FAMU-FSU College of Engineering
Sustainable Engineered Solutions

Solar Car Design:

Design Proposal

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Executive Summary

The FAMU-FSU College of Engineering has tasked this team of engineers with the challenge of building the FAMU-FSU Solar Car. The overall goal of this year's team is to design and develop a 2 year plan to achieve a Solar Car ready for the Shell Eco-Marathon America (SEMA) in spring of 2014. The new design is a very light weight, three wheeled, one man automobile that is capable of utilizing renewable energy to produce an energy efficient vehicle. The vehicle will be designed under the guidelines of the Solar-Battery Electric Prototype division.

During this year, it is not possible to design, test and build the solar car to meet all the specifications of the Shell competition. This year's electrical engineers will focus on the simulation and design of the energy system consisting of solar panels, solar panel protection, DC-DC converter, MPPT controller, batteries, battery management system, battery protection and selection of efficient motor. This year's mechanical engineers will focus on the design, testing and building of the body/chassis, plus the necessary safety requirements, such as Exit Strategy, roll bar and bulkheads, along with the suspension and wheels.

A current and future objective of this project is to work closely with Sustainable Engineered Solutions (SES) to bring in future sponsors for the Solar Car Club. The SES website will be a cornerstone for the procurement of funds as it will act as a medium that the public can both get involved in the project and view the cars progress throughout future years. The website will also help give credit to contributors of the project by displaying their information with links to their website.

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1 Introduction

1.1 Acknowledgements

The senior design team would like to acknowledge the following individuals and organizations for their contributions to the advancement of this project.

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1.2 Problem Statement

The FAMU-FSU Solar Car Team of 2011-2012 provided the first fully functional Solar Car. After showcasing the design and model, the car was procured by a FSU student organization called Sustainable Engineered Solutions (SES). The Solar Car Design this year relies upon three main focuses: a redesigned body and chassis, develop braking and steering systems, a solar panel-battery energy system, and a microprocessor controller. Selection of the focuses was made based on the SEMA design requirements and limitations.

The solar car this year will not be fully functional, yet a redesigned body with necessary safety requirements will be built and a newly designed energy system using solar panels and will be simulated and prototyped, along with the chassis, suspension, and wheels will also be determined. Due to limited time, this year's group won't be able to complete the entire car; however the design and all the purchased parts will be in line with the SEMA rules and requirements. The following year's plan, 2013 is included in this document, located under year 2. The overall goal for these two years is to take the final designed car to competition in Houston, TX. The new design team in 2013 with focus on energy system integration with motor and chassis, install brakes and regenerative braking as outlined in 2012, and finish all necessary safety requirements and communications related to the SEMA in 2014.

The proposed solution approach for all mechanical aspects includes developing models using Pro-Engineer CAD. From the CAD drawings, calculations will be made based on the type of component designed and the parameters specified. A few mechanical components will require the use of simulations to easily change the design parameters and determine the best design (for example, simulating air flow over the chassis the best aerodynamic design).Aerodynamic testing will be done using 1/10th models of the chassis. A materials selection process will be used to properly choose the best materials possible for each component and will lead to purchasing, fabricating, and installing each component. After a component is installed, testing will occur to determine if the component is working properly and if there needs to be additional redesigns or recalculations performed.

The proposed solution approach for all electrical aspects includes development of simulation models for the solar panels, batteries and motor. From the simulations, calculation will be made based on the type of component designed and the parameters specified. The simulations will also determine power efficiencies and voltage/current characteristics during different driving conditions. In order to necessitate simulations, predetermined components and their real-world parameters will be used to complete each simulation scenario.

The deliverables, in March 2013, will ideally replicate a working and integrated energy system along with a fabricated chassis with suspension, wheels and the ability to conform to the predetermined exit strategy.

The final design, in March 2014, will ideally include all working components and integrations for a functioning solar vehicle.

