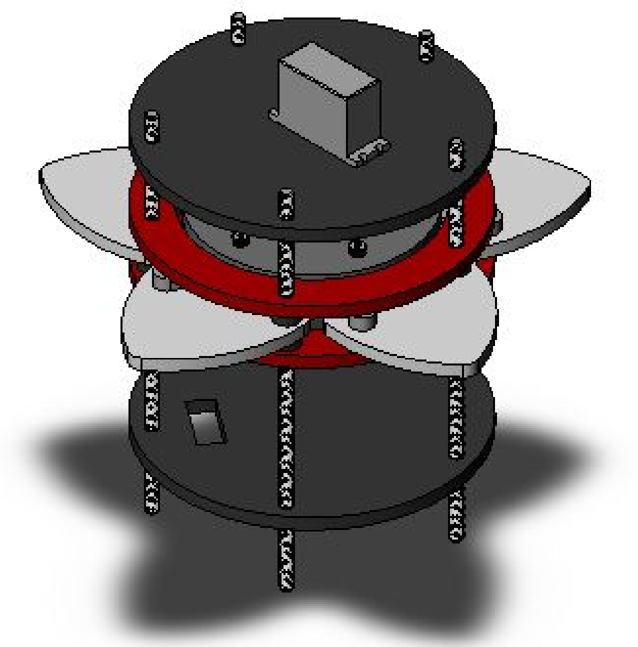
Preliminary Design Report

Century College Rocket Team
Century College



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Executive Summary

The Space Grant Midwest Rocket Competition for 2015-16 has students engineer a rocket with a drag system and onboard data collection device. The rocket would then take two flights, one with the drag system completely off to reach an apogee of at least 3000 ft, and another flight with the drag system turning on (after engine burnout) and off (before apogee) to reach an apogee of 75% of the first flight's apogee. The stability of the rocket had to be kept within 1 to 5 cal in both flights. The competition states that a camera will be onboard to see what state the drag system is in. The rocket was modeled on OpenRocket and SolidWorks. The total length of our rocket is 93 inches from the top of the nose to the end of the fins. The outer diameter of the rocket is 6.155 inches with a total weight of 6.5 kgs. The engine used is a 1364-K454-19A Skidmark with an average thrust of 454.1 N, and a total impulse of 1363.7 Ns. We predict the rocket's first flight will reach a height of 1043 m (3422 ft) while the second flight will reach a height of 880 m (2888 ft). On October 19, 2015 Century College (Century College Rocket Team) began in the Midwest High - Power Rocketry Competition hosted by the Minnesota Space Grant Consortium and Tripoli Minnesota.

Introduction

The Space Grant Midwest Rocket Competition for this academic year has the goal to have students design a high-power rocket that reach a height of at least 3,000 ft on its first flight with a drag system disengaged onboard. That same rocket would be launched a second time with a drag system engaging (after engine burnout) and disengaging (before apogee) to reach a height of 75% of its first flight. Additional criteria of the competition was to include a non - commercial onboard device to collect data of the drag characteristics of the rocket flight as well as an onboard camera to observe the state of the drag system during flight. To achieve this a drag system was designed on SolidWorks while the rest of the rocket was done with OpenRocket simulations. OpenRocket was also used to find drag characteristics with the drag system disengaged while hand calculations were done to drag characteristics with the drag system engaged. This report shows the breakdown of the team's design.

1.0 Design Features of Rocket Airframe

Our design method of our rocket was to form a drag system and create a rocket around it. With that in mind the rocket was created into three sections. The nose/drag system, the engine, and recovery section. All these sections are shown dimensionally in Figure A down below rounded to the nearest inch.

