Project Hermes

2023 NASA Student Launch Initiative
Preliminary Design Review (PDR)

ResistoJets Rocketry 4-H Club of Morris County

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18 USC 707

Glossary

4-H - Youth Organization (Our team's host administration)

FCC - Federal Communications Commission (Government Agency)
FAA - Federal Aviation Administration (Government Agency)
NASA - National Aeronautics and Space Administration (Government Agency)
SLS - The Space Launch System rocket (NASA's current Rocket)

STEM - Science, Technology, Engineering, and Math

MSDS - Material Safety Data Sheet
PPE - Personal Protective Equipment

FPS - Feet per Second
TWR - Average Thrust to Weight Ratio of the Vehicle during Ascent

SLI - Student Launch Initiative
USLI - University Student Launch Initiative

NAR - National Association Of Rocketry (Rocketry Governing Body)
TRA - Tripoli (Rocketry Governing Body)
HPR - High Power Rocketry
K Motor - Using the level 2 K class of high power rocket motors
L1, L2, and M1 - Classifications of rocketry certifications created by NAR and TRA

SDR - Software Defined Radio
USB - Universal Serial Bus
APRS - Automated Packet Reporting system
LIPO - Lithium-Ion Polymer Battery

PDR - Preliminary Design Review
CDR - Critical Design Review
FRR - Flight Readiness Review
LRR - Launch Readiness Review
PLAR - Post-Launch Assessment Review

Contents

1. Summary of PDR report

1.1 Team Summary

Name of team and mailing address:
ResistoJets Rocketry 4-H
[redacted]

Mentor: Luke McConoughey
[redacted]

Our team has spent 120 hours preparing for the PDR milestone.

Social media presence:

Title	Handle	Purpose	Active for:
YouTube	Morris County 4-H YT	Launch/Build Videos	8 Months
Facebook	ResistoJets Rocketry	Community Engagement/Outreach	1 Week
Website	nj4h.space	Club website	1 Week

Table 1. Social Media Presence

1.2 Launch Vehicle Summary

Official target altitude: 3,800 feet

Our primary motor choice is the K1100T with the K695R as a backup.

Size and mass of individual sections:

1. Booster - 4.84 lb, 33.78”
2. Avionics Bay + Payload - 2.98 lb, 13.78”
3. Upper Airframe - 3.54 lb, 45.2”

Recovery system:
Our recovery set-up uses a fully redundant dual deploy system, with a 48” Fruity Chutes Main parachute and a 15” Spherachutes Drogue Parachute. We will be using two Stratologger CF flight computers in our dual deploy system.

1.3 Payload summary:

Payload title: 2022-2023 NASA USLI Payload Challenge:
Our payload is designed to complete the USLI payload challenge. We will be accomplishing this by using a robotic arm on the side of the airframe, consisting of four actuation points. During launch, the payload is folded up and has an aerodynamic shroud profile. Upon landing, the arm will orient itself based on inertial measurements. The arm will support a camera with control motors. Our electronics consist of a Raspberry Pi 4, four motors, and several inertial measurement units.

2. Changes Made Since Proposal

2.1 Changes to Vehicle Criteria

The vehicle core vehicle specifications and design remains largely unchanged from the proposal. In 2.2, changes to the payload are detailed. In relation to that, a new external mounting system has been added to the avionics bay to support the new payload. As a result of this, our simulated altitude has decreased significantly. The vehicle length and total weight has been slightly reduced

2.2 Changes to Payload Criteria

In our proposal, our primary plan was to use a payload design that would come out of the airframe and land on the ground (while tethered to the vehicle). We discussed an alternative design that would be more reliable, but more challenging. In the development of our Payload we encountered many problems with our primary design and chose to switch to the alternate design. We also had problems developing the payload to orient itself correctly and being able to have all the computer systems on the payload. This design was our backup payload but getting ejected from the airframe is something that brings on increased risk.

2.3 Changes made to project plan

Our project plan remains largely unchanged. There are minor adjustments to the expenses, shown in 6.2.1 Line Item Budget. The funding plan has been further detailed. Our project timeline from the Proposal has been updated and advanced to our current point in the project.

3. Vehicle Criteria

3.1 Selection, Design, and Rationale of Launch Vehicle

3.1.1 Mission Statement and Success Criteria

Our mission is to build an innovative and reliable rocket launch vehicle for the purposes of meeting all SLI criteria and achieving multiple awards within the challenge, including (in no particular order):

1. Judge’s Choice Award

2. Altitude Award
3. 3D Printed Award
4. Best Looking Rocket Award
5. Best Rocket Fair Display Award

We, as our team, will share our story to inspire others by demonstrating ingenuity, perseverance, and adaptability all while effectively communicating topics in technologies and science.

We have established a solid foundation for our success criteria, which includes standard launch evaluations, as well as innovative and technological successes. A list of criteria to assess our vehicle performance is provided below:

- Safe and successful launch and recovery of the vehicle in reflyable condition, including a stable, near-vertical ascent. Nominal parachute deployment for both stages of recovery, and a soft landing that does not permanently damage the vehicle
- A small margin of error in actual apogee altitude (<15%)
- Successful deployment into an appropriate operation environment for the payload
- Successful use of 3D printed parts onboard the vehicle
- Successful use of composite material techniques
- Successful use of a reloadable rocket motor
- Successful data-logging throughout the flight suitable for analysis upon recovery
- Innovative and challenging use of materials and fabrication methods
- A well-fabricated and visually appealing vehicle for launch day.

3.1.2 Systems and Alternatives Overview

Our vehicle can be split into these subsystems which work together in conjunction:

1. Aerostructure System - Outlined in Section 3.1.2.1
2. Propulsion System - Outlined in Section 3.1.2.2
3. Avionics System - Outlined in Section 3.1.2.3
4. Payload System - Outlined in Section 4
5. Recovery System - Outlined in Section 3.2

3.1.2.1 Aerostructure System

The Aerostructure System consists of: the main airframe and structure of the vehicle. Controlling a safe and effective housing for all other subsystems. and providing a lightweight, aerodynamic,

and stable shape for flight. Our current system consists of several key points; with more details outlined on the flysheet. OpenRocket simulation, and the proposal changes.

- 4” Diameter G12 Fiberglass Airframe
- 3 Sections - Booster, Avionics Bay, Payload/Upper Airframe
- Standard Dual Deployment Configuration for Avionics Bay
- 0.125” G10 Fiberglass Fin Cores, Carbon Fiber Tip-to-Tip Reinforcement (Totaling a fin thickness of 0.15”)
- Through-the-wall fin design
- Assembly with Glenmarc G5000 Rocketpoxy and US635 Epoxy System Adhesives

First and foremost, with structures engineering, we considered material choices, which are listed below in order of best choice. Our research into these materials and our selection rationales are listed in the NASA SL Proposal.

1. G12 Filament Wound Fiberglass - Commercially Manufactured
2. MAC Performance Canvas-Phenolic Composite
3. LOC Precision Cardboard

Next, our section airframe layout choices are listed below:

1. Standard Dual Deployment Configuration - Booster, Avionics Bay, Payload/ Upper Airframe - Black powder charges located below/ above avionics bay
2. Head End Deploy Configuration - Extended Booster, Avionics Bay, Nosecone - Black powder charges located below avionics bay and inside nose cone
3. Single Separation, Dual Deploy Configuration- Extended Booster, Avionics Bay in Nosecone - Black powder charges located below avionics bay

We ruled out the Head End Deploy configuration due to its lack of sufficient parachute room within the nose cone, its added difficulty of integration, although it does allow for a more efficient layout for higher-performance vehicles. However, since our team is prioritizing reliability rather than maximum performance, the Head End Deploy configuration isn’t optimized for our application.

We also ruled out the “Single Separation, Dual Deploy” configuration due to its need for a more advanced recovery system, including cable cutters (or a Jolly Logic Chute Release) and multiple shock cord lines. This added complexity again adds extra performance and ease of assembly, but its complexity leads to a higher chance of failure and its relative unpopularity rules this configuration out for our application.

For our fincan (booster section) design, we opted for a standard through-the-wall fin attachment method along with other standard rocketry practices including:

- 3 fiberglass centering rings
- Shock cord (harness) attachment by epoxying to motor tube, passing through slots in the top centering ring
- Fins glued to motor tube with internal filets, glued to bottom face of middle centering ring
- Fins reinforced with external filets

All of these designs are considered “tried and true” methods within the High-Power Rocketry community; therefore, these are designs we chose due to its reliable reputation. We also opted to design our fincan with carbon fiber tip-to-tip reinforcement due to the current on-hand availability of the resources needed, its unmatched strength, and for our desire for usage of new technology on the vehicle. Alternatives include swapping carbon fiber for fiberglass or omitting the composite reinforcement altogether, which both will satisfy our needs for the rocket.

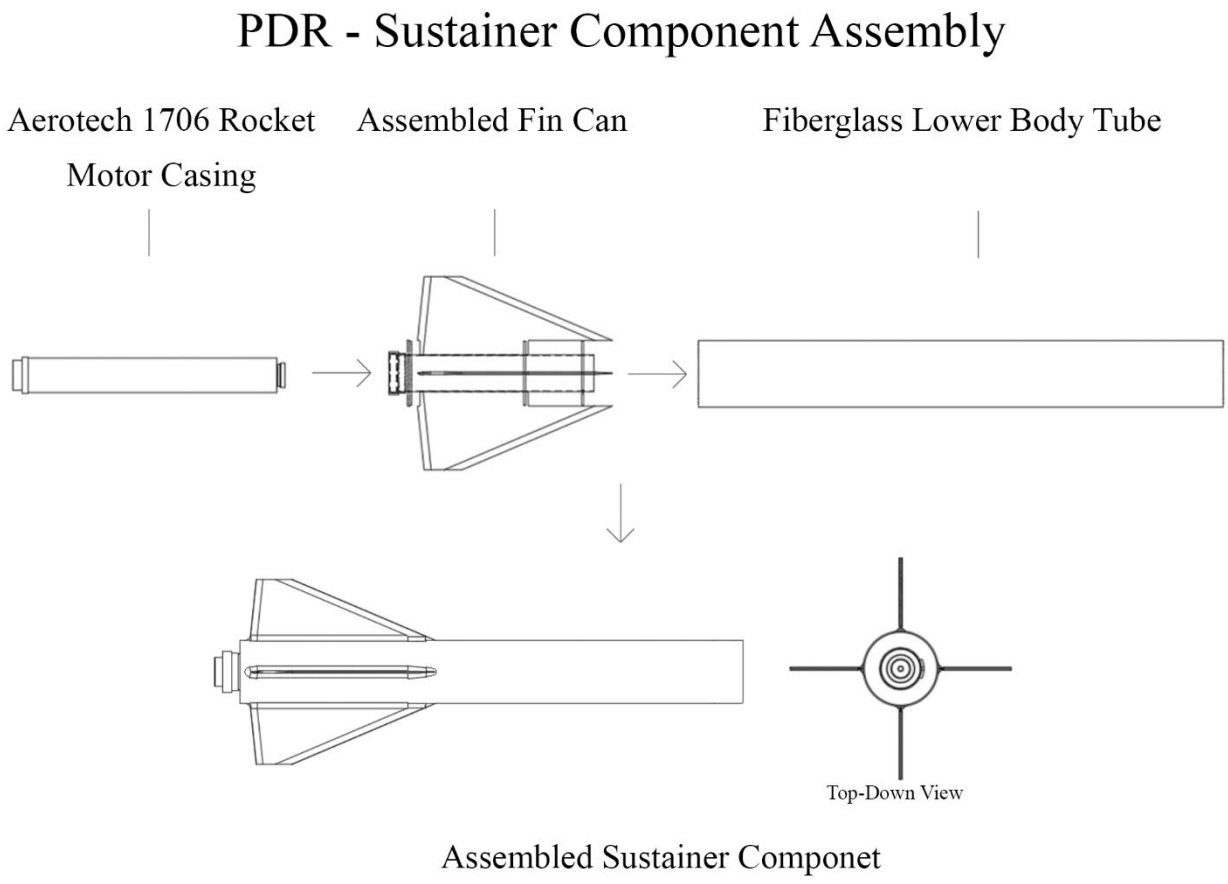


Figure 1. Sustainer Component Assembly Diagram

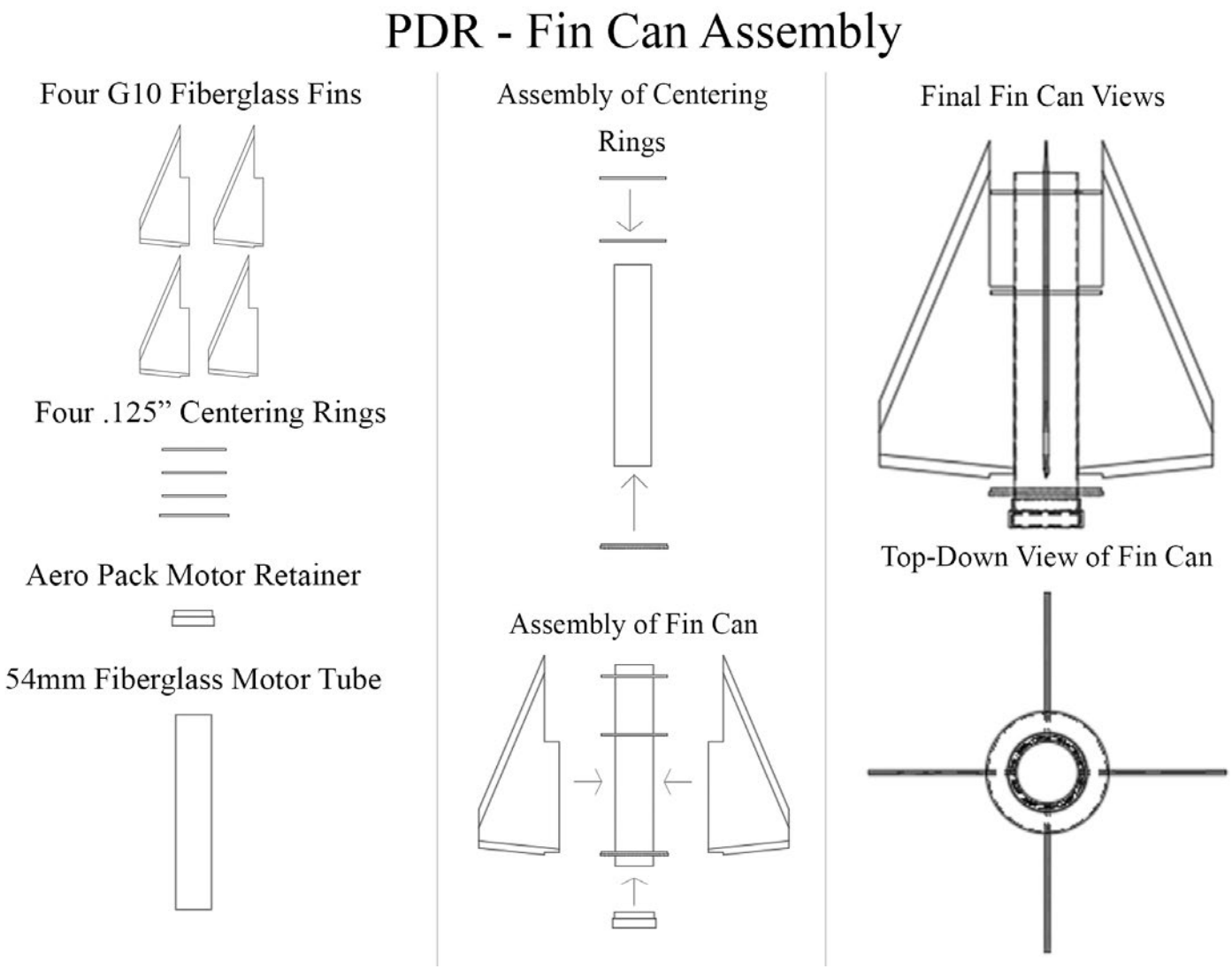


Figure 2. Fin Can Assembly Diagram

Finally, we plan to use G5000 Rocketpoxy and US635 Epoxy System Adhesives to manufacture the aerostructure system due to our current on-hand availability of both materials. The RocketPoxy provides for a great material for filets due to its high viscosity, and in the case we need a different viscosity, we can use the US635 epoxy system along with Aerosil (Fumed Silica) and Q-cell fillers to tailor the viscosity and epoxy properties to exactly our needs.

3.1.2.2 Propulsion System

The Propulsion System consists of the commercial rocket motor and the motor retention. The rocket vehicle was designed around a 54mm K class rocket motor (1280.01 to 2560 Ns). We plan to use an Aerotech RMS (Reloadable Motor System) Rocket Motor, specifically their 54/1706 case size due to our current availability and previous experience with RMS reloads. Another advantage with the 54/1706 RMS size is due to its cost, generally hovering around $110 per propellant reload kit, compared to $150-$250 for single-use Aerotech motors.

Since we will fly the vehicle multiple times, this cost difference can potentially save hundreds of dollars in our budget. We also chose Aerotech over the other major HPR motor manufacturer CTI (Cesaroni Technology, Incorporated) due to reliability issues in CTI 54mm motors as well as having little previous experience with CTI. The final HPR motor manufacturer, Loki Research, has extremely reliable motors. However, being a smaller company (products are commonly out-of-stock), having much higher cost, and having more complex snap ring designs ruled their products out for our application.

We can now consider our top 2 motor choices specifically for the Aerotech 54/1706 case, listed here in order of preference:

Motor Name	Case Size	Total impulse	Expected TWR	Propellent	Burn Time	Average Thrust	Manufacturer
K1100T	RMS-54/ 1706	1,472 Ns	15.08:1	“Blue Thunder”	1.6 seconds	1,110 N	Aerotech
K695R	RMS 54/ 1706	1,514 Ns	10.68:1	“Redline”	2.2 seconds	695 N	Aerotech

Table 2. Motor Details

We ruled out motors with an impulse of >1700 Ns or <1400 Ns, including the K2050ST, K805G, and K1103X. We also ruled out the K185W due to its insufficient ability to create a 5:1 initial thrust to weight ratio, a critical safety criterion we have for propulsion systems. We also ruled out dark matter and metal storm motors due to sparkies not being allowed in Student Launch. The remaining 4 motor options we looked at all met impulse, safety, and initial thrust criteria. Within our team we picked our favorite motors based off of propellant color, ruling out the K513FJ and K550W. Finally, we listed the final 2 motor selections for our flight, coming to the conclusion that the K1100T is our primary selection, and the K695R is our backup selection.

