Flight Readiness Report

NUSTARS
Northwestern University

Team Lead: Shawn Sobel ShawnSobel2017@u.northwestern.edu
Faculty advisor: Nick Marchuk nwu-ndm736@northwestern.edu
Mentor: Judy Lubin Judy@lubin.net

Monica Berg, Katie Varela, Julie Skoll, Evan Mcconnell, John Mccartney, Ethan Trokie, Rob Sanders, Cindy Chen, Andrew Klinker, Andy Corbato, Noah Sims, Yichen Xu, Sam Cohen, Lautaro Cilenti

Table of Contents

Executive Summary

In accordance to the 2016 Space Grant Midwest High-Power Rocket Competition, NUSTARS has designed a rocket that will fly to an altitude between 3000 and 5000 feet with no drag system deployment and 3⁄4 of the previous altitude on the second flight with active drag deployment. In addition, NUSTARS has developed a data-logging package to estimate coefficient of drag over time and a video system to monitor airbrake deployment.

To accomplish an initial altitude of 4304 feet NUSTARS has built a 102 mm diameter 2.97 m long and 12.4 kg rocket, The SpacePuppy (see Fig. 1), powered by a CTI K1440 motor. This white thunder motor has a burn time of 1.64 seconds which accelerates the rocket to a rail exit velocity of 16.6 m/s which helps to ensure takeoff stability. To ensure a safe recovery of the rocket, a redundant set of RRC3 flight computers will deploy a 12 in drogue parachute at apogee and a 72 in main parachute at 800ft.

Figure 1: SpacePuppy on Launch Pad

In order to fly a second time and achieve an altitude 3⁄4 of the previous flight's altitude,NUSTARS has built an active airbrake drag system. The software of this system is powered by an Arduino Mega that is constantly reading: accelerometer, gyrometer, and altimeter data, to ensure correct deployment times. The mechanics of this system are driven by a 150lb linear actuator that deploys four air brakes that are housed flush to the side of the rocket's exterior. In order to follow Tripoli safety code and to ensure that the extreme stresses of deployment do not cause part failures, all interior parts are made of carbon alloy steel, while the actual airbrakes are made of fiberglass.

At this time we have no flight data for the airbrakes due to a catastrophe at take off on May 7th. In order to assure stability and accurate air brake deployment, we will be launching on Saturday, May 14th in Princeton, Illinois.

The data-logging package is run through an interiorly mounted Arduino that calculates coefficient drag from acceleration data. In addition, an 808 HD #16 Micro Keychain Rocket Camera is externally mounted to collect video of the airbrakes deployment status.

Design Features of Launch Vehicle

Overall Dimensions and Specifications

The SpacePuppy is composed of four major sections, each with a 97.6 mm diameter (102 mm outer diameter). The nose cone (61 cm) is made of hollow fiberglass in an ogive shape with a 2 mm bulkhead and steel welded eyebolt connected to its bottom. The parachute bay (91.4 cm), avionics bay (38.1 cm), and booster (107 cm) are all constructed from fiberglass. The parachute bay holds a 72 in parachute, 12 in square Nomex, 5 yards of shock cord, 3 quick links, fireproof wadding and 2 3-gram black powder ejection charges.

Figure 2: Avionics Section with Air Brakes

The avionics bay (see Fig. 2) contains a fiberglass inner tube coupler with a 93.6 mm diameter (97.6 mm outer diameter). The coupler (61.3 cm) is broken up into three main parts. The top part (10 cm) holds the data logger mounted on a sheet of fiberglass. The middle part (38.1 cm) houses the drag system weighing 3402 g. The bottom part (13.2 cm) holds 2 Raven 3 altimeters and 1 Jolly Logic altimeter mounted on a 3-D printed sled. An 808 HD #16 Micro Keychain Rocket Camera is mounted on the outside of the avionics bay.

The booster (see Fig. 3) holds a 12 in drogue parachute, 9 in square Nomex, 2 quick links, 15 yards of shock cord, a recovery harness, 2 2.5-gram black powder ejection charges, fireproof wadding, and 56.4 cm motor mount. Three fiberglass fins are fastened to the booster through slits in the booster tube. The recovery harness, which consists of an inner body tube with a 93.6 mm diameter (97.6 mm outer diameter) and 1 yard of Kevlar shock cord, is epoxied to the inside of the booster.

Figure 3: Booster with Fins

The fins are secured with epoxy and chopper carbon fiber to the booster tube and to the motor tube inside, and then reinforced with RocketPoxy fillets. The fins have a thickness of 0.318 cm, base length of 30.5 cm, top length of 15.28 cm, and height of 16.5 cm. The fin tabs which run through the booster tube to the motor tube have a height of 1.78 cm. The sweep angle is 65^{o}. The overall length of the SpacePuppy (see Fig. 4) is 297 cm with a weight of 12486 grams (with a loaded Cesaroni K1440WT motor).

