Post-Flight Performance Report

Roaring Lions

Normandale Community College

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Executive Summary

On May 22nd, 2017 at the Space Grant Midwest High-Power Rocket Competition we, the Normandale Community College “Roaring Lions” rocket team, successfully flew our high powered rocket twice back to back with two different engines. We successfully recorded apogee on our competition provided Altimeter Two and our dual Stratologgers. Downward facing video of our first flight was recorded and shows a stable and vertical trajectory as well as our drogue and main parachute deployment events. The rocket was safely recovered after the first flight with no damage, and was launched and recovered successfully again the same day. Due to a wiring failure our velocity data was not recorded on our data collection package and our air brake lacked the essential information to deploy. Our rocket reached an apogee of 2686 ft on the first flight using an Aerotech J825R and 3926 ft on our second flight using an Aerotech K185W. Our apogees were close to our predicted values although, the first flight was under the competition floor of 3000 ft. During both flights our drogue parachute deployed at apogee and our main parachute deployed at 700 ft. Our rocket was recovered after both flights from nearby farm fields, less than 1 km from the launch pad, and our data was promptly given to the RSO. In the end our rocket flew beautifully but lacked its crucial data collection and air brake abilities.

Rocket Operation Assessment

Flight Anomalies Analysis

The main anomaly during our flights was a wiring failure between data acquisition and deployment of the active drag mechanism. As described in our Flight Readiness Report, we fabricated a nose cone that would house a pitot tube sensor, transmit data to our avionics bay, and deploy the braking mechanism appropriately. On launch day, the braking mechanism would deploy when the avionics bay was removed from the rocket, but would not deploy when the rocket was put together. After designing and building the avionics bay, we failed to realize how critical it was to have a robust design that minimizes the movement of wires and maximizes the ease of use when it comes to rewiring ejection charges, replacing batteries, and reprogramming the microcontroller. Without this design philosophy in mind, we were subject to errors that were hard to diagnose and resolve out in the field.

Another important anomaly was found after launch day. After testing the electronics, we found that the pitot tube sensor was no longer working. The pitot tube sensor was working before the launch date, but an impact after our first launch could have damaged the sensor or lodged debris in the sensor.

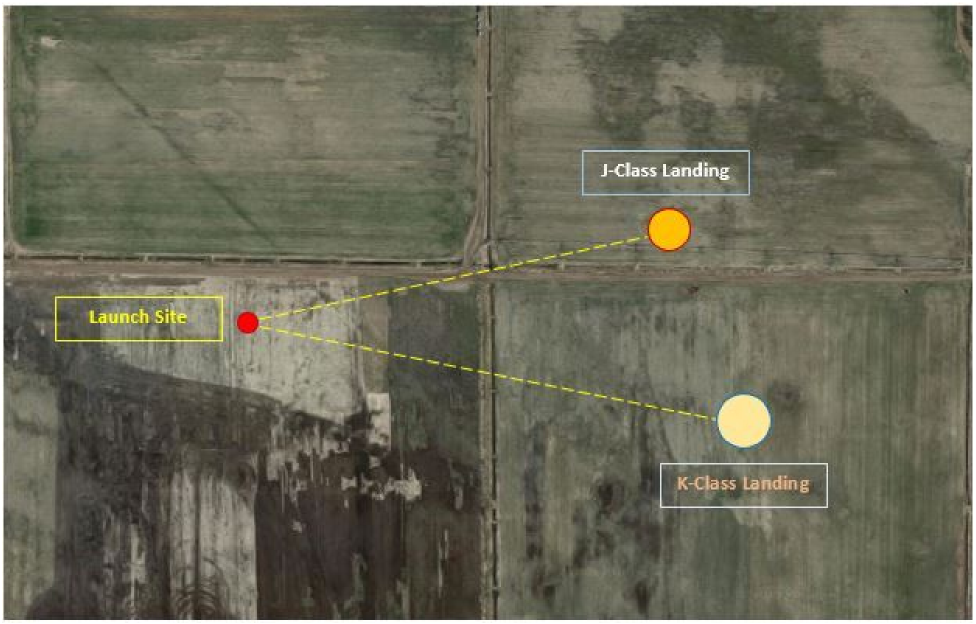
Propulsion System Assessment

Our rockets propulsion system acted very similar to our open rocket simulations. The burn time of our J motor was only 0.02 seconds shorter than advertised and the acceleration and velocity were not far off from the simulated values shown in the table below. The burn time with our K motor was almost 2 seconds off the advertised burn, although we believe the stratologgers gave inaccurate burn time data. The competition provided altimeter two gave values very close to the advertised burn.

