that comes from an aerial photograph or satellite image of your launch day launch field. 4.2.4.1. The location of your launch pad shall be depicted on your image and confirmed by either the NASA management panel for those flying in Huntsville or your local club's RSO. (GPS coordinates are allowed for determining your launch pad location).	The gridded image is a high-quality satellite image of the launch field, and the launch pad location will be depicted.
4.2.5. No external hardware or software is permitted outside the team's prep area or the launch vehicle itself prior to launch.	The hardware and software utilized is implemented only in the launch vehicle or on the ground station.
4.3. General Payload Requirements:	See the payload requirements below.
4.3.1. 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.	Black Powder will be used for ejection charges only.

4.3.2. Teams shall abide by all FAA and NAR rules and regulations.	The team will follow rules set forth by the FAA and NAR.
4.3.3. Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement at the CDR milestone by NASA.	No components will be jettisoned without RSO approval.
4.3.4. 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 UAS payloads.
4.3.5. 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 UAS payloads.
4.3.6. 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 UAS payloads.

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 create a launch and safety checklist based on the launch requirements that will be included in FRR and utilized during LRR and Launch Day. This checklist will be enforced by the team's safety officers.
5.2. Each team shall identify a student safety officer who will be responsible for all items in section 5.3.	Jason Rosenblum and Raymond Pace are the team's chosen safety officers and are responsible for the items listed below.
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. Competition Launch 5.3.1.8. Recovery activities 5.3.1.9. STEM Engagement Activities	The safety officers will monitor the design, construction, and assembly of the vehicle and payload. The safety officers will be present during ground testing procedures and will attend both the subscale launch and full-scale launch, enforcing proper safety procedures. The safety officers will oversee recovery and ensure that team members are following safety precautions when completing recovery activities. The safety officers will also monitor any STEM engagement activities that involve safety hazards.

5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	The safety officers will review the team's manufacturing, assembly, launch, and recovery plans and enforce proper safety protocols during these processes.
5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	The team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data is updated by the safety officers and is shared with the remaining team members through a Microsoft Teams account.
5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	The safety officers will assist in creating and writing the team's hazard analyses, failure modes analyses, and procedures that will be included in reports.
5.4. During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	The team will abide by rules set forth by the safety officers. The team will communicate appropriately prior to attending NAR/TRA launches.
5.5. Teams will abide by all rules set forth by the FAA.	The team has reviewed the rules set forth by the FAA and will abide by all regulations. The team's project plan accounts for these regulations.

4.7 Challenges

4.7.1 Payload Challenges

The team will need to address and minimize compounding errors between the camera pose estimation and inertial navigation systems. Because the error induced by the inertial navigation system grows quadratically over time, the amount of time that the vehicle remains under inertial guidance must be kept to a minimum. This error can be further reduced through calibration, the use of more than one sensor, and the application of Kalman filtering.

The cameras on board the rocket will not be perfectly still. In addition, the camera will not be pointing straight down the entire time. Thus, getting the position of the rocket by performing localization and distance calculation on a tilted image will have its own challenges.

5. STEM Engagement

5.1 STEM Engagement Plan

5.1.1 STEM Engagement

STEM in education will be taken as the interdisciplinary approach to learning all academic concepts applied in a real-world setting related to science, technology, engineering, and mathematics. The fundamental concepts juxtaposed to the engaging connection between students and the world around them highlight the most practical approach to learning. The Swamp Launch Rocket Team strives to share this practical approach with the surrounding community and local schools. The team plans to reach at least 200 elementary and middle school students and 150 high school students. The team plans to take rocketry and engineering to students in a way that is both challenging and rewarding to understand.

5.1.2 Local Schools

The team plans to bring hands-on in-person activities related to physics and engineering to Alachua County Public Schools. For the younger students in elementary school, the team will host space themed arts and crafts and introduce astronomy topics. Middle schools will be able to learn deeper concepts and build bottle rockets in small groups with Swamp Launch Team members and subteam Leads.

Older students in high school can engage in group learning on their own devices and school devices in simulation, design, and CAD to build introductory skills necessary for building rockets and prepare them for technical experiences and engineering processes in college.

