Operation Helios

Preliminary Design Report

Cedar Falls High School

1015 Division Street, Cedar Falls, IA, 50613

September 20th, 2017

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I Summary of PDR

Team Summary

- Cedar Falls STARS
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Launch Vehicle Summary

- Size and mass: 8 feet in length, 4.5 inches in diameter, 8798 grams
- Motor Choice: K590 Cesaroni Motor
- Recovery System: Dual Deployment 108 inch Diameter
- Milestone Review Flysheet

Payload Summary

- Electricity Generation and Documentation
- The main objective of our payload is to measure the voltage, produced by the solar panels, to see if the voltage output changes based on the altitude of our rocket. A successful experiment would qualify when data is read throughout the launch and that data is compared to the control on the ground.

II Changes Made Since Proposal

Highlight all changes made since the proposal and the reason for those changes.

- Changes made to vehicle criteria: The body of the vehicle is no longer designed to be eight feet tall. The body was altered to be a six foot long, and have the 24 inch nose cone placed at the end. This is to reduce the total weight of the vehicle, making it easier to achieve a height of 5,280 feet. This also reduces costs, making it another advantage to the change. The diameter of the rocket was also reduced to be four and a half inches as opposed to the five inch tube we had in our proposal. This reduces the weight, drag, and cost. The reduced weight and drag makes our goal of reaching 5,280 feet much more achievable, and the reduced cost makes our task of fundraising a little easier as well.
- Changes made to payload criteria: While the overall goal of comparing the intensity of the sun as altitude increases, the way in which we go about it has changed. Previously we had planned to have solar panels on the exterior of the rocket charge a battery, which we would compare to the battery charged by a replica of the rocket that was at ground level. While we plan on keeping the solar panels and ground model, we changed our plan of how we tested the measurements. We are now using an Arduino board to measure the voltage produced by the solar panels, and then we will take that information and make a graph, putting the voltage against time. Then we will compare the graph of the voltage produced by the ground model to the graph of voltage produced by the rocket.
- Changes made to project plan: We changed the order in which we would complete each section of the PDR, CDR, and FRR. As we looked more in depth at what each review would need, we saw that sections I-II could not be accomplished until the rest of the project was done. We moved the entire buy, build, and launch schedule of the model rocket back by a month. This is because we saw that we wouldn’t even have a plan for it until the completion of the PDR, and so the build and design process would have to wait. We still have ample time to build, launch, and analyze the rocket. We did not have a schedule for fundraising or coding for the payload in the plan prior to this, so we added them in to make sure we had a scheduled time for this, because it is easy to push aside if not laid out. The backup rocket tests in Platteville, Wisconsin, were pushed up a week to allow ample analysis for the flights. Otherwise, our project plan remains generally unchanged.

III Vehicle Criteria

Mission statement and success criteria

1. The purpose of our mission is to successfully test the intensity of the sun from both a rocket in the sky and a rocket on the ground, and be able to record and compare the data.
2. Criteria for success
    a. Retrieval of unharmed rocket and payload
    b. Accurate voltage readings from both the control body tube on the ground and the rocket
    c. Successfully hitting 5,280 feet AGL
    d. Accurate mirroring of in flight rocket by the ground model

- Material of rocket body
    - One of the leading materials for the construction of our rocket is thick walled cardboard, since it is such a cheap option. As well as being cheap, it is fairly light in mass and it would take much less power to launch it as compared to a fiberglass rocket. However, we determined that this was a poor option since cardboard is very weak, especially when launching using the power class of motor we plan to use with such high stresses that will be put on the airframe during flight. It is also not water resistant, meaning if the rocket were for some reason exposed to moisture it could compromise the rocket entirely.
    - Another material we were interested in was carbon fiber, since it is extremely strong yet also fairly lightweight. Carbon fiber is a great option for durability and strength, which is a major component for us in the design of our rocket. However, carbon fiber is an extremely expensive option to choose. We do not want to waste our limited funding on materials we do not absolutely need, when we can find a much better solution.
    - Our leading material choice for the airframe of the rocket at this point is standard walled fiberglass. It is substantially stronger than a cardboard tube, and will be more than strong enough for our desired mission, yet it is much cheaper than carbon fiber. Fiberglass is easy to work with, as long as we are sure to take safety into account, but it is not nearly as easy to work with as cardboard. It is heavier than a cardboard rocket, requiring a stronger motor to launch it, but the trade off is more than worth it.
- Length

    - Our team was deciding whether to make our body tube eight feet long or six feet long. The main advantage of having an eight foot long body tube is the space it provides both inside and out. We would have more surface area to place our solar panels for the experiment, as well as having ample room to place our electronics, parachutes, ejection charges, and everything else needed to launch and fly a rocket. The problem with having a rocket of this length, however, is that it adds a lot of weight, which would require more thrust to reach the required “off the rail” velocity, and to reach the height goal. It would also cost more to make the eight foot body tube, due to the price of materials.
    - The advantage of having a six foot long body tube would be the reduced weight of the rocket, and the reduced overall cost. From the reduced weight of the rocket, we would need a less powerful motor, reducing safety risks and price all in itself. Also, we would not need to buy the extra two feet of fiberglass tubing to make the rocket the correct length.

      We decided to go with this option, due to these advantages. The rocket will be six feet long, plus the length of the nose cone.
- Diameter
    - Our club was deciding on what diameter of a rocket we wanted, and we narrowed it down to the following diameters: four inches, 4.5 inches, five inches, or 5.5 inches. Our choice of four inches in diameter as an option was based on multiple advantages. The price of a four inch body tube is substantially cheaper than the price of a 5.5 inch tube, which is a definite advantage. Another is the drag created by a four inch tube is much less than the drag of a larger tube, which will decrease the amount of force required to get our rocket to a height of 5,280 feet. This reduction in required force means we do not need as powerful of a motor, cutting costs and safety risks. The last advantage of this diameter is weight. Since it is a smaller diameter, it is much lighter, giving it the same benefits as a rocket with less drag. The one large disadvantage outweigh the advantages, however. Even though a smaller diameter drastically cuts price and safety risks, the small size of it makes it nearly impossible to fit everything we need into the rocket efficiently. We would need to extend the rocket to be able to hold all of our parachutes, electronics, ejection charges, and so on. The skinny diameter also makes it harder to work with our wires and components once they are in the rocket. There is also much less surface area on the outside of the rocket to hold the solar panels, which is a definite downside. We want as much area on the exterior of the rocket as possible, which rules out the four inch diameter body tube and any tube smaller than it.
    - The other extreme of body tube we were looking at was a 5.5 inch diameter body tube. While it has ample room for us to work with the components of our rocket, we decided that due to the increased cost,

drag, weight, and safety risks that go along with a larger diameter rocket, we would not be going with this option or any option larger than this.

    - The Cedar Falls HS Rocket Club decided we would go with a 4.5 inch diameter body tube. While the five inch tube is a strong option due to its reduced safety, cost, drag, and weight, we felt that the increased surface area for our solar panels and the increased maneuverability was not necessary. The space in the body of the 4.5 inch rocket should provide enough room for our parts without needing to cram them in, and risk failure of parachute ejection. The amount of solar panels on the outside will give us sufficiently accurate readings of voltage as well.