1.3 Operating Environment

The FAMU-FSU Solar Car shall be able to operate in standard North American climates. The car needs to be able to withstand normal wear with seasonal changes that a commercial automobile would encounter. The car will be resistant to rain, dust, debris, etc. The car's electronics will be protected electrically and physically and be able to operate in humid conditions as well as dry hot environments. The car will not be built to operate in extreme conditions such as mountainous terrain or heavy snowfall. The car will be able to handle up to a 12 percent grade which can be found on residential roads and have the ability to remain still at a 20 percent graded hill using brakes.

1.4 Intended Use(s) and Intended User(s)

With SES at the FAMU-FSU College of Engineering, the car will be used for future senior design projects and the Solar Car Club. The car will be taken to various events and shows such as the FSU homecoming parade in order to get publicity for current and potential sponsors. This in turn will hopefully generate donations to help the progression of SES and its related projects, and also to generate money for more research in sustainable energy solutions.

This year the intended users will be solely project team members for design and testing. This will change for next year's senior design team; the solar car will be in the home stretch for competition at the SEMA. The solar car club hopes to inspire other engineering students to pursue an increased knowledge of sustainable energy and its immense applications. For either case, the 2 year goal is to design a car fitting all requirements for entering and competing in the SEMA in 2014.

1.5 Assumptions and Limitations

1.5.1 Assumptions

- Vehicle will operate safely and efficiently.
- Batteries will be able to charge from solar panels.
- Mechanical energy will be recycled through regenerative breaking.
- Vehicle will be made to street driving legal regulations.
- Vehicle's completion will be focused toward the SEMA.
- The vehicle will consume no more power than the batteries and solar panels can provide.
- The vehicle will be able to maintain an average speed around 15 mph.
- The motor will be able to run for extended periods of time.
- The vehicle will be able to travel greater than 6 miles.
- The vehicle must me all specifications, rules and regulations set out by the SEMA.

1.5.2 Limitations

- The solar array must be fit into 0.17 square meters.
- The batteries, if Li-ion based, must utilize a Battery Management System (BMS).
- The vehicle must not exceed 3.5 x 1.3 x 1 meters in dimensions.
- The maximum vehicle weight without a driver must not exceed 140kg.

Note: More specific constraints and limitations see Need Analysis and Requirements Document

1.6 Expected End Product and Other Deliverables

1.6.1 Year 1

The end product for year 1 will be a designed, tested and built chassis with suspension, under necessary SEMA regulations. Included with the chassis will be a simulated and verified energy system. Although the energy system and chassis/suspension will not be integrated this year, necessary testing and development of prototypes will be accomplished. The overall assume energy system will be simulated and verified with MATLAB software, and each piece of the physical system will be tested using Dr. Edrington's DC load bank test set up at CAPS. The energy system including the solar panels, batteries, BMS, MPPT, converter will be integrated and tested a hardware-in-the-loop (HIL) case at CAPS. This HIL case will provide derisking for the connection of the motor, so not to cause any damage to all components.

1.7 Concept Generation and Selection

The team considered a variety of options before identifying the best design solution for entry in the SEMA. A number of factors were considered in order to both satisfy design requirements and also design within budgetary constraints. The proposed product design is a unique, original, and innovative design, but this section will discuss alternative concepts that were rejected by the team.

1.7.1 Solar Panels

The main goal is to actually build the solar cells with the help of Dr. Foo and his research team. A back up plan will be designed in case building the solar cells from scratch doesn't work, or doesn't finish in the time determined by the team. After researching the solar cells, manufactoring or buying, a design for the solar array will begin. The solar array must be designed to work simultaneously with the whole electrical system of the car. After the compilation of the designing phase the array must get mounted to the body of the car. It would be best to get the highest current possible which later will be used to boost up the voltage and to charge the battery since the higher the current the faster the battery will charge. Space constrains will be a huge issue with the design, according to the SEMA rules for 2013 the maximum surface area covered by solar cells must not exceed 0.179 square meters.

1.7.2 Battery System

The battery system needs were evaluated once the motor selection was finalized. With a 48V 800W motor it was determined that the batteries would need to provide a nominal voltage of 48V and a nominal current of 40Ah. The regulations of the Shell Eco Marathon restrict the main battery system to lithium-ion based only which greatly simplifies the selection of the battery chemistry. After consulting with Dr. Zheng, he recommended using Lithium Iron Phosphate (LiFePO4) batteries since they offer the high current that the team needs and are the safest and easiest to incorporate into the energy system. In particular he suggested looking into the company A123 Systems who specializes in the manufacturing of lithium ion batteries. However, since our meeting this company has filed for bankruptcy and other options needed to be exhausted.

