NASA STUDENT LAUNCH

2022-2023

Preliminary Design Review

University of South Florida

Society of Aeronautics and Rocketry

4202 East Fowler Avenue, MSC Box #197

October 26th, 2022

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1. Summary of PDR 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. Name of mentor, TRA number and certification level, and contact Information

Jonathan Fitzer.

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

iii. Documented hours spent working on the PDR milestone

A total of 67.5 man-hours were spent working on the PDR milestone.

iv. Team social media presence established

Table 1: Social media presence with handles included

Social Media Platform	Handle
Instagram	@usfsoar

b. Launch Vehicle Summary

The target altitude for SOAR's full-scale rocket will be to reach **4,500ft**.

The preliminary motor choices to power our full-scale are the Cesaroni: **K490**, **K635**, and the **K1200**.

The main airframe is 4" in diameter and the length of the rocket is 113". 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 recovery system will be a dual deploy. At **apogee** a black powder charge separates the upper body tube from the avionics bay and a **streamer** is deployed. The main parachute will then deploy at **700ft** within 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 Proposal

a. Changes made to vehicle criteria

As a result of continued design iterations, certain changes to the launch vehicle, such as its dimensions and internal arrangement of components, have been made. Length of the full-scale launch vehicle has increased from $80in$ to $106in$, as a result of the availability of specific diameter nosecones that are made with specific lengths. The launch vehicle requires a nose cone with a shoulder outer diameter of $4in$, and a base diameter equal to that of the body tube, which is $4.02in$. The launch vehicle no longer consists of three separate sections, being the upper transition/nose cone/payload, midsection/avionics bay, and booster section. It now consists of two large sections, being the upper body tube/nose cone, where the payload will be housed in the upper body tube, and a booster section. This was due to the fact that the size of the payload was significantly reduced, therefore placing it in the upper body tube allowed for more "freedom" in design if any changes would need to be made, as well as providing the system with enough room to function properly.

b. Changes made to payload criteria

Payload design, as a product of discussed vehicle changes and design iterations, has also changed significantly. Rather than attempting to land the payload section of the launch vehicle vertically utilizing deployable landing legs, the upper body tube, housing the payload, will land horizontally. There will be four small holes in the airframe spaced 90° apart. As the camera system (camera and servo motor) spins within the vehicle, a sensor will be used to select the hole that is closest to the oriented Z-axis, and a small-scale gravity gimbal will assist in further aligning the system. Two cuts, roughly the width of the camera system, will be made in the airframe at the possible Z-axis locations on either side of the vehicle. A rack and pinion linear actuator will then push the camera up through the airframe, with the cut piece of the body tube being attached to the top of the system when it deploys, and it will then be able to perform the necessary tasks. Vertical landing was abandoned as a result of several issues. The first being the complexity of the system did not provide an adequate margin of error in case of a failure, and the smaller scale of our rocket did not allow for proper redundant systems to be implemented. The second issue came with housing and deploying the landing legs themselves. Mounting the legs on the outside of the airframe would have caused an unacceptable degree of drag, and housing the legs within the interior of the airframe would not allow much room for the payload, as well as would require multiple cuts/protuberances on/in the airframe. The third issue was that of stability and ensuring that the payload section would land vertically, given the forces acting on the section due to the other attached components of the vehicle, as the payload would not be allowed to jettison from the other sections.

c. Changes made to project plan

There have been a few changes made to the project plan since the proposal. This is mainly reflected within the Gantt chart timeline detailed in Section 6. The updated Gantt chart divides the project into test flight windows of the subscale and full scale rocket. The PDR, CDR, and FRR are all contained within their own respective task sections.

Funding and budgeting has not changed since the proposal. Sources of funding remain as funds acquired from Student Government as the University of South Florida.

Outreach and student engagement remains unchanged as well. Efforts in outreach such as Engineering Expo, the Great American Teach-in, and events on campus are planned to occur during the year.

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, 4in (diameter) by 106in (length) 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 between 2.3 and 2.6
- 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. Review of design at system level and analysis of alternative designs

The design of the launch vehicle for this year's NSL competition is a 4" diameter rocket with 3 symmetrical-trapezoidal fins canted 120 degrees apart from each other. The rocket consists of two independent sections, being the booster section and nose cone/upper body tube.

Initially, SOAR designed the launch rocket to have a conventional retaining ring at the aft portion of the booster. The addition of a boat tail to improve the aerodynamics of the full-scale rocket was accepted as SOAR has not tested this device before. SOAR will test this system by including the boat tail in our OpenRocket simulations and predicting the altitude of the sub-scale launched with this device attached. A $\Delta = \pm\ 50ft$ is the target accuracy with the sub-scale launches as well.

Split-fins briefly were introduced to the design of our full-scale rocket, but upon much consideration these were not selected due to the uncertainty of how OpenRocket would calculate the aerodynamics of that design. Furthermore, SOAR strives to have a rocket that has a functional payload, and adding complexities to the launch vehicle itself is not worth the invested time designing, fabricating and testing this.

iii. Points of Separation

The two points of separation for the full scale rocket 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 acommanying 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.

Further testing on the amount of shear pins needed to hold the rocket together will be done during the sub-scale black-powder test fires.

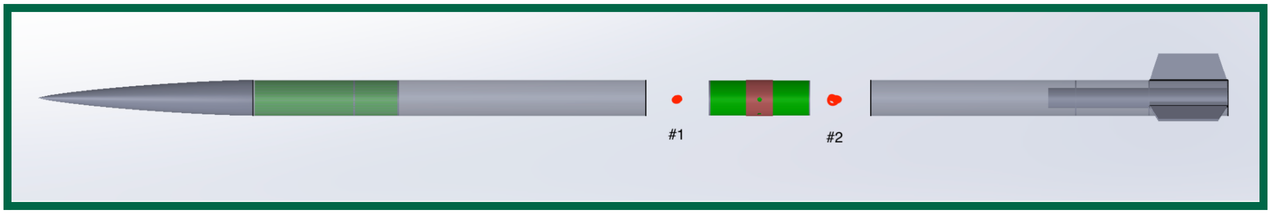


Fig. 1: Locations of points of separation.

iv. Vehicle Design Summary

1. Airframe:

The airframe of the launch vehicle was selected to be constructed as a 4 in. diameter, G12 fiberglass tube. A 6-inch diameter rocket was considered but the extra space was not needed for the payload to work. This also increased the weight of the rocket and therefore would lead to the necessity of a larger motor to power it. G12 fiberglass was the selected material based on its availability and its superior strength to phenolic tubing. It is also significantly cheaper than a same sized carbon fiber tube. The launch vehicle must be able to perform for the duration of the competition, and SOAR has years of experience using this type of material for airframe construction.

2. Fins:

The launch vehicle will include a three-fin design, composed of three carbon fiber fins. Compared to four fins, the three-fin design reduces drag, allowing the launch vehicle to achieve an optimal apogee. The fins have a height of 3.2 in and a thickness of 0.125 in, providing a strong level of stability and stiffness. The material selection of carbon fiber was due to its reduced weight, higher rigidity, and higher strength compared to a conventional G10 fiberglass sheet. The lightweight capabilities of the carbon fiber fins keep the launch vehicle in range of reaching the desired apogee, and the high strength and rigidity of the fins ensure that the launch vehicle can withstand any impact. The fins will be a conventional trapezoidal shape that has been fine tuned to achieve the desired stability for our rocket's specifications.

3. Nose cone:

The nose cone selected has the Von-Karman characteristic. Made of G12 fiberglass, this nose cone provides the best flight characteristics for the speeds that our full-scale rocket will be achieving. A second benefit of this nose cone is that Wildman Rocketry has these nose cones available and the fabrication of an in house nose cone is not necessary. The Wildman Rocketry nose cones also come with an aluminum tip to provide increased stiffness. For these reasons, SOAR will be using the 4" - 6.0-1VK nose cone sold by Wildman Rocketry.

4. Internal Couplers, Bulkheads, and Centering Rings

The internal couplers will be composed of G10 fiberglass sheet. Fiberglass was considered over phenolic tubing since it is stronger and lighter, which is more optimal for the launch vehicle design. All the bulkheads are made from a 0.1875 in thick G10 fiberglass sheet since it can be manufactured in house. The centering rings are also composed from the 0.1875 in thick G10 fiberglass sheet, and one is located at the top of the motor tube, a second one right where the fins begin, and a third one where the fin ends. This provides the fins with the extra strength needed to withstand any impact with the ground. This also assists with the motor tube assembly being as centered as possible with respect to the axis of the body tube.

5. Altimeter Bay

The tubing of the altimeter bay is made of G12 fiberglass. The dimensions of this tubing make it so that the altimeter tubing slides with ease through the main body tube.. The switch band will also be made of G12 fiberglass and will have the same diameter as the body tube. G10 fiberglass sleds will be made from our sheets which will have attachment points for the two altimeters and two batteries.

6. Dimensional view

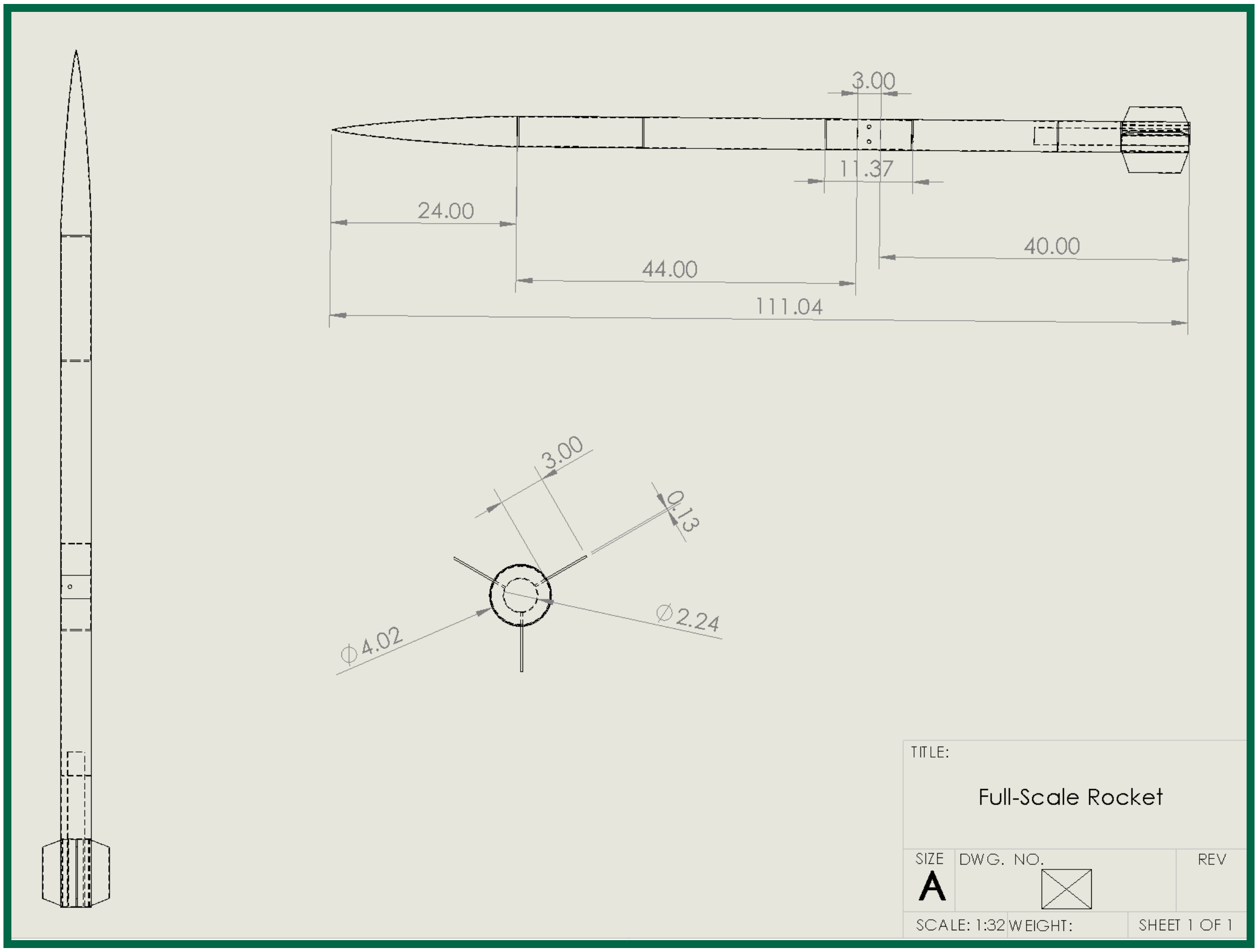


Fig. 2: Dimensional drawing of full-scale

v. Review of motor alternatives

The alternative motor choices that were selected to power the full-scale rocket are the Cesaroni K490 Cesaroni K1200 and Cesaroni K635.

(**Note:** Each motor was simulated on a 12’ 1515 launch rail that is canted 5 degrees towards the wind at a wind speed of 5 mph from the north, with payload and ballast weight being held constant for each motor analysis).

The Cesaroni K490 was chosen as the leading candidate because its target apogee is closest to the 4,512ft. If the manufactured payload is heavier than the simulated payload mass, the ballast system weight will be lowered to combat this change.

See below the simulated values obtained through OpenRocket's simulation program and thrust curve for given motor.

	Name	Configuration	Velocity off rod	Apogee	Velocity at depl...	Optimum delay	Max. velocity	Max. acceleration	Time to apogee
● ✓	K490 w/ Ballast(1....	[K490-GR-10]	62.5 ft/s	4512 ft	N/A	13.7 s	541 ft/s	165 ft/s²	17.7 s

Fig. 3: Simulation values for the Cesaroni K490.

