Project Hrafn

Critical Design Review

Cedar Falls
ROCKET CLUB

Cedar Falls High School
1015 Division Street, Cedar Falls, IA 50613

January 9th, 2023

I) Summary of CDR Report

1.1 Team Summary

- Team name and mailing address
  - Cedar Falls High School Rocket Club
  - 1015 S Division St. Cedar Falls, Iowa, 50613
- Name of mentor, NAR/TRA number and certification level, contact information
  - Tyler Sorensen, NAR #: 99437, TRA #: 16311, Level Two certified, tylersorensen3@gmail.com
- Indication of plans to launch in Huntsville on April 15th or at home during the launch window of April 1st-April 30th.
  - Our team will be launching in Huntsville on April 15th during Launch Week.
- Documentation of hours spent working on the CDR milestone
  - The team has spent 350 hours working on the CDR milestone. Hours include brainstorming/research, vehicle design/development, payload design/development, CDR writing, CDR proofreading, and CDR presentation creation.

1.2 Launch Vehicle Summary

● Official Target altitude (ft.)

4500 Feet

● Final motor choice

Cesaroni K1440

● Size and mass of individual sections

Total Vehicle Mass & Height: 100.5 inches tall, 22.105 lbs (No Motor & Casing)
Nosecone: 26.5 inches tall, 1.89 lbs
Payload Section: 14.7in tall (2 in external), 4.562 lbs (Complete Payload Weight Included)

Recovery Section: 30 inches tall, 4.346 lbs (Parachute & Related Equipment Included)
Electronics Bay: 12 inches tall (2 inches external), 2.577 lbs
Booster Section: 40 inches tall, 8.73 lbs, NO Motor & Casing Mass Included 12.906 lbs, WITH Motor & Casing Mass Included

● Dry mass of launch vehicle (No Ballast)

22.105 lbs

● Wet mass of launch vehicle

26.281 lbs

● Burnout & Landing mass of launch vehicle

23.79 lbs

● Recovery system

Components			
Component	**Selection**	**Component**	**Selection**
Drogue Parachute	18” Fruity Chutes Drogue Parachute	Ejection Charges	4 & 6g Black Powder Charges
Main Parachute	72” Fruity Chutes Iris Ultra Parachute	Altimeters	PerfectFlite StratoLoggerCF Altimeter
Shock Cord	⅜” Tubular Kevlar	GPS	Featherweight GPS Tracker
Protective Wadding	18” Nomex Parachute Protectors & Disposable Recovery Wadding		

Redundancies
With both the drogue and main parachutes, the vehicle descent time, drift calculation, and kinetic energy upon landing are all well below the maximum allowance to account for any slight mass changes, or variable wind speeds. Additionally, the ⅜" Tubular Kevlar shock cord has a strength rating of 3600lb, far above the needs/weight of our vehicle. As for protective wadding, both 18" Nomex parachute protectors and disposable recovery wadding will be used to insure no damage occurs to the parachutes and inside of the vehicle. The vehicle includes a primary and secondary altimeter. The secondary altimeter will be used as a backup for both the drogue and main parachute ejection charges. To ensure parachute deployment by energetics, a larger, secondary black powder charge occurs one second after the initial ejection charge for the drogue parachute and one second (~100 ft) after the main parachute ejection charge is set to ignite.

● Launch Rail size

1515 Rail, 12 feet tall

1.3 Payload Summary

● Payload title

Deployable Rocketry Operational Navigation Equipment (D.R.O.N.E.)

● Summarize payload experiment

This payload includes two primary components, an Unmanned Aerial Vehicle and a deployment system to release the UAV. The UAV is a quadcopter-style system that folds to fit inside the launch vehicle. The UAV is named "Huginn". The deployment mechanism uses threaded rods and stepper motors to drive apart the payload section of the vehicle and allows for the UAV to launch.

II) Changes made since PDR

2.1 Changes Made to Vehicle Criteria

During further research in sourcing specific components for our vehicle, we found that the nosecone was not the exact length as was expected. Our vehicle height was reduced by 3.5” (104 to 100.5 inches tall) as a result of this.

2.2 Changes Made to Payload Criteria

Upon further development of the UAV design, it was determined that the SE0802-19000KV motors selected in the PDR would not provide sufficient thrust to ensure a successful flight. Based on manufacturer-provided thrust data, the Happymodel EX1204 5000KV motor was selected, as it provides sufficient thrust to ensure a greater than 2:1 thrust-to-weight ratio with all components included.
In the electronics used in the payload system, our team decided that a new component would be a huge help to the testing phase. This component is a small 1.47” screen added to the deployment mechanism and the handheld controller. This will allow any errors or problems in the system to be clearly read and understood, rather than an LED or similar indicator that only vaguely shows a problem potentially.

2.3 Changes Made to Project Plan

Sub-scale launch dates were updated due to inclement weather during the original launch date, and a re-launch occurred due to a premature ejection charge failure during the first flight. Additionally, the line item budget was updated according to design material needs and personnel traveling to Huntsville. Testing, safety, and compliance requirements were added/updated, along with the team timeline.

III) Vehicle Criteria

3.1 Design and Verification of Launch Vehicle

Flight Reliability and Confidence

● Include unique mission statement and mission success criteria

Project Hrafn aims to be a first step in foreign intra-planetary UAV navigation while also providing another means to aid in the recovery of rockets and high-powered rockets through UAV application. To do so, the Hrafn vehicle is equipped with a UAV, designated as D.R.O.N.E., with an additional deployment system to deploy the UAV upon vehicle landing. Upon deployment, the UAV will take off and navigate to the designated location through a GPS in possession of a team member, and once the location has been reached, the UAV will guide team member(s) back to the vehicle through another GPS located on the vehicle. A successful mission would include a functioning UAV and deployment system (once the vehicle has safely landed), along with the UAV being able to navigate autonomously to a team member/location, and then guide the team member(s) back to the vehicle, even if the vehicle has moved on the ground since landing.

● Identify which of the design alternatives from PDR were chosen as the final components for the launch vehicle. Describe why those alternatives are the best choices.

Component	**Selection**	**Justification**
Nose Cone	5:1 G12 Fiberglass Ogive	We chose a 5:1 ratio in an ogive shape for the nose cone as it adds a superior aerodynamic advantage which will allow for a greater altitude. We chose fiberglass as our material because it provides a perfect balance between durability, weight, and cost efficiency.
Body Tube	5.15” OD 5.00” ID G12 Fiberglass	We chose the 5-inch diameter body tube because it cut down on weight and drag without sacrificing stability which will allow us to hit our target altitude of 4500 feet. We chose fiberglass for the body tube because of the balance between durability, weight, and cost efficiency.
Couplers	4.998” OD 4.820” ID	We chose 4.998 OD for the couplers to allow them to slide smoothly in between the sections of the body tube during separation. The fiberglass construction of the couplers strikes a balance between cost, strength, and weight.
Fins	3 - Trapezoidal fins G10	We chose a trapezoidal shape for our fins as it has less drag than the clipped delta and has more versatility than the

	Fiberglass 0.1875” thick	elliptical fin shape. We chose 3 fins instead of 4 because it cuts down on weight without sacrificing stability within the vehicle. We chose fiberglass cut to 0.1875 inches thick as it provides the durability and rigidness we require during flight and recovery.
Motor Mount	2.376” (OD) 2.126” (ID) 24” Long G12 Fiberglass	We chose this motor mount size as it was the size required to house the Cesaroni K-1440 motor that we decided to use for our vehicle. The fiberglass was chosen for the motor mount specifically for its chemical strength under high temperatures of the motor burn.
Centering Rings	0.13” G10 Fiberglass	The thickness was chosen because it was enough to retain the components in the e-bay and couplers with minimal weight and the fiberglass was chosen again for its structural integrity.
Bulk Plates	0.2” G10 Fiberglass	The thickness was chosen because it was enough to retain the components in the e-bay and couplers with minimal weight and the fiberglass was chosen again for its structural integrity.
Motor Retainment	AeroPack 54mm retainer (Model #: RA54L)	This motor retainer was chosen for the motor as its size houses the Cesaroni K-1440 well. We also chose this retainer as it is a retainer that we use for most of our projects in our club for TARC, past NASA SLI projects, and personal projects within the club.

● Using the final designs, create dimensional and computer-aided design (CAD) drawings to illustrate the final launch vehicle, its subsystems, and its components.

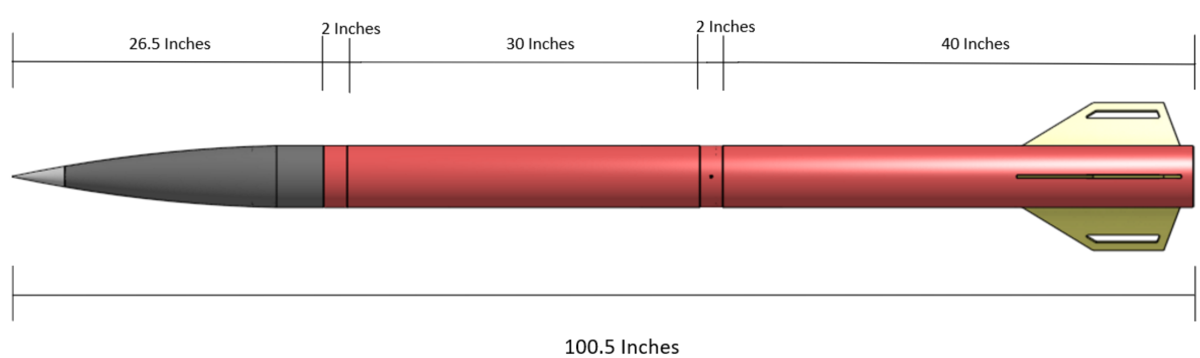


Figure 3.1.1 - Full Vehicle Assembly Dimensions

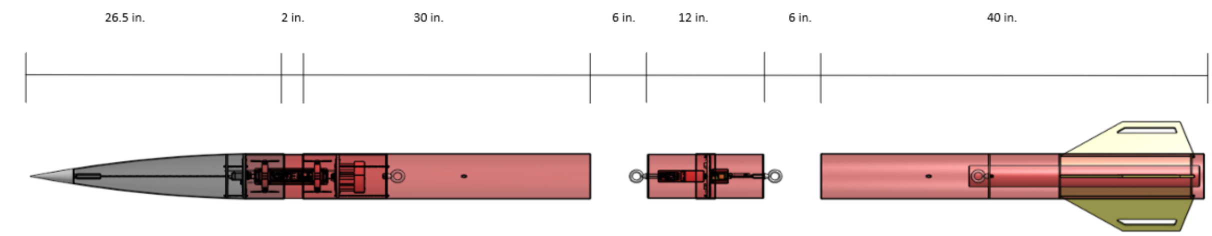


Figure 3.1.2- Full Vehicle Expanded Assembly Translucent (After Parachute Deployment)

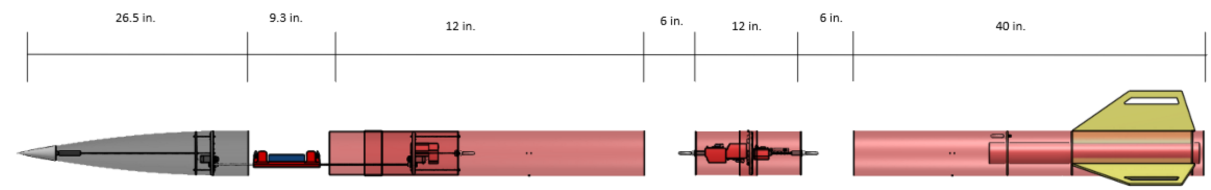


Figure 3.1.3- Full Vehicle Assembly Translucent (After Landing)

● Using the final designs, create dimensional cross-sectional views of each airframe and coupler Component.

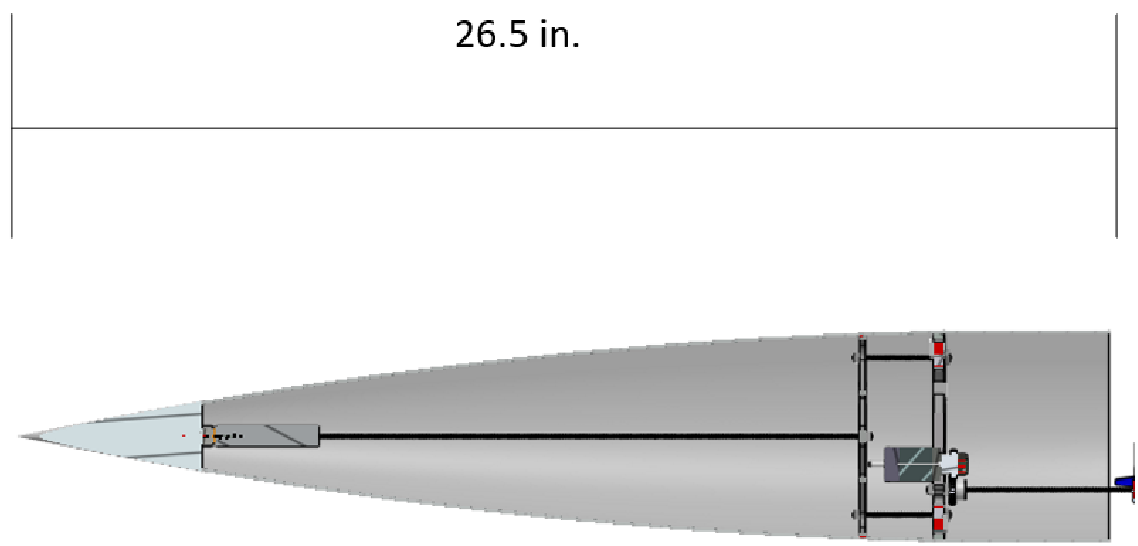


Figure 3.1.4 - Nose Cone

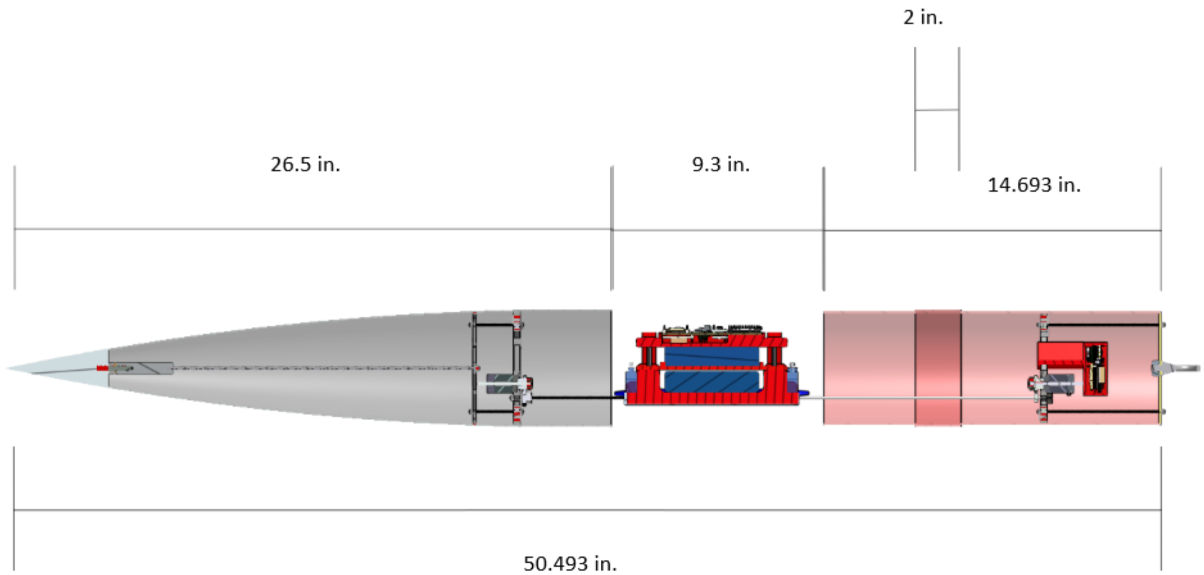


Figure 3.1.5- Payload Coupler with Nose Cone

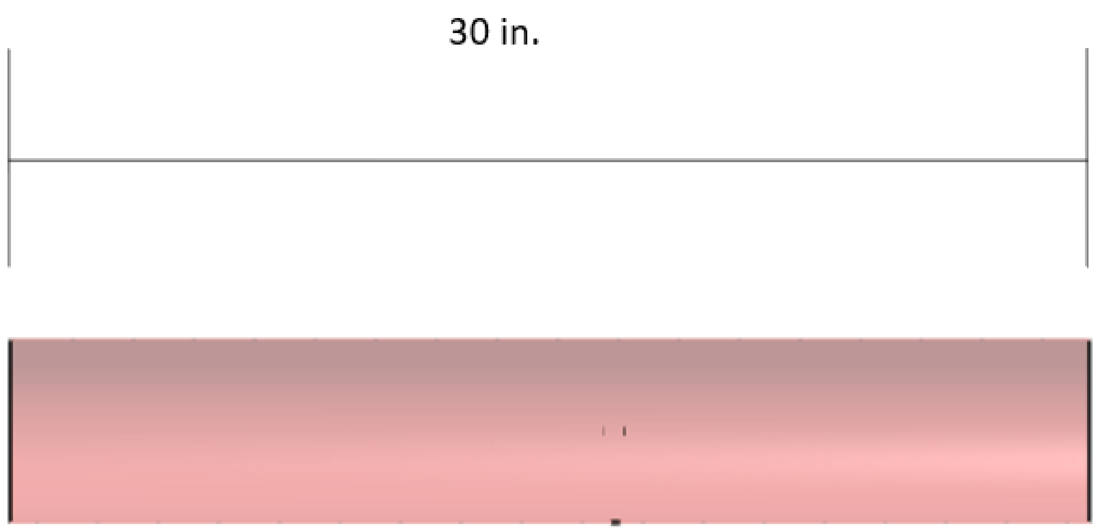


Figure 3.1.6 - Recovery Section

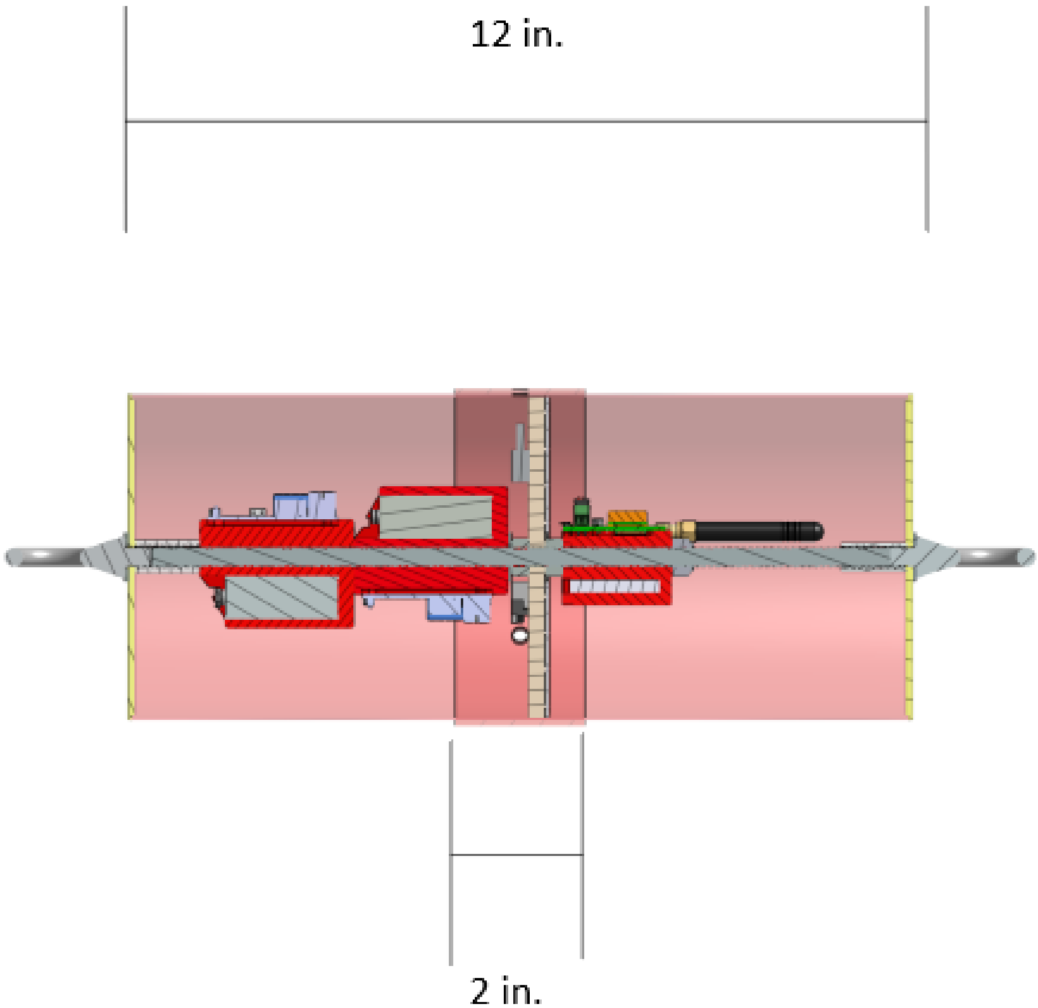


Figure 3.1.7 - Electronics Bay

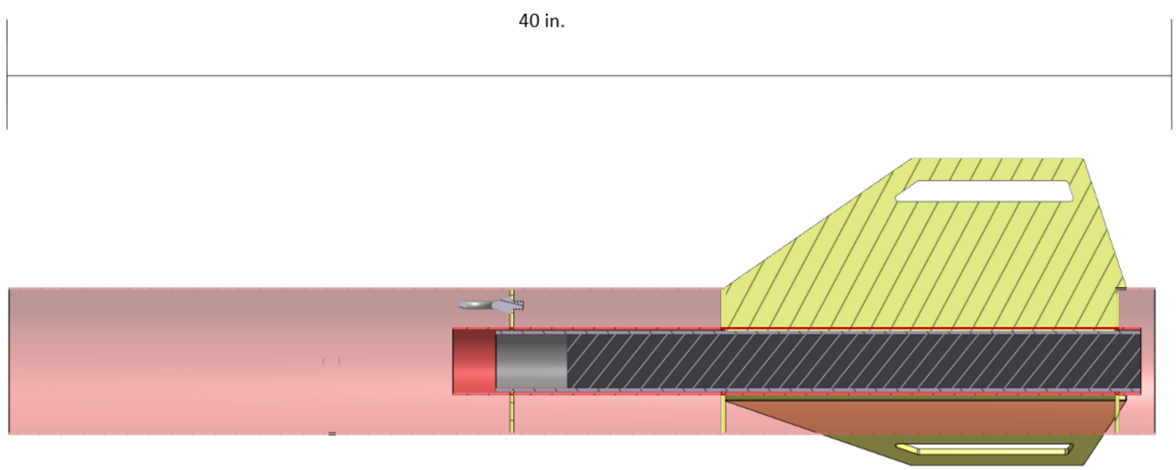


Figure 3.1.8- Booster

● Using the final designs, locate points of separation on each design and show location(s) of energetic materials.

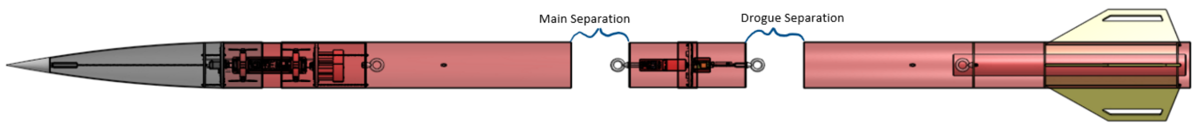


Figure 3.1.9- Points of Separation (In flight)

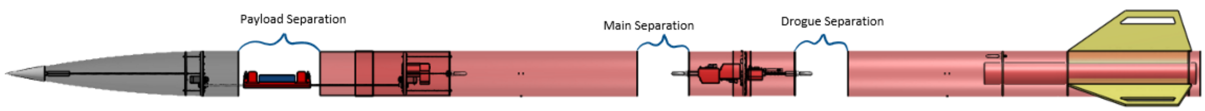


Figure 3.1.10 - Points of Separation (On ground after flight for payload)

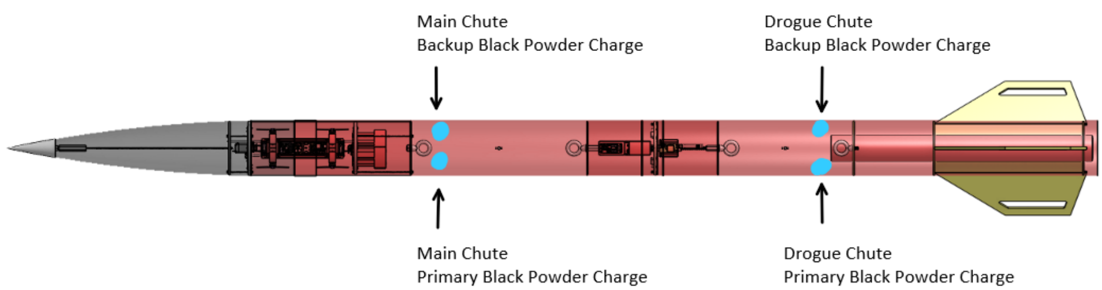


Figure 3.1.11- Energetic Material Locations

● Demonstrate that the designs are complete and ready to manufacture.

As shown previously, the CAD models constructed by the team are matching the masses and dimensions used in RockSim. Detailed and intricate designs can be shown on these models, and have a thorough explanation. These designs, like rivet placement and rail buttons, are specific down to the minute placement. Components in this digital design use actual masses measured from the real components that the team has already ordered and received. With the physical parts in hand or en route, these designs demonstrate that the manufacturing process is ready to begin.

● Discuss the integrity of the design.

○ Suitability of shape and fin style for mission.

The shape and style of the fins are suitable for their functions on this mission. The fins are trapezoidal and have small slots cut into them, as well as being tapered at the ends and being slightly offset from the bottom of the rocket. We decided on the trapezoidal shape because of its natural aerodynamic properties, and the tapered ends help with avoiding producing excess drag. The slots serve the purpose of removing weight from the rocket as well as producing drag and adding to the aesthetics of the rocket as a whole. The fins are offset from the bottom of the rocket for the purpose of structural stability so that the fins do not break when the rocket contacts the ground. This allows us to refly the rocket without significant restoration.

○ Proper use of materials in fins, bulkheads, and structural elements

All structural elements of the vehicle design are composed of fiberglass. The centering rings, bulkheads, and fins use G10 fiberglass while the tubes such as couplers, motor mount, and body tubes, use G12 fiberglass. Since fiberglass is a rigid material this makes it ideal for the vehicle fins. With a slot that allows the fin tab through in order to connect with the internal motor mount tube, coupled with the rigid material of the fins, this limits the possibility of fin fluttering. Already, the fins are stable with the rigidness of the material, although with the additional fin tabs and points of contact, these decrease the chance of fin fluttering at the connection point. Since fiberglass has rigid properties, the bulkheads are also made of it. The bulkheads receive stress from either ejection charges or the parachute harness and by using fiberglass, this limits the chance they break in comparison to plywood or other bulkhead materials.
The other structural element used in the vehicle is adhesives. This team will be using RocketPoxy to attach the fins to the body. Although RocketPoxy takes longer to cure, it has a significant increase in strength when compared to 5-minute epoxy and can withstand much higher temperatures. RocketPoxy also can provide greater strength than fiberglass when used correctly and placed properly.
Bulkheads will maintain position with the use of steel and aluminum rods as well as forged steel eye bolts. The retention system maxed out the available machinery to the team in preliminary testing, presenting that there is a tensile strength of over 1,000 lbs.

○ Sufficient motor mounting and retention

Aeropack retainer + fiberglass centering rings + rocketpoxy ● The motor will be mounted using 3 separate centering rings glued to the inside of the rocket using RocketPoxy filets on both sides of each ring. The motor-mount tube will also be supported by the fins, which are glued to both the outer tube and the motor mount using RocketPoxy, stabilizing both the fins to avoid horizontal movement and the motor mount to avoid vertical movement. We decided to use RocketPoxy as it is incredibly resistant to heat, which the motor mount will have in excess.

○ Estimate the final mass of the launch vehicle as well as the individual subsystems.

