Preliminary Design Report

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Executive Summary

The design objectives put forth for the 2016 Space Grant Midwest High-Power Rocket Competition require each team to design and construct a high-power rocket with an active drag system that will reach an apogee of at least 3000 feet above ground level. This preliminary design of our rocket is the result of pen and paper calculations, OpenRocket and ANSYS Fluent. The rocket is 178.77 cm long, has a diameter of 10.2 cm and a target dry mass of 2.268 kg.

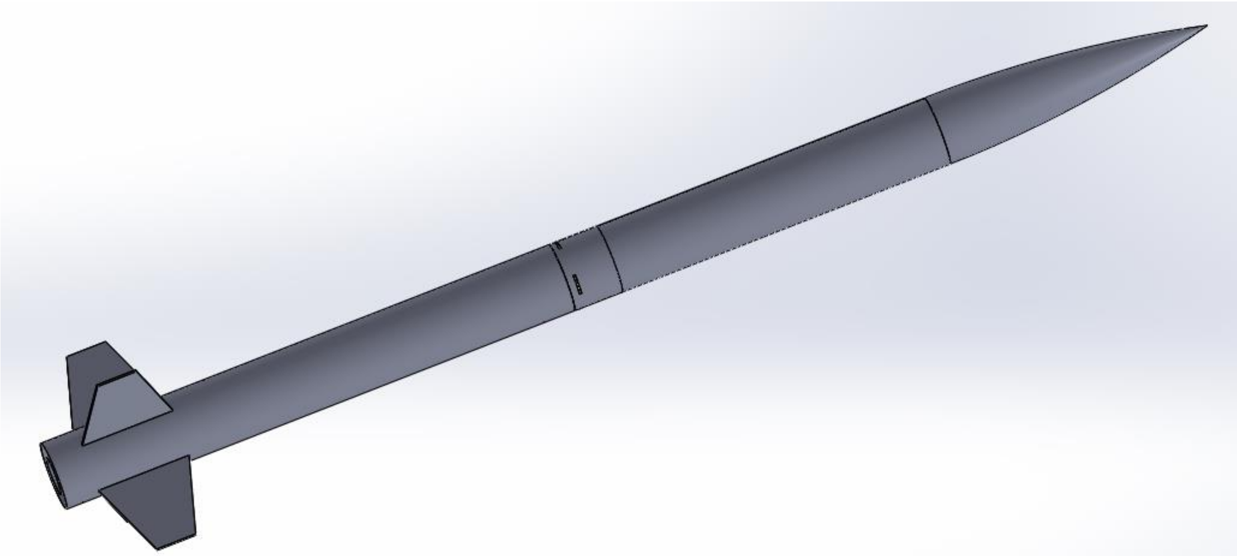
The rocket frame, nosecone and fins were purchased commercially as a kit, Level 2 by MadCow Rocketry. This particular kit was chosen because it is intended for dual deployment and is constructed entirely of G10 fiberglass.

Our active drag system is a rotary design that deploys fins laterally through slots in the airframe. We chose this design because we wanted to maximize the surface area of the control surface without having to exert force directly against the dynamic pressure created by flight. The drag system will operate on a closed-feedback control loop that varies the degree the brake is deployed depending on the current projected apogee. The rocket is designed to be stable at all stages of the flight, both with the air brake fully stowed and fully deployed.

We are also required to have a camera record the status of the drag system throughout flight. Our solution to this challenge is far from complete. Integrating a camera without disrupting the operation of the air brake or interfering with deployment charges has proven to be a design challenge we initially underestimated.

The rocket's propulsion will be provided by a Cessaroni J295. It has an average thrust of 298 N, a burn time of 4 seconds and a total impulse of 1196.3 Ns. Recovery method will be dual deployment with an 18” drogue at apogee and a 48” main at 200 meters above ground level.