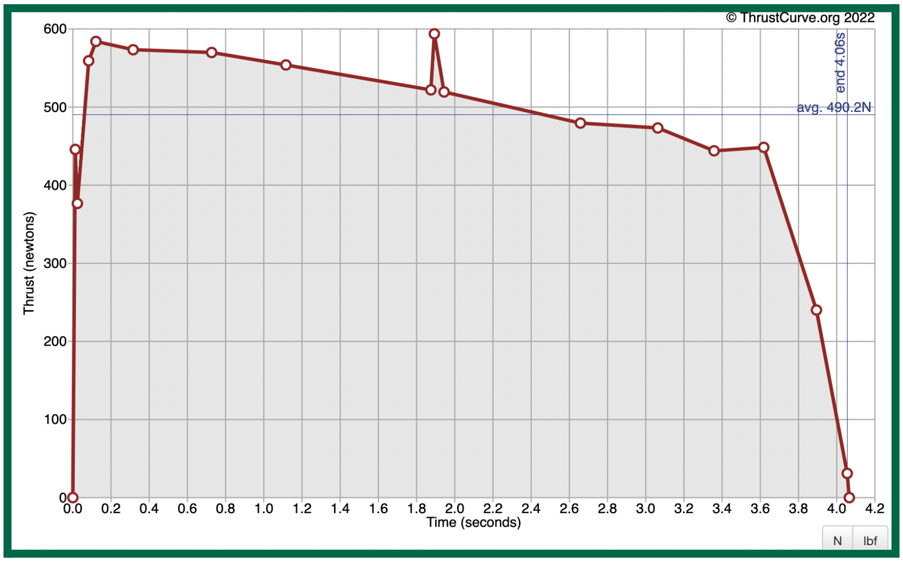
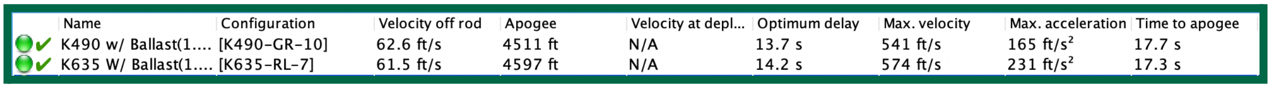


Fig. 4: Thrust curve for Cesaroni K490 [1].

The second motor for consideration for the full-scale rocket is the Cesaroni K635. The target apogee of this motor is estimated to be at 4,598. The purpose of selecting a motor that is above our current selected apogee of 4,500 ft is if the payload system has to increase its weight to future iterations, we can utilize the extra thrust to achieve the target altitude. It is also important to note that the ballast system can be fine tuned to obtain our desired altitude.

See below the simulated values obtained through OpenRocket's simulation program and thrust curve for the given motor.



	Name	Configuration	Velocity off rod	Apogee	Velocity at depl…	Optimum delay	Max. velocity	Max. acceleration	Time to apogee
● ✓	K490 w/ Ballast(1….	[K490-GR-10]	62.6 ft/s	4511 ft	N/A	13.7 s	541 ft/s	165 ft/s²	17.7 s
● ✓	K635 W/ Ballast(1….	[K635-RL-7]	61.5 ft/s	4597 ft	N/A	14.2 s	574 ft/s	231 ft/s²	17.3 s

Fig. 5: Simulation values for the Cesaroni K635.

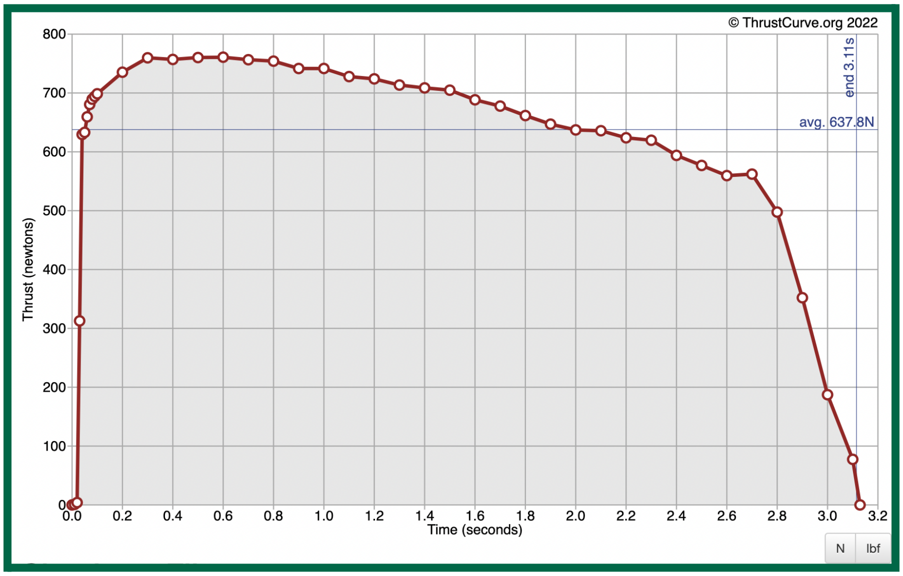
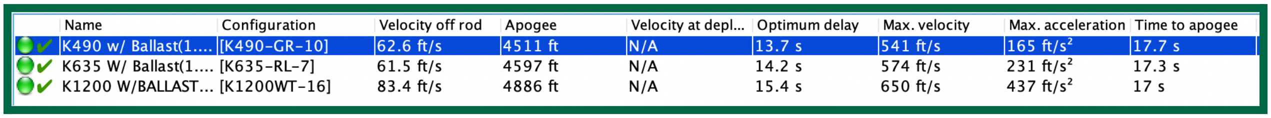


Fig. 6: Thrust curve for Cesaroni K635 [2].

The final motor selection was chosen to be the Cesaroni K1200. The simulated apogee for this motor is 4,886 ft. This is quite off from the 4,500 ft target apogee. The reasoning behind choosing this motor is because of the fact that there were no alternatives for 54mm 5 grains that were close to 4,500ft besides the ones stated previously. This motor could be used if our full-scale rocket gains a significant weight change.

See below the simulated values obtained through OpenRocket's simulation program and thrust curve for the given motor.



	Name	Configuration	Velocity off rod	Apogee	Velocity at depl…	Optimum delay	Max. velocity	Max. acceleration	Time to apogee
● ✓	K490 w/ Ballast(1….	[K490-GR-10]	62.6 ft/s	4511 ft	N/A	13.7 s	541 ft/s	165 ft/s²	17.7 s
● ✓	K635 W/ Ballast(1….	[K635-RL-7]	61.5 ft/s	4597 ft	N/A	14.2 s	574 ft/s	231 ft/s²	17.3 s
● ✓	K1200 W/BALLAST…	[K1200WT-16]	83.4 ft/s	4886 ft	N/A	15.4 s	650 ft/s	437 ft/s²	17 s

Fig. 7: Simulation values for the Cesaroni K1200.

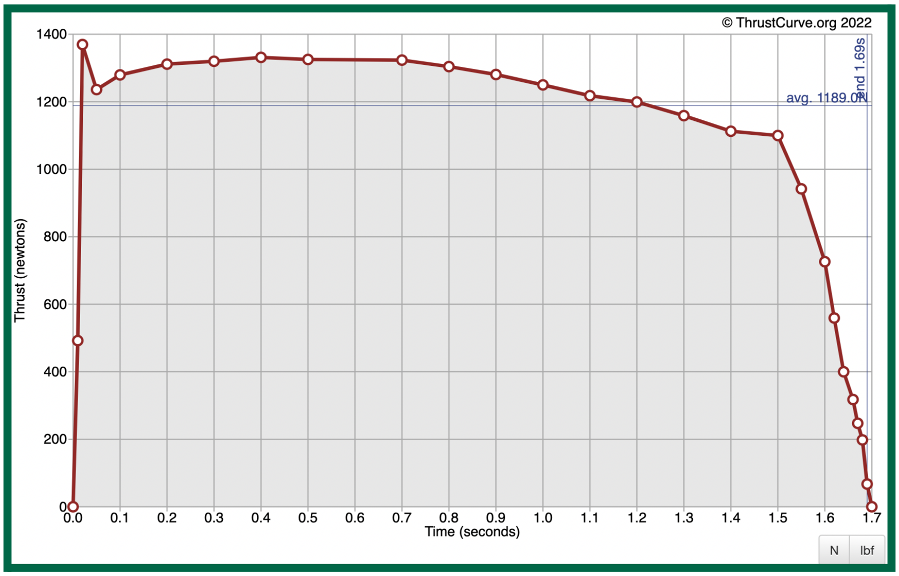


Fig. 8: Thrust curve for Cesaroni K1200 [3].

b. Recovery Subsystem

i. Review of design at component level and analysis of alternative designs

When reviewing whether to use a drogue or streamer to bring down the rocket from apogee, the decision to use a streamer was made because the use of a drogue would slow down the rocket more than the streamer, making the time for descent longer than the 90 second requirement from NASA.

ii. Preliminary analysis of parachute sizing

Parachute sizing was done through the use of code, using the equation in the image provided by NASA [4] to find the velocity given the weight, air density, drag coefficient, and area. The air density is given by the same image which is 1.229 kg/m^3, with the weight from the openrocket, and the drag coefficient and diameter of the parachute given by the provider. Since the units provided are in imperial units we imputed the conversions from inches to meters and pounds to kilograms. Using the diameter given to us we use the formula for the area of a circle to calculate the area of the parachute. After calculating the velocity, we used it to calculate the kinetic energy using the equation for kinetic energy, then converted it back into foot pounds. Finally using this code to test different parachute sizings with the requirements from NASA.

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

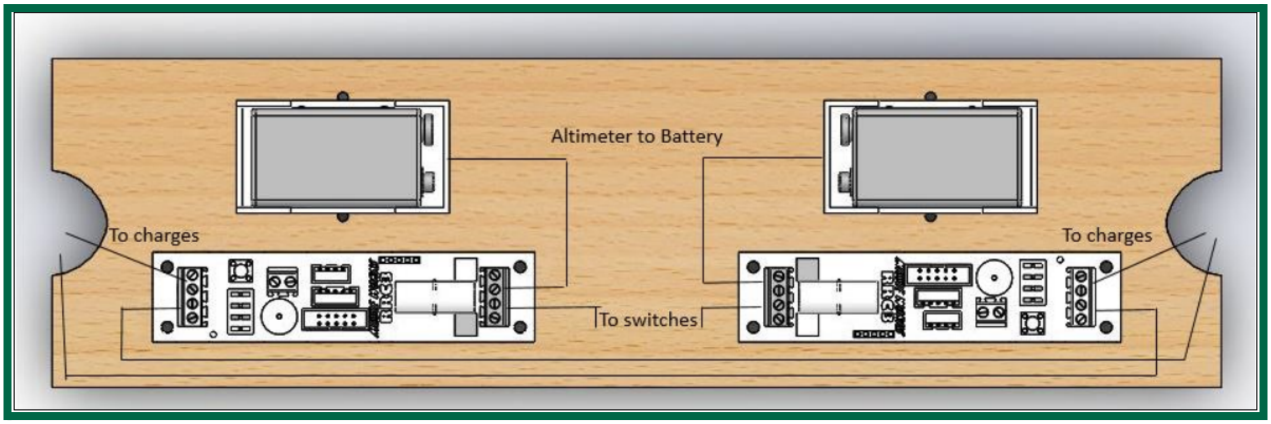


Fig. 9: Altimeter diagram sled for avionics bay.

iv. Choice of leading components amongst alternatives

SOAR has had extensive experience with Misslework RRC3 altimeters. It is taught to new members on how to program these devices for launch. SOAR is able to reuse these devices for future launches as well, leading to cost savings on altimeters.

v. Demonstration of redundancy within the system

The avionics bay will utilize two Missile Works RRC3 altimeters that will be powered by a 9V battery for each unit. The reasoning behind this decision is for redundancy on the recovery system such that if there is a failure on the first altimeter, the second one may activate the black powder charge.

c. Mission Performance Predictions

i. Declaration of team’s official Competition Launch target altitude (ft.)

The official Competition Launch target altitude for SOAR’s full-scale rocket is to reach **4,500 ft.**

ii. Flight profile simulations

With the utilization of the Cesaroni K490 on a **12” 1515** launch rail that will be canted 5 degrees towards the wind, SOAR is able to obtain a sensible simulation of the flight characteristics for the designed full-scale. The simulation still has the same ballast and payload mass configuration as well.

The data provided in the “*Review of motor alternatives*” section still applies to the simulations provided below. OpenRocket provides the user with the ability to create a graph with the information of the rocket's acceleration, altitude, and velocity with a given motor selection.

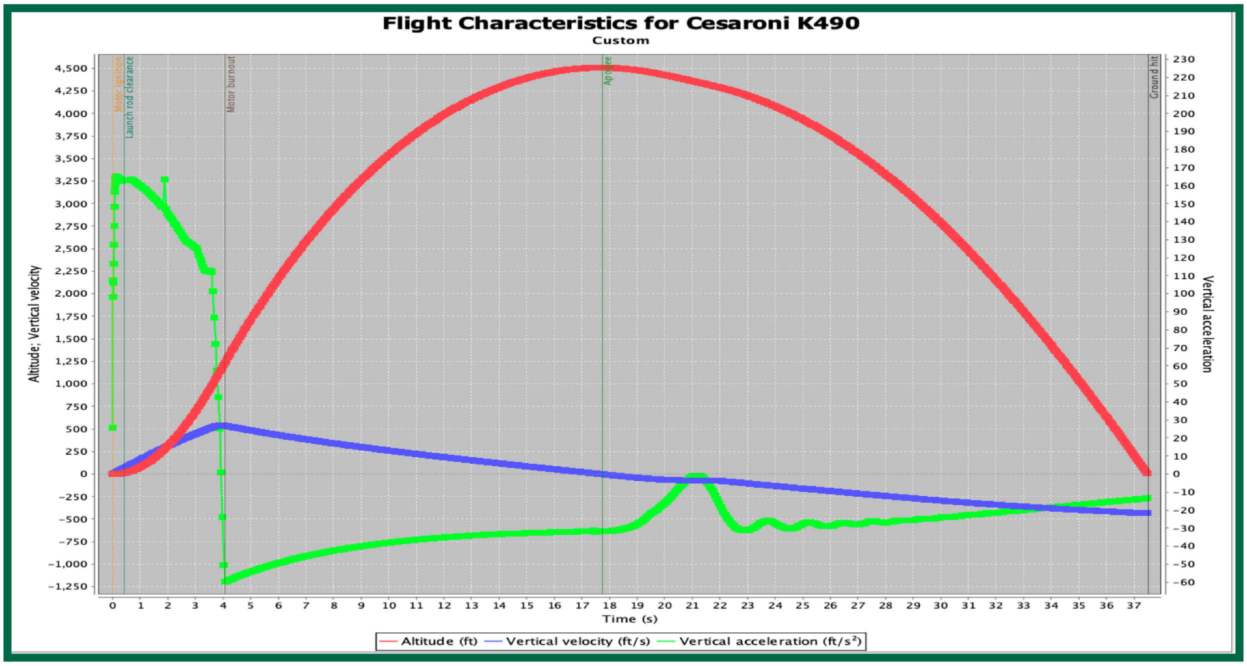


Fig. 10: Flight characteristics of full-scale with K490 motor.

