Project Elijah

PROPOSAL

Cedarville Student Launch 2024-2025

Cedarville University
251 N. Main St.
Cedarville, OH 45314

September 11, 2024

Table 0.0. *List of Acronyms.*

Acronym	Full Name
AGL	Above Ground Level
APCP	Ammonium Perchlorate Composite Propellant
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulation
CNC	Computer Numerical Control
CPR	Close Proximity Recovery
CSL	Cedarville Student Launch
CSO	Chief Safety Officer
ECE	Electrical and Computer Engineer
EES	Engineering Equation Solver
EPL	Engineering Project Laboratory
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCC	Federal Communications Commission
FEA	Finite Element Analysis
FMEA	Failure Modes and Effect Analysis
FRR	Flight Readiness Review
GPS	Global Positioning System
HPR	High Power Rocketry
HPRSC	High Power Rocketry Safety Code
IDE	Integrated Development Environment
MGA	Mass Growth Allowance
MSDS	Material Safety Data Sheet
MVP	Minimum Viable Product
NAR	National Association of Rocketry
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Agency
NSL	NASA Student Launch
PDF	Payload Demonstration Flight
PEGT	Polyethylene Terephthalate Glycol-modified
PLAR	Post-Launch Assessment Review
PPE	Personal Protective Equipment
QC	Quality Control
RSO	Range Safety Officer
SDL	Senior Design Lab
SDS	Safety Data Sheet
STEM	Science, Technology, Engineering, and Mathematics
TRA	Tripoli Rocketry Association
VDF	Vehicle Demonstration Flight
WSR	Wright Stuff Rocketeers

1. General Information

The Cedarville Student Launch (CSL) team proposes *Project Elijah* for the 2024 – 2025 NASA Student Launch (NSL) challenge. This team plans to excel in the NSL with integrity in conduct and excellence in effort, satisfying and going beyond the project requirements contained in the 2024 – 2025 NSL Handbook. CSL aims to develop an intelligently designed rocket that exceeds expectations and to create knowledge bases and standards of excellence to pass on to future teams. All student personnel participating in *Project Elijah* for CSL are introduced below along with the team's faculty advisors and National Association Rocketry (NAR) Affiliation advisor.

1.1. Faculty Advisors

Dr. Thomas Ward
Cedarville University Professor of Mechanical Engineering
Email: tward@cedarville.edu
Phone: 937-766- 7739

Dr. Timothy Tuinstra
Cedarville University Professor of Electrical Engineering
Email: tuinstra@cedarville.edu
Phone: 937-766-3452

1.2. NAR Affiliation

As in the past years, CSL has partnered with the Wright Stuff Rocketeers (WSR) (NAR Section #703) club in Dayton, Ohio for a NAR mentor.

Mentor: Dave Combs, Wright Stuff Rocketeers President

Email: davecombs@earthlink.net

Phone: 937-248-9726

Membership Information: NAR #86830, HPR Certification Level 2

1.3. Student Personnel

Team Leader Information

Grant Parker (Senior Mechanical Eng.)

Sub-Role: Tail Cone Design/Motor Retention

Email: grantparker@cedarville.edu

Phone: 574-993-0677

Safety Officer Information

Jesse DePalmo (Senior Mechanical Eng.)

Sub-Role: Airframe, Motor Systems

Email: jdepalmo147@cedarville.edu.

Phone: 315-710-0351

Team Members:

For the 2024 – 2025 competition, CSL consists of thirteen student personnel with diverse backgrounds valuable to the project, including engineering, accounting, and marketing skillsets.

Table 1.3.1. *List of team members and their roles for the 2024-2025 NSL competition. The team lead and safety officer are excluded from this table.*

Name	Position	Grade and Discipline
Joseph Copeland	Avionics Lead, Airbrakes Controls Lead, Social Media Liaison	Senior Mechanical Eng.
Daniel Hogsed	Chief Engineer, Systems Integration Lead, Manufacturing Lead	Senior Mechanical Eng.
Jack Kealen	Nosecone Lead, Airframe Lead, Launch Officer	Senior Mechanical Eng.
Kenneth Lee III	Electrical CFO, Payload Housing Design, Payload PCB Design	Senior Computer Eng.
Hannah Lucas	Team Accountant	Sophomore Accounting
Jackson Maley	Fin Design, Technical Writing Lead, Shock Cord Mounting	Senior Mechanical Eng.
Seth Mitchell	STEM Engagement Lead, Airbrake Mechanical/Electrical Design	Senior Mechanical Eng.
Rebekah Porter	Electrical CEO, Payload Circuit Design, Payload Electronics Assembly	Senior Electrical Eng.
Andrea Rucci	Social Media Manager	Junior Marketing

Elisa Schmitt	Recovery & Charge Placement, CFD Analysis	Senior Mechanical Eng.
Arkin Solomon	Electrical CTO, Payload Software Design & Development	Senior Computer Eng.

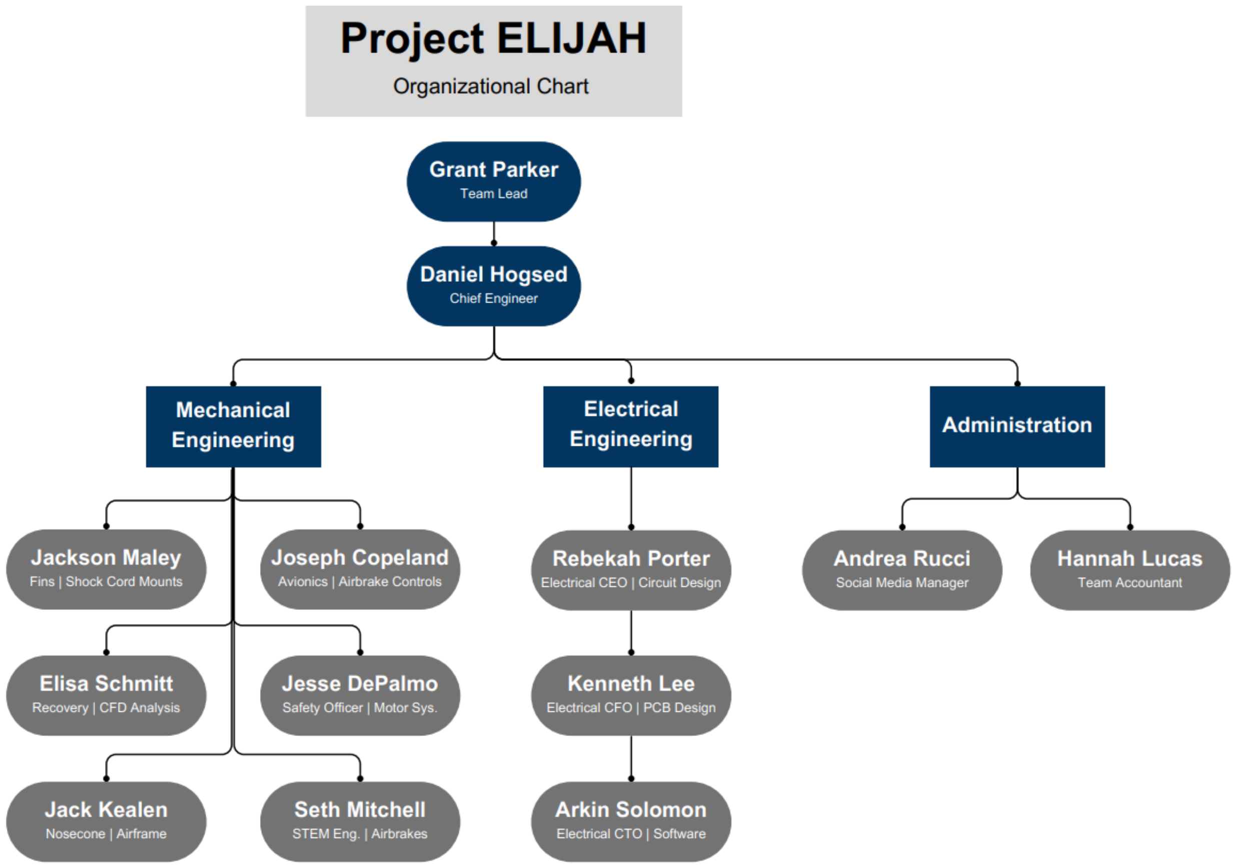

Figure 1.3.1. *Hierarchical Organization Chart for Project Elijah.*

1.4. Total Proposal Hours

This section includes the total amount of man hours put into completing the proposal including the background research done for the conceptual rocket design. Each team member kept track of their own tasks and hours for a total of 271 hours. This included time spent researching designs, conducting meetings, and writing up the proposal. These 271 hours were spread out across 3 weeks and all the team members.

2. Facilities & Equipment

2.1. Senior Design Lab

The mechanical engineering senior design lab (SDL) is shown in Figure 2.1.1. Each workspace has a dual monitor computer setup and is equipped with the software shown in Table 2.9.1. The desks are grouped together by senior design teams. The senior design lab is also equipped with whiteboards to facilitate group brainstorming. The SDL comes equipped with a variety of reference books ranging from mathematics, physics, solid mechanics, fluid mechanics, and electronics.

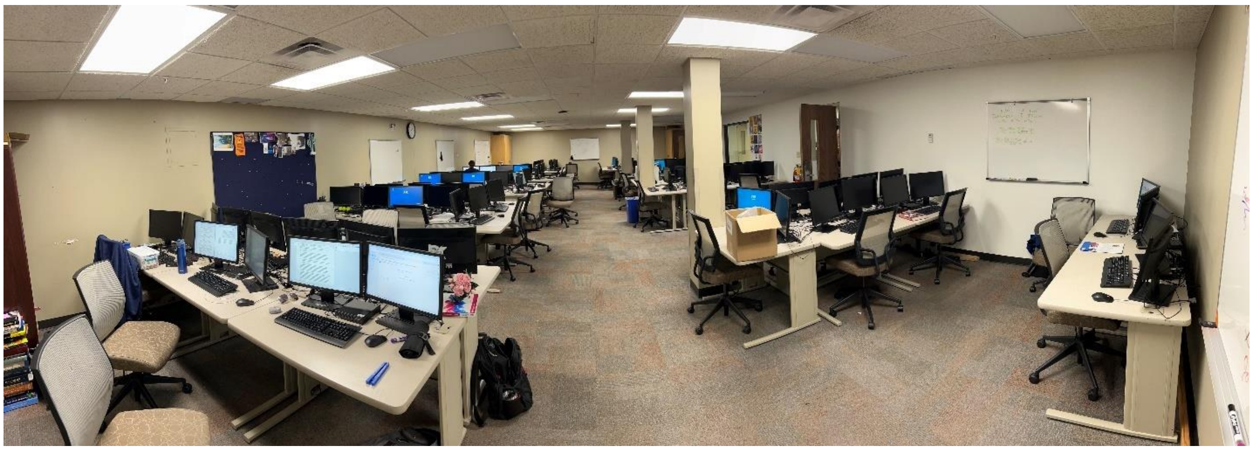

Figure 2.1.1. *Mechanical Engineering Senior Design Lab.*

2.2. Engineering & Science Center Advanced Manufacturing Lab

The Advanced Manufacturing Lab is in the Engineering and Science Center and provides the capability to manufacture components for a rocket while being able to achieve high tolerances and quick turnaround. The lab contains a Computer Numerical Control (CNC) mill and lathe shown in Figure 2.2.1. The hours that the Advanced Manufacturing Lab is available for student access are shown in Table 2.2.1.

Table 2.2.1. *Hours the Advanced Manufacturing Lab is open during the week.*

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1:00p – 10:00p	7:00a - 11:00p	7:00a - 11:00p	7:00a - 11:00p	7:00a - 11:00p	7:00a - 11:00p	7:00a - 11:00p

Figure 2.2.1. *CNC mill and lathe workspace.*

The Advanced Manufacturing Lab contains two Ender 3 3D printers as well as a CNC laser cutter and plasma cutter. The 3D printers will be used for rapid prototyping of components and for the final manufacturing of 3D printed components. The 3D printers and the CNC laser cutter are shown in Figure 2.2.2 and the CNC plasma cutter is shown in Figure 2.2.3.

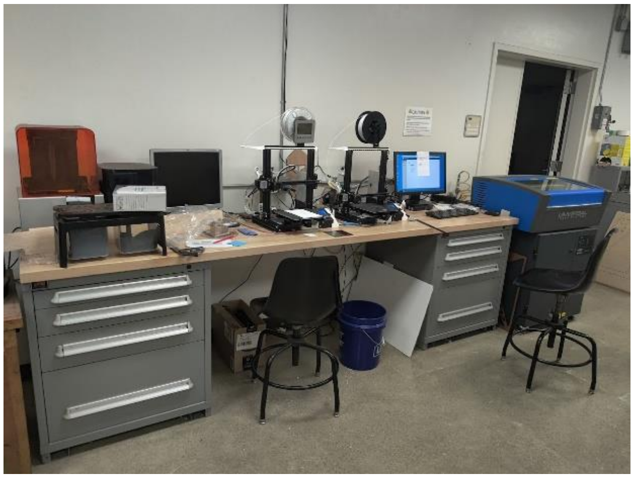

Figure 2.2.2*. Additive manufacturing and laser cutting center*.

Figure 2.2.3. *Shop Sabre CNC plasma cutter.*

2.3. Engineering Project Lab

The Engineering Project Laboratory (EPL) is a manufacturing workspace that gives the ability to manufacture and assemble a wide range of components. All students using the EPL are required to complete a lab safety training course before obtaining access to the lab. Table 2.3.1 contains the hours that the lab is accessible for student use as well as the hours when the lab supervisor is on duty to provide tool specific training for students.

Table 2.3.1. *Hours when the EPL is accessible to students and has a lab supervisor on duty.*

	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Prox Access	12:00P – 10:00P	7:00A – 11:00P	7:00A – 11:00P	7:00A – 11:00P	7:00A – 11:00P	7:00A– 11:00P	7:00A – 11:00P
Lab Supervisor on duty	N/A	9:00a – 5:00p	1:00p – 10:00p	11:00a – 5:00p	1:00p – 10:00p	11:00a – 5:00p	N/A

The EPL contains three separate end mills and lathes for machining metal shown in Figures 2.3.2 and 2.3.3. CSL also have access to a tool crib shown in Figure 2.3.1 which contains a wide variety of hand tools and safety equipment that they will need to manufacture components for the rocket.

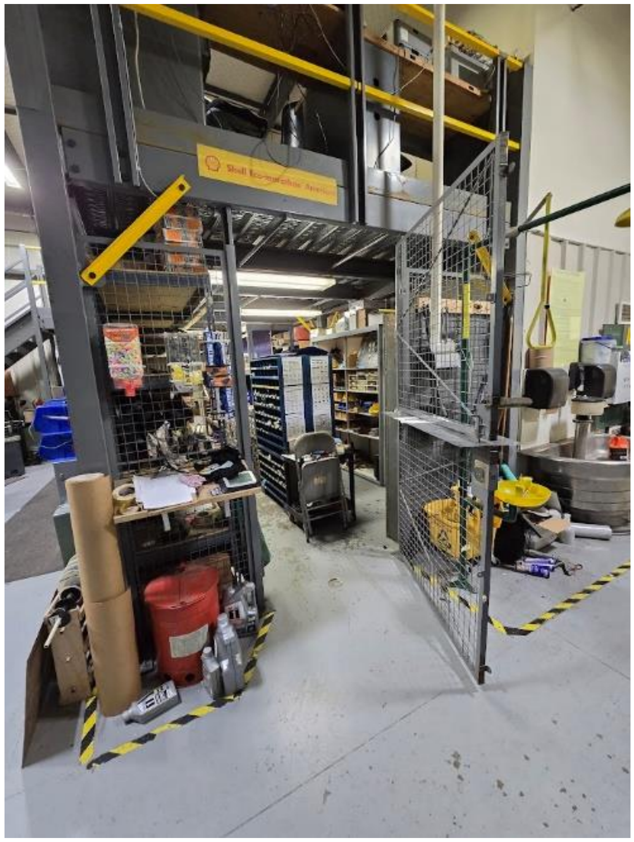

Figure 2.3.1. *Tool Crib.*

Figure 2.3.2. *Machining Lathes.*

Figure 2.3.3. *End Mills.*

The EPL also contains a sheet metal workshop for sheet metal manufacturing needs and a welding area with a plasma cutter and both MIG and TIG welders. The sheet metal workshop is shown in Figure 2.3.4 and the welding area is shown in Figure 2.3.5.

Figure 2.3.4. *EPL Sheet Metal Workshop.*

Figure 2.3.5. *EPL Welding Work Area.*

The EPL also contains a fully equipped painting booth and woodshop. Both have a ventilation system to reduce the risk of personal injury when using these areas. CSL has a team member who is very experienced with advanced rocket painting methods, and they will be utilizing the EPL paint booth to paint the complete sub-scale and full-scale rockets. The paint booth is shown in Figure 2.3.6 and the woodshop is shown in Figure 2.3.7.

