NASA Student Launch Initiative 2007-2008

Washington County (Wisconsin) 4-H Rocketry

Student Launch Initiative

Post Launch Assessment Review

May 23, 2008

Watt's Up!

Electrical Power Generation
from a Rocket Powered Wind Turbine
and Permanent Magnet Generator

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Team

Name: Washington County 4-H Rocketry Club
Location: Slinger, Wisconsin
Members: Cameron Schulz, Katlin Wagner, Ben Pedrick, Brady Troeller
Mentors: Doug Pedrick, Pat Wagner, Ed Kreul, Jim Decker, Dave Duckert

Project Goal

The team's goal is to design and construct a reusable rocket that will travel to a distance of one mile in altitude. The rocket will be stable enough to safely carry a four-pound payload in the nosecone. The payload will generate electrical power by harnessing the wind energy created by the mass of oncoming air pushing against the airframe during ascent.

Project Summary

Vehicle

The rocket's final configuration flew at 22 pounds with a 3.4 stability margin. It was powered by an Aerotech K700W and reached an altitude of about 4973 feet. The prep time took about 1 hour and the launch was delayed at the pad when one of the batteries in the altimeters came loose. We had to bring it off the pad and secure it.

During the launch, the rocket weather cocked after leaving the rail but proceeded to maintain a relatively stable flight. It reached a maximum velocity of 203 meters per second. Both the main and the drogue parachutes opened as planed. The rocket also weather cocked during the test-flight, so the team expected some weather cocking but decided that there was no easy solution for the problem and decided it did not threaten any of our mission success criteria. We think that the rocket didn't fly straight because the center of gravity was too far forward. The vent holes in the top of the payload prevented air from coming out of the hole on the side the wind was blowing. As a result all of the air was forced out the other three holes. This caused the hole opposite the wind to provide a displaced thrust, causing the rocket to pitch into the wind. The conclusion of this issue is that one way to prevent this was to construct a shroud over the vent holes to prevent the wind from entering, and to direct the turbine outlet flow down the rocket.

We found that our altimeters didn't have identical altitude data. The ARTS uses a 10 bit A/D converter and so is accurate to within ~25ft. The MAWD looks like they have slightly better resolution at ~11ft. Neither of those can explain such a big difference, which means that the resulting error lies in the way that each were calibrated against a standard atmosphere, or in the accuracy of the pressure sensor itself. The pressure sensor that the ARTS uses is accurate to +/- 1.8% over its operating range. The MAWD uses a slightly better pressure sensor: +/- 1.5% error. Both are temperature-compensating sensors.

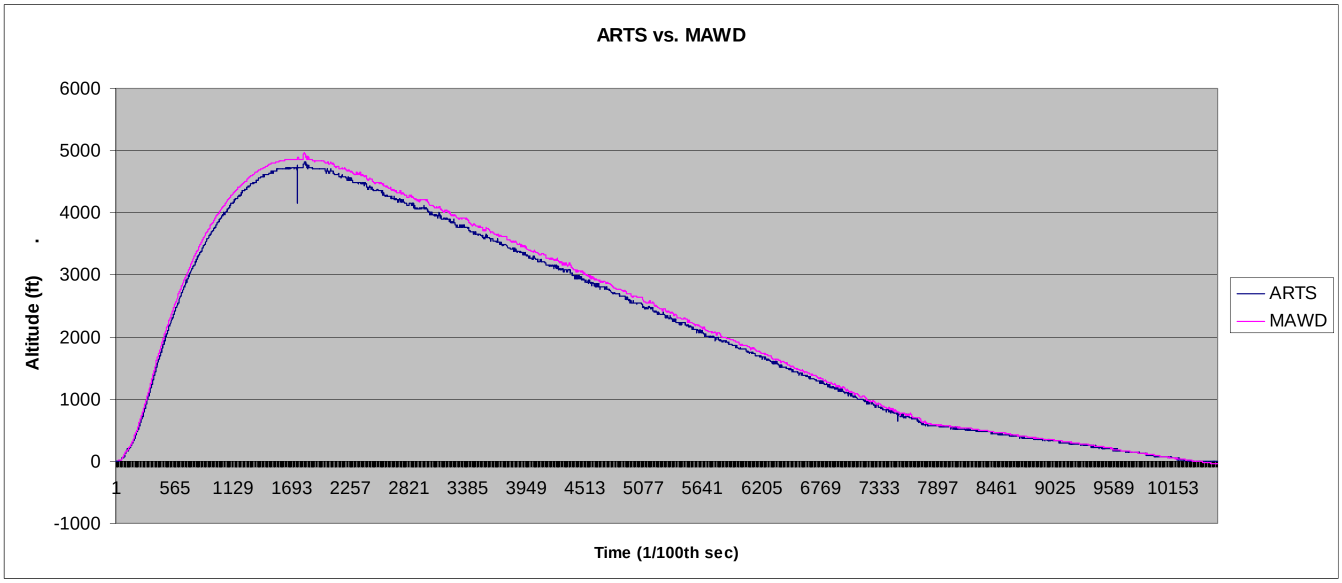

Figure 1. Altimeter Comparison

As a result of the weather cocking the rocket landed a half-mile down range. It was recovered successfully by using a GPS unit that was attached to the parachutes. There was no damage to the rocket and all the data was collected successfully. The rocket obtained an altitude of 4973 feet. We believe that it did not gain as much altitude as planned because of the weathercocking.

