# **Preliminary Design Report**

University of Wisconsin-River Falls

Rocketeers


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## <u>Executive Summary:</u>

### Competition Parameters:

The 2018 Midwest High-Power Rocket competition requires student teams to construct an ‘adaptable’ single stage rocket high-powered rocket using a single or dual deployment recovery system. The adaptable rocket must fly two separate times, using the same I or J class motor. The first launch must reduce the roll of the rocket to keep it oriented in the same direction. The second launch must follow a given set of specific angles that the rocket must roll to and hold for one second.

Teams must also incorporate three LED’s that are programmed to indicate different operations. On the launch pad all LED’s must flash on and off in .2 second intervals. Once launched the LED’s remain lit until three seconds after burn-out. Afterwards, one LED must indicate a clockwise roll, one a counterclockwise roll, and the third is to indicate when the system is in stand-by. After apogee is detected all LED’s must continue to flash for .5 second intervals for the remaining time. The rocket must safely land via parachute recovery system.

Teams must also capture video of the apparent active roll-control mechanism and also that of drogue and main parachute deployments. Students must build a non-commercial on-board sensor that logs the data of the roll. This data will be compared to the video footage of the downward facing camera for accuracy. Prediction of the rocket’s apogee must be predicted by the students and then tested with on-board data collection. The fabrication of the rocket is to be entirely completed by students.

### Overview of Rocket Design:

At a length of 1300mm and a diameter of 101.6mm, the rocket is constructed of G12 fiberglass. Our chosen motor is an Aerotech J800 with a 14 second motor ejection delay. The J800 uses Aerotech’s Blue Thunder propellant which is a high thrust propellant for its total impulse size.

Attached to one of the fins on the rocket will be a flap that is hinged and attached to a servo motor so that the angle can be adjusted. This flap is the system that will be implemented to control the roll of the rocket.

The rocket will have two Mobius mini action cameras attached to the exterior to capture video of the roll control system in action. In addition to the camera itself the rocket will have a set of led lights extruding from the interior within view of the camera which will have a set of commands to signal when the roll mechanism is making corrections or adjustments to the rockets roll.

**Team:**

The UWRF Rocketeers team consists of four members. Team lead Jacob Hanson-Flores and fellow team members Andrew Larson and Austin Dreher are all second year high-powered rocket competitors. Jacob is a physics major while Andrew and Austin are working towards their degrees in mechanical engineering. Last year they worked together on the active drag competition earning the “Most Adaptable Rocket Design Award.” In addition to that we have a former HPR team member Roman Alvarado. Roman is an applied physics major with an emphasis in Biology. Joining the HPR team for the first time will be Tony Caruso, Begad Elmelligy, Bryce Counsellor, and Christopher Ladas.

## Design Features, Mechanical & Electrical Design:

**Rocket Airframe:**

The requirements of the competition challenges student teams to design and build an roll control/stabilization system for our rocket. With these parameters in mind, the airframe design dimensions are 130 cm long with a diameter of 10.2 cm made of G12 fiberglass. There is a 12 inch coupler that is placed halfway through the length of the airframe. Inside this coupler the electronics bay will be housed, along with our X-Bee communication system.

The exterior of the rocket will be equipped with a downward facing camera to capture the roll control on video. An upward facing camera will also be mounted to the airframe to capture the parachute deployments. In addition there will be a set of led lights extruding from the airframe of the rocket which will allow us to visually signal any attempts to stabilize the roll or orientate the rocket to a specific direction per competition parameters.

**Flap Design:**

In order to maintain a low profile and avoid creating additional drag on the rocket. The servo motor will be mounted inside of the airframe adjacent to where the motor sleeve protrudes at the base. We will be using a single flap to control the roll during our test launch. The idea behind this is to maximize efficiency with one fin to create a simplistic way to control the roll and minimize the risk of overcorrection that can be caused by an overly-dynamic system.

The servo motor will be placed facing downward and use a crown gear attached to a rod running from the inside of the rocket to the flap on the fin. The flap will be hinged to the fin at the top with the rod threading through to a section on the end of the fin where it will be mounted to improve the structural integrity.

**Active roll design:**

Our design features a stationary wing with a movable lower flap that is controlled by a servo motor and beveled crown gear. We will have the servo motor hooked up to a HM motor controller which will get its commands from the Arduino uno through the Arduino shield (model: wireless SD R3). The Arduino uno will receive information pertaining to the angular position of the rocket from a Adafruit 9-DOF Absolute Orientation IMU Fusion Breakout BN-0055. We are still experimenting with the magnetometer and gyro settings to determine which one gives us more reliable feedback.

