Team Rocket Post Flight Analysis

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The scoring parameters of this year's Regional Collegiate Rocket Competition were: achieve an apogee of 3,000 feet, closely estimate the recovery location, and recover the rocket in re-flyable condition. An ancillary goal of the competition was to also acquire altitude and velocity data from a source separate of the chute-deploying altimeters. Reflecting on the completed flight, it was quite successful. As opposed to the state competition, where two flights were completed, only one flight was completed at regionals. On this flight, an altitude of 2,769 feet was achieved, the rocket was recovered successfully and data was captured via an alternative means. Each of these three facets will be discussed in greater detail below.

In regards to the flight of the rocket, it was observed that the actual weight was very near to the "theoretical" weight proposed in OpenRocket that resulted in a flight of 2,999 feet. Substituting the "actual" weight into open rocket, stability coefficients of 1.11 (before motor discharge) and approximately 1.77 (after motor discharge) were expected. These theoretical/actual stability coefficients were expected to provide a straight, stable flight. However, in practice, an apogee of 2,769 feet was achieved according to the onboard Raven3 altimeter.

Compared to the preflight estimates of these values, the maximum altitude was approximately 130 feet different (7.67 % error). Potential sources for this amount of error include:

- Incorrect roughness values for rocket exterior
- Incorrect mass used for blast charges
- Incorrect launch conditions (wind speed and deviation)

Changing the wind conditions to those seen at the precise time of flight, an apogee of approximately 2,940 feet was expected. In addition, adding 2 ounces for incorrectly estimated blast charges further decreases this value to 2,887 feet. Using this value as well as the actual launch height of 2,769 feet, an error of 4.087% was found. With this new value for error, it is very plausible that any deviation still unaccounted for can be attributed to variance in the impulse applied by the Caesoroni J-357 Motor.

Upon retrieval of the rocket, it once again was recovered without any significant structural damage. This is an impressive feat seeing as three flights have been conducted on the rocket and one of these three ending with a ground impact velocity of 100 ft/s. With these three flights, stresses on the fins and other structural components begin to become cyclic stresses and one must worry about the fatigue life of the components. However, the entirety of the body is made of fiberglass phenolic sold by Public Missiles which proved itself very well during the two competitions that the rocket was flown at. In addition, the fins were also made of a prism plated fiberglass material. This also assisted in the toughness of the rocket.

Finally, it is necessary to discuss the performance of the secondary data acquisition system. At the state competition, the alternate data logger system did not capture data, upon investigation the prepaid phone used for a cellular connection to monitor GPS data and real time altitude became nonfunctional on launch day. It worked on occasion, but progressively got worse the more it was worked with. Unfortunately there was a bug in the software for the microcontroller that caused it to freeze if the cellular connection to the phone became disconnected when it was trying to transmit data. Because of this, the entire logging system became dysfunctional on many different occasions.

Because of this, a different system was employed. At the regional competition, a full-fledged Arduino Uno in conjunction with an SD card data logger breakout board and an accelerometer were used. Using a custom written code, the SD data logger logged acceleration data in the x, y and z axis for the entire duration of the flight. Overall, data was successfully acquired in all three axes. However, two issues were noted with the altimeter during the flight. The first of these was that the data saturates at approximately 4 G's of acceleration. Returning to the spec sheet for the altimeter, it happens that the saturation for the accelerometer is, depending upon part variance, between 3 and 4 G's. In addition, the altimeter does feel the effects of gravity in whichever direction is currently facing in the z-axis. We did calibrate for this when the rocket is positioned vertically. However, once the rocket was descending via parachute, the payload bay was more than likely no longer vertical. With this, it is impossible to tell the exact orientation of the payload bay and therefore which axes were prone to the effects of gravity. Shown below are the velocity and position plots from the original set of data:

