2018 Flight Readiness Report

Roaring Lions

Normandale Community College

Team Mentor: *Gary Stroick* **Email:** president@offwegorocketry.com
Team Faculty Advisors:
Dr. Susan Kasahara **Email:** susan.kasahara@normandale.edu **Cell:** 612-801-0018
Martin Stickney **Email:** martin.stickney@normandale.edu **Work:** 952-358-8355

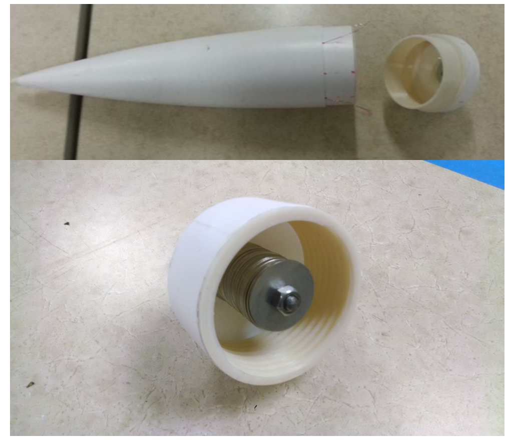
Student Team Lead:
Maxwell Beck **Email:** maxwellbeck97@gmail.com **Cell:** 952-688-1104

Team Members:
Trent Cahoon, Andres Campbell, Evin Onnors, Erick Estrada, Travis Johnson, Sam Kitzerow, Michael Nazario, Mohamed Noor, Feith Sanchez, Paul St. Germain

Table of Contents

Design Summary **3**
Nose Cone 3
Airframe and Couplers 3
Motor 3
Dimensions and materials 4
Motor Mount Tube 4
Centering rings 4
Recovery System 5
Main Parachute 5
Drogue Parachute 5
Shock Cord and Nomex Blankets 5
Cameras 5
Data Logging 5
Active Roll System 6
Stability 6
Center of pressure. 6
Center of gravity 6
Budget **7**
Rocket Construction **8**
Main Parachute Bay 8
Avionics Bay 8
Roll Control System Compartment 8
Tail Section Construction 9
Monitoring System for Parachute Deployment 9
Test Flight Report 9
Predicted vs Real Time Data **12**
Planned Changes/Improvements **12**
Roll Control System - 12

Design Summary

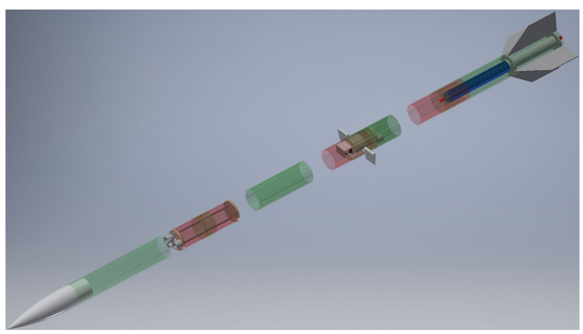


Nose Cone

The nose cone is 3 inches in diameter at the insertion base, 7.57 cm diameter at start of nose angle, 28.58 cm nose length, and 35.56 cm overall length. It is made of polypropylene plastic with an ogive cone shape. The cone neck was sliced in half to allow weights to be inserted so Center of Gravity could be adjusted to the desired location. A 3in long closed eyebolt is fastened through the base of the nose cone to hold additional mass as well as provide a secure point to attach the shock cord.

Airframe and Couplers

The rocket airframe is Blue Tube 2.0 and stands 189cm tall with a diameter of 7.8cm(3 in). The rocket is split into four subsections: Main Parachute Bay, Avionics Bay, Fin Mech Bay, and the Tail Section. All four of these sections are connected to each other via Blue Tube 2.0 coupler and have a mating surface of 3 in (body diameter). To connect non-separating sections, four plastic 5/32in 75 lbf pop rivets were used. The airframe separates at the nose cone and the tail section which are connected with one nylon shear pin each to prevent them from rotating while rolling in air. In the image below, red colors are inner tubes and green tubes are outer tubes.



