TEAM WHOOSH GENERATOR

Post-Flight Performance Report

2016 NASA's SPACE GRANT MIDWEST HIGH POWER ROCKET COMPETITION

MILWAUKEE SCHOOL OF ENGINEERING

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ASSESSMENT OF ROCKET OPERATION

The rocket designed and built by Team Whoosh Generator for the 2016 Space Grant Midwest High-Power Rocketry Competition had two successful competition launches on May 16th, 2016. The rocket reached an apogee of 5177 feet on its first, non-drag system flight. The flight with the drag system engaged obtained at apogee of 4886 feet, which was a 5.6% reduction in apogee. The apogee was far from the desired 25% due to malfunction in the drag system. The rocket was recovered safely and in flyable condition after both launches.

Propulsion and Flight Path Assessment

The propulsion system chosen for the flight was the Cesaroni K570. The motor's expected burn time was 3.6 seconds. The motor actually burned for 3.61 seconds and 3.31 seconds for the first and second flights, respectively. The total impulse of the two motors was compared using the data form the accelerometer. The total impulse for the first launch was 1992 N·s and the total impulse for the second launch was 1935 N·s. Although the total impulses of the two motors were very close, they burned very differently. Below are the thrust curve charts for each launch that were calculated from the accelerometer data.

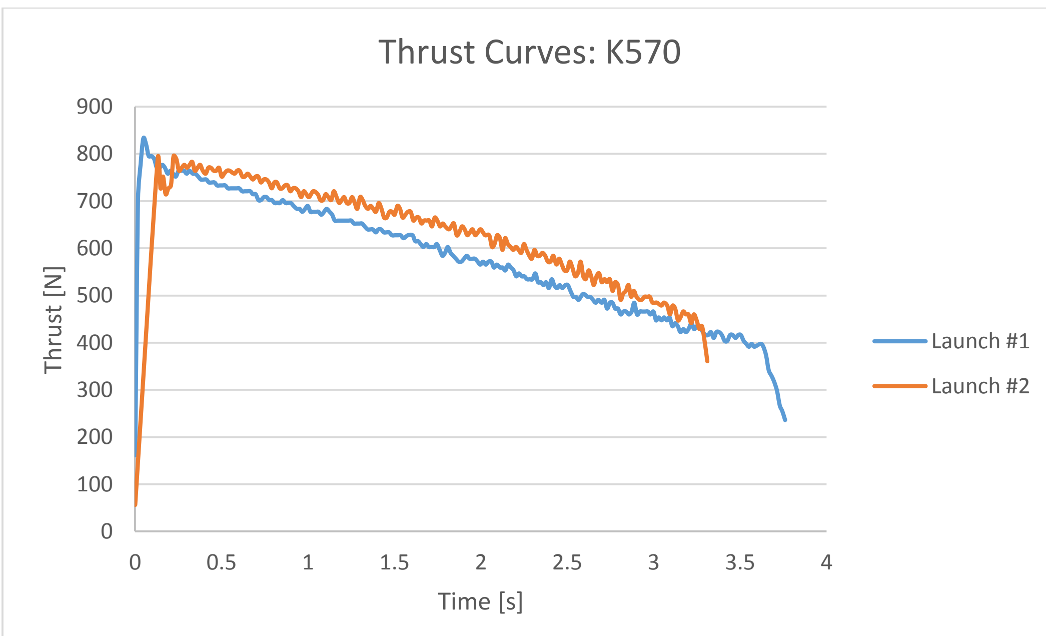

Figure 1: Calculated thrust curves for both launches.

As can be observed, the first launch appears to have a much lower average thrust than the second launch. This was confirmed through analysis of the collected data as the first launch had a calculated average thrust of 575 newtons as opposed to the second launch which had an average thrust of 636 newtons, a 10.2% difference.

The rocket's flight path for the both launches was stable. In the first flight, the rocket angled slightly immediately after it left the launch pad, but then remained on a straight flight path. It appeared that wind was the cause of this misdirection. This did not occur on the second launch when the winds were calmer, and the rocket flew nearly vertical. This flight path difference could have had a slight effect on our final altitude numbers, hurting our drag system percentage decrease.

In Flight and Ground Recovery Assessment

The rocket's recovery system was dual deployment consisting of drogue and main parachutes. The chutes were deployed using black powder charges fired by an ALTS25 altimeter. The drogue chute deployed successfully at apogee and the main chute deployed successfully at 600 feet. The drogue chute also was backed up by a motor ejection charge, but this was not needed. The parachutes were attached to the rocket using Kevlar shock cord attached to U bolts. It is advised to size the shock cords to be 3-5 times the rocket's total length, so each shock cord was sized to be 20 feet long. This sizing worked well as no zippering occurred. To locate the rocket once it reached the ground, a Whistle GPS pet tracker was mounted in the altimeter bay. The rocket's location was successfully tracked throughout the flight using a phone app. The rocket's fins were also prism plated which made the rocket more visible in flight. This made locating the rocket a very quick and easy process.