Criterion	**Expected** (J825R)	**Actual** (J825R)	**Expected** (K185W)	**Actual** (K185W)
Burn time (sec.)	1.2	1.18	6.9	5.05
Max. accel. (G)	18.7	18	4.8	3.34
Max. velocity (ft/s)	520	515	474	461

Flight Trajectory Assessment

Our J825 propelled our rocket vertically and with little roll. After reviewing downward facing video, we can see the rocket rolled about 1.5 times and stayed almost straight up from the launch pad. After the drogue parachute deployed, the rocket began drifting east and once the main parachute deployed the rocket fell with little drift. Our next flight with the K185 took off vertically and began to slant <5 degrees south. Once the drogue parachute deployed the rocket began drifting to the east and once the main parachute opened the rocket drifted slightly further east.



In flight Recovery Assessment

Throughout both flights our recovery system operated flawlessly. Our dual stratologgers (SLs) fired all charges starting with the drogue at apogee each flight. Two seconds after the drogue chute had deployed our backup motor ejection charge fired. The SLs were set to fire the main chute charges at 700 ft each flight. Our SLs recorded firing the charges at 700 ft although, the main chute opened around two seconds later. All and all our recovery system operated as expected throughout the entire flight.

Ground Recovery Assessment

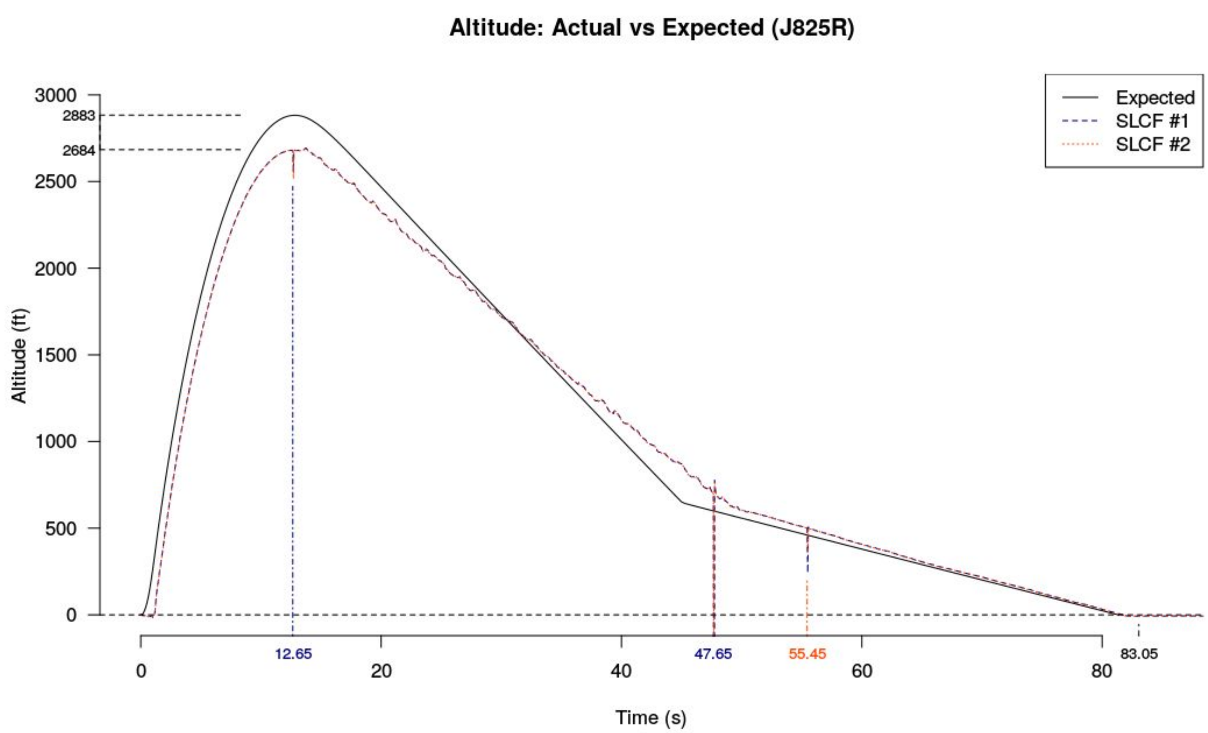
During the Competition launches the GRA (Ground Recovery Assessment) consisted of multi-step procedure. First, after the rocket successfully deployed the drogue and the main parachute, the team waited until the rocket would safely land on the ground. Second, the team walked over to the landing zone, making sure to take the shortest path to the landing zone to minimize the damage to planted crops on the field. Third, once at the landing zone, one of the members proceeded to turn off both of the avionics switches. Fourth, all ejection charges were checked to confirm no live charges remained. Fifth, the recovery team took several pictures of the landing zone as well as the position/orientation of the rocket's fully deployed recovery system, while making sure to not touching anything. Once the pictures were taken of the landing zone, the team proceeded to taking individual pictures of each section of the rocket. The sixth step was to go through post flight checklist, marking off every step. Once finished, the rocket was picked up from the ground and was carried to the post flight check in table to record the previous achieved apogee.