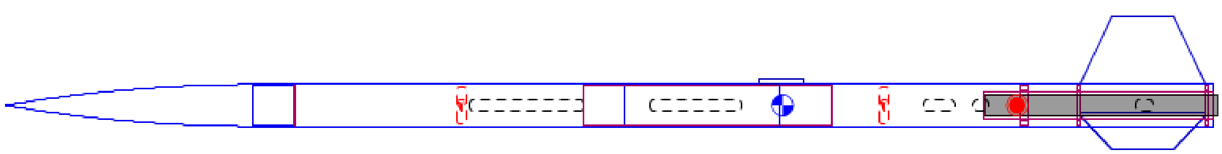

Figure 4: SpacePuppy drawing

Recovery System Design Specifications
Two Fruity Chute parachutes, one main (72 in) and one drogue (12 in) will act as the SpacePuppy's recovery system. The parachutes will be deployed by ejection charges from two Raven 3 altimeters. Both altimeters are placed inside the avionics bay incase one fails, each has the ability to eject the parachute. With the deployment of both parachutes, the estimated landing velocity is 5.98 m/s.

Parachute Bay: The recovery systems main parachute is an annular 72 in rip stop nylon parachute housed in the parachute bay. The Iris Ultra Standard parachute is 379.89 grams and has a 12.67 in (diameter) spill hole. It has 12 shroud lines and is rated for 28 lbs at 20 fps. The theoretical maximum drag coefficient is 2.2 for vertical descent. Five yards of tubular nylon shock cord attached to the parachute is anchored to the nose cone and the end of the avionics bay by steel welded eyebolts. The parachute will be wrapped in a 12 in square of flame-retardant Nomex to prevent charring or burning. Two ejection charges fired from a Raven 3 altimeter will eject the parachute at a downward altitude of 800 ft.

Booster: The recovery systems drogue parachute is an elliptical 12 in rip stop nylon parachute housed in the booster. The Classical Elliptical parachute is 37.14 grams and has a 2.4 in (diameter) spill hole. It has 8 shroud lines and is rated for 0.5 lbs at 20 fps. The theoretical maximum drag coefficient is 1.5 for vertical descent. A recovery harness of an inner body tube with a 93.6 mm diameter (97.6 mm outer diameter) and 3 yards of Kevlar shock cord is attached to the bottom of the booster. Fifteen yards of nylon shock cord attached to the parachute and the recovery harness is anchored to the end of the avionics bay by steel welded eyebolts. The parachute will be wrapped in a 9 in square of flame-retardant Nomex to prevent charring or burning. Two ejection charges fired from a Raven 3 altimeter will eject the parachute at apogee.

Propulsion System
The Cesaroni K1440WT has an average thrust of 1444 newtons and a maximum thrust of 2168 newtons. A total impulse of 2368 newton-seconds is provided by the burn time of 1.64 seconds. The total launch weight of the motor is 1893 grams with dimensions of a 54 mm diameter and 572 mm length. The propellant weight is 1129 grams, making the empty weight 764 grams. The unadjusted delay grain is 17 seconds. To safely use the motor, a minimal diameter of cleared area of 75 ft, a minimal personal distance of 200 ft, and a minimal personal distance of 300 ft for a complex rocket is required.

Design Features of Payload

Data Logger
A requirement of the design is an onboard data collection package that will record the coefficient of drag over time (see Fig.5). The coefficient of drag is calculated through the equation:

$$C_d = \frac{2m(a-g)}{\varrho V^2 A}$$

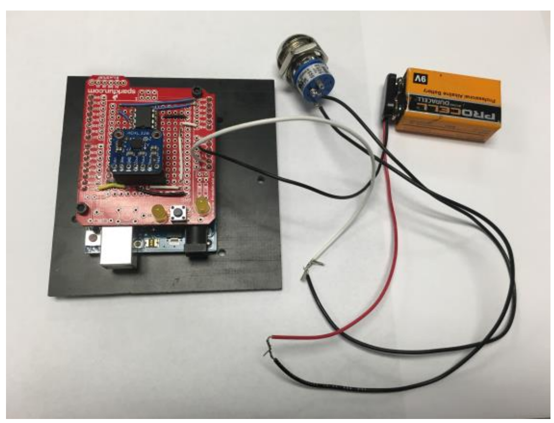

Figure 5: Data Logger with Key Switch and Battery

Where C_d is the coefficient of drag, m is mass, a is the acceleration of the rocket, g is the acceleration due to gravity on earth, ρ is the density of air, V is the speed of the rocket and A is the frontal area of the rocket. In order to calculate the coefficient throughout the flight an Arduino Uno is used in combination with an Adafruit High-G accelerometer and an eeprom storage chip. A key switch is placed interrupting wires coming from the battery for each the Data Logger. This is used to turn the Arduino Uno on and off.

