Micro Electric Urban Vehicle
&
Test Platform

―――――――――――――――――――――――――――――――

―――――――

Functional Requirements and Proposal

Students:

Spencer Leeds
Kyle Dieter
Nate Mills

Advisors:

Dr. Huggins
Mr. Gutschlag

Tuesday, December 2, 2008

Table of Contents

I. Project Summary

As energy costs and concerns for the environment rise due to the constantly increasing use of fossil fuels, there has been a push towards alternative energy sources and products with a low carbon footprint. Carbon emissions and the nation's dependence on dwindling fossil fuels can be drastically reduced by shifting towards renewable energy sources for transportation. Thus, the Electrical and Computer Engineering Department at Bradley University has launched a multi-year project to design a commercially viable urban electric vehicle with a low carbon footprint. The vehicle will be ultra compact, lightweight, and street legal. It will be large enough to hold two passengers and have a maximum speed of 55 mph and a minimum range of 50 miles in all weather conditions that may be seen in a Midwestern city. It will also have all appropriate safety equipment. This type of application can be used throughout the world as a way for the daily commute to be much more economical.

This project is the first phase of Bradley University's Micro Urban Electric Vehicle endeavor. The goals of this phase consist of researching, designing, and implementing a prototype test platform for a low carbon footprint, single passenger, electric urban vehicle. The prototype vehicle will be designed to have a maximum speed of 40 mph and a minimum range of 25 miles in the temperature range that may be seen in a Midwestern city. It will also have all appropriate equipment to allow safe test operation. Additional functional requirements will be developed as part of the project. A major goal of the project is to research the available battery technology, motors, and electronics (the drive system) to implement the prototype test vehicle. Furthermore, the drive system will be designed so regenerative braking can be added in a later version of the prototype. Issues of mechanical design will focus on issues related to power consumption such as weight and size, but the detailed design of mechanical systems (e.g. brakes) will not be considered. Instead, a vehicular platform with appropriate mechanical systems will be purchased for the prototype implementation. Finally, the test platform will be used to verify a driving model. The driving model is a series of calculations based on specifications for the prototype vehicle and typical urban commute. The details are given in Appendix A.

II. Goals

- Research
  - o Battery
  - o DC-Motor
  - o Control electronics
  - o Vehicle Properties
- Design a prototype electric vehicle test platform for testing with the following specifications:
  - o Minimum round trip distance of 25 miles
  - o Maximum speed of 40 mph
  - o Operate within temperature range of -10°F to 100°F
  - o Acquire and display data from the motor and battery subsystems
  - o Operate within a curb weight of 800 to 1800 lbs
- Evaluate and improve the driving model

III. Detailed Project Functional Description

A micro electric urban vehicle test platform is a small electric vehicle designed to test different parameters during various driving scenarios in order to aid in the design of the Bradley University micro electric urban vehicle described in the Project Summary. This test platform vehicle will be propelled by a battery powered DC-motor, which takes the place of the internal combustion engine of an ordinary vehicle. A user will control the speed of the vehicle by changing the voltage applied to the motor. Data will be logged from multiple sections of the vehicle and displayed on a laptop computer for viewing. These data will include: Motor/Wheel RPM, Speed, Battery Current (peak/average), Battery Capacity, Battery Temperature, Motor Temperature, and Motor Current (peak/average). In addition, a driving model will be developed to help select the best motor and battery by modeling many different vehicle and trip characteristics.