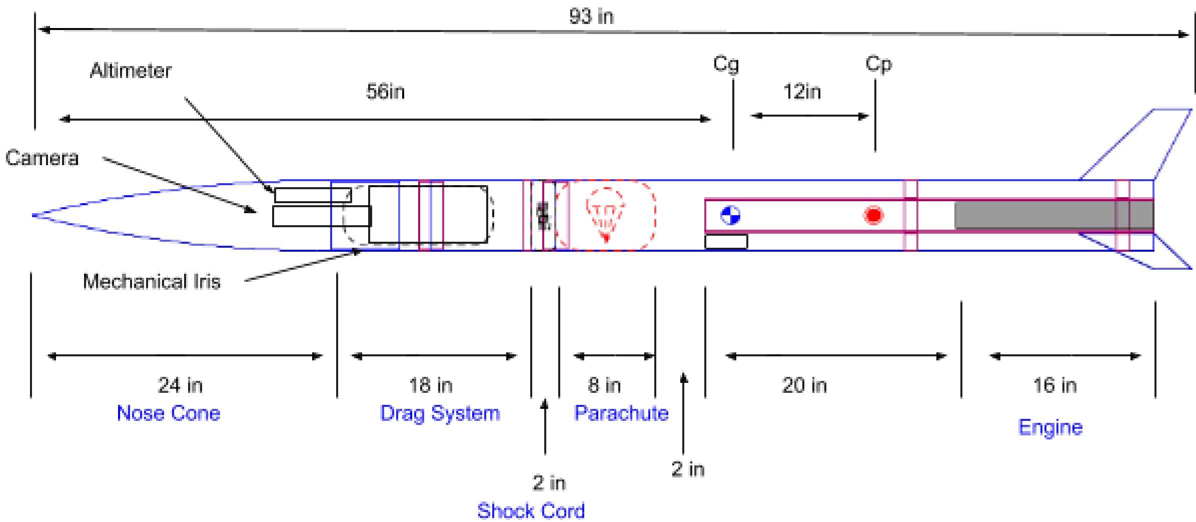


Figure A

1.1 Nose/Drag system section

The nose cone used is a fiberglass 24 inch ogive cone with a ratio of 4 to 1. This would mean it would fit into a 6 inch diameter (6.155 in. outer diameter) rocket airframe. The nose cone also has a 5.5 inch shoulder that slides into the airframe. The drag system area is the drag system in between two small body tubes. The small body tubes are phenolic tubes that have a length of 7 and 10 inches. The 7 inch tube is closer to the nose cone while the 10 inch tube is on the other side of the drag system towards the other end of the rocket. The drag system adds an inch to the overall length of the rocket. This leaves the total length of the drag system area to be 18 inches long. At the end of the drag system there is a .5 inch thick wooden bulkhead that has a diameter of 6 inches. At this bulkhead there are U bolt attachment holes as well as a wire hole for wires to feed down to the remote activated ejection charge. The bulkhead is then secured in the body tube using epoxy adhesive.

1.2 Engine section

The engine section of the rocket is made from 48 inch PT 6.0 phenolic tube. The fins at the end of the rocket have a root chord, height, and sweep length of 6 inches. The tip chord has a length of 3 inches and the sweep angle is 45 degrees. The engine mount is a PT 2.1 phenolic motor mount tube. The motor mount is 36 inches in length. The motor mount is held in the body tube by two plywood centering rings. The size of the center rings are 6 inch outer diameter and 2.1 inch inner diameter. The engine is held in the engine mount with a HAMR aluminum motor retainer. The engine selected is the 1364-K454-19A Skidmark. The dimensions of this engine are 54mm by 404mm (2.13 by 15.91 in). The engine an average thrust of 454.1 N, a maximum thrust of 620.0 N, and a total impulse of 1363.7 Ns. This engine has a burn time of 3.0 seconds and has delay times of 10 to 19 seconds. The thrust curve for this engine is shown below in Figure B.

