Flight Readiness Report

University of Wisconsin-River Falls Rocketeers

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Table of Contents: **Page:**

Recap of Rocket Design:

Overview of Rocket Design

The rocket measures 168 cm long, 10.1 cm diameter, and 4800 g. The rocket requires an extensive amount of drag to successfully complete the competition, achieving the same altitude with the more powerful Aerotech K1100T-L motor as with the less powerful Aerotech J135W-L motor. The airframe flap mechanism, seen in Figure 1, consists of a unique sleeve system that folds up as it contracts in order to fold out the drag flaps securely. The mechanism is able to adjust the extent of folding which then adjusts the amount of drag as the angle-of-attack with the wind changes. The airframe flaps are approximately 42 sq.cm each so that six flaps will provide sufficient area to more than double the effective drag, depending on how long they are deployed.

Figure 1: Inner motor mount section (black, left) and outer drag system sleeve (red, right) prior to installation.

Airframe & Drag System

The main body tube is made of G12 fiberglass with deployable flaps controlled by a small high-torque servo commonly used in robotics. The flap mechanism is 23.5 cm long and fits entirely over the airframe, installed such that it folds upward from the bottom, with the top fixed. Initially, we considered having it fold downward from the top, with the bottom fixed, so that the wind would assist during compression, but our tests showed this was not necessary. Each flap is 7.7 cm x 5.4 cm and is reinforced with a wide nylon strap. When deployed, the flaps significantly increase drag causing dramatic negative acceleration. The rocket is equipped with both upward and downward facing Mobius Mini-Cameras to be sure to capture full operation of the mechanism as well as drogue and main chute deployments.

Recovery System

The rocket incorporates a dual deployment system, controlled by the TeleGPS, consisting of a drogue and single main parachute. The drogue is a 30” Fruity Chutes elliptical design, weighing 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 a 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 are secured with 1500 lb. test Kevlar cord attached to bulkhead with welded eyelets.

Propulsion System

The “low power” propulsion system consists of an Aerotech J135W-L motor, which is 1141 g overall with 633 g of propellant providing an average thrust of 157 N (maximum 274 N). The burn lasts 6.8 sec for a total impulse of 1069 N*s. The “high power” motor is an Aerotech K1100T-L, weighing 1336 g overall with 773 g of propellant providing an average thrust of 1100 N (maximum 2004 N). Its burn lasts for 1.6 seconds, providing a total impulse of 1472 N*s. The delay of each motor is adjusted to provide a backup to drogue parachute deployment approximately 1.5 sec after apogee.

Avionics/Payload System

An Arduino Uno controls the servo motor with the aid of an altimeter. The use of an Altus Metrum TeleGPS is used for mapping the 3D flight profile and dual deployment of parachutes as well as barometric pressure, accelerometer, altimeter and 70cm ham-band transceiver. In addition, a 9 degree-of-freedom Inertial Measuring Unit will measure the rocket’s full 3-D orientation 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.

Rocket Operation Assessment:

On 6 March, 2017, we were able to test launch our rocket with each motor, first with the Aerotech K1100T-L and second with the Aerotech J135W-L. On this day we found that our predictions were fairly accurate. However, the outcome of our second launch required some minor repairs that have since taken place.

The first launch in the higher-power configuration using the K1100T-L with went very well, flying straight and stable to a height of 4330 feet with the drag system deployed via a timed sequence. The expected height without the drag system was 8000 feet, meaning we achieved an altitude reduction of 46%, close to our goal of 50%. The drogue shoot didn't deploy properly as the protective cloth cover was not secured properly and slid up along the shock cord and up the parachute lines making it unable to open, but the main parachute deployed as expected at 500 feet for a smooth touchdown at 23 ft/s only 400 yards southwest of the launch site.

The second launch in the relatively low-risk low-power configuration using the J135W-L motor with the drag system de-activated turned out to be more eventful than expected. We were missing the proper forward sealing cap in our bin of motor mount tube adapter hardware, so we improvised by removing part of the delay so that it would fit properly in the motor casing with spacer and forward closure extended. We decided to rely (for this test launch only) on the altimeter triggered apogee deployment of the drogue parachute without using the motor backup. We were not worried since our first launch was recovered successfully at higher altitude when the drogue failed to open. Unfortunately, we did not communicate this decision well enough and the black powder for the delay charges was mistakenly loaded into the top of the motor casing during final assembly. The flight went perfectly for several seconds, straight and stable as the slow-burning motor lifted the rocket higher and higher, until near burnout when the improperly, insufficiently, delayed backup charge went off and ejected the drogue at high speed, resulting in both parachutes separating completely from the main body, leaving the tail section and electronics section in freefall.