The high level block diagram, shown in Figure 1, depicts the interconnection of each vehicle subsystem. Electronic power signals shall control the motor controller and motor, while mechanical power coming from the motor will set the vehicle in motion. Details on each subsystem are discussed in the Subsystem Block Diagrams section.
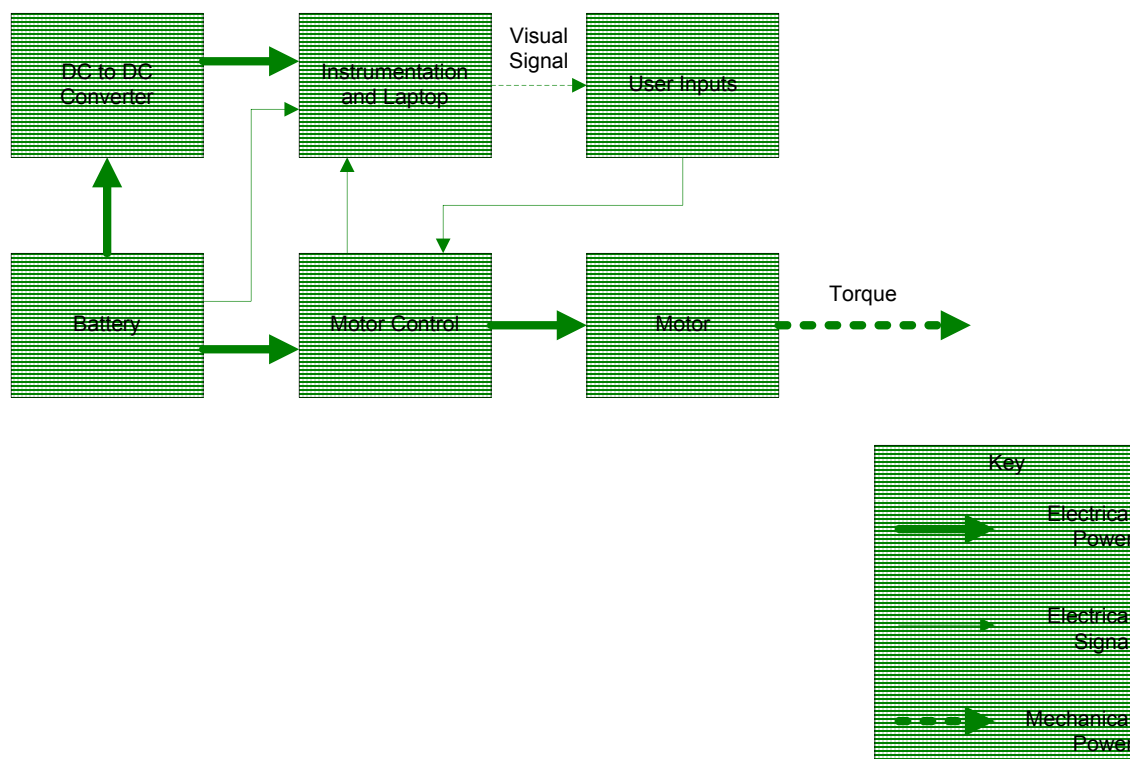
Figure 1: High Level Block Diagram

