2017 - 2018

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

Table of Contents

Executive Summary **2**

Introduction **3**

Mechanical & Electrical Design Overview **3**
Design Features of Airframe 3
Nose cone 3
Mid-Section 3
Tail Section 4
Design Features of Electronics/Payload 4
Stratologger Parachute Deployment Altimeter 5
Arduino Uno 6
Accelerometer - Adafruit FXOS8700 + FXAS21002 6
Altimeter - Adafruit MPL3115A2 6
Magnetometer - HMC5883L 7
Gyrometer - Adafruit FXOS8700 + FXAS21002 7
Communication System - XBEE Pro S2C 7

Predicted Performance **9**
Anticipated Performance 9
Rocket Design Analysis 9
Active Roll and Orientation System Mechanical Overview 11
Recovery System Design Specifications 11
Drogue Parachute 11
Main Parachute 12
Flight Simulation Analysis 12
Active Roll And Orientation System Simulation Analysis 14

Safety **16**
Designed for Safe Flight and Recovery 16
Documented Material Handling Procedures 16
Planned Assembly Procedure 16
Planned Pre- & Post-Launch Procedures 17
Pre-Flight Checklist 17
Physical Inspection & Assembly 17
Pre-Launch 18
Post-Flight Checklist 18

Budget **19**

Executive Summary

The 2018 NASA's Space Grant Midwest High-Power Rocket Competition is designed to challenge college students to safely construct and launch a high-powered rocket on a single motor type. The rocket must have an integrated active roll orientation system allowing specific orientation commands to be followed and verified via a downward-looking video camera. The challenge also requires the teams to construct a non-commercial data collection package to log the orientation of the rocket.

This report explains the competition rocket design in detail. As part of this design the following considerations took place: safety, material cost, maintenance simplicity, low air drag, a stability margin greater than 2, thrust to net weight ratio greater than 5:1, a minimum apogee of 3,000 ft, a high figure of merit, and minimum possible total mass.

To meet criteria, the rocket will be constructed using a 3-in (10.2 cm) outside diameter by 80-in (202 cm) long rocket out of Blue Tube 2.0. The rocket will fly using an Aerotech J-825R motor in a RSM-38/1080 casing leftover from last year. Based on the results of our Open Rocket simulations, the Aerotech J-825R motor will meet the minimum altitude requirement of 3000 ft while also providing adequate coast time in which to execute the roll commands.

To satisfy the roll and orientation system, a 3D-printed controllable fin system is connected to a gearbox powered by a servo motor and controlled via an Arduino with custom programming. The gearbox is specifically designed to fit inside of the rocket while being minimal in weight and providing a safety case for the gears, bearings, and the motor. This mechanism should be adequate in allowing orientation control.

Safe recovery of the rocket will be handled via two redundant StratoLogger CF altimeters as well as the motor's ejection charge. The rocket uses a dual deploy system with a drogue and main parachute located in the middle section and tail section of the rocket. At apogee the StratoLoggers will fire ejection charges to separate and deploy the drogue chute located in the tail of the rocket. 700 ft from the ground the StratoLoggers will fire again to separate the nose cone and middle section and deploy the main parachute. On the ground the recovery team will follow a procedure to disarm the StratoLoggers and safely bring the rocket to the range officer.

Additionally, three optional bonus challenge objectives are available. The hardware to complete all three is the same, however coding required to get the input and outputs needed vary in degree of complexity. Challenge A consists of the rocket's initial instructions being changed after the rocket is on the launch pad. Challenge B requires the ability to obtain flight sensor data off of the rocket while in flight. Challenge C requires the capacity to transmit commands to and

from the rocket while in flight. As of now, it is our intent to attempt all of them and is a work in progress.

Introduction

The core objective of the 2017-18 Space Grant Midwest High-Power Rocket Competition is to design, build, launch, and safely recover a high-powered rocket with an orientation system that controls and logs the roll of the rocket. The rocket must reach at least 3,000 ft (914.4 m), have a GPS tracking device, a downward facing video camera, and a data package capable of recording the orientation of the rocket and sending commands to the orientation device. This preliminary report will give insight into the design and strategy our team will be using at the competition.

Mechanical & Electrical Design Overview

Design Features of Airframe

The rocket airframe is designed in three major sections, the nose cone (27cm), the mid-section(90cm), and the tail section(71cm). The core airframe diameter is 3 inches and stays consistent throughout the rocket apart from the fins and a camera housing. The rocket will separate in two places during flight, first the mid-section and tail section will separate, and second the nose cone and mid-section will separate. This section will cover the general airframe design, with dimensions and materials, and is broken down into the three major sections of the rocket.

Nose cone

The nose cone, ogive in shape and made of plastic, will have small lead weights bolted inside the coupling point to increase stability. An I-bolt attached to the nose cone will connect to the main chute shock cord for added strength and additional stabilizing weight.

