Flight Readiness Report

Roaring Lions

Normandale Community College

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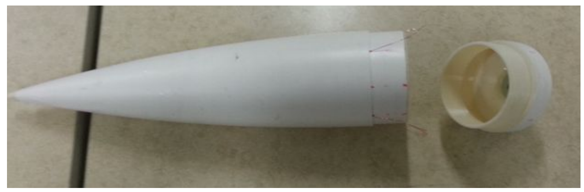


Nose Cone

The nose cone is 4” in diameter and 12.75” in length. It is made of polypropylene plastic with an ogive cone shape. The cone neck was sliced in half to insert the pitot-tube sensor with the rubber tubing. The pressure sensor is mounted on a 3” diameter printed part and epoxied into the cone. The two neck pieces of the nose cone are joined together via two 3D parts that thread together. Both parts are epoxied to the nose cone pieces. Four wires from the pressure sensor run through 4 separate holes drilled at the top of the cone neck and connect with 1.38” copper strips. The strips lay flat on the top half of the neck and act as contact points when linked with the rest of the rocket. Four static pressure ports located at the bottom half of the nose cone allow the internal pressure to equalize for an accurate reading by the pressure sensor.

Airframe (Inner/Outer Shell)

The airframe of our rocket is made out of BlueTube, which stands 72in (183 cm) tall and has a diameter of 4in (10.2cm). The rocket is split into three subsections: Main Parachute Bay, Bay for Braking Mechanism, and Motor bay. All three of these sections are connected to each other by two couplers, one of which is our Avionics bay and the other is used as the Drogue compartment. Both of the couplers are made out of BlueTube and are 8in (20.32 cm) in length as well as 3.9in (9.906 cm) in diameter. To hold all the tubing in place, we used plastic 5/32in pop rivets. Our nose cone is held in place via two things: a snug fit and a set of 4 shear pins.

Motor.

During the process of choosing a motor for launch one and two, our primary design requirements were to be able to lift off the rail at at least 45 ft/s and reach and apogee of at least 3000 ft whilst maintaining a minimum thrust to net weight of 3:1. Furthermore, another factor that went into our decision matrix for selection of motors was cost. Moreover, we were restricted to a limited budget. Finally, upon comparing all the various options in the I. J & K class and simulating results on openrocket. we decided to opt for the J835 and the K185 in order to sustain optimal performance and efficiency during flight.

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	
Aerotech K185	Reload	43.7	27	1417.2	185	6.9	1434	5082

Motor Mounting Techniques & components.

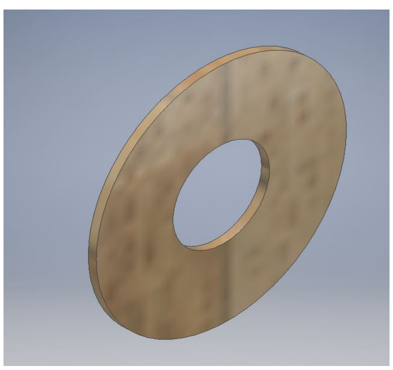


Figure 2.1 Pressure ring w/o rubber

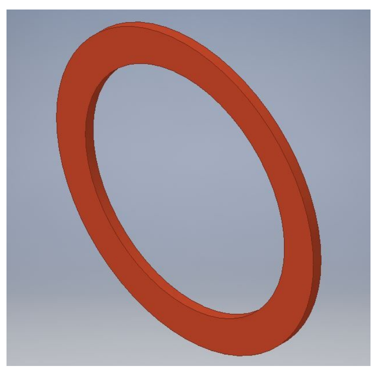


Figure 2.2 Pressure ring rubber seal

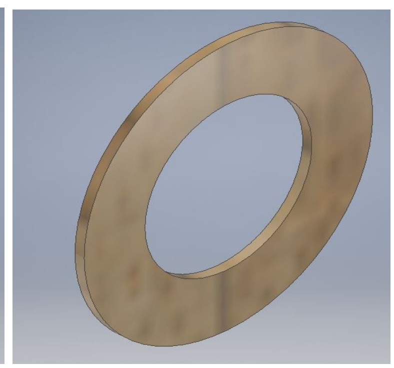


Figure 3 Centering Ring

Our motor mounts were specifically designed to withstand the most extreme shear and normal stresses and forces. It is composed of three 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: pressure ring, 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 problem statement for this part of the design was fitting two very different motor casings into the same motor mount. Moreover, we eventually overcame this challenge by using a mounting adapter. We kept the smaller radius of our pressure ring similar to the radius of the motor mount tube of the K class motor. Furthermore, this allowed us to precisely seal the top hinge on the motor mount tube onto the pressure ring. The pressure ring was revolutionized version of our centering rings. Moreover, we attached a rubber ring around the inner radius of our ring to seal K class motor casing into place. The J class motor mount slid half way 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 rubber 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.

Pressure ring

The pressure ring was made out of plywood with a material density of 0.63 g/cm^3. This integral component has an outer diameter of 9.86 cm, an inner diameter of 3.81 cm. The part was just 19.2 g in total mass and 0.47 cm thick. The inner radius was quoted with a 1 mm thick rubber ring.

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 220lb (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 1in tubular nylon webbing rated at 4000 lb (1.8×10^3 kg). The length of the shock cord for the drogue chute will be 5 yd (4.6 m) long and made of in tubular nylon webbing rated at 4000 lb (1.8×10^3 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 the second blanket will be positioned below the chute for added protection.

Cameras

To log both deployments we are using two E-Flite EFC 721 HD video cameras. They are going to be positioned near the avionics bay. They will face on opposites sides of the rocket to ensure stability. One will be oriented upward to monitor the main deployment, while the other camera will be oriented downward to monitor the drogue deployment. These devices will be housed in laser cut pieces of wood, forming a ellipsoidal shape to ensure an aerodynamic shape.

