2017-2018 MnSGC High-Powered Rocket Preliminary Design Report

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University of Wisconsin-Milwaukee
UWM Rocketry

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Preliminary Design Report

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Executive Summary

The purpose of this document is to inform the Minnesota Space Grant Consortium (MnSGC) judges of the design, fabrication, and progress of the University of Wisconsin Milwaukee’s rocket in the 2018 Midwest Regional Rocket Launch Competition.

This year’s competition is to design and safely fly a single stage high powered rocket that is "roll-orientable". UWM has chosen to fly their rocket using the Aerotech JG500 motor. We will require two motors for the competition date. The rocket will have to fly twice on this motor and be recovered in a flyable condition. On the first flight the rocket must use a roll-control mechanism that can minimize roll. On the second flight the rocket will follow a set of commands to roll to specified angles and hold these angles for a predetermined period of time. The better the rocket can hold these positions the more points will be awarded.

The rocket will use a non-commercial on-board data-logging sensor package to log the roll orientation to compare with a downward looking video camera on the rocket to visually verify the data being collected. As a bonus challenge the rocket can be programmed real time from the launch pad while in flight using a XBEE-radio-based communication system to relay orientation data. Being able to accomplish this bonus challenge will grant more points.

Design Features of Rocket Airframe

Software Simulation

Using spec requirements set forth by the MnSGC along with personal design choices, a schematic simulation of the rocket was created with the Open Rocket software. The rocket centers of gravity and pressure are denoted in the Open Rocket figure shown above as the white-blue checkered and red circles respectively.

The total length of the rocket is 51.25 inches with the maximum diameter of 3 inches occurring at the body tube. The mass of the rocket with the motor in is 6.8 pounds. Measured from the top with the motor in the center of gravity is 35 inches and the center of pressure is at 41 inches. This gives the rocket a stability caliber of 2.0. A stability caliber of 2.0 will ensure that the rocket maintains a safe and straight path during its flight. It is important to note that as the caliber increases over the 2.0 mark the tendency for the rocket to weather cock increases. With the speed the rocket will be traveling at it is not worth the risk to increase the caliber in case of a windy launch day. The key rocket dimensions are also shown in Table 1.

Key Rocket Dimensions	
Max Diameter (***in***)	3
Length (***in***)	51.25
CG (***in*** *from nose tip*)	35.00
CP (***in*** *from nose tip*)	41.00
Stability (***cal***)	2.00

Table 1

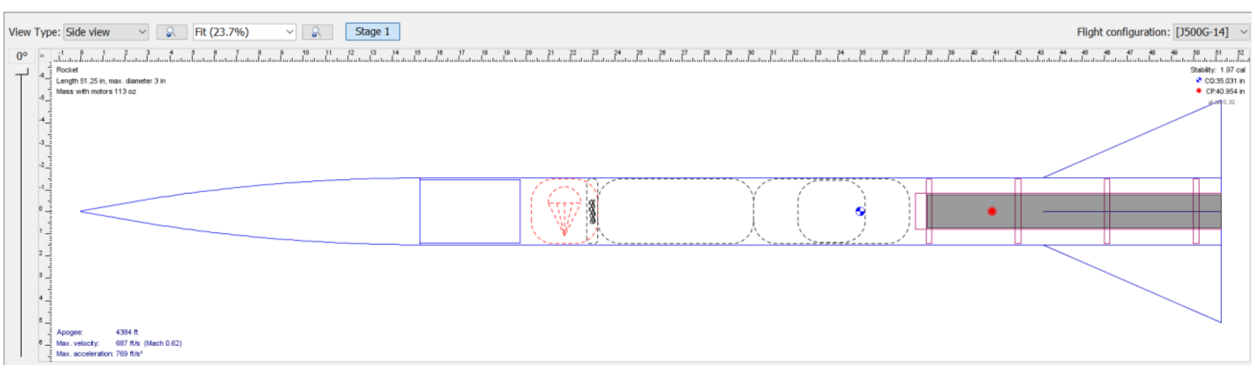


Figure 1: Open Rocket Simulation

Material Selection

All materials used to build the rocket were purchased from Giant Leap Rocketry. They are a reputable model rocket vendor and have served us well in the past.

