University of Massachusetts Lowell

Project: Peregrine Explorer

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Lowell, MA 01851

NASA USLI Flight Readiness Review

March 17th, 2025

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Acronyms

ACS = Altitude Control System

AGL = Above Ground Level

APCP = Ammonium Perchlorate Composite Propellant

ARCS = Avionics & Recovery Control System

CDR = Critical Design Review

CFR = Code of Federal Regulations

CG = Center of Gravity

CMASS = Central Massachusetts Spacemodeling Society

COTS = Commercial Off the Shelf

CP = Center of Pressure

DDIR = Dual Dissimilar Independent Redundancy

DOT = Department of Transportation

FAA = Federal Aviation Administration

FFF = Fused Filament Fabrication

FMEA = Failure Modes and Analysis

FN = Foreign National

FOV = Field of View

FRR = Flight Readiness Review

GPS = Global Positioning System

HPR = High Power Rocket

LCO = Launch Control Officer

LMS = Lawrence Lin Makerspace

LRR = Launch Readiness Review

MSDS = Material Safety Data Sheet

MSFC = Marshall Space Flight Center

MSL = Mean Sea Level

NAR = National Association of Rocketry

NFPA = National Fire Prevention Agency

PCB = Printed Circuit Board

PDF = Portable Document Format

PDR = Preliminary Design Review

PEP = Payload Electronics Package

PERR-C = Passive Electronic Recovery Reporter Capsule

PLAR = Post Launch Assessment Review

PPE = Personal Protective Equipment

PTT = Push To Talk

RF = Radio Frequency

RSO = Range Safety Officer

SL = Student Launch

SLA = Stereolithography

SME = Subject Matter Expert

SOW = Statement of Work

STEM = Science Technology Engineering & Math

TRA = Tripoli Rocket Association

TTS = Text to Speech

UML = University of Massachusetts Lowell

UMLRC = University of Massachusetts Lowell Rocketry Club

USLI = University Student Launch Initiative

VDF = Vehicle Demonstration Flight

1 Summary of Flight Readiness Review (FRR) Report

1.1 Team Summary

University of Massachusetts Lowell Rocketry, 220 Pawtucket st. Lowell, MA 01854
Final Launch Location: Huntsville, AL
Mentor: Howard Greenblatt NAR# 84058 – Level 2. Email: h.greenblatt@comcast.net. Phone: 617-797-1426
Hours spent on FRR: 3806

1.2 Vehicle Summary

Target Altitude	5000 ft AGL
Motor Selection	Cesaroni Pro54-5G K780 Blue Streak Aerotech RMS 54/2560 K1275 Redline (Backup)
Dimensions	Length: 84in Diameter: 4.02 in
Stability Information	From the Nose: CG – 47.29 in, CP – 60.335in. Stability: 3.24cal / 15.8%
Launch Vehicle Dry Mass	Without Ballast: 18.3 lbs With Ballast: 19.1 lbs
Launch Vehicle Wet Mass	Without Ballast: 22.26 lbs With Ballast: 23.1 lbs
Launch Vehicle Burnout Mass	Without Ballast: 19.75 lbs With Ballast: 20.58lbs
Launch Vehicle Landing Mass	PERR-C + Ballast = 3.65 lbs Upper Section = 3.79 lbs Lower Section = 10.42 lbs
Recovery System	Dual-Sep, Dual-Deploy. Telemetrum and Blue Raven Main: 72in. Drogue: 18in.
Rail Size	8ft - 1010

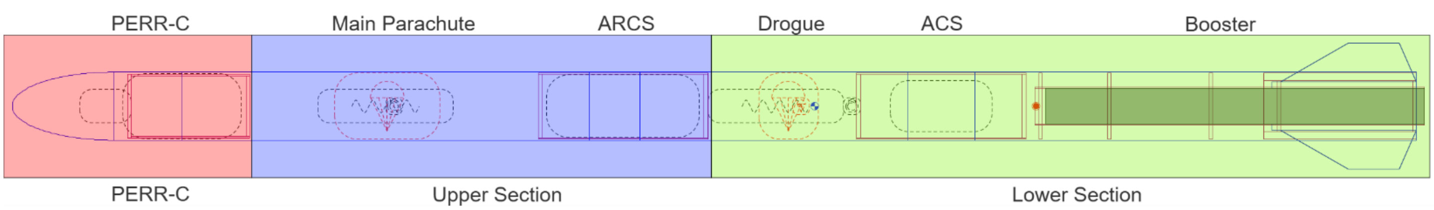


Figure 1.1.1: Diagram of Peregrine Explorer with bay names and independent section highlights

1.3 Payload Summary

UMLRC's 2024-2025 Payload experiment is divided into two systems, the Passive Electronic Recovery Reporting – Capsule (PERR-C) and the Altitude Control System (ACS). The nosecone of the vehicle will serve as the capsule's primary structural element. The system comprises of a custom sensor package and computer system PERR-C, fitted within the nosecone below the STEMNauts flight deck. Upon landing, the PERR-C system will transmit the data gathered by the custom sensor package via 2-M Radio back to NASA at the flight line.

The payload experiment tested the autonomous activation of the ACS subsystem, its aerodynamic effects, and the reliability of shared PEP/ACS code and sensors. To test the autonomous activation of ACS the system was given a time after launch to activate the airbrake, and a time after launch to retract the airbrake. The time allotment was 3.25 seconds after launch to deploy, and 7 seconds after launch to retract. This would give ample time to get coasting aerodynamic characteristics as well for the structures and simulation teams as motor burnout was expected at 1.8 seconds after launch. Additionally, it would give ample time to safely retract the airbrake for an apogee deployment of the parachutes. The reliability of PEP/ACs code and sensors was checked by recording data collected by the ACS system during all stages of flight, this also includes our 915 MHz ground station system.

2 Changes made since CDR

2.1 Changes Made to Vehicle Criteria

2.1.1 Vehicle Recovery System Changes

2.1.1.1 Avionics and Recovery System (ARCS) Arming Pin Redesign

The arming pin structure within ARCS underwent a redesign due to a structural error discovered while integrating ARCS into its flight-ready form. This change consisted of adding additional material to the limit switch mounting points on the 3D-Printed arming pin housing. This change was necessary to ensure the arming pin could handle the loading of all flight events. See Figure 3.2.1.4A for a visual of the updated arming pin assembly.

2.1.1.2 Avionics and Recovery System (ARCS) Junction Box Redesign

The junction box structure within ARCS underwent a redesign such that it could house additional screw switches for more external control of flight computer and on-board camera operations. This change consisted of adding two additional screw switches (a total of four screw switches) within the junction box. This change was necessary to allow the primary computer to be powered and armed separately (rather than auto-arming when power was provided to the computer), and to allow the on-board cameras to be toggled manually on the launch rail before flight. See Figure 3.1.5A for a visual of the new junction box arrangement.

2.1.1.3 Main Parachute Shock Cord Arrangement Redesign

After recovery of the vehicle during the Vehicle Demonstration Flight (VDF), it was noted that the main parachute shock cord was installed incorrectly, where the Main Parachute and Payload locations were swapped. This mistake caused two box stitches to fail, and caused the payload to slowly slide down the main parachute line and contact the main parachute bay during descent. This did not cause a recovery failure, all vehicle sections made a controlled descent and landing.

However, before the stitches ripped, the lack of a second line hanging from the main parachute eliminated any tangling that might have occurred, improved the visibility of the main parachute ejection event from the ground, and would have allowed for more speed reduction before the payload touched down (dropping its kinetic energy at landing). As such, it has been determined that this mistake was actually a superior main parachute shock cord arrangement, and once properly repaired, will be used on future flights for these reasons. See Figure 3.2.1.6A for a visual of this parachute arrangement.

2.1.2 Vehicle Structural Design Changes

2.1.2.1 Modular Fin System Design Changes

The mechanism of which the Modular Fin system was changed from the previous design that used an angled forward edge and an aft retained pin to hold the fin in place to a dovetail rail system. This removed a small protrusion from the aft of the fin which was identified as an area of high risk of damage under normal flight forces.

The internal bracket that the fins are mounted in has switched from glass fiber-filled Polycarbonate to Carbon Fiber-filled PLA. This was a necessary change as multiple printing issues were encountered when printing the fin mount with Polycarbonate relating to warping and bed adhesion.

2.1.2.2 Add-on Fiberglass layers on Fins

In response to slight damage suffered on the VDF, the fins will receive layers of fiberglass to reinforce the leading, trailing, and tip edges of the fin. This is described in detail in section 5.5.2.

2.2 Changes Made to Payload Criteria

2.2.1 Primary Payload Changes

2.2.1.1 PERR-C Mechanical Changes

Minor design changes have been made to PERR-C to accommodate for a multitude of problems. Holes were added to both control the screw switch of PEP and allow external air in for the barometers. The PEP sled was also condensed from a three-sided sled to a double-sided single panel sled to increase allowable mounting area.

2.2.2 Secondary Payload Changes

2.2.2.1 ACS Mechanical Changes

Efforts to reduce both the cost and the weight of the ACS has resulted in a redesigned flap linkage system.

2.2.2.2 ACS Electrical Changes

No major changes were made to ACS electrical design/components, but due to ordering delays, some sensors as well as the custom PCB were unable to be used on this flight but are still planned for use in future flights.

2.2.2.3 ACS Code Changes

No Code changes have been made, as the VDF flight is meant to demonstrate the physical capabilities of the ACS, with finished and tested control logic based on a design and search algorithm to control ACS deployment in future flights.

3 Vehicle Criteria

3.1 Design and Construction of Vehicle

3.1.1 Describe any changes in the launch vehicle design from CDR and explain why those changes are necessary.

The most major change on the launch vehicle was a change to the fin retention system. The design of the slotted fin inserted from the side of the vehicle, was changed to a dovetail that is inserted from the aft end of the vehicle. Further details are elaborated on in section 3.1.5.

3.1.2 Final Locations of Separation, Energetics, and Black Powder.

The locations of separation remain the same as outlined in the CDR. The main parachute separation point is located between the main parachute bay and PERR-C. The main parachute bay is fixed to the fore-side of ARCS using six-radially spaced #4-40 screws, and is designed to separate off the aft-side of PERR-C by shearing four, 45-lb shear pins. The drogue parachute separation point is located between the aft-side of ARCS and the drogue parachute bay. The drogue parachute bay is fixed to the fore-side of ACS using six-radially spaced #4-40 screws, and is designed to separate off the aft-side of ARCS by shearing four, 45-lb shear pins.

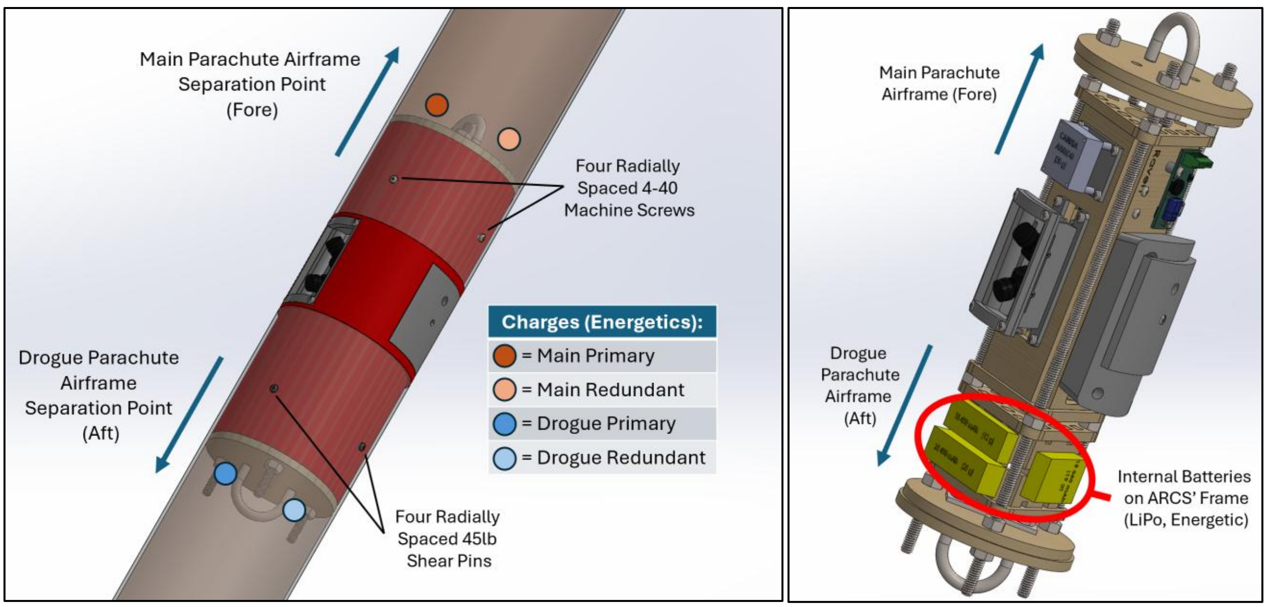


Figure 3.1.2A: Separation Locations and Locations of All Energetics.

The fore-side bulkhead of the Avionics and Recovery Control System (ARCS) houses 4 WAGO connectors used to connect the primary main, and the secondary main parachute ejection charges to their respective flight computers. The aft-side bulkhead of ARCS houses 4 more WAGO connectors used to connect the primary drogue, and secondary drogue ejection charges to their respective flight computers. In other words, the bulkheads are manufactured identically. The ejection charges consist of precisely measured quantities of black powder. As such, each ejection charges will be located close to their respective WAGO connectors, positioned orthogonal to the bulkhead plane to minimize the heat the WAGOS and recovery hardware are subjected to from detonation.

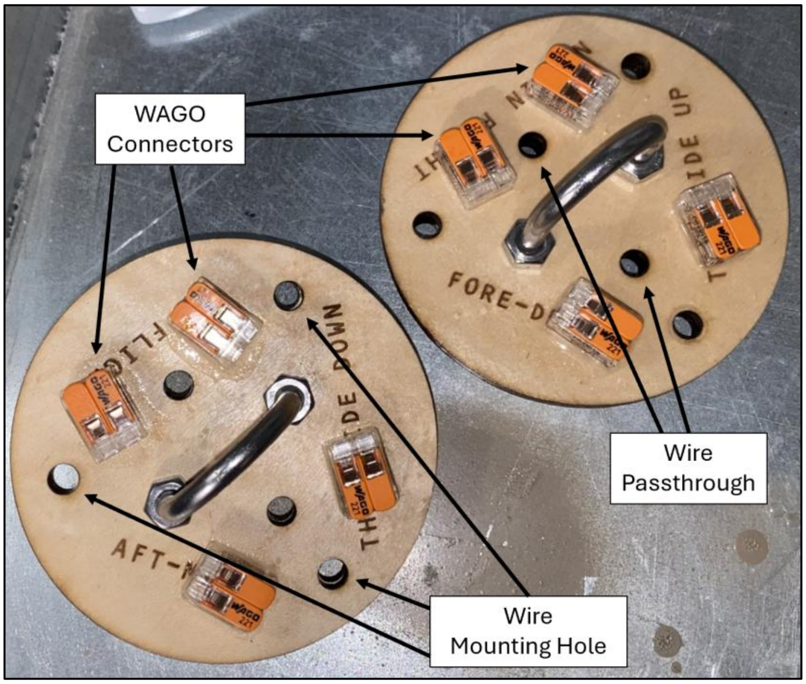


Figure 3.1.2B: ARCS Bulkheads with Ejection Charge WAGO Connectors.

3.1.3 Features Enabling Safe Launch and Safe Recovery

3.1.3.1 Description of Redundancy Features Enabling Safe Recovery

The rocket features several means of redundancy across its recovery system. First, the Avionics and Recovery Control System (ARCS) features two, top of the line commercial flight computers. An Altus Metrum Telemetrum V4 operates as the primary flight computer and fires parachute ejection charges on-time and in accordance to live flight events. Concurrently, a Featherweight Altimeters Blue Raven operates alongside its primary counterpart as the secondary flight computer. Blue Raven fires its Apogee charge with a +1.5 second delay, mitigating over-pressurization of the drogue parachute bay, and fires its main parachute charge 50-feet below Telemetrum V4, preventing a main parachute bay over-pressurization, too.

Blue Raven also sports additional software redundancy, namely in the form of a “panic” main parachute deploy if a maximum programmed drogue decent rate is exceeded. The programmed value is sent to the computer before flight, but does not change between flights; the “panic” descent rate is a characteristic of the vehicle’s geometry and expected recovery profile. The programmed “panic” descent rate was determined to be -175 ft/s, as this descent rate would only occur if the vehicle was returning ballistically under no drogue. Additionally, the vehicle would reach this descent rate rapidly in the event of a double drogue failure, reducing the load on the main parachute and maximizing the chances of a successful main parachute deployment and inflation.

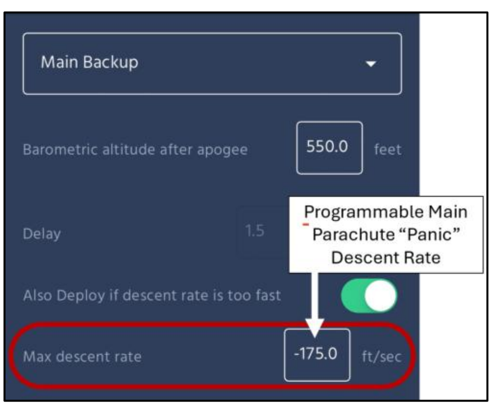


Figure 3.1.3.1A: Blue Raven Max Decent Rate (“Panic” Deploy) Programable UI.

The main and drogue parachutes are connected to their harnesses using bites made in the high-shock rated nylon strapping. All bites are secured together using two box stitches, providing redundancy as having two box stitches distributes all loading, and drops the peak loading each box stich will undergo. Additionally, all recovery hardware is made of galvanized steel, and is rated to significantly greater loads than those that are seen in flight.

3.1.4 Construction of Structural Elements (such as airframe, fins, bulkheads, attachment hardware, etc.)

For bulkhead information, see section 3.2.1.1, second paragraph AND section 3.2.1, second paragraph

3.1.5 Construction of Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.)

The electrical elements are critical to ensure the vehicle has a safe flight and a safe recovery. As such, all wires in all sections of the vehicle are twisted together and secured using heat shrink tubing. Additionally, all non-rigid electrical connections in the vehicle use vibration resistant XT30 connectors, minimizing the chance of an accidental vibration/shock-induced electrical disconnection.

In order to maintain modularity inside ARCS, the junction box features 4 screw switches used to arm different components of the system. From left to right, the switches are labelled "TA", "T", "R", and "C". "TA" stands for "Telemetrum Arm" and will toggle Telemtrum's local arming procedure a self-check on the board. "T" stands for "Telemetrum" which is used to toggle battery power to the board (which is NOT the same as toggling Telemtrum's local arming procedure and self-check). "R" stands for "Raven" and toggles battery power to the Blue Raven altimeter, which also arms the computer at the same time. Lastly, "C" stands for "cameras" and toggles battery power to the camera computers which will immediately start recording once power is detected. Each one of these systems is connected to its respective wiring harness via an XT-30 connector located behind the secondary flight computer sled.

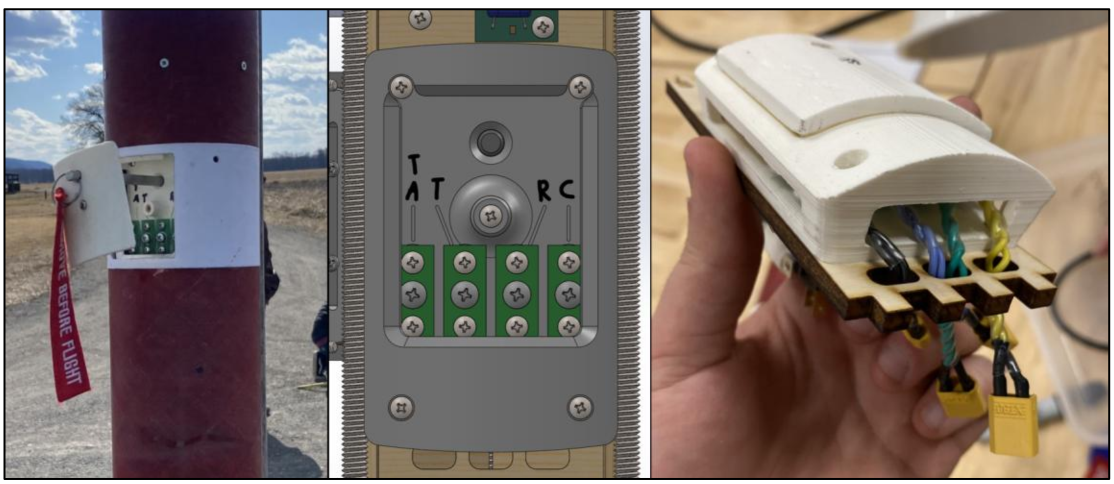


Figure 3.1.5A: Junction Box Screw Switches, Screw Switch Labelling, and Screw Switch XT-30 Connectors.

The 450 mAh LiPo batteries (1S and 2S) are retained using two zip ties each, oriented in a 45° configuration. The 950 mAh LiPo battery (1S) is secured to its sled using a vertical zip tie, and a zip tie oriented at 45° across the battery. These arrangements of zip ties keep the batteries rigidly fixed in place on their respective sleds. Electrical connections to all batteries are routed such that their connectors are only subjected to off-axis loading while in flight, mitigating the risk of an accidental battery disconnection.

Both the primary and secondary (Telemetrum V4 and Blue Raven, respectively) flight computers are secured to their respective sleds inside ARCS using galvanized steel 4-40 machine screws and steel square nuts. These screws hold the board to custom 3D-Printed PLA spacers (loaded axially with the layer lines of the 3D-Print) to ensure that there is a gap of at least 0.125-inches between the lowest point on the board and the surface of the plywood sled it is mounted to. This way, no structural interference can inhibit the thermal or electrical properties of either altimeter.

3.1.5 Include schematics of the AS-BUILT rocket; There is a good chance dimensions have changed slightly due to the construction process.

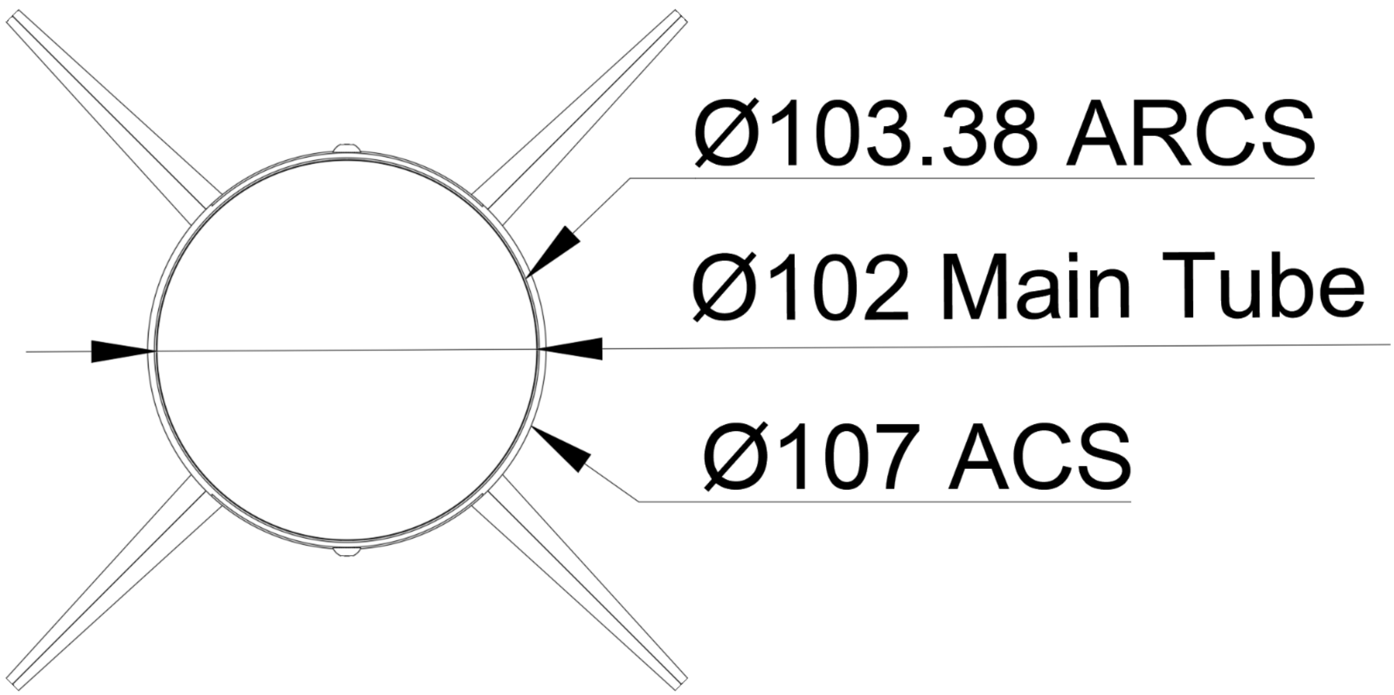


Figure 3.1.8A Rocket Module Diameters (mm)

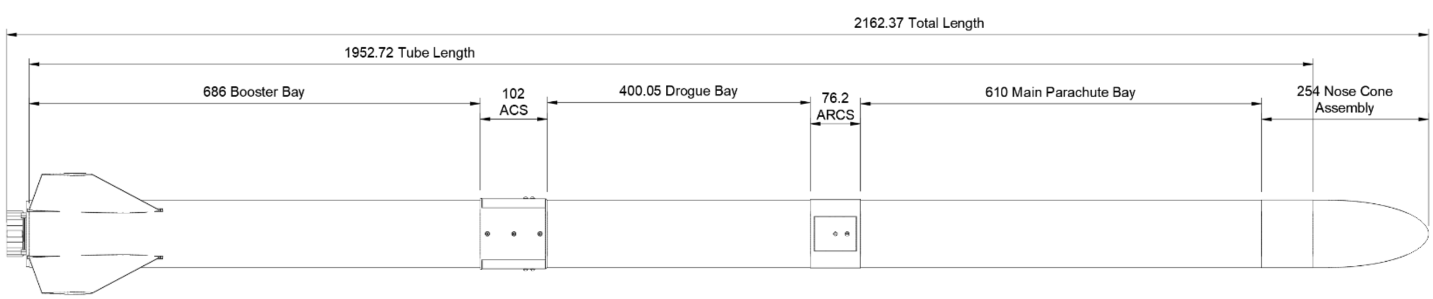


Figure 3.1.8B Full Rocket Dimensions (mm)

The fin mount changes include the removal of the original locking pin design that would engage with the retaining ring, Figure 3.1.8D. The solution for this in the updated design was a dovetail profile along the entire root chord of the fin so the fin would not pull out laterally Figure 3.1.8C. This dovetail design was flat at the bottom and required the retaining ring to press it up into the fin mount tube and prevent it from sliding out.

Updated Fin Mount

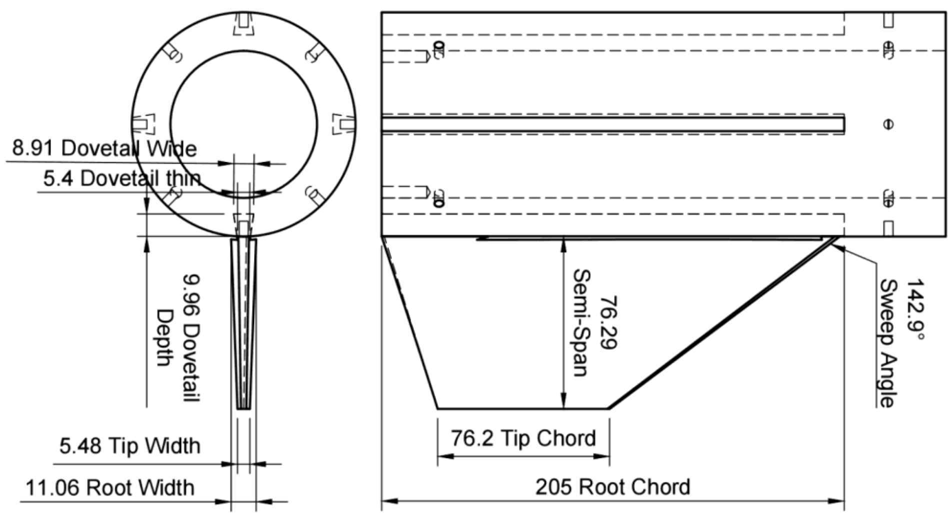


Figure 3.1.8C Updated Fin Mount Diagram (mm)

Original Fin Mount

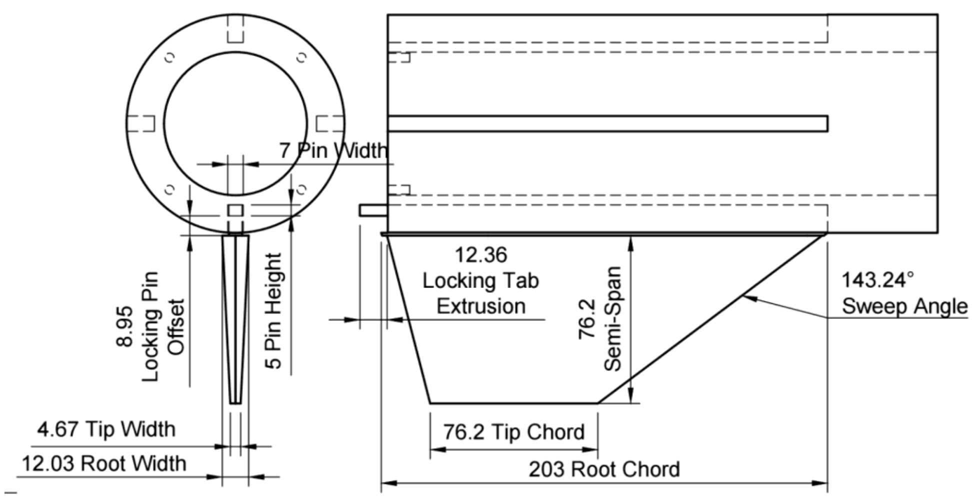


Figure 3.1.8D Original Fin Mount Diagram (mm)

3.2 Recovery Subsystem (ARCS & Parachutes)

3.2.1 Addressing Concerns of Primary Flight Computer Orientation

During the CDR teleconference, concerns were expressed about the “Antenna-Down” orientation of the flight computer on the inside of ARCS. It was stated that Telemetrum V4 (the primary flight computer) would not arm, meaning it would not enter PAD mode, in this downward orientation, which threatened both the safety of the vehicle during recovery, and the capability of ARCS. Additionally, if this concern was true, it would have spawned a significant redesign of the computer arrangement within ARCS. An investigation into this issue subsequently began.

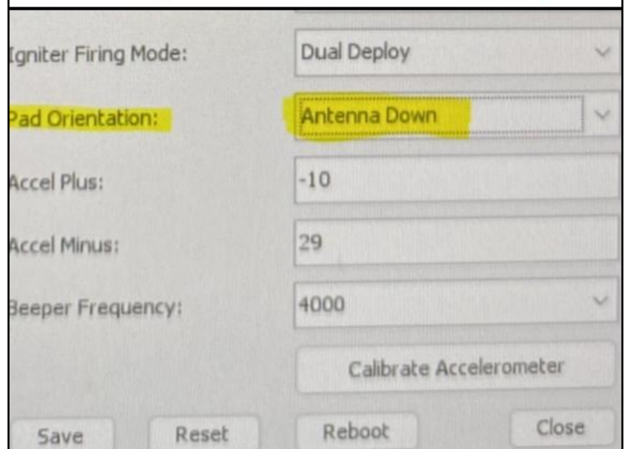
After reviewing the HTML and PDF manuals for Telemetrum V4, it became clear that the “Pad Orientation” could simply be toggled to “Antenna-Down” from its default “Antenna-Up” orientation setting. This orientation toggle can be done in the “Configure Altimeter” section of the Altus OS software. As such, the pad orientation was swapped into “Antenna Down” mode for the Telemetrum V4 that was installed on the ARCS flown on the VDF.

To test this, Telemetrum V4 was booted up in all other orientations except with the antenna facing downward. Unless the antenna was within about 15 degrees of perpendicularity with the ground when the antenna was facing down, the flight computer would enter IDLE mode. However, when the altimeter was oriented within the range considered “Antenna Down”, it would boot into PAD mode every time, signifying that it was awaiting motor ignition to begin recording and transmitting telemetry. In other words, the computer would arm when in the “antenna-down” orientation, operating as intended.

Furthermore, it was found that only Telemetrum V1 was unable to toggle its “Pad Orientation”, and was designed only to be installed in an “Antenna Up” orientation. Telemetrum V1 was last available for purchase in December 2010, about 15 years ago.

As ARCS uses a Telemetrum V4, this orientation issue was a simple fix, and required no physical layout changes to ARCS.

“Pad Orientation” Setting in the “Configure Altimeter” Tab on AltusOS:



NOTE: These settings are saved locally on the Telemetrum V4 computer after programming.

3.2.1 Robustness of the As-Built Recovery System

Peregrine Explorer’s recovery system consists of two main elements: The Avionics and Recovery Control System (ARCS) and the Parachute Layout. As such, each of these elements have been designed with the dynamics of flight in mind, and have been manufactured to uphold the accompanying robustness expectations. Descriptions of the robustness of each wholistic element are provided below, subsequently complemented by a more in-depth description and defense of each individual sub-element (such as bulkheads, wiring, connectors, redundancy features, etc.).

3.2.1.1 Robustness Description of the Avionics and Recovery System (ARCS)

The structure of ARCS is manufactured using laser cut 8mm thick pure bond plywood sheets, ¼-20, 316 stainless steel threaded rods, and 316 stainless steel hex nuts and nylon lock nuts. Additionally, the use of Loctite adhesives, 4-40 steel machine screws and square nuts are used to secure all flight computers, electronic components, and 3D-Printed components to their respective plywood frames. Two zip ties, arranged in an offset 90^{o} configuration across each battery, are used to secure the batteries onto their respective sleds, restricting motion in all degrees of freedom in high-G scenarios.

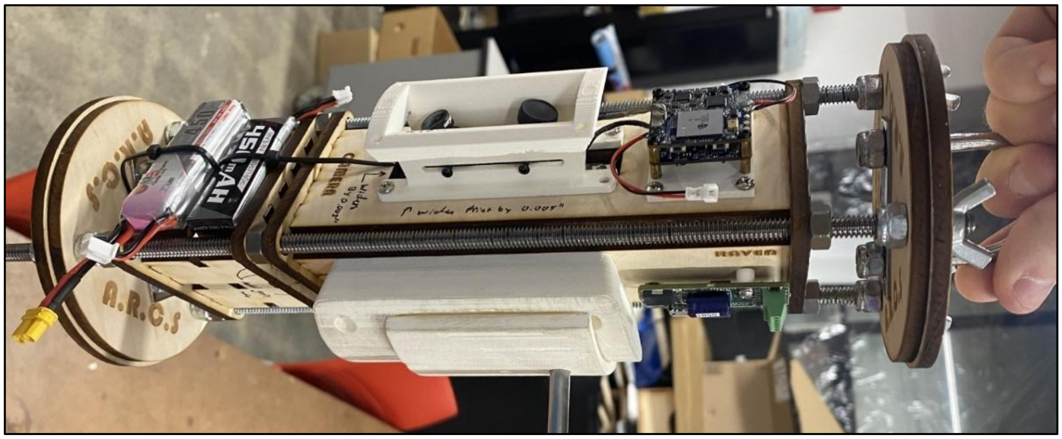


Figure 3.2.1.1A: Late Prototype of ARCS Demonstrating its High Strength Structure.

The bulkheads use an 8mm pure bond plywood and epoxy composite, alongside all 316 stainless steel parachute mounting hardware, providing enough rigidity to handle all recovery events and flight fatigue. Four WAGO connectors are used on each bulkhead to connect the ejection charge wires to the internal flight computers. The wire passthroughs on the bulkheads are ¼-inch diameter and are filled with high-temp extruded hot glue on both the inner and outer sides of the bulkheads. See Figure 3.2.1B for a visual of the bulkheads with their attached WAGO connectors.

As for ARCS's internal wiring, all wire pairs are twisted together and secured together using heat shrink tubing. These twisted pairs are critical to combat any electromagnetic effects the flight computers may cause. As several twisted pairs pass through the center of ARCS, they are zip tied to each other to form four major "arteries" down the center of the ARCS. These arteries are snuggly fitted around the internal arming pin assembly and the inner plywood walls, sufficiently limiting their motion in high-G scenarios. Additionally, several vibration resistant XT-30 connectors are used throughout the bay, allowing for both easy serviceability and efficient cable management inside ARCS.