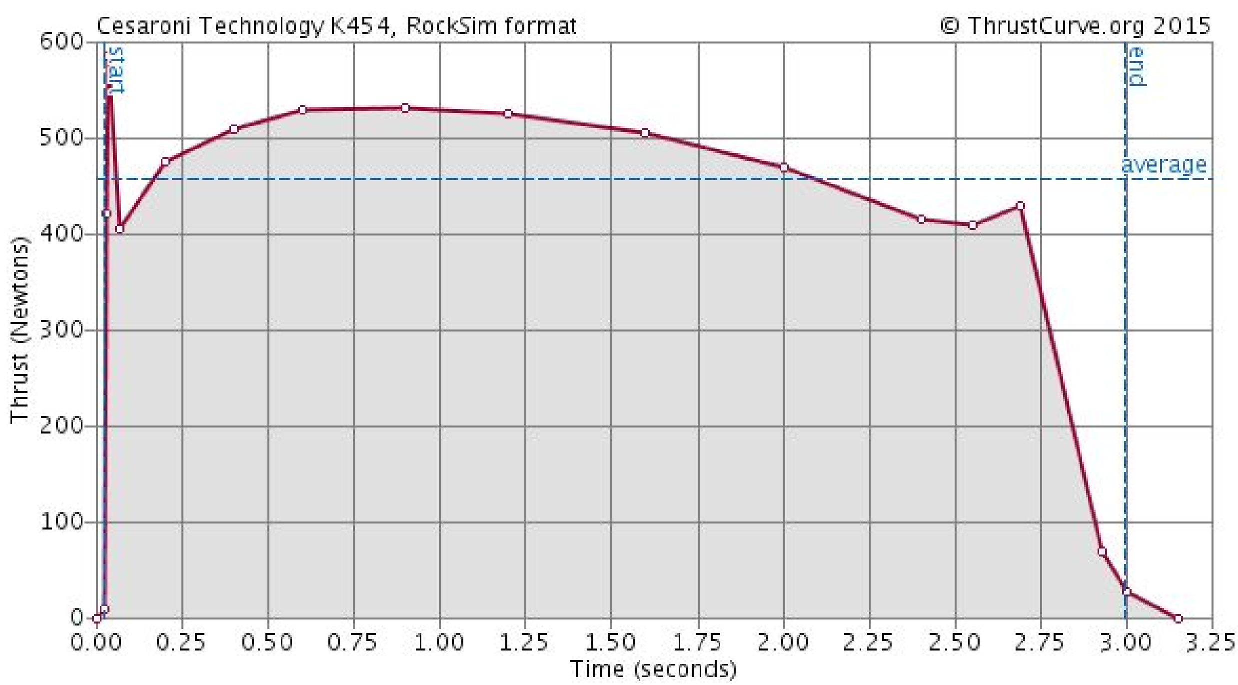


Figure B (http://www.thrustcurve.org/simfilesearch.jsp?id=1551)

1.3 Recovery system

The recovery system packed length was a total length of 10 inches. The parachute we picked can carry a rocket that weighs 6.5 kilograms. The parachute used is the PAR-84HD made from 1.9 oz ripstop nylon. This parachute can carry rockets weighing anywhere from 5.6 kg to 7.37 kg. The parachute length is 84 inches and also has a 16 inch spill hole to allow the rocket to sway less as it is descending. With this parachute the descent rate was estimated to fall at a rate of 19 ft/s which is in the safety parameters. The shock cords used to hold the rocket together through descent is a ¾ inch tubular nylon shock cord with a length of 8 yards. The shock cord itself has a weight rating of 3000 lbs and is attached to the U bolt in the bulkhead and the U bolt that is attached directly to the 48 inch phenolic tube. Our first ejection charge design was to use a spring the would be initially compressed and release at a certain altitude to deploy the recovery system. However due to time constraints this method was not explored and a more standard ejection was implemented. Our ejection charge what then designed to release a small burst of thrust to deploy the recovery system. The remote ejection charge has a size of 5 by 2 cm and is attached to the end of the motor mount with epoxy.

