Post-Flight Performance Report

Wichita State University

Team RISE

Rocket Inspiring Shocker Engineering

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1. Launch Operation and Outcome

1.1 Flight Anomalies

On our first launch during competition day, we had a motor failure that caused critical damage to the rocket body as well as a negative impact to our overall flight performance. The failure consisted of not having enough friction fit between the motor case and motor tube, causing the motor and motor case to come out during flight. The lack of weight of the motor case would have made the booster hyperstable on its own. We believe with the missing cavity of the motor, the parachute was then sucked out the aft end of the booster prematurely, zippering the coupler and body tube it was attached to. Further damage will be explained in Section 1.4.

After assessing the damage and rebuilding the necessary parts, we were able to launch a second time. During this second flight, a fixed transition piece was used instead of the drag chute due to time constraints to rebuild and install the drag chute system. Although a safe flight and successful recovery were achieved, the dart failed to separate, as seen in Figure 1, since the transition got stuck under the lip structure that would normally secure the drag chute closed.

Figure 1. *Booster stuck under dart's lip structure during several flight instances.*

1.2 Propulsion System Assessment

During the first flight, the motor came out of the booster during flight, resulting in a peak acceleration of 31.1 g's registered for the booster. Furthermore, when the motor case was inspected, extra debris, which included some Mylar material clumped within the motor, was observed as seen in Figure 2. Similar damage was observed during the last test flight before competition.

During the second flight, the motor performed close to expected generating a peak acceleration of 29.4 G's for the booster. When the motor case was inspected, no abnormal debris was found, as seen in Figure 3.

Figure 2. *Debris and Mylar clump after first launch.*

Figure 3. *Motor after second launch (top) and after first launch (bottom)*

1.3 Recovery System Assessment

The rocket had a recovery system for both the booster and dart sections. The booster's recovery system utilized the ejection charge included with the motor. The time delay was altered as to ensure the parachute deployed at the proper time. The dart's recovery system consisted of an EasyMini altimeter that was programmed to ignite a main parachute ejection charge at one second after dart apogee had occurred. After a ballistic test flight where the dart was unable to recover due to the boattail being sheared into the dart body, it was decided that the dart would have a redundant ejection charge that consisted of a larger amount of black powder in case a similar situation were to happen. The altimeter was programmed to ignite the charge approximately 1000 feet after dart apogee. The black powder amounts for each respective charge as well as parachute sizes and shock chord lengths are listed in Table 1. Both the booster and the dart were recovered via a parachute that had a flame retardant cloth protecting it from the ejection charge.

The on-board video revealed that the redundant ejection charge was necessary on the first flight. This led the main ejection charge to be increased for the second flight.

	Parachute Sizing	Shock Chord Length	Main Ejection Charge	Redundant Ejection Charge
Dart	24 inches	110 inches	0.2/0.3 grams	0.55 grams
Booster	30 inches	110 inches	0.4 grams	N/A

Table 1. Recovery system for dart and booster *for both launches at competition.*

1.4 Flight Path Assessment and Rocket Location/Recovery Analysis

Location for the booster, drag chute, dart and motor after the first launch can be seen in Figure 4. The dart did not suffer any structural damage, and the electronics were fully functional as well. The booster and drag chute suffered severe structural damage which is explained in detail on Table 2.

Figure 4. *Location of recovered parts after first launch.*

	Damage	Possible Cause	Picture
Shock Cord	Stitching ripped apart	Tug force on shock cord after motor fell out of booster and parachute released out aft end.	
Coupler	Zipped along length and sheared in half	Shock chord zippered coupler first weakening structure then sheared in half at joint due to the hyperstability of booster.	
Petal Hinges	Hinges bent causing structural damage to the carbon fiber booster body tube section	Unexpected high loads were imparted on to the drag chute system.	
Cup	One of the sections where the boattail normally rests sheared off	Broke during impact on the ground.	
Booster Body Tube	Crack along length	Zipper effect on body tube due to tug force from shock chord.	

Location for the booster and dart after the second launch can be seen in Figure 5. Since both parachutes were easily spotted immediately after they were safely deployed, landing site was estimated to be somewhere after the tree line located East of launch pad. There was no need to use the radio tracker since both parachutes were also spotted on the ground. The booster and dart were recovered in perfect conditions

Figure 5. Location of recovered parts after second launch.

with no damage to the structure or the electronics.

