NASA STUDENT LAUNCH

2022-2023

Critical Design Review

University of South Florida

Society of Aeronautics and Rocketry

4202 East Fowler Avenue, MSC Box #197

January 8th, 2023

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1. Summary of CDR Report

a. Team Summary

i. Team name and mailing address

Society of Aeronautics and Rocketry (SOAR) at the University of South Florida. Mailing address: 4202 East Fowler Avenue MSC Box 197 Tampa, Florida 33620

ii. Mentor name, TRA#, certification level, and contact information

Jonathan Fitzer. Member, Previous SOAR President (TRA# 17393, Certification Level III) (813) 389-3876, fitzer@mail.usf.edu

iii. Indication of launch location plans

The team plans to launch in Huntsville, Alabama.

iv. Documented hours spent working on the CDR milestone

A total of man-hours were spent on the CDR document.

b. Launch Vehicle Summary

Target altitude for the full-scale launch vehicle will be 4,500ft.

The motor chosen for the full-scale vehicle is the Cesaroni K520, 4-grain, solid rocket motor with a total mass of 1576 grams, and a burn time of 3.3 seconds.

The main airframe is a 4 inch diameter, with a total length of 115 inches. The launch vehicle maintains a static stability margin of 2.95, with the center of gravity located at 65.655 inches, and the center ofv pressure located at 77.515 inches, measured from the tip of the nose cone. The upper body tube consisting of the payload, ballast system, and nosecone is 10.79 lbs, avionics bay is 3.33lbs, and the booster tube is 3.14 lbs without the motor. The booster tube will consist of three carbon fiber symmetrical-trapezoidal fins spaced by 120° with a root chord of 10 inches, a tip chord of 8 inches, and a height of 3.5 inches. The aft end of the booster tube will use a 54mm anodized aluminum boattail, which will also serve as the retaining ring for the motor.

The recovery system will be a dual deploy. Upon apogee, a black powder charge will separate the upper body tube from the avionics bay, and a streamer will be deployed in place of a drogue parachute, in order to satisfy the kinetic energy and descent time constraints. The main parachute will then deploy at 500 feet by way of a second black powder charge.

c. Payload Summary

i. Payload title

Our payload design name is the Servo Stabilized Camera System (SSCS).

ii. Summarize payload experiment

The payload design will extend a camera and servo outside the airframe using a rack and pinion. Once the camera is aligned in the z-axis, it will follow a series of tasks transmitted through radio frequency commands.

2. Changes Made Since Preliminary Design Review

a. Changes made to vehicle criteria

The dimensions of the full-scale launch vehicle remain as stated (with exception to slight variation) in the Preliminary Design Review, maintaining a length of 115 inches, and an outer diameter of 4 inches. Motor selections have been reduced from three potential options, to one specific option being the K520 4-grain motor. Due to the large impulse of the motor, and the fact that the weight of internal components, such as the payload and avionics, will remain largely unchanged, simulation values project the reached altitude to be well over the target altitude. To manage this fact, a modular ballast system was added to the vehicle. The system will sit within the shoulder of the nose cone, and will be easily accessible by simply removing the nose cone and two threaded rods that support the ballast from the bottom. Once removed, 1 ounce Steel weights can be either added or subtracted in order to meet the target altitude requirements.

b. Changes made to payload criteria

Given the results of our first subscale launches, our main goal continues to be creating a design that extends the camera out of the airframe by a rack and pinion system, and then completes a series of tasks. Our team has already found success in this design. It was found that even with four openings in the body tube and a larger kinetic energy upon landing than intended, the entire tube structure remained intact with little to no visible damage. As we move forward to the full scale, our main focus will be on programming and strengthening the tiny micro servo motors system. To create a stronger assembly, all of the printed components of this gimbal system will have increased thicknesses in all directions and key components, such as the main rack, will be 3D printed with PETG at 100% infill. This was not possible on the previous launches due to the space constraints of the $3in$ body tube. As our team is further along with this design than our original timeline set, we can now spend additional time on programming these motors to be at the correct precise orientation.

c. Changes made to project plan

Few changes have been made to the project plan regarding funding methodology and projected timelines. This is because the funding provided to SOAR at the beginning of the academic year has been sufficient to fund the NASA Student Launch project. Timeline scheduling has proceeded as planned and has not required editing or revising.

Regarding the line item budget, this has been updated to reflect the new acquisitions made by SOAR to build the fullscale vehicle and payload assembly. Although much of the components within the payload remain the same, the transition from PDR to CDR has brought updates to airframe components which are shown in the line item budget.

Within the requirements section, SOAR at USF received feedback on the team-derived requirements which indicated there was improvement to be made. We have made updates to the team-derived requirements which will help the team to more competently move forward in the design and verification of the payload assembly.

3. Vehicle Criteria

a. Selection, Design, and Rationale of Launch Vehicle

i. Unique mission statement and mission success criteria

Per 2022-2023 NASA Student Launch Competition guidelines, the team will design, manufacture, and launch a high-powered, 4-inch diameter by 115 inch long rocket that shall reach a targeted altitude of 4,500ft. Apogee will consist of a staging event in which the upper body tube (consisting of the payload) and the nosecone will separate from the booster. Upon a nominal descent and landing, the payload will utilize a system of sensors and a small-scale gravity gimbal to properly orient the camera system (camera and servo motor) in the Z-axis. Utilizing a rack and pinion linear actuator, the camera system will then be extended through the airframe and be able to perform the required functionality tasks. Success will be solely dependent on specific vehicle and payload performance criteria as described in the NASA Student Launch 2022-2023 handbook, as well as personal performance criteria set by the team. These mission success criteria include the following.

- Reaching a target altitude of 4500ft, with a margin of $\Delta = \pm\ 50ft$
- Maintaining an off-the-rail static stability margin of at least 2
- Maintaining a minimum thrust-to-weight ratio of 5 to 1
- Sustaining an off-the-rail velocity of at least $52f/s = 15.85m/s$
- Maintaining an independent section kinetic energy of less than $75ft - lbf = 101.686J$ upon landing
- Maintaining a descent velocity such that the descent time is no more than 90 seconds
- Camera system is able to receive and complete each required functionality goal, and store images captured
- Launch vehicle is recovered in a condition such that (if need be) it may be launched again within a 2 hour window of landing
- Recording and storing flight data on a removable SD card located within the avionics bay

All listed success criteria are based on the NASA Student Launch handbook, as well as team-decided goals.

ii. Identification and justification of design alternative chosen from PDR

During the initial launch of the sub-scale vehicle, it was found that the off-the-rail stability requirement was not fulfilled, and the target altitude was not achieved as accurately as predicted. Due to the relatively constant weight of the payload/other internal components, and the use of a more powerful motor, in order to obtain more control over being able to reach the predetermined altitude/satisfy the NSL constraints, it was determined that a ballast system was needed for the second subscale launch. The designed system was situated within the shoulder of the nose cone via a bulkhead supported by two, 18-8 Stainless Steel threaded rods.

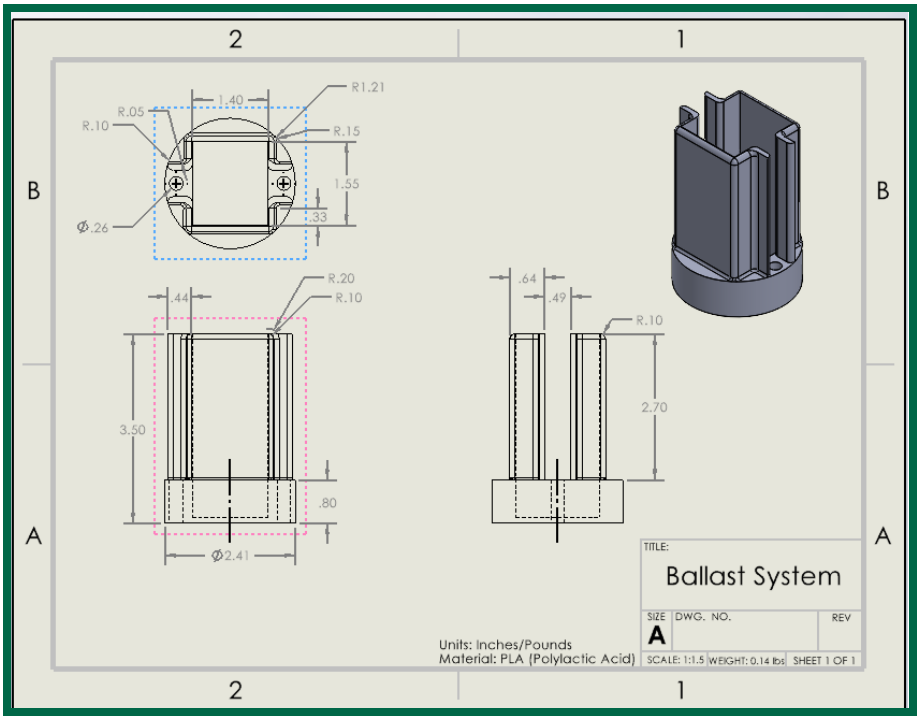


Fig. 1: Solidworks CAD Drawing of Ballast System

The system is 2.41 inches in diameter (fixed to a 3 inch diameter bulkhead), 3.5 inches long, and is capable of supporting up to 24, 1 oz, $1.344\ x\ 0.745\ x\ 0.268$ (inches) steel weights. The designed ballast system proved effective as both the off-the-rail stability and target altitude requirements were met with greater precision. The system will be utilized for the full-scale launch vehicle as the utilized motor class has increased, and the payload/other internal component mass has remained relatively constant.

iii. Computer-Aided Design drawings of launch vehicle and subsystem

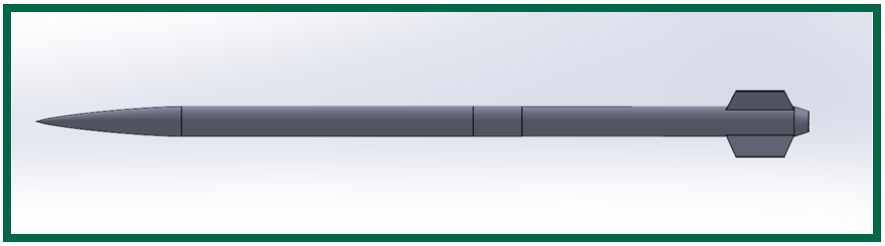


Fig. 2: Side View of Launch Vehicle (Solidworks Image).

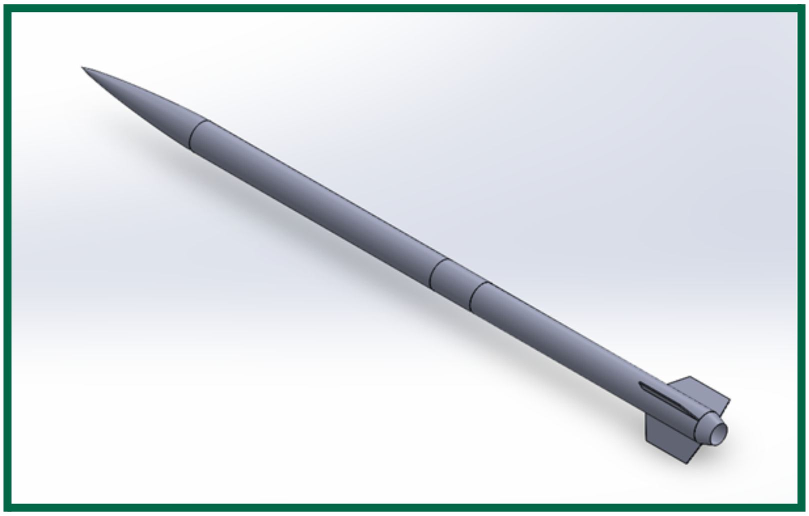


Fig. 3: Isometric view of launch vehicle (Solidworks Image).

iv. Dimensional cross sectional views of airframe, coupler components

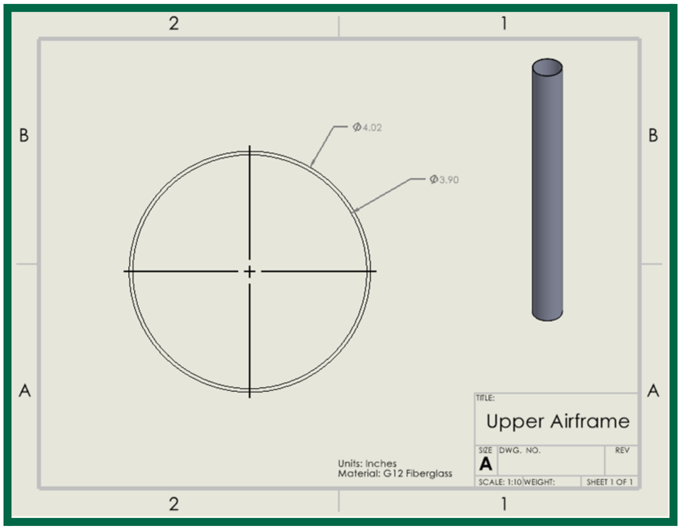


Fig. 4: Airframe Cross-Section View (Solidworks Drawing).

v. Location of points of separation and energetic materials

Upon apogee, a staging event will deploy the drogue parachute from the booster tube, and a second staging event on descent will deploy the main parachute from the upper airframe. This will be done via two black powder charges for each deployment, one main charge and one redundant charge. Points of separation are located at the forward and aft portions of the avionics bay. The nose cone will be connected to the upper body tube through the use of stainless steel screws with accompanying nuts. The upper section of the rocket will then be held together with the avionics bay during ascent by shear pins. The booster tube will also be connected to the avionics bay by shear pins as well.

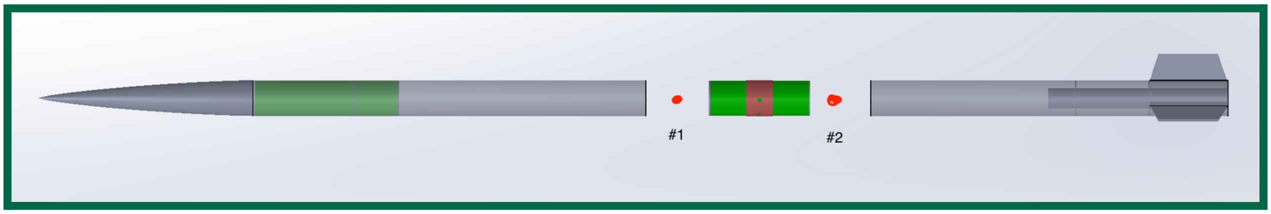


Fig. 5: Locations of points of separation.

vi. Demonstration of design completeness and readiness to manufacture

Manufacturing of the launch vehicle will take place in the SOAR workshop located on USF campus. The process that was utilized for sub-scale manufacturing, and will subsequently be used for the full-scale vehicle, begins with using a single-bevel compound Miter saw to cut the G12 Fiberglass tubes for the airframe, couplers, and motor tube. A CNC machine is then used to cut the fins out of a Carbon Fiber sheet, and the airfoil is sanded by hand. A 3D printed mold is then used to bind the fins to the motor tube, as well as install the centering rings, using the JB Weld steel-reinforced epoxy. The completed motor tube is then able to be secured within the booster tube. The bulkheads that support the internal components of the vehicle are cut out of a G10 Fiberglass sheet utilizing the CNC machine. From there, all internal components are assembled and situated within the rest of the airframe. The process of Additive Manufacturing is also utilized for the majority of the payload structure, as well as for the avionics bay sled, and ballast system. These manufacturing processes have proved to be reliable in building previous launch vehicles for the NSL competition, and confidence in accuracy of the build is high.

vii. Discussion of integrity of design

1. Suitability of shape and fin style

   The chosen fin design is of a symmetrical-trapezoidal shape with a root chord of 10 inches, a tip chord of 8 inches, and a height of 3.5 inches. Three, Carbon Fiber fins will be situated on the aft end of the booster tube, and will be spaced 120° apart. The airfoil of the fins will be to a leading knife-edge, and a trailing rounded-edge. The shape of the fins was chosen as the optimal design as the longer root chord will concentrate the lift force closer to the airframe of the vehicle, rather than towards the edge of the fins. The now lower pressure area around the edges means less of the airflow is acting in that area, and, coupled with the leading knife-edge airfoil, decreases the overall amount of induced drag on the vehicle.

2. Proper use of materials in fins, bulkheads, and structural elements

   The three fins will be constructed of Carbon Fiber. G10 Fiberglass was used for the subscale vehicle as opposed to Carbon Fiber, given that it was a test article and funds needed to be conserved. The decision to use Carbon Fiber for the Full-Scale launch vehicle was made as the material is much stiffer than Fiberglass, aiming to reduce fin flutter, and maintains a high strength-to-weight ratio. Bulkheads and Centering Rings are constructed out of G10 Fiberglass. This material is relatively inexpensive, easy to machine, and has proven to be structurally sound in subscale flights. Hardware such as the nuts/screws and threaded rods to support the ballast system, payload, dead-space coupler, and avionics bay are of 18-8 Stainless Steel to reduce corrosion from black-powder residue. The eye and U-bolts that are mounted to the separation point bulkheads, and serve as attachment points for the shock cords are of 305 Stainless Steel, which provides the least amount of work/strain in comparison to other types of Stainless Steel. The boattail, which also serves as the retaining ring for the motor, is of anodized aluminum to reduce corrosion due to black powder residue. The material used for the fillets between the fins and the airframe is a steel-reinforced epoxy (JB Weld). This is a very versatile epoxy as it can be used on multiple surfaces, and provides a very high degree of strength and longevity.

3. Sufficient motor mounting and retention

   The selected motor is a Cessaroni Technologies 4-grain, K520 solid rocket motor. The motor will be supported by a compatible 4-grain casing that will then be inserted into the motor tube. The boattail will also serve as the retaining ring for the motor, and can be unscrewed for ease of access.