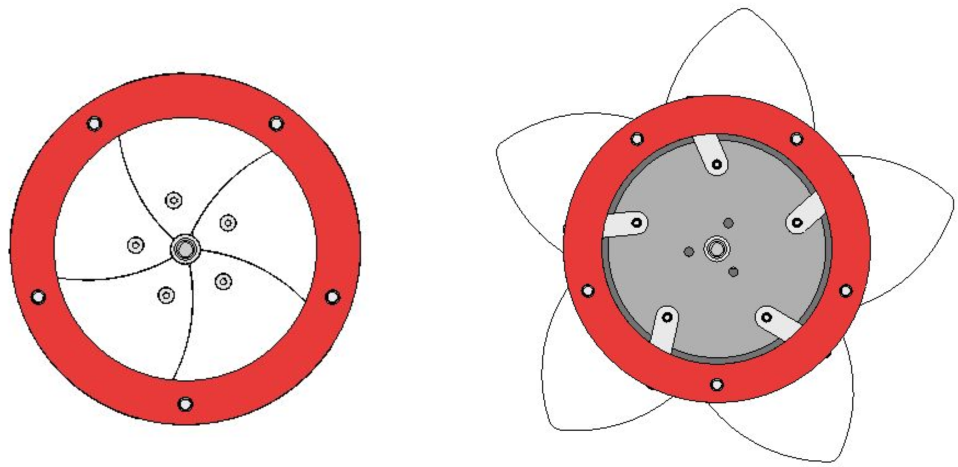
2.0 Design Features of Electronics/Payloads

2.1 Drag System Description and Operation

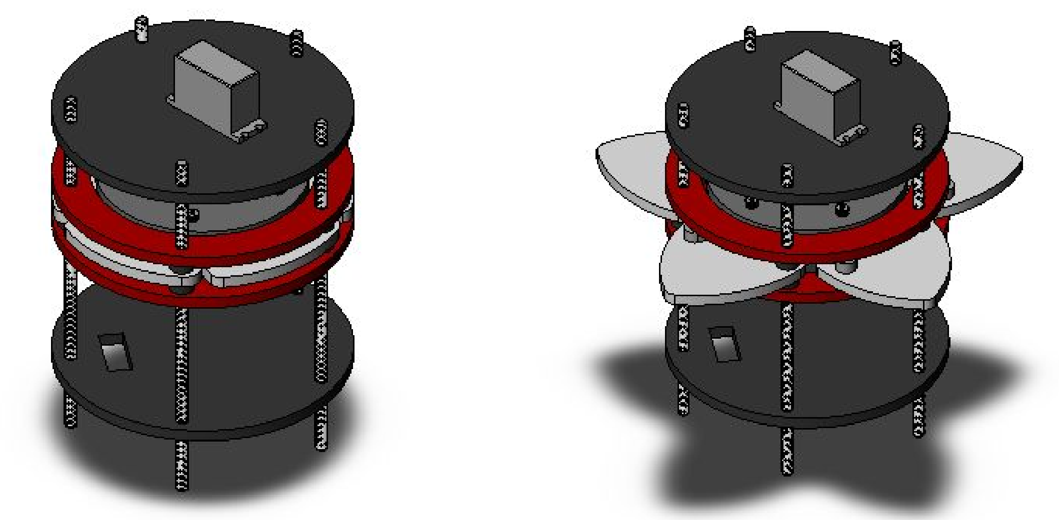
The drag system is modeled after a condensed mechanical iris (see Figures C and D). Each of the drag fins are linked together by bars to a motor plate-motor shaft. In turn, operation of the system is driven by a Parallax standard (180° rotation) servo motor that is run by an Arduino microcontroller to operate the servo for a specified duration and angles of rotation (see Figures E and F). Output ranges between 0-~45° for retracted fins to full open, respectively. The servo’s direction is reversed to 0° to retract the fins. The Arduino’s output is triggered by input from an AIM XTRA v2. altimeter.

2.2 Drag System Orientation

The altimeter, mechanical iris and servo are all mounted on threaded rod via a bulkhead, two brackets and another bulkhead from nose to fins, directionally. The entire drag system spans 18 inches along the airframe, centered around the mechanical iris. The mechanical iris is ~1 in. in width. The additional space consists of a small “USB” camera for recording the drag system operation (~3 in. towards the nosecone of the rocket), the AIM XTRA v2. altimeter (~5.5 in. atop the front, nosecone, bulkhead), and the servo motor, motor shaft, and motor shaft mount (~5 in. attached to the rear, fin, bulkhead). The remaining ~3.5 in. area is used for spacing and two bulkheads on opposite sides of the iris.