Additional collaborations include Hands-On Gainesville, a group dedicated to expanding educational reach. The team plans to work with this organization to teach students more about rocketry and participate in their STEM focused partnered events. The combination of visual lectures and applying knowledge of design will provide an entertaining opportunity for growth in the community. Finally, the team plans to make DIY bottle rocket events with the Boy Scouts and teach basic rocketry.

5.1.3 Engagement at the University of Florida

Swamp Launch Rocket Team plans to pair with other UF organizations to bring Rocketry to more aspects of University of Florida campus life. The team will work with the University of Florida Benton Engineering Council in preparation for UF Engineering Week. Additionally, the team will hold weekly scheduled General Body and Design Meetings to provide general updates on our overall progress, general information on rocketry, and inform new members on all facets of the design process. Inexperienced members will be invited to participate and learn from subteam meetings to increase involvement and education. Finally, it is also Swamp Launch's goal to launch an annual collaboration with the University of Florida's American Institute of Aeronautics and Astronautics (AIAA) chapter and other Aerospace and Engineering organizations at UF to facilitate rocketry events around the local area.

6. Project Plan

6.1 Development Schedule

The team will adhere to a defined project schedule designed to meet all Project Milestones (Table 22). The schedule is primarily created around the Project Milestones and provides time for report drafting and reviewing as well as vehicle design, manufacturing, and testing.

