NASA Student Launch Initiative 2007-2008

Washington County (Wisconsin) 4-H Rocketry

Student Launch Initiative

Critical Design Review

January 22, 2008

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

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

Table of Contents

Table of Figures

Summary of CDR Report

1.1 Team Summary

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

1.2 Launch Vehicle Summary

The launch vehicle specifications are as follows:

Airframe:	Fiberglass
Diameter:	4.0 inches
Length:	82 inches
Weight:	20.5 lbs (motor included)
Motor:	Animal Motor Works – 54mm, K1075GG
Recovery System:	Redundant dual event altimeters that will deploy an 18” drogue at apogee and 60” main parachute at 700 feet

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.

Based on the half-scale results, the launch vehicle design remains similar to the original specification. The motor selection may change to better achieve the altitude goal of 5,280 feet.

1.3 Payload Summary

The payload will generate electrical power by harnessing the wind energy created by the drag of oncoming air pushing against the fan blades during ascent. It will achieve this using a turbine generator mounted vertically inside the rocket. The fan blade assembly will sit atop the rocket in place of the nose cone.

2 Changes Made Since PDR

2.1 Vehicle

The PDR included a vehicle design similar to the current one. The full-scale vehicle remains approximately 8 feet long and 4 inches in diameter. It is based on the Performance Rocketry Mad Dog kit. The most significant modifications to the Mad Dog kit are being done to the upper portion of the rocket to house the scientific payload. The latest design recommends that a straight piece of additional body tube be used at the top of the rocket replacing the standard nose cone. The payload assembly described below will continue to be housed in that section.

The half-scale rocket has undergone several changes as the team learned more about the models' limitations and has helped with the final full-scale design. The nose cone was cut to the diameter of the rocket to accommodate the payload assembly. Based on recommendations from our mentor, and due to half-scale space limitations, the team chose to use a single altimeter - a PerfectFlite miniALT/WD – foregoing redundant altimeters. Recovery sub-assemblies and a different rocket engine (an Aerotech I218R) were also selected. This change was made based on RockSim simulations to size the engine to achieve the 2640 foot altitude goal for the half-scale vehicle.

The half-scale rocket was launched on January 12, 2008 and reached 2342 feet. Detailed results are described in section 3.1.4.3.

The full-scale design continues to contain redundant altimeters because the vehicle is four inches in diameter and will have sufficient room in the altimeter bay to hold them. Based on the results of the half-scale test, the vehicle section holding the payload has changed. The half-scale flight showed that a blunt nose cone with the payload mounted at the very top of the rocket provides for a stable vehicle flight. After analyzing the results of the half-scale launch with RockSim, we have a better idea of the drag penalty incurred by the payload. That in turn has led us to consider the K1075GG by Animal Motor Works for our full-scale motor. This gives a projected flight altitude of 5,392 feet, just over the 5,280 foot goal.

2.2 Payload

The original payload design had the turbines coming out of the side of the airframe just above the motor mount. The generator shaft was perpendicular to the airframe, requiring a vertical fan blade assembly. Vertical fan blade assemblies are not as efficient as horizontal ones since for half of their rotation they have to fight against the direction of the airflow. In order to try to balance the drag, two turbine blade assemblies and two generators were required.

As of PDR the payload is inside of a piece of airframe with the shaft mounted parallel to, and centered within, the vehicle body. The turbine fan is mounted horizontally. This change was done for several reasons: a) only one generator/turbine assembly is needed, reducing the payload weight considerably, b) the additional drag caused by the turbine fans is evenly distributed on the airframe, rather than offset, c) a horizontal wind turbine orientation is more efficient.

Instead of using a commercially made generator as outlined in the PDR we are going to use a motor that is already part of the fan assembly. This DC motor can be used as a generator. We had planned in the PDR to use a cut off nose cone as a bay for the payload. After building the half-scale we found that it would be more efficient to use a short tube with a coupler.

2.3 Activity/Outreach

The PDR outreach plan included a rocket workshop for the Washington County 4-H Cloverbud's (5 to 8 year olds). 40 youth and their parents were in attendance to build and launch a FlisKit Whatchamacallit rocket using a 1/2A3-4 motor with a streamer recovery. The outreach program was incredibly successful. We built and launched all of the rockets in about two hours. The team will hold its second and final outreach session with a 4-H workshop that is geared at teaching other youth aerospace leaders good rocket design construction techniques. Fourteen workshop attendees will build and launch a FlisKit Triskelion rocket on January 26, 2008.

In addition to these two workshops, the team has planned to attend and mentor the Washington County 4-H rocketry project meetings. Our mentors Doug Pedrick and Pat Wagner are the county leaders. In these meetings, younger youth in the county will be given the opportunity to build their county fair rockets with the help of more experienced youth leaders.

3 Vehicle Criteria

3.1 Design, and Verification of Launch Vehicle

3.1.1 Mission Statement

The Washington Co. Wisconsin 4-H SLI Team will design, build, and launch a rocket that generates electrical power by harnessing the wind moving against the accelerating airframe.

3.1.2 Vehicle Requirements and Mission Success Criteria

- The vehicle shall fly to 5,280 feet in altitude.
- The vehicle shall produce a measurable amount of electricity.
- The vehicle shall be able to handle the forces put upon it not only from acceleration and other aerodynamic forces, but also from the stress put on the vehicle from the payload.
- The vehicle shall be in a reusable state when it returns.

3.1.3 Milestone Schedule

4-H SLI Project
Project Start Date: Wed 8/15/07
Project Finish Date: Fri 5/23/08

Project Milestones

Name	Finish Date
Washington County 4-H SLI Project	Fri 5/23/08
RFP (Request for Proposal)	Fri 9/28/07
Submit RFP to NASA	Fri 9/28/07
PDR (Preliminary Design Review)	Wed 11/28/07

Vehicle design	Sat 11/24/07
Review design with team	Sat 11/24/07
PDR due to NASA	Wed 11/28/07
Half Scale Rocket	Sun 1/20/08
Launch half-scale	Sat 1/12/08
Backup launch date	Sat 1/19/08
Full Scale Rocket	Tue 3/11/08
Ground Testing	Mon 3/10/08
Vehicle / Payload integration	Mon 3/10/08
Launch full-scale	Mon 3/10/08
CDR (Critical Design Review)	Mon 1/28/08
CDR due to NASA	Tue 1/22/08
CDR presentation to NASA	Mon 1/28/08
FRR (Flight Readiness Review)	Mon 3/31/08
FRR Due to NASA	Mon 3/24/08
FRR Teleconference w/ NASA	Mon 3/31/08
PLAR (Post launch analysis review)	Fri 5/23/08
PLAR Due to NASA	Fri 5/23/08

3.1.4 Vehicle Design

3.1.4.1 System Level Design

The vehicle design includes modifying a proven rocket from Performance Rocketry – the Mad Dog Dual Deployment. The Mad Dog was chosen because it is an established design with proven launch stability. Performance Rocketry also makes a reduced scale version – the Little Dog that has similar characteristics and was used for the half-scale flight. To accommodate the payload design an additional section of body tube will be used to house the payload. The wind turbine will be mounted in that body tube section – see section 4.1.

The Mad Dog has a four-inch diameter tube that is constructed of fiberglass. Fiberglass was chosen because the design team, along with our mentor, believes it will best accommodate the payload. It is a very strong material that can be modified and extended to support the payload section and carry the additional strain of the wind turbine.

Detailed flight profile simulations, altitude predictions and vehicle data are contained in the Mission Performance, section 3.1.7.

3.1.4.2 Analysis Results

The design analysis is mainly contained in the development and launch of the team's half-scale vehicle. Figure 1 shows the RockSim design of our half-scale rocket.

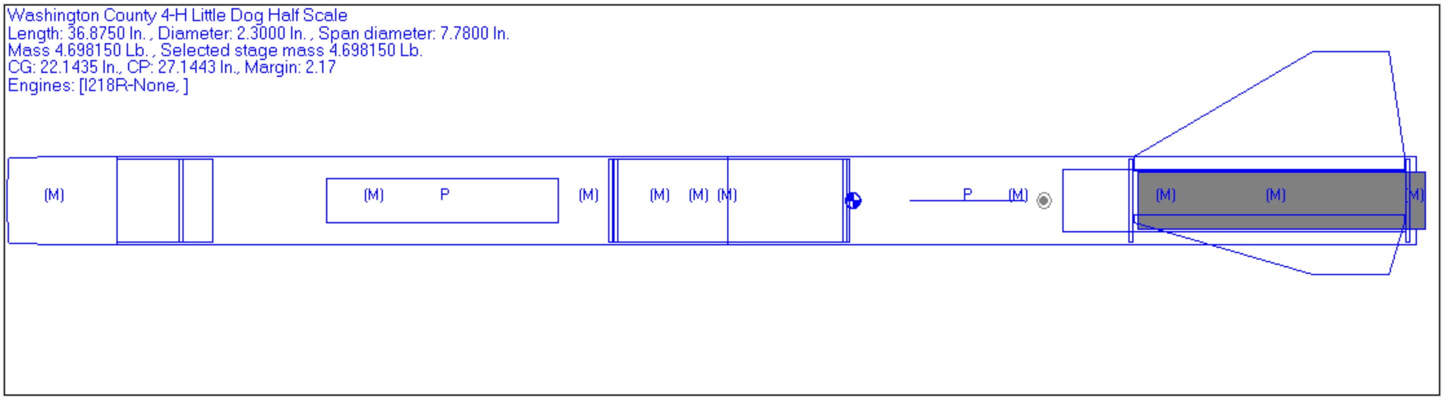


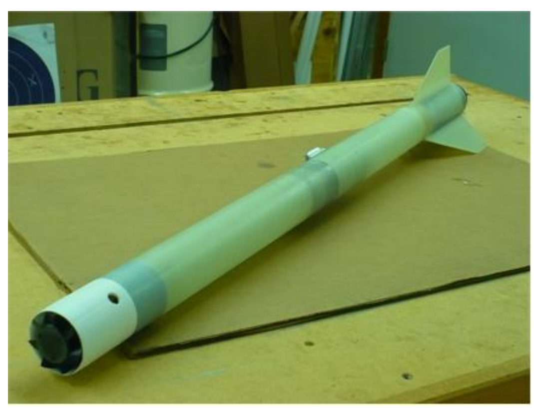
Figure 1 – Half-scale Design

RockSim was used to analyze the half-scale rocket design as well. Based on the design and flight parameters, the following vehicle specifications were determined:

Length	**36.875 inches**
Weight	**4.69 pounds**
Center of Gravity (Cg)	**22.14 inches (from the nose of the rocket)**
Center of Pressure – (Cp)	**4.69 inches (from the nose of the rocket)**
Stability Margin	**2.17 (current measure)**
Coefficient of Drag – (Cd)	**0.45 (predicted)**
Motor	**Aerotech I218R**

Flight simulations identified the following calculated specifications:

Predicted Altitude	**2,748 ft**
Flight speed	**450 ft/sec**
Descent rate – (12" drogue)	**62.1 ft/sec**
Descent rate – (36" main)	**24.8 ft/sec**



One of the flight simulation results from RockSim is shown below:

Washington County 4-H Little Dog Half Scale - Simulation results

Engine selection

[I218R-None]

Simulation control parameters

- Flight resolution: 800.000000 samples/second
- Descent resolution: 1.000000 samples/second
- Method: Explicit Euler
- End the simulation when the rocket reaches the ground.