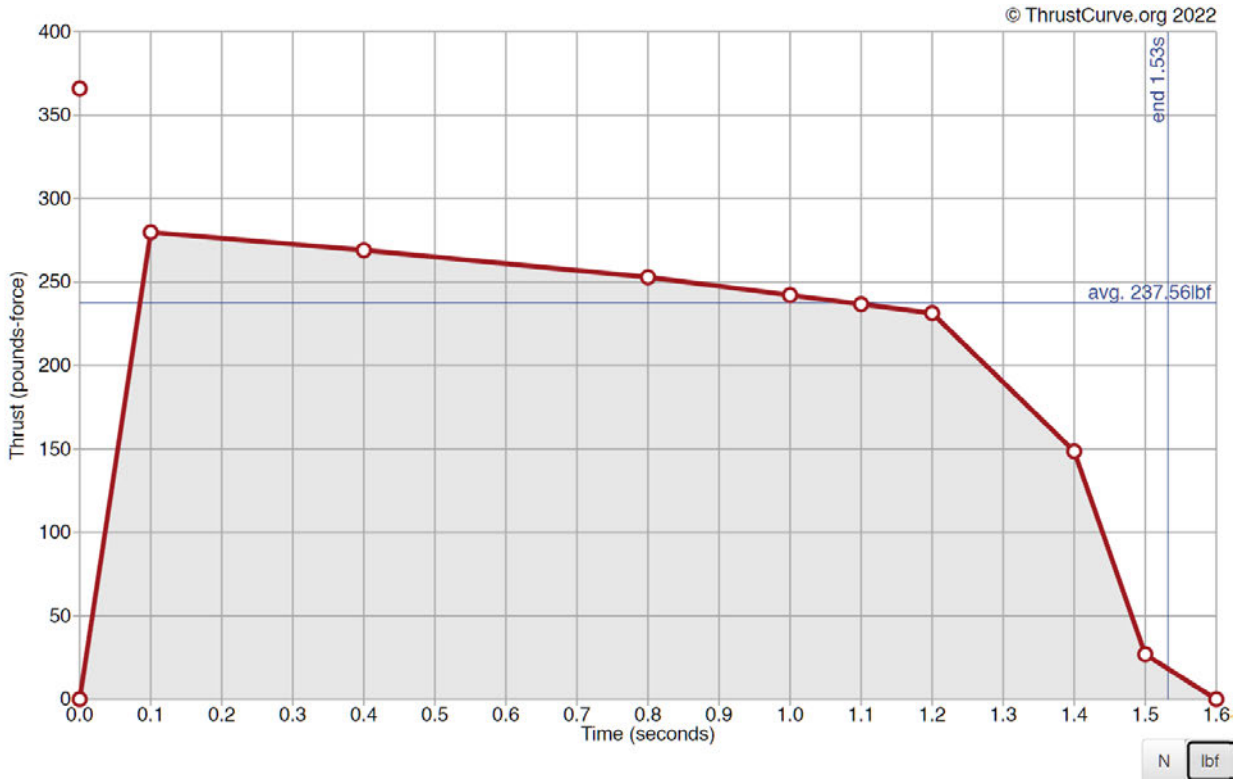


Figure 3. K1100T Thrust Curve

Finally, for our motor retention, we prefer to use an Aeropack 54P standard screw-on retainer. Our motor retention options and alternatives, listed in order of preference, include:

1. Aeropack 54P
2. Mirror Clips

We chose the Aeropack since it's the most common and the most reliable retention method. Mirror clips are still feasible but they're not as sturdy or foolproof, since there is a chance of slipping.

3.1.3 Avionics System

Our avionics consist of two fully redundant and independent flight controllers, 9v batteries, safety switches, and ejection charges. The Flight controllers we will be using are Stratologger CFs. We have RRC3 flight computers as an option or to provide other functionality if needed, but we will be using Stratologger CFs primarily because of our familiarity with them.

PDR - Avionics and Avionics Bay Assembly

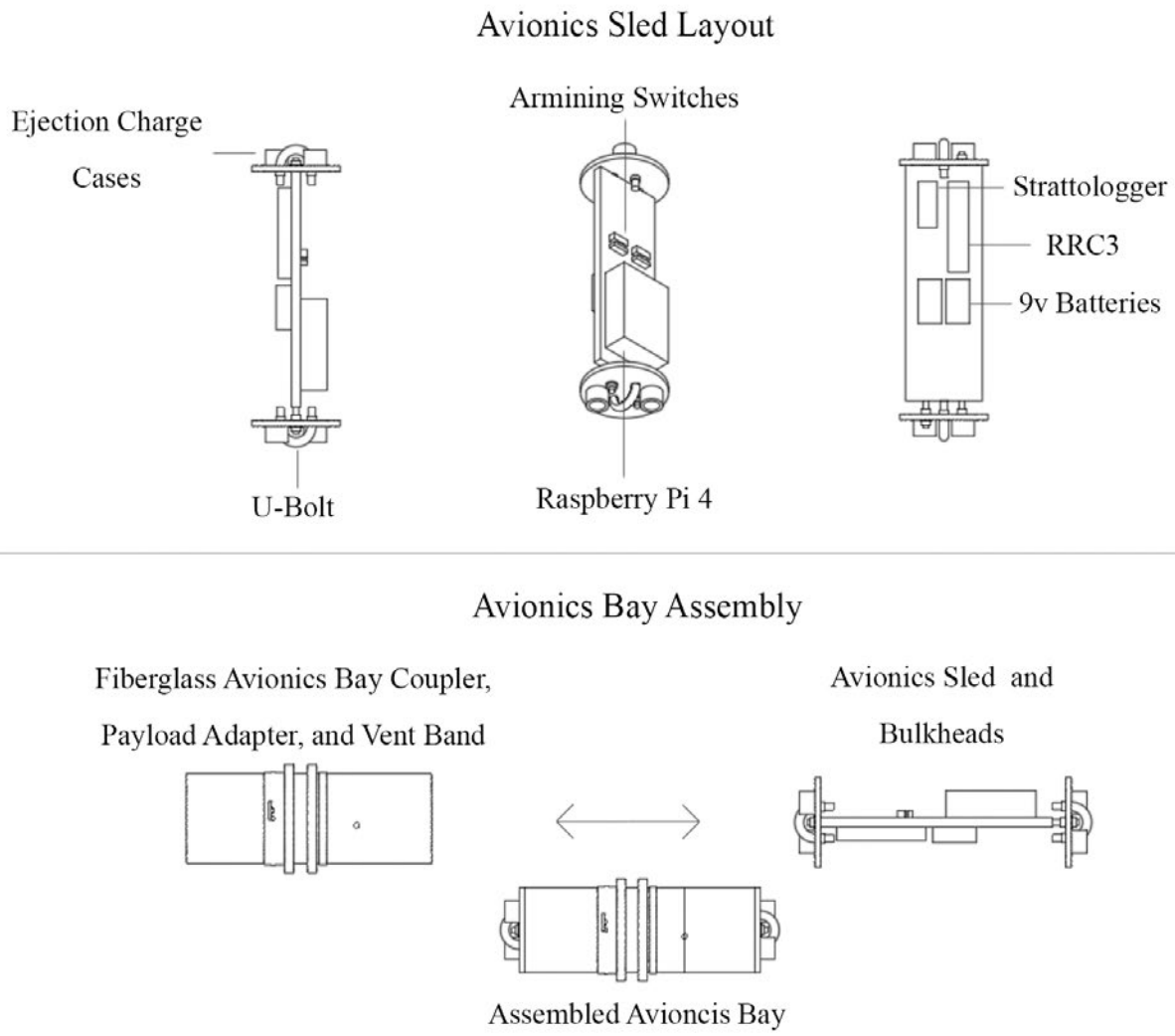


Figure 4. Avionics and Avionics Bay Assembly Diagram

3.1.3.1 Avionics Wiring Schematic

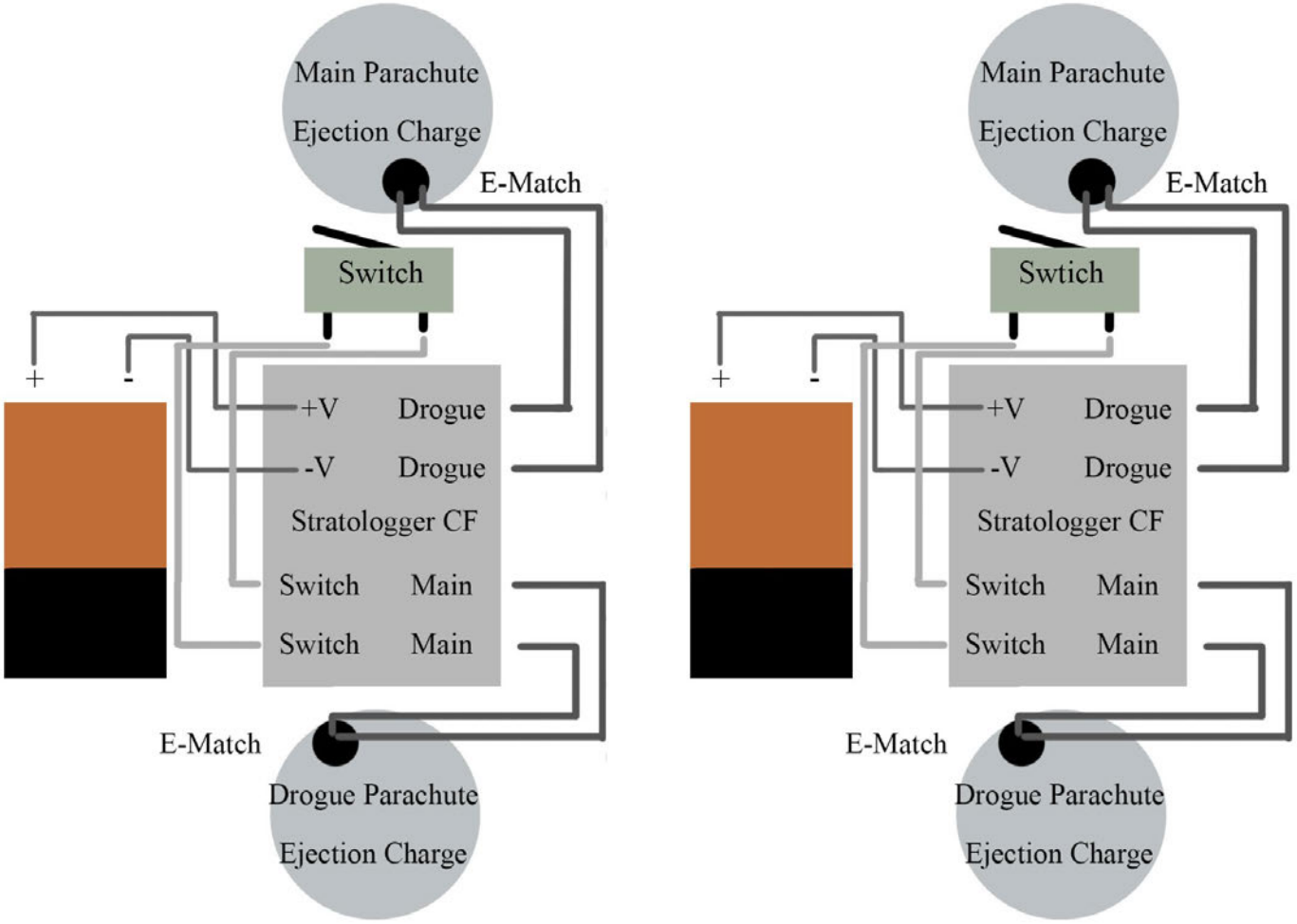


Figure 5. Avionics Wiring Schematic Diagram

3.1.3.2 Ejection Charges

Our fully independent and redundant deployment system results in each ejection flight computer getting its own ejection charges for both the main and drogue parachute separation, resulting in 4 total charges on the vehicle. We calculated our ejection charges using the FFFFg Black Powder Calculator | InsaneRocketry, a tool our members have used on all of their dual deploy launches. Our charges will use FFFFg black powder, the black powder will be housed in a small PVC cap attached to the bulkheads of the avionics bay, connected to the dual deploy computers with an E-Match and wiring.

Purpose	Order	Black Powder (grams)
Drogue Parachute	Primary	1.25
Drogue Parachute	Backup	2.00
Main Parachute	Primary	1.50
Main Parachute	Backup	2.25

Table 3. Ejection Charge Table

3.1.4 Final Rocket Design

Vehicle Specifications:

Thrust to weight ratio	-	15.08:1
Gross lift off weight (lb)	-	14.30
Total length (in)	-	81.15
Diameter (in)	-	4.02 (Max 4.7)
Airframe material(s)	-	Fiberglass
Fin material(s)	-	G10, CFRP
Fin thickness (in)	-	0.15
Center of Pressure (in. from nose)	-	60.92
Center of gravity (in. from nose)	-	50.36
Drogue parachute size (in)	-	15.28
Recovery harness length (ft)	-	25
Main parachute size (in)	-	48 in / 2.2 Cd
Recovery harness length (ft)	-	25

PDR - Vehicle Measurements

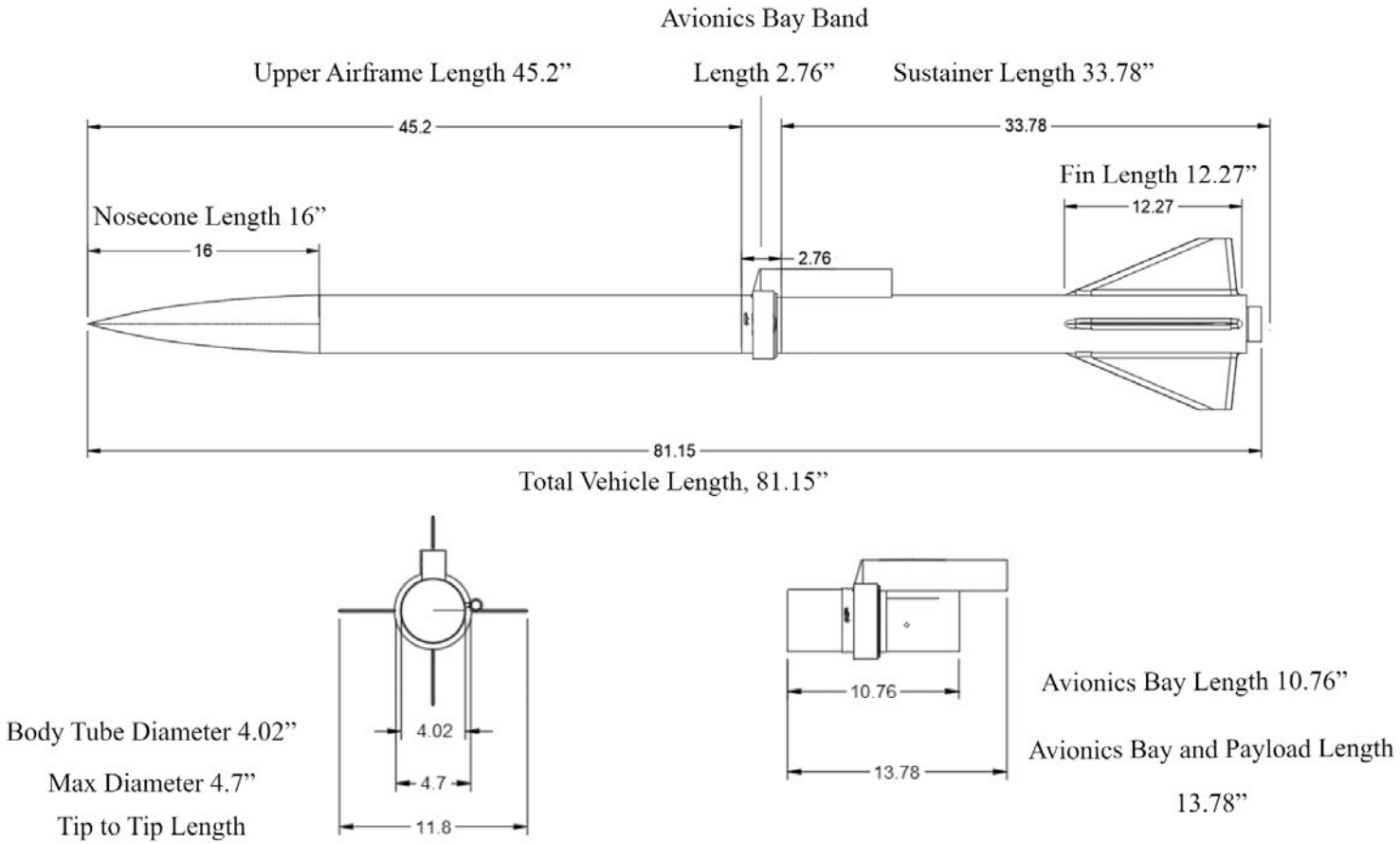
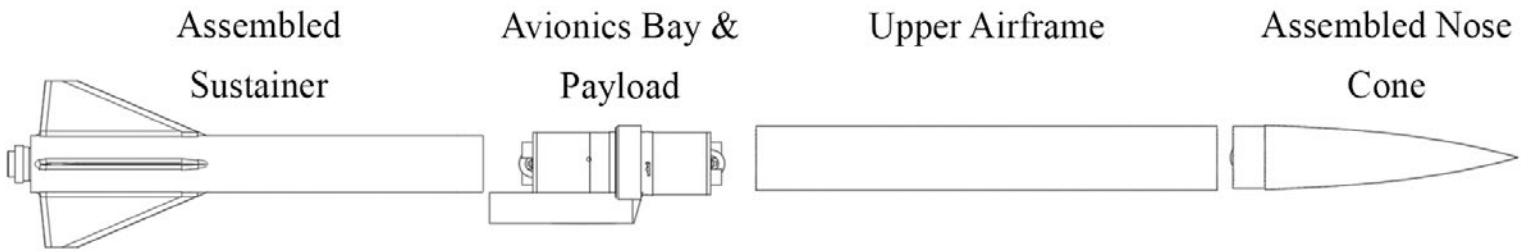
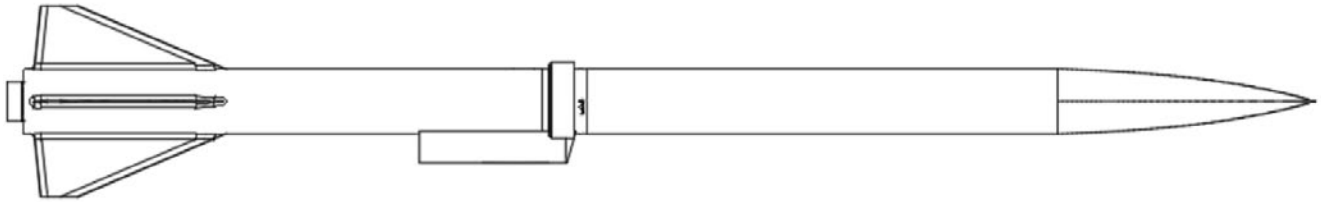