- Nose Cone Material
    - One choice under consideration for the nose cone material is plastic. Plastic nose cones are lightweight and the most cost effective solution. However, plastic nose cones may not be strong enough for our desired mission. A plastic nose cone requires no preparation and would be very time efficient, but it doesn't offer as much strength or dependability as some of the other options.
    - Another choice being considered for the nose cone is fiberglass. A fiberglass nose cone is a good all around choice. It is strong, relatively cheap, easy to buy, and still manages to be lightweight. A premade nose cone can be purchased, therefore requiring no additional work to be done on the nose cone.
    - The third choice for the nose cone is fiberglass with a metal tip. This is the most expensive choice, but it is unparalleled in terms of dependability and durability. However, its downsides are its weight and cost. It is the heaviest and most expensive option, meaning more thrust would have to be generated. It could also create an overstable rocket by moving the center of mass closer to the nose of the rocket and farther away from the Center of Pressure. It is easily available, much like a regular fiberglass nosecone. Another disadvantage of this option is that it may interfere with the electronics onboard the rocket, thus interfering with the mission success.
    - The Cedar Falls High School Rocket Club has decided to go with a standard fiberglass nose cone because it will perform best for our mission due to its cheap but dependable and strong nature.
- Nose Cone Shape
    - Another factor to consider is the shape of the nose cone. The first choice under consideration is the conical shape. This shape is commonly used on many rockets. However, it creates a fairly high amount of drag compared to more rounded nose cones, meaning it will be harder to get the rocket to reach the target altitude of 5,280 feet
    - The second choice for the shape of the nose cone is the ogive shape. The ogive shape provides a good middle of the road path. It has relatively

low drag and it is a shape recommended by our mentor for this mission objective.
    - The third choice for the nose cone shape is the elliptical shape. The elliptical shape creates the least amount of drag. However, in our case, the rocket will be going at speeds high enough that a different nose cone should be used because a different shape will provide a lower coefficient of drag at the velocity our rocket will be traveling.
    - The club has decided to go with an ogive shaped nose cone because it provides a good aerodynamic shape and will not be difficult to make or find for purchase.
- Nose Cone Ratio
    - The two main choices for a ratio of body tube length to diameter are 4:1 and 5:1. A 4:1 is a shorter nose cone, thus creating more drag and decreasing the ability for our rocket to reach a higher altitude such as the desired altitude for the launch of 5,280 feet. However, it is slightly stronger due to its more stubby nature.
    - A 5:1 ratio creates less drag because of the longer length of the nose cone due to fluid dynamics. However, it is more likely to be damaged than a 4:1 nose cone. This length has also been recommended by our mentor, so we have chosen this over the 4:1 ratio due to these reasons.
- Number of Fins
    - One choice being considered for the number of fins is a three fin design. With three fins, the amount of drag is less than with four fins, but it still maintains its stability and is a slightly more lightweight design. This choice has been chosen because of these advantages.
    - The other choice is a four-fin design. With four fins, the drag is increased and we are trying to reduce this in order to reach our target altitude of one mile. The benefit of four fins is the increased stability, but the team does not feel that this benefit outweighs the drawback of the increased drag. The rocket will still be stable with three fins.
- Planform Fin Shape
    - One fin shape being considered for the CFHS Rocket Club's rocket is the trapezoidal shape. The trapezoidal shape offers the advantage of protection when the rocket touches down. It has a lower risk of being damaged, because it doesn't sit so close to the edge of the rocket, meaning it takes less impact on landing.
    - Another fin shape under consideration is the clipped delta shape. It is a classic fin shape and is easy to acquire. The only real difference between this shape and the trapezoidal shape is that it is slightly more likely to be damaged upon the impact of landing since the bottoms of the fins sit flush with the bottom of the booster body tube.
    - The final fin shape under consideration is the tapered swept shape. This shape can help move the center of pressure farther aft if needed,

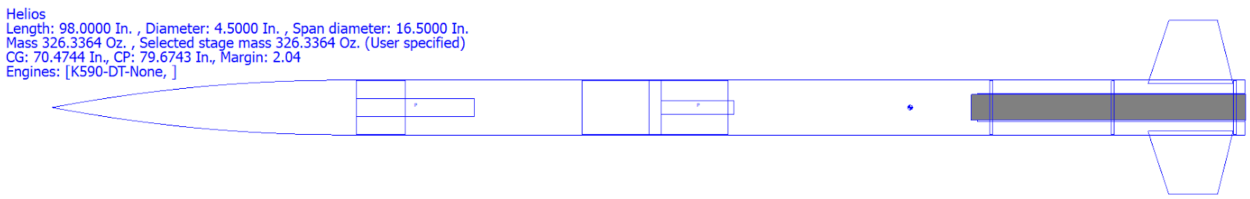
however, this isn't really needed in our current design. This fin shape will also be the most likely to be damaged upon landing since the tips of the fins will likely sit below the bottom of the body tube. For these reasons we will stick with one of the other two.

    - The team has decided to pursue trapezoidal fins, because they fit all of our most important criteria (ease of construction, reduced chance of breakage upon landing, etc.)

- Aerofoil Fin Shape
    - The team has researched the three types of fin aerofoil shaping: Unsymmetric, Subsonic, and Supersonic. Since the rocket will not be traveling at supersonic speeds that design was not considered. The unsymmetric design seemed interesting and has the benefit of adding a small amount of stability, but we also considered the problem it would create with the solar panels collecting data throughout flight. We decided the added stability may not outweigh the potential problems with solar power collection. The subsonic design is the most common, stable, and is easy for the team to create so that is the design the team has chosen to pursue.
- Fin Material
    - The first fin material in consideration is plywood. This material is cheaper than fiberglass and carbon fiber, but it is not as strong as either of these two alternative materials. Considering how heavy this rocket will be and the potential amount of kinetic energy upon landing, as well as the amount of drag force on the fins experienced during flight, this material may not be strong enough to withstand the force of impact of at least two flights.
    - The second material considered is carbon fiber. This is a very strong material, but it is also more expensive. It would be strong enough to withstand the forces experienced during flight and landing, but the benefit of strength may not be outweighed by the cost of the material.
    - The third and final material considered is G12 fiberglass. Since this is the material chosen for the body tube it seems to be a logical choice to pursue. Fiberglass is stronger than the plywood fins, while not increasing the cost of the material significantly. While the carbon fiber fins would be extremely strong, it is an unnecessary upgrade within our budget.
- The Design
    - For the design, it has been decided that the CFHS Rocket Club will use a design with a six foot long fiberglass body tube and a 4.5 inch diameter. For the nose cone, we will use a 24 inch long fiberglass ogive shape. Finally, for the fins, we will use three fiberglass fins in a trapezoidal planform fin shape with a subsonic aerofoil fin shape.
    - Body Tube

    - The body tube will be a six foot long tube with a 4.5 inch diameter made of fiberglass. We chose the material of fiberglass because it is strong enough to accomplish many flights to test as well as the final launch while still being relatively cheap, easy to work with, and light. The length of six feet was chosen because The advantage of having a six foot long body tube would be its lower weight than a longer body tube as well as the reduced cost that comes with less material. Because the rocket will be lighter, we will need a less powerful motor, meaning it will be a more safe launch as well as the motor price will be less because it will be smaller. The diameter of 4.5 inches was chosen because it has enough surface area for our solar panels as well as the payload. Because it is the smallest diameter that can fit what is needed inside of it, it has the lowest amount of drag, cost, and mass of any other option. The body tube is also large enough in diameter to fit the parachute without the risk of deployment failure.
- Nose Cone
    - The nose cone will be 24 inches long made of fiberglass in an ogive shape. The material selection of fiberglass was decided upon because it is a very cost-efficient solution while still being lightweight. Fiberglass is also a strong material, so it will be able to withstand the impact of the landings it will go through. The 24 inch length was chosen because of its lower drag, thus making it easier to reach the height of 5,280 feet. The ogive shape was chosen because it has low drag meaning it is optimal for our subsonic flight, it provides a good aerodynamic shape, and is readily available to purchase. Because of these factors, the ogive shape will be optimal to reach the height goal of 5,280 feet.
- Fins
    - We have decided on a three fin design. The fins will be made of fiberglass in a trapezoidal planform fin shape with a subsonic aerofoil fin shape. We decided on three fins because the stability of a four fin design is not necessary for our rocket. The three fins also decrease the amount of drag, thus increasing the height of our rocket. The fins were selected to be made out of fiberglass because fiberglass is a strong and lightweight material while still being inexpensive. The fiberglass will be strong enough to withstand the impacts of multiple landings and still be a good, lightweight choice for the fins. The trapezoidal planform fin shape was decided upon because it has no downsides compared to other fin shapes. It has a lower chance of sustaining damage due to its shape, thus making it the most dependable and best choice for our rocket. The subsonic aerofoil fin shape was decided upon

due to our rocket being subsonic. This is the optimal aerofoil fin shape because it has low amounts of drag and is designed for subsonic flight.