The magnetometer can be used to read in the strength of the Earth's geomagnetic field after being mounted on the launch pad. By calibrating this initial magnetic field strength we can use the rate of change of the magnetic field strength to determine the orientation of our rocket. One of the foreseeable issues with this method is interference from the electronics within the rocket itself. The other issue is that if our rocket begins to roll early on in the flight and turns 180 degrees before we are able to activate our roll control system, the magnetic field strength would read the same as if it were facing the opposite direction. Because of these issues the gyro appears to be the more attractive option but we will continue testing before making a final decision.

In order to mitigate any interference from the localized electronics within the rocket, we are experimenting with using a faraday cage as well as shielding the wiring that will be sent down to power our servo motor and feed it instructions.

**Recovery System:**

The rocket incorporates a dual deployment system, controlled by the TeleGPS, consisting of a drogue and single main parachute. The small drogue will deploy at apogee and slow the descent while minimizing the amount of drift prior to the release of the main parachute. The drogue is a 30" elliptical from Fruity Chutes weighs 3.1oz with a 15.9 cubic inch packing volume, providing a main chute deployment speed of 25 mph. To meet the competition landing velocity requirement of 24 ft/sec, the main chute is 48" diameter ultra-compact design from Fruity Chutes with a drag coefficient of 2.4 weighing 4.3 oz. with a packed volume of 26 cu.in. Both parachutes will be secured with 1500 lb. test Kevlar cord.

**Propulsion System:**

The propulsion system we are using for the flight incorporates an Aerotech J800 motor, which will provide an average thrust of 696.5 N, with a maximum thrust of 1001 N. The burn will last 1.8 sec, which provides a total impulse of 1229 N*s. The dimensions of the motor are 54.0 mm in diameter and 316 mm long. The total weight of the engine will be 1086 g, with 595.3 g being propellant weight. The motor has a 14 second delay between the end of the burn and the secondary charge that initializes the recovery system. This motor is reloadable, and an order has been placed. The motors will be provided to us at the Tripoli Rocketry Club on the day of our Test Launch and official launch date.

**Avionics/Payload System:**

An Arduino Uno will be used to control the servo motor with the aid of an altimeter. A Raven III altimeter, which contains an axial and lateral accelerometer will be used as a back-up. The use of an Altus TeleGPS will be used for mapping the 3D flight profile and dual deployment of parachutes as well as barometric pressure, accelerometer, altimeter and 70cm ham-band transceiver.

A 9 degree-of-freedom Inertial Measuring Unit will be used for measuring speed and acceleration throughout the flight. The 9 DOF is achieved using accelerometers, gyroscopes, and magnetic field sensors for each of three axes, so this unit will also provide orientation and rotation data for a complete understanding of the entire flight profile for analysis.

For ease of use and accessibility purposes the avionics bay will have female attachments that will line up with match male attachments on the bottom section of the airframe. These attachments will allow us to send information from the avionics bay to the servo motor attached to the base of the airframe and provide a simplistic way to create continuity between the two sections.

From our cumulative past experience the team has agreed to implement a switch accessible from the exterior of the rocket to activate the entire avionics bay after the rocket has been mounted to the launch pad.

The Altus Telemetrum has a built in beeper to give information about its readiness after it has been activated. The idle settings has a sequence of “dit dit” which signals that the telemetrum is prepared to receive directions via usb or radio connection. Once it is on the launch pad and awaiting launch the sequence goes “dit dah dah dit.” If there is an error in any of the sensors the audio signal we must listen for is “dah dit dit dah.” Having these audio signals on hand at the launch pad and becoming familiar with

**Cameras:**

Two Mobius MiniCam cameras will be mounted on the outside of the airframe, with a small shroud similar to the prototype shown here to ease the airflow around the rectangular camera body. The downward facing camera is shown here. The standard USB is pictured for scale. These cameras allow for 1080p HD video at 60fps and are also much more reliable than the keychain cameras often used in the past.