Avionics Bay

The avionics bay holds two Raven 3 flight computers to control the deployment of the drogue and main parachutes. In addition, there is a Jolly Logic Altimeter Two to record flight data for competition data. This will be mounted in the avionics bay and is internally powered. Equipped with a pressure based altimeter, the Raven 3 delivers current to black powder charges in both the drogue and main parachute bays at the desired altitudes to initiate deployment as well as collecting flight altitude data. To ensure functionality two flight computers are used, creating a redundant system. The first Raven 3 model is programmed to deploy the drogue at apogee and then the main parachute at 800 feet. The second computer is programmed to detonate additional charges on a one second delay after apogee and 750 feet. The delay prevents simultaneous charge detonation, while still accounting for primary altimeter malfunction. Two Key switches are placed interrupting wires coming from the batteries for each respective computer. These are used to turn the computers on and off. The avionics bay is located in between the two parachute bays. The main parachute is stored above the active drag system, so the wiring for the drogue moves up the rocket through a hole in the bulkhead, through heat shrink wrapped conduit in the active drag system bay, and finally through another bulkhead hole to the drogue charges. The drogue parachute wiring moves down the rocket through a similar bulkhead hole to the booster bay. To hold the computers within the bay a fiberglass sled (Fig. 6) is positioned using two parallel threaded rods. The rods run through cylindrical channels on both sides of the rear of the sled. These rods are then anchored into bulkheads above and below the bay. Nuts are used to prevent vertical movement of the sled within the bay. On the rear side of the sled two 9 V batteries supply the flight computers respectively. Additionally, the Raven 3 will collect data on flight altitudes. This will be stored in the 8 MB flash memory card on board the flight computer. Using the LCD port this data can be displayed following rocket recovery.

Camera

Attached to the avionics bay is an 808 HD #16 Micro Keychain Rocket Camera with an installed 8 GB class 4 microSD card. It is 50 mm (L) by 32 mm (W) by 13 mm (H) and 17 grams. The camera is secured to the outside of the avionics bay by a 3D printed mount. It has an internal battery which can record movie clip lengths of 5 minutes, 20 minutes, 40 minutes, or 70 minutes. A full battery life requires 2.5 hours of charging. The camera can connect to any PC or MAC through an external USB port.

Active Drag System

Airbrakes

To provide additional drag onto the launch vehicle we have designed an active airbrake system, as seen with and without its body tube in figure 6, which can turn the coefficient of drag from the rocket’s non-deployed value of approximately 1 to over 3, per flow analysis. Exact values of drag could not be calculated from flight data, as the StarPuppy suffered a CATO before airbrake deployment. Data will be collected the 14th of May, prior to competition.

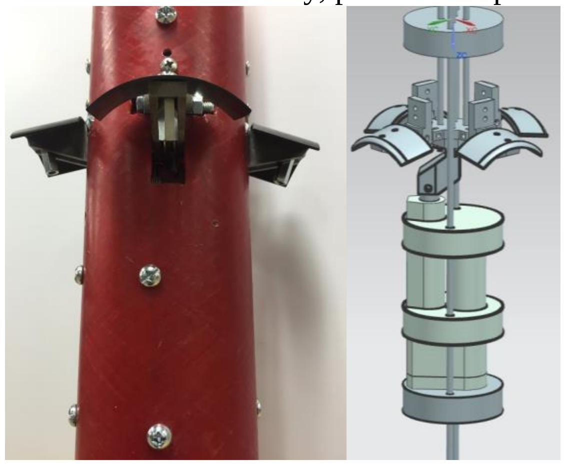

Figure 6: Active Airbrake System with and without its body tube

In order to assure stability, simulations were run in RockSim utilizing worst case scenario of treating the brakes as flat plates. This proved that the airbrakes deployment would only change the stability margin by 2%, an insignificant amount. Additionally, the rocket will be flown with airbrakes operational on the 14th of May to demonstrate stability throughout its flight.

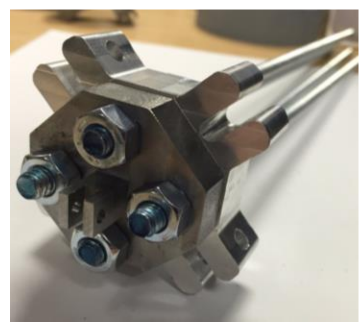

Figure 7: Centered Mount

Figure 8: Fiberglass Brakes

When the flight control system, expounded on below, detects the optimal time for deployment or retraction, a Firgelli 150lb Feedback Linear Actuator pushes or pulls onto a connection piece that centers the off centered load provided by the actuator. From this connection piece, a centered mount is pushed upward. This centered mount has four steel rods that run through the airframe ensuring again that mount moves parallel to the body tube, (Fig. 7). Connected to this centered mount are four arms that push four brackets out of the rocket airframe when moved upward. These brackets have fiberglass brakes bolted onto them, (Fig. 8). Because of this temporary joining, alternative brake designs can be switched into the system if the current brakes are providing too much or too little drag.

Because of the extreme stress experienced by this system, all main components are made out of carbon alloy steel that allows for easy machining while also retaining a high yield strength. In addition, all mechanical connections are achieved using Loctited steel nuts and bolts and nuts. ANYSYS stress analysis on the airbrakes can be found in the PDR.

Electronics

The electronics for the active drag can be separated into two main sections: hardware and software.

Hardware: The active drag system is set into motion by a Firgelli Feedback Rod Linear Actuator. This actuator has a dynamic force capability of 150lbs and actuating speed of .5 inches per second. The movement is powered through a Pololu G2 High-Power Motor Driver controlled by an Ardunio Mega. The Arduino Mega and linear actuator are powered respectively by a 9V battery and two 11.7V LiPo batteries connected in series as a 24 volt source. Additionally the Arduino Mega is taking data through an AltiMU-10 Gyro, Accelerometer, Compass, and Altimeter. The wiring diagram can be found in figure 9 below.