Figure 2.3.6. *EPL Paint Booth.*

Figure 2.3.7. *EPL Woodshop.*

2.4. Electrical Engineering Project Lab

The electrical and computer engineering senior design lab is shown in Figure 2.4.1. As in the mechanical engineering lab, each desk spot has a computer setup, and the desks are grouped together by senior design teams. The electrical engineering senior design lab is also equipped with a whiteboard to facilitate group brainstorming, a soldering station for assembling components, and a central table for group discussions or work without computers.

Figure 2.4.1. *Electrical and Computer Engineering Senior Design Lab.*

2.5. The Barn

The Engineering Lab, nicknamed "the Barn," is the primary location on campus for the team to manufacture components for the rockets and to assemble and store the rockets. Figure 2.5.1 contains an exterior view of the Barn showcasing the garage door that can be opened to provide ventilation when necessary. The hours during which the barn is accessible are shown in Table 2.5.1.

Figure 2.5.1. *The Outside of the Barn.*

Table 2.5.1. *The hours the Barn is open during the week.*

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1:00p - 10:00p	7:00a - 11:00p	7:00a - 11:00p	7:00a- 11:00p	7:00a - 11:00p	7:00a - 11:00p	7:00a - 11:00p

Figure 2.5.2 shows the inside of the Barn. CSL is only one of the teams that use this facility; it is used by two other Cedarville senior design teams. Figure 2.5.3 shows the area that CSL will use.

Figure 2.5.2. *Inside of the Barn.*

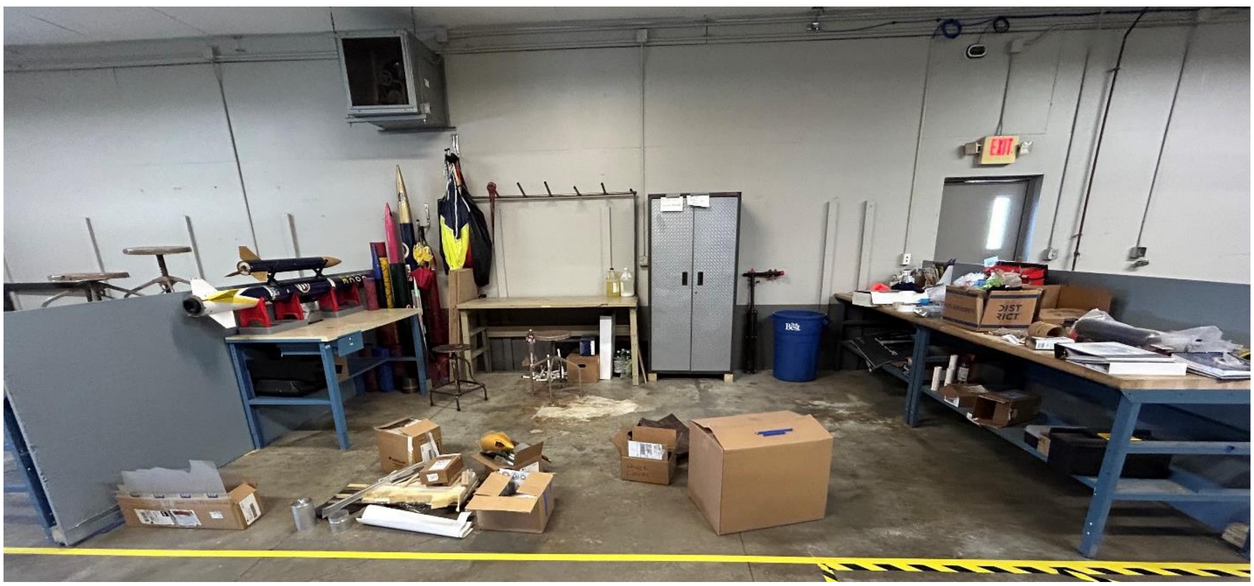

Figure 2.5.3. *CSL's area of the Barn.*

Figure 2.5.4 shows the welding station in the Barn. It is equipped with a chain lift to assist with heavy objects, proper PPE, and proper tools. It is one of the two welding sites at Cedarville and equips CSL to manufacture high quality welds.

Figure 2.5.4. *Welding Station in the Barn.*

2.6. Wright Stuff Rocketeers Launch Sites

The WSR Launch Site is located on 5995 Federal Road outside of Cedarville, OH and is the location where CSL will conduct launches of sub-scale and full-scale rockets under the supervision of the team mentor Mr. Dave Combs. The WSR Launch Site allows launches up to 12,000 feet and is located ten minutes from the university campus. The WSR site has irregular hours but is available with 24-48 hours of advanced notice whenever needed. The layout is shown below in Figure 2.6.1.

Figure 2.6.1. *Layout of Wright Rocketeers Launch Site.*

2.7. Miscellaneous

Miscellaneous equipment facilities are expected to be used throughout the project. These will include 3D printers and other potential outsourced facilities and wind tunnel testing. These facilities and equipment will be used to expedite the manufacturing and assembling of complex components.

2.7.1. Personal 3D Printers

Multiple personal 3D printers are expected to be used during the project. They will allow for the team to have a simple and relatively cheap method for producing complex plastic components. 3D printers also allow for a quick iteration process and an opportunity to get prototypes developed in a short amount of time. The 3D printers used by the team will include Cedarville printers and personal printers. An example of one such printer that will be used is shown in Figure 2.7.1.

Figure 2.7.1. *One CSL Member's Personal 3D Printer.*

2.7.2. Knapheide Manufacturing

The Knapheide Manufacturing Company is a potential contact that may offer their manufacturing capabilities to CSL. They specialize in manufacturing service truck bodies and have a large manufacturing plant in Quincy, IL. Richard Baze, the manager of the Research and Development lab at Knapheide has said in the past that he would be willing to manufacture and fabricate complex aluminum parts if needed. The factory is shown in Figure 2.7.2.

Figure 2.7.2. *Knapheide Manufacturing Company Factory.*

2.8. Needed Supplies & Resources

Materials and equipment needed to design, build, and launch a rocket include but are not limited to the supplies provided in Table 2.8.1.

Table 2.8.1. *Supplies and Resources needed for a proper Rocket Launch.*

Materials and Equipment for Rocket Launch		
• Black Powder	• Drogue parachute	• Fiberglass tube
• Nose Cone	• Altimeters	• Handheld tools
• Epoxy	• Motor retainer	• Batteries
• Wires	• Screws	• Shear Pins
• E-Matches	• 3D printer	• Main parachute
• Shock Cords	• Software	• masks
• Aluminum (Bulkheads, fin / motor retention)	• First aid kit	• Arduino nano
• Safety glasses	• Gloves	• Prototyping Wires

2.9. Software

Cedarville University computers provide access to various software applications for engineering purposes. Team members will be utilizing these applications for specific uses pertaining to the project.

Table 2.9.1. *Relevant Applications which will be used for the Design, Analysis, and Construction of the Rocket.*

Software Name	Software Description	Software Usage
MATLAB	Numerical computer environment used to analyze matrix mathematics to model simulate physical phenomena.	Solve analytical problems using discrete methods.
SOLIDWORKS	Solid modeling computer-aided design application.	Model components of the rocket.
Simulink	MATLAB based program used to graphically model, simulate, and analyze multidomain dynamic systems.	Airbrake control system.
Microsoft Suite	Software package consisting of One drive, and Office 360.	Write documents, edit spreadsheets, create power points, and more.
Discord	Program used for call, messaging, and communication between team members	CSL Communications
AutoCAD	2D computer-aided design tool.	Draft early sketches
Fusion 360	3D computer-aided design tool like SOLIDWORKS but used by other team's members for machining application.	CAM and CNC machine capabilities.

TK-Solver	Mathematical modeling and problem-solving software system with powerful implicit and back solving abilities.	Solving complex systems of equations.
Open Rocket	Free and open-source model rocket simulator.	Model rocket performance.
Abaqus	Finite element modeling software used to preform advanced stress calculations.	FEA
Watt	Linkage design software which can develop the motion of any linkage type given a specific path or motion.	Linkage design
Linkages	Linkage analysis software to analyze the movement, forces, and characteristics of kinematics mechanisms.	Linkage Analysis
Ansys Toolkit	Fluid simulation software known for its high level of precision and accuracy in handling complex physics.	CFD
EES	Engineering Equation Solver is a general equation solver known for its implicit solving and use of use for thermo-fluids applications.	Back solve difficult analytical thermo-fluids problems.
Arduino IDE	Software Application used to write, compile, and upload code to Arduino microcontroller boards.	Programming and deploying code to an Arduino
Visual Studio Code (VSCode)	Software application used to write C++ code which can then be compiled and uploaded to a Raspberry Pi Pico.	Programming and deploying code to a Raspberry Pi Pico
Raspberry Pi Pico plugin for VSCode	Plugin for VSCode used to compile and flash Raspberry Pi Pico microcontrollers, as well as generate CMake files and starter code.	Deploying code to Raspberry Pi Pico

3. Safety

The 2024-2025 Cedarville NASA Student Launch team is focused on the priority of implementing safety measures to guarantee a successful mission. If not managed properly, high-powered rocketry introduces numerous safety risks. This is why there are organizations that help maintain the safety of rocketry that protect the public and the environment from possible danger. The Federal Aviation Administration (FAA) regulates airspace to make sure the rocket path does not interfere will local aircraft. They require the necessary permits to launch a high-powered rocket into local airspace. The NAR promotes safety by providing rocketry safety codes and certifications developed with input from industry experts, professional engineers, and public safety officials. The Federal Communications Commission (FCC) provides aerospace safety by regulating the radio frequencies used for communication with the rocket. This is important to ensure that there are no interferences with paramount communications. These organizations work together protecting the environment and the public while maintaining the safety and legality of high-powered rocketry.

3.1. Safety Officer Identification & Responsibilities

Cedarville Student Launch has elected Jesse DePalmo as Chief Safety Officer (CSO). The CSO role is to guarantee the safety of all team members, students, and the public participating in the team’s activities. This will require the creation, implementation, and revision of safety procedures in areas for the team such as design, construction, assembly, testing, and STEM engagement activities. It is the responsibility of the CSO to promote a strong culture of safety across all areas of the team’s mission and operations through briefing each team member on safety protocols. Once a procedure or plan is set by the team, the CSO has the right to amend team activities to maintain a high level of safety. Other CSO responsibilities include but are not limited to the development and revision of the team’s hazard analyses, safety data sheets, and failure mode analyses. The CSO role requires an understanding of the facilities, equipment, and regulations that exist beyond the team’s direct responsibilities. This includes adherence to the instruction of the NAR, Tripoli Rocketry Association (TRA), High Power Rocketry Safety Code (HPRSC), National Fire Protection Agency (NFPA 1127), and the Federal Aviation Regulations Code 14 (CFR).

3.2. Safety Plan Overview

An essential component of the NASA Student Launch competition is to ensure the safety and well-being of every team member. The safety of the team, public, and environment take priority over the competition itself. Team members are dedicated to following FAA regulations as well as the NAR and FCC safety codes during test launches and other team activities. To guarantee a successful mission, a preliminary safety plan is provided. All team members will be informed about the specifics of the safety plan and will be notified of any updates or revisions.

3.2.1. Risk Assessment

Using safety risk management is a desirable way to identify hazards with the team, public, and the environment. Safety hazards will be evaluated using consistent scales of severity and probability. Each safety risk will be identified by the CSO and will be documented for cause, effect, and mitigation strategy. A hazard will be given a score based on levels of severity and probability. A high score reveals a high-level safety risk that requires mitigation to be addressed immediately. Table 3.2.1 defines the criteria for assigning a certain probability. Table 3.2.2 displays the risk assessment table and codes. The colored cells correspond to the different levels of risk the team has identified. Table 3.2.3 identifies how different risk values correspond to different risk identifications. Table 3.3.4 identifies a severity description to a specific hazard.

Table 3.2.1. Probability Value Criteria.

Description	Value	Description of Occurrence	Probability of Occurrence
Rare	1	Very Unlikely	Less than 5%
Occasional	2	Event Occurs Occasionally	Between 5% and 25%
Often	3	Event Occurs Often	Between 25% and 50%
Likely	4	Highly Likely Event Will Occur	Between 50% and 75%
Frequent	5	Event Expected	Above 75%

Table 3.2.2. Risk Assessment Table and Codes.

Probability	Severity			
	Negligible (1)	Minimal (2)	Major (3)	Catastrophic (4)
Rare (1)	1	2	3	4
Occasional (2)	2	4	6	8
Often (3)	3	6	9	12
Likely (4)	4	8	12	16
Frequent (5)	5	10	15	20

Table 3.2.3. Risk and Acceptance Level Definitions.

Severity	Range	Acceptance Level	Approval Authority
Low Risk	Less than 5	Desired	CSO approval recommended, but not required.
Medium Risk	5 to 9	Undesirable	Mitigation must occur. Document approval from CSO.
High Risk	Greater than 10	Unacceptable	Mitigation must occur before proceeding.

Table 3.2.4. *Danger Level Definitions.*

Description	Value	Team Personnel	Physical Environment	Launch Vehicle	Mission Success
Negligible	1	Minor or No Injuries	No Damage	Insignificant	Complete Mission Success
Minimal	2	Minor Injuries	Minor and Reversible Damage	Mild Damage	Near Complete Mission Success
Major	3	Moderate Injuries	Moderate Reversible Damage or Minor Irreversible Damage	Major Damage	Partial Mission Failure
Catastrophic	4	Life-threatening Injuries	Major Irreversible damage	Irrevocable Damage	Complete Failure

3.2.2. Safety Data Sheets

Detailed safety documents and manuals will provide procedures on the handling of materials and their construction. Material Safety Data Sheets (MSDS) will be referenced before working with relevant materials. Only licensed professionals, team mentors, or the CSO (when applicable) will handle and transport energetics and volatile materials. The hazardous and volatile substances will be stored in compliance with safety regulations.

3.2.3. Materials Safety

Team members will read and be aware of the materials inventory list. This list will give accurate information about the amount and location of materials used for the design, construction, and launches of the rocket. Certain materials require special safety precautions such as specific PPE or approval from the CSO or the Range Safety Officer (RSO). Hazardous materials such as black powder and Ammonium Perchlorate Composite Propellant (APCP) are stored by the appropriate supervisors at WSR. These materials are not to be handled by team members and are not stored on university campuses.

3.2.4. Safety During Design Process

During the design of the payload and the systems of the rocket, the CSO and other team members need to identify potential hazards. The team should consider what materials are being used for the design and look to establish safety measures for the manufacturing and assembly processes. Additionally, the team should research and identify the necessary manufacturing procedures to ensure that the design of the rocket and payload are carried out safely.

3.2.5. Construction Safety

The construction of the rocket and payload requires additive attention and awareness to safety guidelines. All team members need to be trained by the university to use the construction equipment located in The Barn or the EPL. This is required to mitigate risk and safety hazards during the construction process. Power tools, adhesives, and certain processes such as drilling, welding, painting, and sanding have the potential to cause serious risks to the team.

3.2.6. Personal Protective Equipment

All team members must wear the proper Personal Protective Equipment (PPE) in the EPL and Barn or discipline within the team and Cedarville University will occur. Safety glasses, closed toed shoes, and full-length pants are required to be always worn in the EPL and Barn areas. Clothing made of denim is a good material to wear in these areas. If other clothing is worn, it needs to be a fire retardant and abrasion resistant. The table provided are PPE requirements for construction processes in the EPL and Barn.

Table 3.2.5. *EPL and Barn Equipment PPE Requirements.*

Equipment	Hazards	Required PPE
Welding	Burns, cuts, abrasions, falling objects	Requires leather work shoes, long-sleeved denim or cotton duct shirt or leather welding jacket, leather gloves, appropriate face/eye protection, appropriate hearing protection
Painting	Inhalation, eye irritation, skin irritation	Dust/particulate mask, organic vapor respirator, face shield, coveralls, paint hood, gloves – as needed dependent on materials and processes used
Woodworking	Dust inhalation, eye injury, splinters	Dust/particulate mask, face shield, gloves – as needed

3.2.7. Pre-Launch & Post-Launch Briefings

Team members that are wanting to attend and participate during the launch process need to attend meetings that are designed to keep the team, public, and environment safe from potential safety hazards. The CSO and Launch Officer will work together with the team mentor and Range Safety Officer to establish pre-launch, launch, and post-launch procedures that follow the NAR and FAA safety codes. Failure to comply with the safety procedures is a potential risk and will promptly be removed from the launch site.

3.2.8. Environment Safety

The CSO and team members are responsible for minimizing the rocket's impact on the environment while checking for potential environmental factors that could affect the rocket's performance during launch. Team members will follow federal regulations and Safety Data Sheets (SDS) guidelines when handling and disposing of hazardous materials. Weather related events such as high wind or rain could affect the rockets performance on launch day. The RSO has the final say whether to launch or scrub the mission due to weather related conditions.

