2015-2016
NASA Space Grant Midwest High-Power Rocket Competition

Team Rocket Flight Readiness Report

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**Disclaimer: Unfortunately the electronics of our rocket failed and were not able to retrieve rotational or acceleration data from either test flight.*

I. Design Summary

Rocket Airframe

In making our final airframe design considerations for competition launch, our team was very happy with the decisions outlined in our initial design report. We've chosen to continue with the Cesaroni K711 as our competition and test flight motor, despite the high stress levels and velocities of a K class motor. In order to account for this we've very carefully selected and fabricated the airframe.

Our first design considerations were taken in choosing the body tube of our rocket. In order to account for the size requirements needed to readily house all necessary components yet remain small enough not to sufficiently increase drag our team decided on using 98mm blue tube. To compare and contrast the drag of different sizes of tube we the drag force equation which relates cross sectional area and force due to drag. This is outlined in Equation 1 below.

$$Fd = \frac{1}{2}(p)(Cd)(V^2)(A)$$

Equation 1 *– Drag Equation. p = density of fluid, Cd = drag coefficient, V = body velocity, A = frontal area, Fd = force due to drag.*

To increase stability our team also had to make some changes regarding mass positioning. Due to the extremely massive motor, casing, and motor mount tube along with electronics mounted around the motor mount tube between centering rings increasing mass below the center of pressure became a serious concern. To offset this and increase overall stability we increased the rocket length to near eight feet and added about 2 kg mass to the nosecone of the rocket. The electronics bay was also positioned as close to the nosecone as possible.

Blue tube, which is a type of wound cellulose fiber bound with resin, was chosen as our body tube material in order to account for the high stresses placed on our rocket. Blue tube provides just enough strength and flexibility without being overtly massive. It is flexible enough to absorb and distribute impact loads in the case of a hard landing and is not likely to shear when struck with a fast moving, in-tension shock cord.

Each connection point of our rocket was also layered with epoxy for extra strength to account for high stress and provide extra strength, notably around the lip where zippering due to shock cord collision usually occurs. Each fin was constructed with 3/16-inch tempered Masonite (hardboard) which was smoothed on both sides. Fin tabs were constructed between three of the four centering rings for added strength, along with full length epoxy clay fillets in the areas where the finds meet the tube exterior. The fin tabs extend to the motor mount tube housed within the lowermost body tube section. Due to increased stress concentration in the body tube around the motor mount tube four centering rings were added and epoxied to the fin tabs for extra strength.

Active Drag System

Our active drag system is composed of two 19.2 kg-cm torque servos, two metal pull rods (linkages), two plastic control horns for connecting the servo linkages, a plastic transmission arm for each servo, a separate 2S LiPo battery, and two drag tabs which are cut out of plywood and balsa wood, reinforced with aluminum plates, and covered with a carbon fiber and epoxy shell layer. The entire system is controlled by an Arduino 101 housed in the electronics bay.

