Flight Readiness Report

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2017 Minnesota Space Grant Consortium
Regional High Power Rocket Competition

Raider Rocketeers

Milwaukee School of Engineering

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Summary of Design

Airframe

The rocket was constructed using a 4” body tube and stands 65 inches tall. The motor mount section was made from blue tube primarily for its rigidity, the rest of the rocket was designed to use blue tube as well but after an incident during our test launch the upper sections needed to be rebuilt. For the rebuilt sections LOC cardboard was chosen for its price and strength as the budget wouldn’t allow for more blue tube to be purchased.

The nose cone was chosen as the Intelli-Cone from Public Missiles, this is a 16.75 inch long plastic nose cone that is specially made to house an electronics bay. The nose cone is an ogive shape and has room for a 2.1” X 14” e-bay which is home to the direct velocity measurement system.

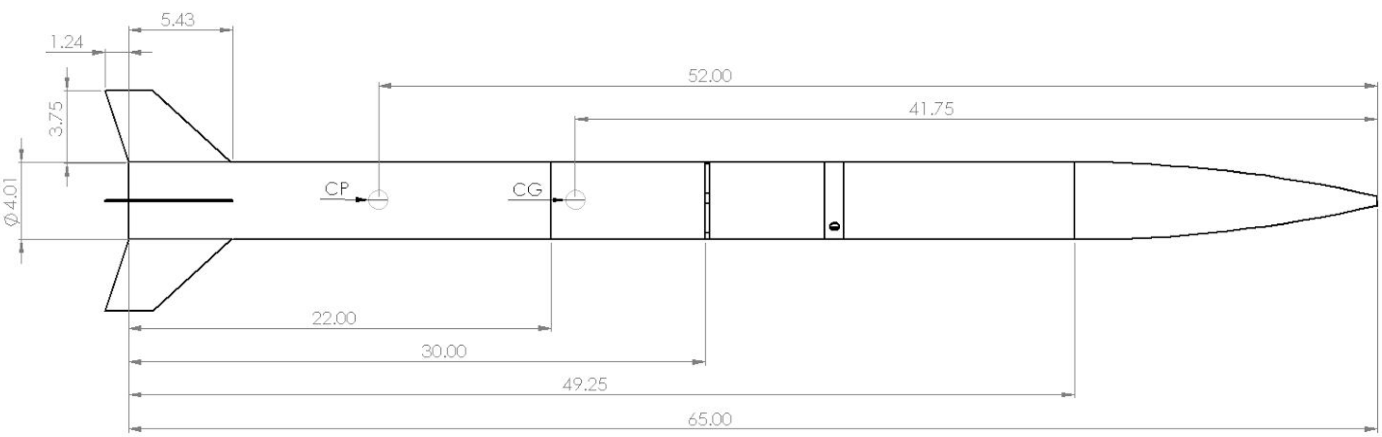

Figure 1: CAD drawing of the rocket with relevant dimensions, CP, and CG marked

Drag System

Using a decision matrix the concept of brake fin system operated by gears was chosen. The main reasons for this were the reliability of gears, ease to take apart, gears ability to translate force, and the ability to change gear ratios if need be. The down side of the gears were that they needed to be custom made for this application and depending on material they could be heavy.

The drag system was placed below the main electronics bay so that the servo could be controlled by the arduino inside. Once the motor burns out an active drag system was the prefered method for controlling the drag as it can adapt to the current conditions of the rocket.

An Arduino Mega will be the processing unit that decides when to deploy the drag fins. The Mega will be constantly reading the altitude from a pressure sensor, as well as acceleration from an accelerometer. Using this data, the Mega will be able to detect lift off and wait until motor burnout to initiate the active drag system while constantly calculating the altitude and acceleration. During the entire flight, the Mega will derive the altitude to calculate the current velocity of the rocket. After motor burn out, the current distance until apogee is calculated using the current altitude and comparing it to the previous flight's apogee. The velocity with respect to the distance until apogee of the flight is compared to the previous flight. If the current velocity is greater than the previous flight at the same distance until apogee, the drag fins are deployed. Based on the difference in velocity between the two flights at that instant, the drag fins are deployed the appropriate amount so the rocket is not slowed too much. This process will continue until the velocity with respect to the distance until apogee of the current flight matches the previous flight. At this point, the drag fins will retract into the rocket and only come back out if necessary. Right before apogee, if the drag fins are deployed, they will be retracted into the rocket per competition rule.

In summary, this algorithm is just comparing the velocities of the two flights and taking action based upon the comparison. This method was chosen due to the simplicity that it offers. All of the complex math is taken care of by using the previous flight path on the J motor. The challenging part is not knowing how much the rocket will slow down under drag fin deployment. The advantage to an active drag system is theoretically the rocket should glide into the exact same apogee as it did with the lower class motor no matter what happens in the flight.