Total Vehicle Mass & Height: 100.5 inches tall, 22.105 lbs (No Motor & Casing)
Nosecone: 26.5 inches tall, 1.89 lbs
Payload Section: 14.7 inches tall (2 inches external), 4.562 lbs (Complete Payload Weight Included)
Recovery Section: 30 inches tall, 4.346 lbs (Parachute & Related Equipment Included)
Electronics Bay: 12 inches tall (2 inches external), 2.577 lbs
Booster Section: 40 inches tall, 8.73 lbs, NO Motor & Casing Mass Included 12.906 lbs, WITH Motor & Casing Mass Included
These masses were also identically reviewed in section 1.2

● Provide justification for material selection, dimensioning, component placement, and other unique design aspects.

Materials
Fiberglass is the main material used for the vehicle. With the durability and strength of the fiberglass, this is ideal for high temperatures and high altitudes.

Dimensions
The 5-inch diameter was chosen for the body of the vehicle due to the payload coupler having an outside diameter of 4.988 inches. This is able to perfectly fit the payload design in the vehicle. This allows for the least amount of mass, lower air resistance and is more cost-effective.

Component Placement
The payload components were placed above the recovery system to ensure the separation of the components. This ensures a good stability margin.

Recovery Electronics Retainment
To reduce vehicle mass, the team has opted for a single steel threaded rod with 3d printed electronics housings rather than the significantly heavier option of two threaded rods with a

plywood sled. The team has used a similar design in prior projects with great success. This design uses a 5/16" steel rod centered in the electronics bay and three PLA printed housings (primary altimeter, secondary altimeter, and GPS tracker).

3.2 Subscale Flight Results

● At least one data-gathering device shall be onboard the launch vehicle during the test launch. At a minimum, this device shall record the apogee of the rocket. If the device can record more than apogee, please include the actual flight data in the report.

Apogee occurred at 1,085 feet above ground level. Under the drogue chute, the subscale vehicle had a descent rate of 30 ft/s or 20.45 mph, and under the main chute in combination with the drogue chute, the vehicle had a descent rate of 20.67 ft/s or 14.09 mph.

Another first launch was performed before this one, but due to an error in the calculated amount of black powder ejection charge for the drogue chute, it instead deployed both the main and drogue chute at apogee, as opposed to just the drogue chute. This caused a slower descent time and more drift, causing the vehicle to land in a concrete parking lot, chipping/breaking one of the fins. The team learned from this experience and correctly calculated the needed amount of black powder (less than previously), and also conducted tests on fin strength for the full-scale vehicle to prevent any breaking of the fin along the weaker fin slot points and how far in and big the fin slots should be.

● Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through lading) shall not be accepted.

Flight on 12-30-2022:

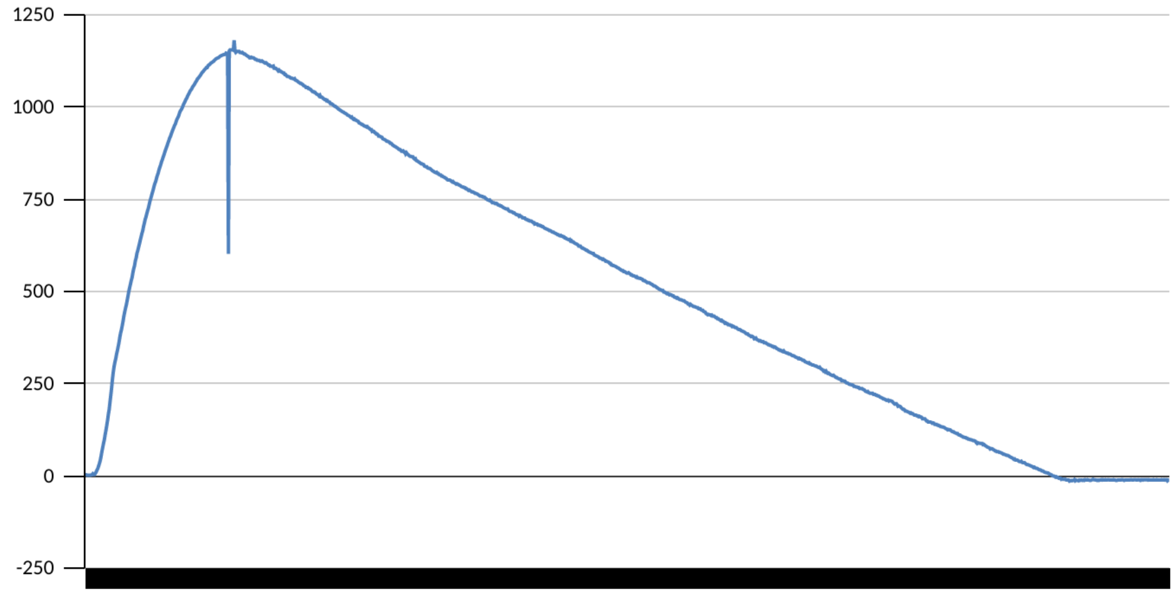


Figure 3.2.1

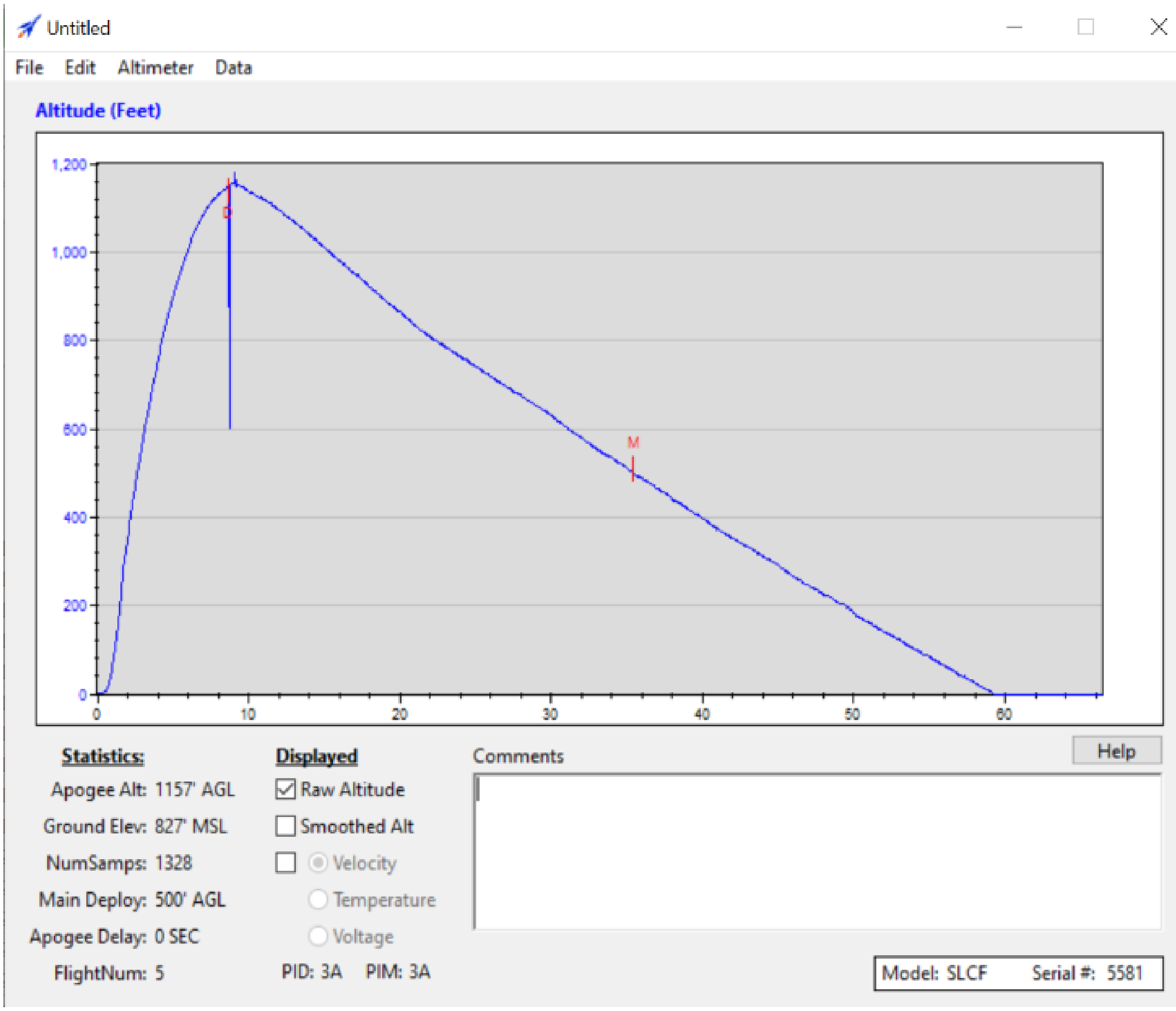


Figure 3.2.2

Details of flight: This flight reached a maximum altitude of 1157 ft. On this flight, the altimeter sent an electronic pulse to ignite the black powder charge for the drogue chute at apogee, however, the black powder charge was too large and caused both the main and drogue to deploy. This influenced the size of the black powder charge that we chose, diminishing it from 2g to 1.5g. Upon landing, the fins were damaged due to the fin slot size and location, we fixed the fins up before the next flight.

Flight on 01-02-2023:

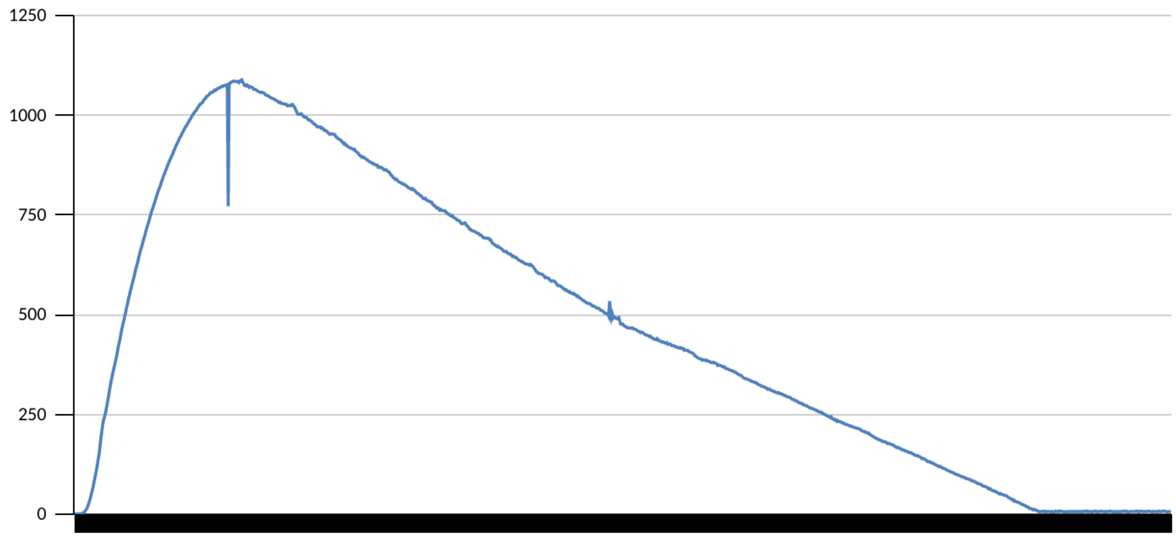


Figure 3.2.3

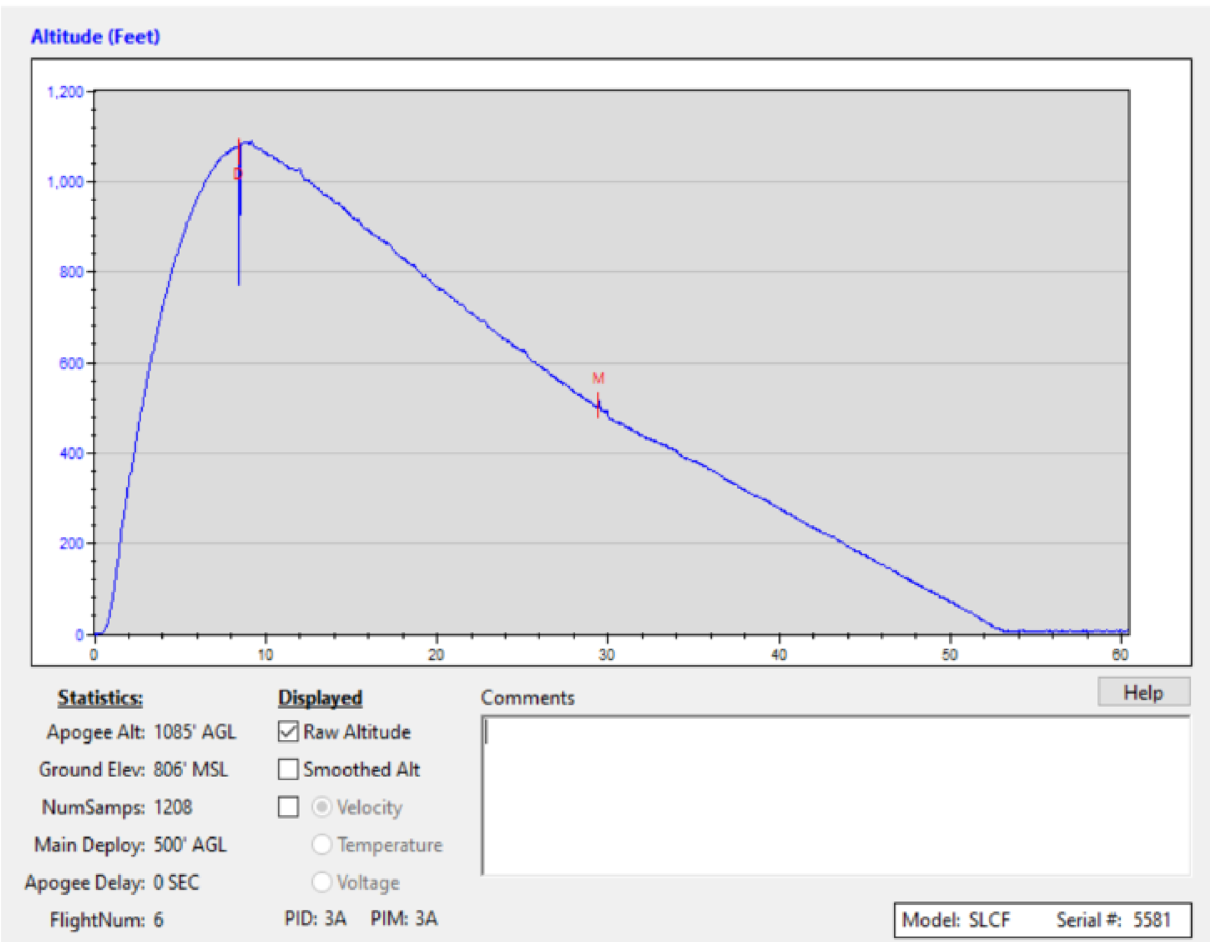


Figure 3.2.4

Details of flight: This flight had a maximum altitude of 1085 ft. On this flight, the black

powder charge for the drogue chute was reduced to 1.5g to ensure that the main would not also be deployed. The chutes deployed at their respective altitudes on this flight and the fins were not damaged. However, we did stress testing on the fins in order to fix the problem with the fins breaking for the construction of the full scale.
Drogue:
30 ft/s
20.45 mph
Main:
20.67 ft/s
14.09 mph

● Quality pictures of the as-landed configuration of all sections of the launch vehicle. This includes but is not limited to nosecone, recovery system, airframe, and booster.

Figure 3.2.5 - Full Landing Configuration

Figure 3.2.6 - Nose Cone Section

Figure 3.2.7 - Recovery System and Electronic Bay Section

Figure 3.2.8 - Booster Section

● Describe the scaling factors used when scaling the rocket. What variables were kept constant and why? What variables do not need to be constant and why?

When designing the vehicle, it was important to scale down all the airframe parts the same scale to keep it consistent. The body tube, nose cone, motor, and fins all were scaled down by 50%. This scaling was done in order to give the team an accurate prediction of the coefficient of drag and stability/integrity of the vehicle design.

Other components were not scaled to 50% in order to ensure a successful and safe flight. The components included rail button size, the motor mounting configuration, and parachute size. For the motor mount, scaling down by 50% wouldn't allow the use of the correct motor for the weight of the subscale vehicle, so a more suitable motor was selected. For the rail button size, our team used a 10:10 to fit the rail size our team has. The parachute being scaled by 50%

would cause a low descent rate, leading to an unsafe amount of drift, which wouldn't be accurate for the vehicle.

In terms of the mass of the rocket, the original plan was to use a ballast to simulate the mass, but the construction of the vehicle was sufficient to simulate mass, so ballast wasn't needed.

- Describe launch day conditions and perform a simulation using those conditions.

Date	Jan. 2nd, 2023
Temperature	36 ºF
Humidity	80%
Wind Speed	4 mph
Air Pressure	30.05 Hg
Cloud Cover	97%
Ground Level	960 ft. ASL

	Results	Engines loaded	Max. altitude Feet	Max. velocity Miles / Hour	Optimal delay	Max. acceleration Gees	Altitude at deployment Feet	Velocity at launch guide departure Miles / Hour	Velocity at deployment Miles / Hour	WeatherCocking
1		[G80NT-10]	1137.15	182.80	7.00	7.08	n/a	49.41	n/a	Safe
2		[G80NT-10]	1158.26	184.64	7.12	7.12	n/a	40.31	n/a	Safe
3		[G80NT-10]	1085.14	182.20	6.77	7.08	n/a	40.29	n/a	Safe

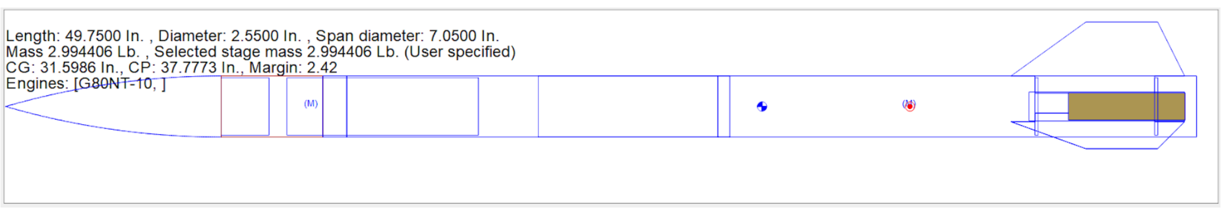


Figure 3.2.10

- Perform an analysis of the subscale flight.
  - Compare the predicted flight model to the actual flight data. Discuss the results.

The Subscale flight was smooth with no real failures, the launch was smooth after a couple of tries to get the motor to ignite. The ascent was stable, though the rocket did not travel straight up, likely because it was pushed by the wind. Both parachutes deployed at the correct times and slowed the descent properly. The parachutes were close to wrapping their cords together,

but nothing bad happened. The rocket landed on the ground with no damage, and the electronics were still functional. Drogue and main chute deployments were very similar between the two. The powder charge for the main chute is unchanged, however, the drogue chute black powder charge was decreased to 1.5 grams from 2.	
Target altitude: 1300 ft.	Subscale altitude: 1085 ft.

○ Discuss any error between actual and predicted flight data.

The cause of the discrepancy between the predicted and actual altitudes was most likely caused by the flight path of the rocket, as well as the coefficient of drag of the rocket. The coefficient of drag is most likely slightly different on the real vehicle than in the Rocksim simulations. This could be caused by the surface texture of the unpainted tube, which differentiates from the simulation, as well as a difference in the taper of the fins. Furthermore, the low temperature on the launch date could have caused an increase in air density, which further increased drag and hindered the launch profile.

○ Estimate the drag coefficient of the full-scale rocket with subscale data.

Our first subscale flight had a drag coefficient of 0.47. The second flight gave us a coefficient of 0.63. We also compared these numbers with last year's full-scale flight which yielded a result of 0.40. Past rockets have been close in both drag coefficients and physical form so using these numbers we will estimate the drag coefficient of the full-scale rocket to be 0.40.

● Discuss how the subscale flight data has impacted the design of the full-scale launch vehicle.

Our subscale flight has impacted our final vehicle design in terms of weight, length, and fin slot configuration. On our flight, our fin slots caused the edge of the fin to break, causing some concern for the location and configuration of the slots. Because of this, we have decided to test various configurations for strength for slot sizes and locations.

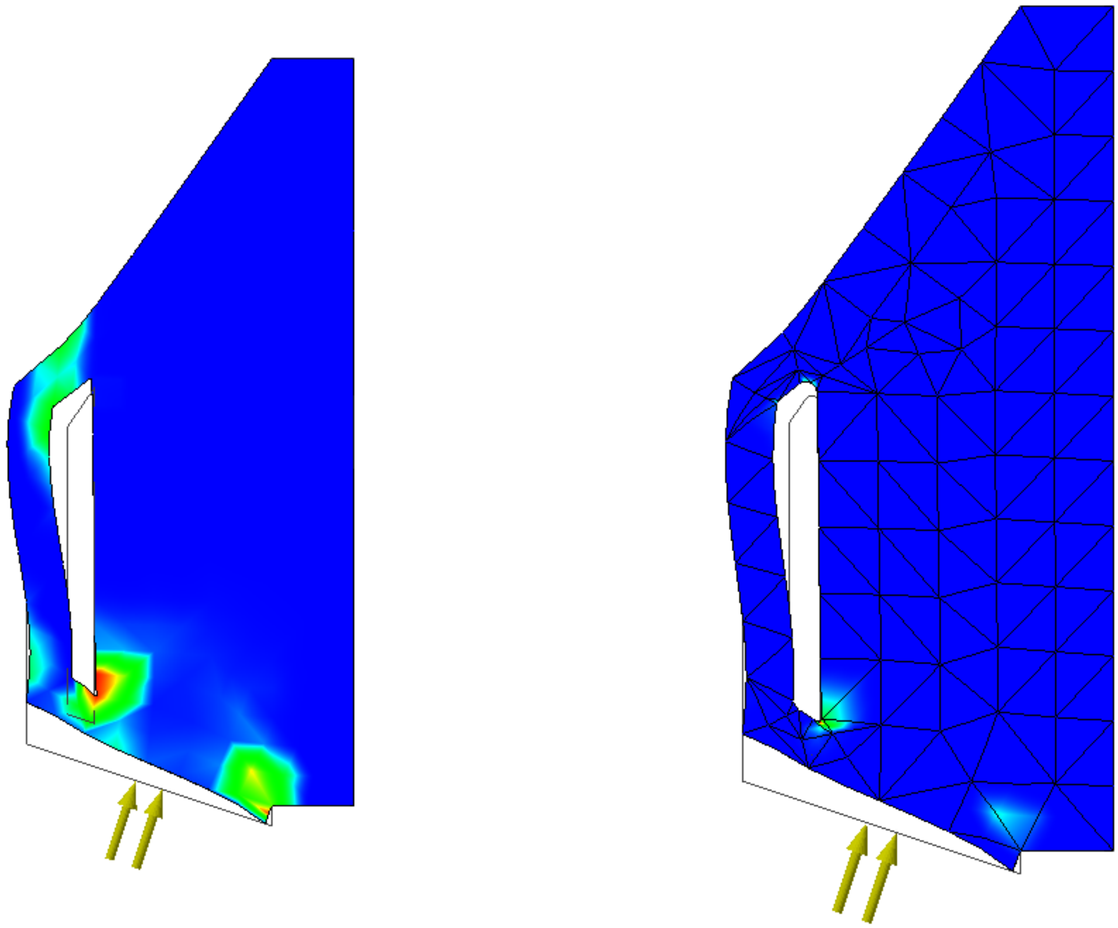


Figure 3.2.11 - fin slot stress testing

Using a stress analysis on Autodesk, we confirmed our original full scale design would work. In making our subscale vehicle, we used a laser cutter to make our fins, which resulted in square corners of the slot (higher stress on the left). Our full scale has the intention of having a fillet on the edges (seen on right). This has very minimal stress placed on the fin compared to the straight edges which will strengthen the integrity of the fins. We will also be machine cutting fiberglass fins for our full scale which will also improve the structural integrity of the fin.

We also made a change to the length and weight of the rocket because after receiving some of our full-scale parts, it was discovered that the nose cone has a length of 26.5 inches exposed as opposed to the 30 inches that we thought at first, this impacted our overall length making it 3.5 inches shorter. This also impacts our weight as well as our payload design.

3.3 Recovery Subsystem

● Identify which of the design alternatives from PDR were chosen as the final components for the recovery subsystem. Describe why those alternatives are the best choices.

Component	**Selection**	**Justification**
Drogue Parachute	18” Fruity Chutes Drogue Chute	The drogue parachute size was chosen specifically for its descent rate and time when paired with a 72” main parachute.
Main Parachute	72” Fruity Chutes Iris Ultra Parachute	The 72” Fruity Chutes Iris Ultra Parachute was chosen primarily for its safe kinetic energy provided in descent. It adequately slows down the vehicle within the kinetic energy requirements in the SLI handbook.
Shock Cord	⅜” tubular Kevlar (3600 lb strength) 25’ long	This ⅜“ tubular Kevlar was chosen for its high strength and non-flammable properties. These properties made it the most durable and reliable shock cord option for our recovery system.
Protective Wadding	18-inch Nomex Parachute Protectors & Disposable Recovery Wadding	In order to protect the parachutes from the ejection charges our team chose to use Nomex. Specifically, we chose a 21 inch octagonal parachute protector and a 12x12 inch square parachute protector, for the main and drogue parachutes respectively. Disposable wadding with fireproof insulation will be used alongside this as an added protection layer for the parachutes and kevlar. This also fills the extra space in the ejection chambers, producing better pressure for a better ejection.
Ejection Charges (Black Powder)	Goex FFFFG (4F Black Powder) Main Chute 3g Primary 5g Secondary Drogue Chute 2g Primary 4g Secondary	The GoexFFFG (4F Black Powder) was chosen for its high quality and reasonable pricing. It ignites and burns quickly in comparison to other black powder variants. This fast ignition and burning ensure that pressure builds up quickly so that the shear pins are broken before any gas can seep out and escape through seams or holes. Size Determination: Main Chute: Four shear pins will be used between the electronics bay and recovery section, each

		requiring 21.4 lbs of force to break. In the past, the team has used 15 psi as a target pressure for ejection charges, as advised by the team mentors and demonstrated in previous projects. $4 \bullet 21.4\ lbs\ =\ 85.6\ lbs$ required $Area\ =\ \pi r^2$ $Bulkhead\ Area\ =\ \pi \bullet 2.5^2 in\ =\ 19.635\ in^2$ $Pressure\ =\ \frac{lbs}{in^2}$ $lbs\ =\ Pressure\ \bullet\ in^2$ $15\ psi\ \bullet\ 19.635\ in^2\ =\ 294.525\ lbs$ This shows that a generated pressure of 15 psi will produce sufficient force to ensure a successful separation of the vehicle with adequate margins. To calculate the amount of black powder required, the ideal gas law (PV=nRT) can be solved for the amount of material, n: n=PV/RT Where: n = Amount of black powder P = Pressure (psi) V = Volume (in^3) R = Combustion Gas Constant (266 in-lbf/lbm) T = Absolute Temperature (Rankine) The combustion temperature of black powder is 3307° R. V = A*h V = 19.635 in^2 * 16.213 in = 318.342 in^3 $n\ =\ \frac{318.342\ in^3 \bullet 15\ psi}{266\ \frac{in-lbf}{lbm} \bullet 3307^o R}$ $n\ =\ 0.005428\ lbs$ $0.005428\ lbs \bullet \frac{453.592 g}{1\ lb}\ =\ 2.46\ g$ This will be increased to 3 g for the primary main parachute ejection charge to ensure

		successful deployment. Drogue Parachute: V = 19.635 in² * 12.453 in = 244.514655 in³ $n = \frac{244.514655\ in^2 \bullet 15\ psi}{266 \frac{in-lbf}{lbm} \bullet 3307^o R}$ $n = 0.004169\ lbs$ $0.004169\ lbs \bullet \frac{453.592 g}{1\ lb} = 1.89\ g$ This will be increased to 2 g force the primary drogue parachute ejection charge to ensure successful deployment.
Altimeters (Backup & Main)	PerfectFlite StratologgerCF Altimeter	Our team chose the PerfectFlite StratoLoggerCF for a multitude of reasons including our own familiarity with the device and its accessibility. The team has used StratoLoggerCF devices on multiple vehicles in the past, including on previous NASA SLI competition vehicles.
GPS Tracker	Featherweight GPS Tracker	Our team is also familiar with the Featherweight GPS Tracker, making it high up on our list with its previous uses. This GPS is only a GPS, not combined with any other altimeter or any other part of the system besides recovering the vehicle. It has a variety of features including a ground station receiver. Our team plans to use the 24B Channel on 921.400 MHz. If the RSO or another official would like us to change our channel/frequency, we will be happy to change it. Our GPS runs off of a 3.7V, 400 mAh Li-Po battery, providing us with 4 ½ hours of tracking time.
Shear Pins	“2-56” Shear pins at each separation point	To avoid any premature separation at any point we will be using many shear pins across our vehicle. The electronics bay and recovery section (main parachute) will be held together using 4 evenly spaced shear pins. The electronics bay and booster section (drogue parachute) will use 2 shear pins. Lastly, the Nose Cone and Payload Coupler will be held together using 4 more shear pins. Each shear pin has a breaking force of 21.4 pounds, potentially slightly higher due to friction forces. The number of shear pins has been

		carefully considered when sizing the black powder charges to ensure enough force is present in the ejection of each stage. A ground demonstration (testing) will occur first to ensure that we will have proper separation during our flight.