IV. Subsystem Block Diagrams and Requirements

A. Battery: The battery subsystem, shown in figure 2, consists of a battery that powers the vehicle's motor, the motor controller electronics, and the various sensors. The battery pack shall utilize an appropriate chemistry (e.g. nickel-metal hydride or lead acid) with capacity to meet the energy requirements determined from the drive model [see appendix A]
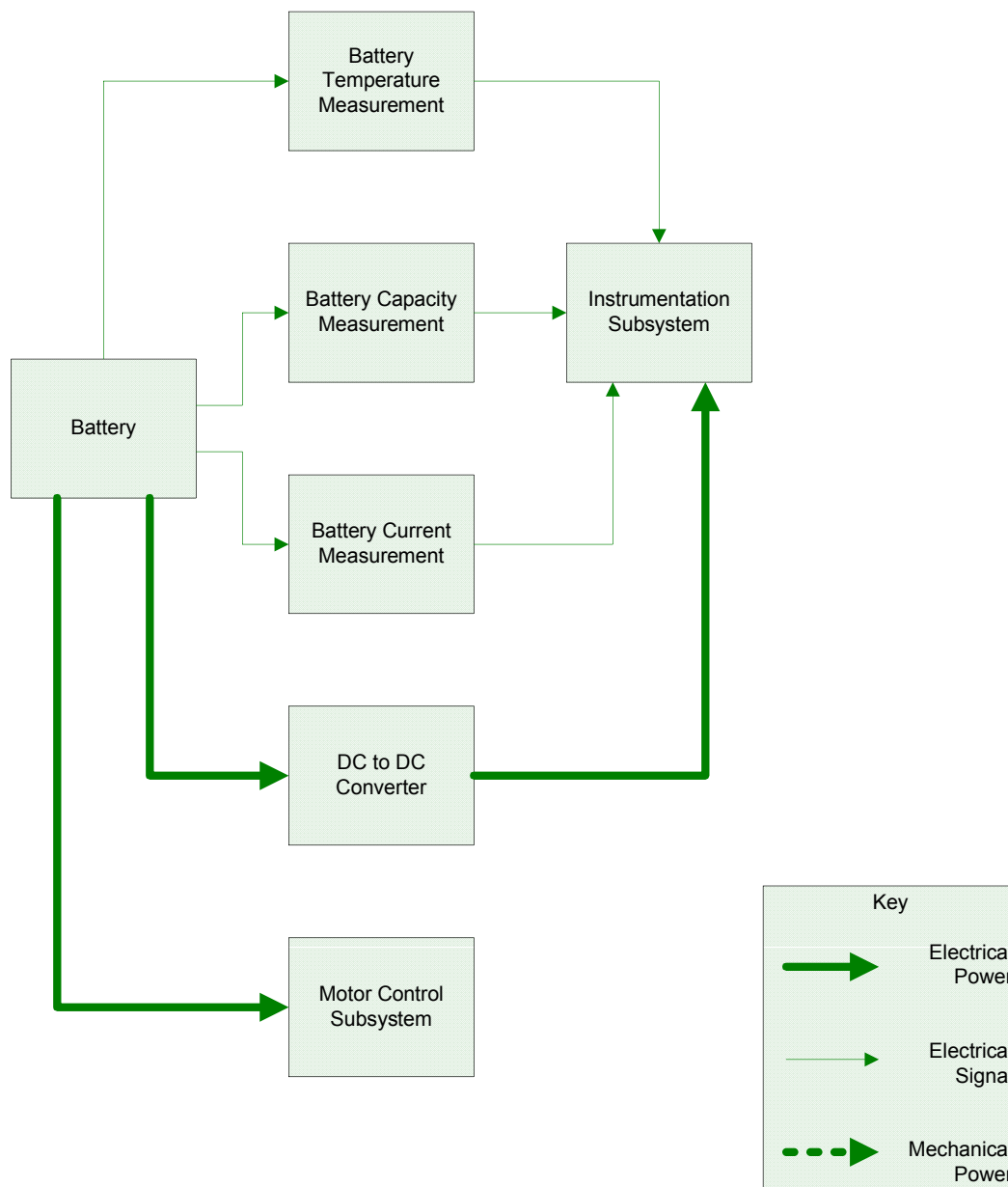
Figure 2: Battery Subsystem

B. Battery Charger: The battery charging subsystem, shown in figure 3, consists of a battery that will be charged by a commercially available battery charger. The battery charger shall be chosen to charge the batter to full capacity in no more than 8 hours.
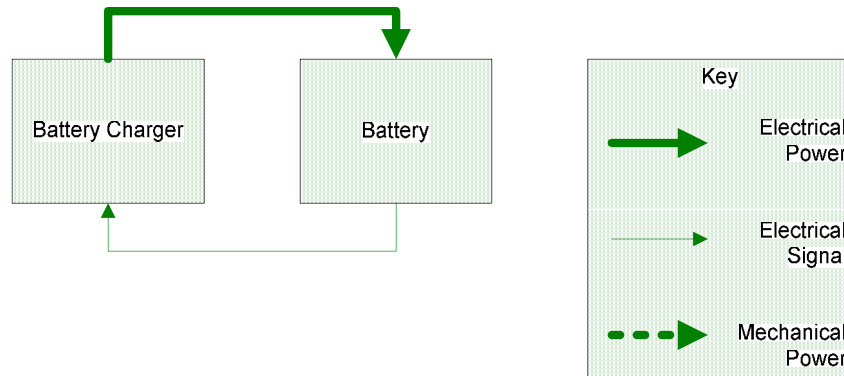

