NASA Student Launch Initiative 2008-2009

Washington County (Wisconsin) 4-H Rocketry

Student Launch Initiative

Flight Readiness Review

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Generate REnewable ENergy

Washington County 4-H Rocket Club
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1 Summary of FRR report

1.1 Team Summary

Name:	Washington County (Wisconsin) 4-H Rocketry Club
Location:	Slinger, Wisconsin
Members:	Katlin, Ben, Isaac
Mentors:	Doug Pedrick, Pat Wagner, Ed Kreul, Dave Duckert

1.2 Launch Vehicle Summary

The launch vehicle specifications are as follows:

Airframe:	Loc Precision Heavy Duty Kraft with Glassine Overwrap
Diameter:	5.5” Outside Diameter
Length:	111 in.
Weight:	30 lbs, with motor
Motor:	Aerotech L850W, 3840 Newtons, 75mm
Stability Margin:	3.16
Recovery System:	Redundant dual event altimeters deploying a 24” drogue at apogee and 120” main parachute at 800 feet
Rail Size:	Standard 80/20 1010, with ¼” rail buttons
Coefficient of Drag:	Unknown – to be determined by test flights

1.3 Payload Summary

The payload consists of three wind turbines, each having a different blade profile, housed inside fin tubes, and a thermoelectric generator that will convert heat from the motor directly into electricity. The goal of the payload is to find the most effective power generating configuration in the experiment.

2 Changes made since CDR

2.1 Changes made to Vehicle Criteria

Vehicle criteria have changed in the following areas since CDR:

- The overall length has changed from 100" to 111"
- The weight has increased from 25 to 30 lbs
- The stability margin has increased from 1.63 to 3.16 (per Rocksim; subject to actual Cg determination)
- The nose cone has been modified to allow the addition of variable weights. This may be necessary to adjust the center of gravity.

2.2 Changes made to Payload Criteria

Payload criteria have changed in the following areas since CDR:

- The turbine fans will sit in shorter tubes placed closer to the top of the fins.
- The heat sink and thermoelectric generator are mounted to a bracket epoxied to the motor mount.
- The payload electronics bay is now using a platter design to make efficient use of available space.

2.3 Changes made to Activity Plan

The project timeline has changed significantly since CDR. It has been impacted by several factors including parts delivery, design complexity, student and mentor time. In the best case scenario a test launch will be held on April 5th. There is still a very likely possibility that the vehicle's first launch will be in Huntsville on Sunday, April 19. The team hopes that is not the case however.

3 Vehicle Criteria

3.1 Testing and Design of Vehicle

3.1.1 Materials use

The materials selected include:

- Thick Kraft paper body tubes, motor mount, electronics bay, payload bay and tube fins with additional interior Kraft paper stiffeners for extra strength
- ¼" aircraft plywood bulkheads on the electronics and payload bay
- ¼" aircraft plywood fins and centering rings
- Standard plastic nose cone
- G-10 fiberglass and 4 ounce fiberglass cloth formed for the thermoelectric generator mount.
- West Epoxy, Kevlar pulp, chopped carbon fiber and JB Weld
- 3 ounce fiberglass cloth

All of the materials are standard materials offered by rocket suppliers and used in the construction of level 2 class high-powered rockets. The adhesive and fillers used are also common to high-powered rocket construction, recommended by our level 3 mentor. The fiberglass cloth is being used to strengthen the fins and attached fin tubes. It is being applied across the width of the booster section of the rocket spanning from one fin tip across the fin tube to the other fin tip. This provides the necessary integrity required to sustain the stress and forces exhibited during a high-powered flight.

3.1.2 Assembly strength and load paths

The assembly has been strengthened by following proper techniques including:

- Through the wall fin attachment
- Fin tube attachment to the fins and main airframe tube at two attachment points
- Solid load paths including
    - Motor retainer to motor mount
    - Motor mount attachment to the aft centering ring using 12, 6-32 cap screws fastened to PEM-style captive nuts
    - Direct fin attachment to centering rings on both sides of all fins
    - Thermoelectric generator bracket mounting directly to the bottom centering ring
    - Heavy duty fillets, inside and outside of vehicle wall
- Electronics and payload bays soaked in West Epoxy for strength
- Electronics and payload bays secured to outside vehicle walls using PEM-style captive nuts
- Recovery System is attached to the electronics bay, payload bay and nose cone using u-bolts and nuts secured with JB Weld

As mentioned above, West Epoxy along with strengthening agents including Kevlar pulp and chopped carbon fiber were used in the assembly of the rocket. In addition, JB Weld was used to secure metal parts and prevent parts loosening due to vibration.

3.1.3 Motor Retention

Positive motor retention is achieved using a commercially available flange mounted motor retainer manufactured by AeroPak, Inc. This includes the motor mount attached using 12, 6-32 cap screws as described above as well as a screw on cap.

3.1.4 Design Integrity

The fin-style used is a standard LOC Precision HyperLoc 1600 high-powered rocket fin size and proven shape for similar sized rockets. The fin tubes are attached at two mounting points: one on a planar fin and one on the main airframe tube.

The heat-sink is surrounded by a reinforced hatch on the airframe tube. This allows for access to the mounting points of the thermoelectric generator and experiment components. It also reduces turbulence and allows better airflow down the side of the rocket.

3.1.5 Workmanship approach

Quality workmanship includes proven construction techniques and load transfer to main components. The exterior of the rocket includes quality epoxy fin fillets, smooth finish, paint and decals completing the project with a professional look.