Mid-Section

The mid-section uses blue tube airframes and couplers and has two coupled internal bays for the avionics payload and orientation device. Attached on the outside of the mid-section, 20 cm from the nose cone, is a clear streamlined plastic camera hood. The hood provides a weatherproof housing for our camera as well, as a way to visually confirm it is recording, and extends ½ in from the rocket airframe. At the top of the mid-section is a 34 cm bay for the main chute and shock cord. Directly under the main chute bay is the removable avionics payload. The payload is constructed out of a 21 cm blue tube coupler and two 1/4 inch thick plywood bulkheads. The forward bulkhead has a U-bolt and two ejection canisters for affixing and ejecting the main chute and shock cord. Behind the avionics payload is the orientation device housing. The housing, made of blue tube, holds the servo motor and fin rotation gearbox. Two 1/4 inch holes in the blue tube airframe, 180 degrees apart and 12 cm from the aft end of the mid-section, allow the two controllable fin shafts to protrude outside the airframe. Two trapezoidal fins slot and bolt into the output shafts of the orientation device and sit behind the center of gravity. These controllable fins extend 7.5 cm from the outer airframe and have a thickness of 1/8th inch. Two cm behind the fins at a 45 degree offset, 180 degrees the camera, sits a forward rail button. 8 cm behind the controllable fin set is a 16 cm coupler to the tail section and a 1/4th inch bulkhead with a U-bolt and two ejection canisters for affixing and ejecting the shock cord and drogue chute.

Tail Section

At the top of the tail section is a 25 cm drogue chute bay that will house our 15 inch drogue chute and shock cord. An I-bolt and shock cord attached to the forward most centering ring will connect the mid and tail section after separation. A second and third 1/4 inch centering ring 20 and 45 cm behind the forward ring will hold the 56 mm motor mount tube and will act as thrust rings to hold the motor during launch. At the end of the motor mount tube is an aluminum motor retainer that will hold the casing from falling out after launch. The main fin set is composed of four fiberglass trapezoidal fins with a height of 11 cm, a tip cord of 6 cm, a root cord of 25 cm, and a sweep angle of 60 degrees. The fins are mounted through the wall and will be adhered with inner and outer epoxy fillets. On the outside of the tail section the aft rail button will be placed 45 degrees from the fins and inline with the forward rail button.

Design Features of Electronics/Payload

The payload was designed specifically for the objective of controlling and sustaining the direction/orientation of the rocket. We explored many methods to control the roll of the rocket such as, reaction wheels, cold gas systems, and aerodynamic systems however, the method that we determined to have the greatest accuracy, precision, and simplicity would be to direct the roll with controllable fins. Knowing that the objective requires us to set our downward facing camera toward a Cardinal direction of North, East, South or West, it was decided that a magnetometer would be required. Upon testing the magnetometer with a prewritten library, we were able to write code to reactively adjust a servo motor based on the orientation of our position. At the same time we developed a 3D design of a gearbox to precisely turn controllable fins which will be touched on in the “Active Roll and Orientation System Mechanical Overview” section. The electronics will be housed in a Blue Tube 2.0 coupler with 1/4 inch bulkheads on each side. Electronics will be organized using custom 3D printed housings to ensure vibration and acceleration cannot damage or disconnect any connections. The housings can be slid out of the back of the payload bay for easy access by removing a locking bolt and pop rivets. All electronic systems will be controlled by key-lock switches in an and-gate configuration to ensure recovery systems cannot be armed accidentally. A diagram of the electrical control system is shown in **Figure 1**.