Figures C and D



Figures E and F

2.3 Electronics

The altimeter used in our rocket is the AIM XTRA v2. Altimeter. This altimeter is a GPS tracking flight computer system. By using the AIM Base receiver connected to a laptop a full telemetry and tracking system is created. The Aim Base receiver takes signals from the AIM XTRA to view the launch data. The AIM XTRA is 10 by 3 cm. The main uses we have for this altimeter is to have onboard data and to send signals to our arduino and ejection charge.

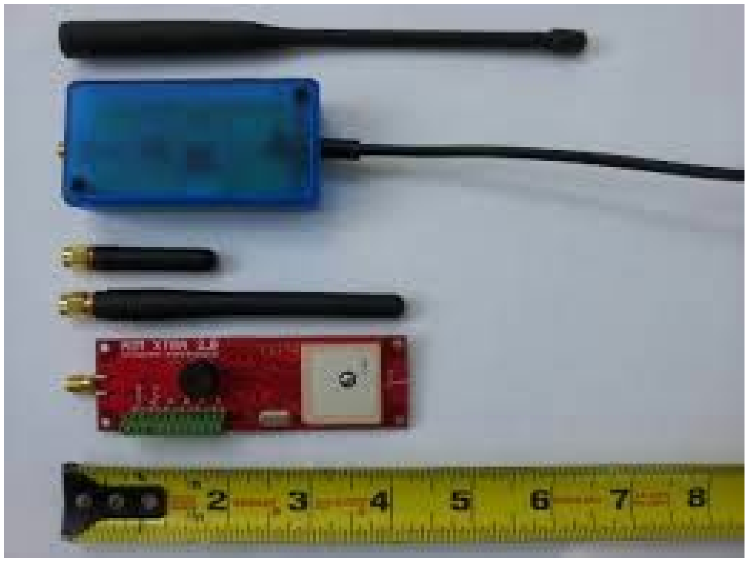


Figure G (Altimeter and receiver)

3.0 Analysis of Anticipated Performance

OpenRocket was used to simulate and predict the theoretical performance of our rocket with the drag system off. OpenRocket gave us the predicted apogee of our rocket as well as the stability of our with the drag system off. The program couldn't however predict the flight performance or the stability of our rocket with the drag system on. This was due to the fact that we could not fully design our drag system fully in the program. The weight of our drag system was able to be simulated in OpenRocket but the drag system drag performance could not be simulated.

3.1 Flight performance assumptions

There were parameters that were assumed to be a certain value in order to use OpenRocket to give us the most accurate/consistent data it can for our rockets performance.

- Parachute coefficient of drag = 1.75
- Ejection charge occurs at apogee
- Altitude of launch pad is at sea level

- Average wind speed = 2 m/s
- Standard deviation of wind speed = .2 m/s
- Turbulence intensity = 10%
- Launch rod length = 2 m

3.2 Drag System Off Estimated Performance (flight 1)

Using OpenRocket we found the total flight time of the rocket. After the rocket is launched the engine burns for three seconds and reaches a peak velocity of 170 m/s (.5 mach). The rocket then takes 11.5 seconds to reach apogee. The rocket at apogee is at a height of 1043 m (3422 ft). 2.5 seconds after apogee the ejection charge deploys the recovery system and the rocket floats down at 19ft/s. The time from the deployment of the recovery system to the landing is 253 seconds. The stability of the of the rocket labeled in OpenRocket was found to be 1.91 cal with a drag coefficient of .43. The graphs below shows the rocket's performance with the drag system off.

