TEAM WHOOSH GENERATOR

POST-FLIGHT PERFORMANCE REPORT

2014 GREAT MIDWESTERN
REGIONAL ROCKET COMPETITION

MILWAUKEE SCHOOL OF ENGINEERING

TEAM MEMBERS:

Kathryn Baisley
James Ihrcke
Eric Johnson
Kirsti Pajunen
Stephan Skibinski

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FLIGHT OVERVIEW

The rocket designed and built by Team Whoosh Generator for the 2014 Wisconsin Space Grant Consortium (WSGC) Regional Rocket Competition had a successful competition launch on April 26th, 2014. At a pre-motor weight of 15.4 pounds, the rocket obtained an apogee of 2815 feet and a maximum acceleration of 232 ft/s^2. Upon descent, all ejection charges went off, the drogue chute ejected successfully, but was tangled and slowed decent by a negligible amount. The main chute deployed and functioned properly, slowing the rocket to a safe landing speed of 18 ft/s. The rocket was recovered safely and in flyable condition.

ROCKET OPERATION

There were a number of factors that affected the launch of the rocket on April 26th, 2014. The weather on the day of the launch was not optimal. There were wind speeds varying from 8 mph to 20 mph with clear skies. The rocket's performance was lower than the projected altitude due to high wind speeds. The black powder charges deployed at apogee, separating the lower airframe from the rest of the rocket and successfully deploying the drogue parachute, which was tangled. The main chute powder charges deployed at roughly 600 ft and the main chute also deployed successfully.

The rocket then drifted back towards the launch site on the main parachute and landed within 500 feet. The team predicted the location of the landing site using an online drift calculator. The predicted location was close to the actual landing site location of the rocket.

ALTERNATE VELOCITY MEASURING SYSTEM

The alternate velocity measurement system (AVMS) that was used took advantage of the force on the nosecone from air resistance. A force sensor was used to measure the force from the nosecone through an aluminum rod. An Arduino then recorded the data onto a micro SD card as an output voltage. After converting the voltage to the proper force that was applied it was input into the drag force equation along with the frontal area, the coefficient of drag, and the density of the air in the atmosphere.

$$F_d = \frac{1}{2}\rho V^2 C_d A$$

The equation was then solved for velocity and plotted vs. time in Microsoft Excel shown in Figure 1.