Launch conditions

- Altitude: 1000.00000 Ft.
- Relative humidity: 30.000 %
- Temperature: 27.000 Deg. F
- Pressure: 29.9139 In.

  Wind speed model: Slightly breezy (8-14 MPH)
    - Low wind speed: 8.0000 MPH
    - High wind speed: 14.9000 MPH

  Wind turbulence: Fairly constant speed (0.01)
    - Frequency: 0.010000 rad/second
- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.087 Degrees from vertical
- Latitude: 43.250 Degrees

Launch guide data:

- Launch guide length: 72.0000 In.
- Velocity at launch guide departure: 69.0121 ft/s
- The launch guide was cleared at : 0.213 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 31.0524 In.

Max data values:

- Maximum acceleration:Vertical (y): 410.632 Ft./s/sHorizontal (x): 38.648 Ft./s/sMagnitude: 412.281 Ft./s/s
- Maximum velocity:Vertical (y): 450.3379 ft/s, Horizontal (x): 21.8533 ft/s, Magnitude: 450.4823 ft/s
- Maximum range from launch site: 1425.17950 Ft.
- Maximum altitude: 2767.00009 Ft.

Recovery system data

- P: main Deployed at : 45.865 Seconds
- Velocity at deployment: 68.5646 ft/s
- Altitude at deployment: 699.99352 Ft.
- Range at deployment: 694.84897 Ft.
- P: drogue Deployed at : 13.151 Seconds
- Velocity at deployment: 8.8794 ft/s
- Altitude at deployment: 2767.00008 Ft.
- Range at deployment: -6.06433 Ft.

Time data

- Time to burnout: 1.501 Sec.
- Time to apogee: 13.151 Sec.
- Optimal ejection delay: 11.650 Sec.

1

3.1.4.3 Test Results

The half-scale rocket was configured with a PerfectFlite miniAlt/WD dual event altimeter. The main ejection charge used 1.5 grams and the drogue used 1.0 grams of black power. This was validated using two methods – the use of the ejection charge calculator found on http://www.info-central.com, and our mentor, Ed Kreul contacted a fellow certified rocketeer who flies the Little Dog rocket. With these two sources, the team was confident the ejection charge was appropriate for the vehicle.

A static test was performed to confirm the charge sizes (see the Recovery Subsystem section below for detail.)

On January 12, 2008 the vehicle was taken to the Richard Bong State Recreation Area in Kansasville, Wisconsin for the test launch at a certified Tripoli launch event. The goal of the launch was to verify the structural stability of the rocket and to obtain a better understanding of the effect of the blunt payload section on the coefficient of drag. The goal of a flight altitude of a half-mile is greatly dependent on the coefficient of drag.

Preflight preparations were performed including configuring the altimeter to deploy the drogue chute at apogee with a mach delay of two seconds as a safety precaution. The main was set to deploy at 700 feet. Before launch, the altimeter was tested by connecting the battery and listening for the proper “beep” sequence for the corresponding settings. The reloadable engine was prepared under the supervision of our certified mentor.

The launch was successful in reaching all of its goals. The flight was very stable and straight. Both drogue and main parachutes successfully deployed as configured.

From the altimeter data collected, the rocket reached a flight altitude of 2,342 feet. The flight data are shown in Figure 2 and indicates that the rocket reached apogee in approximately 11 seconds and a total flight duration of 86 seconds. From the graph it can be deduced that the main parachute deployed at 700 feet as expected. From analyzing the flight data the team concluded that the coefficient of drag predicted dynamically by RockSim was significantly lower than actual. We have concluded that the coefficient of drag was approximately .80, instead of the 0.45 predicted by RockSim.

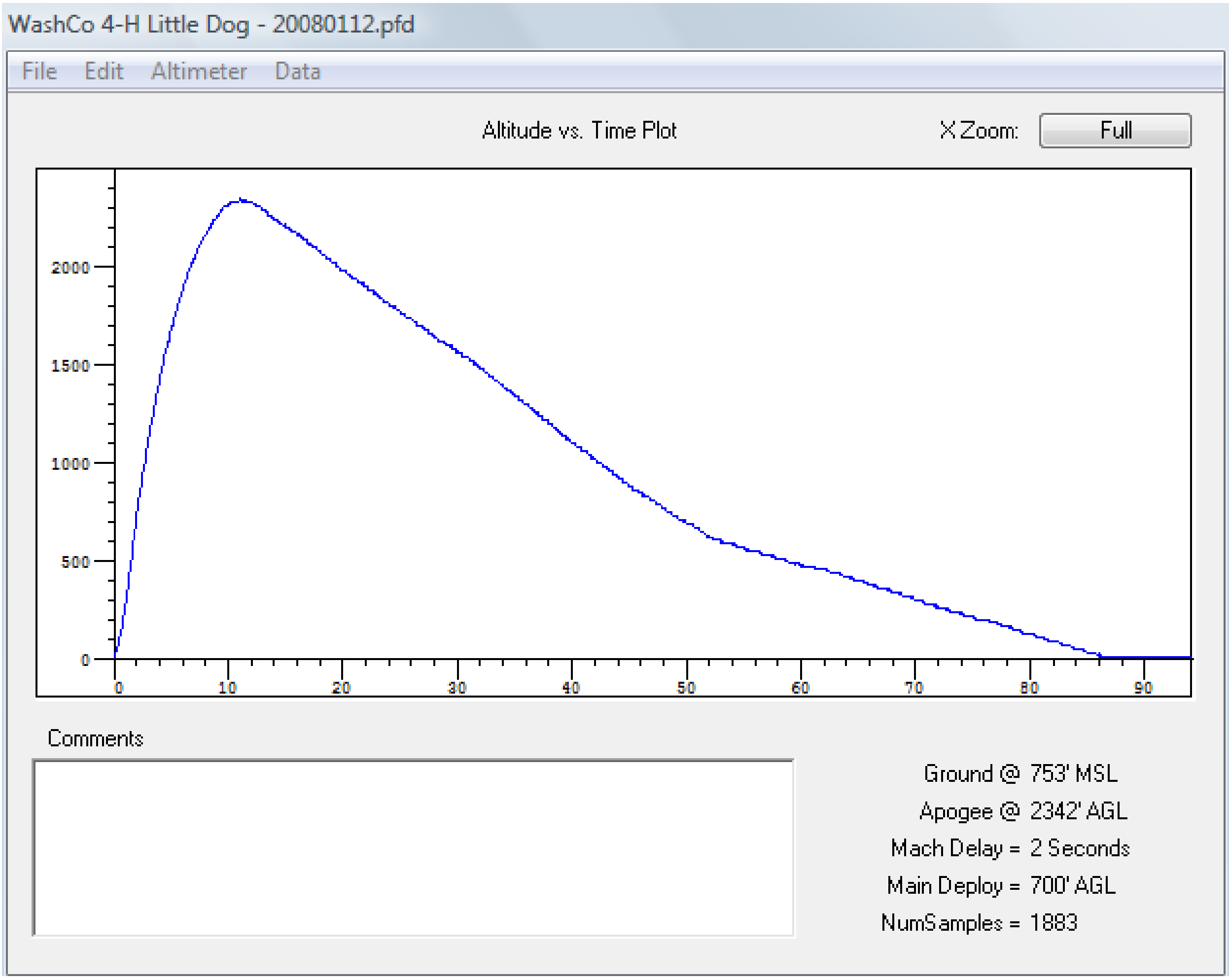


Figure 2 – Flight Telemetry

3.1.4.4 Status of remaining manufacturing

The half-scale model was the main focus of the project team since the beginning of December. (Please see the detailed project schedule on the team's project plan attached at the end of the document for specific dates.)

The remainder of the work effort, also detailed in the project plan includes full-scale model construction.

3.1.4.5 Component, Functional and Static Testing

Once full-scale construction is completed, the following tests will be done on the full-scale vehicle:

- Validation of stability calculations
- Correct motor sizing
- Static ejection charge testing, repeating the same process used for the half-scale test.

- Wind tunnel testing of the vehicle and payload to validate the science experiment will operate as designed.
- Full-scale launch to test flight stability and altitude predictability (contingent on project timeline).

Current simulations indicate that a K1075GG motor from Animal Motor Works will achieve the target altitude. The coefficient of drag predicted by RockSim has shown to be much too low. The coefficient of drag of the full-scale rocket is likely to be worse than the half-scale, but to what degree is uncertain. Full-scale test flights, rather than RockSim simulations, will help us better determine the actual coefficient of drag and in turn the best motor size.

3.1.4.6 Rocket materials, construction, workmanship, assembly

The following section describes the major sub-systems of the rocket and how overall design integrity was achieved on the half-scale model. The same basic techniques and procedures will be used in the construction of the full-scale model.

Booster

The booster section houses several major components including the engine, drogue and recovery harness. Design includes through the wall fin attachment using West System Epoxy. Positive motor retention is being achieved using an AeroPack quick-change motor retainer. It also includes standard 10/10 rail guides using screws through the body tube. Both of these components are attached to the airframe using JB Weld. Both the West system epoxy and JB Weld are strong adhesives recommended by our mentor as adhesives used in high-powered rocketry construction. In addition, the motor casing's forward closure contains an eyebolt. This is the attachment point for the drogue recovery harness. A 3/32nd inch hole is drilled in the booster section to equalize pressure in the airframe with the outside environment.

Recovery

A major component of the recovery system is the altimeter bay that is housed in the coupler between the booster and the upper airframe. It is permanently glued into the upper airframe using JB Weld. The altimeter bay has two mounting rods for the altimeter bay sled. The sled is constructed of G10 fiberglass and has two battery holders and two altimeters mounted to the sled using JB Weld. The altimeter bay has forward and aft closures using double layer fiberglass bulkheads. The bulkheads have u-bolts and terminal blocks attached to the outside using JB Weld. The u-bolts will be attached to the opposite ends of the recovery harnesses for both the drogue at the aft end and the main parachute at the forward end. Altimeter specifications will be reviewed so the proper port holes of the correct size are installed in the airframe to ensure that the altimeters function properly. In the half-scale vehicle, three 3/32nd inch holes were drilled based on the total volume of the altimeter bay.

The altimeters chosen are from different manufacturers to reduce the risk of design failure that is possible when using one manufacturer. They are an RRC2 Mini from Missile Works and an ARTS2 from Ozark Aerospace. The ARTS2 was chosen because it measures instantaneous velocity at a rate up to 200Hz. Velocity data must be collected in order to calculate the actual power efficiency of the generator system versus predicted efficiency.