Rocket Electrical System Diagram

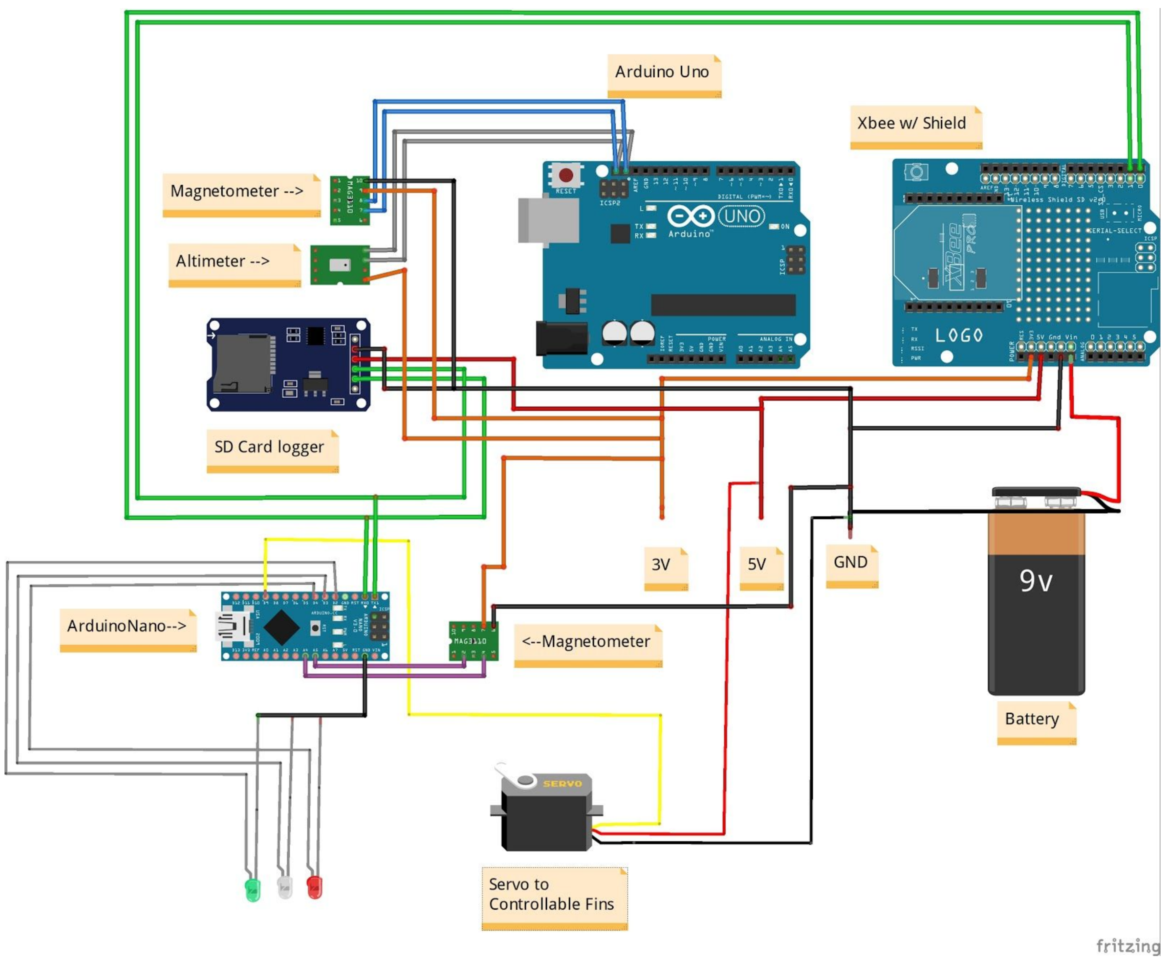

Figure 1

Stratologger Parachute Deployment Altimeter

The rocket will utilize PerfectFlite StratoLogger CF dual deploy altimeters as sensors to deploy the Main and Drogue parachutes. These altimeters sense external pressure via sensing holes to continuously measure the height of the rocket and deploy the drogue parachute at apogee. During descent, they deploy the Main parachute at a preset height of 700 ft. Their onboard data logging capabilities are used to download flight performance onto a personal computer.

Arduino Uno

The central data processing unit will utilize an Arduino Uno to integrate and process the flow of information. It will collect data from a combination Magnetometer/Gyroscope/Accelerometer, and a combination Thermometer/Altimeter. The data will be processed to measure launch and apogee for mission control. The data will also be logged to an onboard SD Card data logging system and relayed to the ground via an XBee radio communication system to a ground based XBee, Arduino, and personal computer.

The two sensors acting as controls to detect launch and apogee are the accelerometer and altimeter. These communicate with the Arduino via the SCL and SDA pins using I2C transmission protocol of these devices. The next two sections describe these two devices and the tests performed on them.

Accelerometer - Adafruit FXOS8700 + FXAS21002

The accelerometer measures the capacitance across two plates to measure the force, and therefore acceleration, perpendicular to its orientation. As the force on the plates increases, it increases the capacitance which is electrically measured and converted into a digital acceleration signal that is read by the Arduino. Using a 1.00 meter long string and a rotational period of 1.00 seconds, the accelerometer measured an acceleration of approximately 40 m/s^2. This is relatively close to the calculated value of 39.5 m/s^2 found using **Equation 1**: $a = \frac{v^2}{r}$.

$$a = \frac{v^2}{r} = \frac{(2\pi r f)^2}{r} = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 (1\ m)}{(1\ s)^2} = 39.5\ \frac{m}{s^2}$$

Altimeter - Adafruit MPL3115A2

As measured at current elevation, the altimeter reads approximately 620 ft. The elevation as referenced by public data provided an elevation of 820 ft. While this is a significant difference from the measured value, the altimeter measures elevation based off air pressure to which it is very sensitive and varies based off current weather conditions. Varying the height from floor to ceiling changes the value approximately linearly with expected height changes. Since the altimeter will only be used to measure the *change* in altitude to detect apogee, this will still be a suitable device to use with an added fixed constant offset.

Magnetometer - HMC5883L

Several magnetometers were tested to find one with the greatest accuracy under extreme conditions. The one found to have the greatest precision, accuracy, and user friendliness, just happen to be the most simple and least expensive, the “HMC5883L”. Now using a standard magnetometer is accustomed to sensing magnetic fields, however we were in search of the Cardinal Directions to which we were required to implement a specific library. Above that, not all magnetic fields around the world are created equal, and so we were required to research our current location’s magnetic declination and input its function in radians to adjust the compass to its true north in our current location. Upon completion of this, we were able to construct the software for our servo motor to adjust our controllable fins, to line up our rocket with whichever direction we choose to do so.

Gyrometer - Adafruit FXOS8700 + FXAS21002

In high roll applications it was determined that magnetometer data would be useless due to the speed at which the data can be received. To bring the rocket from a high roll state to below 50 degrees per second a gyrometer is used. The Adafruit FXOS8700 FXAS21002 package is capable of reading plus or minus 2000 degrees per second of roll with very high precision. Using a simple program that grabs data from the gyrometer we are able to adjust the fins to mitigate roll every 20 milliseconds. The program checks if the rocket is rolling above our set rate and moves the high speed servo to counter the roll. This method will also be used for the sustained orientation flight.

Communication System - XBEE Pro S2C

The Rocket communication system utilizes two 63 mW XBees. The XBees will be connected to the Arduino via a shield. The ground based XBee/Arduino will also be connected to a personal computer via a USB connection. The XBees make it possible to remotely upload a mission from the personal computer provided a base level of code has already been written to the Arduino. Security measures for the XBees to prevent rogue interference commands from other XBees in the vicinity on the same channel will be provided with a two-character security code of “NC”, as well as a PAN ID of 9700.