The concept as shown in figure 2 is that there is a gap in the body tube where the fins will deploy. For strength four steel rods were used to transfer load from the top section to the lower section of the drag system. On each rod there is a fin with an attached gear, and in the center a main drive gear connected to the servo. The rod are connected to bulkheads which are then epoxied to the body tube.

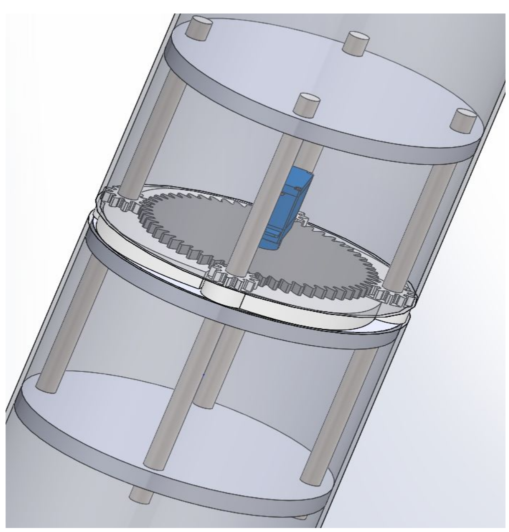

Figure 2: Simplified CAD model of the drag system

The drag fins are constructed of G10 fiberglass with acrylic gears epoxied to them. G10 fiberglass is incredibly rigid with a flexural strength of 65,000psi. As the gears will only be exposed to the forces from the servo an acrylic was chosen as it was much easier to work with and cheaper.

Velocity Measurement

The direct velocity measurement system is housed in the intelli-cone. A pitot tube will be positioned through the top of the nose cone to get exposed to clean air. At the tip, the air will be slowed down to rest, so that the stagnation pressure can be measured. Lower down on the tube is another inlet, where the air flows perpendicularly to the tube. This allows for the measurement of the static pressure of the air. Two tubes connect these pressure measurements, and in between is a pressure gauge which can measure the difference in pressure. This difference in pressure can be used to calculate the air speed:

$$V = \sqrt{\frac{2\gamma RT}{\gamma - 1}\left[\left(\frac{P_o}{P}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

Where γ is the ratio of specific heats for air, R is the specific gas constant for air, T is the static temperature of the gas, P_o is the stagnation pressure, and P is the static pressure. This relation is needed for speeds greater than mach 0.3 due to the compressibility of air becoming a factor, but will fail at supersonic speeds.

Camera System

A Raspberry Pi Zero will be used as the camera system in order to capture significant flight events. In order to capture events on the entire rocket, two cameras will be used; one looking up and the other looking down. Both will be positioned facing outwards, and will use a thin plastic film in order to angle the field of view.

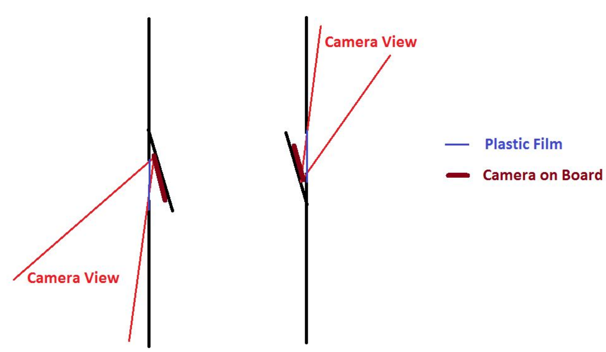

Figure 3: The views of the on board camera system

The video will then be recorded along with a timestamp in order to log significant events, like the drag system and parachute deployments. The data collection system is the Raspberry Pi Zero, and is shown below:

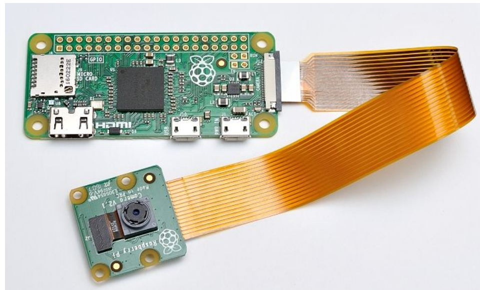

Figure 4: Camera Electronics Package

GPS & Data Transmission

There will be a wireless data transmission system so that various aspects of the rocket performance can be monitored in real time on the ground. The rocket will not be controlled through this transmission network and will operate the same without the network connected. The GPS system, however, relies on the transmission network to locate the rocket after landing, so long-range antennas and a generous power supply will ensure the stability of the network. If the rocket flies outside of the transmission range, data will be logged on a microSD card, and the rocket will continuously attempt to reconnect to resume data transmission. A wiring schematic is shown below in figure 6.