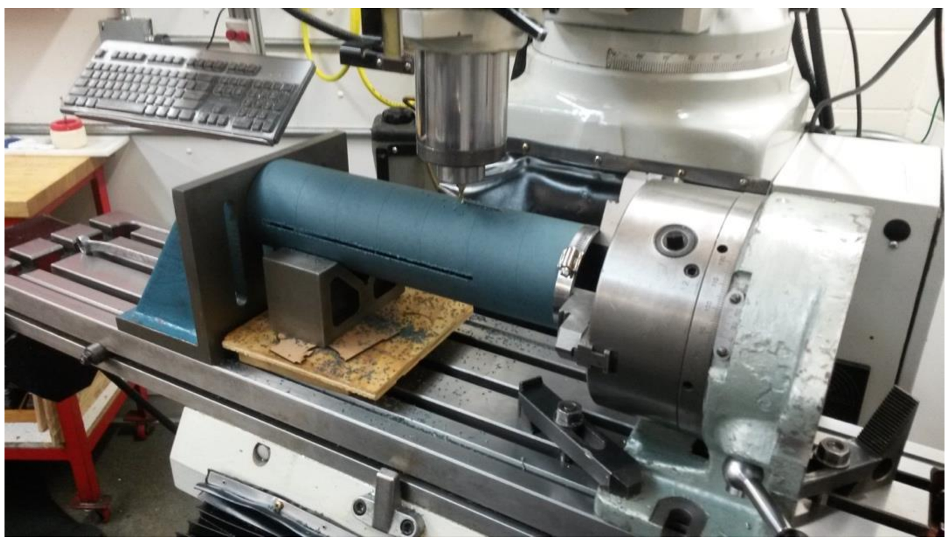
Due to an estimated 35 lbs. drag force per drag tab a composite structure was needed for extra strength. The aluminum plates placed on the drag tabs serve as mounting points for the hinges which are secured to the farthest aft centering ring. The motor mount tube extends about five inches past the base of the aft most centering ring; the drag tabs are conically shaped to shroud the protruding motor mount and act as a boat tail when stowed. The hinge system consists of a bent u-shaped aluminum bracket screwed to the bottom centering ring. The aluminum bracket and reinforcing plates on the drag tabs have holes and a pin is inserted through these holes to fasten the drag tabs to the body of the rocket. As the servos pull on the linkages, the drag tabs will extend outward into the airstream at an increasing angle relative to the vertical axis. Having the drag tabs at the far aft end of the rocket helps to keep the rocket stable during deployment and allows for gradual, rather than sudden, loading. All of the mechanical components for the active drag system will have removable cowlings over them to minimize drag during the flight and to reduce potential damage to delicate linkages. At standard temperature and pressure, assuming the maximum acceleration experienced by the rocket is 20 Gs, the maximum velocity of the rocket is Mach 1.1, and the total cowling weight is less than three pounds, our rocket will have a higher maximum altitude with the cowling in place rather than not (see Equation 1).

Electronics and Payload Bay

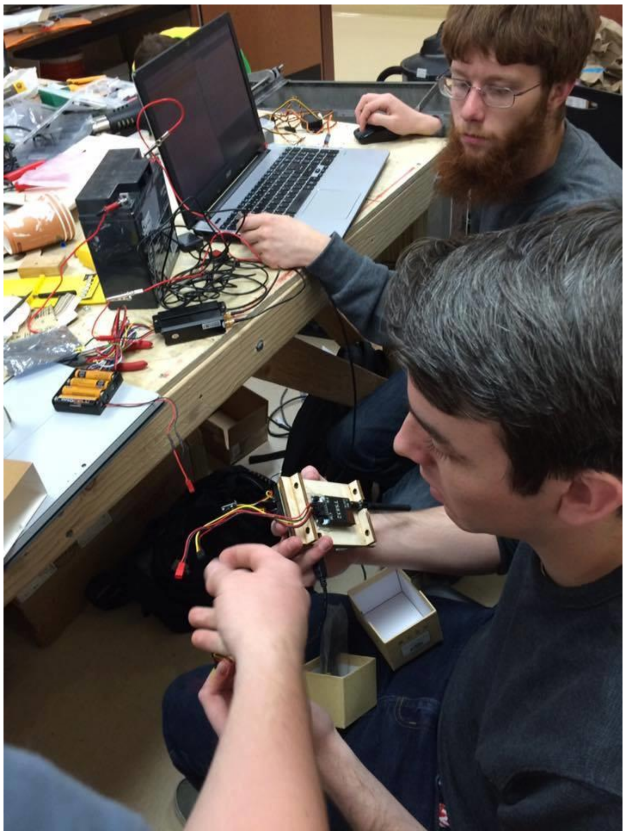
The bulk of our electronics are contained in the electronics bay, which was a pre-made cardboard bay with a plywood mounting plank. Included inside the bay is an Arduino 101, a video transmitter, an accelerometer, and a battery. The Arduino 101 is used to control the servos used for the drag tabs as well as measure and record acceleration and 6 – axis gyroscope values. The Arduino was custom programmed entirely by our team to tailor to the competitions requirements, which include drag system deployment before apogee and accelerometer and rotational data.