- Motor Choices:
    - Cesaroni K590 Motor
        - Ease of use from Cesaroni
        - Dual burning motor
        - Achieves both altitude and rail exit velocity in simulations

Cesaroni K300 Motor

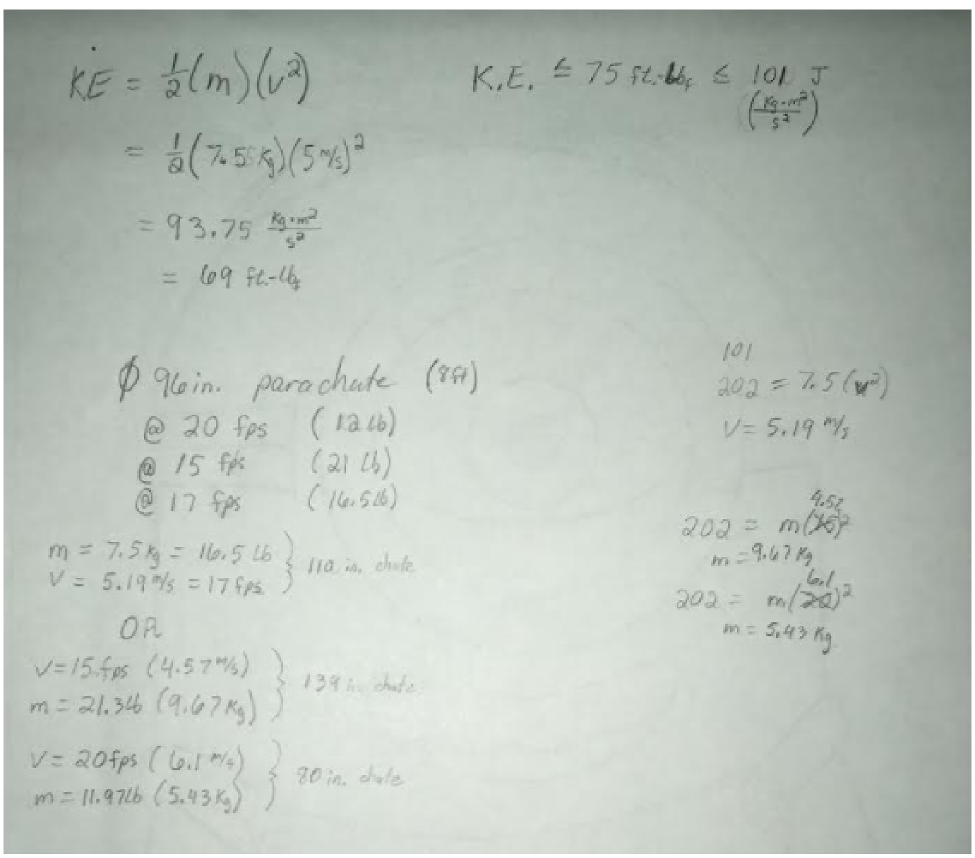
- Ease of use
- Achieve altitude in simulations
- Does not achieve rail exit velocity in simulations

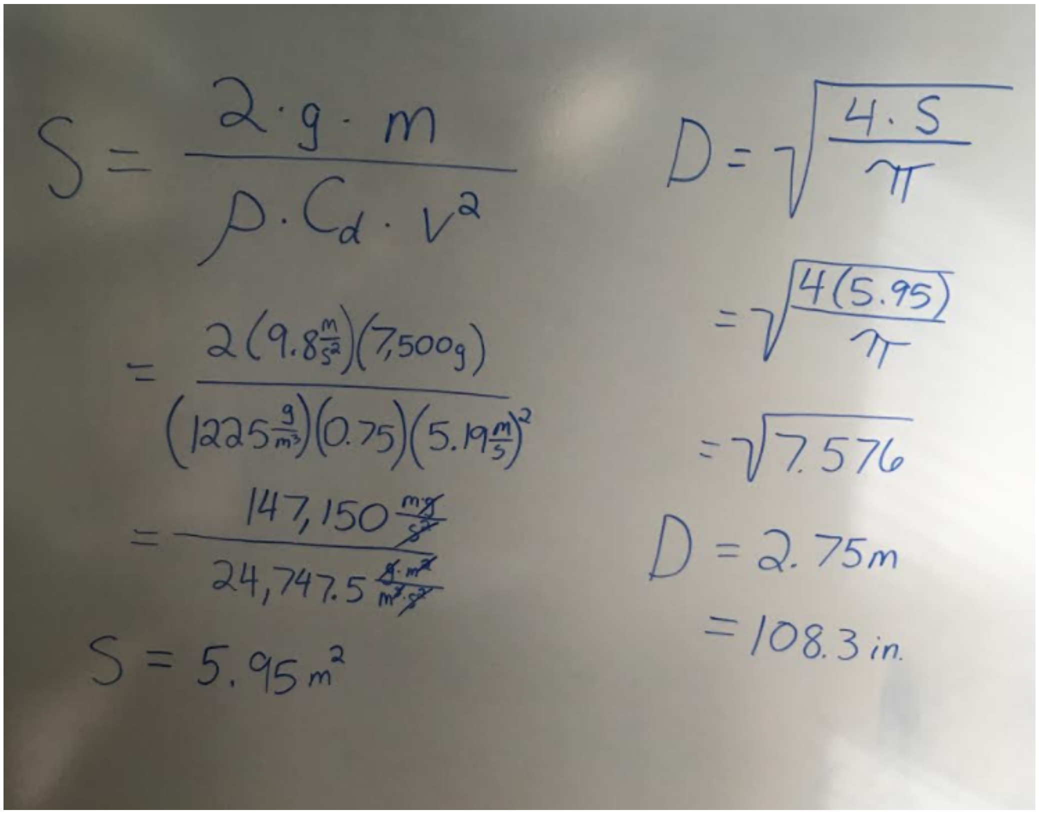
Recovery Subsystem

- Our recovery system will consist of a drogue chute, a main parachute, two shock cords, fireproof wadding, and two independent altimeters with dual deployment capabilities.
    - Drogue chutes
        - 15” drogue Parachute
            - Pros - based on calculations (119 fps) it is determined that this is the proper size that will land the rocket in the required field size.
            - Cons - it might still come down too fast
        - 18” drogue Parachute
            - Pros - it will come down slower and be easier to see.
            - Cons- because of the larger size even being deployed at Apogee the rocket could possibility drift outside the required landing field.
    - Parachutes
        - 120” Topflight Recovery Parachute
            - Pros - The parachute will bring the rocket down at a slower and safer velocity
            - Cons - With the longer descent time, the rocket can potentially drift outside the required landing field.
        - 108” Topflight Recovery Parachute

        - Pros - this is the desired size based on calculations (See parachute section in “Recovery Subsystem” section)
        - Cons - With a longer descent the data might be affected
    - 96” Topflight Recovery Parachute
        - Pros - The size will help the rocket reach the ground faster and the data has a smaller chance of becoming corrupted
        - Cons- The size results in the rocket falling faster than the required ft/lbs/sec
- Shock cords
    - 40Ft 1500# Kevlar Shock Cord
        - Pros - It is stronger because of interwoven fireproof kevlar threads, as well as it is able to handle more pounds of force
        - Cons - It is more expensive per foot.
    - half -inch medium 1200# Nylon webbing shock cord
        - Pros - price per foot of cord is cheaper
        - Cons - The cord is unable to handle as many pounds of force and is not nearly as flame resistant as kevlar.
- Protective wadding
    - Sunward 18in Nomex Black Parachute Protector
        - Pros - It is a strong reusable cloth protector commonly referred to as a “heat shield” or “blast protector”
        - Cons - If not handled and placed correctly, the material could easily slide off shock cord
    - Quest Recovery Wadding
        - Pros - Strong material that will stop the shock cord or parachute from melting
        - Cons - It is a non-reusable material, budget would have to possibly incorporate multiple purchases
- Altimeters
    - Raven3
        - Pros
            - 4 programmable outputs
            - Very compact
        - Cons
            - Not reliable enough
            - Expensive
    - Perfectflite StratologgerCF
        - Pros
            - Reliable
            - Cheap
            - Readily available
        - Cons
            - Uses a larger amount of power

- Telemetrum
  - Pros
    - Can be programed with C
  - Cons
    - Expensive
    - Very advanced

