MORRIS COUNTY 4-H

PROJECT STARDUST

NASA Student Launch 2023-2024 Proposal

[redacted]
resistojetrocketry@gmail.com

September 11th, 2023

TERMS

In approximate order of appearance.

NASA National Aeronautics and Space Administration, government body and host to this competition.

4-H National youth development organization.

SLI NASA Student Launch Initiative, the competition that this proposal and subsequent work is for.

USLI University division of SLI.

ResistoJets Rocketry Our team's host 4-H club.

Tripoli Rocketry governance body.

NAR National Association of Rocketry, rocketry governance body.

HPR High Power Rocketry — NAR definition for rocket motors with more than 160 Newton-seconds of total impulse.

FAA Federal Aviation Administration, government body for regulation of airspace and flying objects.

FCC Federal Communication Commission, government body for regulation of radio transmissions and amateur radio.

NFPA National Fire Protection Association, non-profit organization for eliminating fire hazards and losses of life and property.

N.J.S.A. New Jersey Statutes Annotated, government body for maintenance of state statutes.

MSDS Material Safety Data Sheet, data sheets for safety information pertaining to materials.

PPE Personal Protective Equipment, appropriate equipment necessary to protect personnel from hazards.

COTS Consumer Off The Shelf, components that can be purchased commercially.

AGL Above Ground Level, altitude reading when zeroed for ground level, as opposed to sea level.

FinCan Complete assembly of the fins and body tube that the fins are assembled to.

PETG Polyethylene Terephthalate Glycol, a 3D printing plastic material with potentially desirable properties.

RF Radio Frequency, transmissions from radios yielding radiation and potential interference to other electronics.

GPS Global Position System, a system of satellites used by our rocket's tracker to triangulate its position in flight.

APRS Automatic Packet Reporting System, a ham radio digital format frequently used for tracking objects with GPS data.

PVC Polyvinyl Chloride, common tubing material, used by our team for ejection charge casings.

PDR Preliminary Design Review, second milestone in the NASA SLI, after the proposal.

CDR Critical Design Review, third milestone in the NASA SLI.

FRR Flight Readiness Review, fourth milestone in the NASA SLI.

PLAR Post Launch Assessment Review, fifth and final milestone in the NASA SLI.

TWR Thrust to Weight Ratio, ratio of thrust produced by a vehicle compared to the weight of the vehicle, used to illustrate whether a vehicle will be able to accelerate quickly enough to reach safe velocities.

SAIL STEMnaut Atmospheric Independent Lander, the USLI payload challenge developed by NASA.

STEMnaut Model astronauts to serve as a crew astronaut on the SAIL payload.

CO2 Carbon Dioxide.

IMU Inertial Measurement Unit, used to measure inertia and movement in several axes.

TRL Technical Readiness Level, project management metric used to measure the readiness of technologies needed for various parts of the competition.

TARC The American Rocketry Challenge, a national high school and middle school rocketry competition in which SLI teams must place top 25 in every two years to qualify for SLI.

STEM Science Technology Engineering and Math, an all-encompassing term referring to these fields and outreach for them.

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General Information

(This photograph is from last NASA Student Launch season)

1. General Information

This chapter covers all general information relating to our team for the NASA Student Launch 2023-2024 season.

Our project this year is characterized by growth and expansion, with the goal of ultimately securing our team's future and enabling our club to serve as a place for educational enrichment for many years to come. With these goals in mind, we've adjusted our philosophy and planned our project to best achieve this.

1.1. Contact Information

1.1.1. Adult Educator and Mentor

Britt Wagner
Educator
[redacted]

Luke McConoughey
Mentor
NAR [redacted] L2 — FCC Ham Radio Extra [redacted] — FAA Remote Pilot
[redacted]

1.1.2. Team Members

Sean McConoughey
Team Lead
12th grade
NAR [redacted] JR HPR — FCC Ham Radio Technician [redacted]
Team, Vehicle, STEM Engagement Lead — Social Media, Payload member
[redacted]

Holt Englander
Safety Officer
11th grade
NAR [redacted] JR HPR
Safety OfficerLead
[redacted]

Divya Krishna
11th grade
Payload Lead — Vehicle, Social Media member

Garrett Gregor
10th grade
Social Media Lead — Payload, Vehicle, Safety member

Mya McConoughey
7th grade
Social Media member

Revant Mohanasundaram Vanchinayagam
10th grade
Vehicle and Website member

Robert Galante
9th grade
NAR [redacted] JR HPR
STEM Outreach and Vehicle Member

Brian Sun
11th Grade
TRA M1 Certified [redacted]
Vehicle and Payload Member

1.2. Tripoli and NAR Sections

We will be launching primarily with the Maryland Delaware Rocketry Association, with Tripoli Central Virginia (Battle Park) and URRG (Upstate Rocketry Research Group) serving as a back-up launch-site weather and schedules permitting. Our mentorship, feedback, and assistance structure is not tied to any particular Tripoli or National Association of Rocketry chapter, rather we utilize the resources and knowledge available to us in our 4-H Club, ResistoJets Rocketry.

1.3. Approximate Number of Hours Spent Working on Proposal

Our team has spent approximately 164 hours on the proposal milestone.

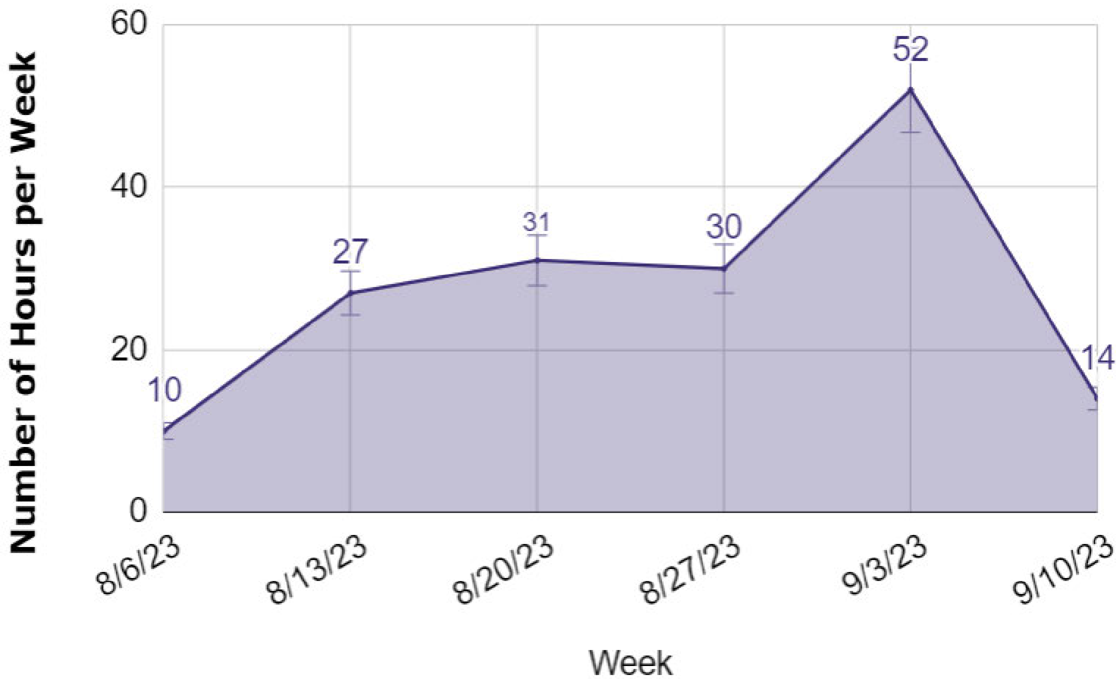


Figure 1: Timeline of hours spent on the proposal milestone

1.4. Teleconferencing Times

In order of preference. (Times in Central)

- Wednesday 4-5pm
- Monday 4-5pm
- Friday 4-5pm
- Wednesday 3-4pm
- Monday 3-4pm
- Friday 3-4pm

1.5. Letter of Administrative Support

[redacted]

Figure 2: Letter of Administrative Support

Facilities/Equipment

(This photograph is from last NASA Student Launch season)

2. Facilities/Equipment

2.1. Workspaces & Facilities

Currently, we intend to conduct all building operations in members' residences, primarily the team leads' house, where we've worked in the past. These facilities have all of the tools needed for our work and generally don't have restrictions on availability that would delay or inhibit our timeline.

Additionally, we have had prior access to Rutgers University's Makerspace in Piscataway, NJ. At this time, we haven't found a need to renew this, but if needed we can re-acquire access on short notice. All in-person work is supervised, and Rutgers Makerspace facility has their own rules and conditions regarding supervision and training.

Our team meets and communicates on our online Discord server at minimum once a week with text channels always open for interim discussions. Meeting virtually for non-physical work benefits our team greatly due to the geographic distribution of our team across the state, making in-person travel times in excess of an hour on average, something most members cannot accommodate on a weekly basis. We do have access to various locations on short notice if we decide to hold a non-building meeting.

Details on safety in facilities can be found in Section 3, Subsection 3.2.2.

2.2. Equipment

2.2.1. Tools/Power Tools (All on hand)

- Scissors
- Drills/Drill Bits
- Composite scissors
- Scale
- Tape measures
- Exacto knives
- Sandpaper
- Prusa XL 3D Printer (Necessary for FinCan)
- Additional 3D printers
- Tapes
- Multimeter
- Wire Cutters
- Wire Strippers
- Dremels
- Allen Keys
- Pliers
- Soldering Iron
- Screwdrivers
- Cordless screwdriver

2.2.2. Software

Design/Programming Softwares:

- OpenRocket
- Fusion360
- Inventor
- PrusaSlicer
- Cura Slicer
- Arduino IDE
- Python
- MatLab/Simulink

Formatting/Organization Software:

- Google Docs
- LaTeX
- Monday
- Discord
- Photoshop
- Premiere Pro
- Illustrator

2.2.3. Resources In Inventory and Needed

In Inventory:

- 5.7oz Carbon Fiber
- Laminating Epoxy
- RocketPoxy
- Various recovery hardware
- 36” Spherahute Drogue Parachute
- 48” Iris Ultra Main Parachute
- PETG plastic for 3D printing
- Strattologger CFs
- BigRedBee GPS Trackers

Needed:

- Composites Mold Release
- Vehicle components: Nose cone, avionics bay, body tubes, 1515 rail buttons, and recovery hardware
- New parachutes, shock cords, and fire-resistant shields
- All payload hardware except 3D printed parts and the computer suite (including 360 camera)
- Additional PETG plastic
- Motor hardware
- Motor Reloads
- Spray Paint
- Masking Tape
- CA Glue

Safety

(This photograph is from last NASA Student Launch season)

3. Safety

The ResistoJets Rocketry team prioritizes safety during all aspects of our project including project management, design, manufacturing, and assembly of the vehicle and payload; pre-launch, launch, recovery and analysis. The Safety Officer, Holt Englander, will, together with the whole team, develop a safety plan, procedures, checklists, and hazard analysis to be used and easily understood by any member of the team. Each team member individually and the team as a whole will abide by any appropriate or otherwise necessary codes and regulations.

3.1. Codes and Regulations (with written agreement)

3.1.1. Compliance with Codes and Regulations

Our team will comply with the following codes and regulations:

Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C: Amateur Rockets The ResistoJets Rocketry team will comply with §101.23 (General operating limitations):

- The rocket will only be launched with a suborbital trajectory.
- The rocket will not be launched into foreign territory.
- The rocket will be unmanned.
- The rocket will not create a hazard to persons, property, or other aircraft.

The ResistoJets Rocketry team will also comply with **§101.25 (Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets)**. Launches will not occur:

- At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails.
- At any altitude where the horizontal visibility is less than five miles.
- Into any cloud.
- Between sunset and sunrise without prior authorization from the FAA.

- Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA.
- In controlled airspace without prior authorization from the FAA.
- Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:
  - Not less than one-quarter the maximum expected altitude.
  - 457 meters (1,500 ft).
- Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight.
- Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

Code of Federal Regulation 27 Part 55: Commerce in Explosives The handling of all motors and energetic devices will be done by our NAR mentor legally and safely.

Additionally, the ResistoJets Rocketry Team will abide by the following regulations and codes, in all applicable instances, including but not limited to operating radio transmitters, launching rockets, and the handling and storage of high power rocket motors:

- FCC Regulations part 97
- NFPA 1127
- N.J.S.A. 21:1C-1 et. seq. MODEL ROCKETS
- NAR High Power Rocketry Safety Code

3.1.2. Written Agreement

Please see the the safety agreement signed by all team members:

Safety Agreement

3.2. Materials and Facilities

3.2.1. MSDS

Below is a table with all of the potentially harmful materials we will be using:

Item Name	Link to MSDS
Rocketpoxy	MSDS
Spray Paint	MSDS
Rocket Motor	MSDS
CA Glue	MSDS
Igniter	MSDS
Black Powder	MSDS
Isopropyl Alcohol	MSDS
3:1 Epoxy Hardener	MSDS
635 Thin Epoxy Resin	MSDS
Carbon Fiber	MSDS
PETG Plastic	MSDS

3.2.2. Facilities

Our main building facilities will be members' homes. Our main safety requirements for a workspace are as follows: well-ventilated, clean, away from any unnecessary or hazardous potential fire/heat sources, fire extinguisher, first aid kit, a sink or other water source in the vicinity.

We plan on using M.D.R.A. as our main launch site for our full-scale vehicle tests and sub-scale vehicle launches. Their safety codes can be seen here: https://mdrocketry.org/mdra-safety-code/.

3.3. Briefings

Before any kind of in-person team activity, whether potentially hazardous or not, we will have a general briefing that will include any safety details that could arise or that we need to take precautions for. This will include everybody's main roles for the activity. Some examples of necessary briefings include, but are not limited to:

- Build sessions will include briefings on any hazardous materials or equipment and what PPE will be needed.
- Ejection tests or launching involving a motor and black powder will include a safety briefing and a reminder that the mentor must carry out any handling of black powder. This will also include an overview of possible failures and catastrophes before, during, and after flight.
- Pre-recovery operations will involve operation planning and briefings, including anything specific to weather conditions, specific vehicle hazards, and recovery process briefings.
- There may also be briefings for STEM engagement activities such as how to make sure children don't hurt themselves on craft supplies (scissors, hobby knives, glue, etc).

Specific hazards for each situation and appropriate precautions will be documented in our full procedures later in the year.

3.4. Motor Safety

All of our motors will be bought from reputable online sellers and shipped with hazmat shipping.

Motors will be stored and transported in a metal ammunition can (or otherwise suitable container depending on the size), and they will be kept in a climate-controlled environment away from any potential fire hazards and ignition sources.

Motors will be assembled according to instructions and glued if required and given the full required curing time before flight.

Energetics shall only be operated and handled by the team mentor.

3.5. Caution Statements

While making safety procedures and checklists, the safety officer together with the team will add caution statements for each step if needed.

Any team member can come to the safety officer after identifying a need for a specific caution statement, and it will be added to the appropriate document or procedures.

A note of what PPE is required will be included in procedures, briefings, checklists, and emails/messages regarding in-person team activity.