Design of Rocket Airframe



In choosing a design for the airframe of our rocket, we opted for a 10.2 cm diameter rocket along with a height of approximately 180 cm. We went with this design as it adequately allows for the incorporation of all of our electronic systems as well as our active drag system. This design is also robust enough to handle a large fifty-four millimeter diameter engine that will boost our rocket to approximately four thousand feet above ground level in cases where the active drag system is not deployed. As for the material of the rocket we decided to use fiberglass for the airframe along with most of the internal, structural components of the rocket. We choose fiberglass as it provides high strength while minimizing weight as well as cost of materials.

In constructing the rocket we used a combination of high strength epoxies that provide strength along with the strategic placement of epoxy clay to add bolstered reinforcement to critical areas that will be induced to high forces such as the motor mount, fins and other areas. In deciding the placement of our active drag system we decided to incorporate it into the coupler of the rocket which joins the two halves. We opted for this area for several reasons. The area with the coupler provided us with the extra strength and support we needed to make the necessary slits in the airframe where the fins of our drag system deploy. The coupler reinforced the area greatly and allowed us to also strongly secure the drag system to the interior of the rocket. This is another reason why we chose fiberglass for the airframe because of its strength and ease of tooling. Placing the drag system approximately in the middle of the rocket will also minimize the chance of the parachute becoming caught on one of the fins should the fins not fully retract properly.

Overall, our rocket provides us with the most compatibility for our drag system, high durability, capable of reaching high altitudes and be the most cost effective. The airframe is an integral and vital system. Without a reliable airframe you cannot reach the minimum altitude requirement, launch multiple times, or even simply deploy your drag system. It is with this in mind that we have taken the proper precautions throughout all of the construction of the airframe to ensure the reliable and resilient nature of our rocket.

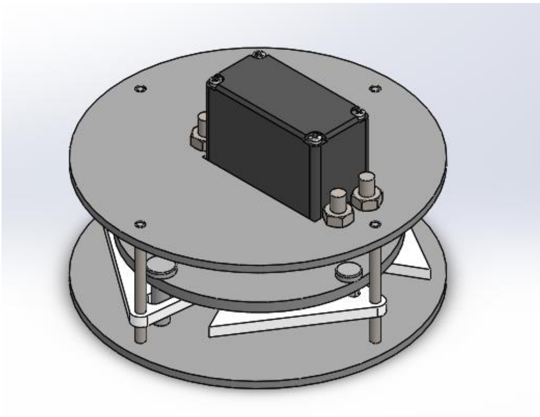
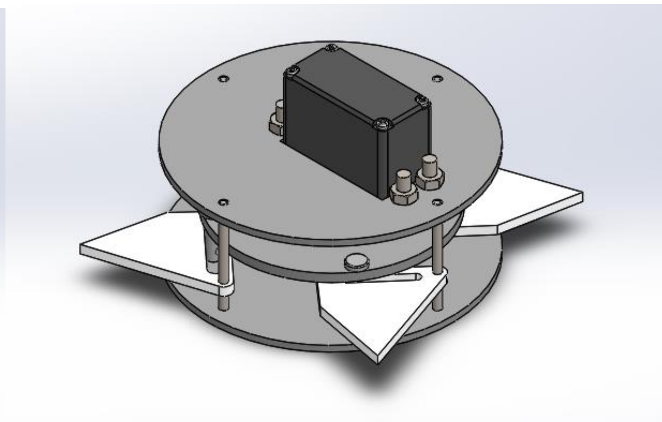
Design of Electronics and Payload

Avionics

The drag system will be controlled from an Arduino Mega. The Arduino uses a fusion of altimeter and accelerometer data to determine the state of the rocket, specifically altitude and vertical velocity. We are currently working on a control loop that will take the state of the rocket and calculate the necessary output to get the rocket to its target altitude. The output is the percentage of airbrake deployed. The airbrake is deployed by a servo motor, which will be controlled directly by the Arduino. The control system will first detect when the rocket is out of the boost phase to deploy the airbrake. It will also use accelerometer and altimeter data to retract the airbrake at apogee. On the first flight, the controller will calculate the apogee of the rocket. It will then use that data and set the control loop to aim for 75% of the initial apogee for the second flight.

A Stratologger altimeter is being used for parachute deployment. It will be set to deploy the drogue at apogee with motor backup. It will then deploy the main chute at an altitude that we select. We plan on using the Stratologger data from the first flight to verify the flight characteristics of the rocket captured by the Arduino. We can then use this data to calibrate our control loop.