3.1.6 Safety and failure analysis

Vehicle safety and failure analysis is included with all project safety and failure analysis in section 3.4.2.

3.2 Recovery Subsystem

3.2.1 Recovery subsystem details

The recovery system includes Top Flight Recovery components for the parachutes and recovery harnesses. A 120-inch main parachute and 24-inch drogue made of rip-stop nylon will safely return the rocket from flight. $9/16^{th}$ inch tubular nylon harnesses, Kevlar chute and shock cord protectors, D-Link connectors and 2500 pound swivels are also included in the recovery sub-system design.

The main parachute's descent rate is 20 ft/s, and the drogue parachute's descent rate is 110 ft/s. The drogue parachute is harnessed to both the payload bay and altimeter bay; the main parachute is harnessed to the altimeter bay and the nose cone. Parachute failure modes are included with all project safety and failure analysis in section 3.4.2.

Based on the equation below, 2 grams of black powder is required for the drogue charge (primary and backup), and 4 grams of black powder for each main charge. The team will validate proper charge sizing prior to the vehicle's first flight with a static charge test.

Equation for determining the number of grams of black powder for the deployment charges is (assuming 15 psi):

$N = .006 * D^2 * L$
where D=diameter and L=length of sections being pressurized (in inches).

Recovery electronics components are those used as part of the team's successful 2007-2008 SLI project: PerfectFlite's miniAlt/WD and Ozark Aerospace's' ARTS. Both are dual deployment altimeters, each independently controlling separate ejection charges for drogue and main parachutes. This is a proven combination of redundancy with the added benefit of two different altimeter manufacturers.

3.2.2 Recovery safety and failure analysis

Recovery safety and failure analysis is included with all project safety and failure analysis in section 3.4.2.

3.3 Mission Performance Predictions

3.3.1 Mission performance criteria

The mission performance criteria as described in the team's Proposal remains as follows:

- The vehicle shall carry a science payload.
- The vehicle shall fly to 5,280 feet in altitude.
- The vehicle shall be in a reusable state when it returns.
- The total motor impulse shall not exceed 4000 Newton-seconds.
- Preparation of the vehicle and payload shall not exceed 4 hours.
- 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.
- All generators function properly and data is recorded

3.3.2 Vehicle Details

The latest RockSim calculations are summarized as follows:

Total vehicle and payload weight:	30 lbs.
Motor:	Aerotech L850W
Predicted Altitude:	5800ft
Coefficient of Drag:	To be determined
Vehicle velocity at launch guide departure:	51fps

Additional vehicle simulation results are included in Figure 1 below.

Engine selection

[L850W-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: 1020.00000 Ft.
- Relative humidity: 35.000 %
- Temperature: 65.000 Deg. F
- Pressure: 30.1206 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: 0.000 Deg.
- Latitude: 42.000 Degrees

Launch guide data:

- Launch guide length: 72.0000 In.
- Velocity at launch guide departure: 50.6631 ft/s
- The launch guide was cleared at : 0.287 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 54.9441 In.

Max data values:

- Maximum acceleration:Vertical (y): 922.999 Ft./s/sHorizontal (x): 7.463 Ft./s/sMagnitude: 922.999 Ft./s/s
- Maximum velocity:Vertical (y): 684.0387 ft/s, Horizontal (x): 16.2904 ft/s, Magnitude: 690.3445 ft/s
- Maximum range from launch site: 1077.46063 Ft.
- Maximum altitude: 5774.47507 Ft.

Recovery system data

- P: Main parachute Deployed at : 65.139 Seconds
- Velocity at deployment: 109.8547 ft/s
- Altitude at deployment: 799.90486 Ft.
- Range at deployment: -450.87270 Ft.
- P: Drogue parachute Deployed at : 18.580 Seconds
- Velocity at deployment: 54.5348 ft/s
- Altitude at deployment: 5774.47507 Ft.
- Range at deployment: -1077.46063 Ft.

Time data

- Time to burnout: 4.697 Sec.
- Time to apogee: 18.580 Sec.
- Optimal ejection delay: 13.883 Sec.

Landing data

- Successful landing
- Time to landing: 104.676 Sec.
- Range at landing: 154.88353
- Velocity at landing: Vertical: -19.7550 ft/s , Horizontal: 16.2905 ft/s , Magnitude: 25.6054 ft/s

Figure 1. Predicted Flight Data

The vehicle uses an Aerotech L850W motor, the trust curve is shown in Figure 2. The motor casing required for this motor is an Aerotech RMS-75/3840. The thrust-to-weight ratio is 6.4:1 (the minimum recommended thrust to weight ratio is 5:1).