3.2.9. STEM Engagement Safety

CSL will educate younger students and teach them about the fundamentals of aerodynamics and rocketry. These events still contain safety hazards and risks even if they are not with black powder and explosives. When students are working on their projects, team members must be supervisors to make sure they listen to directions and when using sharp objects. If STEM events are using glue or small materials, it's important for team members to be extra careful around younger students who may accidentally ingest these items. If an event includes a small rocket launch, team members must comply with standard launch procedures and make sure the students are distanced from the launch site. Students that don't listen to safety instructions will be removed from participating in the STEM activity.

3.3. FMEA Sheets

Failure Modes and Effect Analysis (FMEA) sheets are provided to identify all the safety risks associated with the project,. These sheets provide a plan for how team members can mitigate hazards during the design, construction, assembly, and launch of the rocket. After mitigation has occurred, the risk assessment number will be lower, reducing the risk of the hazard. The CSO and other team members will follow these FMEA procedures if the specific hazard occurs. These tables provide a plan to deal with personnel, vehicle, recovery, environmental, pollution, and other miscellaneous hazards. An example of an FMEA sheet is provided in Figure 3.3.1.

Table 3.3.1. Example of Failure Modes and Effect Analysis Sheet.

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Specific Hazard	Reason for Hazard	Result of the Cause	Probability Evaluation	Severity Evaluation	Risk Evaluation	Barrier to Prevent Hazard	Source for Barrier	Probability after Mitigation	Severity after Mitigation	Risk after Mitigation

3.3.1. Personnel Hazards

Table 3.3.2. *Hazards to Personnel Evaluated by the Defined Risk Assessment Code.*

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Contact with hazardous chemicals	Chemical spills, mishandling of chemicals	Burns, skin irritation, erosion of vehicle.	3	3	9	Wear appropriate PPE, especially gloves and eye protection, in conjunction with clothing that covers the whole body, and the workspace will have a protective layer of material.	Labels will indicate that PPE is required for use, and visual verification with CSO or team lead	2	2	4
Inhalation of toxic fumes	Inhalation of toxic fumes while handling chemicals, especially in confined areas.	Pain, sickness, lung damage	3	3	9	Respirators will be used when handling chemicals that have toxic fumes. These chemicals will only be used in well-ventilated areas.	Labels will indicate that respirators are needed. Visual verification with CSO or team lead.	1	2	2
Contact and inhalation of dust or debris	Contact with dust and debris.	Pain, lung damage, skin irritation	2	2	4	Wear appropriate PPE, including gloves, eye protection, respirator, and clothing that covers the whole body.	CSO will verify that team members wear proper PPE.	1	2	2

Electrocution	Contacting electrical terminals, inadequate caution.	Pain, burns, physical harm, death	4	3	12	Clearly label high voltage equipment and provide a briefing on the proper handling of electronics.	Regular inspection of electronics will be performed. Students will confirm with CSO that they have had appropriate training prior to using labeled equipment.	1	4	4
Abrasion from powered equipment	Mishandling of machinery	Pain, burns, abrasion, cuts, physical injury, death.	3	4	12	Safety training on the proper use of equipment will be required for those using construction. A 10 ft radius will be observed when machinery is in use. Proper PPE will be used.	When power tools are in use the CSO or another team member will be present to supervise and ensure that proper procedure is being observed.	2	2	4
Hearing damage	Loud machinery, explosions, chemical reactions.	Temporary for long term hearing damage.	3	3	9	Ear plugs or earmuffs will be worn while using machinery and at launches and testing of black powder, as well as for all other activities above 90 db.	Ear protection will be part of pre-flight and pre-test check lists. The CSO will ensure that proper ear protection is used, and the CSO will ensure use with machinery.	3	1	3
Electronics catch on fire	Overloading of electrical circuits	Burns, destruction of electronics.	2	4	8	A chemical-based water extinguisher will be kept near electronics.	Sign off by the CSO.	1	3	3

Accidental black powder explosion	Exposure to high temperatures, accidental connection to a voltage source.	Burns, destruction of rocket components, flying debris	4	4	16	Black powder will be stored in an explosive's chest. It will only be handled by the team mentor or CSO after they have reviewed proper handling procedure. Avionics and electric matches will only be armed directly before launch.	Black powder storage will be locked with a key that only the team mentor has. An arming flag will be used on the side of the rocket to show that the vehicle is either armed or unarmed.	1	4	4
Lithium Polymer (LiPo) battery explosion.	LiPo gone bad, or LiPo puncture.	Burns, physical harm from fire.	4	4	16	LiPo's will be stored in a fireproof explosion proof box. And damaged or potentially damaged batteries will be disposed of.	The CSO will store batteries, and the box will be locked with a key that only the CSO has. And weekly battery inspections will be performed to ensure that batteries are not going bad.	1	4	4
Tripping	Untidy work area	Scrapes, cuts, concussion	3	3	9	Workspace will be kept clean; cables will be routed through proper cable covers and marked accordingly.	The CSO will ensure that the work area is clean and make all members aware of any potential tripping hazard	3	1	3

3.3.2. Vehicle Hazards

Table 3.3.3. *Vehicle Hazards Evaluated by the Defined Risk Assessment Code.*

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Catastrophic Fin Failure	Improper construction, extreme stress, fin flutter.	Mission failure, unstable flight, crashing.	4	4	16	FEA analysis will be performed on the fins to verify they are strong enough. A visual inspection will be performed prior to launch.	Construction and analysis will be verified with a construction lead.	3	3	9
Fin's incorrectly oriented	Improperly epoxied, design failure.	Potential mission failure, increased drag, unstable flight.	3	4	12	A fin retention system will be used to attach the fins to the body.	Fins will be tested properly using the fin retention system to ensure proper attachment.	3	2	6
Motor mount failure	Epoxy failure, improperly mounted	Mission failure, rocket destruction.	2	4	8	Motor mount construction will be performed by two people to minimize incorrect placement.	FEA will be performed on the mount to ensure that it can handle the stress. A visual inspection will be performed. And manual force will be applied to it to ensure that it can withstand substantial amounts of force.	2	2	4

Epoxy Failure	Improper curing or application.	Minor damage, parts becoming loose, mission failure.	4	3	12	Proper procedure will be observed for all application of epoxy and the curing of epoxy.	CSL will follow Apogee Rocket and the NAR guidelines for epoxy.	3	1	3
Frame Failure	Stress fractures, improper construction.	Mission failure to no effect.	3	3	9	Visual inspection of the tubes and cutting the tubes will be done with care.	The CSO, Launch Officer, and team mentor will perform a final inspection before launch.	1	3	3
Nose Cone Failure	Improper surface finish, material fracture	Electronics stored in nose cone are damaged, and aerodynamics are negatively affected leading to mission failure.	3	3	9	Visual inspection of the nose cone, and production will be performed carefully.	The CSO will perform a final visual inspection at each stage of construction.	2	3	6
Explosion at Launch	The rocket motor grains are not assembled correctly in the casing.	The rocket will turn into smoke.	3	4	12	Careful assembly of the rocket motor by licensed mentor only with the careful observation of multiple student members to check.	There is no further verification process for motor packing.	2	3	6
Bulkhead failure	Improper seating, or abnormally high stress.	Minor to major damage to internal rocket components, potential failure to recover.	3	3	9	Construction lead will perform physical testing on all bulkheads to ensure proper seating, and proper epoxy procedure will be performed.	Theoretical analysis will be performed to ensure that the bulkhead can withstand force.	2	2	4

Launch lug failure	Lugs are ripped off the rocket due to unexpected forces.	A rocket could veer slightly to massively off course.	3	4	12	Lugs will be secured firmly onto the rocket in correct alignment, and the rail will be inspected for rigidity and orientation.	The CSO will perform visual inspection and verification.	1	2	2
Motor Retainer failure	Excessive stress within motor retainer attachment points or threads.	Motor ejection, Mass imbalance and loss of stability	4	4	16	The motor retainer will be designed to withstand the stress of the launch with a reasonable factor of safety.	The motor retainer will be inspected prior to each flight.	1	3	3
Coupler Failure	Incorrect epoxy application, high lateral stress, in correctly fitted.	The rocket could break into pieces and result in "Mid-flight deconstruction."	3	4	12	Couplers will be reviewed by the engineering lead to ensure that they have been correctly installed.	Couplers will be included on the Quality Control (QC) sheet and checked by the CSO, Engineering Lead, and Launch Officer prior to launch.	1	3	3

3.3.3. Recovery Hazards

Table 3.3.4. *Recovery Hazards Evaluated by the Defined Risk Assessment Code.*

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Parachute Shroud Lines Tangle	Parachute mechanisms and parachutes not wrapped properly.	Parachutes do not fully deploy or do not deploy at all.	3	4	12	Have the CSO, Launch Officer, and team mentor inspect the wrapping of the parachutes.	The Recovery lead and RSO will perform inspection before launch.	2	4	8
Black Powder Misfire	Black powder does not discharge.	Parachutes do not deploy properly.	4	4	16	Make sure the altimeters are sparking and are secure in the black powder.	The Recovery lead and RSO will perform inspection before launch.	2	4	8
Insufficient Black Powder	Black Powder explosion insufficient to separate rocket.	Parachutes do not deploy properly.	3	4	12	Measure out black powder and have second person check measurements.	The Recovery lead and RSO will perform inspection before launch.	2	4	8
Main Parachute Deployment System Fails	Pistons get jammed or stuck.	Main parachute does not deploy.	4	4	16	Ensure mechanisms are set up correctly and working.	The Recovery lead and RSO will perform inspection before launch.	3	4	8
Parachute Shreds	The threads in the parachute fabric tear out	Parachute breaks and provides minimal drag	2	4	8	Check thread quality in parachute.	Place inspection flag.	3	2	6

		during descent.							
Bulkhead Fails	The bulkhead fails by detaching from the rocket or from the parachutes.	Parachutes are detached from the rocket, and rocket goes in straight free fall.	4	4	16	Check for cracks in the bulkhead or its attachments to the rocket along with fraying in the shock cords and shroud lines.	The Recovery lead and RSO will perform inspection before launch.	2	4	8
Shock Cord Snaps	Higher than normal forces on shock cord, especially if speed at apogee is higher than anticipated.	A section of the rocket would be disconnected from the parachute and enter catastrophic free fall.	4	4	16	Inspect the cord for fraying. Perform analysis for apogee	The Recovery lead and RSO will perform inspection before launch.	2	4	8
Premature Deployment Due to Pressure Differential	Incorrect pressure fitting, shear pin failure, abnormally high pressures.	High speeds with large drag could rip the rocket to pieces, and cause parachute failure.	4	4	16	Shear pins will be placed, shear pins will be inspected, pressure differential calculations will be performed.	The Recovery lead and RSO will perform separation testing, and preflight inspection.	2	4	8

Avionics Failure	Power loss, avionics are damaged, incorrect sensor readings.	Failure to deploy parachutes, failure to fire black powder charges.	4	4	16	Redundant altimeters of a different brand and redundant power supplies will be used.	The Recovery lead and RSO will perform inspection before launch.	2	2	4
Zippering	Shock cord violently contacts the body tube causing damage.	Damage, destruction, or complete disassembly of the rocket.	3	3	9	An anti-zippering material will be used to protect the edge of the body tube.	The Recovery lead and RSO will ensure that the anti-zippering material is correctly placed prior to launch.	2	2	4
Switch failure	Vibrations, sudden accelerations.	Vibrations, sudden accelerations.	3	4	12	CSL will use switches that cannot be turned off unless done with intention.	The Recovery lead and RSO will ensure that the arming switches are properly activated.	2	3	6

3.3.4. Environmental Hazards

Table 3.3.5. *Environmental Hazards Evaluated by the Defined Risk Assessment Code.*

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Extreme Temperatures	Seasonal/Poor Weather	Damage to electrical equipment, decrease in functionality.	2	2	4	The weather will be monitored before flights and outdoor tests. The team will ensure indoor work areas are kept at a reasonable temperature. Electronics will be kept in a shaded or cool area and only be mounted directly before launch.	The Recovery Lead and Payload lead will ensure that their electronics maintain functionality in high heat conditions. And cease launch activities if failure occurs.	2	1	2
Humidity	Moisture infusing into water sensitive components.	Damage to sensitive electronics, motor propellants, adhesives, and surface treatments.	2	2	4	The weather will be monitored before flights and outdoor tests. The team will ensure storage areas have reasonable humidity levels.	The CSO will coordinate with the advisor to ensure that the motor propellant is undamaged. Continuity tests will be performed across electronics. Performance tests will be performed to ensure electronics are working properly.	1	2	2

Wind	High winds during descent	Larger drift distances, erratic flight path, instability, unpredictable apogee.	3	3	9	The weather will be monitored before flights and outdoor tests. The team will ensure storage areas have reasonable humidity levels.	The CSO will monitor weather before all fights.	2	3	6
Fog	Regional/Poor Weather	Low visibility, difficult retrieval of vehicle, and potential danger of vehicle impacting observers.	2	3	6	The weather will be monitored before flights and outdoor tests. Launches will be postponed on days/mornings with dense fog. The GPS ground station will be utilized for finding the rocket.	The CSO will monitor the weather before all flights and ensure that spectators are well outside of contact range.	2	2	4
Rain, Hail, & Storms	Water damage, force damage, lightning.	Damage to vehicle airframe, onboard electronic systems, and propellant.	3	3	9	Team members will utilize weather applications to check and be notified of severe weather. All outdoor activities will be postponed.	The CSO will monitor weather before all flights. Team members will have severe weather alert systems on their phones.	1	2	2
Tornadoes	Regional/Seasonal Weather	Extreme risk to team members, extreme damage to buildings and	3	4	12	Team members will utilize weather applications to check and be notified of severe weather. The team will follow the university's emergency plan for tornado warnings.	The CSO will monitor weather before all flights. Team members will have severe weather alert systems on their phones.	2	2	4

		the rocket itself.							
Fire	Dry grass and brush, improper motor use, heat sources too close to propellants.	Burn risks for team members, damage to airframe and electronics, and a potential for small brush fires to extreme wildfires.	3	3	9	Before launches, the surrounding area will be surveyed for dry grass and brush. Heat sources will be kept away from the launch zone before flights.	The CSO and RSO will do a final check and observe the conditions on the launch procedures checklist prior to launching.	1	2	2
Terrain	Launch site selection, bodies of water, uneven ground, and brush.	Tripping and falling hazards for team members. Difficult retrieval of the rocket, minor airframe damage or	2	2	4	Before launches, the surrounding area will be surveyed for difficult terrain and cleared of major obstacles. Adjustments to the launch area and launch direction will be made accordingly.	Team members will survey the launch site before flights. The CSO will verify that heat sources are kept from the launch zone.	1	2	2

		water damage.								
Tall Constructs	Trees, buildings, powerlines, and other man-made constructs.	Damage to vehicle airframe on impact and potential difficulty in obtaining vehicle afterwards.	3	3	9	Before launches, the surrounding area will be surveyed for tall constructs and obstructions. If necessary, adjustments to the launch area and direction will be made.	Team members will survey the surrounding launch site before flights.	1	3	3
UV Light	The Sun, Seasonal weather	Skin damage and sunburn on team members.	1	2	2	The UV index will be monitored before outdoor activities. Sunscreen will be applied to team members.	The team lead will ensure that sunscreen is brought on sunny days.	1	1	1
Wildlife Interference	Animals interfere with launch pad or birds are in the launch air space.	Incorrect launch trajectory, major flight interference.	2	3	6	The launch area and air space will be carefully inspected prior to launch. If an animal is spotted, then the launch will be postponed until the animal is clear.	CSO will perform final clearance check.	1	2	2

3.3.5. Pollution Hazards

Table 3.3.6. *Pollution Hazards Evaluated by the Defined Risk Assessment Code.*

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Waste Pollution	Improper disposal of trash and excessive amounts of unorganized material.	Uncleanliness, damage to environment	2	2	4	Team members will be briefed on proper waste disposal practices, and bins for specific product disposal will be placed in the work area.	Individual team leads will ensure that their teams are properly disposing of materials, and the construction lead will check bins for correct disposal.	1	2	2
Propellant Pollution	Pollution caused by the combustion of the rocket propellant.	Hazardous emissions and fumes	2	3	6	Motors will be properly ignited and only when necessary for tests and launches.	The CSO will understand ignition procedures and will collaborate with the RSO to ensure safe ignition.	1	2	2
Battery Leaks	Puncture and damage to batteries and casings.	Hazardous chemical exposure, risk of fire, and damage to surrounding vehicle airframe.	3	3	9	Batteries will be properly stored and routinely checked before and after flights and tests.	The CSO shall complete battery inspections before and after flights.	2	2	4

Paint & Adhesives	Use of paint and adhesives in the construction of the rocket. Improper use, application, and storage of these elements.	Hazardous chemical exposure from spills, hazardous fumes	4	3	12	Paint and adhesives will be stored properly. Proper PPE will be worn, and careful application techniques will be utilized.	The team will understand proper PPE use and adhesive application.	2	3	6
Noise Pollution	Use of power equipment, motor ignition at launches	Hearing damage or loss	2	3	6	Proper PPE will be worn while using power equipment. Equipment will only be used when needed.	The team will understand proper PPE use when operating equipment or conducting launches. The CSO will verify proper PPE use at launches.	1	2	2
Wildlife & Habitat Damage	Rocket launches and testing near areas with significant amounts of wildlife. Impact of airframe on wildlife and habitats.	Damage to rocket airframe and animals. Littering of rocket pieces.	2	3	6	Sites will be surveyed prior to launch and points of concern will be identified. Adjustments to the launch area and launch direction will be made accordingly. All components will be firmly attached to the body.	Team members will report any wildlife or environmental related issues to the CSO after walk-throughs.	2	1	2

3.3.6. Miscellaneous Hazards

Table 3.3.7. *Miscellaneous Hazards Evaluated by the Defined Risk Assessment Code.*

Hazard	Cause	Effect	Probability	Severity	Risk	Mitigation	Verification	Probability	Severity	After
Ignition failure	Improper ignition placement, malfunctional igniter.	Failure to launch.	2	2	4	All ignition related hardware will be handled by a licensed professional. The pad will not be approached for five minutes after an ignition failure.	The CSO will verify the correct procedure is followed.	1	1	1
Airbrakes Motor Controls Fail	The programming for the motor controls do not actuate the airbrake motor correctly during flight.	Extra drag is either not produced or too much of it is produced. Also, could interfere with launch rail or recovery system.	3	3	9	Perform simulated ground testing on the controls for the air brakes using simulated data to ensure controls are working properly.	The Airbrake system lead will perform the final inspection.	1	2	2
Airbrakes Flaps Break	The flaps break from their connecting rods and come free or no longer work properly.	The rocket's angle of attack drastically changes, or the fins could be damaged.	4	3	12	Check structural integrity of flaps and develop methods to ensure failure of flaps can be mitigated in some way.	The Airbrake system lead will perform the final inspection.	2	2	4

Airbrakes Stepper Motor Failure	Motor burnout, mechanical failure.	Failure to deploy or retract flaps.	2	3	6	Motor testing will be performed prior to final assembly.	The Airbrake system lead will perform the final inspection.	1	2	2

3.4. TRA Mentor Procedures

The CSL TRA team mentor will purchase, transport, store, and install all motors and energetic devices while following the safety codes detailed by the NAR and the TRA. The team mentor will have the power to delegate the handling of hazardous materials to certified personnel. The CSO and the team mentor will ensure that all safety codes are followed by the team and spectators at the subscale and full-scale launches. The TRA Safety code can be found in the provided link.