The roll orientation, roll direction, and hold time data is uploaded to the Rocket in one consecutive batch of commands. The following flow chart indicates the data conversion, transmission and verification process of a single roll orientation command. The final verification step will still contain the security code since it isn’t required to be removed; only the endpoint numerical value needs to be verified with the original that was uploaded.

Flow chart showing how a roll command is uploaded and verified via the wireless Arduino/XBee communication system

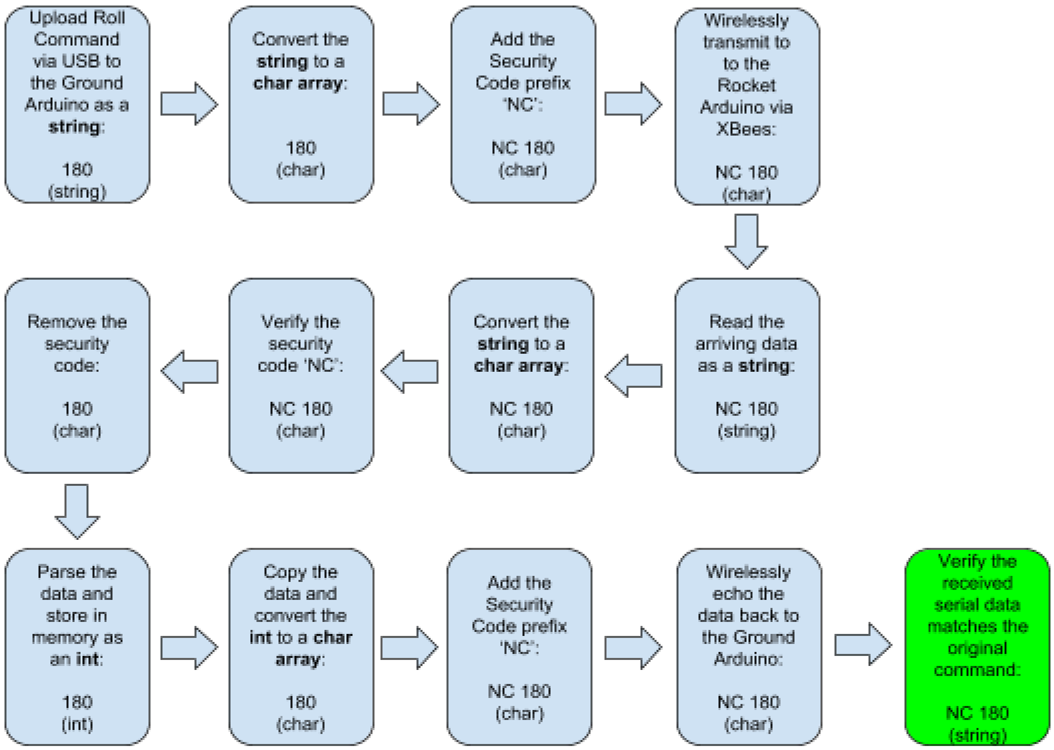

Figure 2

Table 1			
System 1			
	Draw (mA)	"On" time (s)	Total mAh per flight
Uno, Xbee and Sensors	97	120.0	3.23
Stratologger CF	1.5	120.0	0.05
Ematchs	1000.0	2.0	0.56
Servo - idle	5.4	30.0	0.50
Servo - running	150.0	16.0	0.67
		Total mAh	5.01
Stand Alone Items (Integrated Battery)			
Firefly Q6 Camera	0.22	120	26.67
RC-MP Transmitter	NA	NA	NA

Table 1: expected current draw using the formula $\Sigma(Draw * \text{"}On\text{"}\ time) = Total$

Note: For standalone items, the current draw is not of concern since the run-time on full charge is known and provided by the manufacturer. The Firefly will run for an hour from full charge using the integrated 800 mAH battery while the RC-MP transmitter will last 3 weeks using an internal 3v battery. Both items will perform for the entire duration of all launches and beyond. The current draw for system 1 is of concern since it is critical to determined whether enough power will be supplied by the batteries in the system for the entire duration of use.

Predicted Performance

Anticipated Performance

To estimate the overall performance of our rocket with the J825R motor, our team used OpenRocket Software. To determine the overall performance of the rockets active roll orientation system while in flight, Inventor Pro 2018 Simulation was utilized. Shear stress tests and rigidity analyses were performed on the fins to determine the safety and reliability of the fins under aerodynamic loads.

Rocket Design Analysis

The model rocket was designed using OpenRocket Software. Using component volumes, we were able to determine the minimum capacity required for the avionics and mechanical bays. Component masses were inserted as weight components distributed in their respective bays. As shown in **Figure 3**, we have met the design requirement of placing the control surfaces below the center of gravity by extending the length of the rocket and adding a forward mass component in the nose cone. In **Table 2**, we have outlined the overall rocket data including mass, length, CP, and CG. In order to achieve an ideal stability margin and shorten the distance between the CP and CG, we have implemented the use of two controllable fins and four stabilizer fins. The diameter of the J825R motor allows us to use an interlocking fin design for increasing structural reliability. **Table 3** is the Aerotech J825R motor data used for our simulations acquired from the supplier. We have included features such as the external camera, rail buttons, main and drogue parachutes, and components so that the OpenRocket Software simulation will accurately model our anticipated performance.

