Preliminary Design Review Report

Student-Led Observations of Sinusoidal Hydrodynamics

(SLOSH)

NASA Student Launch 2025 for Middle and High School

Madison West High School

30 Ash Street, Madison, WI 53726

October 28, 2024

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Summary of PDR Report

Team Information

Madison West Rocket Club
Madison West High School
30 Ash Street, Madison, WI 53726

HPR Mentor

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Attendance

We plan to attend the launch in Huntsville, Alabama, during launch week.

Hours

In total, we spent 73 hours working on the PDR milestone.

Social Media Presence

- Instagram: @westrocketry
- Facebook: @madison.west.rocketry
- YouTube: @madisonwestrocketry3308
- Website: https://madison-west-rocketry.github.io/SL/

Launch Vehicle

Competition Launch Motor: Aerotech K-1103 (Total Impulse: 1,810 Ns)
Secondary Motor Choice: AeroTech K-805 (Total Impulse: 1,762 Ns)
Target Altitude: 4,500 feet
Recovery: Dual-deployment with two parachutes
Rail Size: 8' 1010
Rail Exit Velocity: 88 ft/s

Individual Sections Size and Mass

- **Nose Cone**: 1.22 lbs
- **Payload Section**: 4.5 lbs
- **Electronics Bay**: 0.44
- **Booster Section**: 1.7 lb
- **Recovery Hardware**: 3.4 lb
- **Vehicle Dry Mass:** 16.79 lb
- **Vehicle Wet Mass:** 20.01 lb
- **Vehicle Burnout and Landing Mass:** 18.18 lb

Payload: Slosh Baffles

Our payload is designed to test the effectiveness of different baffle designs in reducing the amount of slosh in a liquid tank during rocket acceleration. We will record fluid displacement using cameras and sensor systems and fit the data to a damped sine curve.

Changes Made Since Proposal

Changes to Vehicle Criteria

Since we submitted the proposal, we have updated our projected altitude to 4,500 feet, based on our current design and motor choice and to provide more time to gather data. Our revised design will use a K-class motor, as this will allow us to obtain a height that satisfies the requirements of both our project and general guidelines. The increase in motor size also reflects the need for a heavier payload section than previously anticipated.

Changes to Payload Criteria

Since our proposal was submitted, we have looked into alternative methods for recording data, including different sensor types and different methods of data management. These methods are being considered in support of dissimilar redundancy, as we are considering using multiple different types of sensors in case one or several sensors, or sensor types, fail.

Additionally, we have looked into using clear plastic jars as tanks, instead of 3D-printed tanks. These would allow us to record through the walls and ensure our tanks remain waterproof. These jars have built-in lids, which would allow us to easily install baffle systems and access internal sensors. One downside to this is that we would be restricted to available jar sizes, rather than having the liberty to design the structure of the tanks.

Changes to Project Plan

Since our proposal was submitted, our objective for our payload has shifted from solely attaining quantifiable data to visually observing the effects of our baffles and obtaining data to analyze. This allows us to still provide results from our experiment, even if the data we obtain does not meet the standards required for our analysis.

Vehicle Criteria

Mission Statement and Success Criteria

Our mission is to perform a successful launch and landing while measuring multiple slosh baffles to observe which baffle reduces slosh the most. We will consider the mission a success if we collect enough data to understand and compare the differences among the baffles and observe which design best reduces slosh.

Selection, Design, and Rationale of Launch Vehicle

Our vehicle contains 5 systems: the Nose Cone, the Payload Section, the Electronics Bay, the Booster System, and the Recovery Subsystem (addressed separately).

Nose Cone

Our main design for the vehicle's nose cone is a 24"-long ogive fiberglass nose cone with a diameter of 4 inches, manufactured by Wildman Rocketry. This nose cone is long, allowing the vehicle to create less drag than a shorter nose cone. Additionally, the increased mass forward of the vehicle's center of gravity will increase the vehicle's stability, permitting fewer restrictions in other areas of the design to meet stability requirements.

Nose Cone Alternatives

Our primary nose cone alternative is another 24" cone, also made of fiberglass. This is our primary choice for an alternative because we already have it available at the workshop, and it is very light and strong. The major drawback is that it is extremely light (500 g) and will upset the stability of our rocket.

Our secondary nose cone alternative is to 3D print a nose cone. This option gives us a lot of versatility based on our stability margins and design plans. However, the polycarbonate plastic we would use is much less strong and much heavier. The 3D printed material also has lower performance, is less attractive, and is harder to paint and finish. The main issue preventing us from using a 3D-printed nose cone easily is that it would be tough to successfully implement the recovery system that we are using with a 3D-printed part. Another drawback is that the maximum ratio we could 3D print is a 1:1 nose cone length to 4” rocket diameter, which would create a lot of drag.

Upper Section

Our primary design for the vehicle's upper section is placed between the booster section and the nose cone. It is currently 32” and contains the payload section in its middle, the shock cord for the main chute and the main chute itself at its front, and the forward end of the e-bay at its back side. The payload consists of a long section of 4” body tube, terminated on one end with 11” of coupler tubing, with 7” exposed and a removable bulkhead to seal the end of the coupler tubing. The other end of the payload section is terminated with an upper bulkhead. Eye/U Bolts are placed on both bulkheads to allow the connection of recovery equipment. The removable bulkhead is held tight to the coupler tube via 1/4” diameter tie rods, which pass through the entirety of the payload section and secure against the upper bulkhead. This design allows for the removal of the payload via the temporary bulkhead and incorporates the electronics bay, as explained in that section. We don’t have many options for alternatives for this section besides its length, which we can adjust if necessary.

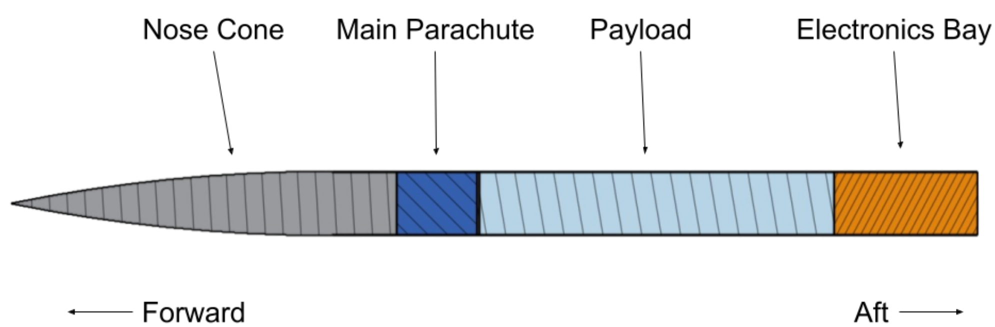

Figure #1: Upper Section Organization

Electronics Bay

Our primary design for the vehicle's electronics bay section is integrated into the payload section. The electronics bay will consist of a 3D-printed mount inside the payload section, retained by the same tie rods that retain the payload. The electronics bay will be located against the removable bulkhead of the payload section, allowing space for wires to be routed through the bulkhead to deployment charges. The electronics bay mount will also contain mounts for batteries and arming switches as required.

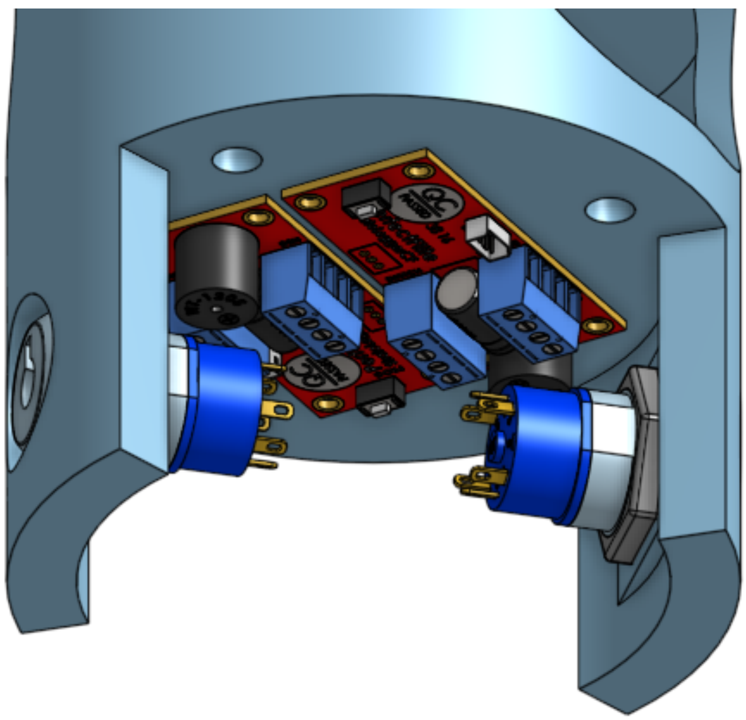

Figure #2: Deployment Computers and Arming Switches Mounting

Booster System

Our vehicle's booster system will consist of the fins, centering rings, a motor tube, a shock cord mount, and the motor itself. The components of the booster system will be constructed using epoxy, using fillets with an approximately 1" radius. The primary fin design will be a trapezoidal 4-fin system made of Garolite G-10 fiberglass. The centering rings will also be made of G-10 fiberglass. The motor tube will be a 20”, 54mm diameter fiberglass tube. We can use different types of fiberglass from different suppliers for all these parts of the rocket, including manufacturing them on our own if necessary. The shock cord will be mounted to the booster section via a loop of Kevlar epoxied to the motor mount. Our primary motor choice is a K-Class AeroTech K-1103 with a total impulse of 1,789 Ns. Our alternate motor choices are an AeroTech K805 (total impulse 1,762 Ns) and a Loki Research K960 (total impulse 1,946.5 Ns).

Recovery Subsystem

Our vehicle will use 2 parachutes for recovery: a drogue parachute and a main parachute. The drogue chute will be deployed at 4,509 feet by the flight computer, and the main parachute will be deployed at an altitude of 700 feet. The drogue parachute will slow the rocket down to approximately 68 ft/s, and the main parachute will slow the rocket down to approximately 18 ft/sec.

Drogue Parachute

The first of these parachutes, the drogue parachute, will be released at apogee by a black powder charge separating the booster section from the payload section. We plan to use a Recon Recovery 20” diameter ripstop nylon drogue parachute in our vehicle, which will provide sufficient drag to slow the vehicle for the majority of its descent. This parachute is more than sufficient to handle the mass and possible variations in the deployment speed of the vehicle and has been tested on vehicles of similar size with positive results. The parachute and shroud lines are relatively resistant to any potential wear or chafing. The drogue parachute will be packed in the booster section directly below the coupler and above the motor assembly. The drogue chute will be deployed with the black powder charge which will separate the booster section from the payload section. Both the parachute and the rest of the rocket will be attached to the booster section (above) with a Kevlar shock cord securely epoxied to the motor mount, and a 1/4”

U-bolt on the upper section. 38 ft of 3/8" Kevlar shock cord will tether and space each vehicle section post-separation. We have chosen a 3/8” Kevlar shock cord over a nylon shock cord because it is extremely chafe-resistant and burn-resistant.