$$V = \sqrt{\frac{2F_d}{\rho C_d A}}$$

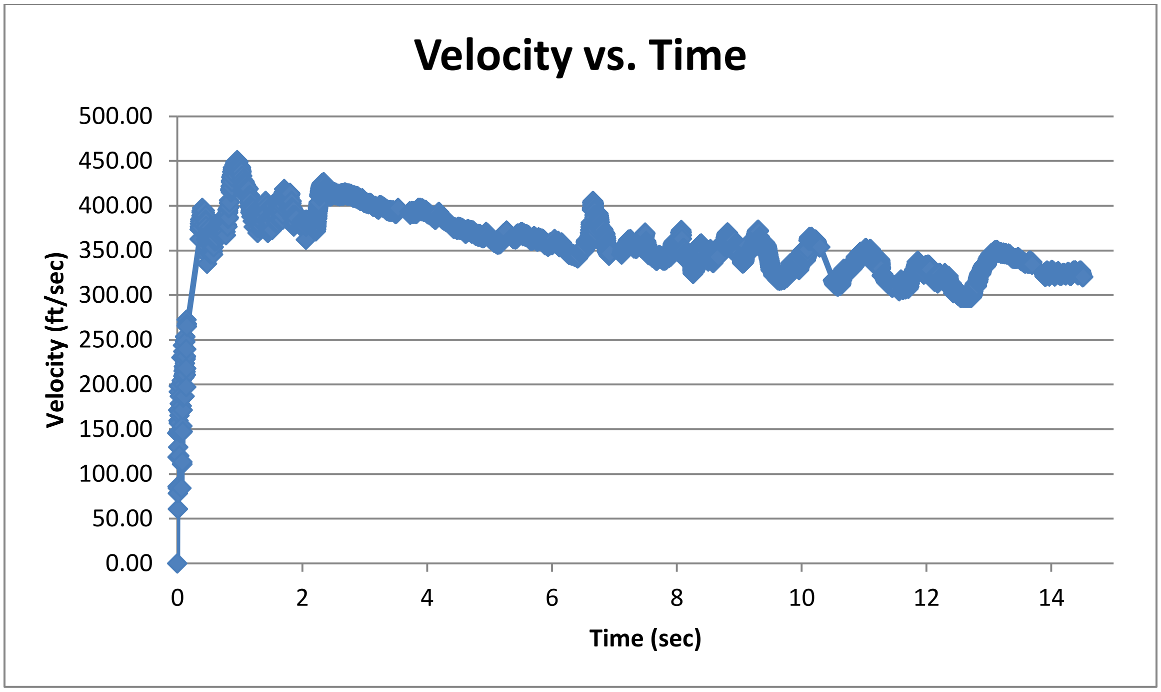

Figure 1: Velocity Data from AVMS

From the graph it can be seen that the velocity increases while the motor is burning. The velocity begins to decrease as the rocket approaches apogee. There is a lot of noise in the data near apogee probably due to the nose cone rattling on the force sensor and the high winds. The calculated maximum velocity by this method was 450.68 ft/s compared to the actual maximum velocity of 462 ft/s.

ROCKET FLIGHT PERFORMANCE COMPARISONS

Computer simulations were run to design and estimate the flight performance of the rocket. The two methods used were OpenRocket and a MATLAB simulation written in previous years and revised by the team this year. The flight data of the rocket was recorded using a Raven III flight data recorder, provided by WSGC. The flight of the rocket matched reasonably well with the predictions of both simulation methods. A comparison between the predicted and actual flight results is shown in Table 1.

Table 1: Flight Performance Comparisons

	Apogee (ft)	Maximum Velocity (ft/s^2)	Maximum Acceleration (ft/s^2)
MATLAB	2958	459	195
OpenRocket	2947	459	201
Actual	2815	462	232
	Percent Error From Actual (%)		
MATLAB	5	<1	16
OpenRocket	5	<1	13

Also, predicted and actual acceleration is plotted in Figure 2.

