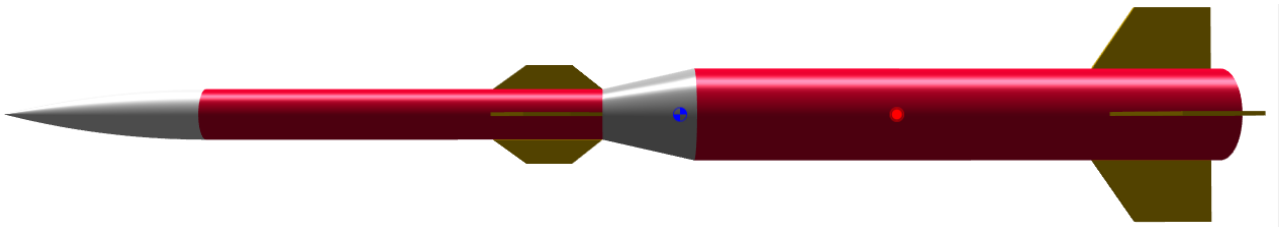

Post Flight Performance Report

NASA Space Grant Midwest High-Power Rocket Competition

The Ohio State University Rocket Team

Chad Walker | *President*

Jack Toth | *Vice President*

Patrick Nienhaus | *Project Manager*

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Elliot Harrod | *Team Member*

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29 May 2015

Introduction

On May 21 the Ohio State Rocket Team performed its only launch of the final version of the Midwest Rocket Competition. The rocket flew well and would have had a completely successful launch if the parachute in the dart had deployed. The dart crashed into the ground and much of the electronics and data were lost. However, what data was saved is sufficient to fulfill this report.

Rocket Flight Analysis

During the final launch of the rocket, the dart parachute failed to deploy due to a malfunction in the igniter. It is impossible to tell for sure what failed in regards to the ignitor as the impact of the dart with the ground destroyed the electronics on the dart. When the rocket was recovered, see Figure 1, the ejection charge was unburned. On-board video also failed to record due to the booster battery dying while on the launch pad. This happened because the rocket was recording data and video for over 15 minutes before the launch. The video recorder died about nine minutes after it was turned on. Thus all data from the booster section was not gathered as the battery died before launch. Both of these issues were beyond the control of the team.

Figure 1: Recovery of Dart and Booster Data

Pre and Post Launch Procedure

Before and after the launch of the rocket, the team followed the Flight Checklist located in Appendix A-1. One point learned from the checklist is that in the future all electronics will be activated from an external switch or pin to reduce complexity before launch.

Propulsion System

The motor burn was normal. The rocket was very stable during lift off. Both stages seemed stable during accent and flew fairly straight upwards according to visual reports and Figure 2. The two stages headed into the wind slightly were not moved to a significant angle and the motor burned out after about one second.

