Flight Readiness Review Addendum: Full-Scale Re-Flight

Roll Induction and Counter Roll

2016-2017 NASA University Student Launch

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Introduction

The Charger Rocket Works (CRW) Team conducted a re-flight of the full-scale rocket on March 19, 2017 in Manchester TN. The primary purpose of this launch was to prove that a new parachute, a Fruity Chute 144" Iris Ultra Compact, allows the rocket to meet the landing kinetic energy requirements for the NASA Student Launch competition. In addition to validating the flight kinetic energies, the re-flight also provided an opportunity for further testing of the roll induction and counter roll payload and further practice with assembly and flight preparation.

Figure 1: CRW Team – Re-Flight Launch

Launch Conditions

The configuration of the vehicle for the re-flight was in the same configuration as both full-scale flights discussed in the Flight Readiness Review, with the exception of the motor and the main parachute.

Figure 2: Viserion during Ascent Phase

The wind speed reached 10 mph on launch day so the CRW team chose to fly on an Aerotech K1000 due to drift concerns instead of the competition motor, Aerotech L2200. The RMS-75-5120 hardware initially purchased for the L2200 (4 grain) motor was utilized for the 2-grain motor with the addition of a grain spacer. This resulted in a lower wet mass of the vehicle, but the burnout mass was equivalent to the final configuration.

Figure 2 shows the re-flight ascent phase. The newly selected Fruity Chute 144" Iris Ultra Compact parachute is shown fully deployed in the vehicles descent phase just before impact in Figure 3.

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Figure 3: Descent Phase

Measured flight data is presented in Figure 4. The vehicle reaches an apogee of 1031 feet with drogue deployment at apogee. Terminal velocity under main occurred at approximately 300 ft AGL and slowly descended to the ground at a velocity of 12.3 ft/s.

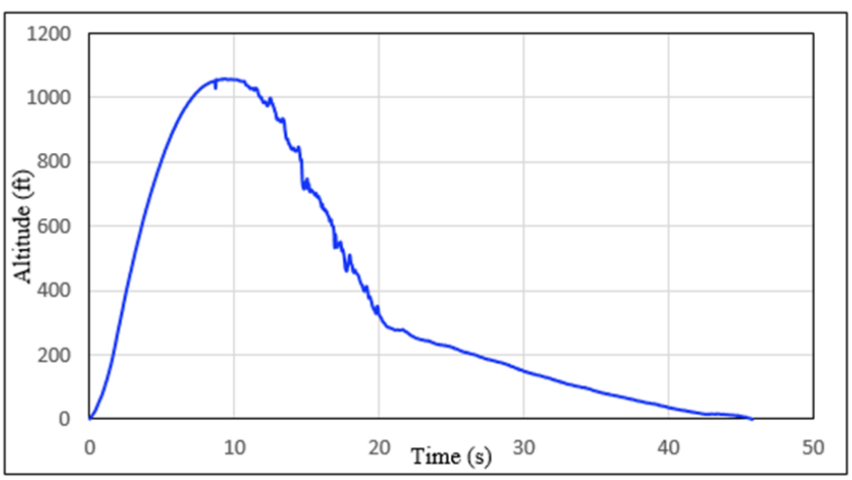

Figure 4: Re-flight Launch Data

Flight Results

While use of the smaller motor allowed for a successful verification of the recovery system and kinetic energy requirements. While the smaller motor allowed for a successful recovery system test, and kinetic energy requirement verification, it should be noted that the flight deviates from the full-scale competition flight predictions and those deviations are depicted in Table 1. It should also be restated that there is a 2.9 pound delta of wet mass between the full-scale re-flight and final vehicle configuration. This is only due to the mass of the propellant and both configurations have a wet mass of approximately 47 pounds with some uncertainty allotted for propellant variation and mass of the spacer. Because a full-scale flight with the competition motor has been conducted, these flight deviations were not considered to be significant for the recovery system test on the re-flight.

Table 1: Flight Characteristics

	Full-Scale Re-Flight	Final Prediction
Wet Mass (lb)	50.2	52.7
Stability Margin (off the rail)	2.33	2.16
Max Velocity (ft/s)	286	636
Velocity off the rail (ft/s)	56.1	74.1
Max Acceleration	135	407
Apogee (ft)	1031	5278

Assessment of New Main Parachute

In the two full-scale flights conducted prior to Flight Readiness Review (FRR), the recovery systems used resulted in safe and controlled recovery descents. Because of vehicle mass, the terminal velocity under the main parachute produced kinetic energy values that exceeded the maximum allowable value for the NASA Student Launch competition. To reduce the terminal velocity under main, a new main parachute was selected prior to the Flight Readiness Review and discussed in detail in the document itself.