Current design specifications show the need for an 18-inch drogue made of rip-stop nylon. The main parachute of 60 inches is required and is made of rip-stop nylon. The parachutes will be harnessed into the airframe of the rocket using solid eye bolts, ¼" Quick Links rated at 600 test pounds, and ¼" swivels rated at 600 test pounds. These are attached to a Kevlar harness that includes a Nomex shield that protects the parachutes from the ejection charge. Location tracking will be done with a T400AM transmitter and receiver from Adept Rocketry that will be attached to the main parachute's recovery harness.

Upper Airframe

The upper airframe will house the main parachute, harnesses and tracking beacon. The recovery harness will be attached to the forward end of the altimeter bay and to the aft bulkhead of the payload section. A 3/32nd inch hole is drilled in the upper airframe to equalize pressure in the airframe with the outside environment.

Payload

The payload section will be built from another fiberglass body tube section. It will be constructed so that the payload bay will be removable. A combination of JB Weld and West System Epoxy will again be used in construction.

Figure 3 is a frontal view of the rocket showing the turbine.

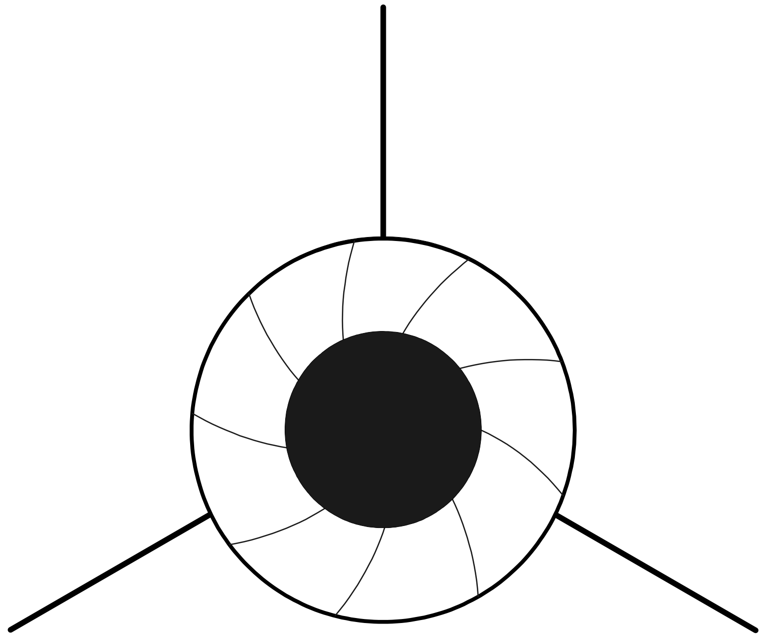


Figure 3 – Frontal View

The payload is detailed in subsequent sections of the document.

3.1.5 Project Risks

Item / Function	Potential Risk(s)	Severity	Potential Cause(s)/ Mechanism(s) of Risk	Probability	Risk Priority	Recommended Action(s)
Full-scale rocket	Full-scale not built on time	10	Unavailability of parts	1	**10**	Order early; Make our own
			Personal schedules don't allow time to complete			Start early; plan ahead; limit outside activities; recruit more people to the team
		3	Wind tunnel not available for testing	3	**9**	Make our own wind tunnel with leaf blower
		7	High-powered site not available on/near dates needed	4	**28**	Multiple launch sites identified. Bong, WI, Princeton, IL, Walcott, IA, Metamora, IL
		7	Weather prohibits flight-testing.	5	**35**	Identify multiple launch dates; complete half-scale early
Science Experiment		7	Inability to determine expected generator RPM for any given airspeed.	8	**56**	Measure wind-speed to RPM in wind tunnel.

		7	Number, size, and shape of turbine blades cannot be determined easily.	8	**56**	Prototype multiple types and numbers of blades; test in wind-tunnel
		9	Inability to create an adequate circuit design.	6	**54**	Start early; test; engineer for worst-case power generation
		10	Unavailability of parts	1	**10**	Make our own; reconsider design
		10	Cannot buy commercial available turbine blades, or they are cost prohibitive.	2	**20**	Redesign with consideration of blade procurement
		7	Circuit design does not measure power generated	4	**28**	Build and test circuit prior to launch. Simulate by turning generator with drill or via compressed air or leaf blower

3.1.6 Construction Plan

Our project plan for construction for the full-scale rocket has been delayed. This is due to several factors including delays in construction and testing of the half-scale rocket, preparation of the CDR and preparation for the CDR presentation and review. Please see the major milestones and project plan included in the document.

3.1.7 Mission Performance

Figure 4 is the current RockSim design diagram for the full-scale vehicle.

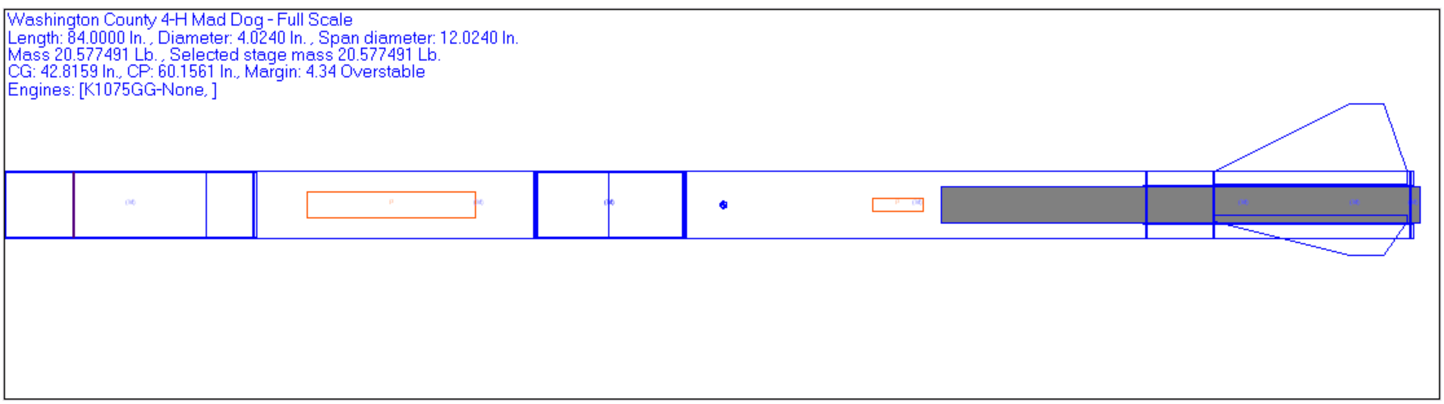


Figure 4 – Full-scale Design

The following key specifications are included in the current design:

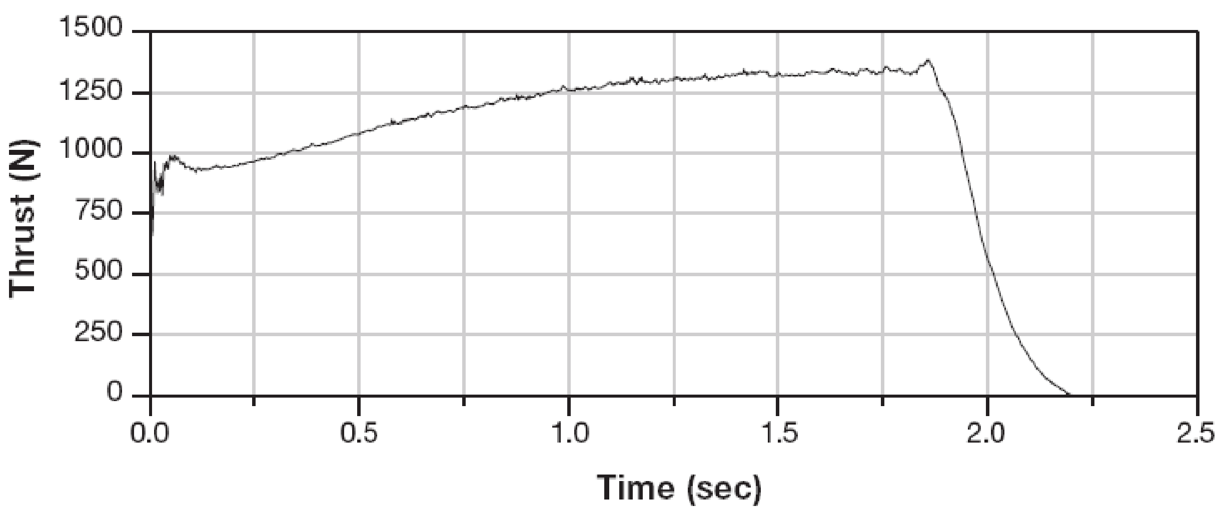
Length	**84 inches**
Weight	**20.5 pounds**
Center of Gravity (Cg)	**42.81 inches (from the nose of the rocket)**
Center of Pressure – (Cp)	**60.15 inches (from the nose of the rocket)**
Stability Margin	**4.34 (current measure)**
Coefficient of Drag – (Cd)	**.80 (based on half-scale data)**
Preliminary Motor Selection	**Animal Motor Works K1075GG**

Flight simulations identified the following calculated specifications:

Predicted Altitude	**5,392 ft**
Flight speed	**780 ft/sec**
Descent rate – 18” drogue	**96.6 ft/sec**
Descent rate – 60” main	**29.0 ft/sec**

The current projected weight for the full-scale is 20.5 pounds. That includes the 4-pound scientific payload located in the nosecone. The current motor is the K1075GG from Animal Motor Works. The thrust curve for this motor is shown in Figure 5.

The velocity of the motor needs to be considered - the current motor selected is projected to make the vehicle velocity approach 530 mph. This needs to be reviewed with the payload team to determine any issues that the wind turbine will have traveling at that velocity. The wind tunnels that we will use have a top end speed of 200 mph. The only way to prove the structural integrity at that velocity is to do full-scale test launches. Power generated by a wind turbine is proportional to the cube of the velocity of the air; faster airflow will need to be balanced with the stress put on the payload components.



Consists of the Animal Motor Works 54-2550 casing and Animal Motor Works K1075GG-P-SM reload kit. No substitutions allowed. Produces 10 to 15 seconds of tracking smoke after burnout.

Figure 5 – Motor Thrust Curve

The simulation results from a representative test are summarized as follows:

Simulation control parameters

- Flight resolution: 800.000000 samples/second
- Descent resolution: 1.000000 samples/second
- Method: Explicit Euler
- End the simulation when the rocket reaches the ground.

Launch conditions

- Altitude: 1030.00000 Ft.
- Relative humidity: 74.000 %
- Temperature: 60.000 Deg. F
- Pressure: 0.00 Mi.