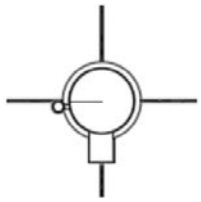
Figure 6. Vehicle Measurements Diagram

PDR - Airframe Assembly



Assembled Airframe





Top-Down View

Figure 7. Airframe Assembly Diagram

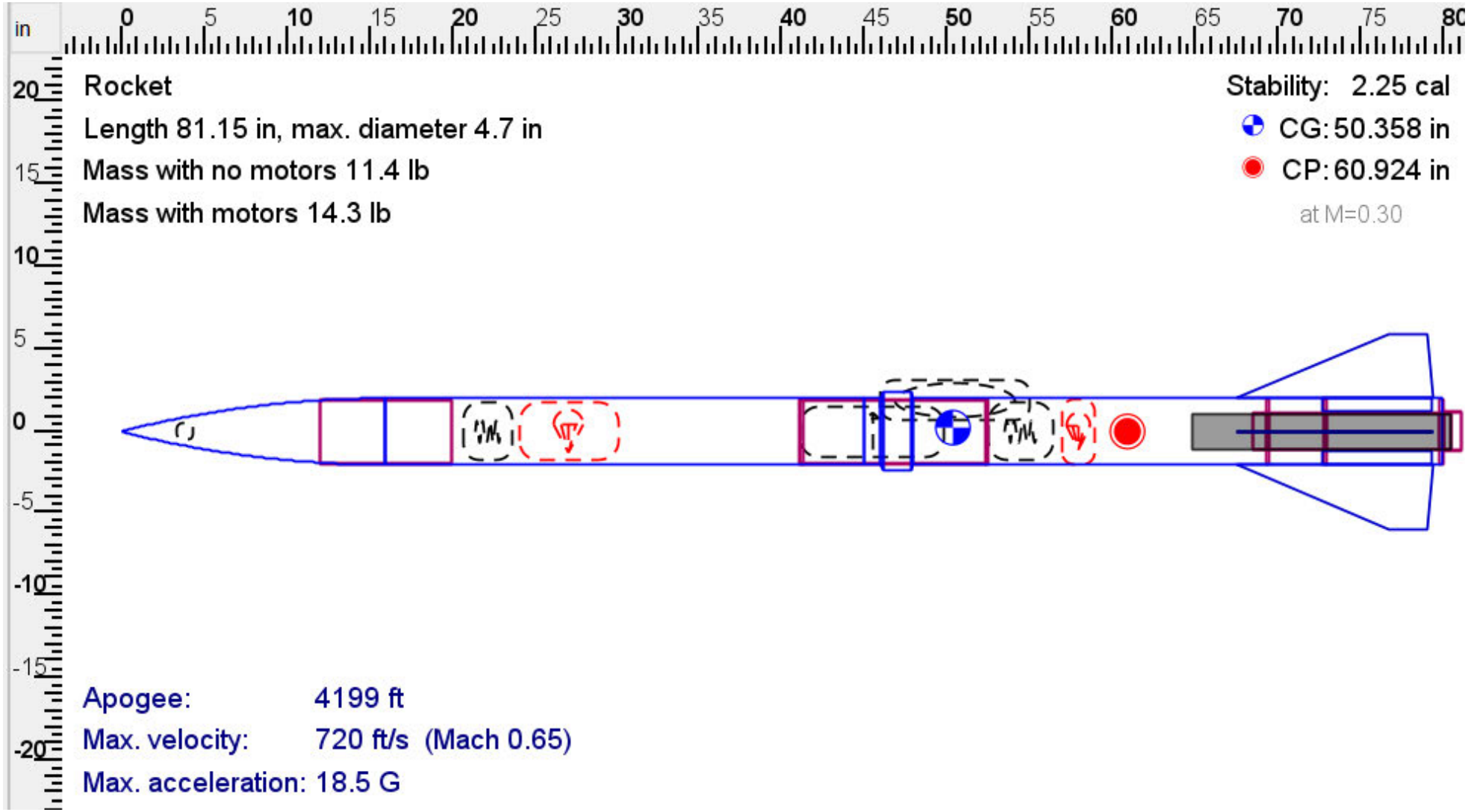


Figure 8. Before Motor Burnout

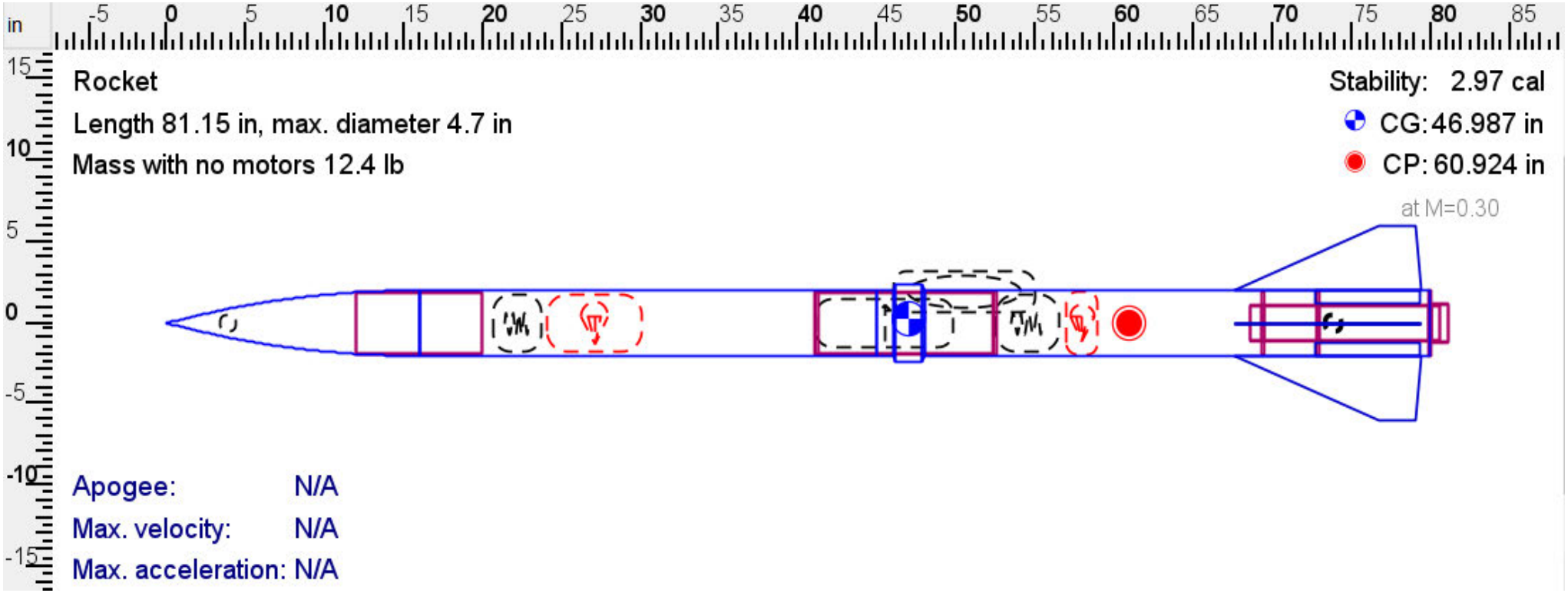


Figure 9. After Motor Burnout

Parts Detail

Sustainer

Nose Cone	Fiberglass (1.85 g/cm³)	Ogive	Len: 16 in	Mass: 202 g
1lb Ballast Weight		Dia_{out} 0.984 in		Mass: 454 g
Nose Cone Shoulder	Fiberglass (1.85 g/cm³)	Dia_{in} 3.92 in Dia_{out} 4.02 in	Len: 4 in	Mass: 75.6 g
Nose Cone Coupler	Fiberglass (1.85 g/cm³)	Dia_{in} 3.75 in Dia_{out} 3.9 in	Len: 8 in	Mass: 219 g
Upper Airframe (Payload Tube)	Fiberglass (1.85 g/cm³)	Dia_{in} 3.9 in Dia_{out} 4.02 in	Len: 29 in	Mass: 656 g
Avionics Bay	Fiberglass (1.85 g/cm³)	Dia_{in} 3.75 in Dia_{out} 3.9 in	Len: 10 in	Mass: 273 g
Lower Bulkhead	Fiberglass (1.85 g/cm³)	Dia_{out} 3.9 in	Len: 0.25 in	Mass: 90.5 g
Upper Bulkhead	Fiberglass (1.85 g/cm³)	Dia_{out} 3.9 in	Len: 0.25 in	Mass: 90.5 g
Avionics		Dia_{out} 3 in		Mass: 300 g
Iris Ultra Parachute [Cd 2.2 (7.5 oz) 41.4 in^3] Fruity Chutes IFC-048-N	Ripstop nylon, lightweight, 3 mil (0.117 oz/ft²)	Dia_{out} 48 in	Len: 3.467 in	Mass: 213 g
Shroud Lines Fruity Chutes IFC-048-N	Nylon IIIa Paraline [flat 6.4 mm, 1/4 in] (0 oz/ft)	Lines: 8	Len: 55.2 in	
Main Chute Harness	Kevlar 1500# (0.068 oz/ft)		Len: 240 in	Mass: 38.6 g
Vent Band	Fiberglass (1.85 g/cm³)	Dia_{in} 3.9 in Dia_{out} 4.02 in	Len: 1 in	Mass: 22.6 g
SLI Payload w/ Camera Shroud		Dia_{out} 2.5 in		Mass: 803 g
Transition (Payload Simulation - Used for drag estimations)	Cardboard (0.68 g/cm³)	Fore Dia: 4.02 in Aft Dia: 4.64 in	Len: 0.1 in	Mass: 0 g
Body Tube (Payload Sim)	Cardboard (0.68 g/cm³)	Dia_{in} 4.483 in Dia_{out} 4.64 in	Len: 1.76 in	Mass: 22.1 g
Transition (Payload Simulation - Used for drag estimations)	Cardboard (0.68 g/cm³)	Fore Dia: 4.64 in Aft Dia: 4.02 in	Len: 0.1 in	Mass: 0 g
Lower Airframe (Booster)	Fiberglass (1.85 g/cm³)	Dia_{in} 3.9 in Dia_{out} 4.02 in	Len: 32 in	Mass: 724 g
Heavy Duty 24" Hemispherical Spherachute [Cd .75 (1.3 oz) in^3] Spherachutes HS-024-HD	Ripstop Nylon, 1.9 oz 5 mil (0.193 oz/ft²)	Dia_{out} 15.28 in	Len: 2 in	Mass: 36.9 g
Shroud Lines Spherachutes HS-024-HD	MIL-C-5040 Type IIA paracord #225 [flat 3/16 x 3/64 in (4.5 x 1.1 mm)] (0.032 oz/ft)	Lines: 6	Len: 24 in	
Booster/ Primary Harness	Kevlar 1500# (0.068 oz/ft)		Len: 360 in	Mass: 57.8 g
Forward Centering Ring	Fiberglass (1.85 g/cm³)	Dia_{in} 2.266 in Dia_{out} 3.9 in	Len: 0.125 in	Mass: 30 g
Mid Centering Ring	Fiberglass (1.85 g/cm³)	Dia_{in} 2.266 in Dia_{out} 3.9 in	Len: 0.125 in	Mass: 30 g
Aft Centering Ring	Fiberglass (1.85 g/cm³)	Dia_{in} 2.266 in Dia_{out} 3.96 in	Len: 0.25 in	Mass: 62.8 g
Motor Tube	Fiberglass (1.85 g/cm³)	Dia_{in} 2.14 in Dia_{out} 2.266 in	Len: 12 in	Mass: 159 g
Aeropack 54P	Aluminum (2.7 g/cm³)	Dia_{in} 2.278 in Dia_{out} 2.4 in	Len: 1.1 in	Mass: 39.7 g
Trapezoidal Fin Set (4)	Fiberglass (1.85 g/cm³)	Thick: 0.125 in		Mass: 586 g

Figure 10. Parts Detail

3.2 Recovery System

Our launch vehicle will use a Dual Separation Dual Deploy system, meaning there are two separation events, one for the deployment of each parachute individually. The separation events are controlled by our avionics system, which consists of 2 fully redundant altimeters and batteries. The avionics system is covered in more detail in Section 3.1.2.3. We will also include separate ejection charges for both systems, which completely isolates each system, ensuring that if one fails, the other isn't affected.

3.2.1 Drogue-Stage Recovery Subsystem

Our drogue-stage recovery subsystem is housed within the booster and is deployed via separation of the booster and avionics bay. The purpose of this subsystem is to provide a stable yet quick descent to prevent drift and to meet the 85 second descent time criteria for Student Launch. Our current drogue-stage recovery subsystem consists of a booster harness, a main harness, and a drogue parachute. The system also includes the necessary attachment methods and separation charges needed to deploy the parachutes.

The most important component within this subsystem is the drogue parachute. First, we needed to figure out an appropriate size range for the drogue. Within our OpenRocket simulation, we ran trial and error tests with multiple sizes at multiple coefficients of drag (Cd's). We targeted a roughly 30-50 second descent time on the drogue parachute, which leaves roughly 30-40 seconds for the main-stage descent. Since our apogee height hovers around 5000 feet and main parachute deployment occurs at 600 feet, we calculated the needed descent rate, which is (5000 ft - 600 ft) / 45 seconds, which is approximately 100 ft/s. Based on this target and our trial and error analysis, we came to the conclusion that a roughly 15-18 inch diameter chute with a low Cd of 0.75-1.25 would be perfect for our drogue parachute.

Therefore, we listed out some parachute options that meet our sizing criteria:

1. Spherachutes 15-inch Heavy-Duty Drogue
2. Fruity Chutes 15-inch Compact Elliptical Drogue
3. Top Flight Recovery 18-inch Standard Chute

Safety and reliability is our #1 priority. We narrowed our search down to specially designed drogue chutes, since in the case of a high angle flight, a high horizontal velocity at deployment may cause standard parachutes to rip apart. We chose the Spherachutes drogue because it's a lot

cheaper than Fruity Chutes, and they have a heavy-duty option, which provides extra thick shroud lines with more robust joints, ensuring that the parachute doesn't rip at the shroud lines.

The next component within the drogue-stage recovery subsystem is the harnesses. This subsystem contains 2 different harnesses, one short harness permanently attached to the booster and a separate 'primary' harness that can be removed if needed.

An alternative is to use an eyebolt attached to the top centering ring where only 1 main harness is required. We decided not to use this technique for two reasons. First, eyebolts are prone to slipping or twisting out of orientation, which can cause a catastrophic failure in the recovery system and leave the booster in freefall. Second, tying the harness onto the eyebolt recessed into the tube is a challenge, even with 4" diameter airframes, as it is hard to reach inside the booster multiple feet and tie a harness properly with 1 hand. This also makes recovery assembly very finicky, resulting in a possible delay at the launch site assembly process and a higher risk of human error.

Therefore, we decided to use the dual-harness system due to its reliability, ease of assembly, and low-risk. Our team's technical lead has also built multiple high power rockets with this design, proving its reliability and adding an experience advantage onto this design.

For the booster harness, we will use a 1 yard long, 1" wide, flat Kevlar harness that will be epoxied to the motor tube and the top-centering ring along a 6 inch surface. The booster harness is made out of 4500-lbs rated Kevlar, which is the highest rated line in our recovery system. We will attach the booster end of the harness with a knot below the slit in the top centering ring so that in the case of a slip, the knot will block the Kevlar from releasing completely. We will epoxy the end of the Kevlar harness to ensure it is securely attached. The harness has a sewn loop on one end, allowing for attachment to the primary harness.

For the primary harness, we will use a 25 foot long ⅜" diameter tubular kevlar harness from OnebadHawk, a respected vendor for harnesses in the high power rocketry community. This harness has 2 sewn loops on each side, allowing for the use of quick-links for non-permanent attachment and general organization. The length of this harness is adequate as it is sized more than 3x the total length of the rocket, which is a standard practice in high power rocketry. This harness is rated to 3600-lbs of strength.

3.2.2 Main-Stage Recovery Subsystem

The main-stage recovery subsystem is housed in the payload tube and is deployed via the separation of the payload tube and the avionics bay. This subsystem provides the necessary descent rate for a safe landing and to meet the impact kinetic energy requirement in the SL

Handbook. This subsystem will be deployed at 600 feet AGL, with a backup charge to deploy it at 500 ft AGL too. The main recovery system consists of one harness, equivalent to the primary harness in the drogue-stage recovery system, and one main parachute.

Similar to how we experimentally discovered the ideal parachute size range for the drogue, the main parachute was sized to a 48 inch chute with a Cd of 2.2, or a 84 inch chute with a Cd of 0.75. From limitations with kinetic energy, we limited the touchdown velocity to no greater than 7 meters per second. We also verified the main chute size range by using parachute descent calculators online, plugging in the desired descent velocity of 20 fps (6.07 m/s) and a mass of 13 lbs (burnout vehicle weight). With the size limitations, here is our list of choices for the main parachute:

1. Fruity Chutes Iris Ultra Classic - 48 inch diameter, 2.2 Cd
2. Spherachutes 84” Hemispherical Chute - Heavy Duty - 0.75 Cd
3. Top Flight Recovery 84” Standard Chute - 0.8 Cd

To meet the SLI required main parachute coefficient of drag, we will use a Fruity Chutes 48” parachute. Additionally, the cost difference between Sphereachutes and Fruity Chutes is a lot smaller in magnitude, which further justifies our decision.