The weight of the full-scale rocket with motor is at 21 lbs and the peak thrust produced by the motor is 132.8 lbf. This leads to a thrust-to-weight ratio of **6.32:1** which satisfies the NSL requirement of a minimum of **5:1**.

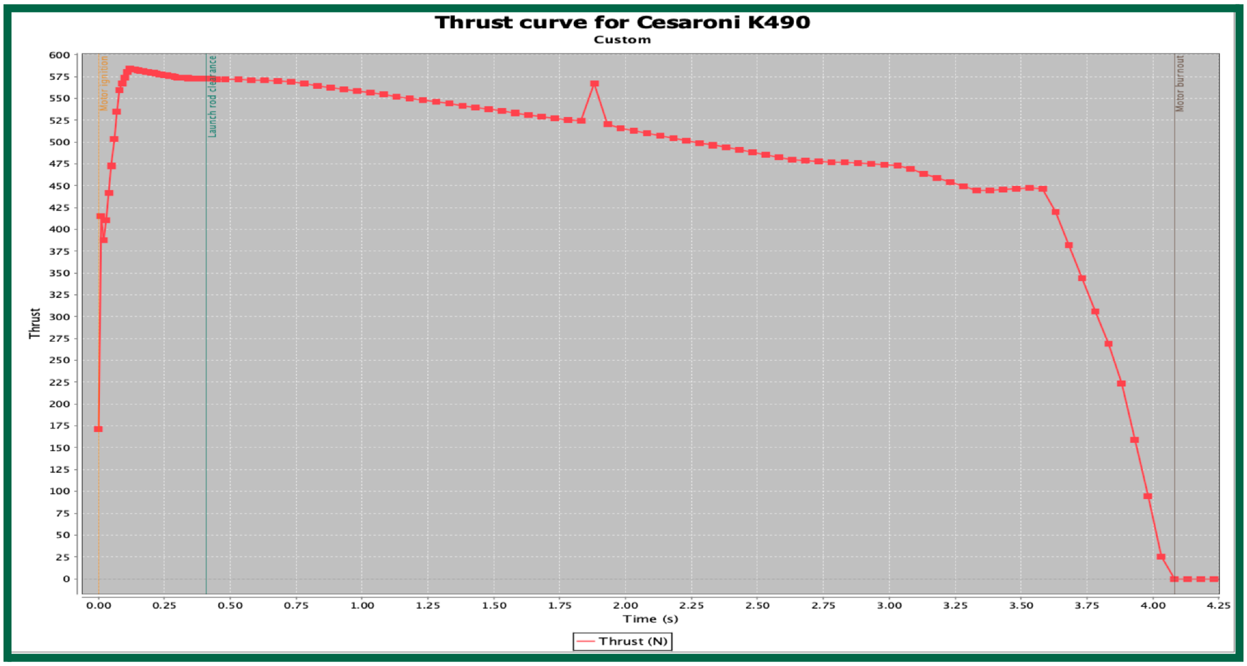


Fig. 11: OpenRocket simulated thrust curve for Cesaroni K490.

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

SOAR’s full-scale stability margin is 2.45 on the launch pad. The center of gravity is located 62.752” and the center of pressure is 72.62” from the nose cone.

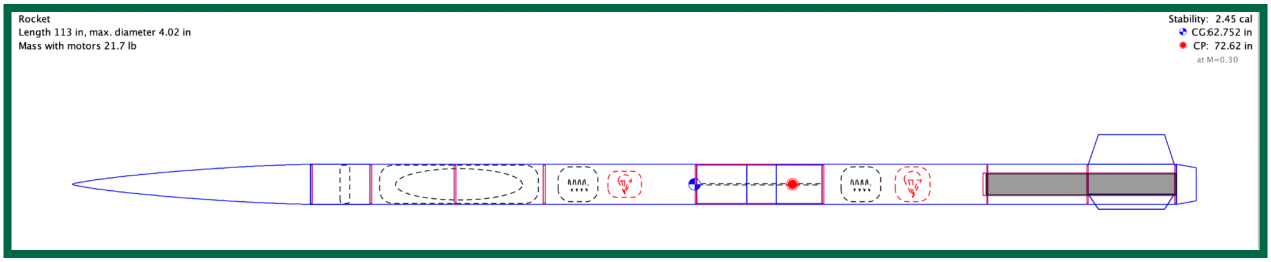


Fig. 12: OpenRocket model of full-scale rocket with CP/CG/Stability values.

iv. Calculation of kinetic energy at landing

Using the formula for kinetic energy, $KE = (1/2)mv^2$, with the total weight of the rocket, and the velocity of the rocket after the deployment of the main parachute, we calculated the kinetic energy of the rocket at landing to be 57.943 ft-lbs.

v. Calculation of expected descent time

When calculating the expected decent time for the rocket we used the equation for the velocity of the rocket, $v = \sqrt{}((2W)/(Cd * r * A))$, to calculate the velocity from apogee to main event, and from main event landing. After finding the two velocities we took the difference in altitudes for both the apogee to main event and the main event to landing and divided by the respective velocity to find the descent time for both sections, Then adding them up two times to find the total expected descent time to be 85.451s.

vi. Calculation of expected drift for five cases

For the calculations of the expected drift we used OpenRocket to simulate the five different wind speed cases, plotting the lateral distance against time for the rocket.

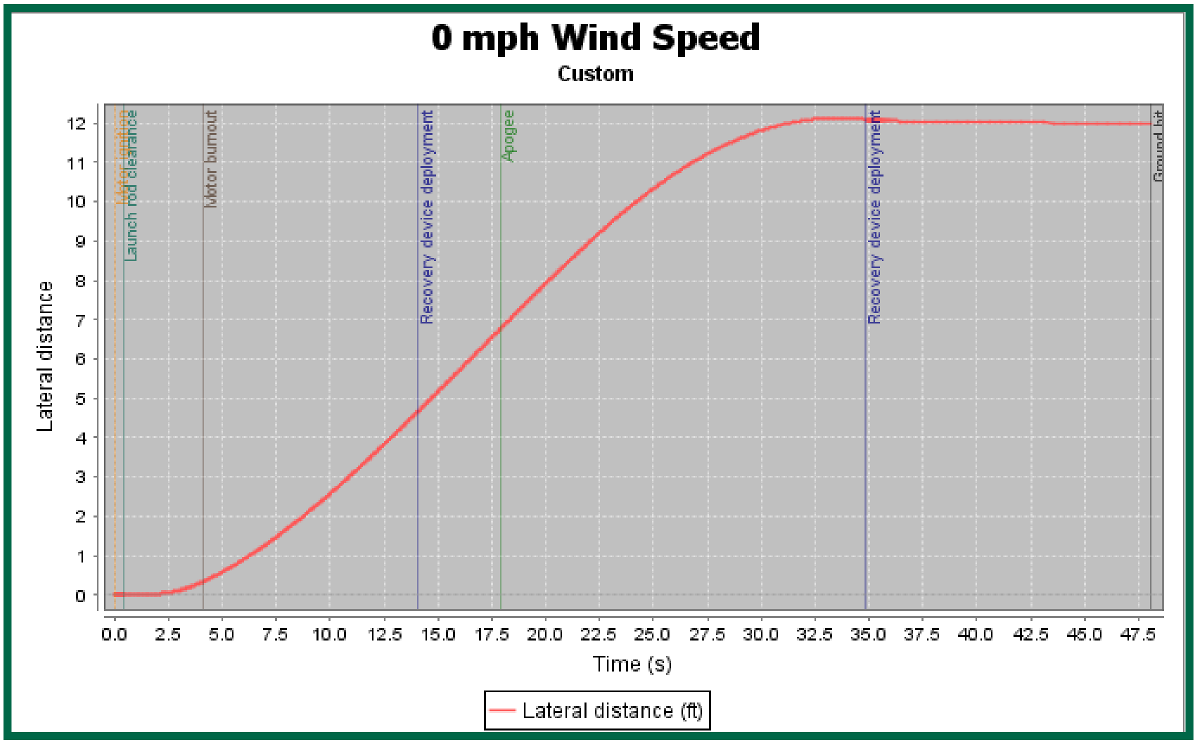


Fig. 13: OpenRocket graph of expected drift distance with 0 mph wind speeds.

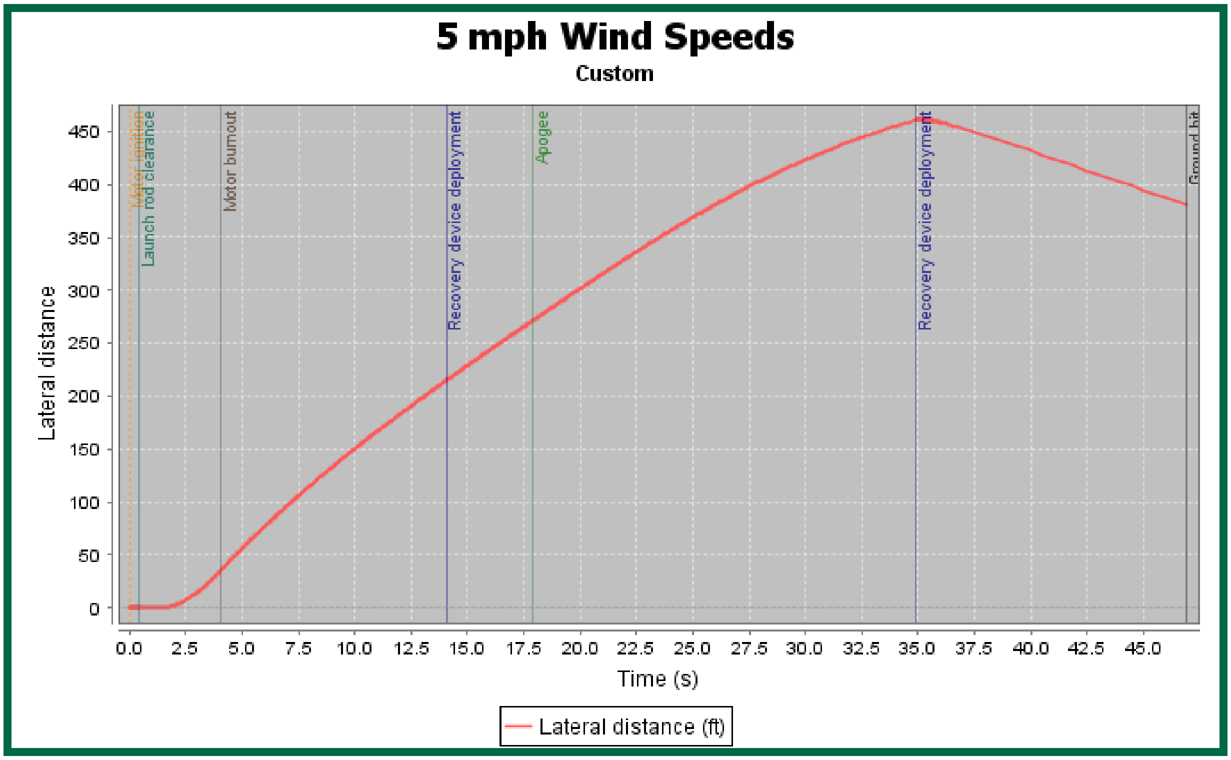


Fig. 14: OpenRocket graph of expected drift distance with 5 mph wind speeds

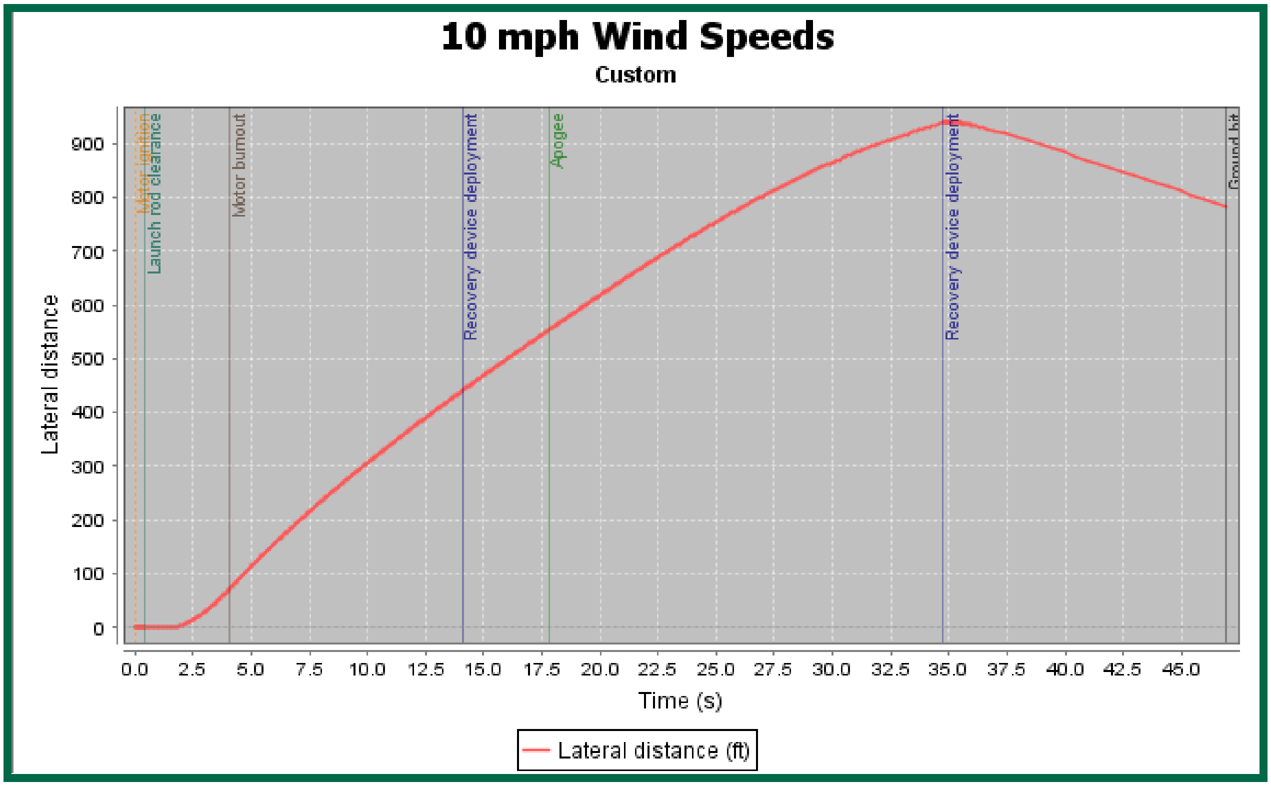


Fig. 15: OpenRocket graph of expected drift distance with 10 mph wind speeds.