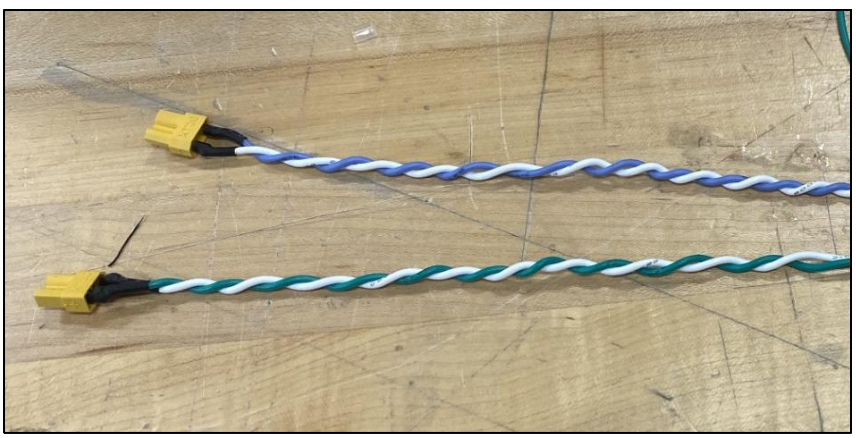


Figure 3.2.1.1A: Example of Twisted Wire Pairs and XT-30 Connectors.

3.2.1.2 Robustness Description of the Parachute Arrangement

The parachute arrangement consists of high visibility ½-inch nylon strapping, complemented by galvanized steel quick links. These quick links are characterized as mounting hardware, and will be exposed to both corrosive ejection charge gases and high heat during flight. Additionally, a set of two box stitches in series were sewn into the shock cord to form a bite, on which the payload/nosecone is secured.

The main parachute is 72-inches in diameter with an 18-inch diameter vent in the center. It is manufactured by FruityChutes, and provides the vehicle with a safe descent velocity of about 20 ft/s when it's fully deployed. It is made out of red and white ripstop nylon, which is arranged in a very visible alternating pattern when the chute is deployed. It is secured to a bite in the main parachute shock cord using a galvanized steel quick link.

The drogue parachute is 18-inches in diameter, and is also manufactured by FruityChutes. It is made of ripstop nylon, and sports the same red and white, easily visible pattern as the main parachute. It provides the vehicle with a safe descent velocity of about 72 ft/s when fully deployed. The vehicle drag also contributes to this controlled descent rate. It is secured to the drogue parachute shock cord using a galvanized steel quick link.

3.2.1.3 Robustness Defense of Structural Elements

Structural elements include the bulkheads, shock cord, parachute attachment hardware, parachute anchoring hardware, altimeter/flight computer mounting hardware, and avionics interior structural hardware.

The aforementioned bulkhead uses a plywood-epoxy composite to increase rigidity and strength under the loading conditions seen during recovery. This type of bulkhead layout has flown in past 4-inch diameter vehicles produced by UMLRC, which experienced similar flight/recovery conditions. As such, utilizing them in this application mitigates the risk inherited by exploring a new method, therefore making them robust enough for flight.

The shock cord, parachute attachment hardware, and parachute anchoring hardware are all made out of materials suited for loading much higher than what will be experienced with the recovery dynamics seen on Peregrine Explorer. The nylon strapping is ½-inch, and made from a high-visibility orange material. Bites for flight hardware are secured using two box stitches on a sewing machine, providing a firm connection that distributes the loading through both box stitches. The recovery hardware uses U-Bolts and quick links that are rated to 800-lb loads, granting a large factor of safety against their expected loading. Overall, the shock cord, parachute attachment hardware, and parachute anchoring hardware are suited for flight on this vehicle, and are robust enough to handle the expected loading during recovery.

The altimeter mounting hardware utilizes 3D-Printed spacers and 4-40 machine screws and square nuts to secure the flight computers to the bay. Having extensive use as altimeter mounting hardware in prior flights, this method has proven its robustness. For more information on the capability and justification of use for the altimeter mounting hardware, read section 3.1.5.

The interior structure of ARCS uses three, high-strength steel threaded rods, high-strength steel hex nuts, and galvanized steel nylon lock nuts to firmly house the 8mm pure bond plywood inner structure. As ARCS is located above the CG of the vehicle, it plays a role in supporting the passive stability of he vehicle. As such, utilizing three threaded rods provides both a structural and stability benefit. The loads seen from recovery events, combined with the robustness of the bulkheads on both sides of ARCS, the structural capability of ARCS provides a monumental factor of safety over expected flight loads. Providing a rigid housing for the altimeters and on-board cameras is paramount to the quality of the data collected by the flight. As such, the internal structure of ARCS proves its robustness, and is considered suitable for flight on Peregrine Explorer.

3.2.1.4 Robustness Defense of Electrical Elements

Electronic elements include the altimeters/computers, screw switches, electrical connectors, arming pin assembly, and internal wiring.

The altimeters/flight computer configuration sports a Telemetrum V4 as the primary computer, and a Blue Raven as the secondary computer. Both of these computer brands and models have flight history with UMLRC, including use on a Supersonic-Capable vehicle. In all past flights, the avionics have performed flawlessly, which is an important consideration when addressing risk in the system. Additionally, both computers are considered high-quality in the industry, and boast a suite of capabilities conducive to redundancy, safety, and ease of use.

The screw switches used in ARCS also have expensive flight history. Here, too, no issues have been observed in any past flights. The 6-32 Screw Switches from Missile Works have proven to be a reliable and effective means of initiating flight computers and sustaining power through the dynamics of flight.

XT-30 connectors are used throughout ARCS to connect screw switches, wiring harnesses, and batteries together. These connectors were chosen for their advertised vibration resistance, small form factor, and successful implementation on past UMLRC flights. Additionally, these connectors are trusted for other high-G, high-vibration applications like FPV Drones and High-Performance RC Cars. For these reasons, XT-30 connectors are deemed robust enough for use in flight.

The arming pin assembly is a custom assembly integrated into ARCS. Its purpose it to physically disconnect the ejection charges from their respective computers when handling the vehicle after the integration of ejection charges. The structure of the arming pin consists of two limit switches, positioned in-line with the flight axis, with a location for a ½-20 pin to depress the switch levers. As such, when the pin is inserted, the switches are depressed, and the electrical connection to the ejection charges is broken.

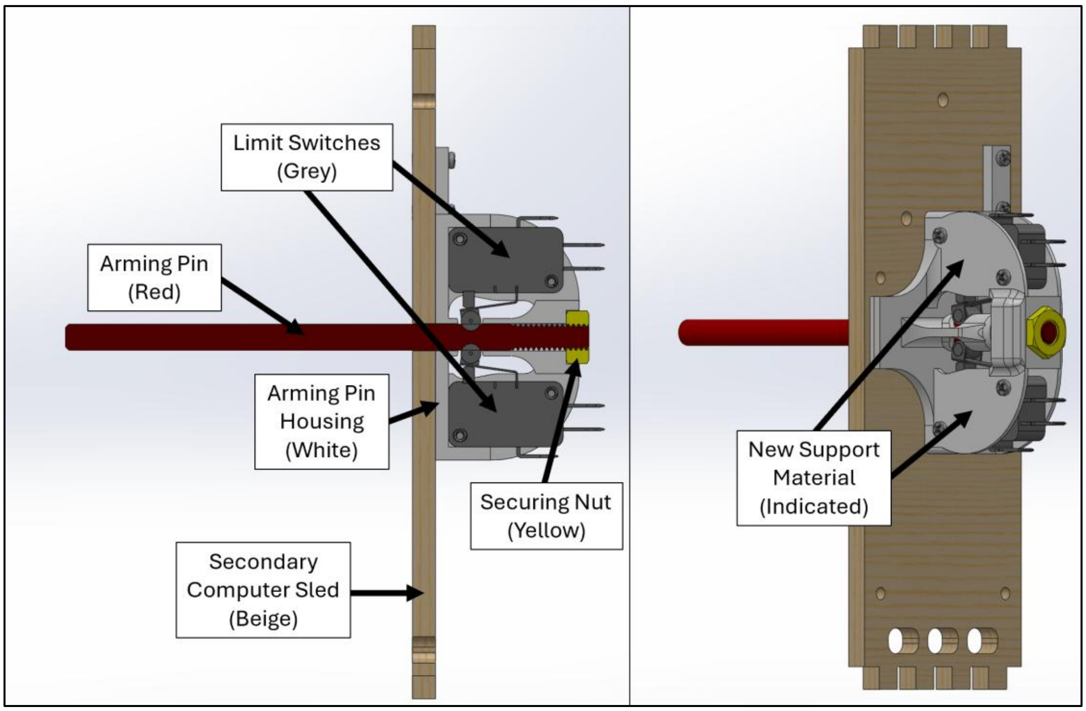


Figure 3.2.1.4A: Arming Pin Assembly Breakdown

The structure of the arming pin results in momentary disconnection of parachute continuity to the secondary flight computer (Blue Raven) due to the high-G loading at liftoff. This issue proved to not pose any risk to the ability for the computer to fire its ejection charges, as testing was conducted using Blue Raven's integrated flight simulator tool. Momentary continuity loss was simulated manually by depressing the switch during what would be the entire 2-second motor burn. The test resulted in Blue Raven sending current to its ejection charges on-time, despite losing continuity for a moment. As such, the robustness of the arming pin assembly's electronics was validated for flight.

Additionally, the arming pin assembly is mounted to the Secondary Computer Sled inside ARCS using both high-strength Loctite adhesive and two physical mounting points. Here, a large surface area of the 3D-Printed arming pin assembly contacts the back of the sled, and is subsequently held in place by two 4-40 machine screws. Several drop tests were conducted to explore the shock-resistant capabilities of the arming pin assembly's adhesive mounting, and all tests resulted in no separation of the two parts. The 4-40 machine screws were added as a means of redundantly securing the assembly to its respective sled.

All internal wiring is twisted together to mitigate any electromagnetic effects. In addition, longer sections of wires are held in their twisted form using heat shrink tubing intermittently placed throughout its length. This method has been used in prior UMLRC avionics systems, and has never resulted in a failure due to electromagnetic effects. As this option is cheap, lightweight, and has flight history, it was deemed robust and ready

3.2.1.5 Robustness Defense of Redundancy Features

Redundancy features include the use of two flight computers, the arming pin, and the redundancy software integrated into Blue Raven (the secondary computer).

The two flight computers on ARCS provide the vehicle with a redundant means of recovery: If one computer fails to light its ejection charges, the other computer is able to operate independently and recover the vehicle. As such, each computer has its own, physically separate wiring harnesses and ejection charge connectors, the only similarity between the two systems being that they both operate inside the ARCS bay. Additionally, every UMLRC flight that uses electronic deployment (as opposed to motor based ejection) has utilized two flight computers to provide redundancy to its recovery events. Overall, the use of two flight computers on-board is considered a robust, proven means of ensuring the parachutes eject on time and the vehicle is safely recovered.

The arming pin assembly provides a means to physically "safe" the vehicle when energetics are present. This feature has provided the team with a simple, integrated way to ensure the vehicle remains safe to handle upon landing, as both of the main ejection charges are not visible unless the main parachute bay is disassembled from the fore-side of ARCS. In addition, the arming pin provides the ability to mark a specific moment in time where all ejection charges ought to display continuity across both altimeters. This capability unlocks the ability to control the communication of ejection charge continuity when the vehicle is fully integrated on the pad, acting as a secondary verification that the telemetry link is displaying proper data about the current state of the vehicle, and is not displaying delayed data. Having clear communication pre-flight, and ensuring all ejection charges have continuity at the same time is critical for ARCS to provide a GO for flight status before launch. As a redundancy feature, the arming pin offers benefits both in safety and in pre-flight communication which makes it robust enough for flight in the eyes of the team.

Blue Raven's software provides the ability to program a maximum expected descent rate under the drogue parachute, which if exceeded, will cause Blue Raven to eject the main parachute early to "save" the vehicle from a entering an uncontrolled ballistic trajectory from apogee. The robustness of this redundancy feature is supported mainly by the quality of the altimeter itself. Blue Raven is able to compare incoming data from several sensors to support the descsitions it makes in real-time. As such, this means of redundant vehicle safety is no different; several sensors are used to justify that the descent rate has actually exceeded its programmed value before current is delivered to its main parachute charge. During the team's subscale flight, there was a miscommunication that resulted in Blue Raven exceeding its programmed descent rate under drogue, causing the main parachute to fire. As such, this redundancy feature (whether intentional or not) has been validated, and therefore proves the robustness of this redundancy feature for flight.

3.2.1.6 Robustness Defense of As-Built Parachute Sizes And Descent Rates

The main parachute is a 72-inch, ripstop nylon chute from Fruity Chutes. The same exact parachute has flown several times on other UMLRC launches of similar caliber (L2 High power, 4-inch diameter). The main parachute is programmed to deploy at 600-ft AGL on Telemetrum, and redundantly at 550-ft AGL on Blue Raven. The main parachute takes about 50-ft to deploy, and once fully opened and inflated, provides a nominal descent rate of 21.5-ft/s. This descent rate allows for the vehicle to remain below the kinetic energy limit at landing. Because of its past flight history, resilience, easily visible patterning, and availability, the main parachute is considered robust for flight.

Figure 3.2.1.6A: VDF Parachute Arrangement

The drogue parachute is an 18-inch, ripstop nylon chute from Fruity Chutes. The same exact parachute has flown several times on other UMLRC launches of similar caliber (L2 High Power, 4-inch diameter). The drogue parachute takes about 35 feet to deploy, and once opened and inflated, supports the vehicle in achieving an average nominal descent rate of 72.4-ft/s (which also includes the speed reduction from vehicle tumbling). This descent rate grants the vehicle with a rapid controlled descent before the main parachute deploys. And so, because of the parachute's past flight history, resilience, easily visible patterning, and availability, this drogue parachute is considered robust for flight.

3.2.1.7 Robustness of Rocket-Locating Transmitters

The Telemetrum V4 is the only rocket-locating transmitter on-board the vehicle. It utilizes an integrated 70cm HAM radio transmitter to provide live telemetry to an operator on the ground during flight/on the pad. When transmitting, Telemetrum V4 speaks to a TeleBT on the ground over 435.050 MHz (Channel 5) HAM frequency, using an integrated ¼-whip antenna. This antenna remains vertical when fully integrated inside ARCS, and is advertised to have an 8-mile effective range in ideal conditions. The TeleBT receives data packets from Telemetrum V4's HAM signal and displays them on the Altus OS software for the ground station operator to view.

Telemetrum locates the position of the rocket using its integrated GPS chip. GPS lock is acquired once at least 10 satellites are in solution, which usually takes about 3 minutes after power is provided to the computer, not necessarily after the computer is armed.

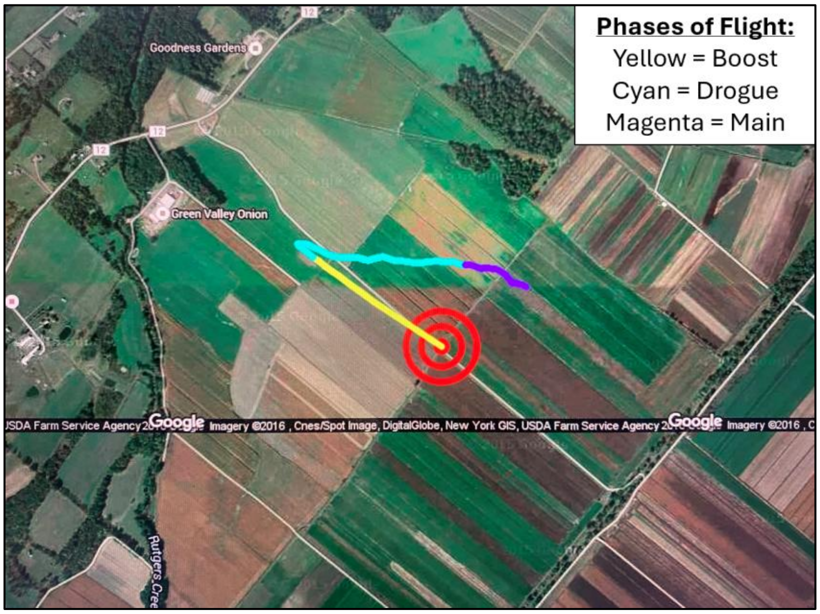


Figure 3.2.1.7A: Path of flight based on Telemetrum V4's GPS data.

Telemetrum provides longitude and latitude information every time a packet is sent to the ground station (which in flight and on the pad, occurs every second). As the vehicle approaches the ground, the computer automatically sends several additional GPS coordinates to the ground station, so there is a higher chance of the vehicle's position being acquired once the proximity to the ground introduces interference/LOS.

3.2.2 Recovery System Sensitivity to On-Board Devices that Generate Electromagnetic Fields.

During operation, most devices produce some sort of electromagnetic field which could alter the behavior of surrounding instrumentation/sensors/computers. As such, much thought has been given to minimizing the magnitude of any/all electromagnetic fields where possible within ARCS/the recovery system.

To minimize the magnitude of these electromagnetic fields, all wires (whether they carry large currents or not) are twisted together with their accompanying wire of opposite polarity. Doing so causes the currents flowing though the wire to produce inverse electromagnetic fields that effectively cancel each other out.

Additionally, as Telemetrum V4 is the only transmitter on-board, it was given an entire sled of the avionics bay to effectively direct all transmissions away from the rest of the bay and outwards through the coupler tube. Telemetrum operates on a wattage suitable for 70cm HAM transmissions that emanate outward from its integrated antenna. As such, Telemetrum has been oriented with its antenna facing downward, while Blue Raven and the bulk of the Avionics wiring are located on the top-side of ARCS. And so, the electromagnetic field that is generated is centralized at the bottom of ARCS, which is the farthest it physically can be from any/all potentially sensitive componentry.

Overall, ARCS has shown high resistance to the generation of electromagnetic fields caused by its own internals. However, larger electromagnetic disturbances produced by devices outside of ARCS could still have an effect on the function of the flight computers and energetics. Although it is important to note that an electromagnetic event large enough to cause any disturbances to the components within ARCS would be well documented by the launch officers hosting all potential high power launches, granting the team awareness of the risks associated with launching in those conditions.

3.3 Mission Performance Predictions

3.3.1 Flight Profile Simulations

Flight simulations to calculate the flight profile were performed in OpenRcoket and RASAero II. In OpenRocket and RASAero II, all flight simulations assumed a launch from sea level, and a 5-degree launch angle off of an 8 foot launch rail, the minimum launch angle set by NASA, as well as a wind speed of 0 MPH. The simulation gathered data for the rocket's altitude, vertical velocity, and vertical acceleration using the Ceseroni K780 motor. The total weight of the rocket (including motor) used for the simulation was 12.8 pounds.

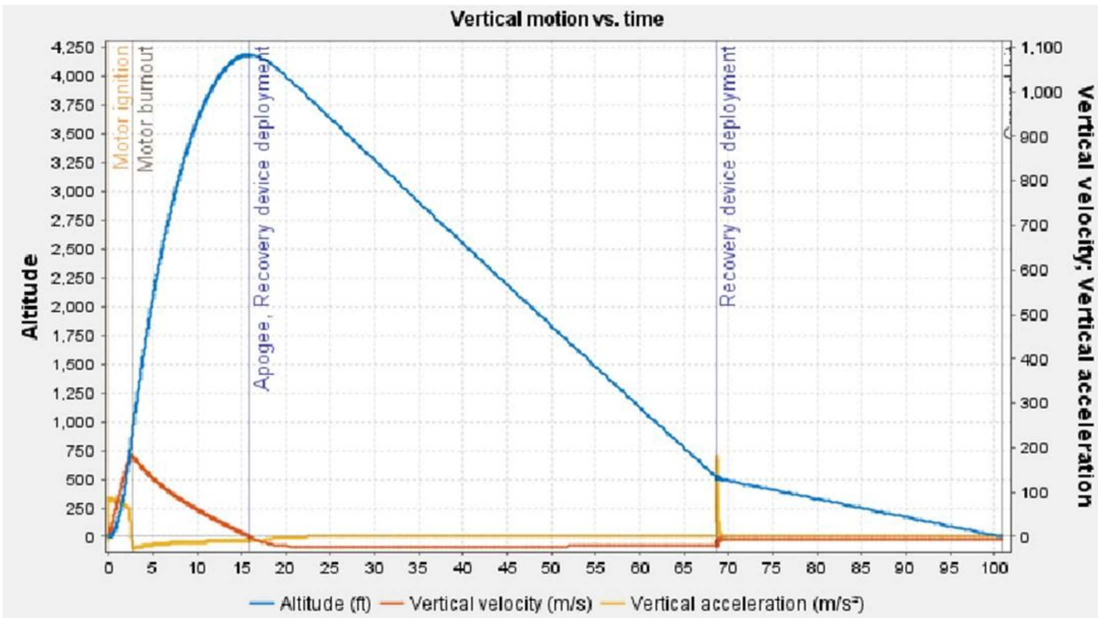


Figure 3.3.1.1: OpenRocket flight provile simulation for CTI K780 motor with altitude, vertical velocity, and vertical acceleration versus time

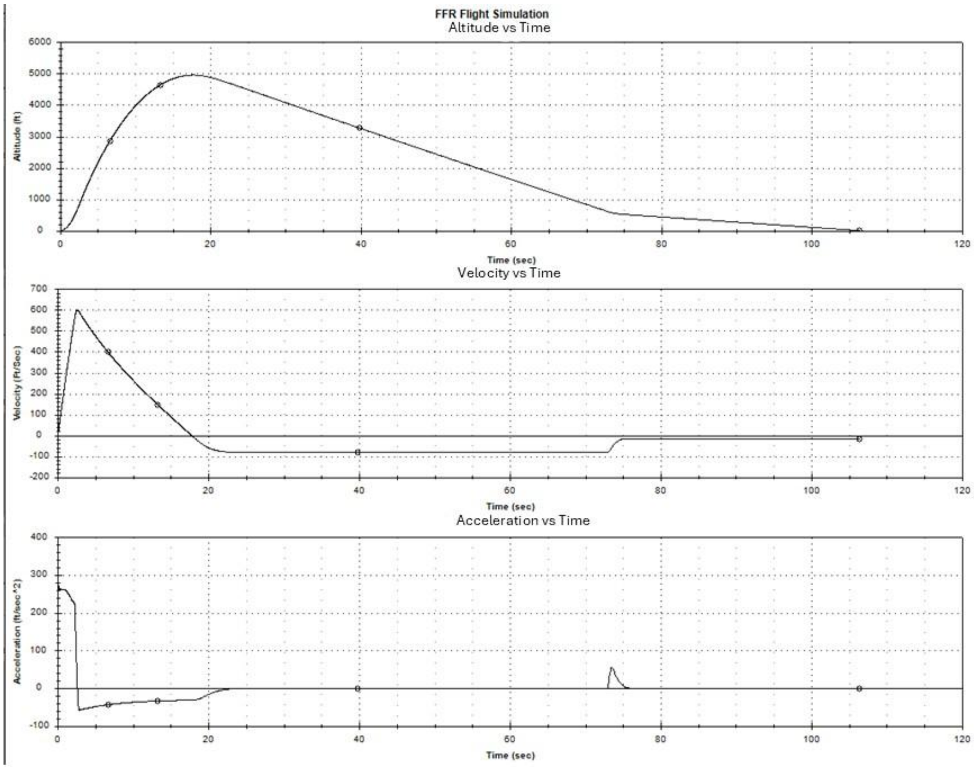
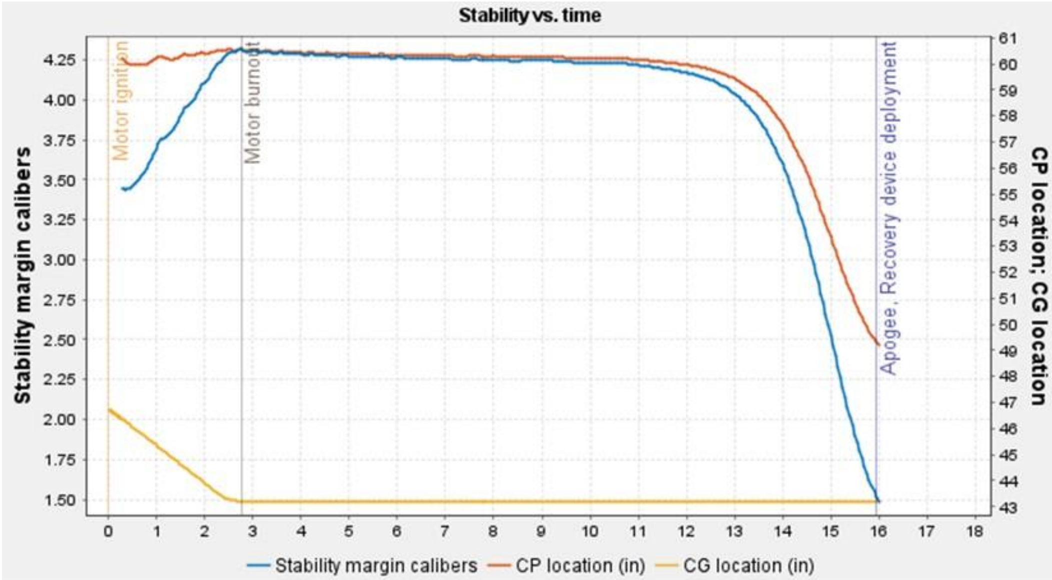


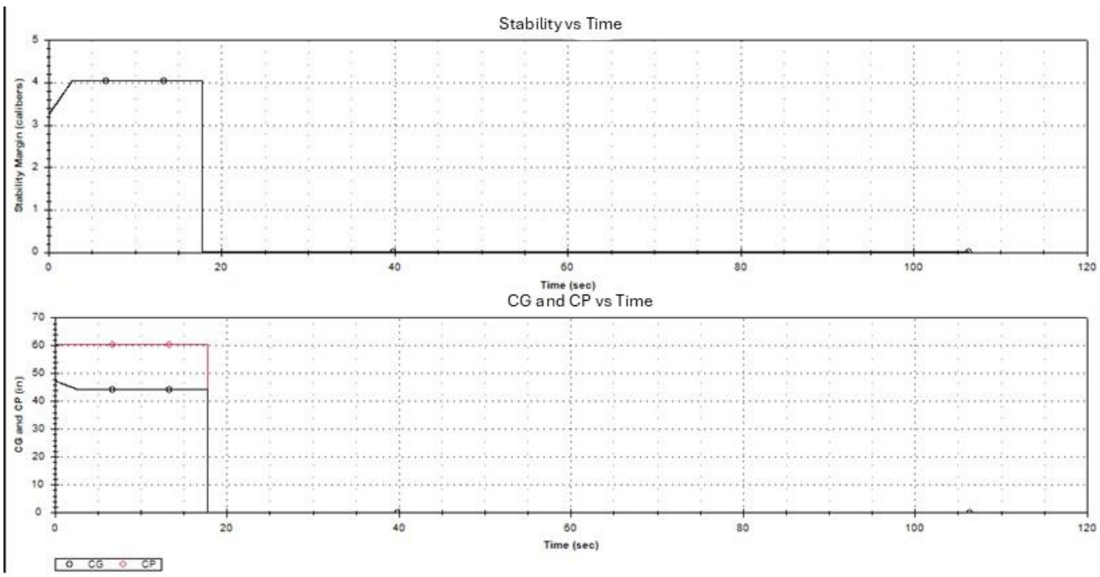
Figure 3.3.1.2: RASAero II flight provile simulation for CTI K780 motor with altitude, vertical velocity, and vertical acceleration versus time

Using the Ceseroni K780 motor in OpenRocket, the apogee was 4187 ft (1276 m), the maximum velocity was 600 ft/s (183 m/s), and the maximum acceleration was 291 ft/s^2 (89 m/s^2). Using RASAero II, the apogee was 4953 ft (1510 m), the maximum velocity was 604 ft/s (184 m/s), and the maximum acceleration was 287 ft/s^2 (87 m/s^2). While the data gathered using the two different software were similar, the RASAero II simulation data was observed to have a higher altitude than the OpenRocket simulation. The difference is likely due to how OpenRocket handles transonic flight calculations compared to RASAero II, the differences in how each software is set up and how they calculate data, as well as the capabilities of each program.

3.3.2 Stability Margin, Center of Gravity, and Center of Pressure



3.3.2.1: OpenRocket stability margin, center of pressure location, and center of gravity location over time



3.3.2.2: RASAero II stability margin, center of pressure location, and center of gravity location over time

On the pad with no ballast, the vehicle has a static stability of 3.4 calibers, and at rail exit has a stability of 4.25 calibers. The center of gravity is located 46.7 inches from the tip of the nosecone, which is in the drogue parachute bay. The center of pressure is located 60.3 inches from the tip of the nosecone, which is just above the motor tube.

3.3.3 Kinetic Energy at Landing

A ground hit velocity of 15.7 ft/s (4.8 m/s) is assumed for the following calculations, which was taken from the descent speed at a 5-degree launch angle with no wind. All components are assumed to be tethered together at ground impact. The mass of each component was simulated using OpenRocket. After all deployments, the launch vehicle will be in 3 sections. From fore to aft, the masses of each section, including parachutes, are: PERR-C at 3.2 lbm, Upper-Section (Main Chute bay, ARCS) at 7 lbm, and Lower-Section (drogue chute bay, ACS, Motor Mount, Spent Motor) at 7.8 lbm with the K780 motor. With the worst-case scenario ground hit velocity, at ground hit, these segments will have kinetic energies of 12.3 lbf*ft, 26.8 lbf*ft, and 29.9 lbf*ft, respectively.

3.3.4 Expected Descent Time

All components of the rocket are assumed to be tethered together for the following calculations. The expected descent time was calculated using OpenRocket and RASAero II. Using OpenRocket, the time to apogee was 15.9 seconds, and the flight time was 101 seconds, resulting in a descent time of 85.1 seconds. Using RASAero II, the time to apogee was 17.5 seconds and the total flight time was 106.3 seconds, resulting in a descent time of 88.8 seconds.

3.3.5 Drift Calculations

Wind Speed (Miles per Hour)	Drift Distance (Feet)
0 MPH	0 ft
5 MPH	624.1 ft
10 MPH	1248.1 ft
15 MPH	1872.2 ft
20 MPH	2496.3 ft

Table 3.3.5.1: Drift calculations based on OpenRocket descent times

Wind Speed (Miles per Hour)	Drift Distance (Feet)
0 MPH	0 ft
5 MPH	651.2 ft
10 MPH	1302.4 ft
15 MPH	1953.6 ft
20 MPH	2604.8 ft

Table 3.3.5.2: Drift calculations based on RASAero II descent times

Drift calculations were completed by hand using data from OpenRocket and RASAero II. All components of the rocket are assumed to be tethered together for the calculations. The calculations were done under the assumption that apogee is reached directly above the launch site, and a constant wind speed is applied to the rocket. The calculations were completed by finding the product of the descent time, measured by taking the time apogee is reached to when the rocket touches the ground, and the wind speeds at different points during descent. The differences in descent times are likely a result of the discrepancy in maximum altitude determined by each program, as discussed above.

4 Payload Criteria

4.1 Changes Since CDR

4.1.1 PERR-C Changes

There have been no changes made to the upper flight deck section of PERR-C or the upper nosecone section. The only change made to the PERR-C structural section itself is the modification of the alignment rails within the payload bay to accommodate a modified PEP sled design, and the addition of a through hole for adjusting the screw switch which controls the power status of PEP, as well as allowing external air into the payload bay to increase the accuracy of the PEP barometer. The existing material choices for the nosecone and bulkhead have not changed, nor have the manufacturing or assembly methods.

4.1.2 PEP changes

No changes have been made to the PEP aboard PERR-C as most of the man hours for the VDF flight were spent on the ACS PEP due to it being a slightly more complicated system and needing to pass this flight as it affects the energetics of the rocket.

4.1.2.1 PEP Mechanical changes for PERR-C

The PEP sled has been modified to accommodate the shift in design need from more component mounting surface area to the need for space to mount larger components within the payload bay. This means that the flight sled has been drastically simplified from a tri-panel folding design down to a single double-sided flight sled with wooden bulkheads sandwiching the plastic sled. Two threaded rods are used to hold the package together, and a singular central threaded rod runs through the center of the entire payload bay to hold PEP's vertical position inside. In addition, the battery holder on the flight sled has been modified with thicker walls and modified zip-tie through hole positions to better secure the battery onto the bay. In addition, the mounting holes on the flight sled have been finalized to accommodate the final PCB design. Additionally, the 2m radio has transitioned from a barebones mounting process, which included disassembling the radio down to the bare PCB, to a fully assembled system where the radio is mounted to the PEP sled fully assembled inside of its plastic housing. This increased volume requirement for the 2m radio was the primary driving factor necessitating the design shift towards the simplified PEP sled.

4.1.2.2 ACS Mechanical Changes

The mechanical system was updated with a redesigned flap linkage mount. This new design incorporates a machined aluminum insert housed within a 3D-printed structure that attaches to the coupler, ultimately reducing the metal content in the bay and lowering both its weight and cost.

4.1.3 ACS Electrical Changes

There have been no changes made to ACS' electrical system in the long term. For this flight the flown configuration was different from the final intended configuration due to ordering, construction, and space considerations. The PA1010D GPS and ADXL375 high-G accelerometer were not included in the currently flown configuration. PCB design was finalized before this flight but due to ordering delays from JLCPCB in Hong Kong China the PCBs were not ready in time for this flight. The consequence of that is that the electronics were not able to be compacted enough to fit in the ACS compartment. The PA1010D is considered as a "nice to have" and was dropped from this flight. The ADXL375 for this flight was considered redundant because the BNO055 that did fly also includes an accelerometer that has a range of 16G's of acceleration. These changes as mentioned are temporary and we expect to have the full suite of sensors on all following flights.

4.2 Proof of construction

4.2.1 PERR-C Construction

4.2.1.1 PERR-C Mechanical

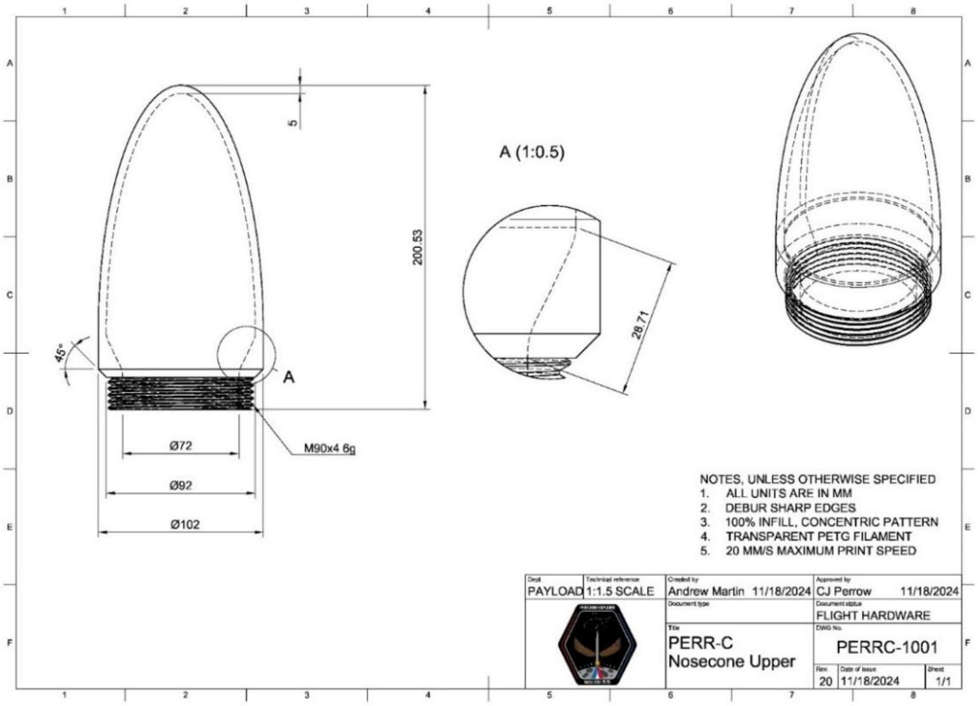


Figure 4.2.1: Dimensioned drawing of the nosecone upper section shows the threaded M90 interface mechanism that secures the nosecone to the lower shoulder.

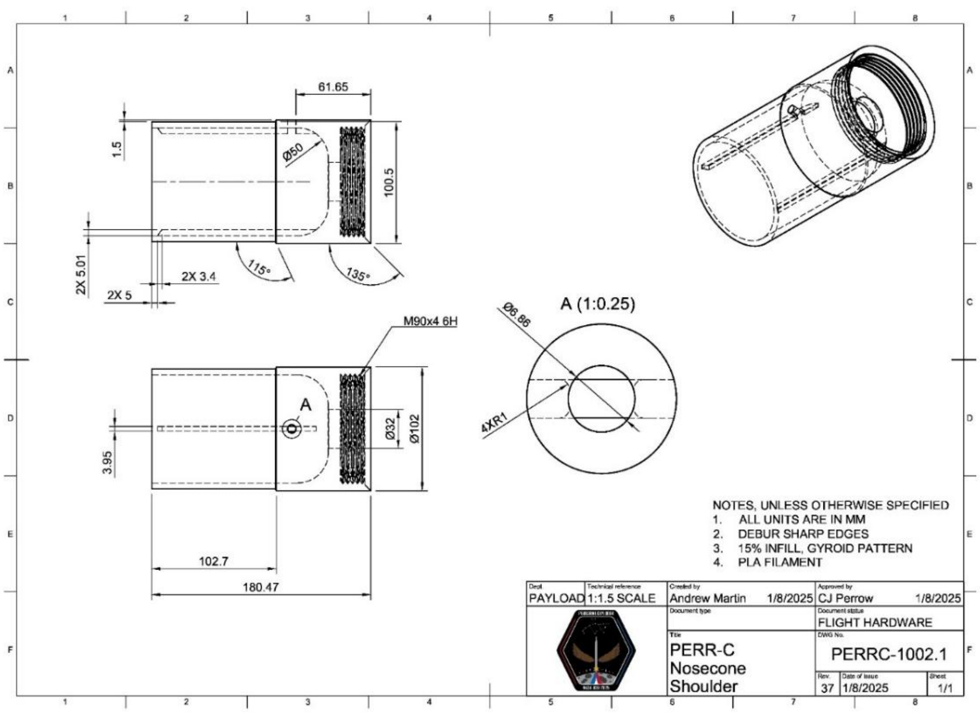


Figure 4.2.2: Dimensioned drawing of the shoulder shows the updated PEP sled alignment rails and screw switch access hole.