II. Construction of Rocket

Every aspect of our rocket was individually selected, constructed, or modified by our team. The construction process began with the creation of the motor mount, which involved milling the 98 mm body tube to create the fin slots and servo slots. Following this, the motor mount was cut to the appropriate length to fit the motor. The two forward-most centering rings were then sanded down to fit the tube coupler. After this we drilled holes in the centering rings for routing the wires, which were epoxied in place. The motor mount tube was then epoxied in place in the main body tube. The next step involved attaching the motor retainer, which was also epoxied.



In creating the ebay for the nosecone we first cut off the bottom of the pre-bought cone. In order to seal off the nosecone from the remainder of the rocket we sanded down a 98 mm bulkhead to fit the diameter of the inner nosecone. Holes for threaded rods and wires were then installed into the bulkhead. To ballast the rocket we poured a pound of lead shot into the nosecone tip. This was secured with another bulkhead which was secured to the nosecone with screws, followed by another bulkhead which was also screwed in to mount the rails of our GPS module. The threaded rods were then installed into the nosecone ebay and the GPS was attached.



The main electronics bay of the rocket was a pre-purchased Madcow cardboard ebay and was modified by our team for our purposes. We first had to assemble the ebay, which involved screwing the bulkheads to the main tube and epoxying the aft bulkhead to the main body. We then drilled holes into the bulkheads for the servo control wires. Next we assembled the mounting board and attached it to the threaded rods. Following we hot-glued the Arduino, altimeter, and video transmitter to the mounting board. We then installed the camera by creating an

aerodynamic fairing on the outside of the body tube and glued the camera to it. The ebay section was finished by wiring each individual module.

In finishing the main body tube section, we first ran a carbon fiber tube from the ebay to the servos to protect installed wires. Following this the wires for the servos were ran through this tube along the inner body of the rocket. To create the fins we hand cut the shapes from tempered Masonite or hardboard. The leading edges were sanded down as best as possible then the fins were secured to the main body through the pre-cut fins slots and epoxied. Epoxy clay fillets were then used on the fins for extra strength and sanded down to improve aerodynamic capability.

We moved on to work on the drag tabs next. Two centering rings were cut in half and sanded down on the outer diameter. Angled streamers were cut to link the two different diameter centering rings and balsa was attached over all the stringers, similar to an airplane wing. A single layer of carbon fiber was laid up on each drag tab for extra strength. Holes were then drilled for the rail buttons and the buttons were installed and epoxied in place. Pressure relief holes were then drilled in all the body tube sections. Shock cord was tied between every section and nomex parachute protectors installed.

The final steps in completing the rocket involved installing the servos and painting the rocket. The servos were installed into the pre-cut slots near the fins and secured with screws. We finished the construction process by spray painting the body, with a choice of yellow and black paint, black on the top and fins, yellow elsewhere.

