NASA Student Launch Proposal

September 11, 2024

Society of Aeronautics and Rocketry

4202 East Fowler Avenue, MSC Box #197
Tampa, Florida 33620

Contents

List of Figures

List of Tables

Table 1: Commonly used acronyms.

Acronym	Meaning
SOAR	Society Of Aeronautics and Rocketry
EECS	Electrical Engineering and Computer Science
CFD	Computational Fluid Dynamics
ABS	Active Air-Braking System
AB	Awesome Ballast
USF	University of South Florida
TRA	Tripoli Rocketry Association
TBRA	Tampa Bay Rocketry Association
NAR	National Association of Rocketry

1 General Information

Table 2: General Team Information.

Role	Name	Contact Information	Additional Info
Adult Educator	Dr. Nicholas Baksh	nbaksh@usf.edu 813-389-3876	-
Team Mentor	Russel Fingers	941-993-9932	TRA number: 28037 Level 2 Certification
Team Mentor	Enrique Hernandez	enriqueh@usf.edu 352-457-2291	TRA number: 22521 Level 2 Certification
Student Team Leader	Alvaro Lazaro Aguilar	alvaro512@usf.edu 813-492-3780	-
Chief of Safety	Lucas Folio	lfolio@usf.edu 202-400-1525	TRA number: 29507

1.1 Project Organization

Based on our previous years' records it's estimated that around 30 students will participate in the NASA Student Launch project with USF SOAR this year. To address the increasing complexity of tasks, especially in EECS, we have split management roles between Mechanical and EECS teams. This change stems from our observation in previous years that dedicated personnel are essential for handling EECS challenges separately from the main mechanical efforts. SOAR is also continuing our *SOAR Specialists* Program, which offers committed team members greater autonomy and responsibility in their area of interest. The Specialists will be assigned as the semester progresses, and they will report to the respective lead in that field. The organizational chart below highlights the key management positions:

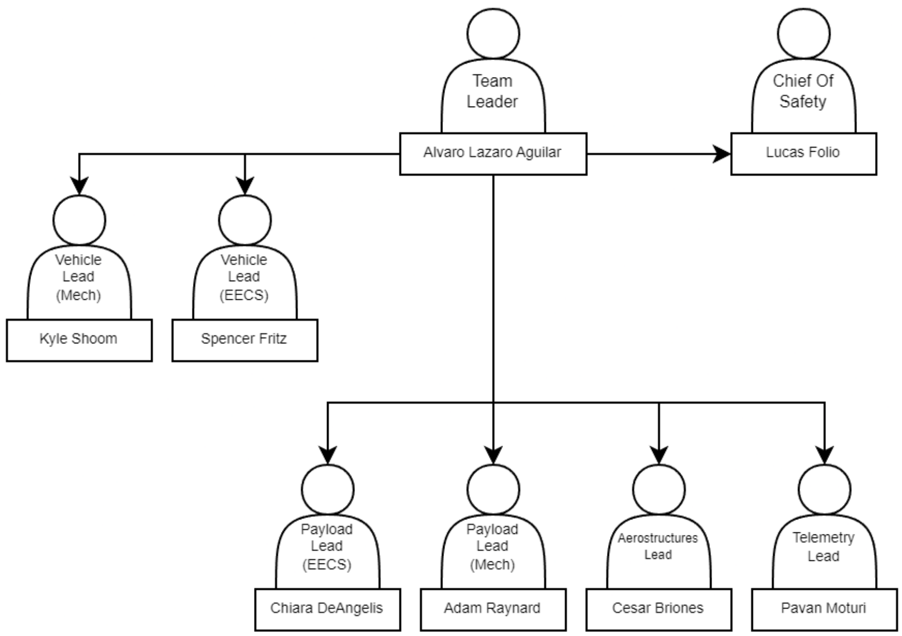

Figure 1: Team Organization

1.2 NAR/TRA Partner Sections

USF SOAR will collaborate with two launch centers for mentorship, project review, and launch support. The primary launch site will be the Tampa Bay Rocketry Association (TRA 17, NAR 934), serving as the main hub for launch operations. As a contingency, Spaceport Rocketry Association (TRA 73, NAR 342) has been designated as a secondary launch facility, to be utilized in the event of a canceled launch or if circumstances beyond our control necessitate an alternative site.

1.3 Hours Spent on Proposal

The team spent 42 hours for the NASA Student Launch Proposal. This accounts for leadership meetings, brainstorming meetings for Payload and Vehicle, and hours spent actually writing and reviewing the proposal document itself.

2 Facilities and Equipment

Table 3: Facilities and Descriptions for SOAR.

Facility	Description
USF Design For X (DFX) Labs	The DFX Labs, located in the Engineering III building, is a dedicated workspace for engineering organizations and clubs at USF. It offers a wide range of tools and equipment for prototyping, fabrication, and project construction. SOAR will use this facility for meetings and rocket/payload development.
Engineering Research Building (ENR)	The Engineering Research Building (ENR) provides a spacious, open-plan workspace for various student engineering organizations. SOAR will utilize this space for project assembly and testing, offering ample room for collaboration and construction.
Varn Ranch (Plant City, FL)	Varn Ranch, the official launch site of the Tampa Tripoli Rocketry Association, provides an open area for SOAR's rocket launches. The site supports flights up to 10,000 feet, ensuring the team can meet launch requirements. Mentors from the Tripoli Rocketry Association will supervise all launch operations.

2.1 Equipment Overview

Table 4: Equipment available across various USF facilities and Varn Ranch.

Equipment	DFX Labs	ENR	Varn Ranch
LPKF ProtoMat S63 PCB3 Milling Machine	X		
Benchman MX CNC Milling Machine	X		
FSLaser – Pro LF 36 Laser Cutter	X		
MakerBot – Replicator 3D Printer	X		
Stratasys – uPrint SE PLUS 3D Printer	X		
Misc. Power Tools	X	X	
Compressed Air	X		
Wi-Fi/Wired Internet	X		
Function Generators	X		
Network Analyzers	X		
Solder Station	X		
Mixed Domain Oscilloscope	X		
Multimeter	X		
Small Hand Tools	X	X	
Powered Hand Tools	X	X	
Cold Saw		X	
Launch Rails			X
Launch System Electronics			X

2.1.1 Hours of Operation

Table 5: Hours of Operation for Facilities.

Facility	Hours
DFX Labs	Monday-Friday, 7:00am to 5:00pm
ENR	Monday-Friday, 9:00am to 3:00pm (after-hours access for SOAR)
Machine Shop (ENG)	Monday-Thursday, 7:30am to 4:30pmFriday, 7:30am to 4:00pm
Varn Ranch (Tampa Tripoli)	Third Saturday of each month, 9:00am to 3:00pm

2.1.2 Personnel Information

Table 6: Personnel Information for USF Facilities and Varn Ranch.

Name	Role	Contact Information
Lucas Folio	Chief of Safety, SOAR, USF	lfolio@usf.edu
Michael Celestin, Ph.D.	DFX Labs & ENR Personnel	mcelesti@usf.edu
John Mackiewicz	President, Tampa Tripoli Rocketry Association	jmackiewicz@tampabay.rr.com
John Kubalok	Prefect, Tampa Tripoli Rocketry Association	-

3 Safety

3.1 Written safety plan

SOAR operates in two main facilities, the Engineering Research Building (ENR) and the DFX Lab, which are both on campus. The subscale, full scale and all other components such as the payload are also constructed in these areas, with occasional smaller projects which do not require heavy machinery or safety procedures are constructed in personal areas which are not documented. The Chief of Safety is responsible for the area and the machinery that SOAR uses, as well as any PPE that members of SOAR use and have access to. Each of these topics get inspected frequently and thoroughly to ensure that they comply with USF EH&S standards, including the amount of PPE and machinery that are available for use by all members. Members are required to receive certificates that allow them to have access to the aforementioned space, and machinery.

3.2 The procedures for NAR/TRA personnel to perform

The Chief Of Safety has the responsibility of ensuring that SOAR keeps their members and audience safe while being in compliance with the NAR safety guidelines and the High Power Rocket Safety Code[1]

a. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

b. **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.

c. **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.

[1] https://www.nar.org/safety-information/high-power-rocket-safety-code/

d. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in 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.

e. **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.

f. **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.

g. **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 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.

h. **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.

i. **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.

j. **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, 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).

k. **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.

l. **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.

m. **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 Chief of Safety will also be responsible for ensuring that SOAR is following the minimum distance requirements, as can be seen below in Figure 2, set forward by NAR in the High Power Rocket Safety Code

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

Figure 2: Minimum distance requirements

n. **Hazardous Materials and Operations** are to be carried out by NAR personnel with the following procedure.

1. A Level II certified member and an NAR/TRA Personnel will oversee any test launch of the vehicle and flight tests of the vehicle.
2. The launch site RSO will be responsible for ensuring proper safety measures are taken and for arming the launch system.
3. If the vehicle does not launch when the ignition button is pressed, then the RSO will remove the key and wait 90 seconds before approaching the rocket to investigate the issue. Only the Project Manager and Safety Officer will be allowed to accompany the RSO in investigating the issue.
4. The RSO will ensure that no one is within 100 ft. of the rocket and the team will be behind the RSO during launch. The RSO will use a 10-second countdown before launch.
5. A certified member will be responsible for ensuring that the rocket is directed no more than 20 degrees from vertical and ensuring that the wind speed is no more than 20 mph. This individual will also ensure proper stand and ground conditions for launch, including but not limited to launch rail length and cleared ground space. This member will ensure that

the rocket is not launched at targets, into clouds, near other aircraft, nor take paths above civilians. Additionally, this individual will ensure that all FAA 14 regulations are abided by.

6. Another certified member will ensure that flight tests are conducted at a certified NAR/TRA launch site.
7. The safety officer will ensure that the rocket is recovered properly according to Tripoli and NAR guidelines.

3.3 Hazard recognition and avoidance plan

3.3.1 Trainings

In order for members of SOAR to engage in the recognition and handling of hazardous materials, new members are required to take multiple trainings which certify them with use of the facilities and equipment that the club provides. These certifications are recorded and need to be renewed on an annual basis as they are proof that members are qualified to use the resources provided. These training sessions include the importance and dangers of the club's supplies as well as how to handle and store said materials. With facility training, members are also required to know the emergency procedures of the area, including emergency exits, fire extinguishers, eye wash stations, first aid-kits and all else that might be needed. If members do not comply with these rules, they are not permitted to enter the areas of the clubs working facilities as well as their materials, machinery or any other equipment that is being used.

3.3.2 Hazardous Reminder

Before any meetings or discussions that contain the use of the areas, machinery or equipment that SOAR uses, the Chief of Safety must remind members the factors that must be considered in the use of these facilities. These factors may include PPE, required certificates, materials and other specifications that depend on the facility.

3.3.3 Launch Checklist

As well as being present at every launch, it is the responsibility of the Chief of Safety to write and provide a checklist to these launches which allows the team to readily see each step of the process of assembling and ensuring the rocket will have a successful and safe flight. This checklist is also reviewed by personnel at launches to certify that everything is done correctly. At the launchpad, there are other items that need to be reviewed such as the e-match placement, rail alignment and altimeter conductivity and these will be done when there are only two to three members.

3.4 Caution Statements Methods

3.4.1 Plans and Documentation

The main facility of SOAR is the ENR workspace where most materials are stored along with equipment and tools, this area has multiple emergency areas and resources along with a booklet that has documented Safety Data Sheets (SDS) for our chemicals and Standard operating procedure (SOP) for equipment.

3.4.2 Safety Procedures

All resources that SOAR members use are required to have a SOP which the Chief of Safety ensures is being followed. These documents have instructions, safety overviews, hazards, materials and Personal Protective Equipment (PPE). Different PPE is required based on different equipment, for example even though gloves are required for sharp hand held tools, they are discouraged to use in automatic rotary tools as they increase hazards. Along with our SOP's, documentation for our equipment and areas include the PPE that is required, suggested and discouraged during operation or use.

3.5 Motor Handling Compliance

In order to comply with all regulations, SOAR conducts their rocket launches through the Tripoli Rocketry Association (TRA) scheduled launch days. The TRA will contact local airports or other personale if the projected height of a rocket is to exceed 10,000 feet, yet SOAR will launch their rocket between the 4,000 - 6,000 foot window, in order to comply with the NASA Student Launch Handbook[2], which implies that this contact is not required. During the preparations for the launch, the team members that are present and willing to go up to the launch pad help load the rocket on the rail. After loading, the team leader and Chief of Safety are to be the only ones to remain at the rail while testing the wire continuity of the altimeter. This is followed by the insertion of the electrical match which is done with great care to avoid generating any static charge that could prematurely set off the match and inadvertently trigger the ignition of the motor. Additionally, the indicator between the two provided wires that is used for remote ignition is checked to confirm that the charge is not active.

3.6 Acquisition, Storage, Transportation and Use of Rocket Motors

SOAR purchases the motors through a reputable and established vendor that accommodates all required regulations and requires a proof of L2 certification, such as wildman rocketry, and apogee components. The mentor for SOAR has this certification and is well versed in the needs of the motor and its compatibility with the competition rocket. During transportation, SOAR stores motors in a container that meets federal, state, and local regulations. To prevent static electricity buildup, the motors are kept off the car's carpet. Vendor deliveries are also handled in a way that complies with regulations and avoids direct contact with any material that could cause electrical shocks.

3.7 Safety Regulation Written Statements

The student team is aware of the regulations and is fully committed be compliant with them. The regulations are described in detail below:

[2]https://www.nasa.gov/wp-content/uploads/2024/08/2025-nasa-sl-handbook.pdf?emrc=77b9f2?emrc=77b9f2

a. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the assessment of the safety inspection or may be removed from the program.

b. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.

c. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team shall not fly a rocket until the mentor has reviewed the design, examined the build, and is satisfied the rocket meets established amateur rocketry design and safety guidelines.

4 Technical Design

4.1 Launch Vehicle

4.1.1 Mission Statement

The main purpose of the launch vehicle is to ensure the success of the payload mission. Therefore, the vehicle team has to work closely with the payload team to ensure that their demands are met and that those demands are feasible and obtainable. The aerostructures team has come up with four different rocket configurations. They vary on recovery system, payload location and deployment methods. The four ideas are arranged from most appealing to least. Therefore, any further sections explaining more details of the launch vehicle will tackle the Type one vehicle configuration.

4.1.2 Type I Configuration

The main feature of the type one launch vehicle is the early deployment of the nose cone. The idea is to treat the nose cone as a separate body and launch it prior to payload deployment. In compliance with the requirements, the nose cone will have its own avionics bay and GPS system. The projected motor is the Aerotech L1500.

4.1.2.1 Vehicle Dimensions

The vehicle has a total length of 107 in, and a diameter of 6.17. In contrast to last competition season, the team has proposed to opt for a bigger rocket diameter. The reasoning behind this choice is the lack of available volume for payload inside of the airframe. This unexpected consequence greatly increased the complexity of the mission, hindering the development of payload. The vehicle will consist of 3 separate bodies, with a total of 4 independent sections. From right to left, the independent sections are the following: nosecone, payload, mid section, booster section. The nosecone is connected to the mid section through a coupler in the nosecone. The payload experiment is stored inside of the midsection until desired deployment. Finally, the mid section is connected to the booster through a shock cord that is also connected to the drogue parachute.

