Post Flight Report

Team RedShift 7

University of Minnesota – Twin Cities

Wisconsin Space Grant Consortium
2014 Midwest Regional Rocket Competition

Figure 1

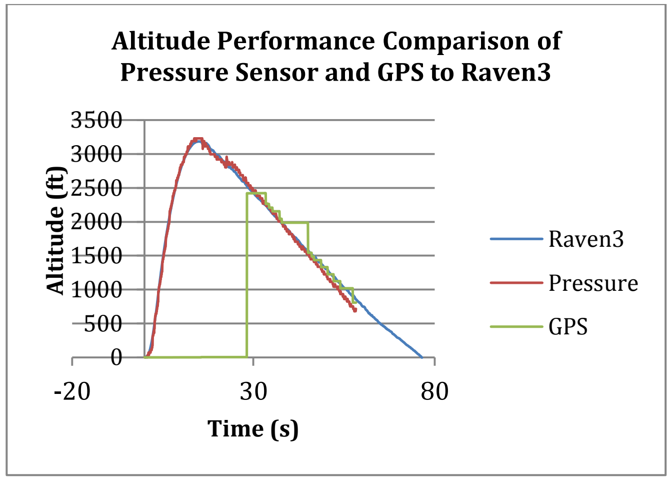

Figure 2

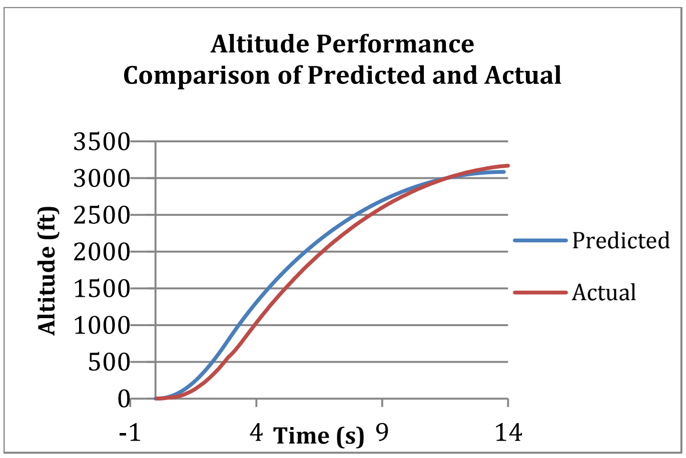

Figure 3

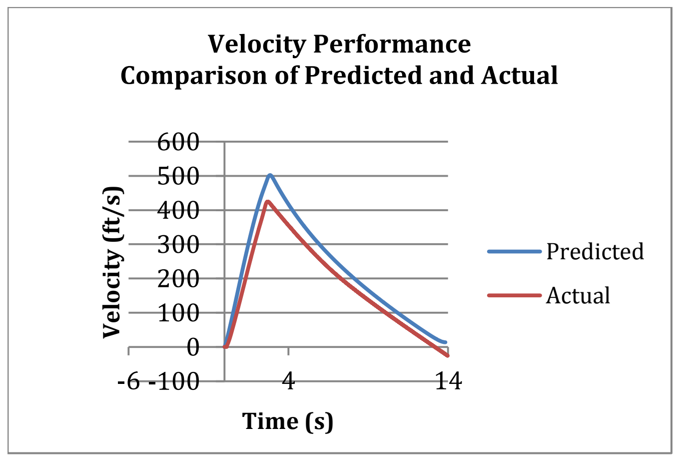

Figure 4

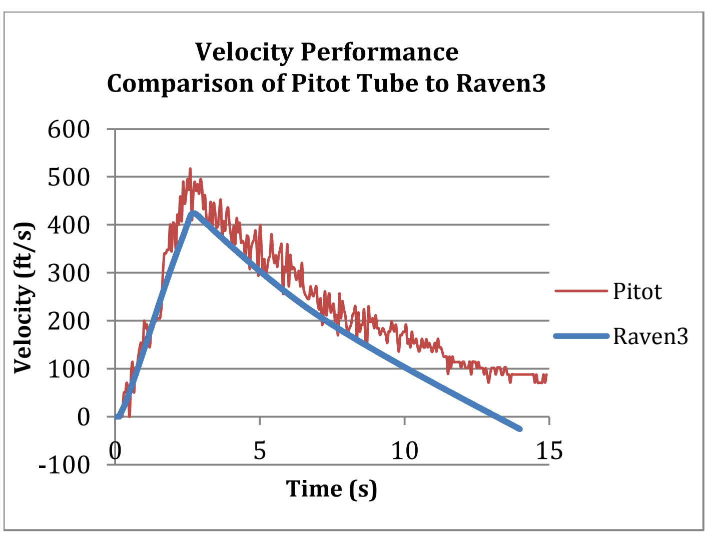

Figure 5

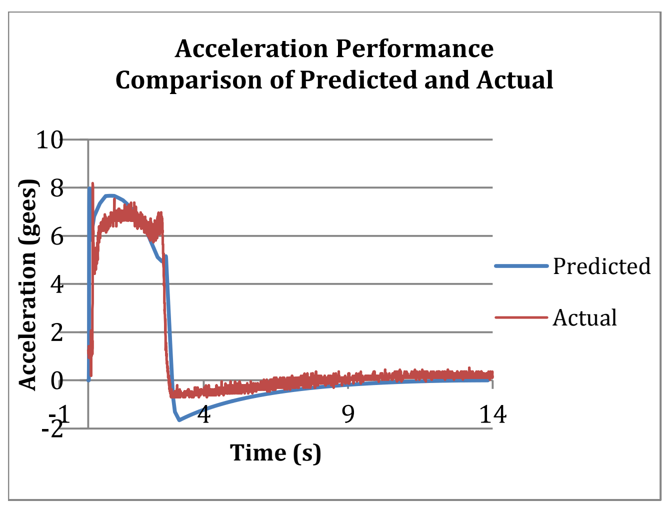

Figure 6

While preparing the rocket for flight, the team was constantly looking at our pre-flight checklist to make sure that everything was being completed. Once everything on the checklist was finished, the rocket was ready to launch. The motor ignited properly and propelled the rocket into the air. The motor burned for approximately 2.7 seconds and reached a maximum velocity of 424 ft/s. As expected, the rocket flew upward with a slight arc caused by the wind until it reached apogee. The drogue parachute ejected successfully 0.38 seconds after apogee. The rocket drifted in the wind a short distance until it was at 900 feet. At 900 feet, the main parachute ejected but did not unfurl. This could have been due to it being wrapped up in the shock cord or shroud lines. The parachute barely fit into the airframe, so it is possible that it got tied up with them as it was packed or ejected from the rocket. Even though the main chute did not open, it slowed the rocket down a by creating additional drag. The rocket still fell at a faster rate than intended, and hit the ground with more force than we would have liked. The impact caused one of the fins to get knocked loose. After the landing, we began to complete tasks on our post-flight checklist. We determined where the rocket was by measuring the angle between the rocket and a reference point. We predicted that the rocket had landed at 45.54404°N 92.92863°W and it actually landed at 45.54406°N 92.92907°W. We then took the rocket to the judges' tent for the post-flight check-in. Unfortunately, because of the loose fin our rocket was determined to be un-flyable. Since then, we have reattached the fin (the epoxy was the only thing that cracked), and our rocket can now be flown again.

Because part of the competition was scored on the characterization of our flight using multiple methods, much thought was put into the sensors we would include in our design. In the end we opted to use two pressure sensors, a GPS unit, and a real time clock.