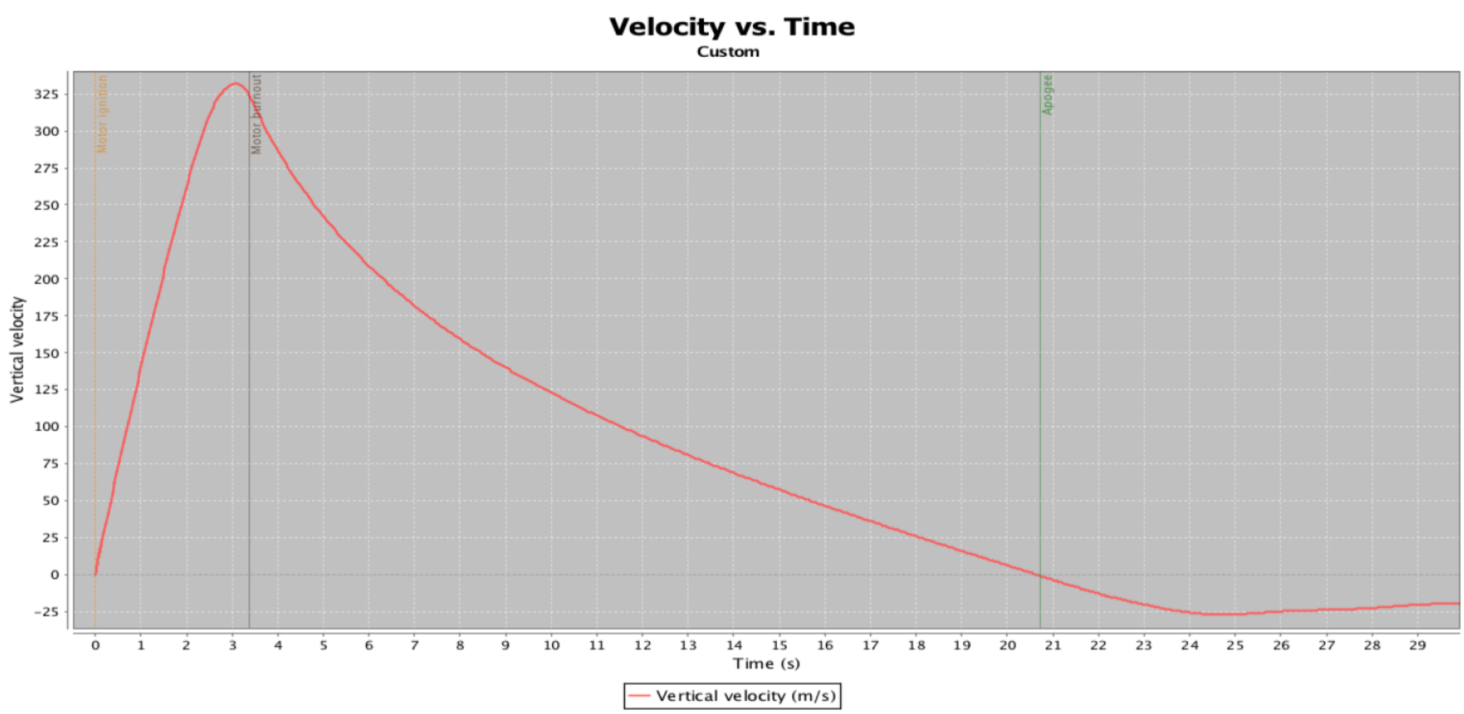
III. Active Drag Features

The active drag system of our rocket was designed to be as aerodynamic, efficient, and simple as possible in order to assure proper function on launch day. Our system consists of two servos installed near the rocket's fins with balsawood/plywood tabs attached which are controlled by an Arduino stored in the ebay. The design and construction of the system was previously outlined in more detail.

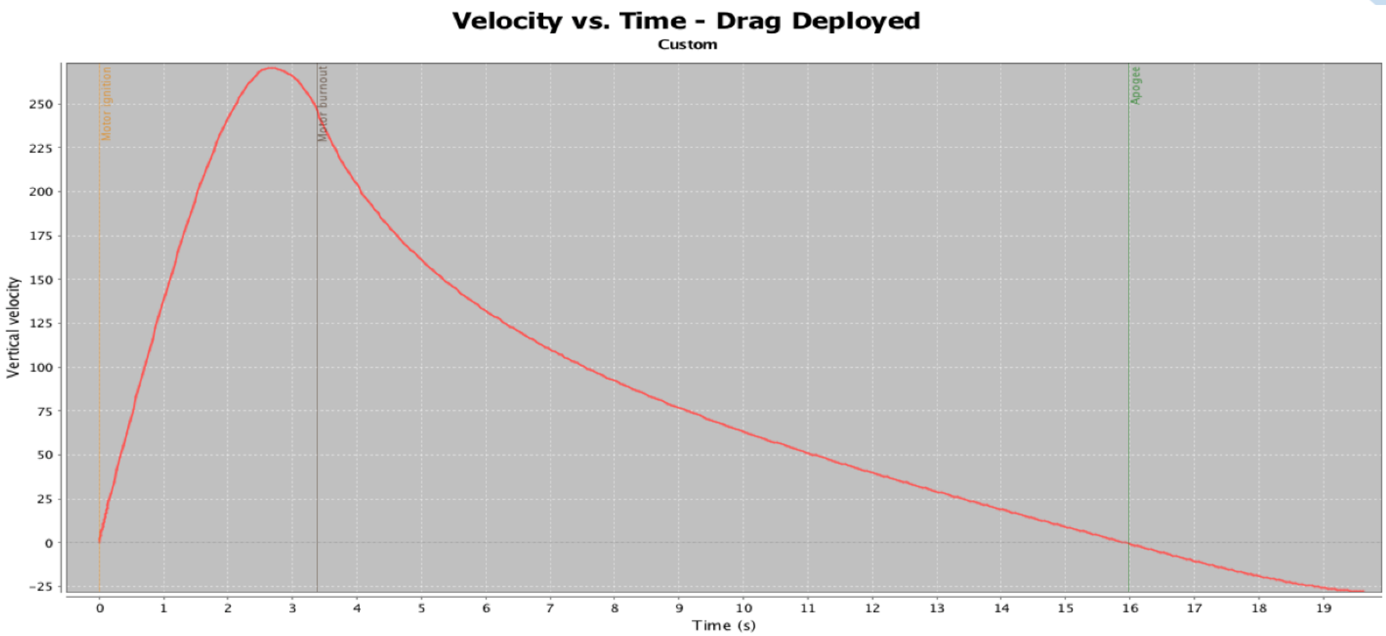
To achieve our goal of 75% of the previous apogee we first ran simulations through Rocksim and Open Rocket to see how much extra drag we would need to create to slow the rocket. We ultimately used these simulations to determine the proper size of the cross sectional area of the deployed drag tabs and time needed to deploy them based on the altitude of the first flight. These models were then programmed into the Arduino, with the idea being that we could program the altitude of the first flight into the Arduino and it would then adjust the drag tab deployment accordingly. The Arduino is programmed to recognize the start of the launch based on a sudden increase in acceleration, which will then initiate the pre-installed drag program.