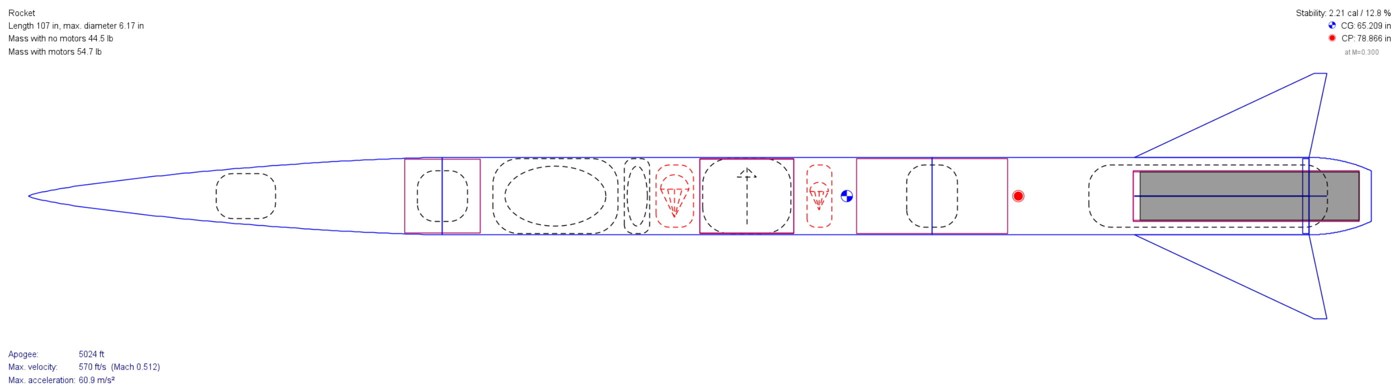

Figure 3: Projected Open Rocket Model.

Table 7: Airframe section lengths of the rocket.

Airframe Section	Length (in)
Nosecone	33
Mid Section	39
Booster	35
Total	**107**

4.1.2.2 Vehicle Mass Statement

Keeping track of the vehicle weight is crucial for ensuring mission success. The team is keen in ensuring that the rocket has a manageable weight that will not compromise any requirement. Below is an estimated prediction of the weight of each major component for each section. The total is calculated for each section and the landing kinetic energy at landing. The main, drogue, and shock cords were not included in the landing mass calculation due to not being technically part of any section.

Table 8: Mass breakdown of the rocket airframe sections.

SECTION MASS	PRE (lb)	MASS %	POST (lb)
UPPER SECTION	8.29	15.14%	8.29
Nosecone	2.29	4.18%	2.29
Ballast	4.00	7.30%	4.00
Avionics Bay 1	2.00	3.65%	2.00
MID SECTION	23.12	42.22%	23.12
Airframe	4.62	8.44%	4.62
Payload	5.00	9.13%	5.00
Retention Payload	1.00	1.83%	1.00
Main	3.00	5.48%	3.00
Airbrakes + Av Bay	7.00	12.78%	7.00
Drogue	2.50	4.57%	2.50
BOOSTER	23.35	42.64%	17.89
Coupler	2.00	3.65%	2.00
Airframe	3.13	5.72%	3.13
Fins	2.02	3.69%	2.02
Motor	10.30	18.81%	4.84
Bolted Fins	5.00	9.13%	5.00
Boat Tail	0.30	0.55%	0.30
Motor Tube	0.60	1.10%	0.60
TOTAL	**54.76**	**100.00%**	**49.30**

4.1.2.3 Concept of Operations

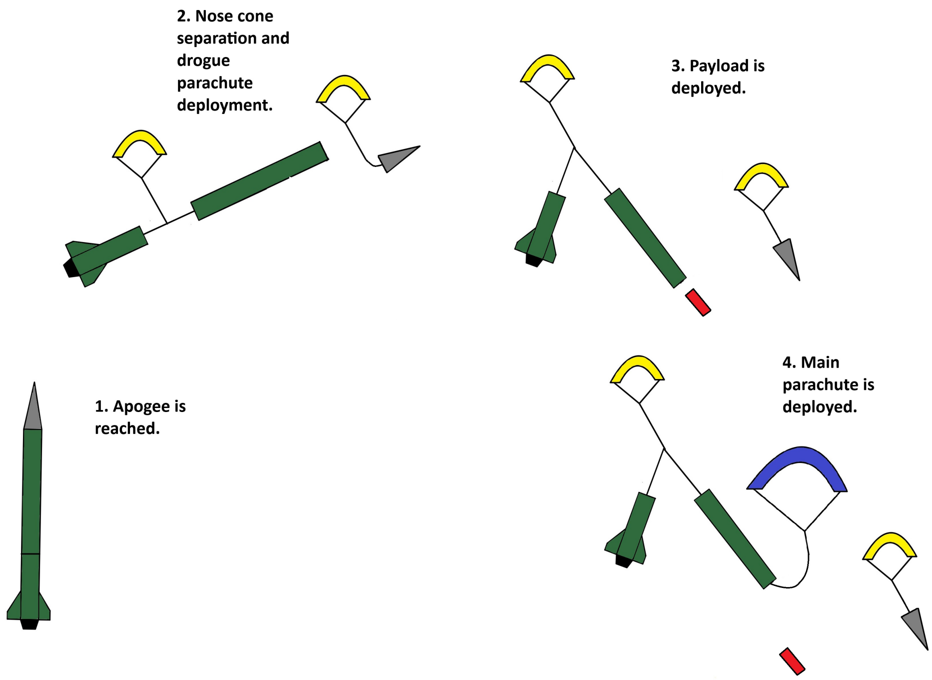

Figure 4: Concept of Operations Type I

4.1.3 Type II Configuration

In the type 2 vehicle, rather than eject the nose cone as its own separate entity to make way for the payload, the nose cone instead houses the payload itself. Much like the type one rocket, the nose cone will require a dedicated avionics bay, as well as plenty of internal space to house the payload and any added ballast.

4.1.4 Type III Configuration

In line with earlier designs, the Type 3 concept will feature two separation points, dividing the rocket into three sections: the nose cone, midsection, and booster. The midsection houses two independent compartments: one for the payload and another for the airbrakes and avionics bay. The nose cone is connected to the midsection via a shock cord, which is also attached to the main parachute. At the opposite end, the midsection is connected to the booster by a shock cord linked to the drogue parachute.

Separation between the midsection and booster occurs at apogee, at which point the drogue parachute is deployed to stabilize the descent. As the rocket descends to approximately 700 feet, the second separation takes place between the nose cone and midsection. At this stage, the payload is deployed, followed by the release of the main parachute to ensure a controlled landing.

A key difference in this design is that, following payload deployment, the nose cone will remain connected to the midsection. This eliminates the need for a separate avionics bay and GPS system in the nose cone, as it won't be treated as an independent section. This approach reduces both the weight and overall complexity of the vehicle. However, the main drawback of this design is the risk of collision between the payload and nose cone during deployment, given their proximity during separation.

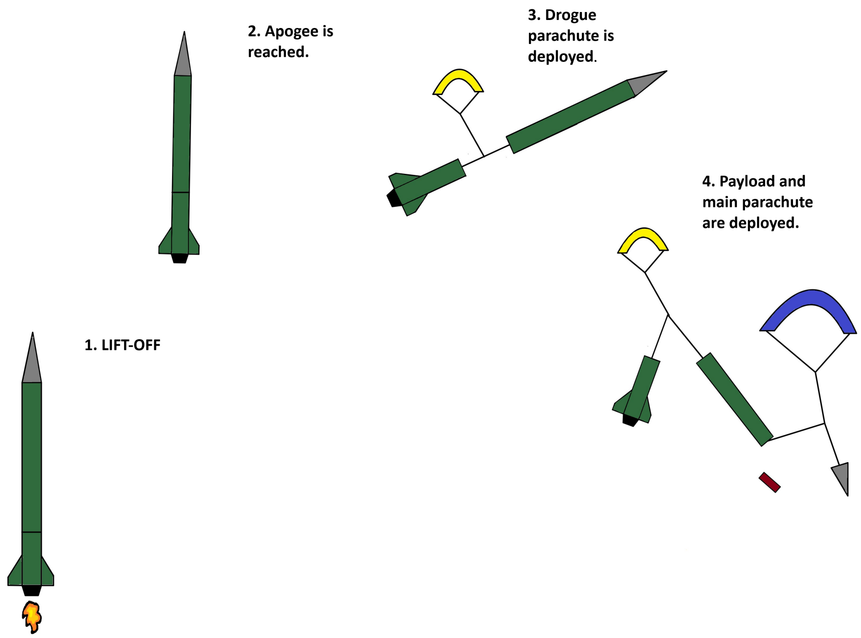

Figure 5: Type III Concept of Operations.

4.1.5 Type IV Configuration

Similarly to type 3, the configuration in type 4 exhibits nearly the same separation and parachute deployment as seen above. However, there are three main differences which separate this layout from type 3, providing a unique solution to ejecting our payload. The reason for this fourth configuration is mainly to provide an alternative in the case potential size concerns or system placements affect have too much of an impact on the design constrictions for the payload.

The first difference would be the addition of having an upper body tube attached to the nose cone during separation. The parachute deployment here is still the same as Type 3's design with the rocket all still being connected via tether during descent. The reason for keeping the upper body tube and nose cone as one piece are directly due to the following differences which allow for multiple benefits surrounding the payload. In difference two, by keeping the nose cone and upper body tube together, the payload can now be stored in the upper body section; allowing for a completely separate dedicated space. This avoids any additional components or systems from getting in the way while simultaneously leaving more space for the payload to occupy and be designed with. With this in mind there is still a problem of having the nose cone block the payload from exiting freely.

Difference three will be a fairing in the nose cone which allows the nose cone to essentially split in half and open up, providing a clear area for the drone to exit out of. By using a fairing, this ensures that nothing can either block or entangle the payload from exiting while providing a completely open space to deploy from. The differences from type 3, while small, have potential to provide a beneficial solution in the case unforeseen issues arise between other configurations.

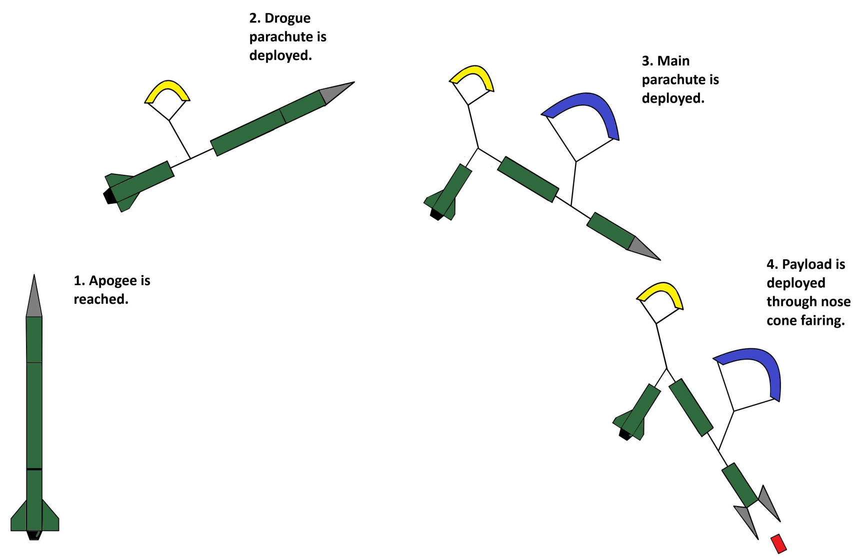

Figure 6: Type IV Concept of Operations.

4.1.6 Launch Vehicle Motor

The selected prospective motor is the Aerotech L1500. Its preliminary choice is based on the quick ignition and high thrust, necessary to ensure the rocket's peak at the right altitude. It should be mentioned that the altitude difference between the predicted apogee and the target apogee is intended. The team is primarily aiming higher than our target apogee because this error is expected to be fixed with the integration of the ABS.

Table 9: Motor Specifications

Category	Value
Manufacturer	Aerotech
Designation	L1500T
Motor Type	Reload
Diameter	98 mm
Length	443 mm
Total Weight	4,659 g
Prop Weight	2,491 g
Avg Thrust	1,500.0 N
Initial Thrust	1,484.5 N
Max Thrust	1,752.0 N
Total Impulse	5,089.3 Ns
Burn Time	3.5 s
Cert. Designation	L1473

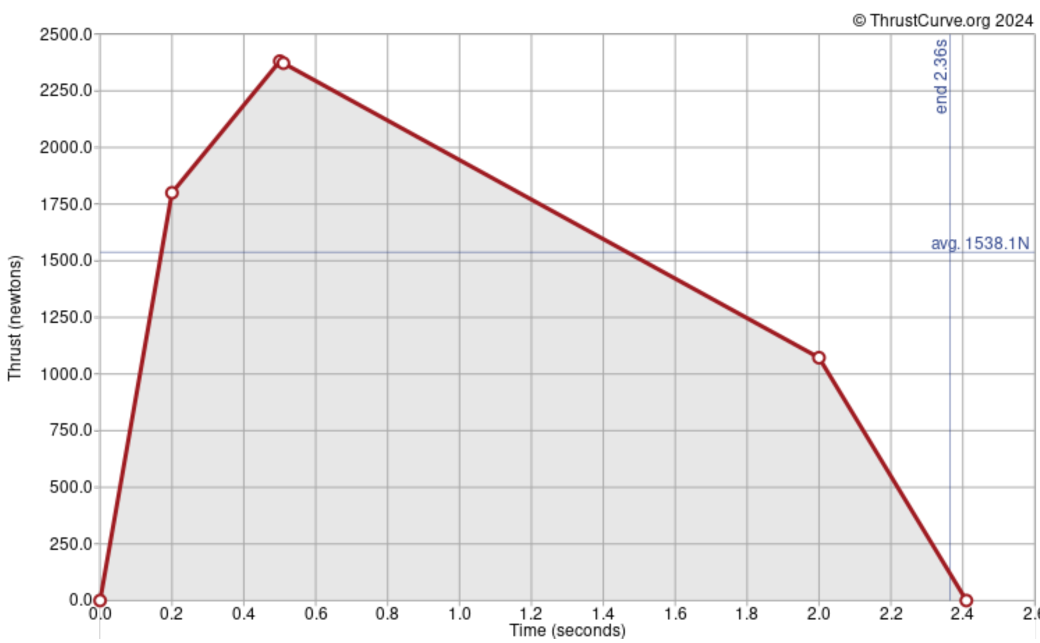

Figure 7: L1500 Thrust Curve.

4.1.7 Apogee

The target altitude is set at 4,300 feet, with the team planning to reach this apogee through the implementation of the secondary payload, the Active Air-Braking System (ABS). The ABS enables dynamic altitude control during flight, minimizing the discrepancy between the predicted apogee and the actual recorded altitude. Ensuring the success of this system is a top priority, as it significantly impacts the competition score.

Current projections indicate a flight altitude of 5,025 feet, approximately 700 feet above the target apogee, which the ABS is designed to correct. This value was calculated through simulations in OpenRocket, based on the general vehicle's dimensions and motor specifications described for the Type One prototype. To further refine these estimates, additional simulations will be conducted using alternative software RockSim and RocketPy.