Wind speed model: Slightly breezy (8-14 MPH)

  - Low wind speed: 8.0000 MPH
  - High wind speed: 14.9000 MPH

Wind turbulence: Some variablility (0.04)

  - Frequency: 0.040000 rad/second

- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.175 Degrees from vertical
- Latitude: 43.250 Degrees

Launch guide data:

- Launch guide length: 72.0000 In.
- Velocity at launch guide departure: 60.5413 ft/s
- The launch guide was cleared at : 0.207 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 39.3913 In.

Max data values:

- Maximum acceleration:Vertical (y): 451.706 Ft./s/sHorizontal (x): 63.135 Ft./s/sMagnitude: 455.951 Ft./s/s
- Maximum velocity:Vertical (y): 771.8209 ft/s, Horizontal (x): 109.3094 ft/s, Magnitude: 779.5210 ft/s
- Maximum range from launch site: 2571.18111 Ft.
- Maximum altitude: 5392.45408 Ft.

Recovery system data

- P: Main Deployed at : 60.444 Seconds
- Velocity at deployment: 111.3015 ft/s
- Altitude at deployment: 799.90158 Ft.
- Range at deployment: 2055.13124 Ft.
- P: drogue Deployed at : 17.284 Seconds
- Velocity at deployment: 57.4426 ft/s
- Altitude at deployment: 5392.45408 Ft.
- Range at deployment: 1272.85761 Ft.

Time data

- Time to burnout: 2.201 Sec.
- Time to apogee: 17.284 Sec.
- Optimal ejection delay: 15.082 Sec.

Landing data

- Successful landing
- Time to landing: 84.279 Sec.
- Range at landing: 2571.18111

3.2 Payload Integration

We will have screw mounts in the forward airframe and coupler to attach the turbine blade assembly. The entire payload (turbine blades, generator and circuit board assembly) will be housed within a coupler and will slide into the payload tube from the top. The assembly will be attached from the outside with pem nuts and screws. The venting ducts will be right below the fans so as much air as possible will be sent right through the tubes and out of the rocket. The duct holes in the outer tube and in the inner coupler will be required to be in alignment following the insertion of the payload bay.

Since we're using a normal fiberglass airframe and a corresponding coupler tube for housing the payload, there should be no problem in fitting the coupler inside of the airframe.

At the bottom end of the payload airframe, a bulkhead and eyebolt will be permanently affixed with JB-Weld. The eyebolt will hold the recovery harness for the main parachute.

3.3 Vehicle Final Assembly Procedures

3.3.1 Pre-Launch Checklist

This is the pre-launch checklist as required as part of the vehicle launch operations. This checklist is to be used on launch day while preparing the vehicle rocket for flight

3.3.1.1 Motor Preparation

- ❑ Prepare motor per packaged instructions for launch
- ❑ Select correct size igniter for engine. Inspect for continuity, resistance, and check pyrogen for cracks or flaws
- ❑ Secure motor and igniter for later installation into rocket
- ❑ DO NOT install igniter until rocket is secure on the pad

3.3.1.2 Recovery System

Recovery System - Drogue Chute

- ❑ Check shock cords for cuts, burns, and tangles
- ❑ Check all shroud lines -- no tangles
- ❑ Check drogue chute for tears and burns
- ❑ Check ejection charge protection for tears

- *Check all connections. Insure all devices are in good condition and properly secured*

- ❑ Avionics bay shock cord to drogue
- ❑ Booster shock cord to drogue
- ❑ Remove blue tape and rubber band used in packing

- *Pack drogue chute in, keep lines even and straight*

- ❑ Fold drogue chute per manufacturer's instructions

- ❑ Insure shroud lines are free from tangles
- ❑ Place drogue in Nomex shield
- ❑ Insure all quick links are secure
- ❑ Insert drogue ejection charge protection/chute into aft recovery compartment

Recovery System - Main Chute

- ❑ Check shock cords for cuts, burns, and tangles
- ❑ Check all shroud lines -- no tangles
- ❑ Check main chute for tears and burns
- ❑ Check ejection charge protection for tears

- *Check all connections. Insure all devices are in good condition and properly secured*

- ❑ Nose Cone shock cord to drogue
- ❑ Avionics bay shock cord to drogue
- ❑ Remove blue tape and rubber band used in packing

- *Pack main chute in, keep lines even and straight*

- ❑ Fold main chute per manufacturer's instructions
- ❑ Insure shroud lines are free from tangles
- ❑ Place main in Nomex shield
- ❑ Insure all quick links are secure
- ❑ Insert ejection charge protection
- ❑ Insert main chute into forward recovery compartment

3.3.1.3 Electronics

Prepare avionics #1

- ❑ Be sure all arming switches are off
- ❑ Ohmmeter test of *NEW* battery under load
- ❑ Install battery in altimeter
- ❑ Secure battery in place with positive battery retention system
- ❑ Altimeter properly programmed and verified
- ❑ Ready avionics bay for altimeter
- ❑ Install altimeter in rocket
- ❑ Insure all pyrotechnics are in disarmed mode during electronics final installation

Prepare avionics #2

- ❑ Be sure all arming switches are off
- ❑ Ohmmeter test of *NEW* battery under load
- ❑ Install battery in altimeter
- ❑ Secure battery in place with wire tie
- ❑ Altimeter properly programmed and verified
- ❑ Ready avionics bay for altimeter
- ❑ Install altimeter in rocket
- ❑ Insure all pyrotechnics are in disarmed mode during electronics final installation

3.3.1.4 Pyrotechnics

Note: All pyrotechnic devices must remain in an unarmed mode until rocket is on pad ready to launch

Pyrotechnics, drogue

- Prepare aft deployment pyrotechnic device and ready for installation into rocket
- Load aft charge into rocket, insure at all times the devices are safe until final launch readiness
- Connect aft pyrotechnic leads to electronic deployment devices drogue chute connections
- Utilizing external disarming mechanisms to insure all electronically discharged pyrotechnics are disabled until final launch readiness

Pyrotechnics, main

- Prepare forward deployment pyrotechnic device and ready for installation into rocket.
- Load forward charge into rocket, insure at all times the devices are safe until final launch readiness
- Connect forward pyrotechnic leads to electronic deployment devices main chute connections
- Utilizing external disarming mechanisms to insure all electronically discharged pyrotechnics are disabled until final launch readiness

3.3.1.5 Motor Installation

- Install motor
- Install motor retaining devices
- Insure all electronic deployment devices are in the non-dischargeable safe mode

3.3.1.6 Final Launch Preparations

Load Rocket on Pad

- Prepare launch pad
- Load rocket on launch rail

Prepare Igniter

- Insert igniter. Be sure it is completely forward and touching fuel grain
- Secure igniter in position
- Assure that launcher is not hot. Disconnect battery from relay box. Assure that key IS NOT remote device and that arming switch is off
- Attach leads to ignition device
- Be sure all connectors are clean
- Be sure they don't touch each other or that circuit is not grounded by contact with metal parts
- Check tower's position and be sure it is locked into place and ready for launch
- Assure that key IS NOT remote device and that arming switch is off

- Connect battery to relay box

Final Launch Sequence

- Arm all devices for launch.
- Insure Flight Witnesses are in place and ready for launch
- Signal LCO & RSO that rocket is ready for launch

Misfire Procedures

- Safe all pyrotechnic to pre-launch mode
- Remove failed igniter
- Resume checklist at "Final Launch Preparations/Prepare Igniters"

3.3.1.7 Post-Recovery Checklist

This is the post-flight checklist as required as part of the flight. This checklist includes steps required to ensure the rocket is in a safe condition after completion of a flight

Normal Post Flight Recovery

- Check for non-discharged pyrotechnics.
- Safe all ejection circuits
- Remove any non-discharged pyrotechnics.

Flight Failure Checklist

- Disarm all non-fired pyrotechnic devices
- Continue Normal Post Flight Recovery procedures

Launch system and platform

- Launch system is an electrically controlled and safety system and is supplied by the hosting club or organization
- The launch pads are heavy duty pads designed for the weight of the rocket and will have a standard rail (10/10 rail size) utilizing stand rail buttons (.25 inch diameter) on the rocket

3.4 Vehicle Launch Operations

This is the launch operations checklist. This checklist is to be used on launch day for vehicle launch.

- Determine flight conditions (temperature, wind, barometric pressure, etc.)
- Prepare the rocket for flight per the flight preparation instructions above
- Set rocket on launch pad
- Clear the launch area in case of pre-mature ignition of ematches
- Arm the electronics
- Arm the igniter
- Second call to clear the launch area
- Countdown to launch
- Launch Rocket
- In case of a misfire, follow mis-fire procedures above

- Locate rocket with tracking device
- Safely retrieve rocket
- Make sure rocket is safe before retrieving altimeter telemetry and payload telemetry
- Perform download of telemetry data for study and validation

3.5 Safety and Environment

3.5.1 Safety Officer

Our team safety officer is Katlin Wagner.

3.5.2 Failure Mode and Effects Analysis (FMEA) of Vehicle

Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Risk Priority	Recommended Action(s)
Recovery		Rocket destroyed on impact.	10	Ejection blow by	1	**10**	Use the right size Kevlar shroud; pack parachute correctly.
		Rocket destroyed on impact.	10	Ematch doesn't lite	3	**30**	Use redundant e-match.
		Rocket destroyed on impact.	10	Not enough black powder	3	**30**	Static ground test amount.
	Parachute or shock cords tear.	High-speed descent.	10	Too much black powder	3	**30**	Static ground test amount.
	Parachute does not fully deploy.	High-speed descent.	10	Shroud lines tangle	2	**20**	Pack parachute correctly.
		Uncontrolled descent.	10	Shock cord snaps	2	**20**	Use proper size cord. Ensure deployment at a lower velocity.
	Drogue, but not main deploys	High-speed descent.	8	Main ejection powder does not light.	2	**16**	Use redundant e-match and redundant event altimeters.
	Main, but not drogue deploys	Main deploys at high speed, potentially overstressing shock cord.	7	Drogue ejection powder does not light.	2	**14**	Use redundant e-match and redundant event altimeters.
	Parachute rips	High-speed descent.	8	Shroud lines not attached well.	2	**16**	Use high-quality, commercial parachute.

		Payload data are non-recoverable	10	Impact with ground dislodges electrical components, losing data.	3	**30**	Use non-volatile memory.
	Altimeter prematurely fires ejection charge.	Experiment is unsuccessful	10	Turbulent air from experiment turbine outflow over static ports causes mis-calculation of altitude by altimeter	5	**50**	Use event timer instead of barometric pressure based altimeter.
Propulsion	CATO	Rocket does not reach desired altitude.	10	Faulty motor.	1	**10**	
	Reloadable motor failure.	Rocket does not reach desired altitude.	10	Motor assembled/loaded incorrectly.	2	**20**	Follow instructions; have more than one person overseeing loading; use single-use motor.
Vehicle	Zippering	Uncontrolled descent.	7	Weak airframe	2	**14**	Use fiberglass airframe.
	Fins break on launch	Unstable flight.	10	Fins too weak; incorrectly installed	2	**20**	Use fiberglass fins; use through-the-wall mount; use strong epoxy
	Weathercocking	Lower than expected altitude, resulting in not as much electricity being generated.	6	Overstability	4	**24**	Design to bring stability margin down to below 2. Use a higher initial thrust motor.
	Motor mount failure	Motor travels up through airframe	10	Improper construction and/or materials.	3	**30**	Use experience from mentor; use strong epoxy; use heavy-duty centering rings

3.6 Listing of personnel hazards

Personnel hazards are possible during both construction and flight.