The conclusion of the team was that the rocket and project were very successful. The rocket and team successfully met all of its mission success criteria. If we were able to change the rocket in any way it was decided that we would have tried to construct a shroud of some sort over the vent holes so that the wind would not have an affect on the vent holes. The integration part of the rocket and payload went very smoothly and as planned. However we would have taken better advantage of space and addressed the CP and CG issues with more thought.

Payload

Our payload contained a data recorder that records temperature, RPM, and volts produced by the generator. Using the volts measured, our circuit resistance of 10.6 ohms, and Ohm's Law, we derived the watts and amperes generated from the following equations:

$$\textbf{Watts} = \frac{\textbf{Volts}^2}{\textbf{Ohms}}$$

$$\textbf{Amperes} = \frac{\textbf{Volts}}{\textbf{Ohms}}$$

At maximum speed (burnout) the turbine was operating at 37,000 RPM and generating

- **56.14 Volts**
- **297.3 Watts**
- **5.29 Amps**

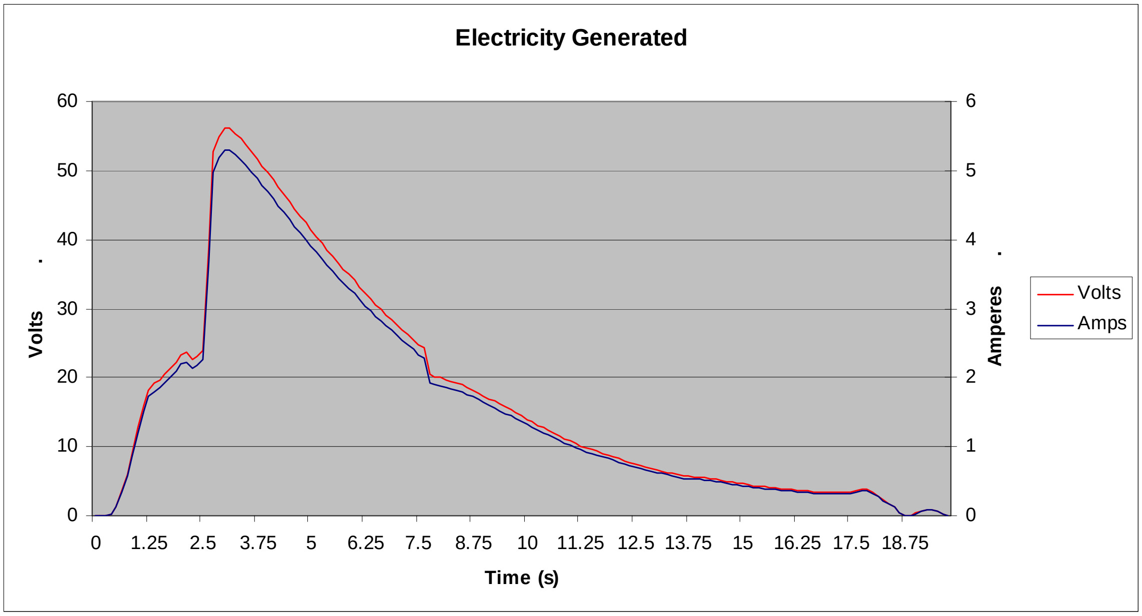

Figure 2. Volts and Amperes over Time