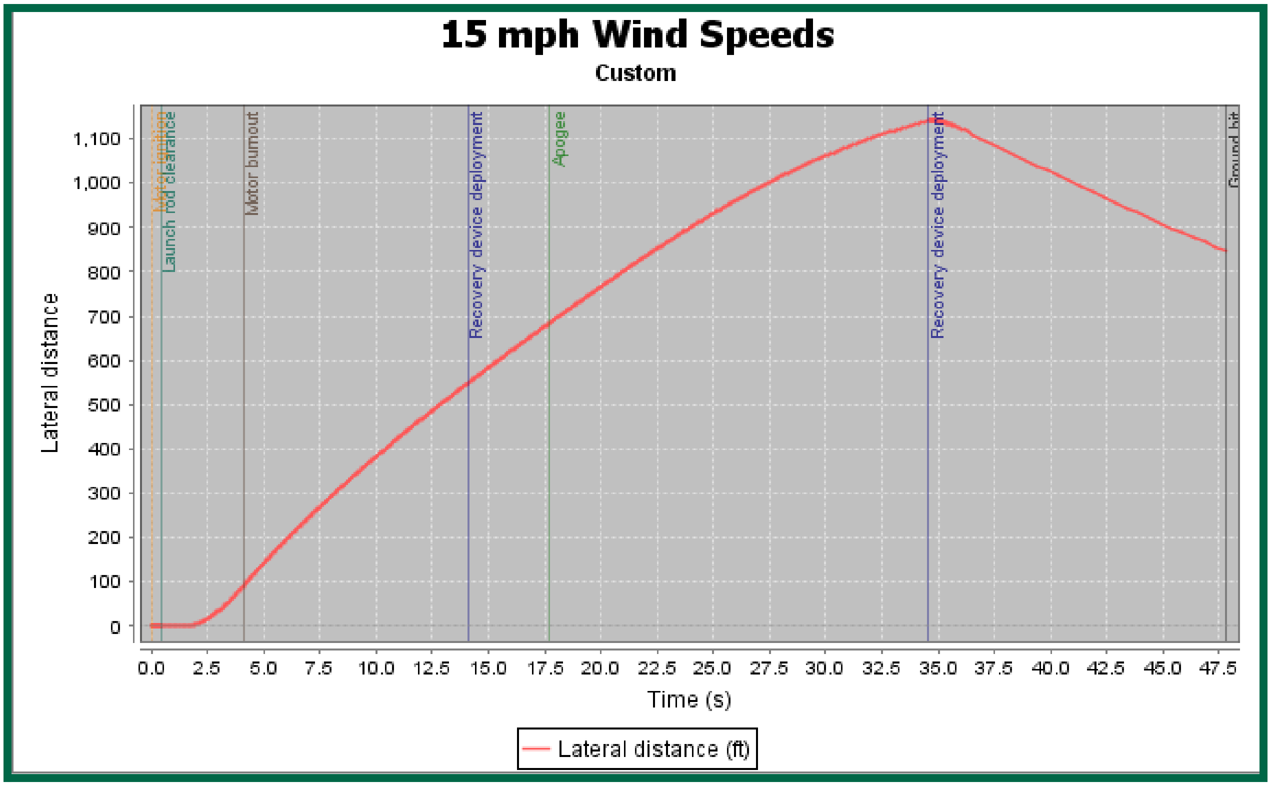


Fig. 16: OpenRocket graph of expected drift distance with 15 mph wind speeds.

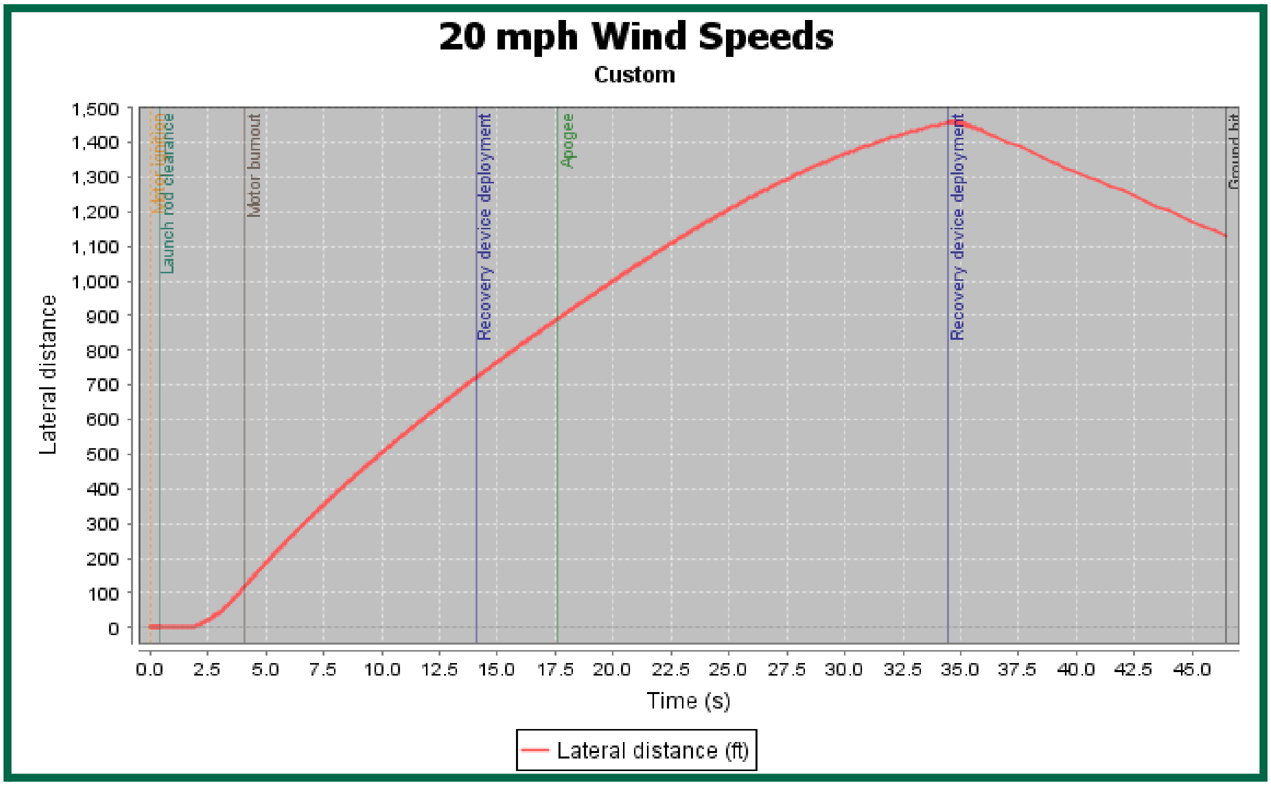


Fig. 17: OpenRocket graph of expected drift distance with 20 mph wind speeds.

vii. Presentation of alternative calculation methods

For an alternative calculation method you can multiply the five different wind speed cases by the descent speed to find the maximum amount of distance the rocket will drift.

viii. Discussion of differences between calculations

Doing the calculations for the rocket through the alternative method would not include any drifting of the rocket as it goes upwards and only would account for the maximum drift as it comes down from apogee. However, the OpenRocket simulation does not account for streamers well and could skew the results a bit.

4. Payload Criteria

a. Selection, Design, and Rationale of Payload

i. Description of payload objective and experiment

Upon landing, the Servo Stabilized Camera System (SSCS) payload design will utilize a series of sensors to determine its orientation along the roll axis. There will be four exit ports positioned 90° apart in the upper body section. Upon landing the rocket will use an internal 10 DOF IMU to determine its orientation relative to the ground, the camera will then use the orientation data to rotate internally and align its position with one of the four holes that is closest with the z-axis. Once the camera is aligned, a rack and pinion system will extend the camera on a servo outside the airframe so it will be capable of taking pictures of the surrounding area. The main computer inside the payload will then begin to receive RF commands and perform a set tasks such as turning 60°, taking pictures, or applying filters.

Team Criteria

The following criteria needs to be met to consider the success of the payload module:

1. The camera module is able to rotate internally, detect, and align with one of the four holes that is closest in the z-axis.
2. The linear actuator is able to extend successfully and place the camera outside of the airframe so it has views of the surrounding area.
3. The two-axis gimbal corrects the position of the camera so it is fully in the z-axis and can rotate 360°.
4. After stabilization of the camera, the payload is able to receive radio frequency commands and complete a series of tasks.

ii. Review of design at a system level and discussion of alternative designs

1. Linear Actuator

A MG90S micro servo will be secured to a bulkhead located in the upper section of the body tube as shown in the figure below. The linear actuator will be mounted on top of the servo so it can rotate within the body tube. The linear actuator will be made up of a second MG90S servo, motor bracket, and a rack and pinion. The rack will be positioned along the centerline of the body tube to maximize the length of the rack and thus maximizing its overall deployable length. The rack will be made of 1018 carbon steel allowing for maximum stiffness and avoiding any possible buckling as it presses against the exit port hole. A metal gear made of 1144 carbon steel will be placed on top of the micro servo to drive the actuation of the rack.

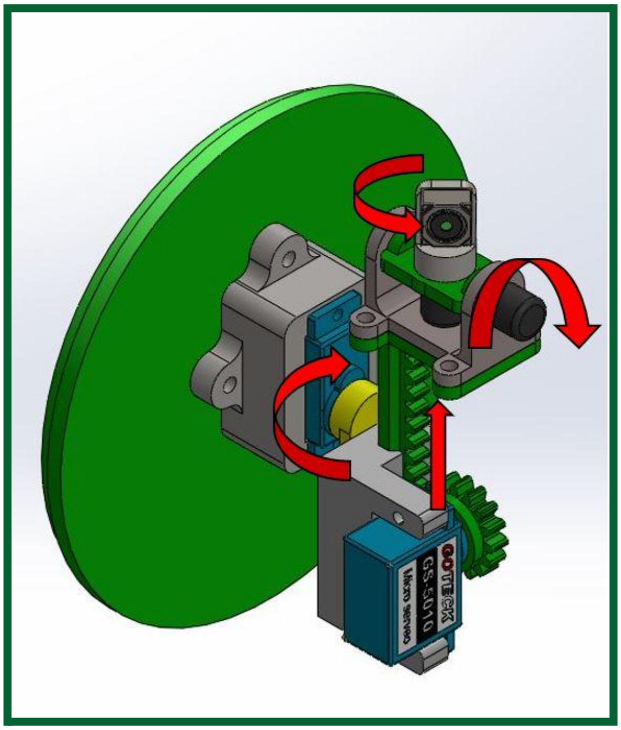


Fig. 18: Solidworks model of the linear actuator.

2. Two-Axis Camera Gimbal

The camera will be mounted on a two-axis gimbal and placed on top of the rack. The gimbal utilizes two Micro Miniature Tiny 8mm Stepper Motors to drive the actuation. Once the camera is extended with the linear actuator, the gimbal will be able to further stabilize the camera and correct for any misalignments in the z-axis. The maximum it would need to correct for is 45° due to its geometry with four possible exit ports. The other stepper motor will allow the camera to rotate 360° and take pictures of the surrounding area. This system along with the camera servos will utilize its own battery source for redundancy.

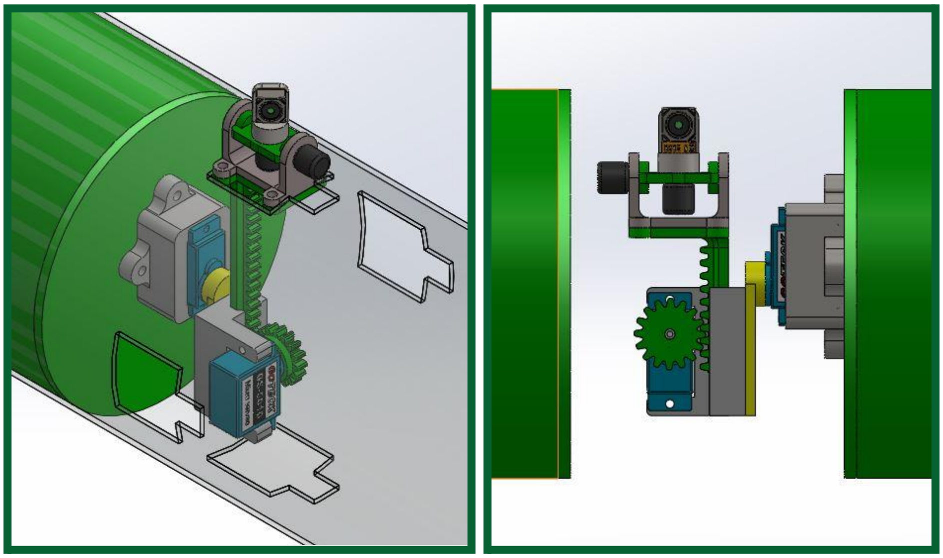


Fig. 19 and 20: Solidworks models of the two-axis camera gimbal (isometric and side view).