TRA Safety Code:

https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=520420.

3.5. Safety Compliance

3.5.1. Compliance with Local Rocketry Club Rules

All team members will follow the NAR HPRSC (effective August 2012) and comply with each personnel procedure.

Table 3.5.1. *NAR HPRSC and the team corresponding compliance action.*

NAR High Power Rocket Safety Code	Team Compliance Action
1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user verification and required licensing.	Team mentors are NAR Level 2 certified and will the only people to handle the rocket motors.
2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.	The rocket design avoids the use of materials that do not meet the standard lightweight materials. If there is any uncertainty with the use of other materials, the team will communicate with NASA competition officials.
3. Motors. 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.	The team will exclusively use motors that are certified by trusted motor manufacturers. The usage of motors will be supervised by team mentors, solely for the purpose of launching the rocket under controlled and safe conditions.
4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in	The team will only launch at NAR/TRA operated launch sites to ensure that the

the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.	appropriate ignition systems are properly installed and functioning as expected.
5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.	The team will follow the instructions of the NAR/TRA Range Safety Officer at the launch site after a misfire. Only necessary personnel are allowed to approach the rocket once the ignitor is set in place.
6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.	The team will rely on the NAR/TRA RSO at the launch site to conduct a 5-second countdown before launch. Team members are instructed to be wary of surroundings and give attention to spectators that could be too close to the launch pad. They are also instructed to look for and communicate with those around them during the rocket descent. Once the rocket is assembled and the motor is installed, the center of gravity (CG) location will be calculated and marked to ensure the stability of the rocket before launch. The team does not plan to conduct simultaneous launches.
7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind	The team will only use launch rails provided at the NAR/TRA launch sites. The team will fully comply with the launcher specifications.

speed exceeds 5 miles per hour, I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.	
8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high-power rocket motor(s) intended to be ignited at launch.	The rocket design will comply with the total motor impulse intended and will comply with the weight limit requirement.
9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.	The team will launch at NRA/TRA approved sites with the RSO present. The team will comply with the FAA regulations of not launching the rocket at any targets, into clouds, or near airplanes. If the wind speed surpasses 20 mph or cloud cover is too low, the launch will immediately be canceled. The team will only use the motor specified in the design so that any part of the rocket will not exceed the expected apogee.
10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet,	Team launches will take place at NAR/TRA approved locations. The RSO has the authority to change locations of the launch site to meet safety regulations.

whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).	
11. Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.	The team will stand back away from the launch site no closer than the Minimum Distance table during launches. If possible, team members are advised to stand further away from potential safety hazards. The RSO and team members will control the traffic flow around the launch site.
12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.	The rocket design will use a parachute as a safe recovery system to ensure the rocket will land safely. Flame-resistant wadding will be used to prevent the spread of fire. A pre-launch checklist will be used provided by the CSO and Launch Officer.
13. Recovery Safety. I will not attempt to recover my rocket 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.	The RSO and team members will work together to keep spectators away from the launch site. Team members are not allowed to retrieve the rocket in dangerous situations or contact the rocket as it descends.

3.5.1.1. Local Rocketry Club Rules

CSL will be performing launches with a local rocketry club that has been identified as the WSR. WSR is Section 703 of the NAR in the southwestern Ohio region that uses complete low-power and high-power ground support equipment like launch systems, pads, rods, and rails. They launch rockets in compliance with the NAR Model and HPRSC. Team members that participate with WSR will comply with the rules and regulations that they have set in place. This includes notifying WSR leadership at least one week in advance for a high-power rocket launch.

3.5.2. Federal Regulations

CSL will adhere to all United States federal regulations concerning the use of the National Airspace System (FAR 14 CFR, Subchapter F, Part 101, Subpart C) and fire prevention guidelines (NFPA 1127) to ensure the safe and legal operation of high-powered rockets.

The team will follow Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C regulations to not operate high-power rockets:

a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails
b) At any altitude where the horizontal visibility is less than five miles
c) Into any cloud
d) Between sunset and sunrise without prior authorization from the FAA
e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA
f) In controlled airspace without prior authorization from the FAA
g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:
    1) Not less than one-quarter the maximum expected altitude
    2) 457 meters (1,500 ft)
h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, has final approval authority for initiating high-power rocket flight; and
i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

3.5.2.1. NFPA 1127 Code

Team members will adhere to the rules and regulations provided by the NFPA 1127 Code for High Power Rocketry to reduce fire dangers and related hazards associated with high power rocketry.

3.6. Safety Statement

The goal of the safety statement is to ensure each team member commits themselves to follow all rules and regulations set in place by the NAR, the FAA, the TRA, Range Officer, CSO, and team mentors. Those that do not comply with the safety statement will be removed from the team as decided by the team lead, CSO, and the team mentor. All team members of Cedarville Student Launch will sign and agree to the following safety statement:

As a member of the Cedarville Student Launch team, I commit to following all safety standards. I will comply with national, state, local, and school regulations in all team-related activities. I will adhere to the safety guidelines and documents concerning the design, construction, testing, launching, and transportation of the rocket. This includes those provided by the university, team, and national organizations such as the NAR, FAA, and TRA. Before performing any tasks, I will make sure I understand all relevant safety materials. I will comply with range safety inspections whether subscale or full scale before it is launched. I understand that the RSO has the final say on all rocket safety issues and can deny the rocket launch due to safety reasons. I understand that by following the safety rules and regulations the team will be rewarded for participation of the exhilarating pursuit of high-power rocketry.

I acknowledge that failure to comply with this statement may result in my expulsion from the team. My signature confirms I have read and agree to abide by the statements provided.

Name Jesse DePalmo

Signature *Jesse DePalmo* Date 09/11/2024

4. Technical Design

4.1. General Design

The overall design of the launch vehicle is to be optimized to complete the competition and course objectives using the minimum dimensions and number of technical resources possible. To achieve these objectives, the team will draw, to a limited extent, from two high-level design decisions employed by previous years' CSL teams. First, the bulk of the rocket airframe is to be constructed from commercially available, uniform diameter G12 fiberglass tubing manufactured for rocketry purposes. G12 fiberglass tubing is commonly used for high-power and even amateur rocketry applications, and it is preferred for its relative strength, dimensional accuracy, radio transparency, and affordability compared to carbon fiber tubes. An example of such tubing is shown in Figure 4.1.1.

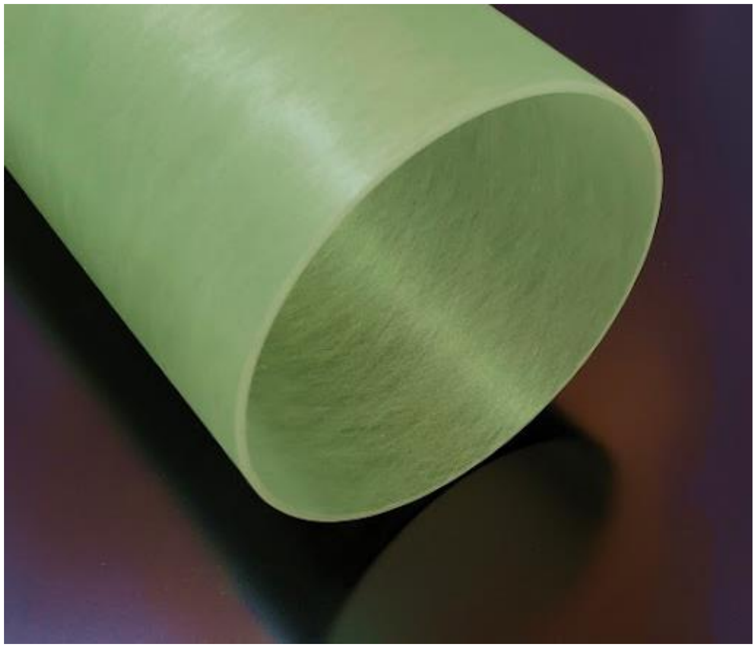

Figure 4.1.1. *Example of an epoxy resin, G12 fiberglass-filament-wound tube made for model rocketry applications (image source: compositewarehouse.com).*

Secondly, the entirety of the modules fixed inside the airframe of the rocket are to be screwed in from the outside of the rocket, not glued in from the inside. This design “policy” is intended to maintain a broader commitment to modularity. Notably, even basic components that are traditionally glued in a rocket, such as the fins, centering rings, and shock cords will be attached in a removable manner. Components will be easily assembled, iterated upon, repaired, and stored under this design philosophy.

4.2. Nose Cone

The nose cone will serve as the first section of the rocket, functioning as the primary aerodynamic component tasked with minimizing drag. In addition to its aerodynamic role, CSL has decided that the nose cone will also house the payload and a small camera, which will integrate multiple functions into this critical structure. To determine the most effective design, the team examined several types of nose cones, including conical, ogive, parabolic, elliptical, and Haack Series. They each offered unique advantages and disadvantages. A comparison of these shapes is presented in Table 4.2.1.

Table 4.2.1. Comparison of Advantages and Disadvantages of Different Nose Cone Types.

Nose Cone Type	Advantages	Disadvantages
Conical	Simple shape, easy to manufacture	Higher drag compared to other shapes
Ogive	Lower drag, aerodynamically efficient for a range of speeds	Slightly more complex to manufacture
Parabolic	Excellent at reducing drag at supersonic speed	Difficult to manufacture
Elliptical	Good for reducing drag at subsonic speeds	Not ideal for supersonic speeds
Haack Series	Optimal for minimizing drag based off specified dimensions	Difficult to design and manufacture

Based on this comparison, the CSL team settled on utilizing a Haack Series nose cone due to its ability to mathematically derive shapes that minimize drag for given dimensions. Figure 4.2.1 shows a basic Haack Series profile.

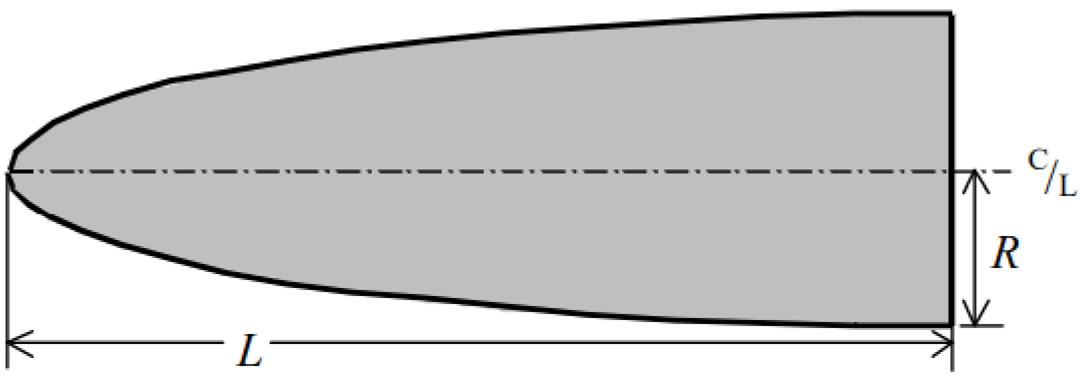

Figure 4.2.1. *Basic Haack Series Nose Cone Profile.*

To address the manufacturing challenges of the Haack Series nose cone, the team chose 3D printing as the solution. This method allows for rapid prototyping and the flexibility to integrate design changes over time. To ensure the nose cone's durability and minimize damage upon landing, a significant portion of the structure will be infilled, which will enhance its strength and enable reusability. Additionally, the team compared various 3D printing materials to determine the most suitable option for the nose cone, with a comparison presented in Table 4.2.2.

Table 4.2.2. Comparison of Advantages and Disadvantages of 3D Printing Materials.

Material	Charpy Impact Resistance $(\frac{kJ}{m^2})$	Strength (MPa)	Compatibility to printers	Approximates Price [$] per kg
ABS	25	40	No	25
ASA	40	37	Yes	35
CF Blends	100	85	No	80
PC Blends	75	59	No	70
PLA	16	57	Yes	20
PETG	50	53	Yes	25

Based on the comparison, PETG was chosen as the material for the nose cone due to its affordability, adequate strength, and resistance, and its compatibility with the team's 3D printers. Other material options were either too costly or not suitable for use with the available equipment. In addition, the nose cone will feature an extended section that integrates into the airframe, providing space to house the payload, as illustrated in Figure 4.2.2.

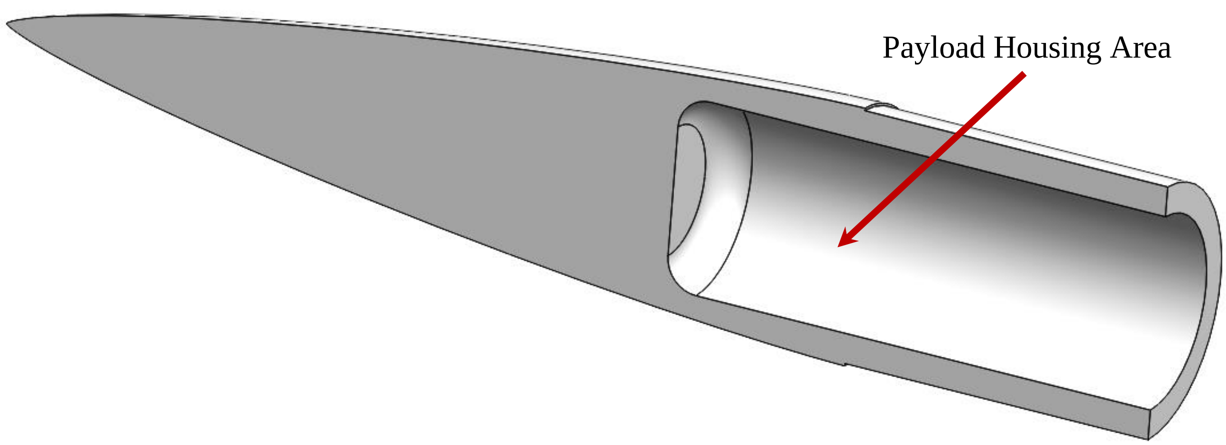

***Figure 4.2.2.** First Haak Series Nose Cone Iteration.*

4.3. Payload

The primary payload system mainly consists of two steps, data collection and data transmission. The data collection will be performed by a series of sensors connected to a microcontroller (a Raspberry Pi 2040) which will perform calculations on the data and store it. Since the main payload will be detached from the avionics system, the sensor information gathered will also be used to detect flight phases to determine when to start collecting data and when to transmit. The radio transmitter will also be connected to the microcontroller and a transmitter and antenna within the rocket's nosecone. The payload will include a MicroSD card reader, which will have the collected flight data written to it which can be analyzed after a payload test or flight for debugging purposes.