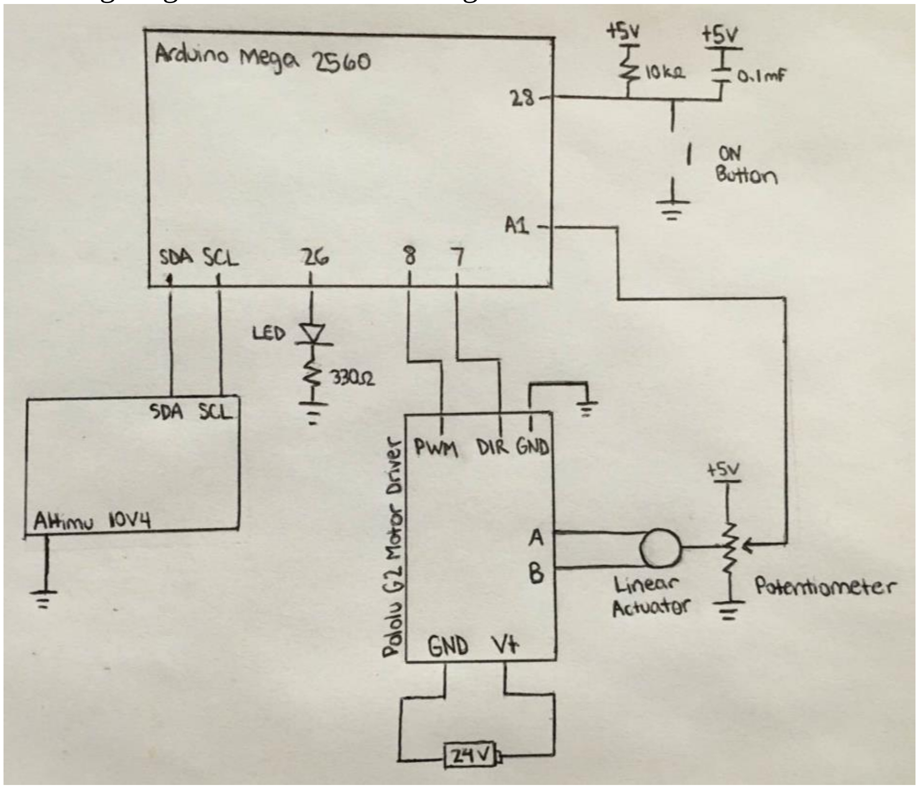

Figure 9: Wiring Diagram

Software:

Sensor System- The Arduino Mega will continuously read and store the accelerometer and altimeter data to create a numerical position and acceleration profile as a function of time. The objectives of the sensors are to acquire the predicted maximum height of the launch vehicle while also acquiring the position, velocity, and acceleration for the entire flight path. This sensor system will be active on all launches, even when the airbrake system is disabled to effectively compare the airbrake system profile with the actual launch vehicle flight path measured by the recovery system altimeters.

Control System- After detecting motor ignition from the accelerometer and barometer, the Arduino measures velocity, acceleration, and altitude values. These values are inputted into a standard kinematic equation to detect an expected apogee altitude. Parameters will be modified with a correction factor after further launch analysis has been done to adjust for greater targeting accuracy. If the calculated future altitude value is greater than the desired altitude, the Arduino sends a PWM signal to the motor driver, which then powers the linear actuator to push the airbrakes out. A feedback potentiometer tells the controller how much the actuator has extended.

If the feedback potentiometer indicates the airbrakes are fully open, the controller turns off the PWM signal and stops moving the actuator. The Arduino then loops through this logic until it reads that the apogee will be lower than the desired value, and retracts the linear actuator. Because of the CATO on the May 7th launch, no flight activation has been achieved, although simulations have been run with programmed flight curves to test the decision making of the control system.

The actuator can withstand 300lbs of force while not moving, so no power is necessary to maintain the air brakes at full deployment position. The full deployment of the air brakes takes between .25 and .5 seconds, the time it takes the actuator to fully extend 1”.

After the controller receives data from the altimeter that the launch vehicle has reached a max elevation, the controller reverses the motor driver direction and it enables the motor driver until the actuator returns to its original position and the air brakes return to closed position.

Construction Techniques

Overall Body Construction

The construction of the body of our launch vehicle was based on many common high power rocketry guidelines. We exercised extreme caution throughout the construction process, ensuring that the materials we used and the processes underwent promoted safe, stable flight. For example, we used closed eye bolts, a fiberglass airframe, and three standard methods for joining surfaces, outlined below.

For joints that would not be under extreme stress, we used West Systems 105 Epoxy and 205 hardener, taking care that the joined surfaces were well sanded in order to promote adhesion. Examples of non-major stress joints are bulkheads and couplers.

The second joining method that we used was utilized on the main fins. To ensure that they were securely fastened to the rocket body, we utilized a through-the-wall fin design. For the inside, we injected West Systems Epoxy and 205 Hardener mixed with chopped carbon fiber. Then, on the exterior of the rocket, we made fillets using RocketPoxy at the base of the fins, (Fig. 10). This method of joining ensures that the fins can withstand strong accelerations and drag forces during its flight and launch.