K(frame) is a filament wound fiberglass resin material. The filament winding improves overall strength of the tube compared to just have a fiberglass tube. This extra strength helps to prevent damage to the rocket upon landing. It is also much lighter than its carbon fiber cousin, allows for electrical signals to pass through it without any delay, and absorbs next to no water. For this reason, K(frame) makes up the bulk of the rocket. Components made from the K(frame) include the body tube and electronics bay.

The fins of the rocket are made from G-10 Fiberglass. G-10 fiberglass is reinforced fiberglass cloth coating in an epoxy resin. These fins are nearly indestructible as learned from past experiences. The fiberglass also cuts nicely using a jig-saw which makes machining custom fins an easy process.

Orbiting away from the fiberglass components leaves the nose cone, centering rings, and motor mount tube. The nose cone (Figure 2) is made of a high impact PVC material. It is much less brittle than its fiberglass counterpart which helps to keep the nose cone intact upon impact with the ground. Our specific nose cone is manufactured with the ability to spray in expandable foam in case there is a need to adjust the center of gravity of the rocket. The centering rings are made of 3/16" birch wood which provide a uniform grain structure and therefor properties for supporting the motor mount tube. The motor mount tube is made of a phenolic resin which allows for a strong adhesion between the centering rings and itself to hold the motor securely in the rocket.

Roll Control Mechanism

In order to achieve the roll-orientable single stage high-power rocket system parameter set forth by NASA's Space Grant Midwest High-Power Rocket Competition, the team will implement a gyroscope mechanism inside the body of the rocket. Applying the gyroscope mechanism inside the body will allow for superior roll control and maneuverability.

Physical Concept

The gyroscope mechanism works by placing a disk with sufficient mass on to the shaft of a DC motor. The motor will be used to spin the mass at some angular velocity. The gyroscope system will now have some amount of angular momentum that can oppose the angular momentum of the rocket. With the means of programming and collecting necessary data to make the correct calculations, the system will reach an equilibrium point which will essentially bring the roll of the rocket to a halt while simultaneously allowing us to control the roll orientation of the rocket.

The motor and disk assembly shown in Figure 2 will be placed inside one of the avionics bay. This way it will be self-contained while also being close enough to be able to wire it up to the necessary components in the other avionics bay. The DC motor mount will be a 3D printed part. The weight mass will be a cylindrical block of steel.

