Team Falcon

Post-Flight Performance Report

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Introduction

Team Falcon built a one-stage rocket, named Falcon Punch, that is three inches in diameter and is seventy-one and three-quarter inches in length. A great deal of work was put into ensuring the rocket weighed enough to accurately reach a maximum altitude of 3000 feet and still maintain a stable flight. This work culminated in Team Falcon installing an adjustable ballast system. The ballast system was specifically designed by Team Falcon for two reasons. The ballast allowed the Team Falcon to adjust the rocket's weight between five pounds and seven and one-half pounds, The weight of the rocket is inversely related to the maximum altitude that can be attained by the rocket. The adjustable ballast also allows for precision tuning of the rocket's center of gravity. This allows Team Falcon to adjust the stability of the rocket, and helps the team to be prepared for adverse weather.

At just under six and one half pounds with ballast, the weight of the rocket on launch day, the center of gravity was measured to be forty-four and seven tenths inches from the nosecone. The center of pressure was measured to be forty-seven and eight tenths inches from the nosecone. Falcon Punch was powered using a Cesaroni I540 rocket motor. The rocket features two sets of fins which provide extra drag, making an apogee of 3000 feet more easily attained. The upper fins also bring the center of pressure closer to the nosecone, making it easier to maintain a stable flight. Falcon Punch's deployment system features two parachutes. The rocket's drogue parachute was designed to be released at apogee, and the main parachute was designed to be released at 700 feet above the launch platform during descent. Flight simulations were performed using fourth order explicit Euler numerical approximations in RockSim v9.0 software.[1] An average of many simulations was then calculated as our predicted flight height.

The drogue parachute was released at apogee to provide a safe and controlled descent until the main parachute was released. The main parachute was released at an altitude of 700 feet during the rocket's descent into the nearby field. Falcon Punch reached an apogee of 2838 feet, attained a maximum acceleration of 525 feet per second squared, and achieved a maximum velocity of 419 feet per second. These values were in statistical agreement with the computer simulations.

Launch and Recovery

Team Falcon's rocket was successfully launched on April 27th 2013 around eleven o'clock in the morning. It was a clear morning, with temperatures around sixty degrees Fahrenheit and low wind speeds. With these ideal conditions, we proceeded with the plan to trim back some of our ballast and fly.

Falcon Punch had two onboard Raven III altimeters, one of which was provided by the Wisconsin Space Grant Consortium (WSGC) and the other was provided by Team Falcon. The altimeter provided by the WSGC was used to collect altitude, velocity, and acceleration data. The altitude data, which measured the rocket's vertical position in relation to the launch pad, was used to determine Falcon Punch's maximum altitude during flight. Team Falcon's altimeter collected the same data.[3] For redundancy, both altimeters were programmed to mirror each other and provided the current to detonate charges for recovery. We had no trouble on the first flight

with this capability and the result was a safely deployed parachute whether or not an altimeter had failed at any point in the flight.

The drogue parachute deployed at apogee, as expected. The main parachute was then deployed at the expected 700 feet softly into the field. The rocket was recovered intact and in flyable condition around eleven-thirty in the morning. The rocket was further from apogee than expected. Due to this, we opted to launch a second flight. This second flight was to be on a Cesaroni I216 motor, which was a backup because of a defective batch of motors from the supplier. We had no data sheets on this and only that it was "5 Newtons" less impulse than the I540. This ended up being much less powerful giving an even less desirable result that we won't dive into in this report.