Figure 2: Rocket after launch #1 landing

Launch Procedures Assessment

Prior to launch day, a checklist of procedures for pre-flight, launch pad, and post-flight tasks was created. The pre-launch procedures involved everything needed to prepare the rocket for launch, including parachute attachment, black powder charge sizing and installation, and body tube assembly using shear pins and removable plastic rivets. The launch pad checklist included arming the camera, drag system, and altimeter bay. The checklist included all of the tones that needed to be listened for when each component was turned on. The list also included instructions on how to insert and attach the rocket motor igniter. The post-flight checklist included disarming all of the electronics on the rocket to preserve battery and also inspecting the rocket for any damage. On launch day, all of these procedures were followed by the team perfectly and as a result two safe flights were recovered.

FLIGHT PERFORMANCE COMPARISON

This section details the results of the flight by comparing the predicted and actual coefficient of drag results. Showing the coefficients of drag against both velocity and time will give evidence to the performance and effectiveness of the drag system.

Table of Flight Characteristics

First, the flight characteristics of both competition flights, the flight without the drag system engaged as well as the flight with the system engaged. First, the characteristics for the flight without the drag system.

Flight Characteristic	Value (Unit)
Rocket Length	64.2 Inches
Rocket Mass	16.9 lbs
Motor Used	Cesaroni K570
Maximum Altitude	5177 feet
Maximum Velocity	681.156 ft/s
Maximum Acceleration	335.417 ft/s^2

Table 1: First Flight Characteristic Table

Flight Characteristic	Value (Unit)
Rocket Length	64.2 Inches
Rocket Mass	16.9 lbs
Motor Used	Cesaroni K570
Maximum Altitude	4886 feet
Maximum Velocity	694.860 ft/s
Maximum Acceleration	335.417 ft/s^2
Percent Altitude Reduction	5.62 %

Table 2: Drag System Flight Characteristic

As seen above, the engaging of the drag system resulted in a 5.62% reduction of the rocket's apogee between flights.

Estimated vs Actual Coefficient of Drag vs Velocity

One of the ways to see the effectiveness of the drag system is to plot the coefficient of drag versus the rocket's velocity. The following plots compares the predicted and recorded graphs for coefficient of drag vs velocity.

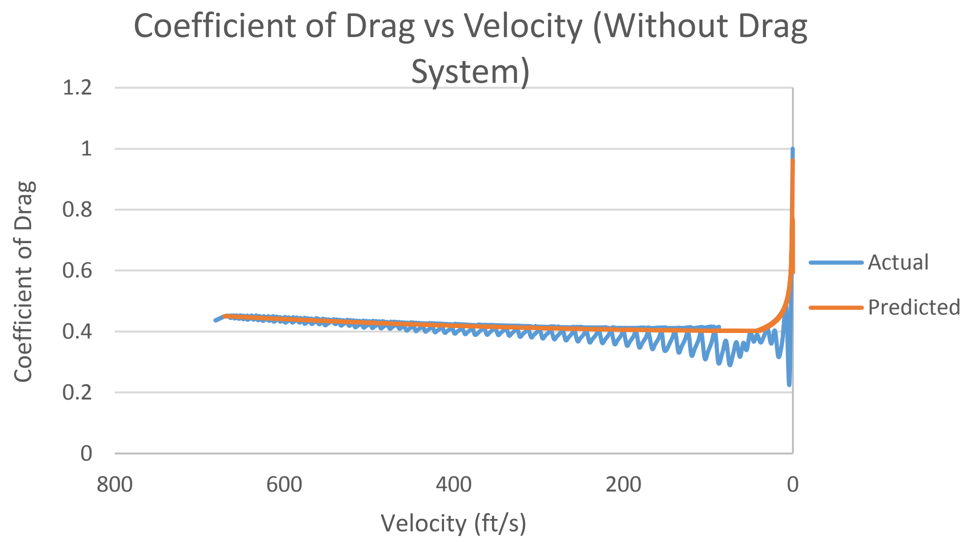

Figure 3: Coefficient of Drag vs Velocity (Without Drag System)