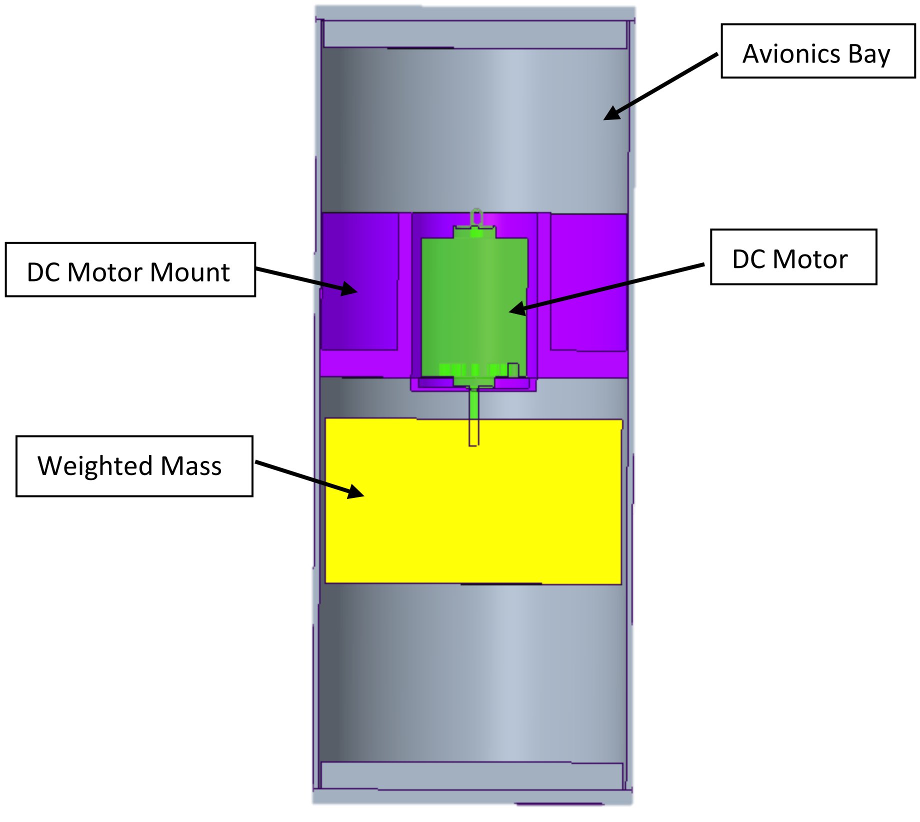


Figure 2

Mathematical Concept

The mechanism takes advantage of the concepts of angular momentum. By definition, the angular momentum of a ridged object is the product of the moment of inertia and the angular velocity. If we define our variables as

$$L = Angluar\ Momentum$$

$$I = Moment\ of\ Inertia$$

$$\omega = Angluar\ Velocity$$

then $L = I \times \omega$. It is important to note that angular momentum is a vector quantity. This means that it has both direction and magnitude.

By defining our variables to account for the rocket's angular momentum we get the angular momentum of the rocket to be equal to L_R, the moment of inertia of the rocket to be I_R and the angular velocity of the rocket to be ω_R. It becomes fairly easy to calculate the angular momentum of the rocket: $L_R = I_R \times \omega_R$. Doing a similar process to calculate the angular momentum of the gyroscope yields the equation $L_G = I_G \times \omega_G$.

If the rocket is modeled to be a thin hoop of some mass m_R then the mass moment of inertia of the rocket can be calculated using $I_R = m_R \times R_R^2$, where R_R is the radius of the rocket. The angular velocity of the rocket ω_R will be determined by the gyroscope in the avionics bay. By using a circular disk of weight m_G and radius R_G the mass moment of inertia of the gyroscope I_G can be calculated using $I_G = \frac{1}{2} \times m_G \times R_G^2$. The angular velocity of the gyroscope w_G will be controlled via the motor and PID controller which will allow the control of the rocket's orientation. Since angular momentum is a vector quantity, if the direction of the angular velocities are opposing each other it is possible for the summation of the two angular momentums to equal to zero. Setting the system equal to zero would effectively cancel the roll of the rocket. Setting the system to a value other than zero will allow the system to change the roll orientation of the rocket.

Design Features of Avionics Bay

Layout

The avionics bay shown in Figure 3 will house of the on-board electronics as well as the roll control system. We will have an elongated electronic bay to accommodate both systems. A StratoLogger altimeter (denoted by the red sensor in Figure 3) will be used to record the altitude, velocity and acceleration of the rocket. The data that the altimeter outputs will also be used to sense when the rocket takes off as well as when it reaches apogee. It will interface with our roll control system so that it activates and deactivates at the appropriate times. The altimeter will also be responsible for igniting our ejection charges upon apogee.

Figure 3: Stratologger Altimeter

As we are only utilizing single deployment we need an accurate way to locate our rocket upon landing. To accomplish this, we will be using a Trackimo GPS locator (Figure 4). The locator does not rely on radio but rather a cell phone signal. The locator has an app that is downloaded on a phone and as long as there is cell phone reception the tracker be able to communicate with the phone. The hardware is very light and fits nicely into a compact space.

Figure 4: Trackimo GPS

The HiLetgo MPU9250/6500 9-Axis 9 DOF 16 Bit Gyroscope Acceleration Magnetic sensor (Figure 5) will be an essential part of our electrical sensors. This sensor allows for easy calculation of the angular velocity of the rocket at any given instance in time. We will also be able to tell the rockets orientation by using the on-board magnetic sensor. This will aid us in the second flight of the competition where we must turn to a specific orientation.