Motor

During the process of choosing a motor for the competition launches, our primary design requirements were to be able to lift off the rail at at least 45 ft/s and reach an apogee of at least 3000 ft while also having a coast time of 10 seconds or longer for maneuvering. Another factor that went into our decision was motor cost. After comparing all options in the I and J motor class and simulating results on openrocket, we decided to opt for the J825R due to its low burn time, high thrust, and because we already have the motor and hardware.

Motor #	*Type*	*Length (cm)*	*Radius (mm)*	*Impulse (Ns)*	*Avg Thrust (N)*	*Burn Time (s)*	*Mass (g)*	*Theoretical Apogee w/o Braking Mechanism (ft)*
Aerotech J825	Reload	47.8	19	974.9	892.9	1.2	875	

Motor Mounting Techniques & components.

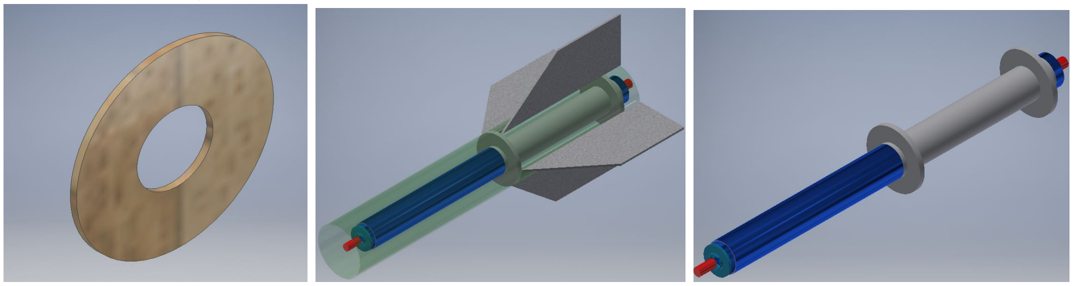


Figure 2 Pressure ring w/o rubber

Our motor mounts were designed using cylindrical geometry as it is one of the strongest shapes when it comes to axial forces. We went with 0.25” wood for the concentricity rings. It is composed of two key parts that are integrated together to secure our motor into place and minimize its impact on other subsections of our rocket. These parts include: mounting tube & centering rings.

The motor mount was designed to circumpass the worst case scenario since it was designed to not only handle forces far greater than those generated by the motor but also withstand highly pressurized gases that may escape back into mounting chamber components and allow these gases to exit safely through the narrow holes that were drilled into our lower centering ring. The J class motor mount slid halfway through the pressure ring before being held into place by frictional forces. The distance between motor ejection charge opening and the motor chamber was determined to be sufficient in case the seal failed to work at some point during the flight.

Dimensions and materials

Motor Mount Tube

The motor mount tube was made out of blue tube that had a density of 1.3 g/cm^3. Furthermore, the tube was 17.8 cm long with an outer diameter of 5.7 cm and an inner diameter of 5.4 cm. Its wall thickness was 0.152 cm.

Centering rings

The center rings had an outer diameter of 9.86 cm, identical to that of the pressure ring. Its inner diameter is 5.4 cm. The material is composed of plywood that has a density of 0.63 g/cm^3 and a mass of 20.5 grams. The centering rings were slightly thicker than our pressure rings. Moreover, both centering rings were 0.584 cm thick and designed to handle double the required shear and normal stresses.

Recovery System

Main Parachute

The rocket's main parachute will be an IFC-48 Chute from Fruity Chutes. The chute is 48 in (121.92 cm) in diameter with an estimated drag coefficient of 2.2. The parachute has 8 shroud lines each rated at 400 lb (180 kg). The parachute has a weight of 7.5 oz (0.212 kg) and a volume of 41.4 in^3 (678 cm^3). It will be connected to the nose cone and a bulkhead in the rocket body via shock cord and closed eye-bolts. The parachute will be ejected at a minimum of 800 ft via a black powder charge triggered by the altimeter.