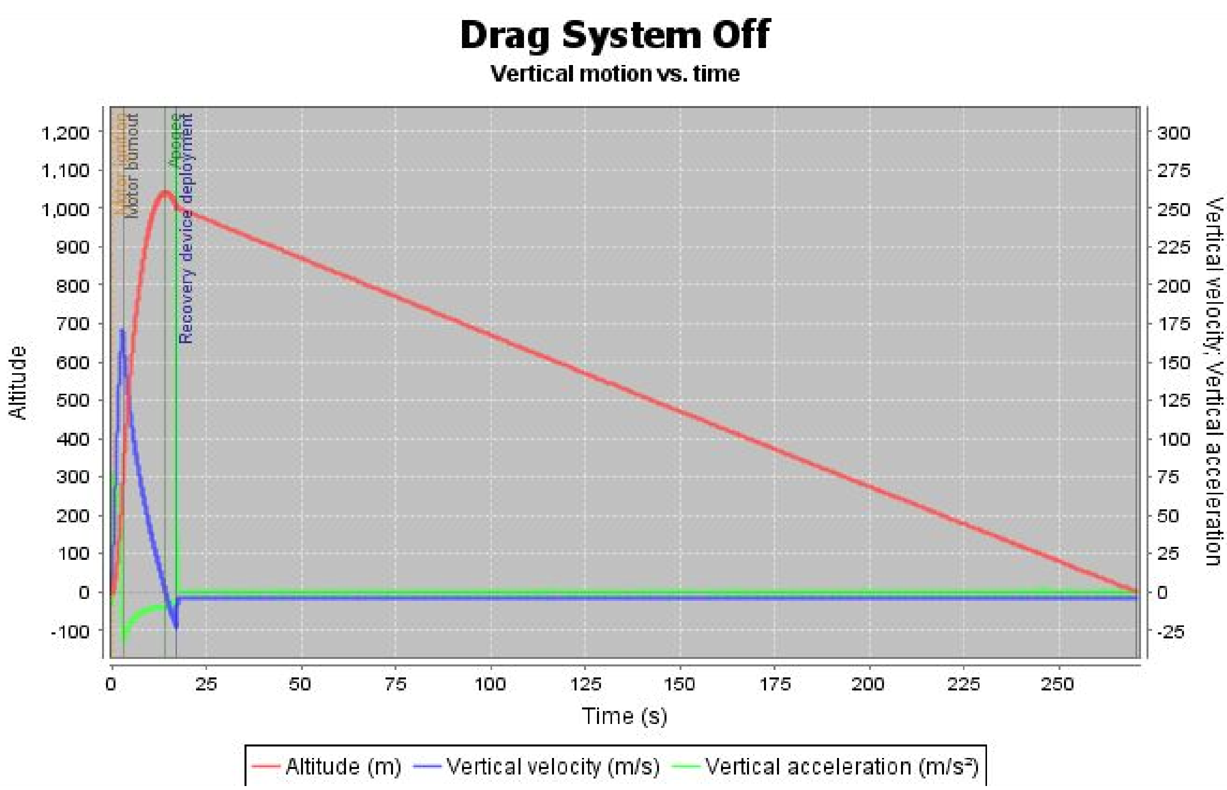


Figure H (Overall flight)