The team started by looking into the batteries and battery management system that was implemented on the first generation solar car. There have been some major improvements in this technology over the years allowing a 10% higher energy density by weight and by volume, and an improved cycle life. Initial thought was to buy separate batteries and configure a battery management system to monitor the voltage, current, and state of charge. Internet research revealed that many companies now sell the batteries, BMS, and charger all together as a pre built pack and that this method would be the most efficient and safest for our car. Two of the battery packs being considered are explained below.

The first battery pack that was from Elite Power Solutions. It is a 48V 2.1kWh System that is advertised for use in electric golf cart, scooter, and motorcycle applications. The package contains 16 GBS 40Ah Li-ion cells weighing 58.8 lbs, an EPS Energy Management System, and a matching charger. The energy management system offers CAN communication capabilities as well as a small monitor that displays the state of charge, voltage, and current of the batteries. The battery pack costs before shipping and a 10%off educational discount, $ 1,728 with CAN and $ 1,643 w/o CAN.

The second company is Tenergy. This company drew the teams attention with their offer of creating a custom battery pack for our car. The team has been in constant communication with multiple representatives for Tenergy for a couple of week discussing the needs of our batteries and battery management system. The team is close to finalizing the design and is waiting on a quote before further evaluation can be made. The proposed batteries to be used are 3.2V 20Ah LiFePO4 flat cell batteries. They are half the thickness of the GBS batteries in the first pack but offer half the capacity. These batteries will be arranged in a 15 series 2 parallel combination and will weigh 37.7 lbs. Both battery packs offer the same voltage and current capacity as well as basic battery management system capabilities. The main differences between the two packs are that in the first pack offers a monitor and user interface to the BMS that is far simpler to read and use than what the Tenergy BMS offers. However the Tenergy pack is more than 20lbs lighter than the Elite Power Solutions pack. There are multiple other pros and cons to both battery packs that will have to be further evaluated to determine which one is the best battery system for the solar car.

1.7.3 Motor/MotorController

To increase efficiency and provide least mechanical losses a in-wheel or hub motor design is desirable. LEMCO is the brand motor the last solar car installed with a 3:1 gear ratio. Unfortunately, no power loss or mechanical loss calculation was provided from last year. Through basic calculations and proper reasoning a geared or chained motor will not provide proper efficiency for the SEMA. The SEMA competition's goal is efficiency, this why a hub motor design was chosen.

During the research phase major solar car competitions were investigated to see what motors have been used in the past. The major vendors were then contacted and datasheets were procured. Unfortunately, most motors used were in the 72-96V range, and SEMA required the nominal voltage to be no higher than 48V. Nu-Gen Motors responded to the issue with our need of a 48 V motor saying that their 96 V axiul-flux dc brushless motor can be run at 48 V, without loss of efficiency, yet the price of the 96 V motor is greater than $15,000 not including a motor controller. This price is far beyond the scoped budget for this year's team.

Cisero motor company had a motor in the 72 V range yet the motor is not available commercially. No response about the possibility of support was received from this company. Budgetary constraints and lead time also deter the purchase of such a motor.

Kelly Controls, LLC offers a 48V 3kW DC Brushless Hub Motor and a motor controller with regenerative braking kit for a total of $1,200. This price is well within our budget. This motor also provides high efficiency at slower speeds which satisfies the SEMA competition goals. This is the option the team will use in the design.

2 Proposed Design

2.1 Overview

The goal of the project this year is to improve upon the solar car that has been built by teams over the past few years. The car will have a carbon fiber body with a single-wheel powered by a motor in the rear, while the two wheels in the front allow for steering and braking. Aerodynamic testing will be done to provide the team with the chassis shape with least drag.

The energy system consists of a packaged battery system include BMS, an array of solar panels, a converter, a motor controller with regenerative braking, and a 48V, 800W motor.