IV. Test Flight Report

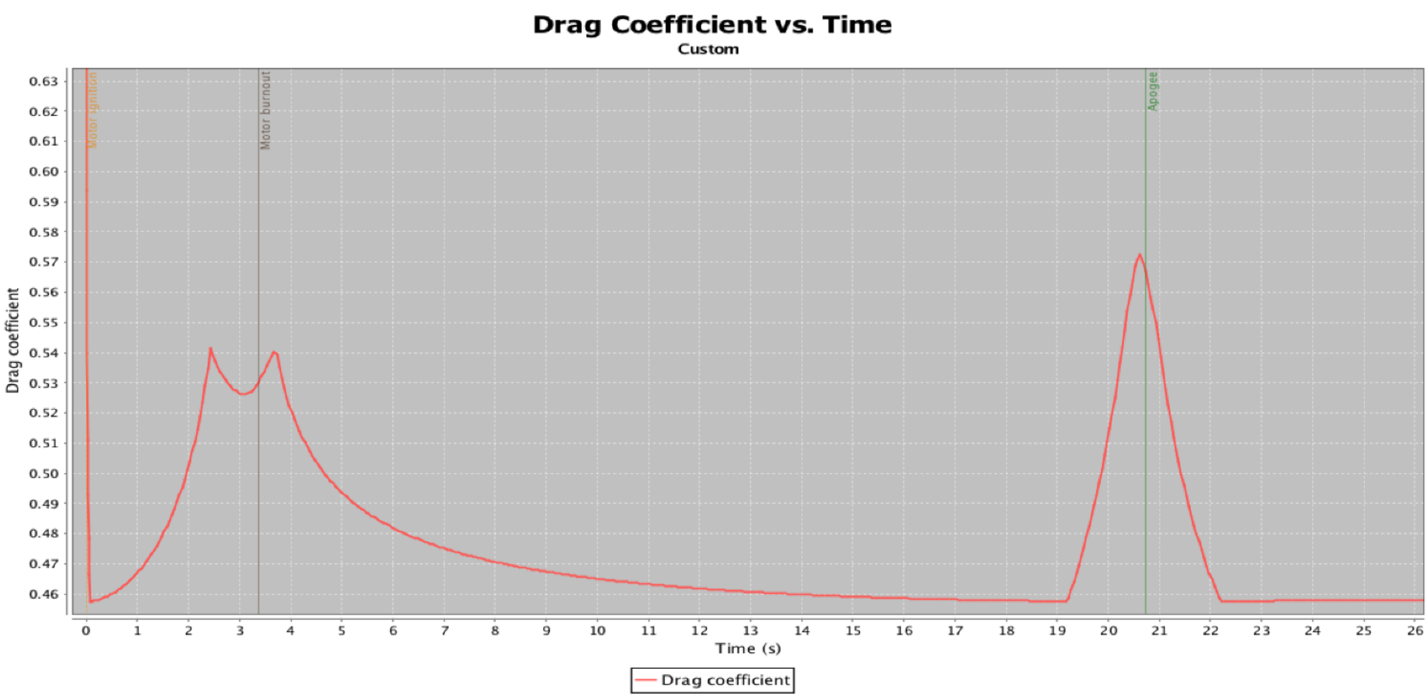
Our Rocket was prepared and test launched April 23rd at Bong Recreational Park. Preparation, launch, and recovery was up to standard, however we unfortunately were not able to recover the acceleration or rotational data from our Arduino as a result of what we determined to likely be an electrical short. Due to this we were only able to include the predicted flight performance information. We were, however, able to determine the apogee of the non-drag and drag flights, which were determined to be 8,123 ft. and 6,213 ft. respectively.