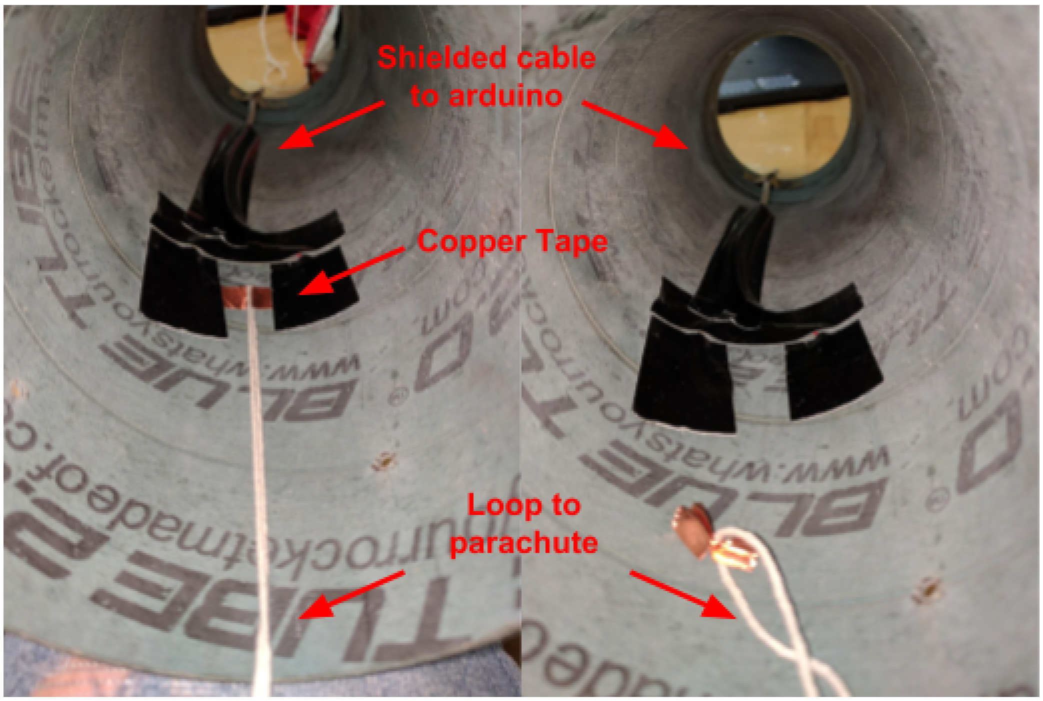
Data Logging

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.

Once completed, an Arduino Nano, acting as the central processing unit (CPU), will collect pressure data from the nosecone, convert the data to velocity & altitude then save the data to an on-board SD micro card.

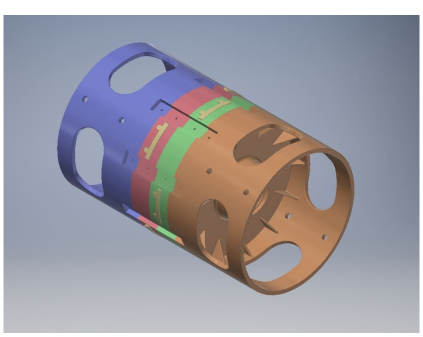
Deployment Monitoring System

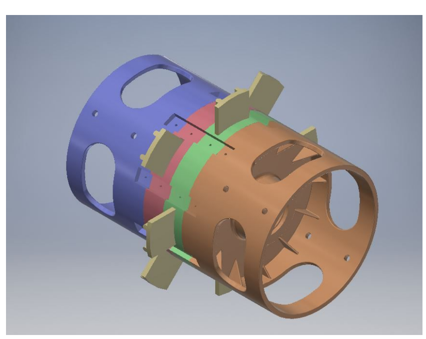
To log the successful separation and deployment of both our drogue and main parachute, we incorporate a similar system to our nose cone's contact leads. When the rocket sections are together our arduino is checking continuity on our nose cone contact patches. When continuity is broken separation of the associated part is logged. All parts with contact patches use shear pins to ensure the vibration and vertical thrust do not interrupt the connection. When lower separation occurs contact patches placed on the lower and midsection separate and create an open circuit. The open circuit is detected by the arduino and is logged as successful drogue separation. To log deployment of parachutes, a loop of light string is tied through the hook at the bottom of the parachute shroud lines. The loop is positioned so that when the parachute is folded some of the loop is accessible from outside our surrounding nomex blanket. The excess loop is then taped using copper tape to the inside of the airframe. Leads from our avionics bay's arduino then connect to both sides of the copper tape. When the parachute is deployed the loop tears the thin copper strip and signals to our arduino that parachute ejection has occurred.

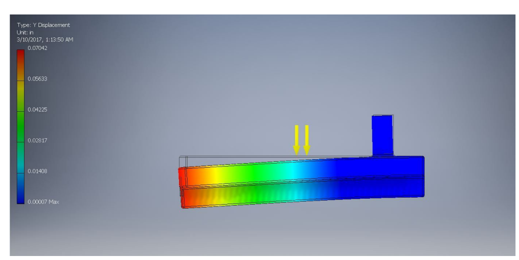


Braking Mechanism

The braking mechanism is entirely 3D printed. Its dimensions are 6in in length as well as 3.88in in diameter when everything is retracted. The breaking 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 due to weight and financial concerns. According to our stress analysis simulations, our braking mechanism should hold up to the air drag loads that will be applied on in while the rocket is in flight. For safety redundancy the whole brake assembly is mounted inside of the middle section airframe.







Stability

Center of pressure.

Using Barrowman's equations, the center of pressure was approximated both with and without the braking mechanism. Moreover, this allowed us to not only determine the ideal theoretical location of the braking mechanism but also the safe range of values for the ideal location of the center of mass relative to the nose cone and center of pressure.