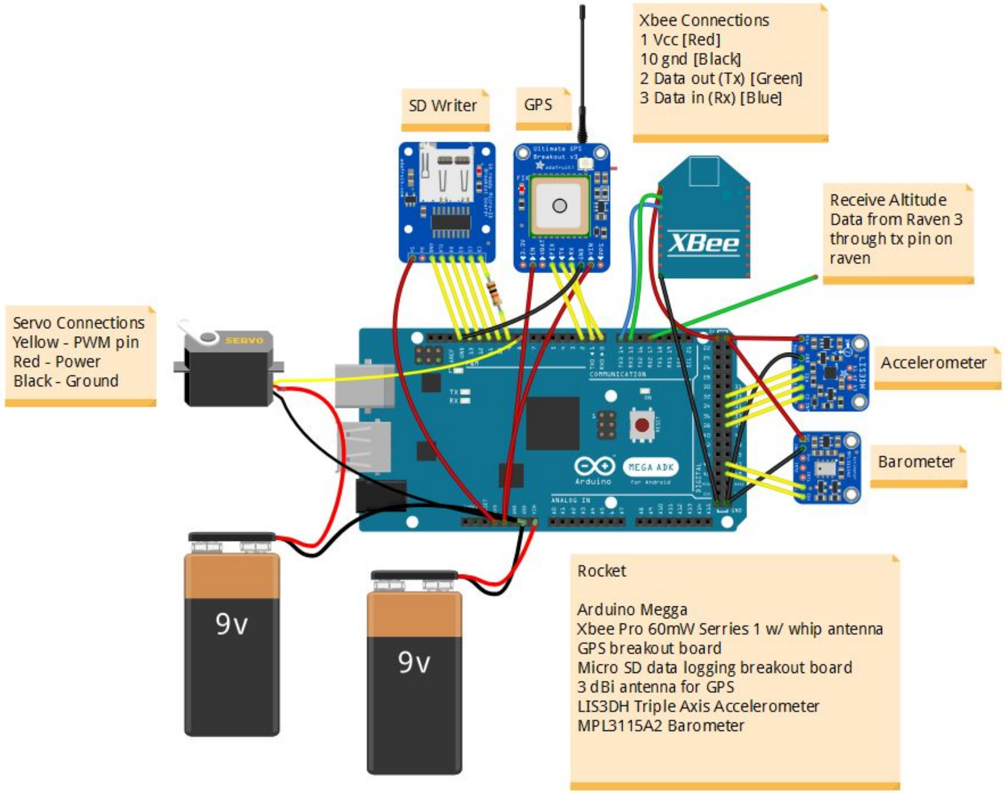

Figure 5: Wiring schematic for the data transmission and GPS system

Budget

PURCHASED		
Product	**Source**	**Final Cost**
4" Madcow ebay	apogee	$ 34.95
4" Blue tube 48" long	alwaysreadyrocketry	$ 38.95
54mm centering rings to 98mm	apogee	$ 8.51
54mmx4" Motor Mount	apogee	$ 8.09
G10 FR4 Glass Epoxy Sheet 0.125" x 12" x 12"	eplastics	$ 23.90
98mm Tube bulkhead	apogee	$ 8.50
Raspberry pi camera system	amazon	$ 81.00
1500# Kevlar Shock Cord (Drogue)	apogee	$ 10.00
Drogue Chute	apogee	$ 63.70
Parachute	apogee	$ 84.00
Blue tube coupler	apogee	$ 20.26
Shear pins	apogee	$ 3.10
20 ft kevlar shock cord	apogee	$ 19.40
shipping	apogee	$ 7.52
54mm motor retainer	apogee	$ 31.03
standard rail button	apogee	$ 3.22
shipping	apogee	$ 5.07
servo	amazon	$ 20.58
intelli cone	public missles	$ 55.94
Hotel		$ 280.00
Travel		$ 200.00
Meals		$ 90.00
Test launch motors	wildman rocketry	$ 237.98
Motor Casing	wildman rocketry	$ 161.00
Wadding	wildman rocketry	$ 5.00
Raven	featherweight	$ 165.00
9V Batteries	Ace	$ 7.12
Building Materials	Home Depot/Ace	$ 111.36
Nose Cone	Public missiles	$ 21.95
Mega, 9dbi antenna, nano, 2 sd card writer	Amazon	$ 62.33
Proto board and pressure sensor	Amazon	$ 20.31
Just Accelerometer	Amazon	$ 18.02
xbee's	Digi Key	$ 78.13
GPS breakout board	Amazon	$ 45.93
16 Gb SD card	Amazon	$ 15.83
GPS antenna and U.FL	Amazon	$ 19.95
9V battery clips	amazon	$ 9.98
Xbee adapter board	micro cont pros	$ 14.00
Pitot Tube	horizon hobby	$ 10.99
pressure sensor	Digi Key	$ 13.80
REPLACMENT PARTS (Below)		
2 LOC Body Tubes	apogee	$ 23.00
LOC Coupler	apogee	$ 4.95
LOC 54mm Body tube	apogee	$ 8.09
Aeropack motor retainer	apogee	$ 31.03
Bulk heads	apogee	$ 12.75
Centering Rings	apogee	$ 17.02
Rail buttons	apogee	$ 3.22
Kevlar shock cord	apogee	$ 29.10
shipping	FEDEX	$ 29.11
		$ 2,274.67

Construction

Construction started with the motor mount. To start the motor tube was cut to length and the bulkheads were epoxied in place at their premarked locations. The stability fins were marked using a laser cutter and then cut out of the G10 fiberglass sheet by hand using a bandsaw. Once the fins were cut out they were then epoxied into place on the motor mount. After the motor mount had dried a eye hook was placed in the top bulkhead for the parachute shock cord to attach to. This process can be seen in figure 7.