OpenRocket Model

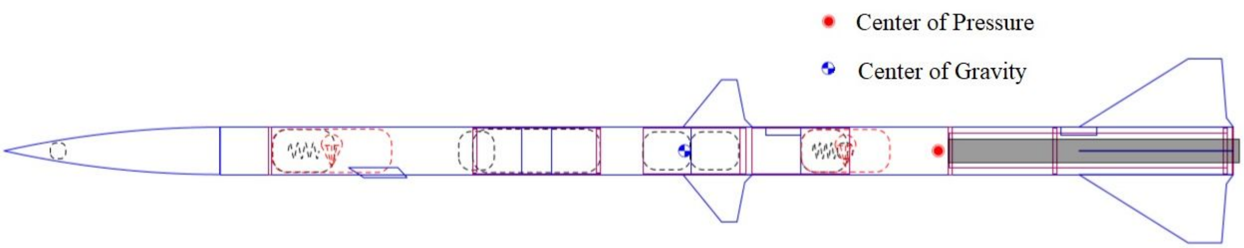

Figure 3

Table 2 - NCC Model Rocket Data	
Mass with motor	157 oz. (4450.9 g)
Length	79.6 in. (2256.6 g)
CG from nose	44.1 in (112.0 cm)
CP from nose	60.5 in (153.7 cm)

Table 3 - J825R Motor Data	
Average Thrust	824 N
Burn Time	1.12 s
Maximum Thrust	1070 N
Total Impulse	929 N
Thrust to Weight Ratio	24.54:1
Propellant Weight	17.5 oz (497 g)

Active Roll and Orientation System Mechanical Overview

Part of the competition requires the ability to control the roll of the rocket. In order to control roll, a gearbox mechanism with interconnected gears that synchronize attached fin movement in an either clockwise or counterclockwise orientation was designed. The power mechanism of the fins is a servo-motor that uses an arduino controller and magnetometer for orientation sensing and adjusting that follows a custom written program with commands built into it. The electronics have been detailed in prior sections of this report.

The gearbox and fins were prototyped out of ABS plastic using a Stratasys Uprint SE Plus 3D printer. Initial thoughts are that the gearbox will be capable of serving its intended purpose. The first mechanical concern is whether the fins will be capable of withstanding all forces experienced in flight, and the second concern is whether the gears will be able to maintain contact with each other under all flight forces. The first concern is addressed within this report under active roll and orientation analysis. The second concern of gear contact has been addressed by the design of the gearbox in which all possible spacing has been filled to leave the gears nowhere to go except onto each other (Forced contact).

Recovery System Design Specifications

The rocket will be using a dual deploy recovery system which requires two parachutes to be ejected. The drogue parachute is ejected first at apogee, followed by the main parachute ejection. In case the drogue chute does not deploy, the main parachute allots for the appropriate terminal velocity. The calculation using **Equation 2** to determine the required diameter of both parachutes is shown below.

Equation 2: $F_d = \frac{1}{2} C_d \rho\, (\pi r^2)\, v_T{}^2$

$$d = 2r = 2\sqrt{\frac{2mg}{C_d \pi \rho v_T{}^2}}$$

Main $v_T = 23.99$ ft/s (7.3152 m/s), Drogue $v_T = 73.3$ ft/s (22.3 m/s), $C_d = 2.20$ (*main*) 1.5 (*drogue*), $\rho = 1.225\, kg/m^3$

Drogue Parachute

The rocket's drogue parachute will be a CFC-15 Chute from Fruity Chutes. The chute is 15 in (38.1 cm) in diameter with an estimated drag coefficient between 1.5-1.6. The parachute has 8 shroud lines rated at 220 lb ($1.00*10^2$ kg). The total weight of the drogue chute is 1.5 oz (.043 kg) with a packing volume of 8.2 in^3 (130 cm^3). It will be connected to a bulkhead in the rocket body and the tail section via shock cord and closed eye-bolts. The length of the shock cord for the drogue chute will be 4 yd (3.6 m) long and made of a 1 in tubular nylon webbing rated at 4000 lb ($1.8*10^3$ kg). 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. Two 13 in (33.02 cm) Nomex blankets will be attached to the shock cord in order to protect the drogue chute from the hot gases. One blanket will be positioned above the drogue next to the bulkhead, and the second blanket will be positioned below the drogue next to the tail. The calculated velocity of the rocket after the drogue is deployed is 75.32 fps (22.96 m/s).

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 consists of 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 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 parachute will be ejected at a minimum of 500 ft via a black powder charge triggered by the altimeter. Two 13 in (33 cm) Nomex blankets will be attached to the shock cord to protect the chute. One blanket will be positioned on top of the parachute and the second will be positioned under the parachute. The calculated landing velocity of the rocket is 20.6 ft/s (6.27 m/s).

Table 4 - Parachute data for motor J825R including the weight of the motor mount.

Type	Predicted Rocket weight		Calc. Main Diameter		Calc. Drogue Diameter	
Name	kg	lb	cm	in	cm	in
AeroTech J825R	2.925	6.06	86.36	34	38.1	15

Flight Simulation Analysis

Using the same OpenRocket Software and model design and data from **Figure 3** and **Table 2**, we were able to gather simulation data and predict the performance of the rocket during flight. The results shown in **Figure 4** and data highlighted **Table 6** demonstrate the ability of the rocket to meet the minimum apogee of 3000 ft. and maximum descent speed of 24 ft/s with a reasonable margin. The conditions of this simulation, as shown in **Table 5**, were chosen in order to begin anticipating realistic flight conditions. The results and conditions of the simulation were also used in other areas of design such as parachute calculations and stress testing on our controllable surfaces.