The parachute selected and presented in the Critical Design Review (CDR) was a SkyAngle Cert-3 XL. Table 2 provides a summary of the landing velocity and kinetic energies of the three sections of the rocket from the first full-scale flight. Under the SkyAngle Cert-3 XL, the rocket had a landing velocity of 17.2 ft/s and had a maximum kinetic energy at landing of 110 ft-lbf.

Table 2: Landing Velocity and Kinetic energies under the SkyAngle Cert-3 XL

Section	Nose Cone	Upper Airframe	Lower Airframe
Mass (lb)	5.03	10.78	23.93
Velocity (ft/s)	17.2	17.2	17.2
KE (ft-lbf)	23.11	49.52	109.93

Because the kinetic energy at landing obtained from the full-scale flight exceeded the 75 ft-lbf NASA requirement, the SkyAngle parachute was replaced with a Fruity Chute 144" Iris Ultra Compact. The Fruity Chute 144" Iris Ultra Compact was flown on the full-scale re-flight. During the descent phase, the rocket body descended at a slow and controlled rate. Flight data was analyzed post-recovery to determine the terminal velocity and kinetic energies under drogue and main. Table 3 displays the terminal velocity and kinetic energies under drogue while Table 4 displays the terminal velocity and kinetic energies under main. As shown in the tables, the terminal velocity under the Fruity Chute parachute was found to be 12.3 ft/s, producing a maximum kinetic energy at landing of 59 ft-lbf, meeting than the NASA SL kinetic energy at impact requirement.

Table 3: Landing Velocity and Kinetic energies under the Drogue Parachute

Section	Nose Cone/Upper	Lower Airframe
Mass (lb)	18.11	25.25
Velocity (ft/s)	58.31	58.31
KE (ft-lbf)	955.87	1333.10

Table 4: Landing Velocity and Kinetic energies under the Fruity Chute 144" Iris Ultra Compact

Section	Nose Cone	Upper Airframe	Lower Airframe
Mass (lb)	5.8	12.31	25.25
Velocity (ft/s)	12.3	12.3	12.3
KE (ft-lbf)	13.63	28.92	59.32

The flight data from the re-flight was plotted and the terminal velocities are shown in Figure 5. It can be seen that there is a significant deceleration when the main is deployed, which results in the terminal velocity needed to meet kinetic energy requirements.

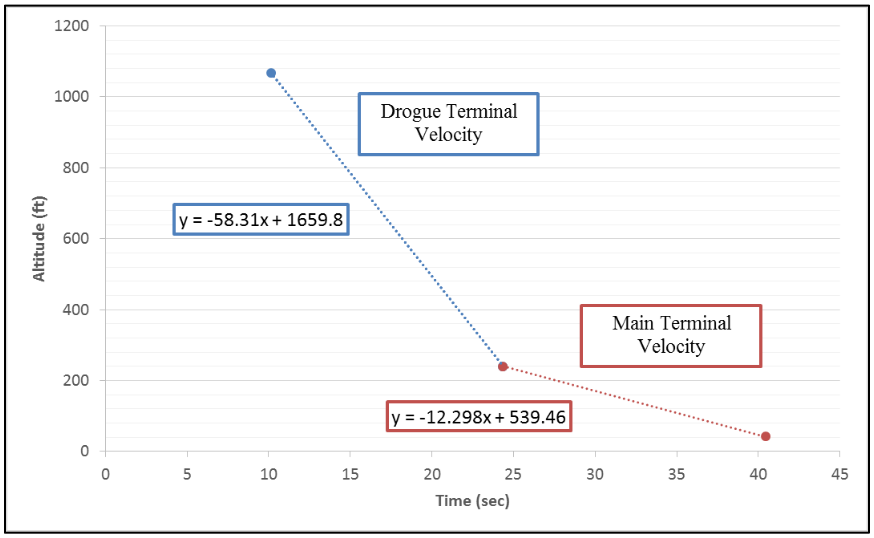

Figure 5: Terminal Velocities

The drift distance can be seen below in Figure 6, with a net drift of 703.46 ft.

Figure 6: Drift Distance

Conclusions

In summary, the re-flight conducted on March 19 met all flight objectives identified in the FRR. The CRW team achieved FRR-predicted values for velocity and kinetic energy at impact, with a maximum kinetic energy at impact of 59.32 ft-lbf. The fruity-chute parachute was successfully deployed via the same configuration discussed in FRR, resulting in a kinetic energy at impact that meets the NASA Student Launch requirement of less than 75 ft-lbf.