Analysis Procedure

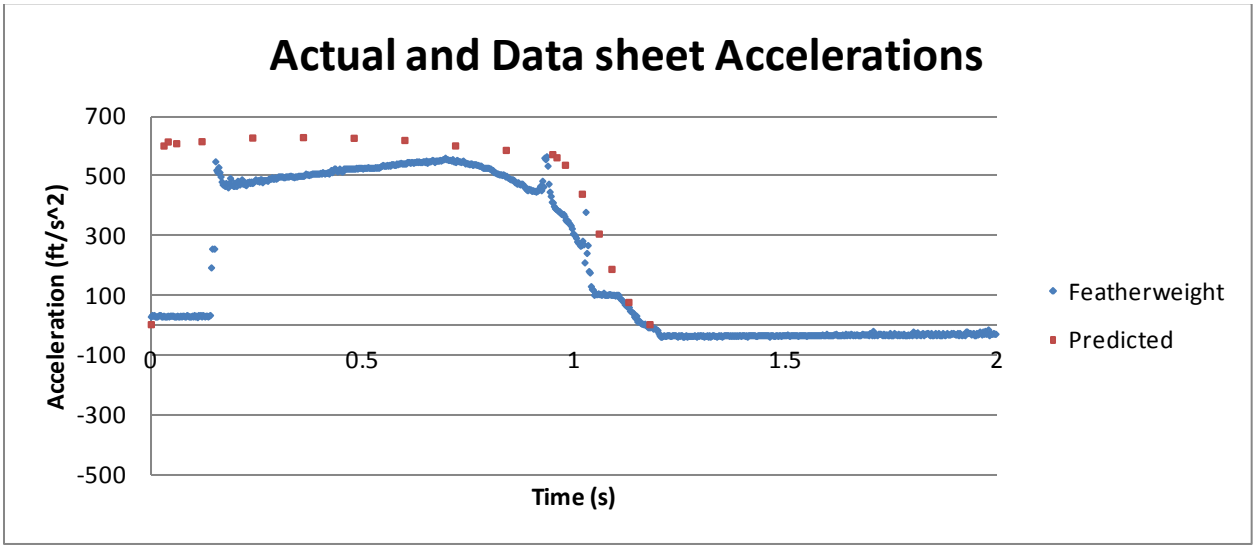
Data from the simulations and the altimeters were exported in a comma delimited format, and imported into Origin v8.6. Origin, a data analysis and graphing software, was used to determine the maximum altitude, velocity, and acceleration recorded by the altimeters and by the RockSim simulations.[3] These values were statistically compared to the maximum altitude, velocity, and acceleration determined by the simulations. The accuracy of the Raven's barometric altimeter is temperature based. If the temperature is warmer than the standard atmospheric model, the altitude measure by the altimeter tends to be off by ten percent or more.[4] At 830 feet above sea level, the standard atmospheric model predicts a temperature of fifty-six degrees Fahrenheit. Unfortunately Featherweight Altimeters does not specify the accuracy of the Raven's accelerometer.[5]

Results and Discussion

Falcon Punch was within one hundred and sixty two feet of the target apogee of 3000 feet according to both of the altimeters onboard. Being within one foot of each other, the two measured values for apogee were within one foot of each other. Table 1 shows the value for apogee measured by the altimeter provided by the WSGC. Falcon Punch's apogee was one deviation (z-score) from predicted value. This means that it is statistically probable that the rocket could have reached an apogee equal to the predicted apogee even though there is a nine percent difference between the values. We believe that the error between prediction and actual for this launch came from a not perfectly straight flight like we expected from the collegiate rocket launch.

Table 1: Comparison of the predicted and actual maximum altitude, velocity, and acceleration experienced by Falcon Punch. The WSGC value for maximum altitude was used for this table.

	RockSim Prediction	Actual	Uncertainty	Z-score	% Difference
Apogee (ft)	3138	2838	284	-1.25	9.6%
Maximum Velocity (ft/s)	545	525	96	0.70	3.7%
Maximum Acceleration (ft/s^2)	551	419	101	-1.31	24.0%



As we can see from the above graph, the predicted flight acceleration follows the same general curve with a couple small differences. The first being that in an ideal world, there's no ignition time and the thrust is immediately there. Second we also notice that the curve is under the data sheet predictions across the board giving us even less thrust than we had anticipated.