Main Parachute

The main parachute for the vehicle will be deployed at an altitude of 700 feet, with deployment triggered by the main flight computer. We plan to manufacture a 66” diameter toroidal parachute, made out of ripstop nylon, which will slow the vehicle to a speed of 18 feet per second for the rest of the descent. As a team, we have experience with manufacturing parachutes, and our mentors are knowledgeable on this subject and have ample experience to support us. The vehicle’s main parachute will be attached to a 38’-long 3/8" Kevlar shock cord tether connecting the nose cone to the payload section of the vehicle. The shock cord will be securely attached to the top of the nose cone using a 1/4" welded eye bolt and to the forward bulkhead of the payload section using a 1/4" U-bolt. The parachute will deploy via a black powder charge, also separating the nose cone from the payload section. Both the parachute and the nose cone will be separately attached to a bulkhead on the payload section with a Kevlar shock cord. A similar, commercially available parachute (66” ripstop nylon toroidal) is rated to withstand the 100 ft/s deployment rate of a 20-lb rocket. This rating is more than sufficient for our purposes, and our mentors will supervise the construction of our parachute to ensure it meets a similar rating.

Shock Cord and Tether Hardware

The vehicle will use a 3/8" Kevlar shock cord for all tethering of vehicle sections. This material is very burn-resistant, with a continuous temperature tolerance of 900°F, and will easily withstand the brief temperature spike of the ejection charge. The material is also very strong, with a breaking strength rating of 4,500lbs. We calculated an optimal cord length of 32’ (384”) for the tether between the payload section and the booster system. The cord length we will use for the tether between the nose cone and payload section is 38’ (456”) for a safety margin.

The vehicle will use a single 1/4" forged eye bolt mounted to the nose cone’s aluminum tip. The other end of the 32’ Kevlar cord will be mounted to the forward bulkhead of the payload section via a 1/4" stainless steel U-bolt. The main parachute will be attached to the shock cord via a 1/4" stainless steel quick link 10.5’ from the nose cone. The 38’ of shock cord connecting the payload section and the booster section will be tethered to the payload section with a 1/4" U-bolt and to the booster section by securely epoxying the shock cord to the motor mount tube. The drogue chute will be attached with another 1/4" quick link 10.5’ from the booster section. The 1/4" quick links, U-bolts, and eye bolt all are rated for significantly higher loads than will be exerted during flight. The Kevlar cord epoxy attachment on the booster has also been tested and easily withstands high loads.

Recovery System Diagram

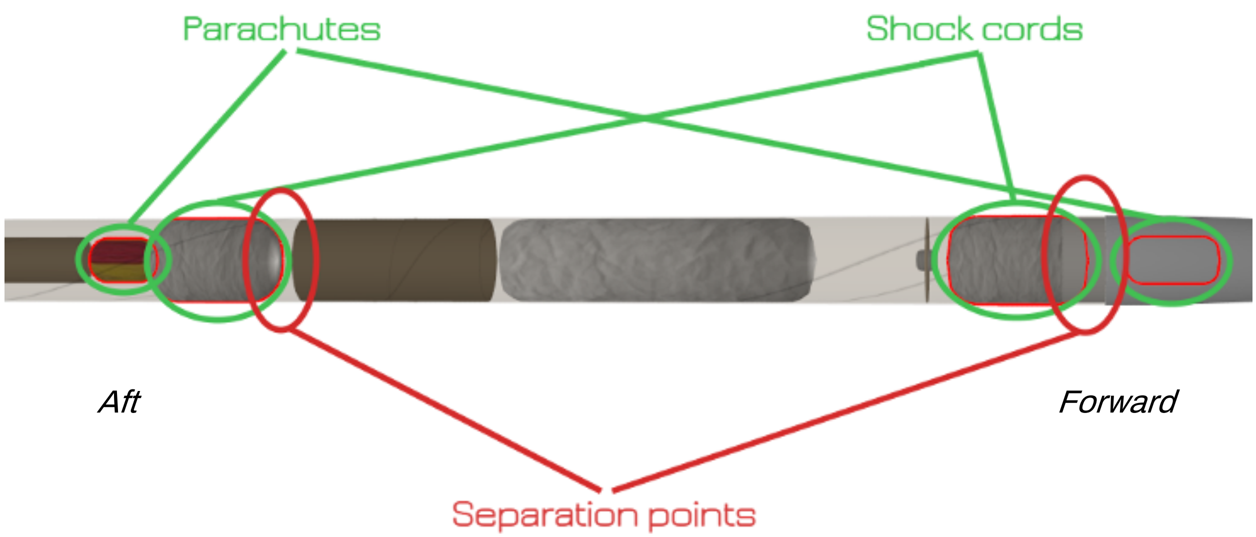

Figure #3: Recovery System Diagram

Deployment Altimeters and Redundancy

Our recovery system will use a Perfectflite Stratologger barometric dual deployment altimeter for our primary flight computer, chosen for its reliability, range of capabilities, and our familiarity with it. We considered other altimeters for the recovery system, but we decided the Stratologger was the best qualified and most reliable in comparison. Additionally, many team members and mentors have experience with this altimeter, which will help eliminate potential user errors. The team is also currently in possession of 4 new and working Stratologgers.

An identical flight computer will provide secondary recovery in case of failure or malfunction of the primary flight computer. This altimeter will be wired to a separate key switch and a separate battery to ensure complete system redundancy. This backup flight computer will also launch its drogue parachute near 4,509 ft and main parachute near 700 feet. However, the backup computer will have a delay of 2 seconds to ensure that both charges are not released at the same time. Our alternate design for our flight computer setup is to use a Stratologger as the main flight computer and a Missile Works RRC3 as the backup for system redundancy. Deployment will still occur at the same altitudes and the second computer will still have a deployment delay of 2 seconds.

Both altimeters will be connected to separately wired 7.4V 2S 100mAh Lithium Polymer batteries, which are lightweight, reliable, and can power the altimeters for several hours. The batteries will be held in a 3D-printed housing in the electronics bay. The altimeters will be wired to two separate key switches mounted through the fiberglass tube of the electronics bay and will be activated on the launch pad. Each altimeter has control over an individual drogue and main charge. Importantly, each altimeter has a completely independent system of power, arming, and deployment. This ensures the system remains redundant.

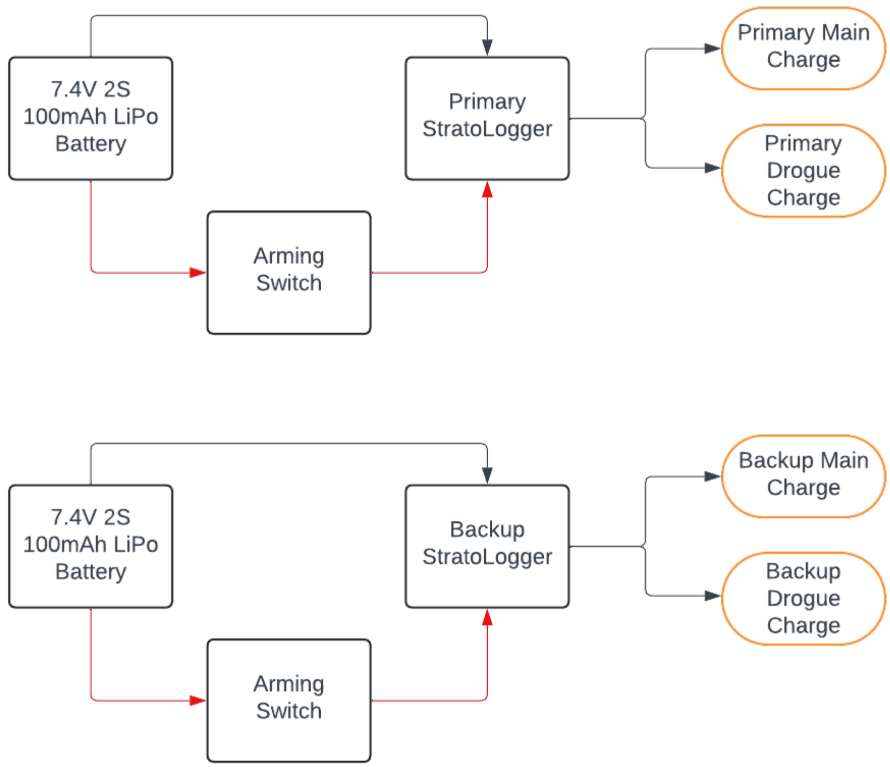

Figure #4: Recovery Deployment Altimeter Wiring Diagram

E-Matches and Charges

The recovery system will use Firewire Initiator e-matches to ignite the deployment charges. These e-matches are low-current and compatible with the Stratologger computers. Several of our HPR mentors have extensive experience with both the Stratologger and Firewire Initiators, and this decision was made per their advice.

Our HPR-certified mentors will prepare and handle all deployment charges, but charge sizing calculations will be performed by students and the results forwarded to the mentors.

Recovery System Alternatives

Alternative Shock Cord

Our alternative shock cord is 10mm width nylon webbing. This material is less flame-resistant than Kevlar, but it is plenty strong and would provide a good alternative if the Kevlar shock cord becomes unavailable. This alternative should be considered as a backup in case our primary shock cord choice becomes unavailable, but it should not be used if our primary material remains available, due to its reduced flame-resistance and current availability.

Alternative Altimeters and Electronics

Our team owns a MissileWorks RRC3 Dual-Deployment Altimeter, which could be used as an alternative to our current altimeter design. If used in combination with a PerfectFlite Stratologger, this altimeter would allow us to use dissimilar redundancy in our recovery system. This altimeter has a good reputation, however the Stratologgers are held to a higher quality control standard. Due to this, this alternative should not be used when compared with our primary design.

Alternative Deployment Charge Igniters

Our alternative for deployment charge igniters are Wildman Rocketry WM01 Ejection Lighters. These igniters are low-current and are designed for deployment charges. These igniters are not as readily available as our primary igniters, so they should be considered only if our primary igniters become unavailable.

Drogue Recovery System Alternatives

Our primary recovery system alternative consists of our 66-inch toroidal main parachute made out of rip-stop nylon. The shock cord will be attached to a secure U-bolt, functioning as an anchor point, and will be located at the top bulkhead in our sustainer tube. The deployment of the chute was tested by the manufacturer for its strength on a 20-lb rocket, with a recorded deployment rate capable of handling decent speeds up to

100 feet per second. Our 32-inch toroidal drogue parachute for our primary recovery system alternative comes with a 38-ft shock cord and will be attached to a U-bolt located at the bottom of the e-bay.

Mission Performance Projections

Flight Profile Simulations

Altitude Profile

Below is a simulated graph of the vehicle's altitude versus flight time under the power of an AeroTech K-1103 motor. The vehicle will accelerate until motor burnout, which will occur approximately 1.69 seconds after launch. Subsequently, the rocket will continue to ascend without propulsion, reaching an apogee of 4,509 feet approximately 16.5 seconds after launch. At this point, the drogue parachute will be deployed. The rocket will then descend until the main parachute deploys at an altitude of 700 feet, 71.9 seconds after launch. Based on parachute profiles and prior flight experience, the average coefficient of drag (C_d) was set to 1.5 for the drogue chute and 1.8 for the main chute in this simulation. 1.8 is a lower C_d than the vehicle will likely experience, but setting it to 1.8 allows simulation under the most pessimistic conditions. The total flight duration is anticipated to be 107 seconds, with a drift of ~1,283 ft under a 15 mph wind.