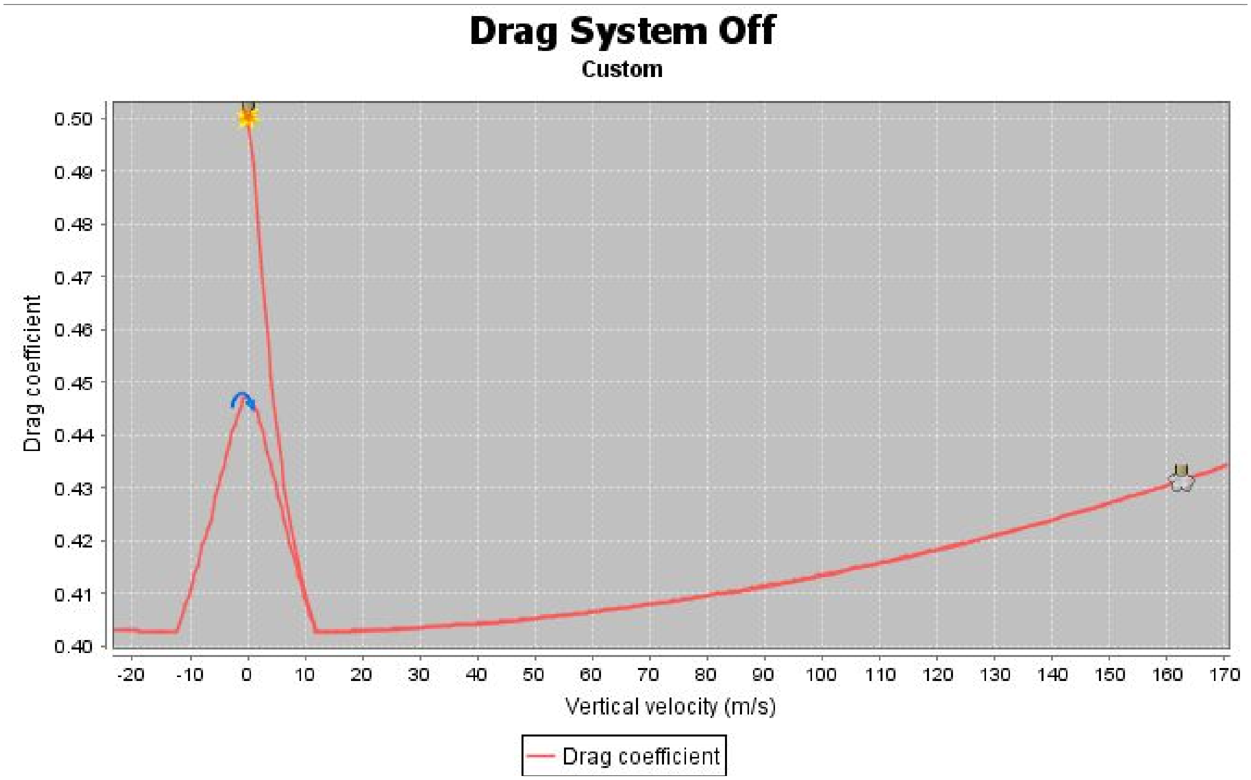


Figure I (Drag coefficient vs. Velocity)