2.2 Top Level Design

2.2.1 Energy System Layout

Figure 2.1 shows the energy system overlayed on the top view of the Pro-E model design. There is a possiblity of using balasts to balance the car to properly distribute the weight. For now the solar panels will be placed on top of the upper shell of the chassis. The battery system will be secured between the top and bottom shell of the chassis directly in front of the driver. The motor is a in-wheel hub motor and will be used as the rear wheel directly behind and below the driver, and will provide regenerative braking to the batteries. The solar panels are connected to a converter that connects to the battery. All mechanical and electrical components will be separated from the driver by bulkheads.

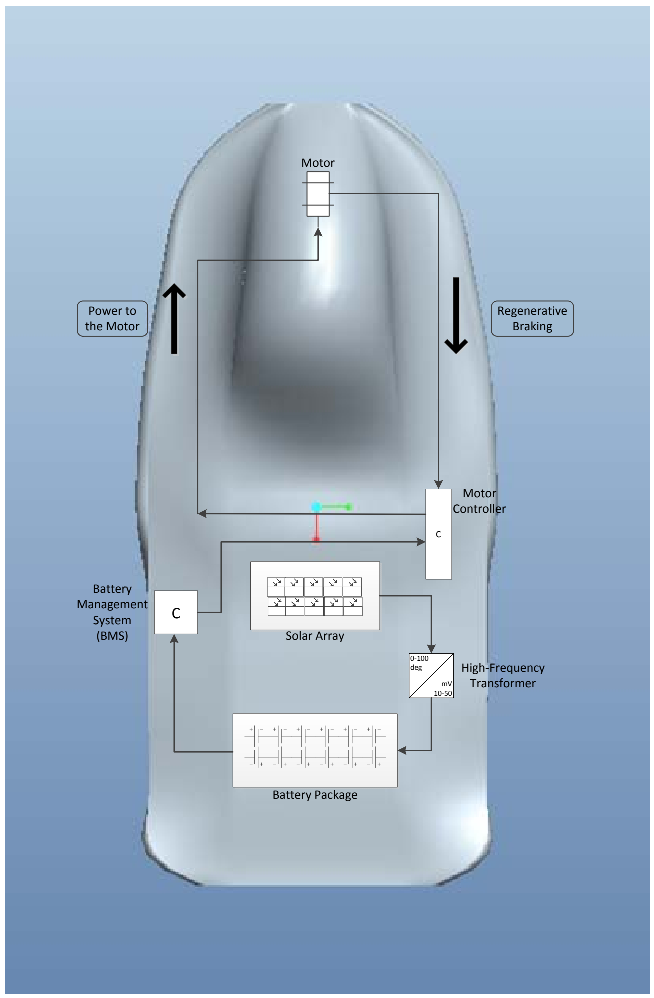

Figure 2.1: Energy System Top-Level Design

2.2.2 Solar Panel Layout

Figure 2.2 shows the outline of the solar array if monocrystalline cells are to be purchased, yet the array's connections and design will ultimately be determined by the type of cells used. Whether they be manufactured or purchased.