4. Estimate of final mass of launch vehicle and individual subsystems

   Launch Vehicle final mass (with motor): 16.5 lb
   Launch Vehicle final mass (without motor): 13 lb
   Launch Vehicle final mass (with optimal ballast weight):17 lb
   Payload Final mass: 8.3 lb
   Avionics Final Mass: 1.2 lb
   Recovery Systems Final Mass: 2 lb

viii. Justification of material selection, dimensioning, component placement, and other unique design aspects

The drogue streamer and its associated shock cord are situated in the booster tube, just above the motor tube. The avionics bay is located directly above, which serves as the deployment point for the black powder charges. The main parachute and shock cord are located in the upper airframe, ahead of the avionics bay. Due to the large amount of space within the upper airframe, a “dead-space” coupler is located just below the payload, and serves as the attachment point for the main shock cord. The Payload is situated at the top of the upper body tube, just below the ballast system which is located in the shoulder of the nose cone. A boat tail, which also serves as the retaining ring for the motor, is utilized in order to reduce the low-pressure drag in the aft of the vehicle created by fin-tip vortices.

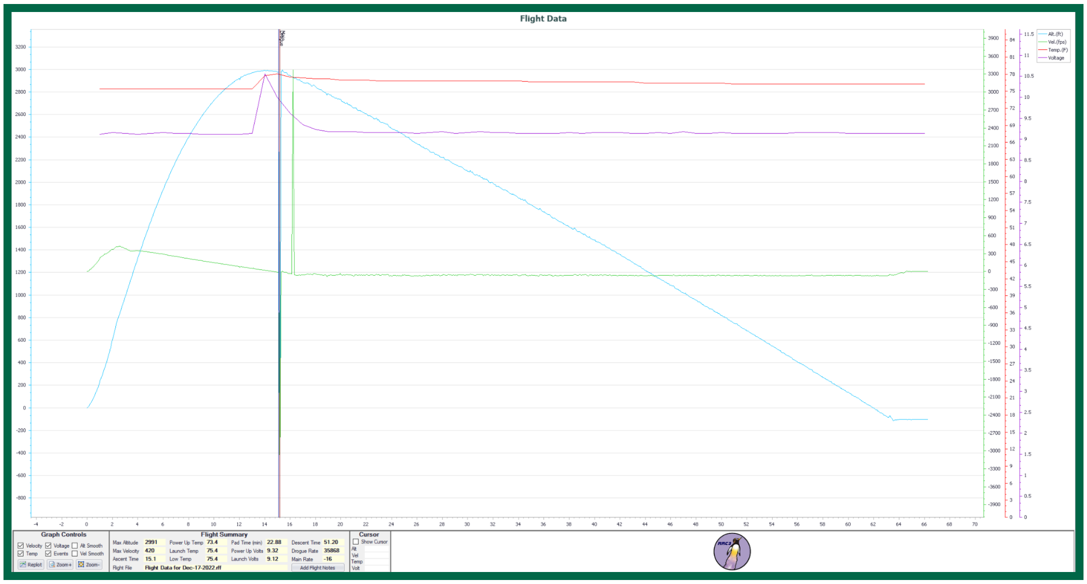
b. Subscale Flight Results

i. Data gathering devices on vehicle

The subscale flight data collecting devices were located in the avionics bay. This consisted of two Missileworks RRC3s which use a barometric pressure sensor to provide our team with data on the flight vehicle’s altitude, velocity, temperature and voltage with respect to the time of the flight. The RRC3 also gives the descent time which can be used to verify our calculated descent time for the flight vehicle. Utilizing the free MissileWorks software, mDACS, and a USB-IO microcomputer adaptor, the team is able to extract flight data from the RRC3 altimeter to the USB-IO microcomputer adaptor to the mDACS software on a windows computer after the launch.

ii. Altimeter flight profile graphs

The flight profiles from the main and backup altimeters are shown below:

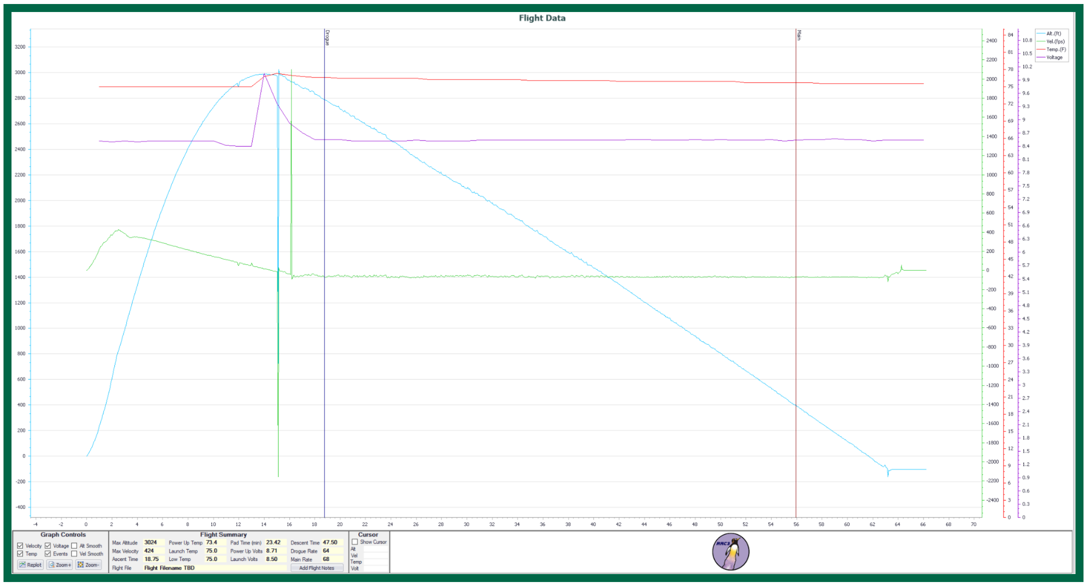


Flight Summary

Max Altitude	2991	Power Up Temp	73.4	Pad Time (min)	22.88	Descent Time	51.20
Max Velocity	420	Launch Temp	75.4	Power Up Volts	9.32	Drogue Rate	35868
Ascent Time	15.1	Low Temp	75.4	Launch Volts	9.12	Main Rate	-16

Flight File: Flight Data for Dec-17-2022.rff

Fig. 6: Main Altimeter Flight Graph



Flight Summary

Max Altitude	3024	Power Up Temp	73.4	Pad Time (min)	23.42	Descent Time	47.50
Max Velocity	424	Launch Temp	75.0	Power Up Volts	8.71	Drogue Rate	64
Ascent Time	18.75	Low Temp	75.0	Launch Volts	8.50	Main Rate	68

Flight File: Flight Filename TBD

Fig. 7: Backup Altimeter Flight Graph

The difference in max altitude from the main and backup RRC3 is a concern for our team and we are looking into solutions to this. Differences in arming altitudes may be the cause, or the RRC3's computational process evaluated the data differently than the other altimeter. SOAR will continue to solve this issues by:

- Full-scale flight testing and assuring that the difference in altimeter values are at an acceptable range of 10 ft.
- Secure the housing of the altimeters such that outside air may not interfere with the sensors.
- Calibration of the arming distance between the two sensors.

iii. Quality pictures of as-landed configuration

The launch vehicle landed in a nearby swamp on land owned by strawberry farmers. Due to this, permission was received, and our mentor retrieved the rocket. Two photos were taken by him of the as-landed configuration.

Fig. 8: Photo 1 of the as-landed configuration.

Fig. 9: Photo 2 of the as-landed configuration.

iv. Scaling factors

Due to the restraints of the competition on having the subscale rocket be 75% the length and diameter of the full scale, this meant that there were minimum values that the full scale must be. From the flight tests of the sub-scale vehicle, it was important to increase the length of the booster section to be similar in length to the upper body tube for flight characteristics. The increase in diameter to the 4” is sufficient for our payload system to have enough space to function and for the recovery systems to be packed correctly as well. Slight adjustments to the fins and lengths were done to create a simulation of our full scale rocket that was able to achieve our projected apogee through a variety of wind speeds and with different ballast weights.

v. Launch day conditions and simulations

Launch day conditions were replicated in simulations to achieve an accurate prediction of flight behavior. An average wind speed of 7 MPH was observed directly before launch. The location of the launch was in Plant City, FL, at the Tampa Bay prefecture (#17) of the Tripoli Rocketry Association. The coordinates of the launch site are 28°N, 82°W. A 96” launch rail was used, canted at 5° downwind. An OpenRocket simulation predicted an apogee of 2780’. The simulations predicted an off-the-rail stability of 1.7 calibers.

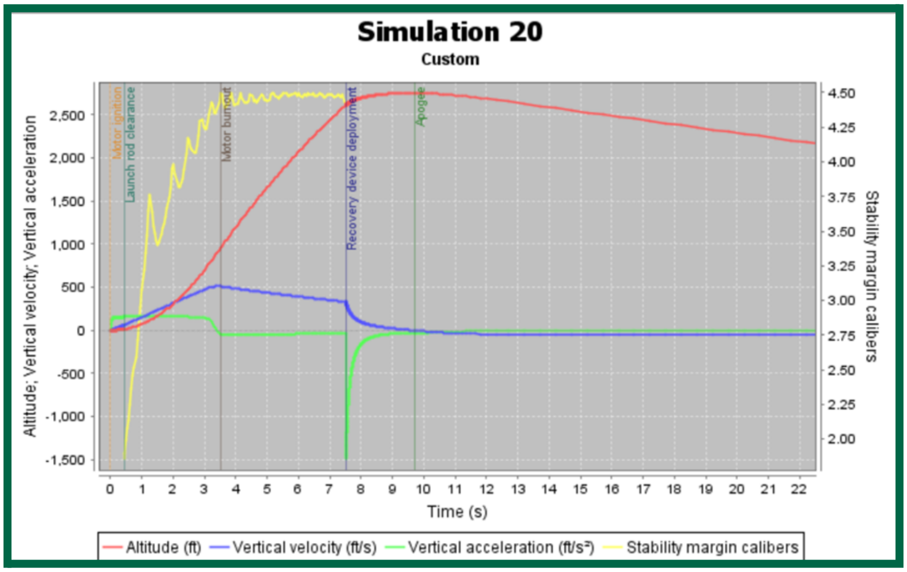


Fig. 10: Zoomed-in plot of Subscale Flight #2, completed in OpenRocket Software.

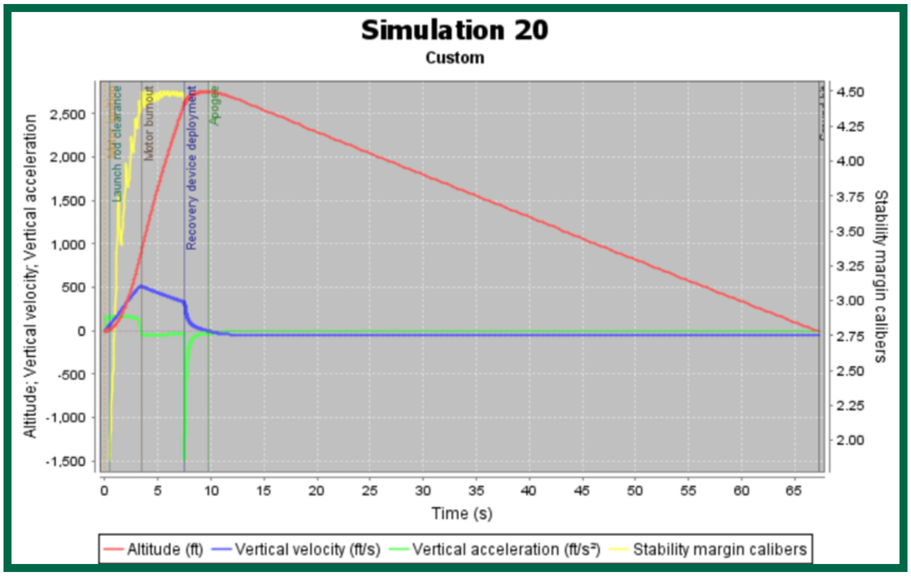


Fig. 11: Full-view plot of Subscale Flight #2, completed in OpenRocket Software.

vi. Analysis of subscale flight

The subscale flight has verified that although we will still implement an aerodynamic cover on the openings of the airframe, there is not an expected risk associated with the lack of covers. The rocket maintained stability and was not observably impacted by the lack of covers on the subscale flight. It is difficult to determine the impact of the lack of covers on the accuracy of the simulations, due to the conflicting reports given by the altimeters. The altimeters have since been recalibrated for any flights moving forward.

The payload of the flight vehicle performed acceptably. There was an issue with one degree of freedom of the moving assembly, as on the morning of the launch a section of the 3D printed actuator broke. This prevented the payload from being able to extend the camera outside of the airframe, and thus from moving forward with the code. However, the launch verified that the electronics system and code will run and survive a launch. The rotating component of the payload was successfully moved, however due to the landing configuration it is uncertain whether or not the code had successfully chosen the correct, vertical opening. Future ground tests will be conducted to replicate successful operation of the code, and future flight tests will hopefully afford the vehicle a more flat landing.

vii. Discussion of impact of subscale flight data on full-scale vehicle

The issue with the broken 3D printed component has also pushed us to replace all 3D printed parts with 100% infill PETG in order to solve the issue, and duplicates will be made of parts to allow for replacement of broken or susceptible pieces.

Regardless of the lack of impact seen from the absence of aerodynamic covers, SOAR will still implement these to minimize the associated drag on the rocket and forces applied to internal components.

The error with the avionics altimeters makes it difficult to determine any changes required to the launch vehicle. This issue has encouraged SOAR to calibrate all altimeters in the shop to prevent further issues.

c. Recovery Subsystem

i. Identification and justification of design alternative chosen from PDR

In the decision whether to use a drogue or streamer, we justified using a drogue since it is what we have more experience in and there was still so much unknown surrounding using a streamer. Another decision was to use a dead weight coupler to connect the main parachute, this will help reduce load on the payload by not directly connecting to the payload section.

ii. CONOPS of recovery system

The result we expect from the recovery system is to release a drogue and main parachute to slow the rocket for recovery. For this purpose a primary altimeter will set off the primary black powder charges, with a second altimeter to release a separate set of black powder charges with slightly more than the first.

iii. Parachutes, harnesses, bulkheads, and attachment hardware

- A 16 inch diameter drogue and a 72 inch diameter main parachute made of nylon.
- The harnesses will be made out of kevlar.
- The bulkheads of the rocket will be made out of fiberglass.
- The attachment hardware will be metal D-links.

iv. Electrical components and demonstration of redundancy

Inside the avionics bay there are two RRC3 altimeters, where both have their own 9V batteries and the second altimeter activates after the first in case the first fails. There is also a RTx/GPS inside the avionics bay.

v. Drawings and sketches, wiring diagrams, and electrical schematics

The wiring diagram for the avionics bay can be seen below with a simplified version showing the connections needed for this system to function. The orange circles are a representation of the electronic matches that will ignite at apogee for drogue and at 500 ft for main deployment.

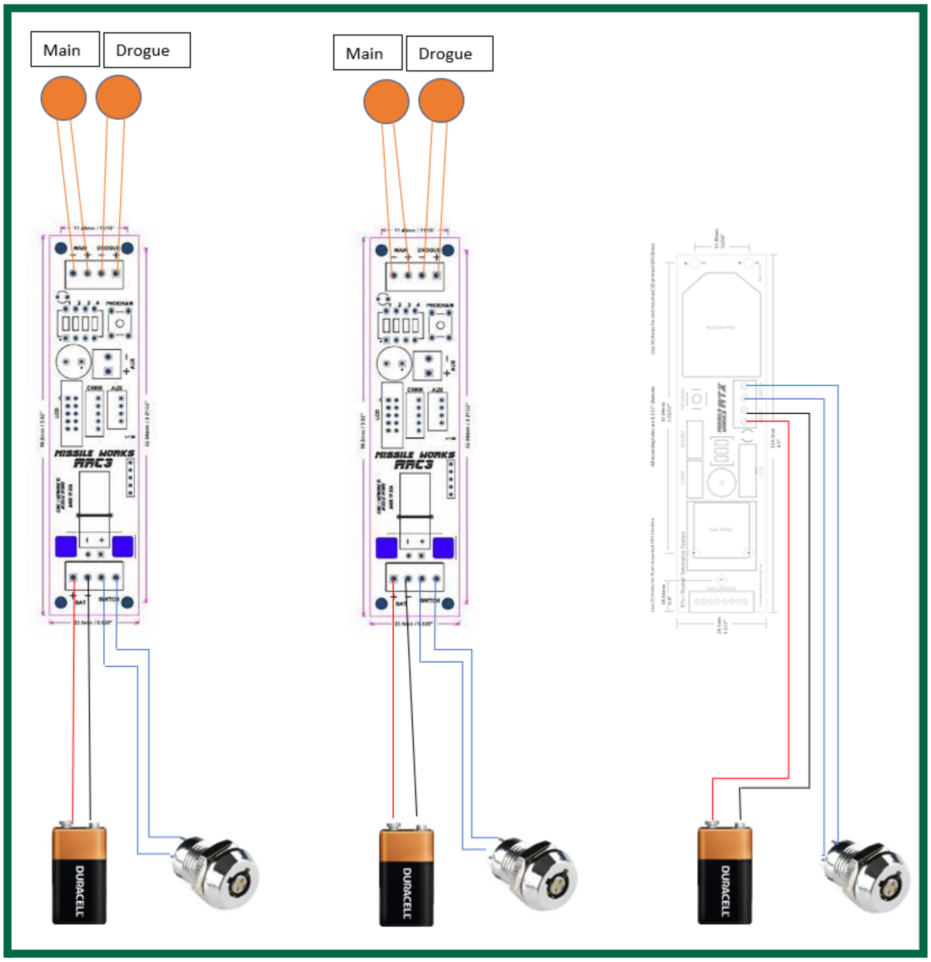


Fig. 12: Wiring Diagram For Altimeter Bay

The cad model for the avionics bay can be seen from the image below.

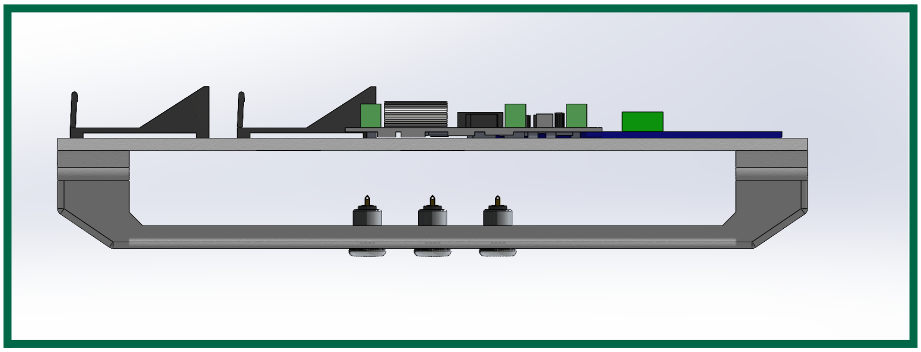


Fig. 13: Side View of Avionics Bay Assembly.