Both flight paths during ascent were consistent and straight as seen in Figure 6. During descent, flight path for the first flight is inconsistent due to the motor friction fit issues. Nevertheless, for the second flight, the recovery locations for both the dart and booster were consistent with the wind direction.

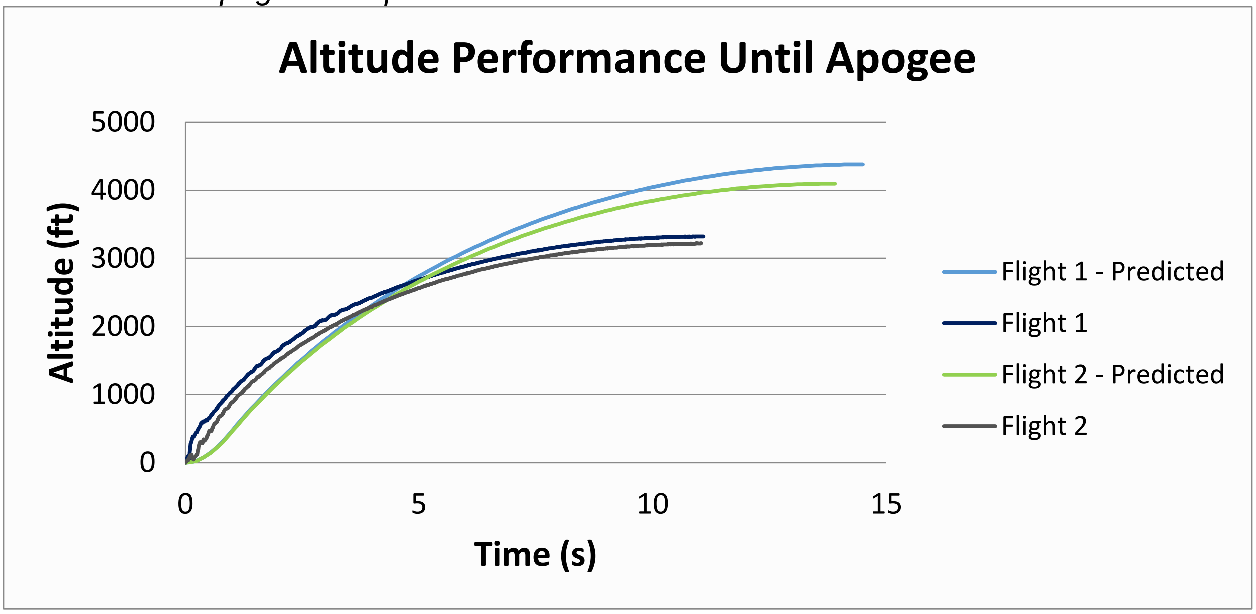
Figure 6. *Flight paths during ascent for first (left) and second (right) flights.*