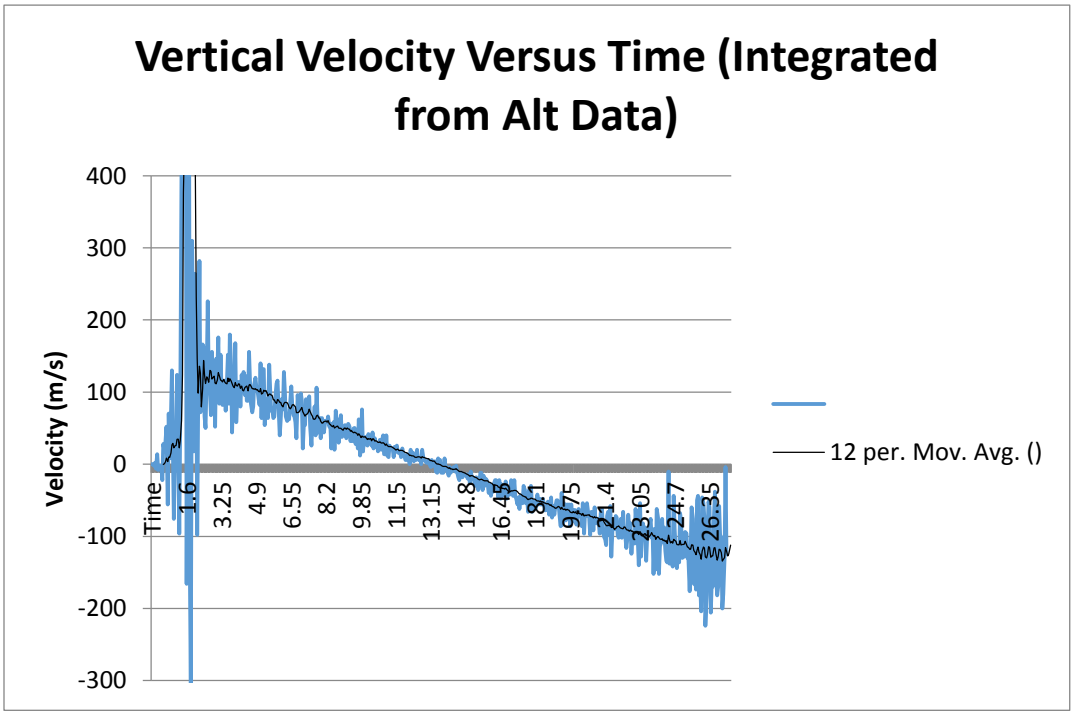

Figure 2: Vertical Velocity of Dart

Flight Analysis

The booster section and the dart section separated quickly following motor burnout and remained stable following separation according to the rotational data in Figure 3. The x-axis in Figure 3 relates to the rotation of the rocket around the axis from the base to nosecone. It is clear that the rocket did not have roll stability and that the rate of roll relates to the vertical speed of the rocket. Aside from roll instability, the dart remained stable throughout flight and corrected itself if it was offset at all. The only time this is not the case is at about 14 seconds into flight where there is a slow but considerable

rotation around the y-axis. Comparing this to the altitude data from Figure 4, it is clear that this rotation is the dart hitting apogee and rotating downwards as it falls back to Earth.