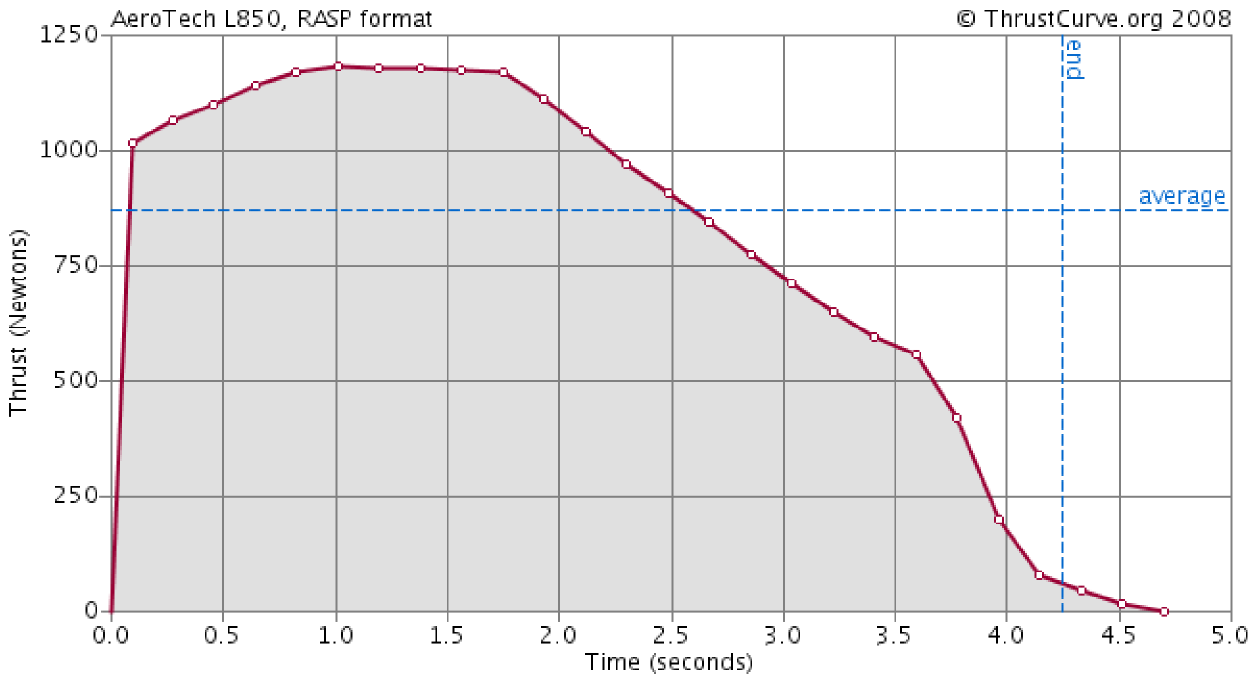

Figure 2. Aerotech L850W Thrust Curve

3.3.3 Analysis results

Currently, Rocksim estimates the vehicle will travel to an altitude approximately 5,800 feet; nearly 520 feet over the goal. Experience has shown that Rocksim tends to overestimate altitude. Rocksim does not adequately model constricted fin tubes (the drag created by the ducted fans is hard to model). A full-scale test flight will provide actual data used to reverse engineer the coefficient of drag. Adjustments to the rocket can then be made to get closer to the altitude goal.

A half scale test launch was conducted in December. The vehicle had six fin tubes with wind turbines in every other fin tube. Electronics and heat sink were not included in the test launch. The vehicle was launched using an Aerotech G80-4T motor propelling the vehicle approximately 440 feet in the air. Rocksim predicted the rocket would go approximately 1,000 feet in the air. With findings from the test launch, the team concluded that six fin tubes had drawbacks of additional drag and mass, and it was unlikely an L850 motor would propel the original design to a mile in altitude. As a result, the team redesigned the vehicle using three fin tubes and three regular fins.

3.3.4 Comparison of predicted to measured values

Currently, Rocksim is predicting the rocket will fly to an altitude of 5,800 ft. However, the team has not been ready to test the full-scale vehicle at a real launch yet. The final comparison of models is yet to be determined.

3.3.5 Key vehicle characteristics

The vehicle has a several characteristics that make it unique. It has three fin tubes attached to the planar fins that will increase drag. Since we are using cardboard and plywood, the fin tubes will be layered with fiberglass cloth. The vehicle also has a shroud that will fit around the video camera. The heat sink will have a hatch cut around it that will make it removable.

Two different views of the vehicle design are shown in Figure 3.