3.6. Risk Assessment

3.6.1. Risk Scale

3.6.1.1. Likelihood Scale

Definitions for the likelihood of hazards occurring and the value that represents them in risk analysis.

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

3.6.1.2. Safety Severity Scale

Definitions for the severity of hazards and the value that represents them in risk analysis.

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.

3.6.1.3. Total Risk Scale

The combination of both the likelihood and severity of a hazard to calculate the overall risk (FAA Risk Matrix)

Likelihood \ Severity	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A	[Green]	[Yellow]	[Red]	[Red]	[Red]
Probable B	[Green]	[Yellow]	[Red]	[Red]	[Red]
Remote C	[Green]	[Yellow]	[Yellow]	[Red]	[Red]
Extremely Remote D	[Green]	[Green]	[Yellow]	[Yellow]	[Red]
Extremely Improbable E	[Green]	[Green]	[Green]	[Yellow]	[Red] *

High Risk [Red]
Medium Risk[Yellow]
Low Risk [Green]

* High Risk with Single Cause Failures

Figure 3: FAA Risk Matrix

3.6.2. General Hazards and Mitigations Tables

Hazard	Cause	Effect	Risk	Mitigation
Vehicle lands in crowd	Incorrect rail angle, high drift, recovery system failure	Personal injury, loss of life, damage to vehicle	D1 High	Angle rail away from designated spectator area, check drift simulations and account for wind direction
Vehicle lands on private property	Unexpected wind, low TWR, recovery system failure	Loss of vehicle, property damage	B4 Medium	Use Proper parachute size, ensure large enough launch area, contact property owner before recovery
Inhalation of harmful fumes	Failure to use PPE, poorly ventilated space	Personal injury	C4 Medium	Make sure everybody is notified of what PPE is needed before it's a hazard, ensure everybody actually uses the correct PPE
Electrocution	Faulty cables and equipment, carelessness	Personal injury, loss of life	E1 High	Make sure everybody is notified of anything with high current before they work with it
Payload fails to jettison	Stuck in vehicle, parachute deployment failure, release mechanism failure	Increased landing velocity, damage to vehicle, damage to payload, risk to main parachute	C2 High	Conduct ground tests to verify system functionality
Payload damages sensitive property	DragBag failure to deploy, payload trajectory facing sensitive property	Damage to property, fines, potential loss of payload	E2 Medium	Angle vehicle launch pad away from sensitive property, verify DragBag functionality on the ground.
CO2 System Failure	Loose connections, over pressure, burst fitting	Personal injury, payload damage	C3 Medium	Have the least number of personnel operate the payload when the system is pressurized, conduct extensive testing of the pressure system

Figure 4: Risks and Mitigations Part 1

Hazard	**Cause**	**Effect**	**Risk**	**Mitigation**
Injury due to power tool	Malfunctioning tool, improper use, no PPE	Personal injury, loss of life	D1 High	Follow safety instructions, inspect tool, brief before use
Fire	Unburnt black powder, premature motor ignition, motor still burning after premature landing	Property damage, loss of vehicle, personal injury	E2 Medium	Mentor handling of motor and black powder, fire extinguisher on hand, ejection system checks, motor inspection
Adverse weather during launch	Rain, high winds, hail, high heat, cold	Damage to vehicle, altered flight trajectory, personal injury	A4 Medium	Check forecast and cancel launch if unsafe, backup launch day, adjust simulations accordingly, personnel briefing for heat/cold
Inadequate launch field	Uneven ground, not enough open space, trees	Loss of vehicle, personal injury during recovery, recovery delay	C3 Medium	

Figure 5: Risks and Mitigations Part 2

3.6.3. Project Management Risks and Mitigations

Risk	Cause	Effect	Risk	Mitigation
Sustainability failure	Members leaving the team, team stopping functional expansion	Workload becomes spread too heavily, quality of work degrades, possible failures to deliver	C3 Medium	Keep active with recruiting, make sure members know what they can help with
Lack of funding	Not enough effort put into contacting potential sponsors	Not able to purchase materials, travel restriction, project on hold	C2 High	Make sure to reach out to potential sponsors, keep relationships active with current or last years sponsors
Launch site not available	Bad weather, scheduling, deadlines, lack of backup	Lack of testing, failure to meet deadlines	B3 High	Have a backup launch site (this is difficult for us because most are very far away), try to get launches in earlier
Material unavailability	Shortages, long delivery time	Schedules pushed back, deadlines missed	B3 High	Multiple sellers, alternate parts, buy in advance

Figure 6: Project Management Risks and Mitigations

Payload Design

4. Payload (SAIL)

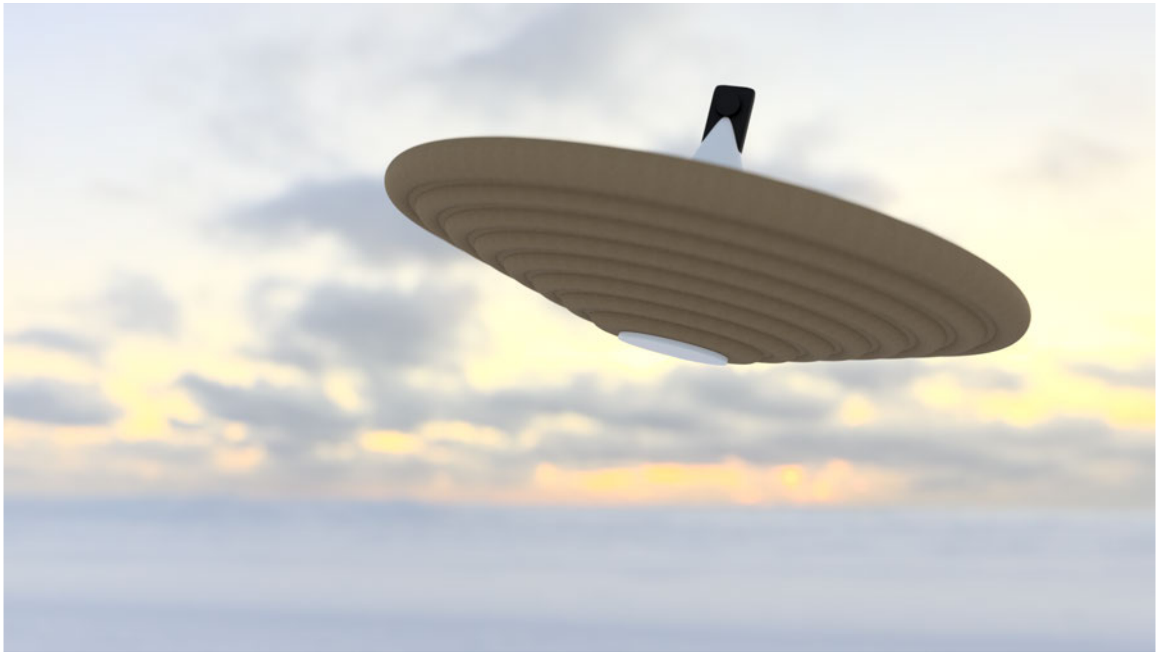


Figure 7: Artistic Render of our primary payload design in flight

4.1. Payload Objectives

During this year's challenge, our team has decided to design a payload corresponding with the University Student Launch Initative's payload challenge, the STEMnaut Atmosphere Independent Lander (SAIL). With our design, we aim to effectively pick our materials to fulfill the weight requirements of 5 pounds while also incorporating 3D printing and engineering principles to safely bring our payload to the ground. To achieve this goal, we have engineered a primary solution, along with two back-up options, that fit within the parameters described in the SLI Handbook.

4.1.1. Safe Landing Criteria

Our design is planned to have am ideal landing velocity of 22 ft/s, with a safe landing of up to 33 ft/s, in order to ensure a safe landing for the STEMnauts. Our inflatable bag section of our payload provides a buffer zone in case of an off-angle bounce or awkward impact with the ground, protecting the rest of the payload from damage on impact.

Our parameters for a safe and optimal landing are as such:

Maximum Velocity: 33 ft/s
Target Velocity: 22 ft/s

Expected Landing Orientation: Upright, slightly angled laying on the side of the DragBag

4.2. Primary Payload (The Drag Bag)

4.2.1. Mission Overview

Our primary payload technology that abides by this year's USLI Challenge is our inflatable drag bag. This is similar in design to NASA's LOFTID Heat Shield, which utilizes a hard shell followed by an inflatable structure and a shell housing the avionics for the payload. This would consist of a CO2 (carbon dioxide) cartridge to inflate the shield upon jettison. As the gas expands rapidly under the atmospheric conditions, the payload will likely land in a specific orientation upon landing.

4.2.2. Technical Design

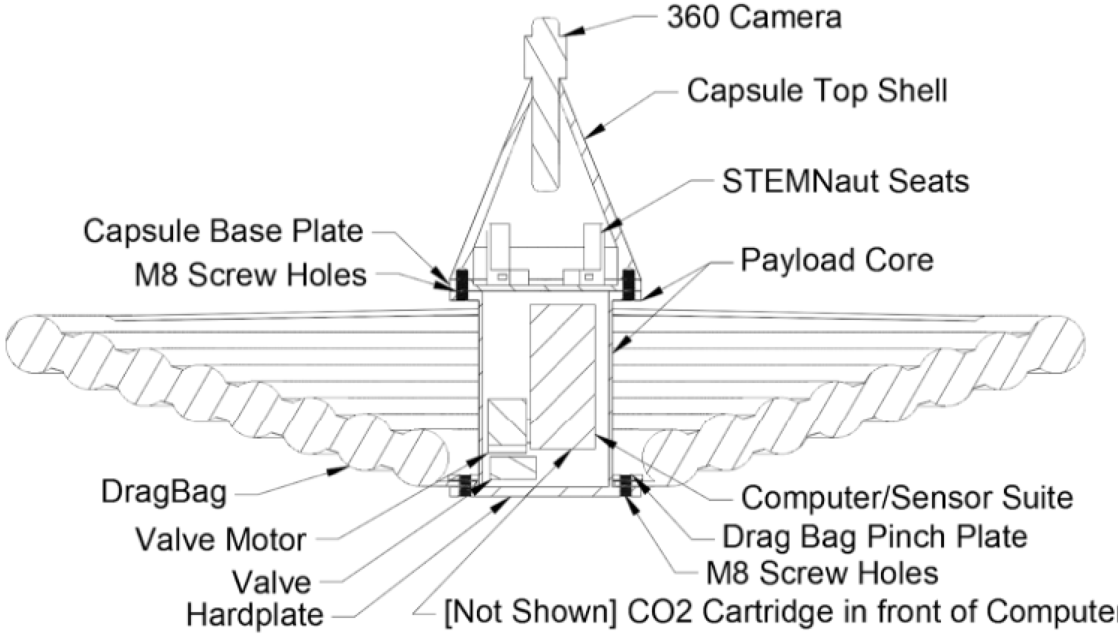


Figure 8: Technical cross section of payload with labels

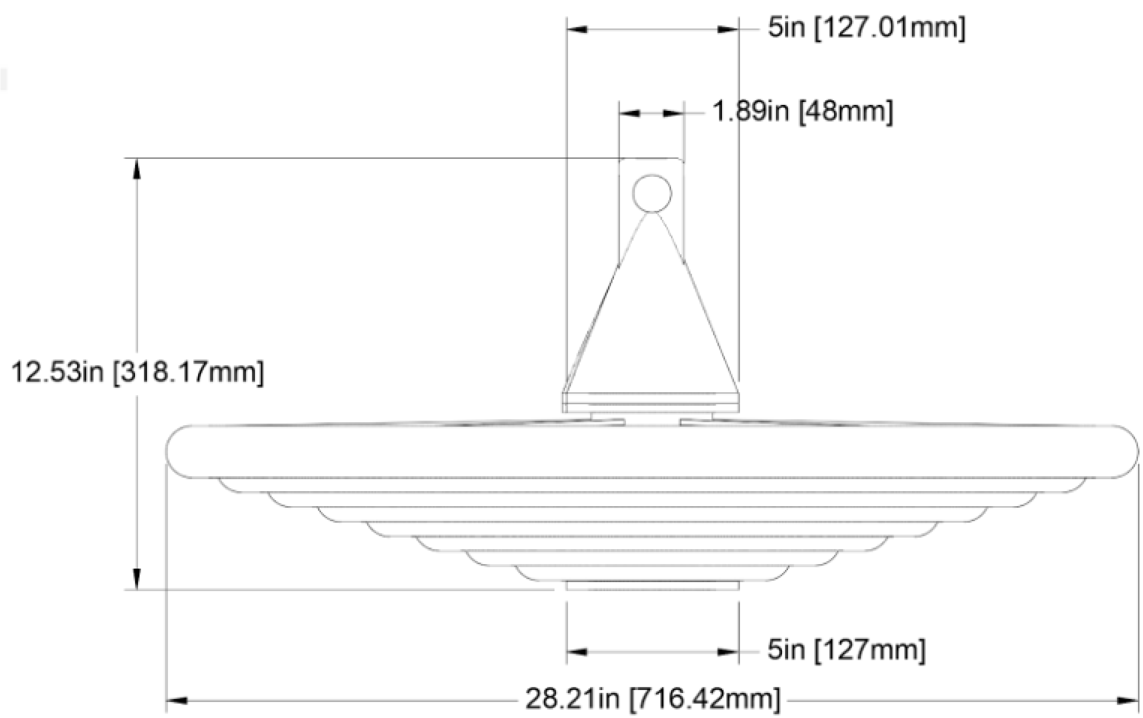


Figure 9: Dimensions of deployed payload

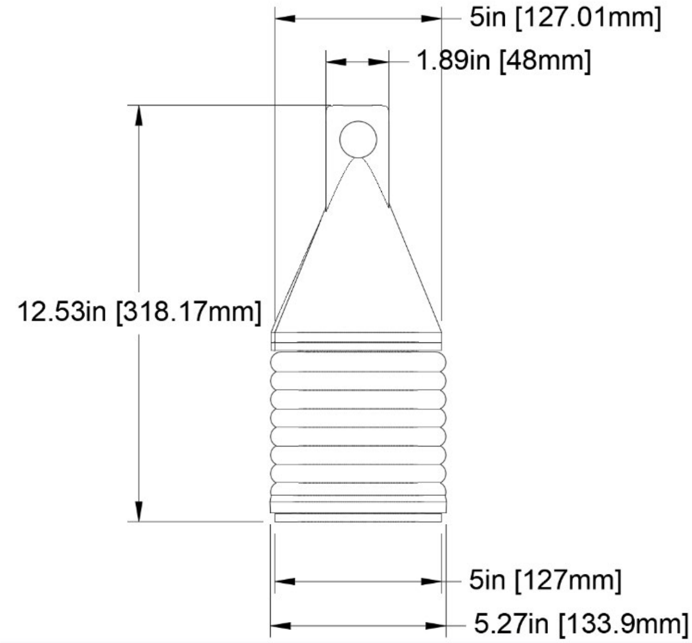


Figure 10: Dimensions of packed payload

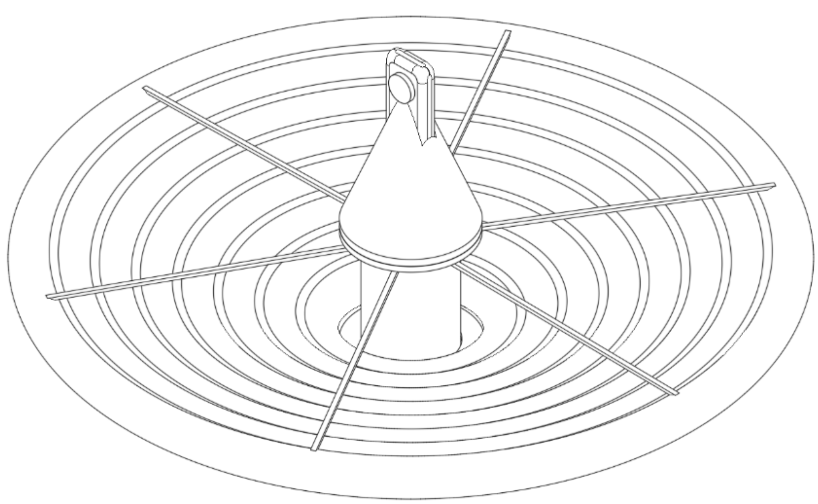


Figure 11: Drawing of the payload showing the top side in detail

The Drag Bag is topped with a 360 camera to capture the deployment of the CO2 cartridge. The STEMnauts are zip tied to seats on a capsule base plate, and in order to protect them, a protective capsule shell is installed. These two sections are screwed together using M8 screws. Beneath the base plate is the payload core, valve, valve motor, and CO2 cartridge. The payload core supplies the majority of the weight to reach the 5 pound minimum. Connected to the deflated drag bag, the CO2 cartridge can easily be deployed. The drag bag itself is analogous to an inflatable and takes some elements from a hot air balloon. The bag is stitched in a way to have each layer's diameter smaller than the previous allowing for a slightly conical shape. Kevlar lines attach the edges of the bag to the main capsule, preventing it from inflating in the wrong direction.