Figure 10: Fillets at the Base of the Fins

All internal centering rings and motor tubes are bonded to the outer body tube using West Systems Epoxy and 205 Hardener. Finally, many of the internal components in the avionics bay are held together by wingnuts on two parallel steel threaded rods. The wingnuts were strengthened with Loctite Blue 242 and tightened in order to provide a strong compressive force to hold the avionics bay together, (Fig 11). All other nuts inside of the rocket were also strengthened using Loctite Blue 242.

Due to a manufacturing defect, the motor casings failed and the rocket experienced a catastrophe at take off, severely damaging the booster portion of the rocket. A new booster will be built with the same construction techniques as the original one.

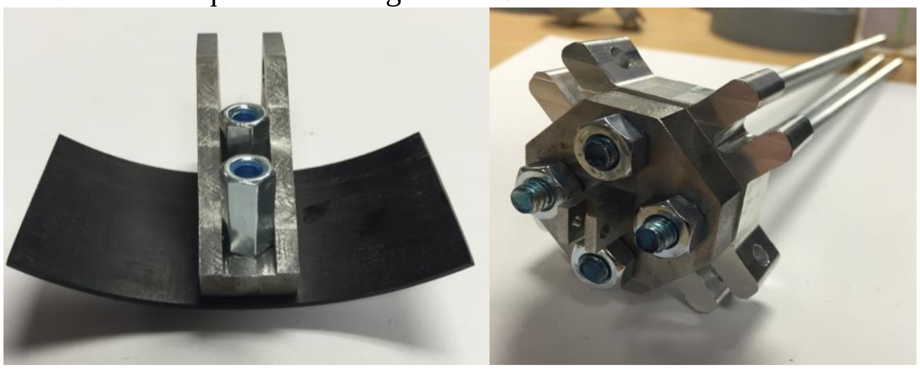

Figure 11: Demonstrating the use of Loctite Blue 242 for internal nuts

Active Drag System Construction

Apart from standard parts like nuts, bolts, and steel rods, many of the components in the active drag system needed to be machined custom for our design. The parts were mostly milled from steel before being fixed together using Loctite and nuts. The parts shown below were all custom made, (Fig. 12).

Figure 12: Custom Parts for the Air Brake System

Slits for the fins were cut into the side of the rocket using a Dremel tool as well as a drill press, and the parts were assembled and inserted into the rocket. The actuator is held in place using

PVC fittings, while the other components are held in place by the steel threaded rods. The image below shows the fin slots with the assembled system inside, (Fig. 13).

Figure 13: Fin Slots with the Assembled System

Rocket Operation Assessment

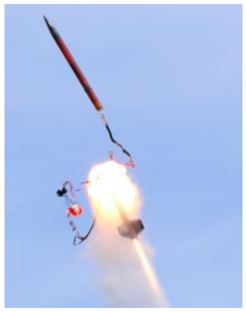

Figure 14: Catastrophe at Takeoff

The rocket experienced a catastrophe at take off during the first test flight of the completed rocket. Based on photos, videos, altimeter data and recovered components the following is the most likely sequence of events at the launch, (Fig. 14 & 15).

Around 0.75 seconds after launch the motor failed and blew a hole through the motor casing about an inch below the forward closure. This caused flames to burn through the fiberglass diameter of the rocket, as well as the shock cord connecting the drogue parachute to the rocket. The bottom stage of the rocket then fell to the ground, burning from both ends.

Figure 15: Remains of the Booster

The rest of the rocket, still intact and functioning, traveled slightly higher, reaching an altitude of 440 ft, and then the nose cone drag separated from the payload bay, releasing the main parachute. From there it descended safely, with both drogue and main parachutes deployed.

Upon inspection of the motor remnants, casing, and fiberglass body it is believed that there was a crack in the motor lining which was not detected during motor preparation, causing the pressure and heat of the motor to be released against the casing, causing it to fail. Once there was a hole in the casing fire from the motor burned through the shock cord and fiberglass.

Test Launch Report

Launch Results vs Predicted Results

Table 1: Predicted Altitude and Velocity Values

	Apogee (m)	Peak Velocity (m/s)
Simulation	1225.8	176.44

In the above table it shows the predicted launch values taken from OpenRocket for the StarPuppy. Due to catastrophic motor failure, we were unable to collect data for the actual launch. Below are graphs of predicted altitude, velocity, and acceleration versus time, drag coefficient versus time, and drag coefficient versus velocity. Despite our full scale rocket having a catastrophic motor failure, our subscale with a 1:2 size ratio with matching stability launched stably and achieved greater than our predicted altitude.