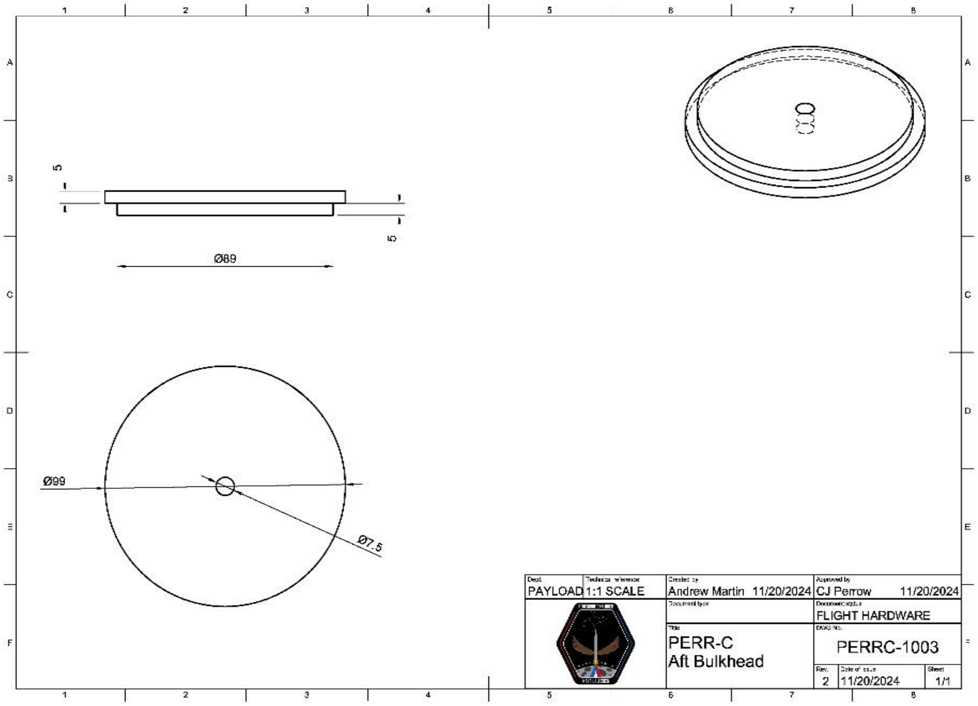


Figure 4.2.3: Dimensioned drawing shows no updates to the existing bulkhead design.

Image 4.2.1: PERR-C during partial assembly, including fitment testing of ballast payload assembly prior to VDF

4.2.1.2 PERR-C PEP

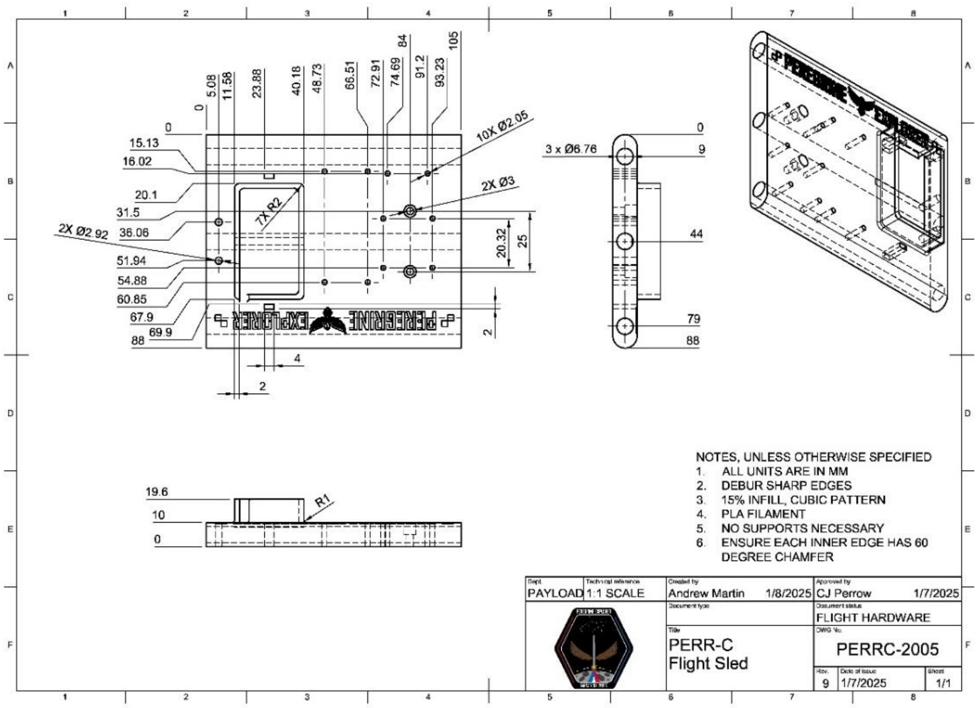


Figure 4.2.4: Dimensioned drawing shows the updated PEP sled including reinforced battery retaining walls and finalized PCB mounting hole locations.

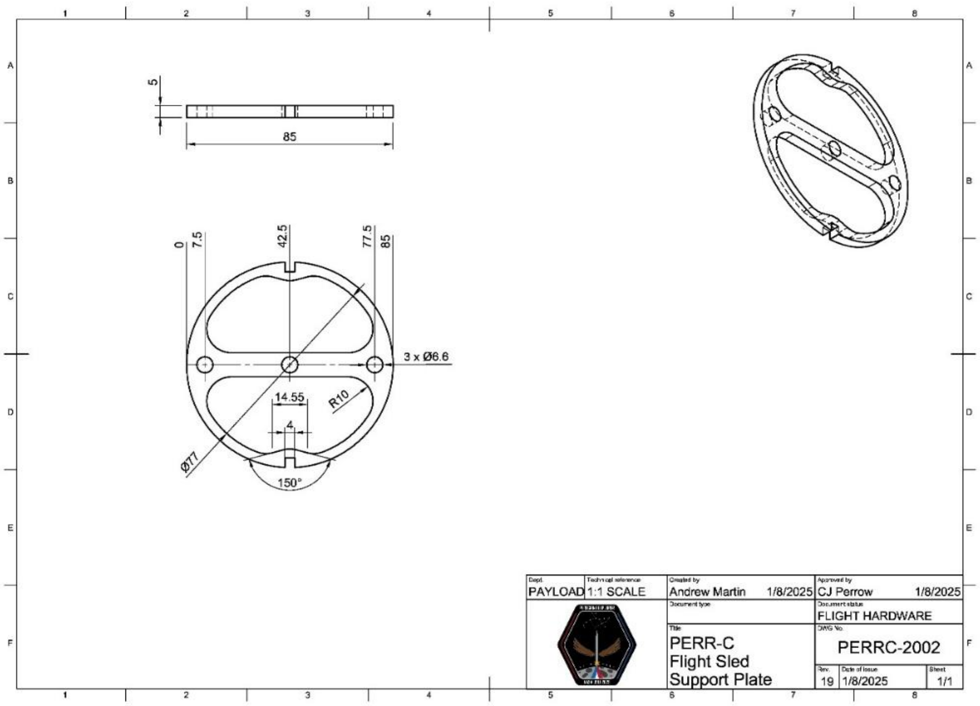


Figure 4.2.5: Dimensioned drawing shows the updated PEP sled support plate design with simplified roll alignment rails.

Image 4.2.2: PEP test package assembled prior to flight. Pennies were used to simulate payload mass and test the structural integrity of the battery mounting system. Square nuts are used with engraved reliefs in the bulkheads to align and assemble the package evenly.

4.2.2 ACS Construction

4.2.2.1 ACS Aero

The aerodynamic surfaces of the ACS included its left and right Aero Braking flaps shown in the picture below.

Image 4.2.3: Image of Full vehicle assembled with the flap manually actuated

The aero-braking flaps experience the highest drag loads at deployment velocity, necessitating a material that is both strong and lightweight. To meet these requirements, we selected a carbon fiber resin composite, which was compression-molded using 3D-printed molds.

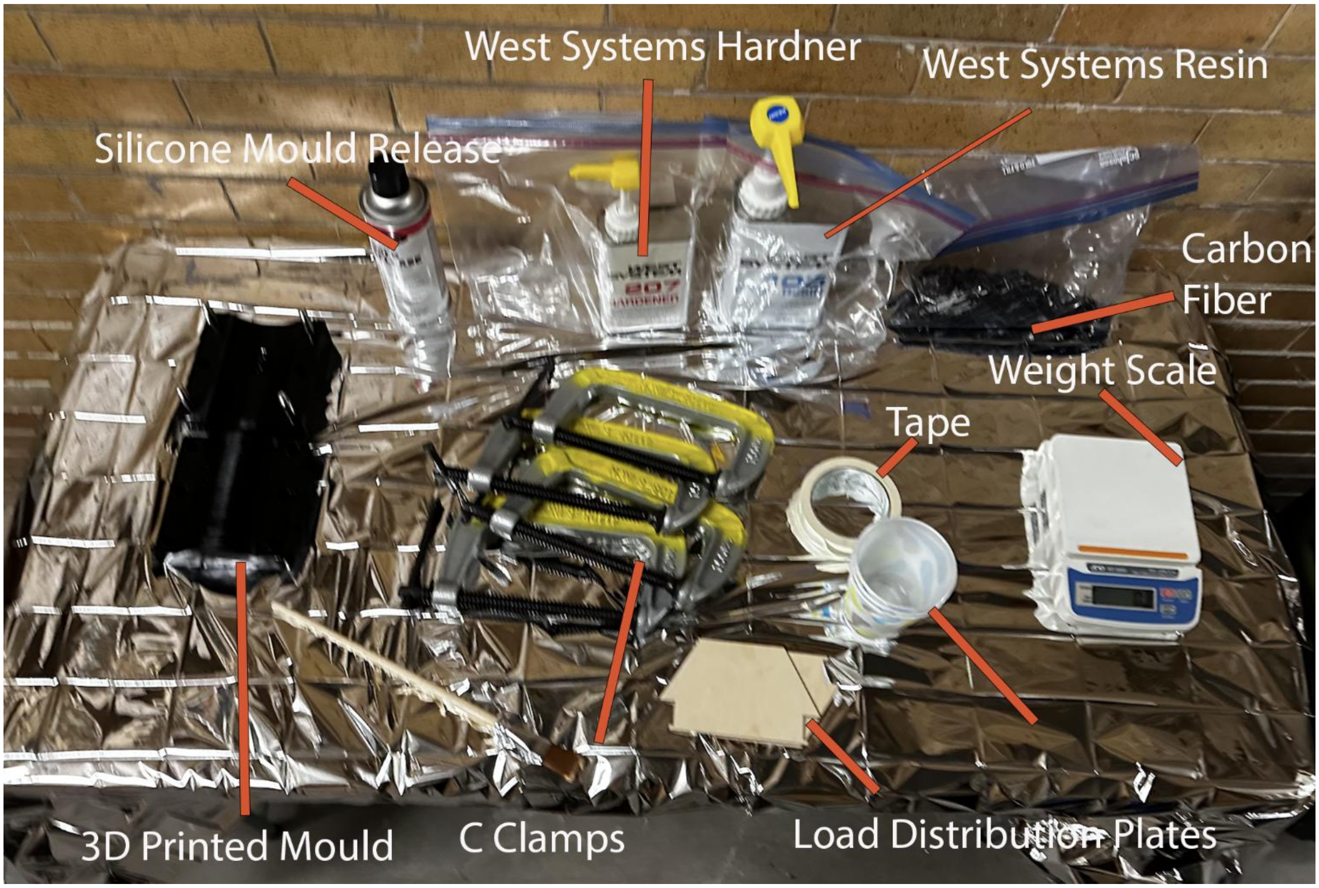


Image 4.2.4: Layout of set up for ACS flap casting

All materials used for the construction of the flap are labeled in the picture above. These include:

- 3D-printed PETG mold – Forms the shape of the flap
- Silicone release spray – Prevents adhesion to the mold
- West System 105/205 epoxy resin and hardener – Binds the carbon fiber and provides strength
- C-clamps – Apply pressure during curing to ensure a compact layup
- 12 mm chopped carbon fiber tow (CT12) – Reinforcement material for high strength-to-weight ratio
- Weight Scale - Measure carbon to resin ratio

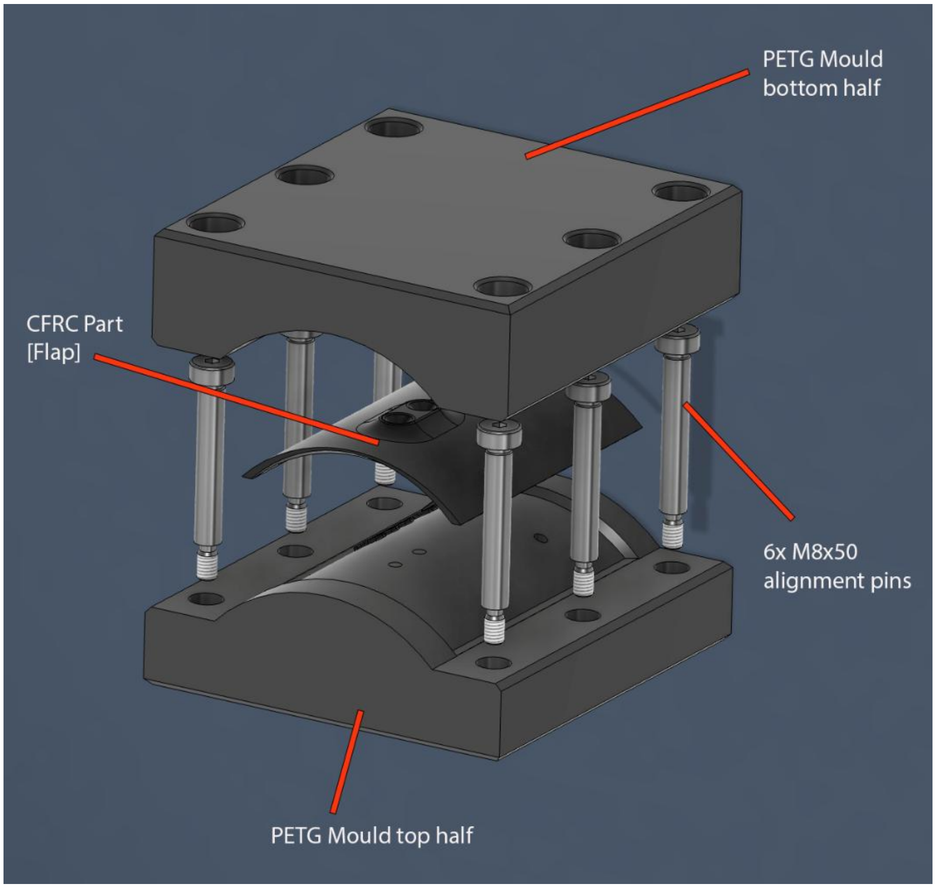


Figure 4.2.6: Exploded diagram of ACS flap mould

The 3D-printed mold consists of two halves that, when pressed together, form a cavity matching the flap's volumetric geometry. This cavity is then filled with the uncured carbon fiber resin composite (CFRC) while it is still in a semi-solid state. To determine the required amount of raw material, we used Fusion 360's material properties tool to calculate the volume and weight of the composite

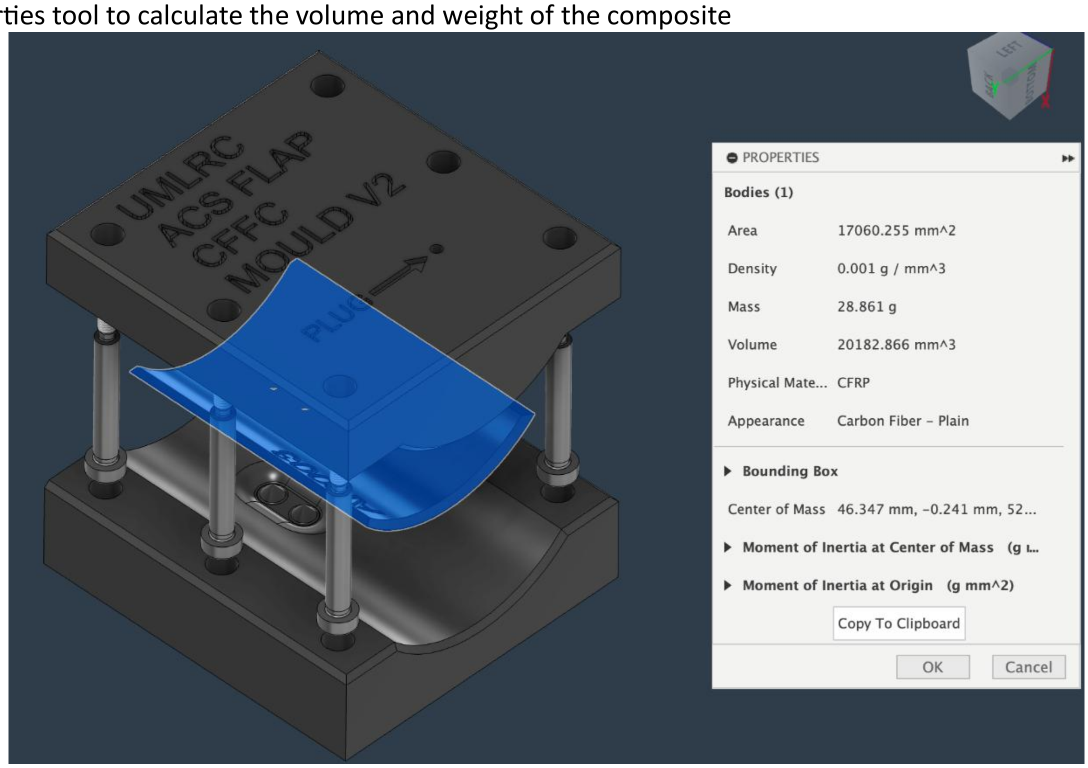


Figure 4.2.7: Screenshot of Properties tab showing Mass, Density, and volume of the cast flap in Fusion360

According to Fusion 360, the theoretical weight of the flap was 28.9g. However, in real-world conditions, factors such as flashing, material variability, and uneven mold fills can affect the final weight. To account for these variations, we added an 11g margin, rounding the estimated weight to 40g.
We then applied the 40/60 rule to determine the carbon fiber-to-resin ratio, resulting in 16g of carbon fiber (40%) and 24g of resin (60%). To ensure even fiber distribution and proper pressurization within the mold cavity, we added a 2g margin, bringing the final material allocation to 18g of carbon fiber and 24g of resin.

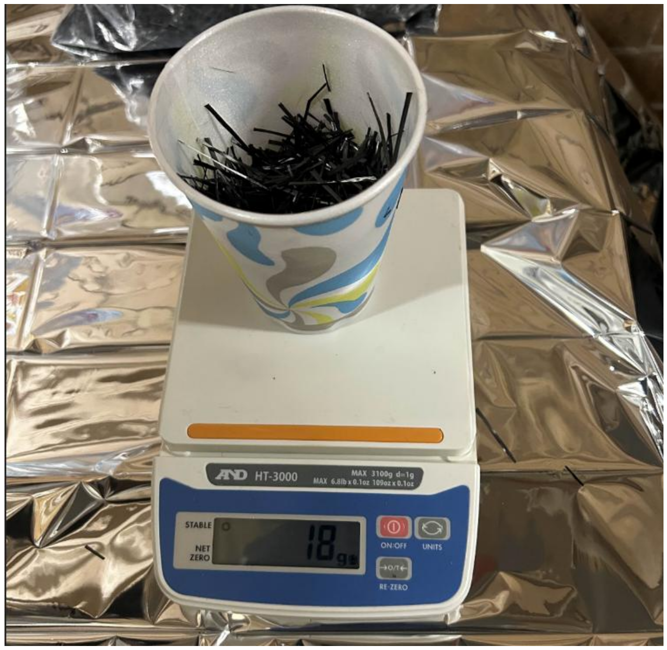


Image 4.2.5: Weighing out Carbon Fiber Tow

The resin weight was intentionally overestimated to ensure sufficient saturation of the carbon fiber. However, the primary method for achieving proper resin distribution was a layered wet-out process. A small amount (1-2g) of chopped carbon fiber tow was first placed into the mold cavity, followed by an even application of resin to fully wet out the fibers. This process was repeated for the entire batch of carbon fiber tow to ensure uniform distribution. Once all the material was in place, the mold was pressurized using four C-clamps to compact the composite and remove excess resin.

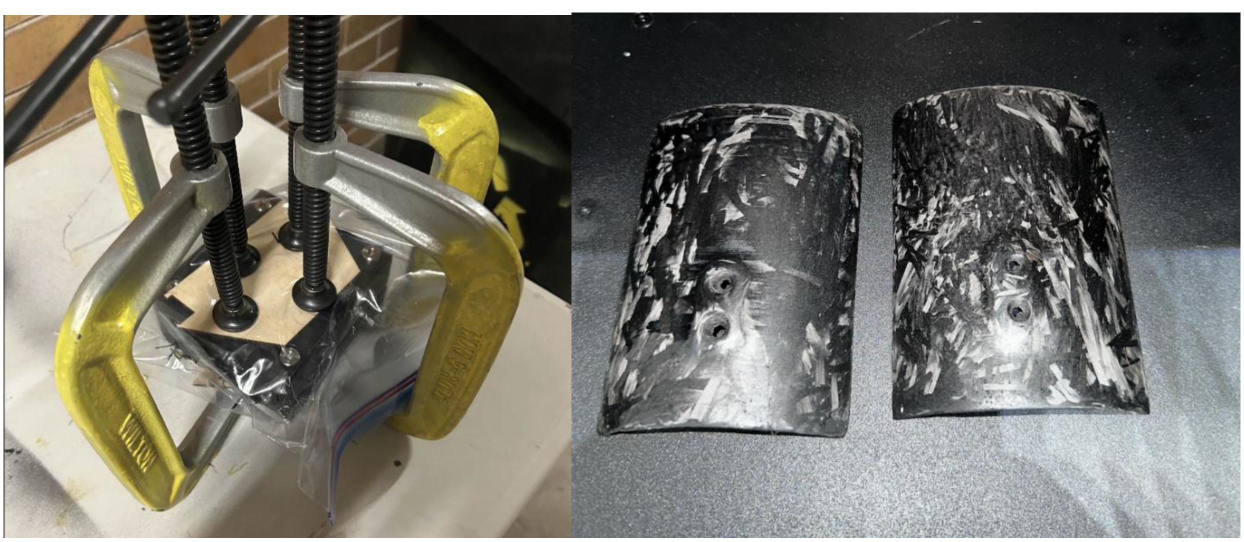


Image 4.2.6: Clamped mould and Final results of ACS Flap

The pressurized mold was left to cure for 24 hours to allow the composite to fully harden. This process was repeated to fabricate two identical flaps, which serve as symmetrical aero-braking surfaces on the vehicle.

4.2.2.2 ACS Mechanical

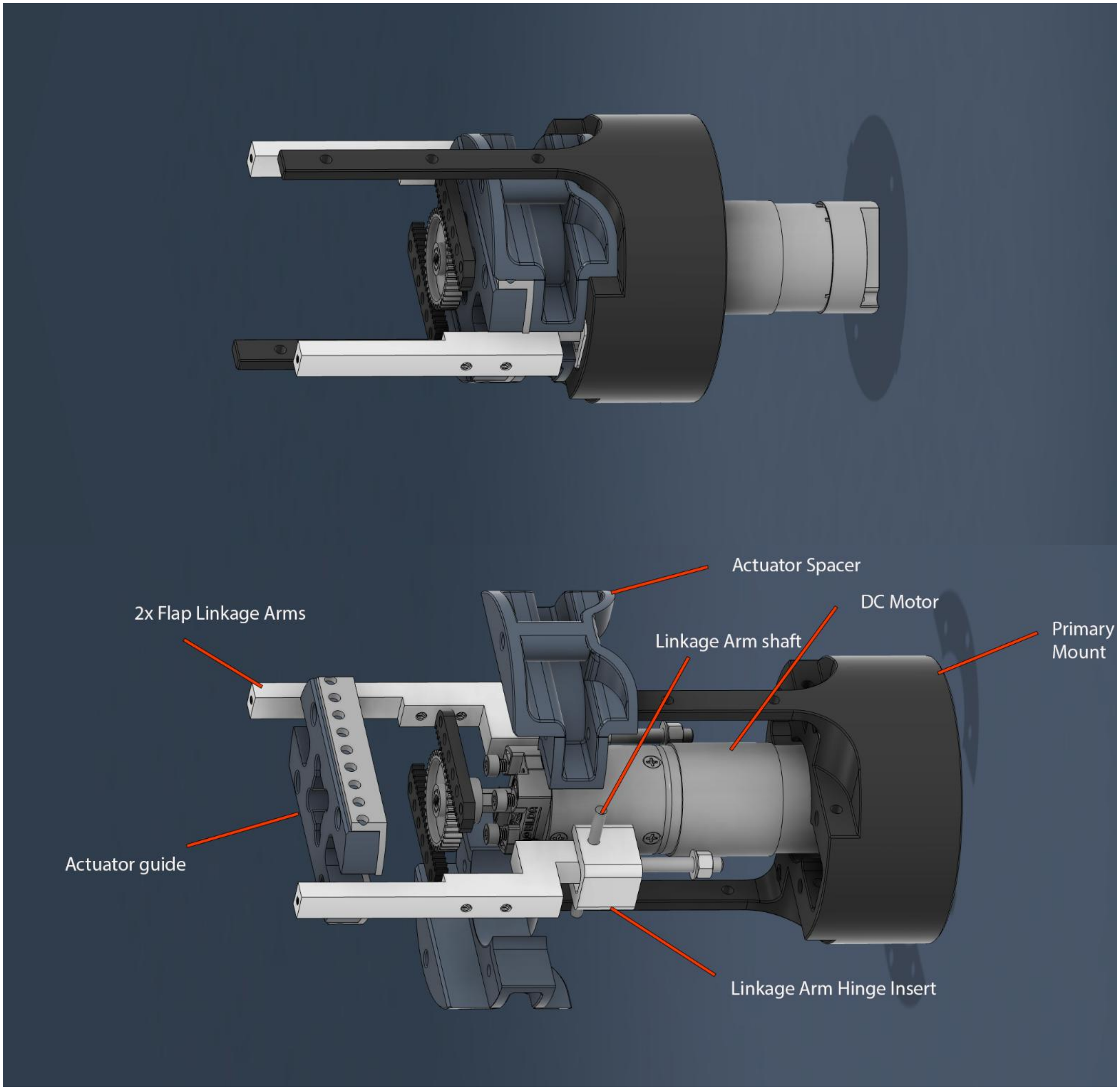


Figure 4.2.8: Diagram of ACS Mechanical Components

The main mechanical subsystem of the ACS consisted of the components listed above. Among these, the two flap linkage arms and two linkage arm inserts were fabricated from 6061 aluminum for strength and durability. All other components were either off-the-shelf parts or 3D-printed, minimizing cost and weight while enabling rapid iteration and hot-swapping of components in case of failure or required maintenance.

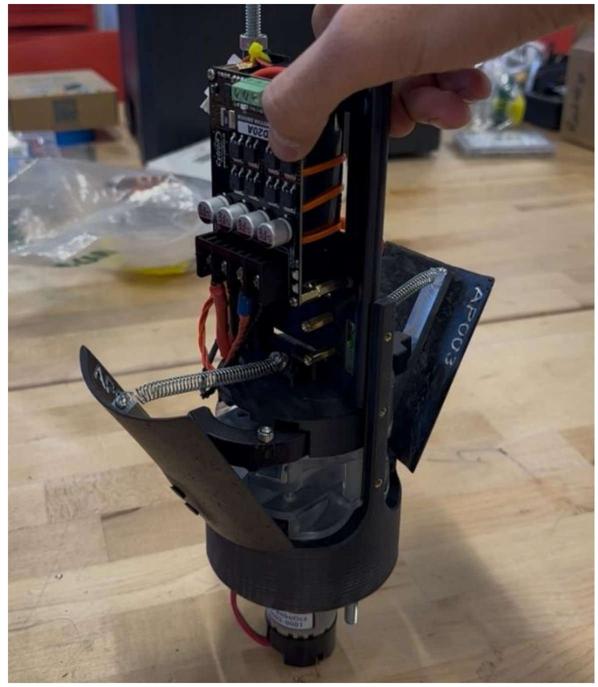
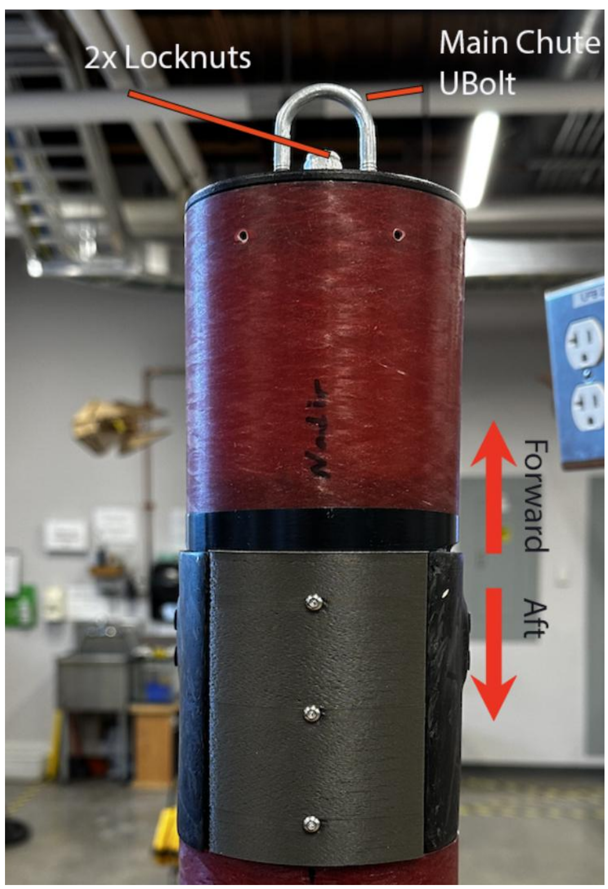


Image 4.2.7: Internals of ACS Bay in closed and Open Configurations

The images above showcase the ACS computer sled, which also functions as the retention spring mount integrated with its mechanical components. This integration is achieved using two ¼"-13in threaded rods, which serve as alignment rails to keep all components properly positioned within the ACS bay. The retention springs are securely fixed to both the computer sled and the flap linkages, ensuring reliable actuation.



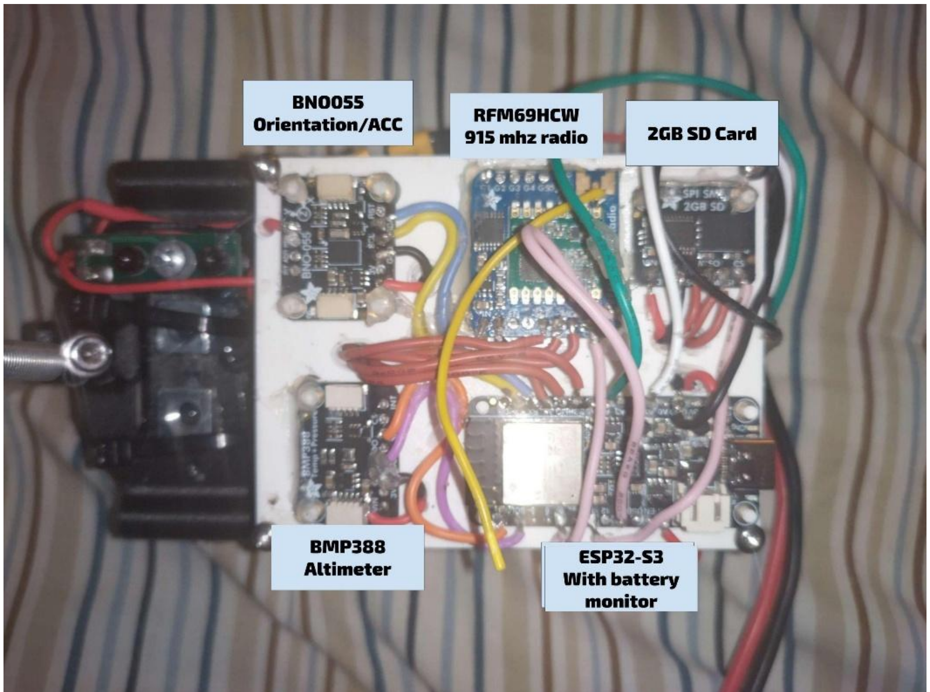
Imgae 4.2.8: ACS Integrated Showing Foreward Bulkhead Attachments

The ¼"-13in threaded rods also serve to secure the bay's bulkheads, ensuring structural integrity. Locknuts were installed at each end of the bay to firmly secure all components, preventing displacement due to vibration and flight instability.