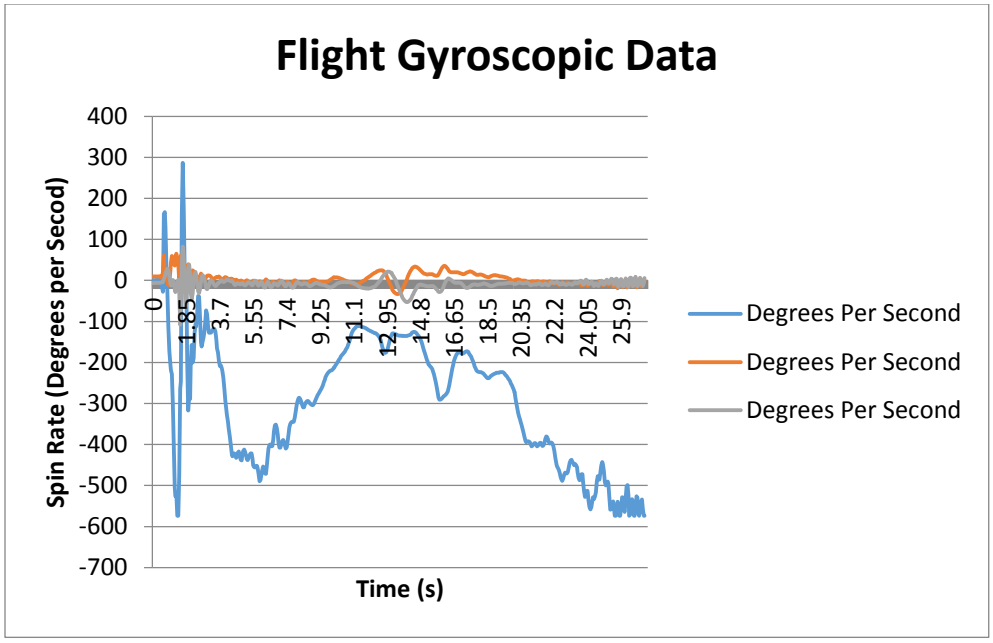

Figure 3: Gyroscopic Rotation Rates of Dart

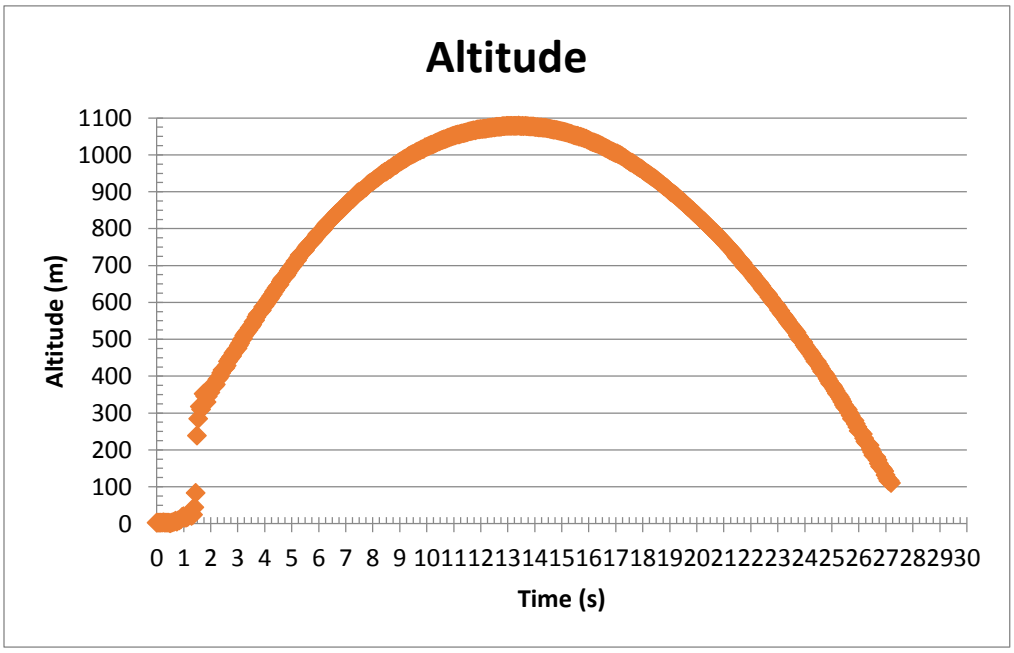

Figure 4: Altitude of the Dart over Time

Recovery System

The recovery system of the booster performed well during flight and allowed the booster section to land safely with only superficial damage. One point of interest is that the booster section did fall faster to the ground than expected. The most likely cause of this is that the parachute strings got tangled during deployment and caused the parachute to not fully deploy. This is reinforced by observations made when recovering the dart section that showed the strings tangled, as shown in Figure 5.

The dart section, as mentioned previously, did not deploy its recovery system and thus fell to the ground ballistic ally. This did a considerable amount of damage to the dart section as shown in Figure 1. Due to the considerable amount of damage it is hard to determine the exact reason the parachute did not deploy. However, when the ignitor was recovered it appeared that it been broken but not burned. This indicates that the failure was in the commercial chip used to control the recovery system as multiple tests of the custom programming had shown it to be reliable in the deployment of the parachute.

Figure 5: Tangled Lines of the Booster Section

Recovery of Rocket

The booster section landed close within 50 yards of the launch section and the electronics were recovered intact with the Altimeter 2 reporting an apogee of about 2400 feet. The dart landed about half a mile to the South Southwest of the launch site. It was buried about 30 inches into the ground and required a shovel to dig it out, as shown in Figure 6. The Altimeter 2 was completed destroyed but data recovered from the SD cards shows a max altitude of about 3536 feet.