4.2.3. Concept of Operations

1. **Payload Assembly**
   a) The payload assembly and flight configuration will take time and can be mostly prepared days before launch, with the exception of the CO2 cartridge installation.
   b) In the final preparations, the CO2 cartridge will be installed, STEMnauts will be zip-tied to their seats, the 360 camera will be charged and powered on, and final M8 screws will be installed.
   c) The Drag Bag will be zip-tied closely to the payload core, keeping it compact for flight.
2. **Vehicle Ascent**
   a) The Drag Bag will be in its folded configuration inside the upper airframe of the vehicle.
   b) The payload's software will be in lockout mode, the conditions of which are detailed in 5.3.
3. **Deployment**
   a) During main parachute deployment below 800 feet, the payload, which is attached to the main parachute shock cord, will be pulled out of the vehicle and in a position that it can release from the vehicle.
   b) When the deployment criteria set in the computer (See 4.3) are met, the payload will mechanically release from the shock cord and separate from the vehicle.
   c) The valve will open, releasing the CO2 into the Drag Bag, causing it to rapidly inflate to just higher atmospheric pressure. This will slow the payload's terminal velocity to a safe landing velocity.

d) The 360 camera will be recording to capture the entire deployment and inflation process.

4. **Landing**

   a) The payload will contact the ground, and as the Drag Bag remains inflated, it will help keep the payload upright.
   b) The payload is intended to land and remain in an upright position.

5. **Recovery**

   a) The recovery team will carefully release all CO2 from the system using a relief valve, deflating the Drag Bag and effectively making the payload safe.
   b) The Payload will be returned to the team area (or inspection area, during nationals) and disassembled to inspect the well-being of the STEMnauts.

4.3. Electronics

At the heart of our payload are the electronics, consisting of computers, a sensor suite, and additional peripheral devices to carry out operations.

The central computer will be a Teensy 4.1, a microcontroller that uses the Arduino IDE and operates similarly to Arduinos, just with additional I/O capabilities. This computer will use a BMP388 barometer (or equivalent) to measure the altitude in order to carry out core functions of the payload. We do not currently have plans beyond the single sensor, however, we can easily add an inertial measurement unit (IMU) and/or redundant barometers. Additional components will be added to indicate payload operationality, such as LEDs or audible buzzers. These serve to indicate to our team that the payload is in a ready-for-flight condition, or if there is a problem that we need to work before flight.

The computer will control two mechanical functions of our payload, the payload release mechanism and inflation of the Drag Bag. A small motor will be used to release a mechanical connection attaching the payload to the vehicle shock cord, sending it into freefall. Secondly, the computer will control a solenoid valve to release the CO2 pressure into the Drag Bag.

The payload software will serve several functions, including utilizing the barometer data to safety lockout decisions, carry out the aforementioned operations, make the payload easily operable, record data, and additional functions as necessary.

To briefly detail safety systems, here is a breakdown of the safety concept of operations.

- On startup, the barometer will take an initial reading to zero-out the ground level for the above ground level (AGL) altitude variable.
- The payload shall not deploy or release on the ground because it will recognize that it is not descending at the expected range for deployment (approximately -20 to -40 ft/s, right after separation from the vehicle during main parachute descent) and because it is not between 500 and 800 feet AGL.
- The payload will not deploy or release during ascent due to potential sensor misreadings due to an apogee detection feature to ensure the payload can only deploy after apogee.
- After the payload detects nominal main parachute descent rate and is below 800 feet AGL and above 500 feet AGL, it will release from the vehicle and enter into a free fall.
- After the payload drops, the payload should detect it is accelerating downwards, if it doesn't match these fall conditions, Drag Bag inflation will not commence.
- Provided it detects nominal release and it is still above 500 feet AGL the CO2 valve will open to inflate the Drag Bag.
- The valve will stay open afterwards, allowing us to manually release all pressure in the system during recovery.

The electronics used in our payload are familiar and the hardware needed for this project is already on hand. Similar software functions have been previously developed by team members. From our first payload tests, this electronic system and its software will be developed and improved, initially supporting basic data collection before being finished to a final form for the full scale flights. We do not have experience with solenoid valves, which makes that a point of interest for early work and proving

We will finalize our payload battery capacity a future time after we conduct full scale operational tests, including operation of valves and motors. We aim to exceed 3 hours of standby time by as much as our payload volume can accommodate a battery for.

Isolated from the primary flight computer, the STEMnauts will have with them an IMU and microcontroller to measure and record flight forces.

4.4. Cost

Another factor for our payload is cost. Our projected cost for our primary payload design is between $265 and $565 depending on whether or not we have a camera.

Item	Supplier	Cost
1 KG PETG 3D Printer Filament	Prusa 3D	$25
Fireproof Nylon for Drag Bag	RockyWoods	$40
Electronics	Teensy, Adafruit	(On hand)
Insta360 One X 360 Camera	Insta360	$300
CO2 Cartridges (12g)		$30-$40
Valve for CO2 Release		$40-$60
Fittings (Various)		$100

Figure 12: Payload Price Estimates

4.5. Risks and Mitigations

Risks	Mitigations
Failure of the shield to inflate or deploy	Conduct ground tests to ensure the payload is ready to fly.
Payload ejects incorrectly	Thoroughly testing deployment systems and properly simulating event conditions to ensure no errors occur.
Payload gets knocked off course/off center	Distribute the weight load to help payload deploy and stay in the proper orientation.
Improper pressure from CO2 release to properly inflate the bag	Using a smaller/larger CO2 cartridge would help in either providing more or less bag pressure.
The payload bounces awkwardly on landing	Altered center of gravity/distribution of mass will ensure a proper angle in case of any awkward bounces or improper deployment angles.
Payload not landing in correct predetermined orientation	Using the DragBag surface to allow the payload to come to rest.
Payload creates improper amounts of drag required to meet descent rate criteria.	Conduct early payload drop tests to determine the proper bag diameter needed.

Figure 13: Payload risks and mitigations

4.6. Design Analysis

4.7. Material Analysis

Many factors including heat resistivity, flexibility, strength, and more were considered in the potential materials used for the "Drag Bag" payload design. Below is a table outlining the possible materials to be used in the challenge:

4.7.0.1. Hard Shell

Material	Description and Breakdown
PETG Plastic (Primary Contender)	PETG or polyethylene terephthalate is a durable, relatively heat resistant, and strong plastic, which can easily be 3D printed. PETG costs around $25 per kilogram. This is the primary material contender for the payload body.
Steel	Steel, an alloy of iron and carbon, is another potential option and is much more cost effective when compared to fiberglass, which was also considered. Due to its high tensile strength, steel can withstand the pressures of the inflatable shield post expansion. Additionally, steel is malleable and can be manipulated into the desired cone-like shape. But, this material is also a good conductor of heat, meaning it could expose the payload to higher amounts of thermal energy than necessary.
Correx	Corrugated polypropylene, or Correx, is made with one layer, unlike cardboard's three layers, and has a fluted structure. Not only is this material flexible, but also resistant to shattering and in many practical applications is used to protect other materials from damage. However, although durable, it does have its limits in ability to withstand external forces. Additionally, many tests to its flexibility consist of simply folding the material, and not necessarily into a convex cone line shape used in this application.
Acrylic	Acrylic is a plastic made from acrylic acid. It has a hard surface and can be easily manipulated to bend using heat. This material is best for its flexibility and ease to work with. Yet a potential concern is its ability to resist temperatures in the rocket due to its malleability.

Figure 14: Hard Shell Material Selection

4.7.0.2. Inflatable DragBag

Material	Description and Breakdown
Nylon (Primary Contender)	Nylon is a type of synthetic polymer that is known for its durability and moisture resistance. This material would be particularly useful as it is easy to sew and shape into the drag bag. Its high tensile strength would make it optimal to survive high impacts as well.
PVC Tarpaulin	PVC Tarpaulin is a polyester filament commonly used for tarps. It has a strong temperature adaptability and has a better strength compared to conventional Tarpaulin. This means with the immense pressure from the CO2 cartridge, it will be able to withstand the stress. However, the PVC material has a possibility of peeling off inside the PVC for a long amount of time.
Vinyl Fabric	Also referred to as PVC, vinyl fabric has a plastic top and woven backing. With the fabric having a chlorine foundation, it prevents from catching fire easily and is a durable fabric. Yet, PVC Tarpaulin is used in inflatables, vinyl fabric is not as tested when it comes to inflatability. This might pose a challenge, but because of the immense pressure of the CO2 it will likely inflate otherwise.
Ethylene Tetrafluoroethylene (ETFE)	ETFE is a fluorine-based plastic that has a high corrosion resistance and can be used in a variety of temperature ranges, actually functioning as its own heat shield. ETFE is used primarily in inflatable buildings and can inflate in high pressures, something that is especially important when using the CO2 cartridge.

Figure 15: Inflatable DragBag Material Selection

4.7.0.3. Capsule

PETG Plastic (Primary Contender)	PETG or polyethylene terephthalate is a durable, relatively heat resistant, and strong plastic, which can easily be 3D printed. PETG costs around $20-$60 per spool. This is the primary material contender for the capsule and the hard shell.
ABS Filament	ABS offers a strong structural support, while also being non-toxic with a high melting point. ABS costs roughly $20-$50 per kilo.
Nylon Filament	Nylon is very tough as well as heat resistant. However, this heat resistance requires a higher grade 3D printer in order to print with nylon. Nylon costs around $18 per kilo.

Figure 16: Capsule Material Selection

4.7.1. Deployment Systems

In order for the payload to jettison from the rocket, there were two main ideas proposed:

1. Parachute Deployment. The primary idea to deploy the payload is to let it out with the main parachute. Specifically, the payload will be attached to the shock cord slightly below the main parachute. This is the safest idea as the drag bag can simply attach to the parachute out of the rocket and deploy the CO2 cartridge on its own with the barometer system.

2. Pistons. Using two pistons to hold the payload in place from the sides, once the rocket reaches its desired altitude, the pistons will release the payload and a third piston underneath will help ultimately push the payload out from the rocket and through the nose cone. Afterward, the cartridge will then be released to inflate the heat shield above 500 feet.

3. Deploying the Cartridge Early. Due to the CO2's expansion, and that too a quick expansion, before fully out of the nose cone, releasing the CO2 early would provide more than enough force to jettison the payload. Additionally, having another piston underneath would help to push the payload into the proper orientation.

4.8. Alternative Payload Designs

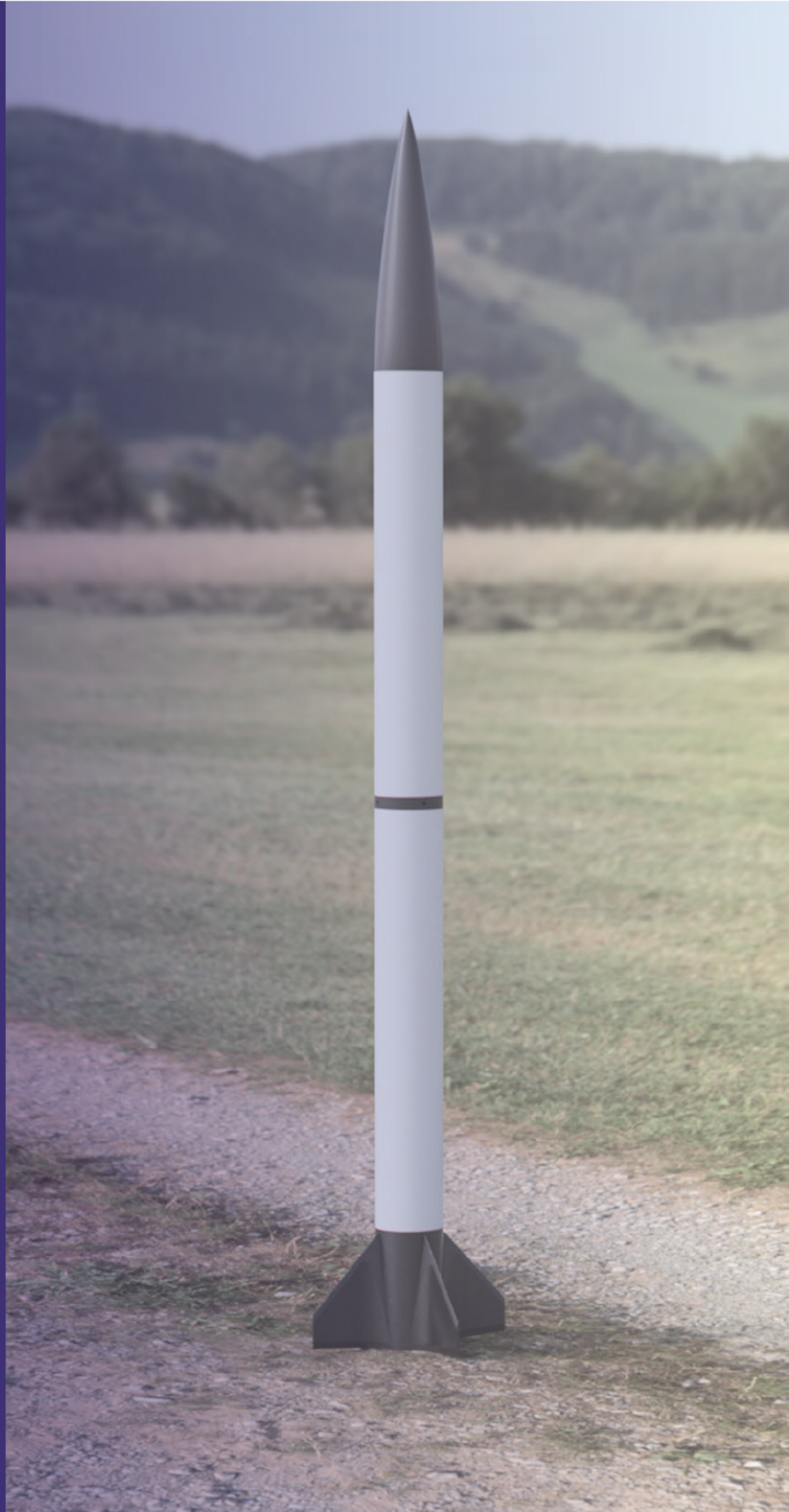
4.8.1. Helicopter Spinner

Taking inspiration from Lenoardo Da Vinci's aerial screw as well as the spinning seeds from a maple tree, the payload would attach to this mechanism and "spin down" to the ground. The design should "screw" through the air like it is moving through a liquid or solid medium. In order to ensure the spinner does not move at a dangerously high speed, the payload portion would have to be heavier. Possible materials could include using canvas and wood for the helix or a stronger material such as fiberglass for the main frame. In this case jettison would be more difficult as there is no thrust provided like that of the CO2 cartridges. As a result, an alternative way to provide thrust must be considered. One potential option is to create a large build up of potential energy to then be released upon jettison. For instance, similar to that of a crossbow or bow and arrow, creating a source of tension that holds the payload back, until it is ready to be released and has enough kinetic energy to exit the rocket in a proper orientation. Also, to minimize heat going to the payload, implementing a simple heat blanket over the payload would protect it before its release.