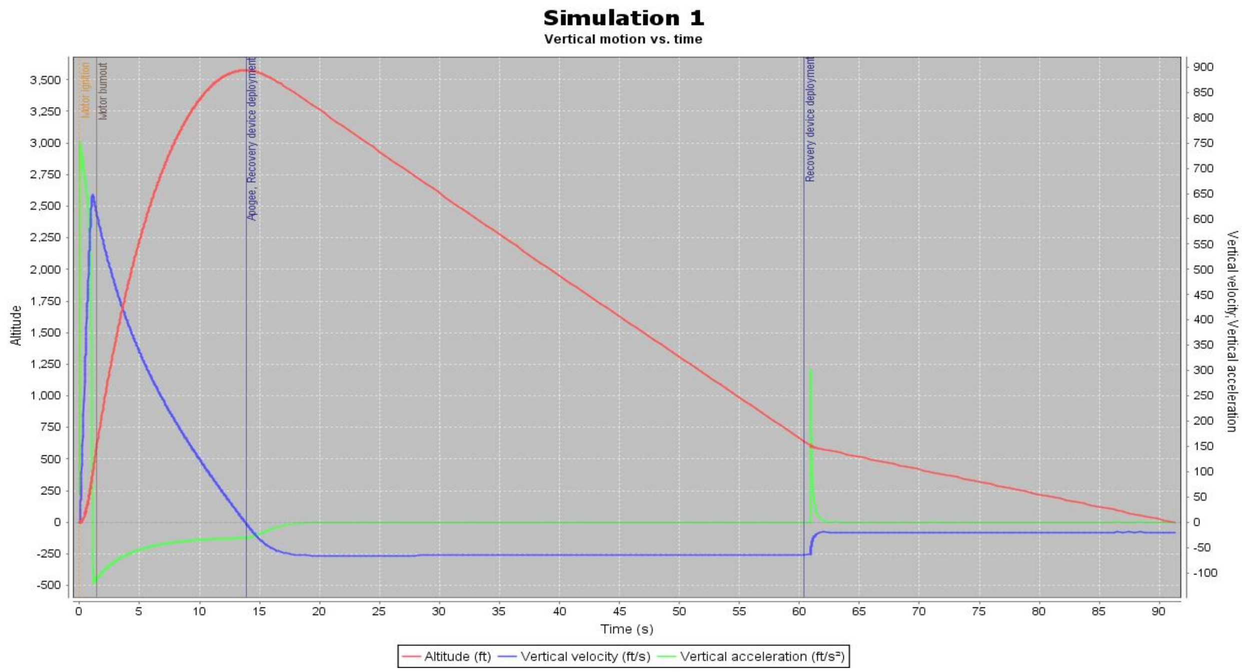

Figure 4

Table 5 - Simulation Parameters	
Average wind speed	10 mi/hr (16 km/hr)
Standard deviation	1 mi/hr (1.6 km/s)
Turbulence intensity	10 %
Wind direction	90 degrees
Ejection charge delay	14 s

Table 6 - Simulation Data	
Apogee	3597 ft (1096 m)
Peak Velocity	648 ft/s (198 m/s)
Peak Acceleration	751 ft/s (229 m/s^2)
Descent Speed	20.6 ft/s (6.27 m/s)

Active Roll And Orientation System Simulation Analysis

The roll-orientation system is located below the avionics bay and above the drogue shoot. An exploded cross-sectional view of the active roll-orientation system is shown in **Figure 5** below.

Based on Autodesk Computational Fluid Dynamics (CFD) simulations ran as shown in **Figure 7**, the maximum possible force applied to the fins of the rocket by a 250 m/s wind will be 231.45 N. To ensure that the results were within the correct order of magnitude, a simplified hand calculation was done using **Equation 3** drag formula below in tandem with parameters obtained from our open rocket model.

Equation 3

$$Drag\ = \frac{1}{2}C_d * p * Asin(\Theta) * v^2 = \frac{1}{2}(1)(1.2\ \frac{kg}{m^3})(0.0047\ m^2)sin(90)(250\ \frac{m}{s})^2 = 176.25\ N$$

As shown above, the CFD software and the hand calculation are within the same order of magnitude, of course the CFD simulation will be more precise as it takes into account variables above and beyond just drag force. Even though the maximum possible force is 231.45 N, the design and software of the roll control system will not allow for roll beyond 45 degrees. This is because not a lot of pitch angle will likely be required to achieve the amount of roll needed for competition commands since we will be using 2 fins 180 degrees from each other. Still, knowing that a failure will not occur even if the fins were in a stall configuration at 90 degrees is proof of design safety.

Under 231.45 N force, a maximum Von Mises stress of 9.735 Kilogram per square inch was noticed as shown in **Figure 6** and **Figure 8**. The Flexural Yield Strength of ABS is 60.6 - 73.1 MPa (8.789 - 10.602 KSI), as stated by the http://www.teststandard.com indicating that the design is fine for flight even at a max angle of 90 degrees. The fins when placed under the same normal force of 231.45 N have a deflection of a maximum of 0.0689” in the direction of the force applied at the tip only as shown in **Figure 6** and **Figure 9**. The overall structure of the wing will remain rigid and intact during use.