Figure 5: MPU9250 Sensor

An Arduino Nano (Figure 6) will be used to do the heaving lifting of our programming requirements. It will be responsible for communicating with all of the sensors to ensure that everything runs accordingly. Some of the communication it is handling includes the roll control system, reading and writing to an SD card to save roll control data and receiving data from the gyroscope sensor to relay command to the roll control system.

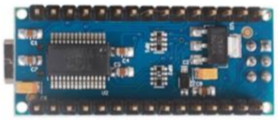


Figure 6: Arduino Nano

The L298 N Driver (Figure 7) is responsible for controlling the spin direction of the DC motor. It is a compact h-bridge that is light weight and provides easy wiring access through the screw terminals. It is able to handle an amperage that is greater than the stall current of the motor.

Figure 7: L298 N Driver

The Wingoneer Micro SD Card Reader (Figure 8) is responsible for reading and writing the data from the gyroscope sensor as well as logging the roll control data. It communicates through serial peripheral interface (SPI) which is capable of communicating with more than one device.

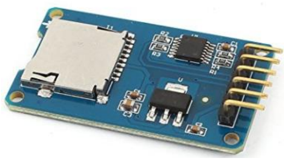


Figure 8: Wingoneer Micro SD Card Reader

Finally, the XBEE radio (Figure 9) will be used to communicate to the rocket from the ground. It is a 60mW printed circuit board which has a range of 1 mile. This will be adequate for communicating to the rocket especially since there will be minimal interference at our launch location.

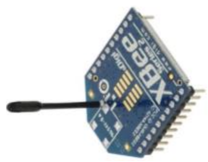


Figure 9: XBEE Radio

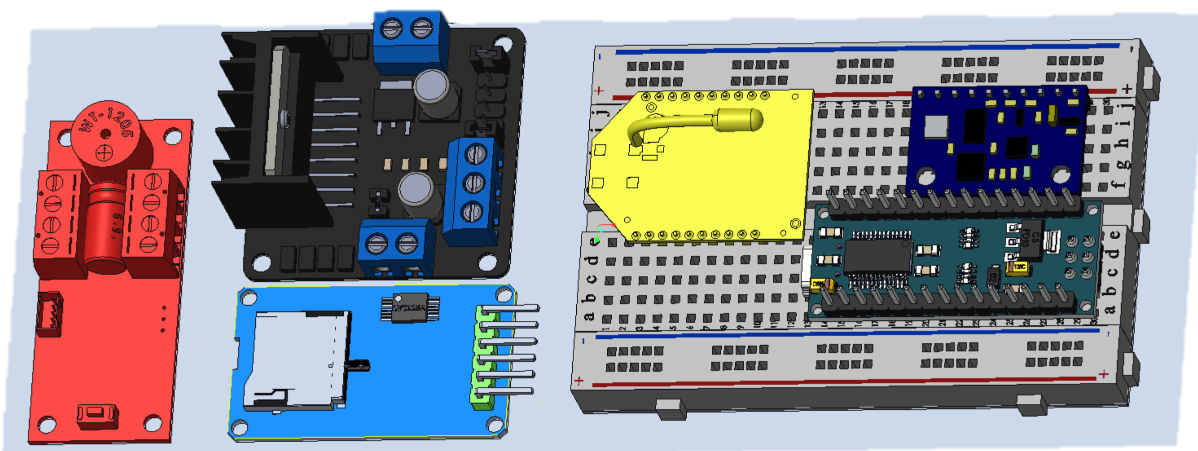


Figure 10: Overview of Electrical Components

Construction of Avionics Bay

The construction of our avionics bay makes it very simple to access, attached and detach to the rocket. The design is rather simple. The bay serves as a coupler connecting the two halves of our rocket. Even though the rocket does not need to be able to separate into three parts because we are only using single deployment, having the body tube cut into two pieces allows for easy access of the bay.