Transmission of data is imperative to the competition, so functional radio transmission is one of the payload team's first priorities. To determine which data to transmit, the team has ordered the data which can be transmitted to NASA in order of feasibility. It is the team's goal to ensure consistent collection of the first four data measurements and consistent transmission of the data by performing incremental testing of data collection and transmission during development. If the payload team determines by the end of the first semester that it would be feasible to transmit more data measurements, the team will continue down the list. The three data measurements listed as "Tentative" would require no additional sensors to be added to the payload; only additional software would be required. Table 4.3.1 shows the determined order of feasibility and Figure 4.3.1 provides a high-level architectural overview of the planned components and their interactions.

Table 4.3.1. *Determined Order of Data Measurement Feasibility.*

Priority	Objective	Expected?
1	Temperature of Landing Site	Yes
2	Apogee Reached	Yes
3	Orientation of On-Board STEMnauts	Yes
4	Time of Landing	Yes
5	Calculated STEMnaut Crew Survivability	Tentative
6	Landing Velocity, G-Forces Sustained	Tentative
7	Maximum Velocity	Tentative
8	Battery Check / Power Status	No

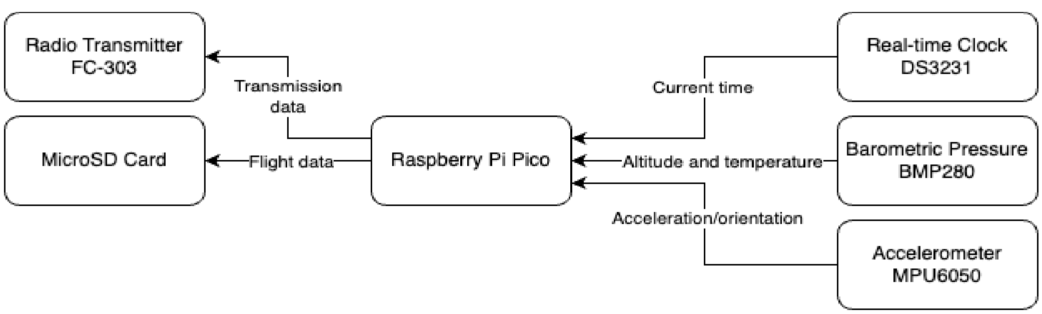

Figure 4.3.1. *High-Level Main Payload System Design.*

4.4. Avionics

The avionics bay will house the electronics used to deploy both the main and the drogue parachutes. CSL will have redundant altimeters manufactured by separate companies to reduce the possibility of a manufacturing defect preventing the parachutes from deploying. These altimeters will each be wired to a separate drogue and main ejection charge for a total of 4 independent ejection charges. The avionics bay will also contain a GPS capable of transmitting the rocket's landing location to a handheld receiver to ease the recovery process and ensure that the rocket is recovered in a timely manner.

All the electrical components for the recovery system will be housed in the avionics bay and will be independent from any circuits for the primary or secondary payload. To fulfill NASA requirements for the recovery system each altimeter will have its own independent battery and will be capable of being armed from the exterior of the rocket using a mechanical arming switch. In previous years, CSL has experienced issues where the power to one of the altimeters is lost during flight. To help to minimize the chance of this problem, pull tests will be conducted on all the wires in the avionics bay before every launch or as feasible. Keeping cable management in mind while designing the avionics section will enable the recovery lead to be able to easily inspect the wiring in the avionics section as needed.

4.5. Recovery

The recovery system will include a dual bay system which will allow for a simpler design compared to a single bay system. An example of a dual bay system can be seen in Figure 4.5.1. It will also work to separate weight more by creating three different sections. The dual bay system will, however, take up more space in the rocket and require more black powder charges. The dual deployment will include a drogue parachute deploying with no more than a 2 second delay at apogee and a main parachute deploying at 600-550 ft Above Ground Level (AGL). This will better allow the rocket to descend to ground from apogee in 90 seconds or less as well as keeping it from drifting outside of a 2500 ft radius allowing it to have a Close Proximity Recovery (CPR). Based on the projected rocket weight, the max speed the rocket can touch down at to ensure kinetic energy at touchdown is 75 ft-lbf or less is approximately 12 ft/s.

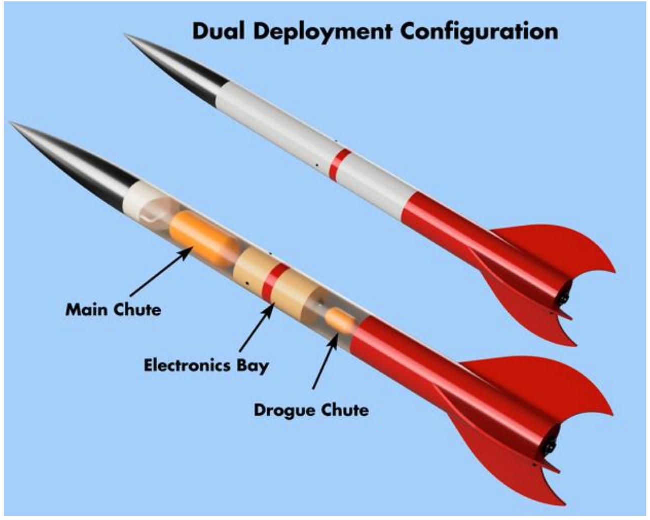

Figure 4.5.1. *Dual deployment recovery configuration.*

Since the drogue parachute will be responsible for most of the descent to slow down the speed of the rocket, its area (which will be approximately ¼ smaller than the main parachute) and what kind of deceleration it can accomplish will be evaluated. This will be done to decide the size needed in the main parachute so that the speed the launch vehicle reaches the ground will be of equal or lesser value than the maximum velocity. When the rocket splits it will be held together by shock cords attached to the parachutes. By utilizing a double bay deployment, the design is split into three sections which will spread out the weight on impact.

In between the two bays of the recovery system, the rocket will include an avionics bay that will house an altimeter along with a power source and GPS to transmit the location of the rocket back to a ground receiver. The altimeter will be instrumental to the deployment of the parachutes at the correct times based on altitude which will communicate to a controller and set off the black powder charges. Placing the avionics section in between the two parachutes will also protect the electronics from any type of interference from the other signals or malfunctions in the payload such as motor or black powder explosion damage.

4.6. Airbrakes

An airbrake system will serve as a secondary payload on the launch vehicle. The goal of the airbrakes will be to induce more pressure drag on the rocket which will lower the apogee of the rocket during the coast phase of the ascent. The intent of adding control surfaces to the rocket is to actively lower the apogee of the rocket to the target altitude during the coast phase of flight.

4.6.1. Airbrake Comparison

There are two types of airbrakes most used in the high-power model rocket hobby/industry: blade brakes and flap brakes. They come in all shapes, sizes, and mechanisms. Blade brakes work by pushing two blades out the side of the fuselage. The second type of airbrake system more common on airplanes is the flap airbrake. It works by actuating a portion of the fuselage material into the stream as the rocket needs to slow down. Figure 4.6.1 shows the two different designs in a CAD model.

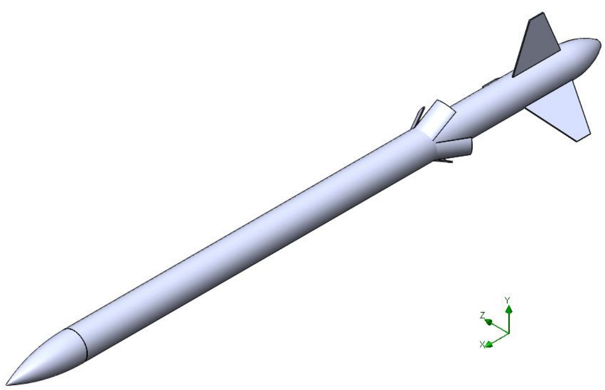

Figure 4.6.1a. *Flap airbrakes on a high-powered model rocket.*

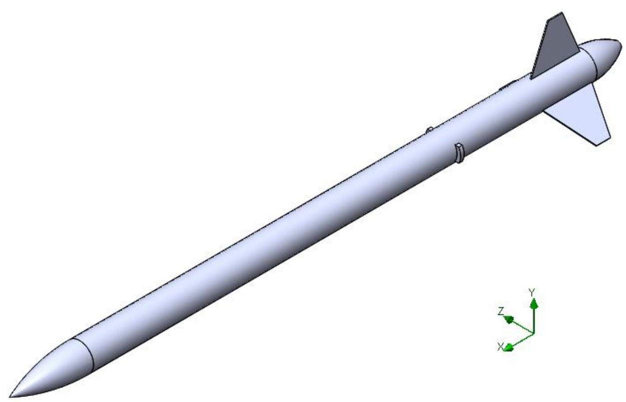

Figure 4.6.1b. *Blade airbrakes on a high-powered model rocket.*

Flap brakes will be used due to the overwhelmingly higher drag force created. Blade brakes were only a choice because they were more vertically space efficient. Since the goal is to make as small of a rocket as possible, then blade brakes were a possiblity, but after a rudimentery Computational Fluid Dynamics (CFD) analysis was conducted, it was decided that the marginal space lost to flap brakes will be worth it.

4.6.2. Airbrake Mechanism

Flap brakes will be used, but the airbrakes need an internal mechanism to drive it. A minimum viable product (MVP) will be designed to facilitate the actuation of the flaps. The first iteration will look like Figure 4.6.2. It has a simple crank slider mechanism which will actuate four flaps around the fuselage since it has the largest amount of surface area to create the most drag. The bulkhead at the top of this mechanism will be held in by standoffs and will secure the threaded rod, which is driven by the motor.

Below the motor, battery, and mechanical mechanisms, which can move and break the fragile components, is the electrical bay. Within the electrical bay there will be a Raspberry Pi Pico, accelerometer, rotary encoders, and 2 altimeters. It is important to note that since the rocket will fully separate, each bay must have its own electrical systems. This is why there will be dedicated altimeters in the secondary payload section, and therefore altimeter vent holes. Since the pressure will change with the flaps opening and closing during flight, the electronics bay will be sealed off from the mechanical portion. Finally, the motor will be controlled by the Raspberry Pi which will be programed using Simulink.

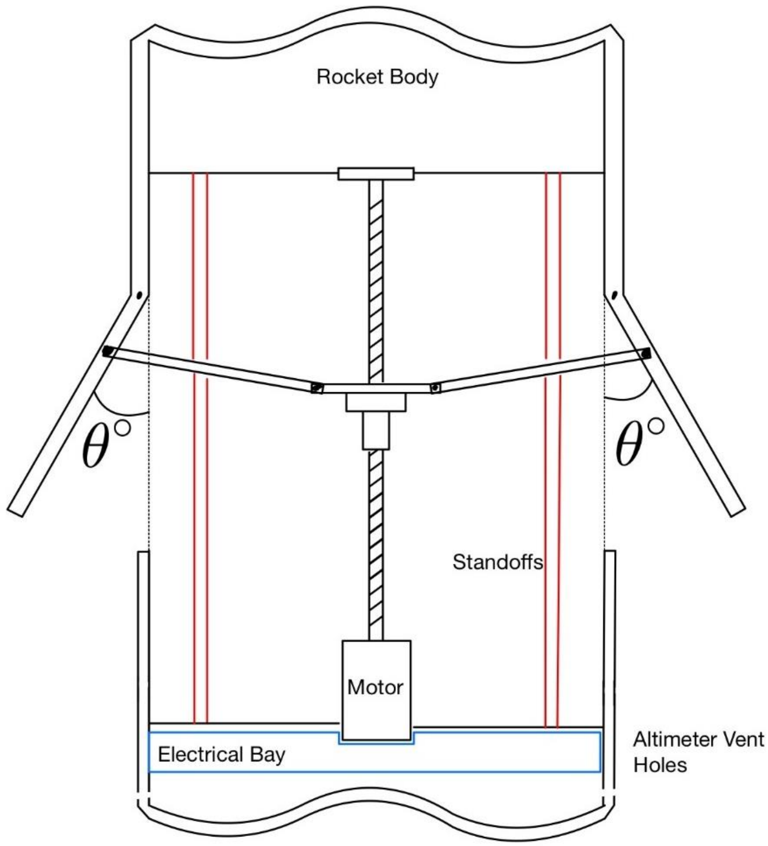

Figure 4.6.2. *Preliminary airbrake mechanical system sketch.*

In conjunction with a CFD CAD model of the rocket, featuring retracted and deployed airbrakes, the rocket's flight will also be modelled in the MATLAB Simulink extension so that a control algorithm for the airbrakes can be created. The controller will be deployed from an onboard Raspberry Pi to actuate the airbrakes in flight. If time and resources permit, a dynamic similitude experiment will be designed so that the airbrakes' control system can be demonstrated inside of a wind tunnel. Additionally, multiple test flights will be conducted with the airbrakes active to gather data and improve the control algorithm.

4.7. Fin Design

The main objective of the CSL's fin design is to increase stability, reduce fin drag, avoid fin flutter, and maintain strength. After much deliberation and research on the matter, CSL decided on trapezoidal fins. Ellipsoidal fins are theoretically the best because they produce the least amount of induced drag according to Apogee Rockets, but the fins themselves are difficult to manufacture. They are mostly designed for transonic applications and not subsonic applications because they delay local shock formations as the rocket approaches supersonic speeds. Trapezoidal fins are not difficult to manufacture, they resist flutter better than most shapes according to Nakka Richard's Rocketry Site, and they are structurally robust. For those reasons, that is why CSL chose trapezoidal fins over any other fin design. The trapezoid shape makes them easy to adjust if the CSL needs to adjust the center of pressure for stability reasons. The reasons CSL chose not to go with the other fin designs were because the pros of the trapezoidal fins outweighed the pros of any other fin choice besides ellipsoidal. Delta fins would be easy to design but the delta shaped fins are susceptible to damage due to the sharp tip, which the CSL team wants to minimize because the rocket needs to be reusable. The CSL team also does not want to go with any swept designs that extend past the end of the rocket to minimize damage upon landing. The team also plans on using three fins instead of four. The reason for this is because it sufficiently lowers drag and reduces the weight in the tail end of the rocket. Since the fins are trapezoidal, the shape can be adjusted to compensate for the change in CP.

In terms of the fin material, the team has decided on G10 fiberglass for this application. The reason for this is due to its incredibly high strength to weight ratio. The density of G10 fiberglass is around 0.065 lb/in^3, and the ultimate tensile strength is around 38,000 psi. The only other option the team considered was carbon fiber. The main reason CSL decided against it was the cost of carbon fiber is much greater than G10 fiberglass. It is durable and comparable to materials with much greater densities. Being lightweight and durable makes using G10 fiberglass perfect for this application.

4.8. Thrust Structure

As was mentioned in Section 4.1, the 2024-25 CSL team intends to remain committed to a glueless, modular design that allows parts to be swapped or iterated upon easily. Modular centering rings that screw into the airframe from the outside of the rocket allow the fins to be fixed in place through slots in the main airframe tube. The rings suspend the motor tube inside the airframe, and the aft ring serves as a mounting point for the tail cone/motor retention system. Figure 4.8.1 illustrates the relative layout of these modular thrust structure components inside the airframe tube.

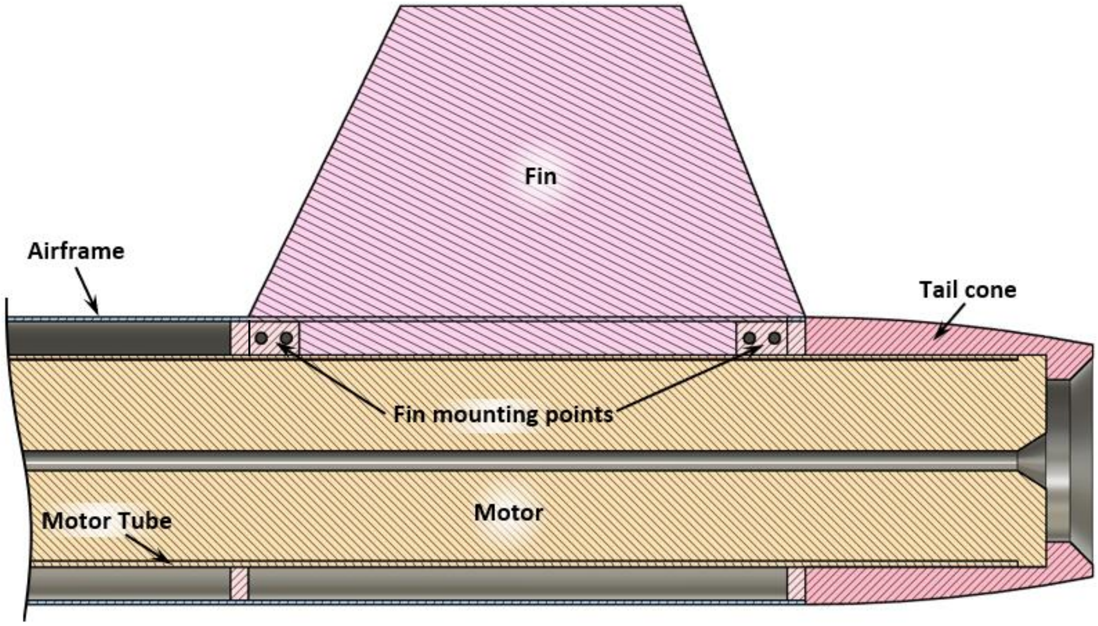

Figure 4.8.1. *Section view of the proposed thrust structure with major components labelled. Note the integration of motor retention into the end of the tail cone, which features a flange that holds the motor in place.*

A commercial motor retention system will be replaced with a tail cone, or boattail, that will simultaneously retain the motor in the aft portion of the rocket and reduce pressure drag due to its geometry. As the rocket travels, the flat end of the airframe causes the flow to detach from the rocket, which increases pressure behind the rocket, which increases drag. To mitigate this detached flow, a curved geometry allows the flow to stay attached longer and have a smaller aft profile once the flow detaches. To facilitate this attached flow, the tail cone will be designed with an ogive geometry that gently transitions from the full diameter of the airframe to the diameter of the aft closure of the motor casing.