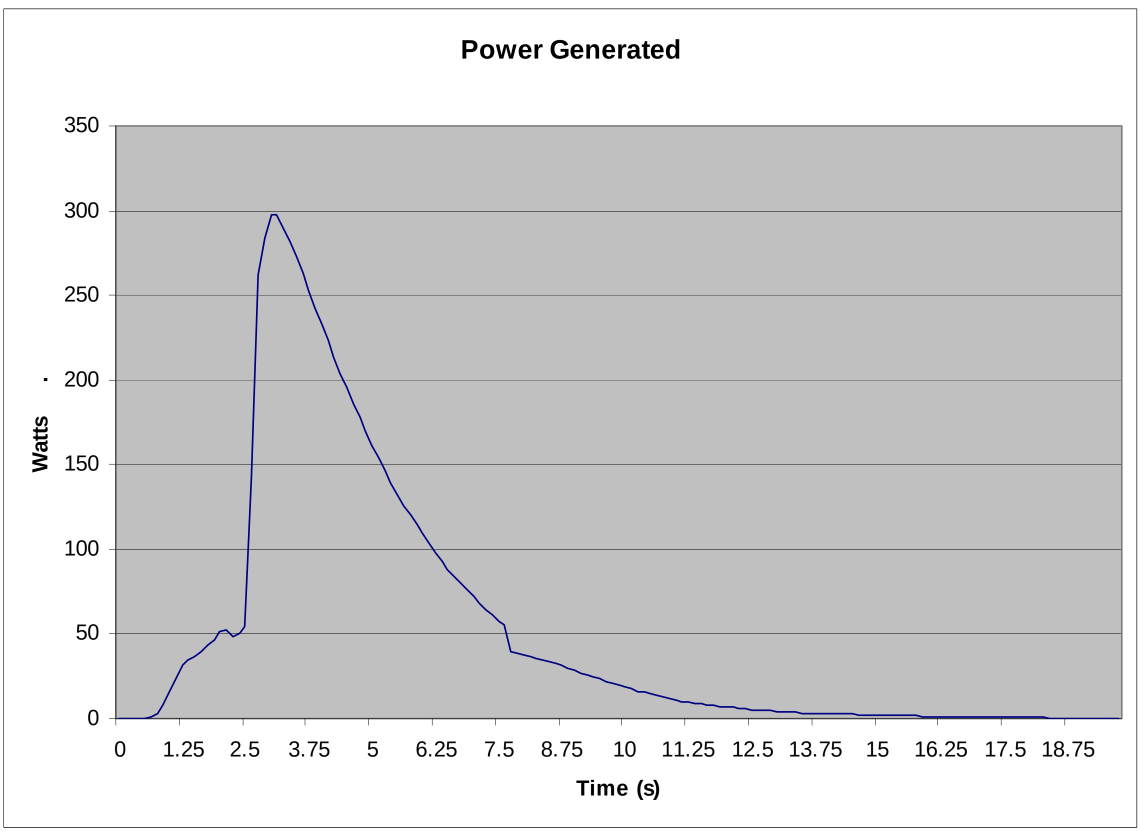

Figure 3. Watts over Time

We had predicted the efficiency of our electrical system by using this formula:

Effective Power = Cp * 0.5 * Swept Area * Air Density * Velocity^3

Swept area is pi*r^2 (r == radius of the swept area, or the blade length minus the central hub area)
Air density in kilograms per cubic meter, and
Velocity in meters per second.
Cp the Power Efficiency

Predicted Power at 203 m/s Wind Velocity					
Blade Length (mm)	**Swept Area (mm^2)**	**Maximum Betz Power (Watts)**	**Power Efficiency (Cp)**		
			10% (Watts)	**20% (Watts)**	**30% (Watts)**
20	2827.433	8634.7446	1454.6	2909.281	4363.921

Solving the equation for efficiency at a maximum power of 297 watts yields about 3.1%. Most commercial generators convert about 25-35% of the energy in the wind to electricity. We expected it to be more efficient and had hoped to be at least 10% efficient on average. We think that the main factor is that the generator (DC motor) was only rated for 7500 RPM while we spun it 5 times faster than that at about 37,000 RPM. The plot of Power Efficiency over time shows the system averaging between 3% and 4% efficiency.