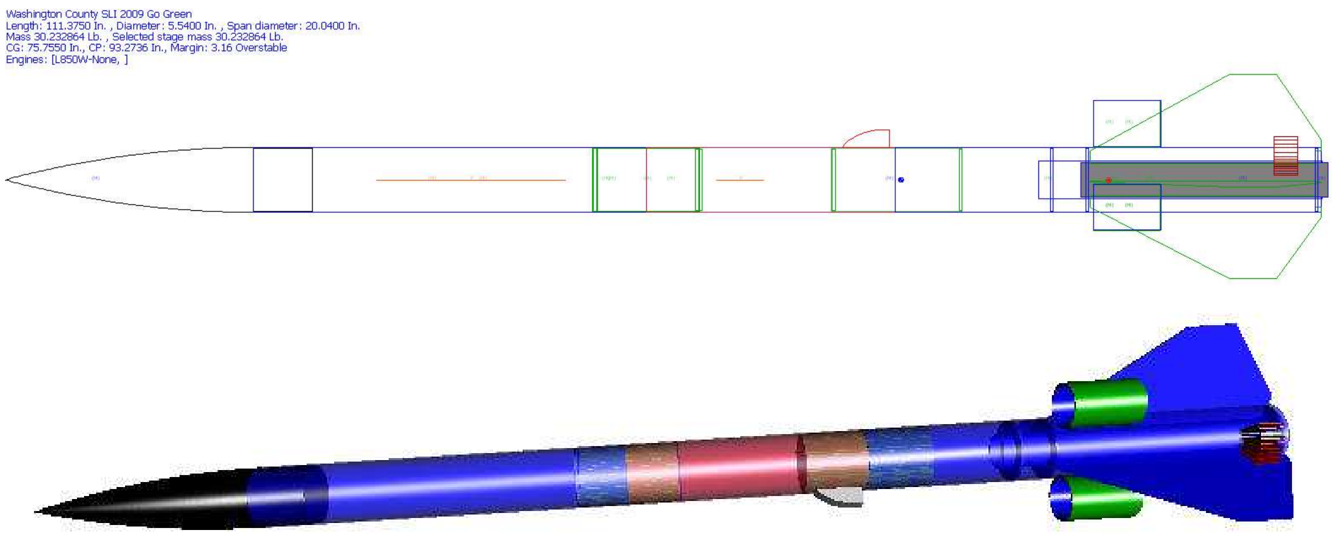

Figure 3. 2D and 3D Views

3.3.6 Safety and failure analysis

Safety and failure analysis, table of failure models, causes, effects, and risk mitigations project safety and failure analysis in section 3.4.2.

3.4 Safety and Environment (Vehicle)

3.4.1 Safety Officer

The team's safety officer is Katlin.

3.4.2 Vehicle failure mode analysis

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	Deployment failure	Rocket destroyed on impact	10	Ejection blow by	1	**10**	Use the right size Kevlar shroud; pack parachute correctly
	Deployment failure	Rocket destroyed on impact	10	E-match doesn't light	3	**30**	Use redundant e-match
	Deployment failure	Rocket destroyed on impact	10	Not enough black powder	3	**30**	Static ground testing of ejection charge sizes
	Parachute or shock cords tear	High-speed descent	10	Too much black powder	3	**30**	Static ground testing of ejection charge sizes
	Parachute does not fully deploy	High-speed descent	10	Shroud lines tangle	2	**20**	Pack parachute correctly
	Deployment failure	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
	Deployment failure	Payload data is 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**	Follow recommended hole sizes for port holes in the altimeter bays

	Separation occurs prematurely	Experiment is unsuccessful	10	Forgot shear pins in nose cone or middle section	3	**30**	Add shear pin installation entry to pre-launch checklist
	Separation of vehicle sections does not occur	High-speed descent, rocket destroyed on impact	10	Shear pins not properly sized for the vehicle and ejection charges calculated	2	**20**	Correctly calculate the necessary shear pins size to be used with the size of the rocket and ejection charges
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	**100**	Follow instructions; have more than one person overseeing loading
	Motor travels up airframe	Experiment is unsuccessful; rocket does not reach desired altitude	10	No thrust ring or poor retention	1	**10**	Ensure positive motor retention is used and installed correctly; add retention entry to pre-launch checklist
	Motor casing falls out on ejection	Safety of people at risk	10	Improper retention	1	**10**	Ensure positive motor retention is used and installed correctly; add retention entry to pre-launch checklist
Vehicle	Zippering	Uncontrolled descent	7	Weak airframe	2	**14**	Use fiberglass airframe
	Tube Fins separate from vehicle body	Unstable flight	10	Fins not properly attached	2	**20**	Use tube stiffeners; screw fin tubes to main vehicle tube
	Weathercocking	Lower than expected altitude, resulting in not as much electricity being generated	6	Over stability	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 proper building techniques with mentor guidance Use strong epoxy; use heavy-duty centering rings

3.4.3 Personnel hazards

Personnel hazards are possible during both construction and flight.

The materials used have remained relatively static as to what was discovered for the Preliminary Design Review. The MSDS documentation was approved to be added to the team's website - http://www.4hrocketry.org/materialsafetydatasheets. Updates include references to Cyanoacrylate glue and liquid electrical tape. In addition, links to NAR and Tripoli safety rules have been reviewed. During static testing of the electronics bay, both altimeters (PerfectFlight MAWD and Ozark Aerospace ARTS) were reviewed and tested to validate proper beep sequences.

Shop safety remains important to the team. The team is supervised by our adult mentors; we use proper safety equipment including eye protection and gloves according the basis shop safety rules and MSDS requirements. There have been no shop safety incidents and has been no exposure to hazardous materials due to the team's diligence.

3.4.4 Environmental concerns

Several potential launch sites in the southeast Wisconsin / Northern Illinois area are available. These launch sites are multi-use recreational sites used by different groups and organizations. In addition, the Bragg farm in Alabama is a private farming site, similar to those in Wisconsin and Illinois. All site-use guidelines and restrictions posted will be followed. Proper safety equipment used by local clubs will be used.

The vehicle and payload pose 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 additional, the team will consult with sponsoring clubs to ensure fire hazard risks are minimized and proper fire equipment is on hand at launches.

3.5 Payload Integration

3.5.1 Integration Plan

Payload / vehicle integration has been achieved in several ways as follows:

- **Payload Bay** – All components necessary to measure the electricity generated are housed inside of the payload bay. The payload bay is designed as the main coupler between the booster section of the rocket and upper vehicle airframe sections. It is constructed out of heavy Kraft paper and additional stiffener tubes as described above in section 3.1.2. The payload bay is attached to the airframe sections using truss-head screws attached to PEM-style captive nuts JB-welded to the interior of the payload bay.

The electronics inside the bay include all data sensor capture equipment and a video camera for on-board video capture. The electronic components are integrated with wiring quick connectors exposed below the payload bay as well as wire connectors at each of the generators on the rocket. Wire leads are mounted, attached and housed inside the airframe.