3. Electronics Sled

The electronics will be housed adjacent to the gimbal in a separate coupler assembly. This ensures that there is easy access to all the required sensors and boards for troubleshooting. The battery will be on the opposing side to counteract the weight from the electronics. Keeping the Cg of the body tube higher will help with the Cp and overall stability of the rocket. The battery will be connected by wires in the dead space where the two axis gimbal sits. 3D printed parts will encompass the sled and switch housings. Threaded rods will be used for support and structure for the coupler bodies. The rotating payload will be in the center of the rocket.

4. Landing Legs

An alternative design would be to land the payload section vertically as shown in the figure below. There would be a clear acrylic tube placed within the payload body allowing the camera to see out of. The camera would rotate internally 360° to see the surrounding area and take pictures. This would align the camera perfectly in the z-axis but the use of the acrylic tube would cause a distortion in the camera photos.

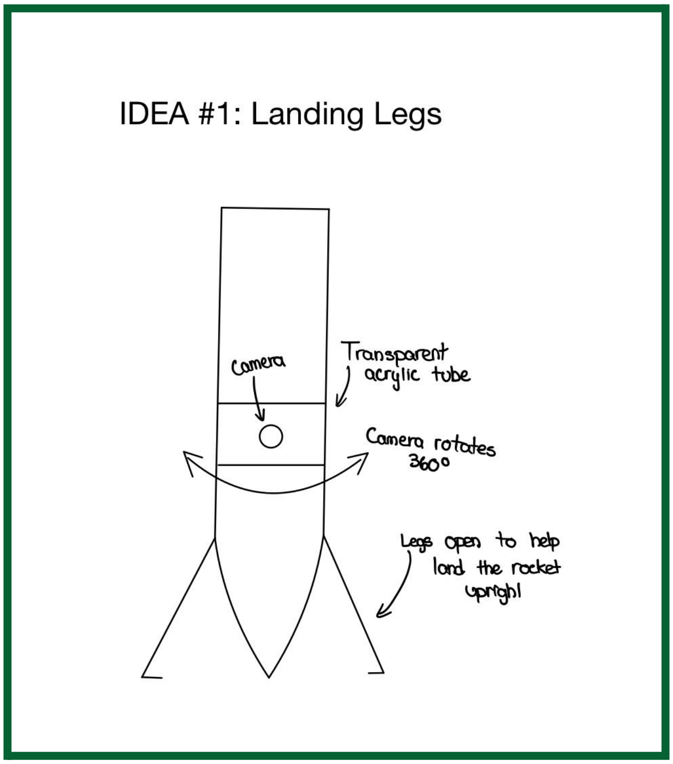


Fig. 21: Diagram of the landing legs payload idea (1).

5. Extruding Stabilizing Spokes

An alternative design to the two-axis gimbal would be spokes that protrude from the body tube and prop up the whole payload. They would be adjustable to help correct for the position of the camera in the z-axis. This system would still be paired with the rotating camera system and only one micro stepper motor on top of the rack to spin the camera 360°. This system is modular in the way we can place the leg system in a coupler body However, 8 extra holes would need to be drilled into the payload tube reducing the overall strength.

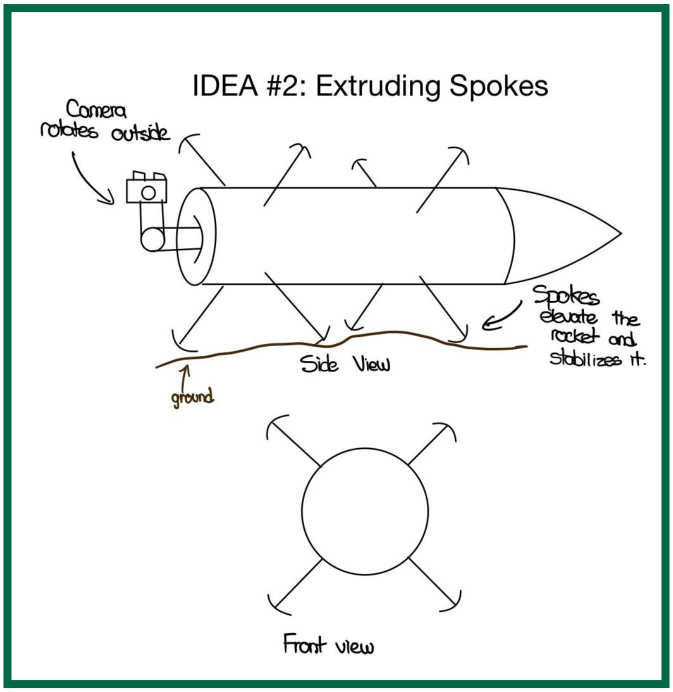


Fig. 22: Diagram of the landing legs payload idea (2).

iii. Analysis of alternative designs

1. Landing Legs

The use of landing legs would position the camera in an optimal position but actually landing the payload upright would be impractical. After reviewing the landing site images, this design would not have a large enough base to account for the rough and rocky conditions. Also, considering the speed at which the payload will land, it will cause the payload to bounce and possibly fall over. If there are high winds, the parachute may pull the payload over even after it lands successfully.

2. Extruding Stabilizing Spokes

Due to our 4in body tube, this really limits how far our legs would be able to extend. Rough estimates show that we would be able to extend the legs 3in outside of the body tube. However, based on the launch conditions provided to us, this would not be enough to stabilize the rocket. When the legs extend, it may not make contact with the ground and thus fail to adjust the orientation of the rocket. With this system we would still need to use the same internal camera rotation system just without the second axis of rotation that is provided on top of the rack. If we find that our body tube rolls around too much during the actuation of the camera, we can implement these legs to keep it from rolling, but not rely on it to position the camera in the z-axis.

iv. Feasibility studies

1. Tensile Testing

Once the fabrication process begins, a tensile test will be conducted on the payload body tube to calculate the effect of the holes on the overall strength. We will then be able to determine if the holes compromise the strength of the tube too much during high impulse events. Previous tensile tests have been conducted with results far withstanding our theoretical forces. We do not expect the holes to compromise the system too much and we can add rib supports on the inside of the body tube for added strength if necessary.

2. Impulse testing of rotating payload

One of the main concerns of the mechanical payload assembly is the strength of the servo connections to the rotating payload assembly. The force and impulse from the recovery deployment could create stress points that cause the structure to fail. FEA can be done to validate the impact loading that will occur. However to have more accurate results we can test this by doing actual drop tests from a drone.

3. Landing Legs

Because we are using a 5-1 von Karman nose cone and it would be facing downwards (illustrated in Fig. 21), creating legs that can extend long enough to reach the ground would be impractical. The legs would also be manufactured out of metal to withstand the forces upon touchdown which would add a lot of weight. Because there cannot be any systems extending beyond the bodytube during flight, we would have to fold the legs up into the payload tube. As mentioned before, the legs would be relatively long and thus infeasible to fold into the body tube.

4. Extruding Stabilizing Spokes

Because each leg will need to extend outside of the body tube, a hole will need to be drilled for each leg. This will reduce the strength of the overall tube and lead to possible fracturing during high impulse events. Each leg will also require its own linear actuator. This will add a lot of unnecessary weight and increase the manufacturing processes. With each leg added, there are more possible points of failure during the actuation of the system.

v. Presentation of payload design with current leading alternatives

The leading alternative to the current payload design is the extruding spokes design shown in Fig. 22. When the payload touches ground, the spokes will extrude from the body, lifting up the rocket from the ground and stabilizing it. Consequently, the camera will come out of the body and will have a gimbal system that will make sure that it is upright. In addition to this, the camera will be able to rotate 360°. All the extruding spokes will come out at the same time, which will ensure that the rocket is lifted and stabilized regardless of the position it landed in. The payload will then receive the commands from NASA and operate as instructed.

vi. Drawings, electrical schematics, and estimated masses for all components

1. Software execution:

The following is a flowhcart detailing the execution order of the software in both our main computer and the slave microcontroller (dotted lines represent the serial communication between the two).

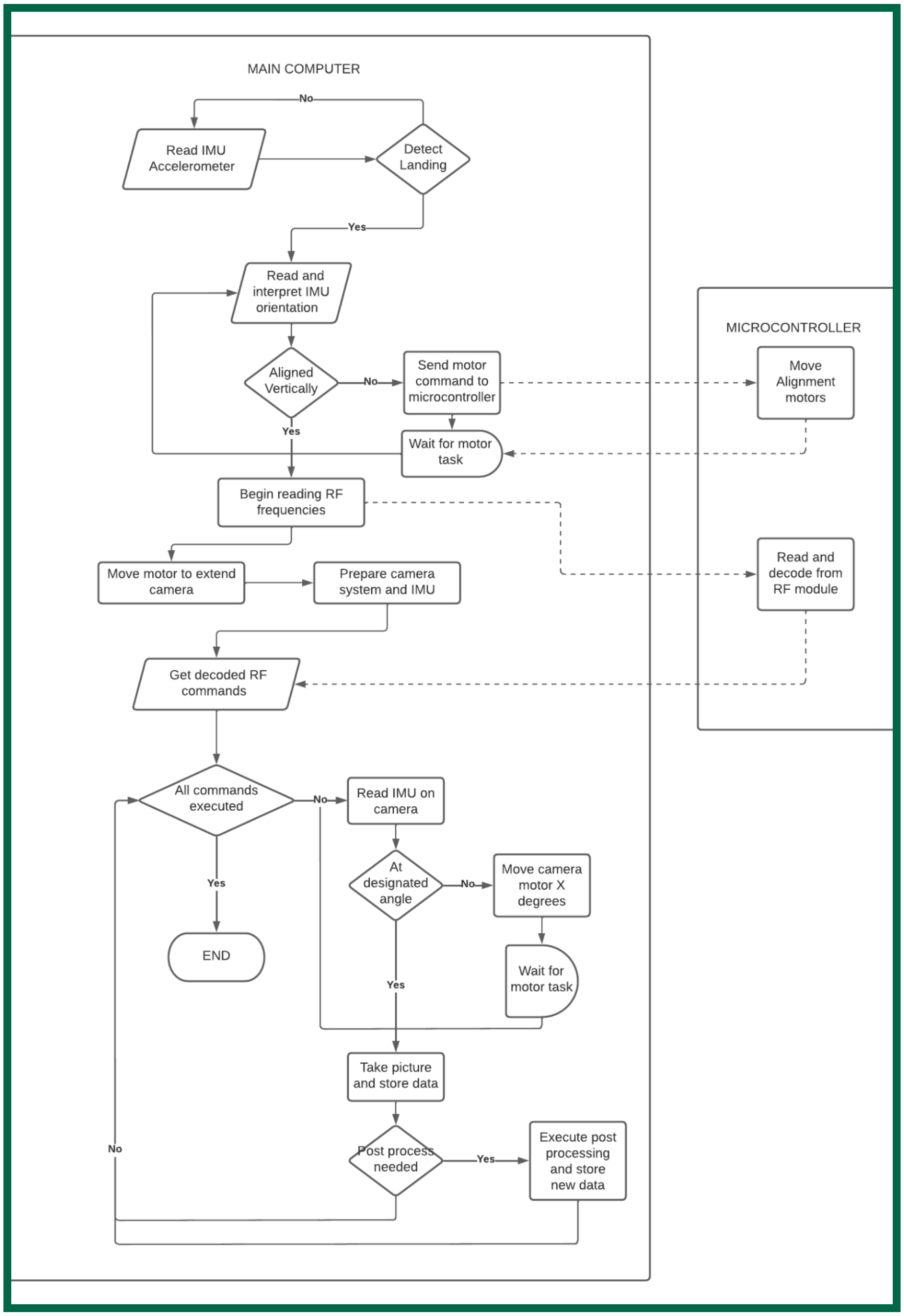


Fig. 23: Electrical schematics.

