Team Air Mail

Post Flight Report

2014-2015 Space Grant Midwest High-Power Rocket Competition

UAH Space Hardware Club Huntsville, AL

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Not pictured: Chris Thackston, Mark Reuter

I. Flight Characteristics

A. Booster

	Length (in)	Stability (cal)	Weight (oz)	Body Tube Diameter (in)	Center of Gravity (in)	Center of Pressure (in)	Apogee (ft)	Peak Acceleration (Gs)	Average Acceleration (Gs)	Peak Velocity (mph)
Predicted	24.8	1	36.6		15.1	17.7	2807	27.3	21.7	501
Actual	25	1	32	2.23	15	17.7	2887	26.9	23.6	549

B. Dart

	Length (in)	Stability (cal)	Weight (oz)	Body Tube Diameter (in)	Center of Gravity (in)	Center of Pressure (in)	Apogee (ft)	Peak Acceleration (Gs)	Average Acceleration (Gs)	Peak Velocity (mph)
Predicted	41.9	1.99	24.5		21.7	24.4	4944	27.3	21.7	505
Actual	39.5	2.22	24.5	1.36	20	24.4	4950	23.1	21.5	495

C. Complete Rocket Design

	Length (in)	Stability (cal)	Weight (oz)	Center of Gravity (in)	Center of Pressure (in)	Separation (ft)
Predicted	63.5	1.39	68.7	43.1	46.7	2137
Actual	61	1.45	64	40.5	46.7	2063

II. Technical Analysis

A. Differences in apogees

There are many factors that come into play when discussing the difference between the simulated and actual apogee of a rocket. Some of the most common include the precise geometry of the rocket, the parasitic drag effect on the rocket, and the surface roughness of the rocket. The team used the software OpenRocket to simulate the flight of the booster and dart. OpenRocket does not precisely simulate the geometry of the tail cone of the dart, transition of the booster, or how they interact during flight: this inevitably caused some error in the simulation. The parasitic drag effects of the rail buttons and the screws are also not incorporated in the OpenRocket simulation. The team had to estimate the surface roughness of all the components. All of the booster and dart body tubes were custom layups fabricated by the team themselves and, as a result, do not have a continuous surface roughness along the length of the tube. Estimating the surface roughness of the 3-D printed parts is also difficult, as it varies depending on print orientation and how well the layers bonded together which can vary over the surface of a part. By varying only the surface roughness of the components of the rocket, the simulated apogee of the dart can be changed by around 500 ft in the OpenRocket simulation.

Apogee	Dart	Booster
Predicted (ft)	4944	2807
Actual (ft)	4950	2887
Difference (ft)	6	80
% Error	0.121%	2.771%

Table 4. Apogee Data. *This table provides the values for the predicted and actual apogees of both the booster and the dart.*

B. Difference in Velocity and Acceleration

One difference between the predictions and recorded values of the peak acceleration and velocity is the difference in peak accelerations between the dart and booster. Theoretically, the dart should accelerate with the booster, and they would only be slowing down separately. However, the peak velocity of the dart is also about 50 mph faster than the booster, suggesting that it continued to accelerate after separation.

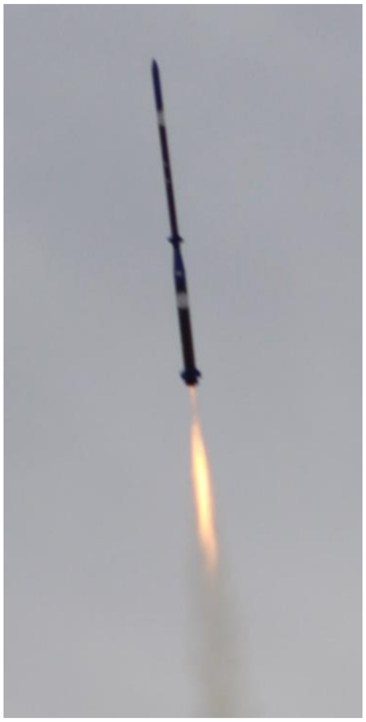

Figure 1: Flight *Booster and Dart during motor burn*

C. Pre- and Post-Launch Procedure

On the flight line, the preflight checklist was used to ensure the rocket was safely assembled and was done so in time to fly. After checking in with the RSO, the flight-pad checklist was used to make sure all altimeters and ejection hardware were properly armed for the flight. After the launch, the post-flight/recovery checklist was followed to make sure everything was done safely, and all data recording systems were safely disabled without losing any data.