Figure 3: Battery Charging Subsystem

C. Motor Control: The motor control subsystem, shown in figure 4, receives signals from the power switch and the accelerator pedal to control the PWM signal applied to motor. The motor controller shall be powered by 48V DC voltage. Furthermore, the motor controller shall accept an appropriately conditioned input signal and control the motor speed with 95% accuracy using a pulse width modulated signal. The motor controller shall have 95% efficiency.
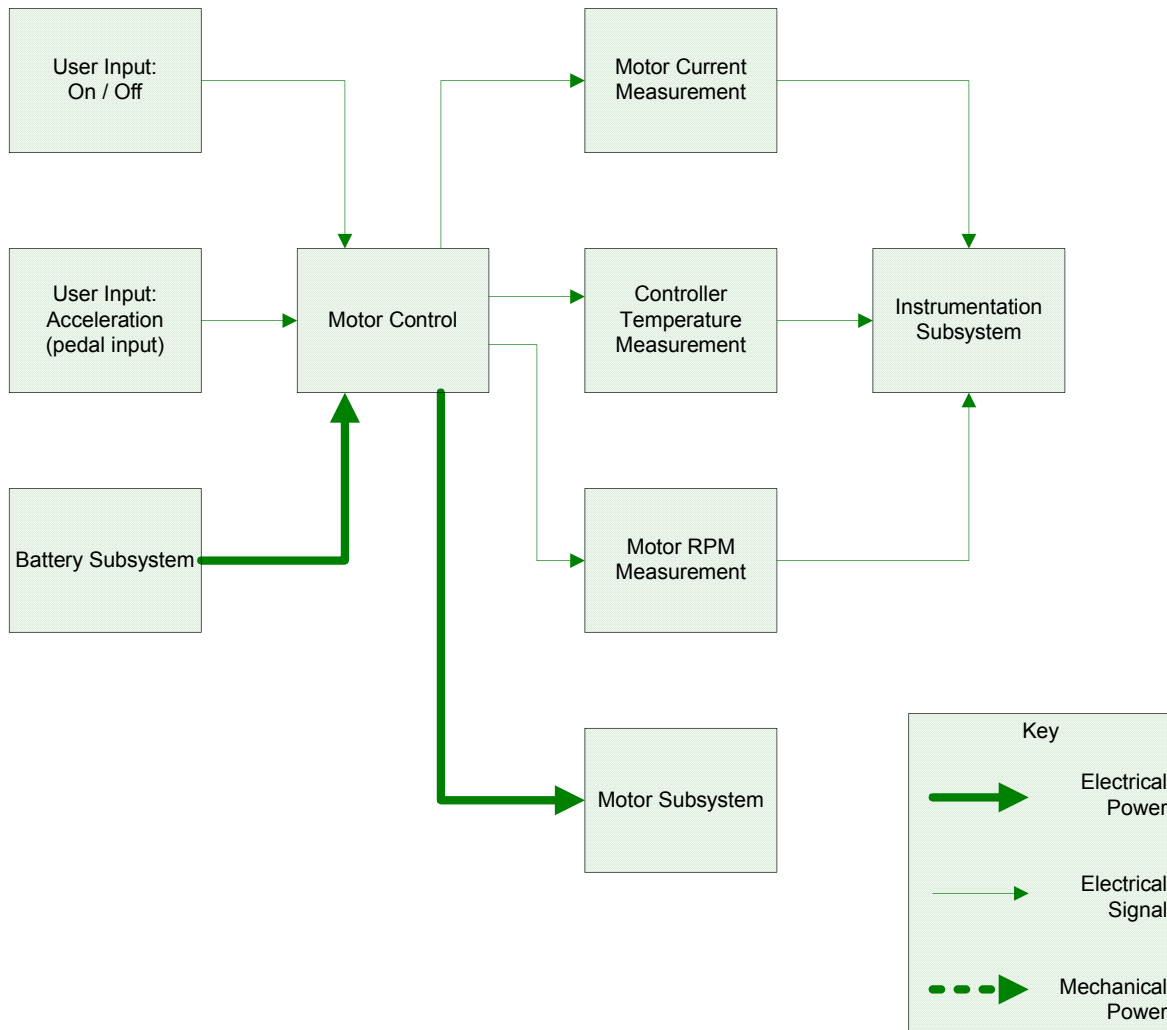