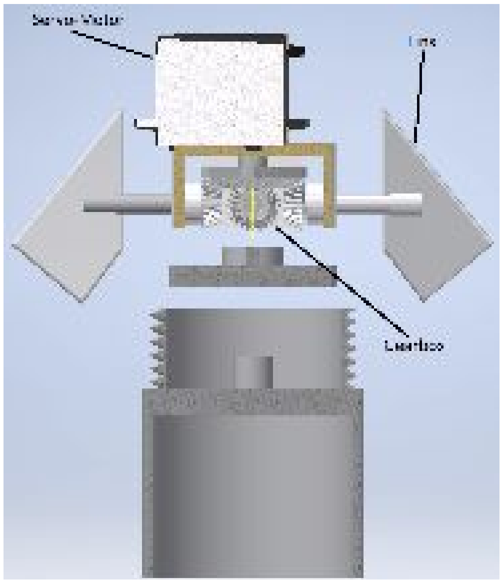

Figure 5

⊟ Result Summary

Name	Minimum	Maximum
Volume	1.95384 in^3	
Mass	0.0748221 lbmass	
Von Mises Stress	0.000000501879 ksi	9.73543 ksi
1st Principal Stress	-3.28427 ksi	11.9613 ksi
3rd Principal Stress	-12.7288 ksi	2.39302 ksi
Displacement	0 in	0.0689014 in
Safety Factor	0.297959 ul	15 ul
Stress XX	-5.65546 ksi	5.40294 ksi
Stress XY	-1.6383 ksi	1.6839 ksi
Stress XZ	-1.09347 ksi	0.99347 ksi
Stress YY	-11.2667 ksi	6.97758 ksi
Stress YZ	-0.134784 ksi	4.8366 ksi
Stress ZZ	-6.98505 ksi	7.60943 ksi
X Displacement	-0.00163468 in	0.00163852 in
Y Displacement	-0.00424984 in	0.00424587 in
Z Displacement	-0.00157541 in	0.0688721 in
Equivalent Strain	0.00000000148312 ul	0.0283812 ul
1st Principal Strain	0.000000000340607 ul	0.0281043 ul
3rd Principal Strain	-0.0304881 ul	0.0000000000141996 ul
Strain XX	-0.00511867 ul	0.0037848 ul
Strain XY	-0.00695896 ul	0.00715264 ul
Strain XZ	-0.00464471 ul	0.00421993 ul
Strain YY	-0.0252094 ul	0.0142663 ul
Strain YZ	-0.000572516 ul	0.0205443 ul
Strain ZZ	-0.00980482 ul	0.0116457 ul