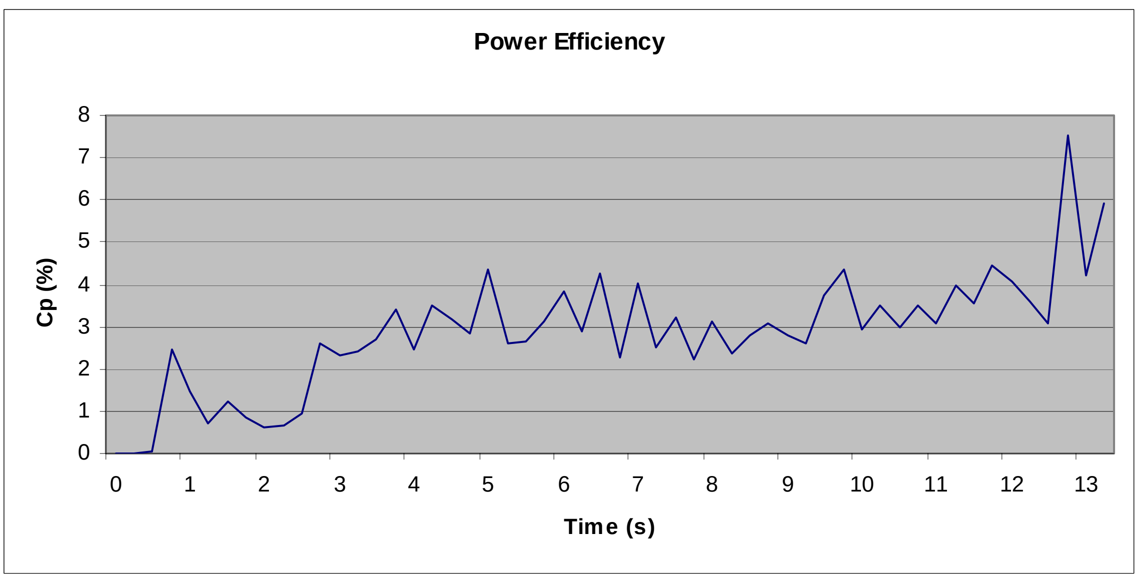

Figure 4. Wind Turbine Power Efficiency

The extra energy could have been given off as heat, as demonstrated in the data recorded by our temperature sensor.

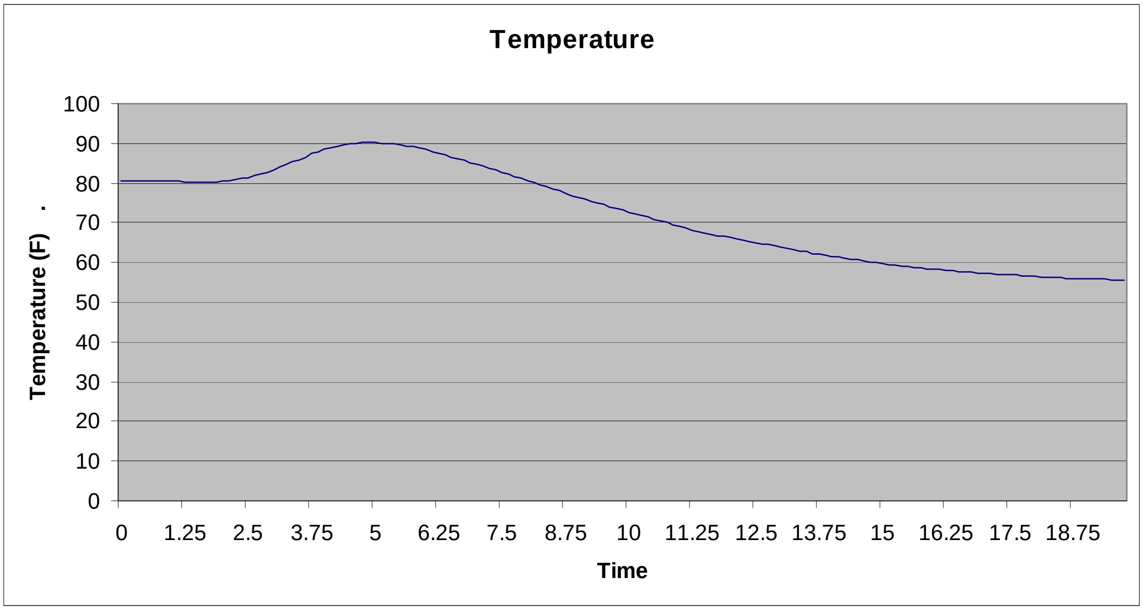

Figure 5. Temperature over Time

We also think that we lost significant energy through the resistor and the generator. The resistor was undersized for what we were putting through it and we lost energy from the heat given off. It was a 10.6-Ohm wire-wound resistor, but rated for only 10W. The entire electrical system was insufficient to adequately convert a high RPM turbine to electricity.

The payload went through many different design changes as we learned more about what we were doing. Looking back on the project we would have made changes to make it better and more efficient. The circuit could also have been made more robust by eliminating the multiple points of failure that could have caused us to lose data. We have learned about the electrical aspects of wind energy. We plan on using what we have learned this year and building on it for a possible second year project.

Outreach

We have had multiple outreach events targeting a diverse youth population. We have held two workshops through 4-H where we taught over 50 youth how to build and launch a model rocket. We also spoke to a local youth group called The Young Astronauts about our experiences in SLI and TARC. Immediately after the SLI launch we drove to the U.S. Space and Rocket Center and spoke to about 140 Wisconsin 4-H youth that were attending Space Camp. In addition to mentoring over 30 4-H members enrolled in aerospace programs this summer, we will also lead a few workshops where we will conduct some simple rocket activities with youth. We estimate that we reached over 270 kids through our multiple programs.

Budget

We went slightly over our budget due to extra circuitry complications and the purchasing of new parts after finding the fins were not put on straight on the booster section of the rocket causing the team to rebuild that section. The total spending was $2831 on the project. For travel we spent $3069.

Conclusion

The team would like to thank NASA and everyone involved in the SLI program for giving us this great opportunity. Everyone had an outstanding time learning about high-powered rocketry, wind energy, and touring NASA. We look forward to next year.