Standard flight computers, such as the competition flight recorder, the Raven 3, utilize barometric pressure sensors to calculate altitude. Because this method is so ubiquitous, and the sensors cheap and easy to work with, we decided to record altitude using a barometric pressure sensor located in the avionics bay. We chose to work with a Honeywell silicon pressure, due to the affordability, operating range, and sensitivity. Using our Arduino Uno, the raw voltage data can be converted into meaningful pressure data quite simply, as the sensor returns a voltage proportional to barometric pressure. This sensor would be used to measure altitude, but another requirement was to also record velocity. After some cursory research, a simple method to record the airspeed of our rocket was found: a pitot tube. A pitot tube measures the pressure of a fluid flowing past, and, using Bernoulli's equation, can give the velocity of said fluid (in this case the rocket's airspeed). Using a form of Bernoulli's equation:

$$P_t = P + \frac{Pv^2}{2} + \rho g h \quad [1]$$

Where P_t is constant, P represents the static pressure, $\frac{Pv^2}{2}$ is the dynamic pressure, and $\rho g h$ is the hydrostatic pressure. Because we assume the static and dynamic pressures to be taken at the same altitude, the hydrostatic pressure can be ignored. Using two sensors, one to record static pressure and the other to record dynamic pressure, the equation can be solved for v:

$$v = \sqrt{\frac{2(p_1 - p_2)}{\rho}} \quad [2]$$

Where $(p_1 - p_2)$ is the difference of pressure between the two sensors, and ρ is the density of the fluid (1013.25 hPa was used in our calculations).

We decided that in addition to the pressure sensors to record altitude and velocity, we'd like to try a more non-standard method. Using a GPS as an altimeter is less common, as it typically has trouble maintaining a GPS lock under high speeds. However, we decided to try and use this method, at least as a back-up to our more traditional pressure sensor and Pitot tube. Our GPS unit was an Adafruit Ultimate GPS breakout, with 10 Hz updates. We chose this sensor because of its affordability, its availability, and its reasonable refresh rate. We did not expect this GPS unit to maintain a lock throughout the ascent of the rocket, and indeed; it didn't. However it did give us good data during our rocket's descent.

The final sensor we included in our avionics bay was a real time clock. This clock was used to monitor the mission time, which allowed us to easily graph the position versus time and velocity versus time of our rocket. Our RTC of choice was the Sparkfun RTC module. This module uses the I2C interface to output the time at 1 Hz.

Figure 2 shows a comparison of the altitude data from our onboard GPS, Raven 3 Altimeter, and the calculated altitude from our pressure sensor. The GPS lost its satellite lock during the ascent so you can see a jump in the graph when the GPS regained its lock. It is clear from *Figure 2* that the GPS, pressure sensor, and Raven 3 altitudes agree for the entire flight with only slight variations. The pressure sensor shows a slightly higher peak altitude than the Raven 3. We believe that the small discrepancy may have been caused by a pressure difference inside of the avionics bay. Even though the area was vented, a small difference in pressure from the surrounding area likely caused this difference. Our maximum altitude as recorded by our Raven 3 altimeter is 3182 feet above ground level, which is higher than the 3085 feet above ground level that RockSim predicted (as depicted in *Figure 3*). We made our RockSim calculations based on the weather conditions on the flight day and added weight to the rocket to achieve the altitude we wanted. Our rocket possibly overshot the target altitude because we may have slightly overestimated the coefficient of drag based on our wind tunnel tests.

It appears that the predicted velocity values derived from RockSim varies from the actual values recorded by our different sensors. For example, the maximum velocity measured by the Raven 3 altimeter was approximately 424 feet/sec, while the predicted value from RockSim was 501 feet/sec, as seen in *Figure 4*. A various number of factors can be responsible, such as a non-accurate drag coefficient and wind conditions. However, the velocity values obtained from the pitot tube did correspond with the predicted values as the the pitot tube recorded a peak velocity of approximately 500 feet/sec (shown in *Figure 5*). In any case, the same trend in which velocity increases as the same function of time is similar in all sets of data. Our prediction thus fits reasonably well to the actual data.

The acceleration of the rocket is related to the velocity. The accelerations measured by the Raven3 and the Arduino are quite similar in form, but the Raven3 has a much larger amplitude variation (as seen in *Figure 6*). This discrepancy may be due to the higher data collection rate of the Raven3 and the inherent error in approximating the acceleration by finding the difference between two velocities and dividing by the difference in time between those measurements (.05 seconds for the Raven3 and .1 seconds for the Arduino).