4.8.2. Glider

Another alternative design is a glider. A glider is a simple aerodynamic plane that isn't propelled by any forces from propellers or engines, instead a glider is deployed at a high height and uses its long sleek aerodynamics design to softly maneuver to the ground. Our design would have a 3D printed glider docked on the side of our rocket, using a rail system programmed to unlock and release the vehicle at a set altitude. From there, an internal mechanism allows the wings to unfold or extend and safely land. Within the glider is a 360 camera as well as space to house our astronauts for their touchdown, as well as a tracker for when the payload lands. Possible materials for this payload include a fiberglass for a stable airframe and 3D filament like TPU or PLA for the fuselage and wings. The main risks associated with this design is the long wing design being knocked back into the rocket around the time of the parachute deployment. This could be catastrophic, as the ripping or tangling of the parachutes with the payload could result in the destruction of both. Another concern is drag before reaching apogee. If the payload were to be docked on the side of the rocket, significant drag and air resistance would ensue, resulting in a reduced apogee. Weight, center of gravity, and wind are all other concerning factors as well. Overall, this payload has a greater risk when it comes to deployment and the stress factors of landing and take-off.

Vehicle Design



5. Vehicle Design

5.1. Vehicle Design Summary

Our vehicle is a 101” long, 5.54” in diameter cardboard and plastic rocket with specific mitigations to strengthen potential failure points. We plan to use a K1050W rocket motor, pending availability. Our rocket will use 1515 rail buttons, and is expected to weigh approximately 15 pounds. The FinCan will be 3D printed, with an external carbon fiber tip-to-tip layup and cardboard motor tube. Our design philosophy is to create a vehicle that is light and easy to construct and that is optimized to support our payload.

Figure 17: Artistic render or our vehicle

5.2. Vehicle Requirements and Constraints

Based on lessons learned from our previous year participating in SLI, the main focus of our vehicle team will strive to design a minimalistic and fail-proof vehicle easy to design and manufacture. Additionally, given the greater challenges presented in the USLI payload competition, we will give special attention to designing a vehicle around the payload, not designing the payload around our vehicle. Thus, we will present a flexible design capable of rapid and major design changes, fast manufacturing, and turn-around times. This gives our payload team more flexibility to design a successful payload, despite the unanticipated project obstacles and challenges that we expect to face throughout the season.

First and foremost, our vehicle will be designed to meet SLI handbook requirements below:

- The launch vehicle must carry an engineering payload to an apogee between 3,500 and 5,500 feet above ground level (AGL).
- The launch vehicle must be designed to be recoverable and relaunchable at least 3-4 times.
- The total impulse of the motor must not exceed 2,560 Newton-seconds, which is in the K-class range.
- The launch vehicle must have a minimum static stability margin of 2.0 calibers at rail exit.
- The launch vehicle must have a minimum thrust-to-weight ratio of 5:1 at liftoff.
- Any structural protrusions must be located aft of the burnout center of gravity, with exceptions for camera housings that have minimal aerodynamic effect.
- The launch vehicle must accelerate to at least 52 feet per second at rail exit.
- The recovery system must use redundant altimeters and commercially available batteries. Altimeters must be armed by a mechanical arming switch accessible from the exterior when on the pad.
- Descent time must be limited to 90 seconds maximum from apogee to touchdown.
- Independent sections must limit kinetic energy to 75 ft-lbf at landing.
- The recovery system must stage deployments, with a drogue at apogee and main at a lower altitude.

Going beyond SLI handbook requirements, we also hope to meet our own vehicle goals and requirements:

- Accommodate the planned payload the best it can, having both enough interior volume and mass margin.
- Quickly manufacturable, with the goal of being able to have all critical components either on-hand or 3D printable as to have the capability to produce replacements in a matter of days.
- Keeping mass down, as previously mentioned, we want to give the payload the widest potential mass margin possible, therefore favoring lighter vehicle materials.

5.3. Technical Design

5.3.1. Technical Drawings

A brief summary of components can be found in 4.1.

We have designed our rocket in OpenRocket and then modeled it in Fusion 360. This is necessary for us in part due to the 3D printed components in our design, but it also allows us to efficiently make technical drawings. We have also designed our payload in Fusion 360, allowing us to easily integrate them conceptually.

Below are the design and technical drawings of our vehicle.

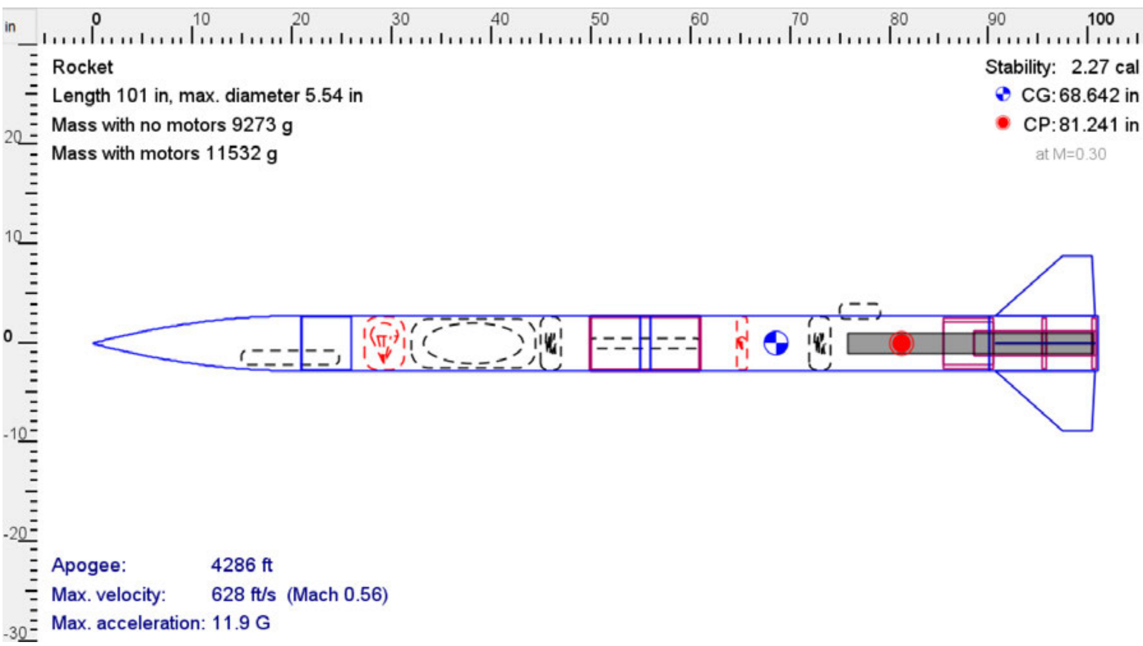


Figure 18: OpenRocket design of our vehicle

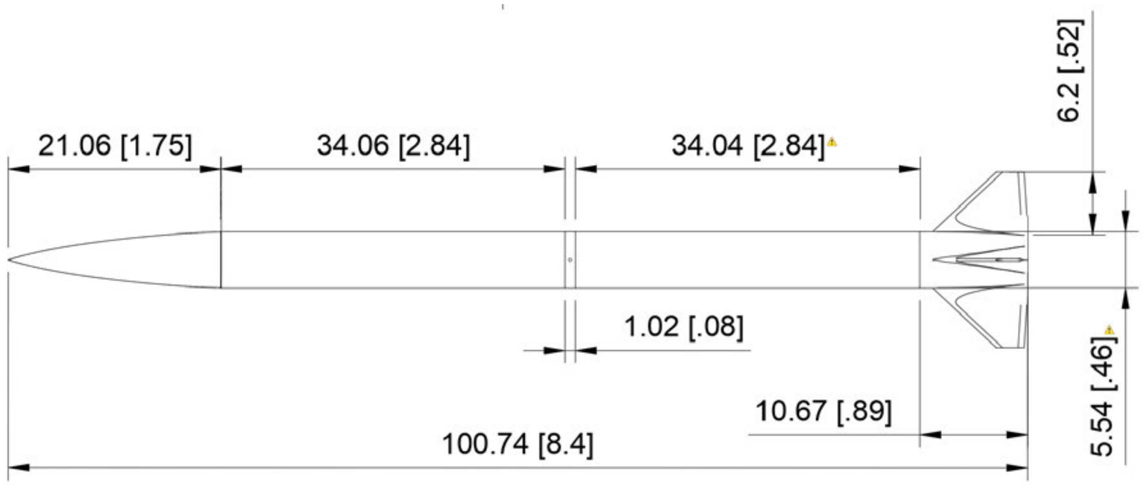


Figure 19: Dimension drawing of our vehicle from a side view

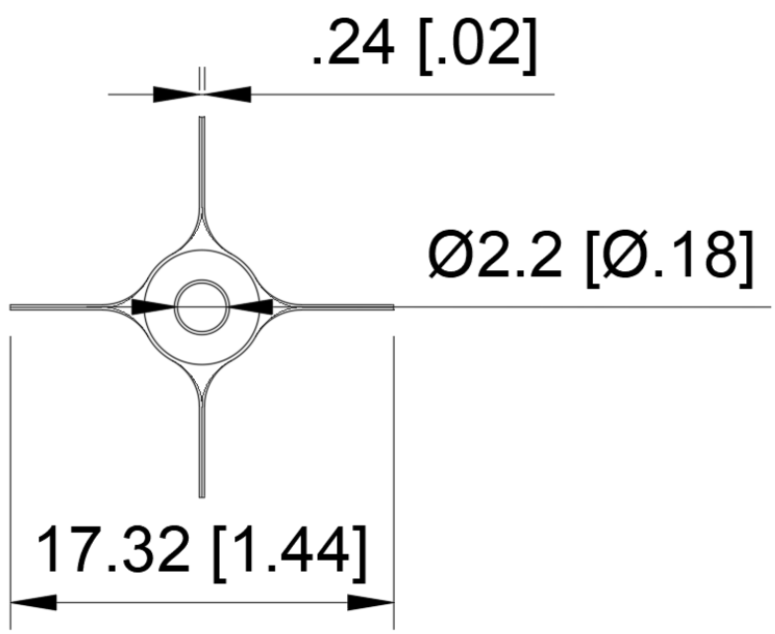


Figure 20: Dimension drawing of our vehicle from a bottom-up view

5.3.2. Hardware Selection

The material selections for the various hardware components of our vehicle were driven by a combination of technical factors and team-derived requirements. The key considerations for material selection for the vehicle, in approximate order of importance, include prioritizing low mass, ease of manufacturing (including procurement of needed parts, preparation of materials, and assembly), short-notice reproduction of the vehicle, and the best accommodation of the payload. Incorporating lessons learned from previous years, we have created the following plan.

5.3.2.1. Final Design

Hybrid 3D Printed, Cardboard, and Consumer Parts

Our thesis of this approach is to minimize manufacturing time and difficulty while allowing us to produce a new vehicle in the timespan of a few days if needed.

All 3D printed parts in this approach would be made using PETG, a plastic with a high melting temperature and hardness, with the drawback of being brittle on occasion. Many of these parts incorporate some form of composite material added post-print to add strength and rigidity characteristics. The key concern with 3D printing parts for the rocket is in regards to the layer lines produced during the 3D printing process, essentially creating hundreds of individual breakpoints in the component. This, while not a concern in every application of 3D printed parts in our vehicle, can be mitigated by sealing in those gaps and adding a reinforcement layer using epoxy impregnated composite materials, such as fiberglass or carbon fiber.

From top to bottom, the components of this approach would be as follows:

- Nose Cone: A commercially available polyethylene plastic nose cone modified to accommodate appropriate recovery hardware and GPS tracker. We intend to utilize a 3D printed GPS tracker bay and mount, where a threaded socket will be epoxied into the base of the nose cone allowing a threaded bay for the GPS tracker to screw into it. Appropriate RF shielding will be added where necessary. The GPS tracker bay system will bear no loads and be operationally isolated from the rest of the vehicle.
- Upper Airframe: Made using cardboard tubing, ideally a thick variant providing more resistance to mishaps.
- Avionics Bay: Made using a modified commercially available avionics bay kit from LOC to make procurement of compatible sized parts easier. A 3D printed avionics bay sled will be added, and any additional reinforcements needed will be made. The avionics bay will use 3D printed guides to ensure alignment of arming switches with holes in the avionics bay switch band.
- Lower Airframe: Made using the same cardboard tubing as the upper airframe.
- Fincan (Section of airframe incorporating the fins, body section, and motor mount): To be 3D printed, incorporating cardboard and composite materials where appropriate. The goal with 3D printing the Fincan, despite many flaws with that approach, is to reduce material preparation, material procurement time, and manufacturing time. To mitigate weaknesses of 3D printing, mainly

3D print lines, the external surface of the Fincan would be laid up with fiberglass or carbon fiber, sealing in the 3D print lines and providing a durable and waterproof outer layer. As for the motor mount, a traditional cardboard motor tube would be epoxied into the Fincan, with a consumer motor retainer epoxied on the end. This is to insulate the plastic Fincan from the heat of the motor. The lower airframe will also have a set of 1515 rail buttons installed.