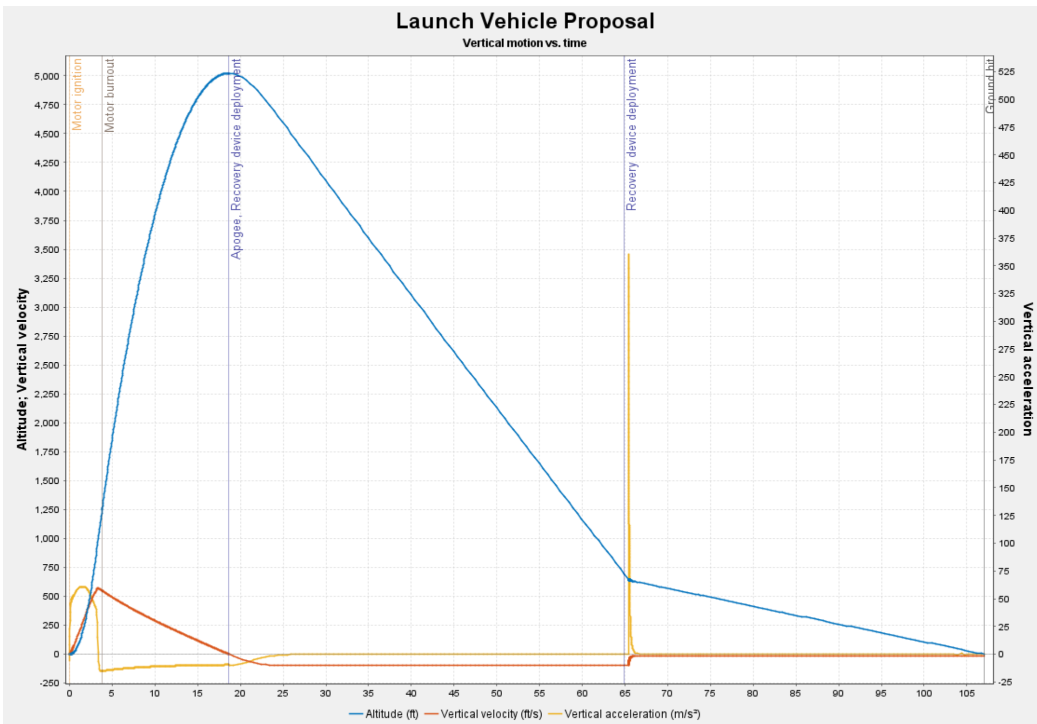

Figure 8: Projected Flight Path from Open Rocket.

4.1.8 Recovery System Design

4.1.8.1 Parachutes

The recovery system described in this action is designed around the Type I vehicle configuration. The team believes that out of all available options, Type I will satisfy the requirements and maximize mission success the most. The recovery system consists of a total of 3 total parachutes: a single nose cone parachute, a main and a drogue parachute. However, it deploys 2 independent bodies during descent. The nosecone and payload experiment are separated from the launch vehicle mid-flight. One parachute is meant for one falling body, and the rest are meant for the launch vehicle, which follows a dual deployment recovery system.The drogue is expected to deploy at apogee altitude. The main is expected to deploy at 700 ft.

The drogue parachute is first to deploy. A black powder charge is being ignited at apogee, pressurizing the lower part of the mid section. This sudden change in pressure exceeds the shear strength of the shear pins, breaking them. As a consequence, the mid and the booster section are separated, releasing the drogue parachute. The preliminary parachute chosen for this application is the Fruity Chutes 24 in parachute, with a drag coefficient of 1.55.

Shortly after, the nosecone is separated from the launch vehicle. It is jettisoned with its own avionics bay and GPS system. This section falls independently from the launch vehicle, and creates a path for the payload to be deployed at a later stage. The nosecone parachute chosen for this application is the fruity chutes 36 in parachute, with a drag coefficient of 2.20

Finally, the main parachute is set to be deployed at 700 ft. Similar to the drogue parachute, the main parachute is deployed with a black powder charge. The main parachute chosen for this application is the fruit chutes 120 in parachute, with a drag coefficient of 2.20

4.1.8.2 Avionics

The main avionics bay stays on the rocket at all times, and is electrically separate from electrical systems on the payload and rocket. This bay will primarily consist of two altimeters: The Altus Metrum Telemetrum altimeter will serve as the primary altimeter, and the Missileworks RRC3 altimeter will function as the backup altimeter. This bay will also consist of other components and sensors to collect data, and is described in the Telemetry section below.

The Missileworks RRC3 altimeter has historically been the altimeter of choice of our team. Due to this, our team is intimately familiar with setup and operation of this altimeter to deploy the main and drogue parachutes. It has proved to be reliable both to our team, and among individuals in the field of amateur rocketry, on top of being relatively cheap. Key features of the Missileworks RRC3 altimeter are that it is capable of deploying main, and drogue parachute charges, along with auxiliary charges based on the needs of the user. It is capable of deploying based on altitude or apogee events, and has an overall altitude range of 100,000 ft above Mean Sea Level. It uses a MSI MS5607 Pressure sensor to obtain barometric and temperature data, and processes this to provide velocity and altitude data.

The Altus Metrum Telemetrum will serve as the main altimeter that we will use in the avionics bay on the rocket to deploy the main and drogue parachutes. We opted to use this altimeter due to the added feature benefits it has, such as a transceiver that operates on the 70 cm radio band, APRS support, and a GPS module, all built into the altimeter on a smaller package. On top of that, the Altus Metrum Telemetrum can also record motion in one axis with a built in accelerometer, another thing the RRC3 cannot provide. The Altus Metrum Telemetrum allows our team to utilize Altus Metrum's proprietary ground station software, AltusUI and AltusDroid, which allows for simpler operation, data collection, and real time analysis. Because of the increased features, and simpler operation, this altimeter enjoys popularity in amateur rocketry, and Altus Metrum has been known to provide reliable products, allowing our team to be confident the Altus Metrum Telemetrum altimeter will meet expectations.

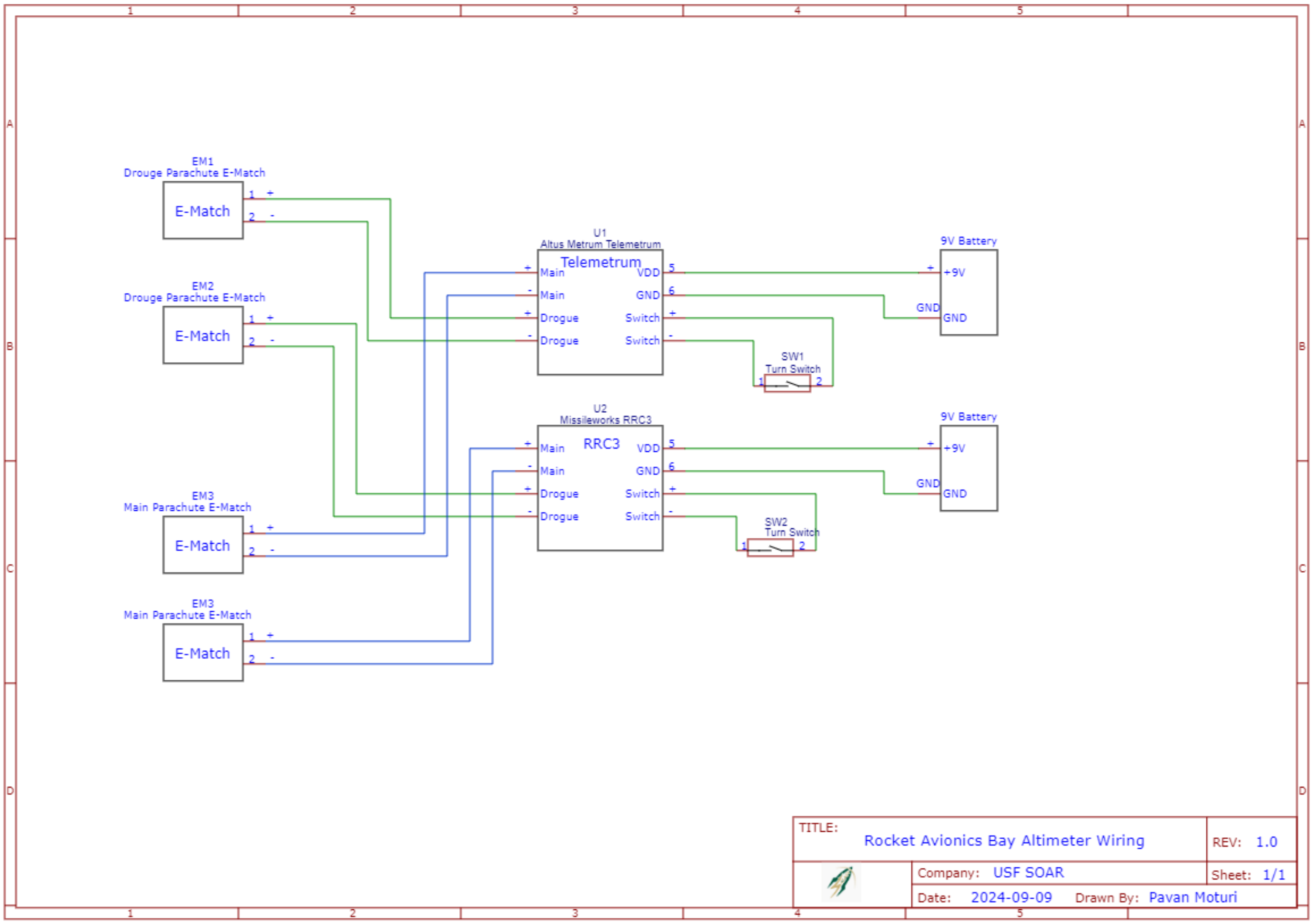

Figure 9: Avionics Bay Wiring Schematic.

For the payload designs that deploy the nose cone as a separate body, specifically Type 1, the nose cone will have its own avionics bay that consists of a primary and a backup altimeter, albeit smaller and more compact. The primary altimeter will be an Altus Metrum Telemini, due to its compact design. The backup altimeter will be an RRC2L, due to its low cost and robust feature set. The nose cone avionics will also consist of other sensors.

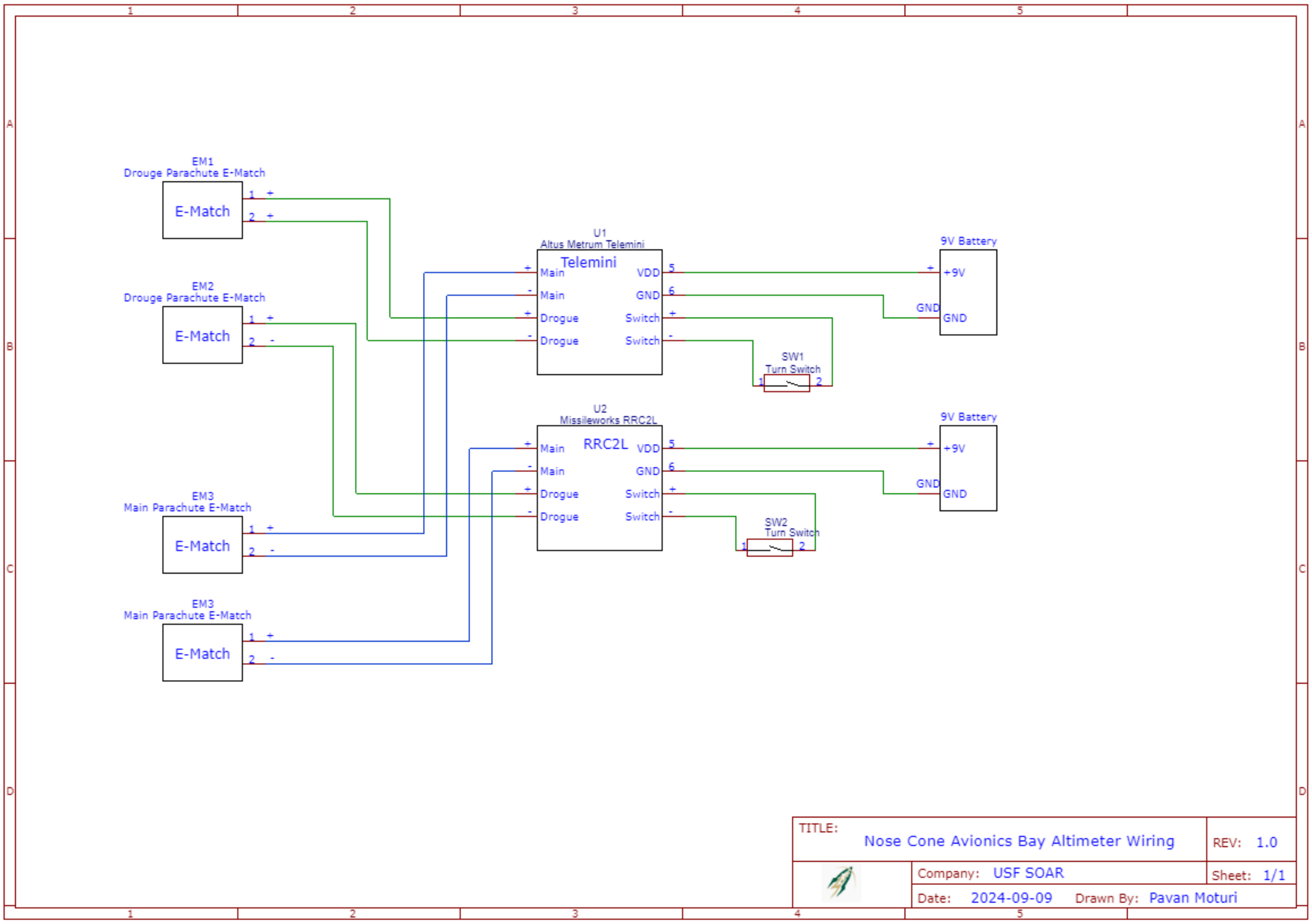

Figure 10: Avionics Bay Nosecone Wiring Schematic.

4.1.8.3 Telemetry

As mentioned above, the main avionics bay on the rocket will consist of the two altimeters; the primary being the Altus Metrum Telemetrum, and the backup being the Missileworks RRC3. Separate from this, the AV bay will house a separate system, consisting of its own lithium ion battery power supply, and two microcontrollers to process and transmit data. These microcontrollers and sensors will be electrically independent from the main altimeters (the Altus Metrum Telemetrum and the Missileworks RRC3). The first microcontroller will be responsible for receiving data from the electrically independent Adafruit BMP390 pressure sensor, Adafruit BNO055 IMU orientation sensor, and other sensors that we believe can record useful flight metrics, including a GPS module. This microcontroller will then log the data to an onboard microSD card, and send the data to the secondary microcontroller. This will be solely in charge of transmitting and receiving data through the transceiver to the proprietary custom ground station unit that we are in the process of completing. This allows for a two way communication between the rocket avionics bay and the ground station. Estimated telemetry that will be sent from the avionics bay on the rocket during flight will be altitude, velocity, temperature, battery voltage, orientation, and GPS data. This data allows our team to analyze the rocket's flight in real time, and track the location of the rocket in real time over long distances.

The avionics bay on the nose cone will also feature a separate system from the the Altus Metrum Telemini and the Missileworks RRC2L altimeters. This separate system, will take into the severely limited space available in the nose cone, it will be a small microcontroller (that is electrically independent of the altimeters) connected to a GPS module and a transceiver that communicates to the proprietary custom ground station that we are completing. This will enable our team to effectively track the location of the nose cone at all times.

4.1.9 Challenges and Solutions

4.1.9.1 Bolted Fins

Based on previous flights and experiences, the team is looking to innovate in fin modularity. The previous design of the stabilizer fins consisted of three trapezoidal-shaped, carbon-fiber fins located at the end of the booster, spaced 120 degrees apart. Even though the fins were quite sturdy and resistant to any impact, the damaging of any structural part would be non-repairable. Last year, a section of the airframe of the booster tube suffered a small but significant impact, leaving a visible mark in the bodytube. Having the physical structure compromised, the team had to rebuild the entire booster section, including the fins. The bolted fins aim to solve this issue by introducing modularity into the equation, and allowing the change of parts without having to rebuild the entire system.