**XBee Pro:**

We have purchased two Xbee Pro S1 radio transmitter/receivers and found that our range is limited indoors. According to the specs of the XBees we should be able to reach a range of 1 mile between the transmitter and receiever in ideal conditions. We are now looking at modifying the antennas on the xbees in order to extend the range of communication. Theoretically, by using a high gain antenna on the receiving end we should be able to pick up the weaks of signals from the rocket during flight. We may consider moving the antenna to the outside of the rocket to get better signal for transmission back to the ground xbee during flight, and also to reduce any noise that may be caused by the internal electronics(such as the AltusMetrum).

The ultimate goal of this communication system is to be able to transmit live information from the onboard transmitter to the ground based receiver. If we are able to do this effectively our next step would be to implement a way to remotely re-program the arduino with a new set of commands, or even send commands as the rocket is coasting towards apogee.

The primary goal at this point is to determine what the limitations of our range are and how we can effectively increase our transmission capabilities so that we are receiving data throughout the entire flight time.

**Construction Solutions & Techniques:**

All 3D design files, laser cut patterns and wood forms are retained in the University of Wisconsin-River Falls Physics Department. All 3D printed and laser cut components were designed using SolidWorks or Creo Parametric Modeling Software. MatterControl, Makerbot and Cura were used to prepare STL files for 3D printing. Nosecone and cylindrical fiberglass materials were cut using a rotary tool and hacksaw. Any flat fiberglass parts used in construction were cut using a RetinaEngrave P-Series 36”x24” Co2 laser cutter.

**Structural Analysis:**

The 3D printed parts are designed and built using the same techniques, machinery, and materials as have been used and flown on previous high-powered rocket flights without any issues as recently as last year. Other structural components have been purchased from high-powered rocketry vendors and similar electronics components from reputable vendors have been used on previous rocket flights.

**Risk Mitigation Analysis:**

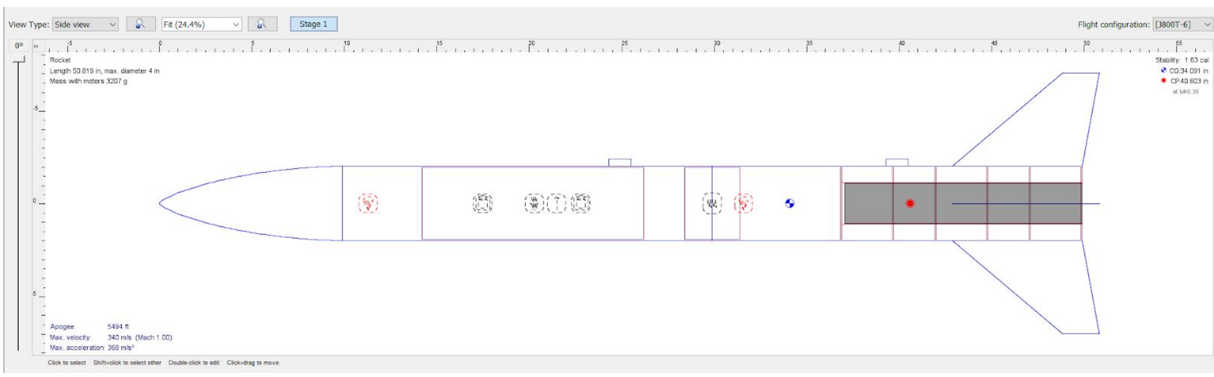
Risk has been reduced with redundancy in systems. The design incorporates two cameras, two sets of drag flaps, and two methods of parachute deployment. The two cameras view mainly up & down, but each also views a small mirror showing the hemisphere behind the camera as well as the main view in front of the camera, so that if any one camera fails there will still be lower quality video available for that hemisphere. The drogue chute deploys either with the delayed charge from the motor or the altimeter apogee sensor.

After we are finished running test on our servo motor and the fin actuator we plan on running test ejections to ensure that our rocket is able to completely separate on the ground. This will help us to determine the proper amount of blackpowder needed to separate the coupler from the airframe to prevent the rocket from coming in ballistic.