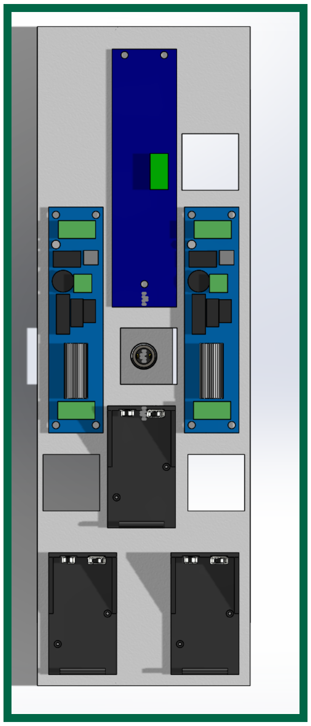


Fig. 14: Top View of Avionics Bay

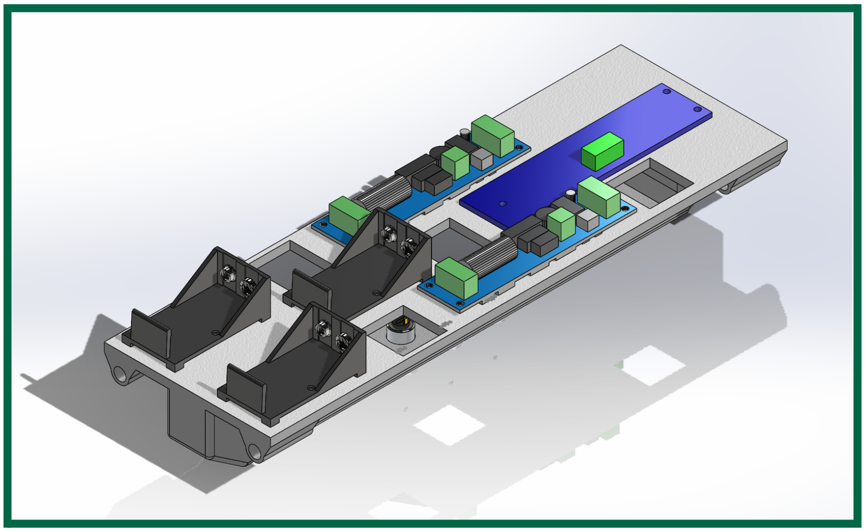


Fig. 15: Isometric View of Avionics Bay

The avionics bay consists of two MissileWorks RRC3 altimeters and the Missileworks RTx/GPS module. These three devices are each to be powered by a 9V battery as recommended by the manufacturer. Three switches will be accessible to the team to turn on the devices on the launch rail. Openings on the sled make it easy to route the necessary wires to each component.

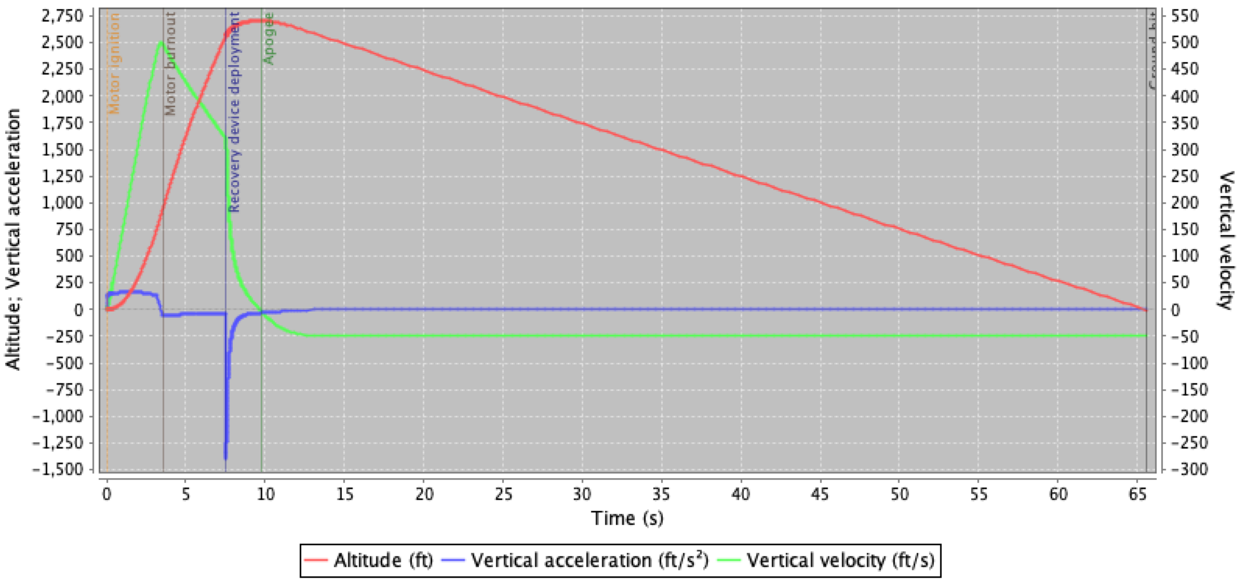
vi. Operating frequency of locating tracker

The operating frequency of the Missileworks RTx/GPS can be selected between 902 and 928 MHZ in a 9 mile radius. Selection of the channel will be finalized closer to launch competition.

d. Mission Performance Predictions

i. Flight profile simulations

OpenRocket simulations have placed our project apogee at about 2750 feet. This is considering a 1.5 pound ballast, with launch conditions listed Section 1.b.v.



ii. Stability margin and simulated Center of Pressure/Center of Gravity relationship and locations

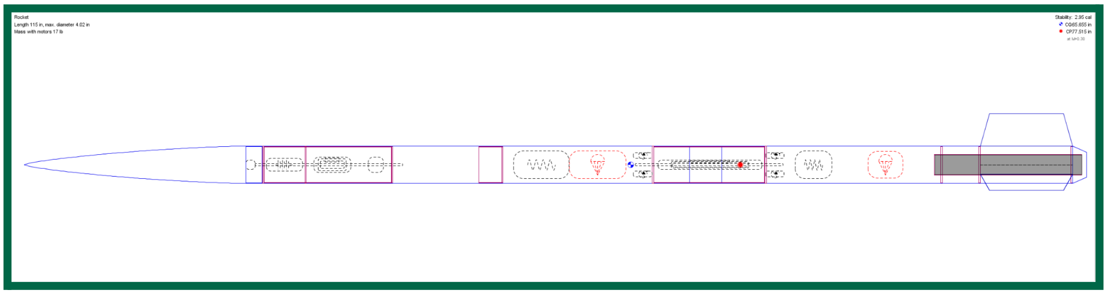


Fig. 16: Locations of Center of Pressure/Center of Gravity

The current stability for the full scale rocket is estimated to be 2.95. The center of pressure and center of gravity were found by measuring from the tip of the rocket.

iii. Calculation of kinetic energy at landing for each independent and tethered section of the launch vehicle

For calculating the kinetic energy for each independent section we used the formula for kinetic energy, $KE = \frac{1}{2}mv^2$, and the masses of each of the sections. For the upper body tube the kinetic energy at landing would be 40 ft-lbs, for the avionics bay 6.08 ft-lbs, and for the booster tube 17.49 ft-lbs.

iv. Calculation of expected descent time

The calculation for the expected descent time was done using code by first finding the speed of the rocket during its descent from apogee to main event with the equation $V = \sqrt{(2 \cdot g \cdot m)/(S \cdot p \cdot C_d)}$, where S is the surface area of the parachute, p is air density and C_d is the coefficient of drag. Then after calculating the distance from apogee to main event and dividing it by the velocity gives us the descent time from apogee to main event. After repeating the process from main event to ground we calculated the total expected descent time to be 79 seconds.

v. Calculation of expected drift for five cases

To calculate the drift cases for five different wind speeds we used OpenRocket to simulate 0, 5, 10, 15, and 20 mph wind cases showing lateral distance over time.

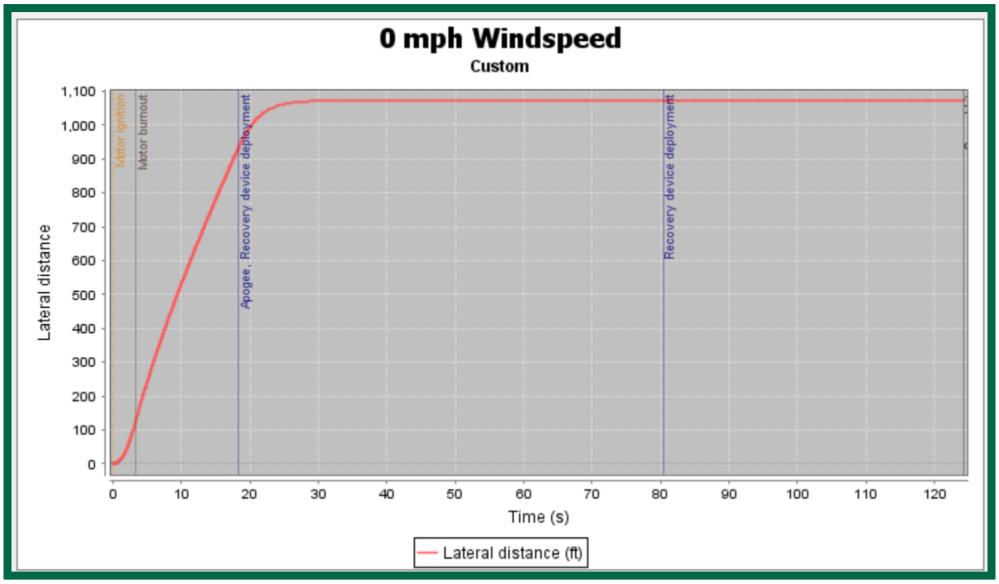


Fig. 17: OpenRocket drift simulation with 0 mph wind speeds

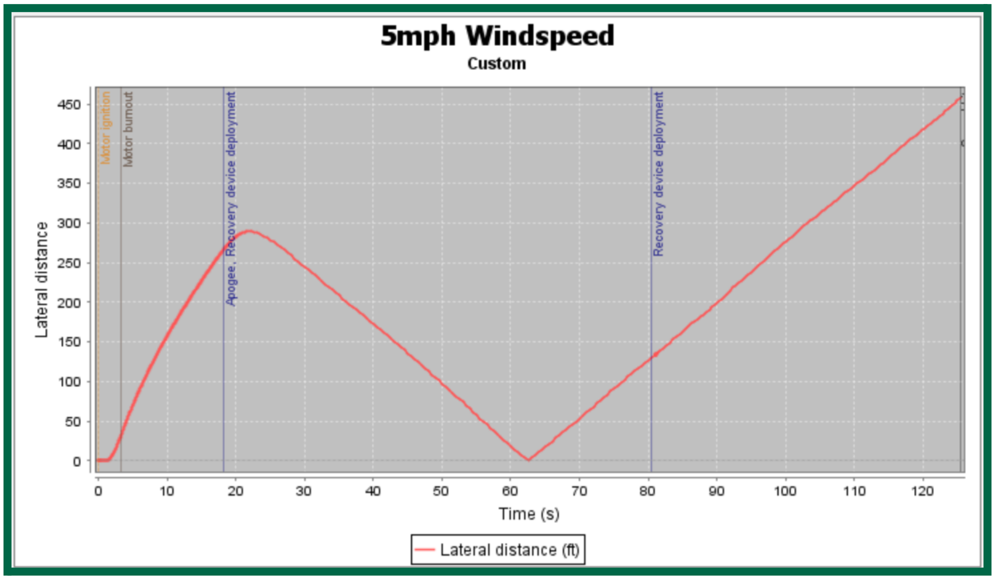


Fig. 18: OpenRocket drift simulation with 5 mph wind speeds

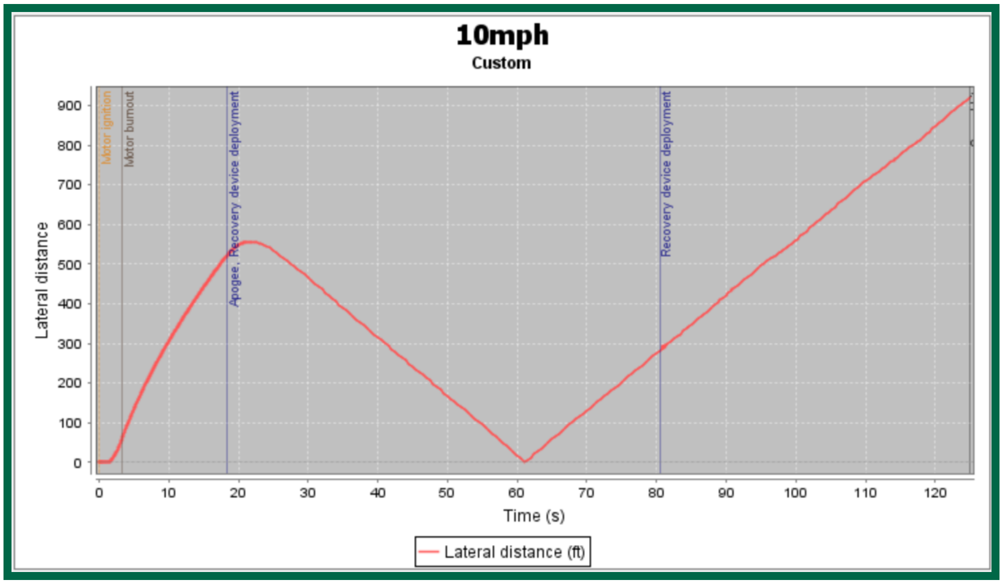


Fig. 19: OpenRocket drift simulation with 10 mph wind speeds

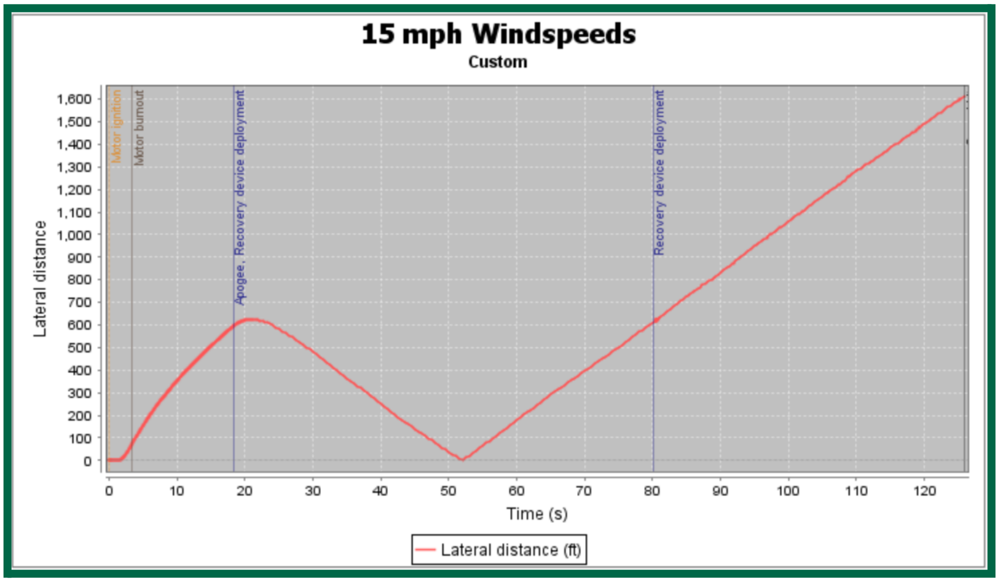


Fig. 20: OpenRocket drift simulation with 15 mph wind speeds

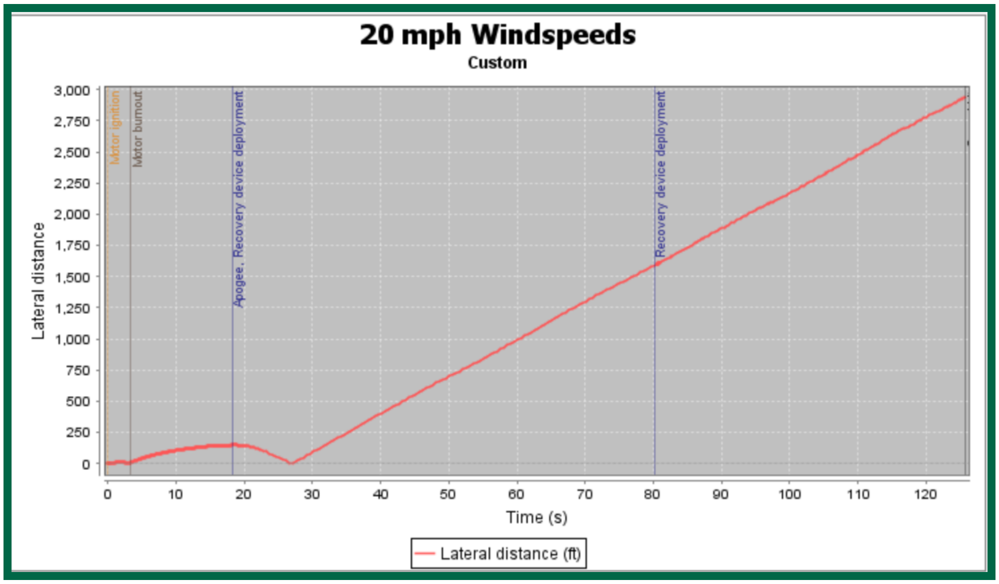


Fig. 21: OpenRocket drift simulation with 20 mph wind speeds

vi. Presentation of alternative calculation methods

Besides doing an OpenRocket simulation to simulate drift cases you can also manually calculate drift cases by multiplying the estimated descent time and predicted wind speed to find the maximum horizontal distance the rocket could travel. Using this method for the five cases and the descent time of 79 seconds. For the five cases of 0, 5, 10, 15, and 20 mph wind speeds the resulting maximum horizontal distance would be 0, 579.3, 1158.7, 1738, and 2317.3 feet.

vii. Discussion of differences between calculations

The alternate calculation method of calculating the maximum horizontal distance with the wind speed and time of descent does not account for any drift due to the drogue and main parachute deploying.

viii. Performance of multiple simulations as verification

When running the simulation in OpenRocket we ran the simulation multiple times to verify that the drift calculations were accurate.