Air Brake

The main goal of this air brake's design is to maximize the amount of surface area normal to the air flow as well as minimize the amount of force needed to deploy the brake. With these objectives in mind a rotary method is the best choice over other methods such as axially actuated plungers or rotating fins with servos.

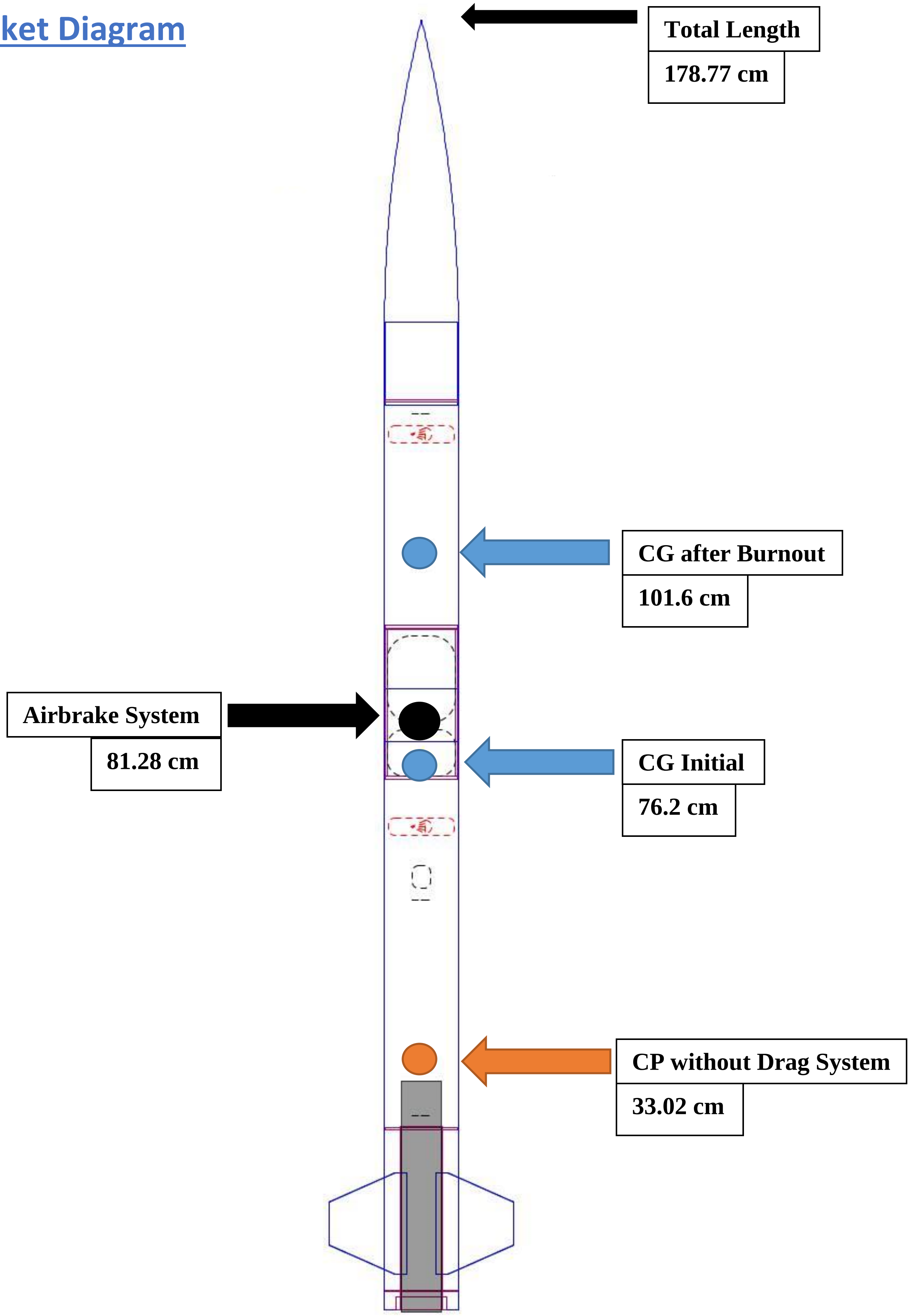
The initial size and shape of the fins was determined by using pencil and paper drafting techniques to construct the four largest triangles possible within the inner diameter of the coupler. After constructing a 3-D model in CAD to simulate the actual motion of the brake surfaces being deployed it became clear that their heights needed to be staggered to avoid mechanical interference with each other. It was also easy to see that a portion of the fins could never be exposed to the flow and provided no structural benefit and was therefore useless. Removing this useless portion also contributes to reducing the chance of the fins interfering with each other on deployment or retraction.