The single harness for the main-stage recovery subsystem is the same exact harness as in the drogue-stage recovery subsystem. We still plan to use quick-links for modular/non-permanent designs. The main difference we have on the main chute system is the attachment to the payload bay, which is done via machined fiberglass bulkhead that is recessed into the payload tube. The bulkhead has a U-bolt attachment, which is a stronger alternative to the eyebolt due to having 2 attachment points, resulting in no possibility of eye-bending, nut looseness, or threading off.

3.2.3 Lines Diagram, Recovery Assembly, and Subsystem Deployment

The Recovery System will be assembled in the following order:

1. Booster harness attached during Aerostructure System assembly
2. Primary harness attached with quick-link
3. Drogue Chute attached to primary harness via a knot and (optionally) a swivel and a parachute protector is added
4. Primary harness attached to lower half of Avionics Bay
5. Main harness attached to bulkhead U-bolt in payload bay
6. Main Chute attached to main harness via a knot and (optionally) a swivel and a parachute protector is added
7. Main harness attached to upper half of avionics bay

8. Parachutes are folded, parachute protectors burrito-wrap the parachutes.
9. The harnesses are Z-folded and recovery subsystems are pushed into their respective tubes.
10. On launch day, with proper safety equipment, our mentor will prepare all ejection charges and connect them to the avionics bay. The avionics bay will not be turned on until vertically on the rail, where we will check for charge continuity.

Each of the 2 recovery subsystems will be deployed with a primary and a backup ejection charge. The sizes of these charges are currently outlined in the PDR flysheet. They were calculated using an online rocketry ejection charge calculator and increased by 50-200% for extra reliability. These charges will be tested and possibly revised after ground testing.

Provided below is a rough drawing for the recovery system lines diagram:

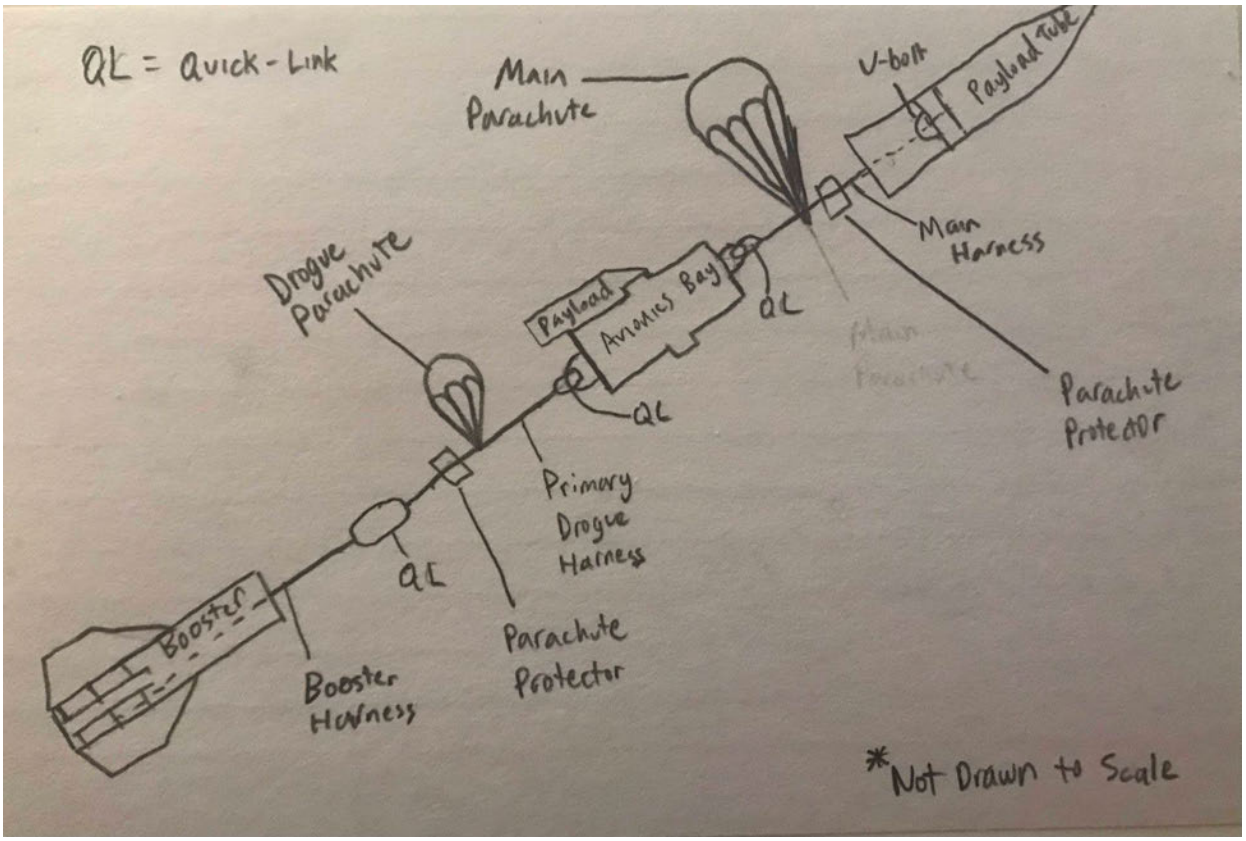


Figure 11. Recovery System Lines Diagram

3.3 Mission Performance Predictions

Our team's official competition launch target altitude is 3,800 feet.

Target Apogee (ft)	-	3800
Predicted Apogee (From Sim.) (ft)	-	4038
Total flight time (seconds)	-	59.7
Time to Apogee(seconds)	-	14.5
Maximum Velocity (ft/s)	-	720
Maximum Acceleration (ft/s^2)	-	595
Ground Hit Velocity (ft/s)	-	19.5

3.3.1 Simulations and Stability

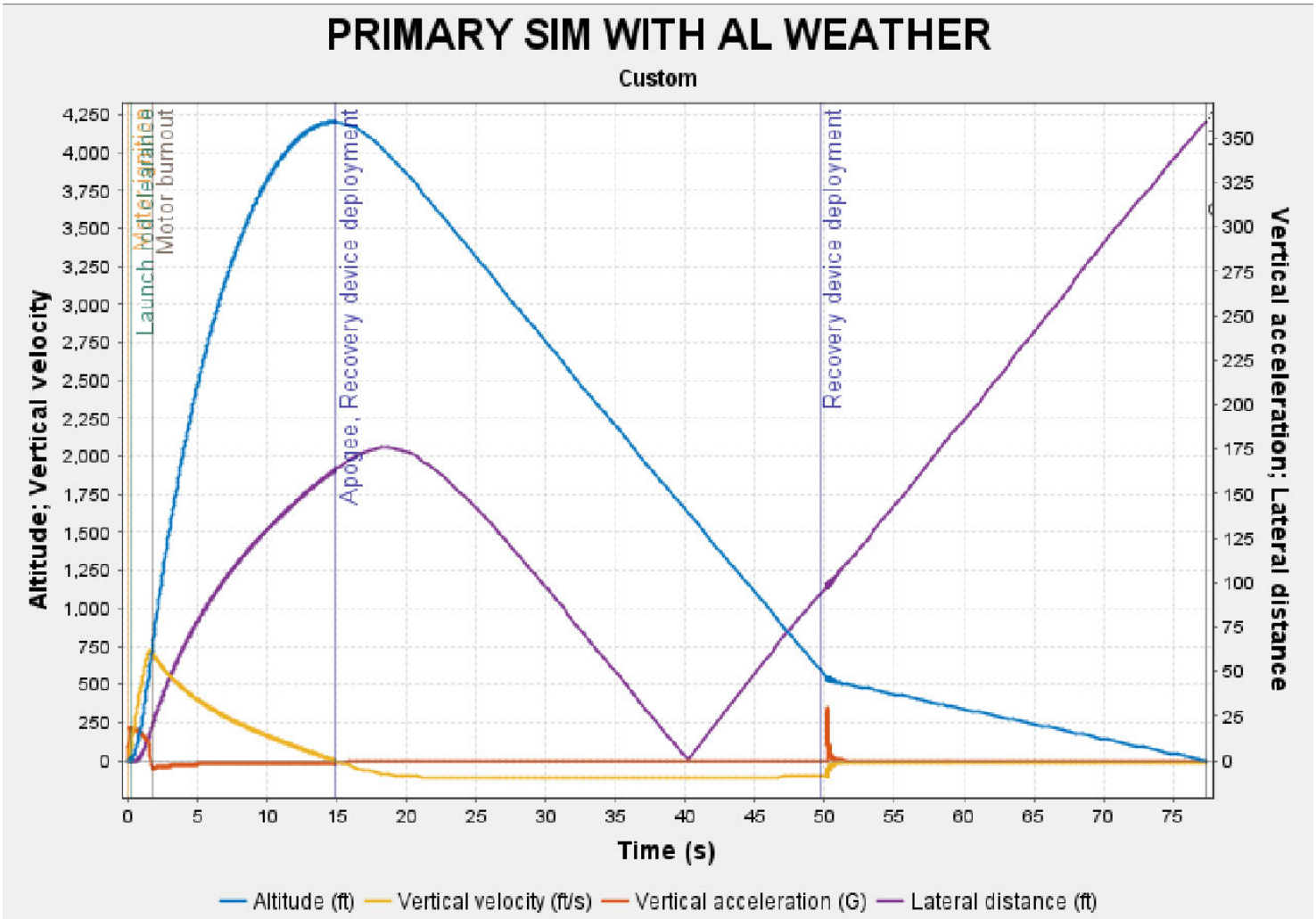


Figure 12. OpenRocket simulation with anticipated conditions in Huntsville in April 2023

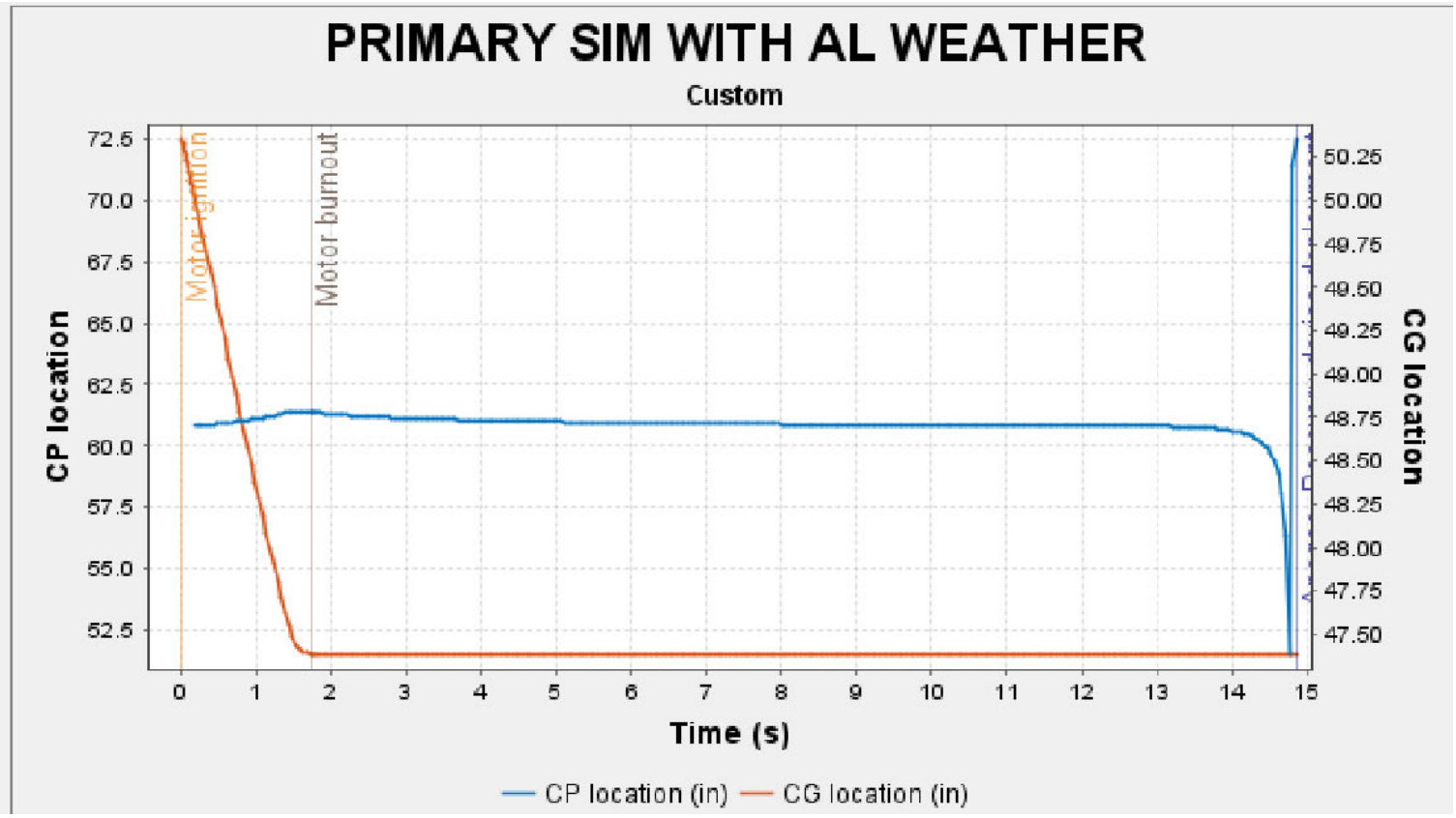


Figure 13. Simulation of center of gravity and center of pressure during ascent

3.3.2 Kinetic Energy Analysis

We used the imperial unit kinetic energy equation to calculate the kinetic energy of each section at landing:

KE (ft-lbf) = ½ mv^2/ g

Where m is in lbm, v is in ft/s, and g is the gravitational constant, which is 32.17 ft-lbm/lbf-sec^2

Landing velocity is 19.4 ft/s
Masses for each of the 3 sections are:

1. Booster - 4.84 lb
2. Avionics Bay + Payload - 2.98 lb
3. Upper Airframe - 3.54 lb

Using the masses and the landing velocity, we calculated the kinetic energies for each of the 3 sections:

1. Booster - 28.3 ft-lbf
2. Avionics Bay + Payload - 17.42 ft-lbf
3. Upper Airframe - 20.65 ft-lbf

Each section meets the 75 ft-lbf upper limit requirement for kinetic energy at landing.

3.3.3 Descent Drift Analysis

The total descent time is 59.7 seconds. If we assume the rocket drifts at a velocity matching the wind speed for the entire descent, then these are the respective drift distances for each simulated wind speed:

1. 0 mph wind speed - no drift
2. 5 mph wind speed - 437 ft drift from apogee
3. 10 mph wind speed - 875 ft drift from apogee
4. 15 mph wind speed - 1313 ft drift from apogee
5. 20 mph wind speed - 1751 ft drift from apogee

These numbers are verified to within 20% accuracy from our OpenRocket Simulations, whose results are listed below:

1. 5 mph wind speed - 240 ft drift from apogee
2. 10 mph wind speed - 594 ft drift from apogee
3. 15 mph wind speed - 906 ft drift from apogee
4. 20 mph wind speed - 1092 ft drift from apogee

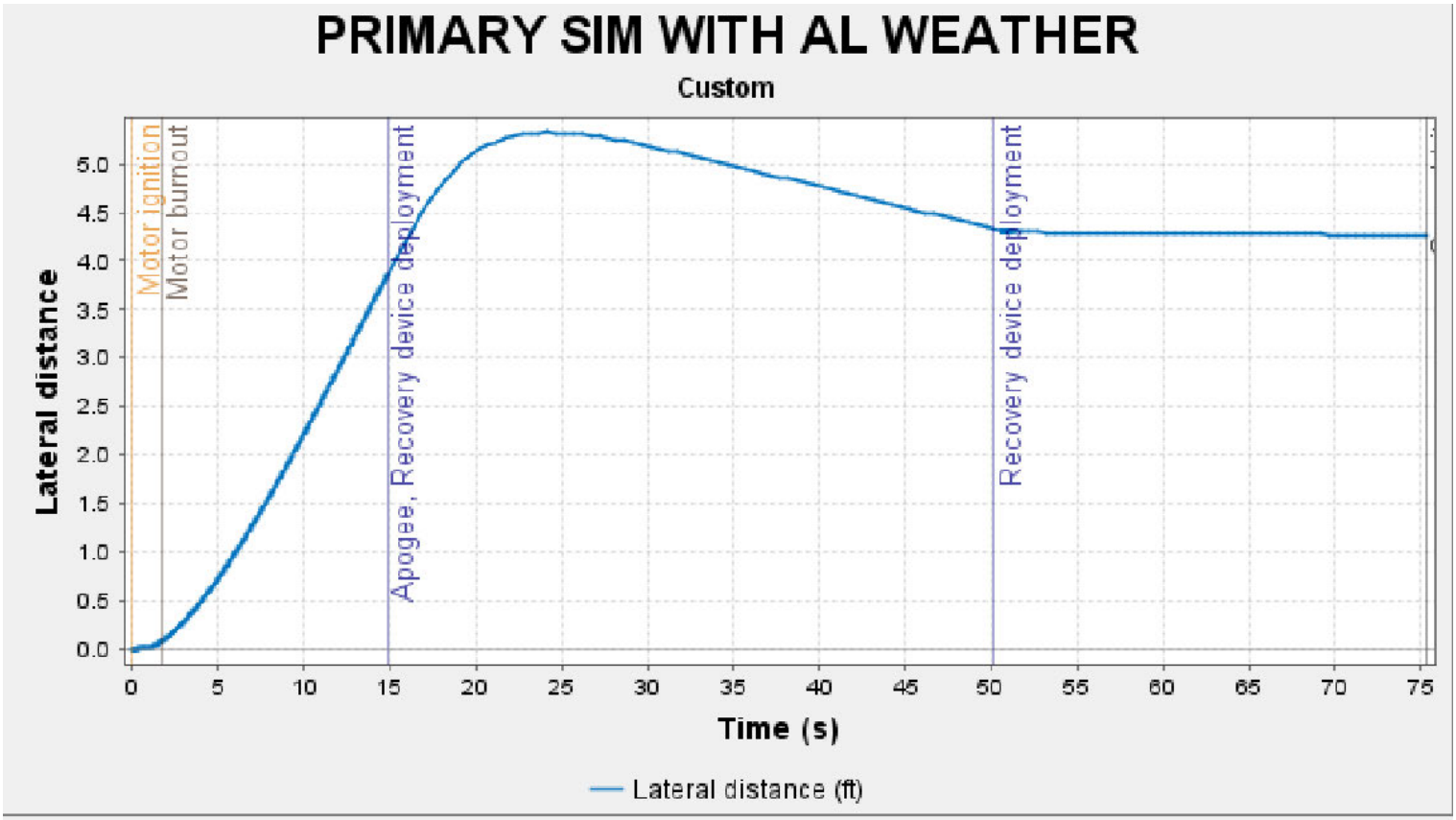


Figure 14. Example of a lateral distance simulation in OpenRocket

To find the drift distance in OpenRocket, we set the wind speed to a fixed value, then we took the difference between the simulated lateral distance at landing (in this case we assume it's negative since it goes in the opposite direction) and the simulated lateral distance at apogee. All of our results in OpenRocket were lower than calculated before, and this is due to weathercocking during the rocket's ascent giving it horizontal velocity in the direction up the windstream. Once the parachutes are deployed it takes a few seconds for the rocket to lose that velocity and start moving down the windstream.