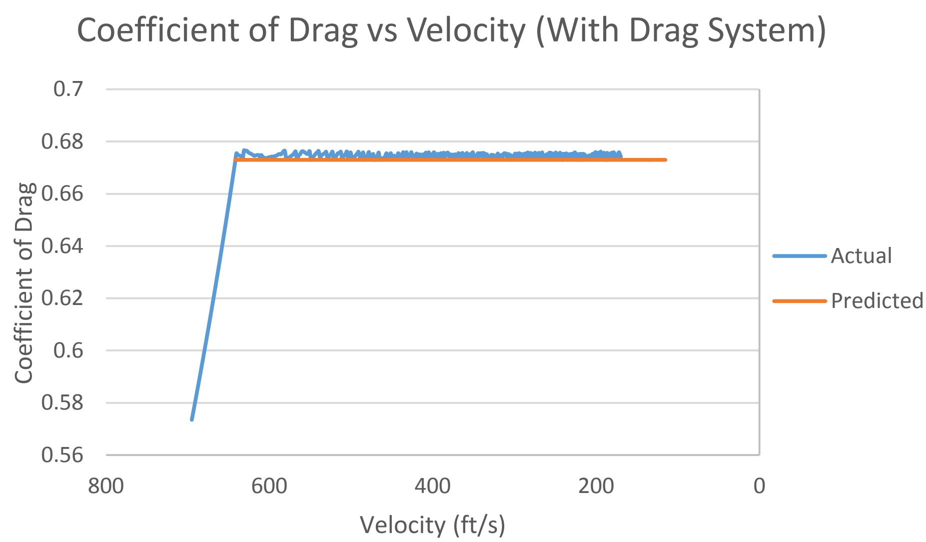

Figure 4: Coefficient of Drag vs Velocity (With Drag System)

Estimated vs Actual Coefficient of Drag vs Time

The second way of seeing the effectiveness of the drag system is to plot the coefficient of drag against time. The following plots documents the predicted and recorded values of coefficient of drag as the rocket climbed to apogee.

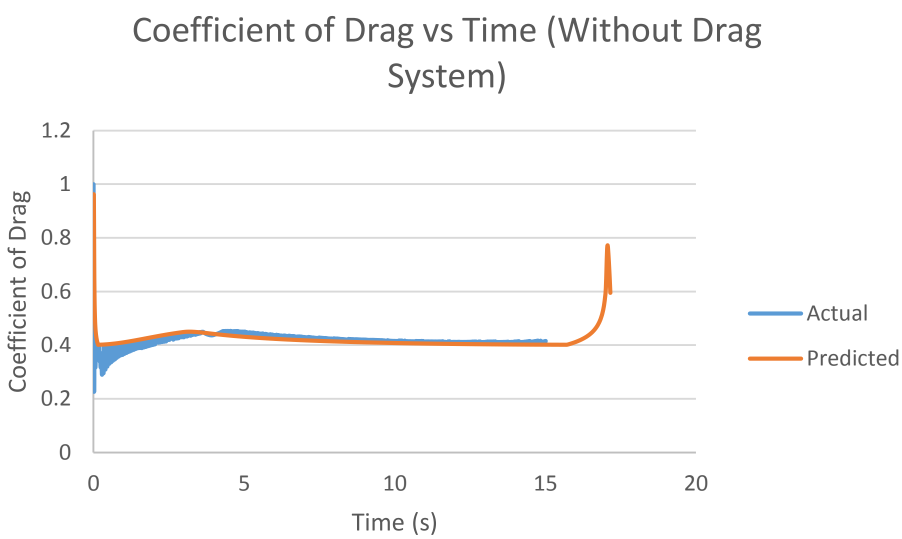

Figure 5: Coefficient of Drag vs Time (Without Drag System)

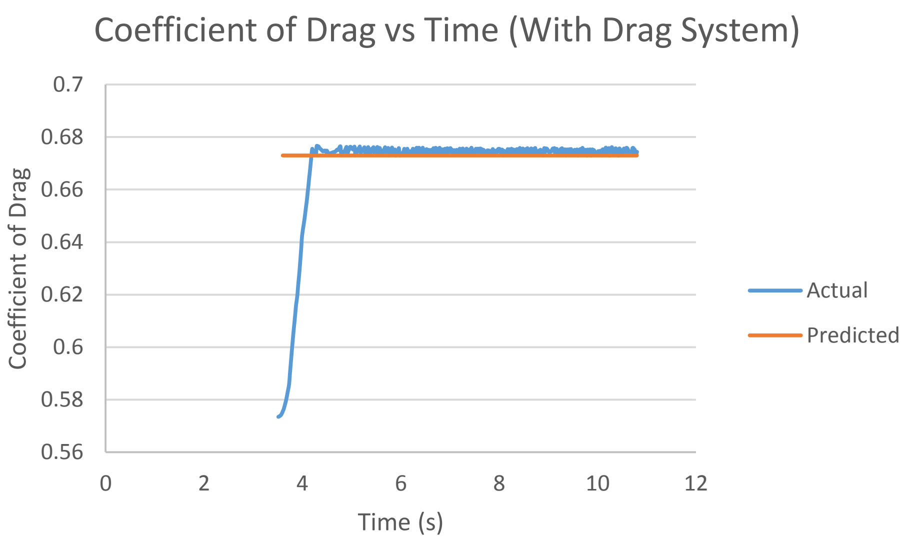

Figure 6: Coefficient of Drag vs Time (With Drag System)