4.9. Projected Apogee & Simulations

Tentatively, the target altitude for the full-scale vehicle is 4100 feet AGL. This value is subject to change until the CDR is due, but at present 4100 feet is a reasonable value based on the altitudes achievable from the current motor selection shown in Table 4.9.1. Figure 4.9.1 shows a plotted flight profile generated from the OpenRocket simulations one of the motor choices.

Table 4.9.1. *Conceptual design simulation data summary for three motor choices. Flight conditions were set to international standard atmosphere settings with the main parachute deployment at 500 ft AGL.*

Motor	Velocity off rod	Apogee	Max. velocity	Max. acceleration	Time to apogee	Flight time
Aerotech K1000T-P	41.6 ft/s	4809 ft	583 ft/s	274 ft/s^2	17.6 s	84.6 s
Aerotech K560W-P	29.3 ft/s	4469 ft	499 ft/s	179 ft/s^2	17.9 s	80.3 s
Aerotech K1800ST-P	52.7 ft/s	4687 ft	602 ft/s	519 ft/s^2	17.0 s	81.1 s

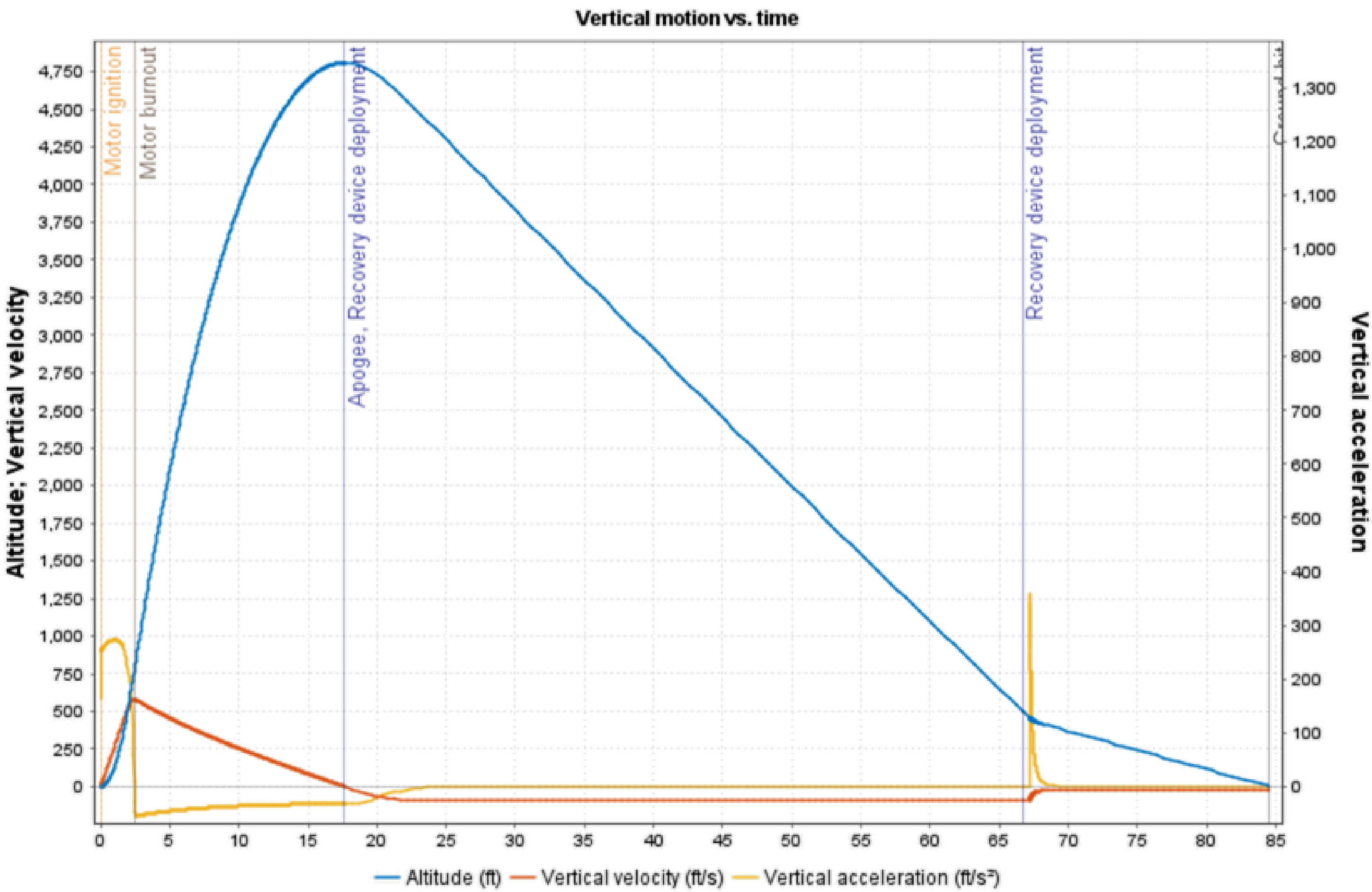

Figure 4.9.1. *OpenRocket plot of the full-scale launch vehicle flying on an Aerotech K1000T-P.*

According to the simulated data presented in Table 4.9.1, the launch vehicle should be able to exceed the target altitude by 300-700 feet, an altitude difference that the rocket's air brakes will account for. Throughout the design process, the launch vehicle's apogee without airbrakes engaged will be monitored so that the control surfaces, once engaged, will be able to bring the apogee down to the target altitude. Due to the sizable lead time associated with high-powered rocket motors of this class, it is far more desirable to modify air brake geometries so that their design sufficiently controls the flight than to experiment with a variety of motor/ballast combinations to achieve the desired altitude. Figure 4.9.1 shows the OpenRocket diagram for the full-scale rocket, and Table 4.9.2 gives general rocket parameters as estimated by OpenRocket.

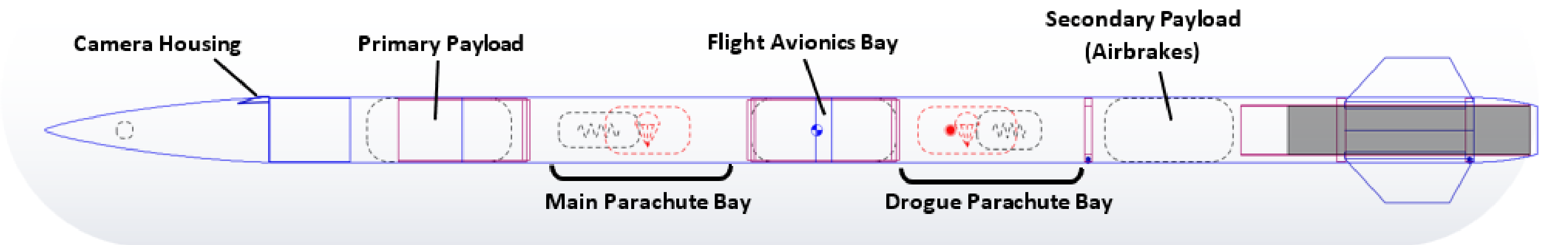

Figure 4.9.2. *Conceptual OpenRocket schematic of the full-scale launch vehicle. Fin shape, airframe dimensions, and CG/CP location are all subject to change.*

Table 4.9.2. *General full-scale launch vehicle parameters derived from OpenRocket simulations*

Wet Mass (Avg)	28.0 lb
Dry Mass	22.1 lb
Length	93.0 in
Max Diameter	4.02 in

4.10. Technical Challenges & Solutions

For the eventual airbrake solution to impact the launch vehicle's ability to reach the competition altitude, the rocket must meet and significantly exceed that altitude so that the control surfaces can vary the overall vehicle drag and therefore control the apogee of the rocket. The current design employs several different strategies to ensure that the rocket is not unnecessarily large or overbuilt for its mission.

In a departure from designs developed by previous CSL teams, this year's proposed design features a slimmer, 4" fiberglass tube airframe to dramatically reduce the amount of energy required to lift the rocket. Although this significantly reduces the volume available for primary payload, the team was comfortable moving to using a smaller airframe since the competition payload is not mechanically complex. The sensor payload that the ECE team will include this year is not projected to require much radial space, certainly far less than a payload with moving parts might require. Additionally, the use of a drag-reducing tail cone in place on the aft end of the airframe will further reduce the amount of energy required to power the rocket.

A comparatively small amount of public research is available concerning airbrakes and their control systems, so the team faces the challenge of developing experimentation methods to test the mechanical design and control algorithms. The CSL mentors, as well as some team members, are aware of opportunities to access wind tunnel testing equipment, so the plan to validate the airbrake system will likely involve dynamic similitude hand-calculations and physical wind-tunnel testing. Such experiments would allow flight data collection without committing excessive time and expensive motors to the effort, as well as develop relationships with wind tunnel research facilities that could be maintained by future CSL teams.

Finally, the CSL launch vehicle design this year features two sizeable, custom-manufactured external components that are guaranteed to weather a great deal of abuse during and after flight: the nose cone and the tail cone. As mentioned in Section 4.4, the nose cone contains various special geometries to accommodate the camera and primary payload, so it will be necessary to manufacture this using 3D printed segments strengthened on the outside with a fiberglass layup. The manufacturing team members will conduct various small-scale construction tests on 3D printed samples to validate the fiber glassing technique. In the case of the tail cone, the final design solution must not only be impact, but also heat resistant. Temperature tests involving real static fires in a motor test rig will ensure that the tail cone is properly heat resistant, and real-world testing with a smaller version of the tail cone on the sub scale rocket will validate the strength of the construction method used.

4.11. Mass Growth Allowance

In a typical airspace system, the system's mass properties are a major constraint on the design and are instituted by regulations or contracts. In the case of the NASA student launch initiative, explicit mass property constraints are up to the discretion of the individual teams. As CSL enters the conceptual design phase, the design team is faced with two vital questions: how much ought the conceptual design weigh, and, as the design matures and the subsystems become fully fleshed out, about how much can the system mass properties be allowed to grow while still maintaining mission viability?

The initial subsystem mass estimates cited in this document are the product of rudimentary calculations and product research. In industry terms, this is known as a system with a low mass maturity. As the design matures, so does the mass property estimate for the entire system, such that the mass maturity can be used as an indicator of design maturity. The mass of each subsystem is recorded, and alongside that data an allowance for the eventual growth of the mass estimate due to the design maturity is included. This property, often given as a percentage, is known as the mass growth allowance (MGA).

In the mass properties analysis of a system, the MGA only serves as a growth allowance above the basic mass numbers available. As design changes trickle down through the subsystems, the difference between the predicted mass properties projected by the MGA and the maximum allowable mass (NTE, "not to exceed") for the contract must be closely monitored. For the NASA SL competition, no such maximum allowable mass for the entire system is mandated in the competition handbook. However, though CSL's design will thus not be able to violate contract on the grounds of mass properties the launch vehicle obviously abides by practical physical constraints. To account for this reality, a vehicle mass properties analysis includes a mass limit, that is, the absolute maximum system mass for which the mission can still be accomplished.

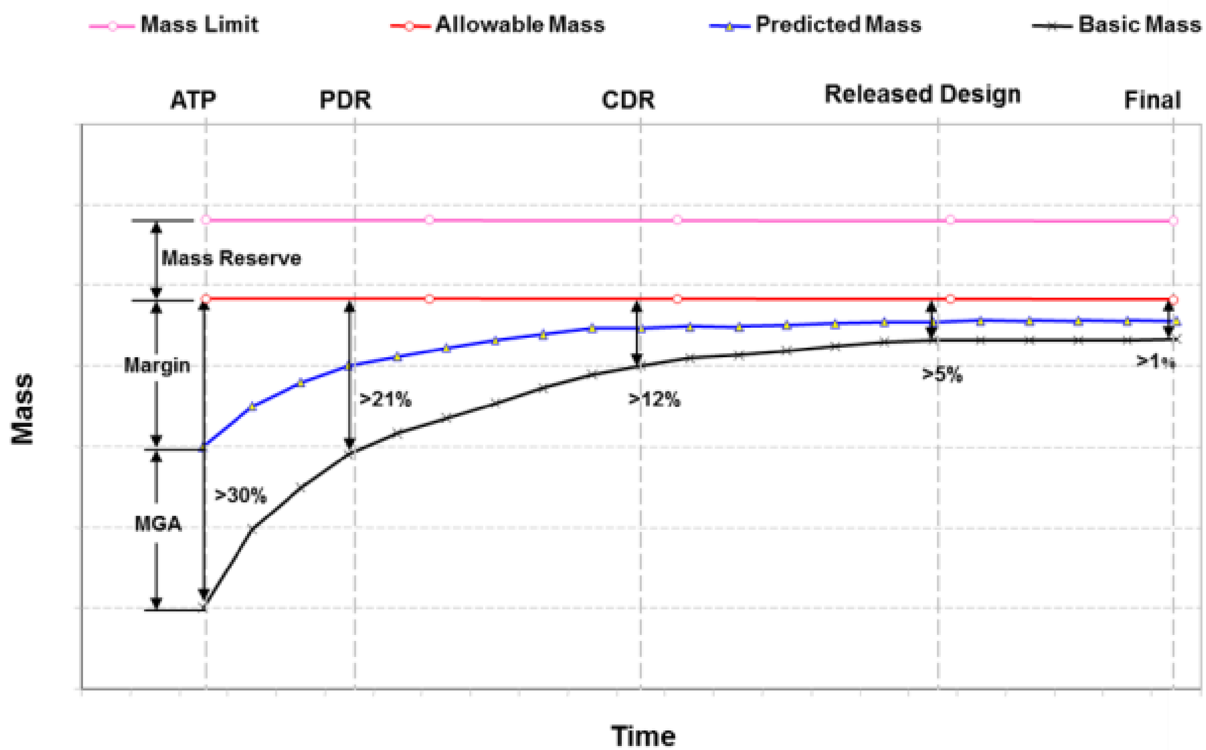

Figure 4.11.1. *Generalized plot of system mass versus time as design maturity increments by project milestones (figure credit: aiaa.org).*

The MGA for the 2024-25 CSL competition vehicle will be based on typical mass property growth rates observed in key launch vehicle components from the past three years of CSL. As the year progresses and basic mass properties are acquired, the chief engineer will maintain a mass properties control plan (MPCP) and attach it to milestone documents.

5. STEM Engagement

5.1. Goal Statement

The STEM Engagement Officer for the 2024-2025 team is Seth Mitchell. CSL hopes to leverage his skills as a former math teacher in inner city schools to excite many students from diverse backgrounds in pre-k to undergraduate level education in more than three Ohio counties. The team will assist by facilitating Direct Educational Engagements. Lastly, the STEM Engagement Officer will mentor an underclassman Mechanical Engineering student as an intern, providing hands-on, life-on-life training in teaching engineering concepts.

5.2. Engagement Plans

The STEM Engagement Officer is responsible for planning and coordinating STEM engagement activities and events. The minimum requirement is to reach 250 students in Direct Educational Engagement. This is defined by NASA in the Handbook as “A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity." If the team decides to participate in Educational Indirect Engagement or Direct/Indirect Outreach Engagement, then it will not count toward the minimum engagement requirement.

Although, the team is not required to facilitate indirect educational and outreach events, they are committed to striving for excellence by connecting with as many students as possible through all four categories of STEM Engagement.

5.2.1. Direct Educational Engagement

Due to the large number of contacts within the Dayton, Columbus, and Cincinnati areas the team has, they are planning to reach all grades from pre-k to undergraduate level. These include the Ohio School of the Blind, the Ohio School of the Deaf, and Inner-City Schools such as Horizon Stem Academy, and Columbus Noble Academy.

5.2.1.1. Pre-k to 2nd Grade

Reaching students in this age group is vital for proper STEM engagement. An article by Rishi Sriram stated, "This first critical period of brain development begins around age 2 and concludes around age 7. It provides a prime opportunity to lay the foundation for a holistic education for children. Four ways to maximize this critical period include encouraging a love of learning, focusing on breadth instead of depth, paying attention to emotional intelligence, and not treating young children's education as merely a precursor to "real" learning." (Au et al.) CSL is committed to students of all ages, and believes that "real learning" does not occur only in universities.