2. Electrical schematics:

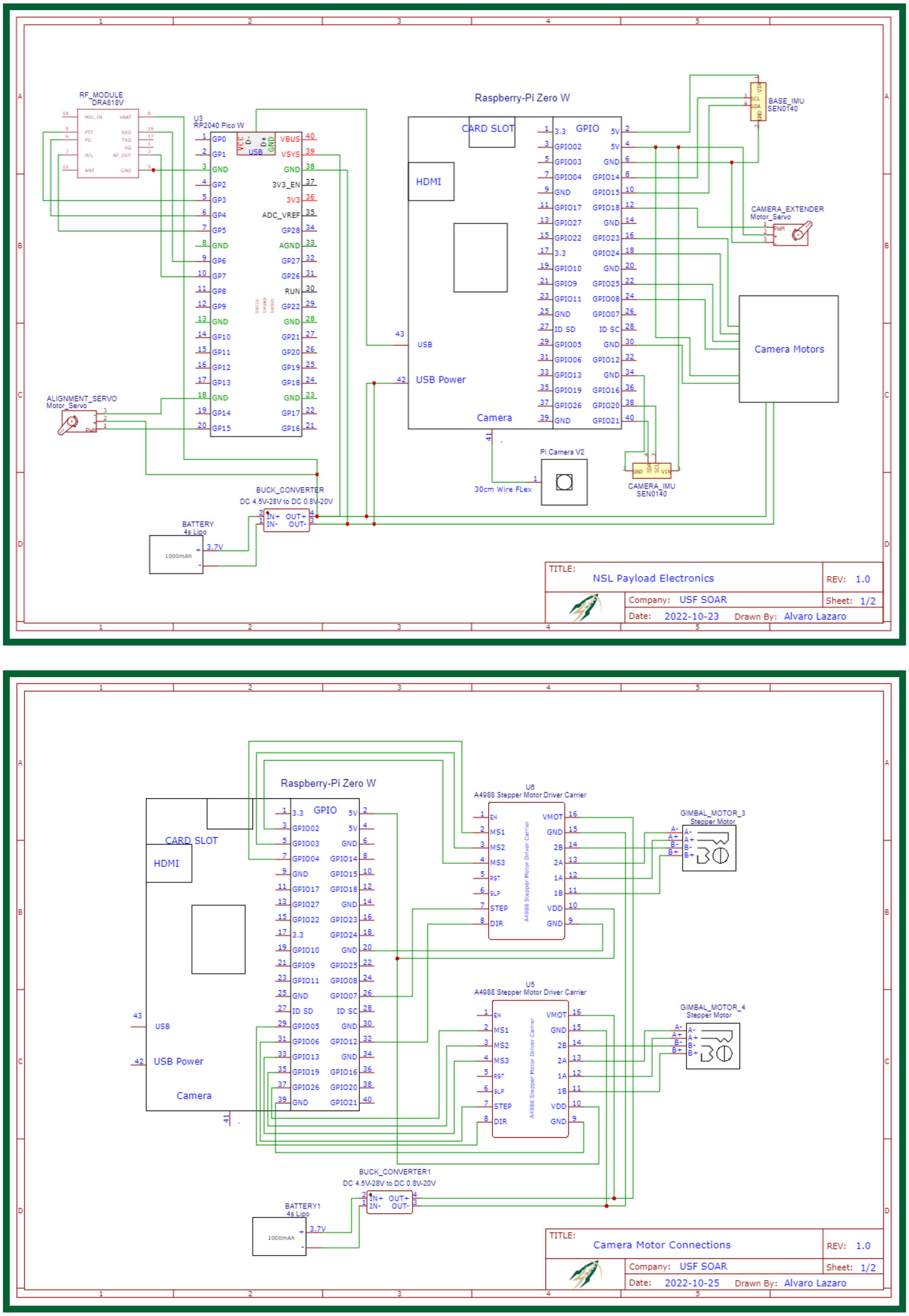


Fig. 24 and 25: NSL Payload Electronics and Camera Motor Connections.

Table 1: Estimated masses.

Name	Weight (kg)
Raspberry Pi Zero	0.009
Raspberry Pi Pico (w Shield)	0.032
4s Lipo battery	0.575
RF module DRA818V	0.009
10DOF IMU (x2)	0.003
Camera	0.0034
Buck Converter	0.05
Servo Motor MG90S (x2)	0.014
Stepper motor (x2)	0.006
Stepper motor driver (x2)	0.0026
Internal structure	0.018
Total	0.7476

vii. Justification of design decisions

1. Servos

The MG90S servo motors come equipped with metal gears but are limited to 180° of rotation. However, they can be easily converted to continuous rotation by removing the gear stop along with the potentiometer and replacing it with two resistors. It will no longer be able to read position but that can be easily corrected in code.

2. Rack and Pinion

The rack will be made of 1018 carbon steel to increase its stiffness and overall strength. This will help prevent the rack from buckling as it presses against the payload tube during deployment. The gear will also be made of 1144 carbon steel to increase wear resistance. The rack and gear will have a pitch of 24 and a pressure angle of 14.5°. Even though 20° pressure angle is industry standard, the cost for these parts did not fit into our budget. The 14.5° pressure angle will meet all of our needs for a fraction of the cost.

3. Number of Camera Holes

Four holes gives enough options for the camera to pop out of and still be able to orient in the z-axis. More holes could be drilled to give a more accurate camera deployment, but it would decrease the strength of the body tube even more. If we drilled less holes, for example 3, the 2-axis gimbal would not be able to completely correct the camera's position into the z-axis.

viii. Preliminary interfaces between payload and launch vehicle

The main interface between the payload and the launch vehicle will be a switch band. The switch band will consist of key operated switches that once activated will turn on the payload and all the avionics/recovery devices. The switches are made so the payload will not turn on without inserting and turning the key in its entirety, thus preventing accidents.

ix. Preliminary design of payload retention system

The payload will be positioned in the upper section of the body tube near the nose cone. The payload will be made up of two couplers positioned within the payload tube allowing for easy removal and access. They will be secured using stainless steel adhesive bolts. Each coupler will feature 3 adhesive bolts spaced 120° apart on each end totally 6 bolts per coupler. Threaded rods will also be passed through each coupler to add extra support.

5. Safety

a. Demonstration of understanding of all components needed to complete project and impact of risks and delays on project

All components of the rocket and payload are necessary for the mission to be successful. These include items ranging from the fiberglass tubes used for construction of the rocket body, to epoxy resin and hardener for gluing pieces together. The main fiberglass components, such as the body tubes and nose cone, will have the largest impact on our mission, as well as the various electronic components that are unique to the SSCS system. This is because both the launch vehicle and payload are integral to the success of our mission. Fiberglass components such as centering rings and bulkheads will have the least impact on our mission, as we possess the capability to manufacture those in house.

b. Preliminary Personnel Hazard Analysis

Hazards to personnel involved with the NASA Student Launch project are the most severe and require the highest mitigation priority. These hazards pose a risk to everyone involved in the NASA Student launch project and threaten their health and safety. Potential risks to the health and safety of all personnel involved are detailed below.

Table 2: Potential risks to health and safety.

Hazard	Cause	Effect	Pre-RAC	Mitigation	Post-RAC

Use of power and hand tools (saws, drills, dremels, etc.)	Improper training on use of power and hand tools, as well as insufficient caution	Mild to severe cuts, burns, etc. to personnel or rocket	4C	Individuals must be trained to properly utilize power and hand tools, as well as wear correct PPE at all times.	4D
Inhalation or 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 grinding surfaces, and proper PPE will be worn when in close proximity to debris.	3D
Sharp edges on rocket or its components	Improperly finished surfaces or edges of components, often in difficult to reach places.	Mild to severe cuts, scrapes, or splinters while handling the rocket.	4D	Attention to detail when finishing rocket surfaces during manufacturing.	4E
Contact with chemicals	Personnel 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 will be worn at all times when handling chemicals, and MSDS sheets will be available and reviewed before working with chemicals.	3D
Fumes while soldering	Soldering iron is to hot or personnel has prolonged	Personnel may feel sick or unwell due to toxic	3D	Personnel will conduct soldering in well ventilated areas.	3E

	contact with soldering iron	fumes			
Harmful contact with metal debris	Utilizing equipment necessary to machine metal parts	Metal splinters in eyes or skin.	3D	Personnel must use safety glasses and wear long sleeves when machining metal parts.	3E
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 whenever handling epoxy resin or hardener.	3D
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 and away from heat sources when in storage; supervised by club officers during launches.	1E
Unstable rocket leaving rail and loss of vehicle control	Improper model of rocket design or incorrect manufacturing procedures	Extreme bodily harm or death; severe property damage	1D	Rocket must be accurately modeled in OpenRocket and attention to detail must be used during manufacturing	1E

Debris from rocket falling on personnel during flight	Sections of rocket breaking off and returning to the ground in an uncontrolled fashion	Risk of bodily harm if debris falls in populated areas	2C	Rocket should be constructed to withstand the forces inherent with flight and separation; deployment charges should be kept to the minimum amount necessary for a successful separation.	2D

c. Preliminary Failure Modes and Effects Analysis of proposed design of the rocket

The Failure Modes and Effects Analysis (FMEA) assesses the risks inherent to our rocket and payload design, as well as the equipment and operations used for launch activities. This analysis, shown in the table below, uses the same criteria as the Personnel Hazard Analysis.

Table 3: Failure modes and effects analysis.

Hazard	Cause	Effect	Pre-RAC	Mitigation	Post-RAC
Igniter fails to activate	Mechanical or electrical failure	Vehicle does not leave launch pad	4C	Electronic match will be replaced, ground support equipment will be tested if hazard persists	4D
Failure of components	Improper installation or general wear and tear	Project is delayed or launch vehicle is damaged	2D	Replace failed parts when practical; review rocket design or final integration and preflight	2E

				checklists when applicable	
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
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
Parachute deployment failure	Altimeter/electronic failure; parachutes and shock cord become entangled	Launch vehicle will not decelerate before reaching the ground; launch vehicle has potential to become ballistic	1D	Packaging of parachute and shock cords will be checked before final integration.	1E
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

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
Catastrophic failure of motor	Improper motor assembly	Launch vehicle is severely damaged or destroyed; ground fires upon landing	1D	Ensure that motors are stored, handled, and assembled properly. All personnel should be a safe distance from the launch pad before final countdown occurs.	1E
Motor retaining ring failure	Recovery system separates with enough force to separate motor from 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
Loss of stability during flight	Damage or loss of fin(s); poor fabrication	Rocket follows 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
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 securely mount avionics and payload to their	3E

				respective body tubes	
Increase in mass during construction	Unplanned addition of components; overuse of epoxy	Launch vehicle does not reach desired altitude	4D	Review OpenRocket design to ensure that accurate weights are taken for each part	4E

d. Environmental concerns

This section addresses risks that the rocket poses to its surrounding environment during launch day activities, as well as steps to mitigate environmental damage to the rocket and its components. The same criteria used in the Personnel Hazard Analysis and Failure Modes and Effects Analysis have also been used here. Environmental hazards are listed in the table below. This table also includes environmental risks posed during preflight and postflight operations.

Table 4: Environmental concerns.

Hazard	Cause	Effect	Pre-RAC	Mitigation	Post-RAC
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
Increased descent velocities	Parachutes are inadequate to slow launch	Potential damage to the ground,	2D	Ensure that selected parachutes are	2E

	vehicle	foliage, vehicles, or structures		sufficient to slow rocket to acceptable descent speeds	
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
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
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 of the rocket, it will be done in a well ventilated area	4E
Harmful substances	Improper disposal of	Impure soil and water can	1D	Chemicals should be	1E

permeating into soil or water	chemicals	eventually affect the health of livestock, wildlife, and humans		disposed of in accordance with their MSDS sheets. Should a spill occur, all proper measures must be taken as soon as possible	
Trash and debris are left at the launch site	Conducting launch operations typically takes place in a high stress environment, and trash may be overlooked.	Trash and debris enter environment, causing damage to livestock and wildlife	4C	Trash bags will be kept on hand to periodically clean the launch site during launch operations	4D

e. Definition of risks associated with the project and mitigation techniques

Risks associated with the project include any potential hazards that may impact the launch vehicle, payload, or mission. These risks have the potential to damage or destroy the vehicle or payload, or negatively impact the status of the mission to the point of failure. Mitigation techniques range anywhere from attention to detail during fabrication and integration of the launch vehicle and payload during construction and launch operations, to conducting sufficient tests to ensure safety, to conducting emergency repairs on our rocket.

6. Project Plan

a. Requirements Verification

Table 5: Requirements, rationale, verification, and appropriate subsystem.

Req #	Requirement	Rationale	Verification	Subsystem
1.1	The vehicle shall reach an apogee of 4,500 feet	USLI Requirement	Simulation, subscale and full scale flight testing	Vehicle
1.2	The vehicle shall be recoverable and reusable	USLI Requirement	Subscale and full scale flight testing	Vehicle
1.3.1	The vehicle shall be composed of a maximum of 4 independent sections	USLI Requirement	Design consideration	Vehicle
1.3.2	Coupler and shoulders interfacing with separation points shall be at least 2 airframe diameters in length	USLI Requirement	Design consideration	Vehicle
1.3.3	Nosecone shoulders at separation points shall be at least 1/2 airframe diameter in length	USLI Requirement	Design consideration	Vehicle
1.4	The vehicle shall be capable of remaining in launch-ready configuration for a minimum of 2 hours without loss of critical functionality	USLI Requirement	Ground testing	Vehicle
1.5.1	The vehicle shall be capable of being launched by a standard 12V DC firing system	USLI Requirement	Subscale and full scale flight testing	Vehicle
1.5.2	The vehicle shall be capable of launch without external circuitry or special ground support equipment (other than what is provided)	USLI Requirement	Subscale and full scale flight testing	Vehicle
1.5.3	The vehicle shall utilize a commercially available e-match or igniter	USLI Requirement	Subscale and full scale flight testing	Vehicle
1.6.1	The vehicle shall utilize a commercially available solid motor propulsion system using APCP, and approved and certified by NAR, TRA, and/or the CAR	USLI Requirement	Design consideration	Vehicle

1.6.2	The vehicle shall utilize a single motor propulsion system	USLI Requirement	Design consideration	Vehicle
1.6.3	The vehicle motor shall provide a total impulse of less than 5,120 Newton-seconds (L-class)	USLI Requirement	Design consideration	Vehicle
1.7	The vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit	USLI Requirement	Simulation	Vehicle
1.8	The vehicle shall have a minimum thrust to weight ratio of 5.0:1.0 at the point of rail exit	USLI Requirement	Simulation, mass measurements	Vehicle
1.9	The vehicle shall accelerate to a minimum velocity of 52 fps at rail exit	USLI Requirement	Simulation, subscale and full scale flight testing	Vehicle
1.10	Structural protuberances of the vehicle shall be located aft of the burnout center of gravity (excluding approved camera housings)	USLI Requirement	Simulation, design consideration	Vehicle
1.11	All LiPo batteries utilized in the vehicle shall be sufficiently protected from impact, and brightly colored, marked as a fire hazard, and easily distinguishable from other payload hardware	USLI Requirement	Design consideration	Vehicle
1.12	The vehicle shall obey guidelines set by the NSL handbook	USLI Requirement	Design consideration	Vehicle
1.12.1	The vehicle shall use rear firing motors	USLI Requirement	Design consideration	Vehicle
1.12.2	The vehicle shall use a motor not expelling titanium sponges	USLI Requirement	Design consideration	Vehicle
1.12.3	The vehicle shall utilize a single motor for each launch	USLI Requirement	Design consideration	Vehicle
1.12.4	The vehicle shall utilize a retaining ring and motor mount for the fitting of motors	USLI Requirement	Design consideration	Vehicle