1.5 Pre- & Post-Launch Procedure Assessment

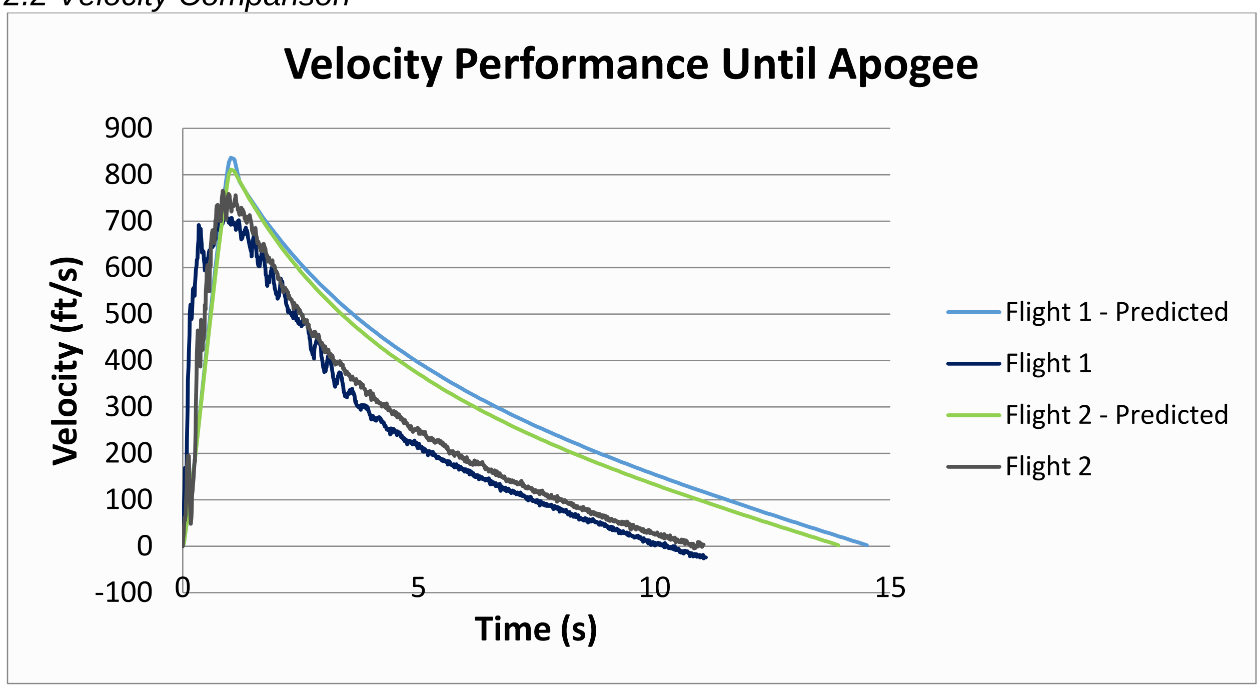
The use of the pre-flight checklist, launch pad and flight arming checklist, and the recovery/postflight checklist enabled the team to have smooth and successful preflight check inspections and postflight check-ins.

2. Flight Performance & Comparison

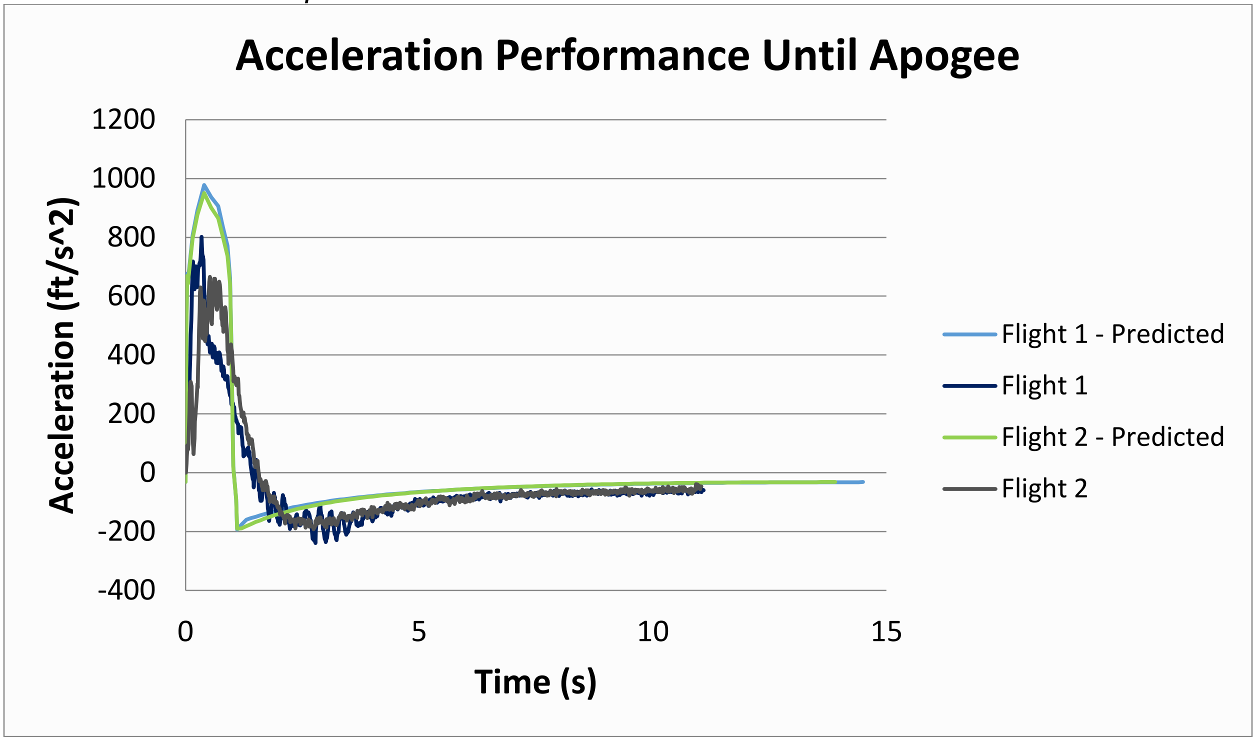
2.1 Altitude & Apogee Comparison



2.2 Velocity Comparison



2.3 Acceleration Comparison



2.4 Flight Performance

Flight performance data can be found in Table 3 below.