4. Payload Criteria

a. Design of Payload Equipment

i. Identification and justification of design alternative chosen from PDR

Our SOAR payload team has chosen to continue with the Servo Stabilized Camera System (SSCS) that was utilized for subscale launches. There are a variety of reasons why we chose to continue with this design. Mainly, this system was proven to be mostly successful during the two subscale launch flights. Though not fully complete, many of the mechanical and electrical components functioned as intended at the proper times. Moving forward, our team can focus on the fine tunings of the program and improvement of existing physical components, rather than pursue a different design that could risk new and unpredictable challenges that arise from a fresh start. Additionally, the current Servo Stabilized Camera System (SSCS) was designed to be integrated into a three inch diameter tube. Simply placing this entire system into a four inch tube allows us to naturally get rid of some of the dimension constraints that challenged us during the initial design. By creating additional space for mechanical components, the system can be improved in different ways, such as increasing thickness all around and adding ribs to create a stronger and more stable system.

ii. Review of design at a system level

1. Drawings and specifications of each component and payload assembly

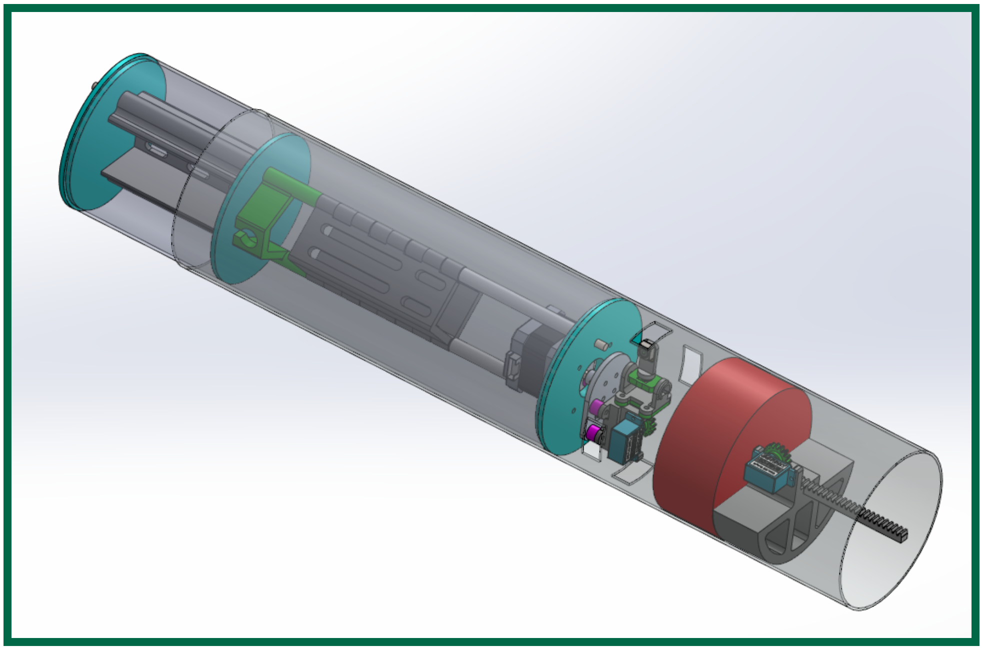
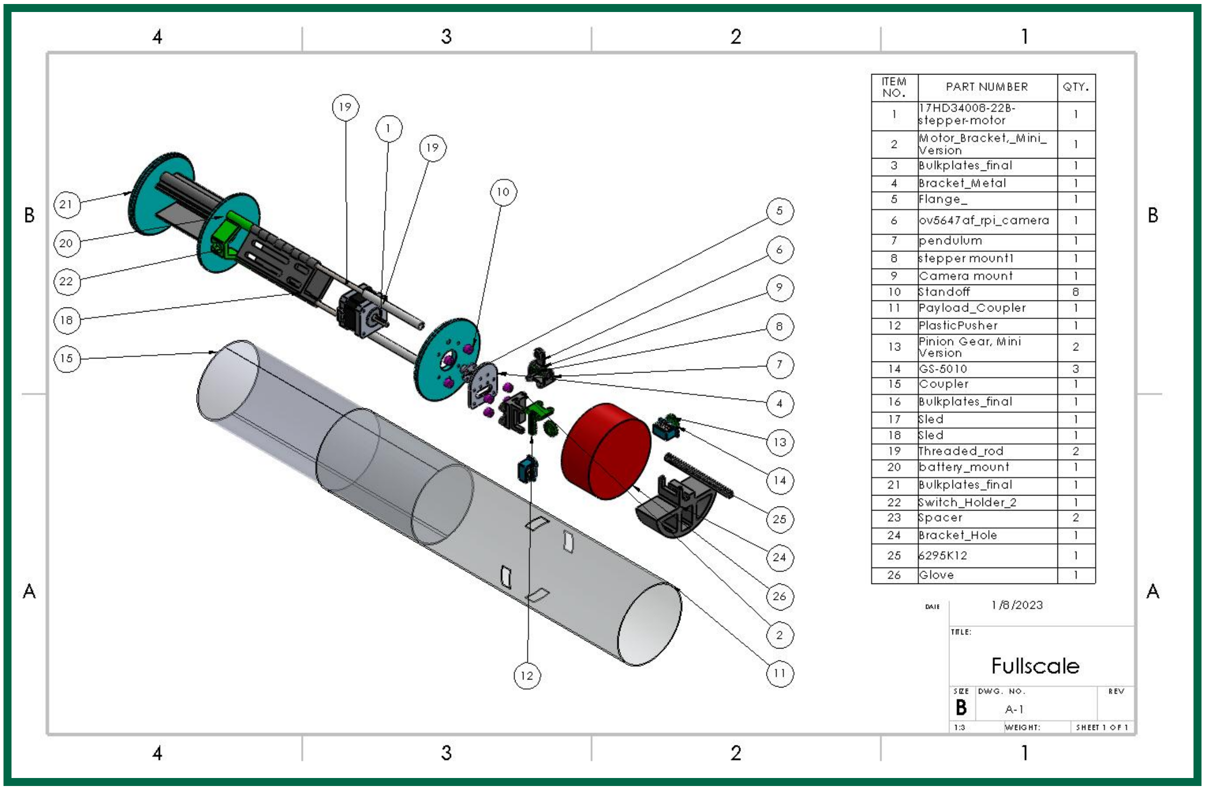


Fig. 22: Isometric view of assembled payload.

The system is nearly identical to the subscale design. This was due to the initial success of the payload launch and overall modularity of the design. This is due to the lack of new parts needed to be manufactured. For example the only changes needed are the couplers, bulkheads, and a 3d printed housing and gear setup. The camera is still going to be housed internally and deployed using a stepper motor to actuate rotation along the longitudinal axis of the rocket, with a rack and pinion to actuate the system perpendicular to the rocket's length. From there the system will use a miniature gimbal to account for the landing orientation of the 4 separate holes in the main tube. Once deployed the camera will adjust to the correct hole and account for angular variations in landing. The camera can then conduct commands given by NASA such as rotating, scanning, and image manipulation.



ITEM NO.	PART NUMBER	QTY.
1	17HD34008-22B-stepper-motor	1
2	Motor_Bracket,_Mini_Version	1
3	Bulkplates_final	1
4	Bracket_Metal	1
5	Flange_	1
6	ov5647af_rpi_camera	1
7	pendulum	1
8	stepper mount1	1
9	Camera mount	1
10	Standoff	8
11	Payload_Coupler	1
12	PlasticPusher	1
13	Pinion Gear, Mini Version	2
14	GS-5010	3
15	Coupler	1
16	Bulkplates_final	1
17	Sled	1
18	Sled	1
19	Threaded_rod	2
20	battery_mount	1
21	Bulkplates_final	1
22	Switch_Holder_2	1
23	Spacer	2
24	Bracket_Hole	1
25	6295K12	1
26	Glove	1

DATE 1/8/2023
TITLE: Fullscale
SIZE B
DWG. NO. A-1
REV
1:3
WEIGHT:
SHEET 1 OF 1

Fig. 23: Exploded view of entire payload assembly.

The figure above shows all of the necessary mechanical components that went into the payload system. Referring to the part numbers on the table in the figure, we can see all of the cad file names used. This will be the reference used to describe each component. Part 1 is the stepper motor we chose to drive the longitudinal rotation of the entire assembly. This motor was chosen due to the smalle height and width dimensions needed to fit in between the threaded rods. The motor bracket for the rack and pinion housing (Part 2) is made of PLA and was designed to house a 9 gram metal geared servo (Part 14).

The rotating payload assembly is shown in the figure below. This encompaseses a bracket that connects to the 3d printed rack and pinion and houses a mini stepper motor for longitudinal rotation of the camera. The second axis is attached dby the mini stepper motor on the bracket which houses another mini stepper motor to rotate the camera 360 degrees.

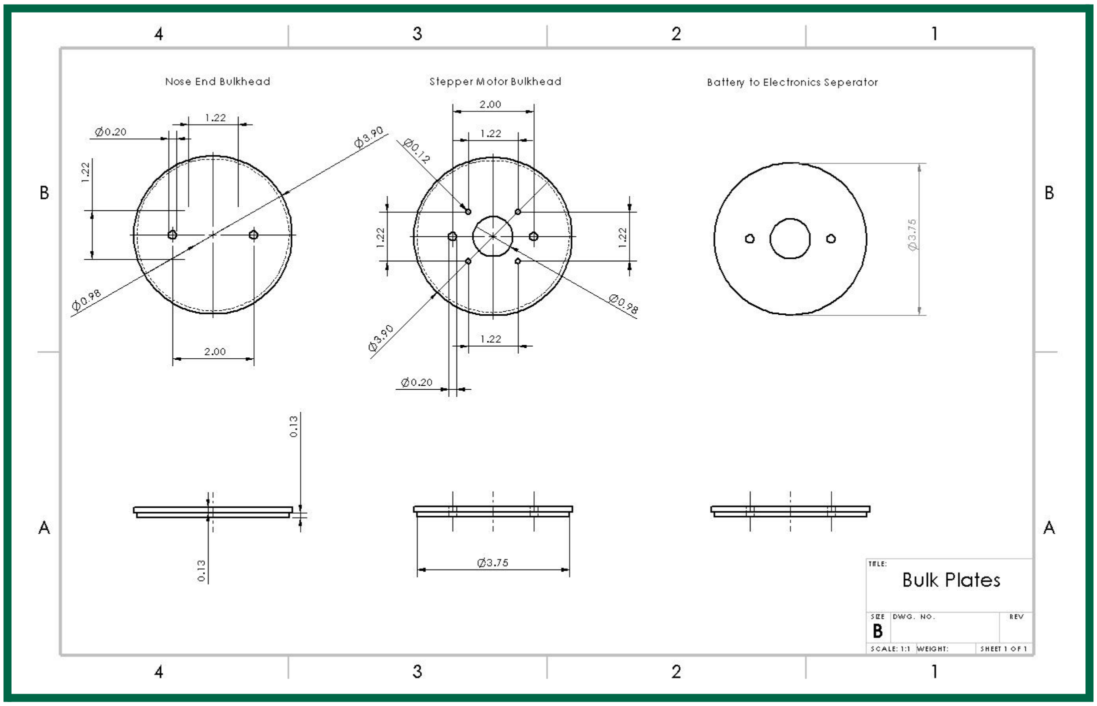


Fig. 24: Payload bulkhead drawing.

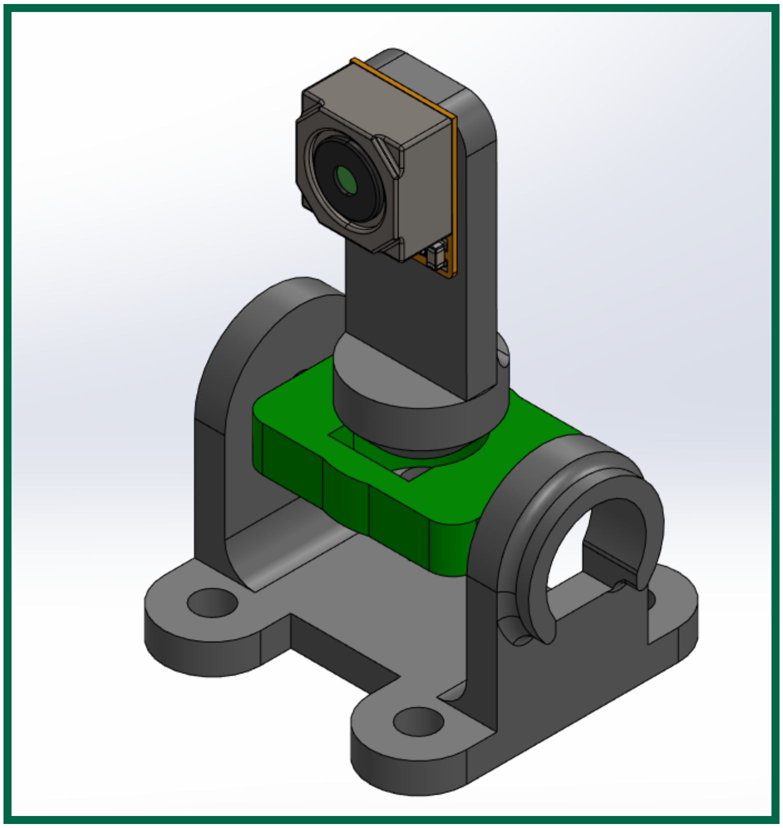


Fig. 25: Rotating Payload Assembly.

The stepper motor is connected to part 21, the bulkplates which contain 3 different variations shown in the figure below. These were carved using the Xcarve machine in fiberglass. Stand offs (Part 10) had to be used to guarantee that wires from the electrical components outside of the coupler section would be able to rotate with the stepper motor shaft freely. These standoffs were made for M3 screws and could be 3D printed for rapid protoyping and variation.

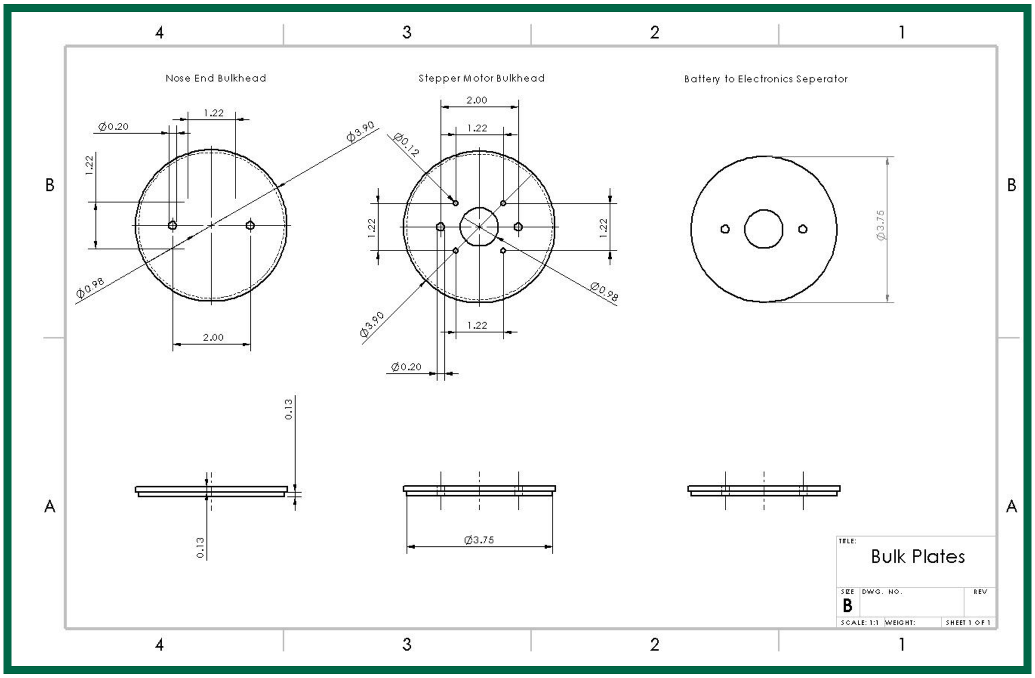


Fig. 26: Bulk Plate drawings for Xcarve manufacturing.

The stepper motor shaft is connected to a steel flange (Part 5) which is subsequently connected to another steel bracket (Part 4) to house the rotating payload electronics. This arrangement of brackets was made to keep the system modular, meaning if one part needed modification, the whole system would not need to be redesigned. Part 12 was the geared rack, and part 13 was the meshed gear. These parts were initially 3D printed however due to stress failures during the subscale December launch this has been switched to carbon steel to ensure maximum strength during the recovery phase. Part 19 works directly to secure all components to the coupler. The threaded rod and rod sleeve are placed two inches apart, the same as subscale coupler design. This was to minimize change in the electronics housings. The Rod sleeve was made from clear plastic tubing which was fitting over the section where the stepper motor is housed. This is to ensure a snug fit and to give space from the bottom of the motor to the electronics housing itself.

Part 18 is the payload sled, this was 3D printed to create a custom made housing for the specified electronics configuration we worked with. The Slot holes on each side were placed to keep the wires in the dual housing so as to not clutter the body tube. This made a very clean setup and allowed for better cable management. Two of these sled parts were needed since they used a door hinge like connection. This is shown in the figure below. This design made very quick assembly and disassembly.