Figure 4: Motor Control Subsystem

D. Motor and Transmission: The motor and transmission subsystem, shown in figure 5, consists of an appropriate motor and transmission that supplies torque to the wheels as well as various sensors which record and output data to the instrumentation subsystem. After considerable research, the team has identified a separately excited DC motor capable of regenerative braking. The torque of the motor shall be sufficient to accelerate the vehicle to a top speed of 40 mph in 10 seconds. The motor shall generate a peak power of 25 HP. The motor shall operate with 85% efficiency and an RPM range at max load consistent with the transmission specifications and speed and acceleration requirements.
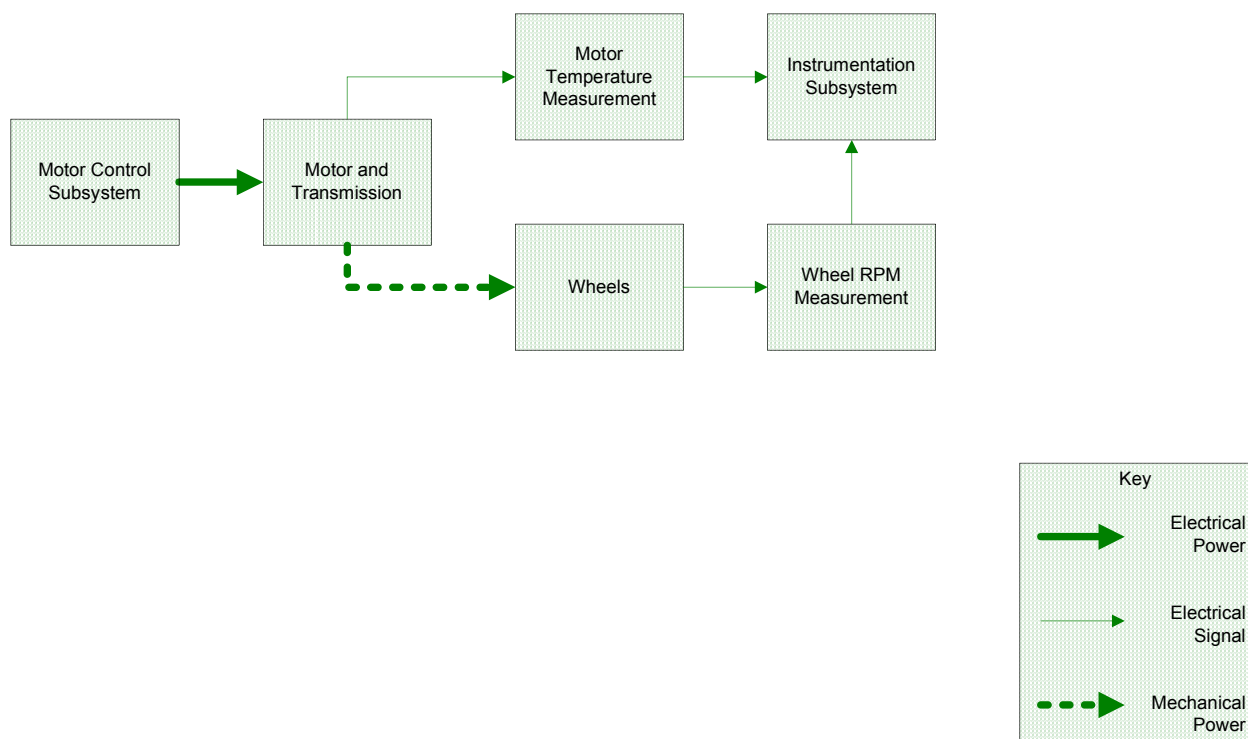
Figure 5: Motor and Transmission Subsystem