Drogue Parachute

The rocket's drogue parachute will be a CFC-15 Chute from fruity chutes. The chute is 15in (38.1cm) in diameter with an estimated drag coefficient of 1.5. The parachute has 8 shroud lines rated at 220 lb (1.00×10^2 kg). The total weight of the drogue chute is 1.5oz (.043 kg) with a packing volume of 8.2in^3 (130cm^3). It will be connected to a bulkhead in the rocket body and the tail section via shock cord and closed eye-bolts. The drogue chute will be ejected at apogee via a black powder charge located on the bulkhead. The backup charge will be the motor's deployment charge.

Shock Cord and Nomex Blankets

The shock cord for the main parachute will be 7 yd (6.4 m) long and made of 1/4in kevlar fiber rated at 3600 lb (1.63×10^3 kg). The length of the shock cord for the drogue chute will be 5 yd (4.6 m) long and made of in tubular kevlar webbing rated at 3600 lb (1.63×10^3 kg). Two 13in (33.02cm) Nomex blankets will be attached to the shock cord in order to protect both parachutes from the hot gases. One blanket will be positioned above the chute and a second blanket will be positioned below the chute for added protection.

Cameras

To log both deployments we are using a Firefly Q60 video camera. It will be positioned near the avionics bay and will be oriented downwards to monitor the drogue deployment and roll orientation lights. The camera will also be monitoring the active roll system and its effects on the rocket. The device will be housed in 3D printed case forming a ellipsoidal shape to ensure an aerodynamic shape.

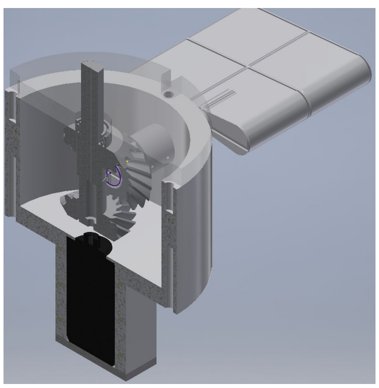
Data Logging

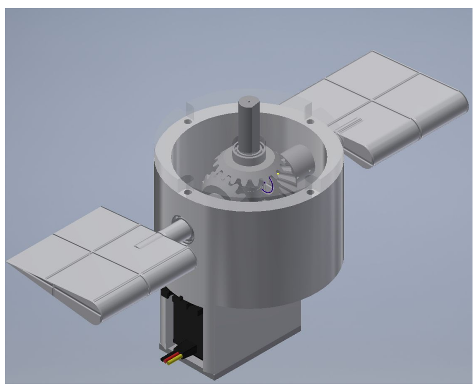
During our flight we will have two Stratologger CFs and an Altimeter 2 as our data logging systems on board as well as recording video by handsets. Each Stratologger CF is capable of logging velocity, temperature, voltage & altitude over time, in addition to ground elevation relative to mean sea level just before launch. The Altimeter 2 records apogee, max & average acceleration, burn time, coast time, and flight time.

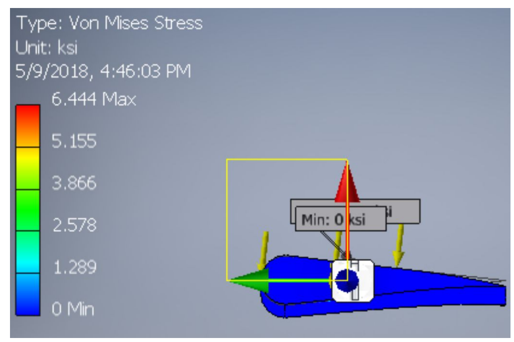
An Arduino will collect data from the magnetometer, convert the data to velocity & altitude then save the data to an on-board SD micro card. A wireless XBee communication system will be used to communicate between the rocket and a ground based personal computer.