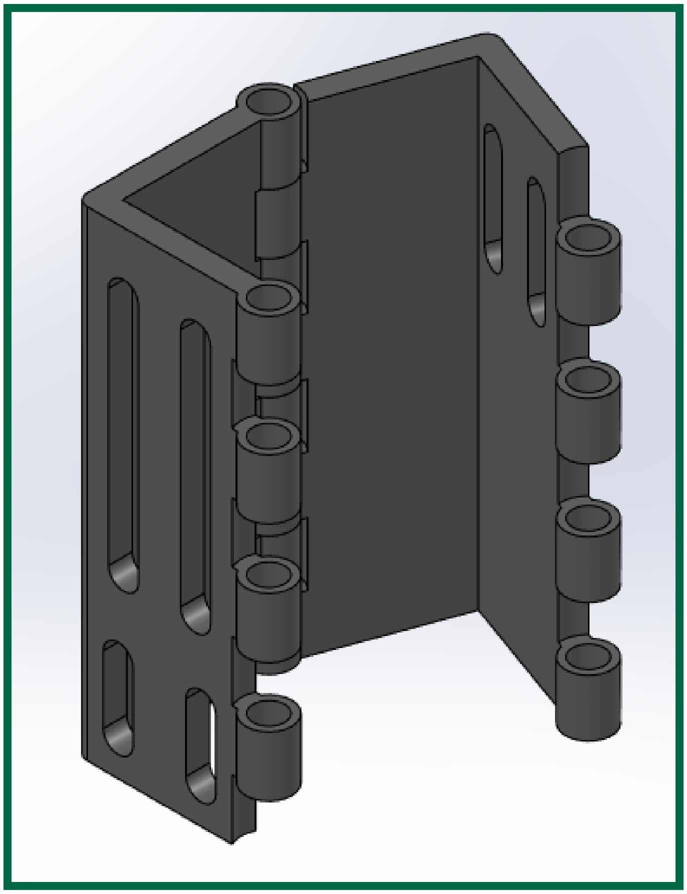


Fig. 27: Payload sled door hinge design.

The Battery is mounted to a 3D printed housing (Part 20) that slides through both threaded rods. This houses a 4s battery needed to power the entire system. A bulk plate is placed on top of this battery to ensure that any electronics aft of this position won't be crushed. This was implemented from the past NSL competition. Lastly the switch housing (Part 22) is 3D printed and is between the electronics sled and the battery bulkplate.

Due to the previous launch concerns of aerodynamic forces and possible induced drag from the open camera holes a cover was made. This cover also includes a foam lined inside to absorb any shock or whiplash from recovery. This system is new to the payload design and should aid in stress formations of printed parts in the rotating assembly. Parts 24-26 encompass a fiberglass piston cup that is filled with soft packing foam, and a rack and pinion system acting along the pistons center.

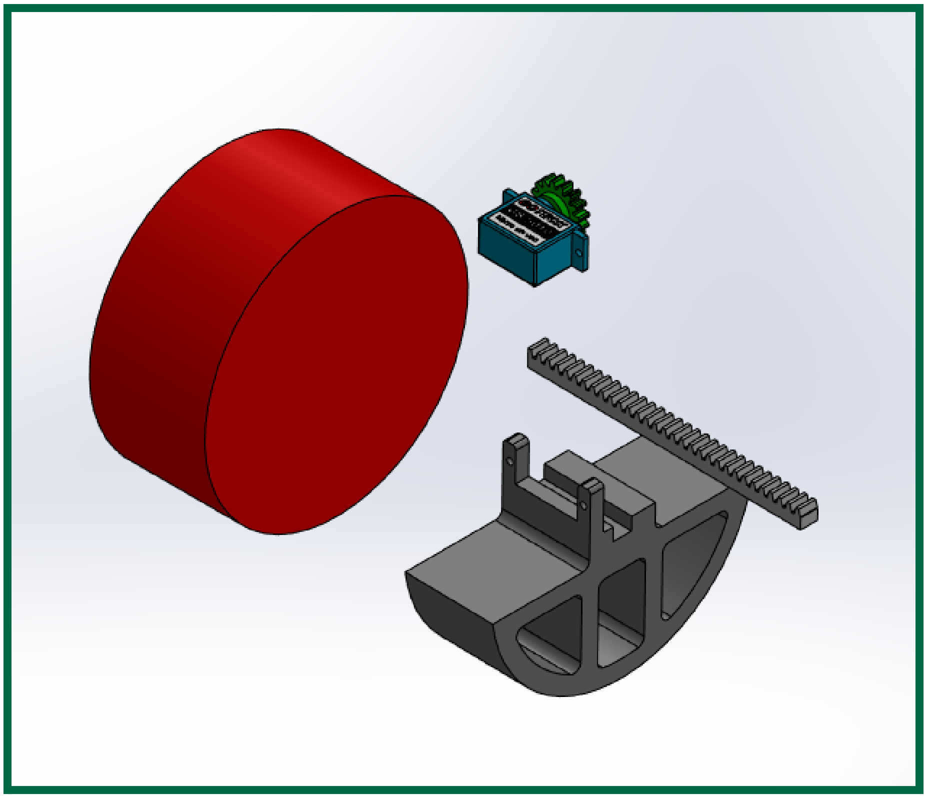


Fig. 28: Aerodynamic cover.

2. Description of interaction between payload components

   The payload system is entirely controlled by the main computer (RaspberryPi Zero). The main computer interfaces with a 9DOF IMU via I2C, enabling it to monitor two main aspects of the mission: detecting launch of the rocket and detecting the angle in which the payload landed. Once landed the main computer interfaces with the Radio Frequency Receiver (DRA818V) to decode the Radio Frequency Commands being transmitted over the 2 meter band. While the Radio Commands are processed, the computer interfaces with a Microcontroller (Raspberry Pi Pico) via a serial connection and sends it commands for motors to execute. The first motor to move is the main stepper motor which, based on the angle data, will rotate towards the hole that's most aligned with the vertical axis, the next motor that's instructed to move from the microcontroller is the servo motor that will take care of pushing the camera out of the payload body tube. Once the Radio Frequency Commands have finished processing they are sent to the Microcontroller so that it moves the Micro Stepper motors to which onto which the camera is directly attached to. The camera itself is directly connected to the main computer, therefore after reaching each desired angle the images are directly stored in the main computer's memory.

3. Description of integration of payload with launch vehicle

   The payload system will be placed in the upper body tube. The bulk of the payload system will be bolted together with threaded rods that run the length of the system. At each end, a bulkplate will be placed at each end and the system will be tightened to a coupler tube. This allows for the entire payload assembly to easily be removed from the upper body tube. Once the payload is in the correct position along the length of the upper body tube, it will be bolted to the outer tube. Three hex nuts that are adhesed to the coupler tube 120 degrees apart will allow the bolts to properly secure the two tubes together. When bolted, the payload must be at the proper orientation within the tube, as the main switch for the payload must align with the single opening in the given section of the upper body tube, to allow the payload to be turned on at the launch site. When properly bolted, the camera should align at the same length of the four openings, which will allow the camera to extend past the airframe.

4. Description of payload retention system

The design of the payload system considers that the upper body tube will land flat along its length. Barring obstacles at the launch site such as overgrown grass, trees, or rocks, the upper body tube should lay flat due to the drift of the parachute that occurs once one end of the tube has touched the ground. As stated, the entire payload system will be bolted to the upper body tube and the upper body tube will be attached to the main parachute. This design allows for an extremely strong connection to the body tube since the main forces on recovery will be acting perpendicular to the screw face. Our main concern when choosing this design was strength since the entire payload assembly will be housed in the coupler section of the payload body tube.

iii. Demonstration that design is complete

The entire payload system design meets the requirements set forth by both the Nasa Student Launch and our organization. Our team can utilize the previous launch as a baseline in determining if there are any other constraints that may prevent the design from being incomplete. We did not find any additional constraints that needed to be considered for the design to be complete. All design changes and modifications will be based on constraints and challenges that our team has already either considered as a problem or is already covered by a specific design feature. Throughout individual testing of the payload outside of launches, as well as the two subscale launches, our team found that the four main criteria can be met. The design accommodates the ability for the entire camera module to rotate internally to the proper orientation, and then be extended out of the airframe by the rack and pinion system. In our subscale launches, we were able to successfully rotate this system and extend out of the airframe at the proper time. However, the correct orientation was not chosen. Given the time remaining to adjust the software and add another IMU for redundancy, this can be corrected. The next two requirements were not tested at subscale launches. This includes the ability for the two-axis gimbal to rotate 360 degrees and for the payload to receive radio frequency commands. Though these could not be tested at the launches, as stated, the 3D model of the gimbal provides the capability for the two axis rotation (with the proper clearance and support material) and testing has been done outside of launches with the micro stepper motors by themselves and the radio frequency commands.

iv. Discussion of payload electronics

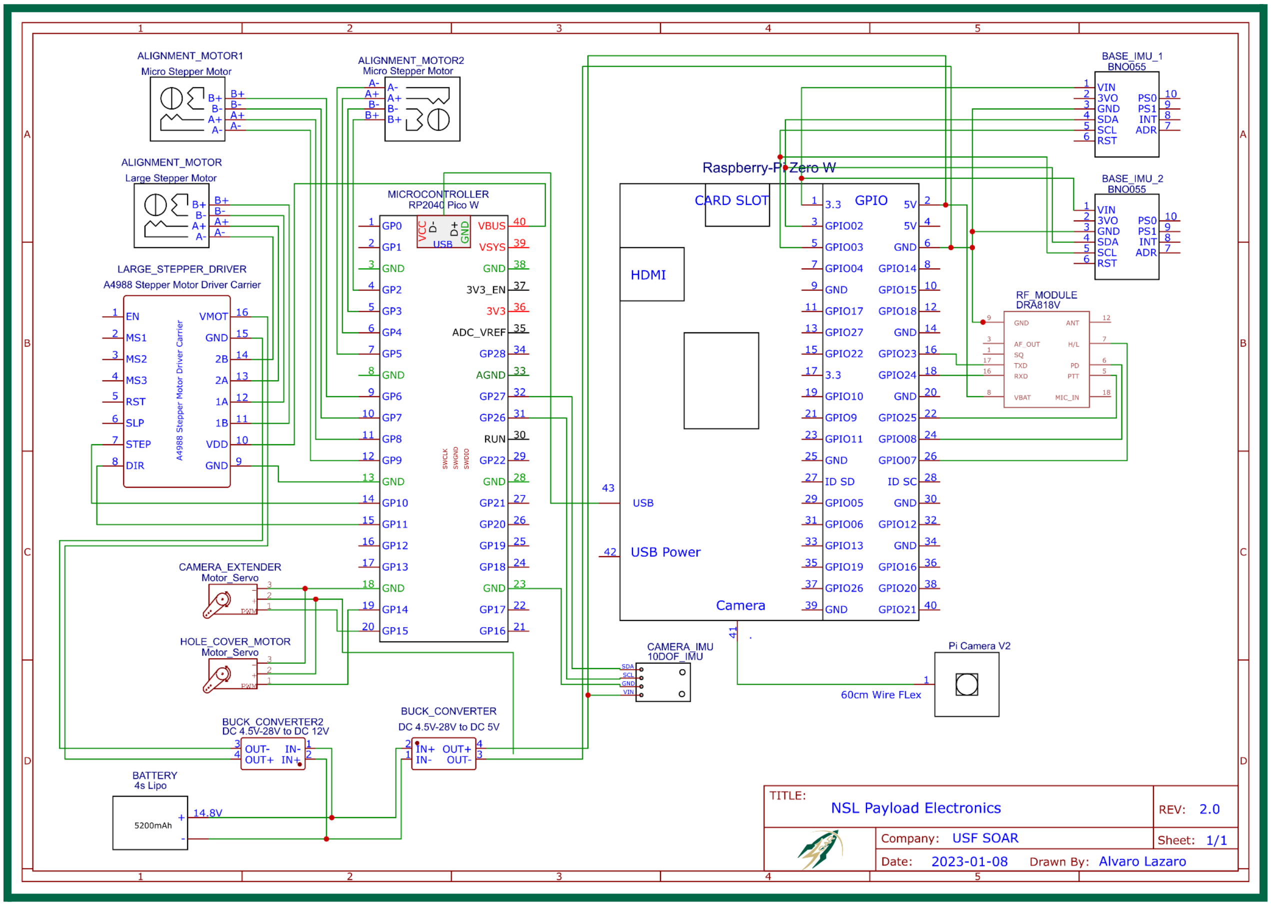


Fig. 29: Payload electronics layout.

The payload electronics broadly consist of a master-slave system between a main computer (RaspberryPi Zero) and a microcontroller (RaspberryPi Pico). All electronics are powered from a 14V LiPo battery, which gets its voltage stepped down via Buck Converters. The main computer is directly connected to the Camera (Raspberry Spy Cam with 120 FOV), the 9 DOF IMU (Adafruit BNO055), the radio frequency receiver (DRA818V) and the microcontroller (via a USB serial connection). The microcontroller is connected to a large stepper motor, a small servo motor, the 2 micro stepper motors at the camera, and also a Piezzo component (indicates the main program is running). From the results observed from the launch, we will be adding another IMU sensor at the time of calculating the vertical alignment angle given that it wasn't able to pick the right hole, and possible IMU inaccuracy is a factor that may have affected it. The microcontroller is also going to be upgraded to be able to deliver 5V through its pins, mainly so that the micro steppers are able to run without draining the voltage out. Upon implementation of those previous 2 improvements the payload electronics should be able to run as intended, so far we can assure the battery system, the master-slave interface and I2C connections with the sensors are functioning properly.

v. Justification of all unique aspects of payload

1. Number of Camera Holes

Four openings were chosen as options for the camera to pass through to extend outside of the airframe. By including four openings, mathematically, the most that the main stepper would have to rotate is 180 degrees in each direction; the most that the micro steppers would have to rotate is 45 degrees. Including enough openings allows these rotations and movements to be limited. Our team capped the number of openings at four as the strength of the body tube would decrease with every additional opening.

2. Rack and Pinion

The rack and pinion system was chosen, as the simplest motion to extend the camera out of the airframe is a linear motion. Though actuators and similar devices could also provide linear motion, the rack and pinion gear provide the most cost and space effective solution. Additionally, with a redesigned PLA reinforced rack and the chosen MG90S servo motor, the system (especially the rack itself) could withstand any forces caused by the body tube or objects outside of the airframe upon landing.

3. Servo Motors

The MG90S Servo Motors were chosen, as with modifications, they would meet the required criteria. Though these motors are limited to a rotation of 180 degrees, this can be overcome by replacing the potentiometer with two resistors and removing the gear stop. Though this would remove the motors ability to read position, our team decided that this can be accounted for in the payload program.

4. Master-Slave Electronics Control system

The master-slave system that incorporates both a computer (RaspberryPi Zero) and a microcontroller enables us to facilitate the development of motor tasks with the microcontroller and sensor data processing with the more effective processor of the computer. It also enables multitasking at the moment the computer is awaiting for RF commands to finish processing, the microcontroller will be executing the preparations needed to execute the camera motions.

5. Mini Spy Camera

The Raspberry Pi Spy Camera was chosen because it's the camera with the smallest and thinnest mounts, that not only facilitates poking the camera out of the hole, but it also leaves space for the mechanical gimbal system and the camera IMU that will check for the angles from the specific commands.

6. DRA818V RF Receiver

The DRA818V was chosen as our RF receiver because it's designed to operate within the range of 134~174MHz, which accounts for the 2 meter radio band on which the RAFCO commands will be transmitted on the day of the launch.

6. Multiple IMUs

The payload incorporates two 9 DOF IMUs to align the camera system with the hole closest to the true vertical axis, the purpose of two IMUs is to provide redundancy given that the alignment is the first operation to be performed just after the whole payload has endured the high speeds of the launch. There is also a 10 DOF IMU which operates independently from the previous two given that it will be the one controlling the camera gimbal when the RAFCO commands are being executed, given that the gimbal will require calculations with more degrees of freedom that's why the 10 DOF IMU was chosen for this specific part of the task.

5. Safety

a. Launch Concerns and Operation Procedures

i. Recovery preparation

Table 1: Recovery preparation checklist.

Prior to Flight	**Safety Officer Signature**
Inspect parachutes for tears, burns, or any other form of damage. ● Skipping this step could result in an unsafe velocity after parachute deployment.	
Inspect shock cords for tears, burns, or any other form of damage.	
Ensure all parachutes are attached to the correct shock cord.	
Ensure eye bolts are secured tightly to bulkheads.	
Ensure tape and other foreign objects are removed from shock cords and parachutes.	
Measure and cut e-matches to their proper length.	
Note: Nitrile gloves MUST be worn when handling black powder. Measure black powder into each charge port and cover with a nonflammable insulation.	

ii. Payload preparation

Table 2: Payload preparation checklist.

Prior to Flight	**Safety Officer Signature**
Ensure all wires are secured within the payload housing.	
Ensure the RaspberryPi Zero is secured to the 3D printed part immediately below it.	
Ensure the 3D printed part attached to the ribbon cable is secured tightly using the small, electronic screwdriver.	
Ensure the motor is attached to the payload with enough freedom to allow it to spin. ● Improperly attaching the motor will result in the motor becoming unplugged or not spinning.	
Push the wires for the micro stepper motor through the hole in the bulkhead.	
Ensure the ribbon cables for the camera are not tight or tangled.	
Ensure the camera is rotated 90 degrees to the right of the IMU. This will cause the camera to be aligned with the large buck converters.	
Ensure all wire connections are secure.	
Insert payload into the payload body tube, with the switch aligned to the correct hole. **Payload lead must confirm inspection.**	

iii. Electronics preparation

Table 3: Electronics preparation checklist.

Prior to Flight	**Safety Officer Signature**

Replace all disposable batteries.	
Ensure all rechargeable batteries are fully charged.	
Ensure all batteries are plugged in correctly and secured to their proper housings. ● Failure to complete this step may result in payload/altimeter failure.	
Ensure altimeters are operable and receiving power.	
Program altimeters to correct altitudes. ● Failure to complete this step accurately will result in failure to reach desired altitude or damage to the launch vehicle upon landing	
All wires are secured to their proper connections.	
Wires are safely inserted within the airframe to ensure no wire is caught between sections.	
Payload wires are routed through the bulkhead and not tightened, in accordance with payload assembly instructions.	
Payload is turned on prior to launch. This is indicated by a green light from within the payload and a sound made by the RaspberryPi Pico.	
Connect e-matches to altimeters to ensure continuity.	

iv. Rocket preparation

Table 4: Rocket preparation checklist.