D. Propulsion System Performance

The I-445 motor had no anomalies in its performance for our competition flight. As the motor burnt, the rocket took the force of the acceleration, which peaked at 26.9 Gs, according to an Altimeter Two. In the accelerometer data, the initial spike represents the motor burnout with is measured to be 1.0 +/- 0.1 seconds. This value fits with the reported motor burn-time of 1.1 second.

E. Flight Path Analysis

The flight path of our rocket was not ideal due to a weather cocking effect coming off of the rail. It was launched from Pad 4, which was having problems the entire day. The rail was shorter than the rails the rocket had been launched from previously. However, this did not affect the flight significantly, and other than that flaw, the flight path was perfect. Separation occurred at motor burnout, creating over 2,000 feet of separation

F. Recovery System Analysis

The motor ejection of the booster deployed a second and a half after apogee, but this did not interfere with the recovery system, which allowed the stage to descend safely. The dart recovery system, powered by two PerfectFlite StratologgerCFs, deployed at apogee.

G. Rocket Location and Recovery

Figure 2: Flight Distances *Overhead view of the launch sites and landing sites of the booster and dart using Google Maps*

The booster was found just on the other side of a group of trees due east of the launch pad. Using Google Maps, the booster's distance from the launch pad has been determined to be 0.45 miles. The dart landed past the booster in a southeast direction. It landed 0.85 miles from the launch pad. Both stages of the rocket were intact and easily recoverable.

H. Flight Anomalies

This flight went well for the most part. The only real anomaly is the angle that the rocket flew at after it left the rail. Other than that, all systems were successful, and the flight went as predicted

III. Data Collection

A. Gyroscopic Data

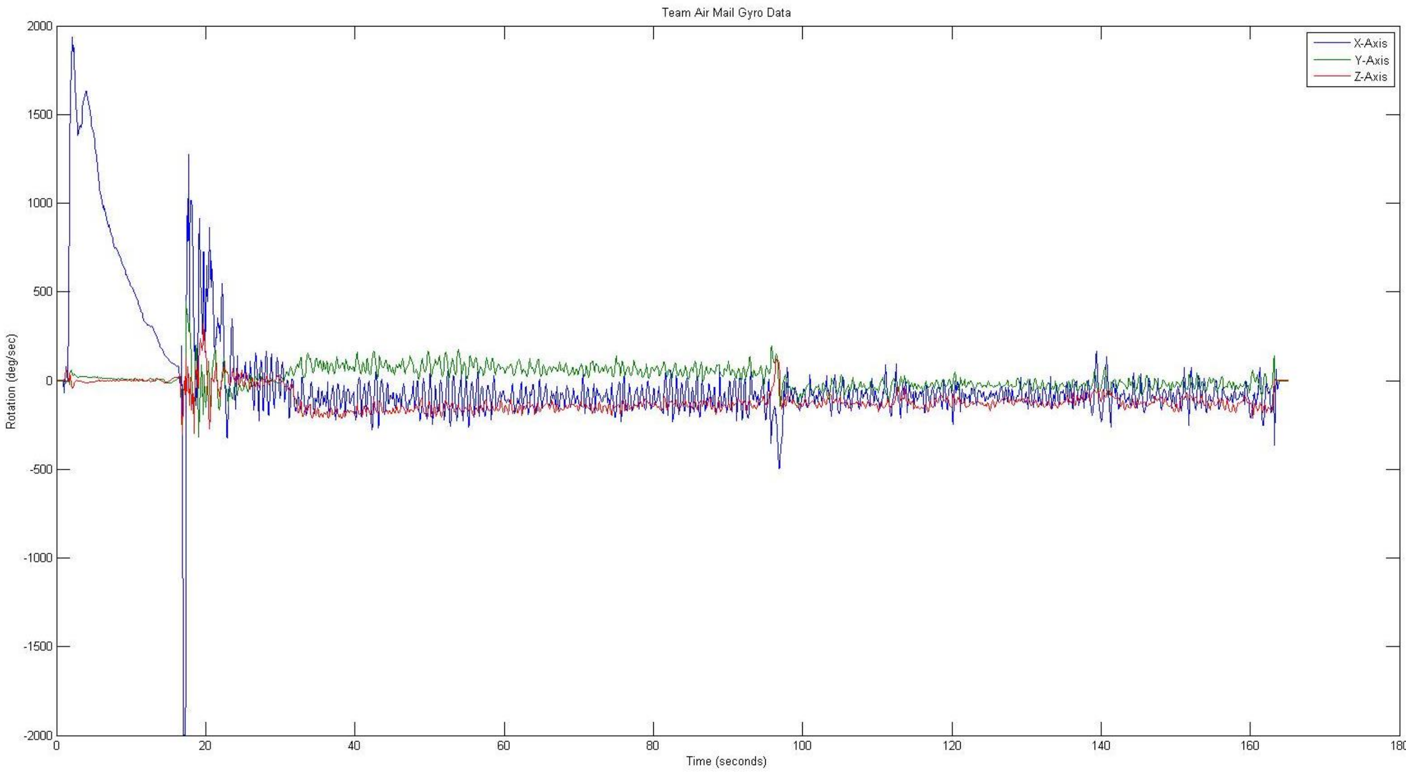

Figure 3. **Gyroscopic Data**. *The recorded rotational data in the X, Y, and Z directions of the dart during flight is graphed over time in seconds.*