Figure 6

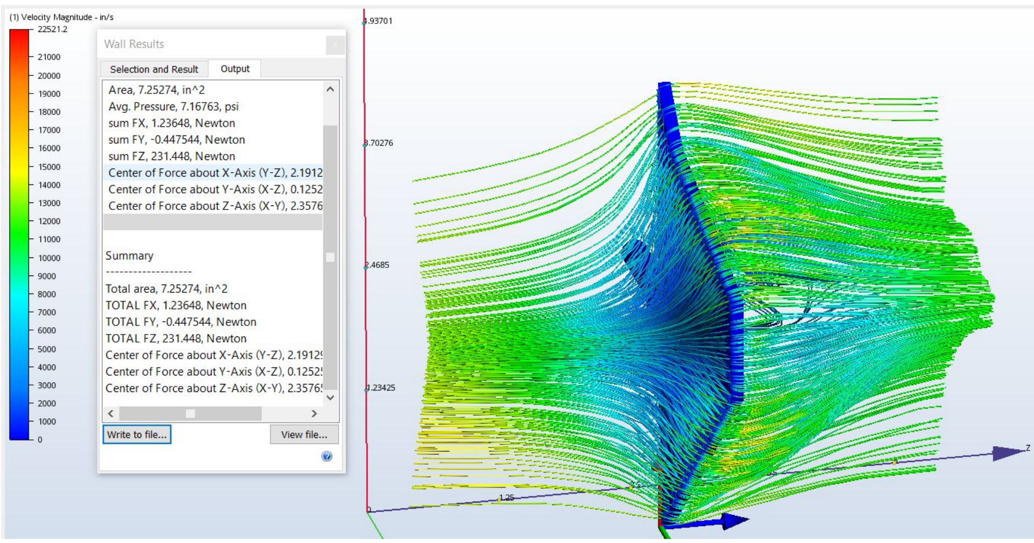

Figure 7

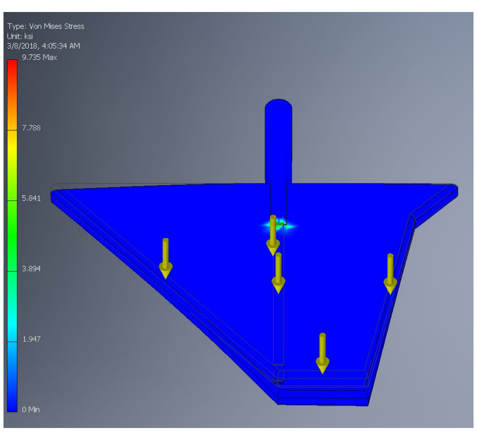

Figure 8

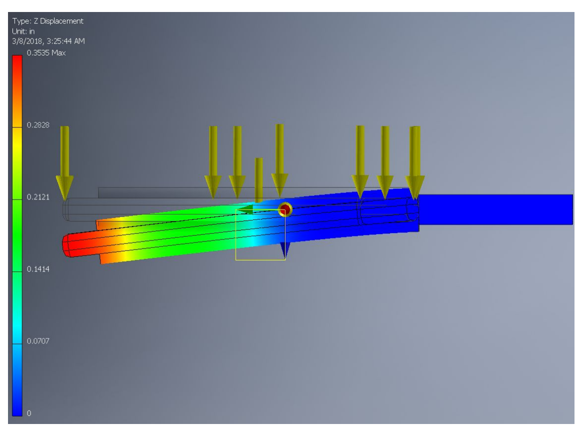

Figure 9

Safety

Designed for Safe Flight and Recovery

- Calculated center of gravity (CG) and center of pressure (CP)
- Calculated drag forces created by model rocket
- Calculated drogue and main parachute diameter
- Designed rocket body around one standard outside diameter
- Designed rocket for dual-deployment
- Aligned thrust with CG on central axis with proper parts that are balanced
- Fins are aligned with rocket body and securely bonded to a flat surface
- The main and drogue parachute is deployed via black powder charge
- The drogue chute will deploy via a backup charge from the motor if the black powder charge fails
- Charges are triggered by altimeter at required altitude
- Nomex flame-resistant blankets are used to protect the shock cord and parachutes from hot gases created by the black powder charges
- Shock cords are secured to closed eye bolts and bulkheads
- Simulations and calculations were done to optimize successful recovery

Documented Material Handling Procedures

Careful consideration will be exercised when handling harsh chemicals to ensure safety. Epoxies and paints will be used in well-ventilated areas where fumes can easily dissipate. Black powder charges will be secured in a controlled environment absent of open flames and excessive heat. Charges will be tested outside in areas with optimal space and prior approval. Charges will only be ignited during testing and launches. Always wear eye protection when handling black powder charges. The rocket and its components will be stored in a dry and cool area when not in use.

Planned Assembly Procedure

The rocket will be composed of five individual sections: nose cone, main parachute bay, avionics bay, roll control bay, and tail section w/drogue chute. Construction of the avionics (AV) and roll control bay will take primary precedence due to the complexity and importance to the rocket. Payload electronics will be assembled and placed inside 3D printed housings with damping material to reduce vibration. As of now the design has the avionics bay inside of a blue tube section, and the entire rocket is of the same bluetube material. An evaluation to make a clear polycarbonate tube section to house the avionics bay for easy equipment checks and visibility of the LEDs will be made. If the polycarbonate tubing is determined to be a source of weakness to the overall integrity of the rocket, the clear tube idea will be discarded. The roll control system will be printed with ABS plastic and assembled in a blue tube bay. A motor mount will then be constructed using a smaller diameter blue tube, wooden bulkheads, and epoxy. The fins will be cut from fiberglass panels and epoxied into slots in the airframe. Holes and slots in the airframe will be cut using a 4 axis laser cutter for precision. An open section in the front of the tail will house the drogue chute. Next the main parachute bay will be constructed with a simple blue tube piece with a bulkhead at one end. The nose cone will be made of polypropylene plastic. Finished sections will then be primed, painted, and fitted with decals. The shock cords and parachutes will be carefully secured and packed inside the rocket. Nomex blankets will be fastened onto the shock cords to protect the parachutes from the black powder charges. The sections will finally be fitted together and secured with shear pins and rivets.

Planned Pre- & Post-Launch Procedures

Pre-Flight Checklist

Physical Inspection & Assembly

- ☐ Inspect rocket for damage
- ☐ Inspect all wiring and connections
- ☐ Test power supply
- ☐ Enter rotation requirements
- ☐ Inspect drogue chute (ensure there are no holes or tears)
- ☐ Inspect drogue shock cord, eyebolts, and Nomex blanket
- ☐ Insert black powder charges w/E-matches for the tail section
- ☐ Prepare and pack drogue parachute into tail section
    - Connect carabinors to closed eye bolts
- ☐ Inspect main parachute (ensure there are no holes or tears)
- ☐ Inspect main chute shock cord, eyebolts, and Nomex blanket
- ☐ Insert black powder charges with E-matches for the main section.
- ☐ Prepare and pack main parachute into main bay
    - Connect carabiners to closed eye bolts
- ☐ Secure nose cone to the main bay with plastic shear pins
- ☐ Secure main parachute bay to avionics bay with bolts
- ☐ Press fit tail section to avionics section
- ☐ Insert shear pins and rivets
- ☐ Inspect camera and mount
- ☐ Assemble motor

☐ Insert and secure motor

Pre-Launch

☐ Ensure motor is secure
☐ Ensure micro SD is installed in aft facing camera
☐ Secure Altimeter 2 into the avionics bay
☐ Turn on aft facing camera
☐ Ensure all section connections are secure
☐ Connect power supply to electronics
☐ Turn on Stratologgers
☐ Ensure LEDs are on
☐ Establish communications via XBee radios
☐ Upload mission to Arduino
☐ Connect E-match to motor
☐ Clear launch area

Post-Flight Checklist

☐ Locate Simba (Simba is the Rockets name)
☐ Take pictures of landing site and rocket
☐ Disconnect power supply
☐ Turn off aft facing camera
☐ Disconnect drogue and main chute from rocket for easy transport
☐ Retrieve provided Altimeter 2
☐ Save all data to personal computer
☐ Extract avionics bay
    - Inspect bay for damage

☐ Retrieve flight data
    - Video data
    - Avionics bay data

Budget

Table 7					
Item	Count	Weight (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

Sources:

http://www.teststandard.com/data_sheets/ABS_Data_sheet.pdf.