Several ideas have been proposed by team members. One potential design involves cutting slots in the airframe to bolt the fins into place. This design minimizes gaps between the modular fins and the airframe, maintaining aerodynamics. Internal support structures will be installed inside the airframe to secure the bolts. Another idea (Figure 11) is to build an internal support structure, called 'fin skeletons.' The skeleton will be made of metal beams with holes to bolt the fins into. The airframe will be slotted to slide the fin-skeleton structure inside. If needed, the structure can be easily disassembled to replace the fins, ensuring the modularity and re-usability of the rocket.

Further analysis will be conducted to balance manufacturability, effectiveness, and other important factors. The team aims to perform computational analysis before beginning prototyping and testing, to optimize cost-effectiveness and provide learning opportunities for team members.

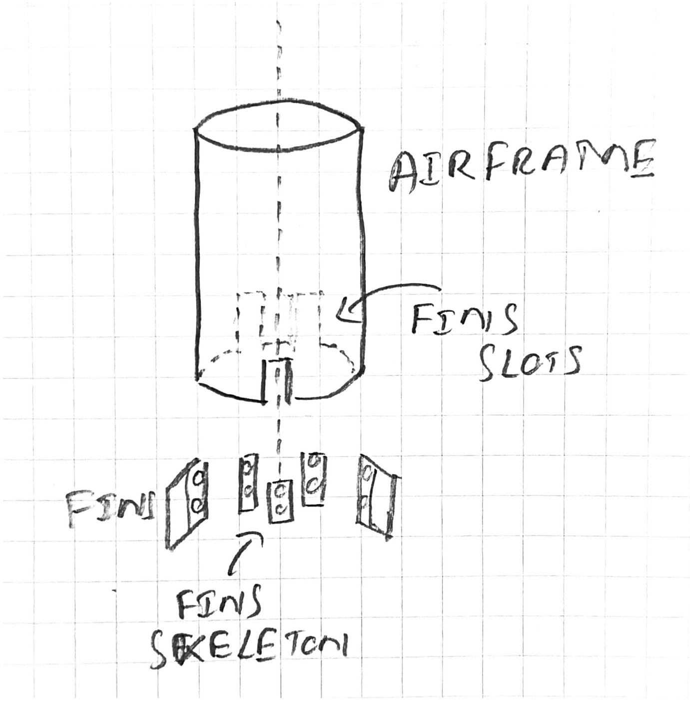

Figure 11: Projected Bolted Fins Design.

4.1.9.2 Awesome Ballast (AB)

To ensure the stability of the rocket, ballast will be added to the nose cone of the rocket. This will further offset the center of gravity from the center of pressure, which will result in a higher caliber of stability. To accomplish this, layers of weights will be inserted into the nose cone. The weights can be made out of many different materials, depending on how much weight is needed and if there will be any electronics in the nose cone. Most likely, the ballast will consist of metals such as aluminum.

4.1.10 Materials

Material selection for the development of the rocket plays a critical role in aspects of stability, safety, and design specifications. The following materials will be broken down for their characteristic properties, methods of construction, and applications to overall design.

4.1.10.1 Fiberglass G10 - Laminated Fiberglass sheet

USES
Potential uses for Laminated Fiberglass sheets allow for the ability to manufacture avionic housings for onboard electrical systems that provide real-time flight data due to a durable enclosure and low electromagnetic interference. Bulkheads utilizing Fiberglass G10 can significantly reduce the weight of the rocket while enhancing performance and fuel efficiency. Additionally, fins manufactured with Fiberglass G10 provide ideal aerodynamic surfaces due to the material's rigidity and smooth finishes for reducing drag as needed.

CONSTRUCTION
Advantages of Laminated Fiberglass sheets are the readily available fabrication of components by clamping the sheets to a router CNC machine then cutting them into custom shapes and sizes needed. Advantages of Laminated FIberglass sheets are the readily available and off-the-shelf part standardization. The sheets are bought at different thicknesses.

4.1.10.2 Fiberglass G12 - Fiberglass Filament Wound Tube

USES
The most common use for G12 Fiberglass would be the composition of the main airframe as well as the coupler and motor tube due to its anisotropic properties which provide sufficient physical and mechanical properties suitable for flight conditions. Properties include a high strength-to-weight ratio, thermal resistance, chemical/corrosion resistance, vibrational damping, and ease of fabrication.

CONSTRUCTION
Fiberglass filament wound tubes are acquired already wound into airframe tubes. They are constructed with many layers of wind angles from 30 Deg to 45 Deg. The tubes will be cut using a miter saw and the borders will be sanded down to prevent any damage to the personnel.

4.1.10.3 Carbon Fiber Sheet

USES
Carbon fiber sheets have a density of approximately 1.6 g/cm^3, which is significantly lower than metals like aluminum or steel. Fins that are made from carbon fiber can be both lightweight and strong, which is ideal for reducing the total weight of the rocket without compromising structural integrity. Due to the large amount of forces that act on the fins such as drag, carbon fiber's high tensile strength and stiffness make it an ideal choice for the construction of fins due to the low probability of deformation.

CONSTRUCTION
Carbon fiber sheets can be cut just as fiberglass sheets by clamping the sheets to a router CNC machine, however cutting carbon fiber releases toxic particles that are harmful to personnel health and can damage electronics due to the conductive properties of carbon.

4.1.10.4 Carbon Fiber Tow

USES
Reinforcing a part with continuous carbon fiber tow allows for more stability while optimizing it for specific load-bearing applications. Certain applications for carbon fiber tow are for strengthening the adhesive bolts as they will go on the coupler and for constructing the boat tail. The boat tail helps to reduce drag and improve the rocket's aerodynamic performance, therefore the shape must remain precise under stress and temperature fluctuations making carbon fiber tow ideal for these requirements.

CONSTRUCTION
For adhesive bolts, it will be mixed with epoxy and put around them. Due to the complex geometry of the boat tail, 3D printing with carbon fiber tow allows for the fabrication of complex geometries

as a single part, improving both performance and reducing the need for post-processing and assembly. However, the process involves reinforcing a polymer matrix (typically a thermoplastic) with continuous strands of carbon fiber tow for retaining the high-strength and lightweight properties. The construction of a boat tail with this material is still something being researched on.

4.1.10.5 Aluminum 6061-T6

USES

6061 aluminum alloy is a popular choice among a variety of applications due to its great mechanical properties and machinability. Specifically for airbrakes, with a tensile strength of 290 MPa (42,000 psi) and relatively low density, 6061-T6 provides an excellent balance of strength and weight, making it ideal for structural components and bolted fins.

CONSTRUCTION

Due to the material being highly machinable, it allows for precise manufacturing of parts with tight tolerances making it suitable for CNC machining.

4.2 Description of Projected Payload

4.2.1 Payload Type A

A main contender for payload is to completely jettison the nose cone from the airframe after apogee. This will allow for a fixed frame drone to be deployed using the jettison system. As shown in Figure 20, the drone will have four motors that will actively slow down the decent of the payload post deployment. Payload electronics and StemNauts will be housed in the center of the drone frame. This simplified drone design allows for little moving parts further avoiding complications, increasing the reliability and safety of the Payload.

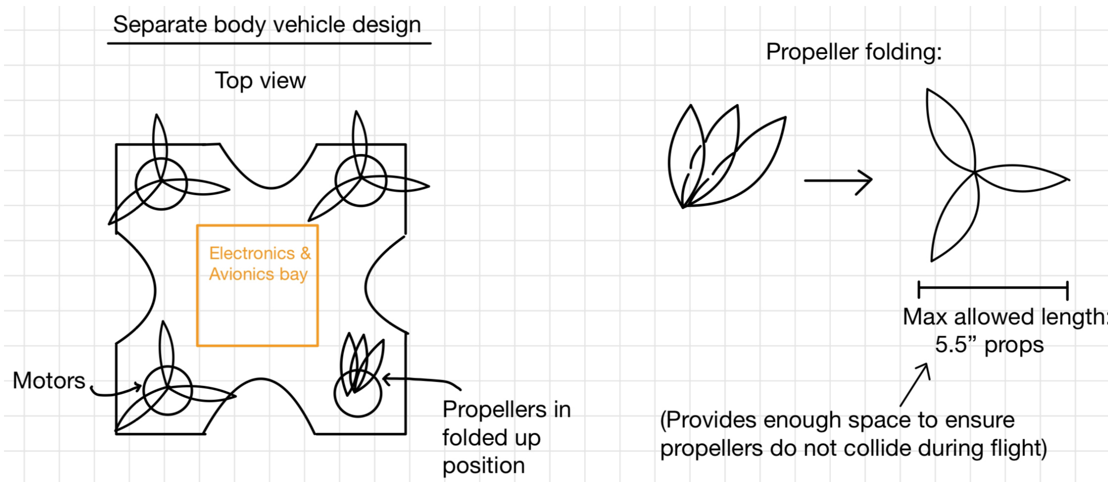

Figure 12: Top View of Payload Type A

For the corresponding EE/CS implementation of this payload type, the payload electronics would be contained in the body of the payload, whether it be a drone, glider, or another aerial device. In the case that it is a drone, a flight controller will be used for autonomous control and landing.

For the payload electronics module, lithium-polymer batteries will be used for power, and this decision was made due to knowledge from previous years. These batteries are better due to their reliability and smaller size that will allow for a better consolidation of space in the sled/unit. As per the STEMCRaFT Mission Requirements, there will be an Adafruit BNO055 IMU sensor, an Adafruit BMP390 barometer, an Adafruit BME680 or temperature sensor, and an Adafruit I2S MEMS Microphone Breakout to measure the survival metrics of maximum and landing velocity, sustained G-forces, apogee reached, landing site temperature, and decibel limit.

An ESP32S3 microcontroller will be used to obtain and store this data, as it can be interfaced with easily for sensor control and takes up less space than other options like Arduino and Raspberry Pi boards. The ESP32 will also connect and output data using an APRS library to a 2M transceiver, which will be either a custom chip like the DRA818v or Software Defined Radio like the Nooelec HackRF One. The final transceiver used between those options will be determined through testing. As per the payload experiment requirements, the data obtained from the sensors listed above will be transmitted via that transceiver upon landing.

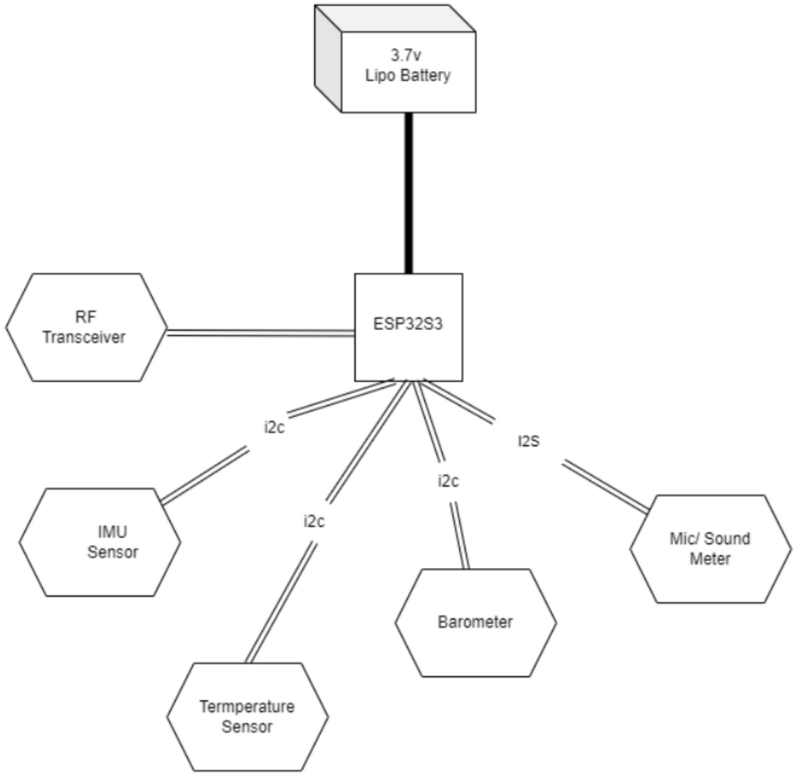

Figure 13: Payload Schematic

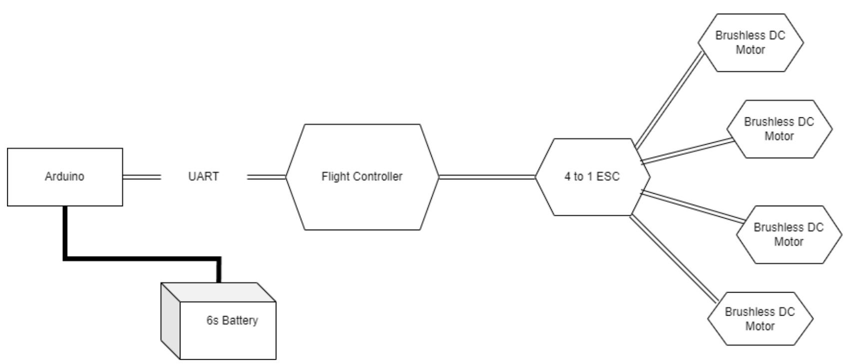

Figure 14: Flight Controller Schematic

4.2.2 Payload Type B

A further idea for the Payload system will be composed of a system that will safely land the proposed StemNauts in an upright orientation that is the same as they are launched. This will be done by a series of folding propellers and landing legs that will allow the entire Payload system to land autonomously. As depicted in Figure 15, this payload system will ensure the orientation of the Stemnauts is maintained through descent and landing.