We plan to utilize the ever increasing access to 3-D printers to manufacture the majority of the air brake's components. This includes the forward and aft bulkheads, the rotating bulkhead and the fins. The rotating bulkhead will be connected to the servo with a stock servo arm and secured with epoxy. Clevis pins with retaining cotter pins connect the rotating bulk head to the fins' slots. Steel clevis and cotter pins are being used as this connection is one greatest stress concentrations in the air brake assembly. Press fitted dowel pins secure the forward and aft bulk heads as well as acting as the point for the fins to rotate about.

Structural integrity is always a chief concern in high-power rocketry, but it is of greater concern for this particular design. While deploying fins normal to the flow is best for increasing drag it also creates a large amount of force only on sections of the rocket aft of the air brake assembly. In order to keep the forward section from separating upon fin deployment steel rods will be mounted that connect the air brake's forward and aft bulk heads to the next bulk head in either direction. This will bolster the overall integrity of the rocket so that force felt upon fin deployment is felt by the whole rocket and not just the aft sections.

In order to reduce plastic deformation we will be printing components out of reinforced PLA. While this is one of the more brittle options available for 3-D printing we have decided that rigidity is paramount for the fins so that they do not deform to the point that they cannot be retracted.

Rocket Diagram



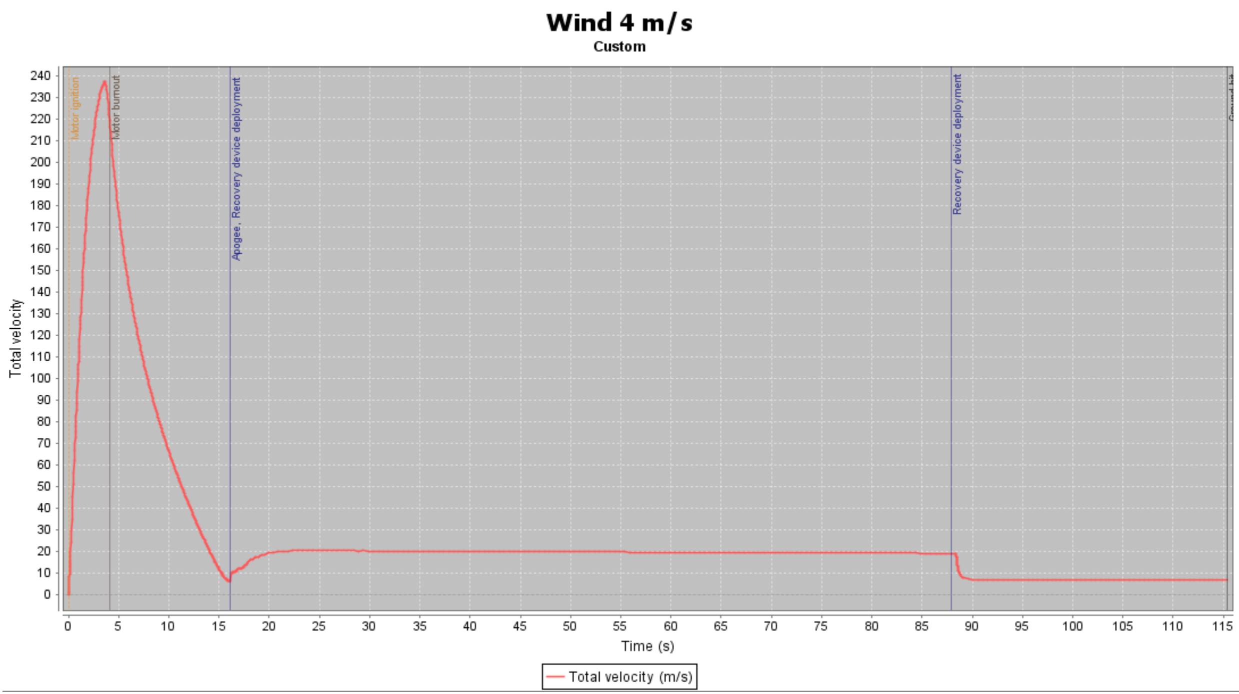
Analysis of Anticipated Performance

All flight simulations were done using OpenRocket. We intend to use ANSYS Fluent to have precise coefficients of drag for different degrees of air brake deployment but have been unable to succeed so far.