● Include a Concept of Operations (CONOPS) of your recovery system.

The recovery system will be activated on the ground with 3 locking push-in buttons. The system will first go into full effect at apogee when the drogue parachute ejection charge fires, with a backup ejection charge at apogee + 1 second. The vehicle will descend at 87.7649 ft/s under drogue and 181.188 ft/s under main. At 600 ft AGL, the main parachute primary ejection charge fires, with the backup ejection charge firing at 600 ft + 1 second (~500 ft). After the vehicle has landed, the GPS in the electronics bay will be used to establish the line of sight. Afterward, with RSO permission, our payload mission will begin.

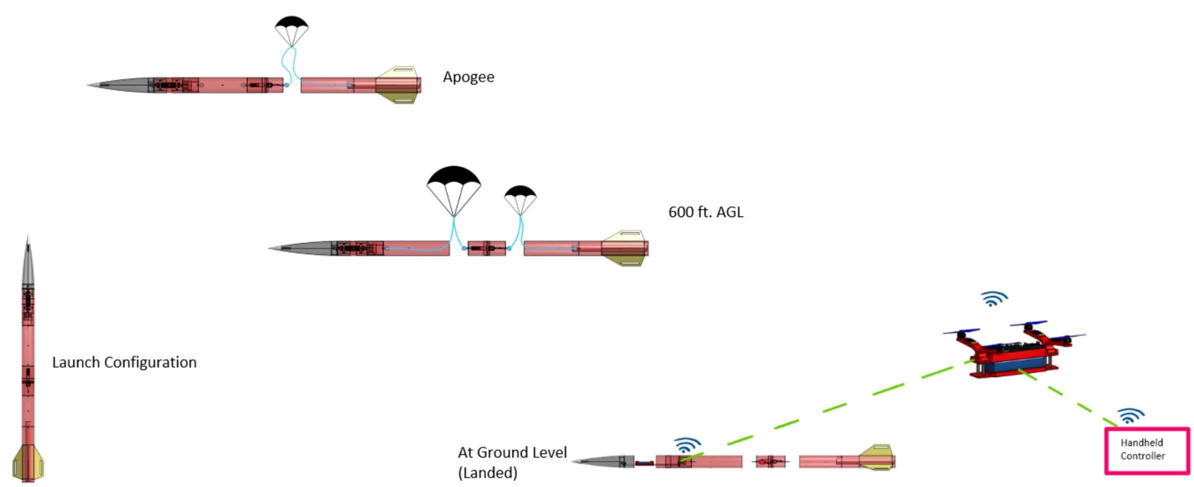


Figure 3.3.1 - CONOPS Visualization Drawing

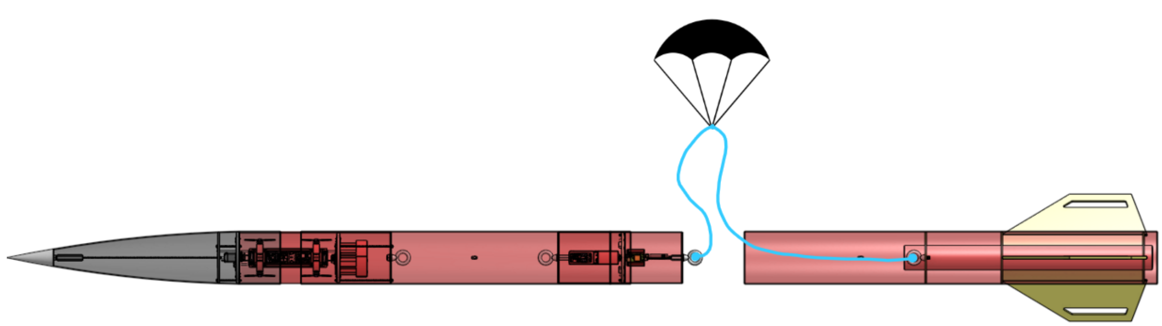


Figure 3.3.2 - First Stage Separation (Drogue)

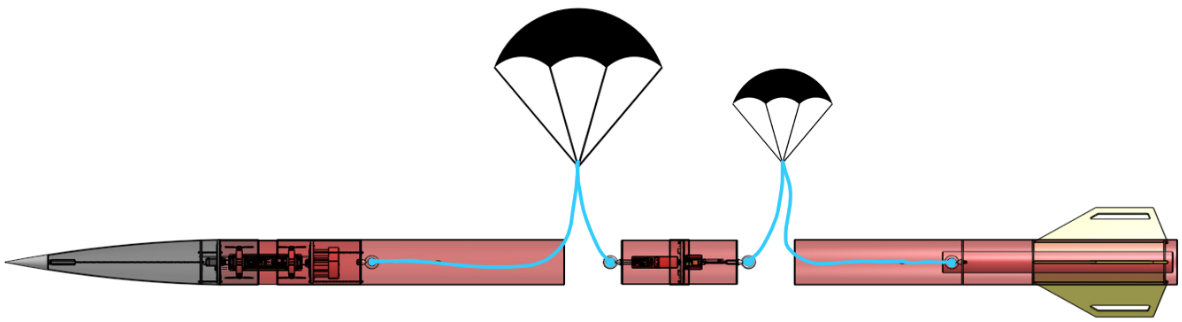


Figure 3.3.3 - Second Stage Separation (Main + Drogue)

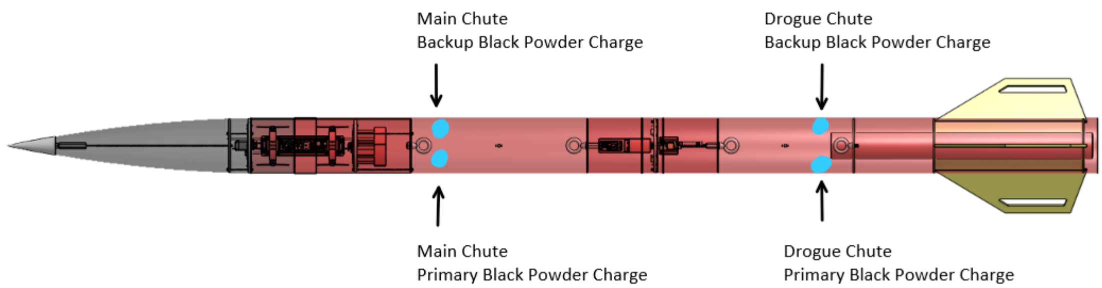
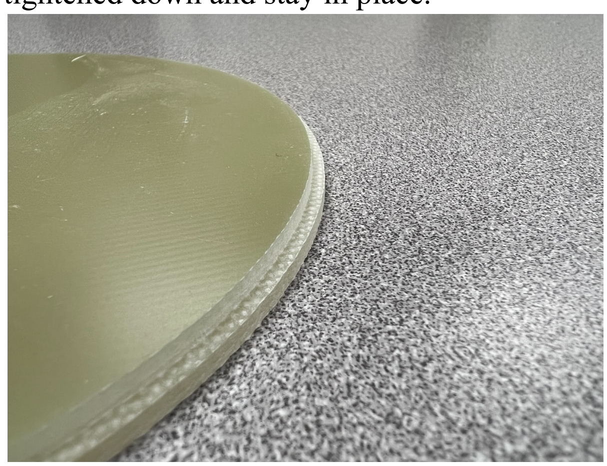


Figure 3.3.4 - Energetic Material Locations

- Describe the parachutes, harnesses, bulkheads, and attachment hardware.

Component	Description
Main Parachute (72” Iris Ultra)	The Iris Ultra 72” Standard Parachute is the main parachute. It is entirely made out of nylon and has a packing density of 0.18oz/cu". It weighs 13.4 oz and has a packing volume of 3.9” (diameter) x 6.2” (length): 74.1cu". This parachute is rated at being able to hold 28 lbs at 20 fps. The coefficient of drag on this parachute is 2.2, which is higher than other average parachutes. It has 12 gores and ⅝” webbing. The parachute's nylon cords can hold 400 lbs per cord, and the parachute has a 1500 lb rated swivel.

	
Drogue Parachute (18” Drogue)	The 18” Fruity Chutes Drogue Chute has an 18” canopy with 8 gores. It is made of ripstop nylon and weighs a total of 2.1 oz. It’s rated as being able to hold 1.2 lbs at 20 fps. The parachute’s coefficient of drag is between 1.5 and 1.6. Each braided nylon shroud line on the parachute can hold 220 lbs, and it has a 1000 lb rated swivel. The parachute has a packing volume of 1.9” (diameter) x 3.5” (length): 9.67in^3. 
Harnesses (⅜” Tubular Kevlar Harness / 2 sections - 30ft)	The harness used to support each parachute is ⅜ Tubular Kevlar, 30 feet long. The harness has two sewn loops as attachment points on either end. They are extremely strong, resilient, and abrasion/fire resistant.

	
Bulkheads (Fiberglass)	The bulkheads are made of G10 fiberglass and are 0.2” thick. To attach the bulkhead to the rest of the vehicle, threaded rods extend through couplers and connect to a bulkhead that is on the other end of the coupler. The bulkheads then stay attached to the vehicle by securing each other around the coupler. The plates securely rest in the couplers and have a lip on them that allows them to rest on the outer edge of the couplers. This edge on the plates provides the ability for them to be tightened down and stay in place. 
Attachment Hardware (5/16” forged steel eye bolts + steel quick links)	5/16” forged steel eye bolts are used to attach the parachute harness to the bulk plates. The bolts are threaded through the plates and secured on the other side using lock nuts with washers in between the nut and the fiberglass to distribute the load and help maintain the structural integrity of the fiberglass. The eye bolts attach to the harness using steel quick

	links. 

● Discuss the electrical components and prove that redundancy exists within the system.

This vehicle includes the Featherweight GPS Tracker. A GPS tracker allows the team to find the vehicle if it leaves visual sight. This redundancy ensures that even with the lost visual sight the team will still be able to recover the vehicle.
The vehicle design includes two separate Perfectflite StratoLoggerCF Altimeters. One of the altimeters is the “main,” while the other is the “backup.” The “main” altimeter will fire its black powder charges at apogee & 600 feet above ground level. The “backup” altimeter will fire its black powder charges at apogee + 1 second & 600 feet above ground level + 1 second, or ~500 feet. This redundancy ensures that even with the failure of an altimeter, the vehicle will still safely be recovered.

● Include drawings/sketches, wiring diagrams, and electrical schematics.

Figure 3.3.5 below shows the wiring diagram that will be used in the electronics bay for the recovery system of the vehicle. There are three independent systems located in the electronics bay comprising two altimeters and one GPS system. The second altimeter is a backup redundancy in the unlikely event that the first charge or altimeter fails.

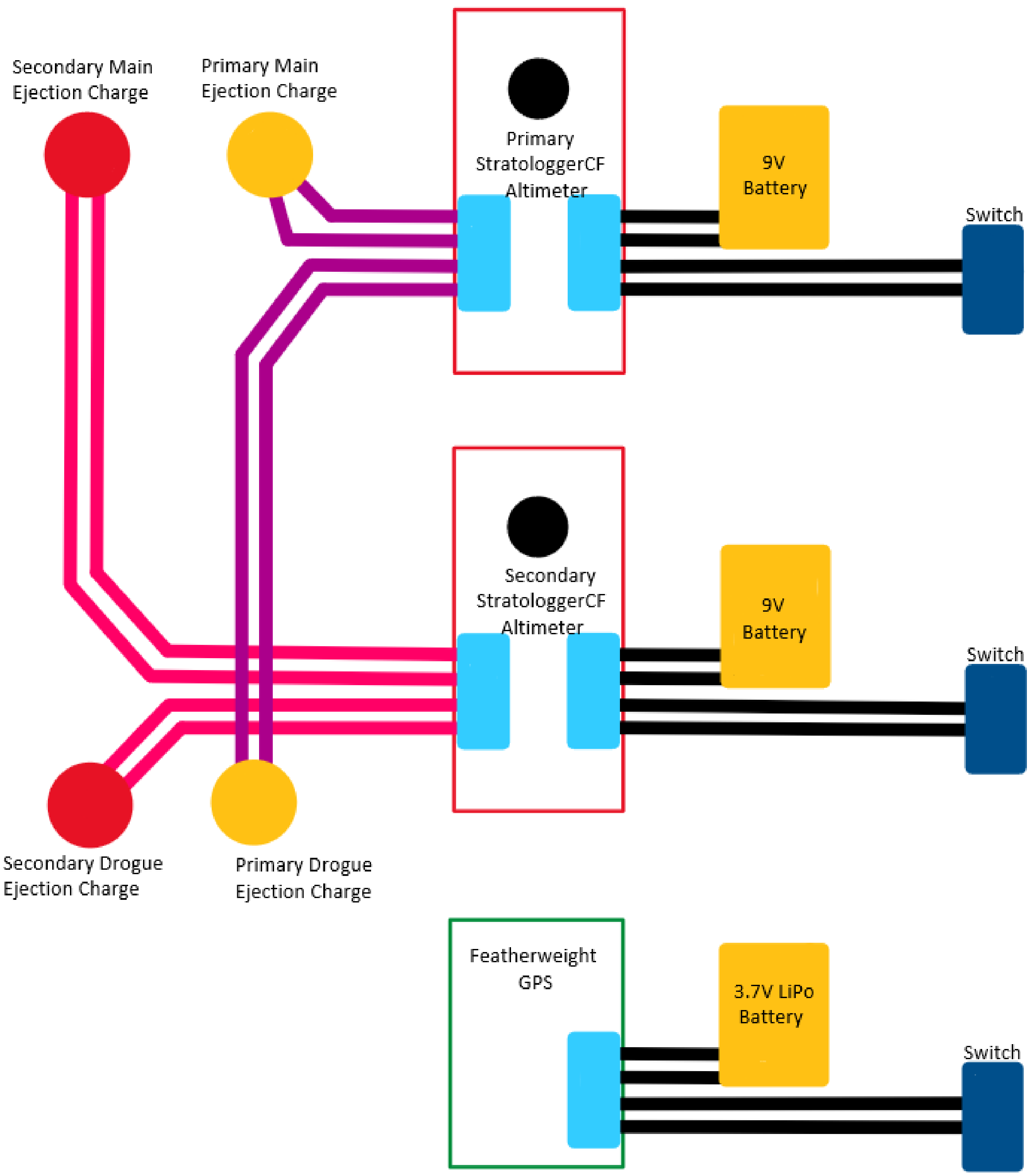


Figure 3.3.5 - Recovery System Wiring Diagram

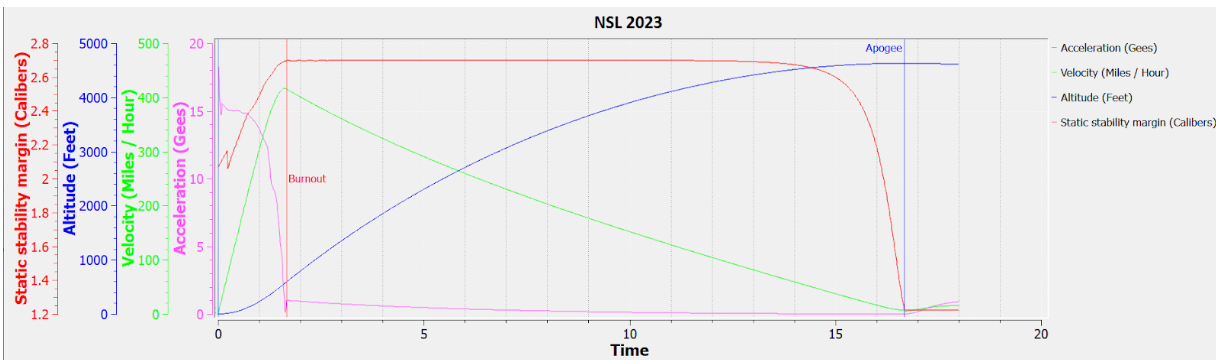
- Provide the operating frequency of the locating tracker(s).

There are a total of 4 GPS devices on the vehicle and payload. Only **ONE** is a featherweight GPS, and it is used to track the vehicle. It is located in the recovery electronics bay (E-Bay).

The channels are easily switchable on the GPS and the team is happy to change the frequency and channel on launch day to whatever the RSO or event organizers require to ensure the best launch for all teams.	
Featherweight GPS Tracker	Channel: 24B - Frequency: 921.400 MHz

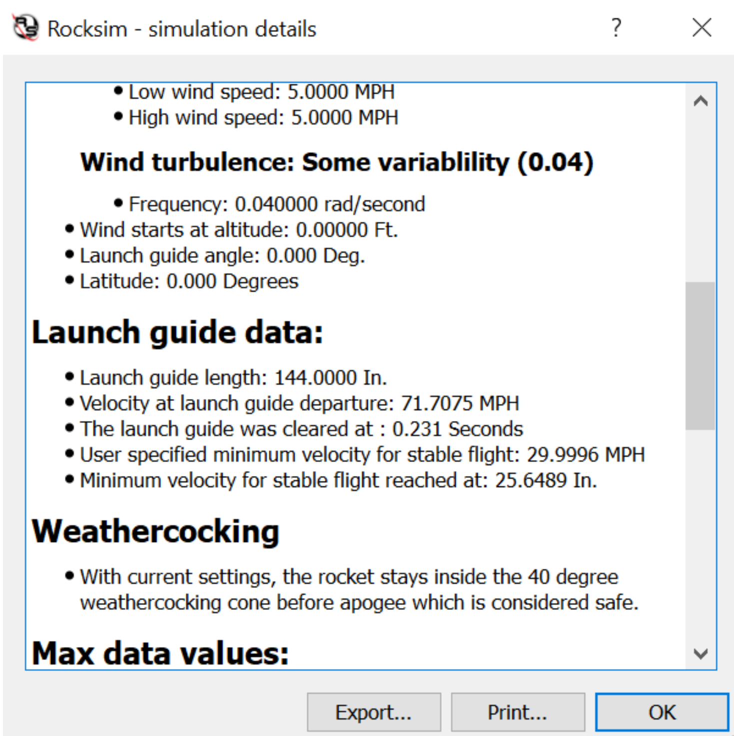
3.4 Mission Performance Predictions (Using the most up-to-date model)

● Show flight profile simulations. This includes altitude, velocity, and acceleration versus time predictions with simulated vehicle data, component weights, and simulated motor thrust curve. Verify that the vehicle is robust enough to withstand the expected loads.



Results	Engines loaded	Max. altitude Feet	Max. velocity Miles / Hour	Optimal delay	Max. acceleration Gees	Altitude at deployment Feet	Velocity at launch guide departure Miles / Hour	Velocity at deployment Miles / Hour	WeatherCocking
1	[K1440WT-Plugge	4629.72	416.45	15.02	17.56	4629.72	71.71	7.02	Safe

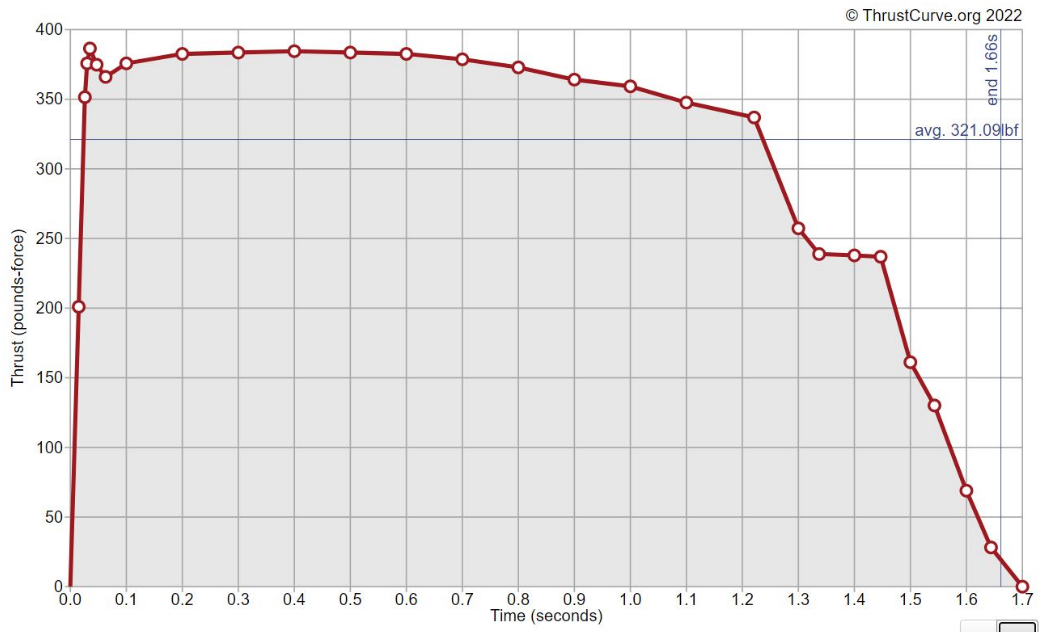
Our estimated CD is 0.40 because our rocket is slimmer than last year's vehicle which also had an estimated CD of 0.40 as well, however, the fin slots may add more drag than last year's vehicle.



Component weights on the pad:

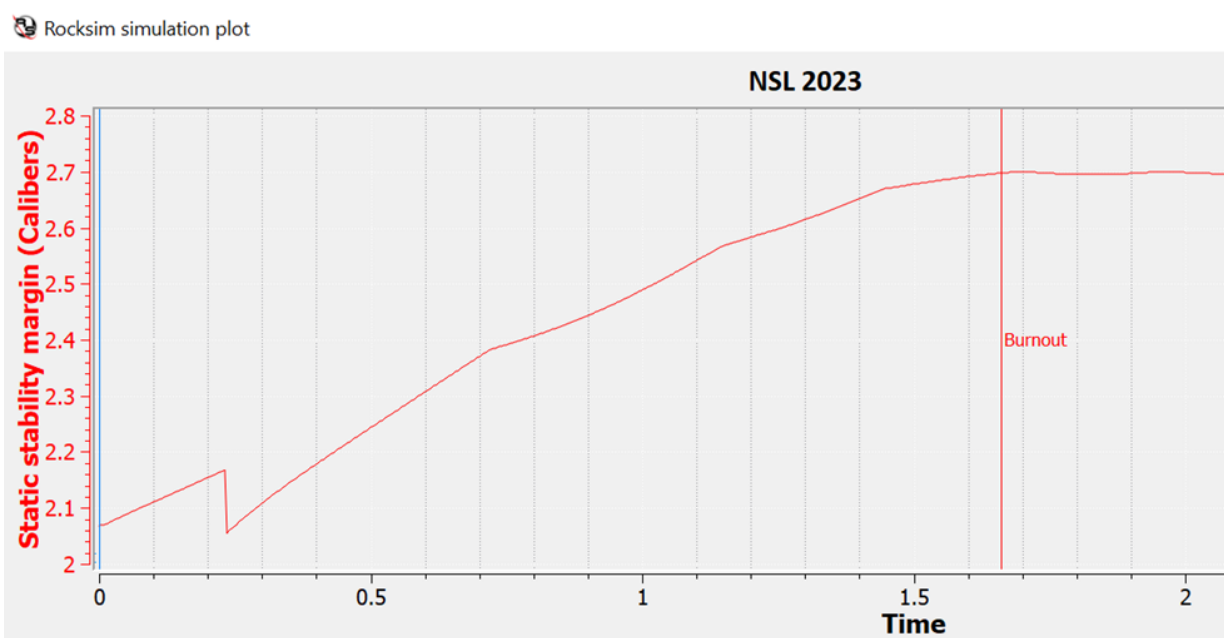
- Booster section: 12.906 lbs
- Recovery section: 4.436 lbs
- Nose Cone section: 1.89 lbs
- Payload: 2.447 lbs
    - D.R.O.N.E: 0.748 lbs
- E-bay: 2.577 lbs

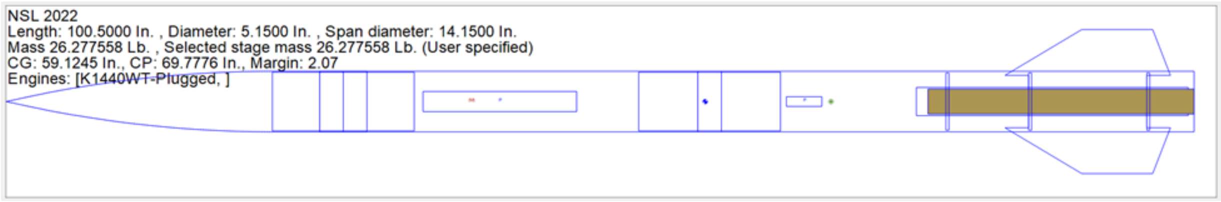
Cesseroni K-1440 thrust curve:



We know that the vehicle will be able to withstand the forces on it during flight. In doing research about the material, the team found that the same fiberglass was used in other vehicles with heavier loads and higher powered motors. Furthermore, past tests with our past rocket have held up with a larger frame and heavier mass.

● Show stability margin and simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.





The stability margin on the pad is 2.07 and the Rocksim simulation plot shows that the stability margin only increases over time, never going below 2. The launch exit can be seen at around t=0.255 where the margin is at 2.16 however it increases after it gets off the rail and as the motor burnout occurs.

- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.

Main Descent Rate

F_g = Force of gravity (weight, in N)
ρ = Density of air
C_d = Parachute's Coefficient of Drag
A = Area of parachute
Total mass: 23.79 lbs or 10.791 kg
1 m/s = 3.28084 ft/s

$$v = \sqrt{\frac{2F_g}{\rho \bullet C_d \bullet A}}$$

$$F_g = 10.791 \bullet 9.8$$

$$F_g = 105.7518\ N$$

$$v = \sqrt{\frac{2(105.7518)}{1.2 \bullet 2.2 \bullet 2.6268}}$$

$$v = 5.522597789\ m/s$$

$$5.522597789 \bullet 3.28084 = 18.11875973\ ft/s$$

Nosecone, Payload, and Recovery Section - 10.79833 lb or 4.89804 kg

1 Joule = 1.35582 ft-lb
1 Foot = 0.3048 m
1 m/s = 3.28084 ft/s

$$KE = \frac{1}{2}mv^2$$

$$v = 5.522597789\ m/s$$

$$m = 4.89804\ kg$$

$KE = \frac{1}{2} \bullet 4.89804 \bullet 5.522597789^2$ $KE = 74.69287243\, J$ $74.69287243\, J \bullet \frac{1\, ft-lb}{1.35582\, J} = 55.090635525163$ ft-lbs The kinetic energy of the nose cone, payload, and recovery section is 55.0906 ft-lbs, which is less than the 75 ft-lb maximum, meeting the kinetic energy requirements.
Electronics Bay - 2.5768529 lb or 1.168841 kg 1 Joule = 1.35582 ft-lb 1 Foot = 0.3048 m 1 m/s = 3.28084 ft/s $KE = \frac{1}{2}mv^2$ $v = 5.522597789\, m/s$ $m = 1.168841\, kg$ $KE = \frac{1}{2} \bullet 1.168841 \bullet 5.522597789^2$ $KE = 17.82429129\, J$ $17.82429129\, J \bullet \frac{1\, ft-lb}{1.35582\, J} = 13.146522593196$ ft-lbs The kinetic energy of the nose cone, payload, and recovery section is 13.147 ft-lbs, which is less than the 75 ft-lb maximum, meeting the kinetic energy requirements.
Booster Section - 10.4167932 lb or 4.7249779 kg 1 Joule = 1.35582 ft-lb 1 Foot = 0.3048 m 1 m/s = 3.28084 ft/s $KE = \frac{1}{2}mv^2$ $v = 5.522597789\, m/s$ $m = 4.7249779\, kg$ $KE = \frac{1}{2} \bullet 4.7249779 \bullet 5.522597789^2$ $KE = 72.05375446\, J$ $72.05375446\, J \bullet \frac{1\, ft-lb}{1.35582\, J} = 53.144122$ ft-lbs The kinetic energy of the nose cone, payload, and recovery section is 53.144122 ft-lbs, which

is less than the 75 ft-lb maximum, meeting the kinetic energy requirements.