To address this critical period of brain development, the Cedarville Team will go to places such as Horizon STEM Academy, which is a school in inner city Columbus where underprivileged students wouldn't otherwise have an opportunity to learn about these hands-on concepts which are so important to their young developing minds. CSL plans to facilitate a fun and educational activity with paper airplanes to teach the students about how pressure differentials work at a very low and basic level. This will give them a framework to understand why principles of science and mathematics matter no matter at what level they are learning.

5.2.1.2. 3rd-5th Grade

In this age group it is important to start applying some principles they have been able to learn in school. This includes a little bit of math and some fun science such as the scientific method, data collection, geometry, and algebra. The boring thing about school is that the students learn about the material, but they can hardly apply it. The Cedarville Team plans to facilitate activities which integrate the current understanding these students have of the world and broaden their knowledge base by giving them a mechanism by which they can apply it.

To apply their knowledge of math and science CSL plans to facilitate a stomp rocket activity. They will then apply their knowledge of the scientific method by proposing a hypothesis of how high the rocket will go and then carry out the experiment, collect data, and use this data to get an actual number for how high their rocket went.

5.2.1.3. 6th-8th Grade

In middle school it is very important not only to be attuned to the needs of the students' education, but to their mental health. According to the article by Mandy Truong at el. they say, "Young people's social relationships during the middle years (8-14) can affect their current and future health and wellbeing, learning and academic performance, and peer and family relationships." (Sriram) The CSL Team is dedicated to the wellbeing of the students they reach out to, wanting them to succeed not only academically, but personally and professionally too. To help facilitate this the team must change the strategy a little bit by not only engaging their students in this age group with STEM concepts, but with activities that will be inviting, and encourage positive social interactions.

STEM activities will be curated which will bring about critical thinking while still staying mindful of positive interactions among each peer group. This will include collaborative learning and the building of bottle rockets. The students will first learn about concepts of water pressure propulsion, the center of gravity of objects, the center of pressure, and newtons three laws of motion using hands on activities.

Once the students have learned about the basic's concepts needed to build a rocket and have understood the challenge of building a rocket, they will have time to design their own bottle rocket in small groups to encourage collaboration and minimize social pressure. Once they design their own rocket, they will hypothesis the apogee of their rocket based on the knowledge they learned previously. They will build this rocket in their groups, and then go outside to launch them giving an opportunity to use the scientific method to compare their predicted apogee to their theoretical number.

5.2.1.4. 9th-12th Grade

High schoolers are ready to engage in multiple types of inquiry and thought such as creative, applied, critical, and metacognitive learning. The team hopes to meet the students where they are and take them further by helping them along by engaging them in the most fun activity yet. This activity will start much like the water bottle rocket activity. The students will start in groups by learning about the same four concepts as mentioned above, although the hands-on concept-based approach will alter due to their higher cognitive ability.

Once they learn about the basic concepts of rocketry, they will have an opportunity to build their own model rocket. CSL will then take them outside to launch it in a competition to see how high they can make the rocket launch.

5.2.2. Indirect Educational Engagement

This form of education is defined by NASA in their handbook as “A count of participants engaged in learning a STEM topic through instructor- led facilitation or presentation.” Although the team is not required to participate in this type of activity, their passion for engaging students in STEM drives them to take part, eager to share and inspire others with their enthusiasm. To facilitate this type of teaching, CSL will take on a lowerclassmen Mechanical Engineering student at Cedarville as an intern to teach them the nuances of both mechanical engineering and soft skills to facilitate a mature and balanced learning environment.

5.2.3. Direct Outreach Engagement

This form of STEM engagement is defined by NASA as “A count of participants who do not necessarily learn a STEM topic but are able to get a hands-on look at STEM hardware.” Facilitating this type of engagement will be a pleasure for the team as they get an opportunity to share their progress with students who might be interested in STEM. The team will share their rocket design with students of any age, allowing them to see and touch both the current and previous subscale and full designs of the rockets. At the end, the team will perform a small model rocket launch in front of the students to exemplify what a rocket launch looks like.

5.2.4. Indirect Outreach Engagement

The last form of STEM engagement is defined by NASA as “A count of participants that interact with the team.” This could be as simple as the team going to the Wright Stuff Rocketeers build night and interacting with the younger members of the club, or the team could go to the Wright Patterson Air Force Museum to set up a table and talk to students passing by.

5.2.5. STEM General Summary

Table 5.2.1. *STEM Engagement Events and Activities.*

Age Group	Activity	Learning Outcome	Engagement Type	Duration
Pre-k to 2nd	Paper Airplanes	Fundamentals of Scientific observations; Application of Basic Concepts; Basics of Critical Thinking; Introduction to Abstract Thinking	Direct Educational Engagement	3 Hours
3th-5th	Stomp Rockets	Scientific Method; Critical Thinking; Data Collection; Experimentation	Direct Educational Engagement	3 Hours
6th-8th	Bottle Rockets	Positive Social Relationship Building; Collaboration; Undertaking the Basic Principles of Rocketry	Direct Educational Engagement	7 Hours
9th-12th	Model Rockets	Understanding Basic Principals of Rocketry; Application of Complex Concepts; Teamwork and Communication Amongst Peers	Direct Educational Engagement	7 Hours
Undergraduate	Internship	Developing a Nuanced View of Mechanical Engineering; Learning Soft Skills; Exposure to industry practices	Indirect Educational Engagement	2 Hours/week for both semesters
k-12	Hand-on Rocket Inspection and Presentation and rocket launch	Gain interest in STEM and Rocketry	Direct Outreach Engagement	2 Hours
k-12	Hands-on Rocket presentation	Gain interest in STEM and Rocketry	Indirect Outreach Engagement	2 Hours

After each STEM event, the form on pages 40-42 as well as the event table on page 43 in the NASA Student Handbook will be filled out, or updated if the activity has been used before, with the event details. The goal will be to at least reach the STEM Engagement goal of reaching a minimum of 250 students by March 1 to allow for an applicable amount of time to finish the documentation and have it submitted to NASA before the March 24 deadline for review.

At each event, a post-evaluation will be available to teachers and staff to give their thoughts on the event and activities. This will help in the planning of future events and gives insight into changes that should be made to the presentation so that the students involved are able to get the most out of it. This will apply for both positive and negative feedback as CSL moves to make this an enjoyable but thought-provoking time. To best make use of this feedback CSL will be utilizing one event plan for all events. This plan will have changes made based on feedback from past events, and/or the audience for the event so an appropriate lesson will be held for each learning bracket.

6. Project Plan

6.1. Plan Overview

To ensure successful completion of project objectives, the CSL team used organizational and project management tools such as Notion for team management, a Work Breakdown Structure (WBS) for project task understanding, and a Gantt chart for a vision of the project timeline.

6.1.1. Timeline

To manage both NASA and Cedarville University's Senior Design course schedules, CSL created a Gantt-style chart that simultaneously tracks both sets of deliverable deadlines, given in Table 6.1.1. It is important to note that CSL will not be traveling to Launch Week. Therefore, CSL will be submitting PLAR within 14 days of final launch and will only perform the final launch after having successful Vehicle Demonstration Flight (VDF) and Payload Demonstration Flight (PDF).

Table 6.1.1. *CSL Project Timetable.*

Cedarville University NASA Student Launch 2024-25 Plan

CSL: Project *ELIJAH* PROJECT NAME | **8/14/2023** START DATE | **05/03/2024** END DATE

Task	Start Date	End Date	Progress	8/12/2024	8/19/2024	8/26/2024	9/2/2024	9/9/2024	9/16/2024	9/23/2024	9/30/2024	10/7/2024	10/14/2024	10/21/2024	10/28/2024	11/4/2024	11/11/2024	11/18/2024	11/25/2024	12/2/2024	12/9/2024	12/16/2024	12/23/2024	12/30/2024	1/6/2025	1/13/2025	1/20/2025	1/27/2025	2/3/2025	2/10/2025	2/17/2025	2/24/2025	3/3/2025	3/10/2025	3/17/2025	3/24/2025	3/31/2025	4/7/2025	4/14/2025	4/21/2025	4/28/2025	5/5/2025	5/12/2025	5/19/2025	5/27/2025
NASA																																													
Student Launch Proposal	8/14/2024	9/11/2024	--																																										
Preliminary Design Review (PDR)	10/3/2024	10/28/2024	--																																										
PDR Teleconferences	11/4/2024	11/26/2024	--																																										
Gateway Registration	11/26/2024	11/29/2024	--																																										
Huntsville Roster (for in person teams)	11/30/2024	12/16/2024	--																																										
Critical Design Review (CDR)	11/30/2024	1/8/2025	--																																										
Subscale Flight	10/7/2024	1/8/2025	--																																										
CDR Teleconferences	1/15/2025	2/6/2025	--																																										
Team Photos	2/6/2025	2/10/2025	--																																										
Flight Readiness Review (FRR)	2/6/2025	3/17/2025	--																																										
Vehicle Demonstration Flight	1/8/2025	3/17/2025	--																																										
Payload Demonstration Flight	3/17/2025	4/14/2025	--																																										
FRR Teleconferences	3/24/2025	4/11/2025	--																																										
Launch Window	4/5/2025	5/4/2025	--																																										
Post-Launch Assessment Review (PLA	4/5/2025	5/28/2025	--																																										
Cedarville																																													
Background Research	8/17/2024	9/6/2024	--																																										
Senior Design Proposal Rough Draft	9/6/2024	9/16/2024	--																																										
Senior Design Final Proposal	9/16/2024	9/30/2024	--																																										
Oral Committee Design Review	11/18/2024	11/22/2024	--																																										
End of Semester Report (Fall)	11/22/2024	12/6/2024	--																																										
Final Report (Draft)	1/7/2025	4/11/2025	--																																										
Final Presentations (Oral)	4/11/2025	4/15/2025	--																																										

6.1.2. Work Breakdown Structure

CSL developed a WBS to better understand the system, subsystems, and components essential to mission success. The WBS, given in Figure 6.1.1, organizes and outlines subsections of the project to aid in task and role assignment.

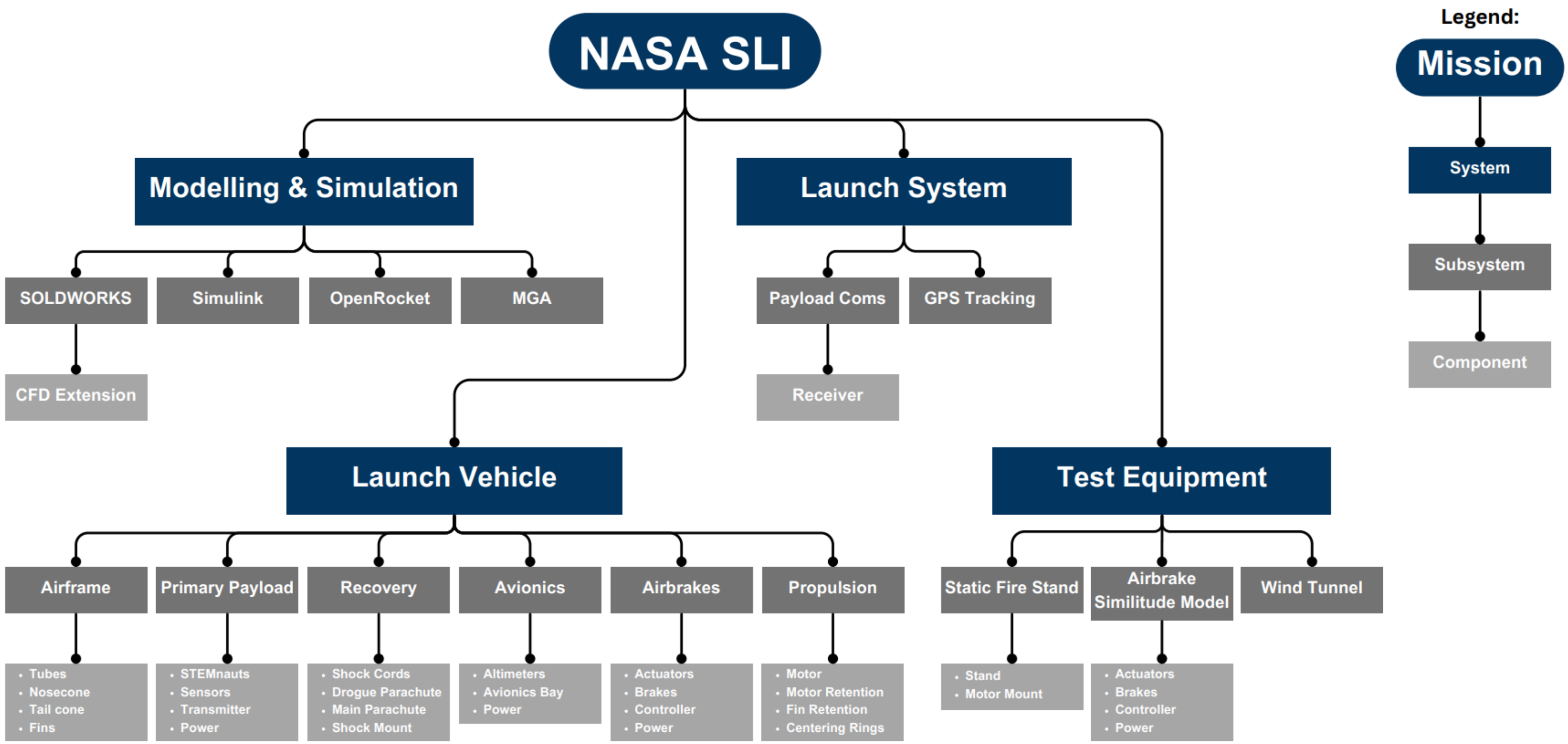

Figure 6.1.1. *CSL Work Breakdown Structure.*

6.1.3. NASA Requirements & Verifications

To foster a rigorous design environment where no competition details are neglected, Table 6.1.2 below lists every NASA handbook requirement pertaining to the technical design of the primary payload, the launch vehicle, and the way they are flown. The status of each of these requirements is noted, as well as the long-term verification plan for completing each item. This table will appear in subsequent milestone deliverables to document the team's progress.

Table 6.1.2. *Project verification table for the 2024-2025 NASA handbook requirements. Note that the requirements pertaining to Huntsville Launch Day are omitted as CSL will not make a physical appearance at the competition fly-off.*

Req. #	NASA Requirement	Verification Plan	Status
1.1	Students on the team will do 100% of the project. The team will submit new and original work.	The team will ensure they do all project reports, designs, construction, and testing.	Incomplete
1.2	The team will create and maintain a project plan for project milestones, budgets, community support, checklists, personnel assignments, STEM engagement, and risks and mitigations.	In addition to the project plans outlined in this proposal, the team will maintain the high- and low-level project plan using project management tools such as Notion	In Progress
1.4	The team will engage at least 250 participants in hands-on STEM activities. This must be completed between moment of project acceptance and the FRR addendum due date.	The team will designate a STEM engagement lead and supporting team members. A multi-stage engagement plan will be created and is outlined in Section 5 of this report.	Incomplete
1.5	The team will create a social media presence to inform the public about team activities.	A social media lead outside of the engineering division will be utilized, and an engineering team member will meet regularly with her to ensure an active social media page	In Progress
1.6	Teams will email all deliverables to NASA by the deadline specified in the handbook. Late submissions of milestone documents will not be accepted	A NASA deliverables checklist will be created to ensure all reports are properly formatted and submitted, and designated editors will be appointed specifically for reviewing the deliverables.	Incomplete
1.8	All deliverables will be in PDF format.	A NASA deliverables checklist will be created to ensure all reports are properly formatted and submitted, and designated editors will be appointed specifically for reviewing the deliverables.	Incomplete

Req. #	NASA Requirement	Verification Plan	Status
1.9	In every report, teams will provide a table of contents, including major sections and their respective sub-sections.	The team has created a pre-formatted document that all new reports will be based on.	In Progress
1.10	In every report, the team will include the page number at the bottom of the page.	The team has created a pre-formatted document that all new reports will be based upon.	In Progress
1.11	The team will provide all computer equipment for video teleconferences with the review panel.	Acquisition of proper rooms, audio equipment, and video equipment will be ensured before every teleconference.	Incomplete
1.13	The team will identify a mentor prior to the PDR. The mentor will be an adult, and they will be certified through the NAR or TRA for the motor impulse of the launch vehicle.	The team has identified a local rocketry club (WSR) and has identified a mentor whose contact info is in Section 1.2 of this document.	Complete
1.14	The team will track the hours it spent working on each milestone.	Per Cedarville University Engineering senior design rules, each team member will keep a logbook that tracks weekly progress and hours worked. Hours will also be logged by spreadsheet.	In Progress
2.1	The vehicle will deliver the payload to an apogee between 4,000 and 6,000 feet AGL.	The team will design the rocket so that simulations and test launches ensure that the rocket reaches an apogee between 4,000 and 6,000 feet.	Incomplete
2.2	Teams shall declare their target altitude goal at the CDR milestone. The declared target altitude shall be used to determine the team’s altitude score.	The team will identify reliable means of simulating the flight path and predicting the altitude so that a target will be determined by CDR.	In Progress
2.3	The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	The vehicle and recovery design will ensure the rocket safely lands. The propulsion system will be designed so that the rocket is reusable.	Incomplete