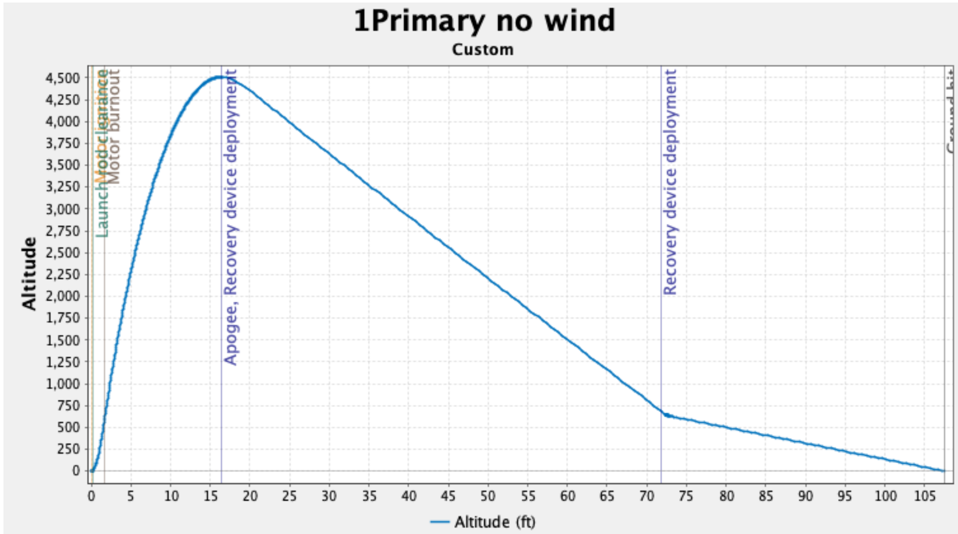

Figure #5: Altitude Profile Simulation

The simulation conducted with no wind reported a small overshoot of our target altitude by 0.2%. This is due to the weight added in the simulation to ensure the rocket will perform. The payload will most likely weigh less than is built into the simulation, resulting in a higher altitude. We have also simulated our rocket with a much lighter payload weight. All requirements will still be fulfilled, including stability, even if the payload is lighter than we expect it to be.

Wind Speed vs. Altitude

We simulated our vehicle under several different wind conditions: no wind, 5 mph, 10 mph, 15 mph, and 20 mph of wind. If the vehicle were to launch in 20 mph winds, the maximum allowed wind speed by the NAR, the vehicle would experience a 90-ft (2.1%) reduction in maximum altitude.

Wind Speed	Apogee (ft)	Δ Apogee (ft)
0 mph	4,509’	0’ (0%)
5 mph	4,502’	-7’ (-0.2%)
10 mph	4,485’	-25’ (-0.6%)
15 mph	4,457’	-53’ (-1.2%)
20 mph	4,420’	-90’ (-2.0%)

Table #1: Wind Speed vs Altitude

Thrust Profile

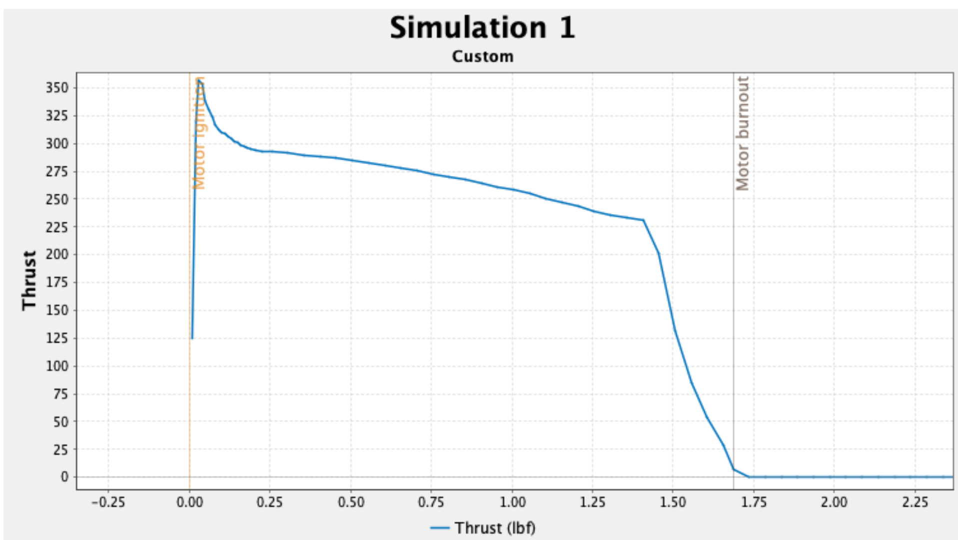

Figure #6: Thrust Profile Simulation

Above is the simulated thrust profile for our primary motor choice, an AeroTech K-1103 motor. After 0.03 seconds, the motor reaches its maximum projected thrust of 1,587.82 N. Its thrust quickly decreases momentarily, then steadily decreases at a slower rate until quickly dropping in thrust, shortly before motor burnout. Our vehicle’s average thrust-weight ratio is 12.3.

Velocity Profile

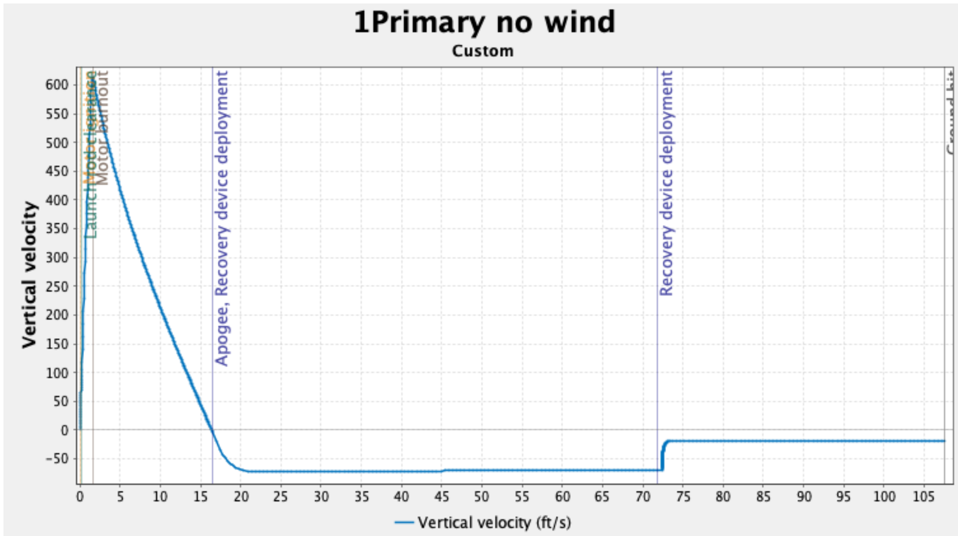

Figure #7: Velocity Profile Simulation

The graph above shows our rocket's velocity profile. The rocket accelerates to a maximum velocity of 609 ft/s (415.2 mph), 1.61 seconds after launch. The vehicle remains subsonic for the entirety of its flight.

Acceleration Profile

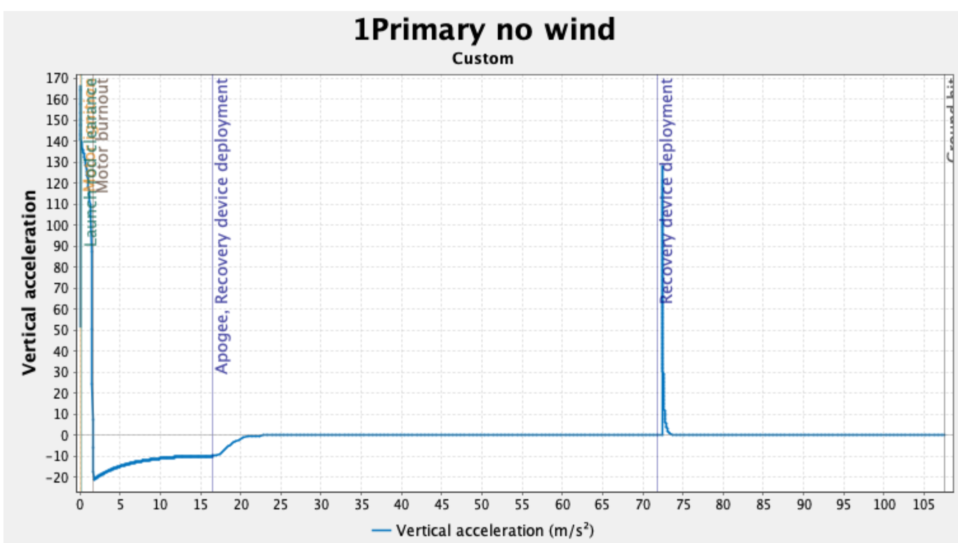

Figure #8: Acceleration Profile Simulation

Above is the graph of our vehicle's acceleration. Inaccuracies in OpenRocket's deployment force calculations provide a force of 36 g at main chute deployment. However, alternative calculation methods result in a force of approximately 4.5 g. Therefore, the vehicle's maximum acceleration during the flight will be 16.8 g (541 ft/s^2) momentarily after ignition. The vehicle, recovery system, and payload will all be designed to endure any and all stresses of the flight.

Vehicle Flight Sequence

This chart shows the vehicle's flight sequence. Our vehicle will be a standard dual-deployment craft, with a primary flight computer used to deploy the drogue and main parachutes. We will also have a backup computer on board in case of failure of the main computer. The drogue parachute will be deployed at the rocket's apogee, and the main chute will be deployed at an altitude of 700 ft. At no point during the flight will the payload separate from the rocket, and the vehicle will be recovered in 3 tethered sections.

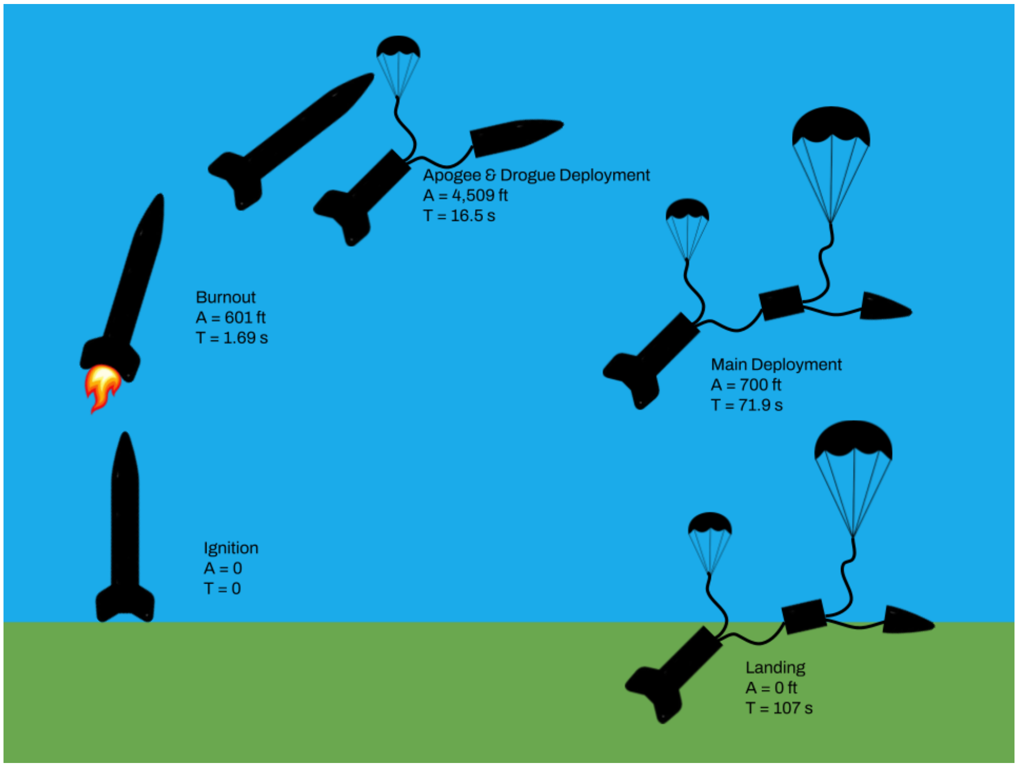

Figure #9: Vehicle Flight Sequence

#	Event	Time (s)	Altitude (ft)	Trigger
1	Ignition	0	0	Launch Controller
2	Burnout	1.69	601	--
3	Apogee	16.5	4,509	--
4	Drogue Deployment	16.5	4,509	Flight Computer
5	Main Deployment	71.9	700	Flight Computer
6	Landing	107	0	--

Table #2: Mission Sequence of Events

Alternate Motor Study

Name	Apogee (ft)	Pros	Cons
AeroTech K-805	4,209'	Less expensive, easily available	Less powerful, less flight time for payload study
Loki Research K-960	4,834'	More powerful, available	More expensive, increased weight

Table #3: Alternative Motor Pros & Cons

After consideration of our 3 motor choices, we settled upon the AeroTech K-1103 as our primary motor choice. We decided on this motor because it will deliver the vehicle to an altitude comfortably in the middle of NASA requirements. It exhibits the power to give ample time for payload study while being lighter weight than other options and being relatively available at the time of purchase.