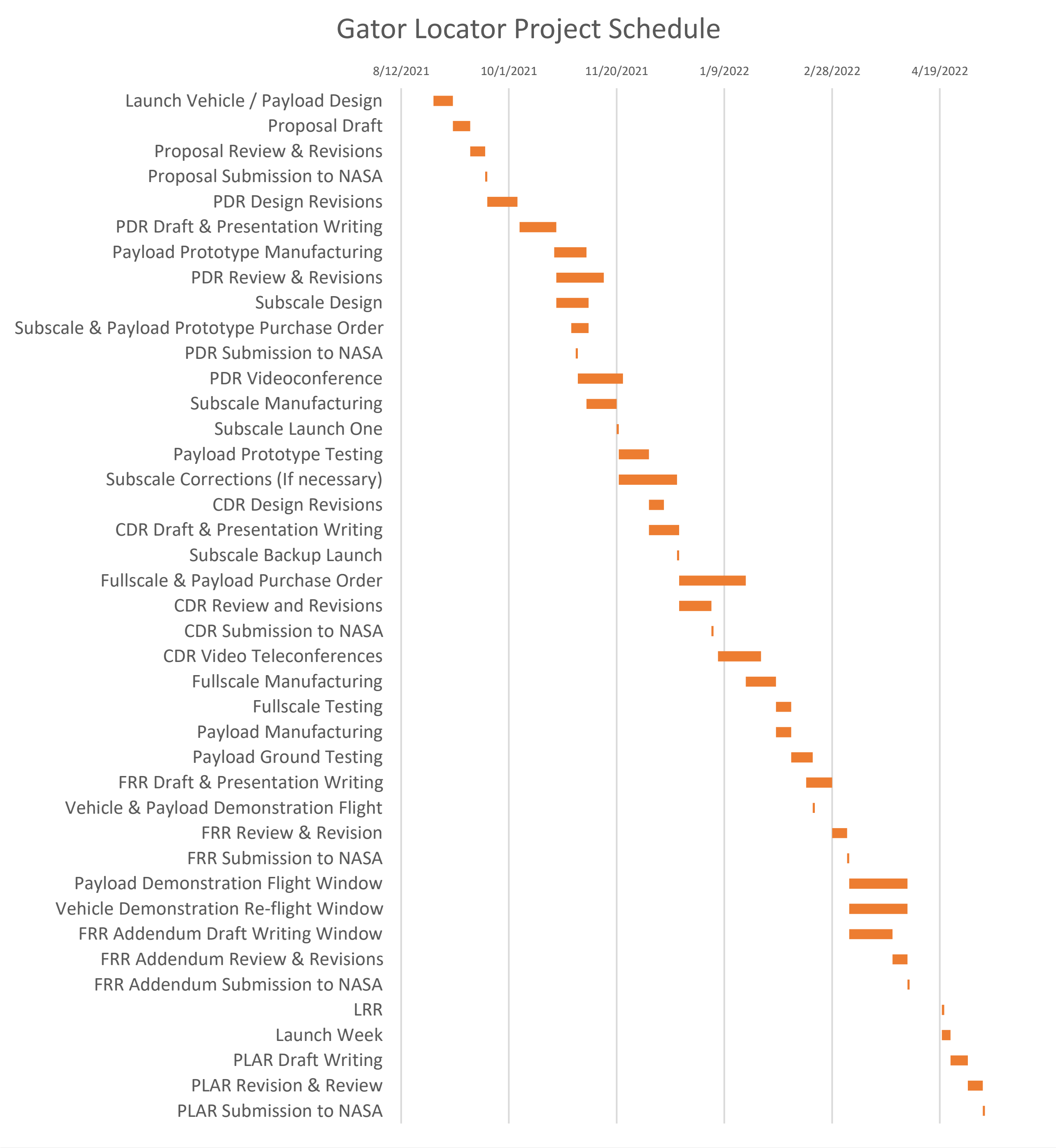

Table 22: Gator Locator project schedule

6.2 Project Budget

The team's expected budget for the 2021-2022 season is just below $5,600.00 (Figure 52), (Table 23). This budget is based off 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 (Table 24) and listed out (Table 25-29). Travel costs are also included in the budget accounting for road travel and hotel stays for the competition and launches.

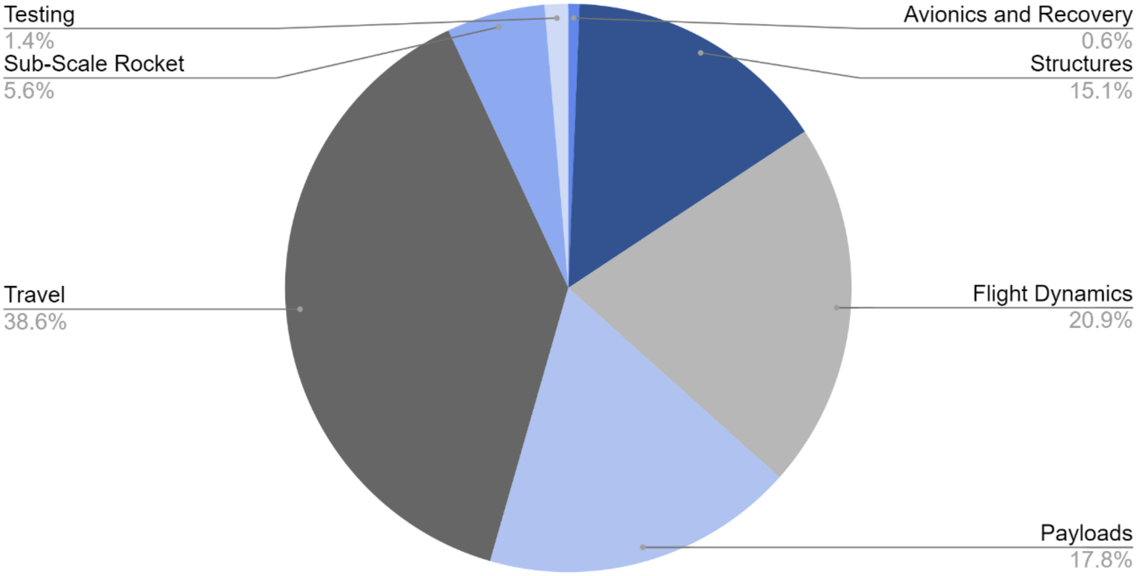

Figure 52: Swamp Launch budget breakdown

Category	Total Cost ($)
Full-Scale Rocket	3,225.00
Travel	2000.00
Subscale	291.23
Testing	70.00
Total:	5586.23