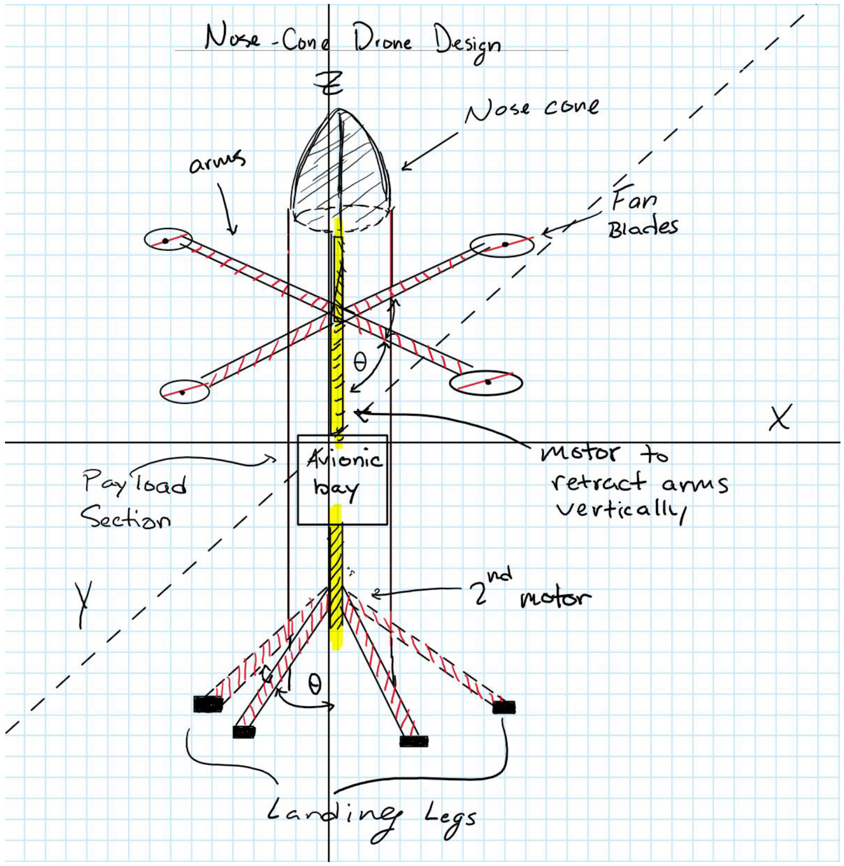

Figure 15: View of Payload Type B Deployed

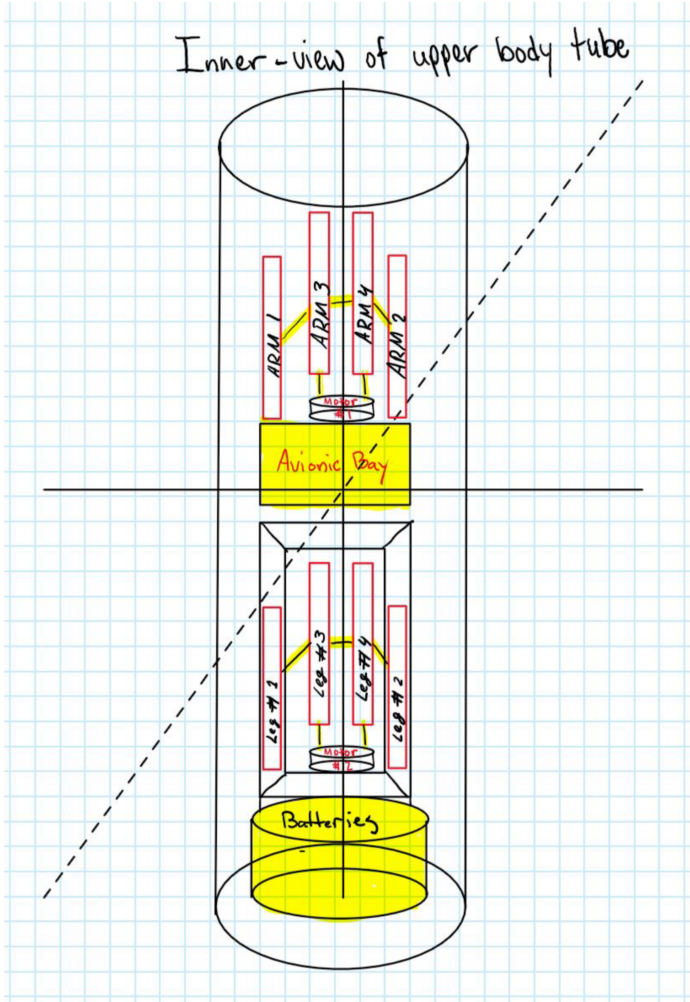

Figure 16: View of Payload Type B Undeployed

4.2.3 Payload Type C

The final ideas for the Payload system will be composed of a capsule that will be descended under a parachute. This Payload system is very simplistic due to the nature of the capsule. Said capsule will house only the electronics and SteamNauts meaning there is very little unused space. Since a parachute will be used for descent there is very minimal chance of payload failing due to mechanical technical issues. The system is depicted in Figure 17.

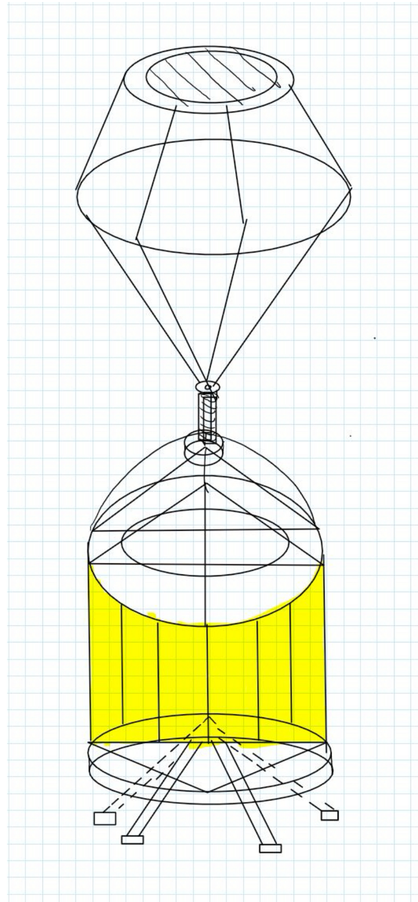

Figure 17: View of Payload Type C

4.2.4 Preliminary Payload Jettison

A preliminary design for jettisoning the payload is using a single lead-screw that will push out the payload in a types. This lead-screw system will allow for diverse features and ease of jettisoning payload from the rocket. Mechanically the system will be composed of a DC motor and gearbox that will allow for the torque to be used to deploy safely and reliably. On the EE/CS side the lead screws that will perform the jettison will use both a distance sensor and motor encoders will be utilized to control their actuation, and keep them locked in place until the correct state is reached. An example of the EE/CS side of payload is shown in Figure 18. The mechanical part is shown in Figure 19.

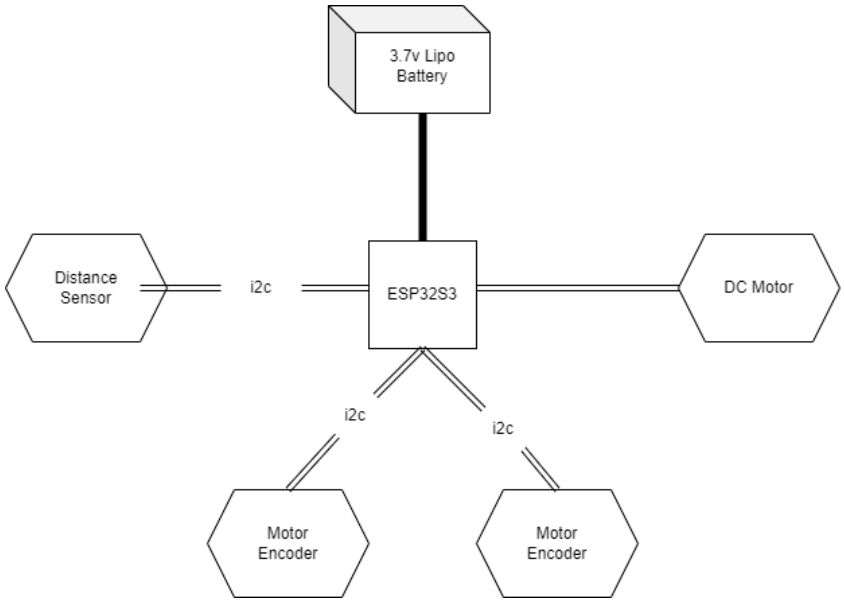

Figure 18: Jettison Electronics System Schematic

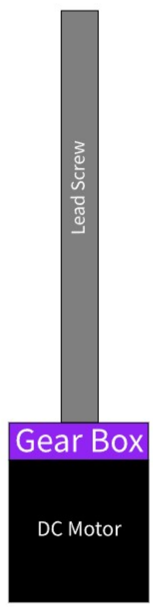

Figure 19: Jettison Mechanism Schematic

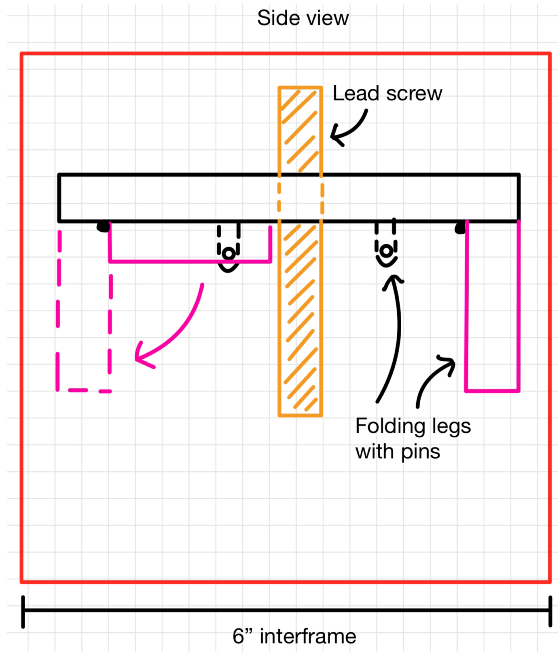

Figure 20: Side View of Payload Type A

4.2.5 Major Technical Challenges and Solutions

4.2.5.1 Effective Payload Jettison System

An effective payload jettison system is crucial for ensuring the safe and efficient release of payload. Electromechanical release mechanisms, such as solenoids or servos, offer precise control over the release process, accommodating various payload sizes and weights. A timed release system, triggered by a programmable timer or GPS, guarantees accurate payload release at the desired location or time. Redundant release mechanisms act as backup systems, ensuring payload jettison even in case of primary system failure. To prevent accidental release during flight, safety protocols, like lock-and-release systems controlled by secure signals, are essential.

4.2.5.2 Robust Drone Arms / Frame

A durable drone frame and arms are vital for withstanding operational stresses and impacts. High-strength materials like carbon fiber or titanium provide a balance of weight and durability. Critical stress points can be reinforced with additional bracing or gussets, while modular designs facilitate easy replacement of damaged parts. Rigorous testing and simulations help identify potential failure points and inform design improvements. Incorporating vibration dampeners reduces stress on the frame from propulsion and external impacts.

4.2.5.3 Accurate sensor Data

Precise and reliable sensor data is essential for drone operations. Regular calibration ensures sensor accuracy, while sensor fusion combines data from multiple sensors to enhance overall accuracy and reliability. Redundancy provides cross-checking and consistency, while environmental considerations mitigate the effects of factors like temperature and humidity on sensor performance. Ensuring that payload electronics endure the entirety of the flight Protecting payload electronics from damage during flight is crucial. Shock-absorbing materials or mountings safeguard sensitive electronics from vibrations and impacts. Weatherproof and insulated enclosures shield electronics from moisture and temperature extremes. Cooling systems, such as heat sinks or fans, are necessary for payloads that generate heat. Regular maintenance, including inspections and component replacements, ensures the electronics remain in good working condition throughout the flight.

4.3 Description of Projected Non-Scored Payload

4.3.1 Mission Statement

The main purpose of the Active Air-Braking System (ABS) is to reduce the altitude error between the predicted altitude at apogee and actual recorded altitude at apogee to a minimum. This secondary payload was introduced as a means to maximize the team's possible scoring by tackling a category that weighs 10% of the entire competition: altitude.

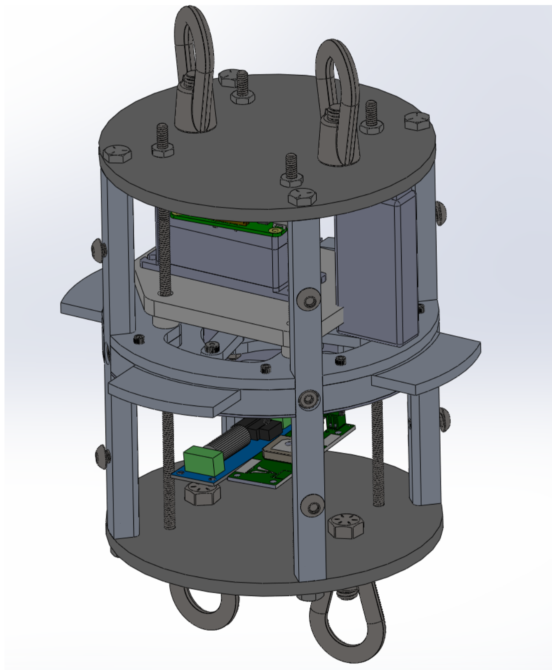

Figure 21: Preliminary Airbrakes Design.

4.3.2 Mechanical Overview

The ABS will consist of 4 plates that extrude from the airframe, generating a sudden increase in drag. Through the use of a PID system, the degree of deployment and total drag will be changed, decreasing the maximum altitude and converging to the desired apogee. Powered by two independent lipo batteries, the ABS generates a maximum of 162 N of additional drag at Mach 0.6.

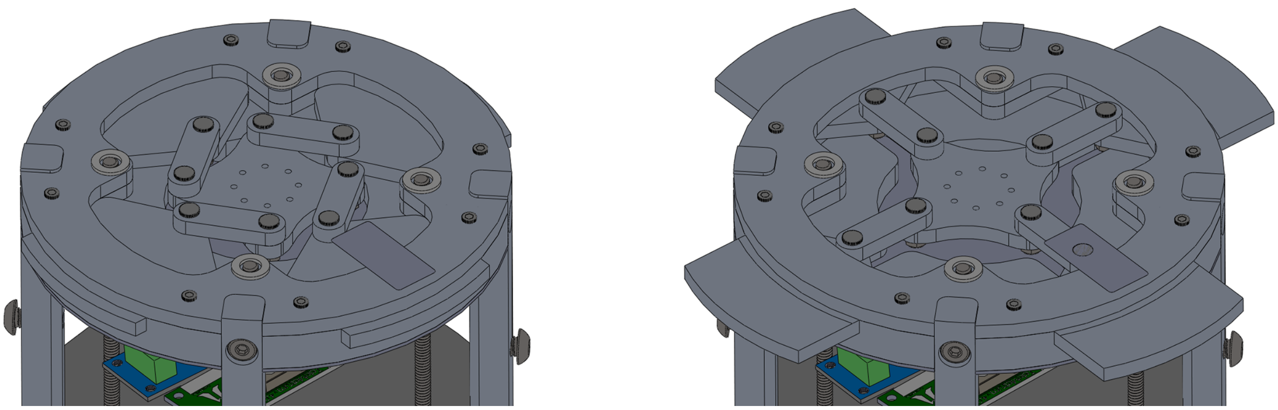

Figure 22: Mechanical Actuation.

4.3.3 EECS Overview

For the electrical implementation of the air brakes system, two BNO055 IMU sensors will be used to get live velocity readings, and a BMP390 barometer will be used for live altitude readings. The central control/processor will be a Raspberry Pi Zero, and to actuate the servo controlling the flaps, a PCA9685 Servo Driver will be used for more accurate and efficient PWM signaling. A state machine will be implemented in software that differentiates four states of the rocket's trajectory as they pertain to the air brakes: burnout, active, full stop, and post-apogee. In a control loop executed only in the active state, live velocity and altitude data will be read in from the sensors and run through a Kalman Filter to ensure its integrity, then substituted into the rocket's calculated drag equation to make a prediction of what the current projected apogee will be. These predictions will be calculated in small time increments using the 4th Runge Kutta method, and if the predicted apogee in a given iteration is higher than the target apogee, the servo controller will actuate the brakes out to a degree calculated in a nested loop that makes predictions for a range of actuation values close to the current one. From these predictions the actuation percentage that yields the least error to the target apogee will be chosen, and this cycle will continue until the apogee is reached or surpassed. In the case that it is surpassed, the full stop state will actuate the servos completely until apogee is reached to minimize error as much as possible.