4. Payload Criteria

4.1 Payload Description

Our team is taking part in the USLI Payload Challenge. The goal of the payload is to, upon landing of the launch vehicle, photograph the surrounding area as instructed by APRS radio packets. They will contain instructions on how to rotate and apply filters to the camera. Our payload will consist of a robotic arm on the side of the launch vehicle. It will self correct to the optimal vertical orientation. Our criteria for success is the following items: in order of percentage of mission completion from least to complete success:

- Systems survive launch and stay powered on throughout the entirety of the mission
- The robotic arm is able to deploy and orient itself to the proper position to take the photographs
- The payload computer receives and processes the APRS commands
- The robotic arm and camera are able to successfully photograph the surrounding area as instructed
- Successfully save the photographs to be reviewed in the PLAR

Our mission with this USLI payload challenge is to push the knowledge and capabilities of our team members. By accomplishing the objectives set out by NASA for this mission. Our goal is to achieve all of these as is required by the USLI Payload Challenge, however, our team may consider it a partial success as long as the pictures are taken and recovered. Furthermore, we want to have synergy between the launch vehicle and payload, where neither negatively impacts the other. This is to ensure safety and success ratio.

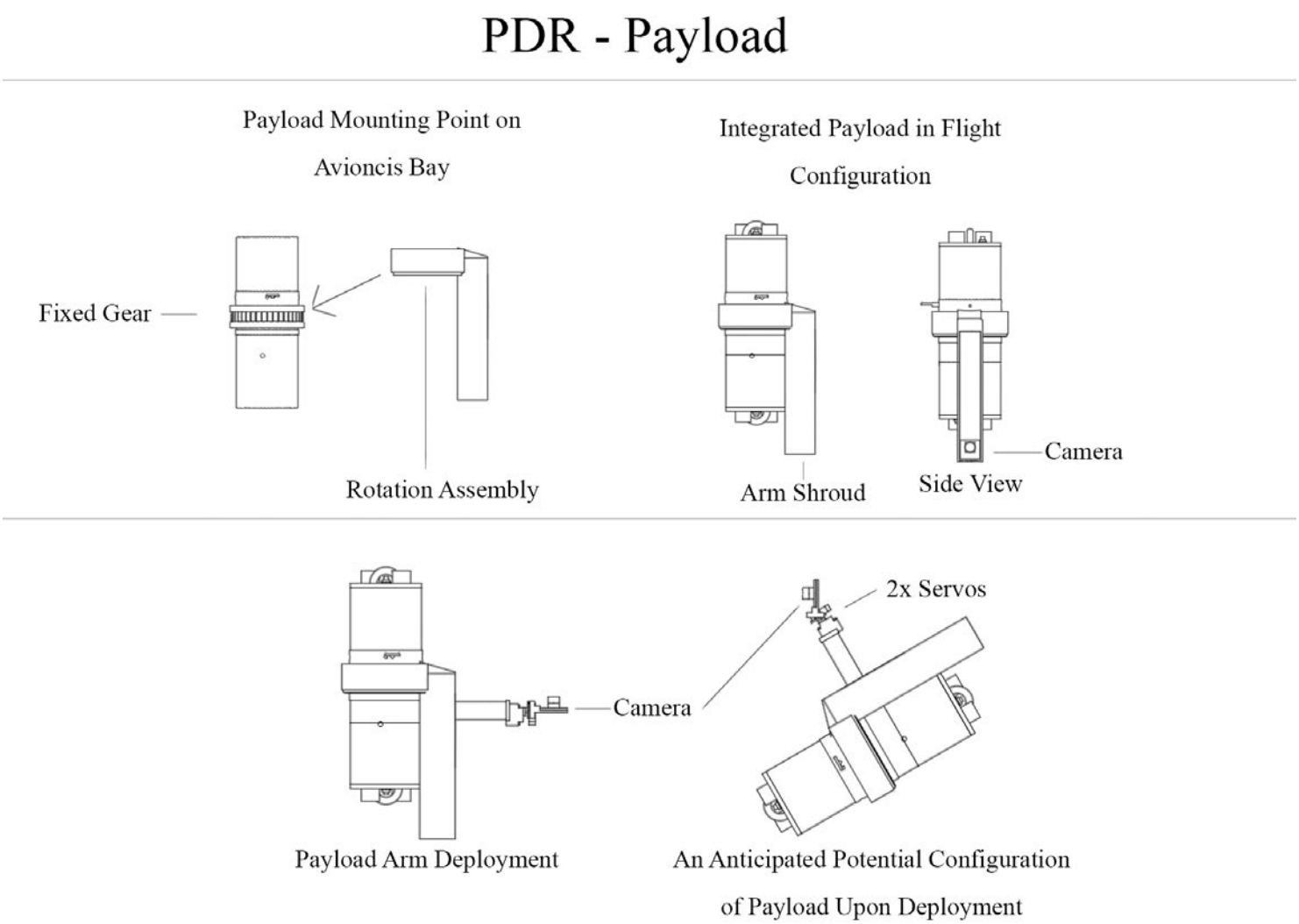


Figure 15. PDR - Payload

4.2 Systems Analysis

Our payload consists of 5 major systems. These are the computer, radio receiver, camera arm, camera, and launch vehicle interface (discussed in 4.3). Each of these systems are critical to the success and safety of our payload.

4.2.1 Computer System

Our computer system uses a Raspberry Pi 4 at its core. This will control the radio, image processing, sensor data, camera system, and payload deployment. We chose the Raspberry Pi 4 because of availability, input/output interfaces, and performance.

4.2.2 Radio

The USLI Payload Challenge requires our payload to receive commands via APRS radio packets and use those instructions to control a camera. We are using the Nooelec NESDR Nano 3 USB software defined radio (SDR) receiver on a Raspberry Pi 4 with DireWolf APRS decoder. Python code will be used to parse the DireWolf logs and extract commands which are then passed on to the servos and camera via OpenCV.

4.2.3 Arm

The arm system consists of a servo that will rotate a carbon fiber tube with the camera system on the end into position. On the camera system, there are two servos that adjust the vertical angle of the camera and the horizontal rotation of the camera. These are to orient the camera to the horizon and to rotate the camera as instructed

4.2.4 Camera

The camera we will be using is an ELP 5 Megapixel USB Camera module. It has a resolution of 2592x1944 pixels and a field of view of 170 degrees. This camera fully supports the OpenCV python libraries. We chose this because we had it on hand and it fit our criteria.

4.2.4 Batteries

Our payload will use a LIPO battery of a currently undecided capacity. The capacity will be determined after we conduct battery life tests of the payload. Our goal will be to have at minimum the same stand-by time as the dual deploy flight computers. The LIPO battery will be shielded with a high visibility orange 3D printed housing. We will be using XT60 or XT30 connectors so that we can quickly disconnect the battery if needed.

4.3 Preliminary Payload/Launch Vehicle Interface and Retention System

Our current plan for the retention of the payload to the launch vehicle is having a spur gear and guide epoxied onto the rocket airframe, or which the payload will be able to rotate around. The payloads mounting bracket will be screwed on to ensure the payload stays in place. See Figure 15 showing the mounting system.

5. Safety

The understanding and mitigation of hazards is paramount to the success of our mission. Hazards to personnel, project, launch vehicle, and environment; as well as risks caused by the environment will be analyzed and defined in this section. We acknowledge that not all hazards will be identified. We also understand that not all potential hazards can be completely mitigated. Besides our detailed list below, we will continue to analyze potential hazards and risks during future design, build, test, and launch phases of this program.

5.1 Hazard Analysis System

In this section we will be defining the hazards by likelihood and severity and the combination of both making total risk. Below is a scale for each. Additionally, information used to research hazards will be included in section 7. Safety Appendix.

5.1.1 Likelihood Scale

The likelihood of a hazard occurring

Value	**Definition**
E	Extremely Improbable
D	Extremely Remote
C	Remote
B	Probable
A	Frequent

Table 4. Likelihood Scale

5.1.2 Severity Scale

The severity/damage of a hazard occurring

Value	Name	Definition of severity
5	Minimal	No risk of harm to people and/or permanent damage to equipment. Minor time or procedure setback.
4	Minor	Possible risk to personnel and/or damage to non-critical equipment. Time setback, possible cost to fix.
3	Major	Likely harm to people and/or damage to critical equipment. Time setback, cost to fix, injury.
2	Hazardous	Injury to people and/or critical damage/failures. Major project setbacks, cost impact, and injury. May result in disqualification if there is not enough time to fix critical failures.
1	Catastrophic	Major damage or injury and/or unable to continue competing.

Table 5. Severity Scale

5.1.3 Total Risk Scale

The combination of both the likelihood and severity of a hazard to get an idea of the general risk (FAA Risk Matrix)

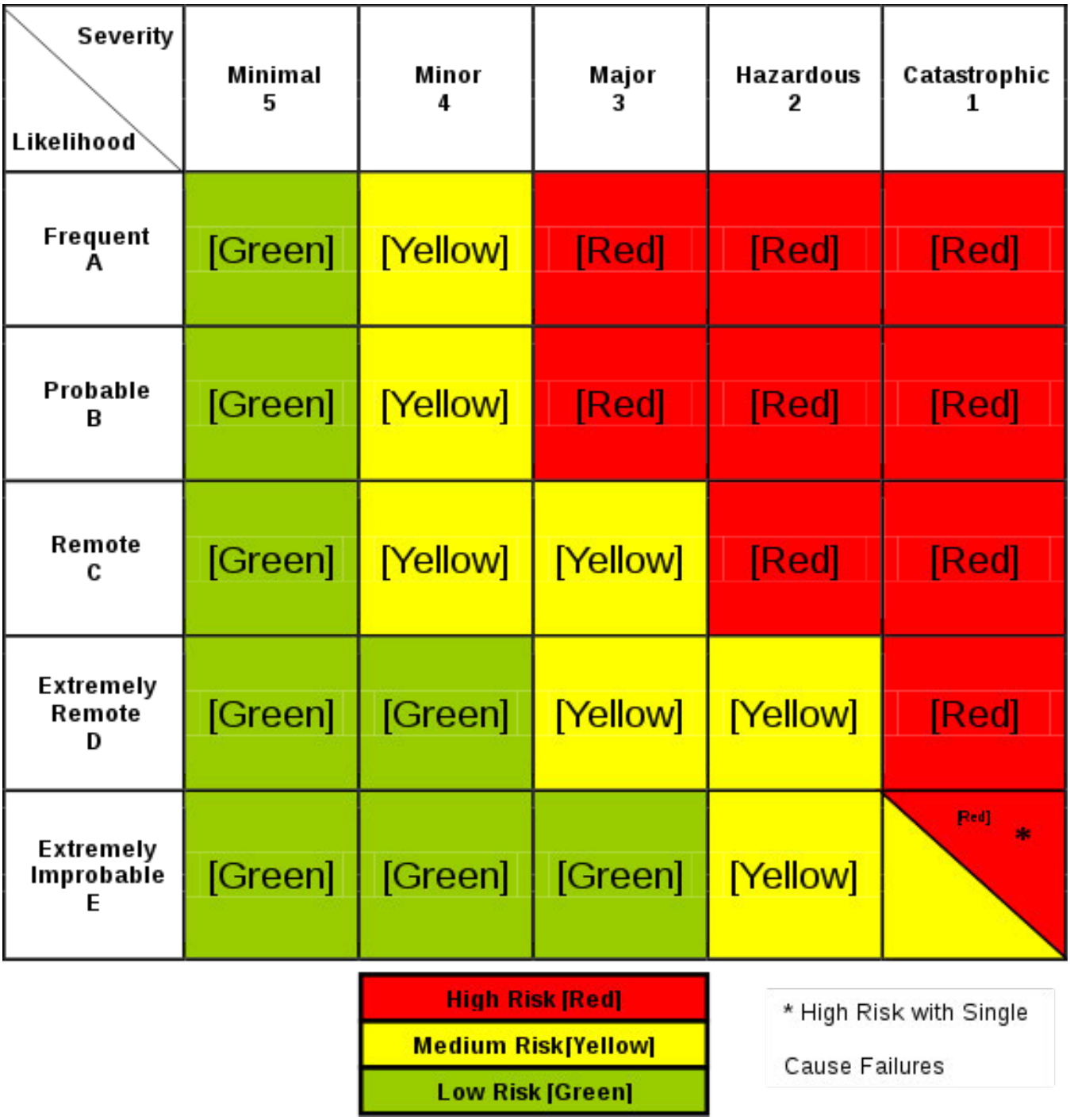


Figure 16. FAA 8040.4B Risk Matrix

Image Source: https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8040.4B.pdf

5.2 Personnel Hazard Analysis

Hazard	**Risk**	**Cause**	**Effect**	**Mitigation**
Inhalation of noxious fumes (glue, paint, epoxy, etc.)	C4 Medium	Improper use or failure to use PPE	Irritation of the nose, throat, and lungs. Repetitive and high amounts of exposure can result in sensitization and asthma	Safety officer and mentor ensure the availability and use of PPE
Glue/epoxy on skin	B5 Low	Failure to use gloves	Skin tearing and burns	Make sure members wear gloves while handling glue and epoxy
Dust or debris in eyes	C4 Medium	Failure to wear eye protection during sanding, drilling, etc	Eye irritation	Safety officer and mentor ensure the use of eye protection
Injury due to power tool misuse	D1 High	Loose clothing, untrained user, faulty equipment	Minor to severe injury, death	Regular inspection of power tools, train the member using the power tool, and proper attire, and make sure the user of the tool has read and understands the user manual
Inhalation of fiberglass dust	C3 Medium	Failure to wear a respirator/mask while working with fiberglass	Irritation of the airways	Safety officer and mentor ensure the use of respirator/mask, and that the space is properly ventilated
Accidental ingestion of fiberglass dust	D4 Low	Failure to use gloves and wash hands after working	Throat and stomach irritation	Make sure members wash their hands after working with fiberglass

		with fiberglass		and wear gloves during the work
Electrocution	D1 High	Compromised power tools, power cords	Minor to major electric shock, death	Checking all power tools, cords, and outlets before work, make sure all members understand the danger of electricity
Collision with launch vehicle	C3 Medium	Failure of parachute or separation, vehicle stability, rail issue	Bruising or concussion	Ensure that the launch vehicle is inspected by the team safety officer, mentor, and RSO before launch, pay attention during launch, make sure heads up is given if the rocket lands near spectators
Motor explosion	D2 Medium	Unburned fuel, accidental ignition	Burns, asphyxiation, death	Make sure motor has fully burned out before recovering, keep potential ignition sources away from motor, motor only to be handled by the team mentor
Tripping hazard	C4 Medium	Messy workspace	Bruising, concussion	Always keep workspace tidy and clean up after each use
Hypothermia, hyperthermia, dehydration	D4 Low	Improper attire, lack of water	Exhaustion, fainting,	Make sure members are properly dressed and have access to water
Accidental black powder ignition	D2 Medium	Mishandling of black powder by improper personnel	Burns, hearing loss	Ensure black powder is kept away from potential fire/heat sources and all handling of black powder is done by team mentor
Hearing damage	D4 Low	Improper distance from launch pad, failure to use	Long or short term hearing loss	Make sure all team members stand the proper distance away from the

		hearing protection while using power equipment		launch pad during launch, ensure members wear ear protection when necessary
Fire	D1 High	Easily flammable materials at launch pad, heat sources in close proximity to flammable material	Burns, asphyxiation, death	Clear launch pad of flammable materials, make sure to separate flammable materials and heat sources in the workspace, keep a fire extinguisher nearby

Table 6. Personnel Hazard Analysis

5.3 Vehicle Failure Modes and Effects Analysis

Hazard	**Risk**	**Cause**	**Effect**	**Mitigation**
Excessive landing speed	B4 Medium	Parachute torn, burned, tangled. Improper parachute size	Damage to vehicle and payload	Ensure that parachutes are properly packed, use correct parachute size
Fin damage	D3 Medium	Damage caused during previous flights, poor construction, improper materials used	Altered trajectory, unstable flight, resulting in damage or loss of vehicle	Stress test fins before flight, and ensure use of strong materials
No ejection	C1 High	Flight computer, ejection charge, or wiring malfunction	Loss of vehicle, potential damage to property, injury to humans	Use proper inspection and procedures when working on the dual deployment system
Early separation	C2 High	Failure of motor, ejection charges, shear pins, or drag separation	Potential for loss of vehicle and damage to property	Conduct ejection tests, ensure ejection charges are properly prepared
Failure to separate	C1 High	Failure of shear pins, ejection charges, late ejection charge	Potential loss of vehicle and damage to property, injury to humans	Conduct ejection tests, ensure ejection charges are properly prepared
Shock cord failure	D3 Medium	Shock cord improperly fastened, tangled	Unintended part separation, recovery failure,damage to or loss of vehicle, injury to humans	Double check that the shock cord can’t get caught on anything, make sure the shock cord is properly secured and stress tested