● Calculate the expected descent time for the rocket and any section that descends untethered from the rest of the vehicle.

Drogue Descent Rate

F_g = Force of gravity (weight, in N)
ρ = Density of air
C_d = Parachute's Coefficient of Drag
A = Area of parachute
Total Mass: 23.79 lbs or 10.791 kg
1 m/s = 3.28084 ft/s

$$v = \sqrt{\frac{2F_g}{\rho \bullet C_d \bullet A}}$$
$$F_g = 10.79 \bullet 9.8$$
$$F_g = 105.7518\ N$$
$$v = \sqrt{\frac{2(105.7518)}{1.2 \bullet 1.5 \bullet 0.1642}}$$
$$v = 26.75075556\ m/s$$
$$26.75075556 \bullet 3.28084 = 87.76494889\ ft/s$$

Descent Time

Drogue:
t = time (seconds)
v = descent velocity (feet per second)
d = descent distance/altitude (feet)

$$t = \frac{d}{v}$$

$$d = 4500\ ft - 600\ ft$$

$$v = 87.76494889\ ft/s$$

$$t = \frac{3900}{87.76494889}$$
$t = 44.43687428$ seconds

Main:
t = time (seconds)
v = descent velocity (feet per second)
d = descent distance/altitude (feet)

$t = \frac{d}{v}$

$d = 600\ ft$

$v = 18.11875973\ ft/s$

$t = \frac{600}{18.11875973}$
$t = 33.11484941$ seconds

Total Descent Time:
$t = 33.60603787 + 44.84814316$
$t = 77.55172369$ sec

The total descent time is 77.6 seconds, which is less than the 90-second maximum.

● Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5 mph wind, 10 mph wind, 15 mph wind, and 20 mph wind. The drift calculations should be performed with the assumption that apogee is reached directly above the launch pad.

Calculated descent time is 77.6 seconds, 1 mile = 5280 ft, and 1 hour= 3600 seconds.

0 mph wind-
$\frac{0\ miles}{1\ hour} \cdot \frac{5280\ ft}{1\ mile} \cdot \frac{1\ hour}{3600\ s}$ = 0 ft/s
77.6 s · 0 ft/s = no drift

5 mph wind-
$\frac{5\ miles}{1\ hour} \cdot \frac{5280\ ft}{1\ mile} \cdot \frac{1\ hour}{3600\ s}$ = 7.33 ft/s
77.6 s · 7.33 ft/s = 568.8 foot drift

10 mph wind-
$\frac{10\ miles}{1\ hour} \cdot \frac{5280\ ft}{1\ mile} \cdot \frac{1\ hour}{3600\ s}$= 14.7 ft/s
77.6 s · 14.7 ft/s = 1140.7 foot drift

15 mph wind-
$\frac{15\ miles}{1\ hour} \cdot \frac{5280\ ft}{1\ mile} \cdot \frac{1\ hour}{3600\ s}$= 22.0 ft/s
77.6 s · 22 ft/s = 1707.2 foot drift

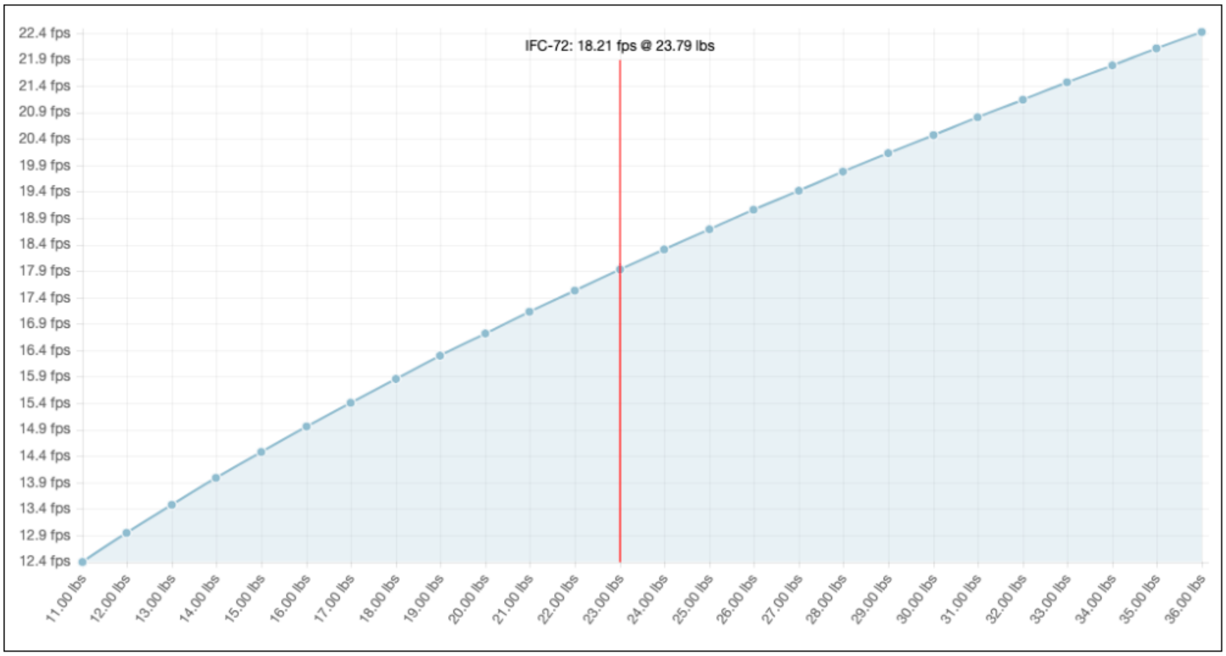
20 mph wind-

$\frac{20\ miles}{1\ hour} \cdot \frac{5280\ ft}{1\ mile} \cdot \frac{1\ hour}{3600\ s}$= 29.3 ft/s

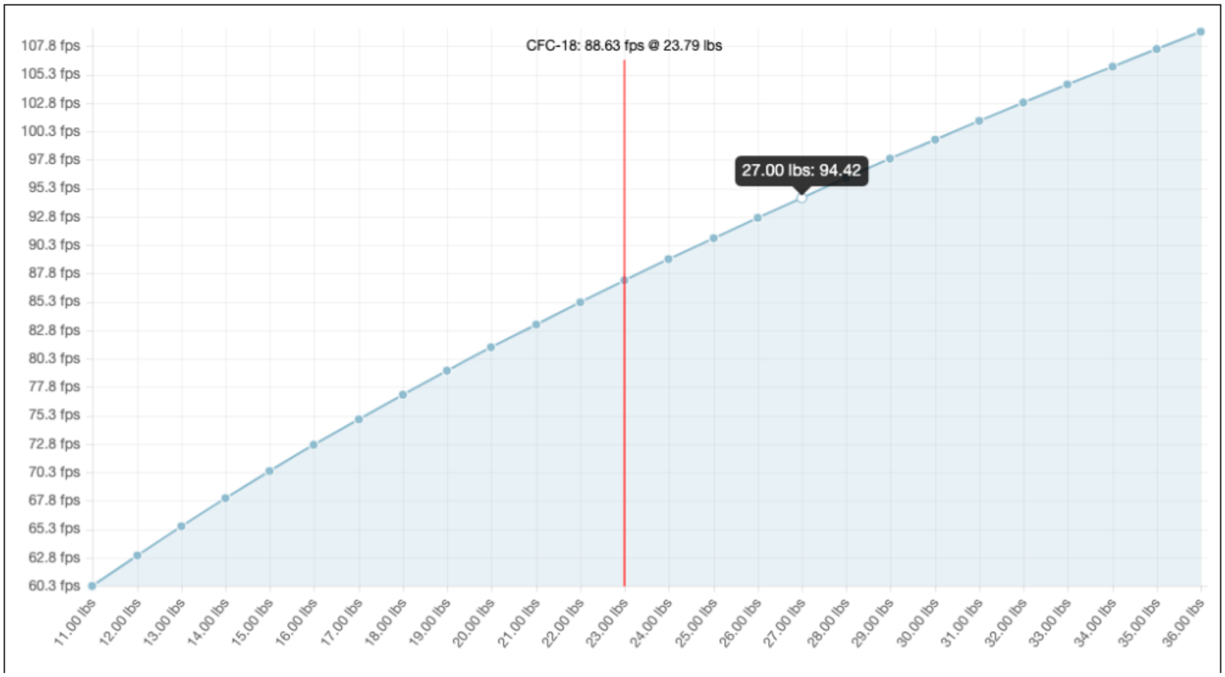
77.6 s · 29.3 ft/s = 2273.7 foot drift.

Calculations estimate that all scenarios of wind speed will result in the recovery area being less than the maximum 2500 foot radius.

● Present data from a different calculation method to verify that original results are accurate.



Main chute descent velocity



Drogue Chute descent velocity

Mass	10.798	lb
Velocity	18.21	ft/s
Kinetic energy	55.6452	ft-lbs

Nosecone, Payload, and Recovery KE calculations

Mass	2.577	lb
Velocity	18.21	ft/s
Kinetic energy	13.28002	ft-lbs

Electronics Bay KE calculations

Mass	10.417 lb
Velocity	18.21 ft/s
Kinetic energy	53.6818 ft-lbs

Booster Section KE calculations
All calculations are done by the websites *omnicalculator.com* or *fruitychutes.com.*

● Discuss any differences between the different calculations.

Both calculated descent rates are within 1.2 ft/s of each other. Any discrepancies between the two are most likely due to rounding errors. The differences are small enough to be considered insignificant

All calculated values of kinetic energy are within 0.6 ft/lbs of each other. Any discrepancies between the two are most likely due to rounding errors. The differences are small enough to be considered insignificant

● Perform multiple simulations to verify that results are precise.

Descent time with ideal conditions: 73.476
Descent time with 5 mph wind: 73.450
Descent time with 10 mph wind: 73.361
Descent time with 15 mph wind: 73.226
Descent time with 20 mph wind: 72.727

Calculations completed by Rocksim demonstrate that the descent time will be less than the maximum of 90 seconds.

IV) Payload Criteria

4.1 Design of Payload Equipment

● Identify which of the design alternatives from PDR was chosen for the payload. Describe why that alternative and its components were chosen.

Deployment Mechanism		
Component	Selection	Justification
Leveling System	Gravitational with 2x 4” Bearings	A gravitational leveling system is the simplest option which is capable of correctly orienting the UAV for deployment without manual intervention. The only additional components required for this method to function are the two 4” bearings. This option was selected over a motor-driven leveling system as it reduces mass and lowers the required power consumption.
Overall Mechanism	Threaded Rod Driven	The autonomous threaded rod driven deployment system was selected due to its reliability and relative simplicity. Compared to other options such as a belt drive, the threaded rod requires many fewer components, reducing weight and potential complications. The use of a threaded rod also allows the deployment system to provide greater structural integrity to the launch vehicle.
Threaded Rod	#4-40 Aluminum Threaded Rod	The #4-40 Aluminum Threaded Rods were chosen because they weigh ⅓ as much as the weight of steel and are strong enough that they will not break during the flight. Following multiple tensile strength calculations, these Aluminum threaded rods are more than 4 times as strong as necessary, with an extra layer of safety on top of that. Aluminum also is nonmagnetic which will ensure that it doesn’t interfere with any electronics within the payload section of the vehicle.
Motors	NEMA 8, 2.8 in.	NEMA 8 motors are good for precise and repetitive movements. It is a bipolar hybrid stepper motor, which has greater torque, precision, and efficiency than other stepper motors. These motors are also very compact, leaving more room in the vehicle for other

		components. This small size also gives the motor a low mass. These motors have a maximum holding torque of 2.8 in.-oz and a maximum speed of 3,000 rpm. It has a radial load capacity of 4.5 lbs and a thrust load capacity of 0.45 lbs.
Motor Controllers	TB67S249FTG Stepper Motor Driver Compact Carrier	The TB67S249FTG Stepper Motor Driver Compact Carrier is arranged in a 16-pin Pololu form which makes it compact. It has adjustable current limiting and by monitoring the actual current it can select an optimal decay mode. It minimizes power and heat by automatically reducing the driving current below the full amount when the motor is lightly loaded. It has a voltage range of 10 V to 47 V, and has built-in protection under-voltage, over-current, and over-temperature conditions. Overall, it was chosen for its compactness, simplicity, and quality.
Gears	14-1/2 Degree Pressure Angle Plastic Gear	14-1/2 Degree Pressure Angle Plastic Gears are quiet and have good corrosion and chemical resistance. Most importantly, these were chosen because they are very lightweight in comparison to metal gears, making them favorable in order to keep the overall mass of the vehicle lower.
Battery	Turnigy Nano-Tech 4S 1600mAh LiPo Pack	The Turnigy Nano-Tech 4S 1600mAh LiPo Pack was selected for its performance. In comparison to non-nano-tech batteries, it has less voltage sag and higher discharge rates. It has 14.8V compared to a lithium polymer drone battery, which has 4.2V. The battery also only weighs 172g, which helps with maintaining a lightweight UAV design.
Screen	Adafruit 1.47" 320x172 Round Rectangle Color IPS TFT Display - ST7789	The Adafruit 1.47” 320x172 Round Rectangle Color IPS TFT Display - ST7789 will provide a visual readout of the payload’s operation status and diagnostics. This display was selected for its relatively low cost and its compact size.
Controller	Teensy 4.0	The Teensy 4.0 acts as our main computer on the UAV. It was chosen for its powerful 600MHz processor, as well as its small overall size and high value.
GPS	Adafruit Ultimate GPS 1616D	The Adafruit Ultimate GPS 1616D was chosen for its reliability and convenience. It has 99 channels to select from, a dBm sensitivity of -165 to allow for

		fainter signal detection, and 10 Hz updates that give more detailed and higher-resolution vehicle tracking capabilities.
Radio	Adafruit RFM95W LoRa Radio Transceiver	The Adafruit RFM95W LoRa Radio Transceiver was chosen for its simplicity. It is less complex than WiFi or BLE, as it doesn't require associating, pairing, or scanning to connect it. The wide range on the radio is also beneficial as it allows for data to be sent across further distances than wireless chipsets.
Servo	Smraza SG90 9G Micro Servo Metal Geared Motor	The Smraza SG90 9G Micro Servo Metal Geared Motor was chosen for its simplicity and low mass. The servo weighs 5.6 oz and no assembly is required. Its running speed at no load is 0.09 ± 0.01 sec/60°(4.8V) 0.08 ± 0.01 sec/60°(6V). Its running angle is 180° and it has a stall torque (4.8V) of 17.5oz/in. The overall operating voltage is 4.8V to 6.0V.

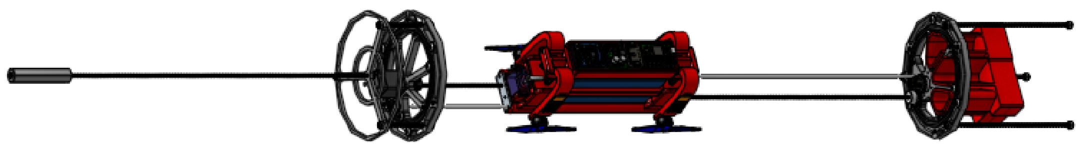
Unmanned Aerial Vehicle		
Component	Selection	Justification
Overall Style	Quadcopter	The quadcopter design was chosen for its simplicity, while still providing extremely precise hovering and maneuverability. The quadcopter is also very popular with hobbyists and commercial users which means that the pre-existing control systems allow for much easier programming.
Folding System	Passive Vertical	Passive vertical is also a simple yet effective folding system. A major benefit of this design is that it reduces points of failure like the motors on an actuated folding system.
Propellers	Gemfan 3025 2-Blade	These 76 mm, 2-bladed propellers were chosen as they provide the correct shaft mounting size for the selected motors, and thrust output data is available for these propellers from the motor manufacturer. The use of these propellers ensures sufficient lifting thrust for a greater than 2:1 thrust-to-weight ratio.
Motors	Happymodel EX1204 KV5000 Brushless Motor	This motor was chosen for its excellent performance. It offers the highest output for its power intake. This motor is also still affordable compared to many other

		options on the market.
Motor Controllers	ESC 2S-6S LiPo Electronic Speed Controller	This motor controller was chosen for its versatility; it can operate a wide array of motors anywhere from 2S to 6S motors. Additionally, this motor controller is a very robust and durable component.
Battery	Turnigy Nano-Tech 4S 1600mAh LiPo Pack	The Turnigy Nano-Tech 4S 1600mAh LiPo Pack was selected for its performance. In comparison to non-nano-tech batteries, it has less voltage sag and higher discharge rates. It has 14.8V compared to a lithium polymer drone battery, which has 4.2V. The battery also only weighs 172g, which helps with maintaining a lightweight UAV design.
Controller	Teensy 4.0	The Teensy 4.0 acts as our main computer on the UAV. It was chosen for its powerful 600MHz processor, as well as its small overall size and high value.
GPS	Adafruit Ultimate GPS 1616D	The Adafruit Ultimate GPS 1616D was chosen for its reliability and convenience. It has 99 channels to select from, a dBm sensitivity of -165 to allow for fainter signal detection, and 10 Hz updates that give more detailed and higher-resolution vehicle tracking capabilities.
Radio	Adafruit RFM95W LoRa Radio Transceiver	The Adafruit RFM95W LoRa Radio Transceiver was chosen for its simplicity. It is less complex than WiFi or BLE, as it doesn't require associating, pairing, or scanning to connect it. The wide range on the radio is also beneficial as it allows for data to be sent across further distances than wireless chipsets.
Gyro	Adafruit LSM6DSO32 Gyroscope	The Adafruit LSM6DSO32 Gyroscope was chosen for its low cost and its greater accelerometer capabilities, with an accelerometer component that goes up to 32g. With an additional 6 degrees of freedom and the ability to rotate up to 2000 degrees per second, this Gyroscope is ideal for the UAV, and its simple and efficient design makes work easier.
Range Finder	Garmin LIDAR-Lite V4	The Garmin LIDAR-Lite V4 was chosen due to its quality and reliability. It has 10 meters of range, is small and lightweight, and uses a low amount of power, making it a perfect component of the UAV.

Altimeter	Adafruit BMP390 Altimeter	The Adafruit BMP390 Altimeter was chosen due to its precision and accuracy. It has an accuracy of ±3 Pascals, which is ±0.25 meters of altitude, which will allow for the UAV to have an accurate altitude during its flight.

Handheld Controller		
Component	Selection	Justification
Buttons	Apiele Waterproof Momentary Push Button Switches	The Apiele Waterproof Momentary Push Button Switches were chosen for their affordability and reliability. As the title states, the buttons are waterproof, which will keep them safe if any water happens to interfere with the system. Their rated current is 5 amps and they have an operating voltage of 12V. They have a rated voltage of 250V and an electrical life of 200 thousand times alongside a mechanical life of 1 million cycles. These buttons are cheap, safe, and will last a very long time.
Screen	Adafruit 1.47" 320x172 Round Rectangle Color IPS TFT Display - ST7789	The Adafruit 1.47" 320x172 Round Rectangle Color IPS TFT Display - ST7789 will provide a visual readout of the payload's operation status and diagnostics. This display was selected for its relatively low cost and its compact size.
Controller	Teensy 4.0	The Teensy 4.0 acts as our main computer on the handheld. It was chosen for its powerful 600MHz processor, as well as its small overall size and high value.
GPS	Adafruit Ultimate GPS 1616D	The Adafruit Ultimate GPS 1616D was chosen for its reliability and convenience. It has 99 channels to select from, a dBm sensitivity of -165 to allow for fainter signal detection, and 10 Hz updates that give more detailed and higher-resolution vehicle tracking capabilities.
Radio	Adafruit RFM95W LoRa Radio Transceiver	The Adafruit RFM95W LoRa Radio Transceiver was chosen for its simplicity. It is less complex than WiFi or BLE, as it doesn't require associating, pairing, or scanning to connect it. The wide range on the radio is also beneficial as it allows for data to be sent across further distances than wireless chipsets.

● Review the design at a system level.
○ Include drawings and specifications for each component of the payload, as well as the entire payload assembly.

Complete Assembly (UAV + Deployment System)
This is the drone positioned inside the deployment mechanism. The deployment system utilizes two threaded rods in both directions that are used to separate the vehicle and allow the drone to fly out of the payload section.
 *Figure 4.1.1 - UAV & Deployment System Assembly*

UAV
The Unmanned Aerial Vehicle will fly out of the payload section of the vehicle and communicate with the handheld controller to navigate its way toward it. From there, the UAV will guide the user holding the handheld controller back to the vehicle.

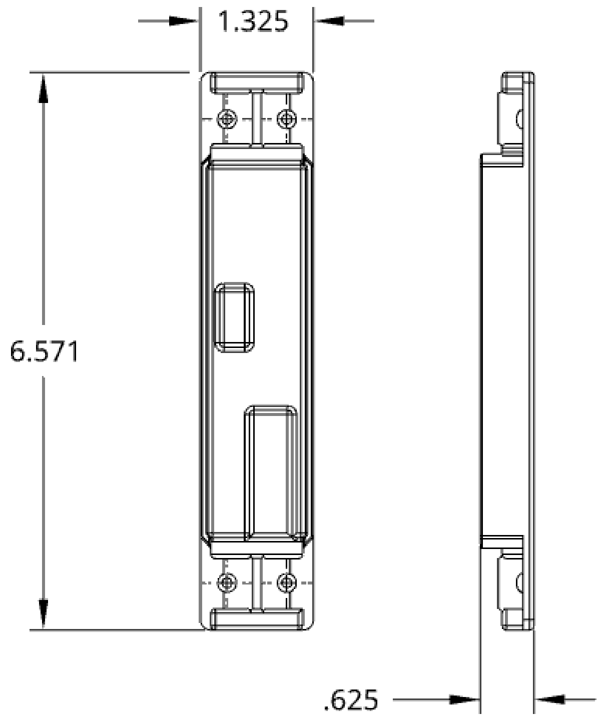


Figure 4.1.2 - Upper Drone Frame

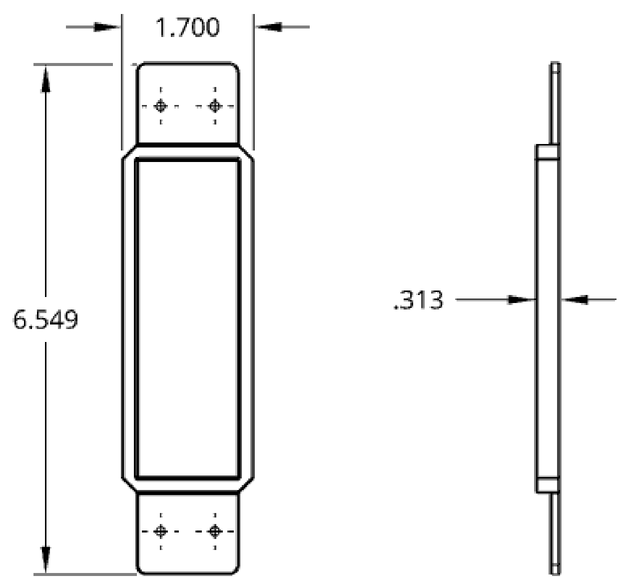


Figure 4.1.3 - Lower Drone Frame

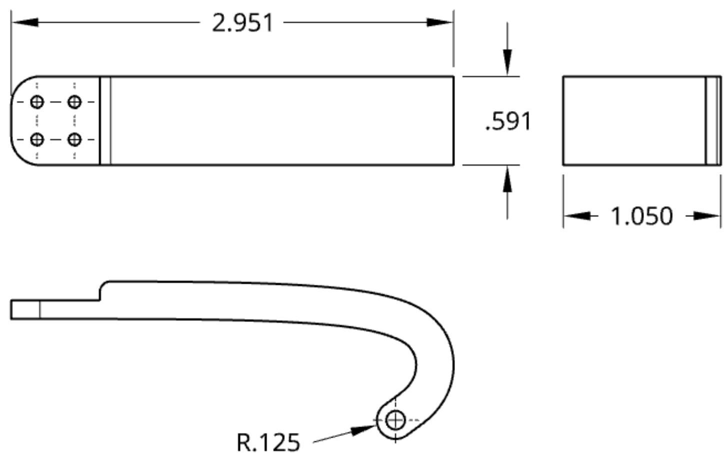


Figure 4.1.4 - Wings

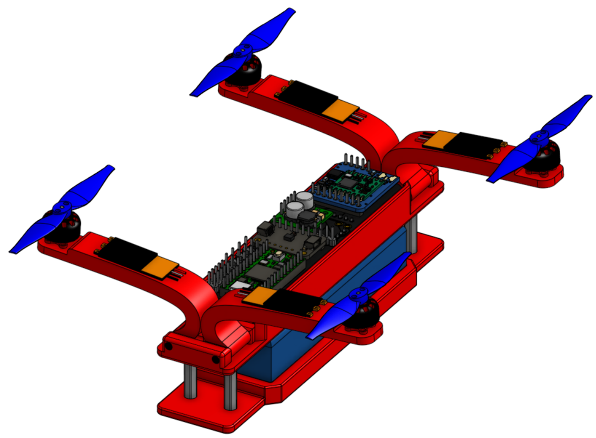


Figure 4.1.5 - Full UAV Design Angle View

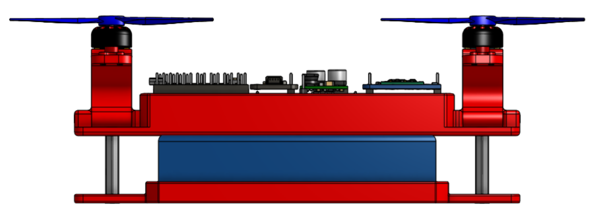


Figure 4.1.6 - Full UAV Design Side View

Deployment System
The deployment system will allow the UAV to fly out of the vehicle. Using the two threaded rods, the deployment system will extend and push apart the rocket.

