UWL Physics Rocket Team: Final Report

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Executive Summary

The goal of this year's collegiate rocket competition was to design and successfully launch a one-stage, high-powered rocket that, during its ascent, would transmit live video from a downward looking camera to a ground based receiver. In order to be considered a successful launch, the rocket was to attain an altitude near 3000 feet, electronically deploy a recovery parachute attached to all parts of the rocket, succeed in transmitting live video throughout the ascent, and safely land in a flyable condition.

To achieve these requirements, the UWL Physics Rocket Team used OpenRocket to sketch a design that best fit the specifications of the competition. After it was discovered that programs such as OpenRocket are capable of doing the brunt of the theoretical work, it was decided that the majority of the essential components of our rocket would be hand built to increase the feeling of personal accomplishment. The design of our rocket utilizes a dual deployment recovery system, with the bottom section housing a custom made motor mount, the middle section housing the electronics for recording flight data, and the top-most section housing the equipment for the recording and transmitting of live video.

Design Features

Rocket design. The design of the rocket began with meeting the requirement of lifting a payload to 3000 ft (915 m) simply and efficiently. After researching the basic elements of rocket design and construction, a single minimum diameter, dual deployment type was selected. Upon receiving the list of motors available and reviewing initial flight simulations, we found that the J357 38mm motor was best suited to reaching the target altitude. Based on the size of the video system components, a 98mm (4in) diameter blue tube airframe was chosen. The rocket design consists of four sections, the nosecone and payload bay, the main recovery bay, the flight electronics bay and the booster with drogue chute.

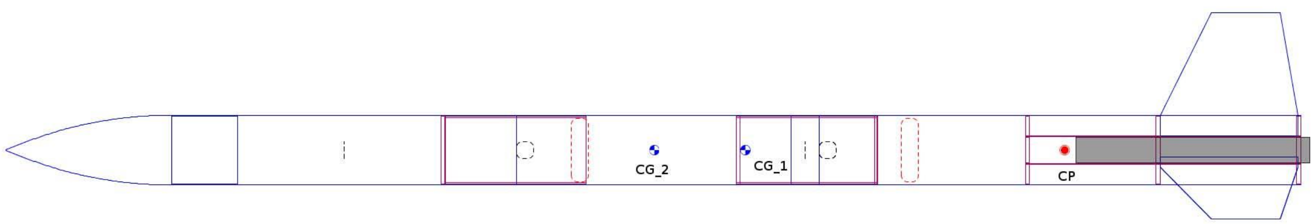
The nosecone is an ogive shape and is fastened to the airframe with removable plastic rivets. The video system is housed just below the nosecone on a removable sled constructed from 3/16 inch plywood and 1/2 inch plywood bulkheads. The payload bay uses as little metal as possible, to keep inference with the transmission antenna at a minimum. The rear bulkhead of the sled holds an eye-bolt serving as the forward attachment point of the main parachute recovery harness. The payload sled is held inside the airframe between the nosecone and a glued in blue tube coupler.

Continuing downward, the main recovery bay holds the main parachute, a Top Flight Recovery 60 in. Crossfire nylon parachute and a 9 meter 1 in. tubular nylon recovery harness. The aft attachment point for the harness is the electronics bay. The e-bay is built from a blue tube coupler and two 1/2 inch plywood bulkheads connected with 1/4 inch threaded rods. A sled for the altimeter, battery, arming switches and flight data recorder is attached to the rods. The e-bay serves as the central structure of the rocket and all components are tethered to one of the two eye-bolts located on either end of it.

The final part of the rocket is the booster section and fin can. The drogue parachute deployed at apogee is stored in the top of the booster section. The motor tube is a 40 cm long, 38 mm diameter paper tube centered with three rings. The fins are attached through the airframe wall to the motor tube with epoxy. The forward centering ring has attachments for the drogue recovery harness and the aft centering ring has threaded inserts for attaching a motor retaining ring.