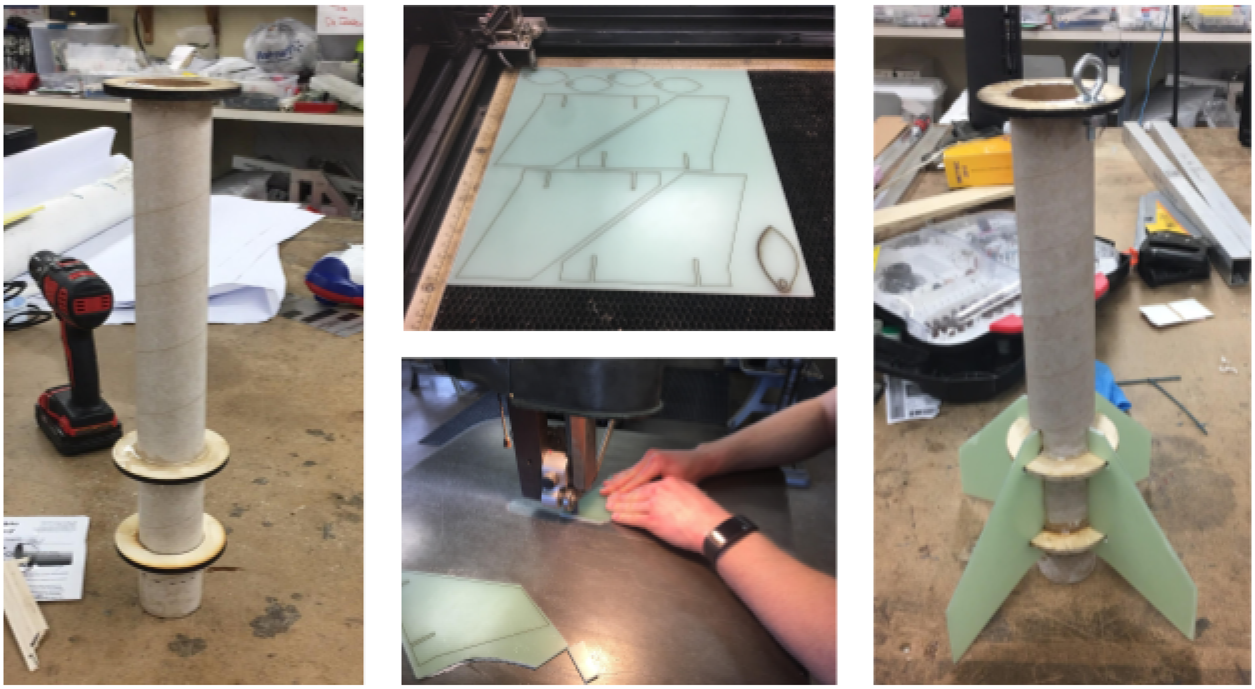

Figure 6: The construction of the motor mount and fins.

The next part of construction was mounting the motor mount into the body tube. Fins slots were cut into the body tube 90 degrees from each other. Once the slots were cut into the body epoxy was applied to the bulkheads and the motor mount was slid into place and allowed to harden.

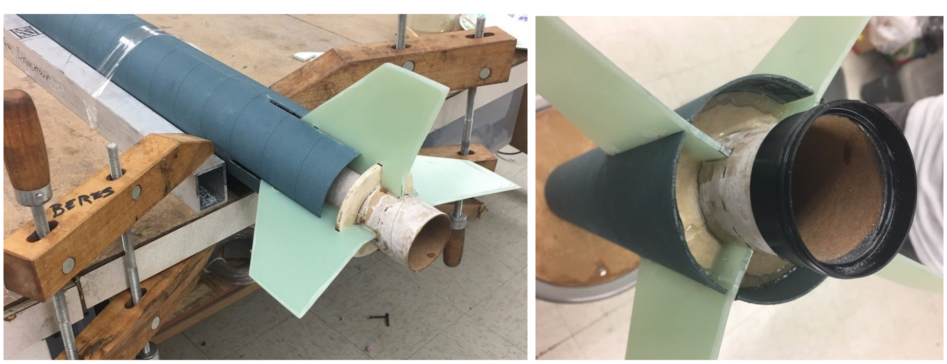

Figure 7: Installation of the motor mount

To build the drag system first custom bulkheads were laser cut out of a high density plywood. The bulkheads were then placed on the four quarter inch rods using nuts to maintain the correct spacing between bulkheads. Once the spacing was correct the nuts were epoxied in place to reduce any possibility of movement. Once the bulkheads were in place epoxy was applied and body tubes were set in place. The electronics were first tested outside the rocket before installing it in place inside the rocket.