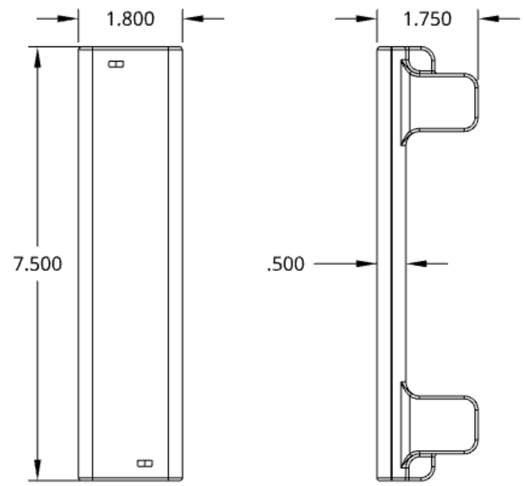


Figure 4.1.7 - Deployment Sled

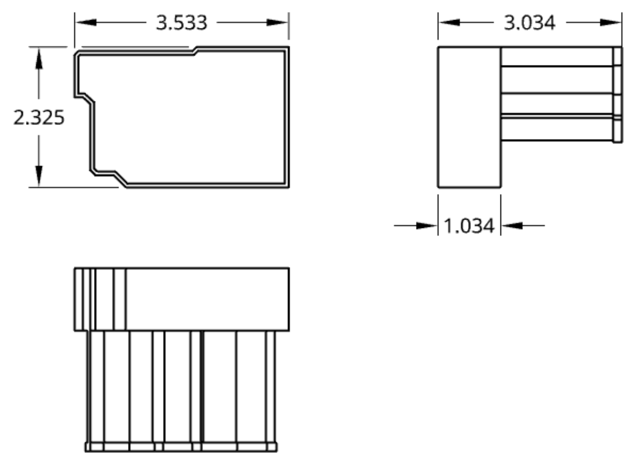


Figure 4.1.8 - Computer and Battery Sled

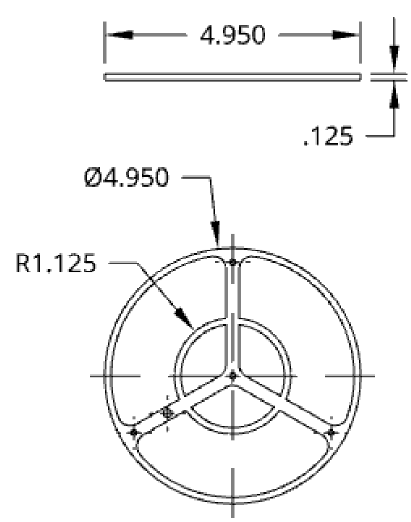


Figure 4.1.9 - Aluminum Nose Plate

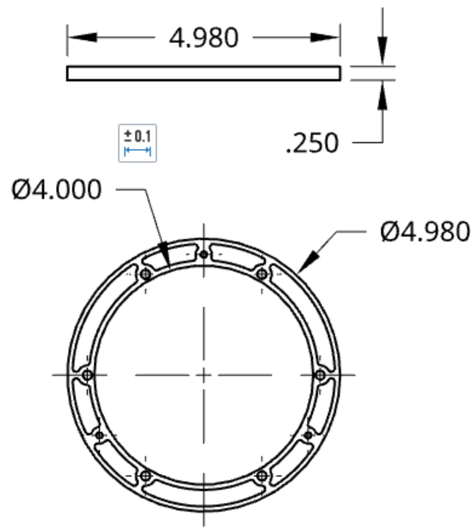


Figure 4.1.10 - Aluminum Coupler Plate

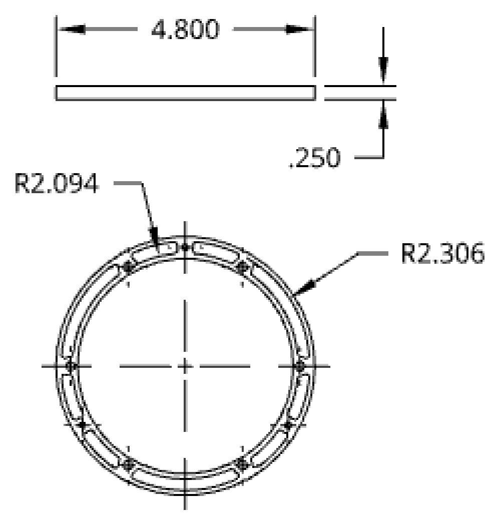


Figure 4.1.11 - Fiber Coupler Plate

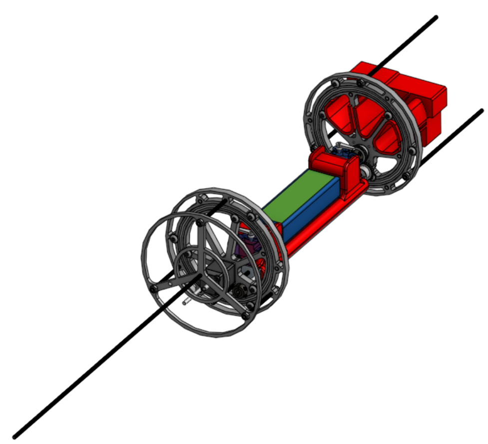


Figure 4.1.12 - Full Deployment System Angle View

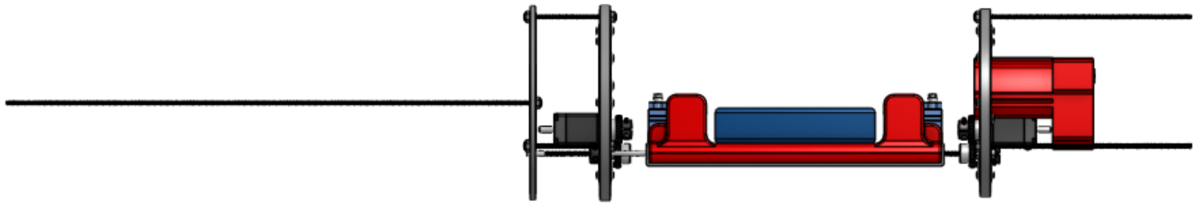


Figure 4.1.13 - Full Deployment System Side View

Handheld Controller
The handheld controller is the simplest component in the design, yet just as important to the success of the mission. It has a screen and 4 buttons connected to a circuit board inside the box. The circuit board also has a GPS, Teensy 4.0, and a barometer for local altitude data live. The screen provides all pertinent information to the operator, while the buttons are able to transmit all important data back to the drone and deployment system.

○ Describe how the payload components interact with each other.

UAV integration with Deployment Mechanism
The UAV is connected to the Deployment Mechanism with a 3D Printed component and two metal servos. The 3D Printed component acts as a bridge to hold the UAV while retaining one of its horizontal axis movements. The two servo motors, placed on both ends of the UAV's lower plate, lock in the other two axes of movement, horizontal in the opposite direction, and vertical. The last integration between the two devices is a signal connection. A four-wire connection, designed to be severed when the UAV launches, uses the onboard computer for the Deployment Mechanism. This connection has an input pin that turns off the voltage regulators, and in turn power for the whole circuit board, on the UAV. It also has two communication pins during start-up, and a common ground pin. This saves a very large amount of battery power, only requiring one computer to be on in flight, and turning the UAV on after the vehicle has landed and is ready to deploy.

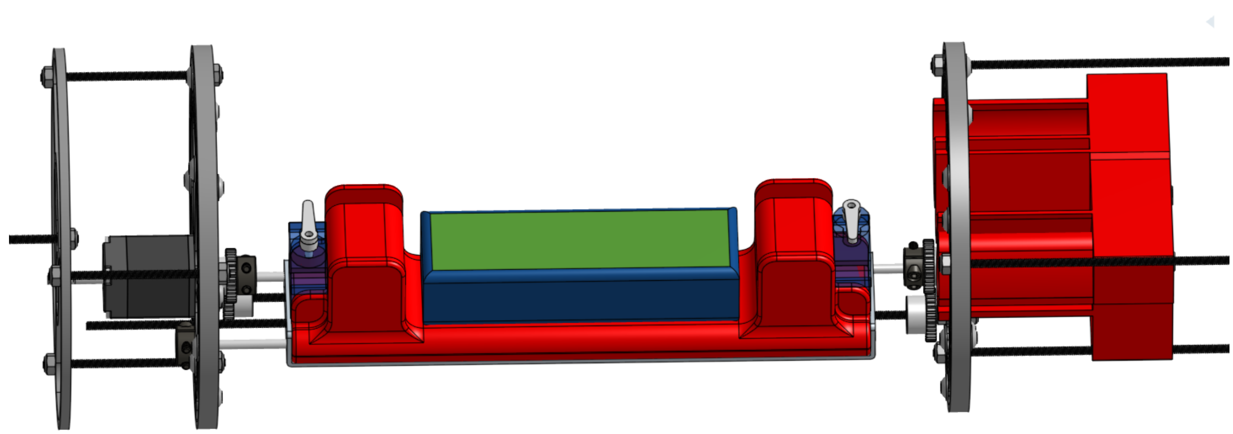


Figure 4.1.14 - Deployment Mechanism Bridge (UAV removed)

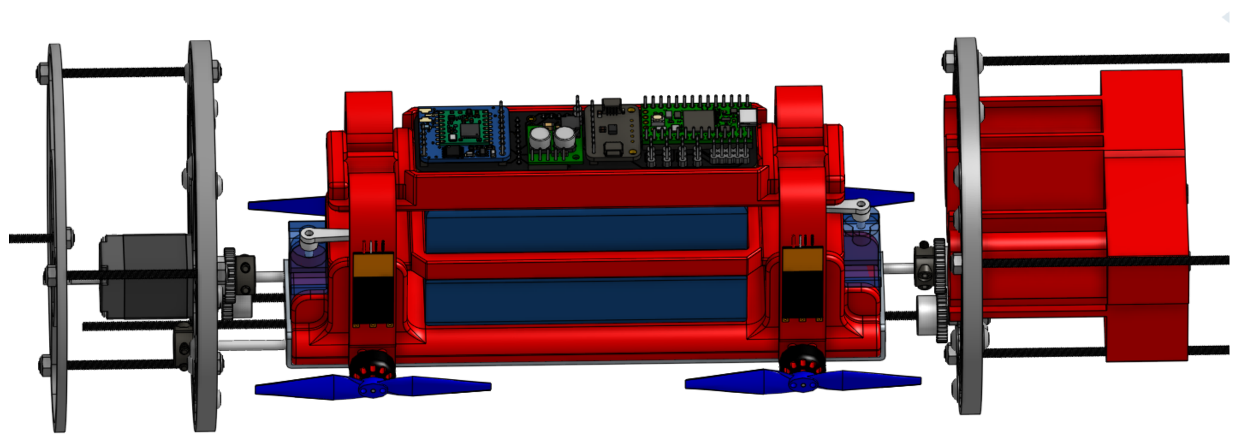


Figure 4.1.15- Deployment Mechanism Bridge (UAV "Latched")

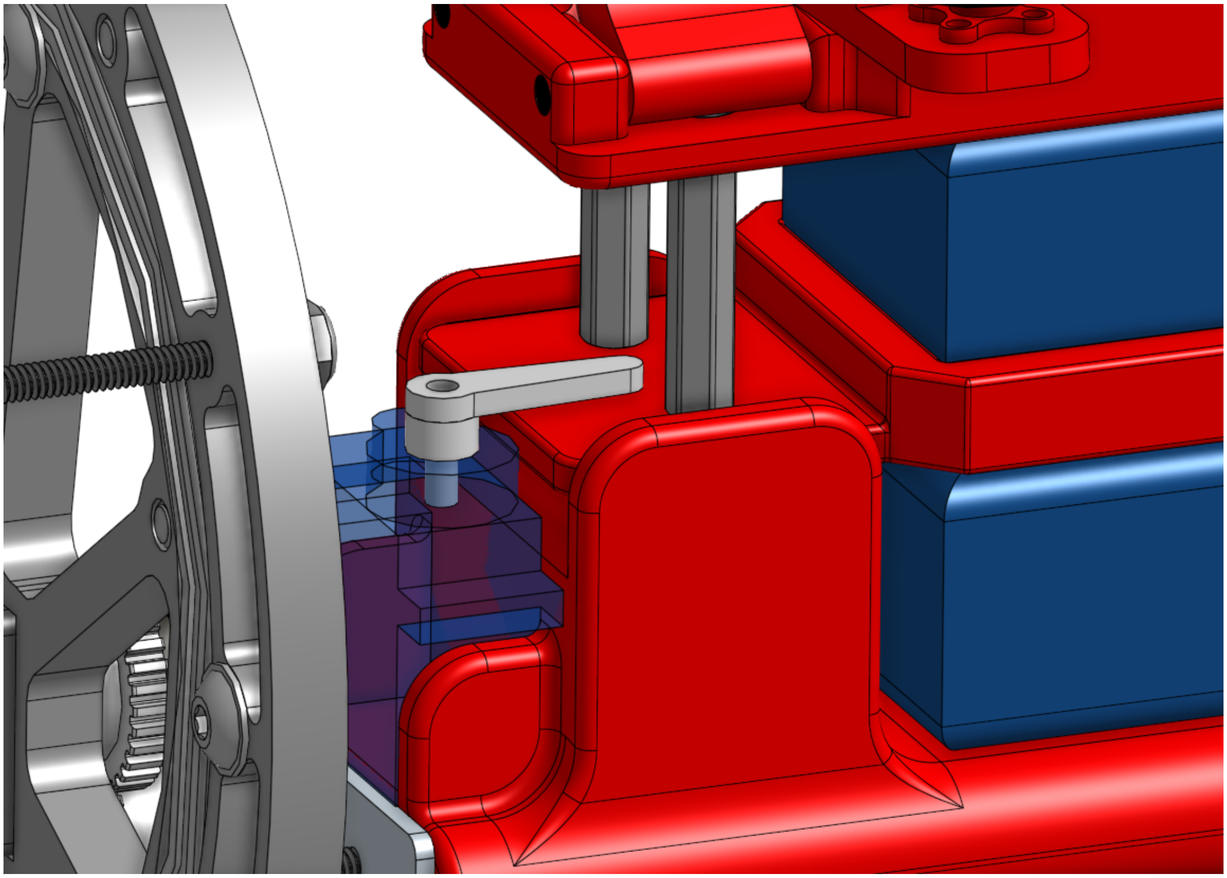


Figure 4.1.16- Closeup of Servo Latching Mechanism

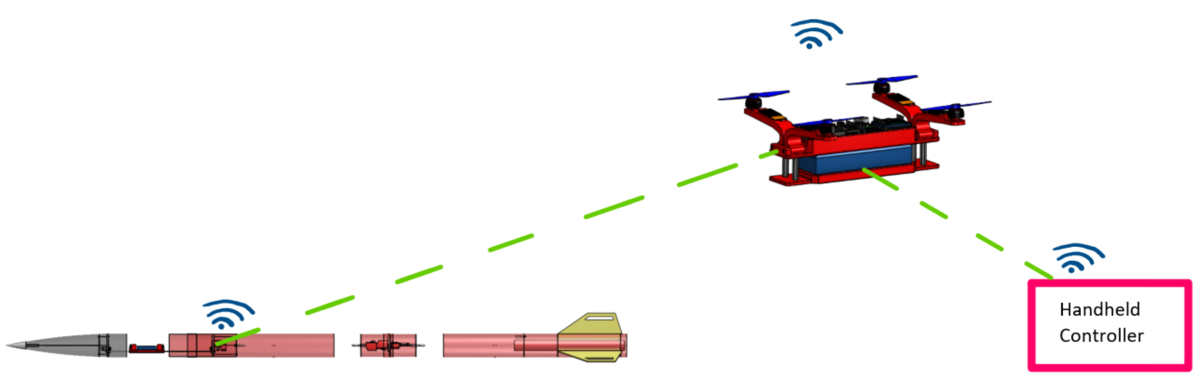
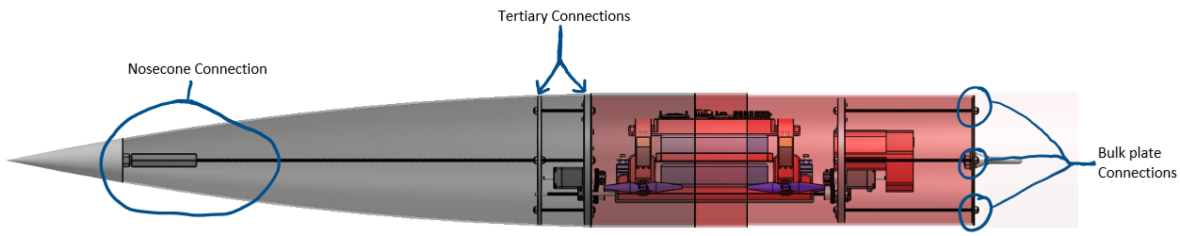
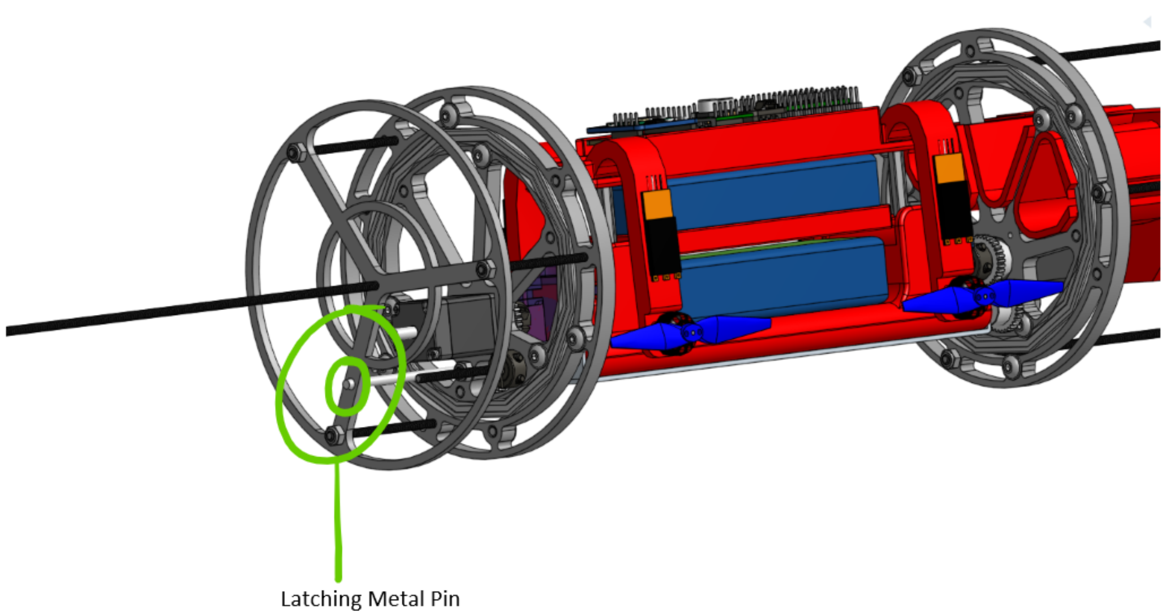
UAV & Deployment Mechanism integration with Handheld Controller
The UAV and Deployment Mechanism have no physical integrations with the Handheld Controller, but rather communicative integrations. The common components across all three devices are a barometric pressure sensor, GPS, and radio. These three devices create an extremely robust system, with local altitude information from all devices being communicated, alongside accurate GPS data.


Figure 4.1.17- UAV, Deployment Mechanism, & Handheld Controller Connection

○ Describe the payload retention system and its integration within the launch vehicle.

Deployment Mechanism Retention in Vehicle
The Deployment Mechanism is secured from two main points, the nose cone and the fiberglass bulk plate at the bottom of the Payload Coupler. There are multiple tertiary connection points in other parts of the Deployment Mechanism where components are tightened against other surfaces to reduce the load and stress on the whole assembly. The rotational movement of components in the deployment mechanism are locked in place during flight by a steel rod. It telescopes out with parts of the deployment mechanism, releasing it from its locked position.
 *Figure 4.1.18 - Deployment Mechanism Nosecone, Tertiary, and Bulk plate retention*
 *Figure 4.1.19- Deployment Mechanism Rotational Lock (Locked)*

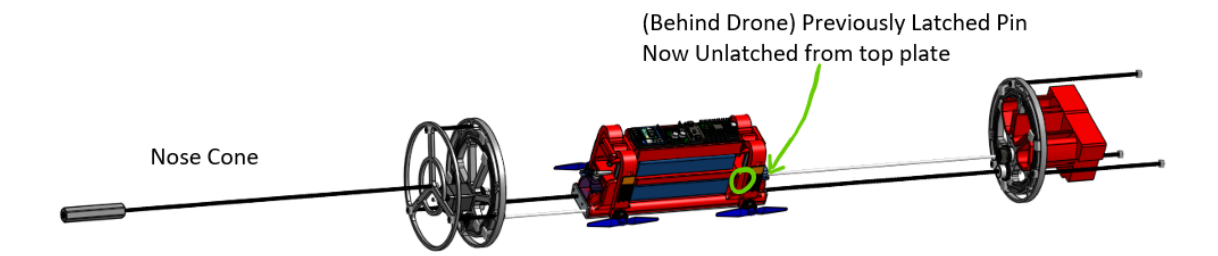


Figure 4.1.20 - Deployment Mechanism Rotational Lock (Unlocked with deployment)

● Demonstrate that the design is complete.

UAV and Deployment Mechanism Design Completion
The previous sections, their respective CAD models, and chosen mechanisms demonstrate that the design is complete. It is at a stage where it can undergo heavy testing to ensure mission success. The team has access to all manufacturing equipment necessary, and a complete CAD model in Onshape has been created. All PCB (Circuit board) designs have been completed using Fusion 360 and are also ready for manufacture. PCB designs are shown below.

● Discuss the payload electronics with special attention given to safety switches and indicators. Include the following:
○ Drawings and schematics, block diagrams, and batteries/power

Payload Electronics
Our payload has a total of two onboard custom circuit boards in our vehicle. These two circuit boards share the majority of identical parts, with different design shapes for their application. One circuit board is the computer that drives the UAV. The other circuit board is the computer that drives the deployment mechanism.
The boards are designed to work together, with signal lines being run from one board to the other in flight. One of these signal lines controls the power to the drone. The deployment sled computer has the ability to turn off the voltage regulators to the drone, which turns off power to the circuit board. This creates huge battery life savings in the event that the vehicle has to wait for up to 2+ hours on the launch pad.

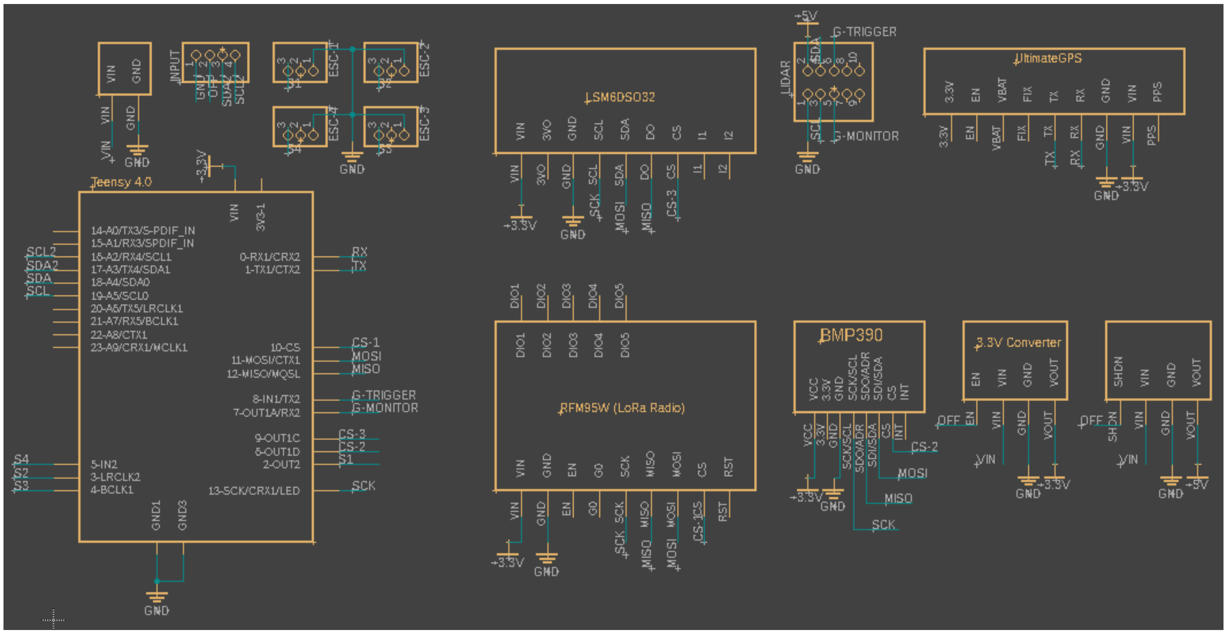


Figure 4.1.21- UAV PCB Schematic

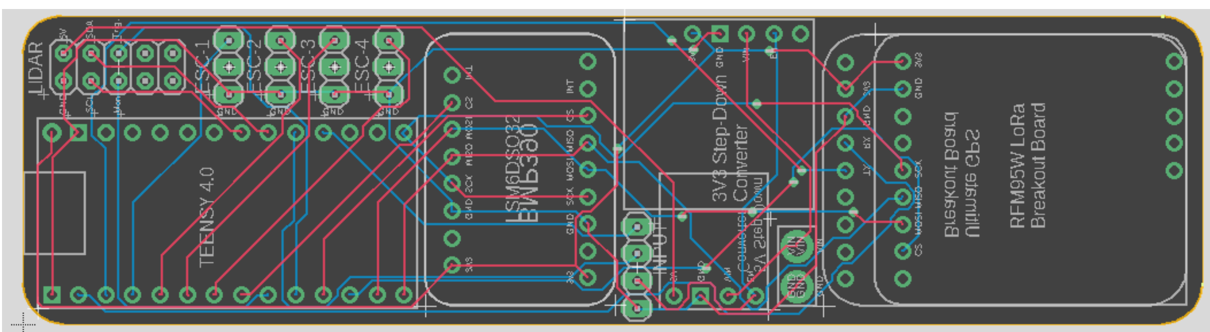


Figure 4.1.22- UAV PCB 2D Board

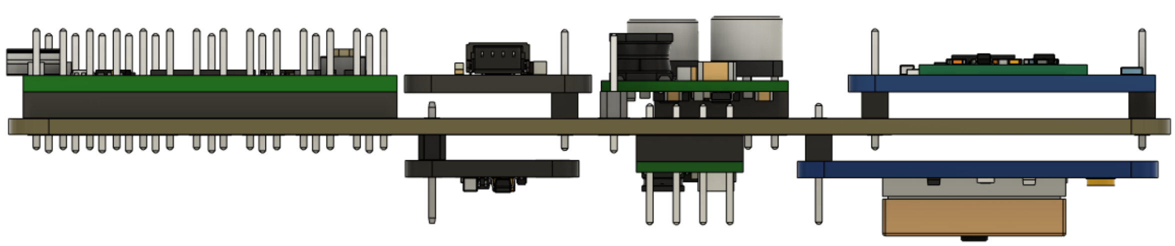


Figure 4.1.23 - UAV PCB 3D Board (Side Profile)

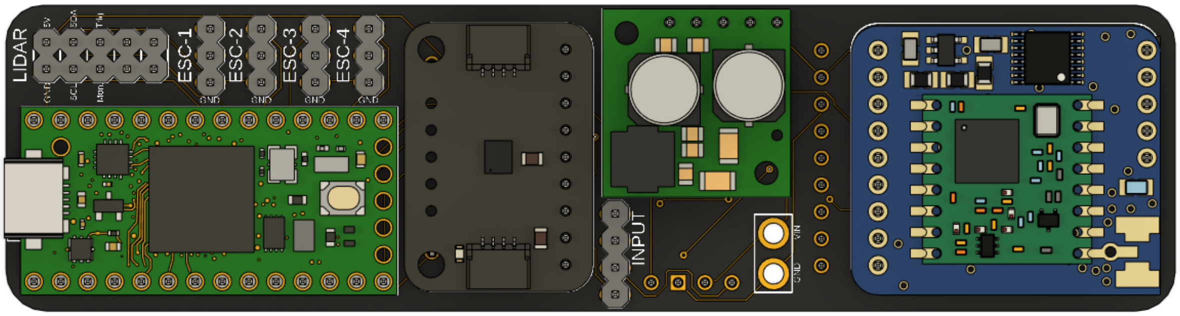


Figure 4.1.24 - UAV PCB 3D Board (Top Profile)

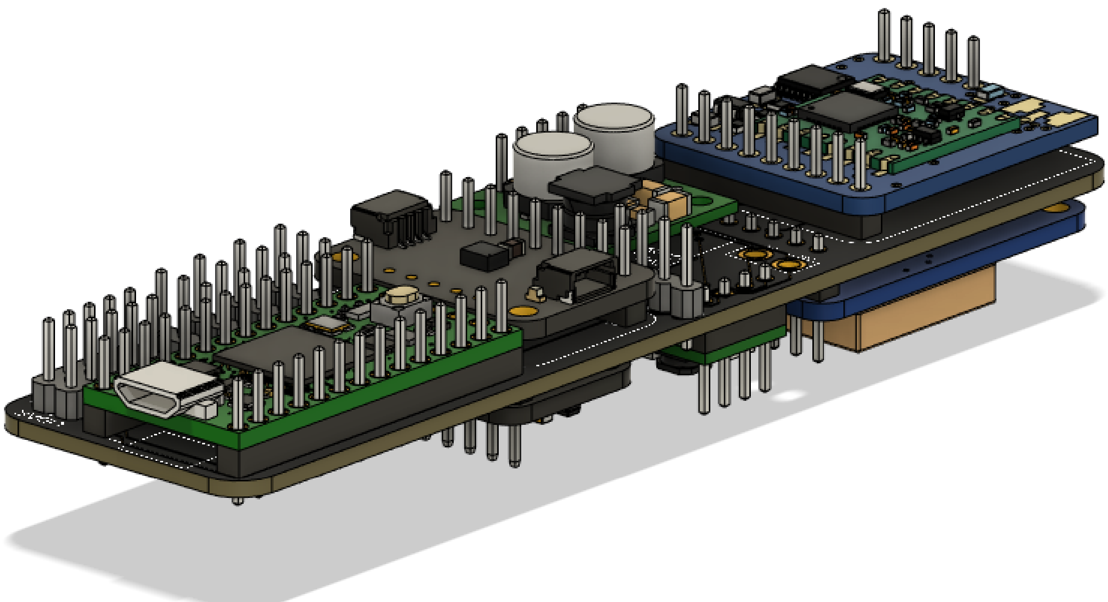


Figure 4.1.25- UAV PCB 3D Board (Isometric View)