During construction, some materials being used may pose a safety risk to team members during their use. These materials may include: epoxy, fiberglass dust, black powder, and handling of the rocket engines. Extreme caution must be used in tandem with these hazardous materials because of the effects they may have on the team members. Power tools will also be used to manufacture / modify the parts needed to integrate the payload and vehicle assemblies. Proper safety briefings, usage instructions, use of proper safety equipment and mentor supervision will be executed during all team involvement of the construction. The Material Safety Data Sheets on all of these materials are at http://www.4hrocketry.com/materialsafetydatasheets.

Flight hazards are a large consideration with a project of this size. Engine failure, recovery device failure, and stable rocket flight are of the biggest concern. Following proper high-powered safety distances will help prevent injury in the event of a motor catastrophe, calculating proper ejection charges pre-flight recovery tests, using redundant altimeters and following specific pre-flight assembly tasks will reduce the risk of flight failure. Proper design simulations under various flight conditions will help ensure the team has the most sound rocket design being placed on the pad at launch time.

3.7 Environmental Concerns

The team has the potential of using several different launch sites in the Southeastern Wisconsin / Northern Illinois area. These launch sites are multi-use recreational sites used by different groups and organizations. We will be following all site restrictions posted, as well as making sure there is proper safety equipment available.

The payload poses little risk to the environment. There is a potential that on board batteries and equipment may fail and expose toxic material to the environment. The team will properly dispose of and clean up any material that may come in contact with the environment.

In addition, the team will consult with sponsoring clubs to ensure fire hazards risks are minimized and proper fire equipment is on hand at all launches.

4 Payload Criteria

4.1 Payload Design

The experiment will use an assembly that can generate electricity from the oncoming flow of the wind against the rocket. It will contain:

- RC Airplane Ducted Fan Assembly - Approximately 3-3.5 in. blades
- eLogger V3 Data Recorder – measures RPM, Watts, Temperature, etc.
- DC Motor from Ducted Fan Assembly used as an electrical generator
- Payload assembly built inside of a standard tube coupler; slides into short section of 4” fiberglass tube
- Air ducts spaced around outside of payload tube.
- Payload approximately 10” in length and 3 pounds in weight.

Figure 6 depicts the current payload design.

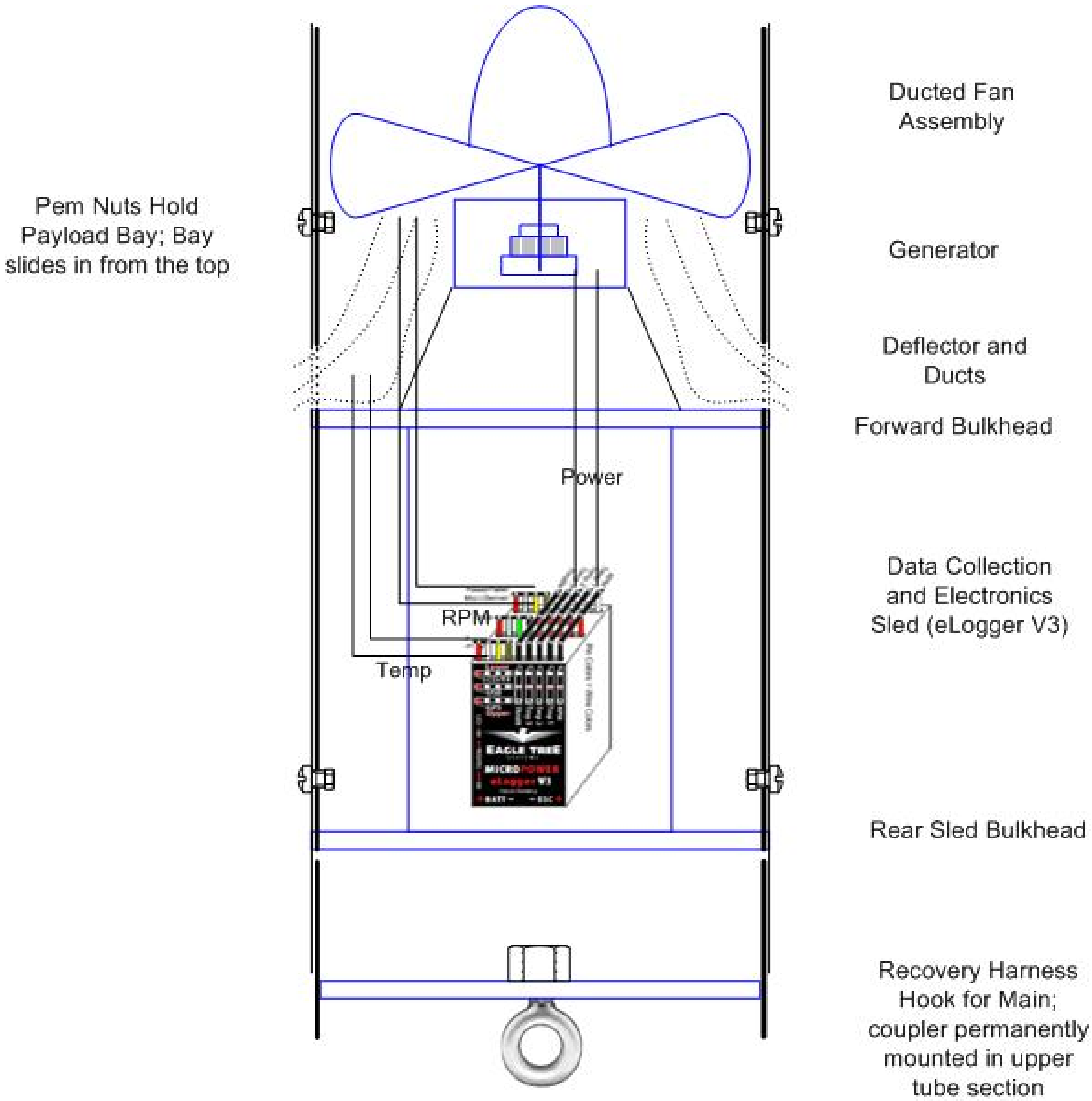


Figure 6 - Payload Schematic

4.1.1 Subsystem Details

Fan Blades

The fan blades will be part of a pre-assembled ducted fan commonly used in RC aircraft. These blades are proven to work at high speeds. The blades are mounted in a molded housing and then attached to the outer tube of our payload. Assuming that the rocket reaches a maximum velocity of 800 fps, 2500 ft^3/min (3 in. diameter blade) of air will go through the assembly. The fan will need to be able to handle the angular velocity and the friction created by moving air. The blade assembly needs to fit within a tube coupler, which has an inside diameter of 3.7 inches. The fan blades come pre-mounted within a molded housing, which will reduce the diameter even more. At the most the diameter of the fans will be 3.5 inches.

Generator
The generator is a DC motor that is mounted to the shaft that passes through the center of the fan blades. This gives a structural and time advantage.

All generators are rated for a maximum number of RPM that they can handle. The components selected must ensure that the maximum rated speed of the generator is above the predicted speed that the fan will spin.

Circuit Components
The circuit will include electronics to record and store the electricity the generator produces. A resistor will act as a load on the circuit and store the generated electricity. The main component is the electronic data collector.

A design concern is limiting – or measuring – the amount of generated current used by the data logger to carry out its operations. The circuit has to be able to handle more than the maximum current output of the generator so that it does not overload in mid-flight. Figure 7 is a circuit diagram of the electrical components of the payload. Unfortunately the eLogger V3 does not have an external power source and instead must draw current from the generator.

Payload Housing
The payload will consist of one assembly that contains all of the electronics and fan blades. This assembly will slide into the airframe tube from the front (top) and be screwed in from the sides. The subassembly will be attached at multiple places so it will be firmly secured to the rocket.

Ducting
The ducts will direct the air to the outside of the rocket so extra air isn't pooling in front of the fan, allowing maximum airflow through the fan. If there are no vents then the air cannot properly go through the fan and it will create unwanted drag, thus reducing the velocity of the fan blades.

The ducting will consist of holes going through the outside tube. There will be 16 holes of ½" diameter equally spaced around the circumference of the airframe. The air will flow through the fans, around the generator and out the sides.

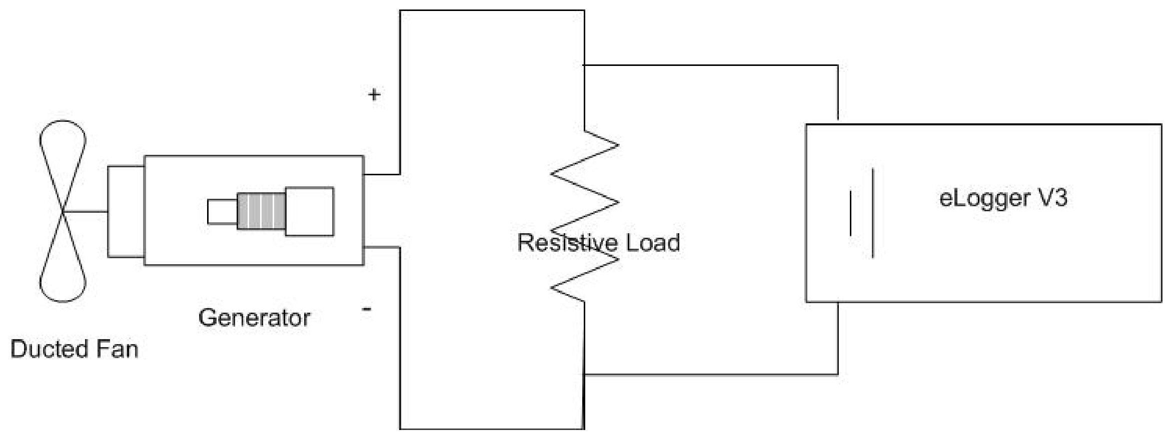


Figure 7 - Circuit Diagram

4.1.2 Workmanship

Even with extra pem nuts, the workmanship could be faulty and the payload could possibly fall out. Of equal concern is getting the fan assembly in straight so it doesn't rub on the outside wall when spinning. We hope to mitigate that by using a commercial ducted fan assembly with an integrated housing. This can only be prevented by working slowly and carefully on the crucial parts of the experiment.