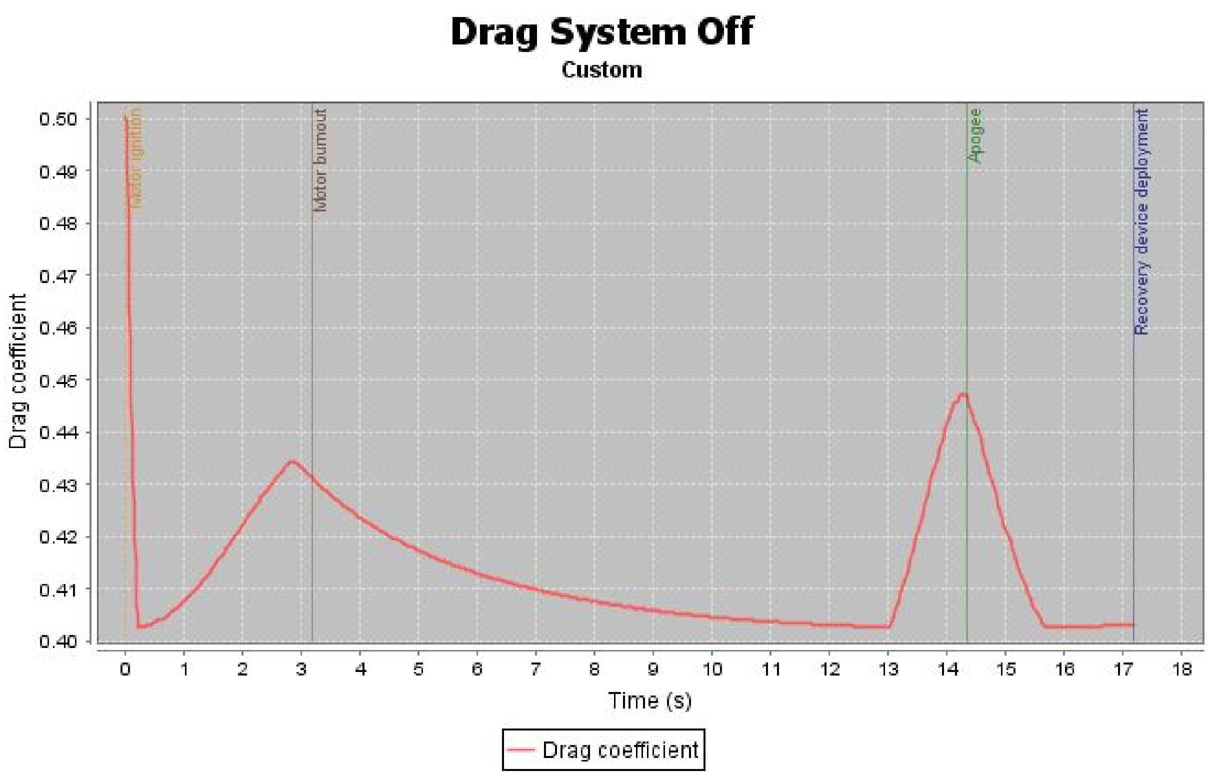


Figure J (Drag coefficient vs. Time before recovery deployment)

3.3 Drag System On Estimated Performance (flight 2)

Due to the limitations of OpenRocket a half scale model of our rocket was constructed and placed in the University of Minnesota's wind tunnel. This was done to acquire information regarding our drag coefficient and our rocket stability with the drag system on. With the information found at the wind tunnel the stability of the rocket with the drag system on was found to be 2.11 cal at an angle of attack of 4 degrees. At any angle 6 degrees and above the rocket stability would go under 1 cal and become unstable. The coefficient of drag was also found with the wind tunnel information and was found to be .64 with the drag system on. With this information the rocket with the drag system engaging and disengaging was found to be at a new apogee of 880 m (2888 ft). This new height is at 84% of the previous flight height. This is however not enough to to reach the 75% that we were aiming for and further methods will we researched before the test flight to correct this.

4.0 Safety

- Phenolic body tubing has chosen based on its strength parameters (any rocket 3.0" through 11.4" that will not exceed 0.85 mach)
- Parachute was chosen based on its carry capacity and descent rate (5.6 to 7.37 kg)
- Shock cord was chosen by the total weight of the rocket
- Wind tunnel used to find stability of rocket
- Epoxy adhesives will be used to secure components together
- OpenRocket was used to simulate rocket performance
- Center of pressure was found for both flights
- Center of gravity was kept constant for both flights
- Stability was kept between 1 and 5 cal for both flights
- Components are placed as accurate as possible
- Recovery system is deployed by a remote charge
- Motor ejection charge is left as a backup for the recovery system

5.0 Estimated Budget

Item	Cost	Quantity
Competition admission fee	$400	1
Tubing, Coupler, Phenolic, 6.0	$14.99	1
Tubing, Phenolic Airframe, 6.0	$41.99	2
Nosecone, Fiberglass, 6.0	$104.99	1
U-Bolt, Large, 4 nuts, Strip Washer	$4.19	2
10/10 Linear Rail Lug, 2 pak	$5.95	1
Bulkplate, 6.0	$6.89	1
Epoxy, Mid-Cure (15 min)	$15.99	1
PT 2.1 phenolic motor mount tube 36" long	$14.00	1
Plywood centering rings 6" to 54 mm	$ 6.90	1
HAMR Aluminum motor retainer	$ 34.00	1
Strap, nylon, flat, 0.75	$1.69 per yard	8
Motor 1364-K454-19A	$114.99 each - $ 200 for Competition = $374.95	5
Parallax Standard Servo	$12.99	1
Assorted drag system fixtures	$35.50	1
Drag system threaded rod	$17.90 ($3.58 each)	5
1 sq. ft. of ¼” aluminum	$33.06	1
10.2 in^3 of ABS plastic	$51 ($5 per in^3)	1
15/32” x 2ft. x 2ft. plywood (bulkheads)	$6.55	1
AIM XTRA v2. Altimeter transceiver and AIM BASE receiver	$420	1
Queen Spy USB “spy camera” video recorder and SanDisk memory card	$23.30	1

Arduino Nano microcontroller	$3.27	1
Ejection charge	$20.00	1
Total	$1702.92	