- **Thermoelectric Generator / Heat Sink** – The thermoelectric generator (TEG) and heat-sink are mounted to an aluminum heat transfer block using four cap screws. They are also attached to the fiberglass mounting bracket. These components are completely removable when the vehicle's hatch is removed, electrical wiring is disconnected and cap screws removed from the mounting bracket.
- **Wind Turbine Generators** – The wind turbine generators remain in the original plastic housing from the manufacturer. The entire housing is epoxied into a plywood adapter bracket, which in turn is screwed into heavy Kraft reinforced fin tubes permanently mounted to the vehicle. Wind turbines can be removed by decoupling each individual wiring harness and removing the wood screws attaching the turbine to the fin tube.

3.5.2 Compatibility

The fin tubes are a smaller diameter than the body tube, helping to reduce drag and making the ducted fan assemblies easier to attach. They will be fiberglassed to the fins to permanently attach them and give the rigidity to survive launch forces. The heat sink and TEG are attached to an aluminum heat transfer component held onto the body tube by a channel bracket. The transition was custom machined for us to fit perfectly on the motor mount. The heat sink is placed into the body tube and then a hatch is placed over it. A cross-section of this arrangement is shown in Figure 4.

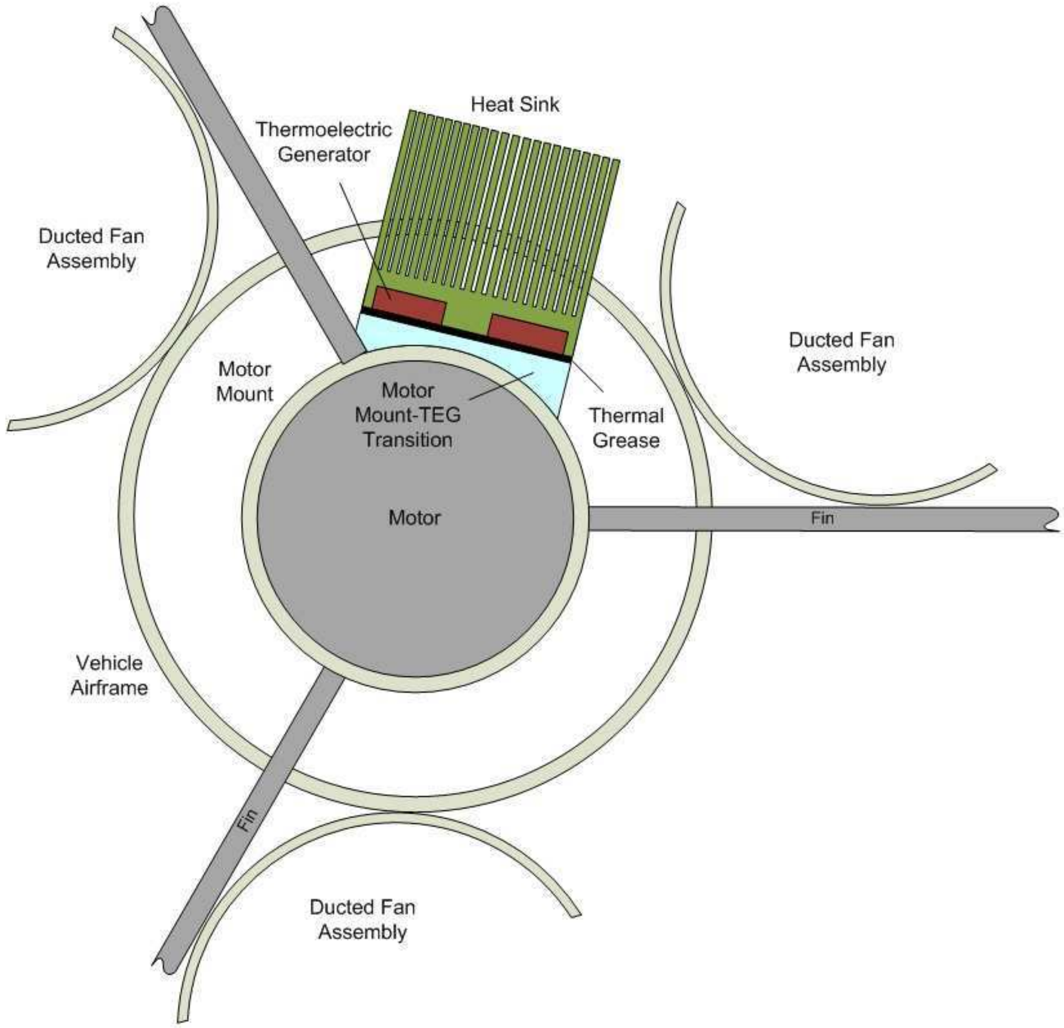

Figure 4. Booster Cross-Section Detail

3.5.3 Payload housing integrity

The payload housing integrity followed the same design techniques as the electronics bay and other rocket components and is described in sections 3.1.2 and 3.1.3 above.

3.5.4 Integration diagrams

To mount the heat transition piece to the motor casing we created a "C-Channel". This C-channel was a structure of custom made fiberglass. The transition is mounted underneath the C-Channel and a square section rises up through an opening in the channel. The heat sink is screwed into the transition from above. The TEG sits in-between the heat sink and the transition. Figure 5 is a picture of C-channel and the transition piece.