Methodology

One of the most accurate methods of finding center of pressure is through the use of Barrowman's Equations. At an angle of attack of 0 degrees, the aerodynamic normal force or the aerodynamic "reaction" force caused on the body tube is 0 as long as the surface is smooth and symmetric (no change of length from its starting point until ending point). Barrowman's Formulas do not take lift generated from the body tube due to the change in angle of attack (caused by wind or overstability) into consideration, mathematical formulas were later derived from the former equations to take lift into consideration when calculating the center of pressure of a rocket body. However, this normal aerodynamic force was found to be negligible for angles of attack less than or equal to 10 degrees and/or at subsonic speeds.

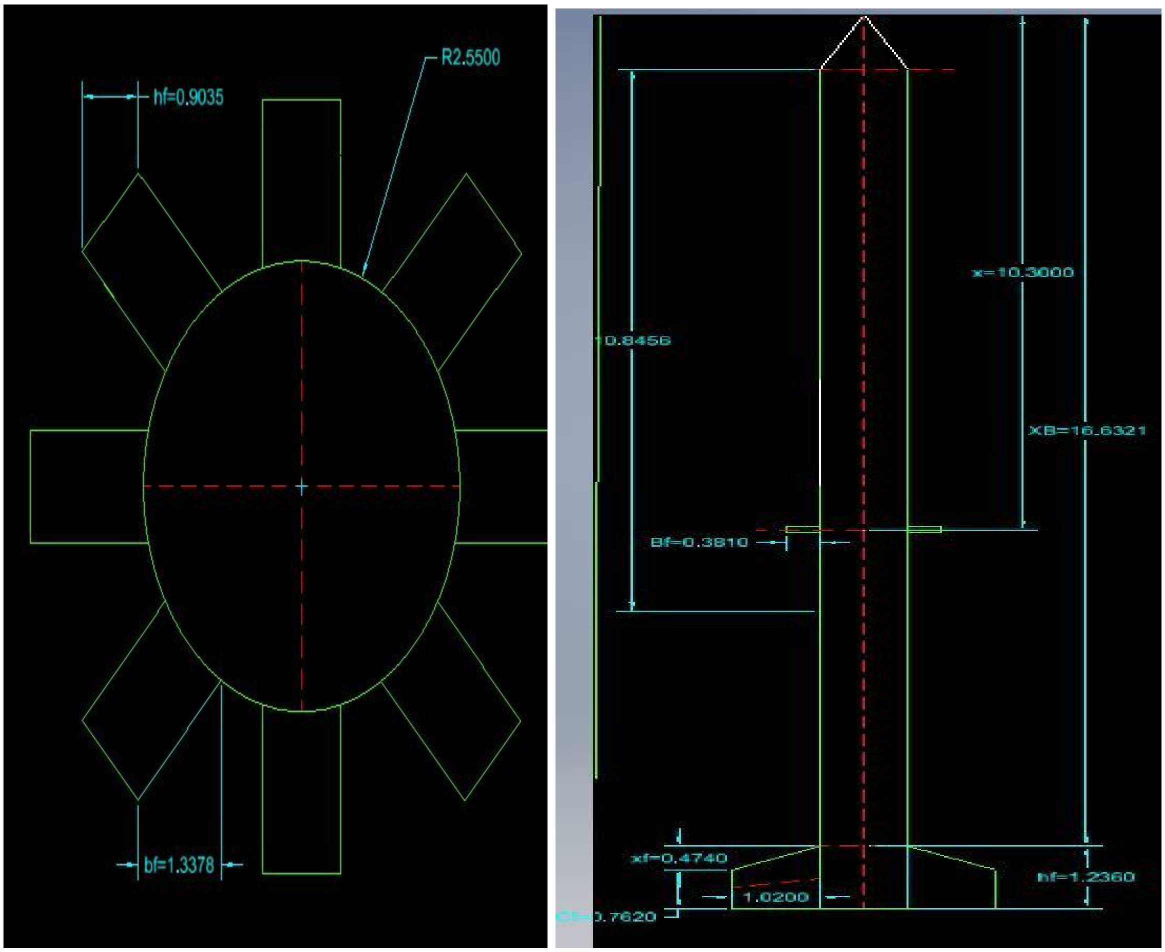
Assumptions

1. The angle of attack of the rocket is less than ten degrees.
2. The effects of compressibility can be neglected ($M a < 0.4$).
3. Viscous forces are negligible.
4. Lift forces on the rocket body tube can be neglected ($(N_F)_L = 0$).
5. The airflow over the rocket is smooth and does not change rapidly.
6. The nose of the rocket comes smoothly to a point .

Approach

To Find center of pressure for rocket, we need the C_p location ($\bar{x}_N$, $\bar{x}_F$) of nose and fins. We must also find the aerodynamic normal forces on the fins and nose tip. We will then use these variables to find the location of center of pressure when the braking mechanism is retracted. We will then compare this model approximation to the reference value obtained through open rocket. Upon confirming our results, we will then derive a formula for the normal aerodynamic forces on the extracted braking mechanism from the same equation used for calculating normal aerodynamic forces applied on the N amount of fins. Finally, we will factor the braking mechanism into our calculations for center of pressure and measure the resultant change in center of pressure with respect to the placement of the mechanism itself.