Prior to Flight	**Safety Officer Signature**
Inspect fins and fillets for cracks, faults in epoxy, or any other issue that may prevent	

flight. - Failure to complete this step could result in catastrophic failure during flight or erratic trajectory.	
Inspect all bulkheads for cracks or other damage, especially near hardware such as eye bolts for shock cord attachment. - Failure to complete this step could result in catastrophic failure of bulkheads during flight.	
Inspect metal hardware such as D-links, retaining rings, and threaded rods for corrosion.	
Ensure the boattail is undamaged and shows no signs of separation from the rest of the airframe.	
Ensure the interior of the booster section is clean and clear of any debris.	
Ensure nuts are tightened adequately.	

v. Motor preparation

Table 5: Motor preparation checklist.

Prior to Flight	**Safety Officer Signature**
Inspect the motor and all associated parts.	
Assemble the motor in accordance with the assembly instructions (if assembly instructions are provided).	
Apply a sufficient amount of silicon gel to parts that require it.	
Ensure parts that do not require silicon gel are not cross contaminated. - Failure to complete this step may result in the motor not igniting.	

vi. Setup on launch pad

Table 6: Launchpad setup checklist.

Prior to Flight	Safety Officer Signature
Ensure power between launch control and the launch pad is disconnected.	
Slide the launch vehicle onto the launch rail, ensuring that all access holes in the airframe are accessible.	
Orient rail to the angle determined by OpenRocket simulations.	
Turn on payload, ensuring that the system is engaged via the green light and Pico.	
Turn on altimeters, listening for the three short beeps that indicate continuity in dual-deploy mode.	
Ensure all systems are active before evacuating the launch pad.	

vii. Igniter installation

Table 7: Igniter installation checklist.

Prior to Flight	Safety Officer Signature
Insert the e-match into the motor until it cannot go any farther, then retract it by one (1) inch. ● Failure to complete this step accurately may result in the motor not igniting.	
Secure the e-match in place using a piece of tape.	

viii. Launch procedure

Table 8: Launch procedure checklist.

Prior to Flight	Safety Officer Signature
Launch vehicle is oriented on the launch rail correctly.	
All personnel are evacuated from the launch pad ● Failure to complete this step may result in bodily harm.	
Launch vehicle is allowed to sit undisturbed after landing for two (2) minutes.	

ix. Troubleshooting

Table 9: Troubleshooting matrix.

	Safety Officer Signature
E-match fails to ignite: ● Check continuity between the e-match and launch control. ● If necessary, replace e-match.	

x. Post-flight inspection

Table 10: Post-flight checklist.

	Safety Officer Signature
Once the launch vehicle has touched down, start a two (2) minute timer to ensure payload deployment.	
Once the timer has elapsed and the RSO gives permission, retrieve the launch vehicle.	
Bring the payload and altimeter bay to the judges for scoring.	
Deactivate all electronics onboard the launch vehicle.	
Disassemble the launch vehicle and clean any parts contaminated with black powder residue	

to prevent corrosion.	

b. Safety and Environment

i. Risk Level Definition

1. Severity

The severity of each risk is determined by comparing the possible outcomes to criteria based upon human injury, vehicle damage, and environmental damage. Severity is graded on a scale between 1 and 4, with 1 being the most severe.

Table 11: Risk severity criteria.

Description	**Personnel Safety and Health**	**Launch Failure**	**Project Plan**	**Environmental**
1: Catastrophic	Loss of life or permanent injury.	Operations are not permitted by the RSO and the mission cannot proceed.	Budget overruns or lack of mission critical components result in project termination.	Severe, irreperable environmental damage that is in violation of laws or regulations.
2: Critical	Severe injury or illness.	Operations not permitted by the RSO occur and the mission is suspended due to a violation of laws or regulations.	Budget overruns or delay of mission critical components that jeopardize mission scope.	Repairable environmental damage that is in violation of laws or regulations.
3: Marginal	Minor injury or illness.	Operations are permitted by the RSO, but hazards related to flight hardware occur.	Minor delays or increased budget.	Repairable environmental damage that is not in violation of laws or regulations.
4: Negligible	Injury or illness treatable via	Operations are permitted by the	Minimal or no delays of	Minimal or no environmental

	first-aid.	RSO and no hazards occur.	components or budget increase.	damage.

2. Probability

The probability of every risk has been assigned a level between A and E, with A being the most probable. The scale of probabilities is determined by analyzing the risks and estimating the likelihood of an accident occurring.

Table 12: Probability matrix.

Description	**Qualitative Definition**	**Quantitative Definition**
A: Frequent	High likelihood to occur immediately or continuously.	Probability $> 90\%$
B: Probable	Likely to occur frequently.	$90\% \geq$ Probability $> 50\%$
C: Occasional	Likely to occur occasionally.	$50\% \geq$ Probability $> 25\%$
D: Remote	Unlikely to occur, but can be expected at some point in time.	$25\% \geq$ Probability $> 1\%$
E: Improbable	Very unlikely to occur and is not expected.	$1\% \geq$ Probability

3. Risk Assessment Levels

Table 13: Risk assessment matrix.

Probability	**Severity**			
	1 - Catastrophic	**2 - Critical**	**3 - Marginal**	**4 - Negligible**
A - Frequent	1A	2A	3A	4A
B - Probable	1B	2B	3B	4B
C - Occasional	1C	2C	3C	4C

D - Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E

ii. Personnel Hazard Analysis

Potential risks to health and safety are outlined in the table below.

Table 14: Personnel hazard analysis and mitigation.

Hazard	Cause	Effect	Pre-RAC	Mitigation	Post-RAC	Verification
Use of power and hand tools (saws, drills, dremels, etc.)	Improper training on use of power and hand tools.	Mild to severe cuts, burns, etc. to personnel or launch vehicle.	4C	Individuals must be trained to properly use power and hand tools, as well as wear correct PPE at all times.	4D	Safety officers more closely oversee manufacturing, reprimanding offenders when necessary.
Inhalation of ingestion of debris	Improper use of PPE or lack of workspace cleanliness	Mild irritation to skin, eyes, or throat. Severe lung irritation or asthma aggravation	3C	Long sleeves will be worn when sanding or or grinding surfaces and proper PPE will be worn when in close proximity to debris	3D	Respirators will be provided to all members in close proximity to debris. Anyone without respirators will be required to stand away from the workspace.
Sharp edges on	Improperly finished	Mild to severe	4D	Attention to detail	4E	Safety officer and

launch vehicle	surfaces or edges of components, often in difficult to reach places.	cuts, scrapes, or splinters while handling the launch vehicles.		when finishing launch vehicle surfaces during manufacturing.		Aerostructures lead will inspect launch vehicle surfaces to ensure edges are sufficiently finished.
Contact with chemicals	Improperly handling chemicals, resulting in fumes or bodily contact due to chemical splashes or spills.	Mild to severe burns on skin, lung damage, or asthma aggravation.	3C	Proper PPE worn at all times when handling chemicals and MSDS sheets will be available and reviewed before working with chemicals.	3D	Respirators and nitrile gloves will be provided to all personnel working with chemicals. Safety officer will ensure their use.
Fumes while soldering	Soldering iron is too hot or personnel have exposed contact with soldering iron.	Personnel may feel sick or unwell due to toxic fumes.	3D	Personnel will conduct soldering in well ventilated areas.	3E	Only Payload and Recovery members are authorized to use soldering irons. Any and all soldering must be done in the lower floor of the ENR

						facility.
Harmful contact with metal debris	Utilizing equipment necessary to machine metal parts.	Metal splinters in eyes or skin.	3D	Personnel must wear safety glasses and wear long sleeves when machining metal parts.	3E	Safety glasses are provided in the ENR facility. Long sleeves, long pants, and closed toed shoes are required for official manufacturing sessions.
Allergic reactions caused by epoxy resin and hardener	Prolonged skin contact with epoxy resin and hardener, and fumes caused by epoxy resin and hardener.	Mild rashes or chemical burns; irritation in respiratory system or sensitization to epoxy resin and hardener.	3C	Gloves should be worn when handling epoxy resin and hardener.	3D	Nitrile gloves are provided in the ENR facility. Safety officer will oversee their use during the manufacturing process.
Premature ignition of solid motor propellant or black powder	Contact with sparks or heat sources.	Smoke inhalation and severe burns; mild to massive property damage.	1D	Motors and black powder will be kept in a firebox away from heat sources when in storage and supervised by club officers	1E	Black powder and solid motors are stored in a firebox in the ENR facility, to which only club officers have access to. During launch

				during launch operations.		operations, black powder and motors are overseen by the safety officer.
Launch vehicle loses stability during ascent and loss of vehicle control	Improper model of launch vehicle design or incorrect manufacturing processes.	Extreme bodily harm or death; severe property damage.	1D	Launch vehicle must be accurately modeled in OpenRocket and attention to detail must be used when manufacturing.	1E	Center of Gravity (CG), Center of Pressure (CP), and stability will be validated by the Aerostructures lead and Safety officer before launch.
Debris from launch vehicle falling on personnel during flight	Sections of launch vehicle breaking off and returning to the ground in an uncontrolled fashion.	Risk of bodily harm if the debris falls into populated areas.	2C	Launch vehicle should be constructed to withstand the forces inherent with flight and separation; deployment charges should be kept to the minimum amount necessary for a	2D	Ground deployment testing will be conducted to produce successful separation and deployment without excessive force.

				successful separation.		

iii. Failure Modes and Effects Analysis

Table 15: Failure modes and effects analysis.

Hazard	Cause	Effect	Pre-RAC	Mitigation	Post-RAC	Verification
Igniter fails to activate	Mechanical or electrical failure.	Vehicle does not leave the launch pad.	4C	Electronic match will be replaced, ground support equipment will be tested if hazard persists.	4D	Safety officer will ensure that e-matches are connected to electrical leads, and will carry extra e-matches if necessary.
Failure of components	Improper installation or general wear and tear.	Project is delayed or the launch vehicle is damaged.	2D	Replace failed parts when practical; review rocket design or final integration and preflight checklists when applicable.	2E	Care will be taken when designing parts to ensure maximum strength. Extra components will be manufactured if time and materials allow.

Unstable launch platform	Launch platform is poorly anchored due to ground conditions.	Undesired/unpredictable rocket trajectory when leaving launch rail.	4C	Ensure launch platform is secured prior to launch.	4D	Ground support equipment will be verified by the RSO before launch procedures continue.
Altimeter failure	Electrical failure; improper programming.	Parachutes will deploy early/late, causing premature/lack of separation of rocket sections.	2D	Test altimeter programming prior to transit to launch site. Two altimeters are used for redundancy, and wiring/programming will be checked during final integration.	2E	The sound sequence provided by the altimeters will be validated to ensure that the altimeters are functioning.
Parachute deployment failure	Altimeter/electronic failure; parachutes and shock cord become entangled.	Launch vehicle will not decelerate before reaching the ground; the launch vehicle has potential to become ballistic.	1D	Packaging of parachute and shock cords will be checked before final integration.	1E	Launch vehicle weight and weather will be recorded to ensure parachutes and shock cord are selected correctly.

Sections fail to separate	Black powder charges are insufficient to separate sections; shear pins do not shear.	Parachutes do not deploy, causing vehicle to become ballistic and causing damage to launch vehicle.	1D	Adequate black powder tests will be conducted to ensure that quantity is sufficient for separation. Attention to detail will be paid when sanding interior surfaces required for separation.	1E	Black powder charges will be weighed to ensure the correct amount was inserted. Igniters will also be checked for continuity to the altimeters.
Sections separate prematurely	Black powder charges fire early due to programming error; fabrication error.	Structural failure, loss of payload, damage to launch vehicle.	2D	Calculate amount of shear pins necessary to negate drag separation; ensure altimeters are programmed correctly.	2E	Shear pins will be inspected for abnormalities or defects; altimeters will be checked to ensure proper programming.
Catastrophic failure of motor	Improper motor assembly.	Launch vehicle is severely damaged or destroyed; ground fires	1D	Ensure that motors are stored, handled, and assembled properly. All	1E	Safety officer will inspect motor components and oversee

		upon landing.		personnel should be a safe distance from the launch pad before final countdown occurs.		motor assembly.
Motor retaining ring failure	Recovery system separates with enough force to separate the motor from the booster section.	Motor and motor casing become ballistic; launch vehicle breaches 90 second descent requirement.	2D	Ensure that centering rings and retaining rings are secured to the interior of the booster section.	2E	Verify that the retaining ring is properly secured to the booster section.
Loss of stability during flight	Damage or loss of fin(s); poor fabrication.	Rocket follows an erratic and unpredictable flight trajectory; loss of launch vehicle.	1D	Ensure that fins are epoxied to the motor tube and outer body tube, as well as filletted properly.	1E	Using preflight checklists to ensure that all components necessary for flight are thoroughly inspected for any abnormalities.
Change in mass distribution during flight	Payload/avionics sled shift during flight.	Decrease in stability of launch vehicle.	3D	Rocket design will include adequate hardware to	3E	Ensure batteries and all components housed

				securely mount avionics and payload to their respective body tubes.		within the airframe are secured to their respective housings.
Increase in mass during construction	Unplanned addition of components; overuse of epoxy.	Launch vehicle does not reach the desired altitude.	4D	Review OpenRocket design to ensure that accurate weights are taken for each part.	4E	During manufacturing, weigh each component separately and place the appropriate mass into the OpenRocket simulation.
Igniter fails to activate	Mechanical or electrical failure.	Vehicle does not leave the launch pad.	4C	Electronic match will be replaced, ground support equipment will be tested if hazard persists.	4D	Validate e-match continuity and check for grounding.

iv. Environmental Concerns

Table 16: Environmental concerns and mitigation efforts.

Hazard	**Cause**	**Effect**	**Pre-RAC**	**Mitigation**	**Post-RAC**	**Verification**

Motor exhaust scorching the ground	Hot exhaust or flames leave the vicinity of the launch pad and burn the surrounding area	Potential fires or damage to launch pad and surrounding area	3D	If possible, make sure the launch pad is located in a sparsely vegetated area. Furthermore, the launch pad should have an adequate flame deflector	3E	Inspect the launch pad to ensure that it is placed over an area with sparse vegetation and that a large metal plate is used to deflect the exhaust.
Increased descent velocities	Parachutes are inadequate to slow launch vehicle	Potential damage to the ground, foliage, vehicles, or structures	2D	Ensure that selected parachutes are sufficient to slow rocket to acceptable descent speeds	2E	Launch vehicle mass will be accurately recorded to ensure accurate simulations. Parachutes will be folded properly.
Wire waste material	Wires or wire related material used in electrical components	Pieces of wire being ingested by local livestock or wildlife	3D	Ensure all wire debris is disposed of in proper receptacles	3E	PPE will be used when handling the sharp ends of wires; specified bins will be provided

						exclusively for wire waste.
Plastic waste material	Plastic used in wrapping of various components or debris from sanding/grinding components	Plastic splinters could be ingested by local livestock or wildlife; debris could find its way into the water system	3D	Ensure all plastic debris is disposed of in proper receptacles	3E	All plastic waste will be removed as soon as practical and the ENR facility will be inspected at the conclusion of manufacturing sessions. Recyclable 3D printing plastic will also be used.
Spray painting	The rocket will be painted using spray paint	Water contamination; fumes released into air	4D	All spray painting will be done by trained professionals in a dedicated workspace. Should any team members need to spray paint any portion	4E	Check any and all spray-painting locations to ensure no spray paint is left.

				of the rocket, it will be done in a well ventilated area		
Harmful substances permeating into soil or water	Improper disposal of chemicals	Impure soil and water can eventually affect the health of livestock, wildlife, and humans	1D	Chemicals should be disposed of in accordance with their MSDS sheets. Should a spill occur, all proper measures must be taken as soon as possible	1E	Inventory of batteries and chemicals will be taken after usage.

6. Project Plan

a. Testing

i. Identifications of tests required to prove integrity of design

The rocket requires various sub-systems to be tested for integrity before final assembly. The avionics bay must be tested to ensure continuity for recovery charges. A multimeter is used to verify the altimeters can detonate the charges. The avionics bay also requires that the altimeter readings and programming be tested to prove that the device can operate properly. Once the altimeters show continuity and the device is programmed the avionics team can conduct black powder testing. This is done to verify the amount of shear pins needed in the separating sections, and to ensure that parachutes are pushed out the proper length.

The Payload sub-system requires various kinds of ground testing to prove design integrity. The first test is conducting a camera rotation test to ensure that the wires are not getting caught around the motor shaft. The entire system is also tested to verify that the payload camera can choose the correct exit hole and account for the angle of exit. This is done by turning on the payload and conducting a violent jerk to initiate the script. This mimics the launch of the rocket. Once the timer is complete we place the payload in various positions and angles to ensure proper performence.

ii. Presentation of test objectives, success criteria and methodology

The test objectives are to verify the successful operation of each subsystem, or to provide evidence that certain failure modes are unlikely or mitigated as best as possible. To that end, there are success criteria which must be met to satisfy a successful test.

In terms of the payload ground tests, success will be judged at certain intervals of the camera system procedure. To qualify as a success, a test of 10 trials must be conducted. All 10 trials must show that the code algorithm is activated by the sudden movement of the payload. All 10 of these trials must also result in the actuation of the motors after the designated delay period. At least 80% of the trials must result in the rotation of the camera assembly, which must also show accurate selection of the correct opening; the camera must successfully orient itself as vertical as possible in these trials. Within a hard-coded test (that is, commands are given to the controllers via a programmed script), the motors must carry out the commands in all 10 trials. In a radio frequency test (that is, the commands are sent through radio frequency channels), the camera system must accurately perform commands in 90% of trials. In all 10 tests, the pictures taken must be stored to an on-board SD card.

Regarding black powder energetic tests, two trials must be conducted using a launch-day configuration of the vehicle. Both trials must show the ejection of recovery components with a clearance no less than five feet from the energetic location.

iii. Justification of necessity of each test

Payload ground tests are necessary to verify the nominal operation of the rotation and linear movement of the payload camera. These are a predecessor to flight tests which will verify both the operation of the camera actuation and the survivability of the electronics sleds in a launch environment.

The black powder tests are absolutely necessary in order to ensure the ejection of recovery components from the launch vehicle. Without the black powder tests, the amount of energetics used would not be accurate and would risk failure of ejection of parachutes.

iv. Discussion of how test results may cause necessary changes to vehicle

Avionics test results can change vehicle parachute configuration if they do not fit properly. Black powder tests can also change the amount of shear pins needed. If the recovery system does not deploy far enough, shear pin amount and parachute folding style or configuration may change.