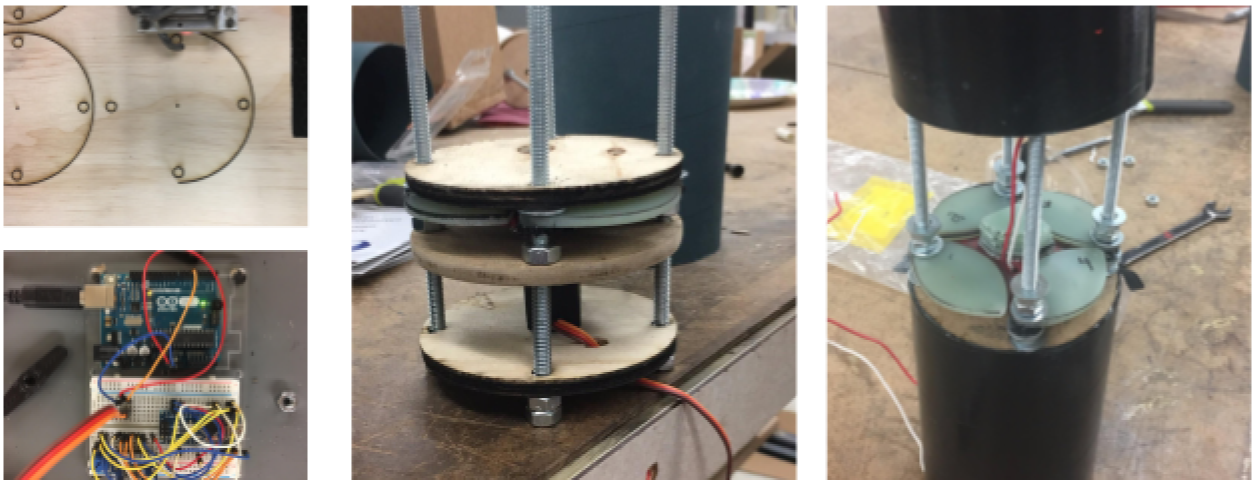

Figure 8: The construction process of the drag system

Parachutes were next attached to the eye hooks on the ends of their respective sections. Tape was applied to the shock cord so that the shock cord would not tear the body tube during parachute deployment.