Parachute damage	B4 Medium	Improperly folded, insufficient heat protection	Recovery failure, damage to or loss of launch vehicle	Ensure proper folding and correct amount of heat protection
Parachute deployment failure	C1 High	Improper fastening, tangled strings, ejection/separation failure, obstructions in deployment path	Excessive landing speed, damage to or loss of vehicle, damage to property or buildings, injury to humans	Properly fold and pack parachute, test ejection system, have a clear deployment path for the the parachute
Rail button failure	C4 Low	Loose/tight rail buttons, misalignment, improper placement	Altered trajectory, damage to vehicle	Make sure the rail buttons are in the correct position on the body of the launch vehicle and aligned correctly
Ignition failure	B5 Low	Malfunctioning motor, cheap igniter, corroded ignition cable/cable leads, no continuity	Unable to launch, late ignition, damage to vehicle	Use high quality igniters, buy motors from reliable sources, Don't use old cables
Forgotten or lost components	D4 Low	Not having all the components to successfully and safely launch the vehicle	Delays, unable to launch, unsafe launch, damage to or loss of vehicle	Have a check list of all components needed to launch
Motor expulsion	E2 Medium	Weak motor retainer, improperly constructed motor mount section	Damage to or loss of vehicle, injury to humans	Use high quality motor retainers installed correctly, proper design and building of motor mount
Battery fire/hazard	D2 Medium	Catastrophic failure resulting in batteries being punctured	Battery catching on fire, exploding	Integrate batteries in a way that provides protection from potential punctures

Payload losing power	C4 Medium	Batteries disconnecting in flight, batteries dying before mission completion	Delays in project, mission failure if during launch week	Test battery connectors, battery life before first launch.
Camera failing to deploy	B4 Medium	Jamming in orientation gears, failure of sensors, servos	Delays in project, mission failure if during launch week	Test all moving parts in a variety of situations before first launch.
Data storage failure	C4 Medium	Data storage device coming loose during launch	Failure for payload to operate, save images	Stress test data storage retention system, use robust retention system

Table 7. Vehicle Failure Modes and Effects Analysis

5.4 Environmental Concerns Analysis

Hazards caused by the environment:

Hazard	**Risk**	**Cause**	**Effect**	**Mitigation**
Accident caused by wind fluctuations	D5 Low	Unexpected wind fluctuation	Vehicle trajectory change to potentially cause accident	Check weather frequently before launch and if proper conditions are not met delay the launch
Low cloud coverage	D5 Low	Unsafe condition for launch due to loss of visibility	Interference or collision with aircraft, birds, humans	Follow RSO’s instruction on when it's safe to launch
Landscape	C5 Low	Launch vehicle landing in trees, bushes, powerlines, and across fast flowing/deep water	Personal injury, loss of rocket	Call power company if the launch vehicle lands on powerlines, call property owner to ask for help/permission to retrieve launch

				vehicle safely
Rain	D5 Low	Rain affecting motor, trajectory, recovery of launch vehicle	Unsafe/unstable launch	Postpone launch in heavy rain if necessary
Humidity	D5 Low	Parts swelling, parachute failure, adhesive improperly drying	Separation failure, unintended separation, recovery failure	Make sure humidity conditions are taken into account when building and launching launch vehicle
Hail	E4 Low	Hail pieces damaging launch vehicle	Airframe damage, trajectory alteration, recovery failure	Postpone launch if hail storm is forecast
Temperature	D5 Low	Air density changes with temperature	Launch vehicle trajectory change	Make sure to include the correct temperature in simulations

Table 8.1 Environmental Concerns Analysis, Hazards caused by the environment

Hazards to the environment:

Hazard	**Risk**	**Cause**	**Effect**	**Mitigation**
Pollution from motor	E5 Low	Fumes, smoke, and gasses from motor	Damaging local ecosystem at launch area	Choosing a launch site away from vulnerable ecosystem
Pollution from vehicle parts	C5 Low	Parts unintentionally separating, launch vehicle landing in unrecoverable location	Damaging local ecosystem at launch area, unintentional littering	Make sure launch vehicle is structurally sound and assembled properly before launch, ensure enough space on the launch site for safe recovery
Pollution caused directly by team members	C5 Low	Team members leave trash behind, don’t clean up properly	Littering, damaging local ecosystem at launch area	Remind team members to pick up all garbage and other materials before leaving launchsite

Collision with property/buildings	E4 Low	Launch vehicle landing/crashing into buildings or property	Damage to property or buildings	Make sure there is enough space at the launch area for safe recovery
Fire	E2 Medium	Motor not burning all the way before landing, unintended trajectory	Motor burning near flammable materials at launch or landing	Keeping flammable away from launchsite, and have a fire extinguisher ready incase of fire
Wildlife damage	E4 Low	Launch vehicle striking birds during flight, colliding with other animals at lower altitudes or landing	Harm to local wildlife	Delay launch if birds are flying over launchsite, Launchpad placement away from animals/nests or burrows

Table 8.2 Environmental Concerns Analysis, Hazards to the environment

5.5 Project Risk Analysis

Hazard	**Risk**	**Cause**	**Effect**	**Mitigation**
Lack of funding	B2 High	Not doing enough fundraising	Not having enough money/supplies to complete project and travel to launch	Don’t leave fundraising until the last minute, be active throughout the program in finding new ways to fundraise
Part shortage	C3 Medium	Ordering parts too late or parts unavailable	Not having necessary supplies to build and launch the vehicle and payload	Order parts early, find alternative sources or parts

Rushed work	B3 High	Improper planning, poor management, or procrastination	Lower quality of reports, presentations, design, and finished product	Don't leave things until the last minute, follow a well thought out project plan
Launch area issue	C3 Medium	Unable to find a suitable launch area, launch area unavailability	Inability to launch and test vehicle and payload	Start early finding and securing a launch area (have a backup if needed)
Workspace issue	C3 Medium	Unable to find a suitable workspace or workspace not available	Inability to build launch vehicle and payload	Start early finding and securing a workspace (have a backup if needed)
Transportation	D4 Low	Inability to find transportation for team members, materials, and launch vehicle	Delays, inability to build, test, and launch vehicle	Secure transportation and have backup if needed (or carpool)
Delay due to weather	E4 Low	Weather (snow, heavy rain, storm, etc.) causing delays	Not being able to finish project in time because of delays	Leaving extra time in the project timeline, remind team members to shovel their driveway!!!
Members unavailable	B3 High	Poor planning, sickness, schedule conflict, or not enough members	Inability or delays to finish project deliverables	Make sure team members have strong immune systems and are free most of the time, have replacement members
Equipment issues	C4 Medium	Non functioning tools or a lack or the needed tools and equipment	Delays, inability to build, test, and launch vehicle	Identify tools that are needed early and make sure to keep them in functioning condition
Poor planning	B3 High	Poor time management, forgetting steps or deadlines in project plan	Working close to deadlines, missing deadlines, unable to finish project in time	Make sure project plan is reviewed by multiple members and is changed as needed throughout the project

Table 9. Project Risk Analysis

6 Project Plan

6.1 Requirements Verification

6.1.1 Vehicle Requirements

Our teams' requirements for our launch vehicle are as follows: a high quality, robust launch vehicle capable of supporting five or more flights while providing us with flexibility to tune our vehicle as necessary. Our vehicle needs to have a burnout center of gravity no more than 47" down from the top of the vehicle (with the current mass estimates) to ensure it complies with the rules for external housings.

6.1.2 Recovery Requirements

We're looking for two things from our recovery system: survivability and reliability. We want our recovery system to be able to survive non-catastrophic anomalies, such as slightly early or late parachute deployments.

6.1.3 Payload Requirements

Our team is participating in the USLI Payload challenge. In addition to the requirements set in the handbook section for this challenge, we aim to have a payload that accomplishes the requirements in the simplest way, while not impacting our launch vehicle drastically.

6.2 Budgeting

6.2.1 Line-Item Budget

This table encompasses all anticipated expenses of our program, including material not yet on hand, travel costs, STEM engagement costs, etc.

Item Name	**Vendor**	**Cost**	**Procurement Cost**
Nose Cone	Wildman	$75.90	$85
Main Parachute	Fruity Chutes	$162	$180
Drogue Parachute	Spherachutes	$32.25	$40

Item Name	Vendor	Cost	Procurement Cost
U-Bolts	Wildman	$8	$15
Shock Cord	OneBadHawk	$52	$60
4x K1100 Motor Reloads	BuyRocketMotors	$547.16	$620
Body Tubing	Wildman	$205.48	$228
Coupler Tubing	Wildman	$37.18	$45
Fin Fiberglass Sheets	Wildman	$54.90	$66
Quick Links	Wildman	$10	$17
Swivels	Wildman	$16	$23
Aeropack Motor Retainer	Wildman	$31	$38
STEM Engagement Supplies	Hardware Stores	$107	$113
Stratologger CF	Stratologger	N/A	N/A
Advertising Material	Various	$50+*	$50+*
Team Apparel	N/A	$225	$225
Website	WordPress	$98	$105
Travel	Various	$11,500	$11,500
Total:		$13,162	$13,360

Table 10. Line-Item Budget

*Advertising is non critical so only the minimum needed for STEM engagement activities is recorded. The advertising material budget may increase with excess funds.

6.2.2 Funding Plan

Our team's funding plan remains largely unchanged from the proposal. We continue to work on the New Jersey Space Consortium funding match. We anticipate that donation matching will cover a large portion of our budget. The remaining funds will be raised through donations from local companies and grants. Our raised funds will go towards these categories primarily:

1. Travel Expenses
2. Expendable Items
3. STEM Engagement

And secondarily:

4. Apparel
5. Advertising/Marketing*

*Our advertising/marketing budget can be scaled in the event we have excess funds.

6.2.3 Material Acquisition Plan

Our materials will be procured on a readiness basis. For example, we will not acquire a majority of parts for the main launch vehicle until after the subscale flight is completed. This is to ensure that we are able to make changes if needed. We may choose to purchase parts we do not expect to need to change, such as motor reloads, if we anticipate availability issues.

PDR - Timeline

6.3 Timeline

Figure 17. PDR - Timeline Diagram

7. Safety Appendix

7.1 Codes and Regulations

Here is a list of codes and regulations we have researched for our hazard analysis:

- NAR HPR Safety Code
    - Relating to wind hazards: We will not launch rockets if wind speeds exceed 20 miles per hour.
    - Relating to Landscape and other hazards: We will not attempt to recover rockets from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.
    - Relating to recovery hazards: We will use a recovery system such as a parachute in our rocket so that all parts of our rocket return safely and undamaged and can be flown again, and we will use only flame-resistant or fireproof recovery system wadding in our rocket.
    - Relating to motor hazards: I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
- Code of Federal Regulation 27 Part 55: Commerce in Explosives
    - Relating to motor and black powder hazards: The handling of all motors and energetic devices will be done by our NAR mentor legally and safely.
- N.J.S.A. 21:1C-1 et. seq. MODEL ROCKETS
- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C: Amateur Rockets
    - Relating to Cloud hazards: Class 2-High Power Rockets or Class 3-Advanced High Power Rockets will not operate At any altitude where clouds or obscuring phenomena of more than five-tenth coverage prevails. At any altitude where the horizontal visibility is less than five miles. Into any cloud.
    - Relating to fire hazards: Class 2-High Power Rockets or Class 3-Advanced High Power Rockets will not operate Unless reasonable precautions are provided to report and control a fire caused by rocket activities.
- NFPA 1122 Code for Unmanned Rockets of the National Fire Protection Association.

7.2 MSDS Information

7.2.1 Epoxy MSDS

Glenmarc Industries Inc. 2001 S. Blue Island Ave Chicago IL 60608
312-243-0800 fax 312-243-4670 email: info@glenmarc .com www.glenmarc.com

Material Safety Data Sheet

Date 04/01/2014

Section 1 PRODUCT INFORMATION

MANUFACTURER:
Glenmarc Industries Inc.
2001 S. Blue Island Ave.
Chicago IL 60608

Emergency Phone:
800-255-3924
Chemtel
Non-emergency Phone:
800-323-5350

Proper Shipping Name: Plastic Material Liquid NOI

PRODUCT NAME:
Rocket Poxy
Chemical Family:
HAZARD RATINGS:
Fire: 1
Health: 2
Reactivity: 0

Section II PRODUCT/COMPOSITION

No.	Component	CAS#	%(optional)	
P	Epoxy resin based mixture	N.A.	<100	
1	Triphenyl Phosphite	101-02-0	<15%	--

Note: contains material(s) regulated as dust hazard, dispersed in a non-hazard from if dust is recreated, appropriate respiratory and/or explosion precautions must still be used.

Section III HAZARD STATUS

Chemical listed as carcinogen or potential carcinogen in NTP, IARC or OSHA 1910(z): This material is neither carcinogenic or potentially carcinogenic

Occupational Exposure limits
OSHA limits have not been established for this product

ACGIH limits have not been established for this product

Section IV REGULATORY STATUS

A. CA Safe drinking water & toxic enforcement act of 1986.

This product may contain traces of or other prop 65 listed chemicals as impurities. However, none are listed as ingredients.

B. CERCLA 40 CFR 302

Releases exceeding the reportable quantity must be reported to the national response center (800)424-8802
RQ Not established or required for this product.

C. OSHA 29 CFR 1910

According to OSHA criteria, the following components are hazardous:

No.	Component	CAS#	%(optional)
P	Epoxy resin based mixture	NA	<100%
1	Triphenyl Phosphite	101-02-0	<15%

D. RCRA 40 CFR 261

Not a hazardous waste by RCRA criteria (40CFR261.20.24)

E. SARA Title III 52 CFR 13378, 52 CFR 21152

NO.	RQ (lbs) (*1)	TPQ(lbs) (*2)	SEC.313 (*3)	313 CAT. (*4)	311/312 (*5)
P	NONE	NOT LISTED	NOT LISTED	NONE	H1
1	NONE	NOT LISTED	NOT LISTED	NONE	H1

Other SARA substances if present are all below the de minimus concentrations
*1 = Reportable quantity of extremely hazardoussubstances sec 302
*2= Threshold planning quantity, extremely hazardous substance, sec 302
*3= Toxic chemical, sec 313 (individual chemical listed)
*4= Toxic release inventory form category sec 313 (40 CFR 372.65 C)
*5= Hazard category for SARA sec 311/312 reporting
H1= Immed (acute) health hazard H2- Delayed (chronic) health hazard. P3= Fire Hazard P4= Sudden pressure release hazard P5= Reactive hazard.

F. TSCA 44 CFR59764

All components listed.

G. VOC SCAQMD Rules

Chemical
NIL
Note: This product does not contain solvents, but may contain ingredients with VP's low enough to be emitted if heated alone when 2 part resins and hardeners re properly mixed together. These ingredients can react together and are consumed without significant atmospheric emissions.

Section V PHYSICAL DATA

Physical state:	Paste
Color:	White
SP. GR.:	1.57
Density:	13.1 lbs/gal.

Section VI FIRE AND EXPLOSION DATA
Flash Point: 250° F (For product or lowest flash point ingredient)
Flammability classification: combustible class (IIB)
Extinguishing media: Water fog, dry chemical, carbon dioxide, or foam
NOTE: Either atmosphere-supply or air-purifying respirators should be available for fire fighters (20 CFR 1910.134)

Section VII HEALTH HAZARD DATA
Effects of overexposure:
Acute:

- Eyes: product is moderately irritating to the eyes.
- Skin: Product is moderately irritating to to the skin and may cause skin sensitization.
- Inhalation: Because of its low volatility this product is unlikely to be an inhalation hazard.
- Ingestion: Product is designed to have a low order of acute oral toxicity.

Chronic:

- No specific hazards known to Glenmarc Industries. Pre-existing eye, skin or lung disorders may be aggravated by exposure to this product.

EMERGENCY AND FIRST AID PROCEDURES:

- Eyes: Immediately flush eyes with large amounts of water for 15 minutes. Get medical attention.
- Skin: Wash affected area immediately with large amounts of soap and water. Remove and wash contaminated clothing before reuse. Contact a physician if irritation occurs.
- Inhalation: Remove victim to fresh air and provide oxygen if breathing is difficult. Get medical attention.
- Ingestion: Do not induce vomiting. Give large amounts of water. Call a physician immediately. Never give anything by mouth to an unconscious person.

Section VIII REACTIVITY DATA

- Stability: stable under normal storage conditions. Unstable at elevated temperatures.
- Incompatibility: Strong oxidizing agents, strong lewis or mineral acids and strong mineral and organic bases/especially aliphatic amines.
- Hazardous decomposition products: Phosphorus compounds, carbon oxides, aldehydes, acids, phenolics and other unknown compounds.

Section IX SPILL OR LEAK PROCEDURES

- If material is spilled: Avid contact with material. Persons not wearing proper protective equipment (see below) should be excluded from the area until clean up is complete. Dike area to prevent spill spreading and scoop up excess to recovery containers. Absorb remnant on noncombustible material such as clay and shovel into containers for disposal.
- Waste disposal method: Dispose of waste in accordance with federal, state and local regulations.

Section X PERSONAL PROTECTION INFORATION

- Respiratory protection: Not normally necessary unless the material is being used in such a way as to produce dust, mist , vapor, fumes or smoke.

SECTION 6 Physical Data
Boiling Point: Not Measured
Melting Point: n/a
Vapor Pressure: <1mm Hg @ 29C
Specific Gravity: 0.97 (H2O=1)
Solubility in Water: Yes
Density: >1 @ 77F
Percent Volatile: 0%
Evaporation rate: <0.01
Percent solid by weight: 100%
Appearance and Odor: Transparent, amine odor, liquid
8.06 lbs/gal

Employee Protection
Respiratory protection:
Applied or exothermic heat may resulting release of free polyamines. In such cases, use a NIOSH-approved respirator as required to prevent over-exposure. In accord with 29 CFR 1910.134, use either an atmosphere supplying respirator or an air-purifying respirator for organic vapors.

7.2.2 Spray Paint

Safety Data Sheet

RUST-OLEUM CORPORATION
* Trusted Quality Since 1921 *
www.rustoleum.com

1. Identification

Product Name:	PTOUCH 2X +SSPR 6PK GLOSS DEEP BLUE	**Revision Date:**	6/1/2022
Product Identifier:	249114	**Supercedes Date:**	11/6/2018
Recommended Use:	Topcoat/Aerosols		
Supplier:	Rust-Oleum Corporation 11 Hawthorn Parkway Vernon Hills, IL 60061 USA	**Manufacturer:**	Rust-Oleum Corporation 11 Hawthorn Parkway Vernon Hills, IL 60061 USA
Preparer:	Regulatory Department		
Emergency Telephone:	24 Hour Hotline: 847-367-7700		

2. Hazards Identification

Classification

Symbol(s) of Product

Signal Word
Danger

Possible Hazards
39% of the mixture consists of ingredient(s) of unknown acute toxicity.