Table 23: Total Project Cost

Subgroup	Total Cost ($)
Structures	782.31
Avionics and Recovery	33.13
Flight Dynamics	1082.34
Payloads	925.34
Total:	3225.00

Table 24: Full-Scale Budget Breakdown and Total

Component	Quantity	Unit Cost ($)	Total Cost ($)
4" 5:1 fiberglass Ogive nosecone w/ metal tip	1	79.95	79.95
4" diameter fiberglass airframe (5 ft)	2	116.75	233.50
2.1" fiberglass motor tube (3 ft)	1	43.20	43.20
3/16" thick, 24" x 24" G10 fiberglass sheets (fins)	2	51.30	102.60
1/2" thick, 24" x 24" plywood (bulkheads, centering rings)	2	17.60	35.20
Jewel (10 oz)	4	14.27	57.08
RocketPoxy (2 qt)	2	85.31	170.62
Shear Pins	4	3.52	14.08
Rivets	4	7.41	29.64
Rail buttons	2	8.22	16.44
Sandpaper	N/A	N/A	Inventory
Total:			782.31

Table 25: Structural Component Estimates

Category	Quantity	Unit Cost ($)	Total Cost ($)
9 V Battery	2	8.00	16.00
Eyebolt	4	4.28	17.12
Main Parachute	1	N/A	Inventory
Drogue Parachute	1	N/A	Inventory
Recovery Harness	2	N/A	Inventory
Swivel	2	N/A	Inventory
Quick Link	6	N/A	Inventory
Altimeter	2	N/A	Inventory
Terminal block	4	N/A	Inventory
Key lock switch	2	N/A	Inventory
Total:			33.13

Table 26: Avionics and Recovery Component Estimates

Category	Quantity	Unit Cost ($)	Total Cost ($)
Motor Retainer	1	46.66	46.66
Motor Forward Closure	1	77.52	77.52
Motor Aft Closure	1	56.18	56.18
Motor Casing	1	203.92	203.92
Thrust Plate	1	44.87	44.87
Aerotech K1050W-PS	3	217.73	653.19
Total:			1082.34

Table 27: Flight Dynamics Component Estimate

Category	Quantity	Unit Cost ($)	Total Cost ($)
Digital Signal Processor	2	86.00	172.00
OV5640 Camera	4	24.99	99.96
XBee Transceiver	4	54.08	216.32
Lithium-Ion Batteries	4	14.50	58.00
IMU	4	59.78	239.12
Altimeter	2	12.98	25.96
Printed Circuit Board	5	12.00	60.00
Wiring	1	5.99	5.99
JST Connector Kit	1	23.99	23.99
1/4-20 Well Nuts	4	6.00	24.00
1/4-20 Fasteners	8	N/A	Inventory
1/4-20 Hex-Nuts	4	N/A	Inventory
Total:			925.34

Table 28: Payload Component Estimate

Category	Quantity	Unit Cost ($)	Total Cost (includes shipping) ($)
3" diameter fiberglass nosecone	1	59.95	59.95
3" diameter fiberglass airframe	2	102.55	205.10
1.5" diameter motor tube (2 ft)	1	26.18	26.18
Total:			291.23

Table 29: Subscale Component List

6.3 Funding

This project will be primarily funded by the University of Florida’s Student Government during the Fall 2021 semester. The team will also be seeking funding from the University of Florida’s Mechanical and Aerospace Engineering Department. The request approval will determine how much funding is allotted to travel and the full-scale rocket build in the Spring 2021 semester. The team sponsor is Aerojet Rocketdyne. The team 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, with additional donations made optional. Funding will first be received by our advisors, Dr. Lind and Dr. Niemi, and will then be allocated to our group. The team has also started an alumni program to stay in touch with dedicated members who have graduated, encouraging them to stay involved and support the future of the group.

6.4 Sustainability Plan

The team is primarily funded by the University of Florida’s Department of Mechanical and Aerospace Engineering Department, which has reliably provided funding over the past several years. Supplemental funding provided by the University of Florida’s Student Government and corporate sponsorships has increased over the past year. The development of business documentation has led to this increase, and it is projected to maintain a higher level of support for further years. Current sponsors include Aerojet Rocketdyne, and the team will continue to seek corporate sponsorships throughout the year.