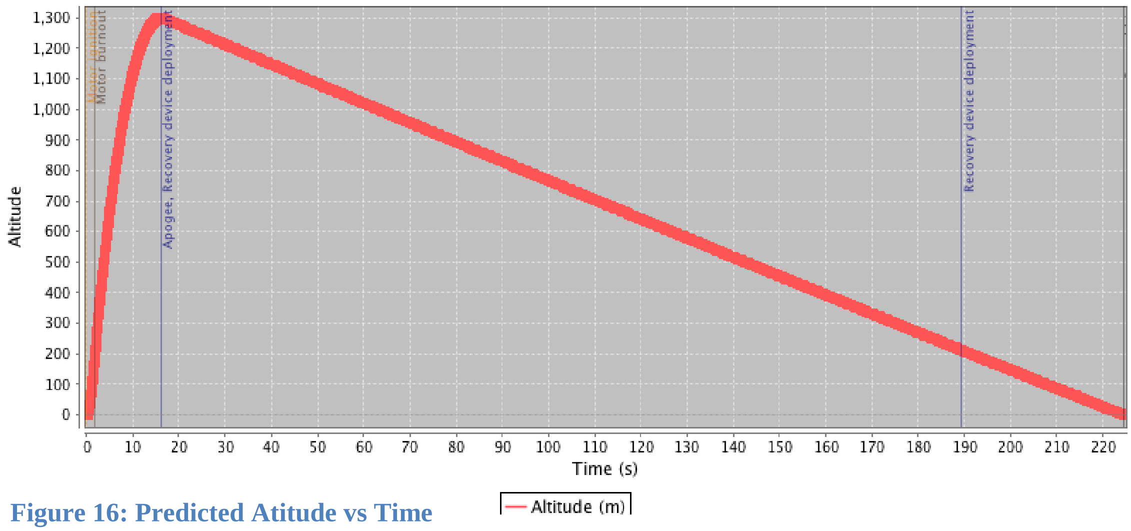

Figure 16: Predicted Atitude vs Time

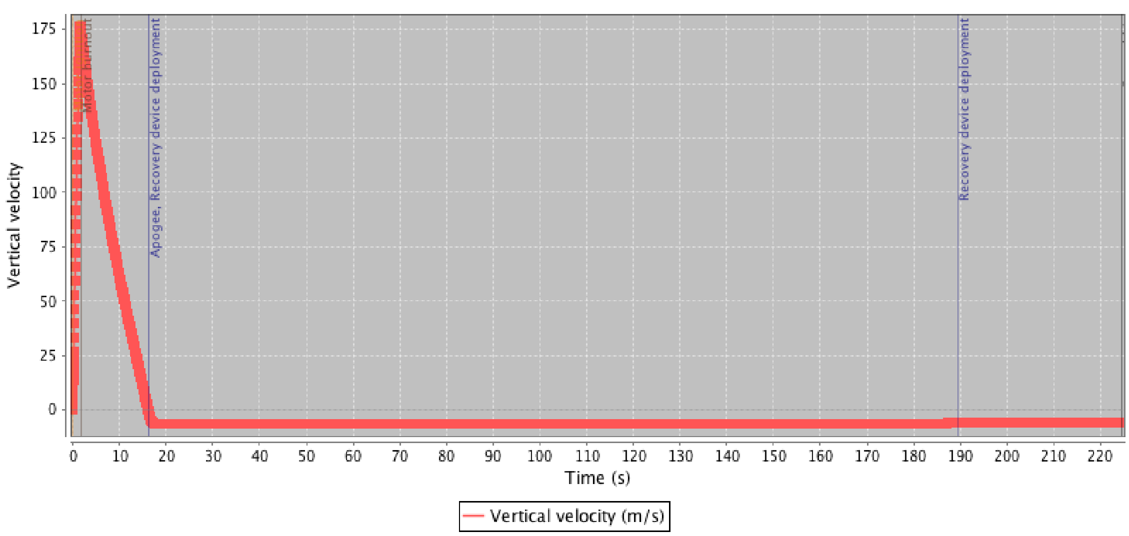

Figure 17: Predicted Vertical Velocity vs Time

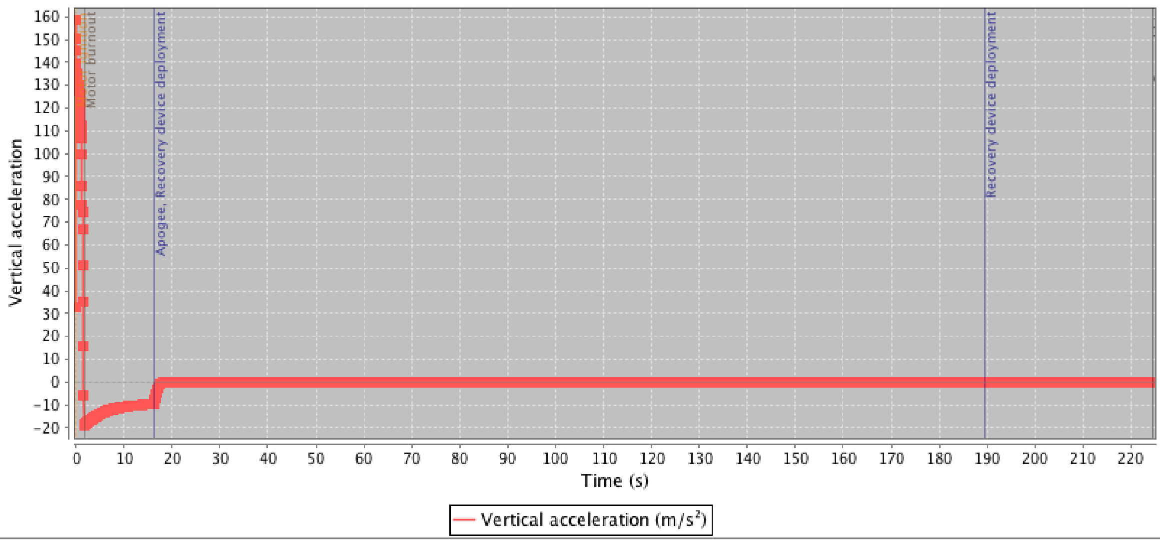

Figure 18: Predicted Vertical Acceleration vs Time

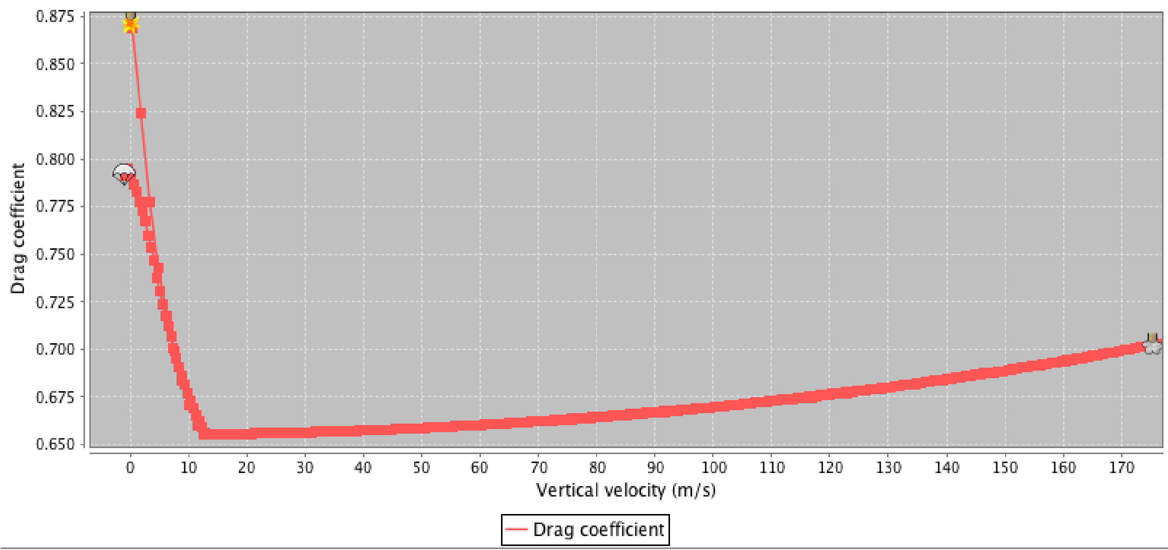

Figure 19: Predicted Drag Coefficient vs Time

Data Logger Analysis

The data logger was able to calculate the drag coefficient and the information was taken from the logger, but the data is not considered useful because of the catastrophe at take off.

Camera Analysis

The camera was fully functional as seen by recording even during the motor catastrophe, but we don't know how well it would have shown the airbrake system.

Potential Design Improvements

During the preparation phase of the rocket, there were several key elements that we noted could be improved on in preparation for our next launch. The access to the Arduino flight recorder was hard to get to and hard to activate. A key switch could be installed to easily activate the Arduino. For the altimeters, we are switching from 2 Raven 3 flight computers to 1 Raven 3 and 1 RRC3 altimeter. The largest failure point in our test flights were the motors. Due to a manufacturing defect, the motor casings failed and the rocket experienced a catastrophe at take off, severely damaging the booster portion of the rocket. The issue was thought to be a problem with a specific batch of Cesaroni Motors. A new booster will be built with the same construction techniques as the original one, and care will be taken to make sure that the motor used does not originate from the same batch.

Budget