5.3.2.2. 3D Printed FinCan

Our 3D Printed PETG FinCan will be printed on a Prusa XL 3D printer which has a build volume of 14”x14”x14”. In order to maximize the length of our fins, we’ll be printing our vehicle diagonally, allowing us to design our FinCan to be 17” wide (up to 19.7” wide).

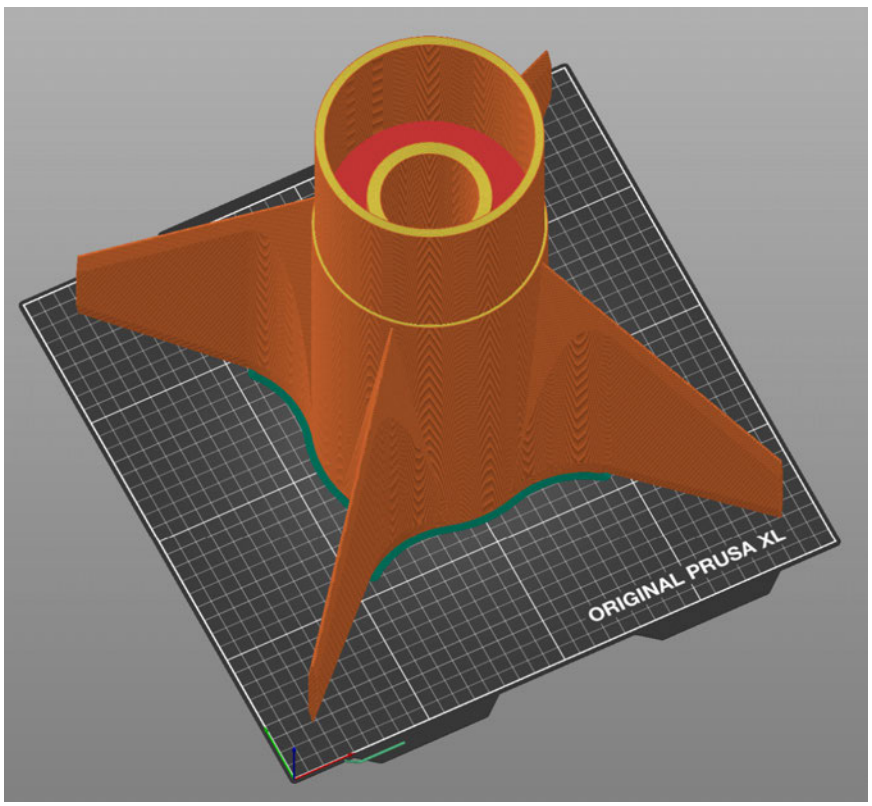


Figure 21: PrusaSlicer Gcode view of our FinCan

Our current design has a large aft surface area from the fillet shapes which will aide in surface adhesion, but additionally, we will print with a brim to further increase this area. The print specifications for the FinCan are as follows:

- Filament Used: 5.38 lb (2.44 kg)

- Print Time: 1 day, 20 hours

After printing, our FinCan will undergo a carbon fiber tip-to-tip layup, meaning carbon fiber will be applied on the surfaces of fins and the interior area between them, such as the 3D printed body. In preparation for this, the FinCan will be heavily sanded, starting with a high grit and then moving towards a low grit, ensuring effective bonding with epoxy. We have conducted successful test applications for this purpose on PETG.

We will use two layers of 5.7oz carbon fiber, the initial layer will be covered with PeelPly, a finishing material that creates a rough surface effective for additional bonding of the next layers in addition to more sanding. The second layer will use Mylar to create a clean glossy surface finish.

5.3.3. Recovery System

Our goal with our recovery system is to have a reliable and robust configuration that is easy to set up and unlikely to need replacements. Using lessons learned from last year, this section will detail recovery hardware and electronics on the vehicle.

5.3.3.1. Recovery Hardware

Our vehicle will use a standard dual separation dual deploy setup, meaning the vehicle will have two independent ejection charge events, each deploying a parachute.

The separation points on the vehicle will be at the nose cone for the main parachute and at the aft of the avionics bay by the lower airframe body for the drogue parachute. Shear pins will be installed at separation points in quantities deemed appropriate through ejection charge tests.

Both segments of our vehicle will use 25-foot-long 7/16th inch kevlar harnesses from OneBadHawk. These harnesses will attach to quick links on eye bolts and U-bolts in the nose cone and avionics bay.

The main parachute, in the upper airframe, will be a 48” Iris Ultra Compact Parachute from Fruity Chutes, which has a 2.2 coefficient of drag in order to satisfy SLI requirements. The drogue parachute will be a Heavy Duty 48” Hemispherical parachute from Spherachutes. These parachutes will be looped through a swivel, which is installed on a quick link tied to the shock cord.

These parachutes will be protected using “Flame Shields” from Rocketman Parachutes. These are circular Kevlar/Nylon fireproof blankets that wrap the parachutes in order to keep them from the heat of the ejection charges. Flame Shields also include a d-ring to attach to the quicklink that the parachutes will be attached to.

5.3.3.2. Avionics

Our avionics plan sticks to using flight computers we have on hand and are familiar with. Two sets of fully independent and redundant Strattologger CF flight computers will control recovery deployment events. These independent systems will each consist of the computer, a 9-volt battery, a power switch, and main and drogue parachute ejection charges. One set of electronics will be designated as the primary set, and the other will be the back-up set with delays on its ejection charges.

We will be using pull pin switches and pins, which are attached to 'remove before flight' tags. These switches cut power to the flight computers when closed and power up the flight computers when opened. These switches will be placed upside down, so any G-forces from flight will push the switches in the open position. As previously mentioned, we will be using 3D printed guides for the avionics bay coupler and sled to effectively line up switches with holes in the switch band in order to address previous issues. We have previously verified that these systems will exceed the three-hour standby time required.

5.3.3.3. Ejection Charges

The final size of our ejection charges and subsequently their cases will depend on the results of ejection charge tests, however, the fundamental design concept will remain the same.

There will be a total of four black powder ejection charges on our vehicle, a primary set of main and drogue charges and a back-up set. The back-up set of charges will be slightly more powerful than the primary set to ensure successful deployment in the event the first set was underpowered.

The charges will be installed in PVC end caps, assembled by the team mentor using fireproof cellulose insulation and tape as necessary. The ejection charge igniters will be plugged into Wago connectors, which will have wires going to the avionics bay. This allows us to install the igniters for the ejection charges after the avionics bay is assembled and the safety switches are installed. The lead wires from the Wago connectors to the avionics bay will be shielded in copper tape to protect them from possible RF interference from the GPS tracker.

5.3.3.4. GPS Tracker

We will be using a Big Red Red Bee 70cm 100mw GPS/APRS Transmitter to track our rocket. This tracker will be operating in Ham Radio bands under the team leads' Ham Radio technician license. We will use an APRS receiving ground station to track the rocket's position, and the coordinates will be displayed on a tablet. These coordinates will then be handed off to the recovery team after landing.

The GPS tracker will be installed in the nose cone using a 3D printed bay detailed in 4.3.1. Copper tape will be installed on the tracker as well as other positions on the avionics bay to shield the flight computers from RF interference.

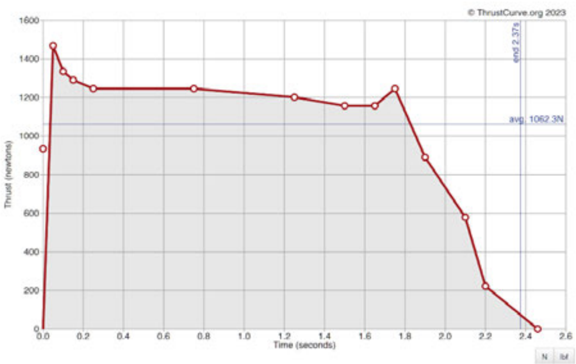
5.3.4. Motor Selection

Our analysis and selection of motor candidates are heavily driven by current availability. Our vehicle design is pushing the upper limit of motors in the K-class, limiting us to both high total-thrust motors and high average thrust motors. We have selected many motors at this time because of dramatic availability shortages at the moment, potentially limiting us at the time of purchase. Due to the nature of our 3D Printed FinCan, we are able to change our motor mount size to a reasonable degree until our final motor selection in the PDR. We will choose our final motor based on simulations, weight of our vehicle, and availability of motors and hardware.

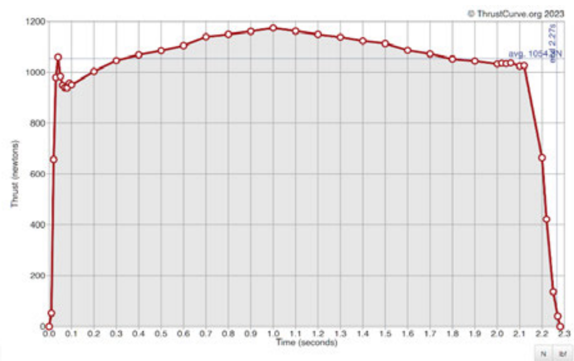
We have selected the following motors, starting with our current preference of the Aerotech K1050W.

Motor Designation	Manufacturer	Case Size	Total Impulse	Average Thrust	Anticipated TWR	Anticipated apogee (ft)	Propellent	Burn Time
K1050W	Aerotech	RMS-54/ 2800	2,426.4 Ns	1,132.9 N	9.63:1	4256	White Lightning	2.1
K1440	Cesaroni Technologies	Pro54-6G	2,372.0 Ns	1,437.0 N	13.01:1	4055	White Thunder	1.7
K1999	Aerotech	RMS-98/ 2560	2,540.0 Ns	1,887.4 N	15.61:1	4083	Warp 9	1.3
K1085	Cesaroni Technologies	Pro75-2G	2,412.0 Ns	1,113.0 N	9.16:1	3870	White Thunder	2.1
K590	Cesaroni Technologies	Pro54-6G	2,397.6 Ns	590.5 N	5.44:1	4161	Classic/Dual Thrust	4.1

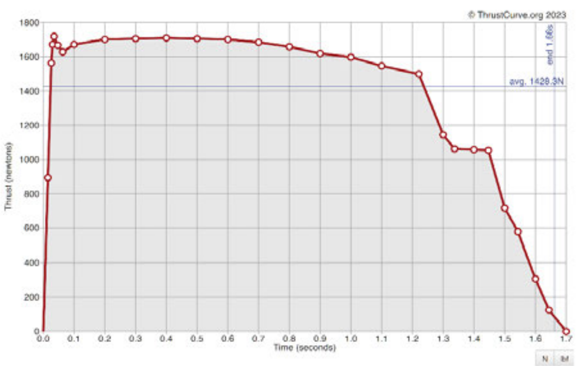
Figure 22: Table of our motor selections



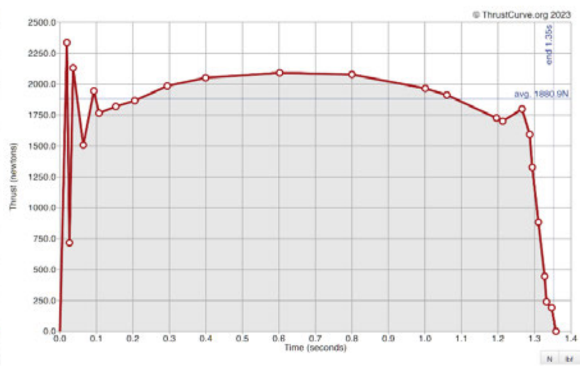
(a) K1050W



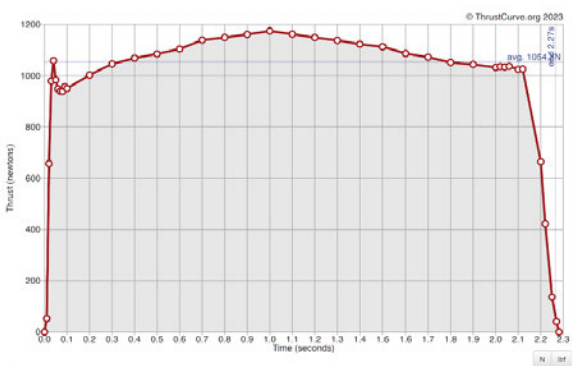
(b) K1085



(c) K1440



(d) K1999N



(e) K1085

(f) K590

Figure 23: Thrust curves of selected motor options

5.4. Simulations

Our primary simulation is conducted with our primary motor selection, the K1050W, under anticipated conditions for the final fly-offs in Huntsville. While we have a wide range of potential motors, they meet critical requirements all similarly, including but not limited to stability, center of gravity location, and thrust to weight ratio. One note about our vehicle and its simulations is that the payload, which is a major mass component, will be jettisoned shortly after main parachute deployment. This changes two factors: the main parachute descent rate, and the ground hit velocity. We will include two data points for relevant conditions, one where the payload is successfully jettisoned, and one where it is retained. These data points will be separated into different sections detailing those situations. Additionally, we are unable to simulate the payload jettison event, so in order to simulate a nominal deployment, we simulated a flight without the payload to obtain the ground hit velocity, and then adjusted the main parachute size to give the same performance. With mass overrides, doing so will only affect the main parachute descent portion.

