NASA Student Launch Initiative 2008-2009

Washington County (Wisconsin) 4-H Rocketry

Student Launch Initiative

Post Launch Assessment Review

May 24, 2009

Generate REnewable ENergy

Washington County 4-H Rocket Club
814 Century Ct.
Slinger, WI 53086

Project Summary

Vehicle Specification

The vehicle configuration was as planned from Flight Readiness Review with the following specifications:

Overall Length:	111 3/8 inches
Diameter:	5.54 inches
Weight (Pad Weight):	32 pounds
Stability Margin:	3.15 calibers
Engine:	Aerotech L850W
Coefficient of Drag:	1.55

At the time of FRR, the team did not know the Coefficient of Drag (Cd) since the rocket had not flown at that time. RockSim predicted an altitude of around 5700 feet. The vehicle was flight tested on Saturday, April 4th in Princeton, Illinois. The launch was successful and the vehicle reached an altitude of 3754 averaged between both altimeters. Using the altitude achieved, the coefficient of drag was estimated to be around 1.55.

Vehicle Flight Summary

The same flight configuration was used at Huntsville as stated above. The observations and flight data are as follows:

- The launch was delayed by nearly 3 ½ hours after two unsuccessful attempts to ignite the motor on the pad.
- We concluded that 2 igniters were faulty and as a result the rocket and payload had to be removed from the pad to recharge the battery on the on-board video camera.
- Once launched, the rocket flew straight and true to an altitude of 3706 averaged between both altimeters.
- We expect that the difference in height was due to the difference in weather conditions and launch sites.
- We also noticed that the rocket behaved like one with fin-tabs as it spun on its vertical axis. This gave the rocket additional stability, but also increased the coefficient of drag and significantly impacted our actual altitude.
- We believe the spin was the counter effect of the rotational torque imparted by the three spinning turbine blade assemblies. All of the turbine blades spun counterclockwise. The vehicle spun clockwise.
- Ejection charges were deployed at apogee as intended, to deploy the drogue parachute.

- The main chute was deployed at 775 feet as intended.
- Both backup charges also fired confirming successful redundant deployment systems.
- The AeroPak positive motor retention system firmly held the motor in place during the entire flight.
- The rocket landed approximately 400 yards from the launch pad making for an easy recovery.
- Inspection after the flight concluded that the airframe structure was sound. There were no stress cracks in the fins, turbine tube fins, or the airframe in general.
- With successful recovery of the vehicle, reloading a motor, repacking parachutes and new ejection charges, the vehicle is safe to fly again.

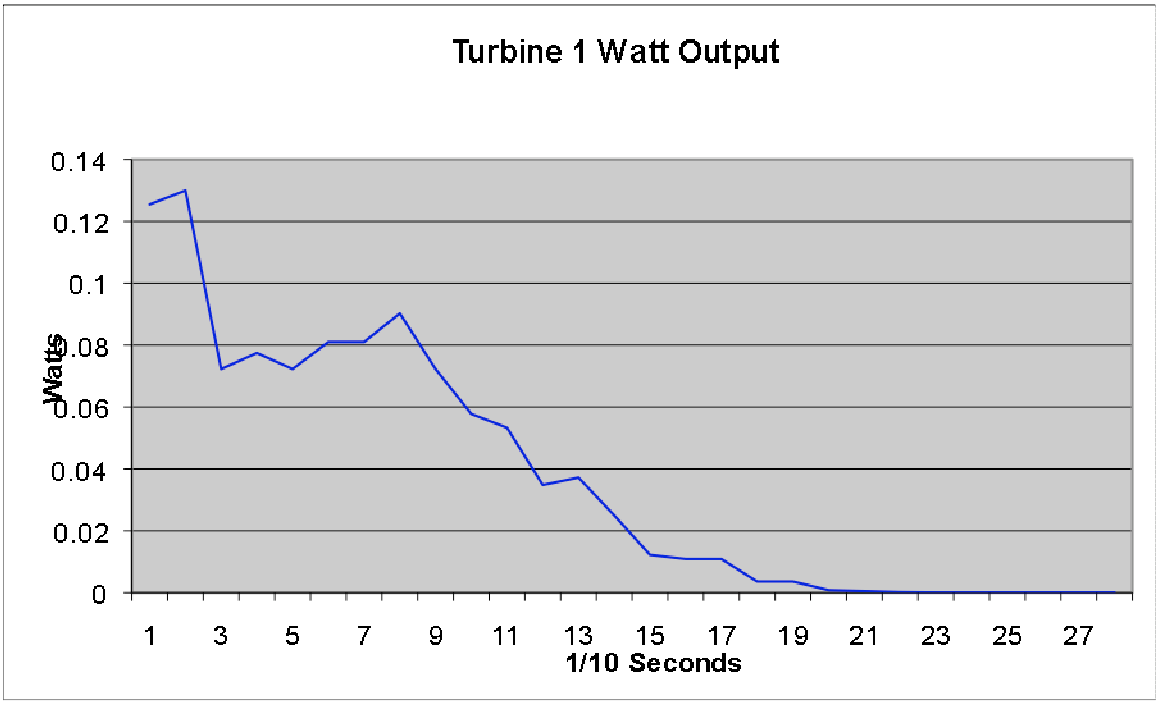
Huntsville Flight Data Summary:

Primary Altimeter Altitude	3649 ft
Backup Altimeter Altitude	3764 ft
Max G's endured	7.474
Max Acceleration	240 ft/sec/sec
Max Velocity	373 mph
Max Barometric Altitude	3649
Drogue Deployment	14.305 seconds after launch
Descent Rate under Drogue	103 ft/sec
Main Deployment	74.375 seconds after launch
Descent Rate under Main	47 ft/sec

Payload

Our payload contained data recorders that measured and stored temperature, RPM, and volts produced by the generators. Using the volts and amps measured we derived the Watts generated using $W=V*A$, or alternatively $W=V^2/R$ for one of the turbines whose data recorder failed to measure current.

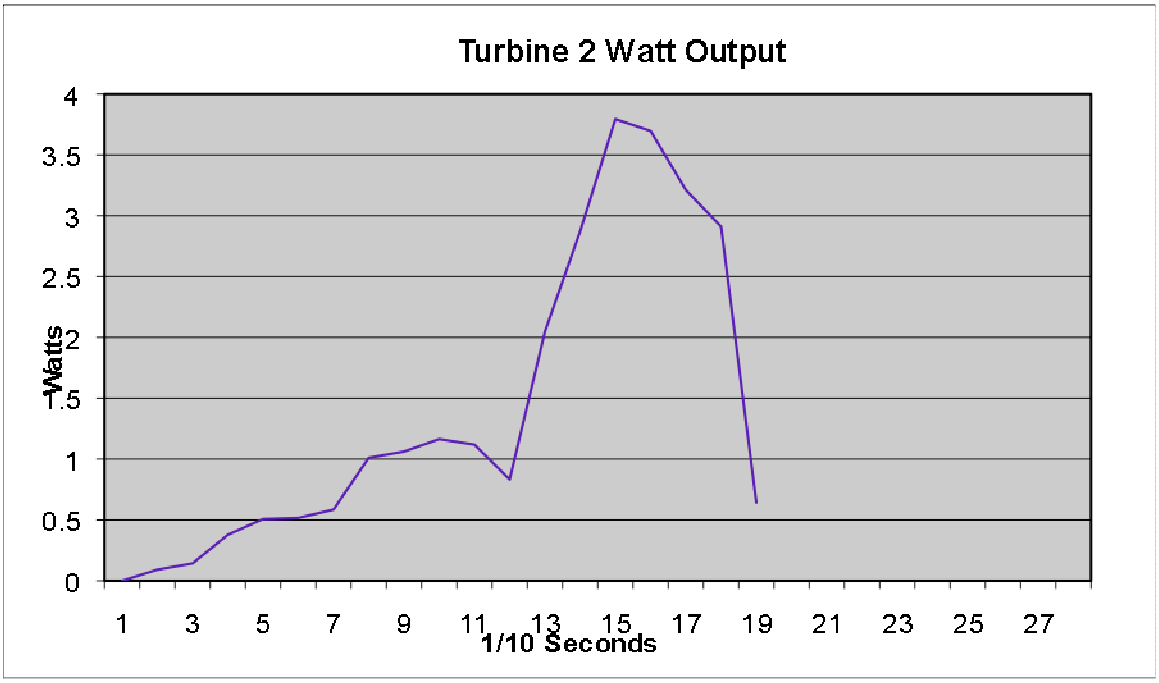
The payload consisted of three ducted fan assemblies. Each assembly consisted of a 65mm RC ducted fan and identical Igarashi DC motors. Each ducted fan consisted of a different number of blades. Turbine 1 had 5 blades, Turbine 2 had 3 blades, and Turbine 3 had 6 blades.