The team will maintain relationships with alumni in order to establish further corporate partnerships. Communication with team alumni has been established through Slack as well as a LinkedIn group. New team members will be recruited through the posting of virtual flyers advertising the team and through in-person tabling events that showcase our previous work. Flyers will include meetings, team information and links for the team's social media where updates are regularly posted. Social media will be used to promote events, socials and general body meetings. An increase in events have shown greater social media engagement, and in turn a higher turnout at our general body meetings and subteam meetings. Socials have also proven to increase member retainment and productivity, as they have established a sense of community within the team.

Swamp Launch will further extend its reach throughout the University of Florida by presenting for various technical societies including the American Institute of Aeronautics and Astronautics (AIAA) and the Society of Women Engineers (SWE). Updates will be sent out biweekly to students within the Herbert Wertheim College of Engineering through the Benton Engineering Council (BEC), team hosted Newsletter, and on the UF Canvas page for all MAE students through MAE Undergraduate Advising.

The team will maintain its relationships with local schools and businesses. In addition to in-person events, online zoom activities will be organized for students in Alachua County Public Schools. Brief lectures and bottle rocket demos will be prepared to create and maintain engagement with local schools. A YouTube channel will be maintained as a method of posting updates on the team for students and businesses to observe.

7. Conclusion

Swamp Launch Rocket Team is confident in its proposed Gator Locator design's ability to successfully complete the request put forth by NASA Student Launch. The team will continue to research, develop, and test the design throughout the competition to ensure it is capable of overcoming any challenges it may be presented with.

Appendix A

Testing Plan

The Safety Officers, the Testing Lead, and the necessary Professors and Teaching Assistants will oversee all testing of launch vehicle and payload components (Table 30, Table 31).

Launch Vehicle Testing Plan

Test Number	Test Name	Required Materials and Machinery	Test Procedure	Justification
1	Airframe Compression Test	Fiberglass airframe, Instron Machine	Place the airframe material in the Instron Machine to simulate compressive forces and record data. Compress airframe both laterally and axially.	Determine if airframe is strong enough to withstand compressive forces that will occur when landing and ensure that it will not be damaged.
2	Airframe Resistance Drop Test	Fiberglass airframe, test parachute	Drop airframe material from height of at least 6 ft to simulate how launch vehicle would land after launch onto a similar landing terrain of grass. Assess resulting behavior of fiber glass.	Ensure that airframe will not be damaged when landing. The height specified will result in expected airframe landing speed of 18 ft/s.
3	Bulkhead Resistance Test	Plywood bulkhead, coupler, eyebolts, Instron Machine	Place coupler inside Instron Machine and pull on eyebolts and bulkhead to simulate how bulkhead would behave during ejection and resulting shear forces.	Ensure that bulkheads will not be damaged when parachutes deploy.
4	Rotation & Rolling Test	Ansys Simulation	Run a computer simulation and evaluate the resulting data concerning the rotation and rolling of the rocket.	Determine how severe the rotation (pitch and yaw moment) and rolling (axis pa effects are during launch and stabilize the launch vehicle accordingly.