Active Roll System

The roll system is primarily 3D printed with a polycarbonate laser cut top. Its dimensions are 2.8''(7.1 cm) diameter x 3.11" (7.9 cm) height. The roll mechanism is located in the middle of the rocket, below the avionics bay and above the drogue chute compartment. We chose to go with 3D printing as the lead time is as short as a few hours and the cost no more than 50 dollars for printing the entire assembly. According to our stress analysis simulations performed on the fins, they should hold up to the air drag loads that will be applied on in while the rocket is in flight. Our initial launch reached 23 g-forces and the mechanism remained undamaged, and in tact. For safety redundancy the entire roll system is mounted inside of the middle section airframe. Von miser stresses were max 6.9 ksi, the Flexural Yield Strength of ABS is 60.6 - 73.1 MPa (8.789 - 10.602 KSI).







Stability

Center of pressure.

Using Openrocket software, the center of pressure was determined to be 143cm from the nose cone. With the mass of propellant the stability margin is 3.55 cal and without it is 5.4 cal.

Center of gravity

The center of gravity was originally found using openrocket and was then updated with measured values after construction. With propellant the center of gravity lies 116cm from the nose of the rocket and without lies 102cm behind. The nose cone design allows for adding or removing up to 500g of mass to change the center of gravity after the rocket has been constructed. Due to the requirement of the fin mechanism being behind the center of gravity, the adjustable c.g. system was designed.

Budget

Table 7					
Item	Count	Weigh t (g)	Cost ($)	Total Weight (g)	Total Cost ($)
Arduino Nano 16Mhz 5V	1	7	22.00	7	22.00
Arduino Uno	2	25	28.00	25	56.00
Hitec Micro servo	1	11	18.99	11	18.99
9 Degrees Of Freedom LSM9DS1	1	2	14.95	2	14.95
Altimeter MPL3115A2	1	2	9.99	2	9.99
E-Flite Camera (Firefly Q6)	1	41	56.99	41	79.98
SD Micro Card Breaker Board	1	0.4	3.49	0.8	6.98
9V Batteries	2	45	3.99	90	7.98
Stratologger CF	2	10.77	71.95	21.54	71.95
RC-MP Transmitter	1	12.75	50.00	12.75	50.00
Jolly Logic "Altimeter 2"	1	6.7	0.00	6.7	0.00
IFC-36 parachute	1	142	125.00	142	125.00
CFC-12 Drogue	1	37	47.00	37	47.00
13 in Nomex blanket	3	170	0.00	510	0.00
7 yd shock cord	1	227	18.00	227	18.00
4 yd shock cord	1	159	15.00	159	15.00
Xbee & Shield	2	3.8	28.50	3.8	57.00
Magnetometer	1	1	3.95	1	3.95
Servo Motor	1	17	14.95	17	14.95
Blue Tube	2		29.95		59.90
Motor J825	3	875	100	875	300
Totals				2191.59	979.62

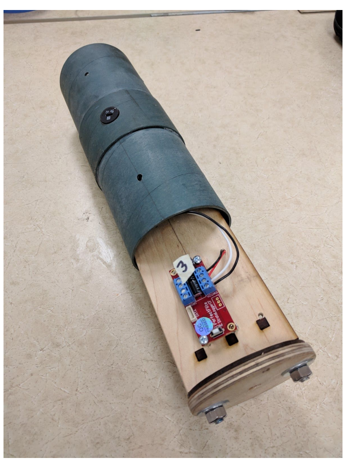
Rocket Construction

Main Parachute Bay

The upper section or the main parachute bay has a simple design. Mainly it is just airframe Blue Tube which is connected to the avionics bay via the use of 5/32in plastic pop-up rivets. The main parachute compartment is 16.5in (41.91 cm) in length and has a diameter of 4in (10.16 cm). The nose cone is attached to the this section through the use of two things: a snug fit and a set of 4 shear pins. Since there were no major material removed from it, a layer of epoxy and fiberglass was not added to increase structural integrity.