At maximum speed the Turbine 1 was operating at only 4512 RPM and generating

- 1.14 volts
- .112 amps
- .09 watts

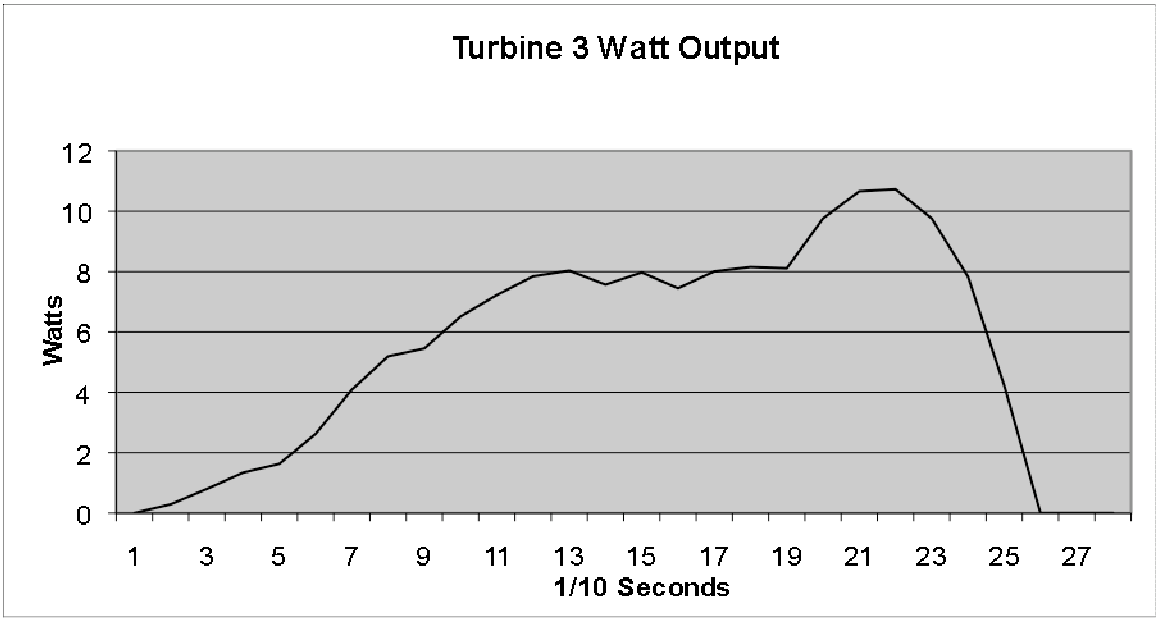
This turbine has 5 fan blades. Its RPM measurements were significantly lower than the other two turbines. The amount of electricity produced was also significantly smaller than the other two turbines. This was completely unexpected. On board video shows no wobble or other impediment that would prevent the fan from spinning freely.