Schematic design



1. Calculating C_p Without Braking Mechanism.

Equations Used

	Centroid (cm)	Normal Aerodynamic Force

Fins (x4)	$\bar{x}_F = [\frac{xf(hf+2cf)}{3(hf+cf}] + x_b + \frac{1}{6}[(h_f+c_f) - \frac{hfcf}{hf+cf}]$	$(C_N)_F = [\frac{R}{wf+R} + 1][\frac{4N(\frac{wf}{2R})^2}{1+\sqrt{1+(\frac{2lf}{hf+cf})}}]$
Nose Cone	$\bar{x}_N = \frac{2}{3} l_N$	$(C_N)_N = 2$

Main plug-in equation for Center of pressure:

$$\bar{X} = [(C_N)_N \bar{x}_N + (C_N)_F \bar{x}_F] \div [(C_N)_N + (C_N)_F]$$

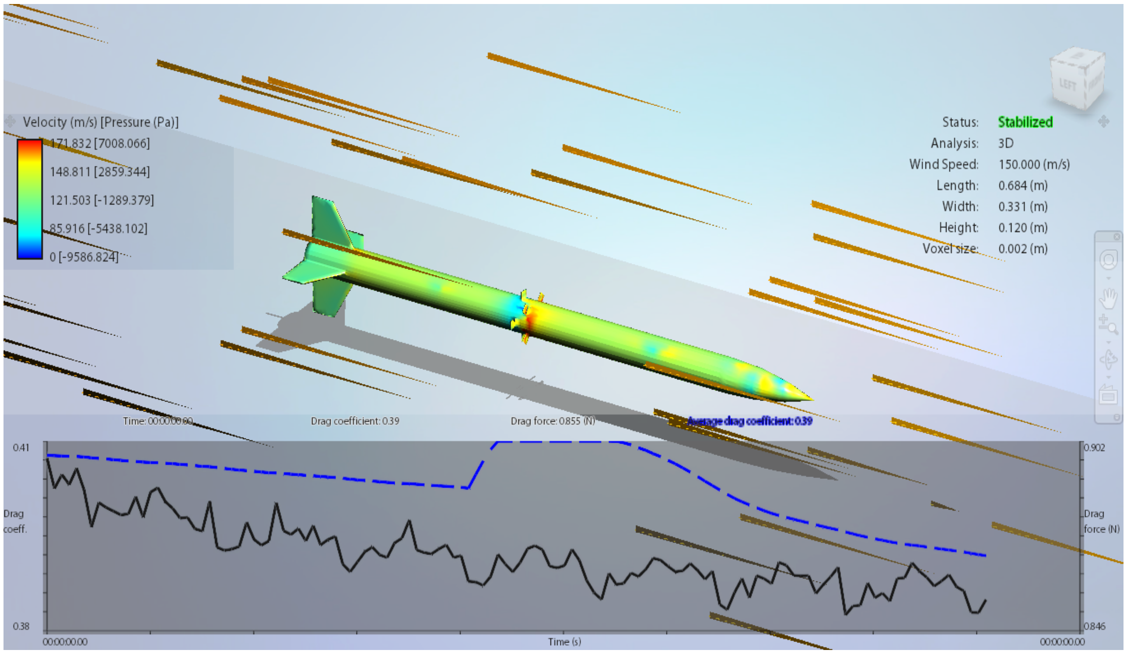
RESULTS

	Reference (cm)	Model (cm)
J Class motor	144	143
K Class motor	144	143

2. Calculating C_p With Braking Mechanism:

Analysis of B/M:

Since barrowman's equations for finding normal coefficients are only applicable for aerodynamic components on the rocket such as the fins. Furthermore, all these components have negligible thicknesses at the leading edge. Moreover, the 3rd dimension/thickness can be ignored. Hence, barrowman's equation for finding normal force coefficient on the fin is two Dimensional. Therefore, the fins are modeled as two symmetrical/identical plates separated by a chord line that is parallel to the direction of the wind. One fin plate on the visible front side of the 2-D schematic (refer to schematic diagram) and the other on the opposite (hidden) side. Similarly, the B/M has two side plates, a front plate, a back plate inside the rocket tube (not needed) and the top plate



Air Flow

As we can see, air flows symmetrically about the chord line in all cases except that of the front side of the braking mechanism, however that can be modeled with the identical front plate of the B/M on the opposing side of the rocket. Furthermore, just like conventional components, the aerodynamic coefficient of side plate and the front plate can be found using the barrowman equations since their chord line is parallel to the wind and air flows symmetrically through the two sides and the two front sides on opposing sides of the rocket. However, since the top plate is both perpendicular to the wind and air does not flow symmetrically about the plate's chord line, we must model it by performing an analysis of the axial and lift forces versus the normal and drag forces in order to prove that the aerodynamic Normal coefficient of the top plate is simply its drag coefficient. We can then factor these three components (w/resp to their centroids) into the main plug in equation.

Equations used

	Normal Aerodynamic Force	Centroid (cm)
Breaking mechanism(TOP PLATE)	$(C_N)_{TB/M} = (C_D)_{TB/M}$	$\bar{X}_{TB/M} = x$ *Where x is the position of the upper tip of the B/M from nose.
Breaking mechanism (symmetrical side plates)	$(C_N)_{SB/M} = [\frac{R}{Bf+R} + 1][\frac{4N(\frac{Bf}{2R})^2}{1+\sqrt{1+(\frac{Bf}{Th})^2}}]$	$\bar{X}_{SB/M} = x + (T_h/2)$
Breaking mechanism (front plate).	$(C_N)_{FB/M} = [\frac{R}{wf+R} + 1][\frac{2N(\frac{Zf}{2R})^2}{1+\sqrt{1+(\frac{Zf}{Th})^2}}]$	$\bar{X}_{FB/M} = x + (T_h/2)$
Fins (x4)	$(C_N)_F = [\frac{R}{wf+R} +1][\frac{4N(\frac{wf}{2R})^2}{1+\sqrt{1+(\frac{2lf}{hf+cf})^2}}]$	$\bar{x}_F = [\frac{xf(hf+2cf)}{3(hf+cf)}] + x_b + \frac{1}{6}[(h_f+c_f) - \frac{hfcf}{hf+cf}]$
Nose Cone	$(C_N)_N = 2$ approx. 2 for most nose cone shapes.	$\bar{x}_N = \frac{2}{3} l_N$