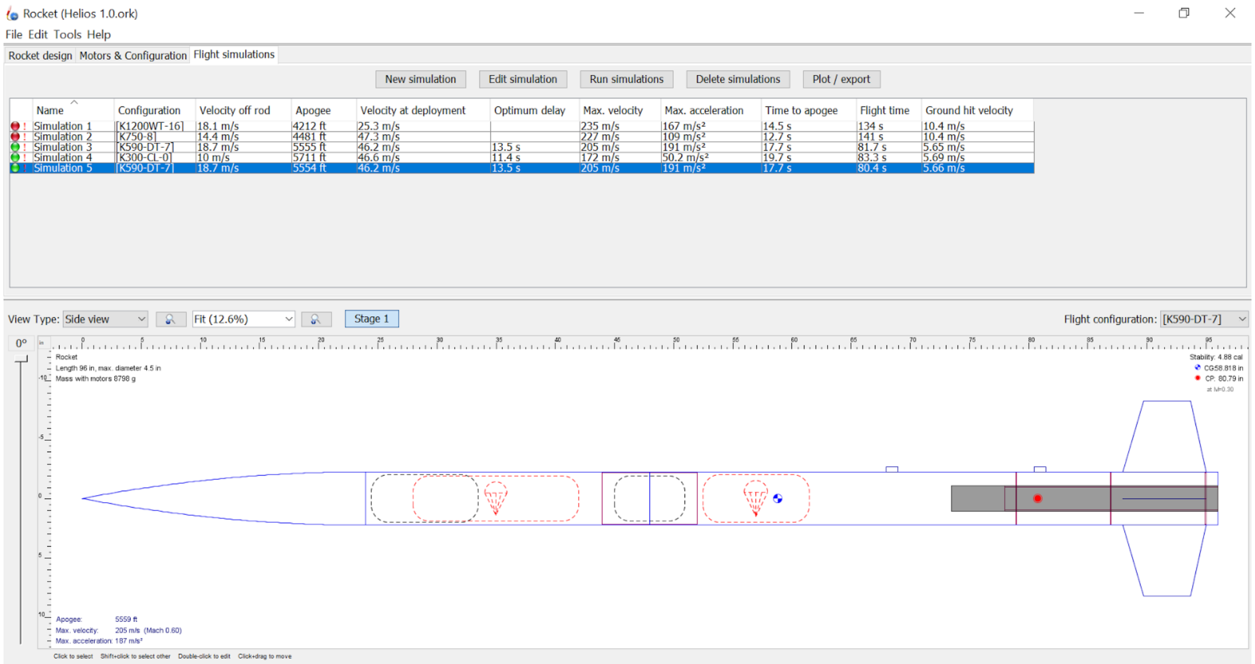
- For the most recent design of our recovery system the 15” drogue parachute was selected because of calculations made demonstrating that 15” is the best size, and for the main chute, the 108” is the best based on the same calculations as done for the drogue chute. The Kevlar 1500# shock cords were selected because they can handle more force and are fire resistant, as well as the fact that these are from the trusted retailer Apogee Rockets. For the protective wadding, we will use quest recovery wadding because it is cheaper and lighter weight.
- Using the estimated mass of the launch vehicle, perform a preliminary analysis on parachute sizing, and what size is required for a safe descent.
  - Step1: Calculate max Mass and Velocity combo’s to stay under the max K.E. of 75 ft.-lbs
    - 15fps - 21.3 lbf
    - 20fps - 12 lbf
    - 17fps - 16.5 lbf
  - 

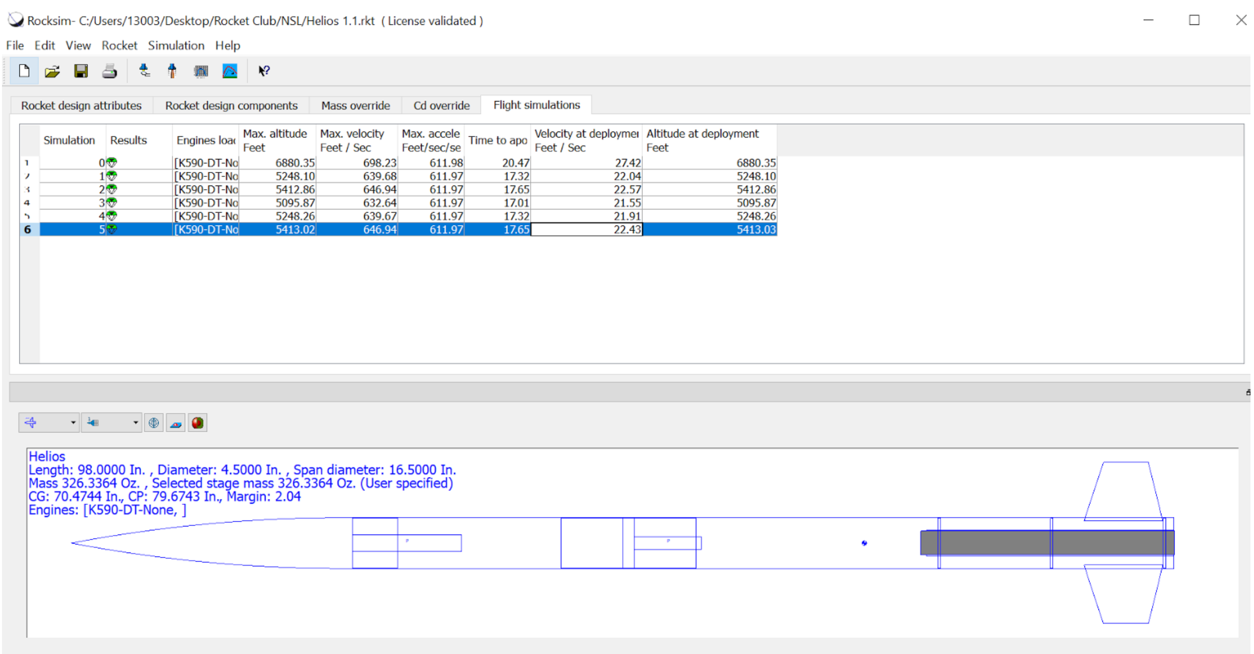
- Step 2: Using equations found on Apogee Components' newsletter, we plugged in the Mass/Vel. combo's into the equation to determine diameters of parachutes that maintain K.E. values. We calculated two examples, but then used online calculators to efficiently find other parachute sizes.
- 

- One thing to mention is that these preliminary sizes don't account for the drogue chute. This means that our estimates have a built-in safety factor, although not very big, since the descent rate will be less b/c the drogue chute will help reduce the rate in addition to the main chute capabilities.

* Prove that redundancy exists within the system.
    - The rocket will use two independently powered Perfectflite StratologgerCF altimeters. Each one will be powered by its own 9V Duracell battery. The main altimeter will be set to deploy the drogue chute at apogee, and the main chute at 800 feet. The back-up altimeter will be set to deploy the drogue chute at apogee+1sec and the main chute at 700 ft.

Mission Performance Predictions





- The altitude is simulated to reach between 5413 feet to 5554 feet., the overall weight of the rocket including motor is 20.4 lbs.The thrust curve for the preferred motor, the CTI K590 is shown below.

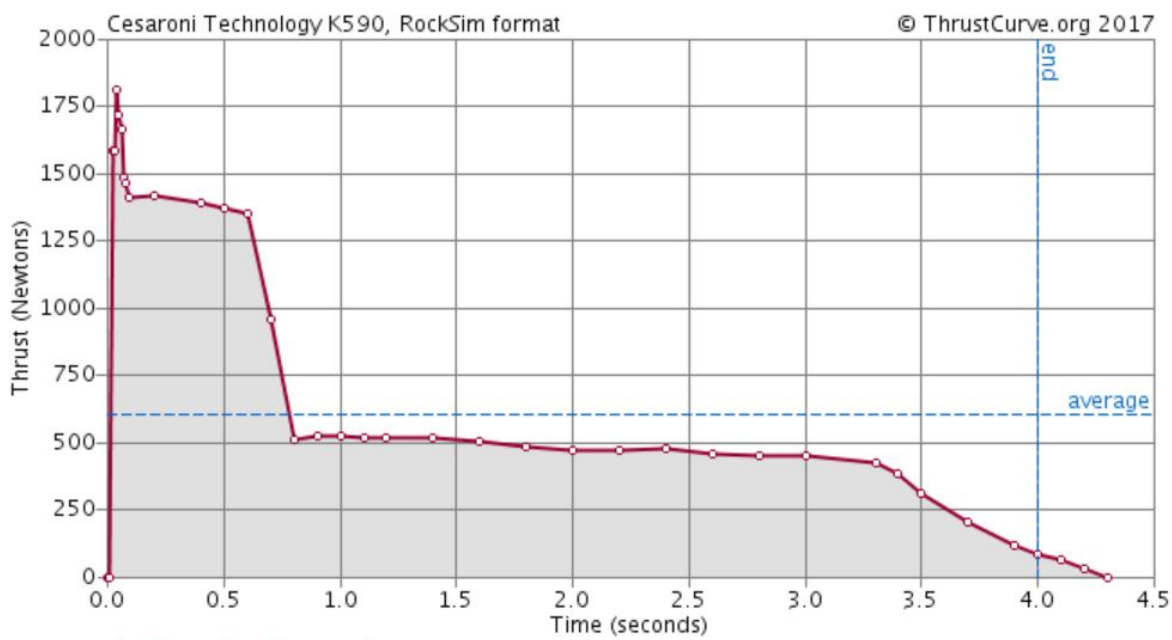
Simulator Data

Motor: Cesaroni K590
Contributor: Thomas Raithby
Submitted: Sep 10, 2008
Last Updated: Sep 10, 2008
Data Format: RockSim
Data Source: Manufacturer
License: Unknown