Figure 5. C-Channel and Transition

4 Payload Criteria

4.1.1 Payload Overview

The payload will generate power using wind turbines attached to the side of the body tube. The turbines will be turned by the force of the wind. It will also generate power by using a thermoelectric generator to harness the heat coming from the motor. The power will be recorded with four data loggers in the payload bay.

4.2 Experiment Concept

4.2.1 Payload Originality and Significance

The experiment is unique, building on an original concept developed by last year's Washington County 4-H SLI team. Energy is a topic that is a problem on a global scale. Harnessing wind power is just one main form of renewable energy being explored in Southeast Wisconsin and across the United States currently. Reclaiming waste heat has many applications and is finding its way into very efficient automobiles. Both of these ideas aren't usually coupled with rocketry, making it unique.

4.2.2 Level of challenge / suitability

Integrating the payload presents many challenges. The rocket booster has to be modified so wires run between the motor casing and the outside airframe. The TEG also was a challenge to integrate. Mating the heat sink, the TEG, a heat transition component, and the motor mount required detailed design and thought. Finding suitable DC motors, ducted fans of different blade configurations, integrating them with the fin tubes, attaching RPM sensor to the fan shafts, and planning the wiring layout posed significant challenge.

The voltage regulator circuit was expanded from last year's experiment to allow for one set of batteries to power all 4 eLogger's in parallel. Significant experience has been gained in making good electrical solder joints.

4.2.3 Mission success criteria

The payload will be successful if all three turbines and the TEG produce electricity with recoverable measurements. The payload must also survive intact and be capable of repeated flights. We expect the rocket to have a straight and stable flight.

4.3 Experiment Design of Payload

4.3.1 Payload review

Fan Blades

Three different types of fan blades are being used in the experiment to see how efficiency varies between designs. Each one has a different fan swept area, number of blades, and/or different pitch. Last year's fan assembly is being reused along with two new fan assemblies. The three fan assemblies will have 3, 5, and 6 blades.

Turbines

Three small DC motors are used as generators. They generate electricity from the rotational energy of the fan blades. Although this is not the most efficient way of generating electricity, other types of generators or motors are either too expensive or too big to fit in the rocket. These turbines are also chosen because they have low torque and spin relatively freely. Each fan assembly will use the same type of motor (Igarishi NN2742) to limit the experiment variables.

Circuit Components

The circuit includes data recorders that keep track of the current produced by the generators. A voltage regulator controls the power used to run the Eagle Tree System eLoggers. There are 4 eLoggers in the circuit, one dedicated to each generator. They are all connected to 4 AA batteries, wired in a parallel circuit. Figure 6 shows the payload bay in its current configuration. As we put the payload together we tested the voltage regulator and the sensor wires to ensure all wires were connected properly.

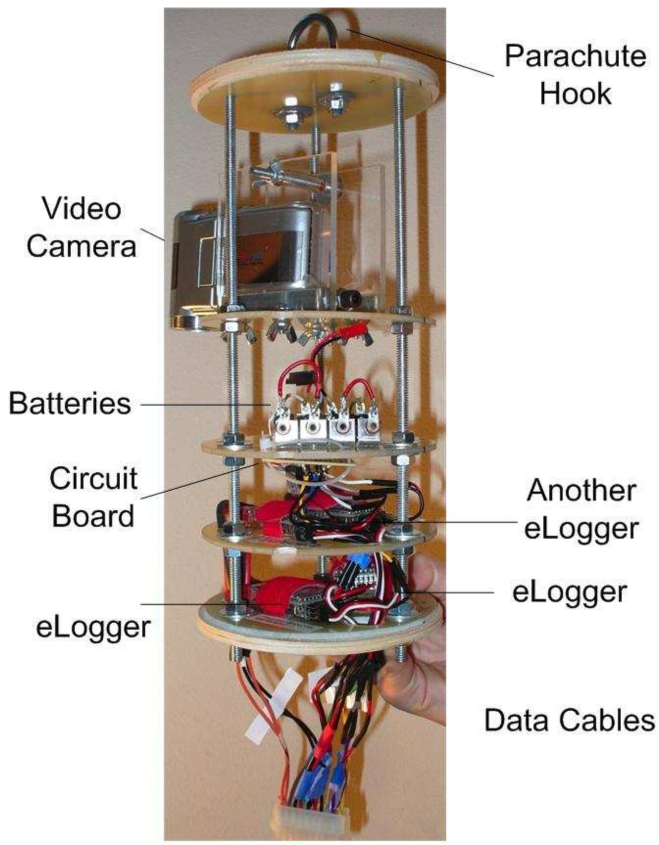

Figure 6. Experiment Payload Bay

Heat Sink

A heat sink is used to dissipate the heat of the motor as it passes through the TEG. The amount of electricity generated is proportional to the temperature difference across the generator. The heat sink is a modified CPU aluminum heat sink and is attached to the top of the TEG and extends outside the rocket. This is shown in Figure 7. The thin ribs of the heat sink will be in the airstream of the moving rocket and should sufficiently cool the generator. The heat sink ribs will act as small fins and may generate a small amount lift, but it should not negatively impact the stability of the rocket.