Main plug-in equation for Center of pressure:

$$\bar{X} = [(C_N)_N \bar{x}_N + (C_N)_F \bar{x}_F + (C_N)_{TB/M} \bar{x}_{TB/M} + (C_N)_{SB/M} \bar{X}_{SB/M} + (C_N)_{FB/M} \bar{X}_{FB/M}] \div [(C_N)_N + (C_N)_F + (C_N)_{TB/M} + (C_N)_{FB/M} + (C_N)_{SB/M}]$$

Results: For our design the new center of pressure after the braking mechanism was deployed was found to be 114cm from the nose cone. (based on design at the time)
Finally, the ideal location for the placement of the braking mechanism was determined to be approximately 100 cm from the nose cone

Center of gravity

class motor with the weight of the B/M plus additional weight in case of future modifications. This gave our current design a stability margin of 2.98. Center of gravity on the J class motor was found to be 116 cm from nose cone on test launch design. These results were found on open-rocket. This gave us a stability margin of 3.54. Finally, in order to be precise we weighed out each part prior and added their actual weight to the software as compared adding their theoretical weight. Our center of gravity was found to be 121 cm from nose cone on the k

Budget

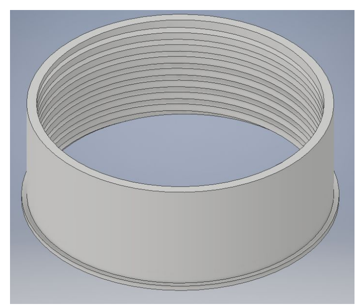
equipment	#	unit cost	Shipping	total amount	Subtotal
Pro Series Launch Pad	1	$53.49		$53.49	
Go Box Launch Controller	1	$39.99		$39.99	
SLS ARCAS	1	$78.09		$78.09	
Aerotech 29mm propellant kit	1	$18.18		$18.18	
Quest Recovery Wadding	1	$7.48	$41.32	$48.80	
Modern High Power Rocketry, 2	1	32.5	4.98	37.48	
Model Rocket Design and Construction	1	38.93	10.66	49.59	
Aerotech 29mm EconoJet Motor	1	$45.99	$7.83	$53.82	
Competition Entry Fee	1	$400.00		$400.00	
Altimeter II	1	$69.95		$69.95	
Slotted Body Tube	1	$7.00		$7.00	
Balsa Sheet	1	$1.69		$1.69	
Coupler	1	$2.53		$2.53	
Coupler Bulkhead Disk	1	$2.68	$9.66	$12.34	
E-Flite Camera	2	$45.22		$90.44	
Couplers	1	$39.95		$39.95	
Airframe	2	$38.95	$17.95	$95.85	
Medium Shock Cord 4 yds	1	$15.00		$15.00	
Medium Shock Cord 7 yds	1	$18.00		$18.00	
12 Elliptical Parachute	1	$47.00		$47.00	
Iris Ultra 36 Standard Parachute	1	$125.00		$125.00	
Insurance	1	$3.00	$19.56	$22.56	
Pressure Sensor	1	$40.50	$7.99	$48.49	
Nosecone	2	$19.76	$14.95	$54.46	
StratoLoggerCF	2	$49.46	$8.78	$107.70	
E-Flite 120mAh batteries	2	$10.49	$4.56	$25.54	
Copper Tape	1	$24.60	$6.85	$31.45	

J-B Weld	2	$11.60		$23.20	
Arduino Nano (16mHz)	1	$9.99		$9.99	
envelope for return	1	$2.99		$2.99	
Aero Pack 54mm Retainer	1	$31.03		$31.03	
Aero Pack 38/54mm Motor Adapter	1	$28.89		$28.89	
54mm Blue Tube Coupler	1	$8.95	$9.31	$18.26	
Rocket Supplies/Maxwell	1	$15.06		$15.06	
Rocket Supplies/Maxwell	1	$35.49		$35.49	
Rocket Supplies/Maxwell	1	$8.02		$8.02	
Airframes	2	$12.49	$9.95	$34.93	
1 lb Goex 4Fg Black Powder	1	$28.30		28.3	
54 mm Blue Tube	1	$23.95	$11.72	$35.67	
Galvanized Steel Eye Nuts	2	$6.03	$6.19	$18.25	
Removable Plastic Rivets	2	$3.71		$7.42	
Electronics Rotary Switch	2	$9.93	$4.86	$24.72	
5 Steel Eye Bolts	1	$50.92	$6.19	$57.11	
USB Data Transfer Kit DT4U	1	$22.46	$4.39	$26.85	
Airframes	2	$38.95	$17.95	$95.85	
Large Shock Cord 1" 4000 lb 5 yds	1	$22.00		22	
Large Shock Cord 1" 4000 lb 7 yds	1	$24.80		24.8	
Iris Ultra 48 Standard Parachute	1	$137.00		137	
15" Elliptical Parachute	1	$50.00		50	
13" Nomex Blanket	2	$32.00	$45.12	$77.12	
Aerotech K185 Motor	3	$112.99		338.97	
Aerotech J825 Motor	3	$72.99		218.97	
38/1080 Motor Assembly for J825	1	$139.99		139.99	
54/1706 Motor Assembly for K185	1	$190.00		190	
54 Fwd Closure Extended	1	$45.00		45	
1010 Airfoil Rail buttons	1	$7.00		7	
Rivets - Black Nylon	1	$4.95		4.95	
MJG Firewire Initiator	24	$2.00		48	
4-40 Shear Pins	2	$1.25		2.5	
					3512.89

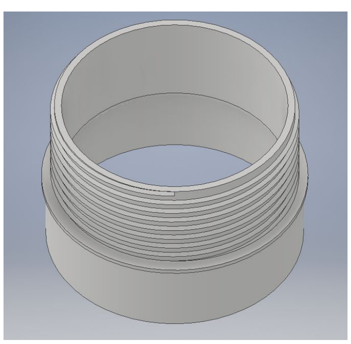
Rocket Construction

Due to an inconsistency in shipping of the materials, complications in the design and parts manufacturing, as well as school work, our construction process was not a one day build. After finalizing our Rocket design in OpenRocket, we converted our 2D design into a 3D design using Autodesk Inventor. As the sections of the rocket were completed or were close to a completion, we started to order parts and materials for those sections. The sections below give more detail to the construction process of each section of our rocket.