Image 4.2.9: ACS in Testing using the Logic Board to Deploy the flaps using the motor controller

4.2.2.3 ACS Electrical

ACS electrically was not in its final Huntsville configuration; we needed a minimum viable product that would have all the capability to run the airbrake and test the most basic sensors and nothing more than that. The sensors included on this flight was the BMP388, and BNO055. The BMP is a barometric altimeter sensor with a rated accuracy of 0.5 meters and the BNO055 is a magnetometer, accelerometer, and gyroscope with a co-processor running high-end sensor fusion algorithms developed by Bosch. Additionally, a SD card and the RFM69HCW 915 MHz radio were wired for data storage and testing the range of our ground station system. The 915 MHz radio was supplied with a wire antenna instead of a professionally manufactured omni-directional antenna due to a shipment delay with DigiKey. The ESP32-S3 Feather from Adafruit was used as a controller which wired to the MD20A motor driver board using the PWM protocol with an additional signal wire for setting the motor direction.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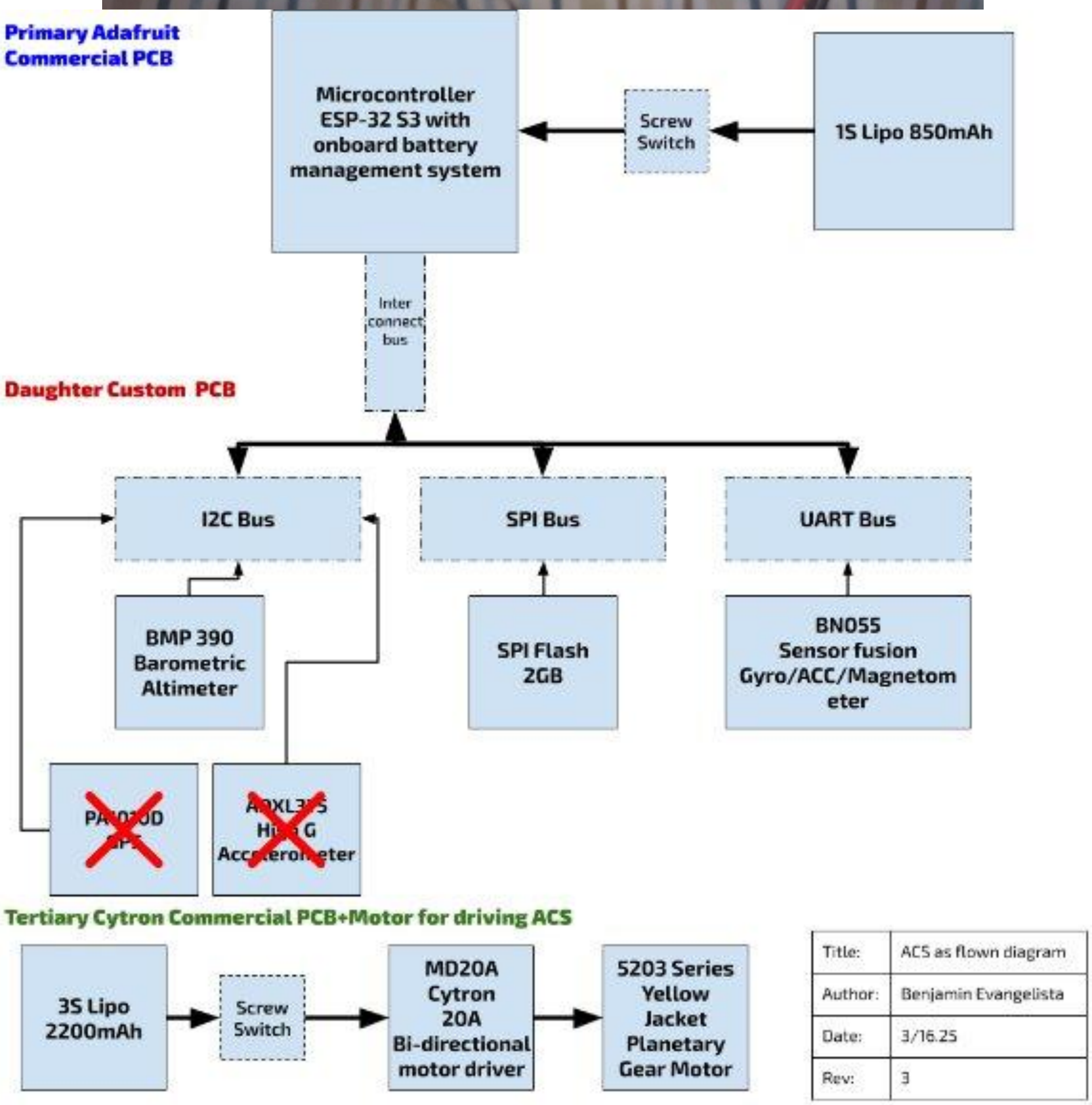
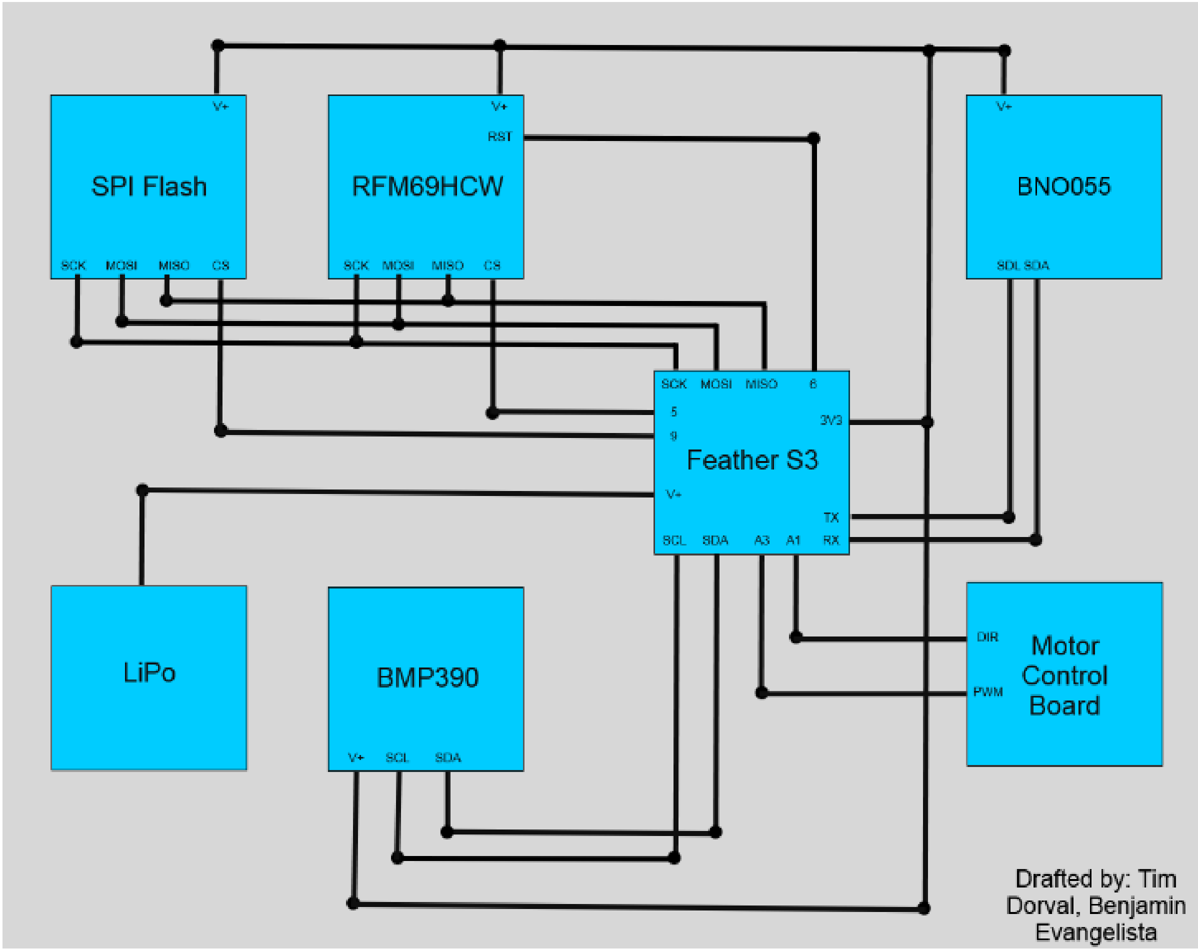
RFM69HCW
915 mhz radio
2GB SD Card
BMP388
Altimeter
ESP32-S3
With battery
monitor


Primary Adafruit Commercial PCB
Microcontroller ESP-32 S3 with onboard battery management system
Screw Switch
1S Lipo 850mAh
Inter connect bus
Daughter Custom PCB
I2C Bus
SPI Bus
UART Bus
BMP 390 Barometric Altimeter
SPI Flash 2GB
BN055 Sensor fusion Gyro/ACC/Magnetometer
Tertiary Cytron Commercial PCB+Motor for driving ACS
3S Lipo 2200mAh
Screw Switch
MD20A Cytron 20A Bi-directional motor driver
5203 Series Yellow Jacket Planetary Gear Motor
Title: ACS as flown diagram
Author: Benjamin Evangelista
Date: 3/16.25
Rev: 3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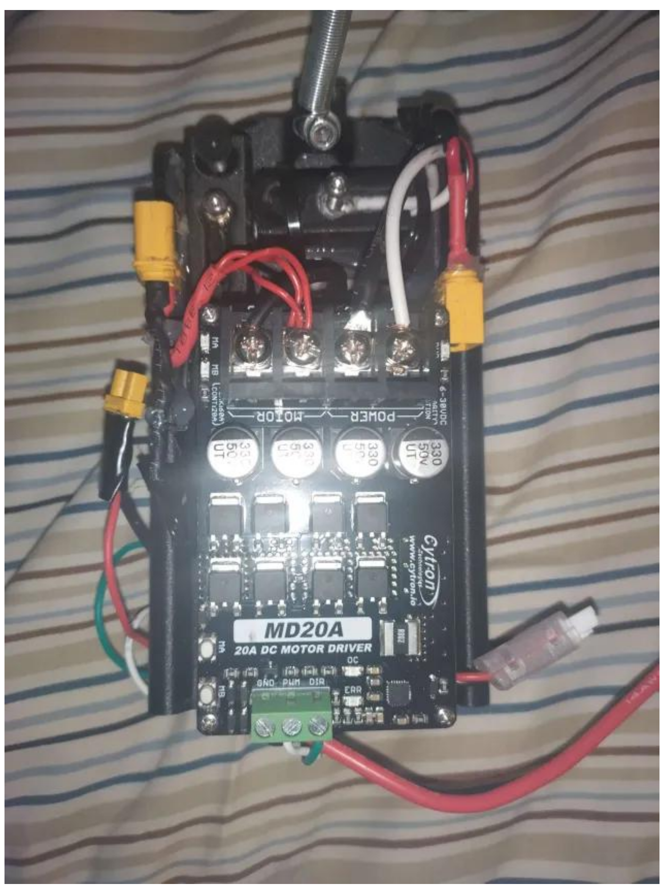
V+
SCK MOSI MISO CS
RFM69HCW
V+
RST
SCK MOSI MISO CS
BNO055
V+
SDL SDA
SCK MOSI MISO 6
5
9
3V3
Feather S3
V+
TX
SCL SDA A3 A1 RX
LiPo
BMP390
V+ SCL SDA
DIR
PWM
Motor Control Board
Drafted by: Tim Dorval, Benjamin Evangelista


MD20A
20A DC MOTOR DRIVER
Cytron

This is explicitly not our final design. The primary reason for using this prototype was ordering delays. The PCB design was finalized before this flight, but the PCBs are coming from JLCPCB in Hong Kong China and were caught up in shipping. Other than shipping delays the reason for not all the sensors being included notably the ADXL375 high G accelerometer is due to space constraints in the ACS compartment and overlapping feature sets. The BNO055 was considered as an adequate temporary stand-in due to its onboard 16G accelerometer and proven track record in industry. The PA1010D was also not included due to space considerations.

4.2.2.4 ACS Code

ACS code was also stripped down to a minimum viable product with emphasis being placed on reliability of data collection above all else. The code is written in Circuit Python. To achieve reliability almost everything was wrapped in try and catch statements. Data storage was iterated on several times, the final choice was writing a folder in the SD card and then in the folder individual csv lines were stored in their own text files. This was done because if one large text file is used and a transient loss of electrical power occurs there is significant risk of total data loss. The one downside to this approach was the data storage rate, which also hindered the process loop time of the flight computer leading to it observing, processing, and recording data at a rate of 2hz.

As mentioned in 4.2.2.2 ACS was actuated via PWM with a motor direction signal, something that the comments don't note is that as assembled the motor direction signal was reversed. This is accounted for else ware in the code.

```python
def set_motor(speed):
    """
    Sets motor speed and direction.
    Speed ranges from -1.0 (full reverse) to 1.0 (full forward).
    0 stops the motor (brake mode).
    """
    MotorSpeed=speed
    if speed == 0:
        motor_dir.value = False  # Brake
        motor_pwm.duty_cycle = 0
    elif speed > 0:
        motor_dir.value = False  # Forward (DIR = Low, PWM = High)
        motor_pwm.duty_cycle = int(speed * 65535)
    else:
        motor_dir.value = True  # Backward (DIR = High, PWM = High)
        motor_pwm.duty_cycle = int(-speed * 65535)
```

Launch detect was done via consecutive thresholding, which only sent the state-machine forward if the count was greater than the active threshold. This is to prevent false detection of launches. These settings were configured at the top of the code before launch. For this launch 10 consecutive accelerations above 20 M/S ignoring gravity were considered enough to trip the launch detect threshold

```python
def detect_launch(acc_z, ActiveThreshold,launch_threshold, count):
    """
    parameters:
        ActivationThreshold (int): Number of consecutive detections needed to confirm launch
        ActivationCount (int): Counter for consecutive detections
    """

    # Detect launch based on acceleration
    if acc_z >= launch_threshold:
        count += 1
    else:
        count = 0

    # Confirm launch if acceleration is sustained for 'ActivationThreshold' readings
    if count > ActiveThreshold:
        return True, count  # Launch detected

    return False, count  # Launch not detected yet
```

On-Pad behavior was set via state 1 of the state machine. Once all the sensors are initialized using their try-catch statements, if any of them registered as failing to initialize the board will communicate that via the ESP-32S3 Feathers onboard RGB LED. By showing a steady red light the operator knows that some sensor failed in startup. By showing steady green the operator knows that all sensors were initialized correctly. Next after a set period, as assembled for this launch it was 20 seconds the airbrake will actuate to demonstrate that there are no mechanical failures in the linkages. Finally, to progress to the next state the computer looks at its absolute orientation and launch detect status to determine if it's safe to move on. As assembled in this launch the lockout angle was set at 20 degrees.

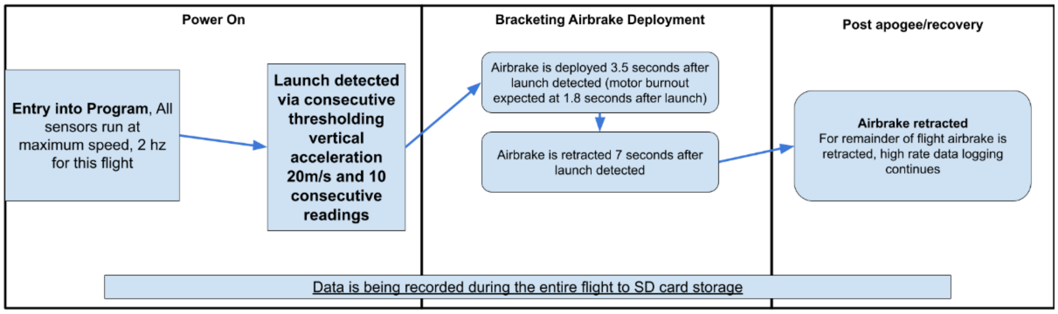
```python
    if State==1: #?? pad
        current_time=time.monotonic()
        if pixel:
            if ErrorInStartup == True:
                pixel.fill((255, 255, 0))
            if ErrorInStartup == False:
                pixel.fill((0,255,0))
        if (current_time-initializationfinizedtime)*1000 > TimeAfterInitializationToTestInMiliSeconds and TestRequired:
            set_motor(-1)  # 50% speed forward
            time.sleep(AirbrakeActuationTime)
            set_motor(0)
            time.sleep(1)
            set_motor(1)
            time.sleep(AirbrakeActuationTime)
            set_motor(0)
            TestRequired=False
        Launch, ActivationCount = detect_launch(abs(AccY), ActivationThreshold, LaunchAccelerationThresholdInMS, ActivationCount)
        #GyroXToTransmit = str(GyroX)[:3] #roll
        #GyroYToTransmit = str(GyroY)[:3] #yaw
        #GyroZToTransmit = str(GyroZ)[:3] #pitch
        if (LockoutAngleInDegrees>abs(GyroY)) and (90-LockoutAngleInDegrees<abs(GyroZ)<90+LockoutAngleInDegrees) and Launch:
            LaunchTime=time.monotonic()
            State=2
```

In flight states were 2 through 4. State 2 represented the motor burning and coast phase of flight. It makes another check to its lockout angles to determine it's in a safe orientation and waits till the ACS deploy time is reached. Once these conditions are met it sets a timer and transitions states to state 3 which has the airbrake deploying. The airbrake deployment is currently a blocking action, this means the whole system sleeps while the airbrake slews to the open position. After the airbrake is open, it waits till the retraction time is met and then retracts the motor. Going into a non-active mode other than saving data for state 4 for the rest of the flight

```python
if State==2: #?? launched
    #!! write code to determine if its okay to deploy the airbrake
    if pixel:
        pixel.fill((255,165,0))
    current_time = time.monotonic()
    if ((current_time-LaunchTime)*1000 > ACSDeployTimeAfterLaunchInMiliSeconds) and (LockoutAngleInDegrees>abs(GyroY)) and (90-LockoutAngleInDegrees<abs(GyroZ)<90+LockoutAngleInDegre
        AirBrakeDeployTime=time.monotonic()
        State=3
if State==3: #?? airbrake triggered to deploy
    current_time = time.monotonic()
    if pixel:
        pixel.fill((0,0,255))
    set_motor(-1)  # 50% speed forward
    time.sleep(AirbrakeActuationTime)
    set_motor(0)  # Stop the motor
    # or (IBaro and AltitudeDelta<10)
    if (current_time-AirBrakeDeployTime)*1000 > ACSRetractTimeAfterLaunchInMiliSeconds:
        State=4
        set_motor(1)
        time.sleep(AirbrakeActuationTime) #change it to non blocking
        set_motor(0)
if State==4:
    if pixel:
        pixel.fill((160,32,240))
```

for saving and transmitting data the code was intended to do it in the most reliable way possible by writing each line of data to an individual file so that corruption of one file doesn't lead to corruption of the others. It increments a file name, opens a new file, and writes the data then closes it. The data sending is very simple on our end for this flight due to no other flights utilizing the 915 MHz band in the area. We sent a packet containing the same data being saved to all the nodes.

```python
    if sdcard and MakeSaveData:
        SDCardFileName=f"{SDCardFolderName}/{FileNum}.txt"
        FileNum=FileNum+1
        File=open(SDCardFileName,"w")
        #File.write("Time(Seconds since power on),Barometer Altitude,GyroX,GyroY,GyroZ,,AccZ,BatteryVoltage,MotorSpeed,StateMachine")
        File.write(",".join([str(time.time()-MET),
                             str(AltitudeInMetersToTransmit),
                             str(GyroXToTransmit),
                             str(GyroYToTransmit),
                             str(GyroZToTransmit),
                             str(AccZPrint),
                             str(BatteryVoltageToTransmit),
                             str(MotorSpeed),
                             str(State)]))
        File.close()
    loop_end_time = time.monotonic()
    loop_duration = (loop_end_time - loop_start_time) * 1000  # Convert to milliseconds
    if rfm69:
        rfm69.send(GyroXToTransmit + "|" + GyroYToTransmit + "|" + GyroZToTransmit + "|" + AltitudeInMetersToTransmit + "|" +
        str(AccZPrint) + "|" + str(BatteryVoltageToTransmit) + "|" + str(MotorSpeed) + "|" + str(State) + "|" + str(loop_duration))
    #
```



4.3 VDF Flight results

The payload experiment was to test 1. The aerodynamic performance of the airbrake 2. Sensor and radio link performance. Unfortunately, the first goal of testing aerodynamic performance was not achieved on this flight due to a failure of the launch detect algorithm. Below is a snippet of the data recorded by the ACS computer.

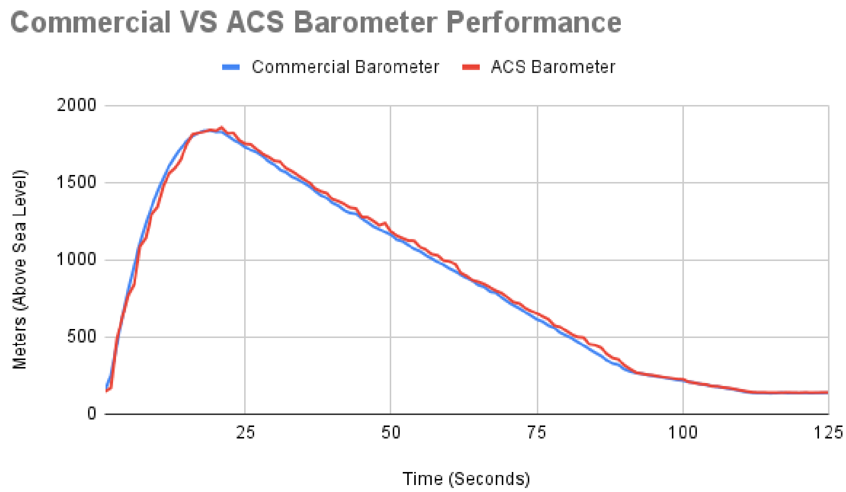
TimeSincePowerOn	AltitudeMeters	RollDegrees	YawDegrees	PitchDegrees	AccZM/S	BatteryVoltage	MotorSpeed	State
642.8	144	3.87	-4.7	-86	-0.1	4	0	1
643.14	145	4.43	-5	-86	-0.5	4	0	1
643.54	148	11.8	-4.5	-86	1.39	4	0	1
644.33	171	9.12	-7.2	-100	12.1	4	0	1
644.53	226	299	1.75	-102	6.99	4	0	1
645.01	347	166	11.8	-77	1.59	4	0	1
645.31	487	14.4	-10	-97	4.28	4	0	1
645.51	558	155	9.37	-76	-3.4	4	0	1

The relevant areas are the rightmost column and the Altitude column. The altitude column shows that the vehicle launched but the state never changed from the pad state (1). Unfortunately, the reason behind this is hard to figure out due to only recording lateral acceleration of the vehicle which was an oversight during coding.

The initial hypothesis for why the launch detection system didn't trigger is because of the accelerometer being incorrectly ranged at some point. The BNO055 accelerometer requires configuration of the range that data can be collected in. By consulting the libraries documentation, it was found that the default setting is 4g range. Which does exceed the 20 m/s acceleration threshold that was set as the trigger for the launch detect system. We also found that our readings exceeded the 2g range, so the vehicle's accelerometer was definitely set at a high enough range to be able to detect launch.

The secondary and most likely hypothesis is that the process loop speed was too slow to register the launch. Referring to the data snippet above there is only 2hz data recording speed which also directly corresponds to how fast the computer was intaking and processing data. This 2hz process loop speed is due to the way the data storage is being done, by conducting a massive amount of IO operations the computer is left unable to conduct most any other operation.

Payload experiment 2 of testing our sensors and radio link was mostly a success, when comparing ACS's acceleration vector, and altitude readings with that of our commercial AV data from Telemetrum and BlueRaven the sensor shows accurate and consistent readings throughout the flight regime. One notable issue is that throughout the vehicle's entire operation only 1 packet was recorded from the ground station which was situated at 500 feet from the pad. The reason for this is twofold: for one, both the vehicle and ground station were equipped with wire antennas and not the commercial omnidirectional antennas that were intended. This is due to an ordering issue. The second reason is due to either a miscommunication or tight integration of ACS with the rest of the vehicle the wire antenna on the vehicle was bent 90 degrees in two places along its length which led to signal propagation issues as wire antennas are supposed to be entirely straight. The code additionally performed adequately other than the issues discussed above.


Commercial VS ACS Barometer Performance
Commercial Barometer
ACS Barometer
2000
1500
1000
500
0
Meters (Above Sea Level)
25
50
75
100
125
Time (Seconds)

5 Vehicle Demonstration Flight

5.1 Flight Information

5.1.1 Launch Day and Conditions

Date & Time	March 9th, 2025 – Liftoff time approx. 3PM
Location	366 County Road 12, New Hampton, NY
Elevation	390ft MSL.
Ground Winds (Speed from Direction)	15mph @ 270deg, Gusting to 25mph
Temperature	45F
Humidity	45%
Cloud Base	Estimated 6200ft AGL
Launch rail type and angle	8ft-1010 @ 7 degrees into the wind

5.1.3 Vehicle Configuration Information

Motor Flown	Aerotech RMS 54/2560 K1275 Redline
Primary Payload (PERR-C) Status	Inactive
Altitude Control System (ACS) Status	Active - Timed deployment
Target Altitude	5000ft
Predicted Altitude (OpenRocket)	5032ft
Estimated Altitude with 3s ACS deployment	~4500ft

5.1.2 Vehicle Mass and Energy Information

Measured Pre-Launch Mass:	Ballast (in PERR-C): 0.83 lbs PERR-C, Main Parachute Bay, Main Parachute: 5.67 lbs Drogue Chute, Drogue Parachute Bay, ACS, Booster (no motor): 9.44 lbs ARCS + ejection charges: 2.52 lbs Aerotech K1275R: 4.37 lbs Total mass: 23.5 lbs
Total Burnout mass:	20.22 lbs
Landing Masses:	PERR-C + Ballast: 3.65 lbs Upper Section: 3.79 lbs Lower Section: 10.42 lbs
Touchdown Velocity	~20ft/s
Touchdown energy	PERR-C: 22.68 Ft-lbf Upper Section: 23.56 Ft-lbf Lower Section: 64.77 Ft-lbf

5.2 Analysis of Vehicle Demonstration Flight

The Vehicle Demonstration Flight was conducted under suboptimal circumstances, as the wind was approaching the 20mph limit. However, there were still points when the wind calmed down. The cloud coverage also posed a potential risk, which pushed the launch later into the day when the cloud base rose above 6200ft (data acquired from National Weather Service Hourly Forecast Graph). Ultimately, due to the closing window for the VDF the decision was made to launch.

The Vehicle Demonstration Flight had the following criteria:

Demonstrate the safe and stable ascent of the launch vehicle	PASS
Demonstrate the safe actuation of the Altitude Control System (ACS)	FAIL – NO ACTUATION
Demonstrate the vehicle's tracking system works throughout flight	PASS
Demonstrate the vehicle's recovery system deploys as intended	PASS
Demonstrate that the vehicle's recovery system tethers keep all sections connected	PARTIAL
Demonstrate the vehicle is able to survive ground impact	PARTIAL
Demonstrate that the Modular Fin system operates as designed and Survives flight	PARTIAL
Demonstrate the vehicle completes descent in under 90s	FAIL
Demonstrate that each section of the vehicle lands with less than 75 ft-lbf of energy	PASSED

Overall, the team concluded that the vehicle did demonstrate safe ascent and recovery, with almost all of the damage sustained to the vehicle after touchdown due to being dragged by high winds. Going forward the team will continue with the Payload Demonstration Flight as planned, proving the successful operation of the primary payload and further verifying the integrity of the structure of the vehicle.

Image 5.2.1: PADCAM2 (GoPro Hero 10) Image of Peregrine Explorer Leaving the rail

Despite the conditions, the flight was nearly perfect. The vehicle pitched slightly into the wind before settling into a small 5-degree oscillation.

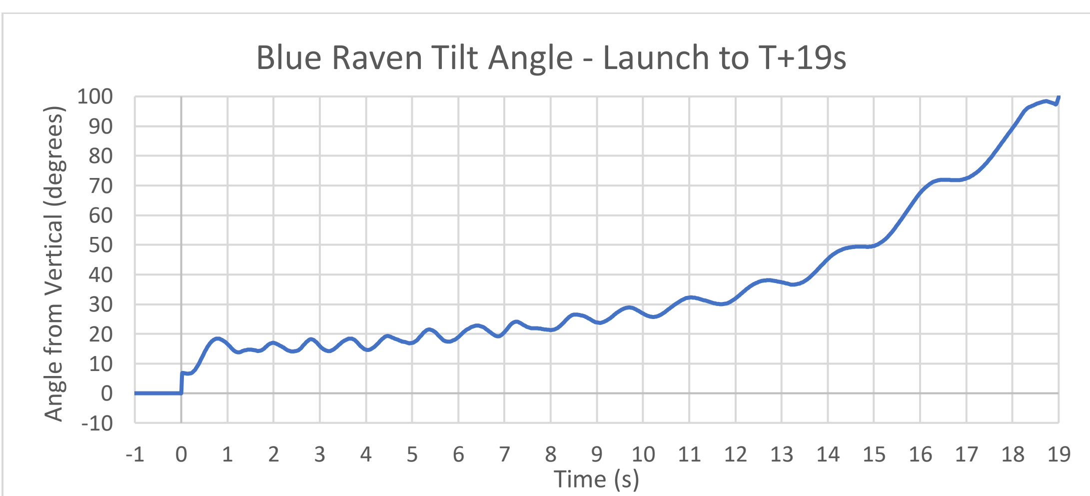


Figure 5.2.1: Blue Raven tilt angle showing oscillation

Max Acceleration (From Boost) (G)	Max Acceleration (Overall) (G)	Max Velocity (ft/s)	Apogee Altitude (ft AGL)	Estimated Cd	Estimated Delivered Impulse (N-s)
13.8 G	17.2 G	672 ft/s	5580 ft	0.36	2138.4

Table 5.2.1: Table of flight values from onboard altimeters

Both altimeters had very consistent data between the two sets, on previous flights (utilizing the same models) there were differences in altitude of up to 200ft (approximately 5% of the total height of the flight). On this flight, the altimeters had extremely similar data and was extremely satisfying to compare and analyze.

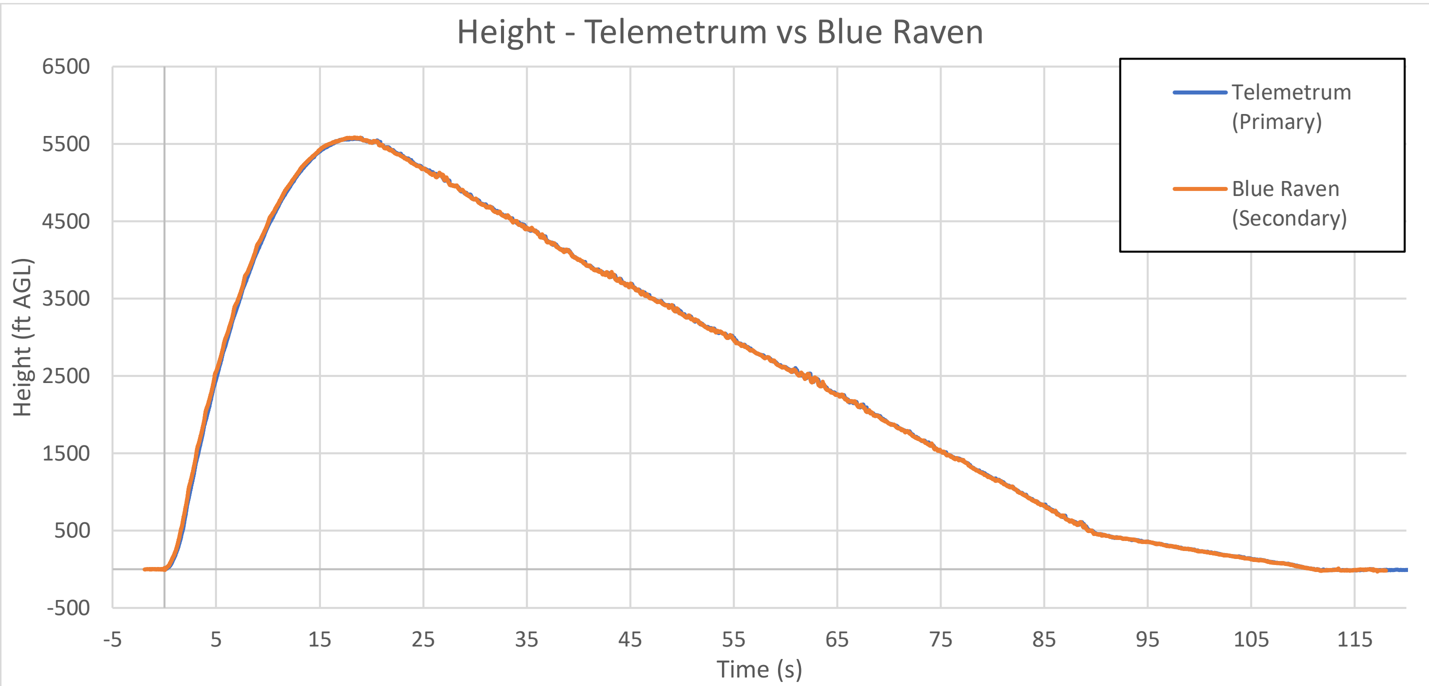


Figure 5.2.2: Altimeters Height Graph (in feet)

Using accelerometer data and velocity data just after burnout, a rough coefficient of drag was calculated to be 0.36, utilizing the surface conditions to calculate the air density. The Cd was then put into OpenRocket and the simulation was compared to the Altimeter Data (see Figure 5.3.2).

Launch and Coast (s)	Drogue Descent	Main Descent	Total Flight time (s)	Total Descent Time (s)	Drift distance from apogee (ft)
18.3 s	69.87 s | 75 ft/s	23.2 s | 20ft/s	111.4 s	93 s	2798 ft

Table 5.2.2: Table of Flight Event Times and Speeds

Since the ACS failed to deploy and the vehicle overperformed simulations, the actual altitude was 10% higher than expected, leading to a higher descent time. Using the recorded descent rates, the estimated descent time from 5000 ft AGL is approximately 85 seconds.

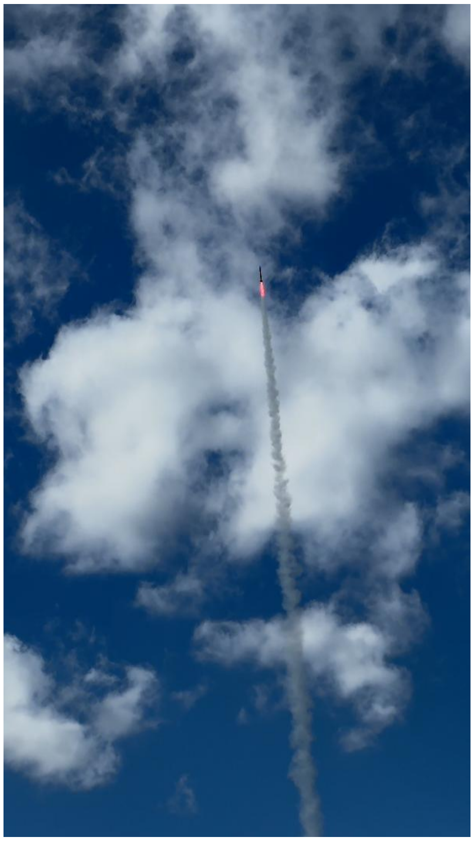


Image 5.2.2: Tracking video screenshot just before burnout

5.2.1 Recovery

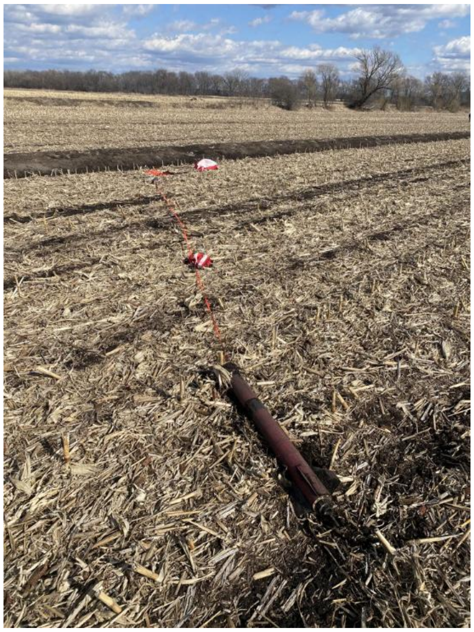


Image 5.2.3 Wide Angle of Vehicle in Landed State


Image 5.2.4: Both sides of the Lower Section at the landing zone


Image 5.2.5: Upper Section and PERR-C in Landed State

Image 5.2.6: Drogue Parachute and Nomex Protector wrapped around tether

Image 5.2.7: Main parachute an tether tangled in the vegetation

5.3 Simulation using Launch Day Conditions

The Simulation using the stock OpenRocket Drag was performed day of using the weather conditions approximately 1 hour before launch.

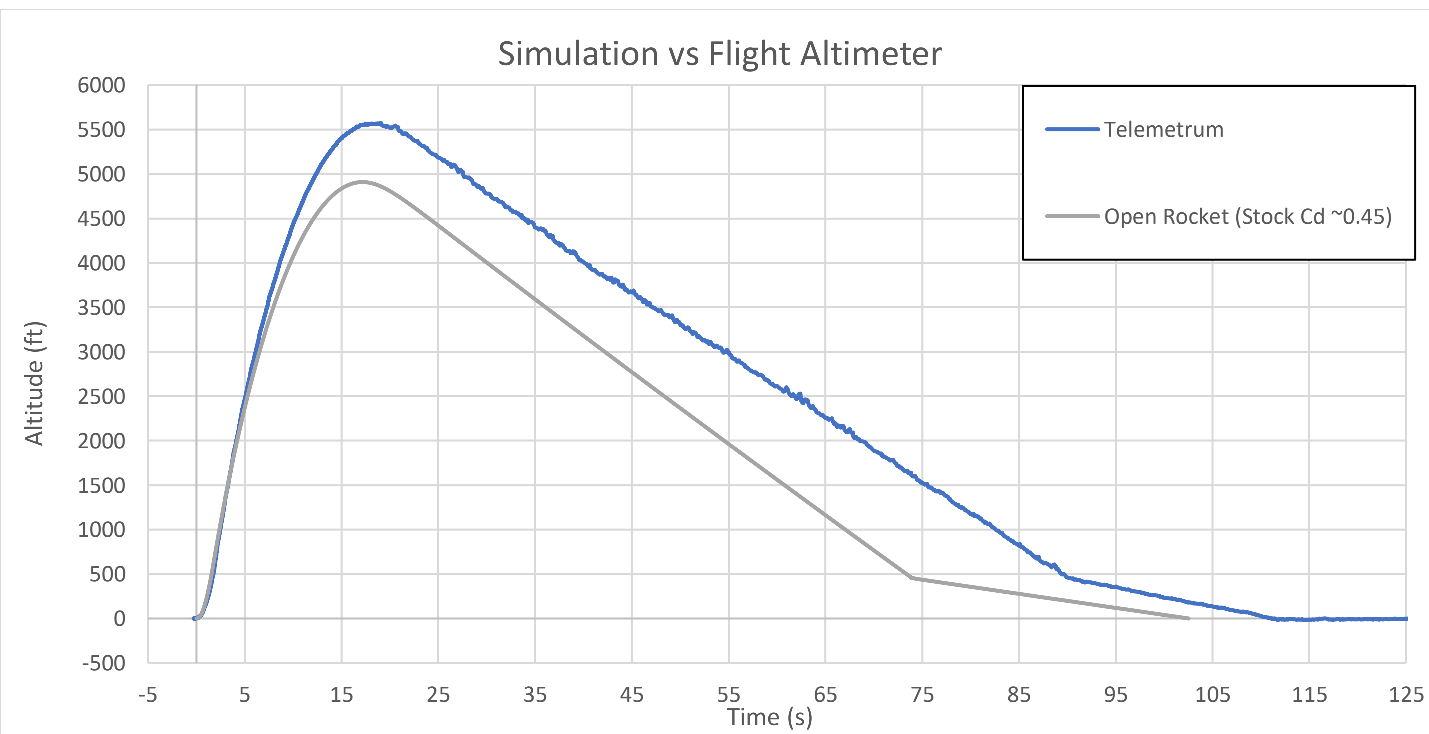


Figure 5.3.1: Preflight simulation vs Actual flight

After recovering the vehicle and analyzing the data, the Coefficient of drag was updated to represent the estimated Cd of 0.36. Comparing the two data sets provides almost identical flight profiles up until main parachute descent, which is was faster on the VDF by ~ 5ft/s. While the chute has some damage on the gores from previous uses, it would not provide enough of a reduction in performance as seen by this flight. As stated by Fruity Chutes, the IFC-72 we use should provide a descent rate of 20ft/s to a 28 lbs payload, the vehicle on descent weighs 27% less than the stated mass. As there are a lot of factors at play with parachute descent rates, such as thermals and slip angles, the team will use a 20ft/s descent rate going forward as a "worst case" scenario for descent velocity.