The budget was calculated using the construction of the subscale, $488.05, the full-scale, $3,319.95, and full-scale CATO rebuild, $368.16. Changes since the planned budget include using extra threaded rod, different nuts and bolts, needed an extra car for transportation, an increase in hotel prices, and new parts to rebuild after our launch failure. The total budget is $4,176.16 with the details shown below.

Table 2: Full-scale Budget

Item	#	Total Cost ($)
4 inch fiberglass coupler 2 feet	1	64.00
4 inch fiberglass tube 4 feet	2	186.76
Nosecone	1	62.10
2' x 3' fiberglass sheet for fins and sleds	2	51.30
Bulkheads	6	32.40
Eyebolts and Nuts	10	25.99
West systems epoxy	1	58.21
RocketPoxy	1	33.25
Spreading sticks	10	2.00
Jar of carbon fibers	1	7.95
Syringes pack	1	4.45
54 mm motor tube	1	13.68
54 mm retainer	1	38.00
30 yards nylon shock cord	1	37.50
5 feet Kevlar	1	5.40
Quick links	6	5.95
72 inch Fruitychute	1	171.00
12 inch Fruitychute	1	47.00
6 feet threaded rod	3	58.31
Titanium pins	20	214.68
Fiberglass centering rings	3	18.90
Raspberry Pi	1	39.95
Motor driver	1	29.95
Accelerometer/Gyro	1	22.95
Arduino Uno	1	24.95
Accelerometer	1	17.95
Storage chip	1	1.95
Actuator Battery	1	26.50
9V battery	4	4.60
Stranded wires, spool	2	30.90
Wingnuts	6	2.70
Terminal blocks	4	7.90
Steel for air brakes, various sizes	5	319.21
PVC centering rings	4	16.80
Nomex 9 inch	1	6.95
Nomex 12 inch	1	8.95
Rail buttons	2	5.00
Linear actuator	1	139.99
RRC3 Altimeter	2	Grant
Subscale motor	1	59.00
Full-scale motor	2	Grant
Education kit	72	282.68
Registration	1	Grant
Hotel	n/a	1830.00
Food	n/a	500.00
Car	3	720.00
Gas	n/a	200.00
Jolly Logic altimeter	1	69.95
Total		3319.95