Req. #	NASA Requirement	Verification Plan	Status
2.11	The rocket will be limited to a single stage.	The chief engineer will ensure that the vehicle is a single-stage rocket.	Incomplete
2.12	The impulse for the launch vehicle will be no more than 5,120 Newton-seconds (L-class).	We will be using a L-class motor that does not exceed 5,120 Newton-sconds as informed by the Motor Data Sheet.	Incomplete
2.13	Pressure vessels on the rocket will be approved by the RSO, have a safety factor of at least 4:1, and will have detailed documentation included in all milestone reviews.	Pressure vessels on the rocket will be approved by the RSO have a safety factor of at least 4:1, and have detailed documentation that will be stored with all other safety documents.	Incomplete
2.14	The launch vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	Using OpenRocket and possibly other calculation methods, the team will ensure that the static stability margin will be at least 2.0 at rail exit.	Incomplete
2.15	The rocket's thrust to weight ratio will be at least 5.0:1.0	CSL will determine the weight of the rocket, and then, using OpenRocket and the motor thrust curve data, CSL will ensure that the thrust to weight ratio exceeds 5:1.	Incomplete
2.16	Any structural protuberance on the rocket shall be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	Burnout CG will be calculated using a testing rig and multiple other methods. Camera housings will be simulated to determine compliance.	Incomplete
2.17	The rocket will have a minimum velocity of 52 fps at rail exit.	Theoretical analysis will be performed on the rocket using OpenRocket, and practical experimentation will be performed to ensure that the rocket has a minimum velocity of 52 fps at rail exit.	Incomplete
2.18	The team will successfully launch and recover a subscale rocket before CDR. The subscale must be a separate, newly constructed rocket and must have an altimeter. Proof of flight is required in the CDR.	The team will construct, launch, and recover a subscale rocket for testing and qualification purposes. This will be done with the help of a local rocketry club and will be completed by CDR.	Incomplete

Req. #	NASA Requirement	Verification Plan	Status
2.19	The team will complete both the Vehicle Demonstration Flight and the Payload Demonstration Flight as outlined by the SL Handbook.	The team lead will ensure that the Vehicle and Payload Demonstration Flights are performed as outlined by the SL Handbook, and prior to any deadlines. They will also submit the results to NASA as necessary.	Incomplete
2.20	The team will create an FRR Addendum for any Payload Demonstration Flight or NASA required Vehicle Demonstration Re-flight after the submission of the FRR.	The team will write an FRR addendum for all necessary changes needed after the submission of the FRR.	Incomplete
2.21	The team will place its name and Launch Day contact information on the rocket airframe and all untethered sections of the rocket.	The team lead will ensure that their name and launch day contact information are on the airframe and untethered sections.	Incomplete
2.22	All Lithium Polymer batteries shall be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	The safety officer will ensure that lithium polymer batteries will be stored in a fireproof LiPo bag. Stickers will denote that they are a fire hazard.	Incomplete
2.23.1-5	The rocket will not use forward firing, hybrid, cluster, or friction-fitted motors.	The team will use a single commercial motor that will be anchored using a motor retainer system.	Incomplete
2.23.6-7	The launch vehicle will not exceed Mach 1 or contain excessive ballast.	Theoretical analysis will be performed on the rocket using OpenRocket, and practical experimentation will be performed to ensure that the rocket does not exceed Mach 1. Ballast use will be reasonable.	Incomplete
2.23.8-9	Transmissions from the vehicle will not exceed 250 mW of power per transmitter and will use unique frequencies and other methods to reduce interference.	The appropriate transmitters will be purchased such that they do not exceed the 250 mW power limit. Research into appropriate frequencies and techniques will be performed.	Incomplete
2.23.10	Excessive and/or dense metal shall not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	The team will not use dense metals for structural components, only aluminum will be utilized in moderation where metal parts are necessary.	Incomplete
3.1	The rocket will deploy a drogue parachute at apogee with a delay of 2 seconds or less. A main parachute will be deployed no lower than 500 feet. Both deployments will not utilize motor ejection.	The launch officer will ensure that altimeters will trigger black powder charges at apogee and at an altitude no lower than 500 feet to deploy the parachutes.	Incomplete

Req. #	NASA Requirement	Verification Plan	Status
3.2	The team will conduct successful ground tests for parachute ejection before the subscale and full-scale flights.	The recovery team will trigger the altimeters so that the black powder charges are fired in a controlled and safe environment for ground testing.	Incomplete
3.3	Each separate section of the rocket will have a landing energy that does not exceed 75 ft-lbs.	Theoretical analysis will be performed on the rocket using OpenRocket and hand calculations to ensure that the rocket's landing energy does not exceed 75 ft-lbs.	Incomplete
3.4	The recovery system shall contain redundant, commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events.	Two altimeters of different brands will be used for recovery. The team member in charge of avionics will ensure altimeter compliance.	Incomplete
3.5	Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries.	Each altimeter will have a dedicated, commercially available battery as a power source.	Incomplete
3.6	Each altimeter shall be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Key-switches or equivalent means will be used to arm the flight avionics.	Incomplete
3.7	Every arming switch will be able to be locked in the ON position.	Key-switches or equivalent means will be used to arm the flight avionics.	Incomplete
3.8	The recovery system, GPS and altimeters, and electrical circuits shall be completely independent of any payload electrical circuits.	Recovery system and payload circuits will be placed in isolated electronics bays within the rocket.	Incomplete
3.9	Drogue and main parachute sections will use removable shear pins.	The recovery lead will be responsible for the insertion and inspection of shear-pins prior to every launch.	Incomplete
3.10	Bent eyebolts shall not be permitted in the recovery subsystem.	Forged eyebolts will be used where required.	Incomplete
3.11	The recovery area will be within a 2,500 ft. radius from the launch pads.	Simulations will be performed on the rocket using OpenRocket and Systems Toolkit, and practical experimentation will be performed to ensure that the drift stays within a 2,500 ft. radius.	Incomplete

Req. #	NASA Requirement	Verification Plan	Status
3.12	The vehicle descent time will be a maximum of 90 seconds.	Simulations will be performed on the rocket using OpenRocket and Systems Toolkit, and practical experimentation will be performed to ensure that the descent time is below 90 seconds.	Incomplete
3.13	The launch vehicle will contain a GPS device that transmits the position of the vehicle or any independent section to a ground receiver.	A GPS will be purchased by the avionics lead, the appropriate tracking software and ground station set up to receive signals will be taken care of by the recovery lead.	Incomplete
3.14	The recovery system electronics will be carefully protected and separate from other transmitters in the launch vehicle.	Electronics will be shielded from interference. Insulation will be applied to electronics. The avionics bay will physically isolate it from all other electronics.	Incomplete
4.1	Design, build, and fly a STEMnaut flight capsule capable of safely retaining four STEMnauts and transmitting, via radio frequency, relevant rocket and STEMnaut landing site data to a NASA-owned receiver located at the launch site. The methods and designs must be safe, obey FAA and legal requirements, and adhere to the intent of the challenge.	The designs and prototypes of the payload will be reviewed and tested for safety, reliability, and conformity to FAA, FCC, and legal requirements.	Incomplete
4.2	The payload must transmit 3-8 pieces of the provided data to NASA. Transmissions may not exceed 5W, and transmissions should start and end with a team member's callsign. The data to be transmitted must be submitted by March 17.	The team will purchase the same radio NASA will use at the competition, and through extensive testing, ensure the data received fulfills these requirements in replications of the final launch.	Incomplete
4.3	The payload will abide by FAA and NAR rules and regulations and will abide by additional rules if the payload is deployed during descent, especially if classified as an unmanned aircraft system (UAS).	The payload will remain attached to the main body of the rocket and will not be jettisoned or deployed from the rocket's body.	Incomplete
5.1	The team will use a launch safety checklist that will be included the FRR and used during the LRR.	The SO will create a safety check list.	Incomplete

Req. #	NASA Requirement	Verification Plan	Status
5.2	The team will select a safety officer that is responsible for the items in section 5.3.	Jesse DePalmo will be the 2024-2025 Student Launch SO.	Complete
5.3.1	The safety officer will monitor the safety of the following activities: ▪ Design of vehicle and payload ▪ Construction methods ▪ Assembly methods ▪ Ground testing ▪ Subscale and Full-scale launch test(s) ▪ Competition Launch ▪ Recovery activities ▪ STEM Engagement Activities	The SO will write FMEA, RPN sheets, safety sheets, verification sheets, and procedure sheets. He will also monitor and observe all events to ensure that rules and regulations are being followed.	Incomplete
5.3.2	The SO will create safety procedures for construction, assembly, launch, and recovery activities.	The SO will write FMEA, RPN sheets, safety sheets, verification sheets, and procedure sheets.	In Progress
5.3.3	The SO will maintain revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS information.	The SO will write FMEA, RPN sheets, safety sheets, verification sheets, and procedure sheets.	In Progress
5.3.4	The SO will help develop the team's hazard analyses, failure modes analyses, and procedures.	The SO will write FMEA, RPN sheets, safety sheets, verification sheets, and procedure sheets.	In Progress
5.4	The team will abide by the rules and guidance of local RSO during test flights.	The SO will ensure that all FAA rules are followed and will collaborate with the RSO to ensure proper test flight safety.	Incomplete
5.5	The team will abide by all FAA rules.	The SO will ensure that all FAA rules are followed.	Incomplete
6.1	The team will pass the LRR during Launch Week. The team's mentor shall be at Launch Week and will oversee rocket preparation and procedures. The team will only launch once at competition.	Team leads will coordinate to ensure that each part of the rocket is prepared for launch. The Engineering lead (Daniel Hogsed) will oversee complete assembly preparations and that all requirements are met.	Incomplete
6.2	If the team does not attend Launch Week, it will launch at a NAR or TRA sanctioned launch. The team will closely collaborate with the RSO, team mentor, and the Launch Control Officer, ensuring that all NASA procedures are followed.	If the team does not attend Launch Week, the team leader (Grant Parker) will organize and schedule proper launching times and delegate responsibilities to ensure that procedures are followed.	Incomplete

6.2. Team Budget

CSL has created an initial budget breakdown after review and consideration of remaining material stock and equipment. This budget should provide an accurate estimate of the costs required to complete the NASA SL Challenge, but some details may change if orderable materials such as rocket motors are out of stock and require alternate purchases. The budget breakdown is given below in Table 6.2.1.

Table 6.2.1. *Preliminary Budget for the 2024-2045 year.*

Master Budget				
System	**Qty**	**Item Name**	**Price**	**Total**
Airframe	2	4 ft of fiberglass airframe (4 in) (G12)	$ 150.00	$ 300.00
	8	Motor reload kit	$ 250.00	$2,000.00
	6	Bulkheads/Centering Rings	$ 5.00	$ 30.00
	2	4 in body coupler (9 in length)	$ 40.00	$ 80.00
	1	5 ft of 3in fiberglass airframe (G12)	$ 170.00	$ 170.00
	4	Fiberglass flatstock (G10)	$ 30.00	$ 120.00
	Total			**$ 2,700.00**
Recovery/Avionics	1	Black Powder Charges (10 oz.)	$ 50.00	$ 50.00
	1	Flame blanket for drogue parachute	$ 50.00	$ 50.00
	1	Main Parachute	$ 180.00	$ 180.00
	1	Drogue Parachute	$ 72.00	$ 72.00
	Total			**$ 352.00**
Electronics/Payload	2	FCC Ham Radio License	$ 35.00	$ 70.00
	1	YAESU FTM-300DR	$ 380.00	$ 380.00
	3	FC-303 Data Radio Transmitter	$ 30.00	$ 90.00
	3	Diamond Antenna Dual-and HT Antennas RH707	$ 30.00	$ 90.00
	2	PCB Manufacturing per Version	$ 40.00	$ 80.00
	1	Micro SD-Card Reader (10-pack)	$ 8.89	$ 8.89
	1	2200mAh 3S LIPO Battery (2-pack)	$ 29.00	$ 29.00
	4	LEGO STEMnauts	$ 5.00	$ 20.00
	1	Wires, Connectors, etc.	$ 20.00	$ 20.00
	Total			**$ 787.89**
Stem Engagement	30	Model rockets	$ 7.00	$ 210.00
	2	Extra Motors	$ 69.00	$ 138.00
	100	Paper Airplanes	$ 0.05	$ 5.00
	10	Stomp Rockets	$ 20.00	$ 200.00
	2	Chloroplast corrugated cardboard	$ 125.00	$ 250.00
	10	Foam Footballs	$ 5.00	$ 50.00
	60	2L Bottle	$ 2.00	$ 120.00
	1	Micro Balloons	$ 22.00	$ 22.00
	1	Fiberglass	$ 50.00	$ 50.00
	1	Launching Material	$ 100.00	$ 100.00
	Total			**$ 1,145.00**

Subscale	1	3 in fiberglass body tubes	$ 150.00	$ 150.00
	4	PETG plastic	$ 20.00	$ 80.00
	1	fiberglass cloth	$ 30.00	$ 30.00
	4	G10 Fiberglass for fins	$ 30.00	$ 120.00
	Total			**$ 380.00**
General Construction	5	Shear Pins (20 ct)	$ 4.00	$ 20.00
	2	Epoxy (quart)	$ 80.00	$ 160.00
	1	Hardener (quart)	$ 80.00	$ 80.00
	1	Fasteners	$ 50.00	$ 50.00
	10	Threaded eye bolt 1/4" X 20" 1"	$ 7.00	$ 70.00
	1	Additional Hardware	$ 500.00	$ 500.00
	10	Firewall Initiator	$ 7.00	$ 70.00
	2	10-10 Rail Buttons	$ 3.00	$ 6.00
	2	Shock Cords	$ 50.00	$ 100.00
	2	Fasteners (50 ct)	$ 12.00	$ 24.00
	1	Fiberglass cloth (5 yd)	$ 30.00	$ 30.00
	50	Non stick plastic for fiberglassing	$ 1.62	$ 81.00
	Total			**$ 1,191.00**
Grand Total				**$6,755.89**

6.3. Funding & Sponsorships

To make required purchases for the NASA SL Challenge, CSL requires funding. Cedarville University’s engineering department will supply a grant for any necessary costs associated with the competition including full and sub scale rocket construction, competition traveling, necessary tools, and outreach not covered by sponsors or donors. CSL will be reaching out to sponsors and donors like local businesses, such as Northrop Grumman in Beavercreek, OH, to potentially obtain funding or resources. CSL seeks to build relationships with these sponsors so that they can become regular supporters of the team.

6.4. Team Sustainability

To ensure great success in NASA’s SL Challenge, CSL has plans for resource and team sustainability.

CSL has a history of maintaining several underclassmen members to assist in project development. Several current senior CSL members have been on the team for four years and will use their knowledge to ensure team success. To promote underclassmen recruitment and future member retention, CSL will be reaching out to several possible students for intern-like experiences. The underclassmen will be able to work alongside knowledgeable seniors and gain valuable experience in application of engineering principles. To pass on the knowledge that team members have gathered, CSL will plan to develop STEM Engagement, General Rocket Design, and Safety handbooks that can be used for the coming years.

For resource and environmental sustainment, CSL will be using resources and materials left by previous teams to eliminate waste such as motor hardware, fiberglass tubing, and aluminum round stock. CSL will also be designing a modular rocket so that if damage is sustained to the system, only the damaged portions will be replaced.

CSL will continue to create and maintain good relationships to further sustain success. The STEM Engagement Officer will make efforts to make a difference in diverse populations like intercity school systems and educational outreach organizations. In doing so, CSL can create an impact in the community and create relationships that foster growth and learning in rocketry.

By regularly interacting with the local NAR chapter and attending their build nights, CSL will maintain relationships with knowledgeable mentors and make new ones with other WSR members. In addition, CSL is transitioning to having a new Faculty Advisor, and he is interacting with the team and learning about the competition process while transitioning into his role at Cedarville University.

7. Summary

The CSL team is dedicated to performing above and beyond the project requirements of the 2024 – 2025 NASA SL Challenge, working with integrity in conduct and excellence in effort. Cedarville University prizes not only performance and ability, but also the character and ethics of their students. Following these values, CSL is committed to be diligent in their design and manufacturing of a mission worthy rocket. CSL is doing this with a concrete plan for a robust design that can confidently reach its apogee and complete its mission. The team has skillful student personnel, knowledgeable mentors, and the equipment required to complete the challenge and to pursue creating a foundation of standardized knowledge for future members. CSL is devoted to pursuing this project with the utmost level of safety with comprehensive documentation and preventative measures and is excited to share a passion of rocketry with people of all ages and backgrounds. Through STEM Engagement and social media presence, CSL hopes to inspire their peers and the future generation to pursue the stars.

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