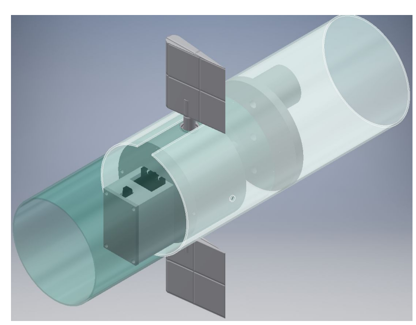
Avionics Bay

The Avionics Bay was constructed using a 21cm Blue Tube coupler and a 5cm Blue Tube airframe. The airframe strip was fixed to our laser cutting jig then, static port holes and key-switch holes were cut. The strip of airframe was then slipped onto the coupler and epoxied in the center. Bulkheads and the avionics platform were laser cut. The avionics bay was then assembled using a pair of ¼ inch steel threaded rods Key-switches were installed and the two Stratologgers and batteries were fastened to the avionics platform.

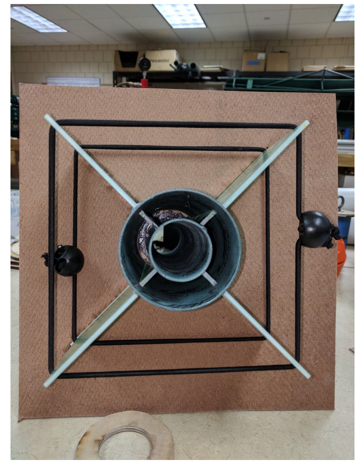


Roll Control System Compartment

The roll controls system is made entirely out of ABS plastic and fits inside of the middle section airframe BlueTube. The roll system was 3D printed, minus the servo motor, bolts and a set of bearings. The whole assembly is held in places with the use of 4 x 5/32in pop-up rivets. Two 0.5” slots were made in the blue tube to allow the fins to connect with the gearbox.



Tail Section Construction



Properly constructing the tail section of the rocket was key to the success of our rocket as a whole. After watching several flights at our local Tripoli launch site end in CATO and bulkhead failure, we chose to reinforce our tail section to handle many times the force experienced in a typical flight. The construction of the tail started with the body tube. The tube was cut and sanded flat then, markings at 45 degree intervals were added using a door frame and protractor. The tail section was then loaded onto a cutting jig and placed in a laser cutter. Fin slots were cut using the laser cutter to ensure a perfectly straight cut. Plywood was then loaded into the laser cutter for making the centering rings and pressure ring required for the motor mount. Once done cutting the edges of the bulkheads as well as the inner edge of the fin slots were sanded and scored to prepare for bonding. The motor mount tube was cut to size and centering rings were JB welded to each end using a modest fillet of JB Weld. The inside of the airframe was lightly sanded and bulkhead positions were marked. A bead of JB Weld was placed on the marked lines then the bulkheads and motor mount were slowly twisted into place. After bulkheads were positioned a fillet of JB Weld was brushed onto the outer edge and inner wall of the airframe. For each step the motor casing was inserted to ensure proper alignment. Once the JB Weld cured, we prepared our fins to be inserted into the airframe. A small bead of JB Weld was applied to the outside of the motor mount tube to adhere with the edge of the fiberglass fins. A laser cut guide was placed onto the tail section to hold the fins perpendicular to the airframe. An epoxy fillet was then used on the visible section of the tail and airframe. The fillet was measured using a scraper with a rounded corner of radius 5% the length of the root chord. Finally, once the epoxy had cured, excess epoxy and JB Weld splatters were cut or sanded off.

Monitoring System for Parachute Deployment

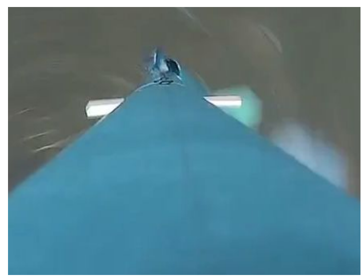
There is a two part system, part video logging and part electronic. The video system, consists of one Firefly Q6 video camera. The camera is mounted externally to the hull and faced downward. The camera has an internal power supply that is rechargeable via USB and uses a micro SD card for video storage. The second system is the dual Stratologger deployment system which also electronically logs the point of ejection charge activation.