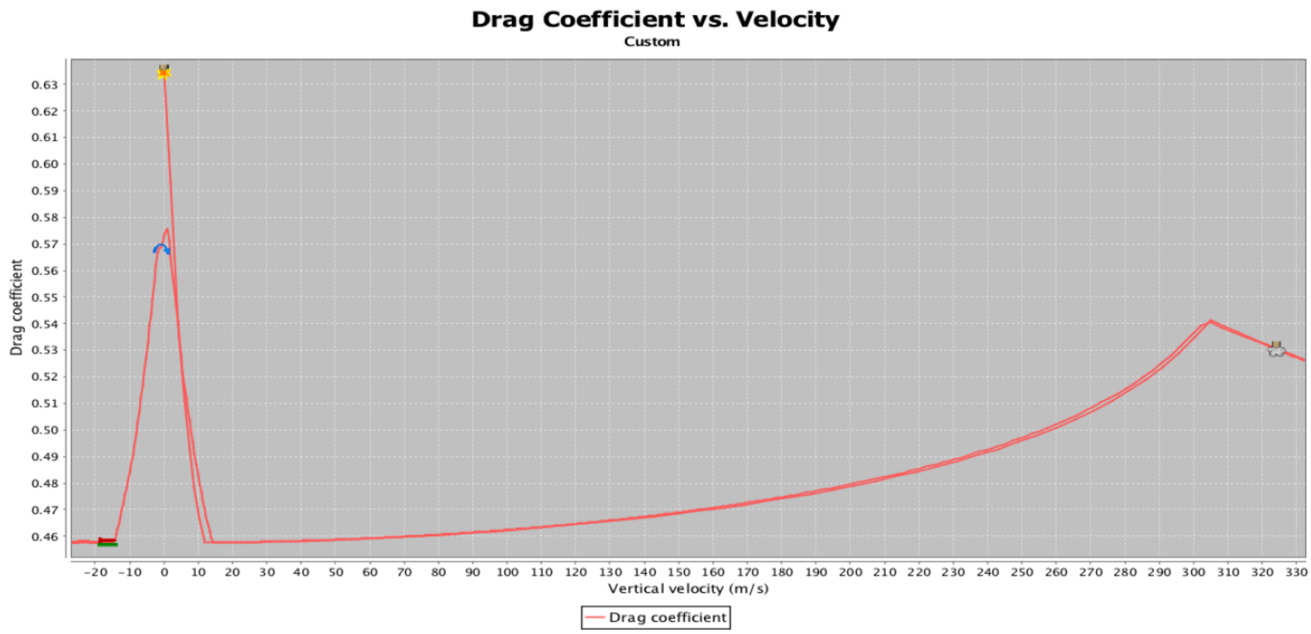
Estimated vertical velocity vs. time plot – drag tabs in stowed position.