4.1.3 Precision of Measurement

The on-board data collection system will be compromised of the Eagle Tree System's eLogger V3. It is has the ability to measure current, volts, watts, temperature, and blade RPM. This was chosen because the electric output of the generator needs to be measured and RPM of the fan needs to be recorded. The base unit weighs only 20 grams. The wiring harnesses for the data collected will add a small amount of weight. Post-flight the eLogger connects via USB to a laptop computer to upload the data recorded during the flight. The software that comes with the eLogger provides virtual playback and graphing of volts, amps, watts, and RPM over time.

The eLogger specifications include:

- Voltage: 5V-70V with 0.02V resolution
- Current: up to 100A with 0.02A resolution
- Current Draw: 30mA with no sensors
- Temperature: 0 – 424° F
- RPM: 100-50,000+
- Size: 2.25" x 1" x 0.5"
- Logging Rate: 1 – 10 samples per second

The eLogger will be run at full fidelity of logging all inputs at 10 samples per second.

The eLogger V3 does not have an external power source. Instead it draws current from the circuit being measured. The amount of current drawn while using all optional sensors as part of ground testing needs to be measured. This will be used in the post-flight analysis to arrive at the true amount of electricity generated.

4.1.4 Integration plan

Screw mounts are used in the forward airframe and coupler to attach the turbine blade assembly. The entire payload (turbine blades, generator and circuit board assembly) will be housed within a coupler and will slide into the payload tube from the top. The assembly will be attached from the outside with pem nuts and screws. The venting ducts will be immediately below the fans so as much air as possible will be sent right through the tubes and out of the rocket. The duct holes in the outer tube and in the inner coupler will be required to be in alignment following the insertion of the payload bay.

Since normal fiberglass airframe and a corresponding coupler tube for housing the payload is used, there should be no problem in fitting the coupler inside of the airframe.

At the bottom end of the payload airframe, a bulkhead and eyebolt will be permanently affixed with JB-Weld. The eyebolt will hold the recovery harness for the main parachute.

4.1.5 Testing and Analysis Results

After launching the half-scale rocket, results of analysis were used to begin designing and constructing the full-scale payload. The assembly in the half-scale vehicle was structurally weak because the parts were taken from different sources. These had to be epoxied together.

During the half-scale launch the fan blades fell out of the nosecone. The most likely scenario is the shock of the drogue or main ejection broke the assembly. From this the team concurred that the full-scale model requires a commercially available fan assembly. An integrated assembly with fan blades, housing, and DC motor should mitigate much of the structural failure of the half-scale payload.

The half-scale vehicle only included a small-scale version of the fan assembly - See Figure 8. It did not carry any electronics during the flight because of cost and time restrictions. The main goal was to test aerodynamics and structure of a payload of this nature.

Figure 8 - Half-Scale Payload Prototype.

4.1.6 Verification plan and status

The payload will be tested as a whole entity. Established contacts with Dr. Riccardo Bonazza at the University of Madison and Professor John Borg at Marquette University have been made. Both have stated they will let us use their wind tunnel for SLI. A wind tunnel is the best environment we can test our experiment in prior to test launches. The structure will be tested as will the ability of the payload to generate electricity.

The primary goals are to prove that a rotating fan assembly connected to a DC motor can generate electricity, and that the eLogger data recorder can measure the electricity produced.

A static ejection test needs to be conducted to ensure that the pem nuts are sufficient to hold the payload in place during ejection.

Since the wind tunnel cannot approximate the air velocity of a real launch, we also plan on conducting two full-scale test launches.

4.1.7 Remaining Work

The final payload design still has to be prototyped before the fiberglass version will be built. No solid design plan has been made yet for the payload. Interface points between the payload and vehicle still need to be designed. The circuitry in the payload is another challenge to overcome. The team needs to learn more about how circuits work in general and must make sure the circuit will be suitable for the electric output of the generator. The ducted fan assembly has not been chosen yet. The team still needs to choose the one that will works the best for the design.

4.2 Payload Concept Features and Definition

4.2.1 Creativity and originality

The experiment the team chose is unique because, to our knowledge, no one has ever attempted to put this type of payload in a high-powered rocket before. The extra drag and turbulence from the irregular nose are the main issue. It can affect the stability and performance of the rocket greatly. The team also has to build an electrical circuit into the payload.

4.2.2 Uniqueness and significance

The team decided to plan a science experiment based around electricity generation. The Milwaukee Journal Sentinel recently reported that Wisconsin emits greenhouse gases at a rate that is about one-third higher than the national average. Wisconsin utilities rely heavily on coal-burning power plants, with several more currently under construction. The United States needs to start looking seriously at renewable and alternative energy sources instead of relying primarily on fossil fuels. Renewable energy is most attractive since it is extracted from natural resources that are continuously replenished. These include wind, sunlight, tides, and geothermal heat. All of these naturally occurring types of energy can be harnessed to generate electricity. The team is interested in exploring renewable energy because it will play a major role in the future of this country.

4.2.3 Suitable level of challenge

There are numerous difficulties in designing a rocket of this type. The main reason is that much of it must be built and designed from scratch. The assembly needs to be built as strong as possible to compensate for the extremely high speeds that it will endure. Other challenges are in the circuit. The team has developed a circuit diagram. There are still many outstanding questions about the electronic system that remain.

4.3 Science Value

4.3.1 Science payload objectives

There are several objectives of the payload:

- Demonstrate that it is possible to generate measurable electrical power
- Compare the predicted and actual power generated
- Compute the efficiency of our wind turbine system using the equation found in section 4.3.4. This will give the percentage of the total energy in the wind that was harnessed by the payload.

4.3.2 Payload success criteria

The payload will be considered a success if it generates enough electricity to be measurable, and if it comes close to generating the amount of energy the team predicts.

4.3.3 Experimental logic, approach and method

The experiment depends on many different variables that will effect how efficient, or how much electricity the generator will produce. Outlined below are some of the major variables that affect the payload.

Independent variables	*Dependent variables*
Motor size and thrust characteristics (in turn affects velocity of the airflow into the turbine)	**RPM of fan blades (dependent upon rocket velocity)**
Coefficient of Drag of the vehicle	**Air density**
	Power generated
	Power efficiency of the generator

4.3.4 Measurement

The on-board altimeters will measure velocity of the rocket, from which the airflow velocity can be inferred. They will also sample the density of the air at various altitudes. The custom circuitry will measure the instantaneous power output of the generator. Using equation 4, the power efficiency of the system can be computed.

A wind turbine extracts energy from moving air by slowing the wind down and converting the extracted energy to mechanical energy by way of a spinning shaft. The shaft then converts the energy into electrical energy using an alternator or generator. The power in the wind available for extraction depends on both the wind speed and the area that is swept by the turbine blades. Wind is made up of moving air molecules. Although each molecule's mass is very small, it is the movement of this mass that results in the kinetic energy that we are attempting to harness. Any moving object with mass carries kinetic energy in an amount given by equation 1:

$$\textbf{Kinetic Energy} = 0.5 * \textbf{Mass} * \textbf{Velocity}^2 \qquad \text{(Eq. 1)}$$

where the mass is measured in kg, the velocity in m/s, and the energy is given in joules.

Air has a known density (around 1.23 kg/m^3 at sea level at 15°C), so the mass of air hitting the wind turbine (which sweeps through a fixed area) each second is given by the following equation:

$$\textbf{Mass/sec} = \textbf{Velocity} * \textbf{Area} * \textbf{Air Density} \qquad \text{(Eq. 2)}$$

where the air density is in kg/m^3. The power (i.e. energy per second) in the wind hitting a wind turbine with a certain swept area is given by substituting the *mass per second* calculation into the standard kinetic energy equation resulting in the following equation:

Power = 0.5 * Swept Area * Air Density * Velocity^3
(Eq. 3)

where **Power** is in watts (or joule/second),
Swept area is pi*r^2 (r == radius of the swept area, or blade length, in meters),
Air density in kilograms per cubic meter, and
Velocity in meters per second.

This equation shows that when the swept area of the turbine doubles, the power also doubles, but when the wind speed doubles, the power available increases by a factor of 8.

It is not possible to extract ALL of the energy in wind and convert it to electricity. In 1919 a German physicist, Albert Betz, calculated that there's a limit to how much power a turbine blade can extract from the wind. He found that no wind turbine can convert more than 16/27 (or 59.26%) of the kinetic energy of the wind into mechanical energy turning a shaft. This fact is now known as the Betz Limit or Betz' Law. Beyond the Betz Limit of 59.26%, more and more air tends to go around the turbine rather than through it, with air pooling up in front. So 59.26% is the absolute maximum that can be extracted from the available power.

There are additional losses as well. Small wind turbine blades are never 100% efficient, even when running at their optimal speed and no generator is 100% efficient in converting the energy in a rotating shaft to electricity due to friction losses from bearings and gearing, and due to magnetic drag and electrical resistance losses in the generator. Even the best commercial wind turbines today only convert between 35-45% of the energy in the wind.

Modifying Equation 3 for the power efficiency of the machine:

Effective Power = Cp * 0.5 * Swept Area * Air Density * Velocity^3
(Eq. 4)

Where Cp is the power efficiency.

5 Safety and Environment

5.1 Safety Officer

The team safety officer is Katlin Wagner.

5.2 Vehicle Safety

5.2.1 Failure Mode and Effects Analysis (FMEA) of Vehicle

Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Risk Priority	Recommended Action(s)
Recovery		Rocket destroyed on impact.	10	Ejection blow by	1	**10**	Use the right size Kevlar shroud; pack parachute correctly.
		Rocket destroyed on impact.	10	Ematch doesn't lite	3	**30**	Use redundant e-match.
		Rocket destroyed on impact.	10	Not enough black powder	3	**30**	Static ground test amount.
	Altimeters fire while on the launch pad.	Injury to Personnel.	10	Static discharge; handling of rocket while armed	1	**20**	Use external safing switches; arm altimeters as last step of launch pad procedures
	Parachute or shock cords tear.	High-speed descent.	10	Too much black powder	3	**30**	Static ground test amount.
	Parachute does not fully deploy.	High-speed descent.	10	Shroud lines tangle	2	**20**	Pack parachute correctly.
		Uncontrolled descent.	10	Shock cord snaps	2	**20**	Use proper size cord. Ensure deployment at a lower velocity.
	Drogue, but not main deploys	High-speed descent.	8	Main ejection powder does not light.	2	**16**	Use redundant e-match and redundant event altimeters.
	Main, but not drogue deploys	Main deploys at high speed, potentially overstressing shock cord.	7	Drogue ejection powder does not light.	2	**14**	Use redundant e-match and redundant event altimeters.
	Parachute rips	High-speed descent.	8	Shroud lines not attached well.	2	**16**	Use high-quality, commercial parachute.
		Payload data are non-recoverable	10	Impact with ground dislodges electrical components, losing data.	3	**30**	Use non-volatile memory.