Stability Margin

Our vehicle has a static stability of approximately 3.77 calibers, which falls above the NASA-required minimum of 2.0 calibers.

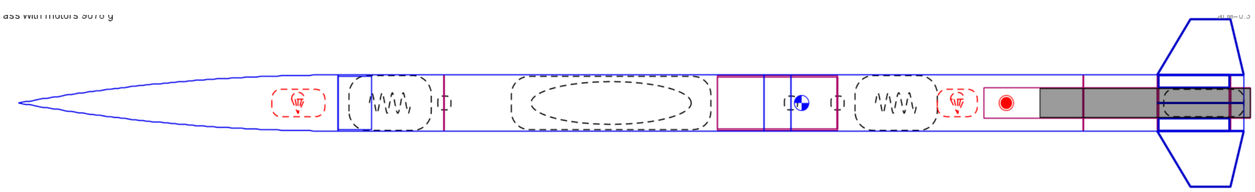

Figure #10: Center of Gravity and Center of Pressure

The center of gravity (blue dot) is 59.022 inches from the top of the rocket. The center of pressure (red dot) is 74.175 inches from the top of the rocket. They are 15.153 inches apart.

Landing Kinetic Energy Calculations

The formula for Kinetic energy is $E_K = 0.5mv^2$, where E_K is total kinetic energy, m is mass, and v is velocity. The kinetic energy for each separate section of the rocket is as follows:

Due to the length of descent, the total vehicle (which will function as one entity because all sections are tethered together) will reach its terminal velocity before it hits the ground. Therefore, each of the individual sections of the vehicle will have reached its terminal velocity before it hits the ground. If some parts of the vehicle hit the ground before other parts of the vehicle, the parts of the vehicle that are still falling may slow down, since their terminal velocity is lowered. However, since this may vary, and to account for a scenario where each part of the rocket hits the ground at the same time, we can use the terminal velocity of the entire rocket to calculate each individual section's kinetic energy.

To calculate the terminal velocity of the full vehicle, we can use the formula $V_t = \sqrt{(2mg/pAC_d)}$, where m is the mass of the falling object (the total mass of the rocket minus the propellant mass:0.5606 slugs), g is the acceleration due to gravity (-9.8m/s/s on earth), p is the air density (1.225 kg/m^3), A is the area of the object (this can be estimated by finding the cross-sectional area of the parachute, which is 3,421.194 in^2 for the main parachute, and 314.15 in^2 for the drogue parachute), and C_d is the drag coefficient (which we will estimate as 2.0 for the main parachute and 1.5 for the drogue parachute). Using these values and the formula for terminal velocity, the terminal velocity of the vehicle will be 17.87 ft/s under the main parachute and 68.1 ft/s under the drogue parachute.

Using the impact velocity of the vehicle and mass of the booster tube (0.186 slugs), we calculated the kinetic energy as 29.7 ft·lbf at impact and 431.3 ft·lbf from when the rocket reaches terminal velocity under the drogue parachute to the release of the main parachute.

Using the impact velocity and mass of the upper section (0.23 slugs), the kinetic energy can be calculated as 36.73 ft·lbf at impact and 533.3 ft·lbf from when the rocket reaches terminal velocity under the drogue parachute to the release of the main parachute.

Using the impact velocity and mass of the nose cone (0.038 slugs), we can calculate the kinetic energy as 6.07 ft·lbf at impact and 88.1 ft·lbf from when the rocket reaches terminal velocity under the drogue parachute to the release of the main parachute.

Calculated Descent Time

According to a flight simulation in the simulation software OpenRocket, our rocket has an estimated flight time of 107 seconds in a scenario with no wind. It will reach apogee at an estimated time of 16.5 seconds. Therefore, the vehicle has an optimal descent time of 90.5 seconds.

Calculated Drift Distance

Given a pessimistic scenario with no horizontal drag and constant wind speed in one direction, the vehicle's drift distance can be approximated with the formula $d \approx wt$, where d = drift distance, w = wind speed, and t = descent time. There is no way to determine the wind speed at the time of launch this far in advance, but assuming a wind speed of 6.7mph (9.83 ft/s, which is about average during spring in Alabama, according to data from the National Oceanic and Atmospheric Administration), our drift distance will approximately equal 889.6 ft: 9.83 ft/s, times our optimal descent time of 90.5 seconds.

Calculation Method Alternatives

To determine the descent rate (terminal velocity) of the vehicle under the drogue and main parachutes, we used various online descent calculators, hand calculations, and OpenRocket. In all of these tests, the terminal velocity under the drogue parachute was 68 ft/s, and the terminal velocity under the main parachute was roughly 18 ft/s. Additionally, the descent time was roughly 90.5 seconds. The slight inconsistencies in the calculations were due to the use of slightly different assumptions for atmospheric air density in various calculations and simulations. Through each of these calculation methods, we found that the drift distance should be roughly 890 ft. The slight inconsistencies in these calculations were due to the slight differences in assumptions of wind speeds.

Performance Simulation Redundancy

To be certain of our simulations and measurements we used the software RASAero II as our alternative simulation software. We recorded very similar results between openrocket and RASAero II. We made sure to use the same motor, double-checked that we used the same mass, and triple-checked the dimensions of all simulations on both software.

Payload Criteria

Payload Objective

Our objective is to test different baffles and determine which is best at preventing liquid slosh in a tank and at keeping the rocket stable and on its planned trajectory. We will test two different designs: rings and panels.

Payload Hypothesis

We predict that the ring baffle design, our primary design, will work 10% better than the panel-based design, by reducing the amount of slosh by 30% compared to the control tank, which contains no baffles.

Payload Requirements

Payload Measurements

To be able to evaluate a reduction in slosh, our payload requires the measurement of the following variables:

- Peak Movements of Fluid
- Horizontal Motion of Fluid
- Vertical Motion of Fluid
- Height of Fluid Motion

Payload Definitions

Our project defines the following terms:

- **Slosh:** The horizontal motion of fluid within the payload.
- **Amplitude:** The vertical movement of fluid within the tank. This is defined as the difference in water level between two given sensor columns.
- **Dampening:** The rate at which the peak amplitude of fluid decreases over time.

Payload Purpose:

The payload will examine the dampening effects of different orientations and shapes of baffles. We will use the results to evaluate each shape and orientation's performance in mitigating fluid movement.

Payload Experimental Evaluation

We will define how effective the baffles are based on the peak movement of fluid and how quickly the fluid dampens within the payload. We will compare these two criteria to a control that doesn't have any sort of dampening apparatus and evaluate the percentage of mitigation. The peak movement of fluid within each experimental baffle will be a percentage of the peak movement within the control baffle, and we will evaluate the dampening effect as the relative difference between the control and the experiment.

Preliminary Payload Design

Our payload contains four systems: a set of tanks to hold our liquid and baffles, a camera capture system to gather visual data from inside the tanks, an electronic sensor system to measure data from inside the tanks, and a data management system to collect and store the data from the sensor system. The preliminary designs for each, as well as alternatives, are listed below.

Tanks System

Our payload will contain a set of liquid tanks, in which our experiment will be conducted. Our preliminary design consists of three tanks, placed vertically adjacent to each other and parallel to the rocket's long axis. The tanks are two separate pieces, screwing together at the base of the tank. Each tank has a clear window at both ends, to allow the camera system to view the insides of the tanks during flight. The tanks are placed vertically, to allow sufficient space for the electronic sensor system to be mounted onto each tank. Each tank will have a different baffle design, including one control tank without baffles.

Primary Design: Rings

Our primary design includes 2 or 3 rings, which will either be epoxied or screwed onto the outside of the tank. Two concentric circles are 3D printed, to allow water to pass through the center but not the outer edges. The ring design allows a substantial amount of water to travel throughout the tank while maintaining stability by decreasing the force of the slosh by slowing the movement of the water. As a simple yet effective design, this baffle shape is easy to produce and install.

A downside to this design is that it could interfere with the electronic sensor system of the payload. The primary design of the sensor system relies on sensors mounted to the walls of the tanks, and this ring design could potentially interfere with them.

This design is feasible because we have the resources and the skills to easily construct different variations of this design. Since the parts are all 3D printed, we can easily build and reproduce them with our 3D printers. We believe this design is optimal in terms of construction and strength.

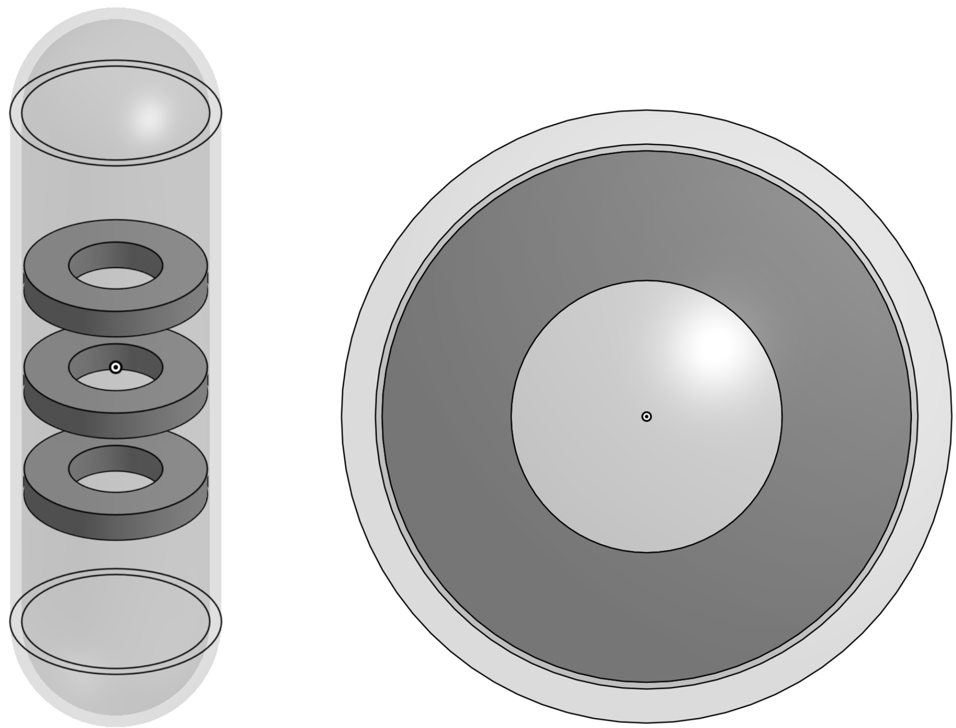

Figure #11: CAD Model of the Preliminary Design: Anti-Slosh Rings

Alternative Design 1: Panels

Our first alternative design consists of panels, which will be epoxied to the sides of the tank. Traditionally, this type of baffle design is metal but could be 3D printed for easier production. The shape of the panels is flat with bent edges. A slot on two sides of the panels creates flexibility, which allows the panels to deform with the force of the water, thereby reducing pressure on the panels. This design will be easy to install. The orientation of the plate is perpendicular to the walls of the tanks. Inside the tank, the panels will be arranged in a circular pattern, with 3 alternating layers. However, this may obscure the camera system from receiving a clear view of the sloshing underneath the baffle. Our first alternative design allows for a relatively easy installment; however, compared to the preliminary design, it is more fragile and more difficult to 3D print.