At maximum speed Turbine 2 was operating at 55,147 RPM and generating

- 6.22 volts
- .61 amps
- 3.8 watts

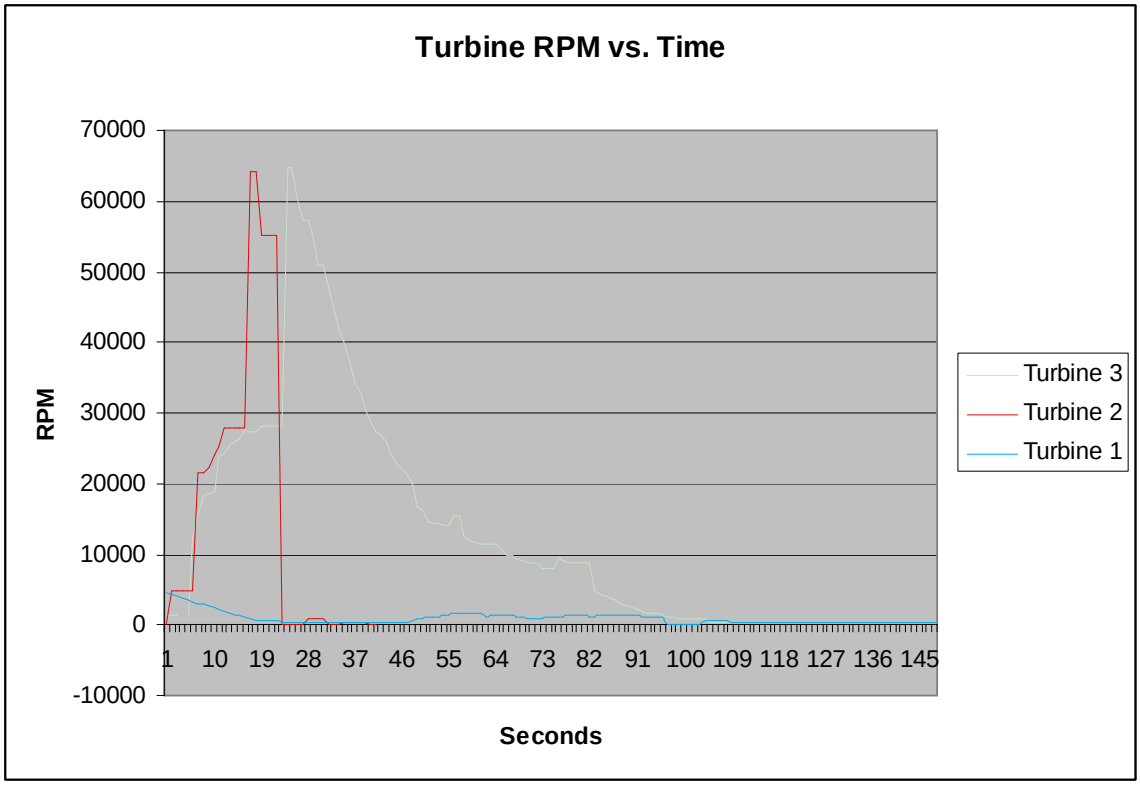
This turbine had 6 fan blades. At burnout, when it was spinning at 64,655 RPM, the shaft of the generator bent and the fan blades shredded as they collided with the housing. We think that at that high rate of rotation any small uneven circular motion would have been magnified from the centrifugal force. Once the blade came in contact with the housing wall, structural failure would have been immediate. The steel shaft of the DC motor was severely bent as well.



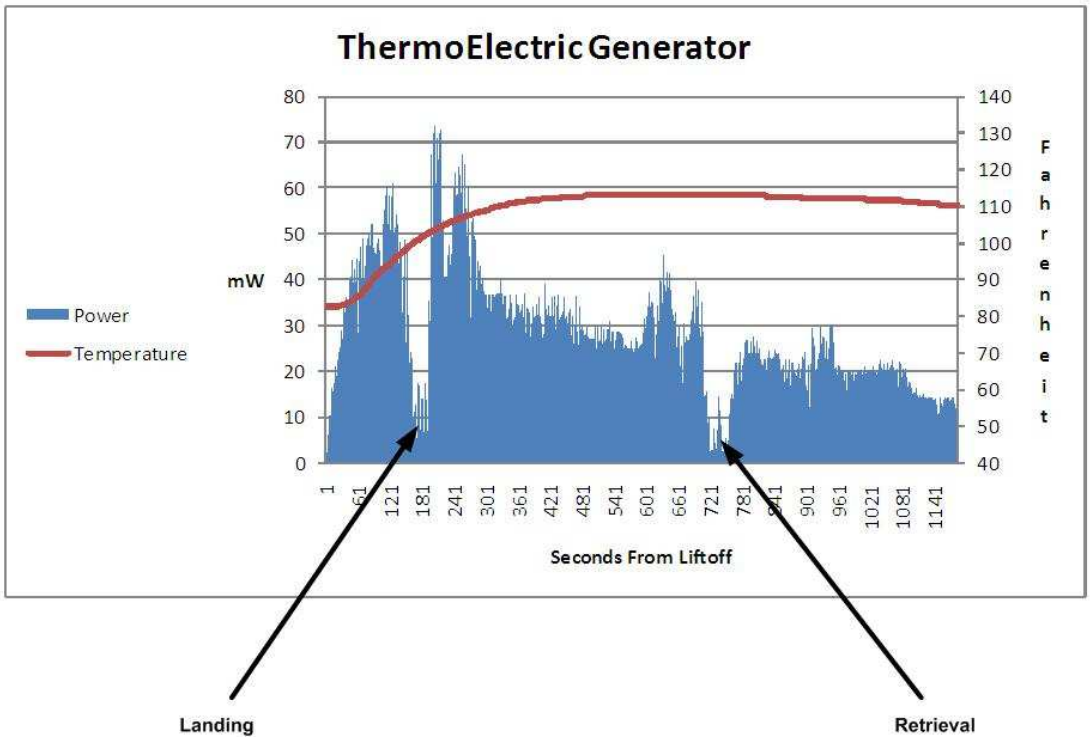
At maximum speed Turbine 3 was operating at 64,655 RPM and generating