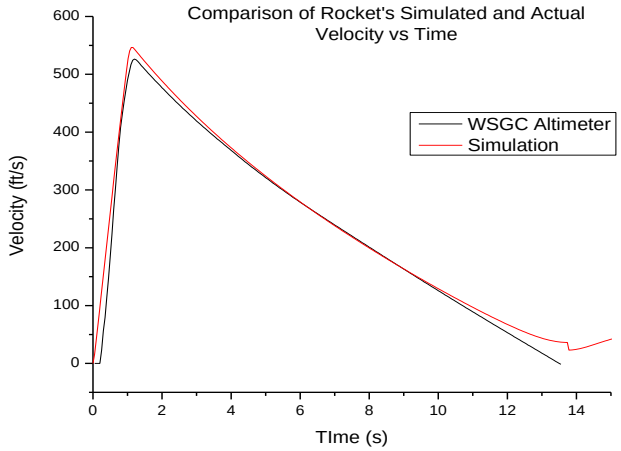
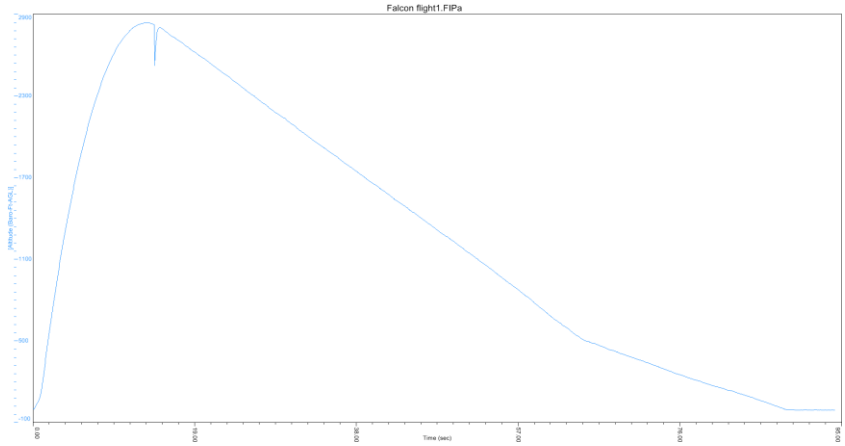


Figure 3. The actual and simulated velocities attained by Falcon Punch during its ascent were compared.[4]

One reason for the lack of precision with the velocity and acceleration measurements may be the fact that the Raven's accelerometer is dependent upon the orientation of the altimeter in relation to the rocket's flight path.[4] If the altimeters are at a slightly different orientation, then the measured values for acceleration and velocity could be very different. In order to get a more meaningful result, further testing is needed to determine the precision and the accuracy of the altimeter's accelerometer. We also noticed on this flight that we did not have an almost perfectly

straight flight, also reducing the target apogee. It is also worth noting that RockSim v9.0 does not account for small imperfections on the rocket that will cause extra drag, and as a result the maximum altitude attained by the rocket will be smaller than the simulated values.



The data produced by the simulations was compared with the data gathered from the WSGC altimeter.[4] We can see the rocket reach it's apogee height and shortly after deploy its drogue parachute. This can be observed from the spike in pressure as it vented some into the altimeter compartment through the small space around the wires. We can also see the main parachute release which is indicated by the shallower slope in the curve.

Conclusion

The competition parameters for this year's WSGC Collegiate Rocket Competition were simple: build a rocket that will reach an apogee as close to 3000 feet as possible, and recover the rocket intact and in flyable condition. Team Falcon's rocket, Falcon Punch, attained an apogee of 2868 feet. Though it didn't meet our expectations, Team Falcon kept to its goals: win this competition and have fun becoming true "rocket scientists"!

References

1. Flight Simulations were performed using RockSim v9.0:
   http://www.apogeerockets.com/Rocksim/Rocksim_information
2. Data collection was performed using two Raven III altimeters:
   http://www.featherweightaltimeters.com/The_Raven.php
3. Data analysis and graphing was performed using OriginPro v8.6: http://originlab.com/
4. "Raven User Manual." *Featherweight Altmeters*. N.p., 01 Jun 2012. Web. 15 Apr 2013. <http://www.featherweightaltimeters.com/uploads/Raven_Users_Manual_12June1.pdf>.