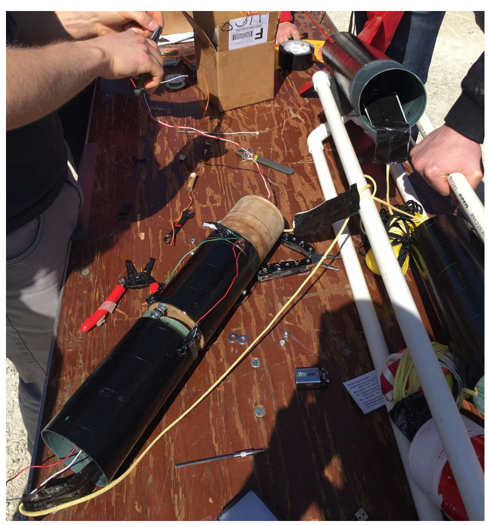

Figure 9: Parachute and shock cord installation

Photos of Completed Rocket and Test Flight

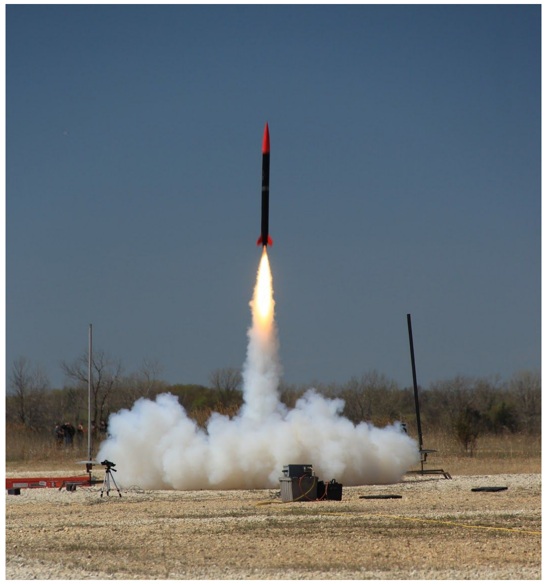

Figure 10: Our completed rocket being launched at the test flight

Test Flight Report

Flight Performance

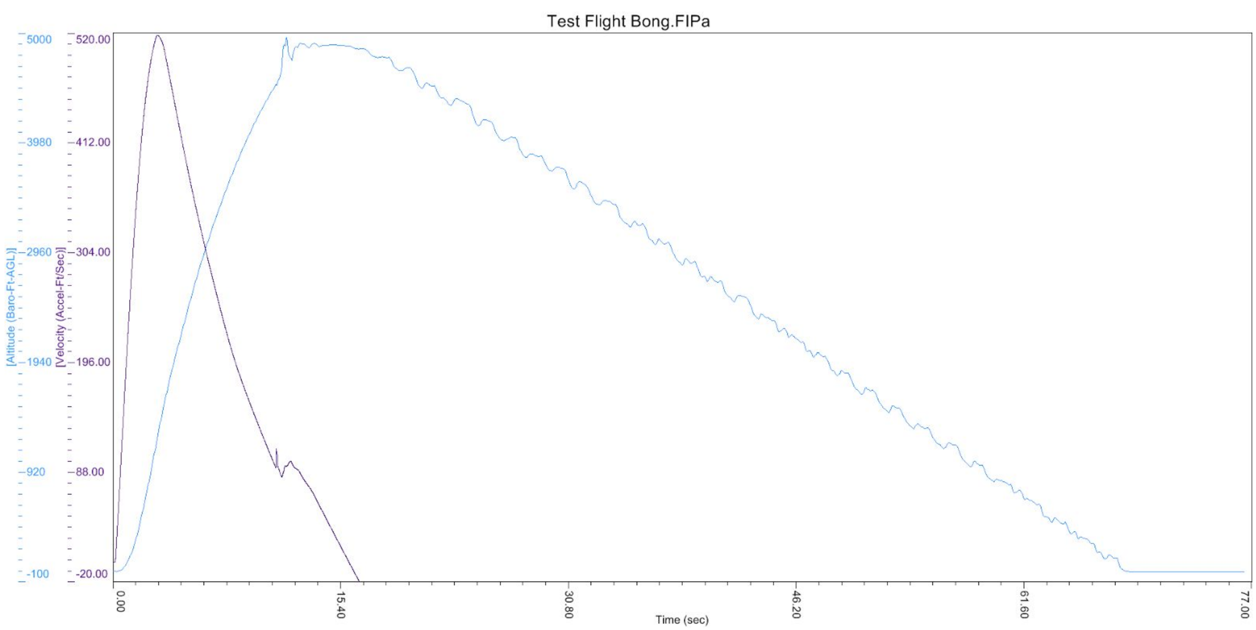

Figure 11: Altitude Data from Test Flight

Apogee from Raven 3: 4,960 ft

Apogee from Barometer: 4,892 ft

It can be seen that there is only a 68 ft difference between the two. Additionally, the apogee predicted from OpenRocket modeling was 5,225 ft.

Electronics System Analysis

Overall, the electronics performed very well during the test launch. Data was successfully recorded onto an onboard microSD card that was recovered. The barometer yielded very accurate results and was only off by 68 ft. The accelerometer data was very noisy but matched the results from the Raven overall. The wireless data transfer network worked great and the rocket did not go out of range. During the flight, data was sent the entire time and was viewed on the computer. Even with the hard landing of the upper portion of the rocket, the electronics bay was in great condition and none of the electronics were damaged.

Recovery system performance

<u>Recovery system user interface</u>

The recovery system of the rocket consisted of an on-board GPS and wireless communication down to a computer. The data coming from the rocket was then displayed using this user interface which allowed us to view the data. The Latitude and Longitude numbers were displayed in addition to the red dot on the map so the team could put the coordinates into their phone and track the rocket themselves. Some additional useful data was also displayed so we could ensure all systems were operational before launch.

Figure 12: GPS Location System

Table of flight characteristics:

	Aerotech J-415	Aerotech K-540
Rocket Mass (kg)	4.46	4.53
Max Altitude (ft)	4960	6590
Max Velocity (ft/s)	518	946
Impulse	1201	1593

Plots of altitude, velocity, and acceleration vs time from test flight:

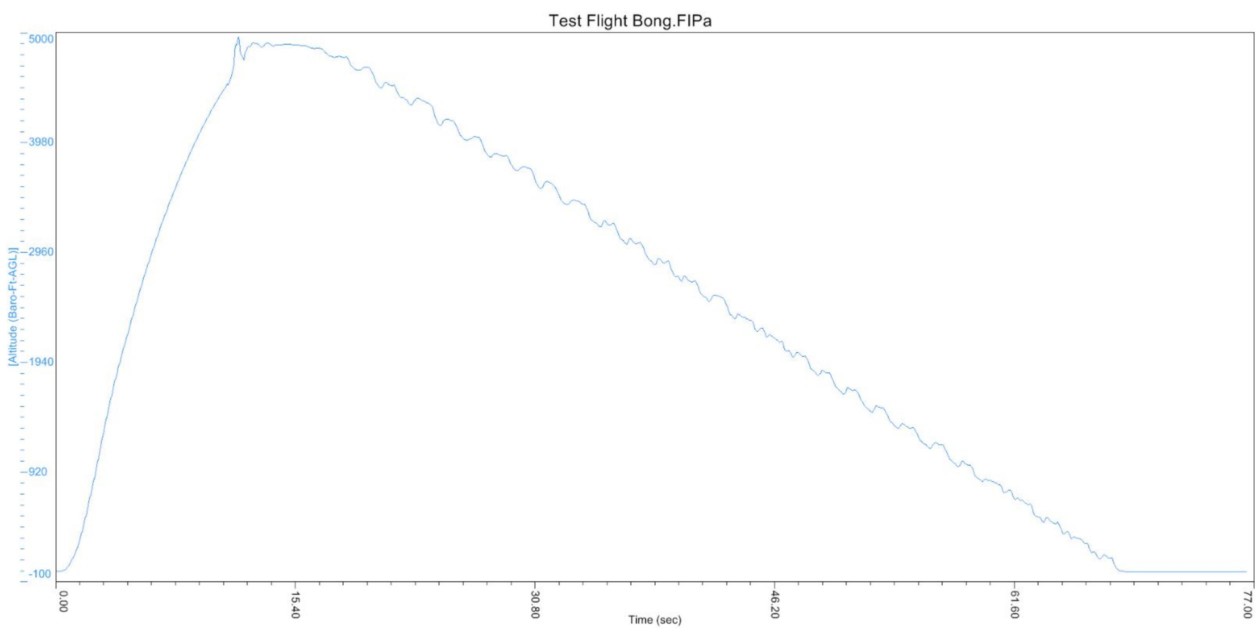

Figure 13: Altitude

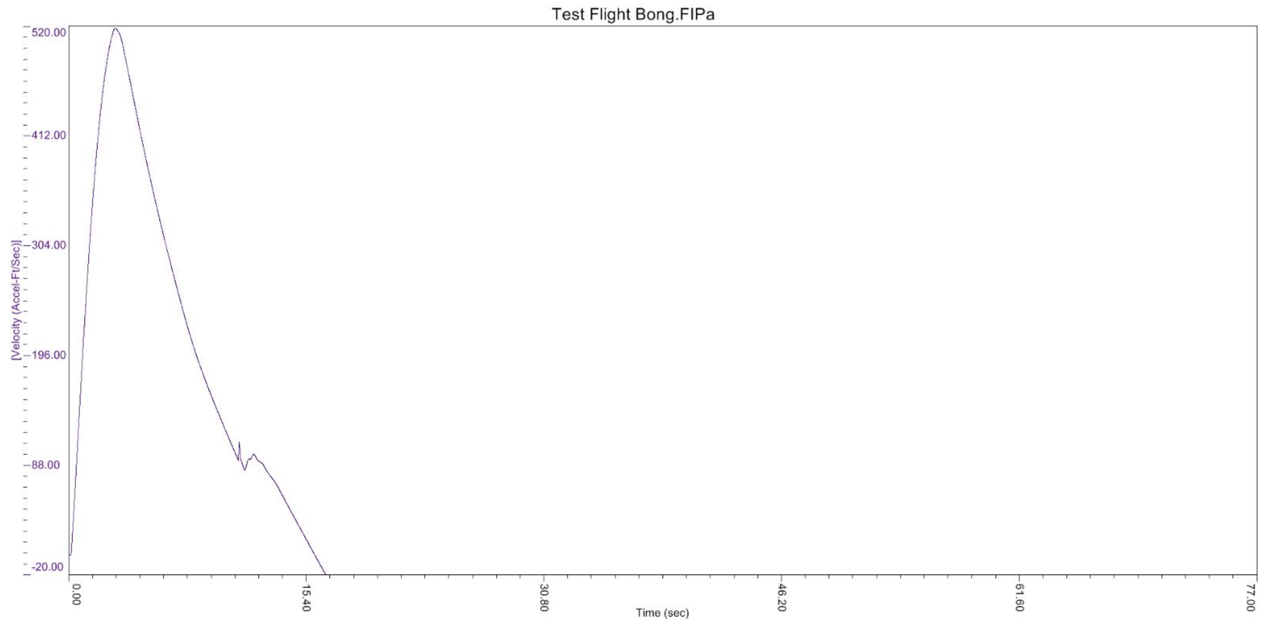

Figure 14: Velocity

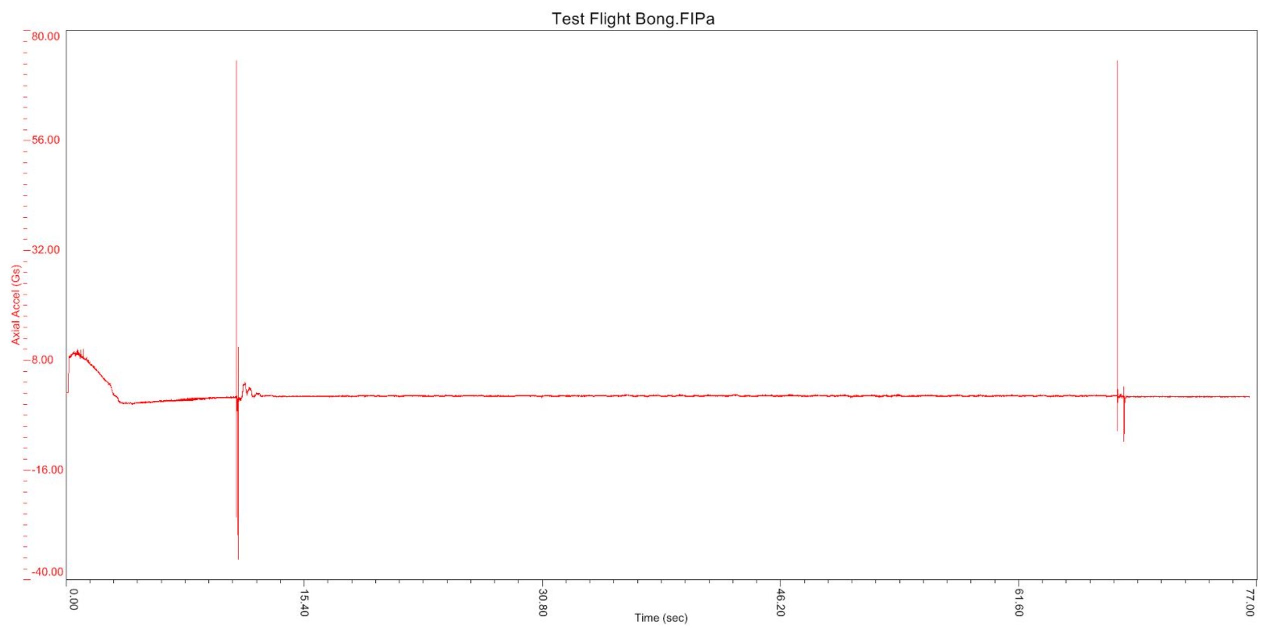

Figure 15: Acceleration

Other Data from Raven 3:

```
Average PreLaunch Altitude (ft)          = Val: 522.00
Average PreLaunch Axial (Gs)             = Val: 0.98
Average PreLaunch Axial Offset           = Val: 0.98
Axial Accel (Gs)                         = Min: -35.46     Max: 73.42
Baro (Atm)                               = Min: 0.8172     Max: 0.9814
Current Draw (A)                         = Min: 0.00       Max: 0.00
Flight Count                             = Val: 2.00
Lateral Accel (Gs)                       = Min: -6.96      Max: 14.00
Motor Ignition Time (sec)                = Val: 0.150
Temperature (F)                          = Min: 88.04      Max: 88.16
Time (sec)                               = Min: 0.000      Max: 16.680
Velocity (Accel-Ft/Sec)                  = Min: -1         Max: 520
Volts Battery (V)                        = Min: 7.48       Max: 7.92
Volts Pyro 3rd (V)                       = Min: -0.02      Max: 0.00
Volts Pyro 4th (V)                       = Min: -0.02      Max: 0.00
Volts Pyro Apogee (V)                    = Min: -0.02      Max: 0.00
Volts Pyro Main (V)                      = Min: -0.02      Max: -0.02
[Altitude (Accel-Ft)]                    = Min: 0          Max: 3462
[Altitude (Baro-Ft-AGL)]                 = Min: -2         Max: 4960
[Altitude (Baro-Ft-ASL)]                 = Min: 520        Max: 5482
[Velocity (Accel-Ft/Sec)]                = Min: -20        Max: 518
[Velocity (Accel-MPH)]                   = Min: -13        Max: 353
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Discussion of results