E. Instrumentation, Data Acquisition, and Display: The instrumentation, data acquisition, and display subsystem, shown in figure 6, shall collect and process data from the motor and battery sensors. This data shall be converted, logged, and displayed on the laptop. The raw sensor data that will be measured is given in Table 1. The laptop shall be powered from its own internal battery and display the sensor data in a usable format for driving.
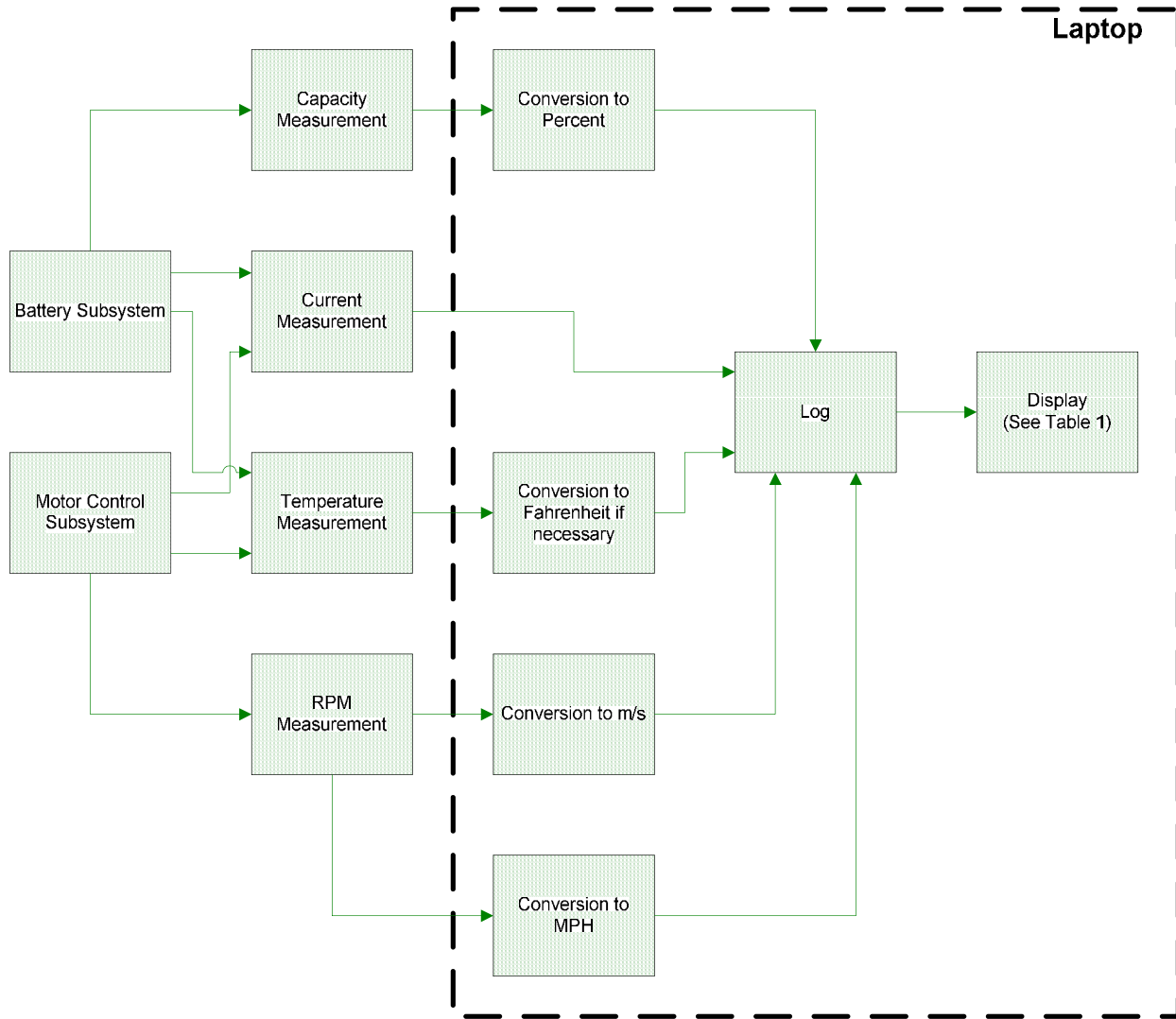
Figure 6: Data Acquisition and Display

V. Project Timeline:

This semester, extensive research has been done on motor and battery types. Calculations were conducted on the physical model of the 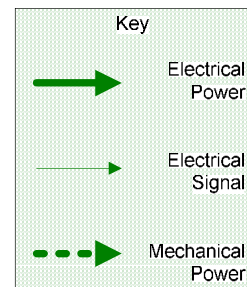vehicle to help select the optimal motor and battery combination. Table 2 is a tentative schedule for the implementation and testing of the micro electric vehicle test platform.

Schedule of Tasks				
Date		Kyle Dieter	Spencer Leeds	Nate Mills
Week 1	27-Jan	Determine instrumentation and sensors.	Study battery specifications.	Study motor specifications.
Week 2	3-Feb	Identify instrumentation & sensor vendors and purchase.	Test battery specifications.	Learn motor control software.
Week 3	10-Feb	Begin programming data acquisition system.	Test battery specifications.	Motor and controller testing.
Week 4	17-Feb	Continue to program data acquisition.	Test motor and battery together.	
Week 5	24-Feb	Test motor and battery with data acquisition.		
Week 6	3-Mar	Test regenerative braking.		
Week 7	10-Mar	Test data acquisition.	Mount motor and batteries on vehicle.	
Week 8	24-Mar	Attach sensors and additional instrumentation to test platform.		
Week 9	31-Mar	Attach sensors and additional instrumentation to test platform.		
Week 10	7-Apr	Gather experimental data from test platform.		
Week 11	14-Apr	Gather experimental data from test platform.		
Week 12	21-Apr	Test vehicle.		
Week 13	28-Apr	Finalize experimental driving model.		
Week 14	5-May	Fine tune vehicle, data, calculations, etc.		