	Flight 1 Predictions	Flight 1	Percent Error	Flight 2 Predictions	Flight 2	Percent Error
	Dart					
Apogee	4380 ft	3359 ft	23.3%	4096 ft	3276 ft	20.0%
Peak Velocity	570 mph	502 mph	11.9%	553 mph	517 mph	6.5%
Peak Acceleration	30.4 G's	23.0 G's	24.3%	29.5 G's	23.3 G's	21.0%
	Booster					
Apogee	742 ft	629 ft	15.2%	4096 ft	3270 ft	20.1%
Peak Velocity	570 mph	602 mph	5.6%	553 mph	583 mph	5.4%
Peak Acceleration	30.4 G's	31.1 G's	2.3%	29.5 G's	29.4 G's	0.3%
Separation Distance	3638 ft	2730 ft	25.0%	0 ft	6 ft	N/A

Table 3. *Flight performance vs. predicted values for both flights*

2.5 Reasons for Differences

Because of flight anomalies, the predicted performance and the actual performance show some differences. In this case, both resulted in lower-than-expected dart altitudes. The predictions for booster performance were slightly more accurate. The higher error in the peak acceleration between the first and second launch suggests that the motor experienced issues during the first launch.

The error in altitude performance during the flight 1 is believed to be caused by the motor case falling out. Since the case had to fall out the bottom of the booster, it is possible that it could have become detached from the booster during the end of the burn when the thrust is decreasing. This would have caused less thrust to be imparted onto the rocket and early dart separation, not achieving its full altitude. The faster spin rate experienced by the dart would also have increased drag and resulted in a lower apogee. This spin could have been caused by an unusual separation from the booster.

For the second launch, the predictions were re-run using the whole rocket configuration since the dart and booster remained together throughout most of the flight. The altitude predictions were still seen to be higher than the actual performance. This is believed to be due to the way the dart and the booster were locked together. When the dart tried to separate, it moved up in the transition area, simultaneously opening a small gap above the booster but remaining wedged together. The dart sat at a slight angle on the booster, which caused an increased projected area while rotating. Finally, drag analysis did not account for air flowing through the fin slots of the transition area because the rocket configuration was only meant to last for 1.1 seconds. Each of these scenarios would increase drag but would require specialized, in-depth research to accurately predict.

The readings for peak velocity and especially acceleration on the booster matched very well for both flights. Even though the flight anomalies happened on each flight, it makes sense that these predictions should still be accurate because peak velocity and acceleration happen before burnout of the motor. The peak velocities and accelerations on the dart should match the booster since they occur during burn, but they are significantly lower on both flights. Since the booster characteristics match so well, this leads to the conclusion that the joint system between the dart and booster affect the kinematic readings for the dart altimeter.

3. Data Results & Comparison

3.1 Video Quality

On-board video was successfully recorded during both launches with a direct downward view using the 808 Keychain Camera with a lens mounted externally to the dart using an extender cable. This camera records HD footage at 30 frames per second. The launch pad is visible during the entire accent. Separation and dart parachute ejection could also be easily viewed in the footage. Figure 7 is an example screenshot from the on-board footage. For part of the flight where rotation was significantly higher (approx. >5rps) the video became warped and curved as seen in Figure 8.

Figure 7. *View from onboard camera*.

Figure 8. *Distorted footage from high rotation rate.*

3.2 Rotation Sensor Data

The rotation logger was programmed to record data every 0.1 seconds at a 2000 degrees per second setting. Data was successfully recorded during both competition launches. The raw data was recorded in milli-degrees per second and converted to revolutions per second after flight. The X-direction of the gyro sensor is towards the nose of the rocket and was the primary focus for data analysis.