Actual vs Predicted Performance

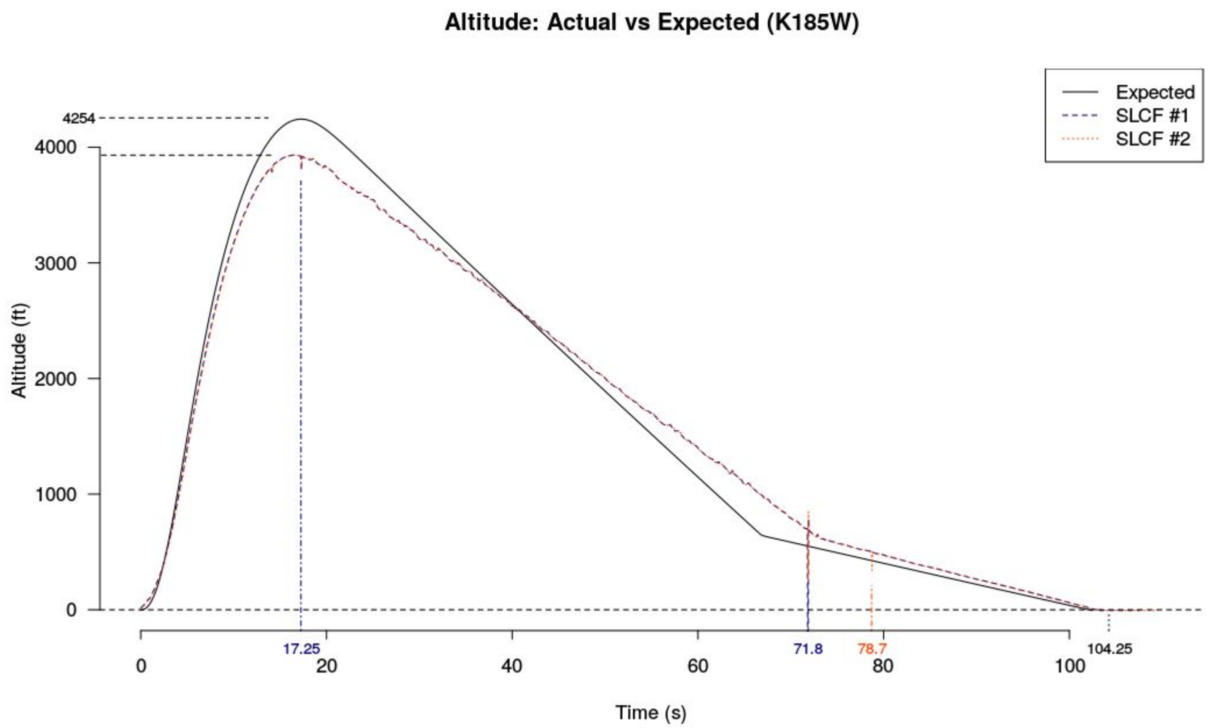
For our performance predictions, we used OpenRocket to simulate the flight and, overall, our actual performance was similar to our predicted performance, but there are improvements to be made in several areas. Mainly, these areas of improvement are velocity achievement and drogue chute effectiveness.