Table 2: Schedule of Tasks

VI. Related Patents:

Patent No.   Title

5,291,960   Hybrid electric vehicle regenerative braking energy recovery
system

-Although patent refers to hybrid vehicles, this regenerative braking system may also work for deep discharge batteries that are found in electric vehicles.

5,585,209   Bipolar lead/acid batteries.

5,941,328   Electric vehicle with variable efficiency regenerative braking depending upon battery charge state.

-As NiMH batteries must be charged at different rates depending on the current state of charge, this patent may help with the difficulties of charging a NiMH battery using regenerative braking.

6,037,751   Method and apparatus for charging batteries.

6,116,368   Electric vehicle with battery regeneration dependent on battery charge state.

6,866,350   Regenerative braking on an electrical vehicle when towed.

7,455,133   Electric four-wheel drive vehicle and control unit for same.

7,546,536   Electric motor.

VII. Applicable Standards:

U.S. Department of Energy – Illinois Electric Laws and Incentives:

Neighborhood Vehicle Access to Roadways
Neighborhood vehicles may only be operated on streets if authorized by the local government and where the posted speed limit is 35 miles per hour (mph) or less. Neighborhood vehicles are allowed to cross a road or street at an intersection where the road or street has a posted speed limit greater than 35 mph. Neighborhood vehicles are defined as self-propelled, electronically powered, four-wheeled motor vehicles (or a self-propelled, gasoline-powered four-wheeled motor vehicle with an engine displacement under 1,200 cubic centimeters) which are capable of attaining in one mile a speed of more than 20 mph, but not more than 25 mph, and which conform to federal regulations under Title 49 of the Code of Federal Regulations, Part 571.500. (Reference 625 Illinois Compiled Statutes 5/11-1426.1)

Underwriters Laboratories:

Standard for Safety, Electric Vehicle (EV) Charging System Equipment, UL 2202
This Standard covers conductive and inductive charging system equipment intended to be supplied by a branch circuit of 600 volts or less for recharging the storage batteries in over-the-road EVs. In an inductive charging system, there is no direct metal-to-metal electrical connection between the charger and the vehicle. Instead, electrical power is passed through an electromagnetic field between the primary winding of a transformer, which is usually located off board the vehicle, to the secondary winding of the transformer which is usually located on board the vehicle. Conversely, in a conductive charging system, power is passed from the charger to the vehicle though direct metal-to-metal contact by way of a coupler or a plug and receptacle suitable for EV charging.

Standard for Safety, Personnel Protection Systems for EV Supply Circuits, UL 2231

This Standard covers devices and systems intended for use in accordance with the National Electrical Code ® (American National Standards Institute/National Fire Protection Association 70), to reduce the risk of electric shock to the user from accessible parts, in grounded or isolated circuits for charging EVs.

Standard for Safety, Plugs, Receptacles, and Couplers for EVs, UL 2251

This Standard covers plugs, receptacles, vehicle inlets, and connectors rated up to 800 amperes and up to 600 volts ac or dc, intended for conductive

connection systems, for use with EVs in accordance with the National Electrical Code ® for either indoor or outdoor nonhazardous locations.

U.S. Department of Transportation:

571.500 Standard No. 500; Low-speed Vehicles

571.305 Standard No. 305; Electric-powered vehicles: electrolyte spillage and electrical shock protection.

National Electric Code 2005 Edition:

Article 625 – Electric Vehicle Charging Systems

Appendix A: Driving Model

The driving model is a series of calculations based on specifications for the prototype vehicle and typical urban commute. The input and output parameters considered are as follows.