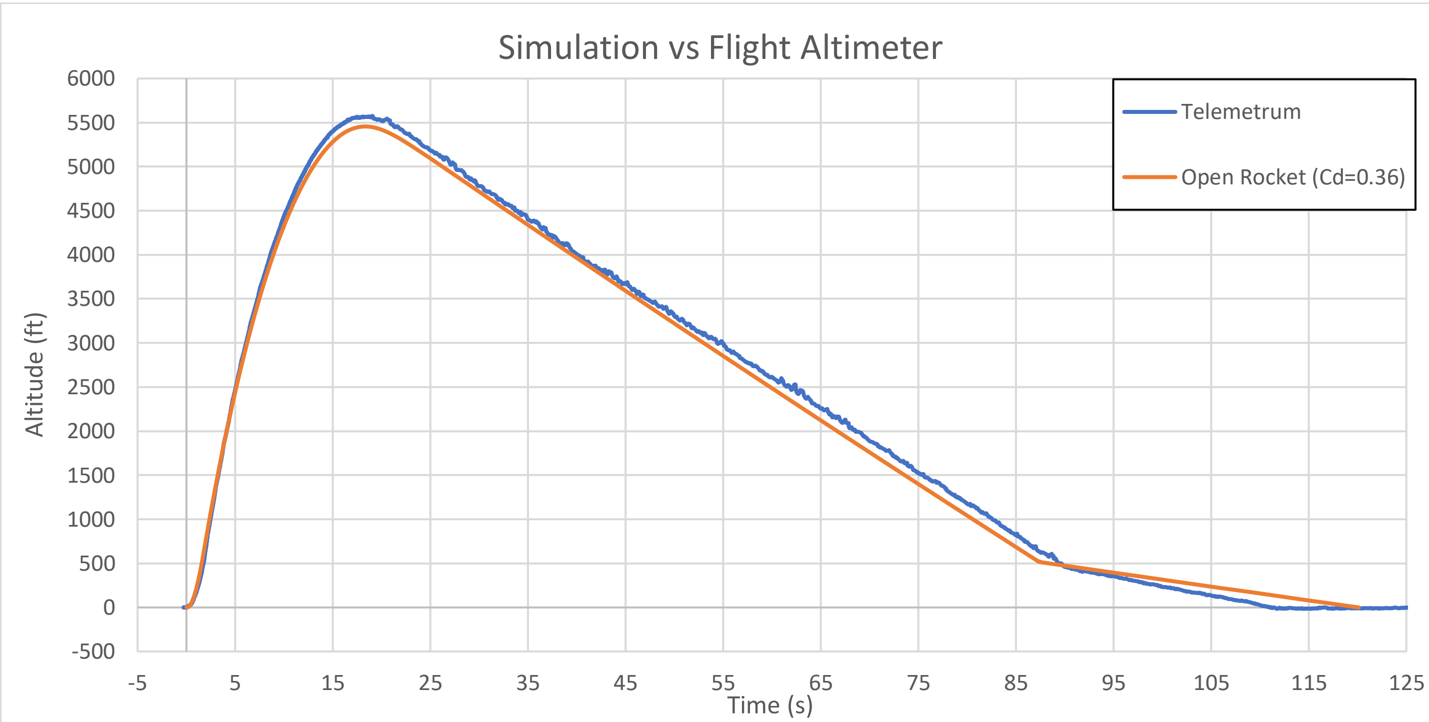


Figure 5.3.2: Comparison between Open Rocket (Cd set at 0.36) and Telemetrum

5.4 Comparison to subscale flight

Data gathered from the subscale flight determined that the minimum coefficient of drag was ~ 0.4.

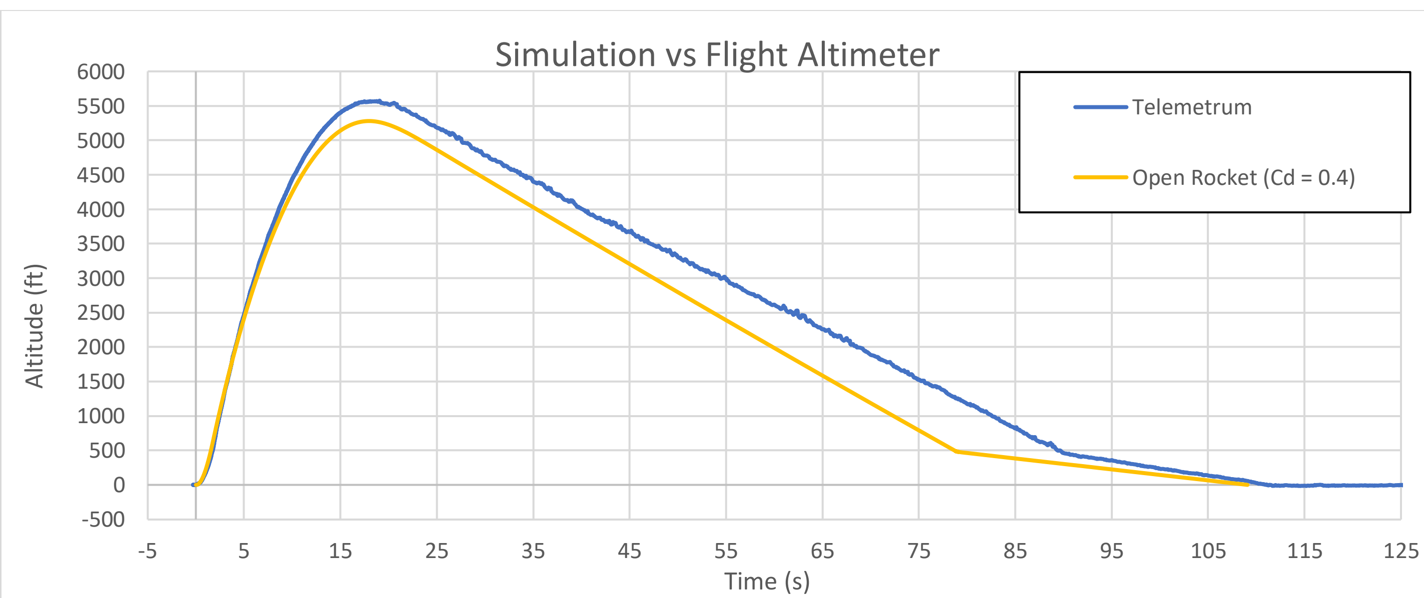


Figure 5.4.1: Comparison of Open Rocket Simulation using Minimum Cd calculated from Subscale to Altimeter Data

5.5 Damage analysis and repair plan

5.5.1 Damage to Fin Retainer

Image 5.5.1: Image of Fin pushed through Fin Retainer on landing (left) and after returning to the flight line (right

The fin retainer is a plywood ring at the base of the rocket (See Image 5.5.2). The purpose of the ring is to retain the fins in the vehicle through the duration of flight. After landing the vehicle was dragged approximately 500 yards, during these fins in slots C and D (The fins in the dirt in Image 5.5.1) pushed through and destroyed the Fin retaining ring.

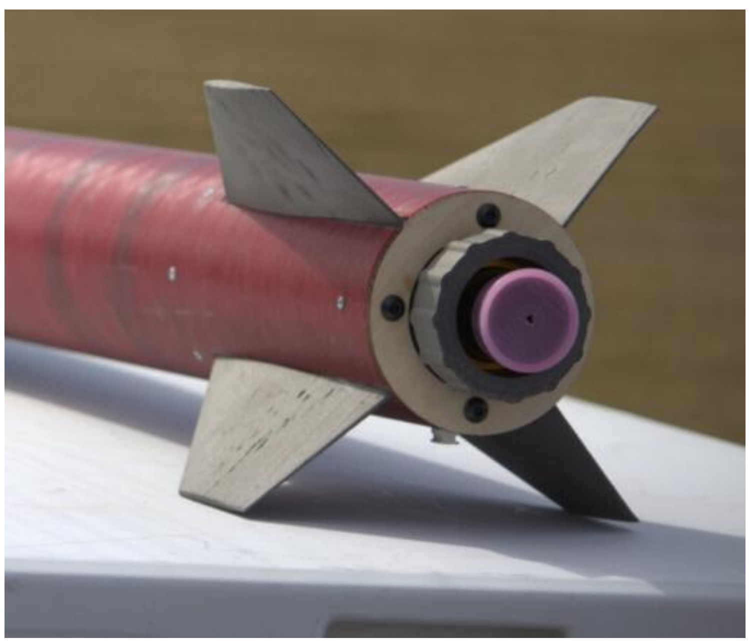


Image 5.5.2: Assembled Booster Section with Motor Integrated, waiting for flight

The Retaining ring uses four ¼-20 bolts that thread into the 3D-printed fin mount to hold it in place. Two out of four of these threads were not stripped before flight. While they were able to screw in and out, they did not provide a sufficient holding force and as the vehicle was being dragged one of the bolts in the stripped holes was dislodged and the fins were able to push through the plywood ring.

Image 5.5.3: Fin Retaining Ring after disassembly

The fin retaining ring will now be made from 1/8 inch thick 6061 aluminum that the club already has in stock, machining will start the week of March 17th. The internal fin mount will be modified to fit ¼-20 heat-set inserts instead of tapped plastic to hold the retaining ring on. This will remove the risk of the threads inside the fin mount becoming stripped and the aluminum plate will be able to withstand the pressures exerted by the fin in the event that it is being dragged by the parachute.

5.5.2 Damage to Fin Trailing edges

All four fins suffered minor delamination of the 3D printed layers during landing, all of which were focused on the last ½ - inch of the tip towards the thin trailing edge. The trailing edge is approximately 1.3mm thick. The team thought that the swept trapezoid shape of the fin would prevent high-impact forces on the tip of the fin, however due to the high lateral velocity and the softness of the soil on landing, the nozzle of the motor became a pivot-point, that forced the fin section into the ground. However, because all 4 fins see delamination of similar states, it can be inferred that the majority of the damage was caused by the dragging action of the vehicle after landing,

5.5.2.1 Pre-flight images of the fins

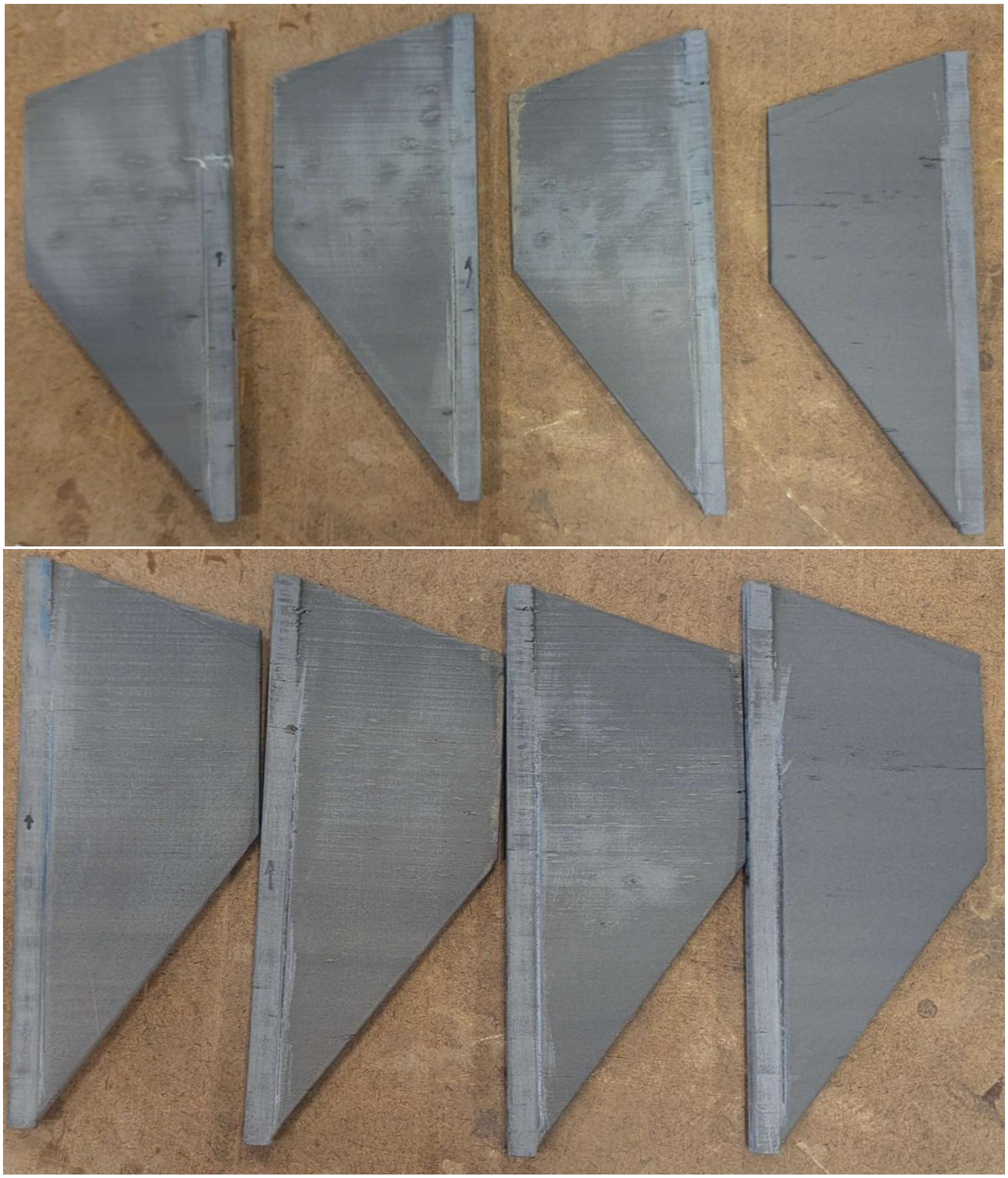


Image 5.5.4: Pre Flight images of both sides of each fin
(From Left to Right Fin Number: 3, 4, 2, 6 going into Slots A, B, C, D respectively)

5.5.2.2 Post Flight Images of the Fins

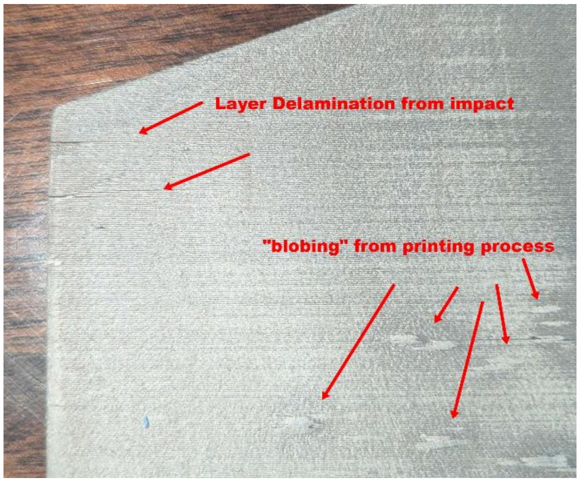


Image 5.5.5: Fin Number 3 Damage

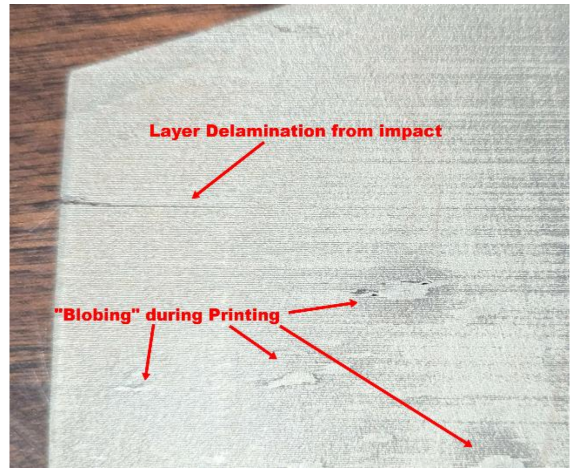


Image 5.5.7 Fin Number 2 Damage

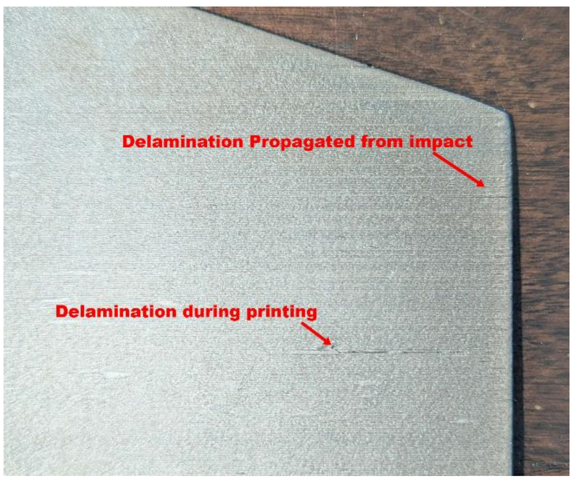


Image 5.5.6: Fin Number 4 Damage

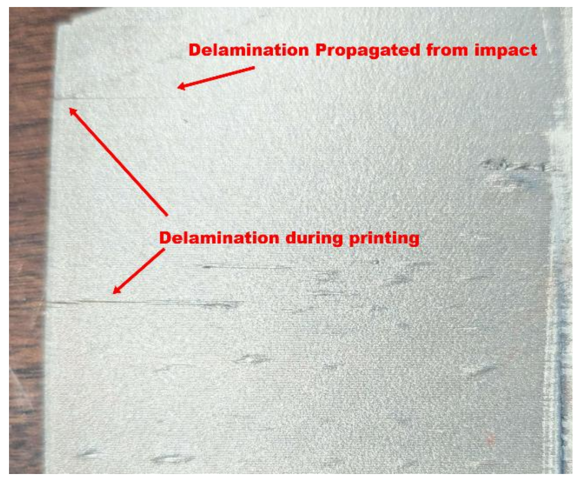


Image 5.5.8: Fin Number 6 Damage

5.5.2.5 Fin Repair and Strengthening plan

To repair and strengthen all produced fins (7 fins total: 4 Primary, 3 Alternates), a multilayer fiberglass layup will be applied to the leading edge, trailing edge, and tip of the fins to prevent further propagation of any current layer delamination and to prevent new delamination spots.

There will be 4 total layers for the layup: 6oz Tip Cover (Green), Leading Edge Cover (Blue), Trailing edge cover (red), 2 oz Tip Cover (Green). The fiberglass will be laid with West system 105 resin with the 206 slow hardener, which is what was used for the ACS flap casting and for previous fiberglass layups within the club. The leading cover will extend approximately 1/2in down, while the trailing edge and tip covers will extend approximately 1–½ inches over the fin.

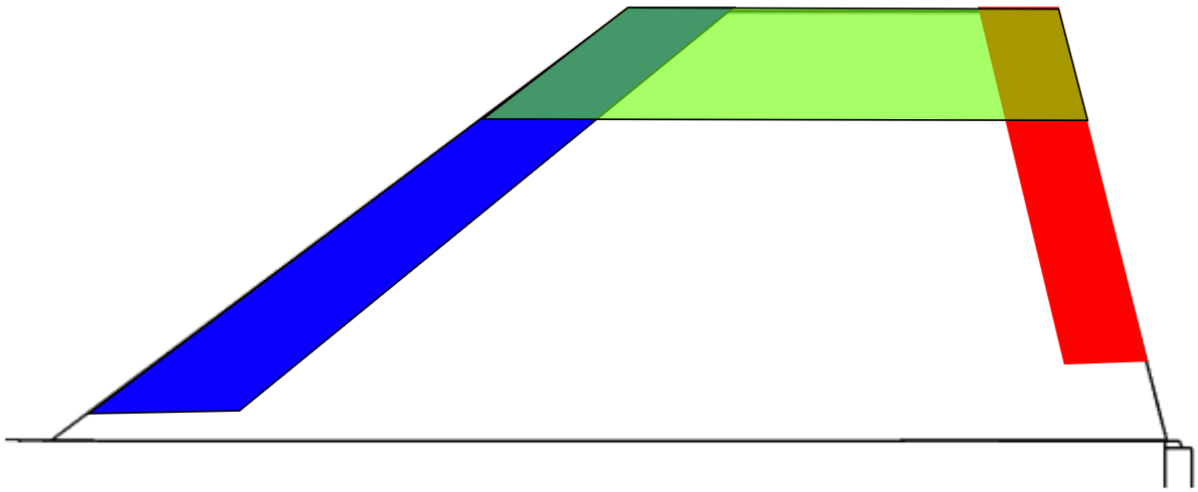


Figure 5.5.1: Diagram of Fiberglass layers for Fin Repairs (Not dimensionally accurate)

5.5.3 Damage to Service Camera Cover

The Polycarbonate film cover for the cameras suffered cosmetic damage after landing when the upper section was being lifted by the main parachute as the vehicle was dragged down wind. The film will be replaced and a complete back up (3D printed frame and film) will be made as an on-hand replacement (in total two of these covers will be available to the team on our next launch day).

Image 5.5.9: Service Camera Cover before (left) and after (right) flight

5.5.4 Damage to Main Parachute Tether

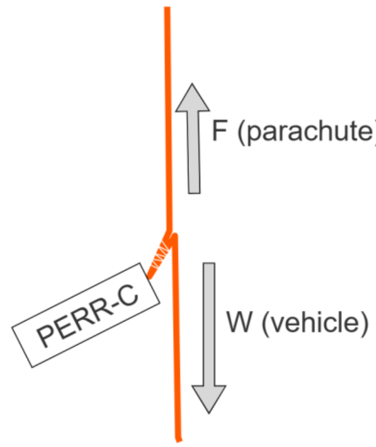


Image 5.5.10: Damage to Main Parachute Tether and mechanism of failure diagram

During the creation of the procedures for this flight, there was miscommunication that led to the main parachute and PERR-C being swapped along the main parachute tether. This switch changed how the force was being applied to the middle attachment point, so that instead of the force transferring through the nylon strap, it was transferred through the box stitches that made the loop. However, because the loop was created by folding over itself, when the quick-link was attached it would remain around the tether in the event that this happened. Allowing the Nose Cone (PERR-C) to slide down the tether rather than separate from the vehicle.

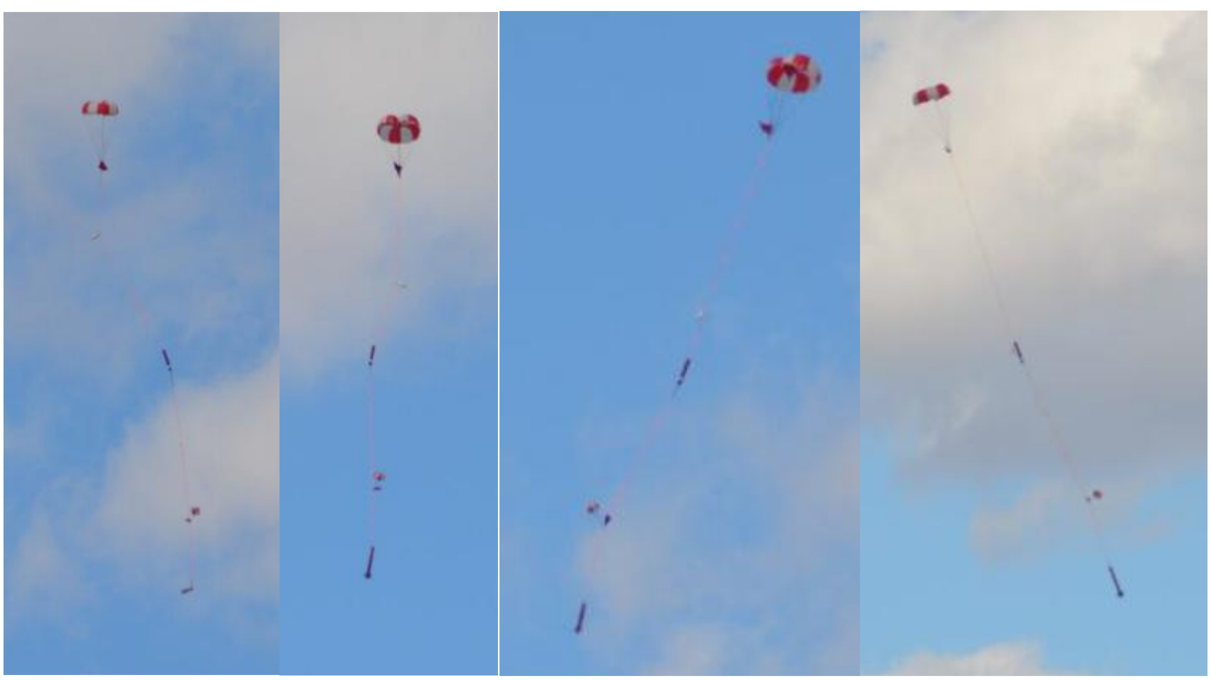


Image 5.5.11: Sequence showing PERR-C sliding down the main tether after tether failure.

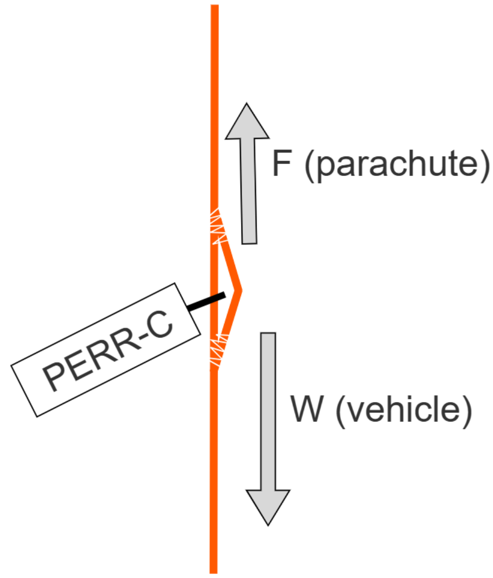


Figure 5.5.2: Proposed new Attachment for PERR-C

A side effect of this mistake was the realization that this orientation was superior to the previous configuration, as it would eliminate any tangling of the tether during descent. This new attachment also maintains the redundancy of if the stitches do fail, PERR-C will remain along the main tether, but slide down to the upper section rather than stay to its designated attachment point.

5.5.5 Damage to PERR-C internal structure

Since the primary payload was not present on this flight, additional ballast was added to the sled to simulate the mass of the logic battery, and logic board inside PERR-C. This was represented by a half-roll of pennies (approx 64g) inside the battery holder. At some point during flight, the lower edge of the battery holder broke and the roll of pennies became loose, slamming into the aft plywood framing ring, fracturing it as well. Since the battery holder is not expected to handle the entire weight of the electronics on the next flight and rather a battery weighing ~ 1/6 the mass of the ballast, only a slight modification is needed, which is increasing the layer thickness of the bottom wall of the battery holder from 2mm to 3.2mm. Seeing as the damage to the plywood ring is because of an impact, no change to the structure is necessary, but a replacement part will be manufactured.

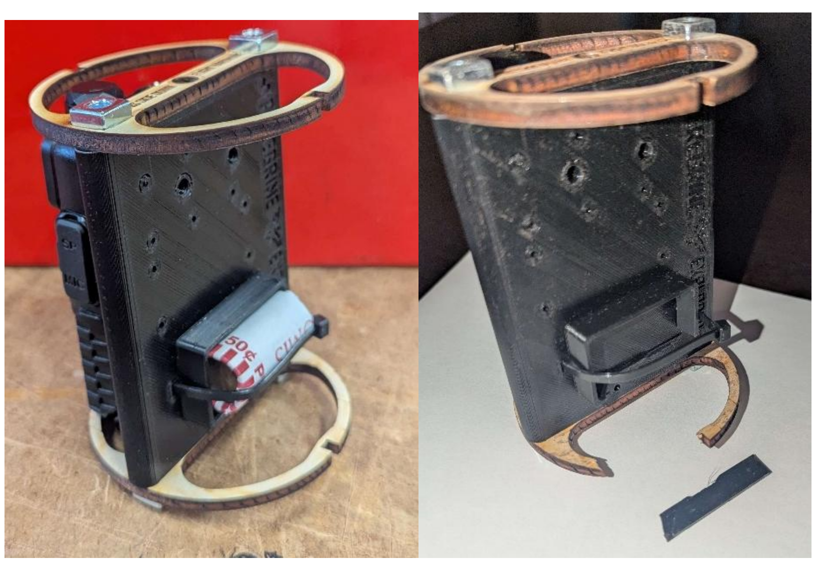


Image 5.5.12: Photos of PERR-C Sled Before (left) and After (right) Flight

5.5.6 Damage to ACS Flap Motor

After landing, when the vehicle was being dragged by the wind, the vehicle may have passed through a ditch that contained water, and the dragging motion scooped up wet soil and vegetation which leaked water into the ACS bay. This water seeped into the motor case causing an electrical fault in the motor, destroying it. Seeing as this hazard could not be avoided, we will replace the motor and hope for better conditions for recovery. Discoloration of the metal on the motor due to shorting can be seen below

Image 5.5.13: Discoloration on ACS Flap motor after electrical fault

5.5.7 PERR-C Recovery Attachment point Loose nut

The Recovery attachment point for PERR-C is a single piece of all thread with an eye-nut for the recovery attachment. This was identified as an area of risk and a jam nut was designated to be placed on the thread after the eye nut to prevent unthreading in-flight, which would result in the separation of PERR-C from the vehicle. For this flight the jam nut was hand-tightened, this was proven to not be enough. For future flights, the jam nut will be replaced by a nyloc nut or the thread will have Purple threadlocker compound applied.

Image 5.5.14: PERR-C Locknut near end of threaded rod after landing

5.6 Lessons learned

5.6.1 ACS Code

ACS code is as far as what we can tell caused the failure of ACS to deploy during flight. The reasons were explored in 4.3.2. The most immediate change is to greatly increase code performance while retaining reliability. This could be done by reducing the number of I/O operations that need to be done during flight. By creating all the necessary files to store the data while the rocket is on the pad, then using the already opened files would front load the intensive operations to before launch. Another potential change is packeting the data into groups of lines, so each text file contains 6 lines of data before moving to the next text file. This would retain an appropriate amount of data protection and reduce significantly the amount of intensive I/O operations.

For future iterations of the launch detection function it potentially could use barometric data by setting a ceiling height combined with altitude based consecutive thresholding launch could be detected in a second method using a separate sensor in case of sensor failure.

Generally, more considerations need to be made in the future for code reviews and what parts to prioritize and de-prioritize when it comes to time constraints.

5.6.1.1 ACS Code Reliability

To ensure computer system reliability and facilitate troubleshooting, safeguards will be implemented to detect when data is not being read or received correctly, as well as general coding errors that can occur before or during launch. These safeguards will include error functions and logging mechanisms. When an issue is detected, the system will display error messages to the ground station UI or log the errors on the flight computer if data is not being received. This will allow for better fault tolerance and help enhance the real-time monitoring to ensure future potential failures and errors can be identified quickly and effectively.

5.6.2 ACS Electrical/Signals

For the future, more effective communication and training about orientation and positioning of antennas and sensors will be a bigger priority, this is to ensure multiple members know how to operate on ACS in the case of the absence of a member on the payload team that does know the operation procedures.

5.7 Planned flights

5.7.1 Peregrin Explorer – Demonstration Flight 2

Target 4-5-25
Goal: Vehicle Demonstration Flight, Payload Demonstration Flight, Airbrakes Demonstration
Planned Demonstration Motor: CTI K780 Blue Streak

5.7.1.1 Mission Criteria

Demonstrate the safe and stable ascent of the launch vehicle
Demonstrate the vehicle's tracking system works throughout flight
Demonstrate the vehicle's recovery system deploys as intended
Demonstrate that the vehicle's recovery system tethers keep all sections connected
Demonstrate the vehicle is able to survive ground impact
Demonstrate that the Modular Fin system operates as designed and Survives flight
Demonstrate the vehicle completes descent in under 90s
Demonstrate that each section of the vehicle lands with less than 75 ft-lbf of energy
Demonstrate the safe actuation of the Altitude Control System (ACS)
Demonstrate that the ACS System is able to accurately control the vehicles altitude during flight
Demonstrate the Primary Payloads ability to detect launch and landing
Demonstrate the Primary Payloads ability to record flight and landing data
Demonstrate the Primary Payloads Ability to autonomously transmit all data points and automatically cease transmissions after a 2 minute durration

5.7.2 Peregrine Explorer – Demonstration Flight 3

Target 4-19-25
Goal: Airbrakes Test Flight
Planned Demonstration Motor: CTI K750 Red

5.7.2.1 Mission Criteria

Demonstrate the safe and stable ascent of the launch vehicle
Demonstrate the vehicle's tracking system works throughout flight
Demonstrate the vehicle's recovery system deploys as intended
Demonstrate that the vehicle's recovery system tethers keep all sections connected
Demonstrate the vehicle is able to survive ground impact
Demonstrate that the Modular Fin system operates as designed and Survives flight
Demonstrate the safe actuation of the Altitude Control System (ACS)
Demonstrate that the ACS System is able to accurately control the vehicles altitude during flight

6 Safety and Procedures

Safety, in all situations, is a paramount team priority. A failure could cause deadline insecurity, pose financial difficulty, and most importantly, severely hurt someone. As such, ensuring that all equipment, environments, properties, and people around the vehicle and launch area are safe is critical. Therefore, writing procedures according to the known danger of any situation is the best way to keep everyone safe at the team's scale.

List of Team Members and Responsibilities

Team Lead "Flight"	Moves team through procedure, Signs off on Critical items for Payload Systems.
Safety Officer "VSO"	Ensures safety gear is being worn, Signs off on critical items from Recovery and Structural Systems.
Operations Time Controller "OPS"	Responsible for managing time on launch day, letting the team know how long they spent on a task. Calls out time after lift-off the launch.
Payload Experiment Systems Officer "EXO"	In charge of all payload (PERR-C / ACS) systems on the rocket
Payload Antenna Operator "PAO"	Operator of the 915mhz high-gain antenna that communicates with PERR-C
Capsule Communication "CAPCOM"	In charge of communicating to PERR-C via its ground station
Structural Systems Officer "Booster"	In charge of assembly of the vehicle and inspection of the aerostructural components
Recovery Systems Officer "RECO"	In charge of recovery systems and tracking systems team. Assembles the ARCS bay.
Telemetrum Tracking Operator "T2"	Operator for the 433mhz High-gain antenna connected to Telemetrum
Telemetrum Data Relay Officer "T-DRO"	Member in charge of using the Telemetrum ground station and calling out vehicle location
RED TEAM	Group of 5 members that brings rocket to pad and prepares the vehicle for flight. Members include the safety officer, team mentor, and a member of the recovery, payload, and structures teams.

6.1 L – 1 Day: Day/Night Before Assembly Procedure

6.1.1 Hazards

In 6.1.2

No more than 2 screws from the forward bolt set can be missing for flight.

Not torquing bolts in step 7 will lead to damage on landing as fins will push them selves out if the vehicle is dragged

In 6.1.3

Missing Step 9 will lead to vehicle separation or damage to ACS flaps and linkages.

In 6.1.4

Missing Step 3 will lead to vehicle separation.

Failing to place risers in Nomex protector in step 9 may lead to burn-through and section separation.

In 6.1.5

Any step missed may result in a recovery system failure, leading to ballistic return or vehicle separation.

6.1.2 Fin Assembly

1. Start with airframe and internal fin mount. Insert fin mount and rotate until it matches the clocking on the vehicle

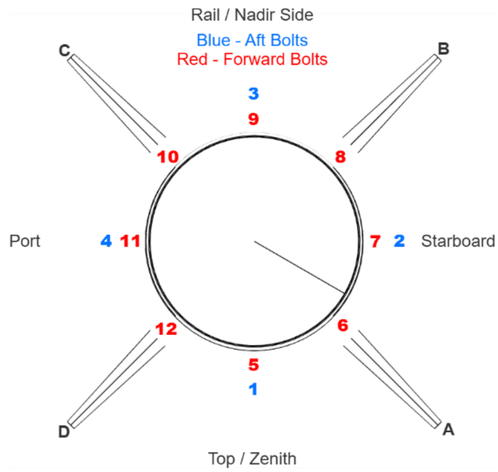


Image 6.1.1: Peregrine Explorer Booster Screw/Fin Numbering (X-axis into page, Y+ zenith, Z+ Starboard)

2. Using four (4) #4-40 x 1/2" Machine screws, begin threading the bolts, starting on the lower attachment points, **Do not Tighten**
3. Repeat for the Forward eight (8) #4-40 x ½" machine screws, **Do not Tighten.**
4. Tighten bolts all bolts **EXCEPT for 3 and 9**
5. Taking two (2) 1010 rail guides and two (2) #4-40 x 1/2" machine screws, secure the rail guides to the bottom of the vehicle (side opposite lettering if painted) in positions 3 and 9.
6. Take four (4) printed fins and slide them into the fin mount.
    a. If fin is still loose, insert a shim to pin the fin to the frame, preventing any movement, use flush cutters or a rasp to remove any excess material so it is flush with the base of the fin mount
7. Take the fin retaining ring and four(4) ¼-20 x ½" machine screws secure the fins to the vehicle.
8. If needed, use 1" wide aluminum tape to cover the gap between the root of the fin and the airframe.