The durability of the design paid off. The fiberglass tubes suffered only a small fracture where the shock cord tried to zipper the lower section, which has since been patched with fiberglass resin and sanded smooth. The lower bulkhead centering-ring above the motor mount with the welded eyelet that secured the lower shock cord pulled completely, but cleanly, out of the lower section. A new centering-ring bulkhead with welded eyelet was epoxied in place in the lower section, as seen in Figure 2. The fins were undamaged, thanks to the strong fiberglass and soft sod landing even at such high speed.

Figure 2: Repaired fiberglass main tube (left) and centering ring bulkhead drogue-parachute attachment (right)

The electronics was unharmed, but the 3D printed electronics bay designed to fit snuggly up inside the nosecone and connect the nosecone to the main tube has cracked upon ground impact, so this was reprinted. The upper section with the drag mechanism upon recovery (partially compressed since the retraction mechanism had released). These components are shows in Figure 3.

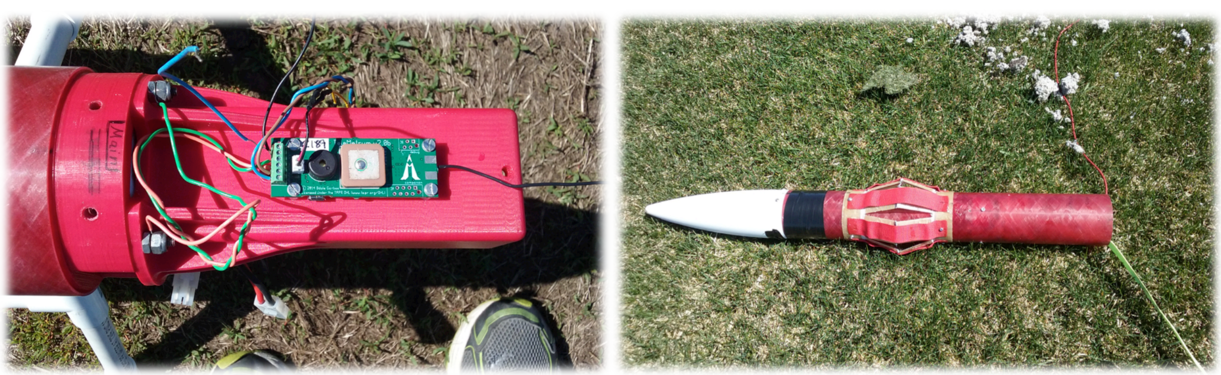

Figure 3: 3D printed electronics bay (left) and upper section with drag mechanism (right) upon recovery after the first test flight.

Figure 4: Repaired rocket, in need of a little cleaning & painting, getting ready to fly.

The center-of-gravity measures 98 cm from the tip with the motor prior to ignition, and 85 cm from the tip after all propellant has burnt away. The center-of-pressure without flaps deployed is located 107 cm from the tip, giving a stability margin of 2.2 to 0.90 so we may add a little weight in the nosecone even though test flights were stable.

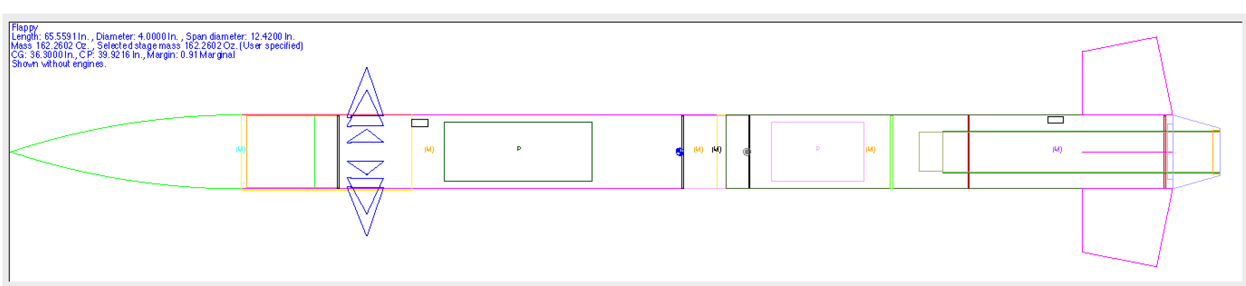

Figure 5: Rocket setup for one of many RockSim simulations

Test Launch Actual vs. Predicted Performance:

The actual performance is shown in this graph of data from the AltusMetrum GPS altimeter, reaching an altitude of approximately 1320 m, with a top speed of 224 m/s and maximum acceleration of 190 m/s^2.