Nose Cone



The nose cone is made of polypropylene plastic with an ogive cone shape. The neck of the cone was cut in half to gain access to the inside. A 3in diameter flat disk was printed to hold the pressure sensor which was epoxied on. A hole was drilled through the tip of the cone for a rubber tube to fit through. The tube was fastened onto the pressure sensor and inserted into the nose cone. Epoxy was added to the tube which was then slid through the previously drilled hole. The pressure sensor with the mount was then epoxied into place, inside the nose cone. Two 3D parts were printed to connect the individual neck pieces together. The two parts thread together to lock in place and were epoxied into the nose cone. Four evenly spaced holes were then drilled at the top of the nose cone neck for contact wires from the pressure sensor to run through. The wires were then taped down with 1.38in copper tape. Four static pressure ports were then drilled at the bottom half of the nose cone.



Main Parachute Bay

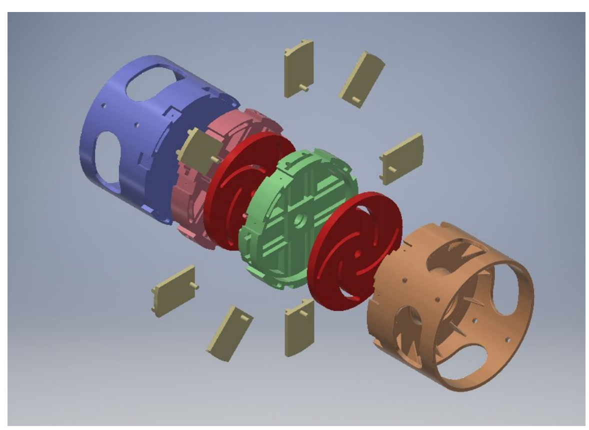
The upper section or the main parachute bay has a simple design. Mainly it is just airframe BlueTube which is connected to the avionics bay vi the use of 5/32in plastic pop-up rivets. The main parachute compartment is 16.5in (41.91 cm) in length and has a diameter of 4in (10.16 cm).

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 the first section of the rocket to be built. A 1 inch strip of airframe and a 8 inch strip of coupler were cut by hand, and ends were sanded flat. The airframe strip was fixed to our laser cutting jig then, static port holes and key-switch holes were cut. Key-switch holes and static port holes were then cut out of the coupler using the same method. 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 ¼ inch steel threaded rod and eye nut. Key-switches were installed and the electronics were fastened to the avionics platform.

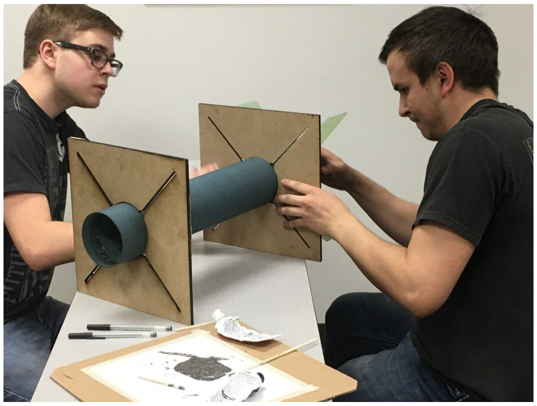
Braking Mechanism Compartment



The braking mechanism is made entirely out of ABS plastic and fits inside of the middle section airframe BlueTube. To be exact, the braking mechanism was 3D printed, minus the screws and a set of bearings, which were bought off of McMaster Webpage. The breaking mechanism was designed to be modular. In other words, if needed, another set of four fins could be added or subtracted from the whole assembly depending on the amount of braking needed for the rocket. The braking mechanism has 58 different parts including bearings and mounting screws. The whole assembly is held in places with the use of 16 x 5/32in pop-up rivets. A total of 8 cutout were made in the braking mechanism compartment BlueTube. To increase the structural integrity of that section, stripps of fiberglass soaked in epoxy resin were added to that section.

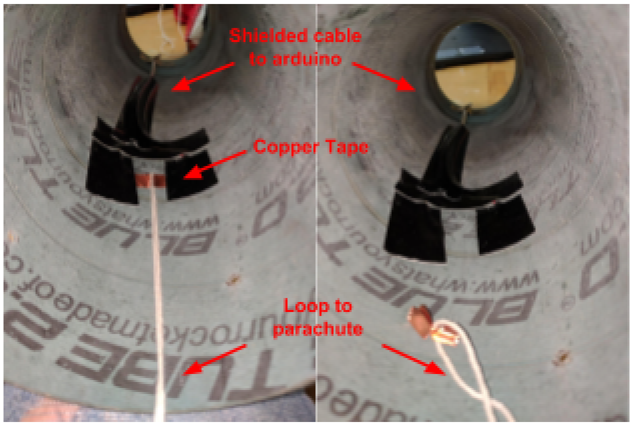
Tail Section Construction

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 beak-circuit design. The first system, the video capturing system, consists of two E-Flite EFC-721 720p HD video cameras. These cameras are mounted externally to the hull with one pointed toward the fore and the second is pointed to the aft. Each camera has an internal 3.7V Li-Po battery that is rechargeable via USB and will each uses an SD micro card to store the video data. The second is multiple break-circuits in which as the parachute is exiting the air-frame it breaks the live circuit. The circuit consists of the Nano supplying power to a wire that runs to the parachute and back to the Nano



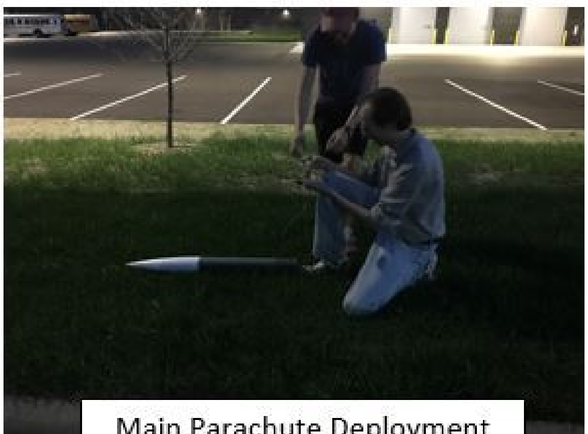
that is sensing the voltage on the wire and logs when the circuit is broken.