5	Nosecone Drag Test	Computational fluid dynamics (CFD) simulation software	Use CFD simulation to measure resulting drag from nosecone oriented at multiple angles.	Ensure drag is not too great on nosecone to affect flight and adjust nosecone accordingly.
6	Body Tube Drag Test	Computational fluid dynamics (CFD) simulation software	Use CFD simulation to measure resulting drag from body tube oriented at multiple angles.	Ensure drag is not too great on body tube to affect flight and adjust body tube accordingly.
7	Main Parachute Drag Test	Computational fluid dynamics (CFD) simulation software	Use CFD simulation to measure resulting drag from main parachute.	Ensure main parachute provides enough drag to slow the launch vehicle during descent.
8	Drogue Parachute Drag Test	Computational fluid dynamics (CFD) simulation software	Use simulation to measure resulting drag from drogue parachute.	Ensure drogue parachute provides enough drag to slow the launch vehicle during descent.
9	Fin Drag Test	Computational fluid dynamics (CFD) simulation software	Use CFD simulation to measure resulting drag from fin configuration oriented at multiple angles.	Ensure drag is not too great on fins to affect flight and adjust fins accordingly.
10	Altimeter Resolution Test	Altimeter	Place the altimeter at multiple heights.	Ensure altimeter is detecting the correct altitude.
11	Main Parachute Ejection Test	Launch vehicle, main parachute, black powder, electric match, copper wires, test stand, altimeter, remote igniter	Fire ejection charge when launch vehicle is configured for ejection.	Ensure that main parachute will successfully deploy when the launch vehicle separates.
12	Drogue Parachute Ejection Test	Launch vehicle, drogue parachute, black powder, electric match, copper wires, test stand, altimeter, remote igniter	Fire ejection charge when launch vehicle is configured for ejection.	Ensure that drogue parachute will successfully deploy when the launch vehicle separates.

13	Recovery Harness Strength Test	Recovery harness, Instron Machine, accelerometer	Induce an instantaneous force on the recovery harness using the Instron Machine. Determine yield strength of recovery harness. Compare strength value to calculated force estimate using accelerometer data and ensure yield strength exceeds expected force.	Determine if recovery harness is strong enough to withstand forces occurring during separation.
14	Zippering Test	Fiberglass, recovery harness	Induce an instantaneous force to simulate deployment.	Ensure there is no damage to the launch vehicle structure.
15	Black Powder Test	Launch vehicle, black powder, electric match, copper wires, test stand, altimeter, remote igniter	Ignite charges to commence ejection. Perform test for main parachute and drogue parachute.	Establish amount of black powder necessary for full separation of airframe and deployment of parachutes.
16	Vibrational Resistance Test	Launch vehicle	Simulate vibrational forces, similar to those expected during launch, on payload.	Ensure launch vehicle will not be damaged during launch due to vibrational movement.
17	Epoxy Weight Test	Epoxy, fiber glass	Weigh two pieces of fiberglass, epoxy pieces together and weigh once more.	Determine weight of epoxy per inch.
18	Epoxy Heat Test	Epoxy, fiber glass	Create epoxy fillet between two pieces of fiberglass and place in sunlight for a minimum of two hours.	Verify that epoxy will not overheat and soften.
19	Epoxy Strength Test	Epoxy, fiber glass, Instron Machine	Create epoxy fillet between two pieces of fiberglass and place in the Instron Machine. Record any resulting separation	Determine if epoxy will uphold during large compressive forces during landing and ensure it will not allow

			between fiberglass bonding surfaces and compare to calculated expected landing forces.	fins to separate from launch vehicle.
20	Parachute Packing Test	Main and drogue parachute, parachute cover, airframe, insulation, recovery harness, eyebolts, swivels	Fold parachute in an appropriate manner and place in airframe.	Ensure that parachute fits in airframe and will deploy smoothly.
21	Parachute Opening Test	Main and drogue parachute, recovery harness, airframe	Drop airframe from height of at least 20 ft.	Ensure that parachute opens correctly and does not get tangled. The drop height was set to give parachute ample time to open during descent.
22	Subscale Demonstration Launch	Subscale model in full configuration	Launch the subscale model.	Ensure all components of the subscale perform successfully.
23	Vehicle Demonstration Launch	Launch vehicle in full configuration	Launch the launch vehicle in its final configuration.	Ensure all components of the launch vehicle perform successfully.
24	Launch Rehearsal	Launch vehicle and payload in full configuration	Fully assemble launch vehicle (without the motor) and payload in appropriate amount of time.	Determine required amount of time to assemble launch vehicle in order to prepare for final launch day and ensure preparation can be completed in less than 2 hours.