	Altimeter prematurely fires ejection charge.	Experiment is unsuccessful	10	Turbulent air from experiment turbine outflow over static ports causes mis-calculation of altitude by altimeter	5	**50**	Use event timer instead of barometric pressure based altimeter; set mach delay
Propulsion	CATO	Rocket does not reach desired altitude.	10	Faulty motor.	1	**10**	Ensure motor is assembled correctly and forward enclosure is on tightly.
	Reloadable motor failure.	Rocket does not reach desired altitude.	10	Motor assembled/loaded incorrectly.	2	**20**	Follow instructions; have more than one person overseeing loading; use single-use motor.
Vehicle	Zippering	Uncontrolled descent.	7	Weak airframe	2	**14**	Use fiberglass airframe.
	Fins break on launch	Unstable flight.	10	Fins too weak; incorrectly installed	2	**20**	Use fiberglass fins; use through-the-wall mount; use strong epoxy
	Weathercocking	Lower than expected altitude, resulting in not as much electricity being generated.	6	Overstability	4	**24**	Design to bring stability margin down to below 2. Use a higher initial thrust motor.
	Motor mount failure	Motor travels up through airframe	10	Improper construction and/or materials.	3	**30**	Use experience from mentor; use strong epoxy; use fiberglass centering rings

5.2.2 Listing of personnel hazards

Personnel hazards are possible during both construction and flight.

During construction, some materials being used may pose a safety risk to team members during their use. These materials may include: epoxy, JB Weld, and fiberglass dust. Extreme caution must be used in tandem with these hazardous materials because of the effects they may have on the team members. Power tools will also be used to manufacture / modify the parts needed to integrate the payload and vehicle assemblies. Proper safety briefings, usage instructions, use of proper safety equipment and mentor supervision will be executed during all team involvement of the construction.

Flight hazards are also large consideration with a project of this size. Engine failure, recovery device failure, and rocket flight are of the biggest concern. Handling of the black powder and the rocket motors also poses a risk. Following proper high-powered safety distances will help prevent injury in the event of a motor catastrophe, calculating proper ejection charges pre-flight recovery tests, using redundant altimeters and following specific pre-flight assembly tasks will reduce the risk of flight failure. Proper design simulations under various flight conditions will help ensure the team has the soundest rocket design being placed on the pad at launch time.

5.2.3 Environmental Concerns

The team has the potential of using several different launch sites in the Southeastern Wisconsin / Northern Illinois area. These launch sites are multi-use recreational sites used by different groups and organizations. All site restrictions posted will be followed and proper safety equipment will be checked to make sure it is onsite.

The payload poses little risk to the environment. There is a potential that on board batteries and equipment may fail and expose toxic material to the environment. The team will properly dispose of and clean up any material that may come in contact with the environment.

In addition, the team will consult with sponsoring clubs to ensure fire hazard risks are minimized and proper fire equipment is on hand at all launches.

5.3 Payload Safety

5.3.1 Failure Mode and Effects Analysis (FMEA) of Payload

Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Risk Priority	Recommended Action(s)
Science Experiment	Electrical failure of the Payload	Experiment is unsuccessful	7	Faulty circuitry and/or electronics	3	**21**	Test circuit;
		Experiment is unsuccessful	7	Water incursion from humidity/rain	3	**21**	Static test with pressurized water.
		Experiment is unsuccessful	7	Dead Battery	1	**7**	Use new battery on every launch.

		Experiment is unsuccessful	7	Stress and Vibration of launch	5	**35**	Ensure all components are rigidly attached; ground shake test
	Mechanical failure of the Payload	Experiment is unsuccessful	7	Turbine shaft breaks	2	**14**	Wind tunnel tests; ensure generator is rated for a higher RPM than expected.
		Experiment is unsuccessful	7	Fan blades break	3	**21**	Ensure blade assembly is rated for a higher RPM than predicted.
		Experiment is unsuccessful	7	Over-rev generator.	5	**35**	Ensure generator is rated for a higher RPM than predicted. Choose a motor that has a longer, flatter thrust curve.
		Experiment is unsuccessful	7	Blades/generator torque breaks attachment to airframe.	4	**28**	Use fiberglass nosecone and airframe tube.
		Experiment is unsuccessful	7	Bird strike on ascent.	1	**7**	Bring retriever dog to fetch bird.

5.3.2 Personnel hazards

An electrical shock hazard is present when handling the payload. Handling the on-board battery should pose no more risk than of handling any household battery. The team's electrical engineer advisor, Mr. Decker, will train us on any additional risks in the circuitry.

A wire mesh will be in front of the turbine, mitigating the hazard of a rapidly spinning blade assembly. This is especially important during static ground testing.

5.3.3 Environmental concerns

Beyond having NiMH batteries on-board, there are no other environmental concerns with our payload.

6 Project Management

6.1 Budget plan

Qty	Item Description	Manufacturer	Cost

Full-scale Rocket			
1	Full-scale Rocket	Performance Rocketry	$150
1	Centering Ring	Public Missiles	$5
1	Main Chute - 60"	Top Flight Recovery	Donated
1	Drogue -18"	Top Flight Recovery	Donated
1	Coupler	Loc Precision	$4
1	Motor Retainer	Aero Pack	$34
1	54mm Motor Mount	Public Missiles Ltd.	$50
1	Recovery Harness	Giant Leap	$60
	Miscellaneous Nuts and Bolts for Payload	Various	$25
Electronics			
1	RRC2 Mini Altimeter	Missile Works	$80
1	Arts2 Altimeter	Ozark Aerospace	$185
	Electric Matches, Light Bulbs, Wiring, Safety Switches	Various Sources	$50
	Black Powder / Pyrodex	TBD	$15
1	T400AM Transmitter	Adept Rocketry	$60
1	Three Element Directional Receiving Antenna	Adept Rocketry	$30
Half-scale Rocket			
1	Half-scale Rocket	Performance Rocketry	$79
1	Centering Ring	Public Missiles	$5
1	Main Chute - 36"	Top Flight Recovery	Donated
1	Drogue -18"	Top Flight Recovery	Donated
1	Motor Retainer	Aero Pack	$29
1	Recovery Harness	Giant Leap	$60
	Miscellaneous Nuts and Bolts for Payload	Various	$25
Propulsion			

1	I218R	Animal Motor Works	$30
2	K1075GG	Animal Motor Works	$200
Payload			
1	3" RC Ducted Fan Assembly	RC Motor Fan	$65
1	1.5" RC Ducted Fan Assembly	RC Motor Fan	$50
1	Circuit Components	Various	$25
	eLogger V3	Eagle Tree Systems	$110
1	DC Induction Generator (Motor)	Hobby Lobby	$120
Outreach			
50	Watchamacallit	Fliskits Inc.	$125 (offset by fee)
2	Educator packs (24 count) of A3/4T	Estes	$75
18	Triskelion Kits	Fliskits Inc.	$155 (offset by fee)
1	Educator pack (24 count) of B6-4	Estes	$50
	Miscellaneous supplies	Various vendors	$30
Miscellaneous Items			
	Website URL License		$120
	Building supplies (epoxy, JB Weld, syringes, gloves)		$200
High-Level Cost Estimate:			$2321

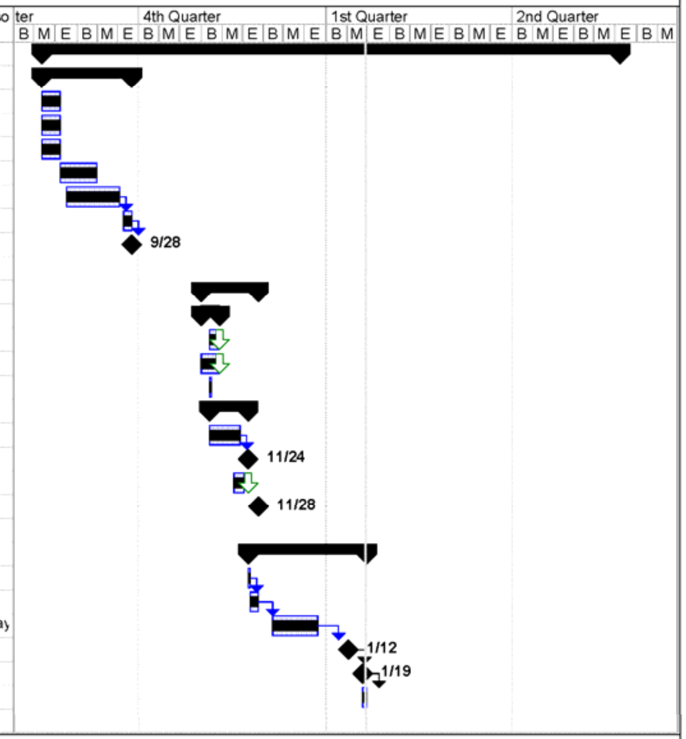
6.2 SLI Project Plan

The detailed schedule follows:

Washington County 4H
SLI Project

2007-2008

ID	Task Name	Duration	Start	Finish	% Complete	Predecessors
1	**Washington County 4H SLI Project**	**275 days?**	**Wed 8/15/07**	**Fri 5/23/08**	**60%**	
2	**RFP (Request for Proposal)**	**44 days?**	**Wed 8/15/07**	**Fri 9/28/07**	**100%**	
3	Initial brainstorming	9 days	Wed 8/15/07	Thu 8/23/07	100%	
4	Assign tasks and responsibilities	9 days	Wed 8/15/07	Thu 8/23/07	100%	
5	Initial payload design	9 days	Wed 8/15/07	Thu 8/23/07	100%	
6	Initial rocket design	18 days	Fri 8/24/07	Mon 9/10/07	100%	
7	Create RFP	26 days	Mon 8/27/07	Fri 9/21/07	100%	
8	Review RFP	4 days?	Mon 9/24/07	Thu 9/27/07	100%	7
9	Submit RFP to NASA	0 days	Fri 9/28/07	Fri 9/28/07	100%	8
10						
11	**PDR (Preliminary Design Review)**	**27 days?**	**Thu 11/1/07**	**Wed 11/28/07**	**100%**	
12	**Payload Design**	**9 days?**	**Thu 11/1/07**	**Fri 11/9/07**	**100%**	
13	Prototype generator	5 days?	Mon 11/5/07	Fri 11/9/07	100%	
14	Paper design of payload circuit	9 days?	Thu 11/1/07	Fri 11/9/07	100%	
15	Investigate off-the shelf components	1 day?	Mon 11/5/07	Mon 11/5/07	100%	
16	**Vehicle design**	**18 days?**	**Mon 11/5/07**	**Sat 11/24/07**	**100%**	
17	Re-work initial design	15 days	Mon 11/5/07	Mon 11/19/07	100%	
18	Review design with team	0 days	Sat 11/24/07	Sat 11/24/07	100%	17
19	Payload - vehicle integration	5 days?	Sat 11/17/07	Wed 11/21/07	100%	
20	PDR due to NASA	0 days	Wed 11/28/07	Wed 11/28/07	100%	
21						
22	**Half Scale Rocket**	**57 days**	**Sat 11/24/07**	**Sun 1/20/08**	**100%**	
23	Finalize design	1 day	Sat 11/24/07	Sat 11/24/07	100%	
24	Order parts	4 days	Sun 11/25/07	Wed 11/28/07	100%	23
25	Construction	21 days	Thu 12/6/07	Thu 12/27/07	100%	24FS+7 day
26	Launch half-scale	0 days	Sat 1/12/08	Sat 1/12/08	100%	25
27	Backup launch date	0 days	Sat 1/19/08	Sat 1/19/08	100%	26
28	Validate Results	2 days	Sat 1/19/08	Sun 1/20/08	100%	27
29						