5.4.1. Primary Simulation

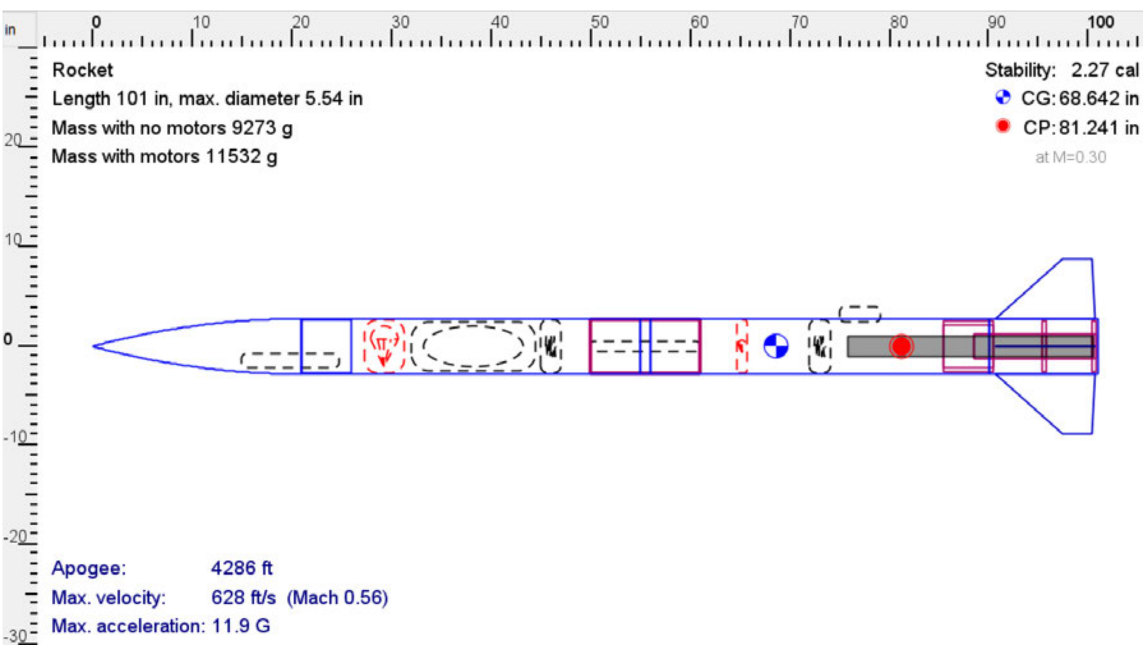


Figure 24: OpenRocket simulated design of our vehicle

Vehicle Parameters:

- Length: 101”
- Maximum Diameter: 5.54”
- Dry Mass: 20.41lb (9,258g)
- Wet Mass: 25.3lb (11,517g)
- Stability Caliber: 2.23
- Main Parachute: 48” (2.2cd)
- Drogue Parachute: 36”

Simulation Parameters:

- Wind: 9.8mph
- Temperature: 71 F
- Pressure: 29.6 in
- Rod Length: 8ft

Performance:

- Apogee: 4298ft
- Velocity at main parachute deployment: 96.2 ft/s
- Maximum Velocity: 629 ft/s
- Maximum acceleration: 39.04 ft/s^2 (11.9G / m/s^2)
- Time to apogee: 15.8s
- Rail exit velocity: 74.5 ft/s

Nominal Recovery Conditions with Payload Jettisoned:

- Total flight time: 86.6s
- Total descent time: 70.8s
- Lateral distance from launch pad: 417ft
- Ground hit velocity: 22.6 ft/s
- Maximum kinetic energy of a single section: 57.7 ft-lbs (FinCan)

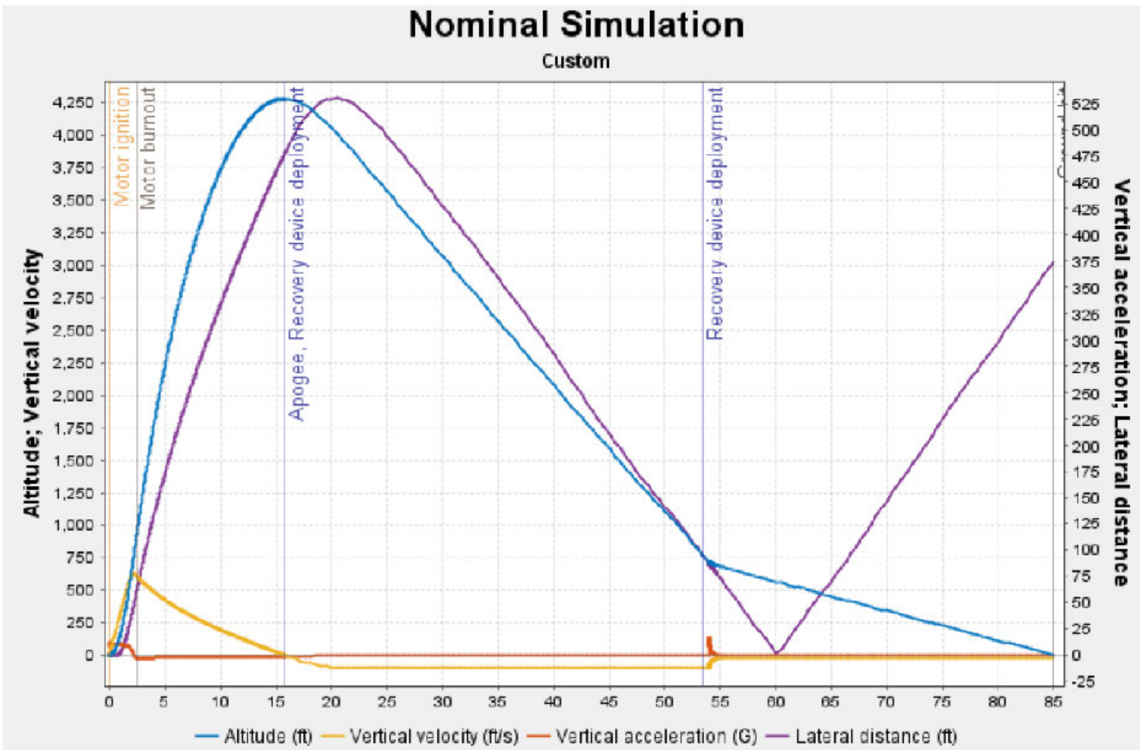


Figure 25: Nominal flight simulation graph

Anomalous Conditions Where Payload Fails to Deploy/Is Retained:

- Total flight time: 81.1s
- Total descent time: 65.3s
- Lateral distance from launch pad: 413ft
- Ground hit velocity: 25.7 ft/s
- Maximum kinetic energy of a single section: 91.6 ft-lbs (Payload bay + avionics bay)

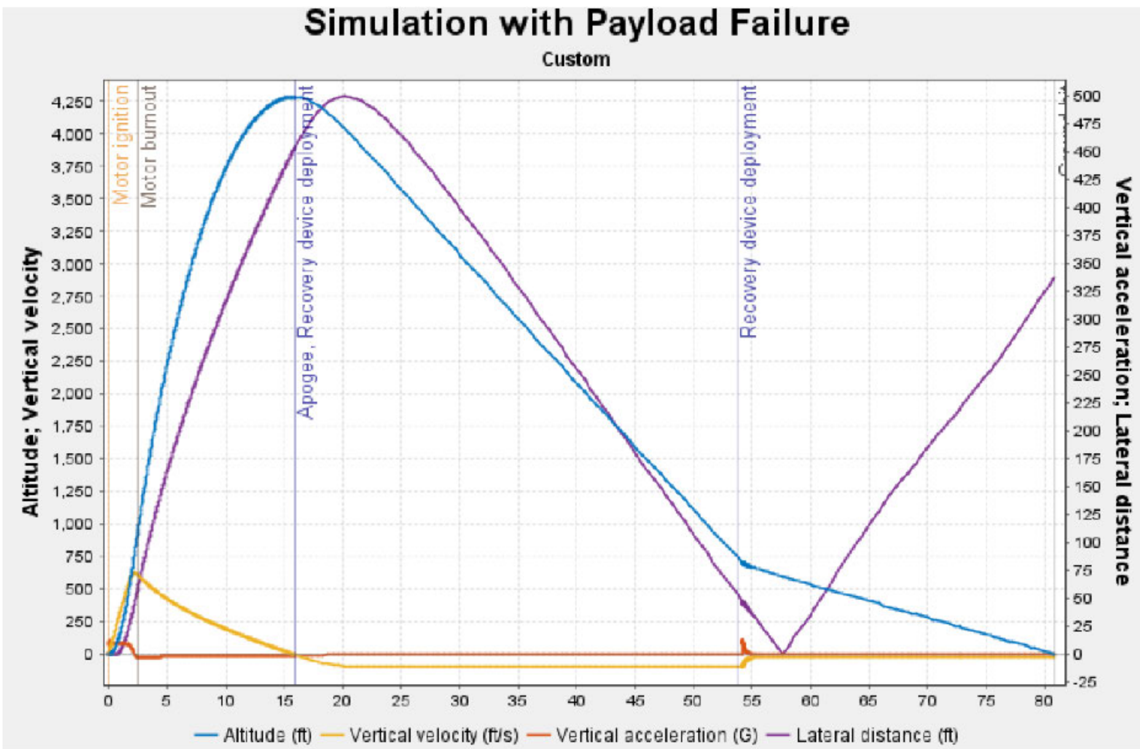


Figure 26: Off-nominal flight simulation graph with payload retained

5.5. Vehicle Design Research and Analysis

We have conducted the following analysis justifying our final design choices.

Material	Usage	Advantage	Disadvantage	Conclusion
Injection molded plastic consumer components	Nose cone	Composites, 3D printing not needed to produce nose cones. Work not needed to produce.	Cannot easily implement GPS tracker into nose cone.	We have selected an injection molded plastic nose cone for our design.
3D Printed FinCan with carbon fiber layup	FinCan	Rapid and short notice production capabilities.	Potentially costly if failed prints occur. Potentially not as durable as some other options.	We have opted to use this method for our vehicle.
Consumer avionics bay kit	Avionics bay	Will fit with the airframe properly, difficult to find correctly sized components otherwise.	Exact specifications of the kit are not available until we have it hands on. Length slightly shorter than ideal, but still acceptable and general lack of alternatives.	We have selected a LOC avionics bay kit for our vehicle.
Phenolic tubing	Airframe (in place of cardboard)	More crush and weather resistance.	Significantly heavier than cardboard, less easy to work with.	We have opted against using phenolic tubing in our final design, however if we find that the phenolic properties are necessary, our design can accommodate this material
Cardboard Fincan with Wood Fins	Fincan, replacing 3D printed/carbon fiber Fincan	Theoretically lighter weight, intrinsically more structurally sound.	Slower to produce, preparation time needed for fin and body tube cutting.	We have opted against using this design to more closely align with our goals.
Fiberglass	Both airframe and fins	Extremely durable and weather resistant.	Heavy, difficult to work with, expensive, and long order wait times.	We will not be using any fiberglass or otherwise commercial composite components in our vehicle.

Figure 27: Vehicle Research Tables

5.6. Subscale Vehicle

We have many objectives we want to achieve with our sub-scale vehicle. We're aiming to make this as much like our full-scale as possible in order to achieve good data and develop relevant knowledge of the vehicle. Due to the nature of our vehicle components, mostly consisting of parts from LOC, it's very easy to get identical parts in a smaller size. We're planning to build a 3" diameter subscale vehicle, or approximately 55% of our full scale. The goals we want to achieve in order are as follows:

1. Demonstrate carbon fiber on sub-scale 3D printed FinCan to verify the technology for the full scale.
2. Conduct ejection charge tests to verify successful jettison of sub-scale payload.
3. Observe flight data, including descent rates and vehicle coefficient of drag.
4. Operate sub-scale payload to test release/jettison functionality, pending readiness.

Initial work on the sub-scale will begin immediately after the proposal milestone, with the first launch opportunity in early October, detailed in the project timeline.

5.7. Cost Breakdown

The tables below details the estimated cost breakdown of our vehicle and additional hardware and consumables. Details of some items and expenses (such as shipping) may be absent from this and as a result a margin will be added to the final budget in 7.3.2.

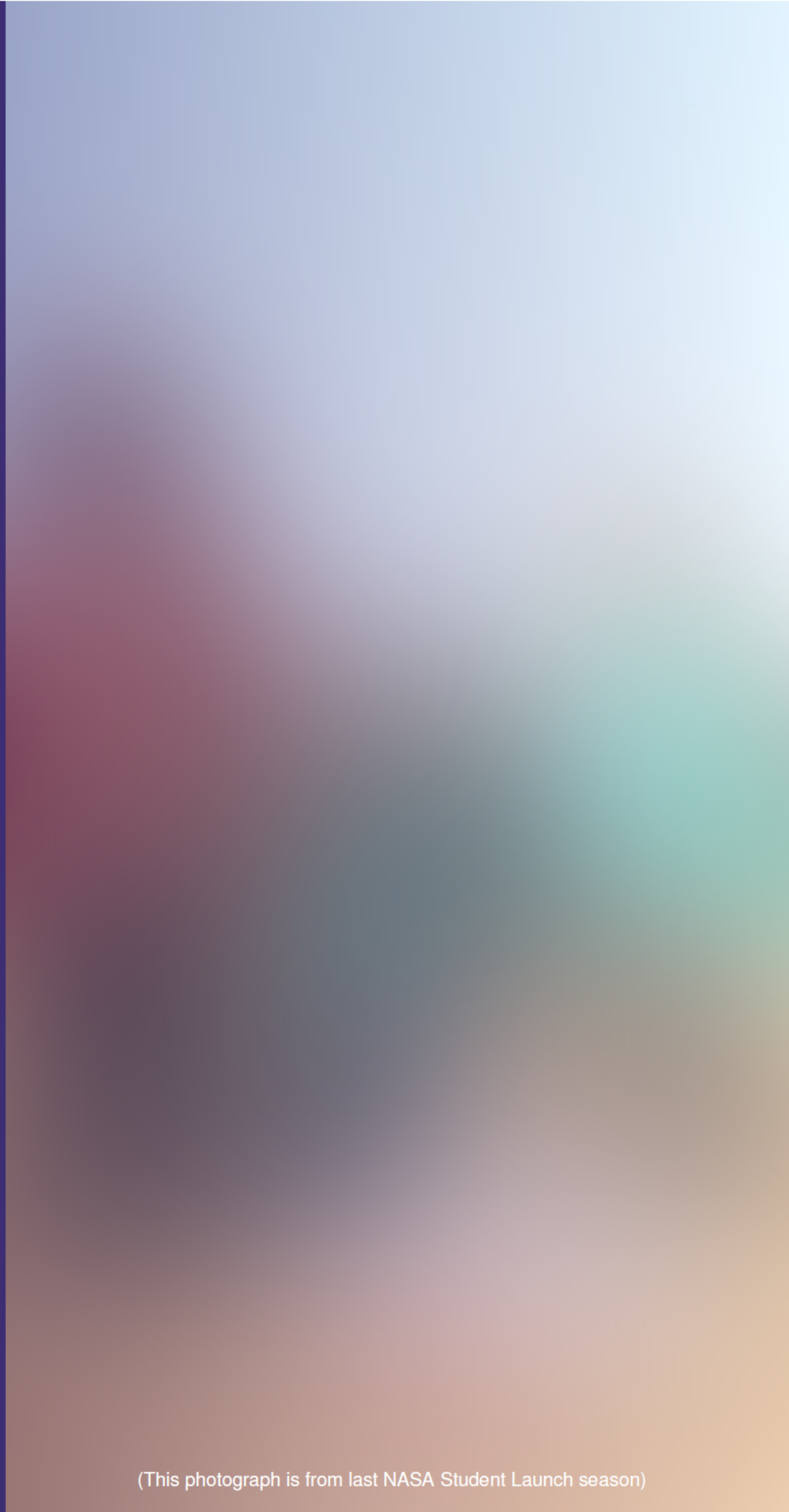
Item	Supplier	Cost
5.38" Plastic Nose cone LONG	Loc Precision	$74.10
5.38" Cardboard Airframe Tubing 34" (2X)	Loc Precision	$82.28
Electronics Bay 5.38"	Loc Precision	$48.26
Cardboard Motor Mount Tubing 54mm 14"	Loc Precision	$4.94
2KG Prusament PETG Jet Black (2X)	Prusa 3D	$100
1515 Rail Buttons (10-pack)	RailButtons.com	$7.50
Carbon Fiber/Laminating Epoxy	US Composites	(On hand)
54mm Aeropack Retainer for LOC tubes	Wildman Rocketry	$31

Figure 28: Vehicle hardware cost breakdown

Item	Supplier	Cost
Aerotech 54-2800 complete hardware	Wildman Rocketry	$268

Figure 29: Motor hardware cost breakdown

STEM Engagement



(This photograph is from last NASA Student Launch season)

6. STEM Engagement

Our current STEM Engagement plan is multifaceted with the goal of satisfying basic requirements first, and then transitioning to a broader outreach plan with longer-lasting impacts.