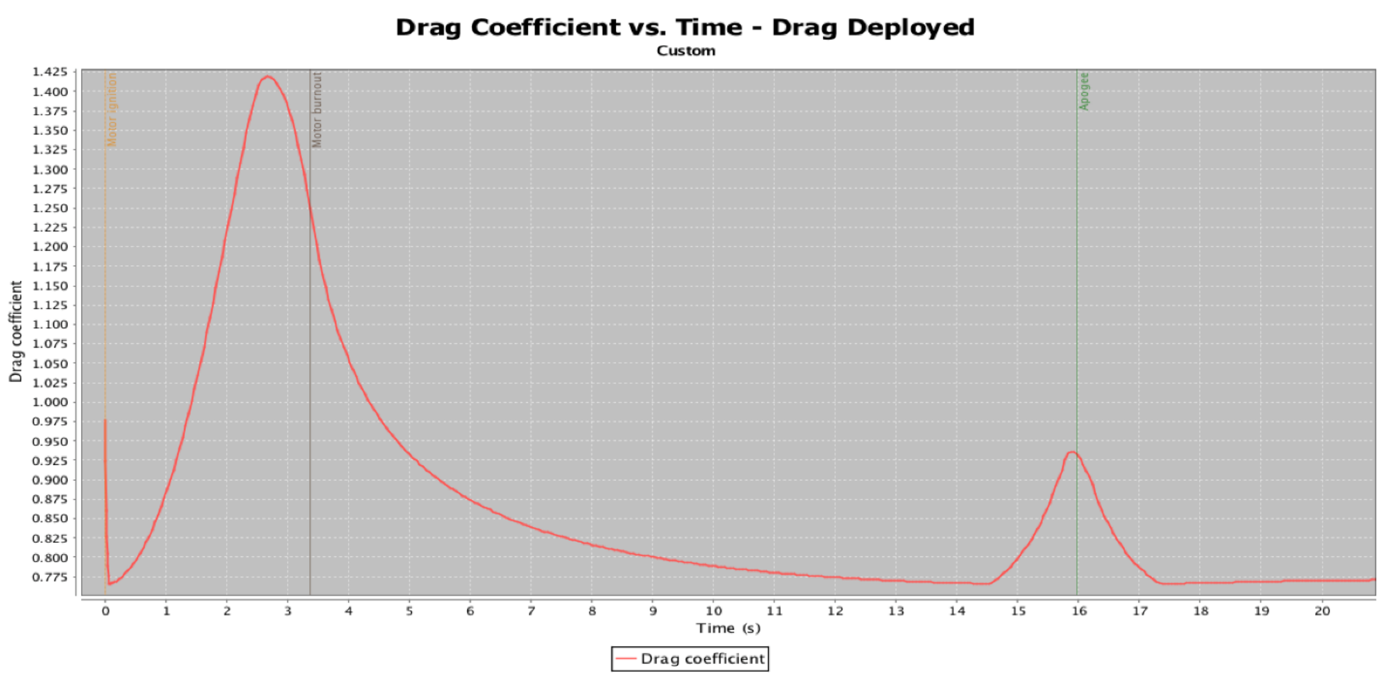
Vertical velocity vs. time plot – drag tabs deployed