During our feasibility study for this design, we came to the conclusion that this design is a good option if something were to go wrong with our preliminary design. This design is slightly more difficult to install than our preliminary design and is slightly more vulnerable to breakage. This design is still a good option, however, because they are easily and individually replaceable. This design provides a solid alternative to our preliminary design.

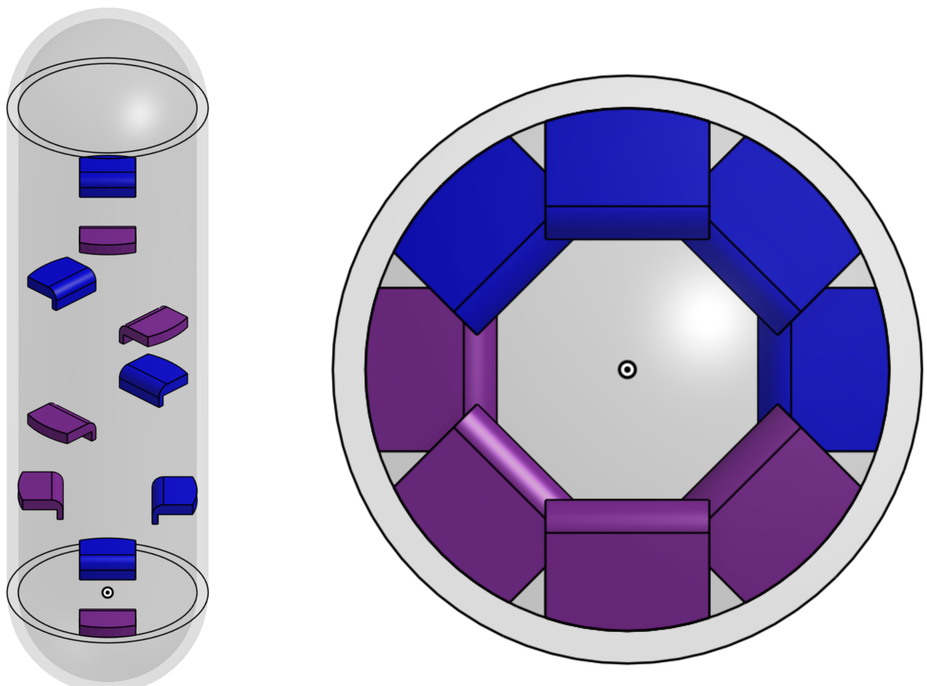

Figure #12: CAD Model of the Alternative Design 1: Anti-Slosh Panels

Alternative Design 2: Anti-Slosh Balls

Anti-slosh balls are common in the tanker truck industry. These balls can be replicated on a smaller scale, by punching medium-sized holes into hollow plastic spheres, or by 3D-printing the spheres ourselves.

This design allows for an easy-to-manufacture baffle system and is a proven design. However, they reduce the amount of fuel capacity in the tanks and may not be as successful at preventing slosh, due to their shape and floating nature. The balls could also disrupt the flow of the fluid. We would also need to manufacture many balls and fill the entire tank with them, which could be complicated and may obscure the camera system.

The feasibility of this design is less than that of our other designs, although it is still a practical option that is worth testing. We know that this design works since it has been proven in multiple real-life situations to reduce tank slosh. This design may be difficult to measure because of how it could disrupt the sensor suite's detection of the water levels, as well as make it harder for light to reach the cameras. We also do not know how well this design works on a smaller scale since it has mainly only been used in larger tanks. This option will still give us results that are worth studying, and that is why we are choosing it as an alternative.

Figure #13: An Example of a Commercial Baffle Ball

Camera Capture System

To get high-resolution and in-depth data, our payload contains a camera capture system to record the inside of the tanks and observe the movement of the water.

Primary Design: End-Mounted Cameras

Our primary design for this system uses two cameras per tank, positioned at either end. These cameras observe two rulers placed on the tank's inner walls, and the movement of the water is observed and measured using the rulers. The inside of the tank is lit with an LED positioned near the cameras, and the water is dyed a dark color to easily distinguish it from the walls of the tank. The cameras are RunCam Split 4s, which save footage to SD cards and can be easily triggered during the arming of the payload.

Additionally, the small form factor of these cameras will allow them to fit in between the tanks with minimal extra space.

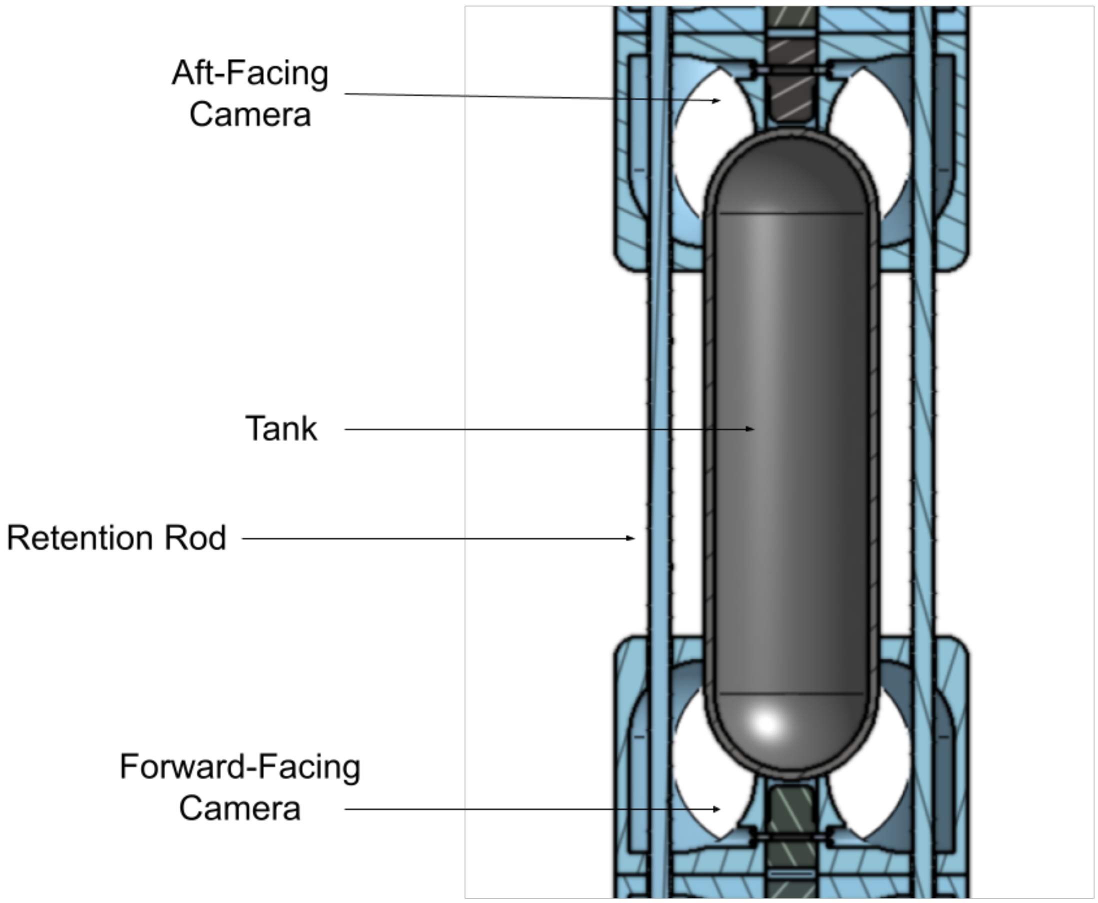

Figure #14: Camera Sensor System Diagram

Alternative Design 1: Rheoscopic Fluid

Our first alternative design for this system utilizes rheoscopic fluid, which allows us to easily visualize the movement of the water below the surface. By mounting the cameras on the sides of the tanks and further back from the tanks, they could record through a clear tank wall and observe the movement of the water inside the tank. This design would allow us to observe how our baffle system restricts the movement of the water under the surface and how the internal currents of the water are behaving. This could provide us with more in-depth results and allow us to more completely evaluate the performance of our payload.

Alternative Design 2: Distortion Grid

Our second alternative design for this system uses a grid pattern on either side of the tanks, with the cameras in the same location. In this design, the water remains transparent, and the grid pattern is distorted as the light passes through the water. The cameras record this distortion and can be analyzed post-flight. This design requires advanced image processing and analysis techniques, but it could provide a good idea of how the water is moving under the surface.

Electronic Sensor System

To detect the presence of water inside the tanks at certain levels, our preliminary design uses several sets of sensors capable of detecting water at different levels inside the tanks. Different sensors will be used for redundancy and to ensure that data is gathered, even if some of the sensors become blocked or otherwise disabled.

Primary Design: Capacitive Non-Contact Sensors

Our preliminary design for this is to use capacitive non-contact water sensors and a set of exposed contacts inside the tank. The capacitive sensors may not be able to detect small splashes of water, but they will be able to detect large movements of water inside the tank. On the other hand, the contacts will be able to detect small amounts of water splashing around inside the tank, but they may remain wet and give false readings. The combination of these sensors will ensure that the sensor system can confidently detect the sloshing of water inside the tank.