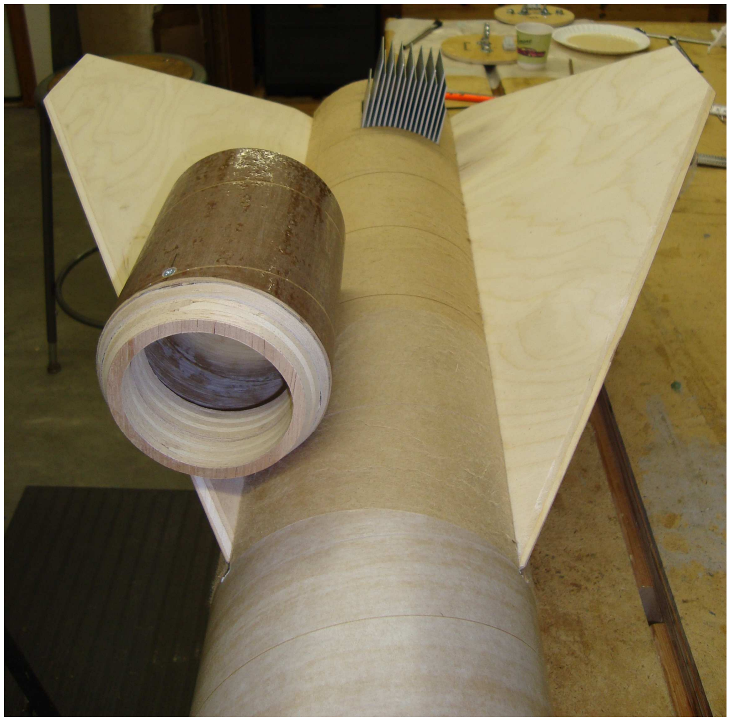

Figure 7. Booster Section

Thermoelectric Generator

When a temperature gradient exists across the two sides of the TEG, a DC voltage is created. If a load is applied, electrical current will flow. The bigger the temperature difference, the bigger the voltage; this is known as the Seebeck effect. In a rocket, significant heat is generated by the burning motor. An aluminum adapter sits between the motor mount and the TEG and will serve to transfer the heat to the device. We don't envision generating a lot of power (compared to the wind turbines) from the thermoelectric devices. We just want to generate electricity from multiple sources. We expect to generate between 2-5W of power from the thermoelectric source.

Video Camera

The video camera we are using onboard is an Aiptek Action HD camcorder. It can record an hour of HD (1280x720) at 60 frames-per-second on a 4GB SD memory card. It will be placed in the upper part of the payload bay and view the TEG heat sink and one of the turbines. The battery cannot last a long time (~1 hour) so there is a risk of it being depleted if the launch is delayed.

4.3.2 Instrumentation precision

Each of the four generators has its own Eagle Tree Systems' eLogger V3 that records the output in Watts, Volts, and Amperes. 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 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

4.4 Payload Testing

4.4.1 Payload Tests

The payload testing being performed involves the thermoelectric generator, the wind turbines, the wiring continuity, the eLogger and camera battery life, and circuit correctness.

- To test the wiring continuity of the altimeters, we created a circuit and turned the switch on and listened for the altimeters to beep correctly.
- To test the camera battery, we are going to see how long it takes to drain its battery while it is in record mode. We are testing this battery so we know the maximum amount of time we have from arming it to launching it.
- For the eLoggers, we are going to see how long it takes to drain four AA batteries that power the eLoggers. We are doing this to see how much time we have from arming it to launch.
- To test the thermoelectric generator, we are going to heat the side that is going on the motor, and cool the other side to see if it generates electricity.
- To test the wind turbines we are going to push air through them (for example, with a blow drier) and see if they work and that the motors are creating the electricity and eLoggers are measuring it.

4.5 Assembly

4.5.1 Construction details

The payload bay had to be designed completely from scratch, using a different design style so we could fit all the necessary electronics. Instead of a traditional payload bay containing a sled, we created ours with a series of G10 fiberglass bulkheads. This created separate “platters” to place parts on, maximizing the total surface area. See Figure 6. All of the wires that were in the payload circuit were soldered to a 20-pin

Molex™ connector taken from a PC power supply. The payload's connector is mated to a wiring harness in the booster section. The harness lies between the motor mount tube and the outer airframe and wires are routed through the fin wall to their intended location. Using a quick connect scheme to attach the payload bay to the booster section of the rocket makes assembly time much shorter.

The turbine fans are set into smaller cardboard tubes that have a plywood reinforcing ring to support them. The fin tubes will be permanently attached to the rocket, but the ducted fans will be removable in case they need to be repaired. The TEG sits in between a transition piece that carries heat from the motor and a heat sink that takes heat away from the TEG. The heat sink and the transition are screwed together with the TEG wedged in between.

The wind turbines and the entire aft section of the rocket will be laminated with fiberglass to reinforce the plywood fins and fin tubes.

4.6 Safety and Environment (Payload)

4.6.1 Payload safety summary

There are not any concerns to safety issues related to the payload.

4.6.2 Safety Officer

The team's safety officer is Katlin.

4.6.3 Failure modes analysis

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; use last year's circuit to reduce design risk
		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

		Experiment is unsuccessful	7	Forgot to arm the eLoggers	1	7	Add entry to pre-launch checklist.
		Experiment is unsuccessful	7	Thermoelectric generator fails due to overheating	6	42	Buy a TEG rated for expected temperature.
	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	Ducted fan blades come loose (screw backs itself out during high-speed spinning)	3	21	Use Loctite to secure screw.
		Experiment is unsuccessful	7	Fan blades break	3	21	Ensure blade assembly is rated for a higher RPM than predicted.
		Experiment is unsuccessful	7	Melted wires due to excessive heat leading from the Thermoelectric generator	4	28	Protect wires with thermal insulation.
		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.
		Camera Does not Record	3	Camera battery life runs out.	6	8	Charge the camera, and not waiting too long to launch.