Drag System State vs Time

An onboard camera system was used in both flights to see how the drag system performed during the competition. The Polaroid Cube was placed directly above one of the drag system flaps, and could see the motor turn the belt, and as a result, the flaps correctly rotating out of the rocket. The first flight's footage showed the drag system correctly locked inside the rocket for the duration of the flight, and as a result is not shown in this report. The footage of the second flight, with the drag system engaged, also correctly showed the drag system engaging post motor burnout. This can be seen as the belt in the video rotates the flaps out of place to the outside of the rocket. The following image shows the belt, and while the video is not included in this report, it shows the belt rotating correctly following motor burnout. The belt is the black line seen through both holes in the image.

Figure 7: On Board Video of Drag System Belt

In Figure 7, the picture on the left is before the drag system was in use and the picture on the right is when the drag system is in use. The position of the belt changes showing whether the drag system is in use or not. The state of the drag system can also be seen indirectly through the above Coefficient of Drag vs Time plots. As time goes on, the coefficient of drag increases, signifying that the flaps indeed go out correctly.

DISCUSSION OF RESULTS

This section highlights and discusses the differences between the predicted and recorded flight data, including apogee, velocity and acceleration, and drag coefficient. Suggested reasoning for these discrepancies is also provided.

Apogee Comparison

For the first flight, without the drag system engaged, the predicted and recorded apogee fell within 0.5% error of each other. This fact demonstrated the successful modeling of the rocket in both OpenRocket and Matlab. However, the flight with the drag system engaged showed significant error. The recorded apogee represents a 22.8% error in the predicted simulations, and the 5.6% reduction in rocket apogee is far off the 25% goal. This error can be attributed to a few things. First, it suggests the estimation and prediction of the drag coefficient of the flaps were incorrect. An incorrect prediction would have led to incorrect analysis and an overestimate of the effective the drag system would have on the rocket's flight. Secondly, when analyzing the onboard video, it appeared that the motor used to rotate the flaps faced significant resistance when turning. A stronger motor may have yielded better results for the drag system. Combining these two errors, the error in apogee can be summed up as a failure in both drag system performance and prediction.

Velocity and Acceleration Comparison

Similar to above, the velocity and acceleration data from the first flight matched very closely with the predictions. The second flight's maximum acceleration was equal to the first flight's, as this event happened before the deployment of the drag system. The maximum velocity of the drag system flight was higher than the predicted velocity, producing an error of 4.8% off the predicted value of 663 ft/s. This error in the maximum velocity is not related to drag system performance, as the maximum velocity of the rocket occurs the instant of motor burnout, the same instant the drag system begins to deploy. The error is small enough to assume that there was no major flaw, although small miscalculations could have led to the error. For example, when the OpenRocket model proved quite accurate for apogee, improper placement of component masses could have put error in the predicted velocity. Also, the addition of small components or changes, such as addition of rivets, static port holes, etc., which were not reflected in the modeling, could account for this error. Likewise, if the simulation conditions were not the same as the conditions at launch, this also could have produced a small error.

Coefficient of Drag Comparison

From the plots shown above, it can be seen that the predicted and actual coefficient of drag results are fairly close to one another. For the plots without the drag system engaged, the average actual and predicted coefficient of drag values were 0.40 and 0.42 respectively resulting in a 4.9% difference. For the plots with the drag system deployed, the average actual and predicted coefficient of drag values were 0.677 and 0.673 respectively resulting in a 0.6% difference. These values are summarized in Table 3 below.

	Coefficient of Drag	
	Without Drag System	With Drag System
Actual	0.4	0.42
Predicted	0.677	0.673

Table 3: Coefficient of Drag Values

It can also be seen from Figures 4 and 6 that the coefficient of drag increased when the flaps came out as expected. It should also be noted, as discussed above, that any error in the coefficient of drag predictions and performance (seen on the graphs above), is most likely due either to incorrect analysis and estimations or to slightly different flight conditions. This can include variable air densities, wind, or possible variable flap areas (since it took a little time for the flaps to come out all the way). For the most part though, the data collected seems to be consistent with the predicted values.