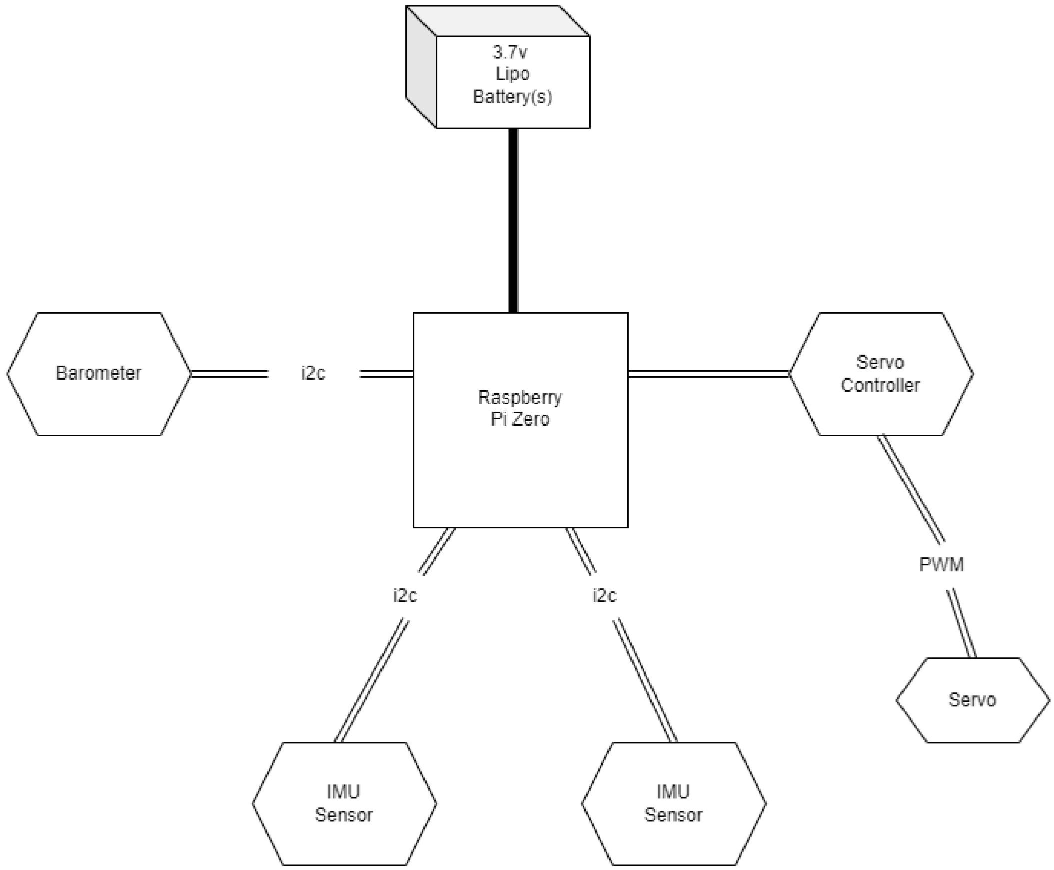

Figure 23: Airbrakes projected schematic.

4.3.4 Integration

While brainstorming ideas for the ABS, integration of the system within the rocket proved to be a high priority as multiple concerns regarding the subject required solutions in order to continue its design. The team began to address many potential problems the system might pose with integration or experience during flight. Problems such as stress, weight, flight characteristics, etc. were all taken into account during the ideas of its integration. Consequently, the size and design of the ABS were also considered during all design proposals for the rocket's layout.

The current proposal for placement of the ABS is to have it located in the midsection of the rocket. This placement allows the ABS to operate at around half the rocket's total length, granting many potential advantages which could have a major impact now and in the foreseeable future. Characteristics such as cg, stability, weight distribution, payload space, etc. are most likely to be benefitted by the placement of this system, which could even allow for easier integration upon other systems with the rocket. Last year we experienced multiple difficulties with integration due to the rocket's layout not granting enough room for all systems to fit in easily. This year, with a bigger diameter and focus on easing integration, all proposed designs seem to work well with each other, even allowing for extra space in case future systems require more. For example, by focusing on integration, the team has been able to optimize space by having the avionics bay and ABS share the same area, freeing up any potential space which could be used later on. Optimizations like these ensure our ABS will not only work well within the rocket, but integrate seamlessly with other systems.

To integrate the ABS, the team is looking towards having the air brakes first retracted prior to being placed within the rocket. The system is to be placed along four aluminum rods which run throughout the length of the ABS system, which is then to be secured tightly by eight quarter inch bolts. The ABS will be placed level to four evenly cut slots which allow the ABS's panels to extend and retract through during flight. Once level, the panels will extend enough so that it is completely flushed with the rest of the midsection tube, ensuring the rocket's flight characteristics are not compromised. The panel's cutouts will allow for just enough error that the panels can move seamlessly while allowing for only small amounts of air flow. The tight fit between the ABS panels as well as securing the system through four rods mitigate the amount the system can vibrate itself during flight. This heavily reduces any potential reasons failure might occur due to integration and give the system ideal conditions to operate as intended.

4.3.5 Simulation and Testing

The team is aware of the high complexity of this system. Therefore, the team will put great effort into simulating and validating said data to ensure mission success. The team has access to Computer Fluid Dynamics software, which is planned to be used for the derivation of the drag coefficient of the mechanism, and expected loads in the plates of the airbrakes. The CFD data by its own, however, is not enough to ensure the validity of a system. It is imperative to test the ABS and ensure that the numbers obtained in CFD are accurate. The team plans to take advantage of the wind tunnel present at USF's establishments.
From a Controls Engineering perspective, the team will develop a Digital Twin of the vehicle using physics and game engine software to test the logic behind the ABS system. This simulation will be developed to interface with a hardware-in-the-loop (HIL) system to ensure the logic and performance of the computing components closely mirror their real-world operation.

4.4 Requirements

4.4.1 General Requirements

Table 10: General Requirements Specification

No.	Description	Verification	Verification Description
NR.1	Students on the team will do 100% of the project. Student team members shall only be a part of one team in any capacity. Teams will submit new work. Excessive use of past work will merit penalties.	Inspection	Students will be responsible for completing all parts of this project. Student leaders will review designs and documents on a regular basis to ensure nothing is being copied from the previous year
NR.2	The team will provide and maintain a project plan to include, but not limited to, the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	Inspection	SOAR's President, Alvaro Lazaro Aguilar will be responsible for providing and maintaining the project plan. The Safety Officer, Lucas Folio will be responsible for providing and maintaining risk mitigation.
NR.3	Team members who will travel to the Huntsville Launch shall have fully completed registration in the NASA Gateway system before the roster deadline. Team members shall include:	Inspection	By the end of the fall semester and early spring semester a confirmation poll will ensure registration of all members is complete prior to travel to Huntsville.
NR.3.1	Students actively engaged in the project throughout the entire year.	Inspection	A list of all active students working on the project will be identified and updated.
NR.3.2	One mentor.	Inspection	The team will identify one mentor.
NR.3.3	No more than two adult educators.	Inspection	The team will identify one or two adult educators.
NR.4	Teams shall engage a minimum of 250 participants in Educational Direct Engagement STEM activities. These activities can be conducted in-person or virtually...	Inspection	The team will plan a minimum of two K-12 outreach events.

No.	Description	Verification	Verification Description
NR.5	The team shall establish and maintain a social media presence to inform the public about team activities.	Inspection	The team will utilize SOAR social media accounts to post about projects, updates, and events for USLI. These social media accounts will be managed by SOAR's Chief of Marketing, Emily Ho.
NR.6	Teams shall email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone.	Inspection	All deliverables will be submitted by the due date by email.
NR.7	All deliverables shall be in PDF format.	Inspection	All deliverables will be converted into PDF format prior to submission.
NR.8	In every report, teams will provide a table of contents, including major sections and their respective subsections.	Inspection	Table of contents will be automatically generated using LaTeX software.
NR.9	In every report, the team shall include the page number at the bottom of the page.	Inspection	The team shall confirm that numbers are included at the bottom of the page for each deliverable prior to submitting.
NR.10	The team shall provide any computer equipment necessary to perform a video teleconference with the review panel.	Inspection	The team will utilize university WiFi and computer equipment to perform video teleconferences.
NR.11	All teams attending Launch Week shall be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted at the NASA Launch Complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5 – 10 degrees away from the crowd on Launch Day...	Inspection	The launch vehicle will be launched using the provided 12-foot rail. The team will abide by the required cant specified on launch day.
NR.12	Each team shall identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization...	Inspection	The team will identify a TRA or NAR-certified mentor to attend launches including the competition launch in Huntsville, Alabama.
NR.13	Teams will track and report the number of hours spent working on each milestone.	Inspection	The team will utilize an hour tracking table for each milestone.

4.4.2 Vehicle Requirements

Table 11: Vehicle Requirements and Verification

No.	Description	Verification	Verification Description
VR.1	The vehicle shall deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,500 feet on their competition launch will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.	Analysis, Demonstration	Openrocket simulations will be used to calculate launch vehicle apogee. Demonstration flights will confirm that the apogee remains within the required range.
VR.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.	Inspection	The target altitude will be calculated during the development of the CDR and included within the deliverable.
VR.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.	Analysis, Test	A recovery system will ensure that the system is fully recoverable and reusable with little to no damage. The recovery systems will be tested on launch days and analyzed using OpenRocket simulations.
VR.4	The launch vehicle shall have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	Inspection	The launch vehicle will have three sections: booster, mid, payload, and falling nosecone.
VR.4.1	Coupler/airframe shoulders which are located at in-flight separation points shall be at least two airframe diameters in length. (One body diameter of surface contact with each airframe section).	Inspection	Coupler (at in-flight separation) length will be a minimum of 12 inches when measured.
VR.4.2	Coupler/airframe shoulders which are located at non-in-flight separation points shall be at least 1.5 airframe diameters in length. (0.75 body diameter of surface contact with each airframe section).	Inspection	Coupler (at non-in-flight separation) length will be a minimum of 9 inches when measured.

No.	Description	Verification	Verification Description
VR.4.3	Nosecone shoulders which are located at in-flight separation points shall be at least $\frac{1}{2}$ body diameter in length.	Inspection	Nosecone shoulder will be a minimum length of 3 inches when measured.
VR.5	The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	Demonstration	The team will practice rocket preparations prior to Launch Day to demonstrate that the vehicle can be prepared for flight within 2 hours.
VR.6	The launch vehicle and payload shall be capable of remaining in launch-ready configuration on the pad for a minimum of 3 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.	Demonstration, Test	All critical on-board components will be tested to ensure that they can withstand 3 hours of delay and still perform properly.
VR.7	The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system. The firing system shall be provided by the NASA-designated launch services provider.	Inspection	The vehicle will be inspected to confirm that it can launch using a standard 12V DC firing system.
VR.8	The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	Inspection	External circuitry and special ground support will not be used.
VR.9	Each team shall use commercially available ematches or igniters. Hand-dipped igniters shall not be permitted.	Inspection	Inspection of the igniter will confirm that the team is using a commercially available igniter.
VR.10	The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	Inspection	An Aerotech L-1500 motor will be used, this can be confirmed through inspection of the motor.
VR.10.1	Final motor choice shall be declared by the Preliminary Design Review (PDR) milestone.	Inspection	An Aerotech L-1500 motor will be used, this information will be included in the PDR.

No.	Description	Verification	Verification Description
VR.10.2	Any motor change after PDR shall be approved by the NASA management team or NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment shall not be approved. A scoring adjustment against the team's overall score shall be incurred when a motor change is made after the PDR milestone. The only exception is teams switching to their secondary motor choice provided the primary motor choice is unavailable due to a motor shortage.	Inspection	A change control request will be submitted upon the change of motor selection. Motor selection will not be changed within deliverable documents unless the change request is approved.
VR.11	The launch vehicle shall be limited to a single motor propulsion system.	Inspection	The launch vehicle will be designed with a single motor propulsion system.
VR.12	The total impulse provided by a College or University launch vehicle shall not exceed 5,120 Newton-seconds (L-class).	Inspection	Inspection will confirm that the selected motor is L-class.
VR.13	Pressure vessels on the vehicle must be approved by the RSO and shall meet the following criteria:		
VR.13.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	Inspection	There will be no pressure vessels onboard the vehicle.
VR.13.2	Each pressure vessel shall include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.	Inspection	There will be no pressure vessels onboard the vehicle.
VR.13.3	The full pedigree of the tank shall be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	Inspection	There will be no pressure vessels onboard the vehicle.

No.	Description	Verification	Verification Description
VR.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.	Analysis	The distance between Center of Pressure and Center of Gravity will be calculated to ensure proper margin. Rocket stability will be optimized through rocket design and integration.
VR.15	The launch vehicle shall have a minimum thrust-to-weight ratio of 5.0:1.0.	Analysis	The thrust-to-weight ratio will be calculated by hand using the average thrust provided by the motor and the vehicle weight.
VR.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) cause minimal aerodynamic effect on the rocket's stability.	Inspection	The only structural protuberance aside from a camera housing (which will cause minimal effect on stability) will be the airbrakes system. The airbrakes system will be located aft of the burnout center of gravity.
VR.17	The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.	Analysis	Openrocket simulations will be used to calculate the off-the-rail velocity.
VR.18	All teams shall successfully launch and recover a subscale model of their rocket. Success of the subscale is at the sole discretion of the NASA review panel. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data shall be reported in the CDR report and presentation at the CDR milestone. Subscales are required to use a minimum motor impulse class of E (Mid Power motor).	Test	A subscale model of the rocket will be designed, built, and launched prior to the CDR. All recorded data will be included in the CDR.
VR.18.1	The subscale model should resemble and perform as similarly as possible to the full-scale model; however, the full-scale shall not be used as the subscale model.	Test, Inspection	The sub-scale model will be tested to show full capabilities during a launch. Inspection will confirm that the sub-scale and full-scale rocket are two separate rockets.
VR.18.2	The subscale model shall carry an altimeter capable of recording the model's apogee altitude.	Test	The altimeter's capability to record apogee will be tested during flight.
VR.18.3	The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.	Inspection	Inspection of this subscale rocket by a team leader will confirm that this rocket is not the same as a rocket from a previous year.

No.	Description	Verification	Verification Description
VR.18.4	Proof of a successful flight shall be supplied in the CDR report, including: Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) will not be accepted; Quality pictures of the as-landed configuration of all sections of the launch vehicle shall be included in the CDR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster.	Inspection	Inspection of the CDR will confirm that altimeter flight profile graphs or a quality video showing successful launch, recovery events, and landing are included. Quality pictures of the landed configuration and all sections of the vehicle will also be included in the CDR.
VR.19	The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter, 100" length rocket, your subscale shall not exceed 3" diameter and 75" in length.	Inspection	The subscale rocket will be measured to confirm that the dimensions do not exceed 75% of the full-scale rocket.
VR.20	Demonstration Flights Requirements: All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown shall be the same rocket to be flown for their competition launch. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly	Demonstration, Inspection	The team will demonstrate a successful flight by launching the rocket at a local launch site and recording proof of the successful launch. Inspection will confirm that this is the same vehicle that will be used during the competition launch.
VR.20.1	The vehicle and recovery system shall have functioned as designed.	Demonstration, Inspection	The vehicle and recovery system will be confirmed to function as designed during a demonstration launch.
VR.20.2	The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.	Inspection	Inspection of this full-scale rocket by a team leader will confirm that this rocket is not the same as a rocket from a previous year.

No.	Description	Verification	Verification Description
VR.20.3	The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply: 1. If the payload is not flown, mass simulators shall be used to simulate the payload mass. 2. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.	Inspection	If payload is not flown, the team will inspect the rocket to confirm that a mass simulator located in the designated payload area is present.
VR.20.4	If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	Inspection	The team will inspect the rocket to confirm that all external surfaces remain active during the full-scale vehicle demonstration flight.
VR.20.5	Teams shall fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances.	Inspection	Inspection will confirm that the motor used during the demonstration flight is the same motor that will be used during the competition.
VR.20.6	The vehicle will be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the competition launch flight. Additional ballast shall not be added without a re-flight of the full-scale launch vehicle.	Inspection	Ballast used for the test flight will be used to confirm that it is the same weight that will be used during the competition flight.
VR.20.7	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA management team or Range Safety Officer (RSO).	Inspection	Inspection will confirm that the components used during the full-scale demonstration flight are not modified (unless approved by NASA management or and RSO).