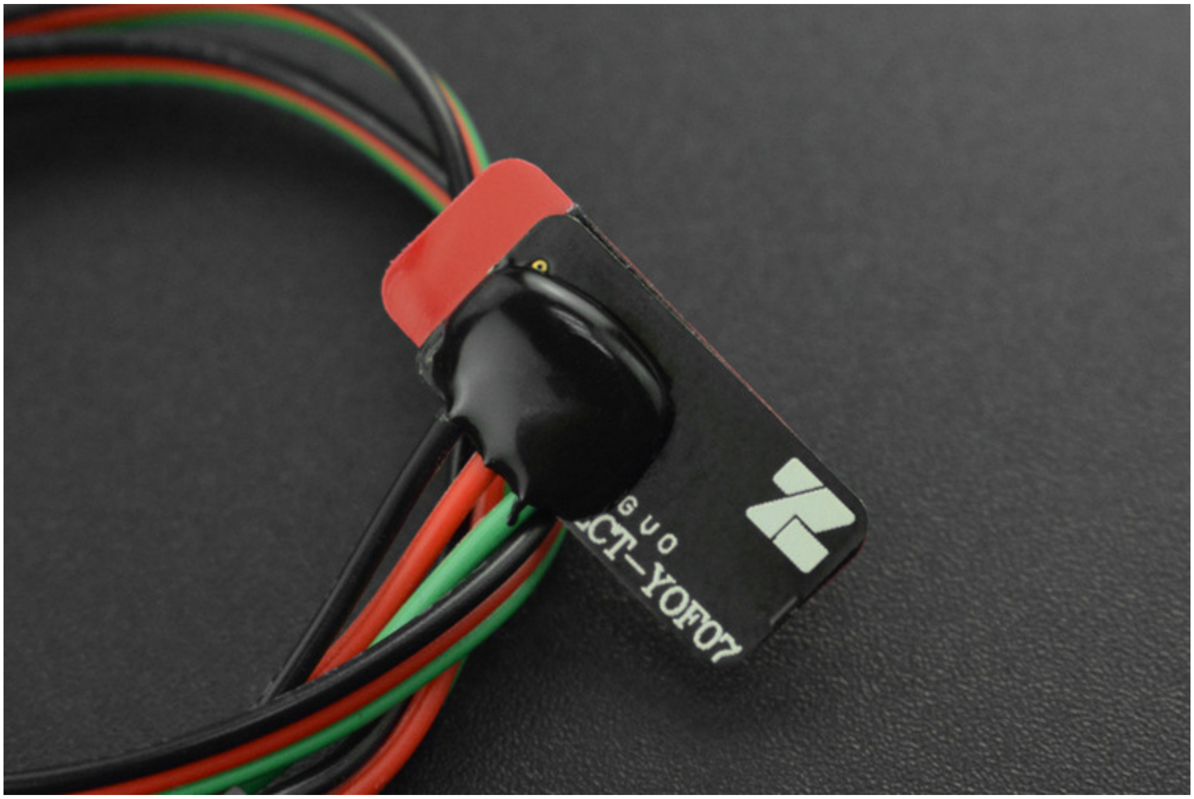

Figure #15: DF Robot Non-Contact Capacitive Water Level Sensor

Alternative Design 1: Laser Rangefinders

Our first alternative design for the sensor system uses a set of laser rangefinders, combined with particulates in the water. The laser rangefinders are mounted in groups of 4 on the top and bottom of each tank, pointing inwards towards the center of the tank. The water holds a particulate, which is detected by the laser rangefinders. Mounting the rangefinders on both sides of the tank allows detection of the water during any phase of flight, even if the water is being pushed forward in the tank, due to aerodynamic or inertial forces.

Alternative Design 2: Photoelectric Level Sensors

Our second alternative design for this system uses photoelectric water level sensors. The level sensors are embedded in the tank walls. They contain light emitters and detectors, and when water comes in contact with the sensor body, the light is refracted into the detector. These sensors do not fail under high temperatures or pressure, due to their unique mechanism. Unfortunately, these sensors are not small enough to feasibly fit within our payload.

Data Management System

Our payload will contain a system to gather and store data from the sensor system. Along with the already described sensor suite, the data management system of our payload will be connected to several 9-DOF Inertial measurement units (IMUs). These IMUs will allow any data we collect to be more easily analyzed and understood. The IMUs will allow us to understand the data we receive, even if the rocket is tumbling or swaying during different parts of the flight. They will also allow us to get a better reading of the acceleration forces during flight, as these IMUs are much more capable than the ones used for launch detection. They are not necessary for the successful function of the payload; they simply make data analysis much easier.

Primary Design: Daisy-Chaining System

Our preliminary design has a printed circuit board (PCB) near each tank, each with an array of connectors and shift registers to gather and condense the data gathered from each tank. This setup will avoid potential problems, such as routing large numbers of wires between tanks and potential capacitance problems from doing so. This design contains a single PCB near the bottom of the payload, with a Teensy 4.0 microcontroller as a daughterboard. This PCB also contains a Ferroelectric Random Access Memory chip (FRAM), for storing data during and after flight, as well as an inertial measurement unit and a barometer, to detect the flight's launch, Apogee, and landing events. The data will be stored in the FRAM until the landing event is detected, at which point the data will be transferred to an external SD card for ease of retrieval. This ensures that all data remains intact during any vibration or turbulence during the flight, and data will only be transferred to the SD card once the vehicle is back on the ground. This system has some redundancy concerns, as there would only be one controller, and if the wires running between the tanks are broken, it could disable large portions of the payload.

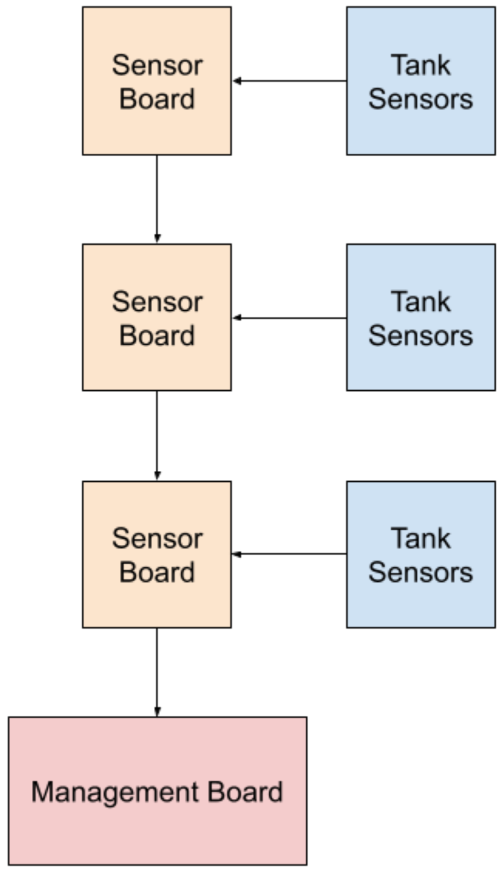

Figure #16: Data Management System Primary Design Data Flow Diagram

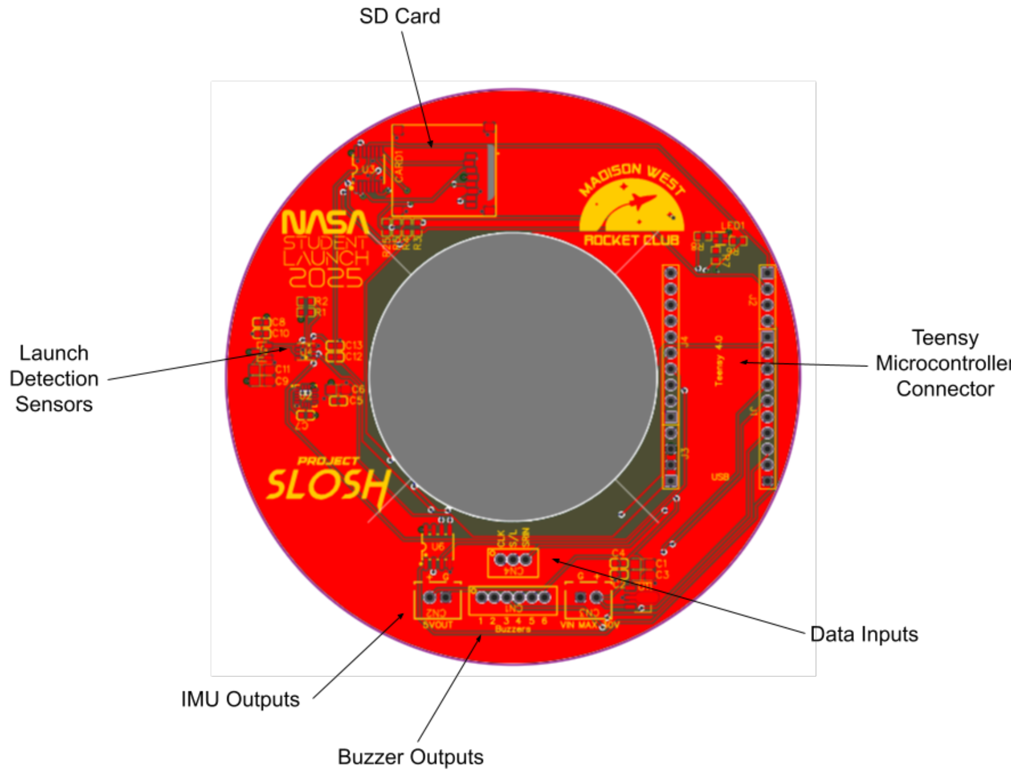

Figure #17: Data Management System Primary Board Layout

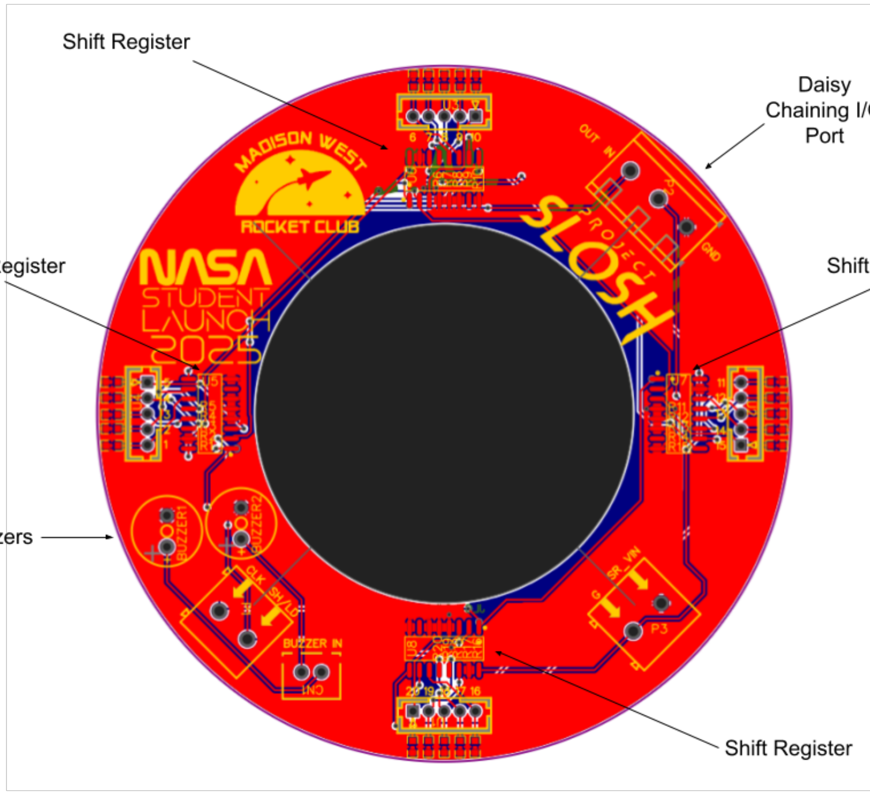

Figure #18: Data Management System Primary Sensor Board Layout

Alternative Design 1: Distributed Management

Our first alternative design for this system houses a PCB near each tank, each with an STM32 microcontroller built into the PCB. Each PCB also contains a FRAM chip, SD card, and launch detection sensors. Each PCB has connectors that allow it to interface with the sensors for its tank. This design will minimize wires traveling between tanks, which will optimize space utilization inside the payload. Additionally, it will mitigate any potential interference or capacitance problems between large bundles of wires, by keeping all the sensor wires near the tanks. However, this system will have an increased cost, due to the large total number of components needed. Additionally, this system may be tedious to program and create difficulties retrieving data, as each PCB will have a separate data storage system and must be programmed individually.