Project: 4-H SLI Project
Date: Sun 1/20/08

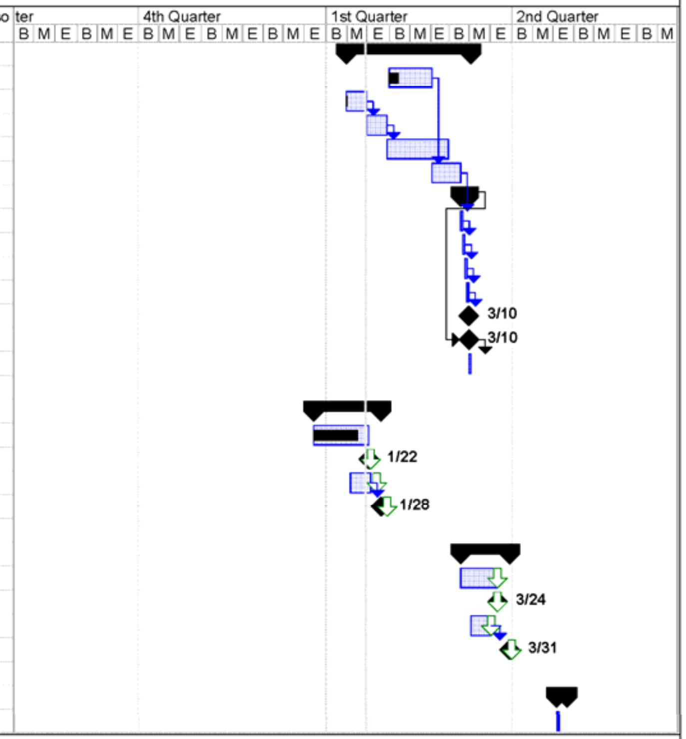
Task		Milestone	◆	External Tasks	
Split		Summary		External Milestone	◆
Progress		Project Summary		Deadline	⇩

Page 1

Washington County 4H
SLI Project

2007-2008

ID	Task Name	Duration	Start	Finish	% Complete	Predecessors
30	**Full Scale Rocket**	**61 days?**	**Fri 1/11/08**	**Tue 3/11/08**	**5%**	
31	Finalize payload design	21 days?	Fri 2/1/08	Thu 2/21/08	20%	
32	Finalize rocket design	10 days	Fri 1/11/08	Sun 1/20/08	3%	
33	Order parts	10 days	Mon 1/21/08	Wed 1/30/08	0%	32
34	Construction	30 days	Thu 1/31/08	Fri 2/29/08	0%	33
35	Build and Test Payload	14 days	Fri 2/22/08	Thu 3/6/08	0%	31
36	**Ground Testing**	**4 days?**	**Fri 3/7/08**	**Mon 3/10/08**	**0%**	
37	Payload testing (electronics)	1 day?	Fri 3/7/08	Fri 3/7/08	0%	35
38	Wind tunnel testing	1 day?	Sat 3/8/08	Sat 3/8/08	0%	37
39	Analyze results	1 day?	Sun 3/9/08	Sun 3/9/08	0%	38
40	Recovery subsystem testing	1 day?	Mon 3/10/08	Mon 3/10/08	0%	39
41	Vehicle / Payload integration	0 days	Mon 3/10/08	Mon 3/10/08	0%	40
42	Launch full-scale	0 days	Mon 3/10/08	Mon 3/10/08	0%	36
43	Analyze Results	1 day?	Tue 3/11/08	Tue 3/11/08	0%	42
44						
45	**CDR (Critical Design Review)**	**33 days**	**Wed 12/26/07**	**Mon 1/28/08**	**58%**	
46	Create CDR document	27 days	Wed 12/26/07	Mon 1/21/08	80%	
47	CDR due to NASA	0 days	Tue 1/22/08	Tue 1/22/08	0%	
48	Create CDR presentation	10 days	Sun 1/13/08	Tue 1/22/08	0%	
49	CDR presentation to NASA	0 days	Mon 1/28/08	Mon 1/28/08	0%	48
50						
51	**FRR (Flight Readiness Review)**	**24 days**	**Fri 3/7/08**	**Mon 3/31/08**	**0%**	
52	Create FRR document	18 days	Fri 3/7/08	Mon 3/24/08	0%	
53	FRR Due to NASA	0 days	Mon 3/24/08	Mon 3/24/08	0%	
54	Create FRR presentation	10 days	Wed 3/12/08	Fri 3/21/08	0%	
55	FRR Teleconference w/ NASA	0 days	Mon 3/31/08	Mon 3/31/08	0%	54
56						
57	**SLI in Huntsville**	**5 days?**	**Wed 4/23/08**	**Sun 4/27/08**	**0%**	
58	Travel	1 day?	Wed 4/23/08	Wed 4/23/08	0%	



Project: 4-H SLI Project
Date: Sun 1/20/08

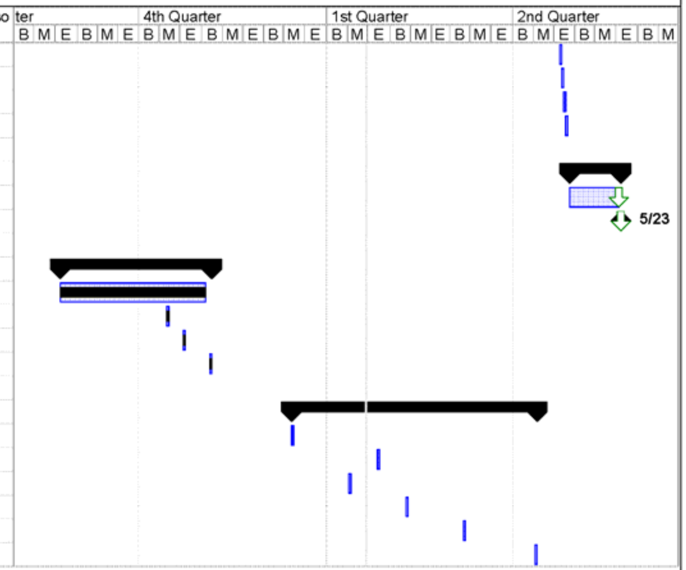
Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

Page 2

Washington County 4H
SLI Project

2007-2008

ID	Task Name	Duration	Start	Finish	% Complete	Predecessors
59	Rocket fair	1 day?	Thu 4/24/08	Thu 4/24/08	0%	
60	Hardware Check	1 day?	Fri 4/25/08	Fri 4/25/08	0%	
61	Launch day	1 day?	Sat 4/26/08	Sat 4/26/08	0%	
62	Return home	1 day?	Sun 4/27/08	Sun 4/27/08	0%	
63						
64	**PLAR (Post launch analysis review)**	**19 days**	**Tue 4/29/08**	**Fri 5/23/08**	**0%**	
65	Create PLA document	18 days	Tue 4/29/08	Thu 5/22/08	0%	
66	PLAR Due to NASA	0 days	Fri 5/23/08	Fri 5/23/08	0%	
67						
68	**Miscellaneous**	**74 days?**	**Fri 8/24/07**	**Mon 11/5/07**	**100%**	
69	Identify Level 2 mentor	71 days?	Fri 8/24/07	Fri 11/2/07	100%	
70	SLI Teams Announced	1 day?	Mon 10/15/07	Mon 10/15/07	100%	
71	SLI teleconference	1 day	Tue 10/23/07	Tue 10/23/07	100%	
72	Team website live	1 day?	Mon 11/5/07	Mon 11/5/07	100%	
73						
74	**Community Outreach**	**119 days?**	**Sat 12/15/07**	**Sat 4/12/08**	**0%**	
75	Cloverbuds rocket workshop	1 day?	Sat 12/15/07	Sat 12/15/07	0%	
76	Tri-County SET workshop	1 day?	Sat 1/26/08	Sat 1/26/08	0%	
77	January county-wide meeting	1 day?	Sat 1/12/08	Sat 1/12/08	0%	
78	February county-wide meeting	1 day?	Sat 2/9/08	Sat 2/9/08	0%	
79	March county-wide meeting	1 day?	Sat 3/8/08	Sat 3/8/08	0%	
80	April county-wide meeting	1 day?	Sat 4/12/08	Sat 4/12/08	0%	



Project: 4-H SLI Project
Date: Sun 1/20/08

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Page 3

7 Outreach Summary

Community outreach currently includes two activities. There was a meeting conducted on December 15, 2007 for the Washington County Cloverbud workshop. Cloverbuds is designed for 4-H youth in 1st through 3rd grade. There were approximately 40 kids in attendance that constructed and launched a Watchamacallit from Fliskits. In addition to learning basic construction techniques and rocket safety the kids were able to launch their newly constructed rocket using Estes ½ A3-4T engines.

As part of the 4-H Space, Engineering and Technology (SET) program, the SLI team will be partnering with our mentors who are also leading the Washington County 4-H countywide aerospace leaders to conduct a workshop on January 26, 2008. The workshop will be geared towards 5th grade (and older) youth to expose them to rocketry at the Tri-County workshop in Sheboygan, Wisconsin. At this workshop kids will be constructing and launching a Triskelion from Fliskits. This workshop will teach youth and parents how to construct and fly a model rocket and the rules needed to participate in rocketry in a safe manner.

In addition to these two outreach events; team members will be helping lead and mentor the Washington County 4-H rocketry project. These meetings will be more in depth meetings discussing higher levels of rocket building. The primary focus of these meetings will to help youth of all ages construct their county fair rocket. Our county 4-H rocketry program currently has 31 youth enrolled in rocketry and aerospace related projects.

8 Conclusion

Refinement and changes will evolve as progress continues on the Washington County 4-H team project – to design, build, and launch a rocket that generates electrical power by harnessing the wind moving against the accelerating airframe. The team is confident that the design of the rocket can integrate the payload. The project continues to be refined and re-worked as the team moves deeper into the detailed design elements.

- The team still has challenges that will need to be over come for FRR:
- The circuit design has to be refined and built
- The payload must integrated into the rocket
- The full-scale rocket must be fully constructed

The project's greatest risk currently is the payload design and circuitry. With continued dedication to the project and leadership from the mentors, the team is confident that they are managing this risk appropriately.

This project is stretching everyone on the team as progress continues. It is providing learning opportunities for everyone involved, pushing the team members to be more creative and think far outside of what they thought they were capable of. The team is making the most of this SLI experience.