Though parts of the custom data logging package, such as the Arduino Nano & SD micro drive were on board during flight, the sensors to detect separation, pitot-static nosecone and chute deployment were not, leaving that system unable to collect data.

Media

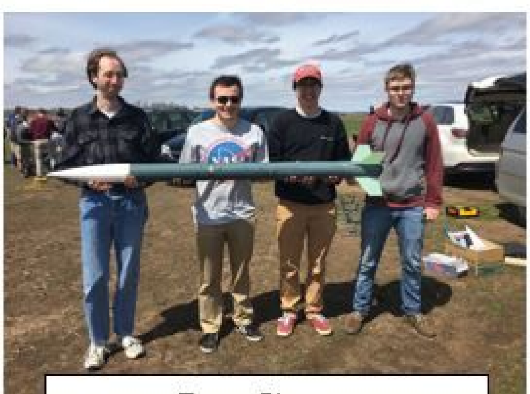
Work Day

Work Day



Main Parachute Deployment Test

Launch Set Up



Team Picture

Before Launch

Test Flight Report

This flight took place on Sunday, April 23rd, 2017. It was originally planned to be in the morning, but because of overcast, we delayed until the skies were clear. Then, before launching we went through a final inspection before building our engine, a J285, and loading it into the engine mount.

The rocket left the rail successfully with a burn time of 1.10s. Then at 5.1s into flight the Altimeter 2 recorded the first drogue chute ejection charge firing during the ascent, and 3.8s before apogee and 4.9s before the first expected discharge of any ejection charge. Upon recovery of the rocket, we found the drogue chute had been forced into the shock cord hole of the nomex blanket, keeping the drogue chute from fully deploying. During the tail ejection, the shock cord broke and the tail and main body reached apogee as separate pieces. Looking at Figure 1 & 2 below, we can see on both graphs a strong disruption starting at 6.60s and lasting to 9.6s. These times can be seen more clearly in the raw data. We believe these disturbances are mostly caused by the tumbling of the separated rocket while at high speeds creating quick changes to the avionics bays pressure. Once the rocket began to free fall, according to both stratologgers, it reached a terminal velocity of about 88 ft/s before the main chute deployed at about 700 ft, snapping the shock cord anchoring it to the avionics bay, but the cord held on to the nose cone and drifted down to the ground at an unknown speed. After separation, the avionics bay continued free falling into the ground at impacted at 50 ft/s 46.75s into the flight.

Analyzing the three different sources of data has it’s own challenges, as the data doesn’t align exactly. All three, both stratologgers and the altimeter two were in the avionics bay, but in slightly different positions, and this may be having an effect on the data as pressure is not ideally the same in all areas. But the data across all three reasonably agree on the events.