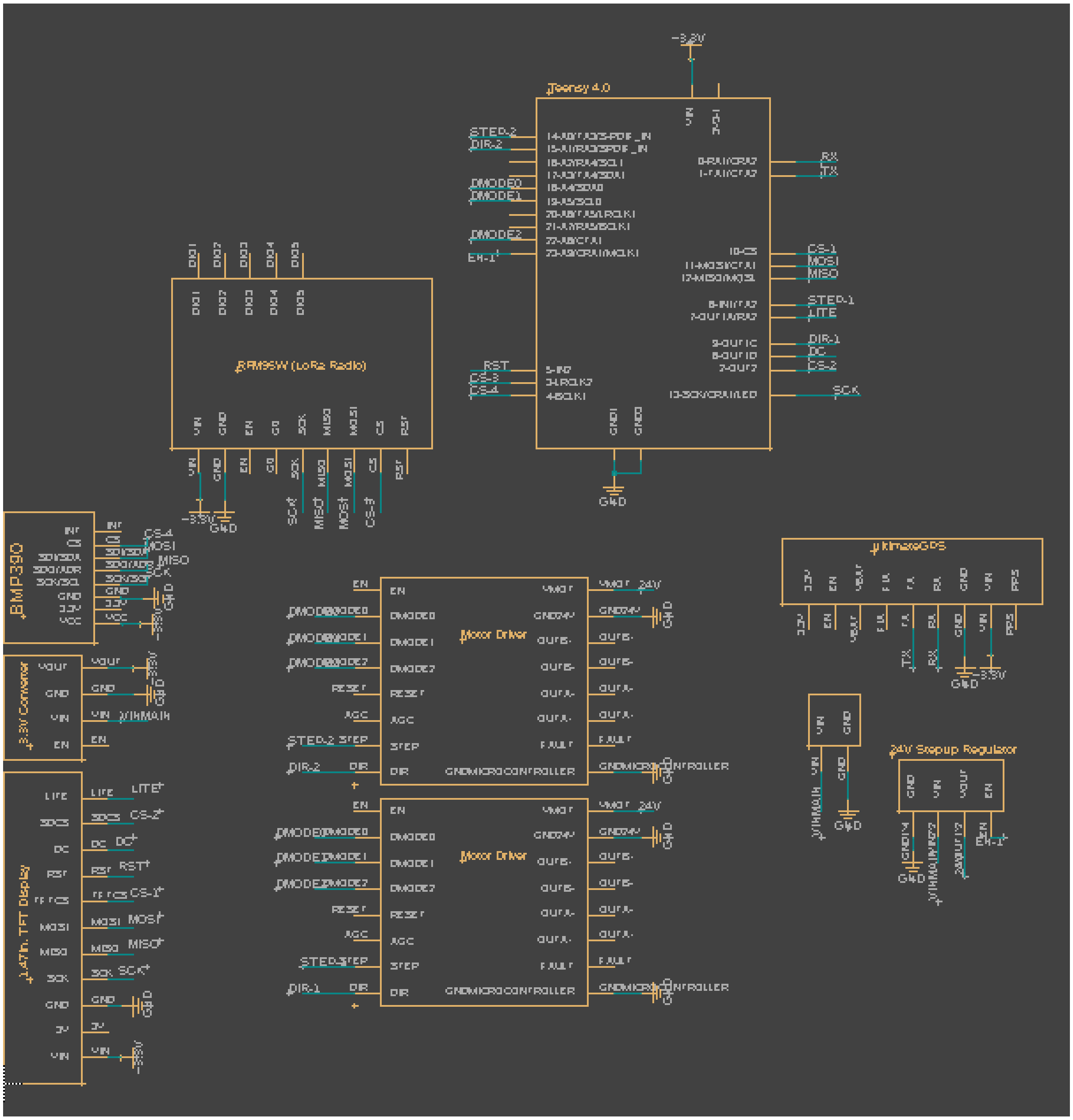


Figure 4.1.26 - Deployment PCB Schematic

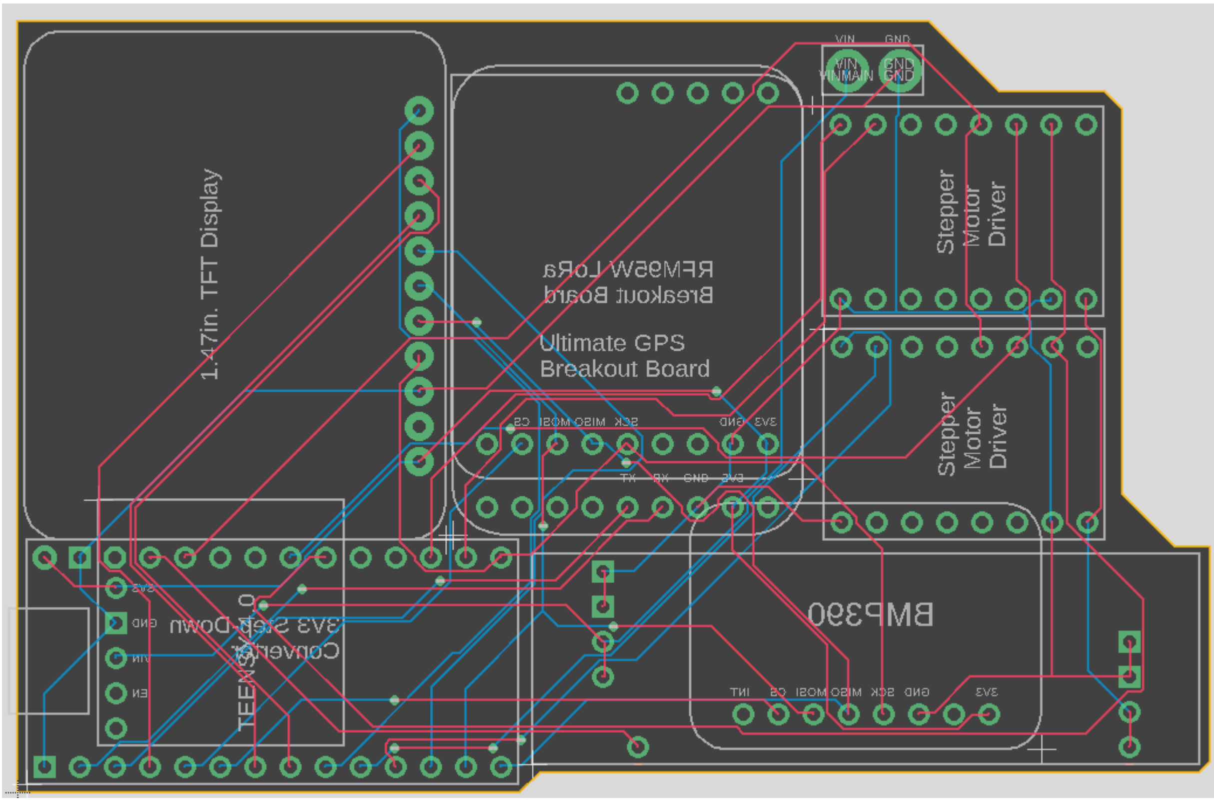


Figure 4.1.27 - Deployment PCB 2D Board

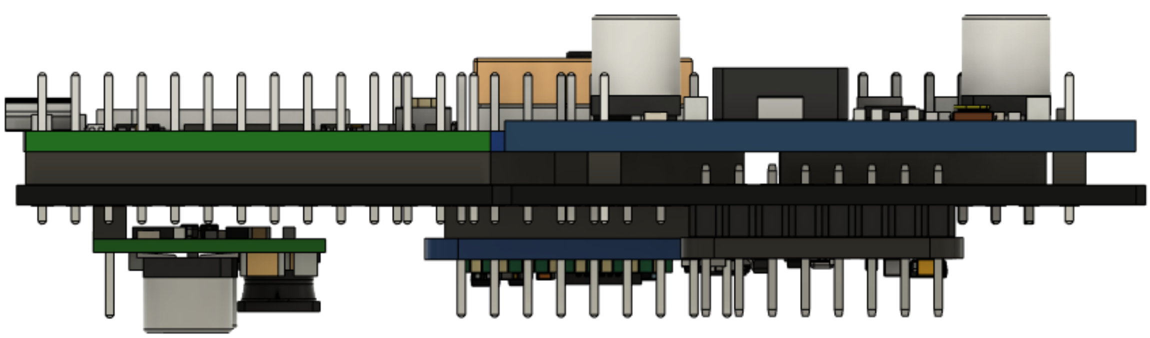


Figure 4.1.28- Deployment PCB 3D Board (Side Profile)

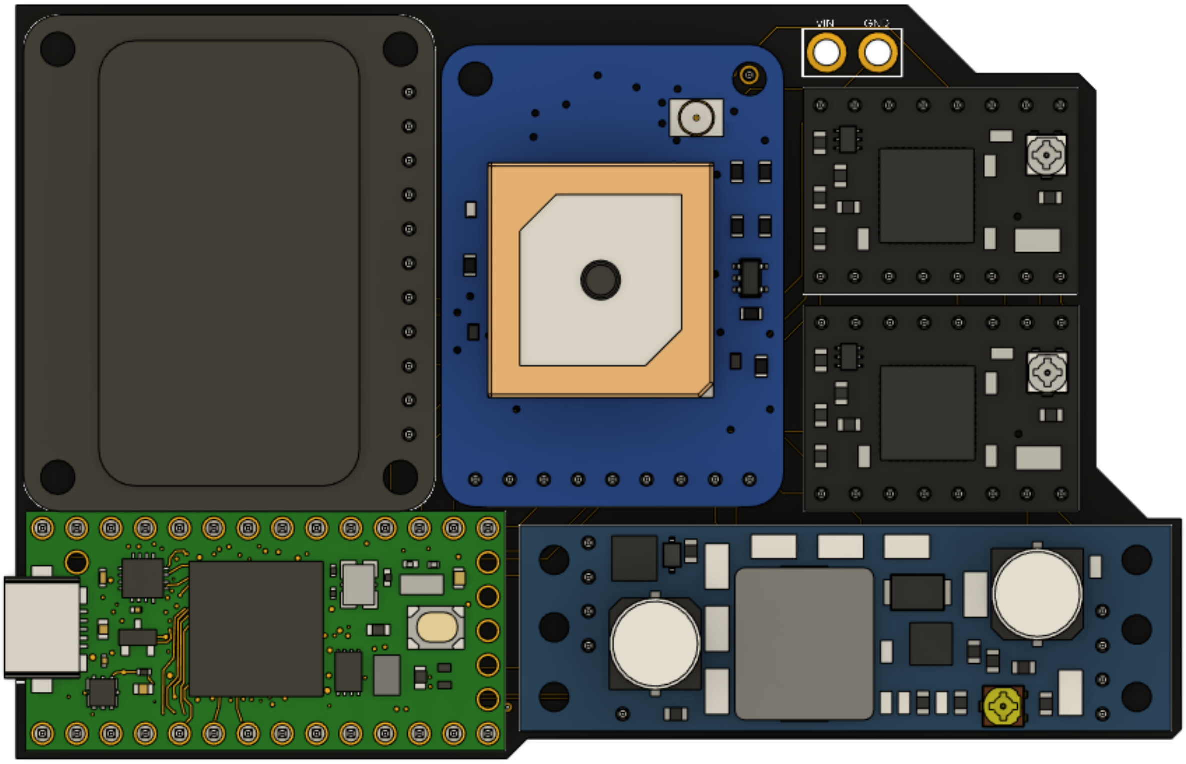


Figure 4.1.29- Deployment PCB 3D Board (Top Profile)

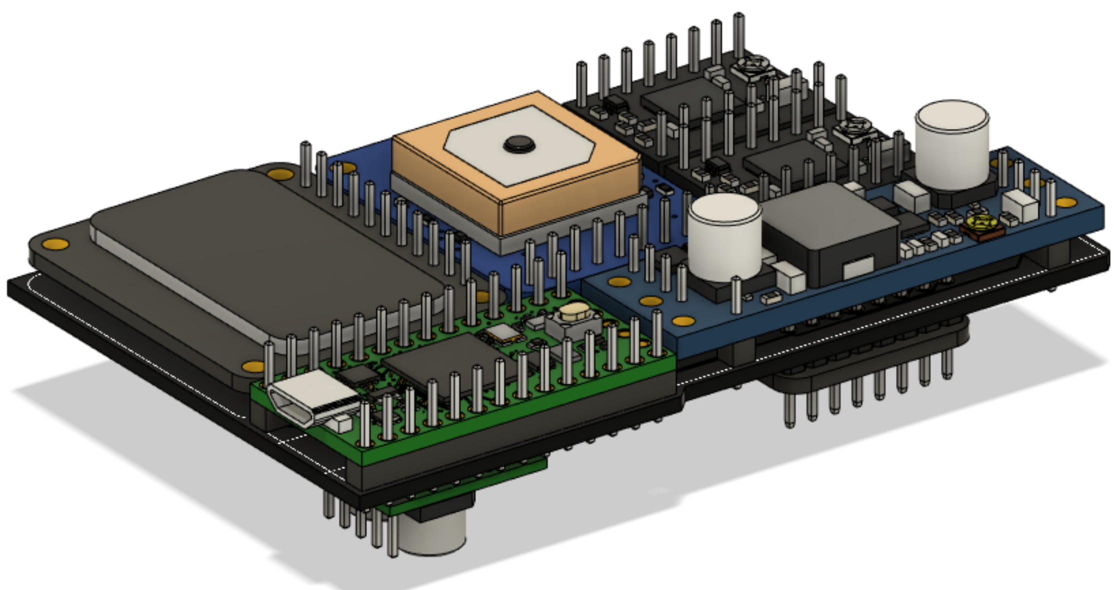


Figure 4.1.30- Deployment PCB 3D Board (Isometric View)

○ Switch and indicator wattages and locations on the vehicle

UAV
The UAV has no switches or direct activation points accessible once the payload has been assembled. There is a tether connected from the deployment mechanism to the UAV.

Deployment Mechanism
The deployment mechanism has a locking-on switch located near a vent hole, allowing a small screwdriver to press a locking button, which activates the system. Once the deployment mechanism is powered on, it establishes communication with the handheld controller. The handheld controller has a display on it that will inform the operator (a team member) of all systems ready, or any faults.

● Provide justification for all unique aspects of your payload (like materials, dimensions, placement, etc.)

Placement & Sizing	Justification
Deployment Mechanism Telescoping	The deployment system uniquely telescopes to allow the UAV to launch from the vehicle. A design composed mostly of aluminum was developed due to the expected loads exerted on the vehicle during launch and separation events. The threaded rods in the telescoping system were chosen for the similar reason of expected loads on the vehicle during separation, where a mechanically driven screw has a larger mechanical advantage.

Material Selection	Justification
#4-40 Aluminum Threaded Rods	Our team performed multiple calculations to determine the load exerted on each portion of the payload during flight. We found that previously we have been using a much stronger aluminum threaded rod than needed. Using the flight data from last year's NASA SLI rocket, we found that we can use #4-40 with an over 300% margin of additional safety.
Majority 3D Printed PLA Composition (UAV)	Other materials were considered in manufacturing the UAV, but it was determined

	that PLA or PETG filament would provide our team with satisfactory results. Our team also has access to the proper tools to manufacture the UAV with this method compared to others.

V) Safety

5.1 Launch concerns and operation procedures

Submit a draft of final assembly and launch procedures/checklists including:

● Recovery preparation

1) Use girth hitch to attach parachutes to kevlar
    a) If improperly attached, the vehicle will not safely descend
2) Level 1 Certification or higher: install ejection charges in the payload and booster section
    a) Certified mentor installing charges decreases the risk of injury
3) Install Nomex onto kevlar cord
    a) If not attached, risk of parachute damage increases
4) Fold parachute until it is long and skinny and then neatly fold into thirds or halves
    a) If folded incorrectly, proper deployment is at risk
5) Secure Nomex around folded parachute
    a) Otherwise the parachute could risk getting caught on fire
6) Bunch the parachute cord in a "Z" pattern
    a) Ensures the cord does not get caught/knotted/stuck as easily
7) Put Nomex-wrapped parachute and folded cord into the vehicle

● Payload preparation

1) Mount motors to wing with four screws each.
    a) Ensure tight and secure connections.
    b) Verify correct propeller placement.
2) Align wings in mounts and install hinge rod.
3) Attach four standoffs to the lower UAV frame.
4) Place the battery inside the lower UAV frame.
    a) Check proper alignment within the frame.
5) Align and secure the upper UAV frame to standoffs.
    a) Verify no battery movement is possible.
6) Inspect UAV. Ensure free hinge movement and correct stopping position.
7) Inspect Deployment Mechanism. Ensure bearings are clear and moving correctly, and verify proper alignment of components.
8) Verify PCB connections
    a) Check UAV and Deployment Sled
9) Set and verify ESC connections to motors and PCB
    a) Ensure secure connections to correct pins
10) Mount UAV on deployment sled, ensure proper alignment, and move servo to hold UAV in place.
11) Connect UAV and deployment sled PCBs.
12) Connect batteries to PCBs

a) UAV and Deployment Sled
13) Insert payload coupler into nose cone.
14) Install and verify placement of four shear pins.

● Electronics preparation

BEFORE ignitor is attached to vehicle: activate the altimeters. The vehicle should be fully loaded and on the launchpad.

1) With a small screwdriver, press the button on the altimeters by pushing the screwdriver through the body tube hole

● Rocket preparation

1) Wipe down the exterior to make sure no dirt or filth is stuck onto the vehicle
2) Check shear pin placement:
    a) there should be two shear pins in the booster section
    b) Four in main parachute separation area
    c) Four in payload deployment system

● Motor preparation

-Performed by a Level One Certification or higher member/mentor-

1) Look over the motor exterior for any flaws or breaks in the wrapping. Use another motor and repeat inspection if any flaws are found.
    a) An imperfect motor cannot be used due to the unpredictability and potential life-threatening hazards the flaws in the wrapping can cause
2) Drill the delay grain of the motor if needed. Use a drill or delay grain drilling tool for the length needed to remove the appropriate amount of grain.
    a) Failure to drill the correct amount will result in the ejection charges firing at the wrong time
3) Insert the motor all the way to the back of the motor casing
4) Put motor casing (with motor inside) into the vehicle's motor mount tube
5) Screw the retention device securely over the motor and motor mount tube
    a) Failure to properly secure motor will result in an unsafe launch

● Setup on the launch pad

Check by Level One Certification member/mentor or higher
(If forgotten, will lead to large safety concerns regarding spectator safety):

1) Make sure the motor cap is screwed on
2) Turn the vehicle to ensure the motor stays in place
3) Make sure the motor is correctly oriented
4) Look for the hole for the ignitor

When motor is properly installed:

1) Carry to launchpad
    a) If the vehicle is visibly damaged along the way or dropped, safety pre-flight checks will be run through again to ensure the vehicle's condition is acceptable
2) Tilt the rail down
3) Gently slide rocket onto the rail
    a) Jostling the vehicle could result in damaged rail buttons, a safety hazard due to the risk of an unaligned take-off, endangering spectators
4) Adjust the tilt of the rail to compensate for weather conditions
5) Retreat to, at minimum, 200 ft, given by the NAR minimum safety distance
    a) Failure to do so could result in bodily harm and goes against the pledge to abide within NAR safety regulations

● Igniter installation

-Performed by a Level One Certified member/mentor-

1) Completely uncoil the ignitor, straightening any twists/turns
2) Insert the ignitor into the motor, all the way down
3) Using the given plug, or masking tape, retain.
4) Split the ignitor into two strands to make a "V" shape
5) Double-check retention: lightly pull on ignitor, make sure the anode and cathode wires are split and the ignitor is deep enough

-Make sure the cord from the launchbox is unplugged:

6) Clip on the clips from the launchbox onto the two wires from the ignitor
7) Make sure they do not touch each other
    a) If the cord is not unplugged, the motor may ignite prematurely, putting team members and spectators in serious risk

● Launch procedure

1) Clear a 100-200 ft radius around the launchpad, making sure no people, large debris, or fire hazards are within 200 ft of the launchpad, per NAR safety regulations, no
    a) The Safety Officer must enforce this. Serious bodily injury could occur if the safety regulation is not adhered to and the launch does not go as expected
    b) Clearing flammable debris ensures the motor ignition does not start a fire, which would be a serious fire hazard
2) Make sure a fire extinguisher is on site
    a) Failure to do so could mean serious property damage if the launch is in a flammable location
3) Once the area is cleared, make sure the launch box is switched off

-Performed by a Level One Certified member/mentor-

4) Project your voice and shout a warning to spectators before plugging in the launch box.
5) Check for continuity by flipping "on" the first switch while giving a verbal countdown all spectators can hear
    a) Failure to loudly verbally communicate with the spectators may lead to a lack of needed awareness from the spectators if the vehicle were to unexpectedly

launch after each step

6) If continuity is not reached, check to see if the cord is plugged in all the way. If it is plugged in all the way, unplug it and wait one minute. After a minute, walk to the launch pad and inspect the vehicle. Inspect the ignitor and make sure it is wired correctly and the two wires aren't touching. Once everything is verified, walk back to the launch pad and repeat the launch procedure.
7) After continuity is reached (red light on) the vehicle is ready for launch
8) Perform another verbal countdown and then flick the second switch, launching the vehicle.
    a) If the vehicle fails to launch, wait one minute, then inspect the vehicle
    b) Is the ignitor far enough in the vehicle? Did it come undone?

- Troubleshooting

If the motor fails to ignite:

1) Check for continuity
2) Inspect the ignitor- is it properly installed?
3) Is the ignitor connected to the launch box cord through claw clips that are not touching?
4) Switch out ignitor
5) Switch out motor

If the altimeters are not turning on:

1) Check to see if the altimeters are connected to the battery by removal of vehicle from the pad and then the removal of altimetes the from vehicle

If the altimeters fail to say the main and drogue ejection charges are not connected:

1) Remove vehicle from pad
2) Check that the altimeters are connected to their respective locations/ejection charges
    a) Flying with no connection with the altimeters and ejection charges would be disastrous to the flight posing safety hazards of unpredictability and mistimed ejection of parachutes

- Post-flight inspection

1) Proceed to the vehicle at least 60 seconds after being still
2) Stay clear of vehicle if it seems to be landing close by
    a) Trying to catch a rocket will result in a safety hazard, along with trying to catch any irregular object falling from the sky
3) After recovering the vehicle, check the exterior for any damage upon landing. Check:
    a) Fins
    b) Nosecone
    c) Bodytube
    d) Parachute
    e) Payload (once ejected)
4) Proceed with payload D.R.O.N.E experiment
5) Record flight data from electronics

5.2 Safety and Environment (Vehicle and Payload)

● Update the Personnel Hazard Analysis, the Failure Modes and Effects Analysis, and the Environmental Hazard Analysis to include:
○ Finalized hazard descriptions, causes, and effects. These should specifically identify the mechanisms for the hazards, and uniquely identify them from other hazards. Ambiguity is not useful in safety work.
○ A near-complete list of mitigations, addressing the hazards and/or their causes○ A preliminary list of verifications for the identified mitigations. These should include methods of verifying the mitigations and controls are (or will be) in place, and how they will serve to ensure the mitigation. These do not need to be finalized at this time, but they will be required for FRR. Example verifications include: test data, written procedures and checklists, design analysis, as-built configuration drawings, and Personal Protective Equipment.

Updated Personnel Hazard Analysis					
Hazard	*Cause*	*Effect*	*Finalized Mitigation*	*Hazard Ranking: Likelihood and Severity* (1 = least likely/severe, 5 = most likely/severe)	*Preliminary Verification*
Failure to raise funds	Inadequate outreach or volunteering to work for funds	Overall failure of project; not enough money for construction or travel.	Limiting our budget to only completely necessary expenses. Commitment and dedication by members of our fundraising team.	S: 5 L: 2	N/A
Missing submission deadline of milestone	Poor planning, laziness of team	Consequences from NASA.	Communication between team members	S: 3 L: 2	Assign specific parts of the document to

documents.	members.		regarding meetings and deadlines. Commitment of team members to put in work.		each team member, and hold them accountable by taking away privileges if not completed.
Forgetting recovery wadding which can subsequently destroy the parachute, leading to catastrophic landing.	Forgetting recovery wadding/No mex in the vehicle for the black powder charge at apogee.	Catastrophic and uncontrolled landing which can result in injury with a high-altitude vehicle traveling toward the ground at a high velocity.	Have a step by step procedure put in place to prevent forgetting to put the recovery wadding/No mex into the vehicle before launch.	S: 5 L: 1	Follow the vehicle preparation launch procedures in 4.1, checking off each step as we go.
Injury while cutting fiberglass	Ignorance of machine operators, inadequate training or preparation.	Extreme bodily injury	Presentations made by Safety Officer to educate team members on how to safely operate machinery.	S: 5 L: 2	Ensure members are being supervised by the safety officer when cutting.
Dust/fiberglass particle accumulation	Inadequate PPE and poor ventilation area whilst sanding	Excessive inhalation of foreign substances, mild-severe lung respiratory damage	Utilize readily accessible PPE and IT rooms. Safety Officer informs the team by presentation of PPE available and proper	S: 1 L: 4	Try to complete work in an open area, to reduce the accumulation of particles.

			sanding procedures.		
Car accident	Driving to and from launches/outreach events/team meetings	Mild to life threatening bodily damage	Basic awareness of surroundings and informational meeting on rules and expectations of fundraising events	S: 5 L: 2	N/A
Getting hit by paper rockets/outreach experiments	Unclear launch area for students, lack of instruction and guidance when presenting	Mild bodily harm	Clear instructions from student leaders to younger students on safety expectations, as well as adequate enforcement of said rules	S: 1 L: 3	Students are told not to hit people with rockets, and are instructed to fly them when others are standing behind them.
Snowball fight	Presence of snow and poor judgment	Mild bodily harm (frostbite, ice to face)	Remind team members and spectators that horse play is not tolerated	S: 2 L: 5	Instructions given to refrain from throwing snow.
Subscale launch					
Launch site lights on fire	Launch site ground too dry, inadequate mitigation equipment (fire extinguisher) on hand	Decimation of launch site, spectators and team members lives put in danger	Proper safety checklist and kit including tools necessary to mitigate potential scenarios. Saturate	S: 5 L: 3	Inspect area, ensure launch pad is intact and ground is saturated prior to launching.

			launch area and have proper launch pad.		
Parachute fails to deploy	Ejection charges fail to cause the body tubes to separate, contingency charges fails, chute releases and backup chute do not activate	Vehicle has an uncontrolled descent, leading to potential spectator and team member bodily harm as the velocity is well above safety guidelines.	Ensure sufficient amounts of black powder, check through simulations to make sure launch should go successfully.	S: 3 L: 2	Follow electronics and motor preparation checklists in 4.1 to best prepare ejection charges and electronics
Vehicle components break upon landing	Inadequate construction and assembly of subscale vehicle	Failed subscale launch	Stick to a detailed schedule so construction is not rushed, apply vital components, such as epoxy, with special care.	S: 3 L: 2	Thoroughly go over parachutes before flight (pre-flight check).