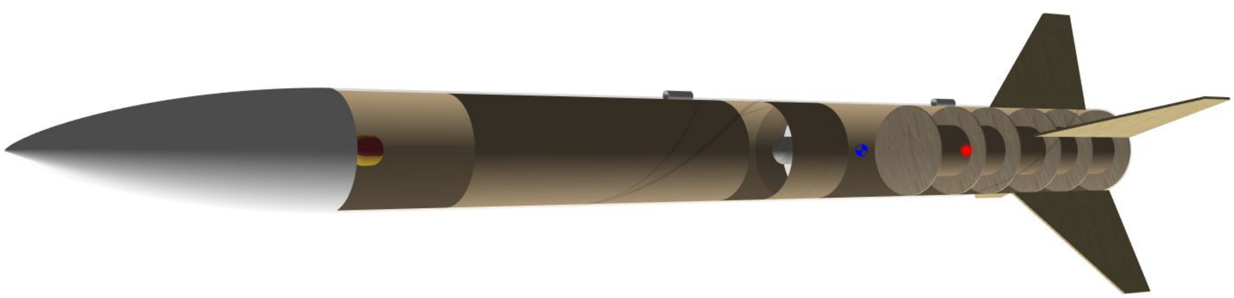
Additionally we will be running test using both the XBee and the AltusMetrum transmitting information simultaneously to ensure we do not have any issues with interference between the transmitters which may cause one or both of our ejection charges to detonate prematurely.

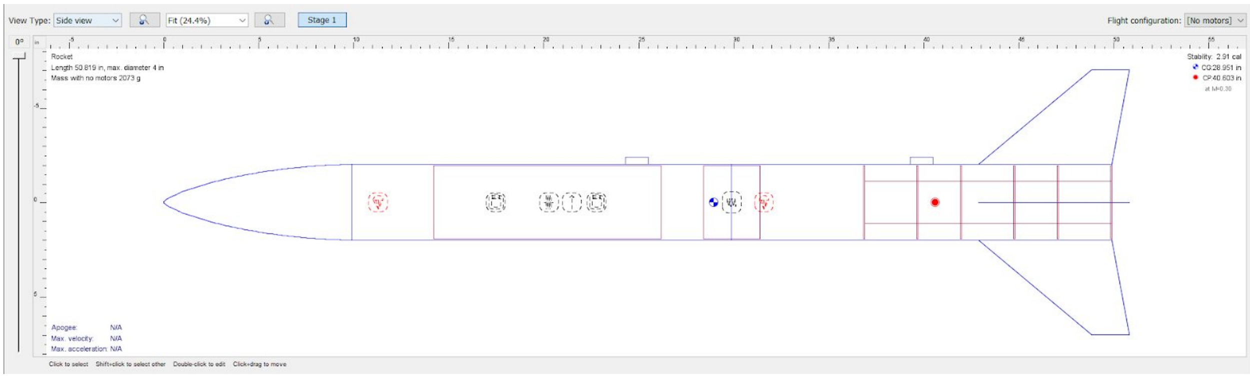
## Diagram of Rocket:

The configuration of the rocket is shown below, without the roll system engaged. Important characteristics are shown below in the diagram. Due to inclarity of the figure, the center-of-pressure is located at 40.603 in and the center-of-gravity at 34.091. These distance values are relative to the front of the rocket. With the J800T-6 motor in place, the stability margin is 1.63. Without the motor, the stability margin is 2.91, the center-of-pressure is 40.603 in, and the center of gravity is 28.951 in.