Table 30: Launch Vehicle Testing Plan

Payload Testing Plan

Test Number	Test Name	Required Materials and Machinery	Test Procedure	Justification
25	Drone Camera Landmark Test	Payload camera, testing drone	Place payload camera on a testing drone and fly it to predicted	Ensure camera can capture 3 landmarks during ascent

			altitude. Perform test for both the cameras.	and descent time.
26	Drone Camera Quality Test	Payload camera, testing drone	Place payload camera on a testing drone and fly it to predicted altitude. Perform test for both the cameras.	Ensure the quality of the images captured is high enough to detect 3 landmarks.
27	Field-of-View Test	Payload camera, testing drone	Place payload camera on a testing drone and measure the distance the camera can see. Confirm observations with calculations of field-of-view. Perform test for both the cameras.	Determine the field-of-view of the cameras.
28	Drone Offset Test	Payload camera, gyroscope, testing drone	Place payload camera on a testing drone and fly it to predicted altitude. Fly drone at multiple angles and observe angle of offset. Apply offset calculations to code.	Determine angle of offset of camera to ensure camera can adjust its angles.
29	Battery Life Test	Battery, payload	Allow battery to run for a minimum of 2 hours.	Ensure that the battery can maintain a charge so that the launch vehicle can be launch-ready for at least 2 hours.
30	Accelerometer Accuracy Test	Accelerometer, recovery harness, eyebolt	Simulate launch movement by	Ensure it is reporting the

			attaching accelerometer to recovery harness and spinning it. Move the spinning accelerometer a straight measured distance.	appropriate displacement.
31	Heat Resistance Test	Payload, fiberglass airframe, thermometer	Place payload inside airframe and leave outside in sunlight for a minimum of 2 hours. Measure temperature using thermometer and assess possible resulting damage from heat.	Ensure that the payload will not overheat so that the launch vehicle can be launch-ready for at least 2 hours.
32	Ejection Resistance Test	Payload, black powder, copper wire, electric match, test stand, remote igniter, launch vehicle	Perform a separation ejection test with payload inside launch vehicle.	Ensure payload will not be damaged from ejection charges.
33	Power Loss Test	Launch vehicle in launch configuration, payload	Momentarily disconnect power when the launch vehicle is configured for launch. Assess if the system's redundancies allow it to recover and continue operation.	Ensure payload will continue operation correctly in a circumstance of loss of power.
34	Vibrational Resistance Test	Payload	Simulate vibrational forces, similar to those expected during launch, on payload.	Ensure payload will not be damaged during launch due to vibrational movement.
35	Payload Drop Test	Payload, airframe, test parachute	Drop payload in airframe from height	Ensure payload will not be

			of at least 6 ft to simulate how payload would land after launch.	damaged when landing. The height specified will result in expected launch vehicle landing speed of 18 ft/s.
36	Strength of Camera Mount Test	Computational fluid dynamics (CFD) simulation software	Use CFD simulation to determine forces on camera and camera mount during launch.	Ensure payload will remain attached securely to the airframe during launch.
37	Static Firing Test	Motor, motor retention system, test stand, fiberglass airframe, payload	Test stand will be designed and built by the Structures Lead. Configure payload and motor inside airframe, place on test stand, and fire the motor.	Ensure that payload cameras and wiring do not overheat as the motor fires.
38	Software Implementation Test	OpenCV software, payload	Run code utilized for payload completely through.	Evaluate if software is properly implemented with hardware and debug code if necessary.
39	Digital Signal Processor (DSP) Functionality Test	DSP, starter kit software	Plug DSP into laptop and run starter kit software.	Ensure DSP is functioning correctly and determine if there are any bugs in the system.
40	Inertial Measurement Unit (IMU)	IMU, testing kit software, DSP	Plug IMU into laptop, orient it in a certain configuration, and collect acceleration	Ensure IMU is measuring correctly and determine if