- 10.95 volts
- .98 amps
- 10.7 watts

This turbine had 3 fan blades, the fewest of the 3 different assemblies. This turbine generated the most electricity at peak. It also did not have any significant structural failure, allowing it to continue to generate until the velocity of the rocket slowed below the torque threshold of the DC motor.



We found that when we put the fan blades and generators through this kind of stress they could not handle it. During both flights with this payload we had multiple failures with the turbine blades and generators. The parts we used are not strong enough to take the stress of the speed of the wind. 65,000 RPM greatly exceeds the 20,000 RPM for which the motor was rated. A design that incorporated gearing could have helped prevent this type of failure, at the expense of increased complexity.



The thermoelectric generator produced electricity in smaller amounts than the wind turbines, but kept generating over a much longer period of time. It did not spike radically like the wind turbines, but consistently generated electricity up until we shut off the data logger about half an hour after the launch. The dropouts in the data are when the rocket landed with the heat sink facing down, and when we retrieved it and moved it around. The temperature shown in the graph was measured from a thermocouple placed on the motor mount. The actual source temperature on the thermoelectric generator is unknown.

Generating electricity from the heat of a rocket motor is not efficient by most standards. Some of this is inherent in thermoelectric technology, but much of the inefficiency in our design was due to a passive heat sink and indirect access to the heat of the motor. Active or liquid cooling may have helped. Rocket motor casings are not allowed to exceed 200 C and manufacturers use heavy liners to contain heat. A different design that somehow used more direct heat would generate more electricity. We were also told, but did not have time to explore, that graphite nozzles result in higher motor temperatures.

Budget

The team went slightly over budget this year as projected expenses were to be at $5,100. The team spent $5465, a 7% variance. Significant fund raising and generous sponsorship greatly augmented our NASA grant.

Outreach

The outreach program continues as planned. As of May, the County 4-H Rocketry program concluded its final monthly workshop in preparation for the Washington County Fair in July of this year. We are conducting a county launch on July 11th, 2009 for all members of the project to launch their rockets before fair judging. The program believes rockets are meant to fly! In total, the program introduced or helped 150 learn and enjoy sport rocketry. With the continued county rocketry project, continued interested in Team America Rocketry Challenge and strong adult leadership, the rocket program reached a sustaining point.

Conclusion

The vehicle and experiment were challenging and stretched not only our knowledge but our time to make the project a success. This was an incredible learning experience again this year for all involved.

Our project depended on many people, businesses, educational resources and county 4-H sponsors. We'd like to recognize them for their support in helping fund this project beyond the NASA funding provided to the project. They include:

Barry Lynch - LOC/Precision
Al's Hobby Shop – Ken Herek
Gary Pletzer - Top Flight Recovery
Wisconsin Space Grant Consortium
Washington County Shooting Sports
Slinger Advancement Association
Washington County UW-Extension - Washington County Leaders' Board
Igarashi Motor Sales USA, LLC
Steve Janz
Marian Pedrick
Jane and Bob Dawson
Randy Yerke - Redwood Signs
Justin Farrand
Dave Duckert

The project would not have been a success without the dedication and commitment from our adult mentors which we'd like to thank:

Ed Kreul
Doug Pedrick
Pat Wagner

We also want to thank the Huntsville Area Rocketry Association (HARA) for the time they volunteer on launch day and vehicle inspection to make it a safe and successful event.

Finally, we want to thank everyone at NASA who are involved in making it possible to learn more about rocketry and the NASA space program. We are grateful and thankful for the untold time and energy put into SLI by Julie, Al, the academic affairs office, HARA, and the many people behind the scenes at Marshall Space Flight Center that help with this program. While in Huntsville, we spoke with several people who spent their own time reading through the proposals and documents. The dedication everyone gave to this project made for a once in a lifetime learning opportunity for us. Thank you!