Alternative Design 2: Hardware Serial Logging

Our second alternative design has no microcontroller. Much like Alternative Design 1, each tank has its own PCB. The function of the PCB is entirely controlled by a set of precisely tuned timers, shift registers, and counters. This system requires no microcontroller, which eliminates the potential risk of code errors or other firmware problems. To accommodate this architecture, multiple features, such as IMU logging, may have to be cut out of the design. This system is also complicated and would require extensive testing to ensure proper functionality. Additionally, this system would require large amounts of hardware iteration, which would increase costs.

Safety

Personnel Hazard Analysis

The following risks could endanger the successful completion of our project (listed with proposed mitigations). Each hazard has two separate rankings of likelihood and severity on a scale of 1-10, 10 being the most likely or severe. This analysis is repeated in the risk table.

Facility Risks

- ***Workshop inaccessible:***
    - **Effects:** Project progress will be slowed and momentarily halted without workshop space.
    - **Mitigation:** If this occurs, the design and manufacturing process can temporarily be relocated to Mr. Lillesand's house. **Likelihood: 8, Severity: 4**
- ***Classrooms unavailable:***
    - **Effects:** Meetings may become more difficult, due to the inconvenience of communicating and switching locations.
    - **Mitigation:** Should the primary room become inaccessible, we can also utilize other options, such as reserving a meeting room in a local library, temporarily meeting in a club member's house, or meeting online. **Likelihood: 3, Severity: 2**
- ***Launch site unavailable:***
    - **Effects:** We cannot launch the rocket and therefore cannot gather data.
    - **Mitigation:** We routinely schedule redundant launch windows to ensure that we will have enough opportunities to carry out all necessary flights. We are currently working with three rocketry

organizations (NAR section WOOSH, QCRC, Tripoli WI) to maximize our launch opportunities. **Likelihood: 3, Severity: 5**

Personnel Risks:

- ***Physical injury:***
  - **Effects:** Physical injury due to any rocket manufacturing will lead to an immediate meeting addressing safety procedures required in the workshop.
  - **Mitigation:** Personal Protective Equipment is mandated during all construction tasks and preparation of the rocket for flight or static test. All preparation/handling of energetics will be done by mentors. Adult supervision is provided at all times. Using headphones and personal electronics during rocketry activities and workshop hours is strictly prohibited. **Likelihood: 3, Severity: 4**
- ***Toxicity:***
  - **Effects:** Improper use of workshop space and excessive exposure to toxic chemicals may lead to slight injury. Any member affected by chemicals used in the workshop may suffer from injury.
  - **Mitigation:** SDS documentation is available for all chemicals used in the project, and dangerous chemicals are avoided as much as possible. Adult supervision is provided at all times, and PPE use is mandated. **Likelihood: 2, Severity: 6**

Budget Risks:

- ***Budget overrun:***
  - **Effects:** Without sufficient funds, project delays may affect production schedules.
  - **Mitigation:** Should our raking fundraiser not gather enough money to fund our project, we plan to create a winter fundraiser to supplement our funds. If this isn't sufficient, we will reach out to former club members and other club-associated people to ask if

they would be willing to donate. We anticipate this would be able to cover any budget deficit. **Likelihood: 5, Severity: 4**

Project Risks:

- ***Project behind schedule:***
    - **Effects:** If project progress falls behind schedule, we will struggle to meet milestones on time.
    - **Mitigation:** Project progress is constantly compared against a list of required milestones, and working hours are extended as necessary to meet all milestones. All deadlines are considered hard. **Likelihood: 7, Severity: 4**
- ***Key team member unavailable:***
    - **Effects:** Progress will be affected by the absence of the team member.
    - **Mitigation:** No task is assigned to a single team member. All tasks are carried out by a pair or a small group of equally knowledgeable students. Students are not allowed to limit their participation in the project to a single area of expertise. **Likelihood: 3, Severity: 3**
- ***Technical roadblock:***
    - **Effects:** Progress will be delayed if a technical issue arises, and additional work will need to be completed.
    - **Mitigation:** A thorough feasibility review is conducted before the Preliminary Design Review Report is submitted. Alternative solutions and advice from experienced mentors will be sought. **Likelihood: 4, Severity: 7**
- ***Personal disagreements:***
    - **Effects:** Team morale may be hindered by personal disagreements within the group.
    - **Mitigation:** Should an intra-team conflict occur, adults will protect the progress of the project and mediate the resolution. All students

were informed of this rule before their admission to the program. **Likelihood: 1, Severity: 1**

- *Part unavailability:*
  - **Effects:** Unavailability of parts will result in project deployment and possible reworking.
  - **Mitigation:** Multiple vendors have been identified for key components to maintain part availability redundancy. All purchasing happens at first availability. **Likelihood: 6, Severity: 3**

Vehicle Risks:

- *Repeated test flight failure:*
  - **Effects:** Repeated test flight failure will cause progress to decrease.
  - **Mitigation:** The rocket design has been supervised by multiple high-power certified mentors, and a thorough examination will be performed before each flight. Consideration will be given to weather conditions, to maximize the probability of safe flight and successful recovery. All flight data will be analyzed, to identify problems before the next flight. **Likelihood: 3, Severity: 5**
- *Vehicle lost/irreparably damaged during test flight:*
  - **Effects:** Vehicle damage during test flight will result in extra manufacturing to fix lost or damaged parts.
  - **Mitigation:** A sufficient time reserve will be built into the project schedule, to allow for vehicle replacement if necessary. The airborne vehicle will be tracked using 2 different redundant methods. **Likelihood: 3, Severity: 5**
- *Propellant unavailability:*
  - **Effects:** Propellant unavailability will lead to project progress slowing.

- **Mitigation:** All purchasing is conducted as soon as practically possible. Motor alternatives are thoroughly investigated during the vehicle. **Likelihood: 3, Severity: 4**

- ***Final vehicle overweight:***
  - **Effects:** The final vehicle overweight will affect the rocket's ability to reach the target altitude.
  - **Mitigation:** 30% of total vehicle weight is added to the initial estimate of vehicle weight, and all simulations are done with a C_d set to 0.7. This ensures the vehicle will still be able to reach the target altitude with an unexpected increase in mass. **Likelihood: 2, Severity: 5**

Payload Risks:

- ***Construction falls behind schedule:***
  - **Effects:** Delay of construction will add an additional challenge to our project and may lead to slowing of progress.
  - **Mitigation:** Construction of the payload, which is mostly 3D printed, will begin as soon as designs are finalized. Several of our team members and mentors own 3D printers, ensuring we remain on schedule for construction. **Likelihood: 7, Severity: 4**
- ***Unexpected integration failure:***
  - **Effects:** Integration failure will lead to progress delay.
  - **Mitigation:** The design of the payload is overseen by multiple engineers, as well as the HPR Mentors, and the integration of the payload is reviewed at each design milestone. **Likelihood: 4, Severity: 7**

Failure Modes and Effects Analysis

The table below highlights each failure mode, along with its potential cause, effect, and mitigation strategies. The risks with highest risk priority number (calculated from combining the Likelihood, Severity, and Ease of Detection) are highlighted in red, and less serious risks are highlighted in light red and yellow, respectively.

Subsystem	Risk Details	Potential Causes	Potential Impact	Mitigation	Likelihood of occurrence after mitigation	Severity	Ease of detection	Risk Priority Number
Structure	Airframe fails to separate	Ejection charges too small Deployment of avionics fail to set off charges	Rocket descends too quickly Potential for loss of rocket	Extensive ejection testing	2	8	2	32
Recovery	Parachutes fail to deploy	Parachute gets stuck in airframe Parachute gets tangled	Rocket descends too quickly Potential for loss of rocket	Design with generous room for parachutes Use easy-to-pack material Test folding procedure to prevent tangling	2	6	5	60
Avionics	Tracking failure	Loss of telemetry form flight computer and commercial trackers	Loss of precise GPS tracking for recovery	Multiple tracking methods	2	9-could make recovery impossi ble	3-check connection strength	54
Structure	Rail guides detach during rail mounting	Structure failure during mounting	Inability to load rocket on launch rail	Rail guides will be surface-mounted with epoxy Caution will be used when loading the rocket onto the launch rail	2	3- could delay launch	1	6
Avionics	Electronics fail to turn on	Broken electrical connections Poor soldering Forces of flight	Unable to deploy parachutes and record data	Testing of electrical connections Preparation of spare electronics	3	4-could delay launch	2-all electronics either give audible signals or transmit to the ground station	24

							while powered on	
Avionics	Overheating of batteries	Extreme temps and long waiting period on pad	Electronics unable to function properly	Keep parts of rocket as cool as possible, prior to loading onto pad Paint rocket a thermally reflective color	5	5-could delay flight or result in avionics not functioning properly	4	100
Avionics/ Recovery	Ejection charges ignite prematurely	Shorted connections Altimeter malfunction	Structural damage Personal injury	Use of PPE around ejection charges Multiple people checking electronic connections and charges	2	8-potential injury or failure to launch	1	16
Propulsion	Ignitor failure	Motor fails to light	Rocket does not launch	Test ignitors Bring multiple ignitors	2	1	1	2
Propulsion	Motor failure	Imperfection in grains Mechanical failure of casing Failure of liner	Potential for catastrophic failure (CATO) Leakage of motor gasses	Check density of motor grains Operate motor at a conservative chamber pressure Test ignition system Use lithium grease and O-rings properly	2	10-potential for CATO	8	160
Structure	Mechanical failure of airframe fins	High angles of attack lead to substantial aerodynamic forces Fins oscillate	Rocket becomes unstable	Surface mounted fins with tip-to-tip epoxy fillets	2	9	6	108
Structure	Mechanical failure of body tubes	High angles of attack lead to substantial aerodynamic forces Bending at	Total loss of rocket	Reasonable margin of stability to limit both angle of attack and wind cocking Thick and strong	3	10	8	240

		couplers leads to high loads		body tubes				

Table #4: FMEA

Environmental Concerns

- ***Wind:***
  - **Effects:** In the event of windy conditions on the day of launch, the rocket's trajectory may be slightly altered.
  - **Mitigation:** The vehicle has been designed to have a stability margin above the specified minimum in the handbook, to greatly decrease the chances of change in trajectory from external factors.
- ***Unable to recover:***
  - **Effects:** In the event we are unable to recover the rocket, the materials used may cause unintentional pollution.
  - **Mitigation:** Multiple tracking systems will be used, to ensure that we know the location of the rocket at all times.

Risk Table

The table below highlights each risk, likelihood of occurrence, and impact. The risks with highest impact and likelihood are highlighted in red, and less serious risks are highlighted light red and yellow, respectively.