At our test launch we predicted a maximum altitude of 5000 ft and in reality it went to 4960 ft. This 40 ft discrepancy could be down to a few things, but the main reason we can postulate was the rocket was launched at a slight angle due to the winds. Although we had taken the wind into account in our analysis we had never added any launch angle to compensate for the drift of the rocket during descent

The maximum velocity achieved was found to be 518 ft/s recorded by our featherweight raven 3 altimeter. From our modeling the estimated maximum velocity was 712 ft/s. The actual velocity number is being used in place of our pitot tube number because our direct velocity measurement system did not arrive in time for our launch. The discrepancy in these numbers is quite significant,

We did not have the camera system working for the test launch so we decided to leave it out but did use some dummy weights to achieve an accurate launch weight.

Planned Changes

During our test flight the there was a failure shortly after apogee. The failure point was the eye hook on the drag system bulkhead was pulled through the bulkhead causing the sections to separate during flight.

Figure 16: Left is an example of the eye hook, right is the section where the eye hook failed

This failure caused the motor mount section to float down with the drogue parachute safely but the top section fell to the ground and was damaged as seen in figure X. Due to this failure the blue tube in this section was destroyed and will need to rebuilt before competition. LOC cardboard body tube is being used to replace this blue tube section due to its low cost and strength.

Figure 17: The broken section of the rocket

Other changes to the rocket include the use of G10 fiberglass for the fins instead of the 3D printed fins with gears attached. Another change for the launch includes using a pitot tube for the direct velocity measurement instead of the hot wire anemometer. This is because a pitot tube is a proven technology, while the hot wire anemometer is less common for a rocketry application.