Test Flight Report

This flight took place on Saturday, 5 May 2018. The scheduled time of meet was at 9:00 AM, and the rocket was launched at 5 pm. A final inspection was conducted before assembling the motor, a J285, and loading it into the engine mount.

The rocket left the rail successfully, but experienced an anomaly shortly after take-off. At 1.7 seconds an explosion occurred at the forward tail section causing it to separate from the main body. Shortly after the explosion the drogue deployed followed by the main parachute. The rocket reached an altitude of 450 ft (137 m) and had a total flight time of 47.9 seconds. Only one main ejection charge and one drogue ejection charges were spent due to a loss of power in one of the Stratologgers upon engine explosion. The main body remained undamaged. The motor casing was completely blown out and the forward tail section was damaged. The fins and lower tail section remained intact.

The catastrophic event is assumed to be caused by an O-ring failure in the motor assembly. It is unknown why the failure occurred. Excessive stress and wear may be a likely cause. Some parts to the motor assembly were loaned to another team who experienced a crash; while the motor casing seemed fine, they were exposed to the forces of a high altitude crash into the ground.



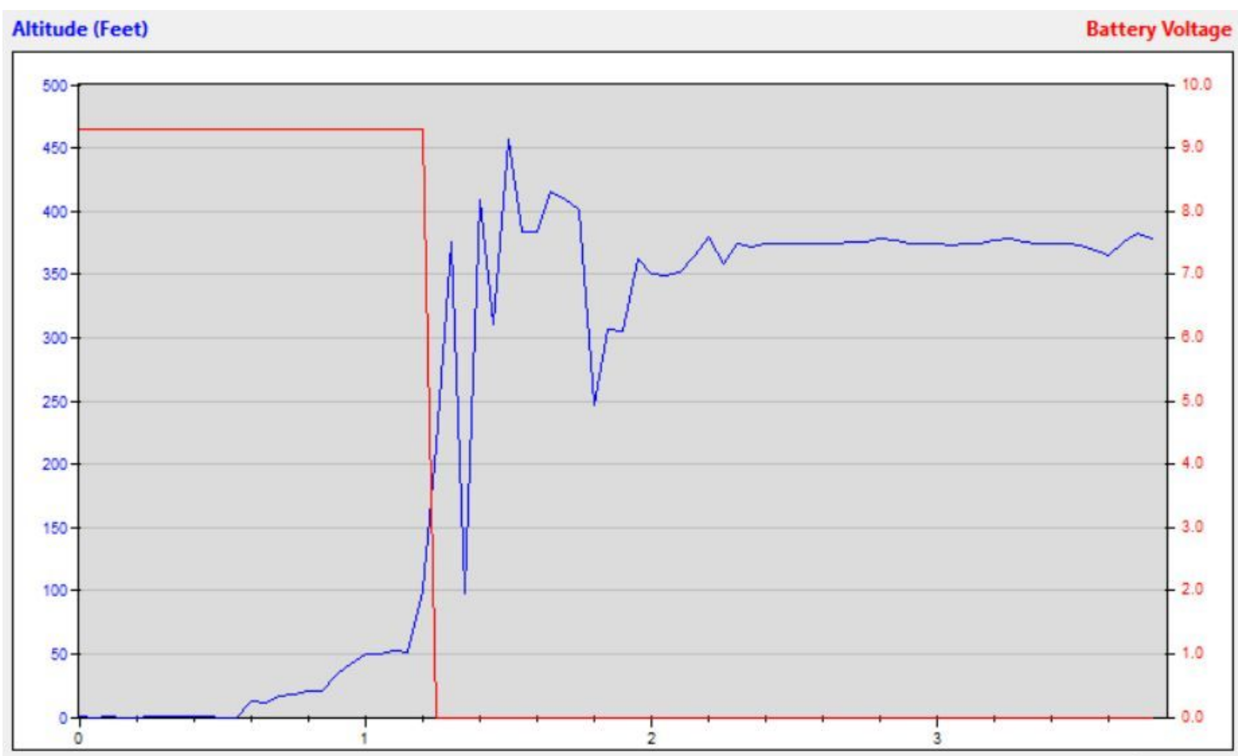


Figure 1: Altitude vs Time & Velocity vs Time from Stratologger #2

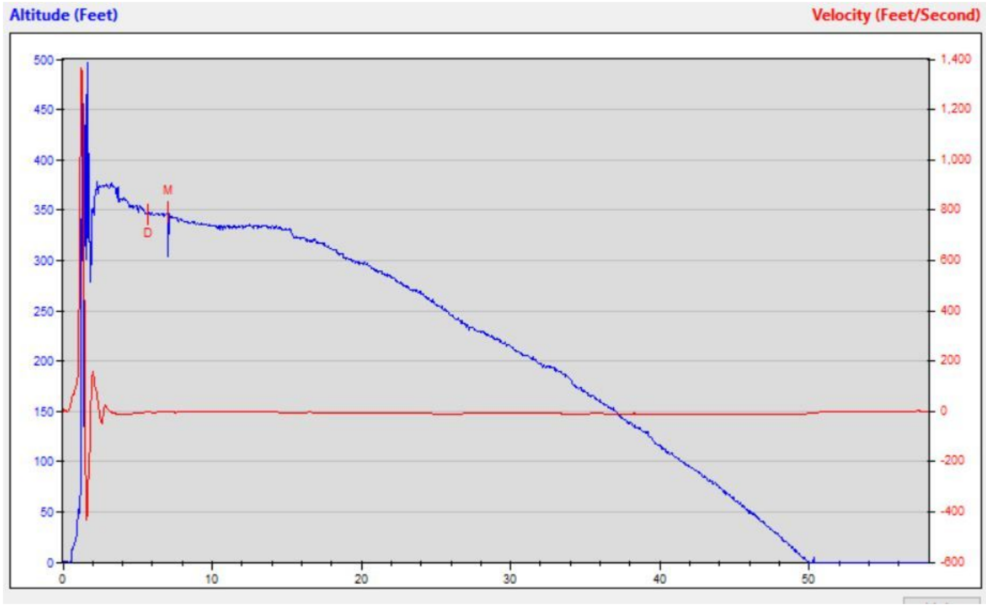


Figure 2: Altitude vs Time & Velocity vs Time from Stratologger #3

Figure 1 shows the point of engine explosion likely triggered a disconnect in the power system to the Stratologger. It has short-term brownout protection and captured data for an additional two seconds before complete shutdown. However, the short duration of the data run is consistent with the data recorded in with the other Stratologger and Altimeter Two.