A major component that allows for easy access to the bay is a little section of the body tube that is glued to the outside of the bay as shown in Figure 11. This section is cut from the body tube and allows access to the bay from outside of the rocket. The lower half of the rocket slips over the bottom half of the bay while the top half of the rocket slips over the top half. Drilling holes into the section of body tube on the bay makes arming the rocket or any other sensors in the bay an easy process.

Figure 11: Avionics Bay

To secure the bay into place it is bolted through the outer tube of the rocket. A simple threaded insert put inside of the bay allows for the bolt to be inserted from the outside which securely holds the bay in place during flight. Our bay will be bolted on both the top and bottom halves as we are only using single deployment.

Flight Performance

With the selected Aerotech J500G motor the Open Rocket predicted apogee of the rocket is 4384 feet shown in Figure 12. Although there is no requirement for altitude in this competition we want to give the rocket plenty of time to coast so we can optimize the amount of time we have to perform our roll orientations. The software estimations for maximum velocity of the rocket is 687 ft/s (Figure 13) with a maximum acceleration of 772 ft/s^2 (Figure 14).

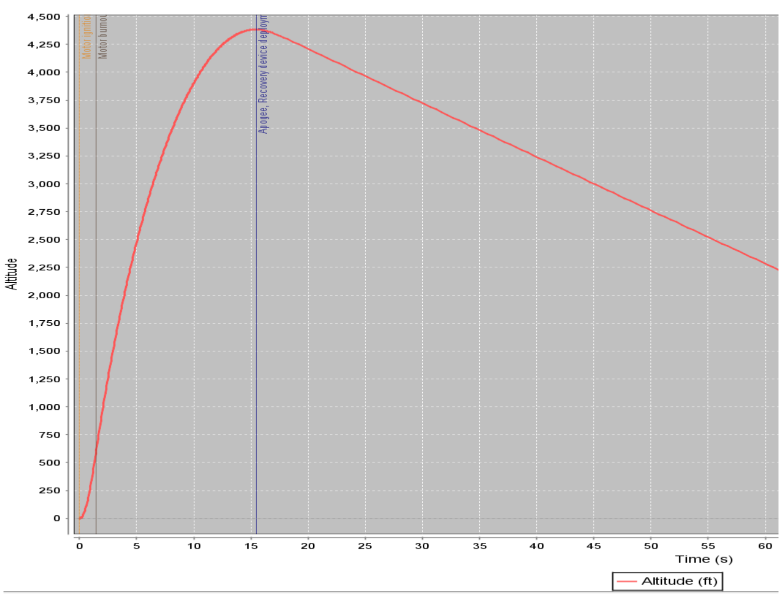


Figure 12: Plot of altitude (ft) vs time (s) from OpenRocket software with Aerotech J500G motor

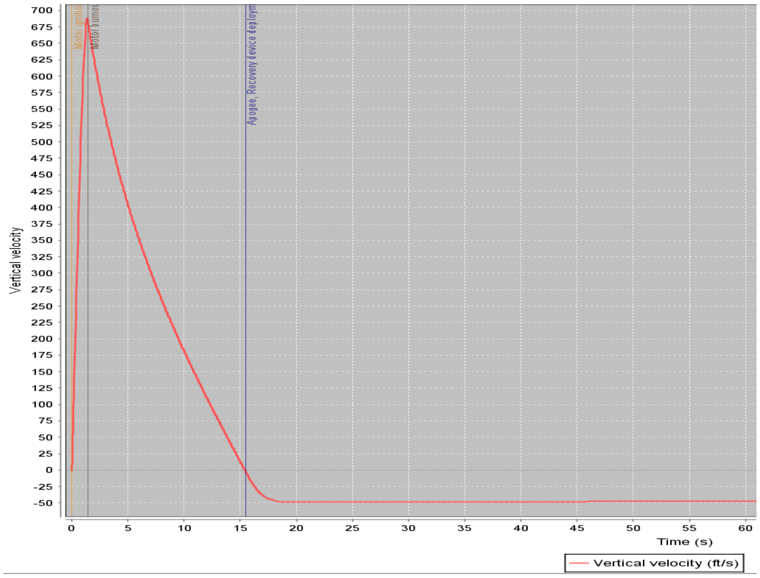


Figure 13: Plot of vertical velocity (ft/s) vs time (s) from OpenRocket software with Aerotech J500G motor