Statistics	Declared	Calculated	Official
Diameter (mm):	54.0	n/a	54.0
Length (cm):	57.2	n/a	57.2
Prop. Weight (g):	1,239.0	n/a	1,169.0
Total Weight (g):	1,994.0	n/a	1,994.0
Avg. Thrust (N):	561.6	606.1	590.5
Max. Thrust (N):	1,812.1	1,812.1	1,497.6
Tot. Impulse (Ns):	2,415.3	2,415.3	2,397.6
Burn Time (s):	4.3	4.0	4.1

Download: Download Now Add to Outbox

Data Graph



Alternates: in Pounds large size

- Stability Margin: The simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.The simulated Center of Pressure is 79.67 in from the tip of the nose cone. The Center of Gravity is 70.47 inches away from the tip of the nose cone. This gives a stability of 2.04. This meets the requirement of a minimum margin of 2.00, and we will confirm this on the final design build as well. If needed, nose weight can be added to increase this margin.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
    - The kinetic energy of the launch vehicle will be under the required maximum of 75 ft-lbf. The equation is:
        - K.E. = ½*m*v^2 = ½*(7.26kg)(5.1m/s) = 94.4J = 69.6 ft-lbf
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, five-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that the rocket will be launch straight up (zero-degree launch angle).
    - In order to calculate the drift, we took the distance the vehicle would descend under drogue and divided it by the descent rate (4480ft / 120 fps) and the same for the main parachute (1000ft / 17 fps) to determine the total time the rocket would be descending (37.3 + 47.1 = 84.4 sec). We then took that and converted it to hours (0.023 hr). Next we took this and multiplied it by the mph of wind in each scenario (ie 0.023 hr * 5 mph = 0.117 miles). The maximum drift allowed is 2500 ft (0.473 miles).
        - For 0 mph wind, and a vertical launch angle, there will be 0ft of drift
        - For 5 mph wind, there will be 0.119 mi. of drift
        - For 10 mph wind, there will be 0.234 mi of drift
        - For 15 mph wind, there will be 0.352 mi of drift
        - For 20 mph wind, there will be 0.469 mi of drift
- Present data from a different calculation method to verify that original results are accurate.
    - Using RockSim to verify with 5 mph wind, the drift is simulated to be 0.284 mi, and at 20 mph it is showing a drift over 1.14 mi
- Discuss any differences between the different calculations.
    - There are multiple differences between both the hand calculations as well as the computer simulations.
- Perform multiple simulations to verify that results are precise.
    - We ran simulations using both RockSim and OpenRocket, and they seemed to be less consistent than desired. The give numbers that seem bigger than our hand calculations. Without enough background and experience in this we need to continue to research this area of the launch events to ensure we meet this criteria.

IV) Safety

When team members operate machinery and construct rockets they will follow the safety contract signed as well as follow NAR and Tripoli rocket safety codes. Only those with tier two certification will handle the rocket motors. During construction and design of the rocket team members will abide by NFPA 1127 fire code and NAR safety codes. Team members will stop what they are doing if the safety officer, Team Leader, or any mentor observes that what that team member is doing is violating any of the requirements stated above. When testing rockets students will refer to minimum distance table shown below.

MINIMUM DISTANCE TABLE

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

When choosing a design to use in the NSL team members will refer to requirements in the safety segment of the handbook as well as NAR high powered rocketry safety code.

Hazard analysis

- Environmental hazards will be presented at a safety meeting to make sure all members of the team will understand the protocols for all potential hazards.
- The sanding of materials is a high risk and personal protective equipment should always be worn.
- Using hazardous chemicals or materials is a high risk.Power tool usage is a medium risk and a presentation on the proper usage and personal protective equipment will be provided.
- Fumes and damages from usage of a soldering iron is a medium risk and personal protective equipment will be included in the presentation.

- MSDS sheets will be available and the proper storage procedure should always be followed. Example chemicals are potassium perchlorate, potassium nitrate, and sulfur. Eyewash stations and other decontamination stations will be known of.
- If a team member is using any of the above tools or processes in an unsafe manner, they will be subject to a review of the safety presentation. After they get approval from a mentor, Safety Officer, or the Team Leader, they can resume their activities.

Risks

Time Risks

- Our first plan to purchase motors is to purchase a Cessaroni K590 dual thrust motor from Apogee Components. Shipping should take 1-2 weeks. However, at this moment in time, the motors are not in stock. Plan B will be to buy them from Wildman Rocketry, and if that doesn't work, we will buy them from a different online vendor. We will plan to purchase our motor several weeks before we need it delivered for launch. Other motors available are Cessaroni K500 and Cessaroni K600. The first consideration for the solar panels are panels from Alta Devices. The only problem with this choice is we are unsure whether their panels are commercially available. If that is so, we would have to go to our second choice, Miasole, or even our third choice, Microlink. Using those would sacrifice efficiency or size respectively.
- Our arduino will most likely be one chosen from the official arduino website, no more than forty dollars. One consideration for a small onboard computer is a raspberry pi. Shipping will take an estimated 1-3 weeks. If none of those options are viable, we will go back to the drawing board.

Budget Risks

- A need for more personal protective equipment, such as safety glasses and gloves, may add some cost to our budget. The budget will not go over a large amount. Any part of the rocket breaking will require additional resources to be ordered. This will cause a time delay and more cost to our budget. So far all of our funding that was expected to come in is on track to be donated. We are constantly evaluating new avenues for fundraising as well.

V) Payload Criteria

Selection, Design, and Rationale of payload

- Describe what the objective of the payload is, and what experiment it will perform. What results will qualify as a successful experiment.
    - The main objective of our payload is to measure the voltage, produced by the solar panels, to see if the voltage output changes based on the altitude of our rocket. A successful experiment would qualify when data is read throughout the launch and that data is compared to the control on the ground.
- Review the design at a system level, going through each systems' alternative designs, and evaluating the pros and cons of each alternative.
- Solar Panels
    - Micro Link
        - Pros:
            - Flexible design
            - Greater than 30% efficiency
            - Waterproof
            - Very thin
        - Cons:
            - Small in size
            - They look unreliable
            - Are meant for wings with a small amount of curvature
    - Miasolé
        - Pros:
            - Size is adjustable
            - Low cost
            - Very Flexible
            - Easy to Install
            - Very thin
        - Cons:
            - Cell size might be too large
            - Low voltage output
            - Low efficiency
    - Alta Devices
        - Pros:
            - Very Flexible
            - Good voltage output
            - Meant for fast moving vehicles
            - Very light and Thin
        - Cons:
            - Very small
            - Would have to buy a lot for full experimental capabilities
            - We aren't sure if they are for commercial use
- Voltage Documentation
    - Arduino Uno

            - Pros
                - Very easy to work with
                - Cheap
                - Many options
            - Cons
                - Can only measure up to 5V
        - Raspberry Pi Zero
            - Pros
                - Easy to work with
            - Cons
                - Limitations for usability
                - Bigger
                - Heaver
                - Expensive
    - Transmitters
        - HAM Radio
            - Pros
                - Long range
                - Easy use with arduino
                - Less than one second update time
            - Cons
                - License needed to operate
        - Zigbee
            - Pros
                - Easy form factor
                - Simple, no license required
                - cheap
            - Cons
                - 5 second update time
    - Altimeters
        - Raven3
            - Pros
                - 4 programmable outputs
                - Very compact
            - Cons
                - Not reliable enough
                - Expensive
        - Perfectflite StratologgerCF
            - Pros
                - Reliable
                - Cheap
                - Readily available
            - Cons