3D model of the

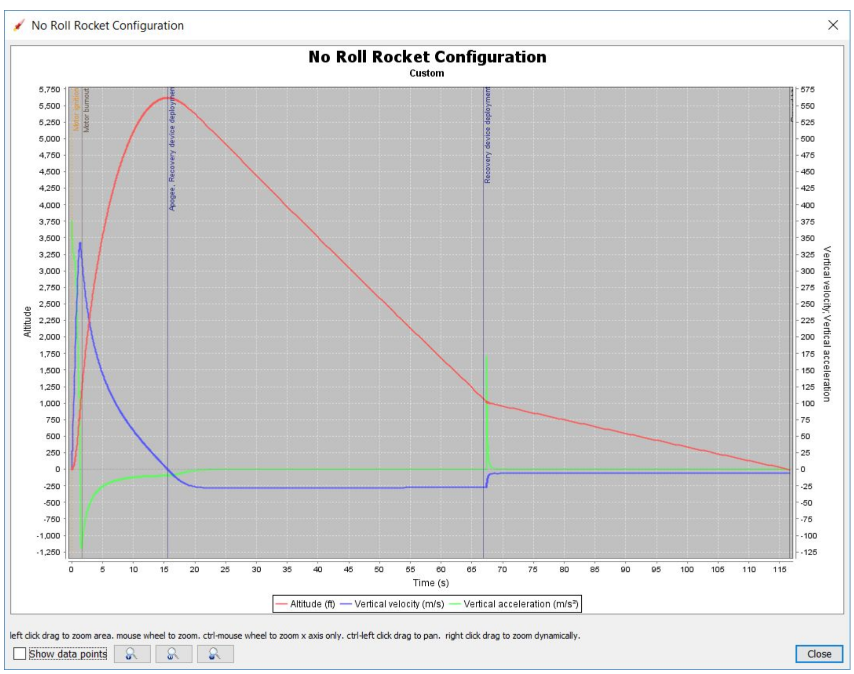




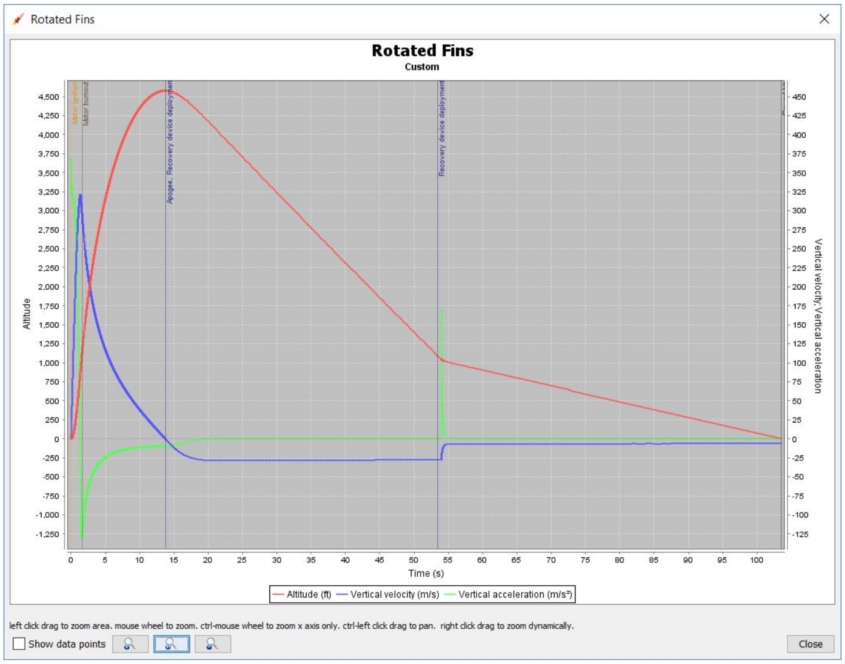

## **Analysis of Predicted Performance**

The motor selection was chosen to have a high impulse and a short burn motor burntime to maximize coast time.  In doing this, we would have the longest amount of coast time allocated to controlling the roll.

The altitude, vertical velocity, and vertical acceleration vs. time plot for the J800T-6 configuration without the roll system engaged is shown here. The maximum velocity is 340 m/s with a corresponding peak altitude is predicted to be 5,496 ft without the roll system engaged.




The altitude, vertical velocity, and vertical acceleration vs. time plot for the J800T-6 configuration with the roll system engaged is shown here.  Unfortunately, the software is unable to simulate an active roll system. Therefore, this reported altitude is the lowest altitude predicted as the roll system is engaged from the launch rail. The maximum altitude expected is 4,579 ft with a corresponding maximum velocity of 321 m/s.




## Innovation

The innovative aspect of this rocket is the roll-control mechanism which will allow us to control the rockets angular velocity. As the rocket slows nearing apogee the drag force on the actuating fin will significantly reduce so our code will be optimized to take this into account and increase the angular position of the fin according to the rockets velocity.

The drag force is the driving factor for our roll mechanism. While it provides a very effective and natural method for stabilizing and controlling the rocket's roll at high speeds, at lower speeds it will require a greater drag force to create a similar effect. This requires a dynamic system which adapts throughout the flight based on the information provided through the on-board flight monitor.

## Safety

Safety is paramount. Standard practices are reviewed and followed by all team members, such as storing & handling of electronics or materials such as paint, epoxy, etc. Ejection charges must only be handled in small amounts in well ventilated areas. The ejection charges will be tested prior to launch to ensure that all systems are behaving in a predictable manner. Throughout the last 6 months our university club advisor has provided us with bi-weekly safety meetings covering best practices ranging from preliminary construction to “rules of thumb” for the range.