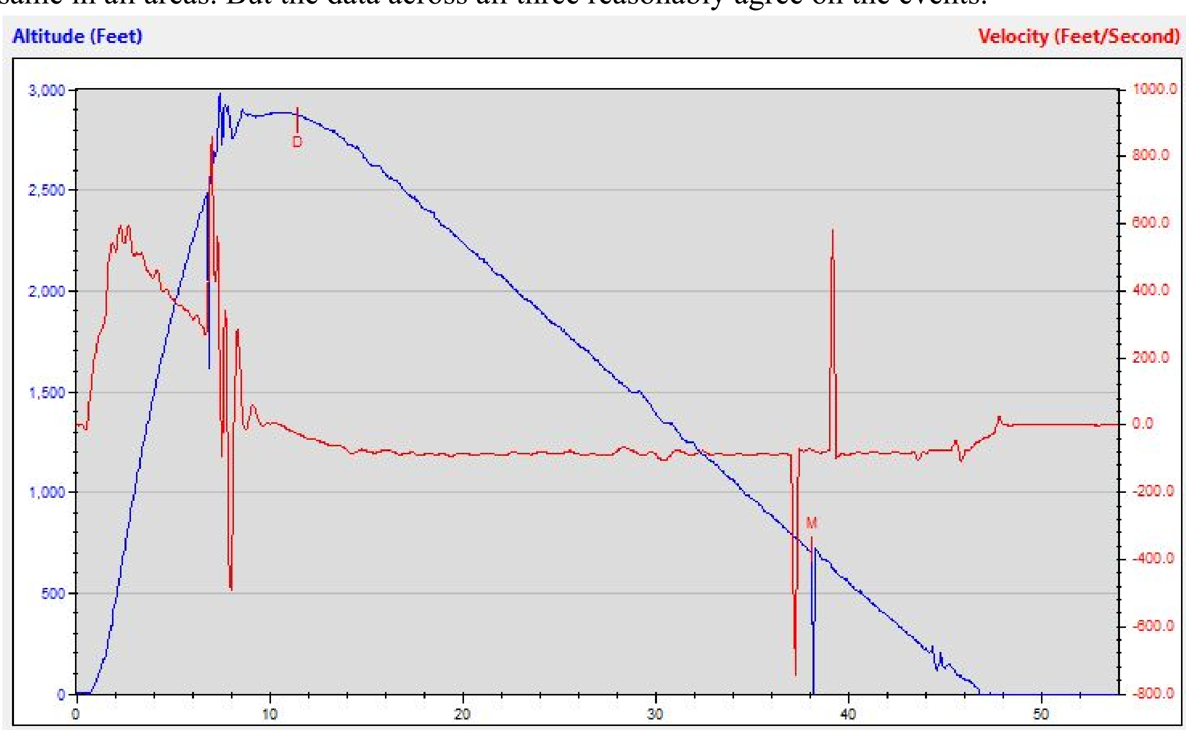


Figure 1: Altitude vs Time & Velocity vs Time from stratologger #1

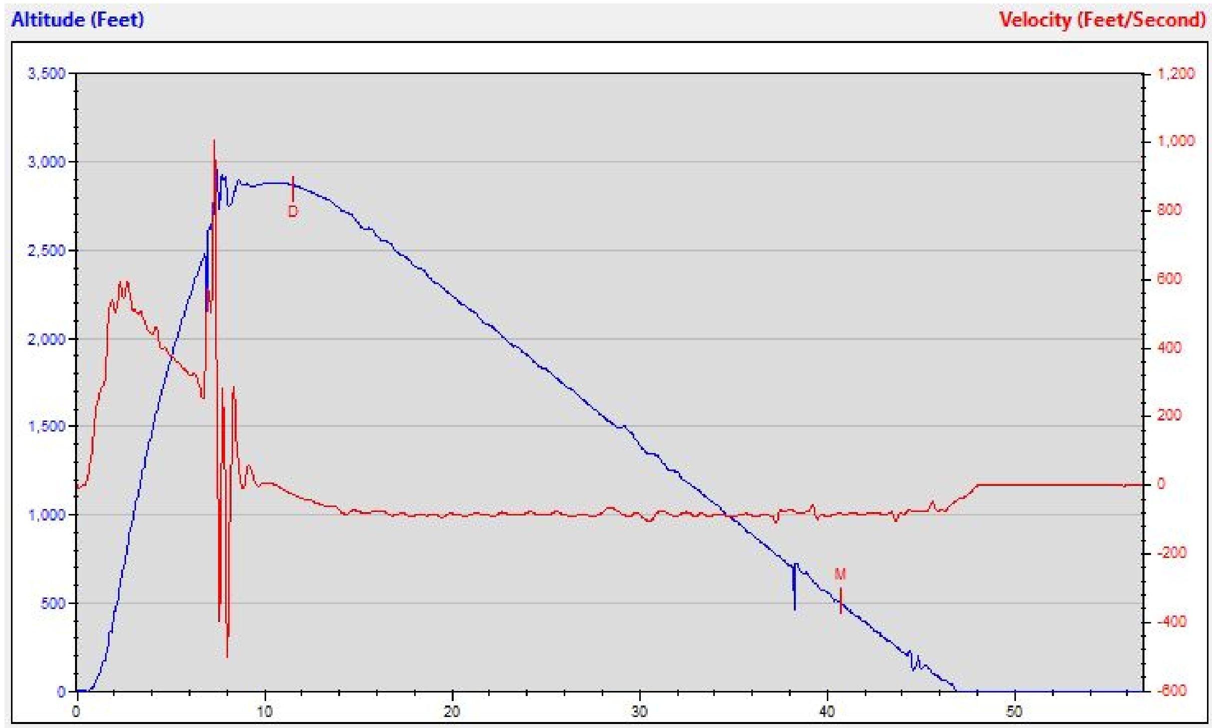


Figure 2: Altitude vs Time & Velocity vs Time from stratologger #2

Apogee	2882 ft
Top Speed	440 mph (645 f/s)
Burn Time	1.10 s
Peak Acceleration	22.7 Gs
Average Acceleration	18.3 Gs
Coast Apogee	8.9 s
Apogee Ejection	-3.8 s
Ejection Altitude	2447 ft
Descent Speed	39 mph (57.2 f/s)
Duration	47.9 s

Table 1: Altimeter 2 data

Predicted vs Real Time Data

According to the OpenRocket simulations, the J825 motor was expected to bring the rocket to approximately 3465 ft. After the test launch, the Altimeter Two and the two Stratologger CFs read an apogee altitude of 2882 ft, 2910 ft, and 2883 ft respectively. Because our delay charge deployed prematurely at approximately 6 seconds into the launch, the force could have changed the orientation, thus increasing our drag and significantly decreasing our apogee.

Regarding our velocity data, the OpenRocket simulations predicted that our rocket would peak at 668 ft/s. However, our actual velocities were much lower, recording 645 ft/s, 640 ft/s, 625 ft/s respectively. This loss in maximum velocity was not due to the premature deployment of the delay charge because the rocket hit maximum velocity roughly two seconds into the launch. All things considered, one major consideration could be due to the motor output itself, with each motor having a thrust variability of ±10%. Another major consideration would be the unaccounted weight of the epoxy and jb weld that was used to put the rocket together. Accounting for the amount of epoxy we used and adding that into OpenRocket, our new maximum velocity was much more reasonable.

Based off the launch plan described, our two cameras to monitor a successful deployment were not used during this period. However, these cameras work well individually.

Planned Changes/Improvements

Recovery System

We are changing the shock cords from 1/2in nylon webbing rated at 1200lb to 1in tubular nylon webbing rated at 4000lb. The previous shock cords rated at 1200lb both snapped during the test launch and needed to be replaced. The cords were also slightly charred where they snapped so Kevlar protector sleeves will be used to cover the ends. We are also changing our main chute from a IFC-36 to an IFC-48 and our drogue from a CFC-12 to CFC-15. This is to reduce the descent velocity of rocket at both deployments and put less stress on the main parachute deployment. Additionally the Nomex blankets will also be tied stationary to shock cord so as to not slide down and over the parachutes.