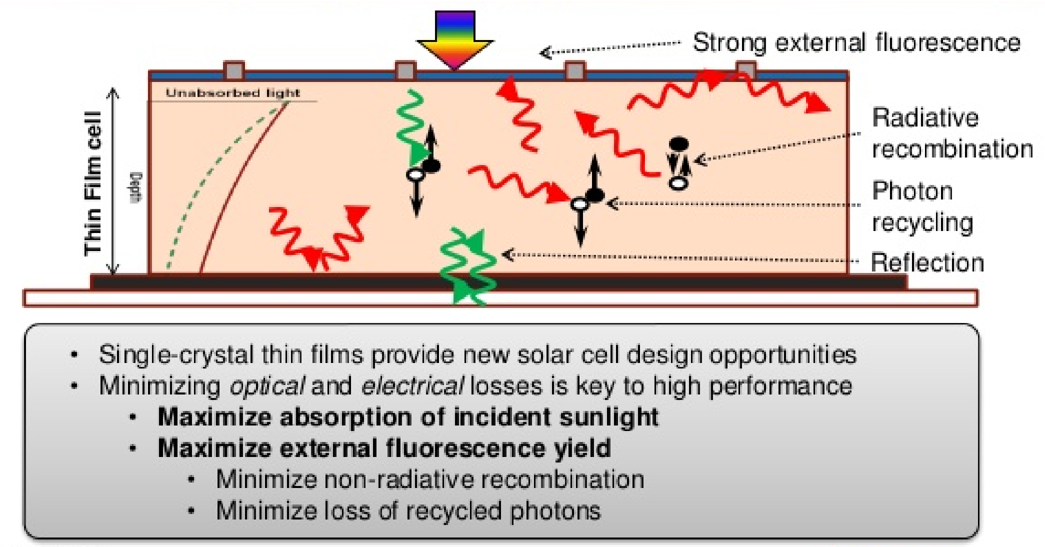
            - Uses a larger amount of power
    - Telemetrum
        - Pros
            - Can be programed with C
        - Cons
            - Expensive
            - Very advanced
- Gyroscopes
    - Adafruit
        - Pros
            - Nine degrees of freedom
            - Durable
            - Highly recommended
        - Cons
            - Expensive
    - Sparkfun IMU Breakout MPU-9250
        - Pros
            - Cheap
            - Nine degrees of freedom
            - Extremely small
        - Cons
            - Very fragile
- For each alternative, present research on why that alternative should or should not be chosen.
    - Solar Panels
        - Micro Link should not be used because of the main purpose of this panel is for UAVs using a very slight curvature not meant for a drastic curve like our rocket. This panel also looks unreliable and isn't really what we are looking for.
        - Miasolé should not be used because it is very large and not conventional for our payload design. This panel has a good efficiency and it is easy to install, but the individual cells are way too large for our application.
        - Alta Devices should be used because it is a small and reasonable size with a good efficiency. These cells would be able to flex around the entire rocket. The cells are easy to install and are extremely resistant to weather.
    - Voltage Documentation
        - Arduino Uno should be used because it is very easy for us to use. This board is the cheaper option and supplies us with many options for what we want to do. This board can only measure up to five volts, but an attachment can be used to increase the the voltage measured.

        - Raspberry Pi should not be used because it has very limited options and will not have enough options for our payload. This board is also much bigger and heavier than the Arduino. The Raspberry Pi is also much more expensive than the alternative option.
    - Transmitters
        - The HAM Radio should be used because it has a very long range. This transmitter is also very easy to use with the Arduino board. With a less than one second needed to update, this transmitter will be very helpful when trying to communicate with our rocket. The only real downside is that a license is required to use this transmitter.
        - The Zigbee transmitter should not be used because it does not have a fast enough update time as the HAM Radio. This transmitter may be cheap and does not require a license, but it will not be very helpful in the Arduino board is used.
    - Altimeters
        - The Raven3 should not be used because it is not a very reliable altimeter. This altimeter is also very expensive and we do not have a ton of money to be spending on altimeters. The Raven3 is very compact, but it is not the right fit for our payload
        - The Perfectflite Stratologger should be used because it is a very reliable altimeter. We have used this brand before and it has been very successful for us. This altimeter comes at a reasonable price and seems to be readily available to us. We feel the Perfectflite is the best fit for our payload based on previous experiences with this altimeter.
        - The Telemetrum altimeter should not be used because it is also very expensive. This altimeter is also too advanced for the application in which we would use it. It can be coded using only C, but that alone is a lot to learn and apply in a very specific way.
    - Gyroscopes
        - The Adafruit gyroscope should be used because it has a very good recommendation from people we know that have used it before. It has nine degrees of freedom and will accommodate all of our payload needs. This gyroscope might be a little more expensive but it is the best option for what we are trying to achieve with our control on the ground.
        - The Sparkfun IMU Breakout MPU-9250 gyroscope should not be used because it is very fragile. We want to put the gyroscope in the rocket and if we have a very fragile one then there is no guarantee that our hardware will survive the trip. The gyroscope is

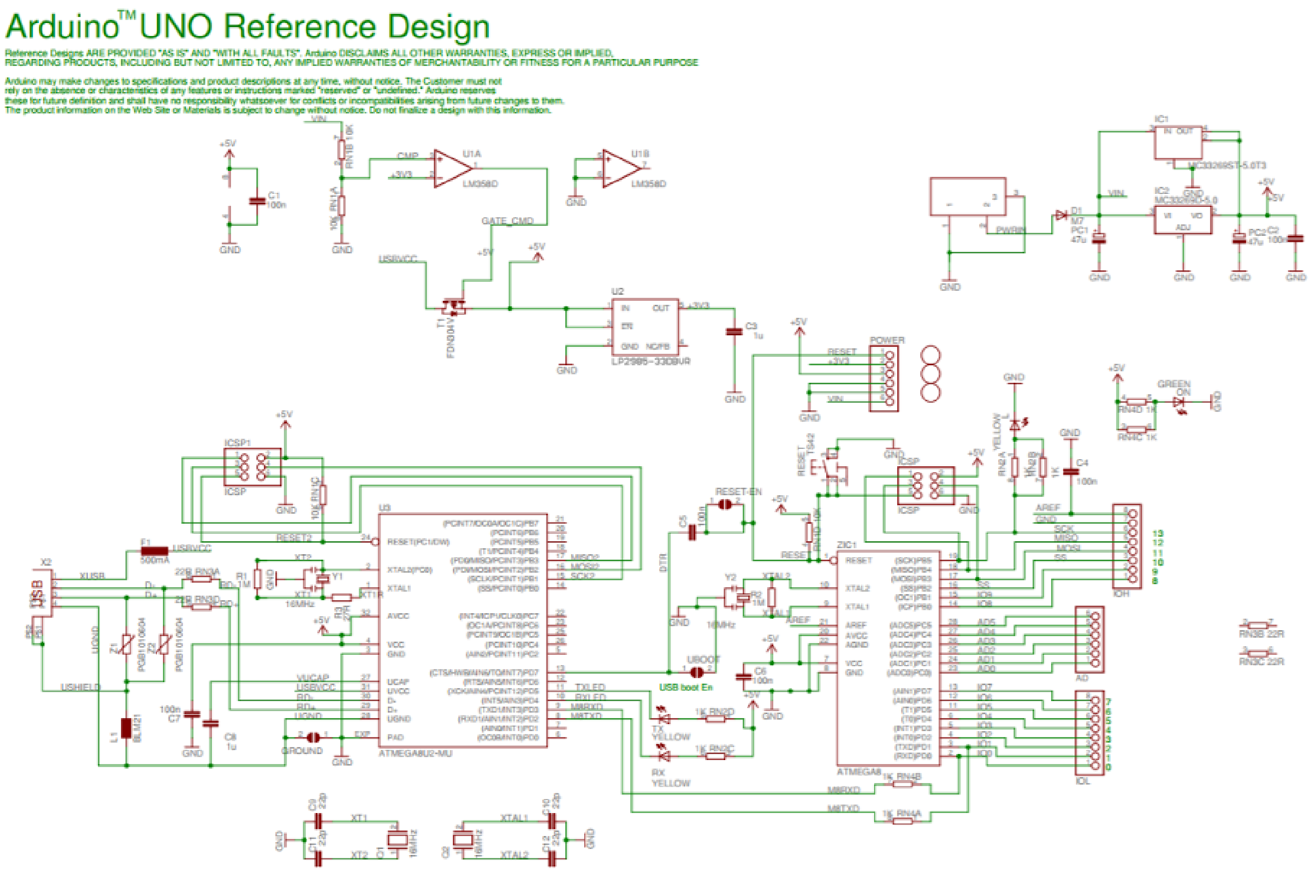
very important in comparing with the control. If there is no control than the experiment will not be very conclusive.