Figure 2 shows the entire length of flight data by the successful Stratologger. The drogue parachute ejection was programmed to deploy approximately two seconds after apogee, which it did. The main parachute was programmed to deploy at 700 ft. This altitude was never reached and it deployed shortly after the drogue parachute deployed.

Apogee	376 ft
Top Speed	440 mph (645 f/s)
Burn Time	0.64 s
Peak Acceleration	23.0 Gs
Average Acceleration	0.0 Gs
Coast Apogee	1.7 s
Apogee Ejection	0 s
Ejection Altitude	450 ft
Descent Speed	8.6 mph (12.6 f/s)
Duration	47.9 s

Table 1: Altimeter 2 data

Predicted Data

Predicted data was found using openrocket.

Apogee	Max Velocity	Max Acceleration
4002.5 ft	202 m/s	227 m/s/s

Planned Changes/Improvements

Roll Control System -

A change that will be implemented into the final design of the roll systems gearbox will be to add through slots or possibly holes on the sides that will allow wires to be ran through. A problem that was experienced in our test launch was that the wires would catch on the tube and not allow the assembly of the gearbox into the gear bay section of the rocket. This was solved by using a file and physically making indented slots onto the body. The proper approach is to update the design of the gearbox to have the slots embedded.

The airfin design was modified from our original design report to have a square fin that has equal cross-sections across its entire length. This recommendation is based off of Apogee's research on their website which discusses the best fin shapes for small rockets. This report can be found at the following. https://www.apogeerockets.com/technical_publication_16.