6.1.3 ACS Assembly

1. Begin by loosening the screws on the Fin arms to detach the extension springs.
2. Place ACS motor assembly inside the Coupler Section.
3. Secure the motor assembly, and side panels to the coupler with six (6) M4 screws.
4. Place the Rack arms into the runner slots on the ACS motor assembly.
5. Place the cover on the rails and slide down to cover the rack and pinion assembly.
6. Take the motor leads and connect them to the ACS motor controller on the ACS electronics sled.
    a. Perform a tug-test to ensure strong connection
    b. Zip-tie the leads to the standoffs to prevent g-loading of the motor wires
7. Slide ACS Electronic sled down the rails
8. Attach the extension springs from the electronics sled to the arms of the ACS and tighten the bolt to secure the spring
9. Push the electronics sled down and secure using the aft bulkhead. Ensure both nuts are torqued tight.
10. Power-On ACS and perform health check
11. Power off ACS and check all screws and nuts
12. ACS is ready for flight

6.1.4 Lower Section Assembly

1. Take the ACS and Booster and mate them following the clocking on the vehicle.
2. Secure the sections with six (6) #4 x 3/8" Sheet Metal screws

3. Take the 8ft drogue riser and a 450lb quick-link and attach the riser to the U-bolt on the forward end of the ACS Bay
4. Take both drogue risers (16ft and 8ft), fold them in half (this creates a bight), and flatten the tether so that it has no twists.
5. Take the bight and fold it over about 3-4 inches. Continue wrapping the tether around until about 4-8” remain.
6. Secure the riser with blue painter’s tape. Repeat for the other risers.
7. Taking two (2) more quick links, feed them through the loops on the risers. The quick link in the middle will connect both risers together.
8. Take the 18” drogue parachute and 12”x12” Nomex protector place them in the middle link and close that link.
9. Wrap the drogue and risers in the Nomex protector.
10. Pass the risers and parachute through the drogue parachute bay and mate the bay to the forward end of the ACS
11. Secure using six (6) #4 x 3/8” Sheet Metal screws.
12. Place all risers and drogue parachute in the drogue parachute bay.
13. Check All Screws on the Lower Section, they should be hand tight
14. The Lower Section is ready for flight

6.1.5 ARCS Integration

1. Remove the service camera shield, arming pin, junction box door, and fore bulkhead from the ARCS frame.
2. Ensure that the screw switches within the ARCS junction box are disconnected/unscrewed.
3. Orient the service cameras such that they are stowed within the interior curve of their mount.
4. Slide the coupler tube upwards and off of the ARCS frame. The aft bulkhead should remain fixed to the ARCS frame.
5. Perform a visual inspection of the ARCS frame and bulkheads. Ensure there are no cracks in structural pieces, disconnected or frayed wires, and/or visual damage to any on-board computers and componentry. Ensure ARCS passes the visual inspection before proceeding.
6. Disconnect and check all battery voltages using a LiPo tester, ensure a nominal voltage on all LiPos in accordance with the peak voltage.
    a. If battery voltage is below the stated peak voltage, swap the battery out for a fully charged one of the same type and resecure it to the frame.
7. Reconnect all batteries to their respective connectors on the ARCS frame.
8. Close Blue Raven’s screw switch in the ARCS junction box and ensure the computer reacts with a startup twill. Once a reaction is seen, disconnect the screw switch.
9. Close Telemetrum’s screw switch in the ARCS junction box and ensure the computer reacts with a startup twill. Once a reaction is seen, disconnect the screw switch.
10. Slide the coupler tube down over the ARCS frame and align it using the visual indicators and clocking on the aft bulkhead and coupler tube.
11. Secure the XT30 parachute connectors from ARCS internals to their respective connectors on the bulkheads using the visual indicators on the connectors. Stow the excess wiring in the region above the topmost triangular frame bracket.
12. Attach the fore bulkhead to the coupler tube making sure to align the clocking before sliding the bulkhead onto the structural threaded rods.
13. Manually orient the service cameras such that they point outwards in their service configuration using the camera alignment tool.
14. Reattach the service camera shield, junction box door, and arming pin by securing them using their respective hardware.
15. When all checks are passed, ARCS Preparation is complete.

6.1.6 Upper Tether Packing

6.1.7 Main Parachute Packing

1. Take the main parachute (Fruity chutes 72” elliptical) and lay it out on a table. Nearby, lay out a 18” or 24” nomex protector
2. Take one panel and lay it flat on the table, take the next panel and fold it so it lays flat on top of the bottom panel.
3. Repeat the folding process until the parachute is in a neat rectangle and the shroud lines sit on one side of the rectangle
4. Take the long way of the parachute and fold it into thirds (1/3rds)
5. Carefully lift the parachute and place it in the middle of the nomex protector. The shroud lines should face towards the hole on the protector
6. Carefully fold the should lines onto the parachute in a zig-zag pattern. Leave enough out so that the swivel link on the parachute can attach with the nomex to the quick link.
7. Taking the upper tether, attach the parachute swivel link and nomex to the short side quick link.
8. Take the upper recovery tether. and put three (3) quick links in the 3 attachment points.
9. Using the middle quick-link as a reference, fold both sides of the tether in half to create a bight
10. From the bight, fold over to a length of 8-10” and begin to wrap until 8-12” remain.
11. Secure both wraps of the tether with blue painter's tape
12. The short side of the tether gets attached to the main parachute, middle gets attached to PERR-C, and long side gets attached to ARCS
13. Fold the parachute over the shroud lines and roll the parachute tightly.
14. Taking the corner of the parachute protector opposite of the attachment point fold the protector over the parachute
15. Take the corner directly to the left or right and fold it over the parachute, wrap the parachute in the protector like a burrito
16. The main parachute and tether are now prepared for flight

6.2 T – 3 Hours: Final Integration and Inspection Procedure

6.2.1 Hazards

In 6.2.2

Steps 1-4 require Eye Protection during testing and integration of Ejection Charges.

In 6.2.9

Gloves are required; eyewear is recommended.
Flames and live batteries should be kept away during this section to prevent accidental ignition. Igniters should never be installed while rocket is stored. Disconnect ignitors if the rocket is to be stored. Shunt must be placed on igniter until rocket reaches the pad. If said shunt is missing, twist exposed igniter cables together multiple times.

6.2.2 Ejection Charge Installation and Upper Section Integration

1. All team members within a 15ft radius of the ARCS section of the vehicle need to put on eye protection
2. The ejection charges will then be removed from their protective case and tested for continuity using a multimeter
    a. Nominal ejection charge resistance of the Wildman WM-02 ejection charge ignitors are 1.5 – 4.5 Ohms
3. The Team Mentor will then attach the respective ejection charges into their respective WAGO connectors on the outer surfaces of both the fore and aft bulkheads using the etched labels as a guide:
    a. Fore bulkhead: Primary and Redundant Main parachute charges as indicated.
    b. Aft Bulkhead: Primary and Redundant Drogue parachute charges as indicated.

4. With the Ejection Charges attached, ARCS should not be powered up to avoid accidentally energizing the ejection charges
5. Attach the quick link with the main parachute shock cord onto the fore bulkhead's U-bolt and tighten it down.
    a. Ensure that the quick link and attached shock chord pass through the upper fuselage, going in the fuselage's fore side and out its aft side.
6. Tighten the quick link shut and pull on the shock cord to make sure it has good connection with ARCS' fore bulkhead U-bolt.
7. Insert the fore side of ARCS into the aft side of the upper fuselage. Ensure that the parachute cord does not get pinched between the ARCS coupler tube and the upper fuselage when inserting.
8. Using the clocking on the ARCS coupler switch band and upper fuselage, align the two sections by rotating them inside one another.
9. Secure the two sections together by inserting and tightening screws into all the now-aligned holes in the upper fuselage.
10. Once all screws are inserted, tighten them down.
11. Once all screws are tight, Upper Section integration is now complete.

6.2.7 PERR-C Programming and Inspection

1. Unscrew the set screw from the nosecone forward section and unscrew the nosecone
2. Remove the flight deck and Crew.
3. Un-install the nut on the forward closure nut and remove the contents of the Service Module
4. Turn on the BaoFang UV-5R and set the channel to the designated channel by NASA Staff
5. Replace the Service Module Frame and secure the system with the nut on the forward bulkhead
6. Replace the Flight Deck and Crew
7. Close the Nose cone until its hand tight and secure it using the set screw(s)

6.2.8 Final Vehicle Integration

1. Take open quick-link from main parachute riser and attach it to the Eye-nut on the back of PERR-C
2. Insert PERR-C shoulder into main parachute bay and rotate until clocking lines up.
3. Take two #2-56 nylon shear pins and cut them so they are less than 3/8 in long
4. Attach PERR-C to the main parachute using both shear pins
5. The upper section is now integrated with PERR-C
6. Take the open quick link from the drogue riser and connect it to the aft U-bolt of ARCS and tighten it
7. Insert ARCS into the drogue parachute bay and rotate until the clocking lines up
8. Take two #2-56 nylon shear pins and cut them so they are less than 3/8 in long
9. Secure the upper section to the lower section using the shear pins.
10. Check all external screws: PERR-C Shear pins, ARCS forward attachment, ARCS Shear pins, ACS forward and aft attachment, Booster fin mount attachment and Rail guide bolts to ensure they are tight.
11. The vehicle is now assembled.

6.2.9 Motor Preparation and Integration

CTI Motor Assembly

1. Put on nitrile or other style of disposable glove meant for use with chemicals, eyewear is optional but encouraged
2. Inspect casing of motor for damage. If the casing is damaged, replace and discard. Modifications to casing can cause potential personal or property injury.
3. Leave protective cap on until prompted to remove.

4. Reloads mainly use one O-ring per closure but potentially may use two if required. Check forward and rear closures for properly installed O-rings. DO NOT PROCEED IF O-Rings ARE DAMAGED, instead contact Pro54 Dealer.
5. Apply a light film of silicone to the O-rings to the inside edge of casing. This is where the load casing is inserted.
6. To the forward end, insert the delay/ejection module. A small gap is present between the forward end and the shoulder is normal.
7. Remove the Forward end from the reload
8. Using a hobby knife, remove the white cap from the ejection charge well
9. Pour the 4F black powder into a container for use in vehicle ejection charges
10. Seal ejection charge well from the delay grain by using epoxy, Thick CA glue and paper, or a screw and O-ring
11. Re-seat the Forward closure onto the reload
12. Insert the reload kit into casing. The forward closure is first. Some resistance to O-rings will be present, ease this by placing the nozzle against the smooth surface and push carefully until completely inserted. Be careful not to damage nozzle.
13. The nozzle should be flush. If not, remove the motor kit and investigate.
14. Begin to remove the nozzle cap. Screw retaining ring onto rear of motor casing until feeling tightness on the casing. It should be snug against rear closure. Do not overtighten, hand use is fine. Cap will rotate 3-¾ urns to full seat against case and 3 turns to engage. Reinstall cap of nozzle.
15. The motor is now ready to be installed. **Do not install igniter until on the launch pad.**

Aerotech Reloadable Motor integration

1. Put on nitrile or other style of disposable glove meant for use with chemicals, eyewear is optional but encouraged
2. Take Aerotech RMS 54/2560 Case, Forward Seal Disk (FSD), Forward Closure, Aft Closure, Reload kit, and super lube and secure a clean area to assemble motor
3. Open the motor reload and open all packages, put the ignitor into a pocket and place any black powder to the side or in an energetics container
4. Forward Closure and Delay Grain assembly
    a. Take the Neoprene disk washer and place at the forward end of the forward closure delay grain hole
    b. Apply a small grain of super lube to a finger and lightly grease the inside wall of the forward closure delay grain hole. **DO NOT GREASE THE AFT FACE OR NEOPRENE WASHER**
    c. Apply a light coat of grease to the o-ring on the delay grain so that it is not dry
    d. Place the delay grain O-Ring side out into the forward closure
    e. Apply a light coat of super lube to the threads of the forward closure
    f. If not using the motor ejection charge with a open forward closure, apply a bead of grease over the hole passing through to the delay grain and cover the opening with blue painters tape, cover using a cross pattern then wrap a strip around the ends of the tape
5. Taking the small o-ring, apply a small amount of grease so that it is not dry and place into the groove on the FSD
6. Place FSD into the phenolic liner of the motor reload
7. Apply a small amount of grease to your palm and lightly grease the outside of the motor liner
8. Place motor liner and propellant grains into the casing
9. Taking one of the large o-rings, lightly grease it so it is not wet and place on the aft groove of the forward closure
10. Screw forward closure onto the side of the case with the FSD
11. Place nozzle into aft end of the casing
12. Taking the last O-ring, apply a light coat of grease so it is not wet, and place on top of the nozzle
13. Grease the threads of the aft closure and screw into the casing
14. Place cap back on nozzle (if removed)
15. Aerotech RMS motor is now Integrated.

Integration into the vehicle

1. Remove the motor retention ring from the vehicle
2. Insert the motor into the motor mount tube
3. Check to see if the thrust ring on the casing is flush against the motor retainer
4. Re-install the motor retaining ring on the vehicle

All protective gear can be removed.

6.3 T – 30 Minutes: Vehicle Arming Procedure

6.3.1 Hazards

Starting in Section 6.3.4 Anyone on the Pad must wear protective eyewear until they are at least 25 ft away as energetics are going live.

IN 6.3.5 All members at the pad are to retreat to 50ft

6.3.2 Installation on Launch Rail and Going Vertical

1. Set Launch Rail to horizontal position and lock (if available) in position
2. Slide Vehicle onto rail ensuring all rail buttons, slide vehicle down to launch stool (typically a rod or angle bracket that the rocket will sit on)
3. Remove all protective coverings (if Necessary) **DO NOT REMOVE ARCS ARMING PIN.**
4. Unlock launch rail and raise to vertical position
5. Secure Rail and remove any protective coverings from vehicle

6.3.3 Vehicle Power-Up and Telemetry Check

1. **CAPCOM:** ensure that PERR-C Ground station is on and set to right channel and settings
2. **PAO:** Aim Antenna at vehicle and confirm antenna is connected to PERR-C Ground Station
3. **RED TEAM:** Turn on Screw Switch for PERR-C, wait for confirmation from vehicle and CAPCOM.
4. **T-DRO:** Ensure that "altOS" is on for both the low-gain and high-gain antenna computers. Check frequencies and callsigns to verify that the ground stations will connect to ARCS.
5. **T2:** Aim antenna at Vehicle and confirm antenna is connected to Computer running AltOS.
6. **RED TEAM**: Open "FeatherWeight Altimeters" app on phone.
7. Open ARCS Junction box by removing the single outer screw and sliding the door along the arming pin. **DO NOT REMOVE THE ARMING PIN AT THIS TIME**. Rotate the junction box door about the arming pin to expose the screw switches.
8. Turn on Screw Switch for Blue Raven, wait for Blue Raven's startup twill and continuity beeping.
9. Using "FeatherWeight Altimeters" app, verify that Blue Raven has all the correct settings programmed in accordance with the Flight Sheet.
10. In the junction box, power Telemetrum on using the Telemetrum screw switch, wait for Telemetrum's startup twill and continuity beeping.
11. Using team GMRS radio, contact T-DRO to confirm telemetrum radio connection to the team ground station.
12. In this state: both telemetrum and Blue Raven Should Report **NO EJECTION CHARGES CONNECTED**, confirm before moving on to next step.
13. Tighten down all screw switches once more. Slide the junction box door back into place on the junction box and press until it clicks into place.
14. Secure the junction box door in place by tightening down the single outer screw.

6.3.4 Parachute Ejection Arming Procedure

1. With Vehicle confirmed on and connected. Don Protective eyewear.
2. Unscrew the Arming pin to unlock it from the vehicle.
3. Remove the Arming Pin. All parachute ejection charges are now physically connected to the computers.
4. Both Computers should beep continuity checks.
    a. Blue Raven
        i. Continuity check order is APO, MAIN, 3rd, 4th
        ii. High Beep Voltage > 3.80V, Low Beep Voltage < 3.80V
    b. Telemetrum
        i. No ignitors: ½ second tone
        ii. Apogee Only: 1 beep
        iii. Main Only: 2 beeps
        iv. Both: 3 beeps
5. Using the featherweight app, check if Blue Raven is showing continuity on "APO" and "MAIN" lines.
6. Using team GMRS Radio, contact T-DRO to check if Telemetrum is transmitting telemetry.
7. Using team GMRS Radio, contact T-DRO to check if Telemetrum is showing continuity on "APO" and "MAIN" lines.
8. If continuity checks (step 4-7) are good, the vehicle's recovery system is now armed and ready for flight.
9. If there is an issue with continuity checks move to section 5.5.3

6.3.5 Motor Arming Procedure

1. **ONLY PROCEED IF THE VEHICLE RECOVERY SYSTEM (ARCS) IS ARMED AND A FINAL GO / NO-GO POLL HAS BEEN CONDUCTED.**
2. Unfurl the motor ignitor.
3. Strip the end of the ignitor lead and twist leads together, this prevents any static electricity from traveling up the wire to the ignitor.
4. Take ~18in of ignitor lead and begin to feed ignitor into the center bore of the motor grains. Feed until resistance is felt.
5. Secure Lead into motor, either by the motor cap, a piece of blue tape lightly placed on the bottom of the nozzle, or wrapped around a standoff on the launch pad
6. Take Launch Controller leads, tap the alligator clips together to check for residual current. Residual Current will result in small sparks being produces when the clips are touched together.
    a. If residual current is noticed **YELL STOP**, Proceed to 6.7.8

7. Untwist ignitor leads, take an alligator clip and clip one lead of the ignitor, wrap any remaining wire around the clip to increase contact area. Repeat for 2nd Lead.
8. The vehicle is now fully armed and ready for flight, RED TEAM retreats from Pad.

6.4 Flight and Recovery Procedure

6.4.1 Hazards

In this section, the vehicle will be in flight, this is truly the time where anything that could go wrong, will go wrong, team members should have reviewed the emergency procedures prior to launch as most scenarios are time-sensitive to the point where procedures are no longer able to be followed, and instead must be memorized.

6.4.2 Final Checks Before Launch

Before launch the team should monitor weather conditions (i.e. using pivotal weather to check weather soundings in the area for wind conditions at altitude) and continuing to monitor Telemetrum and PERR-C for periodic health checks to ensure vehicle remains ready for flight.

6.4.3 Roles During Flight

As boost and ascent only last 20 seconds, roles must be kept simple, and they are. There are 2 general roles: Callers and Trackers.

Callers are CAPCOM, T-DRO, and OPS. As stated in their roles they say their respective data out loud.

OPS: Calls the time after launch every 10 seconds
CAPCOM: Calls any data imperative to the success of the mission
T-DRO: Calls the altitude on Ascent, Apogee, then Altitude and Azimuth during descent for T2 and PAO

Trackers are everyone else. It is recommended that trackers pair up in 2s and 3s so that in the event of a break-up, groups can track individual sections according to emergency procedure 6.7.2B and 6.7.3.

6.4.4 Landing and Payload Mission Procedure

Landing Determination:

1. Visual / Telemetry confirmation that the vehicle has landed or
2. Reasonable time has passed since loss of signal on descent or
3. 5.5 minutes since launch if loss of signal occurs on descent or at apogee with no confirmation of drogue deployment (Ascent time + Main Parachute Deployment at max apogee)

Payload Mission Procedure

1. According to NASA's rules, the team may take no action to activate the data transmission from the STEMCraft
2. The payload has a 2-minute timer after which transmissions will automatically cease
    a. In the event that transmissions do not stop or NASA requests it be stopped early, the stop command will be sent VIA ground station by CAPCOM (section 6.6.2)

6.4.5 Recovery Procedure

Approaching the vehicle (If location is unknown, follow search procedures in section 5.5.10

1. **REDTEAM:** Walk to within 30ft of the vehicle and then don protective eyewear
2. Using AltOS phone app and Featherweight Altimeters app, connect to both computers to determine state of ejection charge continuity on all 4 charges
    a. If a charge is still connected proceed to section 5.5.9 to isolate live charge
3. Reinsert arming pin into ARCS to isolate the ejection charges.
4. Open the junction box on ARCS to turn off both flight computers

6.5 T + 1 Hour: Post-Flight Procedure

6.5.1 Initial Motor Disassembly

1. Unscrew the motor retainer from the motor mount and remove the casing from the rocket
2. Unscrew the aft closure from casing.
    a. **FOR CTI:** Push forward closure with plastic or wooden piece to eject reload assembly from casing. Be careful not to dent/scratch/damage the casing. DO NOT USE METAL TOOLS.
    b. **FOR AEROTECH:** Remove Forward closure from the casing and using finger pull the forward seal disk out of the liner, if liner is not removed, use finger or a screw driver wrapped in a paper towel to push the liner out enough to grab and remove.
3. Using a Isopropyl alcohol wipe, clean the threads of the casing of residue and debris.
4. If the casing is to be reused within a close time frame, check for residue and remove it if needed. Store motor casing in original packaging when not in use.

5. To prevent damage, it is recommended that the closures are fitted to casing during storage. This is to protect threads.
6. As of this time the casing is still dirty and needs to be cleaned further for long-term storage.

6.5.2 Quick Cleaning of Vehicle From Combustion Byproducts

1. To clean the vehicle members should be wearing eye-protection and nitrile gloves
2. Using IPA wipes and rags, clean the hardware that has been exposed to the ejection charges
3. Using a small screwdriver, the broken shear pins should be removed from the vehicle and discarded

6.6 Troubleshooting Procedures

6.6.1 PERR-C GPS Fails To Lock

1. If the GPS on PERR-C fails to lock after 60s a clock update may be required
2. **CAPCOM:** using PERR-C ground station, send command “CLK” + the current time in Unix Epoch to reset onboard Real Time Clock for the GPS

6.6.2 PERR-C 2M Radio Transmission Fails To Stop

1. After 2 minutes the 2M radio transmission for the mission goal should automatically stop
2. In the event that it doesn’t the **Flight, VSO, EXO, and CAPCOM** will work to determine if the vehicle is in a loop, or other cause of failure
3. The command “2MRS” will be sent VIA ground station to halt transmissions

6.6.3 ARCS Computer Fails To Detect Ejection Charge After Arming Pin Removal

1. Check FeatherWeight Altimeters app to see if Blue Raven Beeps are disabled or if the voltages on the APO and Main Lines are above 3.8V
    a. If Bluetooth is not able to connect, check the screw switch to make sure the switch is closed and tight
    b. If voltage is below 3.8V but above 3V the ejection charge is likely a dud, move to step 3, if issue does not resolve remove vehicle and replace ejection charge at flight line.
2. **REDTEAM:** Call T-DRO to verify that the RSSI and packet age are both nominal values for on the pad for telemetrum
    a. If telemetry does not connect, check the screw switch to make sure it is closed and tight
    b. If telemetry is connected on AltOS software go to table tab and look a the bottom of the first column pair to check voltages, if voltages are good but continuity is not beeping, move on to step 3
3. ARCS Restart without arming pin
    a. With arming pin removed, open the faulty computers screw switch and wait 10 seconds
    b. Close screw switch and wait for it to run through start-up self-test
    c. If the issue resolves, add note to flight log and continue to flight
    d. If the issue persists:
        i. Continuity is detected but voltage is low (i.e Batt volt 4.2V, Line volt 3.85V)
            1. The decision to fly can be made by the team only if the faulty charge is on the Main Primary Charge
        ii. All other scenarios
            1. Safe the vehicle and remove from the pad to replace the offending charge and check internal wiring

6.6.4 Launch Misfire

1. When a misfire is identified yell “MISFIRE”.
2. If continuity is still maintained on the ignitor the LCO may attempt the launch again, holding the command for 3-6 seconds.

3. The team will remain in awaiting launch conditions since the motor could still ignite and the vehicle could launch
4. After a second launch attempt, or if continuity is lost, the range will wait for 60 seconds to wait out any slow burning propellant.
5. The team will then recover the vehicle from the pad and proceed to section 6.6.5 to safe the vehicle on the pad, then reverse the procedure of motor arming to disarm and replace the ignitor.

6.6.5 Safeing Vehicle On Pad After Failed Launch Attempt

1. Approach the vehicle with eye-protection
2. Carefully disconnect the motor ignitor from launch controller and twist the leads
3. Insert arming pin into ARCS and twist to lock
4. Remove the motor ignitor from the rocket motor carefully
5. The vehicle is now safe and can be worked on or removed from pad

6.6.6 Vehicle Drifts Outside of LZ

1. If the vehicle is believed to drift outside the LZ, contact the RSO and ask for their steps on how to recover the vehicle
2. Common steps are going to the house the property is believed to be on and asking to enter their property to recover the vehicle.

6.6.7 Live Ejection Charge (Open Parachute Bay)

1. Protective eye wear is required for this procedure.
2. If the charge is visually confirmed to be unfired **OR** If Blue Raven or Telemetrum are showing continuity (or voltage above 3.5v) across a charge, the charge is to be treated as **LIVE.**
3. Remove the ARCS junction box cover, place the arming pin through the hole on the cover, and insert the pin into the vehicle.
4. Check voltages again, if voltages persist, the computer is either in a frozen state or wiring inside the vehicle has been damaged.
5. Power off all computers.
6. If drogue charge, move to step 9
7. If main charge, begin unscrewing forward attachment bolts from ARCS
8. Remove main parachute bay
9. Remove charge from WAGO connector
10. Twist leads together and cover with blue painter’s tape or electrical tape and place into a Ziploc bag to secure it.

6.7 Emergency Procedures

As these procedures are extremely time-sensitive, members should review these procedures before any activity that involves testing the vehicle. Many of these require PPE and all present hazards to personnel.

6.7.1A Catastrophe After Take-Off With No Vehicle Breakup

1. Depending on the severity of the failure, a “heads-up” callout may be needed, if debris could fall near the flight line
2. The team should continue to track the vehicle and monitor for recovery system deployment
3. In the event of vehicle break up move to section 6.6.2B or 6.6.3, after landing proceed to section 6.7.6

6.7.1B Catastrophe After Take-Off Vehicle Causing Major Vehicle Break-Up

1. Team members should try to point at different sections of the vehicle. At most the vehicle should break up into 5 sections that can be considered harmful. Shrapnel and small debris produced from a violent break up will likely not be visible at that distance.
2. In the event that sections of the vehicle are heading to the flight line, yell “Heads Up!” and point to the debris poising the hazard.
3. If the debris is heading towards you, take action to avoid the debris, ideally by moving left or right.

6.7.2 Vehicle section separation

1. Team members should be pointing at the main vehicle, if separated, pairs of team members should communicate to start tracking all sections of the vehicle.
2. In the event that sections of the vehicle are heading to the flight line, yell “Heads Up!” and point to the debris poising the hazard.
3. If the debris is heading towards you, take action to avoid the debris, ideally by moving left or right.

6.7.3 Ballistic Return

1. Team members should maintain a visual and pointing towards the vehicle so that others may find it.
2. A ballistic return is when the apogee deployment does not deploy, and will be called if an event is not noticed within 24s of launch.
3. In the event that sections of the vehicle are heading to the flight line, yell “Heads Up!” and point to the debris poising the hazard.
4. If the debris is heading towards you, take action to avoid the debris, ideally by moving left or right.
5. If the emergency deployment from blue raven occurs, continue to track the vehicle and move to 5.6.9
6. On confirmed impact with the ground or time exceeds 90s since launch, move to section 5.6.10 to locate vehicle
7. Approach vehicle with fire suppression equipment. Follow Sections 5.6.6, 5.6.9, and 5.6.14 when approaching the vehicle

6.7.4 Recovery system failure (non-ballistic)

1. If the drogue parachute shreds, or main parachute fails to open call it out and point to the vehicle so others can locate it.
2. If the main parachute fails to deploy, or is destroyed, the vehicle will land hard and will likely be damaged.
3. The team will watch the vehicle intently looking for signs of fire or other distress from the vehicle
    a. If the vehicle catches fire alert the RSO and move to 6.7.6.
    b. When the RSO Opens the range for recovery approach the vehicle with caution and follow 6.7.9 if a parachute bay is closed.

6.7.5 Fire in the Launch Range

1. If a fire is noticed, immediately alert the Safety Officer and Team lead.

   a. Note: Where there is smoke there is fire. By the time vehicles have landed all smoke trapped in parachute bays or the Smoke charge of the rocket motor should have burned out, so any smoke coming from the vehicle after landing should be assumed as a fire on-board.
2. If a fire is confirmed the Team Lead or Safety Officer will contact the RSO
3. In this scenario, the common fire is a grass fire. All HPR launches are required to have Fire Suppression gear on hand, these are commonly pump-sprayers, rakes, brooms coated in in fire retardant, and fire extinguishers.
4. When combatting a grass fire, conditions can change quickly, members should keep their head on a swivel and look for any embers starting secondary fires.
5. Members can use shoes to stomp out fire, however this is not recommended if they are wearing running shoes.
6. At any point, if the fire is not contained within 10 minutes or if the water supply is running low, the RSO or Safety Officer should Call 911 to report a grass fire.
7. If the vehicle is involved, Follow the steps in 6.7.7B

6.7.6A Personnel Near Vehicle on Fire

1. Personnel Should Immediately clear a distance of at least 100ft, do not help any injured parties at this time, self-extrication is the priority.
2. Wait at least 30 seconds before attempting to approach the vehicle. Work with RSO and other range personnel to determine when to approach
3. Extricating of personnel from the pad
   a. If personnel are withing 30ft of the fire, approach the fire from upwind, the smoke and combustion products are hazardous to breathe in, get low to reduce contact with smoke.
   b. Drag injured or unconscious personnel directly away from fire, provide the best medical care possible and call 911
4. After Personnel are extracted, move to section 6.6.7B

6.7.6B Vehicle on Fire

1. Wait sufficient time as to let hazardous materials burn off, at least 30 seconds
2. Approach vehicle cautiously, as the chance for hazardous material may still be present
3. Combating fire
   a. APCP, Black Powder, and Lithium Battery[1] Fires cannot be extinguished and produce toxic byproducts[2]. **DO NOT ENGAGE PROPELLANT FIRE.**
   b. Wait until any Hazardous Material fire to burn out before approaching with Fire Suppression Equipment. CO2 Extinguishers are preferred, followed by Water, Class-A or AFFF foams, then Dry Chemical[3]
   c. By the time you can approach the vehicle it is likely a total loss, fire suppression is to prevent spread, do not try to save the vehicle.
   d. Let the vehicle burn-out. Only approach once the vehicle has cooled. Use Fire suppressant to prevent fire spread through the grass.
   e. Avoid using water on the vehicle as corrosive byproducts from the combustion are produced.

6.7.7 Launch Controller has residual current

1. Yell "STOP”.
2. Twist motor ignitor leads together to safe the ignitor and secure the ignitor to the rocket with tape, using tape to cover the leads.
3. Hail the LCO to check the launch controller.

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[1] Lithium Fires can be extinguished, however, they require full body PPE and copious amounts of fire retardant.
[2] Common combustion byproducts are LiOH, HCl, SO_x, and NO_x compounds which become corrosive when in contact with water (e.g in lungs or eyes).
[3] Dry Chemical Extinguishers are effective; however they are lung irritants and could be harmful to plant life, which is why water is the primary option.

4. Resume motor arming once issue has been resolved.

6.7.8 Live Ejection Charge (Closed parachute bay)

1. Upon approaching landing zone, the red team will hold off at 30 ft from the vehicle. And all members at the vehicle will don eye protection.
2. The team mentor and Safety Officer will approach the vehicle and quickly insert the arming pin into the ARCS system.
3. The Safety Officer and Team mentor will then unscrew the radial bolts or shear pins that close the parachute bays on either side of the ARCS bay.
4. Once the bulkhead is exposed and the ejection charges are in sight, they are inspected to determine if they are still live.
    a. If the charges are spent, then the team can continue on normally in recovering the vehicle.
5. The Team Mentor will do a pull test on the ejection charge leads to determine if they are still connected to the flight computer leads
6. The live ejection charge will then be removed from the bulkhead
7. Twist leads together and cover with blue painter's tape or electrical tape and place into a Ziploc bag to secure it.

6.7.9 Searching for vehicle after LOS

Downwind Distance from time remaining and windspeed				
Est. remaining descent time	5 MPH	10 MPH	15 MPH	20 MPH
25s	185	365	550	735
35s	255	515	770	1025
45s	330	660	990	1320
55s	405	805	1210	1615
65s	475	955	1430	1905
75s	550	1100	1650	2200
85s	625	1245	1870	2495

Table 6.7.1: Drift table to determine search grid in emergency scenarios

Drawing of the Search Grid

1. From the last Known GPS Location, Draw a line along the wind vector. Use the drift table.
2. At the last known GPS Location, draw a circle with a radius of 150ft or 15% of the drift distance, whichever is greater
3. At the end of the downwind vector, draw a circle with a radius of 300ft or 30% of the drift distance
4. This should create a cone that the vehicle is likely to land in
5. To search for the vehicle, all team members should create a line, with members starting at 20-30 ft apart, while walking down the grid, team members should spread out to no further than 50ft
    a. If the vehicle or section, came in ballistic or in separate sections, it is recommended that the search gird is tighter as the vehicle will have a smaller visual profile.
6. **T2:** Using the AltOS app, connect to the TeleBT receiver for Telemetrum to bring the low-gain 433mhz antenna to the search grid to aid in locating the vehicle.

    433mhz Antenna is a line-of-sight frequency, if terrain is blocking a direct line between the receiver and vehicle data packets will not be received or the signal strength will be greatly diminished.