4.6.4 Personnel hazards

An electrical shock hazard is present when handling the payload. Handling on-board batteries should pose no more risk than of handling any household battery.

4.6.5 Hazard research and mitigation

Hazards for the payload are no different than for the vehicle. Please see section 3.4.

4.6.6 Environmental concerns

Beyond having NiMH and Lithium-Ion batteries on-board, there are no other environmental concerns with the payload.

5 Launch Operations Procedures

5.1 Checklist

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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

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

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

Payload (Science Experiment)

Payload Pre-Prep

- ❑ Install batteries
- ❑ Hook up switch wire quick connect
- ❑ Test switch--look for eLogger LEDS
- ❑ Turn off switch
- ❑ Double--check tightness of nuts on payload
- ❑ Payload platter up through bottom bay
- ❑ Line up PEM nuts up with notches in platters
- ❑ Install camera platter; tighten nuts
- ❑ Insert payload bay into booster
- ❑ Install lower three screws into corresponding PEM nuts

Payload Pad Prep

- ❑ Slide booster section onto rail
- ❑ Install camera
- ❑ Secure tripod bolt to camera
- ❑ Install payload cap
- ❑ Attach parachute harness

- ❑ Match upper and booster sections
- ❑ Arm payload switch

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

Motor Installation

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

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
- ❑ Insure that key is not in the launch 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

- ❑ Connect battery to relay box

Final Launch Sequence

- ❑ Arm all devices 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"

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

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 premature ignition of e-matches
- ❑ Arm the electronics
- ❑ Arm the igniter
- ❑ Second call to clear the launch area
- ❑ Countdown to launch
- ❑ Launch rocket
- ❑ In case of a misfire, follow misfire 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

6 Activity Plan

6.1 Budget plan

The budget has been adjusted to reflect several donations from various sources including several rocket vendors, and monetary donations received from various sources. The team's travel expenses remain slightly unknown as the price of fuel will change with the time of year. Accommodations needs have changed slightly with the need for airfare and an additional night's hotel stay with the changes in the SLI program flight date for high school teams. The budget costs below recognize the donations as zero budget line items reducing the projected cost of the project at just over $4,400.

Sub total - Vehicle	$0.00
Sub total - Electronics	$0.00
Sub total - Recovery	$23.10
Sub total - Experiment	$500.27
Sub total - Build Materials	$104.00
Sub total - Finish	$0.00
Sub total - Launch Materials	$479.00
Sub total - Scale Model Testing	$0.00
Sub total - Outreach	$50.00
Sub total - Project Management	$50.00
Sub total -Travel	$3,200.00
TOTAL COST	**$4,406.37**

6.2 Timeline

The project timeline has changed significantly due to constraints briefly discussed in section 2. With the economic times our mentor's priorities have remained focused on their daytime jobs more than they originally anticipated. The project continues to be challenged by parts deliveries, challenging vehicle/payload integration point construction, and personal schedules. As a result, the test flight dates have been missed and rescheduled. It is still possible that the first flight of the full-scale rocket will occur in Huntsville. Updated project milestones are included below:

Project Start Date: Mon 8/4/08
Project Finish Date: Fri 5/22/09

Project Milestones

Name	Finish Date
Request for Proposal (RFP)	Wed 10/1/08
RFP document delivered to NASA	Wed 10/1/08
Establish Team Website	Wed 11/5/08
Preliminary Design Review (PDR)	Fri 12/5/08
Vehicle concept testing	Sat 9/20/08
PDR document delivered to NASA	Fri 12/5/08
Critical Design Review (CDR)	Mon 2/2/09
Payload design - revision 2	Mon 12/1/08
Vehicle design - revision 2	Tue 12/9/08
Scale vehicle completed	Fri 12/19/08
Fly Scale Model	Sat 12/20/08
CDR presentation delivered to NASA	Thu 1/22/09
CDR document delivered to NASA	Thu 1/22/09
Motor selection due to NASA	Thu 1/22/09
Submit Team info for MSFC Tours	Thu 1/22/09
Submit Invoice to NASA	Thu 1/22/09
CDR NASA Presentation	Mon 2/2/09
Flight Readiness Review (FRR)	Thu 4/2/09
Payload design - final	Fri 2/6/09
Vehicle design - final	Fri 2/6/09
Payload construction completed	Sat 3/21/09
Vehicle construction completed	Sat 3/21/09
Full scale test launch	Sat 3/28/09
FRR document delivered to NASA	Wed 3/18/09
FRR presentation delivered to NASA	Wed 3/18/09
FRR NASA Presentation	Thu 4/2/09
SLI - Huntsville	Sun 4/19/09
Rocket fair / safety check	Thu 4/16/09
SLI launch day	Sun 4/19/09
Post Launch Assessment Review (PLAR)	Fri 5/22/09
Complete SLI feedback survey	Mon 5/4/09
PLAR delivered to NASA	Fri 5/22/09
Miscellaneous	Wed 11/19/08
NASA awards SLI grants	Mon 11/3/08
SLI team teleconference w/ NASA	Tue 10/7/08

6.3 Outreach summary

The team's outreach program remains as described in previous documents. There are three remaining 4-H county project meetings schedules and a final rocket launch prior to the Washington County Fair in late July. The team's outreach has touched approximately 150 youth and adults in total.