3.3 Comparison

To compare the collected data to the on-board video, the video was observed and time stamps were hand recorded using a reference point on the ground. Due to the high spin rate, the footage became warped during sections and therefore no rotation data could be collected from it. The two rotation rates during flight can be compared in the two graphs in Figures 9 and 10 for both flights. There was some error in rotation found for the rotation logger, but there could also be large error in recording rotation by eye from the on-board footage.

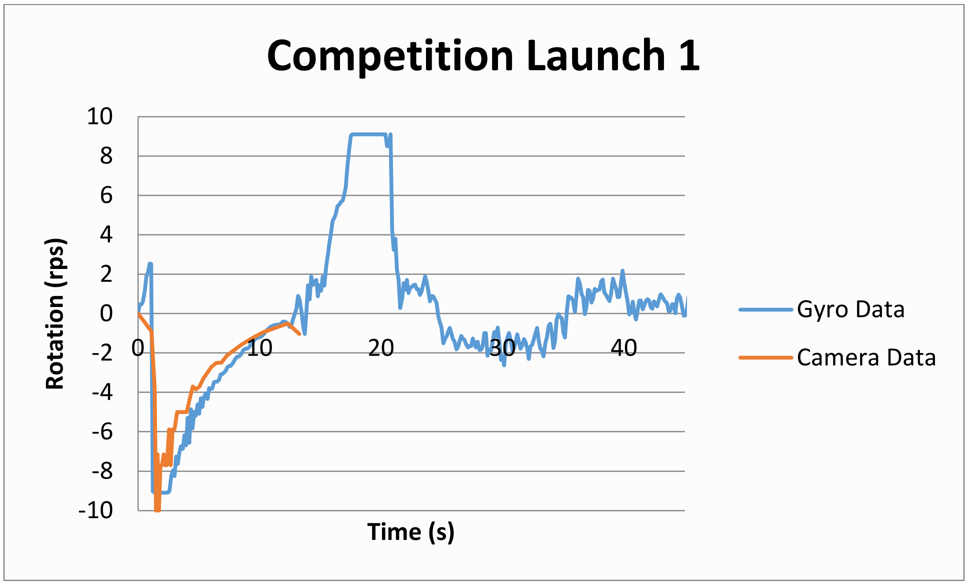


Figure 9. *Launch 1 Gyro Data Comparison*

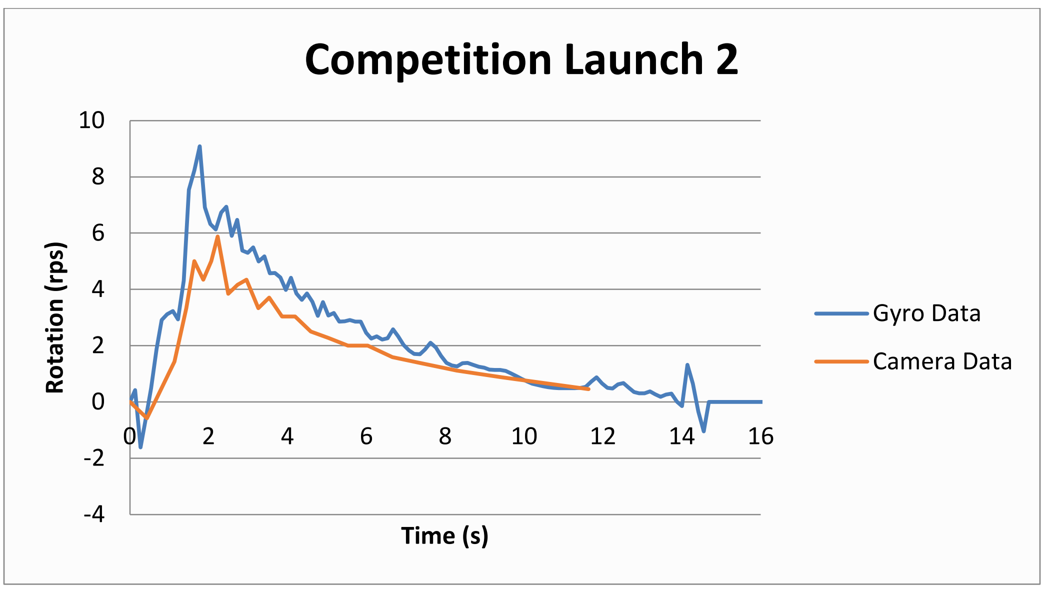


Figure 10. *Launch 2 Gyro Data Comparison*