GHS HAZARD STATEMENTS

Carcinogenicity, category 1B	H350	May cause cancer.
Eye Irritation, category 2A	H319	Causes serious eye irritation.
Flammable Aerosol, category 1	H222	Extremely flammable aerosol.
Gases under Pressure; Compressed Gas	H280	Contains gas under pressure; may explode if heated.
Germ Cell Mutagenicity, category 1B	H340	May cause genetic defects.
STOT, Single Exposure, category 3, NE	H336	May cause drowsiness or dizziness.

GHS LABEL PRECAUTIONARY STATEMENTS

P201	Obtain special instructions before use.
P210	Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. NO SMOKING.
P211	Do not spray on an open flame or other ignition source.
P251	Do not pierce or burn, even after use.
P261	Avoid breathing dust/fume/gas/mist/vapors/spray.
P264	Wash hands thoroughly after handling.
P271	Use only outdoors or in a well-ventilated area.
P280	Wear protective gloves/protective clothing/eye protection/face protection.

P304+P340	IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P308+P313	IF exposed or concerned: Get medical advice/attention.
P312	Call a POISON CENTER or doctor/physician if you feel unwell.
P337+P313	If eye irritation persists: Get medical advice/attention.
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P405	Store locked up.
P410+P403	Protect from sunlight. Store in a well-ventilated place.
P410+P412	Protect from sunlight. Do not expose to temperatures exceeding 50°C (122°F).
P501	Dispose of contents/container in accordance with local, regional and national regulations.

3. Composition / Information on Ingredients

HAZARDOUS SUBSTANCES

Chemical Name	CAS-No.	Wt.% Range	GHS Symbols	GHS Statements
Acetone	67-64-1	25-50	GHS02-GHS07	H225-319-332-336
Propane	74-98-6	10-25	GHS04	H280
n-Butane	106-97-8	2.5-10	GHS04	H280
Aliphatic Hydrocarbon	64742-89-8	2.5-10	GHS08	H304-340-350
Dimethyl Carbonate	616-38-6	2.5-10	GHS02-GHS06	H225-331
1-Methoxy-2-Propyl Acetate	108-65-6	2.5-10	GHS02-GHS07	H226-332
n-Butyl Acetate	123-86-4	2.5-10	GHS02-GHS07	H226-336
Xylenes (o-, m-, p- Isomers)	1330-20-7	2.5-10	GHS02-GHS07	H226-315-319-332
Titanium Dioxide	13463-67-7	1.0-2.5	Not Available	Not Available
Barium Sulfate	7727-43-7	1.0-2.5	GHS07	H332
Solvent Naphtha, Light Aromatic	64742-95-6	1.0-2.5	GHS07-GHS08	H304-332
Ethylbenzene	100-41-4	0.1-1.0	GHS02-GHS07-GHS08	H225-304-332-351-373
Zirconium Acetate	5153-24-2	<0.1	Not Available	Not Available

4. First-Aid Measures

FIRST AID - EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes holding eyelids open. Get medical attention. Do NOT allow rubbing of eyes or keeping eyes closed.

FIRST AID - SKIN CONTACT: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists.

FIRST AID - INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention. Do NOT use mouth-to-mouth resuscitation. If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately.

FIRST AID - INGESTION: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention. If swallowed, get medical attention.

5. Fire-Fighting Measures

EXTINGUISHING MEDIA: Alcohol Film Forming Foam, Carbon Dioxide, Dry Chemical, Water Fog

UNUSUAL FIRE AND EXPLOSION HAZARDS: FLASH POINT IS LESS THAN -7°C (20°F). EXTREMELY FLAMMABLE LIQUID AND VAPOR!Water spray may be ineffective. Closed containers may explode when exposed to extreme heat due to buildup of steam. Closed containers may explode when exposed to extreme heat. Vapors may form explosive mixtures with air. Vapors can travel to a source of ignition and flash back. Isolate from heat, electrical equipment, sparks and open flame. Perforation of the pressurized container may cause bursting of the can.

SPECIAL FIREFIGHTING PROCEDURES: Water may be used to cool closed containers to prevent pressure buildup and possible autoignition or explosion. Full protective equipment including self-contained breathing apparatus should be used. Evacuate area and fight fire from a safe distance. Use water spray to keep fire-exposed containers cool. Containers may explode when heated.

Special Fire and Explosion Hazard (Combustible Dust): No Information

6. Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Isolate the hazard area and deny entry to unnecessary and unprotected personnel. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers. Ventilate area, isolate spilled material, and remove with inert absorbent. Dispose of contaminated absorbent, container, and unused contents in accordance with local, state, and federal regulations.

7. Handling and Storage

HANDLING: Wash thoroughly after handling. Wash hands before eating. Remove contaminated clothing and launder before reuse. Use only in a well-ventilated area. Use only with adequate ventilation. Follow all SDS and label precautions even after container is emptied because it may retain product residues. Avoid breathing fumes, vapors, or mist. Avoid contact with eyes, skin and clothing.

STORAGE: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Contents under pressure. Do not store above 120°F (49°C). Store large quantities in buildings designed and protected for storage of flammable aerosols. Keep away from heat, sparks, flame and sources of ignition. Contents under pressure. Do not expose to heat or store above 120°F (49°C). Avoid excess heat. Product should be stored in tightly sealed containers and protected from heat, moisture, and foreign materials.

Advice on Safe Handling of Combustible Dust: No Information

8. Exposure Controls / Personal Protection

Chemical Name	CAS-No.	Weight % Less Than	ACGIH TLV-TWA	ACGIH TLV-STEL	OSHA PEL-TWA	OSHA PEL-CEILING
Acetone	67-64-1	30.0	250 ppm	500 ppm	1000 ppm	N.E.
Propane	74-98-6	20.0	N.E.	N.E.	1000 ppm	N.E.
n-Butane	106-97-8	10.0	N.E.	1000 ppm	N.E.	N.E.
Aliphatic Hydrocarbon	64742-89-8	10.0	N.E.	N.E.	N.E.	N.E.
Dimethyl Carbonate	616-38-6	10.0	N.E.	N.E.	N.E.	N.E.
1-Methoxy-2-Propyl Acetate	108-65-6	10.0	N.E.	N.E.	N.E.	N.E.
n-Butyl Acetate	123-86-4	5.0	50 ppm	150 ppm	150 ppm	N.E.
Xylenes (o-, m-, p- Isomers)	1330-20-7	5.0	100 ppm	150 ppm	100 ppm	N.E.
Titanium Dioxide	13463-67-7	5.0	0.2 mg/m3	N.E.	15 mg/m3	N.E.
Barium Sulfate	7727-43-7	5.0	5 mg/m3	N.E.	15 mg/m3	N.E.
Solvent Naphtha, Light Aromatic	64742-95-6	5.0	N.E.	N.E.	N.E.	N.E.
Ethylbenzene	100-41-4	1.0	20 ppm	N.E.	100 ppm	N.E.
Zirconium Acetate	5153-24-2	0.1	5 mg/m3	10 mg/m3	5 mg/m3	N.E.

PERSONAL PROTECTION

ENGINEERING CONTROLS: Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits. Use explosion-proof ventilation equipment. Provide general dilution of local exhaust ventilation in volume and pattern to keep TLV of hazardous ingredients below acceptable limits. Prevent build-up of vapors by opening all doors and windows to achieve cross-ventilation.

RESPIRATORY PROTECTION: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

SKIN PROTECTION: Use impervious gloves to prevent skin contact and absorption of this material through the skin.

EYE PROTECTION: Use safety eyewear designed to protect against splash of liquids.

OTHER PROTECTIVE EQUIPMENT: Refer to safety supervisor or industrial hygienist for further guidance regarding types of personal protective equipment and their applications. Refer to safety supervisor or industrial hygienist for further information regarding personal protective equipment and its application.

HYGIENIC PRACTICES: Wash thoroughly with soap and water before eating, drinking or smoking. Remove contaminated clothing immediately and launder before reuse.

Engineering Measures for Combustible Dust: No Information

9. Physical and Chemical Properties

Appearance:	Aerosolized Mist	**Physical State:**	Liquid
Odor:	Solvent Like	**Odor Threshold:**	N.E.
Specific Gravity:	0.766	**pH:**	N.A.
Freeze Point, °C:	N.D.	**Viscosity:**	N.D.
Solubility in Water:	Slight	**Partition Coefficient, n-octanol/ water:**	N.D.
Decomposition Temp., °C:	N.D.		
Boiling Range, °C:	-37 - 537	**Explosive Limits, vol%:**	0.9 - 13.0
Flammability:	Supports Combustion	**Flash Point, °C:**	-96
Evaporation Rate:	Faster than Ether	**Auto-Ignition Temp., °C:**	N.D.
Vapor Density:	Heavier than Air	**Vapor Pressure:**	N.D.

(See "Other information" Section for abbreviation legend)

10. Stability and Reactivity

Conditions to Avoid: Avoid temperatures above 120°F (49°C). Avoid all possible sources of ignition.

Incompatibility: Incompatible with strong oxidizing agents, strong acids and strong alkalies.

Hazardous Decomposition: By open flame, carbon monoxide and carbon dioxide. When heated to decomposition, it emits acrid smoke and irritating fumes. Contains solvents which may form carbon monoxide, carbon dioxide, and formaldehyde.

Hazardous Polymerization: Will not occur under normal conditions.

Stability: This product is stable under normal storage conditions.

11. Toxicological Information

EFFECTS OF OVEREXPOSURE - EYE CONTACT: Causes Serious Eye Irritation

EFFECTS OF OVEREXPOSURE - SKIN CONTACT: Substance may cause slight skin irritation. Prolonged or repeated contact may cause skin irritation.

EFFECTS OF OVEREXPOSURE - INHALATION: Harmful if inhaled. High gas, vapor, mist or dust concentrations may be harmful if inhaled. Avoid breathing fumes, spray, vapors, or mist. High vapor concentrations are irritating to the eyes, nose, throat and lungs. Prolonged or excessive inhalation may cause respiratory tract irritation.

EFFECTS OF OVEREXPOSURE - INGESTION: Harmful if swallowed.

EFFECTS OF OVEREXPOSURE - CHRONIC HAZARDS: May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headaches, paralysis, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. Overexposure to xylene in laboratory animals has been associated with liver abnormalities, kidney, lung, spleen, eye and blood damage as well as reproductive disorders. Effects in humans, due to chronic overexposure, have included liver, cardiac abnormalities and nervous system damage. IARC lists Ethylbenzene as a possible human carcinogen (group 2B). Contains Titanium Dioxide. Titanium Dioxide is listed as a Group 2B-"Possibly carcinogenic to humans" by IARC. No significant exposure to Titanium Dioxide is thought to occur during the use of products in which Titanium Dioxide is bound to other materials, such as in paints during brush application or drying. Risk of overexposure depends on duration and level of exposure to dust from repeated sanding of surfaces or spray mist and the actual concentration of Titanium Dioxide in the formula. (Ref: IARC Monograph, Vol. 93, 2010)

PRIMARY ROUTE(S) OF ENTRY: Eye Contact, Ingestion, Inhalation, Skin Absorption, Skin Contact

ACUTE TOXICITY VALUES

The acute effects of this product have not been tested. Data on individual components are tabulated below:

CAS-No.	Chemical Name	Oral LD50	Dermal LD50	Vapor LC50
67-64-1	Acetone	5800 mg/kg Rat	>15700 mg/kg Rabbit	50.1 mg/L Rat
106-97-8	n-Butane	N.E.	N.E.	658 mg/L Rat
64742-89-8	Aliphatic Hydrocarbon	N.E.	3000 mg/kg Rabbit	N.E.
616-38-6	Dimethyl Carbonate	13000 mg/kg Rat	>5000 mg/kg Rabbit	>5.36 mg/L Rat
108-65-6	1-Methoxy-2-Propyl Acetate	8532 mg/kg Rat	>5000 mg/kg Rabbit	16 mg/L Rat
123-86-4	n-Butyl Acetate	10768 mg/kg Rat	>17600 mg/kg Rabbit	> 21 mg/L Rat
1330-20-7	Xylenes (o-, m-, p- Isomers)	3500 mg/kg Rat	>4350 mg/kg Rabbit	29.08 mg/L Rat
13463-67-7	Titanium Dioxide	>10000 mg/kg Rat	6000	N.E.

7.2.3 Rocket Motor

AeroTech Division, RCS Rocket Motor Components, Inc.

Safety Data Sheet

Prepared in accordance with 29 CFR § 1910.1200 (g)

Section 1. Identification

Product identifier: AeroTech-branded Model rocket motor, high power rocket motor, hobby rocket motor, composite rocket motor, rocket motor kit, rocket motor reloading kit with the trade names White Lightning™, Blue Thunder™, Black Jack™, Black Max™, Redline™, Warp-9™, Mojave Green™, Metalstorm™, Metalstorm DM™ or Propellant X™.

Manufacturer: RCS Rocket Motor Components, Inc., 2113 W 850 N, Cedar City, UT 84721, 435-865-7100, emergency response number: Infotrac (352) 323-3500

Recommended use: Propulsion for hobby rockets.

Section 2. Hazard Identification

Hazard classification: Explosive 1.4S (under 30 grams per motor or propellant grain), explosive 1.4C (30 to 62.5 grams per motor or propellant grain) and explosive 1.3C (over 62.5 grams per motor or propellant grain).

Signal word: Flammable

Hazard statement: Caution: Rocket motors and reload kits are flammable; rocket motors may become propulsive in a fire. All propellants give off varying amounts of Hydrogen Chloride and Carbon Monoxide gas when burned, Mojave Green propellant also produces Barium Chloride.

Pictograms: 

Precautionary Statement: Do not smoke near rocket motors and reload kits and keep away from open flames and other heat sources.

Description of any hazards not otherwise classified: N/A

Unknown toxicity statement: N/A

Section 3. Composition/Information on Ingredients

Chemical name: N/A

Common name and synonyms: Model rocket motor, high power rocket motor, hobby rocket motor, composite rocket motor, rocket motor kit, rocket motor reloading kit.

Chemical Abstracts Service (CAS) number or other unique identifiers: N/A

Impurities and stabilizing additives: N/A

The chemical name and concentration of all ingredients: These products contain varying percentages of Ammonium Perchlorate, Strontium and/or Barium Nitrate dispersed in synthetic rubber with lesser amounts of proprietary ingredients such as burn rate modifiers and powdered metal fuels. Rocket motor ejection charges contain black powder.

Trade secret statement: The specific chemical identity and/or exact percentage (concentration) of composition of some ingredients has been withheld as a trade secret.

Section 4. First Aid Measures

Necessary first-aid instructions: If ingested, induce vomiting and call a physician. If combustion products are inhaled, move to fresh air and call a physician if ill effects are noted. In the case of skin contact, wash area immediately and contact a physician if severe skin rash or irritation develops. For mild burns use a first aid burn ointment. For severe burns immerse the burned area in cold water at once and see a physician immediately.

Description of the most important symptoms or effects, and any symptoms that are acute or delayed: Coughing, tightness of chest in the case of inhalation, redness, blistering or charring of skin in the case of burns, upset stomach, vomiting, or diarrhea in the case of ingestion.

Recommendations for immediate medical care and special treatment needed, when necessary: If ingested, induce vomiting and call a physician. If combustion products are inhaled, move to fresh air and call a physician if ill effects are noted. In the case of

skin contact, wash area immediately and contact a physician if severe skin rash or irritation develops. For mild burns use a first aid burn ointment. For severe burns immerse the burned area in cold water at once and see a physician immediately.

Section 5. Fire-Fighting Measures

Recommendations of suitable extinguishing equipment, and information about extinguishing equipment that is not appropriate for a particular situation: Use water when fighting any propellant fire, foam and CO2 are ineffective.

Advice on specific hazards that develop from the chemical during the fire, such as any hazardous combustion products created when the chemical burns: Rocket motors may become propulsive in a fire. All propellants give off varying amounts of Hydrogen Chloride and Carbon Monoxide gas when burned, Mojave Green propellant also produces Barium Chloride.

Recommendations on special protective equipment or precautions for firefighters: Full-face respirators recommended to prevent from inhaling toxic combustion byproducts.

Section 6. Accidental Release Measures

Personal precautions and protective equipment: N/A

Emergency procedures, including instructions for evacuations, consulting experts when needed, and appropriate protective clothing: N/A

Cleanup procedures: Put motors and reload kit components back into shipping bags. Disposable rubber gloves are recommended for handling Mojave Green propellant grains.

Section 7. Handling and Storage

Precautions for safe handling: Disposable rubber gloves are recommended for handling Mojave Green propellant. Keep away from flames and other sources of heat. Do not smoke within 25 feet of product. Do not ingest. Do not breathe exhaust fumes. Keep in original packaging until ready for use.

7.2.4 CA Glue

TMI PRODUCTS
248 Claridge Curve, Peachtree City, GA 30269
770-631-7897 fax: 770-755-5200 MainOffice@TMIProducts.net

Material Safety Data Sheet
May be used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200. Standard must be
consulted for the specific requirements.

U. S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTIFY (As used on label)	NOTE: Blank spaces are not permitted. If any item is not applicable or no information is available, the space must be marked to indicate it.
Stick Fast CA Adhesives: All grades/viscosities CA Thin, CA Medium, CA Thick, CA Extra Thick, CA Gel, CA Flexible, CA Wood Finish, CA Colors	

Section I

Name	Emergency Telephone Number
TMI Products Inc **Stick Fast Adhesives**	888-255-3924 813-248-0585
Address (Number, Street, City, State and ZIP Code) 248 Claridge Curve	Telephone Number for Information (770)-631-7897
Peachtree City, GA 30269	Data Prepared 03-13-2012
	Signature of Preparer (Optional)

Section II – Hazardous Ingredients/Identity Information

Hazardous Components (Specify Chemical Identity: Common Name(s) OSHA PEL ACGIH TLV Other Limits Recommended		% Optional)
Ethyl Cyanoacrylate	7085-85-0	>80%
Acrylic Polymer – N.J.T.S. Reg NO 56705700001-5863P	Trade Secret	<15%
Hydroquinone	123-31-9	< 0.15%

Section III – Physical/Chemical Characteristics

Boiling Point	Specific Gravity (H2O =1)
More than >212°F	1.05 – 1.16
Vapor Pressure (mm Hg)	Melting Point
Less than 0.2mm @ 75°F	NE
Vapor Density (AIR = 1)	Evaporation Rate (Butyl Acetate = 1)
Approximately 3	N/A
Solubility in Water:	VOC:
Polymerized by water	<2%, <20g/L; California SAQMD method 316 estimated

Appearance and Odor:
Clear viscous liquid with a sharp, irritating odor. (Odor threshold: 1 – 2 ppm)

Section IV – Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
≥176°F (C.C.)	NA	N/DA	N/DA

Extinguishing Media:
Foam, CO_2, dry chemicals

Special Fire Fighting Procedures:
Use self-contained breathing apparatus.