The first part of our plan focuses on in-person events, such as presentations, exhibits, and conferences. Through past experiences with holding STEM events, we've decided that the most efficient form of outreach we can conduct are table-top exhibits where kids can stop by, we can teach them about a STEM concept, and then they can observe it through a hands-on activity. We have already begun scheduling and conducting these events. In July, at our county 4-H fair, we held a model rocket build event where we had 12 students learn how to build and launch their first model rockets.

Additionally, we have several future events:

- Organizing a STEM day at our county college where we will have guest speakers like former Astronaut Charles D. Walker and a host of hands-on activities for K-12 students to participate in. (Anticipated 200-500 participants)
- Model rocket build workshops with local girl scout troops (20-50 participants)
- STEM concept demos at local events and STEM fairs (Such as the Sussex County Maker Faire and Morristown Festival on the Green)

Through these activities, we aim to engage a significant number of students in diverse activities rapidly, allowing us to shift our focus to more long-term impacts later in the season.

Our long-term goal is to provide resources across the nation to make it easier for new teams to form for the American Rocketry Challenge and form a foundation. We aim to partner with several organizations to ensure the good reception of these resources and will spearhead the project and produce the content ourselves. By Summer 2025, we want to see the impacts of this work from new teams forming for the 2024-2025 TARC season.

Specifics of this plan are detailed in the following timeline.

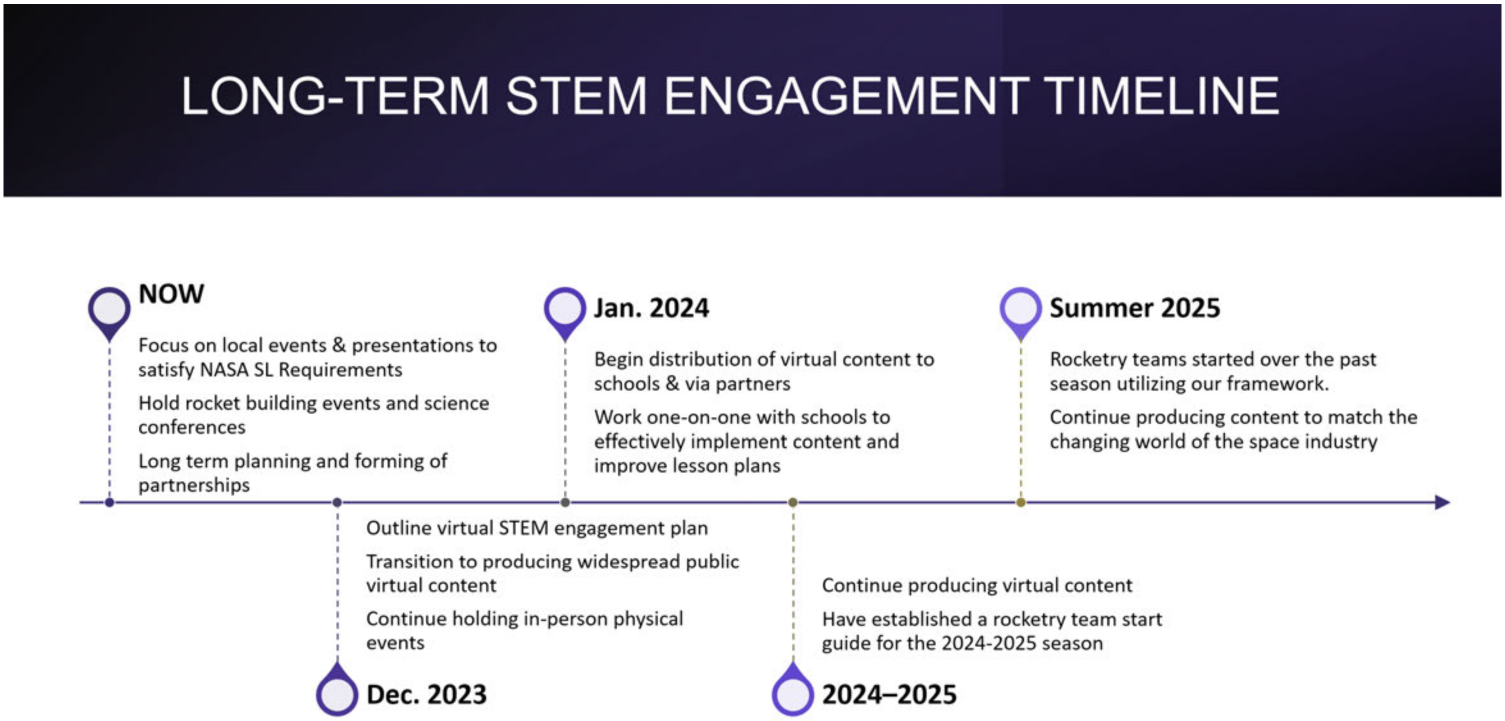


Figure 31: Long term STEM engagement plan timeline

Project Plan

(This photograph is from last NASA Student Launch season)