Payload test results can drastically change the design of the electronics and hardware onboard. If the payload is not choosing the proper exit hole and accounting for the proper angle of execution, software will need to be changed to accommodate these errors. If this does not fix the issue then there will need to be hardware changes to ensure success.

v. Presentation of results of completed tests

Within payload testing, it was found that the code did not successfully select the correct orientation most of the time. Moving forward, the code will be revised in order to more consistently provide the correct orientation. The payload has not been tested to verify operation of the camera and radio frequency command use.

Black powder charge tests were conducted to verify the ejection of parachutes with 2g of black powder energetics. This was increased from a previous estimate of 1.5g in a previous subscale flight.

b. Requirements Compliance

i. Verification plan for requirements listed in handbook sections 1-5

GENERAL REQUIREMENTS

Table 17: General requirements

Req #	Requirements	Identification	Verification
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.	Inspection	Only students are allowed to participate in USF SOAR. Each team lead will ensure that only USF students are attending SOAR meetings, design/build days, and writing sessions. The team's mentor will handle the motor and black powder assembly, see section 1.1.3 Team Mentor. Previous reports will only be used for reference to ensure consistency in standards.

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.	Inspection	The Team Lead and Vehicle Lead will communicate with the sub-team leads to ensure completion of the project plan in accordance with each sub-team's needs. The Team Lead will communicate project milestone requirements with the team. The Team Lead will work with the sub-team leads to organize community outreach events for the STEM engagement requirement. The Vehicle Lead will create and maintain an accurate budget. The Safety Officer will create checklists during the project and design risk/mitigation charts.
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.	Inspection	The list of team members who plan to attend Launch Week activities has been created and verified with the team. The tentative number of team members who plan to attend is 14. One mentor will be attending. No adult educators plan to attend.
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 inperson 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 39–42.	Inspection	The STEM engagement events are being organized and planned by the team leads. The requirement of 250 minimum participants will be verified by documenting all past and future events. These events will be verified before the FRR deadline (03/07/2022).

1.5	The team will establish and maintain a social media presence to inform the public about team activities.	Inspection	The Team Lead has created an Instagram account for the SOAR NSL 2023 competition. This account is separate from the main SOAR account and will be used to promote/communicate all team events and updates. The main SOAR account will occasionally promote the NSL account for further outreach.
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 overall 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.	Inspection	The Team Lead will send each deliverable to the appropriate NASA project management team personnel by the accurate deadline. In the event that the Team Lead is unavailable to send the deliverable, the Vehicle Lead or a sub-team lead will send the deliverable. If the file is too large, the Team Lead will provide a link for the NASA management team.
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.	Inspection	SOAR understands this requirement and will corporate with providing any information that NASA requires from our team.

1.8	All deliverables shall be in PDF format.	Inspection	The Team Lead will ensure each deliverable has been proofread, properly formatted, and saved in PDF format before submission.
1.9	In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Inspection	The team will continuously update the table of contents with each section/sub- section that is written. The Team Lead will verify the final table of contents before submission.
1.10	In every report, the team will include the page number at the bottom of the page.	Inspection	The Team Lead will verify each page has been numbered during the proofreading session.
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.	Inspection	The SOAR team can provide adequate computer equipment for video teleconferences. A secure, quite room will be booked for each Milestone Presentation with the College of Engineering Department at USF.

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.	Inspection	The full-scale rocket will be appropriately designed to support the launch pads and rails provided by NASA during Launch Week. Will be verified with the vehicle design section of the design review documents.
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 8 General and Proposal Requirements 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	Inspection	The Team Mentor has been identified and meets the qualifications set by the NSL 2022 Handbook. See section 1.a.iv Team Mentor.

	Week in April.		
1.14	Teams will track and report the number of hours spent working on each milestone.	Inspect	Each team member will be responsible for reporting the date and amount of time spent working on each milestone. See section 1.1.5 Hours Spent Working on the CDR Milestone.

VEHICLE REQUIREMENTS

Table 18: Vehicle Requirements

Req #	Requirements	Identification	Verification
2.1	The vehicle will deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,500 feet on their competition launch will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.	Analysis	The target apogee altitude of this vehicle is identified as 4,500 feet. OpenRocket analysis will be used to verify this target altitude. The subscale launch will also be utilized as data to verify our final motor choice for the full-scale design.
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.	Inspection	The target altitude was identified as 4,500 feet by the PDR Milestone.
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.	Analysis/Inspection	The launch vehicle will be modeled in OpenRocket, and significant calculation analysis will be done to determine the descent velocities and kinetic

			energies of the two separately falling pieces. The four-parachute system will be utilized to ensure the safe recovery of the launch vehicle sections. The Safety Officer will inspect the vehicle to determine the reusability of the launch vehicle after the launch.
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. 2.4.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 2 airframe diameters in length. (One body diameter of surface contact with each airframe section). 2.4.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	Inspection	Three independent sections are designed for the full scale vehicle. Coupler/airframe requirements will be followed and nose cone shoulder requirements will be followed as well.
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.	Testing	The launch vehicle will be assembled various times beforehand to ensure a timely assembly on launch day. An assembly checklist will be created by the Safety Officer, and the assembly will be timed.

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.	Testing	The payload system and avionics bay system will be provided with adequate battery systems to sustain power for the 2-hour minimum time. The launch vehicle will be appropriately secured to maintain flight readiness on the pad.
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.	Demonstration	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.
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).	Inspection	All required electrical components and circuitry will be secured within the avionics bay and payload section. The only equipment to initiate launch will be the 12-volt firing system provided.

2.9	Each team shall use commercially available e-matches or igniters. Hand-dipped igniters shall not be permitted.	Inspection	Commercial e-matches will be used for the avionics black powder charges. Ematches for the motor will be provided by the manufacturer when purchased.
2.10	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). 2.10.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone. 2.10.2. 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	Inspection	The selected motor will be a commercially available solid motor propulsion system using APCP. The final motor selection will be identified by the CDR Milestone, see section 1.2 Launch Vehicle Summary

2.11	The launch vehicle will be limited to a single motor propulsion system.	Inspection	The launch vehicle will only contain a single motor for the flight.
2.12	The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newtonseconds (L-class).	Analysis	OpenRocket analysis will be used to determine the total impulse of the launch vehicle. The vehicle will be designed with a total impulse less than 5,120 N-sec.. The final motor selection is not bigger than an L-class, see section 1.2 Launch Vehicle Summary.
2.13	Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: 2.13.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews. 2.13.2. 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. 2.13.3. 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	Inspection	Final vehicle design does not include pressure vessels.

	put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.		
2.14	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.	Analysis	OpenRocket analysis will be used to determine the static stability of the launch vehicle at the rail exit. The center of pressure and center of gravity measurements will determine the rocket's static stability. The rocket will be designed to have a minimum of 2.0 at the rail exit.
2.15	The launch vehicle will have a minimum thrust to weight ratio of 5.0 : 1.0.	Analysis	OpenRocket analysis will be used to determine the minimum thrust to weight ratio. The vehicle will be designed to have a minimum of 5.0:1.0 thrust to weight ratio.
2.16	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.	Analysis	No structural protuberances are present in the final launch vehicle design. A camera mount may be implemented on the upper airframe tube in accordance with requirements if desired

2.17	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	Analysis	OpenRocket analysis will be used to determine the vehicle's rail exit velocity. The launch vehicle will be designed to accelerate to a velocity of 70 ft/s feet/sec. at rail exit.
2.18	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). 2.18.1. 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. 2.18.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude. 2.18.3. The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project. 2.18.4. Proof of a successful flight shall be supplied in the CDR report. 2.18.4.1. Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted. 2.18.4.2. Quality pictures of the as landed configuration of all sections of the	Demonstration / Inspection	Construction of subscale rocket in accordance with competition requirements demonstrated in PDR and CDR milestones. Successful flight data from the 12/17/22 test flight included in CDR milestone. See 3.b.i Recorded Flight Data Selected motor for subscale demonstration flight (I120) meets motor requirements. Subscale design

	launch vehicle shall be included in the CDR report. This includes but not limited to nosecone, recovery system, airframe, and booster. 2.18.5. 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.		
2.19	All teams will complete demonstration flights as outlined below. 2.19.1. Vehicle Demonstration Flight—All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown shall be the same rocket to be flown for their competition launch. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.). The following criteria shall be met during the full-scale demonstration flight: 10 General and Proposal Requirements 2.19.1.1. The vehicle and recovery system will have functioned as designed. 2.19.1.2. The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project. 2.19.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply: 2.19.1.3.1. If the payload is not flown, mass simulators will be used to simulate	Analysis/Demonstration	Vehicle demonstration flight will be performed and reported in accordance with competition timeline. The primary vehicle demonstration flight launch date is scheduled to occur on February 19th at the Tripoli Tampa launch site. The backup date for the demonstration flight is March 5th at the Tripoli Fort Myers launch site. Data from successful flight will be included in a manner adjacent to subscale flight results by the FRR milestone deadline. Further modifications to launch vehicle after test flight will be performed as deemed acceptable by NSL requirements and issues addressed in the redesign will be explicitly stated in the FRR milestone deadline

	the payload mass. 2.19.1.3.2. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass. 2.19.1.4. 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. 2.19.1.5. 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. 2.19.1.6. 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. 2.19.1.7. 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). 2.19.1.8. Proof of a successful flight shall be supplied in the FRR report. 2.19.1.8.1. Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted. 2.19.1.8.2. 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. 2.19.1.9 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. 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. 11 General and Proposal Requirements 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. NO EXTENSIONS WILL BE GRANTED.		
2.20	An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASArequired VehicleDemonstrationRe-flight after the submission of the FRR Report. 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.	Inspection	SOAR will submit an FRR Addendum in the case of not completing a Payload Demonstration Flight prior to the FRR Milestone Report deadline.

2.21	The team's name and Launch Day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	Inspection	Each individual section of the launch vehicle will have the team's name and contact information visible without requiring the vehicle to be opened or further separated.
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.	Inspection	The Safety Officer will ensure that all Lithium Polymer batteries are appropriately secured and protected to prevent impact with the ground. They will all be clearly marked and designated as fire hazards and will be distinguishable from the rest of the payload hardware
2.23	Vehicle Prohibitions 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, MetalStorm, 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. 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	Analysis/Inspection	Forward firing motors are not included in the final launch vehicle design. The motor selected for the full-scale flights (K520) does not expel titanium sponges. Only a single launch motor will be utilized for each flight. Maximum flight velocity as predicted by OpenRocket will not exceed Mach 1. Only up to 4 lbs of ballast may be included in the launch vehicle. LORA transmitters will not exceed 250 mW of power per transmitter. Dense metal will not be utilized in the launch vehicle design and lightweight metals will be included only in areas deemed necessary by large expected operating stresses.

	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). 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. 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.		

RECOVERY REQUIREMENTS

Table 19: Recovery Requirements

Req #	Requirements	Identification	Verification
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.	Analysis	The drogue, streamer, and main parachute will be programmed to release at the appropriate altitudes with a reasonable kinetic energy during the drogue stage descent for the streamer in the upper section.
3.1.1	The main parachute shall be deployed no lower than 500 feet.	Analysis	The main parachute will be programmed to deploy at an altitude above 500 feet with a back-up deployment in case of

			initial failure.
3.1.2	The apogee event may contain a delay of no more than 2 seconds.	Analysis	The apogee event will be simulated accordingly to remain within a 2 second window
3.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	Inspection	The motor will remain secured in the launch vehicle for the duration of the flight
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.	Demonstration	The Safety Officer and Recovery Sub-Team Lead will conduct ground ejection tests for the electronically initiated parachutes/drogue/streamer before each launch.
3.3	Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	Analysis	Hand calculations will be used to determine the launch vehicle's kinetic energy at landing. The upper-section and lower-section of the rocket will be designed to have a kinetic energy at landing below 75 ft-lbf.
3.4	The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	Inspection	The launch vehicle's design included commercially available, redundant altimeters. There will be two altimeters responsible for deployment.
3.5	Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	Inspection	Each altimeter will be powered by its own individual battery. New batteries will be tested and inserted for each launch to remove any possibility of battery failure
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.	Inspection	The avionics bay will have mechanical arming switches to activate the altimeters. The launch vehicle will be designed to allow for switches to be accessible from the exterior.

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).	Demonstration / Inspection	The arming switches can only be activated by inserting and turning the switch keys. The avionics bay will be appropriately secured to verify that it will remain locked in the ON position despite flight forces that will occur. Verification can be found by simulating flight forces on the avionics bay.
3.8	The recovery system electrical circuits will be completely independent of any payload electrical circuits.	Inspection	The avionics bay will be located in a separate section of the rocket. The electronics of each section will be completely isolated from the other.
3.9	Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Inspection	The launch vehicle will be designed with spots for shear pins to be inserted. Each separation point will be utilizing shear pins.
3.10	The recovery area will be limited to a 2,500 ft. radius from the launch pads.	Analysis	Calculations for drift will be completed to verify the launch vehicle will land within the 2,500 feet radius from the designated launch pad.
3.11	Descent time of the launch vehicle will be limited to 90 seconds (apogee to touch down).	Analysis	Written code was used to determine the total descent time of the launch vehicle. The separate sections will both be analyzed to land within the limited 90 second window
3.12	An electronic GPS 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 GPS tracking device.	Inspection	The avionics bay will include a GPS tracking device to verify the landing position of each section. The GPS system will be tested and supplied with ample power before each launch.

	3.12.2. The electronic GPS tracking device(s) will be fully functional during the official competition launch.		
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.	Inspection	The electronics will be placed separately in the avionics bay to provide ample room between the transmitters. The Payload electronics will be placed in a separate section of the launch vehicle to prohibit any further interference. Any other onboard devices that may interfere with the recovery system electronics will be properly shielded from the recovery system.

PAYLOAD EXPERIMENT REQUIREMENTS

Table 20: Payload experiment requirements

Req #	Requirements	Identification	Verification
4.1	College/University Division—Teams shall design a payload capable upon landing of autonomously receiving RF commands and performing a series of tasks with an on-board camera system. The method(s)/design(s) utilized to complete the payload mission shall be at the team's discretion and shall be permitted so long	Inspection / Demonstration	The payload system will undergo a series of unit tests for each component of the mission: alignment after landing, gimbal alignment, RF processing, picture storage. And it will also undergo a series of drop tests to ensure it's capable of landing still operational

	as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. 13 General and Proposal Requirements An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety.		and capable of performing the series of tasks outlined by the RF commands
4.2.1	Launch Vehicle shall contain an automated camera system capable of swiveling 360º to take images of the entire surrounding area of the launch vehicle. 4.2.1.1. The camera shall have the capability of rotating about the z axis. The z axis is perpendicular to the ground plane with the sky oriented up and the planetary surface oriented down. 4.2.1.2. The camera shall have a FOV of at least 100º and a maximum FOV of 180º. 4.2.1.3. The camera shall time stamp each photo taken. The time stamp shall be visible on all photos submitted to NASA in the PLAR. 4.2.1.4. The camera system shall execute the string of transmitted	Inspection / demonstration	A gimbal system was created with two micro servos, where one motor produces 360 degrees of rotation about the camera base and a second adjusts the camera face to be completely upright and thus aligned with the z axis. The program will run the string two minutes after the initial acceleration of the launch. The program will also note the time stamps of the photos taken.
4.2.2	NASA Student Launch Management Team shall transmit a RF sequence that shall contain a radio call sign followed by a sequence of tasks to be completed. The list of potential commands to be given on launch day along with their radio transcriptions which shall be sent in a RF message using APRS transmission in no particular order are: A1—Turn camera 60º to the right B2—Turn camera 60º to the left C3—Take picture D4—Change camera mode from color to grayscale E5—Change camera mode back from grayscale to color F6—Rotate image 180º (upside down). G7—Special effects filter	Inspection / Demonstration	The software inside the main computer shall be revised to check it contains a dictionary list that's accurate to the given potential commands. The software will also be thoroughly revised to ensure the call sign input can be easily set by only modifying a minimal part of the codebase.

	(Apply any filter or image distortion you want and state what filter or distortion was used). H8—Remove all filters. 4.2.2.1. An example transmission sequence could look something like, "XX4XXX C3 A1 D4 C3 F6 C3 F6 B2 B2 C3." Note the call sign that NASA will use shall be distributed to teams at a later time		
4.2.3	The NASA Student Launch Management Panel shall transmit the RAFCO using APRS. 4.2.3.1. NASA will use dedicated frequencies to transmit the message. NASA will operate on the 2-Meter amateur radio band between the frequencies of 144.90 MHz and 145.10 MHz. No team shall be permitted to transmit on any frequency in this range. The specific frequency used will be shared with teams during Launch Week. NASA reserves the right to modify the transmission frequency as deemed necessary. 4.2.3.2. The NASA Management Team shall transmit the RAFCO every 2 minutes. 4.2.3.3. The payload system shall not initiate and begin accepting RAFCO until AFTER the launch vehicle has landed on the planetary surface.	Inspection / Demonstration	(Before arriving at the launch site) A member of SOAR, with a level at or above ham radio technician license, will send a series of commands over the 2m radio band, the computer will listen through the DRA818V module and output the commands to a log file. The log file must have most of the commands exactly as they were sent for this aspect to be working.
4.2.4	The payload shall not be jettisoned.	Inspection	The payload is bolted to a coupler tube that is slid into the main body tube. Once in the body tube, the payload is securely bolted in with ¼ inch screws that bolt into adhesive nuts on the inside of the body tube.
4.2.5	The sequence of time-stamped photos taken need not be transmitted back to ground station and shall be presented in the correct order in your PLAR.	Analysis / Inspection	The current payload design and components don't have the functionality to send any data back to base over RF. The main computer wll be tested to ensure a series of images are stored in its main memory without data loss.