Figure 6: Digging out the Dart

Data Collection

The data collected from the onboard video, unfortunately, cuts out before the rocket is launched so there is no video of the rocket in flight. The rotation sensors data are shown in Figure 3. This data is fairly consistent and fluid throughout flight until motor burnout and separation when the x-axis data begins to oscillate wildly. This is most likely just variation at the shock of going from 19 G's to -1 G as well as pulling away from the booster section. After this the rotation increases until it hits a maximum rotation rate at about 6.5s. At this point the rotational values appear to be related to the speed of the booster as it reaches its apogee and the proceeds to come back now. The z and y axes have very little occurring during flight with minor variations occurring and then being corrected. The y and z axes due have a large amount of rotation at the lead up of the rocket to apogee as it begins to turn around in flight.

Predicted vs. Actual Results

The results will be divided into three sections to determine the rocket's performance compared to the predicted results, peak acceleration, velocity and altitude. The predicted peak acceleration was 255 m/s^2 but the results only showed a max acceleration of 186 m/s^2. This was surprising but may be due to the motor burning slower than expected and so not getting the full acceleration out of the motor.

The peak velocity was found to be 180m/s which is lower than the expected 221 m/s from the simulation results. The last section altitude was the closest to the predicted value with a peak altitude of 1078 m compared to the 1200m that were predicted. Overall, the results were slightly lower than predicted but that is not unusual considering the simulated results were under ideal circumstances.

Conclusion

The rocket was launched and, from the data, had a stable flight aside from some roll as it flew. The dart and the booster hit an apogee of 2400 feet and 3600 feet respectively for a separation of 1200 feet. Once the dart hit apogee it fell back to Earth quickly and came down ballistic before burying itself in the ground.

Appendix A-1 Pre and Post Launch Checklist

Pre Flight Checklist

1. Is our dart loosely fitting?
2. Are drag fins closed?
3. Motor assembly
4. 16 second ejection charge on motor
5. Motor secured to booster with retainer
6. Booster chute wadding
7. Booster chute
8. Booster electronics armed
9. Rapid recording light flashing

Dart Checklist

1. Avionics armed and recording
2. Camera on and recording
3. Electronics bay securely housed
4. Camera in wind breaker
5. All 6 security screws placed
6. Continuity on ejection
7. .8 grams of black powder
8. Igniter exposed and packed
9. Wadding
10. Chute
11. Loose fitting nose cone

Pad and Flight Arming Checklist

1. Rocket set up on launch pad upright and angled slightly towards the wind
2. Place Igniter securely into the motor
3. Connect ignition switches to ignitor
4. Everyone clear of the area
5. Check for Continuity of circuit
6. Check to Ensure that no one is in the launch area
7. Begin Countdown
8. Launch

Recovery and Post Flight Checklist

1. Have Team 1 follow and recover booster section
2. Have Team 2 follow and recover dart section
3. Recover Dart Section
4. Recover Booster Section
5. Recover Transition Piece (if separated from booster)
6. Recover Nose Cone (if separated from dart)
7. Return to launch site
8. Check Electronics to ensure there is no damage
9. Remove mini SD cards to recover data and video
10. Check the Altimeter 2's to find apogee of both booster and dart
11. Bring Data and Rocket to Judges

Appendix A-2 Flight Characteristics of Rocket

General Statistics

Mass Initially	1859g
Mass Final	1617g
Mass Propellant	333g
Average Thrust	446N
Burn Time	1.07s
Initial Stability	1.29
Dart Stability at End	1.95
Dart Length	61.2 cm
Booster and Transition Length	60.5 cm
Location of Center of Gravity from nose	82.1 cm
Location of Center of Pressure from nose	91.9 cm

Dart Statistics

Dart Length	61.3cm
Dart Stability	1.95
Dart Mass	595g
Location of Center of Gravity from nose	22.5 cm
Location of Center of Pressure from nose	30.6 cm