1.12.5	The vehicle shall travel at a speed of less than Mach 1 during flight	USLI Requirement	Simulation, subscale and full scale flight testing	Vehicle
1.12.6	The vehicle shall utilize ballasts less than 10% of total unballasted weight of the vehicle in a launch-ready configuration	USLI Requirement	Design consideration	Vehicle
1.12.7	Transmissions performed by the vehicle prior to landing shall utilize less than 250 mW of power per transmitter	USLI Requirement	Ground testing	Vehicle
1.12.8	Transmitters shall minimize interference by utilizing unique frequencies, handshake/passcode systems, and other means of interference mitigation	USLI Requirement	Ground testing	Vehicle
1.12.9	The vehicle shall limit the use of light-weight metal, and shall be constructed without excessive use of dense metal	USLI Requirement	Design consideration	Vehicle
2.1	The recovery system shall obey the guidelines set in the NSL handbook	USLI Requirement	Design consideration	Recovery
2.1.1	The main parachute shall be deployed at 650 feet	USLI Requirement	Subscale and full scale flight testing	Recovery
2.1.2	The apogee event shall contain a delay of less than 2 seconds	USLI Requirement	Subscale and full scale flight testing	Recovery
2.1.3	The vehicle shall utilize deployment methods other than motor ejection	USLI Requirement	Subscale and full scale flight testing	Recovery
2.2	Each independent section of the vehicle shall have a maximum kinetic energy of 75 ft-lbf at landing	USLI Requirement	Simulation, subscale and full scale flight testing	Recovery
2.3	The recovery system shall contain redundant, commercially available barometric altimeters	USLI Requirement	Design consideration	Recovery

	specifically designed for the initiation of rocketry events			
2.4	Each altimeter shall have a dedicated power supply, and all recovery electronics shall be powered by commercially available batteries	USLI Requirement	Design consideration	Recovery
2.5	Each altimeter shall have a dedicated mechanical arming switch, accessible from the exterior of the rocket airframe while the vehicle is in a launch ready configuration on the pad	USLI Requirement	Design consideration	Recovery
2.6	Each arming switch shall be capable of being locked into the ON position, without possibility of being disarmed from flight forces	USLI Requirement	Subscale and full scale flight testing	Recovery
2.7	The recovery system, GPS and altimeters, and recovery electrical circuits shall be completely independent of payload electrical circuits	USLI Requirement	Design consideration	Recovery
2.8	Removable shear pins shall be used for both main and drogue parachute compartments	USLI Requirement	Design consideration	Recovery
2.9	The recovery area shall be limited to a 2,500 ft. radius from the launch pad	USLI Requirement	Simulation, subscale and full scale flight testing	Recovery
2.10	The vehicle shall have a descent time of less than 90 seconds from apogee to touch down	USLI Requirement	Simulation, subscale and full scale flight testing	Recovery
2.11	GPS tracking devices shall be installed in the vehicle and will transmit position data of the vehicle to a ground receiver	USLI Requirement	Subscale and full scale flight testing	Recovery
2.12	The recovery system electronics shall be minimally affected by other on-board	USLI Requirement	Subscale and full scale flight testing	Recovery

	electronic devices during flight			
2.12.1	Recovery altimeters shall be physically located in a separate compartment within the vehicle from other radio frequency transmitting device and/or magnetic wave producing device	USLI Requirement	Design consideration	Recovery
2.12.2	Recovery system electronics shall be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics	USLI Requirement	Design consideration	Recovery
2.12.3	Recovery system electronics shall be shielded from all onboard devices which may generate magnetic waves to avoid inadvertent excitation of the recovery system	USLI Requirement	Design consideration	Recovery
2.12.4	Recovery system electronics shall be shielded from any other onboard devices which may adversely affect proper operation of the recovery system electronics	USLI Requirement	Design consideration	Recovery
2.13	The recovery system shall contain a commercially available electronic board to store and record flight data to an SD card	Flight verification	Design consideration	Recovery
2.14	The recovery system shall survive the impulse forces of deployment of the main parachute	Flight feasibility	Subscale and full scale flight testing	Recovery
3.1	The vehicle shall contain a payload capable upon landing of autonomously receiving RF commands and performing a series of tasks with an on-board camera system	USLI Requirement	Ground testing, subscale and full scale flight testing	Payload

3.2	The launch vehicle shall contain an automated camera system capable of swiveling 360 degrees to take images of the entire surrounding area of the vehicle	USLI Requirement	Ground testing, subscale and full scale flight testing	Payload
3.2.1	The camera shall have the capability of rotating about the z axis	USLI Requirement	Ground testing, subscale and full scale flight testing	Payload
3.2.2	The camera shall have a FOV of at least 100 degrees and less than 180 degrees	USLI Requirement	Design consideration	Payload

b. Budgeting and Timeline

i. Line item budget

Purchasing within SOAR is handled through reputable vendors, so material vendor selection is mainly based on vendors who have fulfilled previous orders for SOAR without incident.

Table 6: Line item budget for individual components of the airframe and payload sections.

Component	Vendors	Market Value	Shipping
3in Fiberglass Body Tube, 5'	Wildman Rocketry	$112.81	$25.20
3in Fiberglass Coupler Tube, per inch	Wildman Rocketry	$2.54	$25.20
Boat-tail adapter	Wildman Rocketry	$53.00	$15.85
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 (Pack of 10)	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 1G Case	Wildman Rocketry	$49.64	$15.83

Cesaroni 1G Motor	Wildman Rocketry	$65.84	$62.23
Servomotor	Amazon	$15.00	$0.00
54mm Fiberglass Motor Tube, 2'	Wildman Rocketry	$31.68	$27.23
3in Von Karman Fiberglass Nose Cone	Wildman Rocketry	$64.90	$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

Applicable taxes are not a consideration for the line item budget, as Student Business Services purchases are tax-exempt.

ii. Funding plan

Sources of funding for the NASA Student Launch 2022-23 competition will be sourced from Student Government funding to the Society of Aeronautics and Rocketry. The budget allocation to SOAR for the school year is much more than required for the construction and testing of the SSCS payload and rocket. Allocation of the budget is as follows:

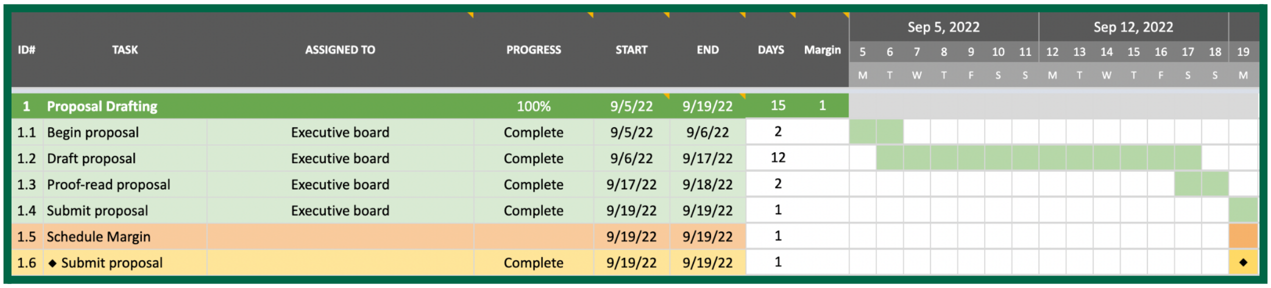
Table 7: Budget allocation, expenses incurred, and amount remaining.

CATEGORY	BUDGET	EXPENSES	AMT. REMAINING
Consumables	$ 1,000.00	$ -	$ 1,000.00
Aerostructures	$ 3,000.00	$ 765.49	$ 2,234.51
Payload	$ 3,000.00	$ 830.60	$ 2,169.40
Avionics & Recovery	$ 1,457.63	$ -	$ 1,457.63
TOTAL	**$ 8,457.63**	**$ 1,596.09**	**$ 6,861.54**

Material acquisition is handled through the Student Business Services branch of Student Government at the University of South Florida. Once an item is determined to be required by SOAR for the advancement of the NASA Student Launch project, a purchase request is submitted to the financial officer of the club. The financial officer then submits a purchase order to Student Business Services, who then fulfill the order with the budget allotted to SOAR. Shipping and receiving is handled by Student Business Services, and a club member is requested to pick up the materials when the delivery arrives.

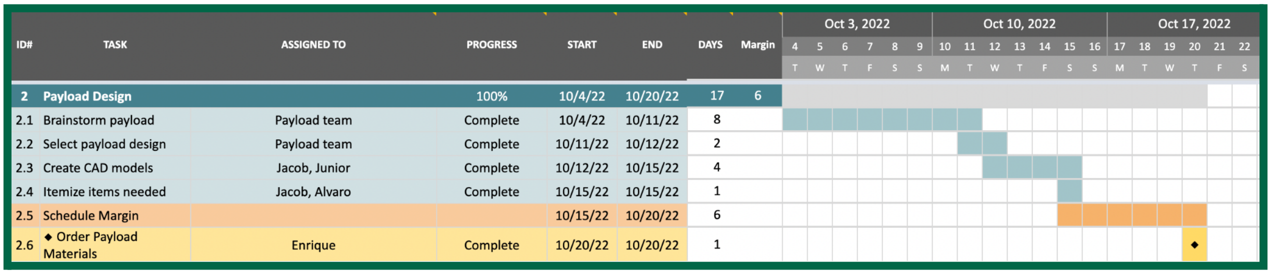
iii. Timeline of all team activities and durations

The following Gantt chart has been constructed for the 2022-23 NASA SL competition timeline.



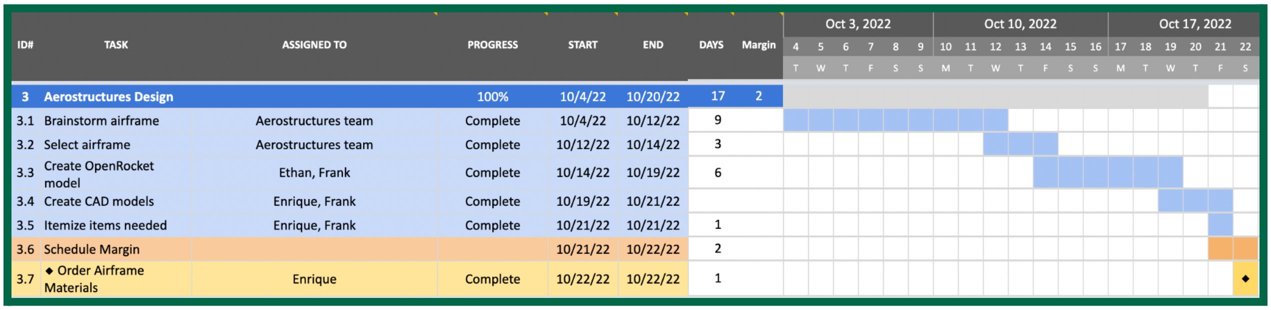
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
1	**Proposal Drafting**		100%	9/5/22	9/19/22	15	1
1.1	Begin proposal	Executive board	Complete	9/5/22	9/6/22	2	
1.2	Draft proposal	Executive board	Complete	9/6/22	9/17/22	12	
1.3	Proof-read proposal	Executive board	Complete	9/17/22	9/18/22	2	
1.4	Submit proposal	Executive board	Complete	9/19/22	9/19/22	1	
1.5	Schedule Margin			9/19/22	9/19/22	1	
1.6	◆ Submit proposal		Complete	9/19/22	9/19/22	1	

Fig. 26: Proposal drafting timeline.



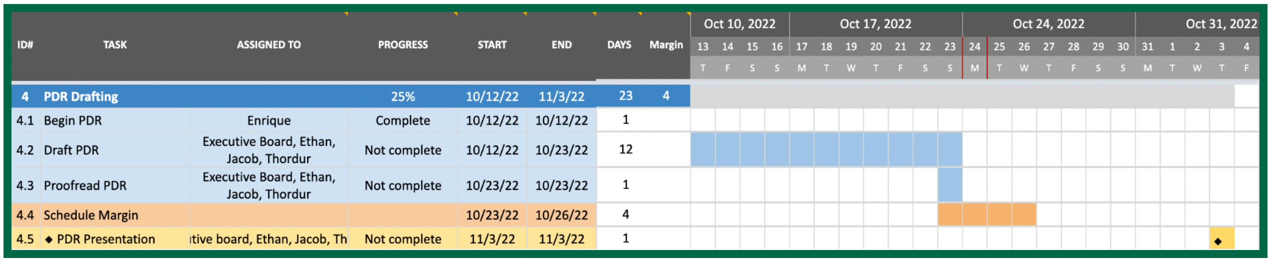
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
2	**Payload Design**		100%	10/4/22	10/20/22	17	6
2.1	Brainstorm payload	Payload team	Complete	10/4/22	10/11/22	8	
2.2	Select payload design	Payload team	Complete	10/11/22	10/12/22	2	
2.3	Create CAD models	Jacob, Junior	Complete	10/12/22	10/15/22	4	
2.4	Itemize items needed	Jacob, Alvaro	Complete	10/15/22	10/15/22	1	
2.5	Schedule Margin			10/15/22	10/20/22	6	
2.6	◆ Order Payload Materials	Enrique	Complete	10/20/22	10/20/22	1	

Fig. 27: Payload design timeline.