4.3.1	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.	Inspection	The launch vehicle will only utilize energetics during in-flight recovery systems. SOAR will not have any surface operations for this competition.
4.3.2	Teams shall abide by all FAA and NAR rules and regulations.	Inspection	The team leads will ensure to read the FAA and NAR regulations and keep them in mind during development and tests.
4.3.3	Any secondary payload experiment element that is jettisoned during the recovery phase will 14 General and Proposal Requirements receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement the CDR milestone by NASA	Inspection	No secondary payload experiment is currently projected to be performed
4.3.4	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 permission to release the UAS.	Inspection	SOAR's payload current design doesn't implement a UAS.
4.3.5	Teams flying UASs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112–95 Section336; see https://www.faa.gov/uas/faqs).	Inspection	SOAR's payload current design doesn't implement a UAS.
4.3.6	Any UAS weighing more than .55 lbs. Shall be registered with the FAA and the registration number marked on the vehicle.	Inspection	SOAR's payload current design doesn't implement a UAS.

SAFETY REQUIREMENTS

Table 21: Safety Requirements

Req #	Requirements	Identification	Verification
5.1	Each team will use a launch and safety	Demonstration	The Safety Officer will create

	checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.		launch and safety checklists to be included in the FRR report and used during the LRR, as well as distribute copies to the various team leads.
5.2	Each team shall identify a student safety officer who will be responsible for all items in section 5.3.	Demonstration	SOAR conducts interviews for the Chief of Safety (CoS) position at the end of each academic year in order to be prepared for the following NSL competition.
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 5.3.1.2. Construction of vehicle and payload components 5.3.1.3. Assembly of vehicle and payload 5.3.1.4. Ground testing of vehicle and payload 5.3.1.5. Subscale launch test(s) 5.3.1.6. Full-scale launch test(s) 5.3.1.7. Competition Launch 5.3.1.8. Recovery activities 5.3.1.9. STEM Engagement Activities 5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities. 5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data. 5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	Inspection/Demonstration	The Safety Officer will be present during all sanctioned fabrication sessions to ensure all safety guidelines are being followed during the manufacturing process. During ground testing, the safety officer oversees all tests to ensure that they are being conducted in a safe manner. The safety officer will also monitor activities during launch operations and use various checklists to maintain correct assembly processes in order to facilitate a successful launch and recovery. These checklists include but are not limited to payload assembly, launch vehicle integration, and recovery. The safety officer will also create and update documentation regarding workspace safety and material/chemical inventory.
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	Analysis	SOAR has established a working relationship with their local TRA Prefecture and works closely with them to ensure all launch vehicles and

	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.		payloads are authorized under TRA and NAR guidelines.
5.5	Teams will abide by all rules set forth by the FAA.	Analysis	The Safety Officer will stay up to date with FAA guidelines regarding high powered rocketry and forward any new information to the rest of the organization.

ii. Updated list of team derived requirements

Table 22: Team Derived Vehicle Requirements

Requirements	**Method of Meeting Requirement**	**Verification**
The launch vehicle reaches the target altitude of 4,500 feet, within a margin of ± 50 feet.	Data Analysis	Multiple simulation tools, such as OpenRocket Software and Rocketpy (MATLAB/Python), will be utilized to provide as accurate predictions as possible before flight, allowing adjustments to be made to the ballast system as needed.
The launch vehicle is able to withstand all aerodynamic forces sustained during flight, with negligible effects on performance.	Visual confirmation (any structural damage)/Data Analysis	The use of a boattail, and the switch from Fiberglass to Carbon Fiber fins aim to increase the performance of the vehicle, which can be verified through the use of CFD (Computational Fluid Dynamics).
The launch vehicle is able to withstand the force of impact with the ground in the event of recovery system failure,	Structural Analysis	Proper material selection, as well as efficient configuration of the launch vehicle can be verified through the use of FEA (Finite

to the point where, if need be, the vehicle can be launched again within a time period of 2 hours.		Element Analysis).

Table 23: Team Derived Recovery Requirements

Requirements	Method of Meeting Requirement	Verification
Obtain an accurate altitude reading to compare to simulations	Utilization of a designated altimeter to use its recorded max altitude	The altimeter set to being the main altimeter in the avionics bay will have its data used for comparing projected apogee
Verify that parachute can deploy during recovery event	Black powder testing prior to vehicle launch	Main and drogue parachute must be able to escape the body tube during these tests with an acceptable amount of black powder while being in accordance with safety protocols.
Altimeter bay arming	Manufactured holes in switch band must be large enough to allow a key to enter and arm altimeters	Sanding of the key hole will be done if the size is too small to activate the switch.
Pre-Launch altimeter flight configuration	Assurance that altimeters are set to current flight conditions of launch day.	Using the accompanying LCD display with the Missileworks RRC3 provides the team with easy diagnosis of what settings the altimeters are on.
GPS Configuration	Proper coordinate position is showing correctly on LCD screen	Calibration of Missileworks Rtx/GPS device during launch day to set the proper position. Verifying that the GPS module at the ground station is for the ground.

Table 24: Team Derived Payload Requirements

Requirements	Method of Meeting Requirement	Verification
The payload system must be able to activate in a	The main computer will continuously read from the IMU	10 trials will be conducted, where the whole payload will be moved

timely manner upon landing	until it detects a significant change in velocity, then it will wait for 2 minutes (it's supposed to have landed by then) and check again if the payload is stationary to start the mission.	around with great force to simulate the launch. The computer will make sounds with a small piezo once the program starts running. The sound must be emitted through all the trials to confirm activation is working.
The camera system must be aligned as close as possible to the vertical axis	The payload tube will have 4 specific openings, one of the openings will be chosen by the computer based on the IMU data on which could be the closest one to the vertical axis, to account for any slight misalignment a gimbal system attached to the camera will finish aligning to the vertical axis	10 trials will be conducted, where the whole payload will be dropped and placed at different angles and the camera system must come out of the right opening most of the time, which will ensure the first part of the system is working. The gimbal system must also align correctly in most of the trials independent if the right hole was chosen for the second part to be working.
The payload system will be able to store the images from the camera safely	The Main Payload computer will be directly connected to the camera via a ribbon cable. Upon taking a picture it will be immediately stored in main memory, if any processing is needed it will be retrieved and then modified.	The main computer will take a series of pictures, with different post processing commands. After some of the images are taken different scenarios will be simulated: the breaking of the ribbon cable, a power failure, among others we might deem necessary to simulate. Afterwards, if inside its main memory at least some images were preserved and the program didn't get stuck due to the complications, it will be ready.

7. Budgeting and Timeline

a. Updated Line Item Budget

There have been a few changes to the line item budget, and the new catalog is given below.

Table 25: Line item budget for individual components of the airframe and payload sections.

Component	Vendors	Market Value	Shipping
4in Fiberglass Body Tube, 5'	Wildman Rocketry	$128.43	$25.20
4in Fiberglass Coupler Tube, per inch	Wildman Rocketry	$2.86	$25.20
Boat-tail adapter	Wildman Rocketry	$78.00	$20.95
Raspberry Pi Zero	Amazon	$15.99	$0.00
Raspberry Pi Pico	Amazon	$13.25	$0.00
4S LiPo Battery	Amazon	$98.99	$0.00
Raspberry Pi Camera Board	Adafruit	$29.95	$13.34
Raspberry Pi Camera Cable	Adafruit	$3.95	$13.34
IMU Sensor	DFRobot	$39.50	$21.00
IMU Breakout Board	Adafruit	$29.95	$13.34
Photosensitive Sensor Module (Pack of 10)	Amazon	$7.99	$0.00
128 GB Micro SD Card with Adapter	Amazon	$17.21	$0.00
Cesaroni 4G Case	Wildman Rocketry	$87.90	$15.83
Cesaroni 4G Motor	Wildman Rocketry	$153.10	$74.70
Servomotor	Amazon	$15.00	$0.00
54mm Fiberglass Motor Tube, 2'	Wildman Rocketry	$31.68	$27.23
4in Von Karman Fiberglass Nose Cone	Wildman Rocketry	$93.50	$34.70
Metal Pinion	McMaster-Carr	$20.44	$9.77
Metal Rack	McMaster-Carr	$19.29	$9.77
J-B Weld 8281 Steel-Reinforced Epoxy (10oz)	Amazon	$17.98	$0.00
Structural Fiberglass 4'x4'x3/16"	McMaster-Carr	$283.31	$116.20

b. Updated Funding Plan

The funding plan remains the same as previously stated in past documentation. SOAR has managed its budget to allow the continuation of NASA Student Launch through the funding it receives from Student Government. The expense chart has been updated to reflect the current expenditures.

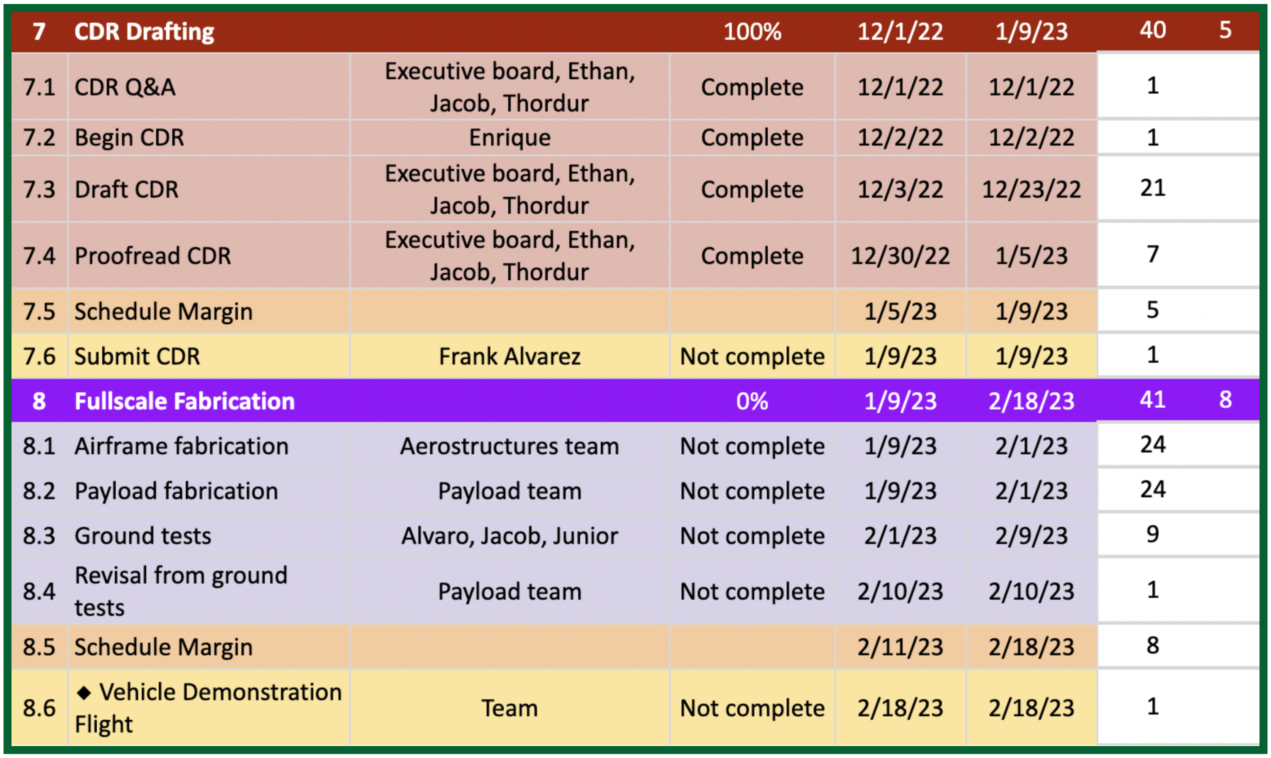
Table 26: Budget allocation, expenses incurred, and amount remaining.

CATEGORY	BUDGET	EXPENSES	AMT. REMAINING
Consumables	$ 1,000.00	$ -	$ 1,000.00
Aerostructures	$ 3,000.00	$ 2,552.13	$ 447.87
Payload	$ 3,000.00	$ 1,059.74	$ 1,940.26
Avionics & Recovery	$ 1,457.63	$ 131.50	$ 1,326.13
TOTAL	**$ 8,457.63**	**$ 3,743.37**	**$ 4,714.26**

It has been determined that the funding allocations are appropriate to continue NASA Student Launch. Payload and avionics and recovery still retain an ample amount of funding to continue purchases. Aerostructures has submitted all major components to be purchased by Student Government, and still has a few hundred dollars to purchase unexpected components or to replenish hardware. Consumable funding will be used this semester to replace depleted fastener and adhesive stocks.

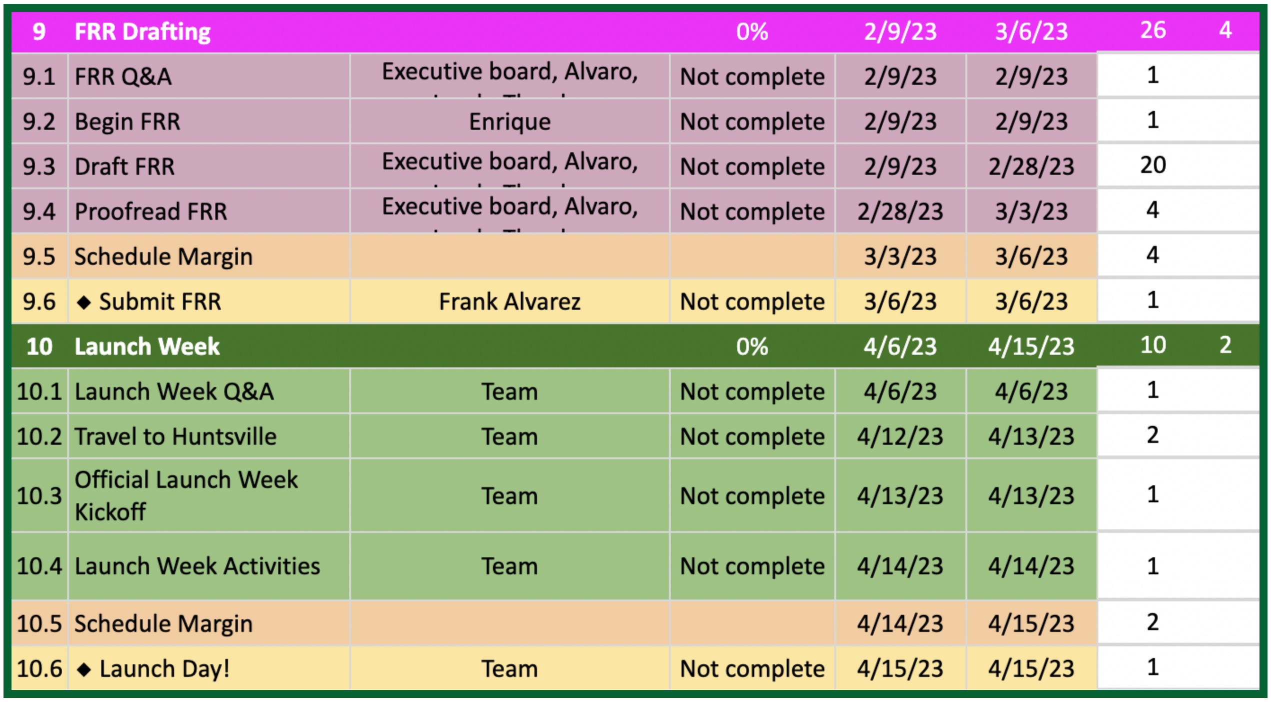
c. Updated Timeline

The project timeline has progressed as expected, and no changes have been made from the fullscale fabrication into the launch week sections. The remaining sections of the project timeline follow.



7	**CDR Drafting**		100%	12/1/22	1/9/23	40	5
7.1	CDR Q&A	Executive board, Ethan, Jacob, Thordur	Complete	12/1/22	12/1/22	1	
7.2	Begin CDR	Enrique	Complete	12/2/22	12/2/22	1	
7.3	Draft CDR	Executive board, Ethan, Jacob, Thordur	Complete	12/3/22	12/23/22	21	
7.4	Proofread CDR	Executive board, Ethan, Jacob, Thordur	Complete	12/30/22	1/5/23	7	
7.5	Schedule Margin			1/5/23	1/9/23	5	
7.6	Submit CDR	Frank Alvarez	Not complete	1/9/23	1/9/23	1	
8	**Fullscale Fabrication**		0%	1/9/23	2/18/23	41	8
8.1	Airframe fabrication	Aerostructures team	Not complete	1/9/23	2/1/23	24	
8.2	Payload fabrication	Payload team	Not complete	1/9/23	2/1/23	24	
8.3	Ground tests	Alvaro, Jacob, Junior	Not complete	2/1/23	2/9/23	9	
8.4	Revisal from ground tests	Payload team	Not complete	2/10/23	2/10/23	1	
8.5	Schedule Margin			2/11/23	2/18/23	8	
8.6	◆ Vehicle Demonstration Flight	Team	Not complete	2/18/23	2/18/23	1	

Fig. 30: Timeline sections of CDR drafting and fullscale vehicle fabrication.



9	**FRR Drafting**		0%	2/9/23	3/6/23	26	4
9.1	FRR Q&A	Executive board, Alvaro,	Not complete	2/9/23	2/9/23	1	
9.2	Begin FRR	Enrique	Not complete	2/9/23	2/9/23	1	
9.3	Draft FRR	Executive board, Alvaro,	Not complete	2/9/23	2/28/23	20	
9.4	Proofread FRR	Executive board, Alvaro,	Not complete	2/28/23	3/3/23	4	
9.5	Schedule Margin			3/3/23	3/6/23	4	
9.6	◆ Submit FRR	Frank Alvarez	Not complete	3/6/23	3/6/23	1	
10	**Launch Week**		0%	4/6/23	4/15/23	10	2
10.1	Launch Week Q&A	Team	Not complete	4/6/23	4/6/23	1	
10.2	Travel to Huntsville	Team	Not complete	4/12/23	4/13/23	2	
10.3	Official Launch Week Kickoff	Team	Not complete	4/13/23	4/13/23	1	
10.4	Launch Week Activities	Team	Not complete	4/14/23	4/14/23	1	
10.5	Schedule Margin			4/14/23	4/15/23	2	
10.6	◆ Launch Day!	Team	Not complete	4/15/23	4/15/23	1	

Fig. 31: Timeline sections of FRR drafting and launch week activities.

8. References

"RTX," *RTx*. [Online]. Available: https://www.missileworks.com/rtx/.

"RRC3," *RRc#*. [Online]. Available: https://www.missileworks.com/rrc3//.