Risk	Likelihood	Severity	Impact
Workshop inaccessible	High	Low	High
Project behind schedule	High	Low	High
Construction falls behind schedule	High	Low	High
Unexpected integration	High	Low	High

failure			
Propellent unavailability	High	Low	HIgh
Technical roadblock	Low	High	High
Part unavailability	Medium	Low	Medium
Vehicle lost	Low	Medium	Medium
Repeated test flight failure	Low	Medium	Medium
Launch site unavailable	Low	Medium	Medium
Toxicity	Low	Medium	Medium
Budget overrun	Medium	Low	Medium
Final vehicle overweight	Low	Medium	Medium
Physical injury	Low	Low	Low
Key team member unavailable	Low	Low	Low
Classrooms unavailable	Low	Low	Low
Personal disagreements	Low	Low	Low

Table #5: Risks

List of Applicable Safety Data Sheets

Propulsion and Deployment

Ammonium Perchlorate
Aerotech Reloadable Motors
Aerotech Igniters
Firewire Initiators
Pyrodex Pellets
Black Powder
Nomex (thermal protector)

Glues
Elmer's White Glue
Two Ton Epoxy Resin
Two Ton Epoxy Hardener
Bob Smith Cyanoacrylate Glue
Super-glue Accelerator
Super-glue Debonder

Soldering
Flux
Solder
Solder Braid

Painting and Finish
Automotive Primer
Automotive Spray Paint
Clear Coat

Construction Supplies
Kevlar
Fiberglass Cloth
Fiberglass Resin
Fiberglass Hardener
Self-expanding Foam (Marine grade)

Solvents
Ethyl Alcohol 70%
Distilled Water
Isopropyl alcohol

Payload Materials
Aluminum
Acrylic
Polycarbonate

Project Plan

Team-Derived Vehicle Requirements

- Stability
    - The vehicle should be stable, such that it does not experience "overcorrection" as it ascends.
    - The vehicle should be able to handle sudden disruptions, such as wind gusts or thermals, as it ascends with minimal disturbance to the flight profile.
    - These requirements ensure the vehicle will provide a stable, reliable base for our payload.

Team-Derived Recovery Requirements

- Events Timing
    - The apogee recovery event should occur within 3 seconds of its planned time. This ensures that the vehicle will be traveling at a speed within the acceptable parameters of the drogue chute.
    - The main recovery event should occur within 3 seconds of its planned time. This ensures that the vehicle will have sufficient time to slow down before touchdown and will not drift too much under the main chute.

Team-Derived Payload Requirements

- The sensor and camera systems must detect a decrease in slosh compared to the control tank.
- The tank must not leak any water during the flight.
- Fluid movement data must be successfully and accurately collected.

Budgeting

Line Item Budget

Expense Area	Item	Quantity / Size	Vendor	Unit Price	Total Cost	Shipping Fees + Taxes	Notes
Full Vehicle	Fiberglass 4" Body Tubes	66"	Wildman Rocketry	$141.27	$141.27	$90.42	Shipping fees are included in the first occurrence of each company
	Fiberglass 4" Coupler Tube	9"	Madcow Rocketry	$33.00	$33.00	$26.87	
	FIberglass G10 Fin Stock	2x 1 sq ft	McMaster-Carr	$29.38	$58.76	$10.00	
	Fiberglass Motor Tube 54 mm	20"	Mach 1 Rocketry	$30.00	$30.00	$41.00	
	Centering Rings G10 Stock	1 sq ft	McMaster-Carr	$29.38	$29.38	$10.00	
	Drogue Chute 12" Recon	12"	Wildman Rocketry	$31.95	$31.95	$1.60	
	Fiberglass Bulkhead Stock G10, 1/4"	1 sq ft	McMaster-Carr	$29.38	$29.38	$2.94	
	Fiberglass 4" Body Tubing for e-bay Spacer	2"	Wildman Rocketry	$141.27	$141.27	$7.06	
	Main Chute 66" Toroidal	66"	Fruity Chute	$342.93	$342.93	$20.70	
	Fiberglass Nose Cone	4" dia, 24" len	Madcow Rocketry	$97.00	$97.00	$4.85	3D Print Possible
	Tubular Kevlar Shock Cord	2x of 38' of 10mm	Giant Leap Rocketry	$107.66	$107.66	$5.99	
Total	-	-	-	$1,013.22	$1,042.60	$221.43	-
Scale Vehicle	Fiberglass 2" (54mm) Body Tubes	33"	Wildman Rocketry	$52.27	$52.27	$89.21	
	Fiberglass 2" (54mm) Coupler Tube	4.5"	Madcow Rocketry	$17.00	$17.00	$36.26	
	FIberglass G10 Fin Stock	1 sq ft	McMaster-Carr	$29.38	$58.76	$10.00	
	Fiberglass Motor Tube 29 mm	10"	Mach 1 Rocketry	$7.50	$7.50	$4.31	
	Centering Rings G10 Stock	1 sq ft	McMaster-Carr	$29.38	$58.76	$10.00	
	Drogue Chute 5"	5"	Wildman Rocketry	$31.95	$31.95	$1.60	
	Fiberglass Bulkhead Stock G10, 1/8"	1 sq ft	McMaster-Carr	$29.38	$58.76	$10.00	

	Fiberglass 2" Body Tubing for e-bay Spacer	1"	Wildman Rocketry	$52.27	$52.27	$2.61	
	Main Chute 27" Toroidal	27"	Fruity Chutes	$139.54	$139.54	$17.65	
	Fiberglass Nose Cone	2" dia 12" len	Madcow Rocketry	$40.00	$40.00	$2.00	3D Print Possible
	Tubular Kevlar Shock Cord	2x 19' of 10mm	Giant Leap Rocketry	$26.92	$26.92	$5.99	
Total	-	-	-	$455.59	$543.73	$189.63	-
Payload	3D-Printed Parts	N/A	Self_Made	$100.00	$100.00	$3.77	
	RunCam Split 4	6	RunCam	$82.99	$497.94	-	There might be a cheaper vendor available
	Capacitive Water Level Sensors	60	DF Robot	$10	$600.00	$15	There might be a cheaper vendor available
	Adafruit BNO085 9-DOF IMU	3	Adafruit	$24.95	$74.85	$16.34	There might be a cheaper vendor available
	Data Gathering Custom PCB	5	JLCPCB	$12	$60.00	$10.45	
	Data Management Custom PCB	5	JLCPCB	$12	$60.00	$3.00	
	2S Lipo Battery	2	Amazon	$16.99	$33.98	-	
Total	-	-	-	$1,734.26	$1,426.77	$48.56	-
Launches	Scale Model Motor (Aerotech G138)	2	Aerotech	$31.99	$63.98	$78.10	
	Full-Scale Motor (Aerotech K1103X)	5	Aerotech	$167.99	$839.95	$42.00	
	Test Launch Site Fees	5	Tripoli Wisconsin / NAR	$15.00	$75.00	-	
Total	-		-	$214.98	$978.93	$120.10	-
Travel/Transport	Flights	19	Southwest	$309.00	$5,871.00	-	Subject to change with ticket prices
	Lodging	5 rooms for 5 nights	Embassy Suites	$127.00	$3,175.00	-	
	Rental SUV to haul vehicle	6 days	TBD	$150.00	$900.00	-	
	Rental minivans for transport in AL	2 minivans for 6 days	TBD	$200.00	$1,200.00	-	
Total	-	-	-	$786.00	$11,146.00	-	-
Total	**-**	**-**	**-**	**-**	**$15,138.03**	**$579.72**	
Total Cost	**$15,717.75**						

Table #6: Budgeting

Funding Plan

Funding Sources and Allocation of Funds

Madison West Rocket Club has multiple methods to earn enough funding to sustain a significant effort within the NASA Student Launch. We typically rake yards during the fall season and raise funds to continue the Rocket Design and development process without any interruptions. As of Wednesday, October 26th, 2024, we have earned approximately $1,200 from 3 weeks of fundraising. However, based on prior rocket club raking seasons and current demand, we have 47 more yards to rake, and many clients will donate well over $200 per yard, making our original fundraising goal of $7,000 feasible. In the event we are unable to attain our funding goals, we have 3 alternatives to obtain additional funding: Calling for donations from the community, developing a snow shoveling program to earn money in the winter, and finding sponsors for the club.

Material Acquisition Plan

Thanks to our club's long history, we have accumulated a large amount of extra materials in our workshop. We have fiberglass tubing, casings, shock cord, and a nose cone for our rocket. In the event the vendors either do not have the product we need, or they are unable to provide it to us in a reasonable time, we will use the previous ones we have acquired from our workshop. We will need to purchase materials that we are unable to 3D print for our payload, as well as motors.

Timeline

Timeline Key

	Workshop
	Organizational Meeting
	SLI Writing Sessions
	NASA SL Events Dates and Due Dates
	School
	Fundraising and Outreach

Timeline

November 2024	
Monday 4-Tuesday 26	PDR Video Teleconferences
Friday 8	Workshop
Saturday 9	SLI Writing Session
Monday 11	Organizational Meeting
Wednesday 13	Outreach
Friday 15	Workshop
Saturday 16	SLI Writing Session
Monday 18	Organizational Meeting
Friday 22	Workshop

Saturday 23	SLI Writing Session
Monday 25	Organizational Meeting
Wednesday 27- Friday 29	No school
Friday 29	Gateway Registration Deadline
Saturday 30	SLI Writing Session
December 2024	
Sunday 1	Fundraising
Monday 2	Organizational Meeting
Friday 6	Workshop
Saturday 7	SLI Writing Session
Monday 9	Organizational Meeting
Friday 13	Workshop
Saturday 14	SLI Writing Session
Monday 16	Organizational Meeting
Friday 20	Workshop
Saturday 21	SLI Writing Session
Monday 23- Tuesday 31	No school
January 2025	

Wednesday 8	Subscale Flight Deadline
Wednesday 8	CDR Due
Monday 13	Organizational Meeting
Wednesday 15	CDR Teleconferences
Friday 17	Workshop
Saturday 18	SLI Writing Session
Monday 20	Organizational Meeting
Friday 24	Workshop
Saturday 25	SLI Writing Session
Monday 27	Organizational Meeting
Friday 31	Workshop
February 2025	
Saturday 1	SLI Writing Session
Monday 3	Organizational Meeting
Friday 7	Workshop
Saturday 8	SLI Writing Session
Monday 10	Team Photos Due
Tuesday 11	FRR Q&A

Tuesday 2/11- Monday 3/17	Work on FRR
Friday 14	Workshop
Saturday 15	SLI Writing Session
Monday 17	Organizational Meeting
Friday 21	Workshop
Saturday 22	SLI Writing Session
Monday 24	Organizational Meeting
Friday 28	Workshop
March 2025	
Saturday 1	SLI Writing Session
Monday 3	Organizational Meeting
Friday 7	Wingra Science Night
Saturday 8	SLI Writing Session
Monday 10	Organizational Meeting
Friday 14	Workshop
Saturday 15	SLI Writing Session
Monday 17	FRR Due
Wednesday 19	Outreach

Thursday 20	Outreach
Friday 21	Workshop
Saturday 22	SLI Writing Session
Monday 24	FRR Teleconferences
Friday 28	Workshop
Saturday 29	SLI Writing Session
Monday 31	Organizational Meeting
April 2025	
Monday 7	Organizational Meeting
Friday 11	Workshop
Monday 14	Payload Demonstration Flight
Thursday 17	Launch Week Q&A
Friday 18	Workshop
Wednesday 30	Team Arrives in Huntsville, AL
May 2025	
Thursday 1- Friday 2 Saturday 3	All-day Launch Week Events Launch Day

Sunday 4	Backup Launch Day
Monday 19	Submit PLAR

Table #7: Timeline