6.7.10 The vehicle lands on a power line

1. If the vehicle lands on a power line, do not attempt to recover the vehicle
2. Contact the local electrical service to request a team of linesman to recover the vehicle

6.7.11 Lithium Battery Fire on flight line before vehicle integration

1. If the battery has rapidly puffed but not ignited yet, attempt to quickly release battery from vehicle
2. If the battery is not attached to a section of vehicle toss it quickly away and **YELL FIRE**, try to toss it away from people and not at people
3. If an appropriate extinguisher (Class D) is available you can attempt to extinguish the battery
4. If you are not able to remove the battery quickly and it catches fire immediately back away from the system and let it burn

6.8 Vehicle Inspection and Sign Off / Accountability Sheets

The following pages have the inspection guide sheets for the vehicle at different stages of assembly, integration, arming, and recovery. There will be 3 two-sided sheets for each launch. Vehicle Integration Inspection Sheets A and B run through Sections 5.1.2 to 5.1.7 Which is the majority of vehicle integration. Each Sheet splits responsibility and allows for parallel assembly to occur with the vehicle, the Safety Officer and Team Lead will oversee one half of the assembly. The Vehicle Launch and Recovery Inspection Sheet covers Sections 5.1.8, all of 5.2, 5.3.5, and 5.3.6, which is the final integration checklist, and both pre and post-flight inspections. The Sheets feature a location for a member to sign off and write down the time of completion

6.8.1 Vehicle Integration Inspection Sheet A – Payload Systems

PEP Inspection

Are all wires connected and secured to the frame		
Are the Batteries secured to the frame?		
Are the Batteries full (4.2V, 8.4V or 12.6V)?		
Are the batteries healthy, showing no signs of puffiness?		
Is the 2M Radio set to frequency: ___________		
Is the 915MHz Radio set to frequency: ____________		
Has the system connected to the ground station and reported healthy Prior to integration?		
EXO Sign-Off		
Safety Officer / Team Lead Sign-Off		

PERR-C Inspection

Are both bulkheads structurally sound, showing no signs of fatigue?		
Is the eye-nut and jam-nut on the aft end tightened down and threadlocked?		
Is the service module frame (sled) secured to the rail?		
Is the forward bulkhead secured with a locknut?		
Is the Fight deck secured to the System, are the crew strapped in?		
Does the 3D printed airframe show any signs of fatigue?		
Are the set screws installed and tight?		
EXO Sign-Off		
Safety Officer / Team Lead Sign-Off		

ACS Integration

Does the structural elements of the air braking system appear intact and show no signs of fatigue?		
Are all screws and nuts on the deployment system snug?		
Are the Aerodynamic surfaces intact and show no cracks?		
Are the electrical systems secure, connected soundly, and tied down?		
Does the airframe section pass a visual inspection? Are the forward and aft mounting holes intact and showing no sign of damage?		
Are the bulkheads intact, showing no signs of fatigue?		
Is the forward U-bolt intact, showing no signs of fatigue? Are all retaining nuts on the U-Bolt?		
Are all nuts closing the bulkheads present and tight?		
EXO Sign-Off		
Safety Officer / Team Lead Sign-Off		
Team Mentor Sign-Off		

Payload Systems Final Inspection

Has PERR-C passed pre-flight start-up testing?		
Has PERR-C passed pre-flight inspection?		
Is the 2M radio set to frequency:______________		
Is the 915MHz radio set to frequency:_____________		
Has ACS passed pre-flight start up testing?		
Has ACS passed flap actuation test?		
CAPCOM Sign-Off		
EXO Sign-Off		
Safety Officer / Team Lead Sign-Off		
Team Mentor Sign-Off		

6.8.2 Vehicle Integration Inspection Sheet B – Vehicle Structures and Recovery Systems

Booster Inspection

Using a flashlight, inspect the visible sections of epoxy on the motor mount for any cracks or other signs of fatigue?		
Are the rail buttons present, secured using #4 screws, and showing no signs of damage?		
Are the edges of the fins intact, is there any sign of damage to the fins?		
Has the Fin Retention Ring been attached, is it hand-tight?		
Can all 12 fasteners for the fin can installed and secured?		
Are the fins securely installed in the vehicle? (Do they wobble when pushed?)		
Are the holes for the forward attachment points intact and showing no signs of fatigue?		
Booster Section Leader Sign-off		
Safety Officer / Team Lead Sign-Off		

ARCS Inspection and Integration

Are all internal wires to the computers secured in their terminals, connectors, and tie-downs?		
Have the Service Cameras been Adjusted into flight position and been secured?		
Are flight batteries charged and in healthy condition (4.2V or 8.4V)?		
Is Blue Ravens Battery Secure, does the computer power on and report healthy?		
Is Telemetrum's battery secure, does the computer power on and report healthy?		
Are the bulkheads showing signs of structural fatigue, are both nuts present on the back of the U-Bolt?		
Does the airframe section show any signs of fatigue?		
Are the forward and aft bulkhead rails secured by nuts, are they torqued down?		
Recovery Section Leader Sign-Off		
Safety Officer / Team Lead Sign-Off		

Motor Assembly and Integration

Motor Date Code:		
Does the motor packaging show any signs of damage or holes, has the propellant been exposed to water?		
Does reload come with all materials: Closures, O-rings, Liner?		
Are the O-rings in good health, are they dry / cracked?		
Has the ejection charge been removed, and the hole to the delay grain been filled?		
Are all closure rings secured and tight?		
Has the Motor Retaining ring been attached, is it hand-tight?		
Safety Officer Sign-Off		
Team Mentor Sign-Off		

Vehicle Final Integration

Is the Upper Section Integrated and signed-off?		
is the Lower Section integrated and signed-off?		
Are the Payload Systems Integrated and Inspected?		
Has the main parachute been packed and secured to the vehicle?		
Has the drogue parachute been packed and secured to the vehicle?		
Are the Launch lungs secured to the vehicle, are they loose?		
Are all shear pins installed?		
Has Speed Tape been applied to shear pins and non in-flight separation points?		
Safety Officer Sign-Off		
Team Lead Sign-Off		
Team Mentor Sign-Off		

6.8.3 Vehicle Launch and Recovery Inspection Sheet

Final Go / No-Go poll

EXO		
PAO		
CAPCOM		
RECO		
T2		
T-DRO		
BOOSTER		
OPS		
VSO		
FLIGHT		

Vehicle Arming Steps

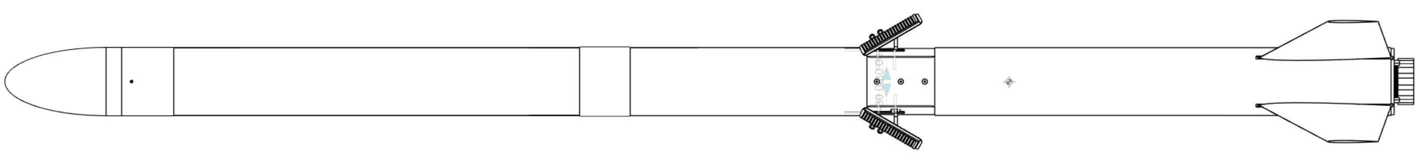
Has the range been cleared by the RSO for the Red team to enter		
Have all protective coverings been removed from the vehicle?		
Are both computers on and reporting healthy?		
When removing the arming pin, do both computers report good continuity on all 4 ejection charges?		
Has the ignitor been inserted, secured to the launch pad, and connected to the controller		
Final Check for remove before flight (RED) tags on the vehicle		
Team Lead Sign-Off		
Safety Officer Sign-Off		
Team Mentor Sign-Off		

Post Flight Inspection

Did the vehicle fly on a straight path with no major pitch events?		
Did telemetry connection to the vehicle continue throughout the flight with little to no interruption?		
Have Photos been taken of the vehicles landed configuration?		
Has the vehicle been safed after the flight before continuing inspection?		
Did the recovery system operate as intended?		
Are all sections of the vehicle still connected?		
Is there any damage to the parachute bays (zippering) as a result of a high deployment velocity?		
Is there any damage to the section from impact with the ground due to high descent velocity (chipped edge of fiberglass tube, cracked fin, cracked motor retention ring, etc.)?		
Safety Officer Sign-Off		
Team Lead Sign-Off		

Damage Assessment

Detail under each section below and highlight damaged regions on the wireframe



PERR-C Recovery System / ARCS Altitude Control System Booster

Team Lead Sign-Off:_______ Safety Officer Sign-off:________

6.9 Hazard Analysis Methods

Hazard analysis is based on two factors: Likelihood and severity. Likelihood is the rarity of which events occur, and severity is what impact(s) an event will cause.

6.9.1 Failure Occurrence Likelihood

Level	Category	Definition
0	Rare	Failure mode is Extremely Unlikely to happen
1	Unlikely	Failure mode is unlikely to occur
2	Plausible	Failure mode has average odds to occur
3	Likely	Failure mode is likely to occur
4	Common	Failure mode has happened before and/or is very likely to happen

Table 6.9.1: Risk Likelihood Table

6.9.2 Failure Effect Severity

Level	Category	Health and Safety	Equipment	Environment	Project
A	Negligible	No First aid required	Cosmetic Damage	No risk or damage to environment	No impact to Project timeline or goals
B	Minor	First aid was provided. Less than 1 day recovery time.	Damage is noted but can continue to operate with little to no detriment to the machine.	Slight damage to the environment, no clean up or action needed	Less than 1 day delay, no long-term impact
C	Moderate	First Aid Provided. Gause or other large bandage, Recovery time over 1 day	Reversible machine failure, requiring near-immediate repairs.	Damage to the environment that requires team intervention, but no long-term effects or reporting needed.	Delay of up to 1 week, may impact testing / flight schedule, no effect of deadlines
D	Major	Serious Injury requiring hospitalization, no long-term effects.	Total machine failure requiring repairs before continuing usage	Severe damage to the environment, immediate team intervention is required, reporting to the relevant agency	Delay of over 1 week, testing/ test flights will slip. Risk of missing the deadline
F	Catastrophic	Life Threatening injury or serious injury that results in long-term injury/disability	Total irreversible failure of equipment requiring replacement	Extreme damage to the environment requires immediate government intervention	Delay of over 1 month, high risk of missing deadline, retirement from competition.

Table 6.9.2: Failure Effect Table

6.9.3 Risk Analysis

The table below uses the likelihood analysis and Severity analysis to create a Risk Hazard Matrix. The Matrix is then color-coded into the following Categories. The categories are based on the severe weather risk categories provided by the Storm Prediction Center, where White/No-Risk is of least concern, while Magenta/High Risks are of utmost concern and should be a focus of prevention efforts.

- White: No-Risk
- Green: Marginal

- Yellow: Slight
- Orange: Enhanced
- Red: Moderate
- Magenta: High

		Severity				
		A - Negligible	B - Minor	C – Moderate	D – Major	F - Catastrophic
Likelihood	1 – Rare	1A	1B	1C	1D	1F
	2 – Unlikely	2A	2B	2C	2D	2F
	3 – Possible	3A	3B	3C	3D	3F
	4 – Likely	4A	4B	4C	4D	4F
	5 – Very Likely	5A	5B	5C	5D	5F

Table 6.9.3: Risk Analysis Matrix

6.9.3 Personnel Hazard Analysis Matrix

Hazard	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Hearing Damage	4 (Proximity of loud or high-pitched noise)	D (Long term hearing damage)	4D - Moderate	Ensure team is wearing hearing protection if around loud/high-pitched for longer than 10 minutes	Call out before use to make sure team members are informed about hazards	1D - Enhanced
Improper use of hand tools: sharp tools (box cutters, x-axto knife,s, chisels)	4	D (Lacerations)	4D - Moderate	Educate members on proper techniques and proper tools for certain operations. Ensure proper tools are available	If a member is not using the tools correctly, correct them	2D - Enhanced
Improper use of hand tools: blunt tools (Hammer, mallets, pry-bars)	4 (Members grabbing the nearest tool, not the correct tool)	C (broken fingers or bones in hands)	4C - Moderate	Educate members on proper techniques and proper tools for certain operations. Ensure proper tools are available	If a member is not using the tools correctly, correct them	2C - Slight
Dehydration/Heat exhaustion	4 (Hot sunny days, working in hot labs)	B (Fatigue or passing out risk)	4B - Enhanced	Reminding members to drink water and wear breathable clothes, if signs of dehydration or heat exhaustion are present, members must be forced to take break and drink water	Oversight by officers	3B - Slight

Entanglement with large machinery	3 (Working with manual machines)	F (Loss of body part, severe injury, required hospitalization	3F - Moderate	Members only allowed to use machinery are trained properly, use of buddy system in labs. Removal of all jewlery, loose clothing, and tieing hair back to prevent entanglement. Recomendation for team members to request parts to be manufactured on CNC machines to eliminate risk	Before operating machine, members will inspect each other to verify that all hazards have been eliminated prior to energizing machine. Work with machines will be supervised by university staff with experience until members are deemed skilled enough.	1F - Enhanced
Dust exposure	3 (Particle debris, Smoke,)	D (Short-term respiratory damage, respiratory distress, eye irritation, short-term eye damage)	3D - Moderate	Wearing appropriate PPE; N95, eyewear, lab coat (optional). Working in well-ventilated area. Wash with water	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1C - Slight
improper use of power tools	3 (Cuts from drill bits, rotary tools, exact-o blades/box cutters	D (Lacerations, avulsions, hospitalization, plausible)	3D - Moderate	Secure hair, clothing, jewelry, wear proper shoes. Appropriate PPE	Call out before use to make sure team members are informed about hazards	1D - Enhanced

Contact with falling equipment	3 (Dropped items or falling items)	C (Injuries including bruising, cuts, hospitalization in worst case scenario)	3C - Enhanced	Secure items that are heavy to worktables, use carts to transport heavy/bulky items. Any item over 40 lbs is a team lift so that no member is straining themselves.	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1C - Slight
Contact with hazardous chemicals (excl. epoxy and adhesives)	3 (Chemical spills, improper chemical usage)	C (Chemical Burns, toxic exposure)	3C - Enhanced	Wearing appropriate PPE; Gloves, lab coat, and eyewear. Wash with water. Dispose in proper container	Call out before use to make sure team members are informed about hazards. Oversight by team officers	1C - Slight
Electrocution	3 (Work with custom PCBs, LiPo batteries)	C (Short-term nerve damage, electrical burns)	3C - Enhanced	Ensure team is working with proper PPE, treating all electronic circuitry as if it is live	Oversight by team officers	2C - Slight
Tripping Hazards	3 (Equipment not put away, wires on ground)	C (Upper body injuries, bruising from walking into objects)	3C - Enhanced	Brief team on picking up equipment in hazardous way	Enforce cleaning procedure	1C - Slight

Contact with chemical vapors (excl. epoxy and adhesives)	2 (Use of solvents to clean parts during manufacturing, clean up spilled epoxy or adhesives)	B (Irritation to eyes, lungs)	3B - Slight	Wear proper PPE. Including; gloves, eye protection, lab coat, rinse with water if come into contact	Safety team subsystem leads, will enforce PPE usage, safety procedures	1B - Marginal
Epoxy or Adhesive Contact/Exposure	3 (Assembling components on vehicle, small repairs, fabricating test samples)	B (Skin, Lung, Eye Irritation)	3B - Slight	Wear appropriate PPE; gloves, N95, glasses optional	Call out before use to make sure team members are informed about hazards	1B - Marginal
Contact with heat sources	3 (Working with epoxy or sharp tools)	B (2nd Degree or blistering burn, First degree or superficial Burn, Skin Irritation)	3B - Slight	Ensure that members are wearing the proper PPE, letting items cool after working them	Call out before use to make sure team members are informed about hazards	1B - Marginal
Fire	2 (damaged electrical components, improper disposal of rags soaked in solvent, working with hot materials around dust)	F (Loss of workspace, severe burns to personal)	2F - Moderate	Know where fire prevention equipment is stored, store hazardous material in proper containers	Make sure all members are informed on fire safety protocol	1F - Enhanced

6.9.5 Failure Mode Effect Analysis

HAZARD	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Onboard Vehicle Fire	1 (Electric fire/fire spread due to motor failure)	F (Falling debris, unaccounted for vehicle separation, ground/brush fire)	1F - Enhanced	To reduce or prevent fire spread, install “fire compartments," separating critical hardware from each other.	Cover exposed wires with insulators and install heat insulators if needed.	1F - Enhanced
Fastener Failure	2 (Excessive force)	F (Irreversible damage to vehicle, falling debris, dangerous flight path to people and surroundings)	2F - Moderate	Increase number of simulations and increase safety factor of flight critical components to 2+	Physical testing to confirm manufacturer specifications	1F - Enhanced
Thrust Structure Failure	2 (Poor construction, motor overperformance causing excessive force)	F (Irreversible damage to vehicle, falling debris)	2F - Moderate	Increase number of simulations and increase safety factor of flight critical components to 2+	Physical testing of motor mount assembly to 200% the expected force of boost	1F - Enhanced

Recovery System Failure: Drogue Stage	2 (Bad product control on ejections charge ignitors, airframe shoulders having high friction, drogue parachute failure)	F (failure to prevent ballistic trajectory, high energy non-ballistic descent)	2F - Moderate	Implement checks for ignitors to ensure continuity, size primary and backup ejection charges to be at least 130% the required force to deploy the system, ensure both parachute and protector are intact before use	Ground testing and maintenance of the airframe to prevent binding	1D - Enhanced
Structural Failure of Bulkheads	2 (Poor construction, faulty modeling/simulation)	F (Falling debris)	2F - Moderate	Design components to a safety factor of 2	Testing of bulkheads to validate computer modeling	1F - Enhanced
Damaged NoseCone, Payload Compartment	2 (Poor,Construction, Flight/transportation damage)	D (instability, Damage to payload, Dangerous flight path to personal and surroundings)	2D - Enhanced	Ensure that the descent rate of section is below damaging levels, provide protective packing when transporting	Inspect material between launches	1C - Slight

Component Misalignment: Motor mount tube/assembly	2 (Poor construction, bad manufacturing plan, bad product control of construction components	D (Launch vehicle does not follow flight path, severe instability)	2D - Enhanced	Use tools from CNC lab to measure all components to verify eccentricity and location	Have multiple engineers verify measurements	1D - Enhanced
Commercial Rocket Motor Failure	2 (Faulty motor preparation, defect from manufacturer)	F (Destruction of vehicle section, Falling debris)	2F - Moderate	Purchase propellant from reliable sources, only team mentor is allowed to handle and assemble the motor	Safety officer will observe preparation and integration	1F - Enhanced
Recovery System Failure: Tether, Riser, or Shock Cord Failure	3 (Excessive force, Burn through from the ejection charge deployment)	F (Falling debris, high-energy non ballistic landing)	3F - Moderate	Use higher quality materials, fire resistant materials/coverings, use tethers that are 200% the strength of the expected loading	Ground testing and inspections between flights and testing. During assembly, multiple engineers verify that connections are torqued to spec	1F - Enhanced
Recovery and Tracking Avionics Power Failure	3 (Faulty wiring, design not resistant to flight forces)	F (Recovery device may not deploy, Ballistic landing)	3F - Moderate	Testing avionics bay assembly to investigate reaction to flight forces, observe set up before and after test flights to validate data	Continuity and "pull tests" will be performed during avionics bay integration to test wire connectivity and attachment	1F - Enhanced

Recovery System Failure: Main Stage	4 (Bad product control on ejection charge ignitors, airframe shoulders having high friction, Main parachute failure, failure to fully deploy from parachute bay	D (High energy non-ballistic landing)	4D - Moderate	Implement checks for ignitors to ensure continuity, size primary and backup ejection charges to be at least 130% the required force to deploy the system, ensure both parachute and protector are intact before use	Ground testing and maintenance of the airframe prevent binding	1D - Enhanced
Altitude Control System Mechanical Failure	3 (material failure of the ball screw, linkages, or aerobraking surfaces)	F (leaving vehicle in unknown aerodynamic state, Dynamic Instability, unsymmetrical deployment leading to high AOA at high velocity)	3F - Moderate	Ensuring all mechanical parts of a safety factor of 3+.	Extensive ground testing: wind tunnel testing, simulated load testing. Asymmetric deployment studies.	2F - Moderate
Altitude Control System Electrical Failure	3 (custom PCB being manufactured wrong causing electrical fault)	D (fire, fatal damage to component leading to ACS staying in the same deployment state)	3D - Moderate	Increased electrical design studies are needed to ensure the PCB design is sound.	Ground testing including testing a sacrificial board to failure to find true limits of system	1C - Slight

Structures: Damage to Thrust Structure	2 (Hard landing due to recovery failure; Landing on Rock, Paved Road, or Compacted Dirt Road)	D (irrepriable damage to Motor Retention System, motor mount assembly damage)	2D - Enhanced	Designing structure to withstand loads twice as high as expected from motor thrust and landing	The structure will be tested by applying a load of at least 180 lbs	1C - Slight
Structures: Thrust structure failure	1 (Motor Peak thrust breaking thrust struture, landing force causing structure failure)	D (irrepriable damage to Motor Retention System, motor mount assembly damage)	1D - Enhanced	Designing structure to withstand loads twice as high as expected from motor thrust and landing	The structure will be tested by applying a load of at least 180 lbs	1C - Slight
Structures: Damaged Body tube	3 (landing on hard or sharp object, hard landing)	C (Section of vehicle needing repair or replacement)	3C - Enhanced	Following standard practice of recovery system recovery to ensure that the vehicle	Ground testing to ensure that parachute ejection charges work and performing parachute drop tests to ensure the vehicle will be recovered safely	2C - Slight
Moduluar Fin Mount: Damage to Fins	4 (landing on hard or sharp object, hard landing)	B (Broken 3D Pritned Fin)	4B - Enhanced	Fin material choice and design is made to impact landing force and will bend but wont break	Fins will be tested on ground in a 3-point bend test and will be tested with the parachute drop test and vehicle demonstration flight	2B - Marginal

Moduluar Fin Mount: Damage to Fin mounting Structure	2 (landing on hard or sharp object, hard landing)	B (Broken 3D Pritned Fin)	2B - Marginal	Fin mount material choice and design is made to impact landing force and will bend but wont break	System will be tested with the parachute drop test and Vehicle Demonstration Flight	1B - Marginal
Modular Fin Mount: Damage to Fin Retention system	5 (Fin pushing through retainer)	C (Broken Plywood part)	5C - Moderate	Ensure all contact points are solid and not stripped	perform a pull test of attachment bolts, bolts should hold when subjected to a pulling force greater than 25lbs (Hand pull)	2C - Slight

6.9.6 Environmental Hazard Analysis

HAZARD	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Collisions with Structures	3 (Structures are near minimum clearance for High-Power at Amesbury (1500ft))	D (Damaging Roof, landing on hard surface damaging vehicle)	3D - Moderate	Aiming rocket away from structures. Weather forecasting winds at the surface and at altitudes to visualize wind shear to aid in determining launch direction	Doing simulations with different wind scenarios to find the furthest distance a rocket will drift down/cross range	2D - Enhanced
Contact with Wildlife	1 (Wildlife interacting with vehicle after landing)	C (Animal interacting with residue from flight or damaging vehicle)	1C - Slight	Install deterrents on the vehicle to scare off wildlife. This includes buzzers.	Safety briefing talking about what hazards may be present, educating members on how to interact with wildlife	1B - Marginal
High Temperature	2 (Hot weather in Huntsville, abnormal heat in winter)	C (On-board batteries and support overheating causing damage, heat exhaustion stroke)	2C - Slight	Observing weather forecast and temperatures above 80F classified as hot weather. 90F and above is classified as extreme heat. Bringing pop-up tents, providing shade for the team and equipment, as well as bringing water for the team.	Ensure team members are properly prepped for extreme heat. Possibly running a car with AC to provide a cooler environment for equipment and team	2B - Marginal

Battery Leakage	2 (Battery damage from flight)	D (Fire or chemical residue from combustion of hazardous material)	2D - Enhanced	Protect battery from flight forces and landing forces.	Safety briefing about what hazards may arise or be present, inspect battery between flights for damage	1C - Slight
Fire	2 (Motor failure near ground, on-board fire continuing to landing)	F (Fire on ground, pollution from)	2F - Moderate	Using ground protector next to the launch pad, bringing fire suppression equipment.	Safety briefing about hazards that may be present, walking through emergency proceudre's during drtess rehersals	1F - Enhanced
Unstable Ground	2 (Loose rocks/dirt, mud)	B (Personal or equipment falls)	2B - Marginal	Inspect area of launch pad and prep-area for ground hazards	Safety briefing about hazards that may be present	1A - None
Landscape	3 (Trees, streams, rocks)	D (Unable to recover rocket, water damage to components or electronics, physical damage)	3D - Moderate	Scout out launch-field for hazards and aim away, use forecast to determine wind to help aid aim	Inspect launch site pre-launch to verify mitigation	3B - Slight

Visibility	3 (Exceeding operating limitations of 14 CFR 101.25)	D (Scrubbing launch, delay of 1 day to 1 week)	3D - Moderate	Weather forecasting and scheduling back up at launch windows to allow for weather related delays	Check weather forecasts and creating a launch weather criteria list to allow a safe launch at range	2D - Enhanced
Pollution from vehicle Debris	3 (Debris from vehicle from an in-air failure or damage during landing)	C (Small pieces of debris left from vehicle that pose minimal effect of the environment)	3C - Enhanced	If a failure is noticed, the team forms a “Police Line” and searches the field for debris. Landing site is investigated for debris	Initial inspection of vehicle at landing zone and preparation area to determine if any items have been dislodged or removed	2A - None
Pollution from Team	3 (Wrapper from motor reload, trash from vehicle integration, snack-wrappers)	C (Small debris from team)	3C - Enhanced	f a failure is noticed, the team forms a “Police Line” and searches the field for debris. Ground will be searched for any trash	Installing Pack-in/Pack-out mentality in team. “Leaving field better than when arrived”	2A - None
Humidity	4 (Humid climate)	C (Condensation creating electrical shorts, humidity affecting adhesive or materials)	4C - Moderate	Construction and storage of construction materials and motors in climate-controlled rooms, electronic boards given conformal coating to give them resistance to short across traces	Check forecast before launch	3B - Slight

Winds	4 (High winds preventing launch, winds blowing in unsafe direction)	D (Scrubbing launch, rocket landing outside launch site)	4D - Moderate	Forecast and back-up launch days	Checking forecast and creating a launch weather criteria list to ensure safe launch	3B - Slight
Rain/Weather	4 (Cannot launch in rain or cloud cover)	D (Scrubbing delay launch, delaying of 1 day to 1 week)	4D - Moderate	Weather forecasting and schedule back up windows in case of weather delays	Checking forecast and creating a launch weather criteria list to ensure safe launch	3B - Slight
Low Temperature	4 (Cold plunge in New England Region with temperatures below 40F)	D (Damage to propellant reload, hypothermia and frostbite, reduced performance of battery)	4D - Moderate	Bring heaters, handwarmers, and insulating equipment under 40F. Activities limited/suspended below 10F	Check forecast. If necessary, suspension of outside activities may be called at any point, provide running car with heat	4B - Enhanced
Pollution from Motor Exhaust	5 (Combustion by products from firing commercial rocket motor)	A (Small quantities of greenhouse gases, hydrochloric acid, NOx/SOx compounds)	5A - Slight	Use NAR/TRA approved rocket motors	Motors used to launch test vehicles and competition flight will be inspected by safety officer to ensure compliance	5A - Slight

Severe Weather	3 (Severe Weather Reaches its peak mid to late april in the southern US and Great plains)	D (Tornadoes, Powerful Straight line winds, Hail delaying launch and threatening Personnel)	3D - Moderate	Observe weather forecasts from the Storm Prediction Center (SPC) and National Weather Service (NWS). Researching Safe shelter locations near locations the team will be at	Weather forecasts are given to the team through a discord channel starting 192hrs out from launch or travel	1D - Enhanced

6.9.7 Project Hazard Analysis

HAZARD	Likelihood	Severity	Risk	Mitigation	Verification	Post Mitigation Risk
Lack of Funding	4 (First Year Attempting NASA USLI, No Current Corporate Sponsorships)	D (Unable to afford Equipment, Unable to Attend Launch in Huntsville)	4F - High	Aggressive Fundraising Campaigns (Crowdsource Campaign and looking for sponsors)	The Business Team Lead will work with the Student Launch Team lead to ensure the club is raising enough money for the competition	4C - Moderate
Failure to Receive parts	2 (ordering from unreliable sellers)	C (Multiple day delays from shipping, ordering new parts)	2C - Slight	Order parts from verified sellers and legitimate websites	Verifying links and auditing purchase orders	1B - Marginal

Damage or Loss of Parts/gear	3 (improper part care during construction, testing, or launch)	C (cannot construct vehicle or continue testing)	3C - Enhanced	Creation of multiple replacement parts when applicable, owning spare sets of equipment	Extra parts ordered for all needed systems	3B - Slight
Rushed/bad workmanship	3 (Approaching deadlines, unreasonable schedule expectations)	D (Testing failures & launch failures due to low-quality construction)	3D - Moderate	Built-in schedule buffers so deadlines aren't stressing	Pre-flight inspection and following tolerances	2C - Slight
Unavailable Launch Area for Test Flights	3 (Unhappy neighbors, fields not in condition to fly, no-waiver to fly)	F (delay of multiple weeks to get to flight, disqualification from the project due to no subscale & vehicle demonstration flight data)	3F - Moderate	Being in contact with multiple NAR sections near us, like St. Albans, VT CRMRC. Attempting launches early in the period to allow for scheduling issues	The Safety officer will work with team mentor to secure fields for testing at least 45 days in advance.	1B - Marginal
Testing failure	3 (bad design, unforeseen mechanisms leading to failure, commercial component failure)	D (Damage to vehicle, failure of subscale or vehicle demonstration flight)	3D - Moderate	Following standard practice as set by team's mentor, designing critical systems to be redundant. Making contingencies and being prepared to retest quickly after a potential failure	Safety officer will ensure that all sub-systems are being designed with a proper safety factor and considerations	3B - Slight

Loss of work area	2 (Fire, loss of lab privileges, Closures during school breaks)	F (Inability to construct vehicle)	2F - Moderate	Follow regulations and rules set by team and workspace occupied	Team Officers will ensure that the team will be utilizing each space we occupy correctly and follow the rules set in place by the safety agreement	1F - Enhanced
Failure in construction equipment	2(Improper maintenance, improper use)	D (Long-term delay in project for replacement)	2D - Enhanced	Ensure members using tools and equipment are trained properly, owning back-up equipment that can be used in the event of a failure	Each member will be responsible for maintaining equipment following the team safety agreement	1B - Marginal
Insufficient Transportation	4 (lack of funding or space to bring available members to off-campus testing, launches, or workplaces)	C (Loss of sufficient labor, loss of transfer of knowledge to new members, loss of work efficiency)	3C - Enhanced	Organize and budget for transportation early and plan expenses in advance	Project management and team leads will be responsible for communicating when activities are being held and plan transportation to the events	2B - Marginal
Lack of members available to work	4 (shared class deadlines or mid-term exams takes out sections of team)	C (Some classes may require multiple days of studying before an exam)	4C - Moderate	Work with team members to “forecast” when class work will be high to help schedule time to work on project with the rest of the team	Team leads meetings to verify that members are not being overloaded with school and project work	2B - Marginal

Lack of Knowledge	5(members new to the club / hobby not understanding what each component does)	B (needing to take a section of the meeting to educate groups of members on standard rocketry practices)	5B - Moderate	Create a resource of online tutorials for members to look at, and create our own PowerPoint slide decks with similar information	Have set meetings throughout the semester where a team lead will discuss their section of the rocket and what every part does	3B - Slight
Bad Timeline Communication	5 (Members not knowing what to work on, sub-teams skipping critical tasks)	C (creates confusion in the team and can potentially derail the project or cause a backlog of work during the milestone reports)	5C - Moderate	Make Sub-team meetings more efficient, creating task checklists, opening new operations positions to aide in project management	Oversight by operations team.	4B - Enhanced

7 Project Plan

7.1 Testing Plan

7.1.1 Avionics Testing

The following tests represent the standard testing sequence for commercial recovery avionics when integrating into a new rocket.

7.1.1.1 LED "Cold" Ejection Testing

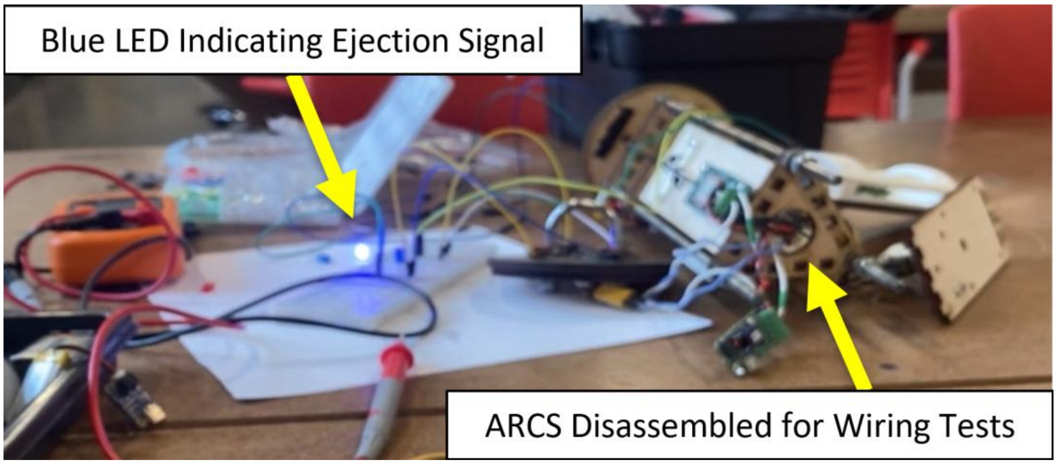


Image 7.1.1: LED "cold" Ejection Testing

During Assembly of ARCS, "Cold" ejection tests were done, to ensure the wiring of the system was correct by simulating an ejection charge activation using LED's.

7.1.1.2 ARCS Continuity Testing

Before Parachute ejection testing, a series of continuity tests were conducted using jumper wires on the WAGO Connectors, with ARCS fully assembled. The following tests were conducted on both Telemetrum and Blue Raven separately, and at the same time:

1. Main Only
2. Drogue/APO Only
3. Both Main and Drogue/APO
4. Arming Pin in
5. Pulling arming pin out with computers on
6. Pushing arming pin back in

Tests were repeated multiple times, with neither computer failing to detect continuity when it should, or detecting continuity of the wrong line (i.e reporting main is connected when drogue is connected). This test proved that all 4 charges connections are wired independently from one another and that the arm/disarm pin works as intended as a safeguard from stray current.

7.1.1.3 Parachute Ejection Ground Tests "Pop Tests"

The purpose of the Pop test is to make sure that the ejection charge sizing is appropriate for the vehicle. The minimum criteria for a successful test is set at the shearing of the two #2-56 Shear pins, from there the team can make an informed decision if another test is needed, if the charge is of sufficient size, or if the ejection charge needs to be increased in size. In total, 6 pop tests were conducted: 4 Failures, 1 Success, and 1 Partial Success – No Retest Needed.

Test	Drogue or Main	Size	Result
1	Drogue – 4 Shear Pins	0.68g / 15.4 PSI	Failure
2	Main – 4 Shear Pins	1.55g / 15.4 PSI	Failure
3	Main – 4 Shear Pins	1.95g / 20 PSI	Failure
4	Drogue – 4 Shear Pins	0.85g / 20 PSI	Not Tested –> Recycled into New Charge
5	Drogue – 2 Shear Pins	1.0g / 23.5 PSI	Failure
6	Main – 2 Shear Pins	2.3g / 23.5 PSI	Success – Full Ejection
7	Drogue – 2 Shear Pins	1.17g /27.5 PSI	Partial Success
8	Main – 2 Shear Pins	2.7g / 27.5 PSI	Not Tested -> Flown VDF

Table 7.1.1: Ejection Charge Test List

Image 7.1.2: Sequence of Main Parachute Ejection during Pop Testing

Despite test 7 not fully ejecting the drogue parachute, the decision was made to not retest because the shear pins did shear. The decision was made with the team mentor Howard, to increase the size of the primary charge by 4 PSI and a redundant charge 20% higher that the new primary would be made. The key factors into this choice were the fact that the static test was conducted at an angle, adding new forces onto the vehicle that would not be present in flight, and the fact that the vehicle would either self-separate when tumbling or the back-up charge would fully separate the vehicle after the shear pins broke.