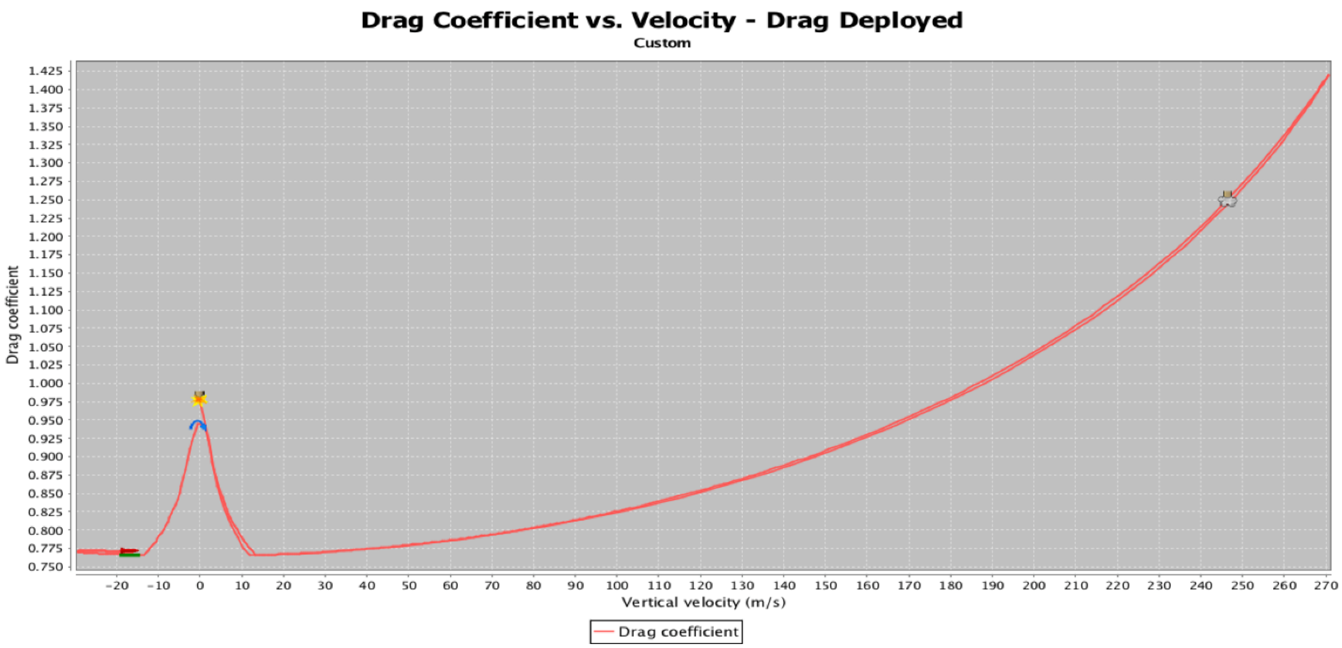
Estimated drag coefficient vs. time plot – drag tabs in stowed position.



Estimated drag coefficient vs. velocity plot – drag tabs in stowed position. Data is plotted in chronological order despite the x-axis designation of vertical velocity.



Estimated drag coefficient vs. time plot – drag tabs deployed position.



Estimated drag coefficient vs. velocity plot – drag tabs deployed. Data is plotted in chronological order despite the x-axis designation of vertical velocity.

V. Planned Changes and Improvements

After our initial flight we were forced to make a few changed in order to improve the functionality of our rocket. Our drag tabs, which were originally made of insulation foam core, were replaced with a balsawood/plywood composition to improve overall strength. We also added on/off switches to our Arduino, altimeter, and servos to easily control each system's individual power. Finally, we made the decision to improve the paint work and repainted the entire rocket with a new black and yellow scheme.

VI. Budget

Our rocket and final travel expenses mounted to near $2000. In addition to the $2000 funding provided by the Wisconsin Space Grant Consortium, our group was awarded $500 to purchase parts from the UW-Madison College of Engineering. Changes have been made since the original budget estimate with new parts ordered due to final design changes and an increase in travel expenses. The table below documents all parts ordered and other fees associated with the competition.

Purchase	Cost
4" Blue Tube Coupler x 2	21.90
44" Angel Parachute	69.00
54mm Retainer	31.03
54mm to 98mm Centering Rings x 4	32.40
98mm Blue Tube	38.95
98mm Coupler Bulkhead x 5	21.25
ALTS25 Altimeter	99.00
Arduino 101	30.00
Cesaroni 54mm 6-Grain Case	105.93
Cesaroni K711-18A Motor (after discounts) x3	307.94
Drogue Parachute Protector	8.15
Electronics Bay x 2	69.90
Electronics Rotary Switch x 3	28.38
Eyebolts with Washers and Nuts	4.50
FIXIT Epoxy Clay	11.95
GPS Module	30.95
Hi-Speed Servo	32.93
Hotel and Travel Expenses	650.00
Kevlar Shock Cord	46.00
MicroSD card breakout	17.97
Mini Camera	40.99
Nylon Shear Pins	2.95
Parachute Protector	10.49
PNC-4" Nosecone	21.95
Rail Button	3.07
Registration Fee	400.00
Retract Servo x 2	72.00
RocketPoxy Epoxy	38.25
Servo Wire	14.68
Terminal Block x 2	6.50

Tracking Powder	6.25
Universal Gearbox	9.98
USB B to A Male Cable	2.95
Wireless AV Transmitter	45.80
Total Cost:	$2333.99