B. Accelerometer Data

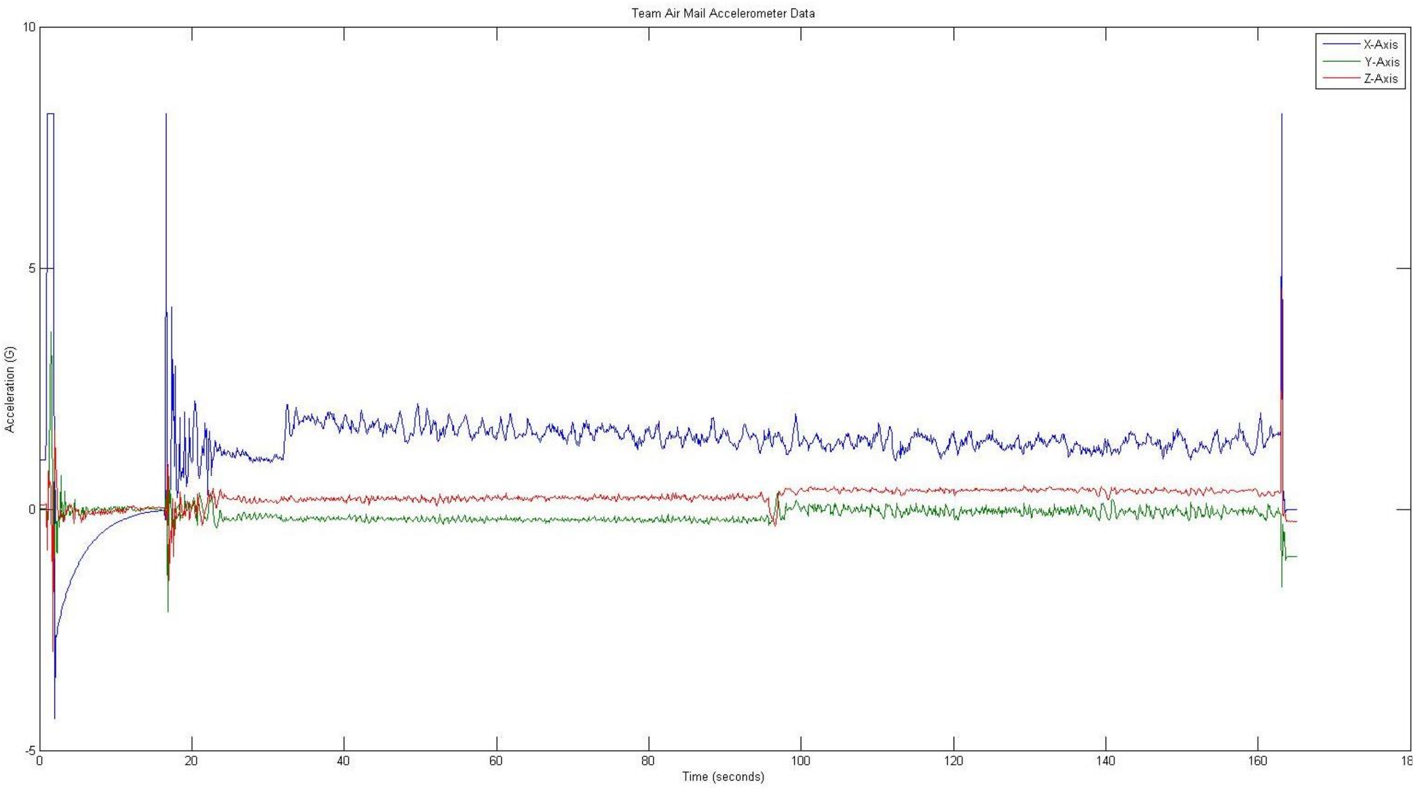

Figure 4. **Accelerometer Data**. *The recorded acceleration in the X, Y, and Z directions of the dart during flight is graphed over time in seconds.*