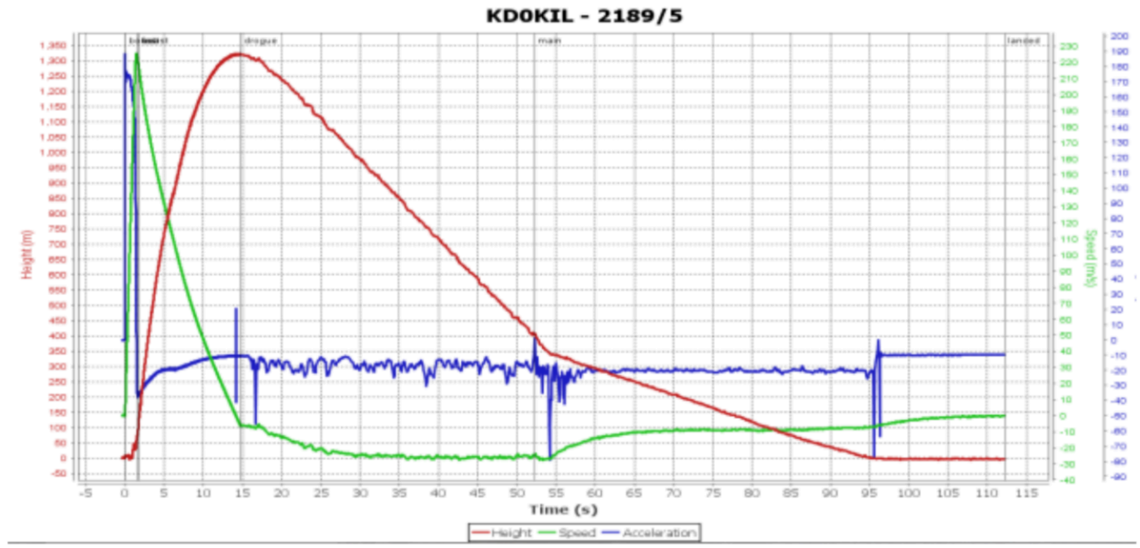

Figure 6: Test flight data from AltusMetrum GPS altimeter

The motor selection was chosen so that the higher power motor configuration would reach twice the altitude if there were no drag system. The peak altitude with the K1100 is predicted to be 6260 ft and the peak altitude with the J135 is 3139 ft, without drag deployed, which is in fact 50.0% of the more powerful engine.

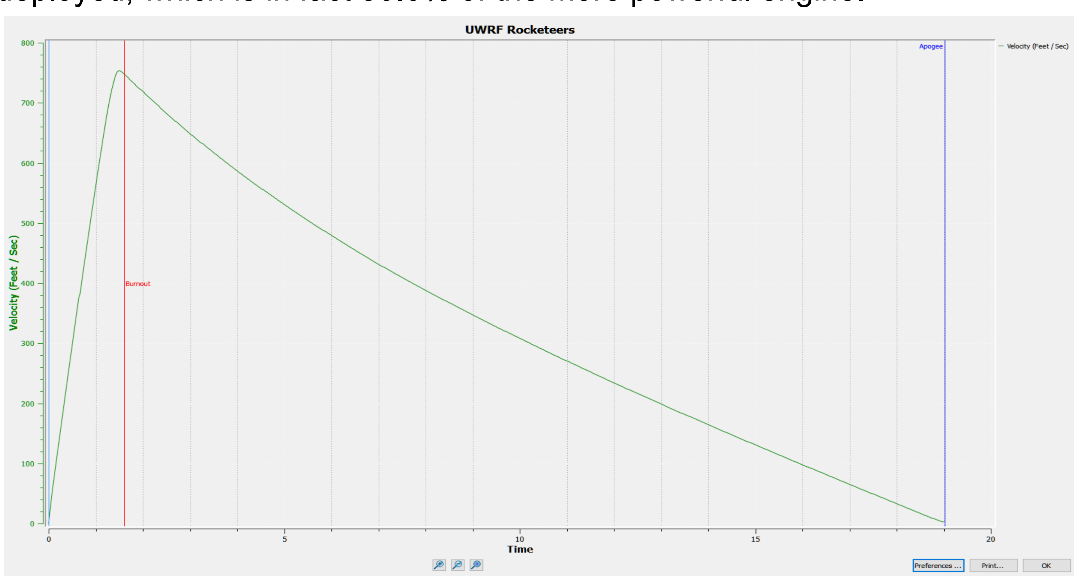

Figure 7: Predicted flight data showing a maximum speed of 740 ft/sec which is precisely what was achieved in the test flight, 224 m/s.

Findings and Future Work:

Reviewing video showed the drag system able to withstand the high speed winds encountered, so for the competition flight we plan to initiate deployment of the drag system up to one second earlier to decrease the velocity sooner after burnout in order to reduce the peak altitude to precisely whatever altitude is reached during the first launch that day using the lower power motor. This should enable a reduction in altitude closer to 3000 ft if the low power motor tops out in that range.

Test launches were extremely helpful in teaching all of us the importance of communication, packing of adequate launch supplies (parachute packing, ematches for black-powder canisters, accessory power outlet, wiring, tools, voltmeter), having a checklist for launch preparation and launchpad configuration (expected altimeter sounds for dual-deployment continuity and flight ready), motor assembly (grease, o-rings, delay charge setup), charging batteries, etc.