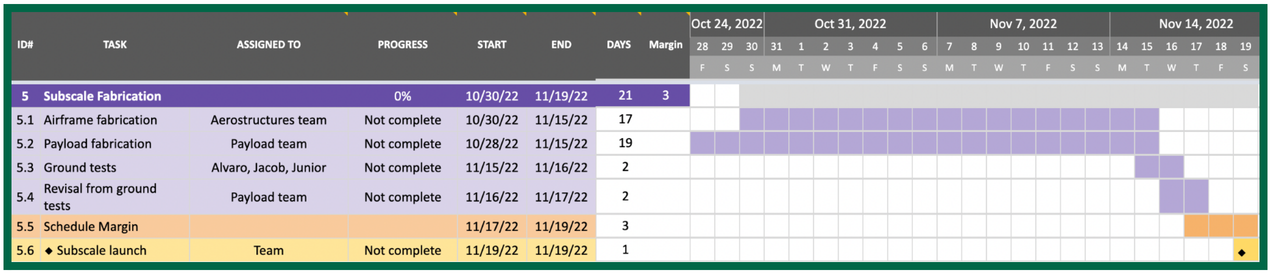
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
3	**Aerostructures Design**		100%	10/4/22	10/20/22	17	2
3.1	Brainstorm airframe	Aerostructures team	Complete	10/4/22	10/12/22	9	
3.2	Select airframe	Aerostructures team	Complete	10/12/22	10/14/22	3	
3.3	Create OpenRocket model	Ethan, Frank	Complete	10/14/22	10/19/22	6	
3.4	Create CAD models	Enrique, Frank	Complete	10/19/22	10/21/22		
3.5	Itemize items needed	Enrique, Frank	Complete	10/21/22	10/21/22	1	
3.6	Schedule Margin			10/21/22	10/22/22	2	
3.7	◆ Order Airframe Materials	Enrique	Complete	10/22/22	10/22/22	1	

Fig. 28: Aerostructures design timeline.



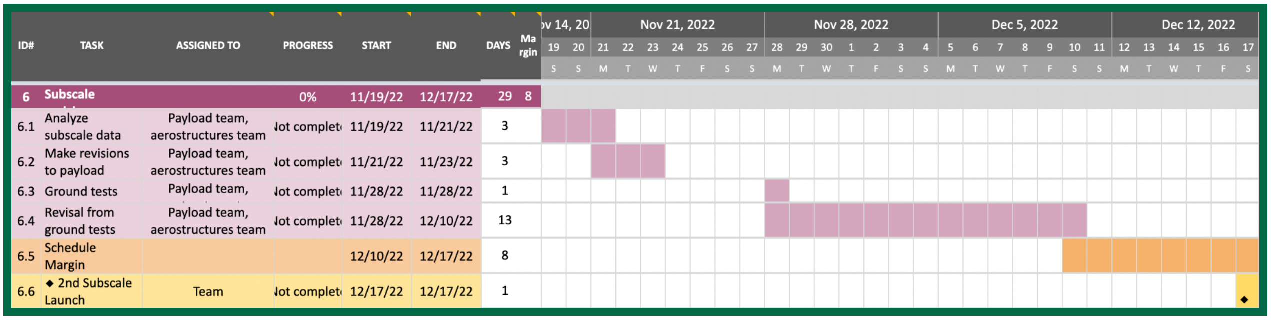
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
4	PDR Drafting		25%	10/12/22	11/3/22	23	4
4.1	Begin PDR	Enrique	Complete	10/12/22	10/12/22	1	
4.2	Draft PDR	Executive Board, Ethan, Jacob, Thordur	Not complete	10/12/22	10/23/22	12	
4.3	Proofread PDR	Executive Board, Ethan, Jacob, Thordur	Not complete	10/23/22	10/23/22	1	
4.4	Schedule Margin			10/23/22	10/26/22	4	
4.5	◆ PDR Presentation	ıtive board, Ethan, Jacob, Th	Not complete	11/3/22	11/3/22	1	

Fig. 29: Preliminary design review timeline.



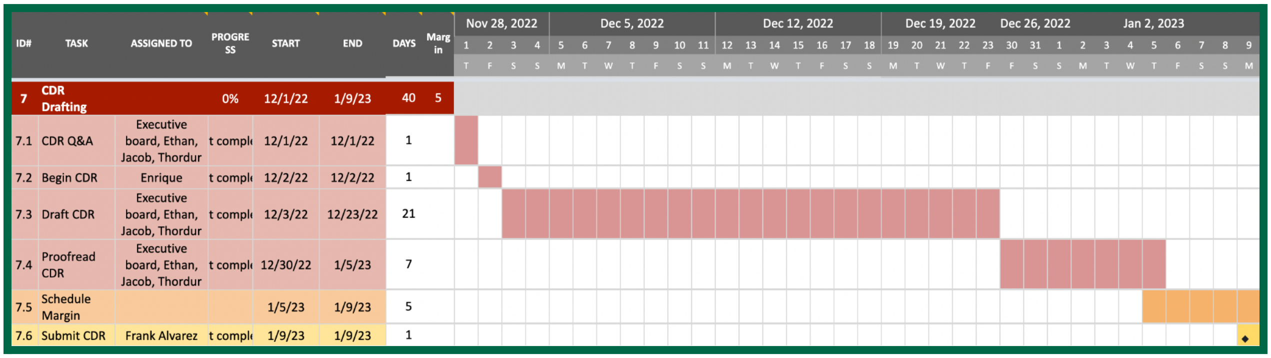
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
5	Subscale Fabrication		0%	10/30/22	11/19/22	21	3
5.1	Airframe fabrication	Aerostructures team	Not complete	10/30/22	11/15/22	17	
5.2	Payload fabrication	Payload team	Not complete	10/28/22	11/15/22	19	
5.3	Ground tests	Alvaro, Jacob, Junior	Not complete	11/15/22	11/16/22	2	
5.4	Revisal from ground tests	Payload team	Not complete	11/16/22	11/17/22	2	
5.5	Schedule Margin			11/17/22	11/19/22	3	
5.6	◆ Subscale launch	Team	Not complete	11/19/22	11/19/22	1	

Fig. 30: Subscale fabrication timeline.



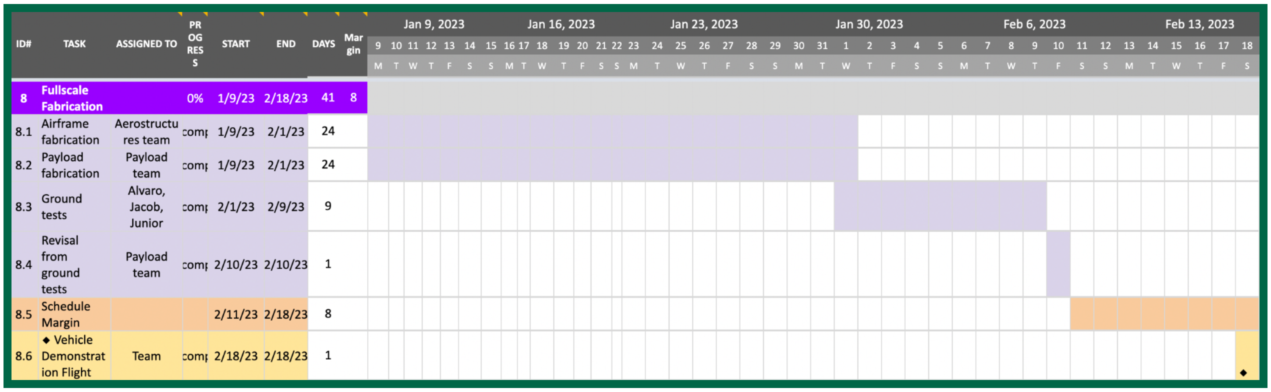
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
6	Subscale		0%	11/19/22	12/17/22	29	8
6.1	Analyze subscale data	Payload team, aerostructures team	ıot complet	11/19/22	11/21/22	3	
6.2	Make revisions to payload	Payload team, aerostructures team	ıot complet	11/21/22	11/23/22	3	
6.3	Ground tests	Payload team,	ıot complet	11/28/22	11/28/22	1	
6.4	Revisal from ground tests	Payload team, aerostructures team	ıot complet	11/28/22	12/10/22	13	
6.5	Schedule Margin			12/10/22	12/17/22	8	
6.6	◆ 2nd Subscale Launch	Team	ıot complet	12/17/22	12/17/22	1	

Fig. 31: Second subscale launch timeline.



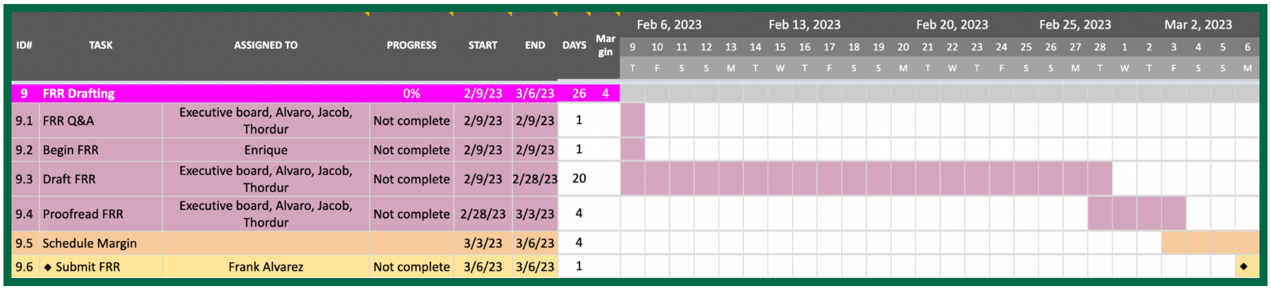
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
7	CDR Drafting		0%	12/1/22	1/9/23	40	5
7.1	CDR Q&A	Executive board, Ethan, Jacob, Thordur	t comple	12/1/22	12/1/22	1	
7.2	Begin CDR	Enrique	t comple	12/2/22	12/2/22	1	
7.3	Draft CDR	Executive board, Ethan, Jacob, Thordur	t comple	12/3/22	12/23/22	21	
7.4	Proofread CDR	Executive board, Ethan, Jacob, Thordur	t comple	12/30/22	1/5/23	7	
7.5	Schedule Margin			1/5/23	1/9/23	5	
7.6	Submit CDR	Frank Alvarez	t comple	1/9/23	1/9/23	1	

Fig. 32: Critical design review timeline.



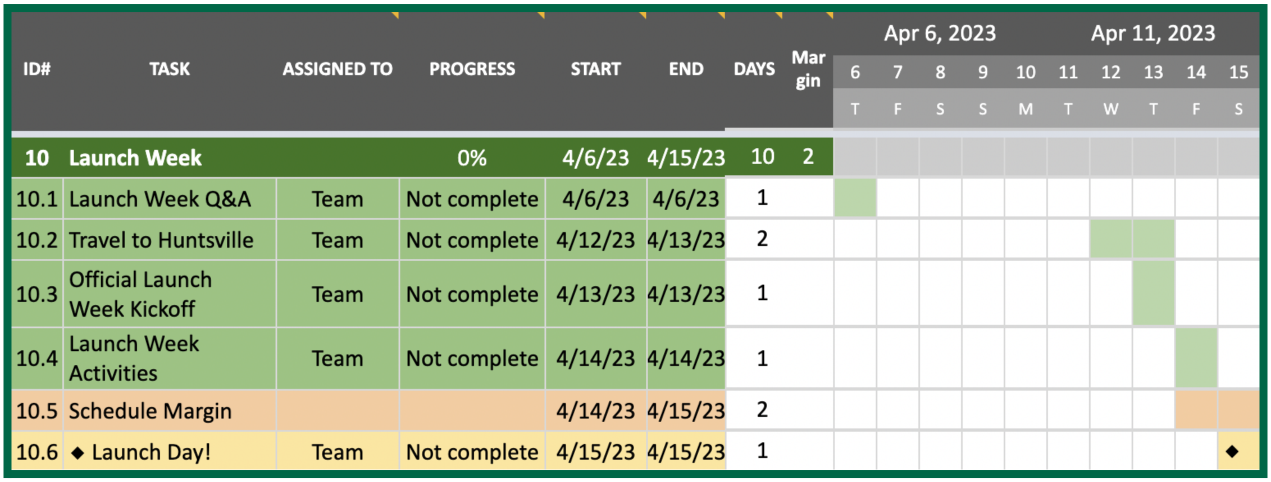
ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
8	Fullscale Fabrication		0%	1/9/23	2/18/23	41	8
8.1	Airframe fabrication	Aerostructures team	comp	1/9/23	2/1/23	24	
8.2	Payload fabrication	Payload team	comp	1/9/23	2/1/23	24	
8.3	Ground tests	Alvaro, Jacob, Junior	comp	2/1/23	2/9/23	9	
8.4	Revisal from ground tests	Payload team	comp	2/10/23	2/10/23	1	
8.5	Schedule Margin			2/11/23	2/18/23	8	
8.6	◆ Vehicle Demonstration Flight	Team	comp	2/18/23	2/18/23	1	

Fig. 33: Full Scale fabrication timeline.



ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
9	FRR Drafting		0%	2/9/23	3/6/23	26	4
9.1	FRR Q&A	Executive board, Alvaro, Jacob, Thordur	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, Jacob, Thordur	Not complete	2/9/23	2/28/23	20	
9.4	Proofread FRR	Executive board, Alvaro, Jacob, Thordur	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	

Fig. 34: Flight readiness review timeline.



ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	Margin
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. 35: Launch week timeline.

7. References

[1] “Thrustcurve Hobby Rocket Motor Data,” • *ThrustCurve*. [Online]. Available: https://www.thrustcurve.org/motors/Cesaroni/1990K490-16A/. [Accessed: 23-Oct-2022].

[2] “Thrustcurve Hobby Rocket Motor Data,” • *ThrustCurve*. [Online]. Available: https://www.thrustcurve.org/motors/Cesaroni/1994K635-17A/. [Accessed: 23-Oct-2022].

[3] “Thrustcurve Hobby Rocket Motor Data,” • *ThrustCurve*. [Online]. Available: https://www.thrustcurve.org/motors/Cesaroni/2014K1200-16A/. [Accessed: 23-Oct-2022].

[4] T. Benson, “Velocity During Recovery,” *NASA*. [Online]. Available: https://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/rktvrecv.html. [Accessed: 23-Oct-2022].

[5] T. V. Milligan, “Using Streamer Recovery Instead of Parachutes,” 20-Jul-2004.