Figure 1: Diagram of the Rocket

Video System Design. The video system is a commercially available system for first person view flying of radio control model aircraft. The video camera is lightweight and has a 768x480 pixel resolution. The transmitter is an 800 mW transmitter operating on 1280 MHz through an inverted vee antenna. This frequency requires an Amateur Radio license, and our control operator



for the flight was team member Joseph Krueger, KC9VUD. Operating on 1280 MHz will reduce the interference to our system compared to more commonly used bands. The 800 mW TX power output helped to ensure video quality throughout the flight. The transmitter and camera are powered by a 460 mAh lithium polymer battery. On the ground, the receiver is connected to a circularly polarized “bi-quad” antenna. This antenna was designed and built by Mike Cook, AF9Y. The circular polarization of the receiving antenna allows wide angle reception of the video signal. This allows the antenna to remain fixed and receive the rocket signal during ascent.

Construction of the Rocket

Construction of the airframe began by squaring the ends and cutting all blue tube body tubes to length using a compound miter saw. The spiral ridges in the body tubes were filled using epoxy clay. After sanding primer was applied using rattle cans. The final paint red and yellow paint will be applied last in order to protect the finish.

Bulkheads and centering rings were cut from 1/2 inch plywood using a plunge base router and circle guide. The holes for the motor tube were drilled using a 1 5/8 inch forstner bit in a drill press. This proved to be a perfect fit for the 38mm tube. The fins and electronics sleds were cut using a jigsaw from 3/16 inch plywood and assembled with epoxy and wood glue.

One of the more technically challenging aspects of the build were the through-the-wall fin slots. The slots were cut using the plunge base router and a purpose build jig to hold the body tube. To assemble the fins and motor mount the fore and mid centering rings were epoxied to the motor tube and then epoxied into the body tube. The fins were aligned through the slots and held by hardboard cutouts while epoxy was dripped down the internal joints. After the fins were cured the aft ring was installed onto the motor mount completing the assembly of the booster section. The external fin joints were filled with epoxy clay to blend the airframe and the fins together for painting. The plywood bulkhead, rings and fins that we built are similar materials to those from rocketry suppliers.

Analysis of Performance
Before flight, simulations were made using OpenRocket to determine anticipated flight performance of the rocket. The center of gravity for with no motor loaded in was predicted to be located at the middle of the rocket, 95 cm from the nose. The CG with motor installed is 106 cm from the nose. The calculated center of pressure is 154 cm from the nose. Flight simulations using these values and measured data of the rocket predict an apogee of 835 m (2740 ft), maximum acceleration of 114 m/s^2 and a maximum velocity of 142 m/s (Mach 0.42). The time to apogee was predicted to be 13 seconds with landing following at 100 seconds. The rear drogue parachute will be deployed at apogee by the altimeter and the main parachute will be deployed at 250 m.

These calculations did not account for various factors such as wind speed and high humidity, and the fact that the final mass of our rocket was higher than the designed mass. Most of the unaccounted for mass came from a change in material of our main recovery harness, which added just under a kilogram of mass to our final design. Due to these factors, our apogee was recorded at just over 2060 feet as opposed to the 2740 feet we predicted before the launch. Our time to apogee was 13.5 seconds, with a time to landing following at 113 seconds. Both our main and rear drogue parachutes were deployed at apogee. The rocket was recovered in flyable condition; the only damage sustained was to our drogue parachute, which had been damaged by the backup charge. Our video system performed admirably, with only minor cutoffs of our video feed during ascent. Any cutoffs were symptoms of the fact that the low cloud ceiling the day of launch obscured our view of the rocket, which meant that when the wind caught it and moved it outside the predicted launch path, we were unable to reposition the receiving antenna to maximize the signal (because we were unaware that the shift in location had happened).

Conclusion
Due to our relatively simple rocket design, coupled with a reliable video system, we were able to outcompete the other Wisconsin teams. This was our first foray into rocketry, and having completed the competition we feel that we have learned many valuable lessons about the subject. This year we crafted our rocket out of Bluetube body tubing, without the knowledge that this material has a history of swelling up in humid environments and thus hindering flight performance on days such as our own launch day. We learned that it is better to design your rocket to attain a final apogee above the desired limit, because there will always be factors you cannot account for. This combined with newly attained knowledge of more efficient design features will hopefully culminate in a more efficient rocket design in future competitions.