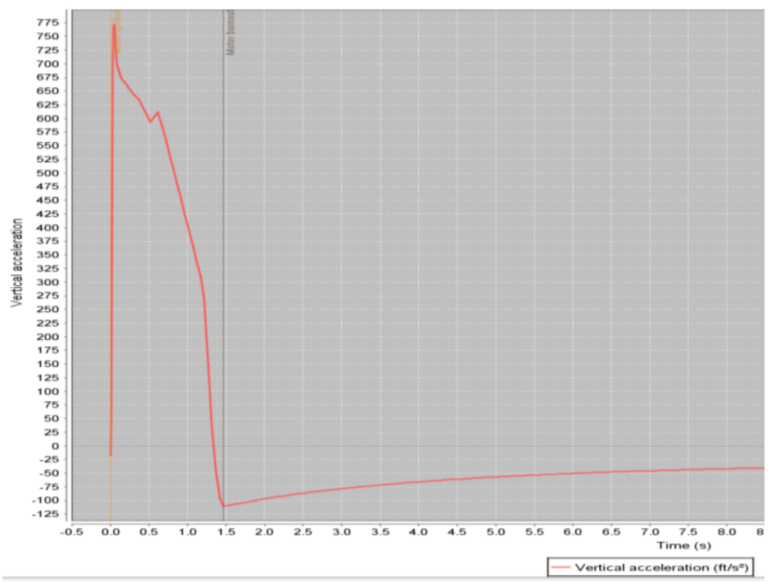


Figure 14: Plot of vertical acceleration (ft/s^2) vs time (s) from OpenRocket software with Aerotech J500G motor

Budget

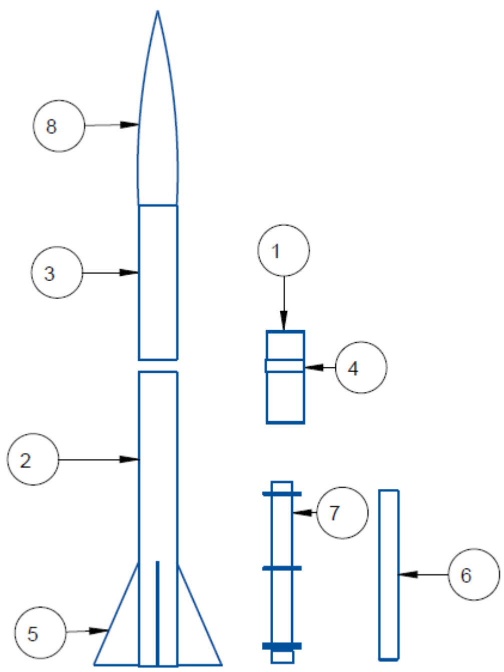
MnSGC Midwest Regional Rocket Competition 2018
UWM Rocketry
University of Wisconsin Milwaukee