No.	Description	Verification	Verification Description
VR.20.8	Proof of a successful flight shall be supplied in the FRR report, including: 1. Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted. 2. Quality pictures of the as-landed configuration of all sections of the launch vehicle shall be included in the FRR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster. 3. Raw altimeter data shall be submitted in .csv or .xlsx format.	Inspection	Inspection of the FRR will confirm that proof of successful flight is included in the deliverable. This will include altimeter data in the proper format and quality pictures of the as-landed configuration of all sections of the launch vehicle.
VR.20.9	Vehicle Demonstration flights shall be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST-TIME FLIGHTS. Teams completing a required re-flight shall submit an FRR Addendum by the FRR Addendum deadline.	Inspection	FRR will include proof of a vehicle flight demonstration and will be submitted before the deadline.
VR.21	Payload Demonstration Flight Requirements: All teams shall successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown shall be the same rocket to be flown as their competition launch. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed.	Demonstration	A demonstration flight with payload will take place at a local launch site prior to the deadline.

No.	Description	Verification	Verification Description
VR.21.1	The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.	Inspection	The payload will be inspected during launch to verify that it does not deploy before intended.
VR.21.2	The payload flown shall be the final, active version.	Inspection	The payload will be inspected to verify that the final version is being flown.
VR.21.3	If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.	Inspection	The FRR will be inspected to confirm that either the above criteria have been met and included in the document or a FRR addendum is included.
VR.21.4	Payload Demonstration Flights shall be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	Inspection	The FRR will be submitted before the deadline, inspection of the document will verify that the payload demonstration flight is completed and included.
VR.22	An FRR Addendum shall be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.	Inspection	Inspection will verify that an FRR Addendum is included if needed.
VR.23	The team's name and Launch Day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	Inspection	A visual inspection will verify that the launch day contact information is visible in or on the airframe and on any section of the vehicle that separates during flight that is not tethered to the airframe.
VR.24	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.	Inspection	Inspection will confirm that Lithium Polymer batteries are either visibly marked and protected or not used at all.

No.	Description	Verification	Verification Description
VR.25	Vehicle Prohibitions		
VR.25.1	The launch vehicle shall not utilize forward-firing motors.	Inspection	Forward-firing motors will not be included in the vehicle.
VR.25.2	The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).	Inspection	The selected motor does not expel titanium sponges.
VR.25.3	The launch vehicle shall not utilize hybrid motors.	Inspection	The selected motor is a solid motor.
VR.25.4	The launch vehicle shall not utilize a cluster of motors.	Inspection	A single solid motor will be used.
VR.25.5	The launch vehicle shall not utilize friction fitting for motors.	Inspection	Aerostructures Lead will make sure selected motor will not utilize friciton fitting
VR.25.6	The launch vehicle shall not exceed Mach 1 at any point during flight.	Analysis, Test	OpenRocket simulations will be used to determine the vehicle's maximum speed and ensure that it does not exceed Mach 1. Test flights will confirm that the vehicle does not exceed Mach 1 during flight.
VR.25.7	Vehicle ballast shall not exceed 10% of the total un-ballasted weight of the rocket, as it would sit on the pad (i.e., a rocket with an un-ballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	Analysis	The team will ensure that the ballast does not weigh more than 10% of the rocket's weight by weighing the rocket and the ballast and performing calculations to verify.
VR.25.8	Transmissions from on-board transmitters, which are active at any point prior to landing, shall not exceed 250 mW of power (per transmitter).	Demonstration	The team will select transmitters that comply with the power limit, plus the team will utilize equipment such as a spectrum analyzer to measure signal strength, derive power output, and make sure said power is below 250mW.
VR.25.9	Transmitters shall not create excessive interference. Teams shall utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.	Demonstration	The team will utilize unique frequencies and bandwidth on its transceivers. Additionally, the team will make sure to utilize software and cryptographic practices to ensure security and reliability of information packets.

No.	Description	Verification	Verification Description
VR.25.10	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.	Inspection	Inspection of materials used and their weight will confirm that excessive and/or dense metals are not utilized.

4.4.3 Recovery Requirements

Table 12: Recovery System Requirement and Verification

No.	Description	Verification	Verification Description
RR.1	The full-scale launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO.	Inspection	The recovery system will be verified to be compliant with these requirements.
RR.1.1	The main parachute shall be deployed no lower than 500 feet.	Analysis, Inspection	The main parachute will deploy at 700 ft.
RR.1.2	The apogee event shall contain a delay of no more than 2 seconds.	Demonstration	The altimeters will be set with a 1-second delay for drogue deployment.
RR.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	Inspection	The motor will not eject.
RR.2	Each team shall perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the sub-scale and full-scale vehicles.	Inspection, Test	The vehicle lead will perform ground ejection tests prior to each flight.
RR.3	Each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf at landing. Teams whose heaviest section of their launch vehicle, as verified by vehicle demonstration flight data, stays under 65 ft-lbf will be awarded bonus points.	Analysis, Demonstration	Before manufacturing, the aerostructures team will verify the validity of the projected kinetic energy.
RR.4	The recovery system shall contain redundant, commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	Inspection	Two independent recovery systems will be placed in the avionics bay.

No.	Description	Verification	Verification Description
RR.5	Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries.	Inspection	The telemetry lead will ensure to account for dedicated power supply in the recovery system design. Additionally the telemetry lead will select commercially available batteries.
RR.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.	Inspection, Test	Prior to a launch, the altimeter's switches will be tested.
RR.7	Each arming switch shall be capable of being locked in the ON position for launch (i.e., cannot be disarmed due to flight forces).	Inspection, Test	Prior to a launch, the altimeter's switches will be tested.
RR.8	The recovery system, GPS and altimeters, and electrical circuits shall be completely independent of any payload electrical circuits.	Inspection, Test	Through testing the telemetry lead will ensure GPS and altimeter's system operate as expected regardless of the state of the payload system
RR.9	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	Inspection	The aerostructures lead will ensure compliance with this requirement.
RR.10	Bent eyebolts shall not be permitted in the recovery subsystem.	Inspection	The team will inspect the recovery system design prior to manufacture.
RR.11	The recovery area shall be limited to a 2,500 ft radius from the launch pads.	Analysis, Demonstration	A dual-deployment recovery system will be used to reduce the launch and landing distance.
RR.12	Descent time of the launch vehicle shall be limited to 90 seconds (apogee to touch down). Teams whose launch vehicle descent, as verified by vehicle demonstration flight data, stays under 80 seconds will be awarded bonus points.	Analysis, Demonstration	The team will perform several descent time calculations for worst-case scenarios.
RR.13	An electronic GPS tracking device shall be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	Inspection	The telemetry lead will ensure the construction of a ground receiver that can continuously track GPS coordinates.

No.	Description	Verification	Verification Description
RR.13.1	Any rocket section or payload component, which lands untethered to the launch vehicle, shall contain an active electronic GPS tracking device.	Inspection	The telemetry lead will review all designs to account for more GPS devices for independent sections.
RR.13.2	The electronic GPS tracking device(s) shall be fully functional during the official competition launch.	Test, Demonstration	The GPS system will be tested several times prior to launch to ensure precision and reliabilty.
RR.14	The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	Inspection, Test	The recovery system will be tested with all devices onboard.
RR.14.1	The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	Inspection	The recovery system will be contained in a separate avionics bay.
RR.14.2	The recovery system electronics shall be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.	Inspection, Test	The recovery system will be tested with transmitting devices onboard.
RR.14.3	The recovery system electronics shall be shielded from all on-board devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	Inspection, Test	If one of the designs utilizes magnetic genrating devices, the recovery system will be tested with said devices onboard.
RR.14.4	The recovery system electronics shall be shielded from any other on-board devices which may adversely affect the proper operation of the recovery system.	Inspection, Test	The recovery system will be tested with all devices onboard.

4.4.4 Payload Requirements

Table 13: Payload System Requirements and Verificiation

No.	Description	Verification	Verification Description
STEMCRaFT Mission Requirements			
PR.1	Teams shall choose a minimum of 3 pieces of data from the below list to a maximum of 8 to transmit to the NASA receiver. • Temperature of landing site • Time of landing • Apogee reached • Maximum velocity • Battery check/power status • Landing velocity, G-forces sustained • Orientation of on-board STEMnauts • Calculated STEMnaut crew survivability probability • Maximum altitude	Demonstration	The team will transmit 8 pieces of data to the NASA receiver during demonstration. The data to be transmitted will be (1) Temperature of landing site, (2) Time of landing, (3) Apogee reached, (4) Maximum velocity, (5) Landing velocity, G-forces sustained, (6) Orientation of on-board STEMnauts, (7) Calculated STEMnaut crew survivability probability, (8) Maximum altitude.
PR.2	The payload shall not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe.	Inspection	The payload will not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe.
PR.3	Payload shall transmit on the 2-M band. A specific frequency shall be given to the teams later. NASA shall use the FTM-300DR transceiver.	Inspection	The telemetry lead will ensure that the payload shall transmit on the 2-M band at the specified frequency as provided.
PR.4	All transmissions shall start and stop with team member call sign.	Inspection	Call sign "KQ4FYU" shall be used to start and stop all transmissions.
PR.5	Teams shall submit a list of what data they will attempt to transmit by NASA receiver by March 17.	Inspection	The team will submit a list of what data they will attempt to transmit by NASA receiver by March 17.
PR.6	Teams shall transmit with a maximum of 5W and transmissions shall not occur prior to landing.	Demonstration	Components will be tested prior to integration with vehicle to demonstrate a maximum transmission of 5W or below.

No.	Description	Verification	Verification Description
PR.7	Teams shall not transmit on the specified NASA frequency on launch day prior to landing.	Demonstration	All components that transmit radio frequencies will be tested to demonstrate the ability to transmit on a unique frequency.
General Payload Requirements			
PR.8	Black powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations.	Inspection	Black powder and other similar energetics will only be used for recovery.
PR.9	Teams shall abide by all FAA and NAR rules and regulations.	Inspection	All FAA and NAR regulations shall be followed as outlined in the safety section of the proposal. Energetics shall not be used as deployment of the payload. In-flight recovery systems shall be the only permitted use of black powder charges or similar energetics.
PR.10	Any payload experiment element that is jettisoned during the recovery phase shall receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement by the RSO or NASA.	Inspection	Prior to the payload experiment element being jettisoned, real-time RSO permission shall be received during the recovery phase.
PR.11	Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, shall be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS.	Inspection, Demonstration	Either the permission to release the UAS will be confirmed through inspection, or a demonstration of a remotely controlled release system will be shown through a test flight.
PR.12	Teams flying UASs shall abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112–95 Section 336).	Inspection	The team shall abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336).
PR.13	Any UAS weighing more than .55 lbs. shall be registered with the FAA and the registration number marked on the vehicle.	Inspection	Visual inspection will confirm that any UAS weighing more than 0.55 lbs includes a marked registration number on the vehicle.
Notes: An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety			

4.4.5 Safety Requirements

Table 14: Safety Requirements and Verification

No.	Description	Verification	Verification Description
SR.1	Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.	Inspection	The Safety Officer, Lucas Folio, will use a launch and safety checklist and include the final checklists in the FRR, LRR, and all Launch Days.
SR.2	During test flights, teams shall abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams shall communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	Inspection	The team will communicate with the RSO via email and phone calls to confirm allowance of vehicle flight configuration at the launch site prior to any launch days.
SR.3	Teams shall abide by all rules set forth by the FAA.	Inspection	The safety officer will ensure that all rules set forth by the FAA are abided by.
SR.4	Each team shall identify a student safety officer who will be responsible for all items in Section 5.3.	Inspection	The team has identified Lucas Folio as the Safety Officer.

No.	Description	Verification	Verification Description
SR.5	The role and responsibilities of the safety officer shall include, but are not limited to: • 5.3.1. Monitor team activities with an emphasis on safety during: – 5.3.1.1. Design of vehicle and payload – 5.3.1.2. Construction of vehicle and payload components – 5.3.1.3. Assembly of vehicle and payload – 5.3.1.4. Ground testing of vehicle and payload – 5.3.1.5. Subscale launch test(s) – 5.3.1.6. Full-scale launch test(s) – 5.3.1.7. Competition Launch – 5.3.1.8. Recovery activities – 5.3.1.9. STEM Engagement Activities • 5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities. • 5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and SDS/chemical inventory data. • 5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	Inspection	The safety officer will be present during all launches to monitor team activities with an emphasis on safety, implement procedures, and maintain and write risk analysis and FMEA.

5 STEM Engagement

One of SOAR's most important events is the USF's Engineering Expo, held every February. This on campus engineering event focuses on showcasing hundreds of elementary, middle, and high school students the importance of math, science, engineering, and technology. Many student led organizations, USF research labs, and engineering companies participate in this event, making it one of the biggest on campus. During this two-day event, SOAR plans to engage 250+ students through interactive educational activities.

In addition to the Engineering Expo, USF also plans to participate in the America Great Tech In event, where some members would attend middle and high schools to teach about science and engineering through rocketry based activities. Like in previous years, this event engages hundreds of students.

6 Project Plan

6.1 Timeline and backups

The timeline graphic presented below outlines the primary sequence of events anticipated for achieving the objectives of the project. It also highlights alternative routes to be followed in the event of setbacks, which are a common occurrence in rocketry. Launch success is never guaranteed due to factors such as technical deficiencies, weather-related cancellations, or other external influences. Therefore, this graphic presents 5 potential pahts (A.0, A.1, A.2, B.0 & B.1) to ensure that project goals are met with the highest probability of success, providing contingency plans for each major milestone in the timeline.