One of the most important aspects is the pre-flight checklist which ensures that all systems(electronic and mechanical) are properly checked and prepared for launch. Our preliminary flight checklist is listed below:

**Recovery Systems**

[ ] Visually inspect all cords and connection points
[ ] Ensure parachute properly folded and loaded
[ ] Visually inspect ejection charges

**Electronic Systems**

[ ] Confirm 7.2V main battery
[ ] Confirm 3.3V camera battery
[ ] Visual confirmation of SD card on flight computer
[ ] Flight 1=Disconnect servo | Flight 2=visually observe servo initialization
[ ] Power on main switch in nosecone
[ ] Confirm "ready" LED on main computer
[ ] Confirm loaded position of competition altimeter
[ ] Power on GPS/recovery system controls
[ ] Turn on video capture, visually confirm power up sequence camera 1
[ ] Turn on video capture, visually confirm power up sequence camera 2
[ ] Listen for Telemetrum pad sequence “dit dah dah dit”

**Propulsion System**

[ ] Model/Type confirmed: _______
[ ] Mass:__________g
[ ] Install Motor
[ ] Ensure motor retainer fully secured

**Airframe**

[ ] Visual inspection of nosecone
[ ] Visual inspection of sheer pins
[ ] Visual inspection of fins

**Operational Items**

[ ] Secure nosecone on rocket
[ ] Capture photograph of rocket on launch pad
[ ] Continuity of ignition wires

**Budget:**

The UWRF Rocketeers team earned a $2,000 USE grant from the UWRF office of undergraduate research to subsidize the construction of the rocket.

Estimated Budget

| Item | Cost ($) |
|---|---|
| Meals | $100.00 |
| Travel | $100.00 |
| Registration Fees | $400.00 |
| Total | $600.00 |

Equipment Budget

| | | | | | |
|---|---|---|---|---|---|
| ADXL345 6DOF sensor | $39.95 | | 1 | | $39.95 |
| Power HD 1501MG high-torque servo | $19.95 | | 2 | | $39.90 |
| Power HD AR3606HB continuous rotation servo | $14.95 | | 2 | | $29.90 |
| Arduino RB-ARd35 Motor Shield Rev3 | $23.50 | | 1 | | $23.50 |
| Apogeerockets 4” 5:1 fiberglass nosecone | $39.95 | | 1 | | $39.95 |
| TeleGPS | $321.00 | | 1 | | $214.00 |
| Bluetooth module for Arduino HM10 | $16.99 | | 1 | | $16.99 |
| Subtotal | | | | | $521.19 |

Additional components are itemized in the table on the following page.

| Item | Cost ($) | Weight (g) | Qty | Unit | Total Cost |
|---|---|---|---|---|---|
| G-12 Body Tube 98 mm | $0.77 | 1824 | 152 | cm | $117.00 |
| G-12 Coupler | $20.78 | 277 | 2 | ea | $41.56 |
| Tailcone Assembly | $12.00 | 97 | 1 | ea | $12.00 |
| G-10 Sheet 1' x 1' | $28.00 | 346 | 2 | ea | $66.00 |
| Parachute | $74.65 | 75.2 | 1 | ea | $74.65 |
| Bulkhead 98mm | $6.00 | 33.1 | 5 | ea | $30.00 |
| 4" Centering Ring | $4.85 | 20.8 | 2 | ea | $9.70 |
| 2 pack of large rail guides | $10.00 | 11.2 | 1 | ea | $10.00 |
| Mobius Mini Camera | $75.00 | 28.3 | 2 | ea | $150.00 |
| Transition | $35.00 | 100.3 | 1 | ea | $35.00 |
| Eye Bolt | $0.50 | 36.2 | 3 | ea | $1.50 |
| Sheer pins | $2.95 | 1 | 2 | ea | $5.90 |
| Kevlar Harness 25' x 7/16" | $35.00 | 5/ft | 1 | ea | $35.00 |
| Jolly Logic Alt. THREE | $99.95 | 10.5 | 1 | ea | $99.95 |
| Aerotech J800T-6 | $93.00 | 1086 | 6 | ea | $558.00 |
| Total Cost | | | | | $1,246.26 |

**Team Photo:**

The following montage shows the team members. From left to right, we have, Begad Elmelligy, Roman Alvarado, Jacob Hanson-Flores, Austin Dreher, Bryce Counsellor, Andrew Larson, and Tony Caruso.  Christopher Ladas was taking the picture.