Image 7.1.3: Result of Partial Success Drogue Ejection

7.2 Requirements Compliance Plan

Requirement ID	Summary	Verification Type	Verification Plan	Status
1.1	Teams must be made of 100% students. Excluding Team mentor and Advisors. Students must design and build vehicle. Students are not allowed to handle motors or black powder.	Not Applicable		Compliant
1.2	Teams will provide and maintain a project plan for: milestones, budget, community support, checklists, personnel assignments, STEM engagement and Risk mitigation	Not Applicable		In-Progress
1.3	Team members will register on NASA Gateway if travelling to Huntsville	Not Applicable		Completed
1.4	Teams will engage a minimum of 250 participants in educational Direct engagement STEM activities.	Not Applicable		Not Started
1.5	Teams will establish and maintain a social media presence	Not Applicable		Completed
1.6	Teams will deliver all projects deliverables on time to NASA	Not Applicable		Compliant
1.8-10	All deliverables will be in PDF format, contain page	Not Applicable		Compliant

	numbers, and Table of Contents			
1.11	Teams will be capable of performing video teleconferneces.	Not Applicable		Compliant
1.12	Teams attending launch week will use the provided launch pads	Not Applicable		Not Started
1.13	Each Team will identify a “mentor”	Not Applicable		Compliant
1.14	Teams will report the number of hours worked on each milestone	Not Applicable		Compliant
2.1	Vehicle will deliver the payload to an altitude of 5000ft.	Analysis		Compliant
2.2	Teams shall declare their target altitude at the CDR Milestone	Not Applicable		Completed
2.3	The Launch vehicle will be recoverable and reusable, able to launch on the same day without repairs.	Demonstration	Inspect each component for damage after first launch. Verify functionality and prep for second launch. Confirm ready for relaunch.	In-Progress

2.4	Vehicle Section Shoulders, shall be of sufficient length to prevent bending or unNot Started separation	Inspection	Design verified by Safety officer and Team Mentor	Not Started
2.5	Launch vehicle shall be capable of being prepared for flight within 2 hours of the FAA COA activation	Demonstration	Conduct timed demonstration where vehicle is fully prepped 2 hours before activation. Time this by recording full configuration and activation process, while ensuring compliance with safety and operation requirements. Confirm flight readiness in specific time frame.	Not Started

2.6	The vehicle shall be able to be ready on the pad without losing critical functionality for at minimum 3 hours.	Test	Performing a power on test and timing the computer, measuring the battery voltage as the test goes on to project the maximum time the vehicle can be powered on	Not Started
2.7	The vehicle shall be able to be launch by standard 12-volt launch controllers	Inspection	Design verified by Safety officer and Team Mentor	Compliant
2.8	The vehicle shall require no external circuitry to launch	Inspection	Design verified by Safety officer and Team Mentor	Compliant
2.9	Teams will use commercially available e-matches or igniters	Not Applicable		Compliant
2.10	The launch vehice will use a commercially available solid rocket motor that is approved by TRA, NAR, or CAR	Analysis		Compliant
2.11	The Launch Vehicle shall be limited to a single motor propulsion system.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
2.12	The total impulse provided by a College or University launch vehicle shall not exceed 5,120 Newton-seconds (L-class).	Analysis		Compliant

2.13	Pressure vessels on the vehicle must be approved by the RSO	Not Applicable		Not Applicable
2.14	The launch vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	Analysis		Compliant
2.15	The launch vehicle shall have a minimum thrust to weight ratio of 5.0:1.0.	Analysis		Compliant
2.16	Any structural protuberance on the rocket shall be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	Analysis		Compliant
2.17	The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.	Analysis		Compliant

2.18	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 the 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).	Demonstration	Demonstration of a 75% scale vehicle, with similar aerodynamic and stability factors to prove the vehicle is stable.	Completed

2.19.1	Vehicle Demonstration Flight — All teams shall sucessfully 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 (drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.).	Demonstration	Vehicle demonstration flight of the full scale vehicle in competition configuration demonstrating recovery systems and active energy control systems (ACS)	In-Progress

2.19.2	Payload Demonstration Flight — 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 (if applicable) as designed	Demonstration	Vehicle demonstration flight of the full scale vehicle in competition configuration demonstrating recovery systems, active energy control systems (ACS), and Payload Systems	In-Progress

2.21	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	Design verified by Safety officer and Team Mentor	Not Started
2.22	All Lithium Polymer batteries shall be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	Inspection	Design verified by Safety officer and Team Mentor	In-Progress
3.1	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.	Test and Demonstration	Demonstrated on VDF	Compliant
3.1.1	The main parachute shall be deployed no lower than 500 feet.	Analysis	Analyzed from Demonstration flight Data	Compliant

3.1.2	The apogee event shall contain a delay of no more than 2 seconds.	Analysis	Analyzed from Demonstration flight Data	Compliant
3.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
3.2	Each team shall perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles.	Test	Assemble recovery mechanisms similar to in flight to ensure all safety and measuring equipment is in place. Activate system to configure with no malfunctions with recording of results. Any failures must be addressed and retest until reliable performance.	Completed
3.3	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		Compliant

3.4	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	Design verified by Safety officer and Team Mentor	Completed
3.5	Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
3.6	Each altimeter shall be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
3.7	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	Design verified by Safety officer and Team Mentor	Compliant
3.8	The recovery system, GPS and altimeters, and electrical circuits shall be completely independent of any payload electrical circuits.	Inspection	Design verified by Safety officer and Team Mentor	Compliant

3.9	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
3.10	Bent eyebolts shall not be permitted in the recovery subsystem.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
3.11	The recovery area shall be limited to a 2,500 ft. radius from the launch pads.	Analysis		Compliant
3.12	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.	Demonstration	Demonstrated on VDF	Failed
3.13	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	Design verified by Safety officer and Team Mentor	Compliant
3.13.1	Any rocket section or payload component, which lands untethered to the launch vehicle, shall contain an active electronic GPS tracking device.	Not Applicable		Not Applicable

3.13.2	The electronic GPS tracking device(s) shall be fully functional during the official competition launch.	Demonstration	Monitor performance from GPS calculating its accuracy of tracking and transmitting the correct vehicle position throughout flight.	Not Started
3.14	The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	Test and Demonstration		Compliant
3.14.1	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	Design verified by Safety officer and Team Mentor	Compliant
3.14.2	The recovery system electronics shall be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.	Inspection	Design verified by Safety officer and Team Mentor	Compliant

3.14.3	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	Design verified by Safety officer and Team Mentor	Compliant
3.14.4	The recovery system electronics shall be shielded from any other on-board devices which may adversely affect the proper operation of the recovery system electronics.	Inspection	Design verified by Safety officer and Team Mentor	Compliant

4.1	USLI Payload Mission objective: College/University Division — Teams are tasked with designing, building, and flying a STEMnaut flight capsule capable of safely retaining four STEMnauts and transmitting, via radio frequency, relevant rocket and STEMnaut landing site data to a NASA-owned receiver located at the launch site. STEMnauts are physical representations of the crew on-board the rocket. The method(s)/design(s) utilized to complete the payload mission shall be at the team's discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. NASA reserves the right to require modifications to a proposed payload.	Test and Demonstration		In-Progress
4.2.1	Teams shall choose a minimum of 3 pieces from the below list to a maximum of 8 to transmit to the NASA receiver.	Demonstration	Confirm the success of transmission to receiver and reception of data under simulated launch conditions.	Not Started

4.2.2	The payload shall not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe.	Inspection	Design verified by Safety officer and Team Mentor	Compliant
4.2.3	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.	Demonstration	Test transmission functionability under controlled conditions. Ensure system operates as intended. Record results and verify their compliance.	In-Progress
4.2.4	All transmissions shall start and stop with team member call sign.	Demonstration	Monitor and collect information confirming proper identification at start and stop of each communication. Verify complaince	In-Progress
4.2.5	Teams shall submit a list of what data they will attempt to transmit by NASA receiver by March 17.	Inspection		Compliant

4.2.6	Teams shall transmit with a maximum of 5W and transmissions shall not occur prior to landing.	Demonstration	Simulate fligtht conditions. Monitor transmission power and timing. Verify and ensure complaince with stated requirements.	Not Started
4.2.6.1	Teams shall not transmit on the specified NASA frequency on launch day prior to landing.	Demonstration	Monitor pre-launch and flight phase frequency. Verify all transmissions comply with requirements.	Not Started
4.3.1	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.	Not Applicable		Not Applicable
4.3.2	Teams shall abide by all FAA and NAR rules and regulations.	Inspection		Compliant
4.3.3	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.	Not Applicable		Not Applicable

4.3.4	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.	Not Applicable		Not Applicable
4.3.5	Teams flying UASs shall abide by all applicalbe FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	Not Applicable		Not Applicable
4.3.6	Any UAS weighint more than .55lbs. shall be registered with the FAA and the registration number marked on the vehicle.	Not Applicable		Not Applicable
5.1	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.	Not Applicable		Not Started
5.2	Each team shall identify a student safety officer who will be responsible for all items in Section 5.3.	Not Applicable		Completed
5.3.1	Monitor team activities with an emphasis on safety during:	Inspection		In-Progress
5.3.1.1	Design of vehicle and payload	Not Applicable		In-Progress
5.3.1.2	Construction of vehicle and payload components	Not Applicable		In-Progress

5.3.1.3	Assembly of vehicle and payload	Not Applicable		In-Progress
5.3.1.4	Ground testing of vehicle and payload	Not Applicable		In-Progress
5.3.1.5	Subscale launch test(s)	Not Applicable		Completed
5.3.1.6	Full-scale launch test(s)	Not Applicable		Compliant
5.3.1.7	Competition Launch	Not Applicable		Not Started
5.3.1.8	Recovery activities	Not Applicable		Compliant
5.3.1.9	STEM Engagement Activities	Not Applicable		Not Started
5.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	Not Applicable		In-Progress
5.3.3	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and SDS/chemical inventory data.	Inspection		In-Progress
5.3.4	Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	Inspection		In-Progress

5.4	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.	Not Applicable		Not Started
5.5	Teams shall abide by all rules set forth by the FAA.	Inspection		Compliant

Table 7.2.1: Requirement Compliance Plan

7.3 Budget and Funding Summary

7.3.1 Line Item Budget

Part	P/N	Q of Parts	Material	Source	Q of Materials	Base Cost	Tax	Total Cost
Nosecone Bottom		1	PLA	Makerspace	N/A	$-	$-	$-
Nosecone top		1	PETG	Makerspace		$-	$-	$-
I-Nut	3274T71	1	Steel	Mcmastercarr			$-	$-
1/4 20 steel threaded rod		1	Steel	Mcmastercarr			$-	$-
5ft body tube	GT12 3.9	4	Fiberglass:GT12 3.9	Wildman			$-	$-
Coupler tube 1in	GT12 3.9	60	Fiberglass:GT12 3.9	Wildman		$2.33	$0.15	148.5375
Fins		4	Polycabonate	Makerspace			$-	$-
2 Meter Radios		1		Amazon		$49.99	$3.12	$53.11
Flight Batteries		1		Amazon		$21.99	$1.37	$23.36
BNO055	4646	1		Adafruit		$29.95	$1.87	$31.82
3S Li-Po		1		Amazon		$34.99	$2.19	$37.18
PWM tester		1		Amazon		$8.99	$0.56	$9.55
ACS motor driver	2448	1	18-8 Stainless Steel	Adafruit		$6.95	$0.43	$7.38
McMaster Threaded Stud	97042A176	2	18-8 Stainless Steel	McMastercarr		$8.92	$0.56	$18.96
Heat Shrink Tubing		1		Amazon		$11.99	$0.75	$12.74
Multi-Wire Stripper Tool		1		Amazon		$19.99	$1.25	$21.24
4-40 Square Nuts	94855A281	1	Zinc plated steel	Mcmastercarr		$3.37	$0.21	$3.58
XT30 Connectors		1		Amazon		$11.99	$0.75	$12.74
4-40 Heat Set Inserts		1		Amazon		$10.99	$0.69	$11.68
ESP32-S3 feather	5477	1	Electronics	Adafruit		$17.50	$1.09	$18.59
BMP388	3966	1	Electronics	Adafruit		$9.95	$0.62	$10.57
ADXL375	5374	1	Electronics	Adafruit		$24.95	$1.56	$26.51
ICM-20948 9-DOF Gyroscope	4554	1	Electronics	Adafruit		$14.95	$0.93	$15.88

RFM69HCW Transceiver Radio	3070	1	Electronics	Adafruit		$9.95	$0.62	$10.57
Raspberry Pi Pico 2 - RP2350	6006	1	Electronics	Adafruit		$5.00	$0.31	$5.31
Breadboard	443	2	Electronics	Adafruit		$19.95	$1.25	$42.39
MPL3115A2	1893	1	Electronics	Adafruit		$9.95	$0.62	$10.57
Flash Memory	6038	1	Electronics	Adafruit		$10.95	$0.68	$11.63
GPS Chip	4415	1	Electronics	Adafruit		$29.95	$1.87	$31.82
Jumper Wires		1	Electronics	Amazon		$7.99	$0.50	$8.49
Remove Before Flight Tags x10		1	Cloth	Amazon	N/A	$17.99	$1.12	$19.11
PolyLite™ ASA (1kg)	PF01011	1	PLA	Polymaker	1kg	$31.99	$2.00	$33.99
PolyLite™ PETG (1kg)	PB01015	1	PETG	Polymaker	1kg	$22.99	$1.44	$24.43
PolyLite™ PETG (1kg)	PB01024	1	PETG	Polymaker	1kg	$22.99	$1.44	$24.43
PolyMax™ PC (750g)	PC02004	1	PC	Polymaker	750g	$38.99	$2.44	$41.43
							$-	$-
Total						$518.48	$32.41	$727.62

Table 7.3.1: Line-Item Budget

7.3.2 Updated Funding and Material Acquisition Plans

7.3.2.1 Funding Sources

As of the FRR, all funding covering the cost of materials has been acquired from various departments at the University. This includes the Francis College of Engineering, the Mechanical Engineering Department, and the Student Government Association. The funding from these sources has been previously reported and is divided as follows.

Funding source	Funding Amount
Francis College of Engineering – Dean's Office	$2,500
Mechanical Engineering Dpt.	$2,500
Student Government Association	$1,324
Additional SGA Grant	$1,251

Table 7.3.2: Vehicle Funding Source Summary

These funds cover materials that have either already been purchased or will be purchased in preparation for the Payload Demonstration flight.

The remaining funding that is required is $7000 to cover the cost of bringing 15 members of the team to Huntsville for launch week. Provided below is the breakdown of the travel plan.

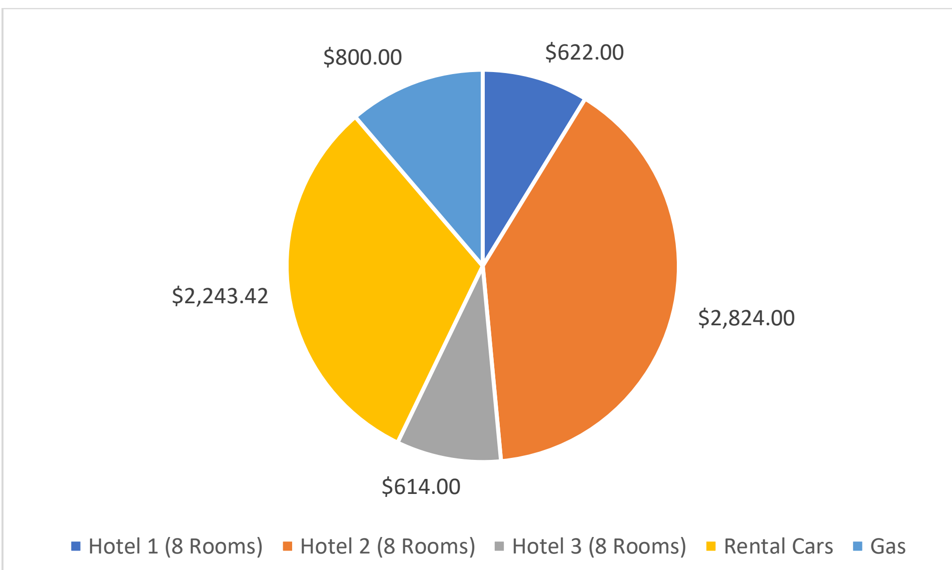


Figure 7.3.3: Travel Cost Breakdown

7.3.2.2 Material Acquisition Plan

The remaining materials to purchase for the Payload Demonstration Flight include various components for communication between PERR-C and the Payload Telemetry Ground Station, and an ACS actuation motor to replace the one damaged on the Vehicle Demonstration Flight. The total cost of these components amounts to $300.

Appendix A – Vehicle Demonstration Flight Card & Sign Off Sheets

UML Flight Log Card

Flight: Peregrine Explorer - VDF

Motor(s):

AT RMS 54/2560 K1275 Redline

Ejection Charges

Charge Line	Telemetrum Drogue/APO	Blue Raven APO/drogue	Telemetrum Main	Blue Raven Main		
Size	1.36g / 32psi	1.64g / 34 psi	2.34g / 24 psi	2.7g / 28 psi		
Timing	Apogee + 0	Apogee + 1.5s	600ft AGL	550ft AGL		

Simulated Flight Characteristics

Expected Apogee	5032 Ft ACS -> 4500ft
Expected V_{Max}	652ft/s / 444 mph / Mach 0.586
Expected A_{Max}	14.8 G
Wet Stability Margin	3.33 cal / 16.2 %
Simulated Dry Mass	8091g / 10125g loaded
Notes:	-175 ft/s Blue Raven Emergency Main deploy speed
Primary Flight Goals	☑ Safe Flight ☑ Stable Ascent ☑ Recovery Device Deployment ☑ Good Recovery ○ No Damage / in flyable state ☒ ACS Provides Stable drag induction
Secondary / Tertiary Flight Goals	☑ Onboard Cameras record flight ☒ record ACS activation ☑ record Parachute deployment

UML Flight Log Card

Overall Flight Outcome

Recorded Apogee	TM : 6574 ft BR: 5580 ft
Velocity	TM BR: 670 ft/s or 454 mph
Recovery Device Deployment Notes	Both parachutes deployed on primary command main parachute tether Box stitch failed leading to PERR-C sliding down tether to the upper section
Mission Notes	ACS did not deploy, logic board failed to detect launch.

Post Flight Write-Up:

High-winds led to the vehicle being dragged ~500 yds.

Damage:

Fin retain ring – Destroyed
ACS Camera Cover – Damaged → Replaced for cosmetics
Main riser – PERR-C attachment point destroyed
ACS Motor – Water damage → Destroyed

5.6.1 Vehicle Integration Inspection Sheet A – Payload Systems

PEP Inspection

Are all wires connected and secured to the frame		
Are the Batteries secured to the frame?		
Are the Batteries full (4.2V, 8.4V or 12.6V)?		
Are the batteries healthy, showing no signs of puffiness?		
Is the 2M Radio set to frequency: ________		
Is the 915MHz Radio set to frequency: ________		
Has the system connected to the ground station and reported healthy Prior to integration?		
EXO Sign-Off		
Safety Officer / Team Lead Sign-Off Not flying - VDF	[signature]	

PERR-C Inspection

Are both bulkheads structurally sound, showing no signs of fatigue?	✓	[initials]
Is the eye-nut and jam-nut on the aft end tightened down ~~and threadlocked~~?	✓	[initials]
Is the service module frame (sled) secured to the rail?	✓	[initials]
Is the forward bulkhead secured ~~with a locknut?~~ Ballast	✓	[initials]
Is the Fight deck secured to the System, ~~are the crew strapped in?~~ NO crew	✓	[initials]
Does the 3D printed airframe show any signs of fatigue? NO fatigue	✓	[initials]
~~Are the set screws installed and tight?~~		
EXO Sign-Off	✓	CF
Safety Officer / Team Lead Sign-Off	[signature]	

ACS Integration

Does the structural elements of the air braking system appear intact and show no signs of fatigue?	✓	
Are all screws and nuts on the deployment system snug?	✓	
Are the Aerodynamic surfaces intact and show no cracks?	✓	
Are the electrical systems secure, connected soundly, and tied down?	✓	
Does the airframe section pass a visual inspection? Are the forward and aft mounting holes intact and showing no sign of damage?	✓	
Are the bulkheads intact, showing no signs of fatigue?	✓	
Is the forward U-bolt intact, showing no signs of fatigue? Are all retaining nuts on the U-Bolt?	✓	
Are all nuts closing the bulkheads present and tight?	✓	[illegible]
EXO Sign-Off	CP	GP
Safety Officer / Team Lead Sign-Off	✓	[illegible]
Team Mentor Sign-Off	✓	MG

Payload Systems Final Inspection

Has PERR-C passed pre-flight start-up testing?		
Has PERR-C passed pre-flight inspection?	✓	[illegible]
Is the 2M radio set to frequency:____________		
Is the 915MHz radio set to frequency:____________		
Has ACS passed pre-flight start up testing?	✓	[illegible]
Has ACS passed flap actuation test?	✓	[illegible]
~~CAPCOM Sign-Off~~		
EXO Sign-Off	CP	CP
Safety Officer / Team Lead Sign-Off	✓	[illegible]
Team Mentor Sign-Off	✓	MG

5.6.2 Vehicle Integration Inspection Sheet B – Vehicle Structures and Recovery Systems

Booster Inspection

Using a flashlight, inspect the visible sections of epoxy on the motor mount for any cracks or other signs of fatigue?	✓	
Are the rail buttons present, secured using #4 screws, and showing no signs of damage?	✓	
Are the edges of the fins intact, is there any sign of damage to the fins?	✓	
Has the Fin Retention Ring been attached, is it hand-tight?	✓	
~~Can~~ are all 12 fasteners for the fin can installed and secured?	✓	
Are the fins securely installed in the vehicle? (Do they wobble when pushed?) NO	✓	
Are the holes for the forward attachment points intact and showing no signs of fatigue?	✓	
Booster Section Leader Sign-off	✓	
Safety Officer / Team Lead Sign-Off		

ARCS Inspection and Integration

Are all internal wires to the computers secured in their terminals, connectors, and tie-downs?	✓	
Have the Service Cameras been Adjusted into flight position and been secured?	✓	
Are flight batteries charged and in healthy condition (4.2V or 8.4V)?	✓	
Is Blue Ravens Battery Secure, does the computer power on and report healthy?	✓	
Is Telemetrum's battery secure, does the computer power on and report healthy?	✓	
Are the bulkheads showing signs of structural fatigue, are both nuts present on the back of the U-Bolt?	✓	
Does the airframe section show any signs of fatigue?	✓	
Are the forward and aft bulkhead rails secured by nuts, are they torqued down?	✓	
Recovery Section Leader Sign-Off	✓	
Safety Officer / Team Lead Sign-Off	✓	

Motor Assembly and Integration

Motor Date Code: 09 032413	✓	[illegible]
Does the motor packaging show any signs of damage or holes, has the propellant been exposed to water?	✓	[illegible]
Does reload come with all materials: Closures, O-rings, Liner?	✓	[illegible]
Are the O-rings in good health, are they dry / cracked?	✓	[illegible]
Has the ejection charge been removed, and the hole to the delay grain been filled?	✓	[illegible]
Are all closure rings secured and tight?	✓	[illegible]
Has the Motor Retaining ring been attached, is it hand-tight?	✓	[illegible]
Safety Officer Sign-Off	✓	[illegible]
Team Mentor Sign-Off	✓	MG

Vehicle Final Integration

Is the Upper Section Integrated and signed-off?	✓	[illegible]
is the Lower Section integrated and signed-off?	✓	[illegible]
Are the Payload Systems Integrated and Inspected?	✓	[illegible]
Has the main parachute been packed and secured to the vehicle?	✓	[illegible]
Has the drogue parachute been packed and secured to the vehicle?	✓	[illegible]
Are the Launch lungs secured to the vehicle, are they loose?	✓	[illegible]
Are all shear pins installed?	✓	[illegible]
Has Speed Tape been applied to shear pins and non in-flight separation points?		
Safety Officer Sign-Off	✓	[illegible]
Team Lead Sign-Off		
Team Mentor Sign-Off		

5.6.3 Vehicle Launch and Recovery Inspection Sheet

Vehicle Final Inspection

Has the section on PEP assembly been signed off?		
Has the section on PERR-C assembly been signed off?		
Has the section on ACS assembly been signed off?		
Has the section inspecting all sections of the payload systems been signed off?		
Has the section on booster assembly been signed off?		
Has the section on ARCS integration and integration been signed off?		
Has the section on motor assembly and integration been signed off?		
Has the section on vehicle final integration been signed off?		
Safety officer Sign-Off		
Team Lead Sign-Off		

Final Go / No-Go poll

EXO	✓	dP
~~PAO~~		
CAPCOM	✓	LVM
RECO	✓	[illegible]
~~T2~~		
~~T-DRO~~		
~~BOOSTER~~		
~~OPS~~		
VSO	✓	[illegible]
FLIGHT		

Vehicle Arming Steps

Has the range been cleared by the RSO for the Red team to enter	✓	
Have all protective coverings been removed from the vehicle?	✓	
Are both computers on and reporting healthy?	✓	
When removing the arming pin, do both computers report good continuity on all 4 ejection charges?	✓	
Has the ignitor been inserted, secured to the launch pad, and connected to the controller	✓	
Final Check for remove before flight (RED) tags on the vehicle	✓	
Team Lead Sign-Off	✓	
Safety Officer Sign-Off	✓	
Team Mentor Sign-Off		

Post Flight Inspection

Did the vehicle fly on a straight path with no major pitch events?	✓	
Did telemetry connection to the vehicle continue throughout the flight with little to no interruption?	✓	
Have Photos been taken of the vehicles landed configuration?	✓	
Did the recovery system operate as intended?	✓	
Has the vehicle been safed after the flight before continuing inspection?	✓	
Are all sections of the vehicle still connected? Flight connecting piece failed, no separation	✓	
Is there any damage to the parachute bays (zippering) as a result of a high deployment velocity? NO	✓	
Is there any damage to the section from impact with the ground due to high descent velocity (chipped edge of fiberglass tube, cracked fin, cracked motor retention ring, etc.)?	—	—
Safety Officer Sign-Off	✓	
Team Lead Sign-Off		

1. Damage to fin Trailing edges (3/4), Damage to fin retainer.

Appendix B – ACS Logic Board Code

```
#basic libraries
import time
import board
import neopixel
import os
import busio
import digitalio
import math
import storage
#Sensors+SD card+motor driver pwm
import adafruit_rfm69#Radio
import adafruit_bno055#Gyro
import adafruit_bmp3xx#Barometer
import adafruit_gps#GPS
import adafruit_adxl37x#High g accelerometer
import sdcardio#SD card
from adafruit_max1704x import MAX17048
from adafruit_lc709203f import LC709203F, PackSize
import pwmio
#!! update pinout on all initialization steps including all sensors and airbrake pwm
#?? setpoints
LockoutAngleInDegrees=20 #pitchover in which that the airbrake won't deploy
LaunchAccelerationThresholdInMS = 20 #!! amount of acceleration to incriment the activation count, change to something reasonable
ActivationThreshold = 10 #!! amount of accumulated activations for launch detect to be activated
ACSDeployTimeAfterLaunchInMiliSeconds = 3250
ACSRetractTimeAfterLaunchInMiliSeconds = 7000
TestRequired=True #!! should the airbrake actuate on the pad to test?
TimeAfterInitializationToTestInMiliSeconds = 20000
AirbrakeActuationTime = 0.15
```

```
MakeSaveData=True #!! change this to true before launch

#?? only use this on non-launch days do not change unless Ben tells you to

ReadFile=False

#PWM for motor


PWM_PIN = board.A1

motor_pwm = pwmio.PWMOut(PWM_PIN, frequency=20000, duty_cycle=0)  # 20kHz PWM

motor_pwm.duty_cycle=0


#initialize direction on motor

DIR_PIN = board.A3

motor_dir = digitalio.DigitalInOut(DIR_PIN)

motor_dir.direction = digitalio.Direction.OUTPUT

State=1 #?? State machine control variable


#1 is pad

#2 is launch

#3 is airbrake deployed

#4 is airbrake retracted


#data tables

Data=[]

AltitudeDeltaTable=[]

MotorStartTime=None

AltitudeDelta=0

ActivationCount = 0 #!! do not change, just initialization

blink_interval = 0.5  # Adjust blink speed (seconds)

last_blink_time = time.monotonic()

led_on = False  # Tracks LED state

LaunchTime=0

motor_start_time=None
```

```
AirBrakeDeployTime=0

SDCardFolderName=""

BatteryMonitor=None

BatteryVoltage=0

BatteryVoltageToTransmit=""

FileNum=0

SDCardFileName=""

MotorSpeed=0

MET=time.time()


#initalization of sensors

ErrorInStartup=False

# I2C and SPI initialization

i2c = board.I2C()

i2c.try_lock()

i2c_address_list = i2c.scan()

i2c.unlock()

spi = busio.SPI(board.SCK, MOSI=board.MISO, MISO=board.MOSI)

#spi = board.SPI()

spi.unlock()

# UART initialization

uart = busio.UART(board.TX, board.RX)


#Onboard neopixel

try:

   pixel = neopixel.NeoPixel(board.NEOPIXEL, 1)

except Exception as e:

   print("NeoPixel initialization failed:", e)

   pixel = None

   ErrorInStartup=True

#
```

```
#onboard battery Monitor
if 0x0b in i2c_address_list:
    lc709203 = LC709203F(board.I2C())
    # Update to match the mAh of your battery for more accurate readings.
    # Can be MAH100, MAH200, MAH400, MAH500, MAH1000, MAH2000, MAH3000.
    # Choose the closest match. Include "PackSize." before it, as shown.
    lc709203.pack_size = PackSize.MAH1000
    BatteryMonitor = lc709203
elif 0x36 in i2c_address_list:
    max17048 = MAX17048(board.I2C())
    BatteryMonitor = max17048
#gyro
try:
    Gyro = adafruit_bno055.BNO055_UART(uart)
except Exception as e:
    print("Gyro initialization failed:", e)
    Gyro = None
    ErrorInStartup=True
#
#Barometer
try:
    IBaro = adafruit_bmp3xx.BMP3XX_I2C(i2c)
    if IBaro:
        GroundAltitudeInMeters = IBaro.altitude
except Exception as e:
    print("Barometer initialization failed:", e)
    IBaro = None
    ErrorInStartup=True
#
#Accelerometer
#!! NO GPS OR ACC ON FLIGHT 1, THIS IS EXPECTED AND NORMAL DO NOT UNCOMMENT THIS CODE
```

```
GPS=None
"""
try:
    Acc = adafruit_adxl37x.ADXL375(i2c)
except Exception as e:
    print("Accelerometer initialization failed:", e)
    Acc = None
    ErrorInStartup=True
#
#gps
try:
    GPS = adafruit_gps.GPS_GtopI2C(i2c, debug=False)
    GPS.send_command(b'PMTK314,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0')
    GPS.send_command(b"PMTK220,1000")
except Exception as e:
    print("GPS initialization failed:", e)
    GPS = None
    ErrorInStartup=True
#
"""

#
#SD card
try:
    csSDCard = board.D11
    sdcard = sdcardio.SDCard(spi, csSDCard)
    vfs = storage.VfsFat(sdcard)
    storage.mount(vfs, "/sd")
    if not(ErrorInStartup) and MakeSaveData:
        #this section of code just gives us a random name for the folder to store our data in
        x,y,z=Gyro.euler
```

```
        pressure=lBaro.pressure
        temp=Gyro.temperature
        temp2=lBaro.temperature
        x2,y2,z2=Gyro.magnetic
        foldername=str(abs(x+y+z+pressure+temp+temp2+x2+y2+z2))
        SDCardFolderName = f"/sd/{foldername}"
        os.mkdir(SDCardFolderName)
        SDCardFileName=f"{SDCardFolderName}/{FileNum}.txt"
        FileNum=FileNum+1
        File=open(SDCardFileName,"w")
        File.write("Time(Seconds since power on),Barometer
Altitude,GyroX,GyroY,GyroZ,,AccZ,BatteryVoltage,MotorSpeed,StateMachine")
        File.close()
    if ReadFile:
        print("Reading Folder Structure\n")
        stack = [("/sd", 0)]  # Stack to manage directories and their indentation level

        while stack:
            current_dir, tabs = stack.pop()  # Get the next directory and its indentation level
            for file in os.listdir(current_dir):
                if file == "?":
                    continue  # Skip potential corrupt entries

                file_path = f"{current_dir}/{file}"
                stats = os.stat(file_path)
                filesize = stats[6]
                isdir = stats[0] & 0x4000

                if filesize < 1000:
                    sizestr = str(filesize) + " B"
                elif filesize < 1000000:
                    sizestr = "%0.1f KB" % (filesize / 1000)
```

```
        else:
            sizestr = "%0.1f MB" % (filesize / 1000000)

        indent = "    " * tabs
        prettyprintname = indent + file
        if isdir:
            prettyprintname += "/"
        print('{0:<40} Size: {1:>10}'.format(prettyprintname, sizestr))

        # If it's a directory, add it to the stack to process later
        if isdir:
            stack.append((file_path, tabs + 1))
        else:
            # If it's a file, print its contents
            try:
                with open(file_path, 'r') as f:
                    print(f"{indent}Contents of {file}:")
                    print(f.read())  # Print the entire file contents
            except Exception as e:
                print(f"{indent}Failed to read file {file}: {e}")
except Exception as e:
    print("SD Card initialization failed:", e)
    ErrorInStartup=True
#
#Radio
try:
    csRadio = digitalio.DigitalInOut(board.D9)
    reset = digitalio.DigitalInOut(board.D13)
    rfm69 = adafruit_rfm69.RFM69(spi, csRadio, reset, 915.0)
    rfm69.tx_power=20
    RSSI=rfm69.rssi
```

```
except Exception as e:
    print("Radio initialization failed:", e)
    rfm69 = None
    ErrorInStartup=True
#


def get_delta(value, history, delta=1, max_entries=10):
    # enough history to calculate delta
    if len(history) < delta:
        prev_value = value  # default to current value if history is too short
    else:
        prev_value = history[-delta]

    # calculate delta
    d_value = value - prev_value

    # add current value to history
    history.append(value)

    # keep the history limited
    if len(history) > max_entries:
        history.pop(0)  # remove the oldest entry

    return d_value
#!! check if gyro initializes its angles based on startup angle, if so it would need to be started flat on the rail
def set_motor(speed):
    """
    Sets motor speed and direction.
    Speed ranges from -1.0 (full reverse) to 1.0 (full forward).
    0 stops the motor (brake mode).
    """
```

```
    MotorSpeed=speed
    if speed == 0:
        motor_dir.value = False  # Brake
        motor_pwm.duty_cycle = 0
    elif speed > 0:
        motor_dir.value = False  # Forward (DIR = Low, PWM = High)
        motor_pwm.duty_cycle = int(speed * 65535)
    else:
        motor_dir.value = True  # Backward (DIR = High, PWM = High)
        motor_pwm.duty_cycle = int(-speed * 65535)
def detect_launch(acc_z, ActiveThreshold,launch_threshold, count):
    """
    parameters:
        ActivationThreshold (int): Number of consecutive detections needed to confirm launch
        ActivationCount (int): Counter for consecutive detections
    """

    # Detect launch based on acceleration
    if acc_z >= launch_threshold:
        count += 1
    else:
        count = 0

    # Confirm launch if acceleration is sustained for 'ActivationThreshold' readings
    if count > ActiveThreshold:
        return True, count  # Launch detected

    return False, count  # Launch not detected yet

#!! add func to record LaunchTime, ACC, Gyro, Altitude, RSSI, Motor Deployment true/false, State, time.monotonic
initializationfinizedtime=time.monotonic()
```

```
#set_motor(-0.5)
#time.sleep(0.4)
#set_motor(0)
set_motor(1)
time.sleep(0.2)
set_motor(0)
previous_time = time.monotonic()  # Initialize the time tracker
while True:
  loop_start_time = time.monotonic()  # Start timing
  #?? sensor read
  # GPS read (only if GPS was initialized successfully)
  if GPS:
    GPS.update()
    Lat = GPS.latitude
    Lon = GPS.longitude
    GPSAltitude = GPS.altitude_m
  else:
    Lat, Lon, GPSAltitude = None, None, None
  if Lat is not None and Lon is not None:
    LatToTransmit = str(Lat)[:10]
    LonToTransmit = str(Lon)[:10]
  else:
    LatToTransmit = "0000000000"
    LonToTransmit = "0000000000"
  #
  # Barometer read
  if IBaro:
    AltitudeInMeters = IBaro.altitude
    AltitudeInMetersToTransmit = str(AltitudeInMeters)[:4]
    AltitudeDelta=get_delta(AltitudeInMeters, AltitudeDeltaTable, 5, 10)
  else:
```

```
    AltitudeInMeters = 0
    AltitudeInMetersToTransmit = "0000"

# Gyro read
if Gyro:
    try:
        GyroX, GyroY, GyroZ = Gyro.euler
        AccX, AccY, AccZ = Gyro.linear_acceleration
        GyroXToTransmit = str(GyroX)[:4] #roll
        GyroYToTransmit = str(GyroY)[:4] #yaw
        GyroZToTransmit = str(GyroZ)[:4] #pitch
        AccXPrint = str(AccX)[:4]
        AccYPrint = str(AccY)[:4] # vertical acceleration
        AccZPrint = str(AccZ)[:4]
    except RuntimeError as e:
        print(f"Uart Error: {e}")
        GyroX = GyroY = GyroZ = 0
        AccX = AccY = AccZ = 0
        GyroXToTransmit = GyroYToTransmit = GyroZToTransmit = "000"
else:
    GyroX = GyroY = GyroZ = 0
    AccX = AccY = AccZ = 0
    GyroXToTransmit = GyroYToTransmit = GyroZToTransmit = "000"
#
#radio connection
if rfm69:
    RSSI=rfm69.rssi
else:
    RSSI=0
#battery monitor
if BatteryMonitor:
```

```
        BatteryVoltage=BatteryMonitor.cell_voltage
        BatteryVoltageToTransmit=str(BatteryMonitor.cell_voltage)[:2]
    else:
        BatteryVoltage=0
        BatteryVoltageToTransmit=""
        ErrorInStartup=True
    #??
    if State==1: #?? pad
        current_time=time.monotonic()
        if pixel:
            if ErrorInStartup == True:
                pixel.fill((255, 255, 0))
            if ErrorInStartup == False:
                pixel.fill((0,255,0))
        if (current_time-initializationfinizedtime)*1000 > TimeAfterInitializationToTestInMiliSeconds and TestRequired:
            set_motor(-1)  # 50% speed forward
            time.sleep(AirbrakeActuationTime)
            set_motor(0)
            time.sleep(1)
            set_motor(1)
            time.sleep(AirbrakeActuationTime)
            set_motor(0)
            TestRequired=False
        Launch, ActivationCount = detect_launch(AccY, ActivationThreshold, LaunchAccelerationThresholdInMS, ActivationCount)
        #GyroXToTransmit = str(GyroX)[:3] #roll
        #GyroYToTransmit = str(GyroY)[:3] #yaw
        #GyroZToTransmit = str(GyroZ)[:3] #pitch
        if (LockoutAngleInDegrees>abs(GyroY)) and (90-LockoutAngleInDegrees<abs(GyroZ)<90+LockoutAngleInDegrees) and Launch:
            LaunchTime=time.monotonic()
            State=2
```

```
  if State==2: #?? launched
    #!! write code to determine if its okay to deploy the airbrake
    if pixel:
      pixel.fill((255,165,0))
    current_time = time.monotonic()
    if ((current_time-LaunchTime)*1000 > ACSDeployTimeAfterLaunchInMiliSeconds) and
(LockoutAngleInDegrees>abs(GyroY)) and (90-LockoutAngleInDegrees<abs(GyroZ)<90+LockoutAngleInDegrees):
      AirBrakeDeployTime=time.monotonic()
      State=3
  if State==3: #?? airbrake triggered to deploy
    current_time = time.monotonic()
    if pixel:
      pixel.fill((0,0,255))
    set_motor(-1)  # 50% speed forward
    time.sleep(AirbrakeActuationTime)
    set_motor(0)  # Stop the motor
    # or (IBaro and AltitudeDelta<10)
    if (current_time-AirBrakeDeployTime)*1000 > ACSRetractTimeAfterLaunchInMiliSeconds:
      State=4
      set_motor(1)
      time.sleep(AirbrakeActuationTime) #change it to non blocking
      set_motor(0)
  if State==4:
    if pixel:
      pixel.fill((160,32,240))
  #transmit
  if sdcard and MakeSaveData:
    SDCardFileName=f"{SDCardFolderName}/{FileNum}.txt"
    FileNum=FileNum+1
    File=open(SDCardFileName,"w")
    #File.write("Time(Seconds since power on),Barometer
Altitude,GyroX,GyroY,GyroZ,,AccZ,BatteryVoltage,MotorSpeed,StateMachine")
```

```
        File.write(",".join([str(time.time()-MET),
                str(AltitudeInMetersToTransmit),
                str(GyroXToTransmit),
                str(GyroYToTransmit),
                str(GyroZToTransmit),
                str(AccZPrint),
                str(BatteryVoltageToTransmit),
                str(MotorSpeed),
                str(State)]))
        File.close()
    loop_end_time = time.monotonic()
    loop_duration = (loop_end_time - loop_start_time) * 1000  # Convert to milliseconds
    if rfm69:
        rfm69.send(GyroXToTransmit + "|" + GyroYToTransmit + "|" + GyroZToTransmit + "|" + AltitudeInMetersToTransmit + "|" + str(AccZPrint) + "|" + str(BatteryVoltageToTransmit) + "|" + str(MotorSpeed) + "|" + str(State) + "|" + str(loop_duration))
    #
```