Table 3: Subscale Budget

Item	#	Total Cost ($)
2 inch fiberglass tube 3 feet	1	41.89
2 inch fiberglass coupler 1 foot	1	24.00
Nosecone	1	22.49
2' x 3' fiberglass sheet for fins and sleds	1	51.30
Bulkheads	2	7.20
Eyebolts and nuts	3	5.97
West systems epoxy	1	58.21
RocketPoxy	1	33.25
Spreading sticks	5	1.00
Jar of carbon fibers	1	7.95
Syringes pack	1	4.45
29 mm motor tube	1	9.95
29 mm retainer	1	23.00
10 yards nylon shock cord	1	13.50
3.7V battery	2	4.50
Quick links	3	2.97
48 inch Fruitychute	1	119.00
Fiberglass centering rings	2	5.40
2 feet threaded rod	1	19.77
Stranded wires, spool	1	15.45
Wingnuts	2	0.90
Terminal blocks	2	3.95
9 inch Nomex	1	6.95
Rail buttons	2	5.00
Total		488.05

Table 4: Full-scale CATO Rebuild

Item	#	Total Cost ($)
4 inch fiberglass tube 4 feet	1	93.38
2' x 3' fiberglass sheet for fins	2	51.30
54 mm motor tube	1	13.68
54 mm retainer	1	38.00
5 feet Kevlar	1	5.40
30 yards nylon shock cord	1	37.50
Fiberglass centering rings	3	18.90
6G case	1	105.00
Rail buttons	2	5.00
Total		368.16

Appendix

Pre-Launch Procedure

Date: ___________________

- ☐ Inspect shock cords for damage
- ☐ Inspect shock cord connections to nose cone and parachute tube
- ☐ Inspect shock cord connections to avionics bay and booster tube
- ☐ Inspect wiring Altimeter bay
- ☐ Inspect wiring in Data Collection bay
- ☐ Ensure fresh batteries are connected to altimeters in Altimeter bay
- ☐ Ensure camera in altimeter bay has sufficient charge
- ☐ Ensure Raspberry pi is on and collecting data
- ☐ Inspect camera connection to body tube
- ☐ Ensure all electronics in avionics bay are securely attached
- ☐ Ensure all electronics in the data collection bay are securely attached
- ☐ Inspect rail guides, ensure rail guides are securely attached and aligned vertically
- ☐ Ensure motor is properly assembled
- ☐ Install motor
- ☐ Inspect motor retainer for damage, ensure it is securely attached
- ☐ Record mass and type of motor before launch below

Type of Motor: ___________________________

Mass of Motor Before Launch: _____________

- ☐ Inspect black powder charges in booster bay
- ☐ Inspect connections to black powder charges in booster bay
- ☐ Add fireproof wadding to booster section
- ☐ Inspect booster bay parachute
- ☐ Properly fold booster bay parachute
- ☐ Inspect booster bay Nomex
- ☐ Wrap booster bay parachute in aforementioned Nomex
- ☐ Attach parachute package to shock cord using quick link, ensure secure connection
- ☐ Insert parachute into booster bay
- ☐ Inspect active drag system
- ☐ Inspect active drag fins
- ☐ Visually inspect fins and fillets
- ☐ Attach avionics bay to booster section
- ☐ Ensure avionics bay is securely attached to booster section by sheer pins
- ☐ Visually inspect rivets between parachute bay and avionics bay
- ☐ Inspect black powder charges in parachute bay
- ☐ Inspect connections to black powder charges in parachute bay
- ☐ Inspect parachute bay parachute
- ☐ Properly fold parachute bay parachute
- ☐ Inspect parachute bay Nomex
- ☐ Wrap parachute bay parachute in aforementioned Nomex
- ☐ Attach parachute to shock cord using quicklink, ensure secure connection
- ☐ Insert parachute into parachute bay
- ☐ Add fireproof wadding to parachute bay
- ☐ Turn on camera
- ☐ Arm the three altimeters in altimeter bay
- ☐ Turn on data tracking system

☐ Ensure radio transmitter has a fresh battery

☐ Ensure radio transmitter is properly secured shut

☐ Attach radio transmitter to parachute bay shock cord

☐ Insert nose cone into rocket body

☐ Ensure nose cone is securely attached to main rocket body using sheer pins

☐ Place rocket on launch rail

☐ Insert igniter into motor, ensure it is fully inserted and secure using motor cap

☐ Attach igniter to trigger, ensure no short circuit is present

☐ Visually inspect rocket one last time

☐ Take pictures/selfies

☐ Clear launch area

☐ Maintain Visual on rocket

Post-Launch Procedure

☐ Locate rocket using radio receiver

☐ Inspect rocket for damage

☐ Take pictures (selfies!) of rocket

☐ Disarm Altimeters

☐ Turn off Camera

☐ Disconnect batteries from electronics

☐ Retrieve flight data

☐ Record empty motor mass

Mass of Motor After Launch: ________________

☐ Clean out motor tube