Peak Altitude Comparison to Expectations

The rocket, Norman, underperformed in terms of altitude by 199 ft with the J825R as shown in the following graph. Also, the with only the drogue deployed the rocket descended at 59.75 ft/s, but in simulation, it was 71.8 ft/s, which lead to an earlier deployment of the main chute in the simulations.

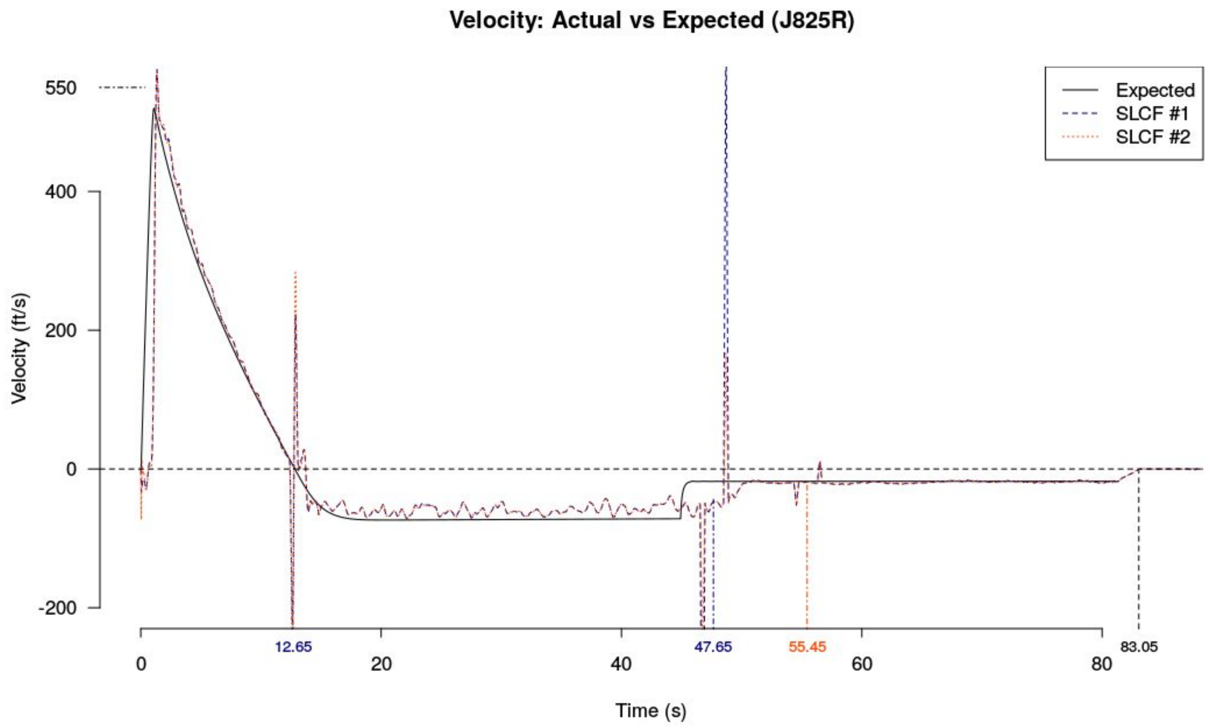


In our next graph of altitude of the K185W, we can see Norman again underperformed in altitude with our predicted apogee of 4254 ft, and our recorded altitude was 3931 ft. Here, we predicted our drogue chute to slow us to a speed of 71.8 ft/s, but our measured velocity was 60.4 ft/s.