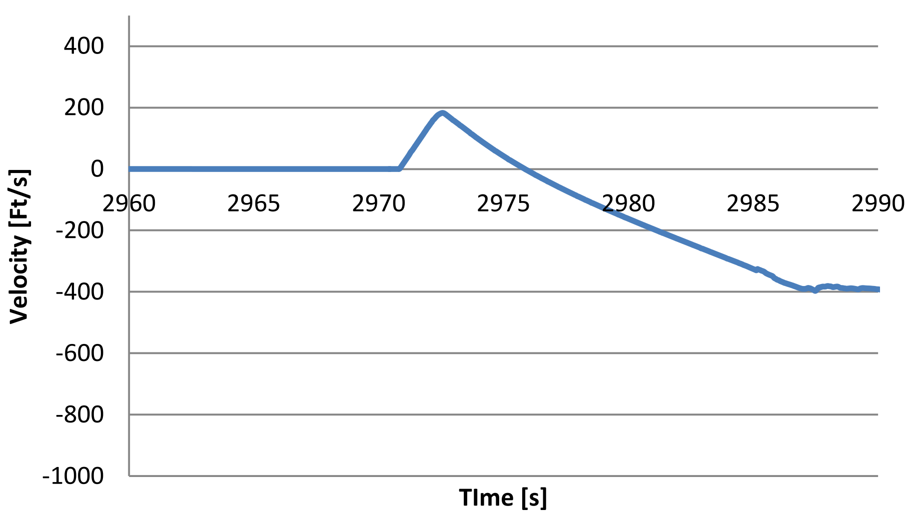

Figure 1: Alternate Data Velocity Data

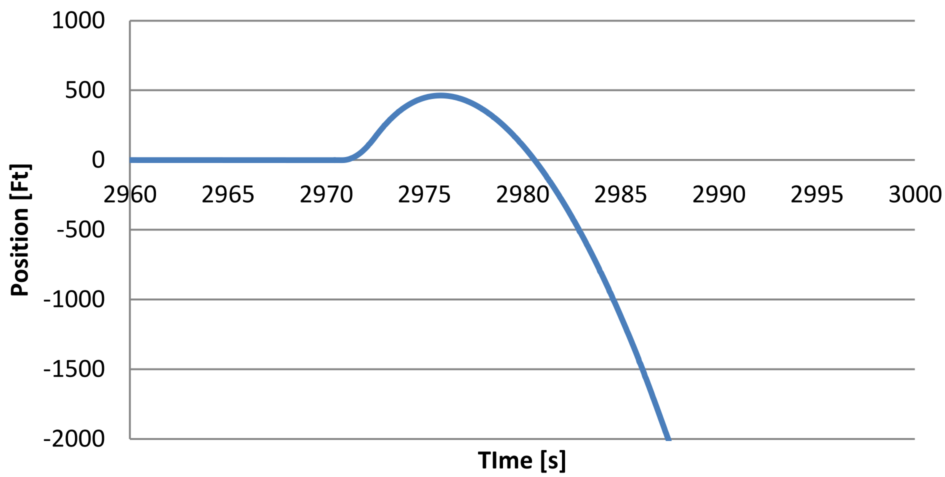

Figure 2: Alternate Data, Integrated for Position

However, it becomes immediately clear that neither value even approaches those found from primary data acquisition. In addition, the position plot shows a large segment of negative values which would suggest that the rocket was underground. Both of these suggest that this data was incorrect. Revisiting the issue mentioned previously, the acceleration data did saturate upon launch. For an approximately one second period of time, the acceleration saturated at approximately 4 G's when the theoretical value from OpenRocket was approximately between 11 and 13 G's over this range. Using these theoretical values, new plots for the velocity and position of the rocket were derived and shown below:

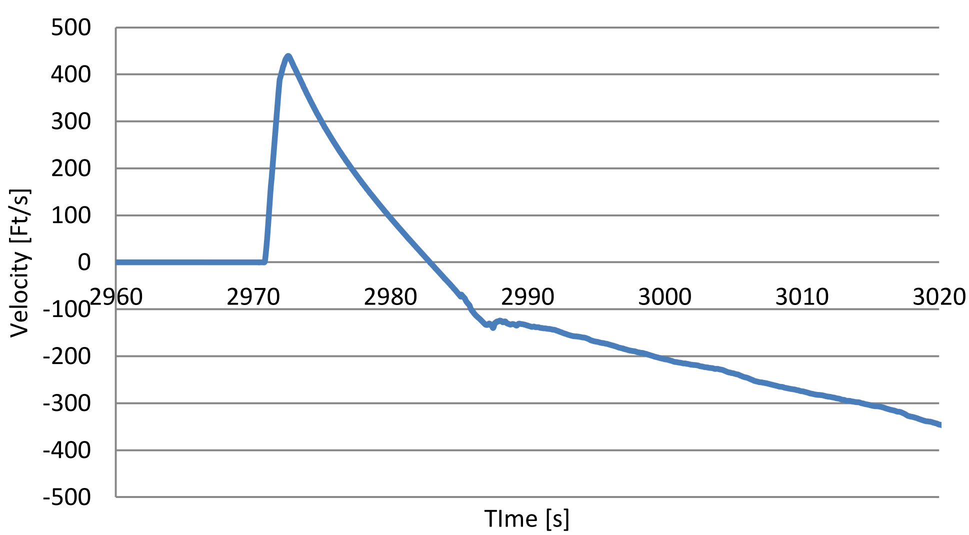

Figure 3: Alternate Velocity Data, with Saturation Values Changed

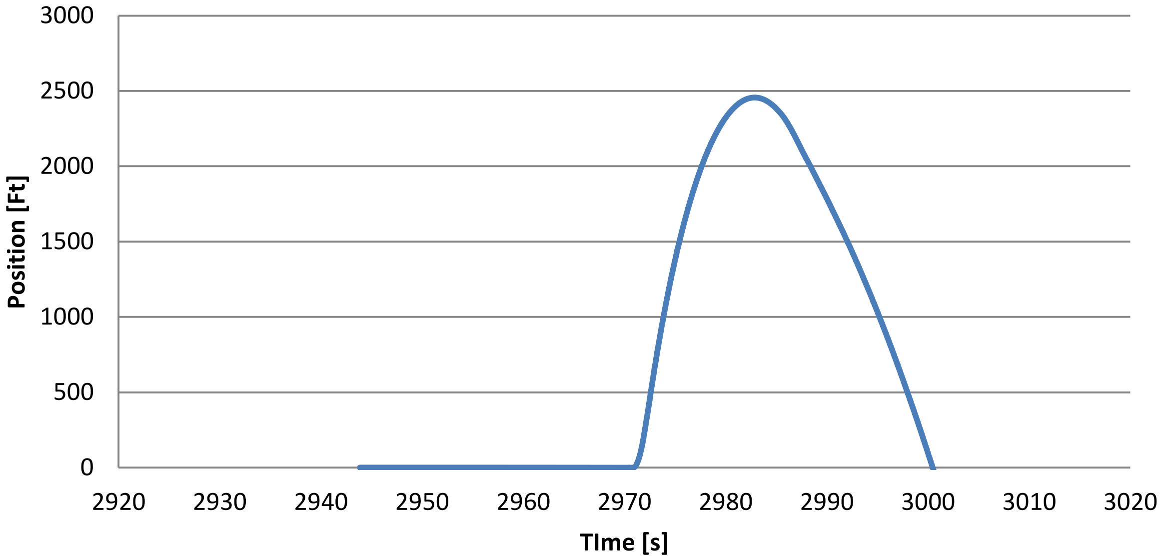

Figure 4: Alternative Data, with Saturation Values Changed and Integrated for Position

From this new, altered data, a maximum velocity of 439.31 ft/sec and a maximum height of 2,456 feet were acquired. Compared to theoretical data from OpenRocket, the maximum velocity measurement was now off by 18.19% and the maximum height measurement off by approximately 11.30% when compared to the actual flight. Based on the overall low resolution of the accelerometer, the uncertainty of the data during the saturation range, as well as the uncertainty of the precise angle of the rocket off the launch, both of these errors can be considered acceptable.

In conclusion, this year's launch was one that can be deemed highly successful. Building off of mistakes made in last year's competition, this year's rocket was built far more robustly and this paid large dividends on each of the two flights. In addition to the robustness which led to a recoverable rocket following each launch, the altitude on the second launch was also only 7.7% off of the goal of three thousand feet. Combining this with a recoverable flight, this placed Team Rocket in the running as far as flight score for engineering teams and is something we should be very proud of. Looking to the future, another design consideration Team Rocket should consider is adding a ballast section such that each and every rocket flown is at the precise weight and stability suggested by OpenRocket.

Finally, we would like to thank the WSGC and all of its affiliates for all they have done for us this year. It was greatly appreciated and definitely did not go unnoticed.