Failure Modes and Effects Analysis					
Hazard	*Cause*	*Effect*	*Finalized Mitigation*	*Hazard Ranking: Likelihood and Severity* (1 = least likely/severe, 5 = most likely/severe)	*Preliminary Verification*
Parachute gets tangled	Failure to package correctly,	Vehicle has an uncontrolled	Take time to correctly pack	S: 4 L: 2	Inspection of parachute and folding cord

	freak accident	descent	parachute		pattern included in pre-flight check.
Parachute does not deploy	Ejection charges fail to cause the body tubes to separate, contingency charges fails, chute releases and backup chutes do not activate	Vehicle has an uncontrolled descent	Ensure sufficient amounts of black powder, check through simulations to make sure launch should go successfully.	S: 4 L: 2	Ejection charge inspection included in pre-flight check. Calculations to determine how much ejection charge is needed.
Motor fails to ignite	Faulty motor, ignitor not set up correctly, launch box issues	Vehicle does not launch	Ensure clips are properly attached and not touching launch pad	S: 1 L: 3	N/A
Inclimate weather on launch day	Bad luck	Vehicle launch is postponed	Plan launch date accordingly	S: 1 L: 2	N/A
Motor explodes on launchpad	Malfunctioned motor	Potential fire, vehicle and launchpad unusable	Store and transport motor appropriately	S: 5 L: 1	Motor inspection included in pre-flight check.
Fins break upon landing	Poor application of fins, flaw in fin material	Failed subscale launch	Assemble and construct vehicle without rushing, taking special care to filleting fins and allowing proper bonding time	S: 2 L: 2	Go through preflight checklist and inspect parachutes
Vehicle lands	Weather	Potential	Don't fly	S: 2	N/A

in hazardous area	conditions, imperfect flight	injury recovering vehicle, potential property damage, vehicle damage	with winds of over 20 mph, ensure launch site is clear of surrounding trees, debris, or bodies of water that the vehicle could land in	L: 2	
UAV crashes upon release from vehicle	Rotors have damage during flight, caught on deployment mechanism, control system malfunction	UAV destruction, project failure, potential property and person damage	Pad UAV during flight, provide back up plans for control system and deployment mechanism, such as manual release of UAV for imperfect flights	S: 3 L: 2	Inspect payload security when going through pre-flight checklist, as well as several tests for the UAV releasing out of the vehicle before launch day.
UAV crashes during flight	Control system malfunction, loss of battery life, collision with surroundings, sticky bearings	Project failure, potential collision with objects or personnel, loss of data	Proper testing of UAV before launch, address any issues beforehand	S: 3 L: 2	N/A
UAV fails to avoid obstacles	Control system malfunction	Collision with obstacle, destruction to property and UAV	Significant testing beforehand, recording malfunctions and adjusting after each test	S: 3 L: 2	Team members will be within sight of the UAV and have practiced extensively
UAV fails to	Damage to	UAV unable	Provide a	S: 1	There is a

release from vehicle	deployment mechanism, parachute interference, surrounding debris interference	to complete project	manual release as a backup method	L: 2	manual release, where team members will eject the UAV
Data from UAV fails to be collected	Control system malfunction, failure to set up correctly, battery life runs out	UAV unable to fly to target and back to the vehicle's location	Significant testing beforehand, recording malfunctions and adjusting after each test	S: 2 L: 2	Inspect electronics bay when going through pre-flight checklist
Data collection system runs out of battery	Failure to charge before launch, the vehicle travels farther than UAV can travel on current battery life.	No data is collected, UAV is unable to fly to target and complete project goal	Follow launch day checklist and preparation. Charge battery.	S: 5 L: 2	N/A
Emergency-Stop fails	Control system malfunction, out-of-range	UAV crashes, UAV releases from vehicle uncontrolled/ unsafely	Understand max range of E-Stop controllers and stay well within bounds. Test E-Stop before launch repeatedly	S: 4 L: 2	Per FAA guidelines, team members will be within eyesight of the vehicle (without visual aid) before operating the UAV and will be alongside the UAV for the duration of the experiment, ensuring the E-Stop has no range issues.

UAV wings fail to extend	Not protected well enough during flight, surrounding debris catches on UAV	UAV crashes	Provide E-Stop to ensure UAV is operating safely, have clear launch zone/site	S: 3 L: 2	This is verified during testing of UAV and flight training
Launch rail falls over	Inclimate weather, Uneven ground	Dangerous launch, too hazardous of a launch angle, potential severe harm of spectators and buildings	Ensure a level launch site, don't fly with winds of over 20 mph	S: 5 L: 1	N/A
Spectator injury	Too close to launchpad, lack of proper launch day procedures	Spectator harm, lawsuits	Enforce NAR safety code and mandatory distance table	S: 5 L: 2	Follow safety procedures and use launch preflight checklists
Parachute opens too early	Ejection charges failed to deploy properly	Vehicle drifts out of range, lands in unauthorized zones	Ensure sufficient amounts of black powder, check through simulations to make sure launch should go successfully.	S: 3 L: 2	Go through preflight checklists in 4.1, specifically the motor preparations section
Collision between UAV and person	Strong wind, ignorance of people, poor programming of UAV.	Severe personal injury, destruction of UAV.	Launching only in safe weather, sufficient UAV flight testing, making sure all flight spectators are	S: 5 L: 2	N/A

			attentive.		
Collision between UAV and object	Strong wind, poor programming of UAV, failure to account for obstacles.	Destruction of UAV, damage to surrounding private property, and subsequent financial liability.	Sufficient flight testing, accounting for all possible objects that may interfere with flight.	S: 5 L: 2	N/A
Sticky Bearings	Clogged up, not greased enough	UAV crashes	Use UAV efficiently, regrease when necessary, and clean out before testing	S: 4 L: 2	Verified through 4.1 launch procedures checklist
UAV catches on billowing parachute and crashes	Team deploys UAV while vehicle is still in motion and doesn't accelerate vertically fast enough	UAV crashes, damage to parachute	Deploy UAV when vehicle comes to rest, or under a safe velocity of the vehicle, tested prior to launch date	S: 3 L: 5	N/A

Environmental Concerns					
Hazard	*Cause*	*Effect*	*Finalized Mitigation*	*Hazard Ranking: Likelihood and Severity* (1 = least likely/severe, 5 = most likely/severe)	*Preliminary Verification*
Unpredictable weather during launch	Temperature changes, air pressures changes,	Unsafe wind gusts, launch delayed, unsafe flight	Check the forecast beforehand. Practice	S: 3 L: 2	N/A

	weather patterns, seasonal change, cloud patterns, etc.	due to sudden weather shifts	caution over getting the launch in, plan for multiple launch dates		
Uneven landing ground/excessive foliage on landing area	Vehicle drifted outside of target landing zone, windy	Harm to environment as vehicle lands, harm to payload and vehicle	Check the forecast beforehand, and launch within a safe wind speed of 20mph or less. Launch in a large flat area with least possible variables involved	S: 2 L: 2	N/A
Contamination of ground by vehicle motor during launch	Insufficient, or lack of, pad underneath vehicle	Damage to soil and Earth, residue and contamination of environment possible with contents of motor	ensure the vehicle and launch pad is positioned correctly.	S: 2 L: 2	Verified by Team Safety Officer and RSO

VI) Project Plan

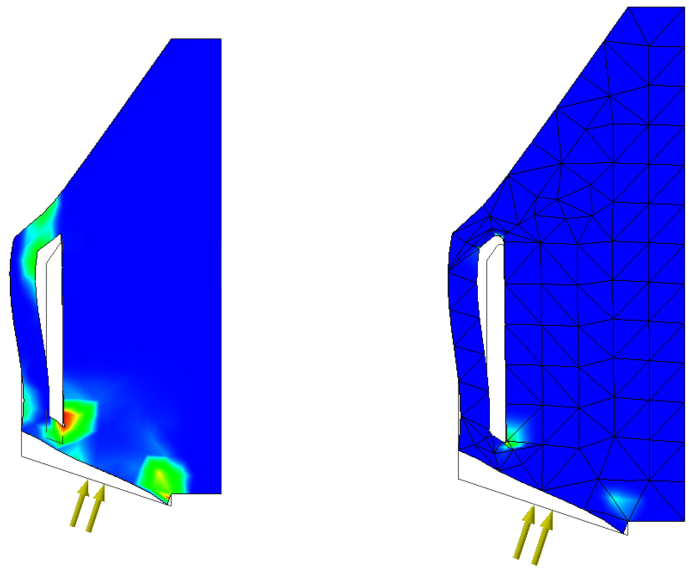
6.1 Testing

● Identify all tests required to prove the integrity of the design.
● For each test, present the test objective and success criteria, as well as testing variable and methodology.
● Justify why each test is necessary to validate the design of the launch vehicle and payload.
● Discuss how the results of a test can cause any necessary changes to the launch vehicle and payload.
● Present results of any completed tests.
○ Describe the test plan and whether or not the test was a success.
○ How do the results drive the design of the launch vehicle and/or payload?

Test Name	Ground Ejection Demonstration
Test Objective + Variable	Determine the proper amount of black powder to ensure successful ejection of the drogue and main parachutes. Variables would include grams of black powder used.
Success Criteria + Methodology	In order to determine the optimal amount of black powder to ensure proper parachute ejections, we will adjust the amount of black powder in the charges (by grams), following calculations. Success will be defined as a specified amount of black powder to properly deploy the drogue parachute (initial and secondary charges) and main parachute (initial and secondary) at their proper respective times.
Test Justification	During the subscale flight, the drogue black powder charge was too powerful and deployed both the drogue and main parachute. To ensure this does not happen in the full-scale vehicle and proper parachute deployment occurs at the proper time, testing will be done to ensure the black powder ejections charges are not too powerful or weak for their respective deployments.
Necessary Changes	Upon testing, the amount of black powder, in grams, will be adjusted to ensure the ejection forces are not too great or little for proper parachute deployment.
Test Plan Description + Test Success	Once the full-scale vehicle is assembled, the calculated black powder charge(s) will be tested in the body tube of the full-scale vehicle to ensure the forces of the ejection

	charges are appropriate to separate the proper sections and deploy the parachute(s). The main and drogue charges will be tested, while the vehicle is at a 35° angle
Significance of results	Testing results will cause the amount of black powder (in grams) to change, slightly increasing or decreasing the weight of the vehicle and space needed to house these charges.

Test Name	Fin Slot Location and Size
Test Objective + Variable	Improve structural integrity of fins, variables would be the location of the slot and the size.
Success Criteria + Methodology	In order to have the best structural integrity of the fins, we will adjust the variables of size and location of the fin slot through Autodesk Inventor. Success will be defined by what location and size combination proves the maximum strength/support at the fin slot points
Test Justification	During the subscale flight, the fin chipped/broke along one of the fin slots due high forces being applied in that one area. To ensure the fin does not break during the full–scale flight, testing is needed to adjust the fin slot to provide maximum strength and durability
Necessary Changes	Upon testing, fin slot size and location from the fin edge will be adjusted.
Test Plan Description + Test Success	The location of the fin slot will be tested through Autodesk Inventor with stress testing. Success would be a fin with a fin slot with little to no locations of increased stress at certain point(s). Preliminary testing indicates that rounding the corner of the fin slot significantly reduces stress forces.

	
Significance of results	Test results will change the fin slot location and size/shape of the fin slot, affecting the weight of the vehicle as well as the center of pressure.

Test Name	Drone Battery and Drone Deployment System Life
Test Objective + Variable	Ensure sufficient battery life to allow for 2+ hours on pad prior to flight. The measured variable will be the operating time of the battery system.
Success Criteria + Methodology	To test the battery life of the drone, the drone will fly continuously until the battery dies to determine the battery life of the drone. Additionally, the drone will be left on standby to determine the battery life of the drone waiting on the launchpad to ensure it can sit on the launch pad two hours before deployment. Success will include the drone being able to be on standby for 2 hours and successfully having enough battery life to complete its mission after deployment. The deployment system battery life will also need to be tested through the same methods of being on standby for as long as possible while still being able to function in the end.
Test Justification	To ensure the drone and deployment system can properly function and complete their mission after being on standby on the pad, battery life needs to be tested to

	ensure they can do so.
Necessary Changes	If battery life is found not to be sufficient, either a larger battery will be used, or power consumption will be reduced.
Test Plan Description + Test Success	The battery life of both the drone and deployment system will be tested to determine if the current batteries supplying power are sufficient to power the drone and deployment system through standby and the mission. Success will be if they both have a battery life that allows them to function through standby and the mission
Significance of results	Results will indicate whether a larger battery is needed or energy consumption needs to be decreased.

Test Name	Drone Deployment System Performance
Test Objective + Variable	Ensure the drone deployment system properly deploys the drone. The variable will be the proper clearance to allow the drone to take off.
Success Criteria + Methodology	Success would be clearance and deployment of the drone allowing it to take off. Tests will be performed with the drone in the system to see if the system deploys the drone properly.
Test Justification	This test is needed to ensure that the drone, the main aspect of our payload, is able to take off and complete its mission.
Necessary Changes	If the drone is not able to take off due to the system, the system will be modified to work properly and allow proper clearance.
Test Plan Description + Test Success	The drone will be placed on the deployment system with that section of the vehicle on the ground. The deployment sequence will then commence at a team member's command. If the drone is able to deploy from there, that will qualify as a success.
Significance of results	Results of this test will result in modification of the deployment system to ensure it allows for proper clearance and deployment.

Test Name	Drone GPS Homing and Manual Transmitter
Test Objective + Variable	Ensure the drone is both able to track and locate/navigate the transmitter held by a team member and locate/navigate to the vehicle. Additionally, ensure the “Emergency-Stop” on the manual transmitter functions properly to turn off the drone in case a safety issue arises. as well as the button for when to locate the vehicle instead of the manual transmitter. The variable is the drone's response to the manual transmitter and ability to locate the vehicle and manual transmitter.
Success Criteria + Methodology	Success would be the drone being able to navigate to both the manual transmitter and vehicle at appropriate times while responding to commands from the manual transmitter. This would be tested by ground tests with a drone locating both the manual transmitter and vehicle (or simulated vehicle), while also responding to the “Emergency-Stop” and button to change from locating the manual transmitter to the vehicle.
Test Justification	This test is needed to ensure the drone and manual transmitter can function properly to not only carry out our mission, but do it in a safe manner.
Necessary Changes	If the drone is not able to locate the vehicle and/or manual transmitter, and/or is not responding to commands from the manual transmitter, radio signals and GPS will need to be adjusted/fixed to ensure proper communication and locating.
Test Plan Description + Test Success	The drone will be put on the ground and tasked with locating the transmitter after being “deployed”. After it has been located and navigated to, the button on the manual transmitter will be pressed to tell the drone to locate the vehicle. The drone will then locate and guide/navigate team members to the vehicle. Then the “Emergency-Stop” will be tested to turn off the drone. Success is defined if the drone properly locates and navigates to each device/vehicle, and responds to commands from the manual transmitter.
Significance of results	Results of this test will result in modification of the GPS and radio signals on the drone, vehicle (only for the payload), and manual transmitter, to ensure they function as intended.

Test Name	Drone Performance
Test Objective + Variable	Ensure the drone functions/flies properly. The variable will be the drone's ability to fly and maneuver during flight.
Success Criteria + Methodology	Success would be the drone being able to fly while maneuvering in all possible directions for the purpose of our payload. To test this, we would have to manually control the drone and ensure it flies and can maneuver during flight.
Test Justification	This test is needed to make sure the drone functions and can fly/maneuver for the purpose of our payload.
Necessary Changes	If the drone is not able to fly/maneuver, the reason why will be located and fixed, or the design will be modified so it can do so.
Test Plan Description + Test Success	To test drone maneuverability and flight, the drone would be controlled manually by a team member. The member would first test if the drone can lift off the ground and maintain flight. Then, they would test the maneuverability of the drone, up, down, left, right, etc., to ensure it can fly properly. Success would be the drone taking off, maintaining flight, and being able to maneuver in all directions properly.
Significance of results	Results of the test would result in design modifications to the drone, to limit weight, increase lift, and/or increase maneuverability.

6.2 Requirements Compliance

● Create a verification plan for every requirement from sections 1–5 of the project requirements listed in this handbook. Identify if tests, analysis, demonstration, or inspection are required to verify the requirement. After identification, describe the associated plan needed for verification.

General Requirements:

● 1.1 Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). Teams will submit new work. Excessive use of past work will merit penalties.

Method	Inspection
Outcome	The team has created a new design and has only referenced previous work for data purposes. No other people or groups have designed any part of the vehicle. Installation of igniter and ejection charges was done by the team mentor.
Status	Ongoing

● 1.2 The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.

Method	Inspection
Outcome	The team has a project plan in the Proposal, PDR, and CDR (section 5). A project plan will also be included and updated in the FRR.
Status	Ongoing

● 1.3 The team shall identify all team members who plan to attend Launch Week activities by the Critical Design Review (CDR). Team members will include:
1.3.1 Students actively engaged in the project throughout the entire year.
1.3.2 One mentor (see requirement 1.13).
1.3.3 No more than two adult educators.

Method	Inspection
Outcome	Those attending NASA launch week have submitted all necessary forms to the NASA Gateway. The team mentor is included on Gateway.
Status	Completed upon submission of CDR documents package.

● 1.4 Teams shall engage a minimum of 250 participants in Educational Direct Engagement STEM activities in order to be eligible for STEM Engagement scoring and awards. These activities can be conducted in-person or virtually. To satisfy this requirement, all events shall occur between project acceptance and the FRR due date. A template of the STEM Engagement Activity Report can be found on pages 121–124.

Method	Inspection
Outcome	Currently, partnerships have been established with junior highs to do activities during their enrichment time, as well as educational preparation programs to help with these activities. Contacts have also been established with elementary schools

	and girl scout troops to start collecting participants. Activities are starting to begin shortly after the semester ends on Jan 12.
Status	Ongoing

● 1.5 The team will establish and maintain a social media presence to inform the public about team activities.

Method	Inspection
Outcome	The team has an active Twitter and Instagram account that can be viewed at the handles @CFHSRocketClub (Twitter) and @cfhsrocketclub (Instagram). The pages will stay updated throughout the course of the project.
Status	Ongoing

● 1.6 Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient. Late submissions of PDR, CDR, FRR milestone documents shall be accepted up to 72 hours after the submission deadline. Late submissions shall incur an over-all penalty. No PDR, CDR, FRR milestone documents shall be accepted beyond the 72-hour window. Teams that fail to submit the PDR, CDR, FRR milestone documents shall be eliminated from the project.

Method	Inspection
Outcome	All deliverables have been submitted by their respectable deadline and any necessary revisions have been made within the 72 hour period.
Status	Ongoing

● 1.7 Teams who do not satisfactorily complete each milestone review (PDR, CDR, FRR) shall be provided action items needed to be completed following their review and shall be required to address action items in a delta review session. After the delta session the NASA management panel shall meet to determine the teams' status in the program and the team shall be notified shortly thereafter.

Method	Inspection
Outcome	Our team has completed all deliverables satisfactorily and are prepared to complete the necessary action items included in the delta review session.
Status	Ongoing

● 1.8 All deliverables shall be in PDF format.

Method	Inspection
Outcome	As of 1/6/2023 all submittables have been submitted in PDF format and will continue to be submitted in this format.
Status	Ongoing

● 1.9. In every report, teams will provide a table of contents including major sections and their respective Sub-sections.

Method	Inspection
Outcome	Every report has included a table of contents (reference the beginning of this CDR). All reports will continue to have one.
Status	Ongoing

● 1.10. In every report, the team will include the page number at the bottom of the page.

Method	Inspection
Outcome	Every report has included page numbers at the bottom of the page (reference this report). Every report will continue to have them.
Status	Ongoing

● 1.11. The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.

Method	Inspection
Outcome	Our team has access to the necessary equipment for video teleconferences and has always previously been prepared for such events.
Status	Ongoing

● 1.12. All teams attending Launch Week will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted at the NASA Launch Complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on Launch Day. The exact cant will depend on Launch Day wind conditions.

Method	Inspection

Outcome	The team will be using a 15:15 Rail, 12 feet tall, as specified in section 1.2 of the CDR.
Status	Complete

● 1.13 Each team shall identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor shall maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to Launch Week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend Launch Week in April.

Method	Inspection
Outcome	We have identified Tyler Sorensen as our mentor. He is Level 2 Certified through NAR and has successfully flown and recovered over two flights with a motor impulse higher than K. He claims the rocket and will travel with the team to Launch Week.
Status	Ongoing

● 1.14. Teams will track and report the number of hours spent working on each milestone.

Method	Inspection
Outcome	Through CDR the team has tracked and included the number of hours spent working on milestones. The team will continue to do this. See section 1.1 for reference.
Status	Ongoing

2 Vehicle Requirements

● 2.1. The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on their competition launch will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.

Method	Analysis

Outcome	Our projected altitude is 4,629.722 ft. 4,500 ft is our target goal as past experience shows that simulation altitude always projects higher than the launch day altitude. The projected altitude and goal fall well within the range of the altitude requirements.
Status	Ongoing (until flight data collection is recovered)

● 2.2. Teams shall declare their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score.

Method	Inspection
Outcome	The target altitude is 4500 feet. The altimeter in the vehicle is able to record the altitude during launch.
Status	Design complete, components acquired, construction ongoing

● 2.3. The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.

Method	Inspection
Outcome	The subscale launch proved that the vehicle can be launched and reusable. The team has implemented a recovery system that lessens the likelihood of damage done to the vehicle.
Status	Design completed, construction ongoing

● 2.4. The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.

Method	Inspection
Outcome	The vehicle will have 3 sections, showcased by figure 3.3.3 in section 3.3, this section explains the recovery process of the sections.
Status	Design Complete, construction ongoing

● 2.4.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 2 air-frame diameters in length. (One body diameter of surface contact with each airframe section).

Method	Inspection

Outcome	Looking at the figures in section 3.1, the designs of the coupler are shown. The coupler is 12 inches long, over twice the diameter of the vehicle, which is 5 inches.
Status	Construction ongoing

● 2.4.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.

Method	Inspection
Outcome	The figures in 3.1 show that our team is not using the nose-cone shoulder as an in-flight separation point. The coupler is greater than 2.5 inches (½ of the body tube diameter).
Status	Complete

● 2.5. The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.

Method	Demonstration
Outcome	Sections 3 and 4 illustrate the components of the vehicle and payload. Those components are made to be assembled in less than 2 hours, proved by a test flight.
Status	Scheduled for Feb 18 (backup date = February 25)

● 2.6. The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.

Method	Demonstration
Outcome	The GPSs and altimeters will last the minimum of two hours due to manufacturer claims from the GPS manufacturer (3 hours claimed) and the altimeters from past experience. The two batteries will also last longer than 2 hours. The battery from drone operation will not be used until activated by team members post-flight and the battery for the drone sled deployment will use 0.3 milliamps compared to the 1600 milliamp capacity. These electronics will be waiting for a signal to start using the battery. We will prove the capabilities through testing, as the batteries have just been received.
Status	In progress- test scheduled January 27th

● 2.7. The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated launch services provider.

Method	Inspection and Analysis
Outcome	The team selected a K1440 motor, which uses a firewire initiator to ignite. The team used firewires in the past, for the subscale and previous launches. These were activated using a 9 volt DC battery, meaning the 12 volt DC system will also be successful.
Status	Complete

● 2.8. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).

Method	Inspection
Outcome	As shown in the previous sections of sections 3 and 4, the vehicle utilizes internal circuitry and is independent, not needing any special ground support equipment to initiate the launch. The only support needed would be the 12 volt DC firing system, which fits within the requirements and is provided.
Status	Complete

● 2.9. The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).
2.9.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone.
2.9.2. Any motor change after CDR shall be approved by the NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment will not be approved. A penalty against the team's overall score will be incurred when a motor change is made after the CDR milestone, regardless of the reason.

Method	Inspection
Outcome	The selected motor is a Cesaroni K1440. This is commercially available and is approved by NAR/TRA/CAR. It has already been purchased. Final motor choice is declared in the CDR and will not be changed for altitude adjustment purposes.
Status	Complete (upon submission of CDR package)

● 2.10. The launch vehicle will be limited to a single motor propulsion system.

Method	Inspection
Outcome	The vehicle has been designed to be a single motor propulsion system, shown by the designs in section 3.
Status	Completed

● 2.11. The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).

Method	Analysis and Inspection
Outcome	The selected motor of the K1440 has a max impulse of 2,437 newton-seconds, claimed by NAR. This is less than the max impulse of 2,560 Newton-seconds.
Status	Complete

● 2.12. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:
2.12.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.
2.12.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.
2.12.3. The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.

No pressure vessels are included within the vehicle, as shown by section 3.

● 2.13. The launch vehicle will 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.

Method	Inspection
Outcome	Shown in section 3.4, the vehicle has a static stability margin of 2.16 at rail exit and a margin of 2.07 at the pad. These are both above the minimum of 2.0. Due to the CG moving forward as the motor burns, the stability margin will increase. This means that the stability margin is guaranteed to be above the minimum requirement of 2.0.
Status	Design completed, construction ongoing

● 2.14. The launch vehicle will have a minimum thrust to weight ratio of 5.0 : 1.0.

Method	Analysis
Outcome	Due to the average thrust of our selected motor (K1440) being 323 pounds and the weight of the vehicle on the pad being 26.281 lbs, our thrust to weight ratio is 14.27:1. Using max thrust, the ratio would be greater.
Status	Design complete, construction ongoing

● 2.15. Any structural protuberance on the rocket will 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.

Method	Inspection
Outcome	Structural protuberances would just be the fins of the vehicle, aft of the burnout center of gravity. The center of gravity will move forward as the motor burns because of the decrease of the propellant mass. The CG will remain in front of the fins directly after the motor finishes burning out, as it is already in front of the fins shown in section 3.
Status	Design complete, construction ongoing

● 2.16. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.

Method	Analysis
Outcome	The RockSim shows the vehicle exiting the guide rail at a velocity of 105.17 fps, exceeding the minimum of 52 fps. This is shown in mph under the simulations in section 3.4
Status	Design complete, construction ongoing

● 2.17. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Success of the subscale is at the sole discretion of the NASA review panel. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data shall be reported in the CDR report and presentation at the CDR milestone. Subscales are required to use a minimum motor impulse class of E (Mid Power motor).

Method	Inspection
Outcome	Flights are completed and the results are in section 3.2. A G80 motor was used to fly the vehicle.
Status	Complete

● 2.17.1. The subscale model should resemble and perform as similarly as possible to the full-scale model; however, the full-scale will not be used as the subscale model.

Method	Inspection
Outcome	Subscale is closely related to the design for the full-scale vehicle. This can be seen further in section 3.2.
Status	Subscale completed, full scale in progress

● 2.17.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude.

Method	Inspection
Outcome	The altimeter incorporated in the subscale launch recorded the altitude throughout the launch as seen in section 3.2.
Status	Testing completed

● 2.17.3. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.

Method	Inspection
Outcome	The team created a plan for the subscale rocket based off of the design of the full scale rocket for this year. As seen in section 3.2 there are new reports for the different plans for this year's launch.
Status	Construction complete

● 2.17.4. Proof of a successful flight shall be supplied in the CDR report.

Method	Inspection
Outcome	According to the data found in section 3.2, the flight reached a height of 1082 feet and successfully deployed the separation sections.
Status	Flight completed and successful

● 2.17.4.1. Altimeter flight profile graph(s) OR a quality video showing successful launch and recovery events as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted

Method	Inspection

Outcome	As seen in the altimeter graph in section 2.3 the flight is fully shown from beginning until end.
Status	Complete

● 2.17.4.2. Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the CDR report. This includes but not limited to nosecone, recovery system, airframe, and booster.

Method	Inspection
Outcome	Section 3.2 shows quality pictures of the subscale and its landed configuration.
Status	Complete

● 2.17.5. The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter 100" length rocket your subscale shall not exceed 3" diameter and 75" in length.

Method	Inspection
Outcome	Our full-scale vehicle will be 5” in diameter and 100.5” length. For the subscale rocket, the body tube was scaled down by 50%, meaning 2.5’’ and the length was cut down 50% at around 50.25’’.
Status	Complete

● 2.18. All teams will complete demonstration flights as outlined below.
● 2.18.1.1. The vehicle and recovery system will have functioned as designed.

Method	Inspection
Outcome	As shown by the subscale section in the CDR, the images show the vehicle fully intact and recovered by the recovery system. The graphs show the vehicle launching off the pad successfully.
Status	Complete

● 2.18.1.2. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year’s project.

Method	Inspection
Outcome	As shown by the diagrams in section 3, this full scale is uniquely designed and built specifically for this year. Looking through past projects of ours, there is a

	distinct difference between projects, vehicle design, and safety.
Status	Complete

● 2.18.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:
2.18.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.
2.18.1.3.2. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.

Method	Inspection
Outcome	During the full-scale demonstration flight, the payload will be flown.
Status	Ongoing

● 2.18.1.4. If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.

The payload doesn’t change the external surface.

● 2.18.1.5. Teams shall fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances.

Method	Demonstration
Outcome	The team is using the K1440 for the Vehicle Demonstration Flight, the same motor for the competition launch.
Status	Launch scheduled for 2/18, back up is 2/25

● 2.18.1.6. The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the competition launch flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.