The IMU data collection board was orientated so that the positive x axis was pointed out of the nosecone of the rocket. Therefore, the almost two thousand degree per second spike at the beginning of the gyroscopic data is just after the takeoff of the rocket. Since the x direction is facing the sky, the x direction experienced the highest acceleration which the accelerometer read as about 7gs for the initial spike, marking the thrust produced by the motor. However, the Jolly Logic Altimeter Two recorded max accelerations of 27gs. Since each of the highest accelerations was around the same value, the true acceleration most likely maxed out the accelerometer sensor used. The simulation also predicted a max acceleration around 27 Gs, also lending credence to that being the correct value. The timing of the spikes would still be accurate, even if the maximum values are not. Therefore, the second spike in the acceleration, and spikes in the x axis' rotation, around 20 seconds is the result of the black powder charge, which deployed the parachute. The next 140 seconds is the descent of the rocket, while the final spike in acceleration at 160 seconds is the dart's landing

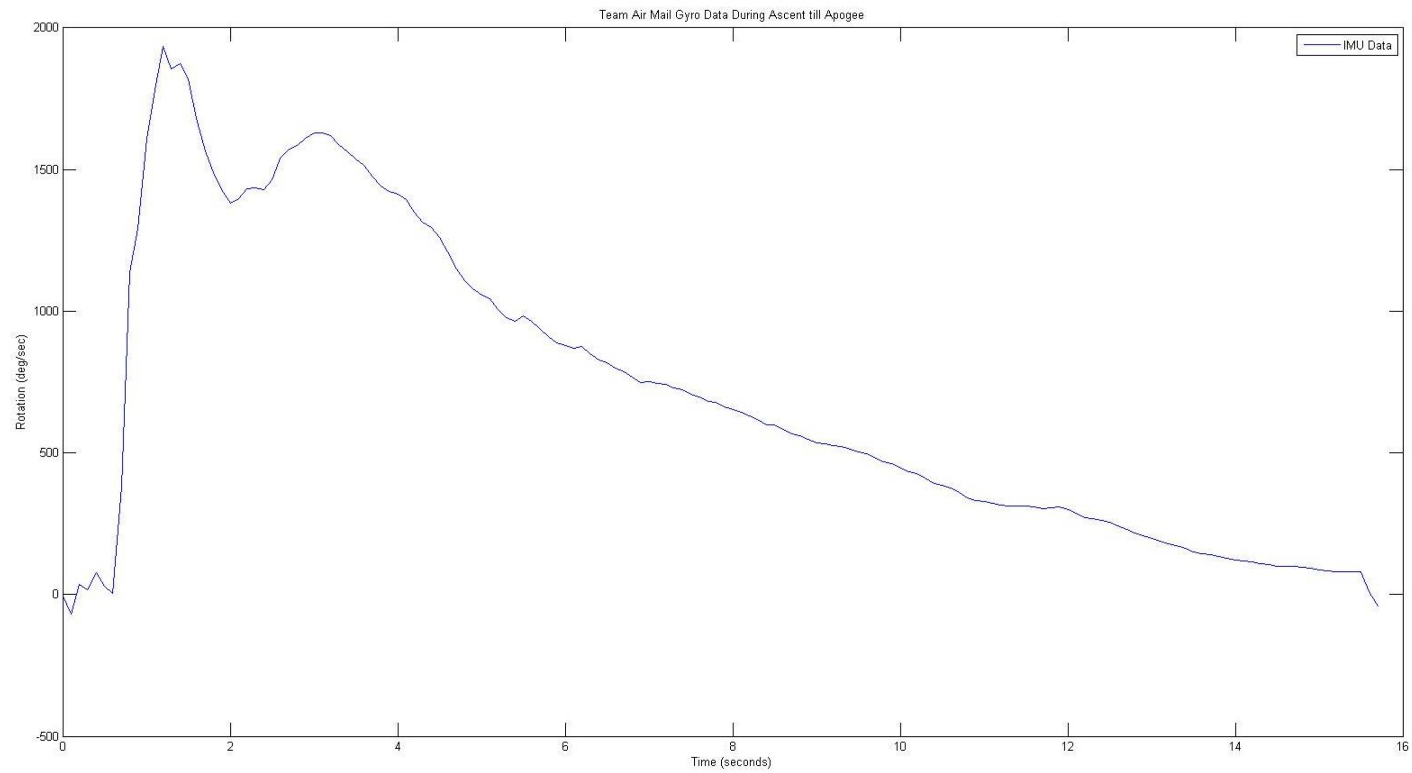

Figure 5. IMU Data. *Although the flight was recorded, the video file was corrupted only was just recovered. The team did not have a chance to compare the two sets of data. This is the rotational data from the IMU that would have been compared to the video.*

Figure 6. Separation. *A still from the recovered video from just after the booster and dart separate.*