- After evaluating all alternatives, present a payload design with the current leading alternatives, and explain why they are the leading choices.
    - The solar panel that is leading is the Alta Devices panel. This panel is very durable, being made of gallium arsenide. This company has figured out how to "recycle photons" by allowing to light to bounce off the back of the panel and be used again to produce electricity. The efficiency continues to increase with innovations to the design made by the company. This solar panel is very easy to install on any surface with a curve and stays there throughout the duration of its use.
    - The voltage documentation board that is leading is the Arduino Uno. This board has a very large amount of options and will fill all of the tasks needed for our payload. This board is also very user friendly and will be easy to learn because we are not experts in coding. The Arduino board may only be able to measure up to five volts, but an attachment can be applied to the board to measure more than five volts. This board is our best option and can easily communicate with the HAM Radio.
    - The transmitter that is leading is the HAM Radio. This transmitter is very reliable with a very large range. The HAM Radio also updates in less than a second, which will be very reliable when trying to collect data and conclude our experiment as a whole. This radio will ensure than our rocket is found and that we never have the problem of losing our rocket or that data that we collect. This radio also communicates well with the Arduino Uno which makes it easier for us when we are setting everything up and making sure the volt reader works 100% of the time.
    - The altimeter that is leading is the Perfectflite StratologgerCF because we know how it works. We have used a Stratologger altimeter in the past and know that it is one of the best altimeters out there for commercial use. This altimeter comes at a price, but without a reliable altimeter our data could be skewed and our entire experiment would not be as accurate. Our whole experiment relies on how high we are in the air and what the solar panels read at that height. Knowing the altitude is the most important part to our experiment.
    - The gyroscope that is leading is Adafruit gyroscope because it has been highly recommended for our experiment. We have a very reliable reference and that person has told us that the Adafruit gyroscope is our best option. It may be a little more expensive, but without the best products the experiment will not be the best. The gyroscope must be durable to withstand the shocks of launch and the other gyroscope did not fit up to that standard.
- Include drawings and electrical schematics for all elements of the preliminary payload with estimated masses.

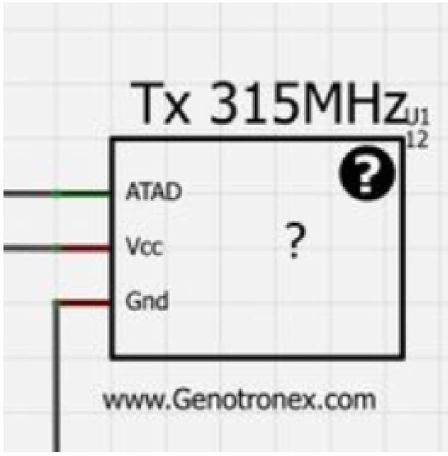
- Alta Devices (Single Cell 180mg)



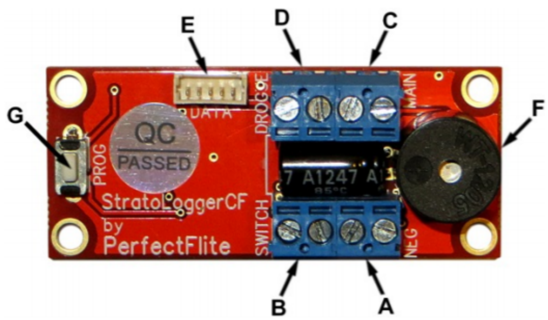
- Arduino (25g)



- HAM Radio (4g)



- Perfectflite StratologgerCF (10.77g)



A) **Battery Terminal Block:** Connect a 4 volt to 16 volt power source here. Ensure that the negative battery terminal is connected to the terminal labeled "NEG". *Polarity (POS/NEG) must be correct or altimeter won't power up. Reverse polarity will not cause damage.*

B) **Power Switch Terminal Block:** Remove factory supplied jumper and connect a power switch here. *Must be connected to an external switch or shorted with a jumper or the altimeter will not power up.*

C) **Main Ejection Output Terminal Block:** Connect to the electric match for the main deployment charge (if used), or leave unconnected otherwise. ***DO NOT SHORT CIRCUIT!***

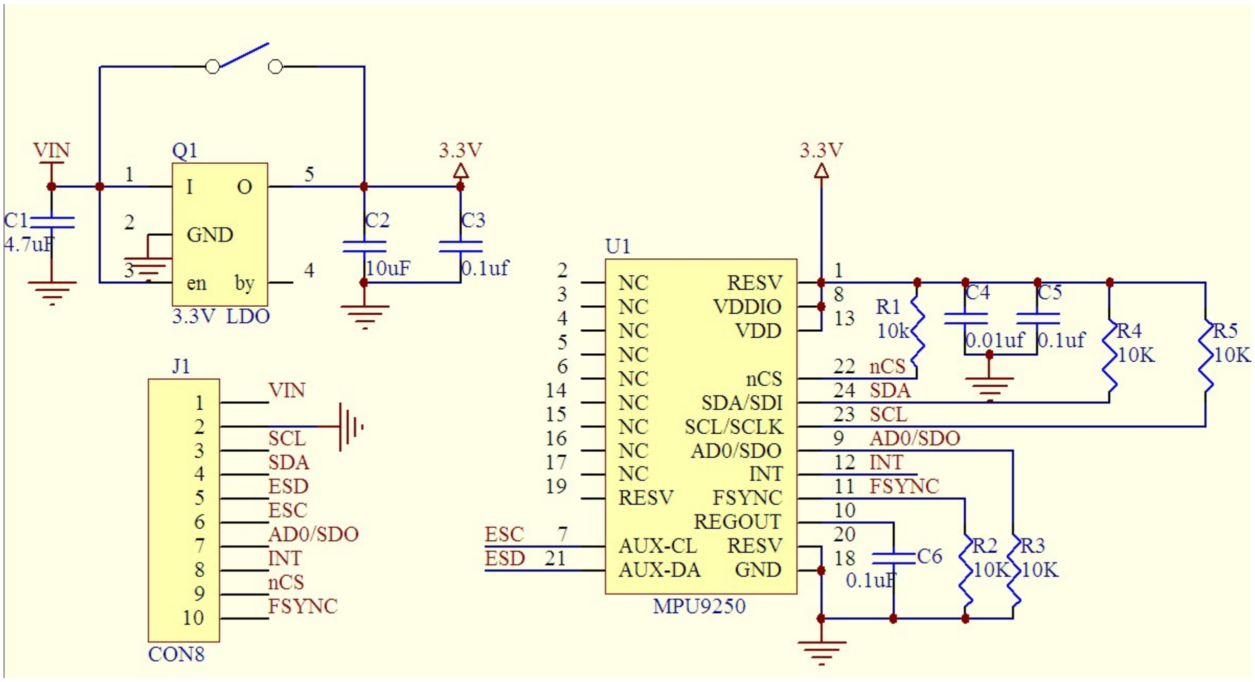
D) **Drogue Ejection Output Terminal Block:** Connect to the electric match for the drogue/apogee deployment charge (if used), or leave unconnected otherwise. ***DO NOT SHORT CIRCUIT!***

E) **Data I/O Connector:** For connection of the optional data transfer kit or user-supplied in-flight telemetry equipment.

F) **Beeper:** Audibly reports settings, status, etc. via a sequence of beeps.

G) **Preset Program Button:** For selecting and modifying the 9 user settings presets (see pages 20-22).

- Adafruit Gyroscope (2.3g)



- Describe the justification used when making design selections.
    - We went with the products that were the most reliable and were the best option for each part of the payload. Each piece of the payload was analyzed and assessed on how that specific part would either make the payload better or worse. The main driving factor was on how everything was chosen and what alternative would be the easiest for us to use and create the best overall data we need for success.
- Describe the preliminary interfaces between the payload and launch vehicle.
    - The payload will be a set of small flexible solar panels adhered to the upper body tube of the rocket. These panels will have wires fed through the wall of the rocket and wired into the electronics bay. The electronics bay will be a sealed compartment within the rocket's main body tube that will house the voltage reader and storage device. The gyroscope and radio transmitter will also be housed in this bay as well.

VI) Project Plan

Requirements Verification

- General Requirements
    - Project will be done 100% by the students.
        - Teacher will be present but will not be involved in the production of the entire project.
    - Team will meet all deadlines completely on time.