The vehicle does not have any ballast weight.

● 2.18.1.7. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO).

Method	Inspection
Outcome	After the full-scale demonstration flight, the vehicle will not be modified. If for some reason it needs to be modified, there will be an additional full scale launch.
Status	TBD

● 2.18.1.8. Proof of a successful flight shall be supplied in the FRR report.
2.18.1.8.1. Altimeter flight profile data output with accompanying altitude and velocity versus time plots are required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.

Method	Demonstration/Analysis
Outcome	Proof of successful flight will be inputted into the FRR report after launch. Altimeter data will be collected and inputted as well, with accompanying graphs.
Status	Incomplete, reliant on launch on 2/18 (backup = 2/25)

2.18.1.8.2. Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the FRR report. This includes but not limited to nosecone, recovery system, airframe, and booster.

Method	Demonstration
Outcome	Quality pictures are prepared to be taken upon recovery of the full scale, to be put in the FRR report.
Status	Incomplete, reliant on launch on 2/18 (backup = 2/25)

● 2.18.1.9. Vehicle Demonstration flights shall be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight shall submit an FRR Addendum by the FRR Addendum deadline.

Method	Demonstration
Outcome	The vehicle demonstration is scheduled for 2/18 (backup 2/25), before the FRR submission deadline.
Status	Scheduled for 2/18 (backup 2/25)

● 2.19.2. Payload Demonstration Flight—All teams will 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. The following criteria shall be met during the Payload Demonstration Flight:
2.19.2.1. The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.
2.19.2.2. The payload flown shall be the final, active version.
2.19.2.3. If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.
2.19.2.4. Payload Demonstration Flights shall be completed by the FRR Addendum deadline.

Method	Inspection
Outcome	The UAV will deploy manually after the vehicle is stationary and fully recovered. The deployment sled will keep the payload secure (see payload section) until manually ejecting the UAV. The deployment mechanism is designed to not be impacted during flight. The payload flown will be the same in the competition launch as the Payload Demonstration Flight, the final, active version. The additional flight and FRR Addendum will be utilized if the above criteria are not met.
Status	Incomplete (pending launch)

● 2.20.1. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch.
2.20.2. Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly a final competition launch.
2.20.3. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.

Method	Inspection
Outcome	We will meet all criteria and submit the FRR package on time. We acknowledge that the failure to complete the FRR package and Vehicle Demonstration

	Re-Flight will not be permitted to fly.
Status	TBD

● 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.

Method	Inspection
Outcome	After construction of the vehicle, the Safety Officer will inspect the vehicle and ensure the contact information is eligible and clearly written.
Status	Construction ongoing

● 2.22. All Lithium Polymer batteries will 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.

Method	Inspection
Outcome	All lithium polymer batteries will be secured from impact, marked as a fire hazard, brightly colored, identifiable from other payload items. The safety officer will make sure the batteries are labeled.
Status	TBD

● 2.23.1. The launch vehicle will not utilize forward firing motors.
2.23.2. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, Metal Storm, etc.)
2.23.3. The launch vehicle will not utilize hybrid motors.
2.23.4. The launch vehicle will not utilize a cluster of motors.
2.23.5. The launch vehicle will not utilize friction fitting for motors.

Method	Inspection
Outcome	The selected K1440 motor is not forward firing, does not utilize motors that expel titanium sponges, and doesn't use hybrid motors, cluster of motors, or friction fitting for motors.
Status	Complete

● 2.23.6. The launch vehicle will not exceed Mach 1 at any point during flight.

2.23.7. Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).
2.23.8. Transmissions from onboard transmitters, which are active at any point prior to landing, will not exceed 250 mW of power (per transmitter).

Method	Analysis
Outcome	The maximum velocity does not exceed Mach 1. Refer to section 3.4 simulations.
Status	Complete

● 2.23.9. Transmitters will not create excessive interference. Teams will utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.

Method	Inspection
Outcome	The Featherweight GPS Tracker unit utilizes a different channel that is specific to the designated frequency. With this process, it will mitigate interference with or to other teams.
Status	Completed

● 2.23.10.Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.

Method	Inspection
Outcome	There is no excessive, or dense metal use on the vehicle. In section 3.1, aluminum and steel is used in limited amounts.
Status	Completed

3 Recovery System Requirements

● 3.1. The full scale launch vehicle will 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.
3.1.1. The main parachute shall be deployed no lower than 500 feet.
3.1.2. The apogee event may contain a delay of no more than 2 seconds.
3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.

Method	Demonstration and Inspection
Outcome	Look at section 3.3. The main chute will deploy at 600 ft. There will be a backup at 500 ft and it will be demonstrated on the test launch.
Status	Design Inspection Complete, demonstration set for 2/18 (backup 2/25)

● 3.2. Each team will perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full scale vehicles.

Method	Demonstration
Plan	There will be a ground demonstration to ensure deployment and charges are large enough.
Status	Scheduled for 2/11

● 3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.

Method	Inspection
Plan	Section 3 shows that all sections land with a kinetic energy of less than 75 ft-lbf at landing
Status	Design complete, construction ongoing

● 3.4. The recovery system will 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.

Method	Inspection
Outcome	The altimeters used are commercially available. We will be using altimeters from PerfectFliteDirect.
Status	Complete

● 3.5. Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.

Method	Inspection
Outcome	The vehicle’s altimeters will have their own, dedicated power source. This power source is from a 9V Duracell battery. This will allow the power not to be shared with the rest of the electronics.

Status	Design complete, construction ongoing

● 3.6. Each altimeter will 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.

Method	Inspection
Outcome	The altimeters that are used on the vehicle all have their own power supply coming from a 9V Duracell battery. The recovery electronics will also come from a 9V Duracell battery.
Status	Design complete, construction ongoing

● 3.7. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).

Method	Inspection
Outcome	The switches being used in the design (see section 3) can be locked on.
Status	Design complete, construction ongoing.

● 3.8. The recovery system, GPS and altimeters, electrical circuits will be completely independent of any payload electrical circuits.

Method	Inspection
Outcome	The recovery system and payload never interact. See more in section 3.1.
Status	Complete

● 3.9. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.

Method	Demonstration and Inspection
Plan	Four removable shear pins are located at each separation point, which houses the main and drogue chutes.
Status	Design complete, construction ongoing

● 3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads.

Method	Analysis

Outcome	The drift calculations show that the drift is limited to less than 2,500 ft even with 20 mph winds.
Status	Complete

● 3.11. Descent time of the launch vehicle will be limited to 90 seconds (apogee to touch down).

Method	Analysis
Outcome	Based on the calculations using the chosen parachute, the descent time of the vehicle is 77.6 seconds, which is less than the 90 seconds given. View in section 3.4.
Status	Completed

● 3.12. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.
3.12.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.
3.12.2. The electronic tracking device(s) will be fully functional during the official competition launch.

Method	Inspection
Plan	As all pieces of the vehicle are tethered together, only one GPS is needed. Section 3's figures show the GPS implemented in the design of the vehicle.
Status	Design completed, construction ongoing

● 3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).
3.13.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.
3.13.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.
3.13.3. The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.
3.13.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

Method	Inspection

Outcome	In section 3 where the recovery electronics design is shown, the GPS is in a different compartment, separated by a plywood bulk plate with a chicken wire grid.
Status	Design complete, construction ongoing

4 Payload Experiment Requirements

● 4.1 High School/Middle School Division—Teams may design their own science or engineering experiment or may choose to complete the College/University Division mission stated below. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.

Our team will be designing our own experiment in the high school division.

● 4.4.1. Black Powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics shall not be permitted for any surface operations.

Method	Inspection
Plan	Black powder is used in the recovery section and is not included in the payload, which utilizes electronics and mechanical processes to eject the payload manually.
Status	Complete

● 4.4.2. Teams shall abide by all FAA and NAR rules and regulations.

Method	Inspection and Demonstration
Outcome	The Safety Officer will thoroughly review and educate team members on all FAA and NAR rules and regulations, making everyone abide by them during all rocketry activities.
Status	In progress

● 4.4.3. Any secondary payload experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement of the CDR milestone by NASA.

Method	Inspection
Outcome	At no point in the flight of the vehicle will any secondary payload be jettisoned from it during the recovery phase.

Status	Completed

● 4.4.4. Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given to release the UAS.

The team will deploy a UAV manually after the vehicle is stationary and permission is given by the RSO. Deployment will not be initiated during the descent of the vehicle.

● 4.4.5. Teams flying UASs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).

Our team will abide by all of these regulations.

● 4.4.6. Any UAS weighing more than .55 lbs. shall be registered with the FAA and the registration number marked on the vehicle.

Method	Inspection
Outcome	The team's UAV will weigh more than .55 lbs. The team is intending to register with the FAA and correctly display the registration number on the vehicle.
Status	Design complete, construction ongoing

5 Safety Requirements

● 5.1 Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.

Method	Inspection
Outcome	The safety officer has made the preliminary safety checklists and will be found in section five of the CDR.
Status	Preliminary checklists complete, finalized at the FRR due date

● 5.2. Each team shall identify a student safety officer who will be responsible for all items in section 5.3.

Method	Inspection

Outcome	The team safety officer has been chosen. It is Jillian Kellum (23jilkel@student.cfschools.org)
Status	Completed

● 5.3. The role and responsibilities of the safety officer will include, but are not limited to:
5.3.1. Monitor team activities with an emphasis on safety during:
5.3.1.1. Design of vehicle and payload

Method	Inspection
Outcome	The design of the payload and vehicle has met all safety requirements made by NASA SLI, NAR, and FAA. The safety officer monitored the design process to make sure all designs were within regulation, as well as team leads.
Status	Completed

5.3.1.2. Construction of vehicle and payload components

Method	Inspection
Outcome	Members, before constructing the vehicle, viewed a presentation on safety while constructing, and the best way to protect themselves. The safety officer was present in the construction of the subscale, and will be present for all forms of constructing the full scale.
Status	In progress

5.3.1.3. Assembly of vehicle and payload

Method	Inspection
Outcome	The safety officer was present for the assembly of the subscale vehicle. They will be present for the full-scale assembly as well.
Status	In progress

5.3.1.4. Ground testing of vehicle and payload

Method	Inspection

Outcome	The safety officer will observe and monitor the ground testing to ensure all members follow proper safety procedures.
Status	In progress

5.3.1.5. Subscale launch test(s)

Method	Inspection
Outcome	Our team launched the subscale vehicle twice due to an imperfect flight the first time. To make sure there is a clear, safe flight from the subscale, another flight was required and done. The first time, the black powder charge was too powerful and ejected both the main and drogue chute at apogee, separating both parts of the vehicle. This descent rate was too low and the drift too high. In order to make the recovery of the rocket safer, the black powder charge was lowered from 2 grams to 1.5 grams. Safety was the main priority before, during, and after the launch, despite the mistake in the first subscale launch. After the black powder had an adjustment, the subscale was flown again and was perfect.
Status	Completed

5.3.1.6. Full-scale launch test(s)

Method	Inspection
Outcome	The safety officer will be present and carefully monitoring the launch process to ensure that all safety precautions are met, which includes NAR and FAA regulations.
Status	In progress

5.3.1.7. Competition Launch
5.3.1.8. Recovery activities

Method	Inspection
Outcome	The safety officer is trained to observe the team members during the launch in Huntsville. The other members have been shown a presentation on launch safety prior to the launch.
Status	In progress

5.3.1.9. STEM Engagement Activities

Method	Inspection
Outcome	The safety officer will inspect the activities of all students participating in outreach activities, as well as rocket club members. All outreach events begin with a safety brief before starting, and rocket club members are briefed on hazards that may occur so they can keep the outreach students safe.
Status	In progress

● 5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.

Method	Inspection
Outcome	The safety officer is expected to enforce safety procedures on the other team members. These procedures will align with the safety presentation.
Status	In progress

● 5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.

Method	Inspection
Outcome	The safety officer will update the hazard analysis, failure modes analysis, procedures, and MSDS/chemical inventory data for every document. The updated version is found in section 4.
Status	In progress

● 5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.

Method	Inspection
Outcome	The safety officer wrote the entirety of the team's hazard analyses, failure modes analysis, and procedures.
Status	Completed

● 5.4. During test flights, teams will 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 should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.

Method	Inspection
Outcome	Our team will discuss with the RSO prior to every launch and confirm all safety requirements are met. Additionally, our team will talk to the President of the NAR chapter and the RSO before attending any NAR or TRA launch.
Status	In progress

● 5.5. Teams will abide by all rules set forth by the FAA.

Method	Inspection
Outcome	The team's safety officer will abide by the requirements set by the FAA. The officer will then inform the team to ensure that these rules will be followed.
Status	In progress

● Update the ongoing list of team derived requirements in the following categories: Vehicle, Recovery, and Payload. These are a set of requirements for mission success that are beyond the minimum success requirements presented in this handbook. Create a verification plan for each team derived requirement identifying whether test, analysis, demonstration, or inspection is required with an associated plan.

- Vehicle
    - The vehicle must have a minimum inner diameter of greater than 4.98 inches to secure the UAV deployment system and UAV.

Method	Inspection
Outcome	Section 3.1 shows the design of the vehicle is 5 inches, which will be enough to fit the UAV deployment system.
Status	Completed

    - The vehicle must have the fewest amount of fins in order to reduce weight while maintaining a safe and secure flight within NAR regulations

Method	Inspection
Outcome	In section 3.1, it shows that 3 fins are used which will ensure enough stability while still minimizing drag and weight.
Status	Design complete, construction ongoing

- The vehicle must have fin slots to adjust the stress on fins

Method	Inspection
Outcome	In section 5.1, a stress test is shown to acknowledge the best shape of the fin slots to reduce the stress points on the fins. The diagram shows the positive impact the fin slots will have, as well as the aesthetic benefit.
Status	Design complete, construction ongoing

- The vehicle must have a rail button 2 calibers away from the center of pressure and one one the center of pressure to ensure stability on the launchpad.

Method	Inspection
Outcome	There is a detailed design in section 3.1 that shows the placement of the rail buttons, which fit with these requirements.
Status	Design complete, construction ongoing

- Fins must have filleted epoxy to ensure they are securely attached.

Method	Inspection
Plan	During and after construction, inspections will be made to ensure the fins are properly secured and attached to make sure optimal construction is occurring.
Status	Construction ongoing, inspection pending

- Recovery
  - The parachutes must descend the rocket at safe rate that limits KE upon impact and drift

Method	Inspection
Outcome	Shown in section 3, the parachute will let the rocket fall at a safe rate, demonstrated by the graphs. The descent rate falls within NASA guidelines and meets the team’s Safety requirements.
Status	Design complete, construction ongoing

  - Each parachute section, where it is housed, must have a vent hole to prevent pressure separation upon ascent

Method	Inspection
Outcome	As shown in section 3.1, all parachute chambers have a pressure vent hole.
Status	Design complete, construction ongoing

- The vehicle must have four shear pins at each separation point

Method	Inspection
Outcome	Section 3.3 shows the shear pins implemented in the design of the full scale, four in each point of separation.
Status	Construction ongoing, design complete

- The main ejection charges must generate double the force needed to break the shear pins.

Method	Inspection
Outcome	Section 3.3 shows that the pressure produced by the main charge is more than double than the force to break the shear pins.
Status	Complete

- Payload
  - The team must have a manual Emergency-Stop for the UAV

Method	Demonstration
Plan	The team will manually deploy the UAV once the vehicle is recovered. After manual ejection, the team can control the UAV through a handheld controller, within sight of said UAV for the duration of the flight. A manual E-Stop will be implemented, ensuring safety for all involved.
Status	Design completed, construction ongoing

  - The payload experiment should include a handheld controller to ensure the payload doesn't deploy in flight

Method	Inspection/Demonstration
Plan	A handheld controller was developed and will be used as a safety measure to prevent the UAV from ejecting prematurely, containing an E-Stop.

Status	Design complete, construction ongoing

- Select the appropriate number of motors/propellers to ensure there is a >2:1 thrust to weight ratio

Method	Inspection/Demonstration
Plan	The team has selected motors based on manufacturer data which indicates a sufficient thrust output. The team plans to perform tests of the UAV system which will verify the performance of the selected motors.
Status	Motors acquired, awaiting testing

- Ensure the payload fits inside the vehicle (propellers and other components are contained)

Method	Inspection
Plan	2-bladed propellers were selected in order to fit in the 5 inch diameter body tube and 4.98 inch sled deployment system.
Status	Design complete, construction ongoing

6.3 Budgeting and Timeline

- Provide an updated line item budget for all aspects of the project with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.

Item:	Cost:	Quantity:	Total Cost:	Vendor
Motors & ESCs (comes in pack of 4)	$45.00	1	$45.00	Amazon
Propellers (custom)	$2.00	4	$8.00	Various Locations
Microcontroller	$25.00	2	$50.00	Best Buy
Radio (for Remote Override) (Custom Built)	$100.00	1	$100.00	Various Locations
GPS Module	$18.00	1	$18.00	Amazon
Altimeter	$16.00	1	$16.00	PerfectFliteDirect
Gyro	$30.00	1	$30.00	Apogee Components
Battery	$45.00	2	$90.00	Best Buy
Camera	$150.00	1	$150.00	GoPro

				Website
Lidar/Ultrasonic	$26.00	1	$26.00	Amazon
Cesaroni K1440 Motor	$196.26	3	$588.78	Off We Go Rocketry
5" Fiberglass body tube (per ft)	$39.60	8	$316.80	Wildman Rocketry
Cesaroni 54mm 6-Grain Hardware Set	$135.00	1	$135.00	Apogee Components
5:1 Ogive Filament Wound Fiberglass 5" nosecone	$127.71	1	$127.71	Wildman Rocketry
72" Parachute	$265.71	1	$265.71	Fruity Chutes
18" Drogue Parachute	$70.95	1	$70.95	Fruity Chutes
5" Fiberglass body tube coupler	$56.89	2	$113.78	Wildman Rocketry
RocketPoxy structural adhesive	$65.00	1	$65.00	Wildman Rocketry
G10 Fiberglass 12"x12"x0.125" sheet (for fins)	$18.00	3	$54.00	Wildman Rocketry
Kevlar Shock Cord - 3600#- Main Chute (per ft.)	$0.97	40	$38.80	Wildman Rocketry
Kevlar Shock Cord - 3600#- Drogue Chute (per ft.)	$0.97	40	$38.80	Wildman Rocketry
Tube Bulkhead - 5"	$7.70	4	$30.80	Home Depot
3/8" U-bolts	$5.49	4	$21.96	Home Depot
Motor Mount Tubing - 54mm fiberglass	$27.00	1	$27.00	Wildman Rocketry
Centering Ring - 5" x 54mm inner dia. Fiberglass	$8.80	4	$35.20	Apogee Components
AeroPack Retainer - 54mm	$31.00	1	$31.00	Wildman Rocketry
1/4" quick links	$0.99	6	$5.94	Home Depot
4-40 Nylon shear pins (20-pack)	$1.00	6	$6.00	Home Depot
Removable Plastic Rivets (10-pack)	$5.00	5	$25.00	Home Depot
1/4" threaded steel rod (3ft. each)	$1.75	2	$3.50	Fastenal
PerfectFlight StrattologgerCF altimeter	$69.95	2	$139.90	PerfectFliteDirect
Scale Model	$500.00	1	$500.00	Various Locations
Aerotech G80-10 Motor for Subscale	$50.00	2	$100.00	Apogee

Rocket				Components
Rocket Tracker Transmitter	$150.00	1	$150.00	Featherweight Altimeters
Rocket Tracker Receiver	$190.00	1	$190.00	Featherweight Altimeters
1/4" threaded steel rod (3ft. each)	$1.75	1	$1.75	Fastenal
12V DC Stepper Motor	$13.99	1	$13.99	Amazon
Deluxe Servo	$15.99	2	$31.98	Amazon
Coupler Bulkhead - 5"	$11.50	3	$34.50	Wildman Rocketry
Tax:	$258.78			
Shipping and Handling	$200.00			
Total Cost:	$4,110.63			

2023 NSL Budget - Travel						
Hotel:	**Cost per room**	**Number of Rooms**		**Number of nights**		**Total Cost**
Embassy Suites	$240.81	5		4		$4,816.20
Gas:	**Cost per Gallon**	**Number of gallons for one-way trip**		**Number of Vehicles**	**Trips**	**Total Cost**
	$3.50	47		3	2	$987.00
Travel Tax:	**$337.13**			**Total Travel Budget:**		**$6,140.33**

● Provide an updated funding plan describing sources of funding, allocation of funds, and material acquisition plan.

Our main source of funding is coming from local businesses. Members first looked at all donors who have given in the past, before reaching out to them again to see if they are willing to donate again. Members then looked at a variety of other local businesses, before deciding on the ones that were most likely to give to the club. They based the decision on several different factors such as whether a student in the club or the club itself has a connection to it, the relation of their work to rocketry, and the size. The businesses that best fit these criteria were then contacted by either going to the business to ask in person or by a written letter. Some donors wish for their money to go towards purchasing equipment only, so they are given a list of needed materials with the vendor and a location of where to ship the purchases. Otherwise, businesses choose to give with a check. The team has also utilized match donations offered at some businesses such as John Deere and Collins Aerospace. If parents of a club member work at a company like this and choose to donate, their employer will match the donation, doubling the amount the club receives. Along with all of these sources of funding, the club has also looked into different grants from places such as the Iowa Space Grant Consortium. The last method of funding involves team members working for businesses/organization entities. Some examples of this include directing parking traffic and working in concessions at our local university's sporting events. After receiving the funds, materials are obtained through various methods, including purchasing physical materials at local stores, and ordering them through online vendors such as Amazon, Wildman Rocketry, etc., taking into account the shipping and team timelines.

● Provide an updated timeline, including all team activities and expected activity durations. The schedule should be complete and encompass the full term of the project. Deliverables should be defined with reasonable activity duration. GANTT or milestone charts are encouraged.

August
- 8/17 - Request for Proposal Released
- 8/30 - Team Meeting - 1 hr

September
- 9/1 - Team Meeting - 1 hr
- 9/5 - Team Meeting - 30 min
- 9/6 - Team Meeting - 1 hr
- 9/8 - Team Meeting - 1 hr
- 9/11 - Proposal Revisions - 3 hr
- 9/13 - Team Meeting - 1 hr
- 9/15 - Team Meeting - 1 hr
- 9/17 - Proposal Revisions - 2 hr
- 9/18 - Proposal Proofreading - 1 hr
- 9/19 - Submit Proposal - 30 min
- 9/20 - Team Meeting - 30 min
- 9/22 - Team Meeting - 30 min
- 9/28 - Team Meeting - 1 hr

October
- 10/4 - Team Meeting - Awarded Proposals Announced - 1 hr
- 10/6 - Team Meeting, PDR Q&A - 2 hr
- 10/7 - Team Meeting - 1 hr
- 10/11 - Team Meeting, start ordering materials - 1 hr
- 10/13 - Team Meeting - hr
- 10/18 - Team Meeting - 1 hr
- 10/19 - Sections I-III of PDR Completed
- 10/20 - Team Meeting
- 10/24 - Sections IV-VI of PDR Completed

- 10/25 - Team Meeting - 1 hr
- 10/26 - PDR Submitted
- 10/27 - Team Meeting, PDR presentation run through - 1 hr
- 10/31 - Team Meeting, PDR presentation run through - 1 hr

November
- 11/1 - Team Meeting, PDR presentation begins - 1 hr
- 11/3 - Team Meeting - 1 hr
- 11/8 - Team Meeting - 1 hr
- 11/9 - PDR Presentation - 1 hr
- 11/10 - Team Meeting - 1 hr
- 11/15 - Team Meeting - 1 hr
- 11/17 - Team Meeting - 1 hr
- 11/21 - PDR Video Teleconference
- 11/22 - Team Meeting - 1 hr
- 11/25 - Outreach Events Planned
- 11/29 - Team Meeting - 1 hr

December
- 12/1 - CDR Q&A, post Q&A discussion - 2 hr
- 12/5 - Deadline to order subscale materials, deadline to plan subscale launch dates
- 12/6 - Team Meeting - 1 hr
- 12/7 - Subscale planning - 30 min
- 12/8 - Team Meeting - 1 hr
- 12/9 - Subscale planning - 30 min
- 12/12 - Subscale planning - 30 min
- 12/13 - Team Meeting - 1 hr
- 12/15 - Team Meeting - 1 hr
- 12/16 - Subscale planning - 1 hr
- 12/19 - Subscale construction
- 12/20 - Team Meeting - 1 hr
- 12/29 - CDR work - 2 hr
- 12/30 - CDR work - 3 hr

January
- 1/5 - Team Meeting, check over CDR - 1.5 hr
- 1/7 - CDR work (final revisions) - 5 hr
- 1/8 - CDR proofread - 1 hr
- 1/9 - Subscale Flight Deadline and submit CDR, presentation slides, and flysheet report by 8:00 am
- 1/10 - Team Meeting - 1 hr
- 1/11 - CDR Presentation practice - 30 min
- 1/12 - Team Meeting - 1 hr
- 1/17 - Team Meeting - 1 hr
- 1/18 - CDR Presentation practice - 30 min
- 1/19 - Team Meeting - 1 hr
- 1/24 - Team Meeting - 1 hr
- 1/26 - Team Meeting - 1 hr

- 1/27 - Battery Test
- 1/31 - Team Meeting - 1 hr

February
- 2/2 - Team Meeting - 1 hour
- 2/6 - 1 hour FRR work time
- 2/7 - Team Meeting - 1 hour
- 2/9 - Team Meeting - 1 hour and FRR Q&A
- 2/14 - Team Meeting - 1 hour & FRR Work time - 1 hour
- 2/16 - Team Meeting - Sections V-VII of FRR completed
- 2/18 - Full-scale launch completed
- 2/21 - Team Meeting FRR presentation complete
- 2/23 - Team Meeting - 1 hour
- 2/25 - FRR work time - 3 hours, Back up full-scale launch date
- 2/28 - Outreach interactions completed by now & Team Meeting - 1 hour

March
- 3/2 - Team meeting - 1 hour
- 3/4 - FRR Work time - 3 hours
- 3/5 - Check over FRR presentation and report
- 3/6 - Vehicle Demonstration Flight deadline *and* FRR report, presentation slides, and flysheet submitted to NASA project management team by 8:00 a.m. CST.
- 3/7 - Team meeting - 1 hr & FRR Presentation Practice (30 min)
- 3/8 - FRR presentation practice - 30 minutes
- 3/9 - Team meeting - 1 hour
- 3/10 - FRR presentation practice - 30 min
- 3/12 - FRR video teleconferences start
- 3/14 - Team meeting - 1 hour
- 3/16 - Team meeting - 1 hour
- 3/21 - Team meeting - 1 hour
- 3/23 - Team meeting - 1 hour
- 3/28 - Team meeting - 1 hour
- 3/30 - Team meeting - 1 hour
- 3/31 - FRR video teleconferences end

April
- 4/1 - Launch window opens for teams not traveling to Launch Week. PLAR must be submitted within 14 days of Launch.
- 4/3 - Payload Demonstration Flight and Vehicle Demonstration Re-flight deadlines, *and* FRR Addendum submitted to NASA project management team by 8:00 a.m CDT. (Teams completing additional Payload Demonstration Flights and Vehicle Demonstration Re-flights only)
- 4/4 - Team meeting - 1 hour
- 4/6 - Launch week Q&A & Team meeting - 1 hour
- 4/11 - Team meeting - 1 hour
- 4/12 - Teams travel to Huntsville, AL, Launch Readiness Review (LRR) for teams arriving early
- 4/13 - Official Launch Week Kickoff, LRRs, Launch Week activities

- 4/14 - Launch Week activities
- 4/15 - Launch Day and Awards Ceremony
- 4/16 - Backup launch day
- 4/18 - Team meeting - 1 hour
- 4/20 - Team meeting - 1 hour
- 4/25 - Team meeting - 1 hour & PLAR work time - 1 hour
- 4/27 - Team meeting - 1 hour & PLAR work time - 30 time
- 4/30 - Launch window closes for teams not traveling to Launch Week. PLAR must be submitted within 14 days of launch.

May

- 5/1 - Teams traveling to Launch Week: Post-Launch Assessment Review (PLAR) submitted to the NASA project management team by 8:00 a.m. CDT, Final revisions, submit PLAR - 3 hours