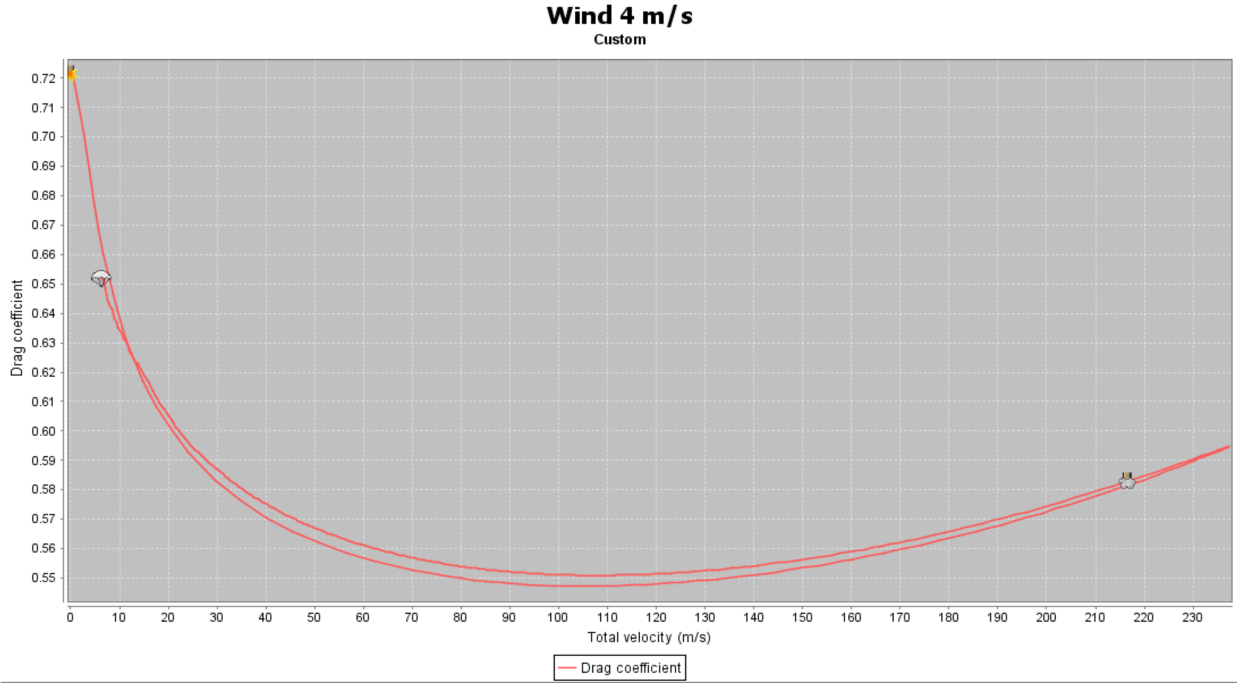
Max apogee: 1600 m

Max velocity: 237 m/s

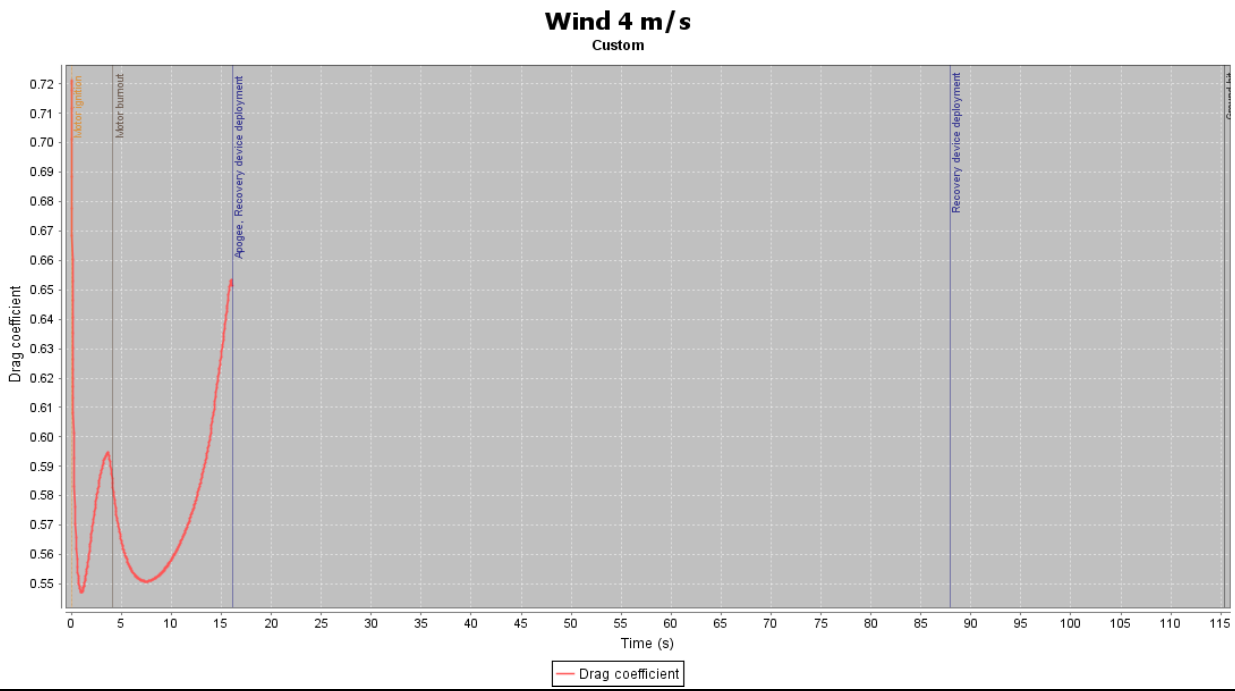
Velocity vs. Time:



Coefficient of Drag vs. Velocity:



Coefficient of Drag vs. Time:



Budget

Rocket including avionics:

Part	Quantity	Price
Level-2 Rocket kit by MadCow Rocketry	**1**	**259.95**
54 mm motor casing	**1**	**64.85**
Motor aft closure	**1**	**42.75**
Motor retainer	**1**	**31.03**
Cessaroni J295	**3**	**269.00**
Arduino Mega	**1**	**45.95**
IMU	**1**	**39.95**
Mobius Camera	**1**	**82.95**
XBee antenna	**2**	**75.90**
Stratologger	**1**	**58.80**
Altimeter	**1**	**9.95**
Electronics mounting hardware	**1**	**40.00**
Shear pins	**1**	**2.95**
XBee Explorer	**1**	**9.95**
XBee USB explorer	**1**	**24.95**
MicroSD card reader board	**1**	**7.50**
Rocket Total		**1066.43**

Air brake assembly:

Part	Quantity	Price
Servo	**1**	**13.49**
Medium Clevis Pin	**1**	**7.61**
Short Clevis Pin	**1**	**13.33**
Dowel Pins	**4**	**16.52**
Cotter pins	**4**	**0.45**
3D printed components	**7**	**36.43**
Air brake total		**87.83**

Travel:

Expense	Price
Car/gas	**525**
Hotel	**200**
Travel Total	**725**

Total Expenses:

Rocket	**1066.43**
Air brake	**87.83**
Travel	**725**
Total	**1879.26**