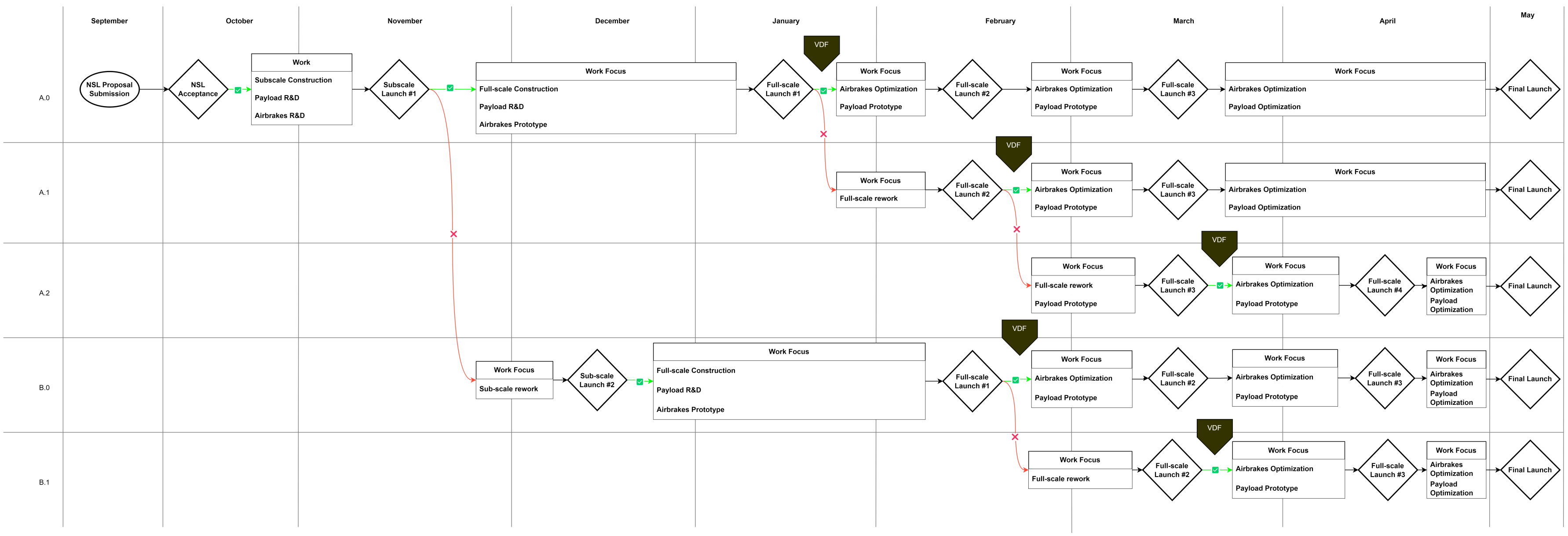

Figure 24: Foreseen technical project timeline with backup plans

6.2 Detailed Gantt Chart Plan

The Gantt Chart detailed in this section correspond to Timeline A.0, which assumes the optimal scenario where all launches proceed without delays or failures. This timeline outlines the maximum amount of engineering work required and represents the ideal case in which the project progresses without major disruptions. The Gantt Chart iself offers a detailed visual representation of the project's work packages, key dependencies, and milestones. Each task is clearly defined, showing its relationship to other tasks in the project. All tasks are grouped with their respective milestone (the purple diamonds), therefore any item above a milestone icon is assigned to it (The charts are divided into multiple parts for clarity and readability.)

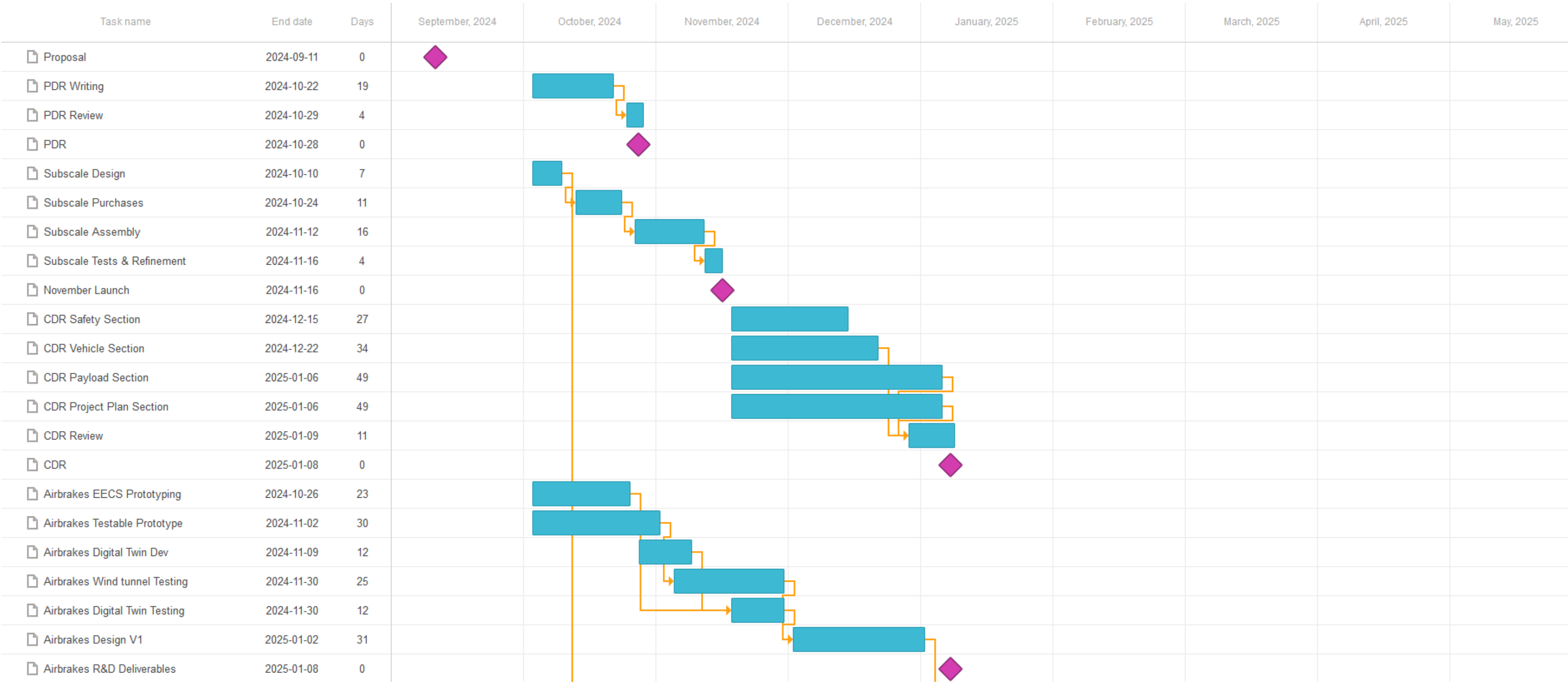

Figure 25: Gantt Chart detailing work, dependencies and milestones (PART 1)

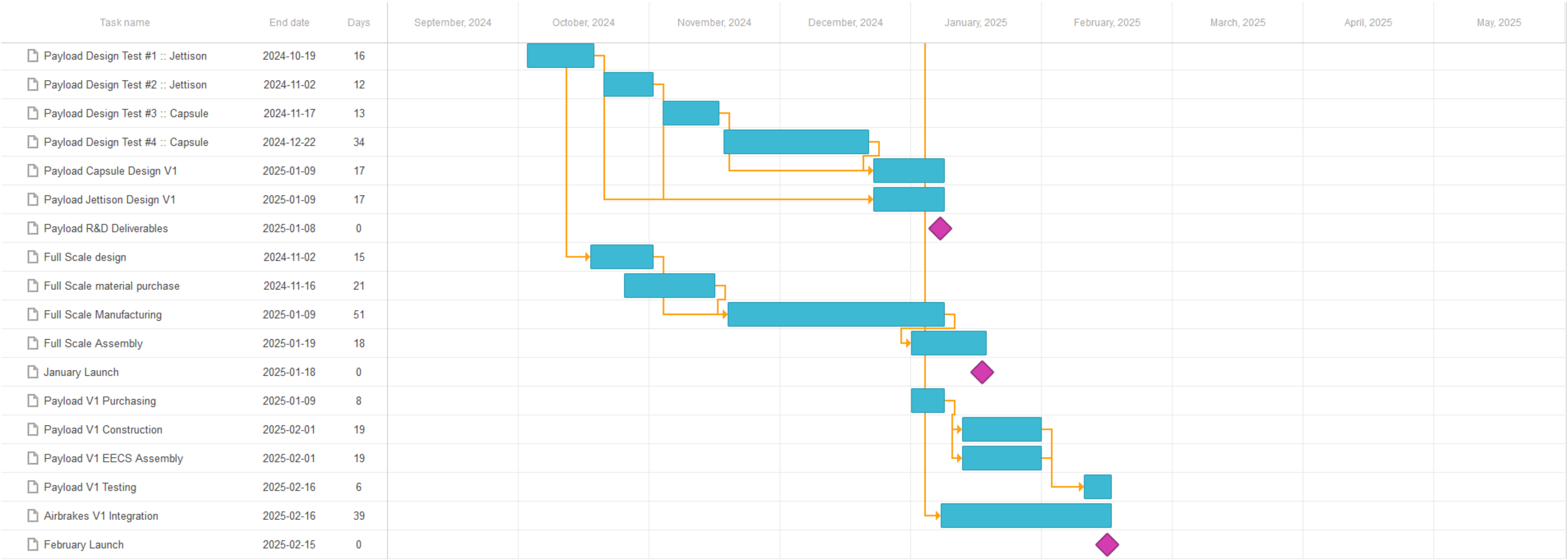

Figure 26: Gantt Chart detailing work, dependencies and milestones (PART 2)

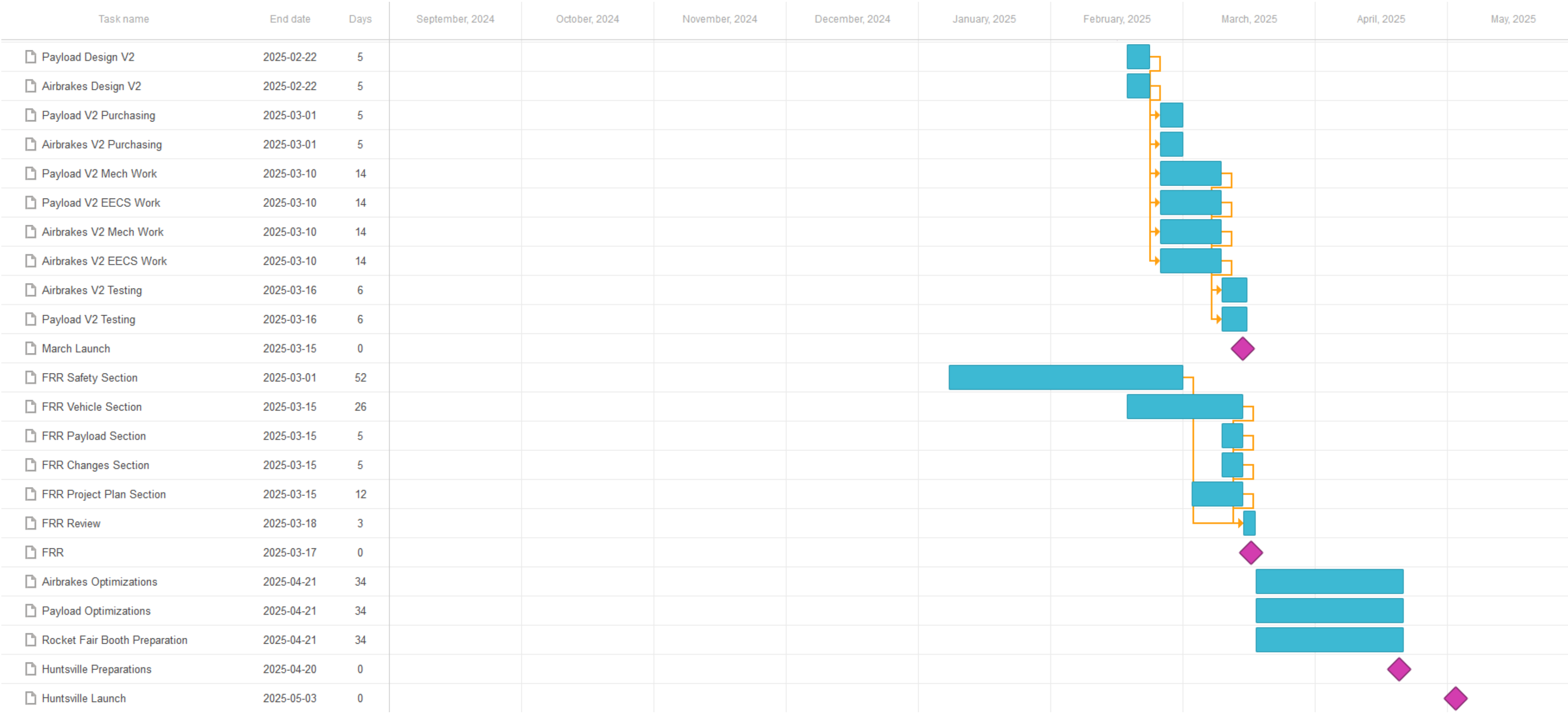

Figure 27: Gantt Chart detailing work, dependencies and milestones (PART 3)

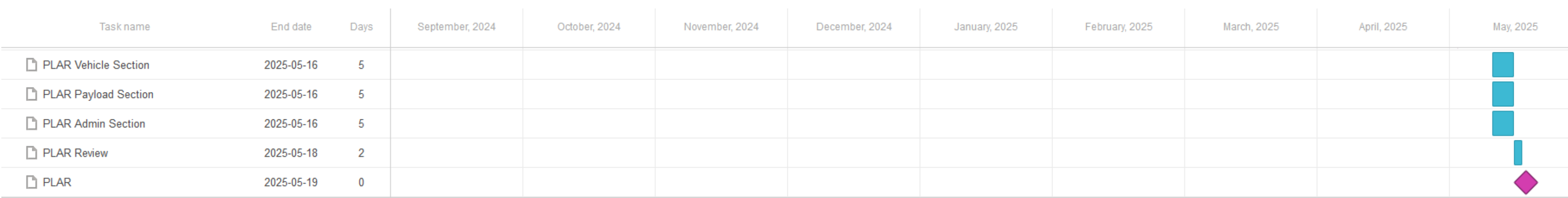

Figure 28: Gantt Chart detailing work, dependencies and milestones (PART 4)

6.2.1 Milestones

The following milestones correspond to the previous Gantt Chart, highlighted here for clarity. Some of the milestones are derived from the NASA Student Launch Handbook, others from the known schedule of the club's upcoming rocketry launches, and others are self imposed milestones such as the R&D deliverables; meant to keep work moving forward in the more independent type projects like the main Payload and the ABS (secondary payload).

- **Proposal** - Due by September 11, 2024
- **PDR** - Due by October 28, 2024
- **November Launch** - Due by November 16, 2024
- **CDR** - Due by January 08, 2025
- **Airbrakes R&D Deliverables** - Due by January 08, 2025
- **Payload R&D Deliverables** - Due by January 08, 2025
- **January Launch** - Due by January 18, 2025
- **February Launch** - Due by February 15, 2025
- **March Launch** - Due by March 15, 2025
- **FRR** - Due by March 17, 2025
- **Huntsville Preparations** - Due by April 20, 2025
- **Huntsville Launch** - Due by May 03, 2025
- **PLAR** - Due by May 19, 2025

6.3 Budget

SOAR has been allocated $17,325 by the Student Government at the University of South Florida for the 2024-2025 school year, with $8,000 specifically allocated to the NSL project. Of this amount, $3,000 is designated for the payload, consistent with prior expenditures in the NASA Student Launch challenge. An additional $4,000 is allocated for aerostructures and launch supplies to support the construction and preparation of the launch vehicle. $300 are allocated for general Consumable items. And $700 are allocated for specifically Telemetry equipment, since the club intends to develop custom devices to integrate with our current system. Additionally, repurposed materials, including leftover fiberglass tubing, microcontrollers, single board computers and other general electronics from previous projects, will be utilized for the NSL project. Travel expenses will be covered by a separate stipend provided by the Student Government.

Table 15: Budget Breakdown.

Category	Allocated Budget
Consumables	$300.00
Aerostructures & Recovery	$4,000.00
Payload Mech & EECS	$3,000.00
Telemetry	$700.00
Total	$8,000.00

References

[1] National Aeronautics and Space Administration, ”2025 NASA Student Launch Initiative Handbook and Request for Proposal,” 2024. [Online]. Available: https://www.nasa.gov/wp-content/uploads/2024/08/2025-nasa-sl-handbook.pdf?emrc=77b9f2?emrc=77b9f2 [Accessed: Sep. 10, 2024].

[2] National Association of Rocketry. ”High Power Rocket Safety Code.” 2018 [Online]. Available: https://www.nar.org/wp-content/uploads/2018/08/High-Power-Rocket-Safety-Code.pdf [Accessed: Sep. 10, 2024]