Preliminary Budget

Component Description	Quantity	Cost Per Unit	Total
(K)frame Airframe 76mm, 48" long body tube	1	$ 94.40	$ 94.40
Plastic ogive nosecone - PINNACLE - 3.00"	1	$ 20.47	$ 20.47
7" Long electronics bay for 3.00" airframe	2	$ 28.87	$ 57.74
24" Tac-1 Parachute for recovering the rocket	1	$ 35.99	$ 35.99
Low Drag Rail Button - Delrin (2 pack)	2	$ 3.49	$ 6.98
StratoLogger CF Altimeter used to eject parachute	1	$ 59.95	$ 59.95
Trackimo GPS Locator	1	$ 139.99	$ 139.99
Phenolic MMT-1.525 (38mm) 18" for holding motor in place	1	$ 7.99	$ 7.99
15 foot Shockloop, 1/4" Tubular KEVLAR for connecting parachute to body tube	1	$ 17.41	$ 17.41
Threaded Slimline 38mm Starter Set for holding motor in the rocket	1	$ 35.68	$ 35.68
1/4" Birch Centering Ring 3.00" to 38mm for G10 for holding motor mount in tube	5	$ 5.76	$ 28.80
G-10 Fiberglass Sheet 0.125" (1/8") 12" x 48" for cutting custom fins	1	$ 98.69	$ 98.69
U-bolts ¼"	8	$ 4.69	$ 37.52
Quick links ¼"	8	$ 2.34	$ 18.72
Nylon Rod 3" diameter by 1'	1	$ 48.83	$ 48.83
12V DC Motor 11200 RPM	4	$ 7.45	$ 29.80
AeroTech JG500 Motor	2	$ 60.00	$ 120.00
11.1V 1500 mAh Lip Battery	1	$ 23.99	$ 23.99
Lipo Battery Charger iMAX B6AC Version 2 Digital LiPo	1	$ 56.99	$ 56.99
Weller Digital Soldering Station	1	$ 138.37	$ 138.37
LHI XT-60 XT60 (6 Pack)	1	$ 6.80	$ 6.80
Micro SD Storage Board For Arduino for communicating with SD card	1	$ 5.91	$ 5.91
22 AWG Stranded Wire	1	$ 20.95	$ 20.95
Arduino Nano	1	$ 24.95	$ 24.95
SanDisk Ultra 32GB microSDHC for storing measured electricity data	1	$ 10.59	$ 10.59
Loctite Epoxy Quick Set 0.85-Fluid Ounce for gluing centering rings and fins	1	$ 5.24	$ 5.24
Registration Fee (Paid for by the WSGC)	1	$ 400.00	$ 400.00
Hotel/Travel	1	$ 413.64	$ 413.64
Total			$ 1966.39

Appendix

A1 Rocket Assembly Drawing

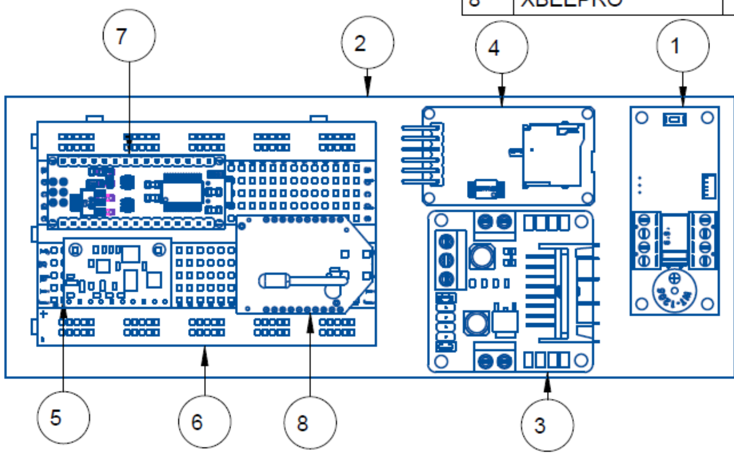


ITEM	DESCRIPTION	MATERIAL	QTY
1	AVBAY	FIBERGLASS	1
2	BODYTUBEBOTTOM	FIBERGLASS	1
3	BODYTUBETOP	FIBERGLASS	1
4	EBAYSEPERATOR	FIBERGLASS	1
5	FINS	FIBERGLASS	4
6	JG500	SOLID STATE FUEL	1
7	MOTORMOUNT	PHENOLIC	1
8	NOSECONE	HIGH IMPACT PVC	1

NAME: BEN DUCETT	UWM ROCKETRY	SCALE: 1:8
DATE: 3/5/18	2017-2018	SHEET: 1:1

A2 Avionics Bay Assembly Drawing

ITEM	DESCRIPTION	MATERIAL	QTY
1	ALTIMETER		1
2	EBAY_BOARD		1
3	L298N		1
4	MICROSD_READER_ASSEMBLY		1
5	PART_GY-801		1
6	SOLDERLESS BREADBOARD		1
7	USER_LIBRARY-ARDUINO_NANO		1
8	XBEEPRO		1



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