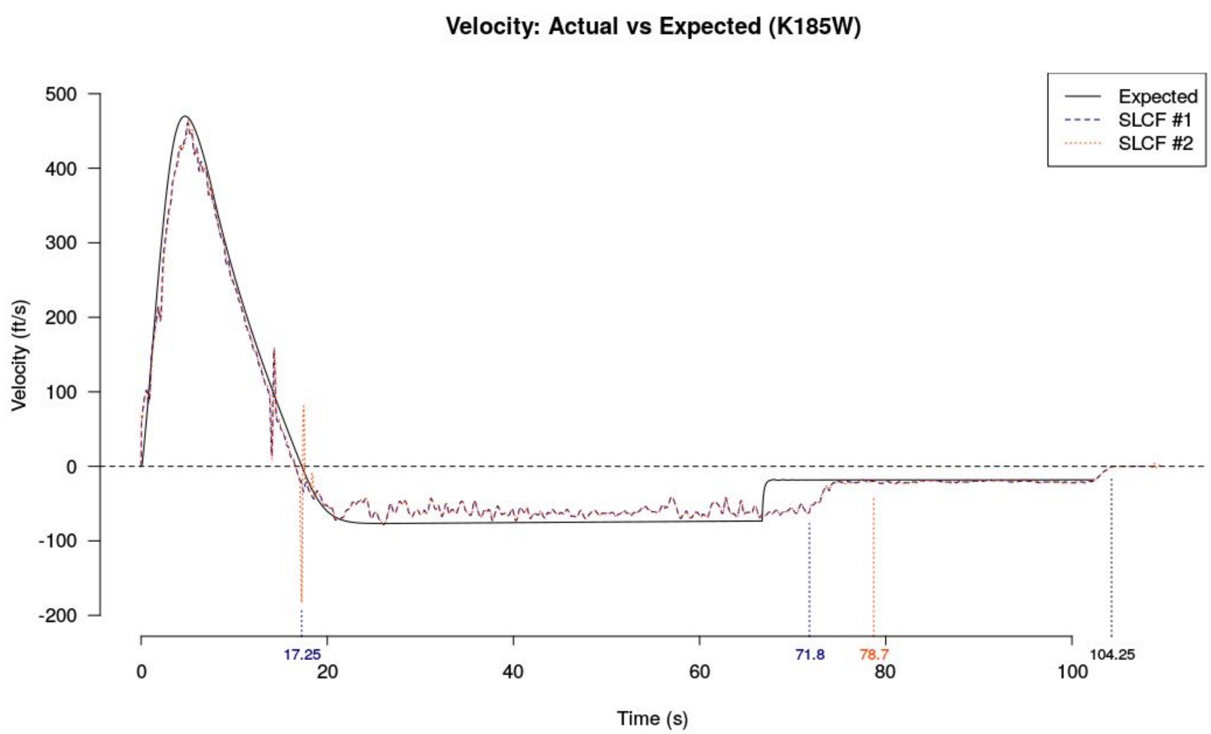


Velocity and Acceleration Comparison to Expectation

Our stratologgers (SLs) recorded data shows similar peak velocity and peak acceleration to our simulated data. The peak velocity with our J825R was 576 ft/s but our expected velocity was 520 ft/s. These values are within our margin of error considering our altimeter two recorded 515 ft/s on the same flight. The peak acceleration with our J825 was 18 Gs, 0.7 Gs less than our predicted value but this could be due to the 10% deviation between rocket motors. With our K185 motor our peak velocity was 461 ft/s where our predicted value was 474 ft/s though, this difference may be due to additional drag not included in our open rocket simulations. The K185 peak acceleration was 3.34 Gs much less than our predicted value. We believe the variance may be due to the additional drag induced by our external camera housings.



For the K185W flight, because of technical difficulties, we didn't deploy the braking mechanism. Then, using OpenRocket, we expected a max velocity of 474 ft/s and the SLs recorded 461 ft/s.



Velocity vs Time Data Collection and Comparison to Expectations

We're unable to compare measured to expected data from our pitot tube measurements because our data collection system failed at launch. When we activated the avionics on the launch pad for the J825, the LED signalling a status update of the rocket indicated a power failure of the Arduino Nano. Although there would be no data collected during launch, the recovery system was functioning properly, so, upon discussion, it was decided to launch anyway and we would try again with the next launch. But as fate would have it, our nosecone sensor was damaged on the first launch and without it were unable to deploy the air brake or collect data for the second launch.