7. Project Plan

7.1. Project Timeline

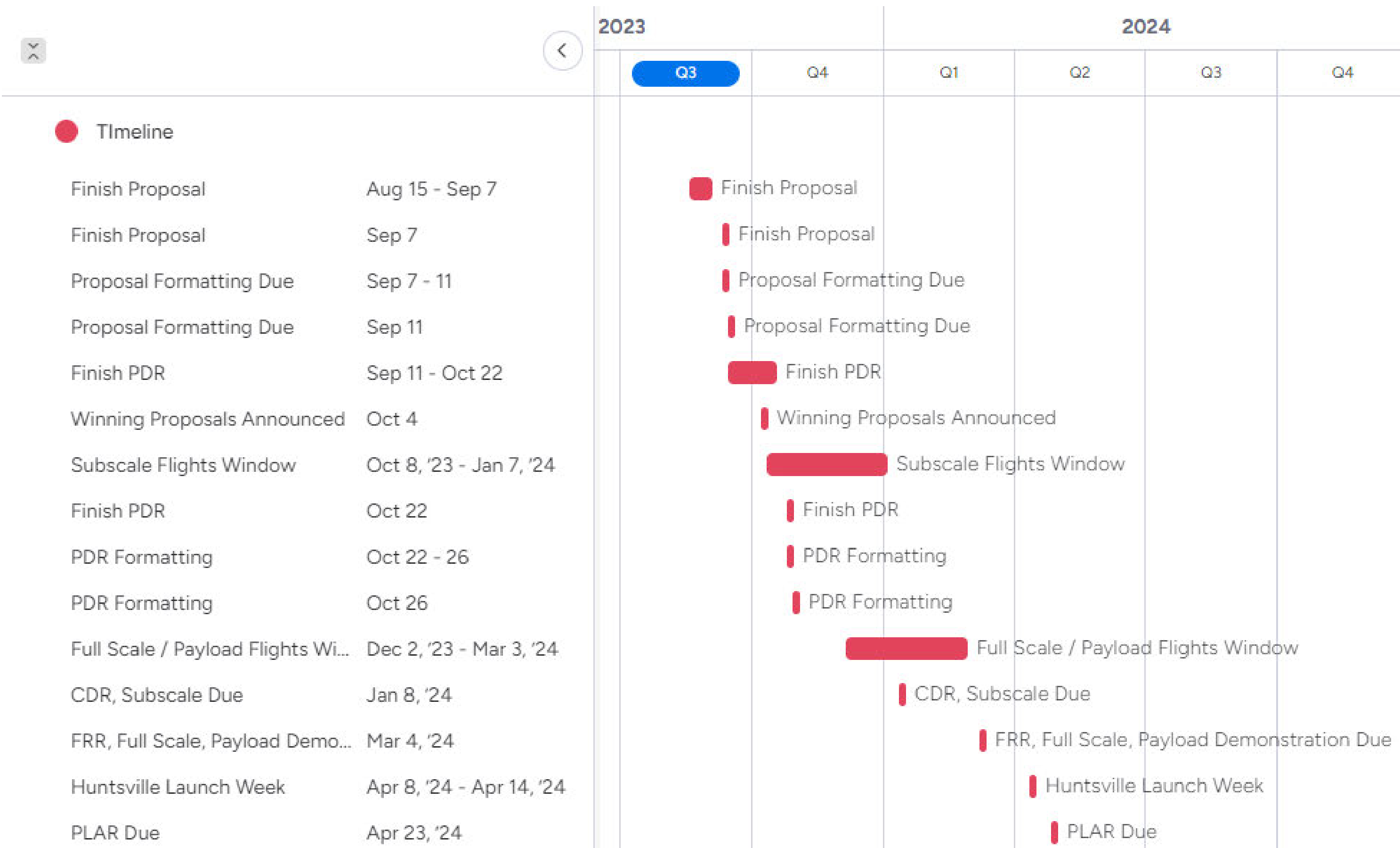


Figure 32: Key Project Milestones

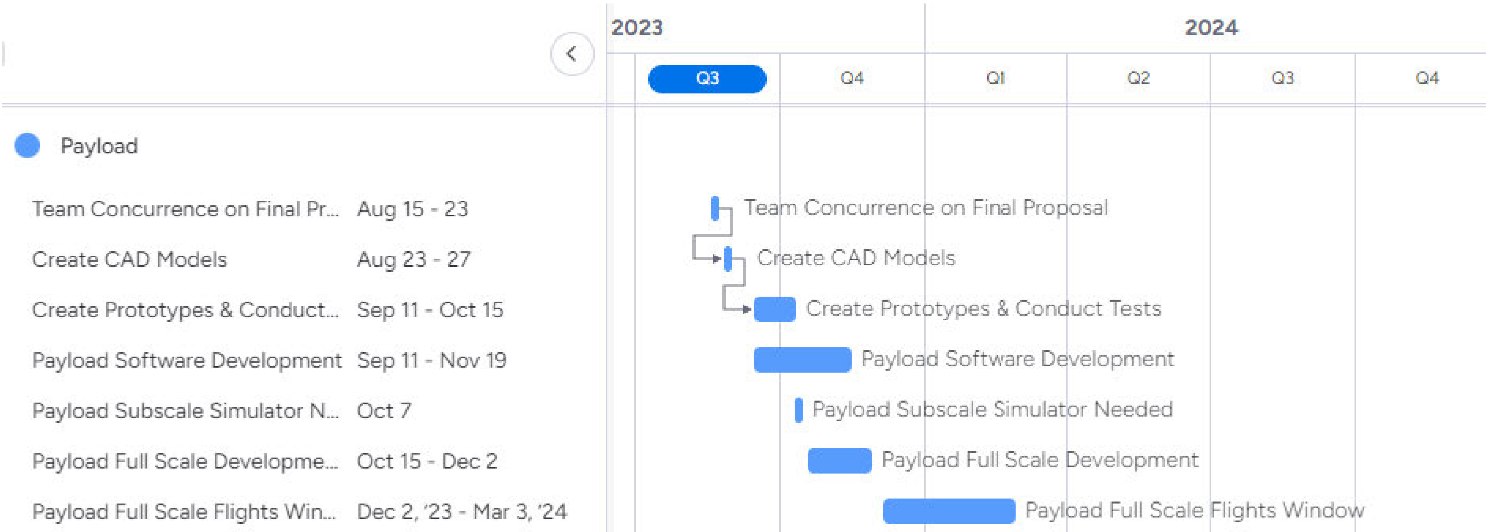


Figure 33: Payload Timeline

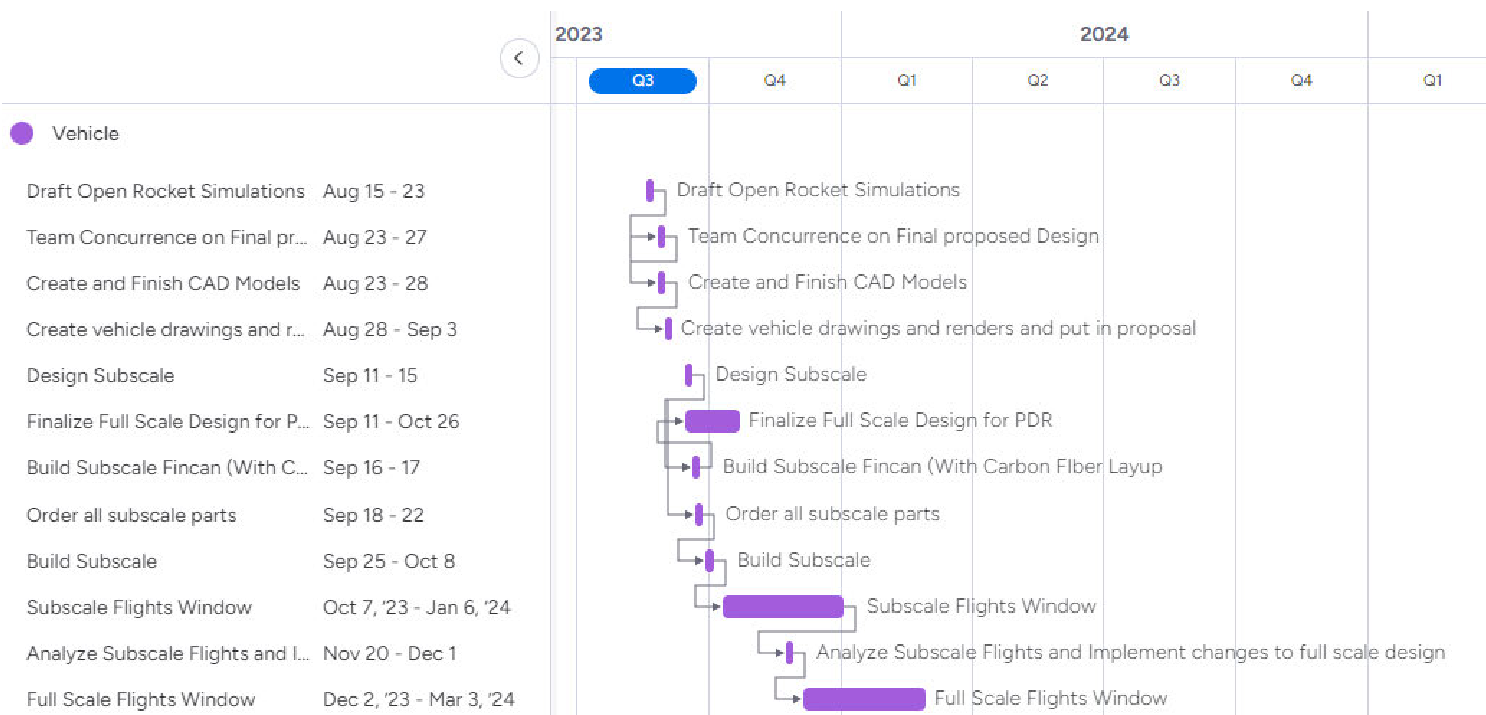


Figure 34: Vehicle Timeline

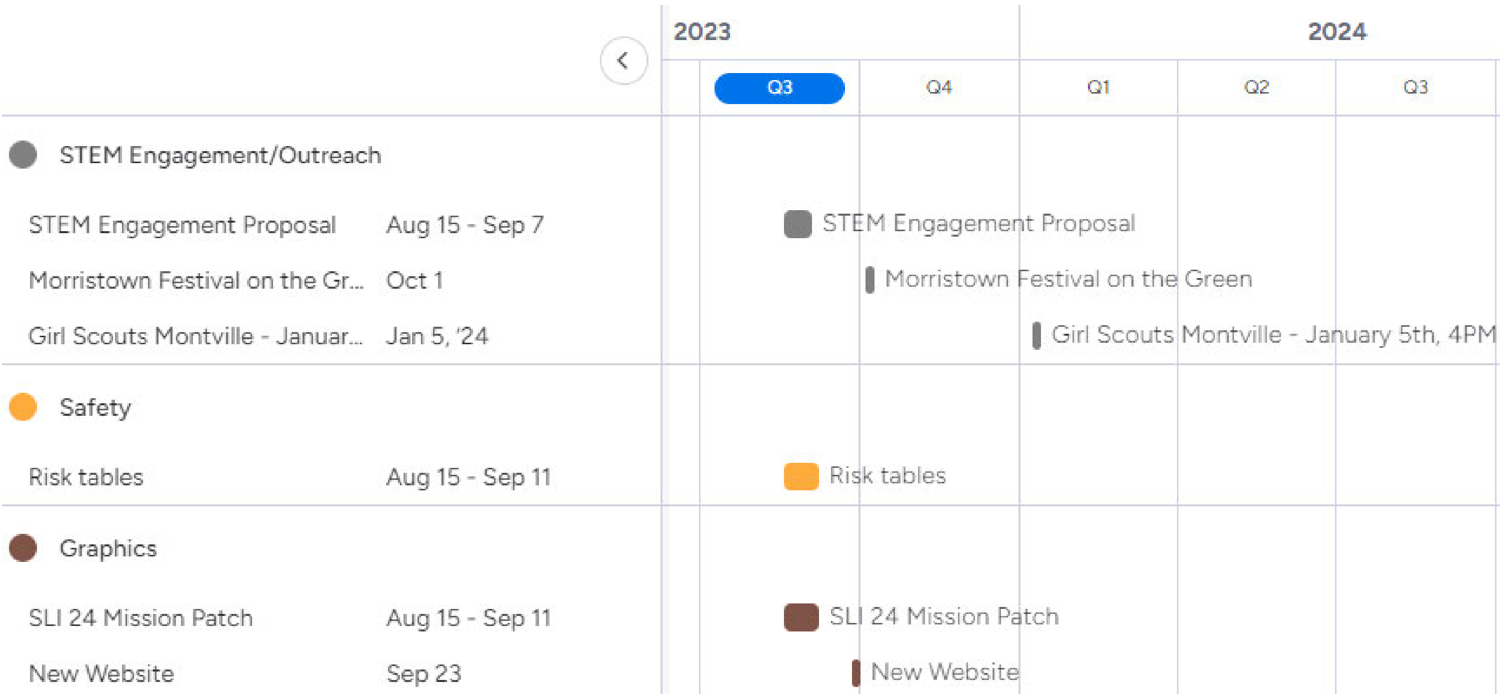


Figure 35: Miscellaneous Timeline Items

7.2. Technical Readiness

In order to manage our timeline and identify risks, we have conducted an objective analysis of technical readiness of our payload, vehicle, and other aspects of our work and intend on maintaining this throughout the year showing where progress has been made.

We will be utilizing NASA Technical Readiness Level (TRL) definitions for this, with adaptations as needed. Our determined TRL for each area may come from past experience or specific research conducted for the purpose of this design, specific details will be provided on the scope of each TRL.

For our purposes, “space environment” in the TRL scale will simply mean having been flown before by our team yielding relevant data, not necessarily specifically for this project. “Flight qualified” and “flight proven” will only come as a result of testing specific to this project

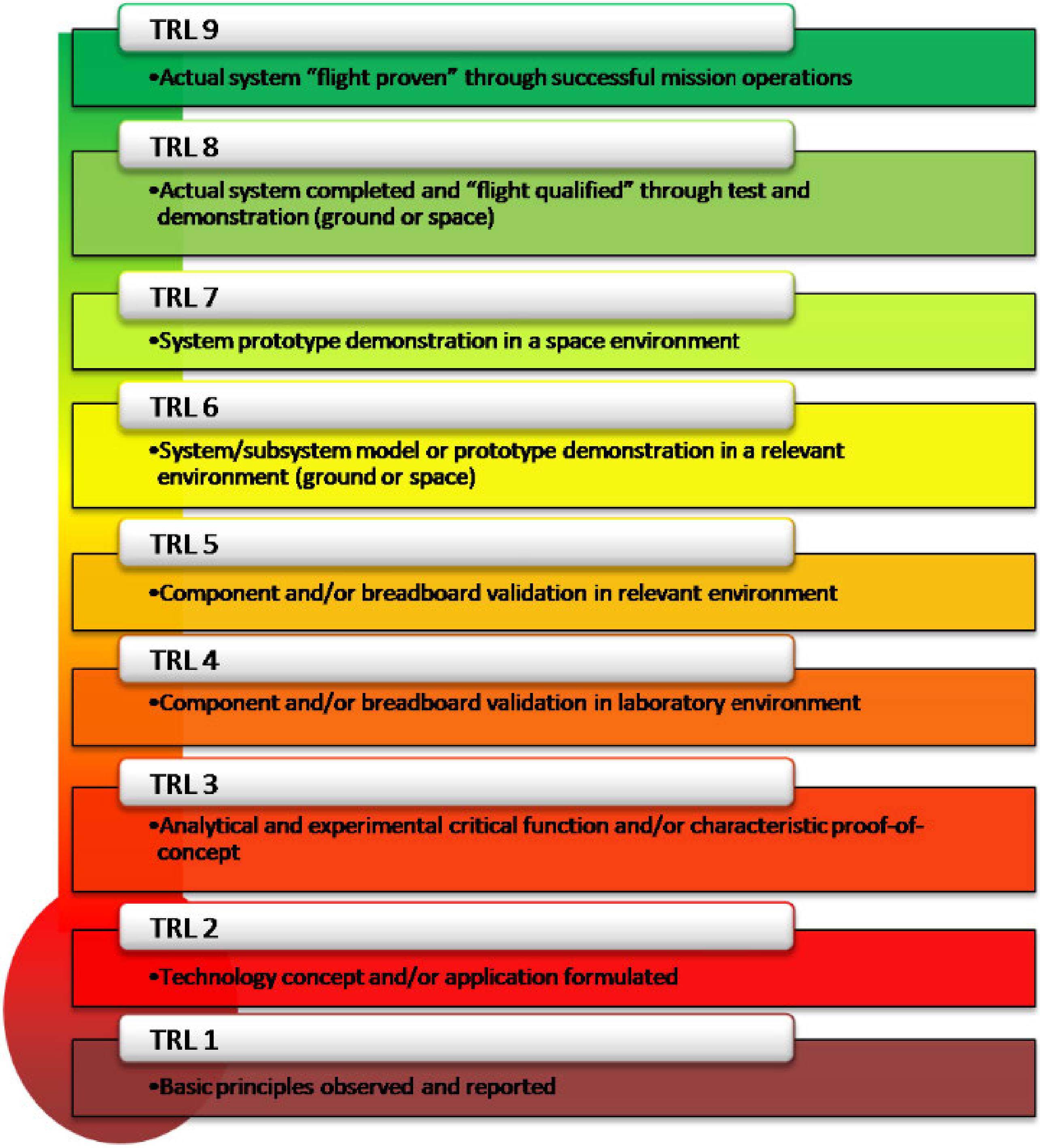


Figure 36: NASA Technical Readiness Level scale

Component	TRL	Description	Confidence	Not Tested
Vehicle	5	Successful small scale demonstrations, full scale prototypes able to be conducted early-on.	High	Innovative full-scale components
Payload	2	Basic plan and concept documented.	Medium	No hardware or software tests conducted.

Figure 37: Overall project technical readiness

Component	TRL	Description	Confidence	Not Tested
Carbon Fiber on PETG for FinCan Layup	6	Successful layup of mock-up 3D printed PETG fin with carbon fiber specific for this project. Past successful flight carbon fiber laid-up 3D printed fins.	Medium	Full-scale layup verifying proper adhesion on the angles of the full-scale FinCan
Nose cone GPS screw-in tracker bay	2	Paper design and size-spec laid out, no conceptual errors found.	High	No hardware built for tests, no RF efficacy testing conducted.
3D Printed motor tube with cardboard inner tube as insulation	6	Past flight successfully conducted using parallel hardware concepts.	Medium	Endurance of 3D printed parts against a full sized K motor intended for flight.

Figure 38: Vehicle technical readiness

Component	TRL	Description	Confidence	Not Tested
DragBag inflatable heat shield/pressurization system	2	Basic concept noted and planned.	Low	No hardware tests conducted.
Avionics and software for deployment	6	Parallel hardware flown and tested for different purposes.	High	Interfaces with DragBag valve or release mechanisms, flight lock-out methods.
Payload deployment from vehicle	2	Basic concepts noted and planned.	Medium	No hardware tests conducted.
DragBag inflatable heat shield construction	2	Basic concept noted and planned	Medium	No hardware tests conducted.
General Mechanical Connections	2	Basic Designs Noted	Medium	No hardware tests conducted.

Figure 39: Payload technical readiness

7.3. Budget and Funding Plan

7.3.1. Funding Plan

Having the proper funding for our team is crucial. Through working with sponsors, earning grants, and crowdsourcing, our team is working to fully fund this year's operating budget.

We have no funds leftover from last year's NASA Student Launch project, and minimal money available from the rest of the club.

As of 9/5/2023, the New Jersey Space Grant Consortium has pledged a price-match for other raised funds up to $5,000. So far, our only source of funding is $105 raised through GoFundMe, which will be priced-matched after our withdrawal.

We do not see our current funding situation as a major risk factor at this time, as most of our funding last year was gained after proposal acceptance during the PDR and CDR milestones. We are working with the rest of our previous sponsors to re-secure our partnership this year, as well as talking with potential corporate sponsors to secure additional funding.

7.3.2. Budget

Our early budget involves a slight range due to possible omission of components, reuse of components, etc. We expect that our budget will decrease over time, however at this time we are going to fundraise with this target in mind. Our maximum optimal funding for this year is $16,772.16.

Figure 40: Vehicle Budget

Component	Quantity	Cost Per	Total
Full Scale Vehicle	2	$348.08	$696.16
Subscale Vehicle	1	$200	$200
Motor Hardware	2	$268	$536
Full Scale Motors	5	$209	$1045
Subscale Motors	3	$45	$135

Vehicle total: $2,612.16

Figure 41: Payload Budget

Component	Quantity	Cost Per	Total
Payload Hardware	2	$265-$565	$530-$1130

Payload total: 30-$1130

Figure 42: Miscellaneous Budget

Component	Quantity	Cost Per	Total
Travel Vouchers	8	Up to $1,500	$12,000
Team Shirts	10+	$53	$530+
STEM Engagement and Outreach Supplies	1	$500	$500

Vehicle total: $13,030

Total budget: $16,172.16 - $16,772.16

7.4. Sustainability Plan

Sustainability remains one of our highest secondary priorities. Ensuring growth, public support, and knowledge transfer is critical to the continuance of our club and teams year over year. As our club's original members begin to age out of the team, ensuring that these objectives are met before we leave is a high priority.

To address these items, we've been implementing several plans over time. Firstly, to address growth, we've been working both over the last Summer as well as developed plans to grow our team. Since the last Student Launch season, we've grown our team from a total of 5 to 8 members, introducing 4 new people to the team. So far, this has yielded a much more comfortable team size, ensuring work is well distributed, but it also permits the loss of some members while still having an operable team. To gain these members, we have exhibited at various events, like Rutgers Day and the 4-H Fair, where members of the public can solicit information about our club and give us an opportunity to recruit them. Additionally, we have reached out to local schools and TARC teams to recruit students that already have an interest in STEM. Throughout the rest of the year, our sustainability plan will tie into our STEM Engagement plan, which focuses on exhibiting at public events. We intend to actively recruit potential candidates during these public events. Any presentations or events we hold will also have this information available for potential members. Our NASA Student Launch member count goal by the end of the year is 10-15 members, with a significant portion having institutional knowledge to run the club and team in the years to come.

As for public and sponsor support alike, our plan remains mostly unchanged, with a slightly elevated emphasis on attending social/networking opportunities in our community with organizations or people of interest. One example of this would include attending a Morris County Board of Commissioners meeting to properly inform our local government about our program so they understand how they can support us. The objective of increasing public support is to have increased support during fundraising, wider reach when holding events, and wider knowledge of our existence to aid in recruiting.

Our final part of our sustainability plan regards knowledge transfer (i.e. the framework and facilitation of forwarding institutional knowledge and information about how to effectively compete in the NASA Student Launch and American Rocketry challenge). This is a new challenge for our team as the original members begin to depart over the coming seasons. To address this, we've started identifying the future leaders of the team and investing time in them to discuss administrative matters with them so that they can run the team without difficulty. Throughout the year, we work to transfer knowledge as things come up about the competition itself, team/club management, and leadership skills.

7.5. Social Media Plan

At the moment, our SLI team along with the club are active on: Facebook, Instagram, Flickr, and YouTube. We also have our website, nj4h.space.

The team's social media members will be assisting our social media lead, Garrett Gregor, with multiple functions throughout the competition. Posts are made approximately once a week on both Facebook and Instagram. These social media platforms have brought us major success with catching the eye of the public, engaging potential sponsors, and attracting visitors to our STEM Engagement events.

The main goal with our social media plan is to expose students looking for ways to get involved in STEM fields to rocketry. Besides this, our pages help update our followers and sponsors on how we are using our resources and educating students through our STEM Engagement program.

In addition to our social media plan, we are transitioning our website from WordPress to Google Sites to redesign and update our website and to give us more flexibility at no cost, unlike WordPress. This will be deployed before the end of September.

The last segment of our social media plan is to complete the following goals: post what we've been working on, film and document most aspects of the competition process, and to educate and inspire the public. For example, sub-scale launches, events, and most importantly our full scale and finals launch would all receive social media and/or video documentation for the public to see. Through high-quality work and informational posts, we hope to gain attention from a larger audience.

8. Conclusion

We appreciate your time and careful consideration of our proposal.

Participating in last year's Student Launch was not only an profound educational experience but also deeply rewarding for every member of our team.

This year, we've applied all that we've learned to this proposal which we believe highlights our growth and aspirations. We're eager for the opportunity to demonstrate this over the coming nine months.

Thank you and we look forward to working with you again.

- Morris County 4-H ResistoJets Rocketry