- Vehicle Weight and Force
- Trip Length
- # of Stops
- Maximum Velocity
- Acceleration Time
- Kinetic Energy at 100%, 95%, and 80% Efficiency
- Steady State Energy Loss at 100%, 95%, and 80% Efficiency
- Steady State Power
- Peak Power
- Torque
- Average Wheel Speed (During Acceleration)
- Motor Power

User Selected Parameters:
Curb Weight (kg)
Trip Length (km)
Stops
Maximum Velocity (m/s)
Acceleration Time (s)
Wheel Radius (m)

Driving Model Equations:

Total Weight (kg)
$CurbWeight + 150$ (driver and load)

Average Velocity (m/s)
$$\frac{[(\#Stops+1)(V_{max})(T_{acc})(\frac{1}{2})(V_{max})]}{(TripLength)(1000)} + \frac{[(TripLength)(1000)] - [(\#Stops+1)(V_{max})(T_{acc})(\frac{1}{2})(V_{max})]}{(TripLength)(1000)}$$

Acceleration (m/s²)
$$\frac{V_{max}}{T_{acc}}$$

Total Kinetic Energy with % Loss (kJ)

$$\frac{[(\frac{1}{2})(Weight_{Total})(V_{max}^2)(\#Stops+1)(1+\%Loss)]}{1000} +$$

$$\left[\frac{[(TripLength)(1000)-(\#Stops+1)(Acceleration)(T_{acc}^2)]}{(TripLength)(1000)}*\frac{[(\frac{1}{2})(Weight_{Total})(V_{max}^2)(\%Loss)}{1000}\right]$$

Steady State Energy with % Loss (kJ)

$$\left[\frac{[(TripLength)(1000)-(\#Stops+1)(Acceleration)(T_{acc}^2)]}{(TripLength)(1000)}\right]*\left[\frac{[(\frac{1}{2})(Weight_{Total})(V_{max}^2)(\%Loss)]}{1000}\right]$$

Steady State Power with % Loss (kW)

$$\frac{(Energy_{SS})}{\left[\dfrac{[(TripLength)(1000)-(\#Stops+1)(Acceleration)(T_{acc}^2)]}{V_{max}}\right]}$$

Peak Power (kW)

$$\frac{(Weight_{total})(V_{max}^2)}{(T_{acc})(1000)}$$

Force (N)

$$(Weight_{total})(Acceleration)$$

Torque (N*m)

$$(Force)(WheelRadius)$$

Peak Motor Power (kW)

$$\frac{(Torque)(2\pi)(WheelRadius)}{(60)(1000)}$$

Wheel Speed (RPM)

$$\frac{(V_{max})(60)}{(2\pi)(WheelRadius)}$$

Driving Model Example:

Curb Weight (kg)	Total Weight (kg)	Trip Length (km)	Stops	Max. Velocity (m/s)	Average Velocity (m/s)	Acceleration Time (s)	Acceleration (m/s²)
350	500	40	0	18	17.9757	6	3

Kinetic Energy with 0% Loss (kJ)	Steady State Energy with 5% Loss (kJ)	Steady State Energy with 10% Loss (kJ)	Steady State Energy with 20% Loss (kJ)	Total Kinetic Energy with 5% Loss (kJ)	Total Kinetic Energy with 10% Loss (kJ)	Total Kinetic Energy with 20% Loss (kJ)	Steady State Power with 5% Loss (kW)
81	4.039065	8.07813	16.15626	89.089065	97.17813	113.35626	0.0018225

Steady State Power with 10% Loss (kW)	Steady State Power with 20% Loss (kW)	Peak Power (kW)	Force (N)	Torque (N m)	Motor Power (kW)	Avg. Wheel Speed (rpm)	Wheel Radius (m)
0.003645	0.00729	27	1500	375	26.96355	686.9694	0.25

Table A-1: Driving Model Example

Appendix B: Bill of Materials

Equipment List:

Part Name	Model	Description	Quantity	Price
		Bill of Materials		
TBD	TBD	Stingray Go Kart Frame	1	TBD
TBD	TBD	D&D SepEx DC Motor	1	TBD
TBD	TBD	Alltrax DCX DC Motor Controller	1	TBD
TBD	TBD	Lead Acid Batteries	4	TBD
TBD	TBD	Laptop	1	TBD
TBD	TBD	Acceleration Potentiometer	1	TBD
TBD	TBD	Main Contactor	1	TBD
TBD	TBD	Circuit Breaker	1	TBD
TBD	TBD	Battery Fuse	1	TBD
TBD	TBD	Shunt	1	TBD
TBD	TBD	DC to DC Converter	1	TBD
TBD	TBD	Battery Charger	TBD	TBD
TBD	TBD	RPM Sensor	1	TBD
TBD	TBD	Current Sensor	1	TBD
TBD	TBD	Temperature Sensor	1	TBD
TBD	TBD	Voltage Sensor	1	TBD

Table B-1: Bill of Materials