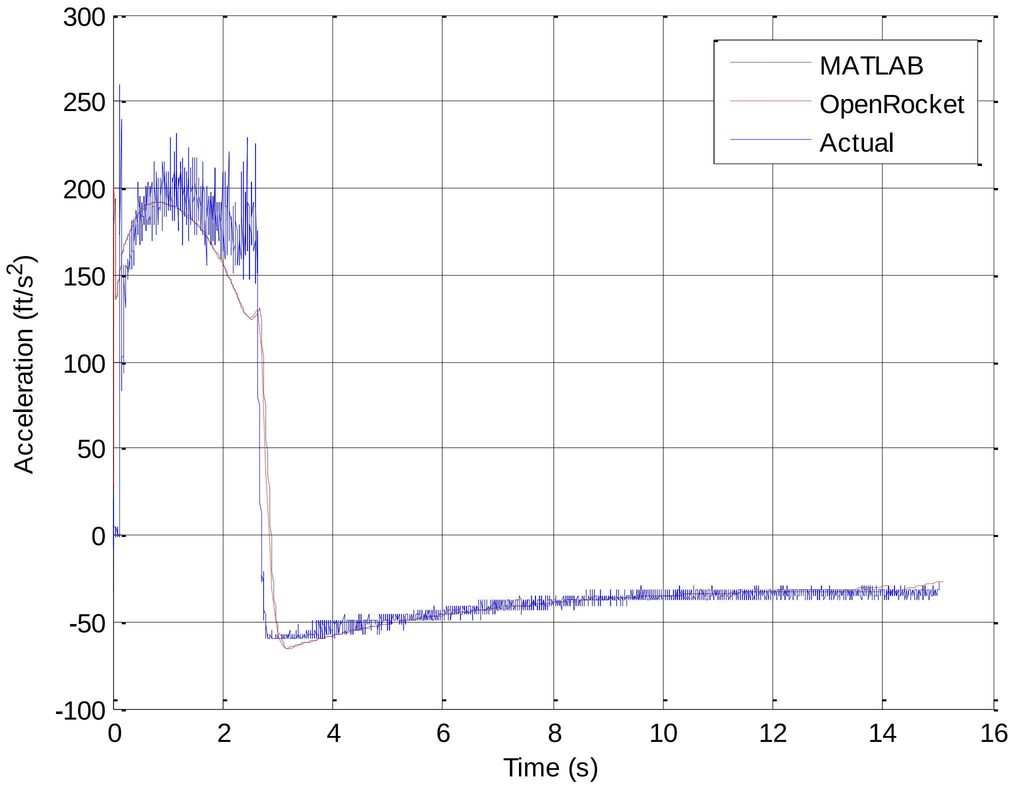

Figure 2: Comparison between Predicted and Actual Acceleration

The time to apogee was about 15 seconds, which was as predicted. The rocket undershot the desired altitude of 3000 feet by 185 feet. This was fairly successful because MATLAB predicted an apogee of 2958 feet and OpenRocket predicted 2947 feet. Since the actual apogee and these two predicted values had a percent error of 5%, the simulations were good representations of the actual flight. However, the amount of undershoot was more than expected, based on results of previous flights. This was likely because the simulations were not accounting for the amount of wind during the flight. MATLAB could not take wind into account, but for the OpenRocket simulation, a 12 mph wind was inputted into the simulation. However, the actual wind speeds during the time of flight were more likely around 20 mph accounting for the undershoot. These high winds caused most team's rockets to undershoot because of dramatically increased drag.

The maximum acceleration of the rocket was very close to the expected value. The actual maximum acceleration was 232 ft/s^2, with predicted accelerations of around 200 ft/s^2. This is a percent error of about 13%. While this is not an extremely large percent error, it is significant. The difference in maximum acceleration from the predicted and actual can be accounted for in many ways. The most significant contributor to this discrepancy is likely the weather conditions on launch day. The air was probably less dense than normal, with a temperature around 46 degrees Fahrenheit. It was also very windy, contributing to turbulent flow occurring sooner on the rocket than it normally would. The faster jump to turbulent flow reduced pressure drag on the rocket, allowing for a higher acceleration. Another significant contributor to the rocket seeing a high acceleration could be the motor performing differently than predicted. The motor could have had a different amount of propellant (or was manufactured differently) than stated in the motor specifications, producing a different thrust profile during the duration of the motor impulse. This could have caused the increase in maximum acceleration. In Figure 2, the acceleration at apogee (15 seconds) is about -32.2 $ft/^2$. The reason this is negative is because 32.2 ft/s^2 was subtracted from all data to account for the rocket at rest having "1G" conditions. At apogee, the rocket reaches 0G, which is zero gravity, so it appears as -32.2 ft/s^2 on the plot.

PROPOSED DESIGN CHANGES

For future launches a few key changes are planned. The first is changing the cardboard airframe since it was determined to be inferior to the fiberglass counterparts when it comes to resistance to water and other elements. For future launches and landings, a fiberglass airframe would be more durable and thus more reliable. The second change is having a GPS always on board to aid in the quick recovery of the rocket as well as possibly implementing a loud high pitched pulse sound in case it lands in deep brush. Possibly the most important design change would be making the weights much easier to change than the current design. If more weight could have been removed to account for the high winds, the apogee would have been closer to 3,000 feet. A system should be designed in which weight can be secured during flight but still capable of being removed or rearranged inside the rocket. This will cause the location of the center of gravity to change and thus the apogee of the rocket's flight. This means the simulations will be more representative of the rocket's actual performance. The combination of these changes would minimize time needed to locate the rocket, allow for the possibility of more launches, and increase the ability to quickly change the weight of the rocket.

CONCLUSION

On April 26th, 2014, Team Whoosh Generator flew and successfully recovered the rocket in flyable condition. It had a pre-motor weight of 15.4 pounds. The rocket flew to an apogee of 2815 feet and had a maximum acceleration of 232 ft/s^2. This was 132 feet off from the predicted apogee of 2947 feet. At apogee the ejection charges separated the lower airframe and deployed the drogue chute which was tangled. The main chute deployed at 600 ft, minimizing drift. The proximity of the landing site to the launch site allowed the team to accurately predict the coordinates of the landing site.

Overall, it was a successful flight. With the successful recovery of the rocket, beneficial data and observations were retrieved and evaluated in this report, allowing for greater understanding of rocket flight in general and how to improve for future rockets and flights.