Recovery System Analysis

Deployment Monitoring Data

The day before launch, we found one of our camera batteries had failed and it was too late to replace it. For this reason, we had only one camera operational during the first launch, and we chose to have it facing aft. What follows are screenshots taken from the video recorded by this functioning camera and a link to the full video from the J825 launch. Then just before the second launch, the last camera failed as well, leaving us with only the moments before the launch.

Another system we put in place to detect the deployment of the main and drogue parachute were copper contacts placed at sections of the rocket that were designed to separate in flight. The Arduino would then log the time of separation. Due to a communication failure with the Arduino, the data was never logged during the first flight and skipped on the second flight.

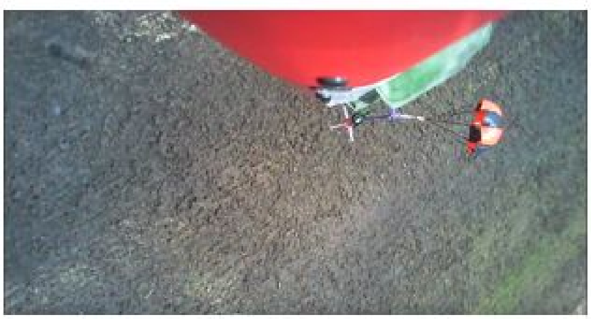
Up/Down Video Images and Links to Posted Flight Videos

Launch

Drogue Ejection

Drogue Deployment

Main Deployment



Touch Down

Onboard video link: http://bit.ly/2rD3PRQ

Pre and Post-Launch Procedure

<u>Pre-Flight Checklist</u>

Avionics

- ❏ Visually inspect rocket
- ❏ Inspect all wiring and connections
- ❏ Test power supply
- ❏ Connect power supply to electronics
- ❏ Inspect Pitot tube and altimeters
- ❏ Secure main parachute bay to avionics bay with bolts

Main Parachute

- ❏ Inspect main parachute (ensure there are no holes or tears)
- ❏ Inspect shock cord, eyebolts, and Nomex blankets
- ❏ Insert primary black powder charge (2.1 g) with e-match
- ❏ Insert Secondary black powder charge (2.52 g) with e-match
- ❏ Prepare and pack main parachute into main chute bay
- ❏ Secure nosecone to the main bay with the 4 plastic shear pins
    - ❏ Ensure there is a connection between the two contact leads

Drogue Parachute

- ❏ Inspect drogue parachute (ensure there are no holes or tears)
- ❏ Inspect drogue shock cord, eyebolts, and Nomex blankets
- ❏ Insert black powder charge (2.1 g) with e-match
- ❏ Prepare and pack drogue parachute into the drogue chute bay of the tail section
- ❏ Press fit tail section to avionics section

Motor

- ❏ Assemble motor
    - ❏ Type___________________, Mass______________________
- ❏ Insert motor into the rocket
- ❏ Ensure that it is secure

Final visualization

- ❏ Ensure there is no damage
- ❏ Ensure all section connections are secure
- ❏ Ensure motor is secure
- ❏ Ensure camera is on and secure

Launch

- ❏ Maintain visualization of rocket
- ❏ Take pictures

<u>Launchpad Checklist</u>

Cameras

- ❏ Inspect cameras and mounts
- ❏ Turn on cameras (listen for beeps and look for flashing light for confirmation)
    - ❏ Camera #1
    - ❏ Camera #2
- ❏ Securely mount cameras (ensure that they won't come loose)

Avionics

- ❏ Turn altimeter #1 on (listen for confirmation)
- ❏ Turn altimeter #2 on (listen for confirmation)

Motor

- ❏ Insert E-match
- ❏ Test for continuity

<u>Post-Flight Checklist</u>

- ❏ Locate Norman
- ❏ Take pictures of landing site and rocket
- ❏ Inspect rocket for damage
- ❏ Cover Pitot tube hole
- ❏ Turn off altimeters
    - ❏ Altimeter #1
    - ❏ Altimeter #2
- ❏ Remove cameras from rocket
- ❏ Turn off cameras
    - ❏ Camera #1
    - ❏ Camera #2
- ❏ Disconnect power supply
- ❏ Retrieve flight data
- ❏ Record empty mass of motor

Sponsors

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