	Functionality Test		and orientation data. Compare collected data to measurements made of the current orientation.	there are any bugs in the system.
41	XBee Radio Functionality Test	XBee radio, serial converter, X-CTU software, DSP	Plug the XBee transmitter and XBee receiver into separate laptops and send data packets through X-TCU.	Ensure the XBee radios are able to establish a connection.
42	Microprocessor Functionality Test	Microprocessor, computer	Plug microprocessor into computer and upload an example program.	Ensure microprocessor is functioning correctly.
43	SD Card Functionality Test	SD card, computer	Write data to the SD card through the DSP. Read back data and confirm that it matches the originally written data.	Ensure SD card is functioning correctly.
44	Wire Tube Test	Cardboard wire tube, centering rings, airframe	Configure wire tube set-up and determine if tube interferes with centering rings and if tube fits in airframe.	Ensure that wire tube is large enough to protect wires without compromising motor position.
45	Payload Demonstration Flight	Launch vehicle and payload in full configuration	Launch fully constructed payload in launch vehicle.	Ensure payload captures 3 landmarks and defines location.

Table 31: Payload Testing Plan

Testing Safety by Reference Number

Table 32 outlines the necessary safety precautions that must be taken when performing the listed tests. The table refers to each test by its number and includes a description of the safety steps that will be taken.

Test Number	Safety Precautions

1	The Instron Machine will only be operated by permitted personnel while other team members will maintain a safe distance from the machine when in use.
2	The airframe will be dropped at a safe distance away from team members or pedestrians.
3	The bulkhead will be dropped at a safe distance away from team members or pedestrians.
4	Not applicable, negligible risk.
5	The wind tunnel will only be operated by permitted personnel and team members will maintain a safe distance from the wind tunnel.
6	The wind tunnel will only be operated by permitted personnel and team members will maintain a safe distance from the wind tunnel.
7	The wind tunnel will only be operated by permitted personnel and team members will maintain a safe distance from the wind tunnel.
8	The wind tunnel will only be operated by permitted personnel and team members will maintain a safe distance from the wind tunnel.
9	The wind tunnel will only be operated by permitted personnel and team members will maintain a safe distance from the wind tunnel.
10	Not applicable, negligible risk.
11	Team members will maintain a safe distance from the launch vehicle during ejection.
12	Team members will maintain a safe distance from the launch vehicle during ejection.
13	Team members will maintain a safe distance from the launch vehicle during induced force.
14	Team members will maintain a safe distance from the launch vehicle during induced force.
15	Team members will maintain a safe distance from the launch vehicle during ejection.
16	Team members will maintain a safe distance from the launch vehicle during vibrational simulation.
17	Not applicable, negligible risk.
18	Not applicable, negligible risk.
19	The Instron Machine will only be operated by permitted personnel and other team members will maintain a safe distance from the machine when in use.
20	Not applicable, negligible risk.
21	The airframe will be dropped at a safe distance away from team members or pedestrians.
22	Team members will follow safety regulations set by the NAR/Tripoli Range Safety Officer.
23	Team members will follow safety regulations set by the NAR/Tripoli Range Safety Officer.
24	Not applicable, negligible risk.

25	Team members will maintain a safe distance from the drone during takeoff and landing.
26	Team members will maintain a safe distance from the drone during takeoff and landing.
27	Team members will maintain a safe distance from the drone during takeoff and landing.
28	Team members will maintain a safe distance from the drone during takeoff and landing.
29	Not applicable, negligible risk.
30	Team members will maintain a safe distance from accelerometer when spinning it.
31	Not applicable, negligible risk.
32	Team members will maintain a safe distance from the launch vehicle during ejection.
33	Not applicable, negligible risk.
34	Team members will maintain a safe distance from the launch vehicle during vibrational simulation.
35	The payload will be dropped at a safe distance away from team members or pedestrians.
36	The wind tunnel will only be operated by permitted personnel and team members will maintain a safe distance from the wind tunnel.
37	Team members will maintain a safe distance from the launch vehicle during firing and fire extinguishers will be provided in case of emergency.
38	Not applicable, negligible risk.
39	Not applicable, negligible risk.
40	Not applicable, negligible risk.
41	Not applicable, negligible risk.
42	Not applicable, negligible risk.
43	Not applicable, negligible risk.
44	Not applicable, negligible risk.
45	Team members will follow safety regulations set by the NAR/Tripoli Range Safety Officer.

Table 32: Testing safety list