Unusual Fire and Explosion Hazards:
Irritating organic vapors.

TMI PRODUCTS
248 Claridge Curve, Peachtree City, GA 30269
770-631-7897 fax: 770-755-5200 MainOffice@TMIProducts.net

Section V – Health Hazard Data

Threshold Limit Value:
Ethyl Cyanoacrylate: ACGIH TWA: 0.2ppm; Hydroquinone: OSHA TWA: 2mg/m3

Effects of overexposure:
Ingestion: not likely. The product will polymerize rapidly, adhering to the mouth. **Inhalation:** may be irritating to respiratory system above recommended exposure limits. Remove to fresh air. If breathing is difficult, seek medical attention. Vapors are irritating to eyes and mucous membranes. Prolonged and repeated exposure to vapors may produce allergic reactions with asthma-like symptoms in sensitive individuals. **Skin:** Irritating - will bond instantly with small gaps.

Emergency and First Aid Procedures:
Ingestion: Insure breathing passages are clear. Saliva will separate any solidified product within two days. Prevent accidental swallowing. **Eyes:** Irritating. Immediately flush with warm water for at least 15 minutes, get prompt medical attention and apply gauze patch. Cyanoacrylate will bond to eye protein and cause a lachrymatory effect which will help de-bond the adhesive. Keep eye covered until de-bonding is complete (usually within 1-4 days). **Skin:** bonds rapidly and strongly. May cause burns. Immerse bonded surface in warm soapy water. Peel or roll surface apart with aid of blunt edge. Do not pull apart with direct opposing action. If skin is burned by a large drop, (due to heat generated by the polymerization) seek medical help. If the lips are accidentally bonded, apply warm soapy water, encourage maximum wetting and pressure from saliva inside the mouth and peel or roll lips apart. DO NOT TRY TO PULL LIPS APART. Burns: should be treated normally after the lump of cyanoacrylate is released from the tissue.

Section VI – Reactivity Data

Stability			Conditions to Avoid
	Unstable		Elevated temperatures, direct sunlight, and sources of ignition.
	Stable	X	

Incompatibility (*Materials to avoid*)
Polymerized by contact with water, alcohol, amines and/or alkalis.

Hazardous Decomposition Products: None.

Hazardous Polymerization			Conditions to Avoid:
	May occur	X	Rapid polymerization will occur in the presence of water, amines, alkalis and alcohol. Avoid skin contact.
	Will not occur		

Section VII – Spill or Leak Procedures

Steps to be taken in case material is to be released or spilled:
Remove all ignition sources. Ventilate area, prevent product from entering drains. Flood with water to complete polymerization. Scrape off floor.

Waste Disposal Method:
Cured material can be disposed of as non-hazardous waste. Polymerize as above. Incinerate in accordance with EPA and local regulations.

Section VIII – Special Protective Information

Respiratory Protection *(Specify Type)*
At high vapor concentrations, an approved self-contained breathing apparatus should be worn.

Ventilation	Local Exhaust	Special
	Positive down draft exhaust ventilation should be provided to maintain vapor concentration below TLV.	None
	Mechanical: Not Applicable	Other: None

Protective Gloves:	Eye Protection:
Use nitrile gloves and aprons as necessary to prevent contact. Do not use PVC, nylon or cotton.	Chemical splash goggles or safety glasses with side shields.

Other Protective Equipment:
Polyethylene/Polypropylene coats or aprons (not rubber or cotton)

TMI PRODUCTS
248 Claridge Curve, Peachtree City, GA 30269
770-631-7897 fax: 770-755-5200 MainOffice@TMIProducts.net

Section IX – Special Precautions

Precautions to be taken in handling and storing:

Keep away from heat, sparks, flames and direct sunlight. Avoid contact with eyes, skin and clothing. Wear chemical resistant gloves when handling. Avoid inhalation of vapors. Skin contact through clothing may cause burns.

Other Precautions:

Keep away from children. Avoid contact with polymerization initiators such as water, alcohol, amines or alkalis. Store in tightly closed, labeled containers at or below 75°F. Keep in well, ventilated area away from heat, sparks and open flames.

Section X – Regulatory Information

CERCLA/SARA 311/312 Immediate health hazard, Delayed Health Hazard, fire, Reactive
WHMIS Hazard Class B.3, D.2B
All ingredients are listed or exempt from listing on the TSCA inventory and the DSL

Estimated HMIS Code: Health Hazard (2) Fire Hazard (2) Reactivity (1)

Section XI – Transportation Information

DOT (49CFR172):
Exception: Unrestricted if not more than 450 L
Proper shipping name: Combustible liquid, n.o.s. (cyanoacrylate ester)
Hazard class or division: Combustible liquid
Identification number: NA1993,
Packing group III

ICAO/IATA: International Air Transportation
Exception: Primary packs not more than 500mL are unregulated by this mode of transportation and may be shipped unrestricted.
Proper shipping name: Aviation regulated liquid, n.o.s., (cyanoacrylate ester),
Identification number: UN3334
Class 9
Packing group: None

Water Transportation (IMO/IMDG)
Proper shipping name: Not regulated
Hazard class or division: None
Identification number: None
Packing group: None

7.2.5 Igniters

AeroTech Division, RCS Rocket Motor Components, Inc.

Safety Data Sheet

Prepared in accordance with 29 CFR § 1910.1200 (g)

Section 1. Identification

Product identifier: Copperhead™ igniter, FirstFire™ igniter, FirstFire Jr.™ igniter.

Manufacturer: RCS Rocket Motor Components, Inc., 2113 W 850 N, Cedar City, UT 84721, 435-865-7100, emergency response number: Infotrac (352) 323-3500

Recommended use: Igniters for initiating hobby rocket motors.

Section 2. Hazard Identification

Hazard classification: Explosive 1.4S.

Signal word: Flammable

Hazard statement: Igniters are flammable and may give off varying amounts of Hydrogen Chloride and Carbon Monoxide gas, soot and carbon fibers when burned.

Pictograms: 

Precautionary Statement: Do not smoke near igniters and keep away from open flames and other heat sources.

Description of any hazards not otherwise classified: N/A

Unknown toxicity statement: N/A

Section 3. Composition/Information on Ingredients

Chemical name: N/A

Common name and synonyms: Rocket motor igniter, initiator, starter.

Chemical Abstracts Service (CAS) number or other unique identifiers: N/A

Impurities and stabilizing additives: N/A

The chemical name and concentration of all ingredients: Igniters contain varying percentages of Ammonium or Potassium Perchlorate, carbon black and carbon fibers dispersed in a flammable binder with lesser amounts of proprietary ingredients such as burn rate modifiers and a powdered metal fuel.

Trade secret statement: The specific chemical identity and/or exact percentage (concentration) of composition of some ingredients has been withheld as a trade secret.

Section 4. First Aid Measures

Necessary first-aid instructions: If the pyrotechnic composition is ingested, induce vomiting and call a physician. If combustion products are inhaled, move to fresh air and call a physician if ill effects are noted. In the case of skin contact, wash area immediately and contact a physician if severe skin rash or irritation develops. For mild burns use a first aid burn ointment. For severe burns immerse the burned area in cold water at once and see a physician immediately.

Description of the most important symptoms or effects, and any symptoms that are acute or delayed: Coughing, tightness of chest in the case of inhalation, redness, blistering or charring of skin in the case of burns, upset stomach, vomiting, or diarrhea in the case of ingestion.

Recommendations for immediate medical care and special treatment needed, when necessary: If ingested, induce vomiting and call a physician. If combustion products are inhaled, move to fresh air and call a physician if ill effects are noted. In the case of skin contact, wash area immediately and contact a physician if severe skin rash or irritation develops. For mild burns use a first aid burn ointment. For severe burns immerse the burned area in cold water at once and see a physician immediately.

Section 5. Fire-Fighting Measures

Recommendations of suitable extinguishing equipment, and information about extinguishing equipment that is not

storage and being handled: Product is stable at normal temperatures.

Other.

Indication of the possibility of hazardous reactions, including a statement whether the chemical will react or polymerize, which could release excess pressure or heat, or create other hazardous conditions. Also, a description of the conditions under which hazardous reactions may occur: Coating on tip of product autoignites at 550 deg. F.

List of all conditions that should be avoided: Open flames, smoking near product, acids, other heat sources.

List of all classes of incompatible materials: Acids, peroxides.

List of any known or anticipated hazardous decomposition products that could be produced because of use, storage, or heating: Oxides of carbon, Hydrogen Chloride, soot, carbon fibers, metal oxide fumes.

Section 11. Toxicological Information

Information on the likely routes of exposure: Inhalation, skin exposure, ingestion.

Description of the delayed, immediate, or chronic effects from short- and long-term exposure: Pyrotechnic coating on igniter tip is an irritant in the case of skin and eye contact, may be extremely hazardous in the case of ingestion, and may be toxic to kidneys, lungs and the nervous system. Symptoms include respiratory irritation, skin irritation, muscle tightness, vomiting, diarrhea, abdominal pain, muscular tremors, weakness, labored breathing, irregular heartbeat, and convulsions. Inhalation of large amounts of combustion products may produce similar but lesser symptoms as ingestion.

The numerical measures of toxicity: N/A

Description of the symptoms: Coughing, tightness of chest in the case of inhalation, redness, blistering or charring of skin in the case of burns, upset stomach, vomiting, or diarrhea in the case of ingestion.

Indication of whether the chemical is listed in the National Toxicology Program (NTP) Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions) or found to be a potential carcinogen by OSHA: N/A

Section 12. Ecological Information

Data from toxicity tests performed on aquatic and/or terrestrial organisms: N/A

Potential for the chemical to persist and degrade in the environment either through biodegradation or other processes: Unknown.

Results of tests of bioaccumulation potential: N/A

The potential for a substance to move from the soil to the groundwater: Unknown.

Other adverse effects: There are concerns that perchlorate has the potential for thyroid problems in certain individuals.

Section 13. Disposal Considerations

Description of appropriate disposal containers to use: None. Igniters should be disposed of by burning.

Recommendations of appropriate disposal methods to employ: Discharge igniter at a safe distance using a 12 volt car battery or similar power source. The pyrotechnic coating on the igniter will burn until consumed. Dispose of spent igniter in an inert trash receptacle.

Description of the physical and chemical properties that may affect disposal activities: None anticipated.

Language discouraging sewage disposal: Do not dispose igniters in a sewer system.

Any special precautions for landfills or incineration activities: Do not dispose of igniters in landfills. Dispose by burning as described above.

7.2.6 Black powder

1 **SAFETY DATA SHEET-BLACK POWDER**

Section 1: Identification

Product Identifier: Black Powder (includes all grades)

Manufacturer's Name: GOEX Powder, Inc.

Address: P.O. Box 659
Doyline, LA 71023-0659

Informational Telephone Number:1-(318) 382-9300

Emerg. Phone Number: 1-(800) 255-3924 (Chem Tel)

Recommended Use: for use in competitive and recreational shooting, muzzleloading hunting and the U.S. Military .

Section 2: Hazard(s) Identification

Hazard category:	Signal Word	Hazard statement	Pictogram
Division 1.1	Danger	Explosive; mass explosion hazard	

Target Organ Warning: Above OSHA levels, chronic exposure may cause skin irritation and damage to the respiratory system, and acute exposure can cause skin, eye, and respiratory irritation.

Section 3: Composition/information on ingredients

Component	CAS-Number	Weight %
Charcoal	16291-96-6	8-18%
Sulfur	7704-34-9	9-20%
Potassium Nitrate	7757-79-1	70-76%
Graphite (note: not contained in all grades of black powder)	7782-42-5	<1%

Section 4: First-aid measures

Ingestion: * Not a likely route of exposure. If ingested, dilute by giving two glasses of water and induce vomiting. Avoid, when possible and contact a Poison control center for advice on treatment, if unsure.

Eye Contact: * Not a likely route of exposure. Flush eyes with water.

Inhalation: * Remove patient from area to fresh air. If not breathing, give artificial respiration, preferably by mouth to mouth. If breathing is difficult, give oxygen. Seek prompt medical attention. Avoid when possible.

Skin Contact: * wash the affected area with copious amounts of water. Some persons may be sensitive to product.

Injury from detonation: * Seek prompt medical attention immediately.

Note to Physician: * Treat symptomatically.

Section 5: Fire-fighting measures

Extinguishing media: * Water may be used as the extinguishing method. DO NOT FIGHT EXPLOSIVES FIRES. Evacuate the area according to Emergency Response Guide 112 guidelines. Isolate the area and guard against any intruders.

Special Procedures: * Black Powder is extremely flammable and may deflagrate. Get away and evacuate the area.

Unusual Hazards: * As with any pyrotechnic, if under confinement or piled in slight confinement, Black Powder can explode. No known toxic fumes are emitted, but good ventilation should still be present.

Flash Point: not applicable.

Auto ignition Temp: Approximate range: 392°-867°F /(200°-464°C)

NFPA Ratings: **Health=1** **Flammability=3** **Reactivity=1**

Advice and PPE for Firefighters: * Fires involving Black Powder should not be fought unless extinguishing media can be applied from a well protected and distant location from the point of fire. Self-contained breathing apparatus (SCBA) and protective clothing must be worn. Follow Emergency Response Guide 112. Wash all clothes prior to reuse.

Section 6: Accidental release measures

Personal precautions, protective equipment and emergency procedures:
* Non-flammable or flame retardant clothing should be worn when cleaning up spilled material. Material is sensitive to ignition from sources such as heat, flame, impact, friction or sparks. Therefore, non-sparking utensils should be used.

Spill/leak response: * Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in cleanup procedures.

Environmental precautions:

* Clean up spills immediately using non-sparking utensils Do not dispose of in the ground.

* Spill residues may be disposed of per guidelines under Section 13: Disposal Considerations.

Section 7: Handling and storage

Storage Conditions: * Store in a cool, dry place in accordance with requirements of 27CFR555.201-555.219 (ATF Subpart K)

* Avoid heat, impact, friction and static. Protect against heat effects. Keep away from heat, open flame and ignition sources.

* Absolutely no smoking around open powder or packages. Keep away from combustibles. Avoid electrostatic charges.

* Store in a cool, dry place Do not store in the same area with highly combustible materials.

* Keep containers closed at all times when not being used. Keep out of reach of children. Open and handle container with care.

* Follow all local, state and federal laws when storing this product.

Section 8: Exposure controls/personal protection

Personal protection for routine use:
* Respiratory protection is not normally needed. If significant dusting occurs, a NIOSH approved dust mask should be worn. Good ventilation is recommended when working with Black Powder. Gloves may be worn to protect skin. Safety glasses with side shields are recommended for eye protection. Flame retardant outerwear such as coveralls or lab coat may be worn.

Health Hazards (Acute or chronic): * TLV is unknown for ingestion of dust.

Signs/Symptoms of Exposure: * Burning or itching of the eyes, nose or skin; shortness of breath.

First Aid Procedures: * Remove the patient from exposure and if skin contact, wash the affected area with water

Section 9: Physical and chemical properties

Physical State:	Granular powder	**Solubility:**	Good in water
pH:	6.0-8.0	**Vapor Pressure/Density:**	not applicable
Appearance:	Black in color	**Auto-ignition Temp.:**	392° -867° F /200° -464° C
Odor:	No odor detectable	**Boiling Point:**	Not applicable

Section 10: Stability and reactivity

General Information: * Loading data and the instructions for loading must be observed.

Hazardous decomposition: * Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.

Conditions to Avoid: Avoid heat, impact, friction or static. Protect against heat effects. Keep away from heat, open flame and ignition sources. A violent burn or deflagration could occur by above mentioned items.

Substances to Avoid: Avoid contact with alkaline substances or strong acids.

Section 11: Toxicological information

* LD_{50} Values: unknown

* TLV unknown for ingestion of dust. Some persons may be unusually sensitive to the product.

* None of the components of Black Powder are listed as a carcinogen by NTP, IARC or OSHA.

* Routes of entry include Skin, Inhalation and Ingestion. (Acute Toxicity=Category 4) per Table A.1.1 of 29CFR1910.1200

Section 12: Ecological information

* Do not dispose of powder or residues into any water streams or bodies of water. Avoid spilling powders onto any soils. Clean up any spills promptly.

* No known adverse effects on marine or other aquatic organisms.

Section 13: Disposal considerations

* Care must be taken to prevent environmental contamination from the use of this material. The user has the responsibility to dispose of unused material, residues and containers in compliance with all relevant laws and regulations regarding treatment, storage and disposal for hazardous and non-hazardous waste. Powder can be burned in very small quantities and in very thin layer and must only be ignited from a safe distance.

Waste Disposal: * Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with Federal Regulations under the authority of RCRA (40CFR Parts 260-271).

* Do not dispose of the black powder container into a fire.

Section 14: Transport information

Label required: Explosive

Highway:

Class or division: 1.1D or 4.1 Flam Solid-(if <100 pounds).

UN Number: UN0027 (NA0027 for 4.1 Flam Solid)

Shipping Name: Black Powder

Air Transport: **Forbidden!**

Maritime IMDG

Class or division: 1.1D

UN Number: UN0027

Shipping Name: Black Powder

Section 15: Regulatory information

* All products related to Black Powder are reported annually as per Community Right-to Know (Tier II). Black Powder has been approved by PHMSA and copies of the approvals are on file with Environmental, Health and Safety Manager.

Section 16: Other information

Prepared By: Mark Wendt, Environmental, Health and Safety Manager email: mwendt@hodgdon.com

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Disclaimer:

The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.