        - A countdown calendar will be added to the website for the closest upcoming deadline.
    - The team will hold a educational engagement activity once a month
        - Will be held at the same regard as the PDR, CDR, and FRR. A calendar will be setup on website to make sure deadline is met.
    - The team website will be hosted and updated at least once a week
        - This will be done by the Outreach Manager Andre Bryan at least every Tuesday during the mandatory weekly meeting.
- Vehicle Requirements
    - The rocket will reach an apogee of 5,280 feet
        - We'll test this with the altimeter.
    - The rocket will hold an altimeter to measure the altitude
        - We'll test our altimeter at every test flight.
    - Altimeter will have its own power supply
        - This will be tested at every test flight.
    - The rocket will be easily recoverable and reusable
        - This will be tested at every test flight.
    - Rocket's payload will hold all circuitry with the ability to measure and store information gathered
        - This will be tested at every test flight.
- Recovery System Requirements
    - Drogue and main parachute. Drogue chute deployed at apogee, while main parachute deployed at a lower altitude
        - This will be tested at every test flight.
    - Motor ejection won't be used for primary or secondary stage.
        - This will be tested at every test flight.
    - Recovery will be in a 2500ft. Radius of launch pad
        - A radius of 2500ft. will be marked around the launchpad at every test flight.
- Experiment requirements
    - Rocket will carry solar panels to measure sun's output at different altitudes
        - This will be tested at every flight by measuring the voltage out.
    - Onboard electronics to measure and store data about voltage output
        - This will be tested at every flight by downloading measurements to a computer and making sure the data matches up.
    - Solar Panels will accurately read the intensity of the sun
        - This will be tested at every flight by downloading measurements to a computer and making sure the data matches up.
    - Onboard gyroscope will accurately send information to ground model
        - This will be tested at every flight by downloading measurements to a computer and making sure the data matches up.
    - Ground model will accurately mirror the in flight rocket

        - This will be tested at every flight by making sure measurements match up.
- Safety Requirements
    - Completed safety checklist before every launch
        - This will be checked by safety officer and mentors
    - Safety officer at every launch directing team members and/or spectators to dedicated safe spaces
        - This will be done at every test launch to ensure full safety during every following launch.
    - No NAR/TRA codes will be violated at any launch
        - This will be another job dedicated to the safety officer, and his job to ensure the safety of any team members and/or onlookers.

Budgeting and Timeline

- Line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees.
- Funding plan describing sources of funding, allocation of funds, and material acquisition plan.
- Timeline includes all team activities, and activity duration. Schedule appears complete, and encompasses the full term of the project. Deliverables are defined with reasonable activity duration. GANTT charts are encouraged.


Task Name
Q4
Q1
Q2
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
1 PDR Process
2 Sections III-VI of PDR
3 Sections I-II and PDR Prese
4 Fundraising Applications
5 CDR Process
6 Sections III-IV of CDR
7 Sections V-VI of CDR
8 Sections I-II and CDR Prese
9 Acquisition of Materials
10 Model Rocket Build
11 Launch Model Rocket
12 Backup Model Launch
13 Midwest Power Launch
14 Cedar Valley STEM Fair
15 Future Rocketeers Outreach
16 Future Rocketeers Outreach
17 FRR Process
18 Sections III-V of FRR
19 Section VI-VII of FRR
20 Sections I-II and FRR Prese
21 Acquisition of Materials
22 Coding Process
23 Rocket Build
24 Future Rocketeers Outreach
25 Future Rocketeers Outreach
26 Future Rocketeers Outreach
27 Plateville Trip, Rocket Laun
28 Plateville Trip, Rocket Laun
29 Plateville Trip, Rocket Laun
30 Huntsville Trip
31 PLAR Posted

Budgeting

2018 NSL Rocket Budget			
Item	Cost	Quantity	Total
Cesaroni K590 Motor	$148.95	3	$446.85
4.5" Fiberglass bodytube (per ft)	$30.00	6	$180.00
Cesaroni 54mm 6-Grain Hardware Set	$99.00	1	$99.00
5:1 Ogive Filament Wound Fiberglass 4.5" nosecone	$99.00	1	$99.00
108" Parachute	$100.00	1	$100.00
Parachute Protector	$30.00	1	$30.00
15" Drogue Parachute	$19.95	1	$19.95
4.5" Fiberglass body tube coupler	$19.95	3	$59.85
RocketPoxy structural adhesive	$65.00	1	$65.00
G10 Fiberglass 18"x24"x 0.125" sheet (for fins)	$27.00	4	$108.00
Kevlar Shock Cord - 1500# - Main Chute (per ft.)	$0.97	40	$38.80
Kevlar Shock Cord - 1500# - Drogue Chute (per ft.)	$0.97	40	$38.80
Tube Bulkhead - 4.5"	$7.99	4	$31.96
3/8" U-bolts	$5.49	4	$21.96
Motor Mount Tubing - 54mm fiberglass	$36.00	1	$36.00
Centering Ring - 4.5" x 54mm inner dia. Fiberglass	$9.99	1	$9.99
AeroPack Retainer - 54mm	$31.03	1	$31.03
1/4" quick links	$0.99	6	$5.94
4-40 Nylon shear pins (20-pack)	$1.00	6	$6.00
Removable Plastic Rivets (10-pack)	$5.00	5	$25.00
1/4" threaded steel rod (3ft. Each)	$1.75	2	$3.50
PerfectFlight StrattologgerCF altimeter	$54.95	2	$109.90
Solar Panels	$10.00	20	$200.00
Adafruit 9-axis gyroscope	$35.00	1	$35.00
Adafruit Feather - 32u4 RFM96 LoRa Radio	$35.00	1	$35.00
Arduino	$30.00	2	$60.00
433MHz Receiver	$0.00	1	$0.00
Rechargeable batteries	$10.00	3	$30.00
Misc. wiring for solar panels	$75.00	1	$75.00
Ground Station Equipment (servos, hardware, etc.)	$150.00	1	$150.00
Scale Model	$500.00	1	$500.00
Cesaroni Motor for Scale Model	$50.00	2	$100.00
	$0.00		$0.00
	$0.00		$0.00
	$0.00		$0.00
	$0.00		$0.00
	$0.00		$0.00
TOTAL:	$0.00		**$2,751.53**

Total budget: $6,950

a. We are budgeting $500 to the motors to our rockets. We plan on using K590 Cesaroni motors, which cost between $150-$175 each after Hazmat shipping.

We plan on needing to use at least three of these, for our test launches and final flight, and we are budgeting extra just in case there is a problem with one of the other engines, or if the launches do not turn out successful.

b. There will be $2,000 of our budget devoted to travel. For the trip to Huntsville, Alabama the team is going to need two hotel rooms for a span of about four nights, with each hotel room costing about $125 per night, adding up to a total of $1,000. We will also need to purchase gas for the school van we will be taking down there. With the current price of gas, that will cost around $300. Since a substantial amount of work and launching will be done in Platteville, Wisconsin, which is 122 miles away, we will need to add about $700 to our budget for our multiple trips up there. All of these added together makes our budget for travel. If we change travel plans to fly to Huntsville, we still need to account for hotels and rental car prices/gas, but the total travel budget will double to $4,000.
c. Our rocket team will be budgeting $600 towards the scale model version of our rocket that is a requirement of the project. We will need to pay for the fiberglass/cardboard needed for the body, the nose cone, the parachute and its shock cord, the motor, motor mount, fasteners, and everything else needed to complete it.
d. The Cedar Falls Rocket Club is going to need to spend about $2,751.53 on materials for our final rocket. It will cost a substantial amount of money to make our rocket since it is out of fiberglass, and since it is around eight feet tall. The solar panels and accompanying electronics that will be necessary will account for another large part of our budget. Electronics used in the payload will be nine axis gyroscope, HAM Radios, receivers, voltage readers, and arduinos for transmitting solar panel data and gyroscope data.
e. As part of our research, we will have a solar panel stationed on the ground during the rocket's flight. This panel will be communicating with the rocket in order to keep the direction of the panels on the rocket in sync with the panels on the ground throughout the entire flight using a Ham radio receiver to send information to the gyroscope to orient the panels correctly.
f. Our itemized budget plus travel expenses total just over $5,800, but we are making our total budget $6,950. As part of our safety plan, we want to account for unexpected expenses such as broken parts, extra items we need to

purchase, and additional travel expenses. We are using a 20% overage as our basis for our Total Budget amount. We will also plan to continue to fundraise after we have reached this target of $6,950 so that we can have a start-up fund ready for next year's team.