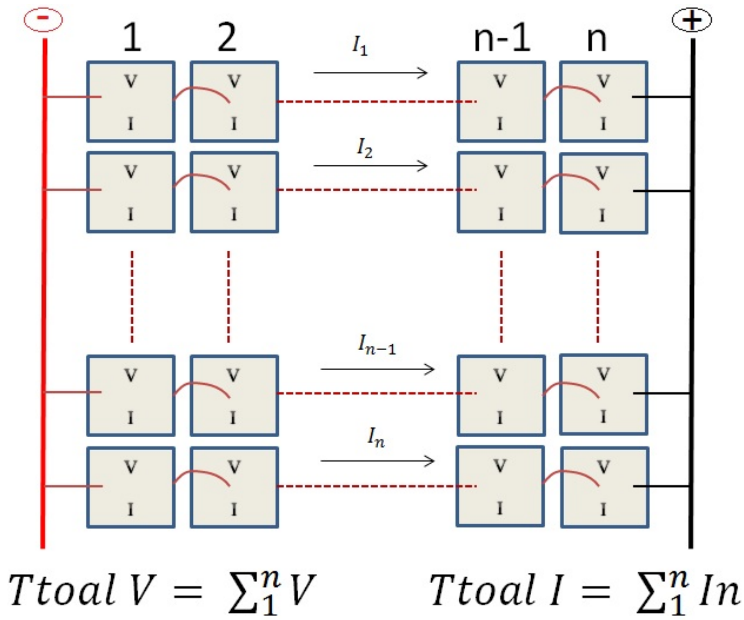

Figure 2.2: Solar Array Layout

2.2.3 Boost Converter Design: Option 1

The overall boost converter design is shown in Figure 2.3. This basic circuit uses an external signal at a particular duty cycle to control the switch and provide the batteries with the proper voltage for charging.

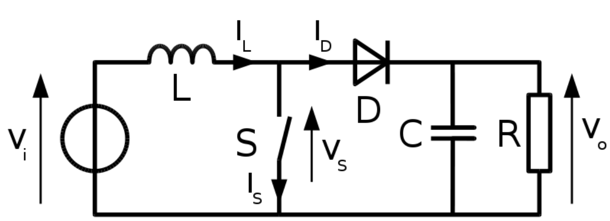

Figure 2.3: Boost Converter Electrical Circuit Design

2.2.4 High Frequency Transformer Circuit: Option 2

The overall high frequency transformer is shown in Figure 2.4. This circuit may be useful to boost a really small voltage to the proper level to charge the batteries.

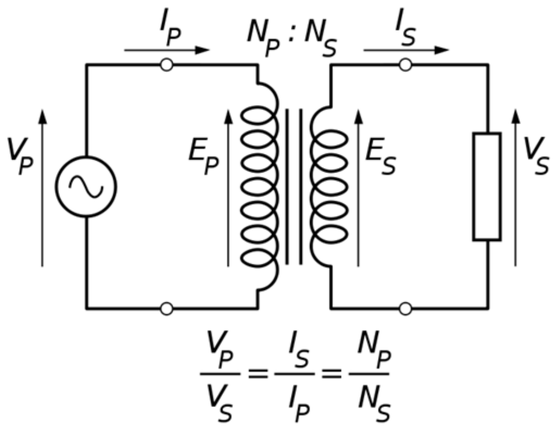

Figure 2.4: High Frequency Transformer Circuit

NOTE: A decision has not been made whether to use a boost converter or a high frequency transformer

2.2.5 Chassis Design

Figure 2.5 shows the PRO-E model for the first of three design to be tested on the 1/10th scale.

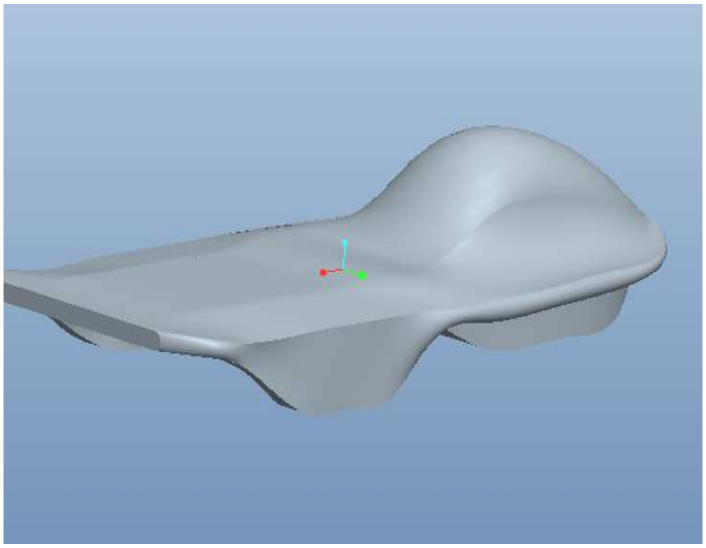

Figure 2.5: PRO-E Model of Chassis

2.2.6 Cockpit/Roll Bar Design

Figure 2.6 shows a representative model for the roll bar including the dimensional measurements required by SEMA regulations

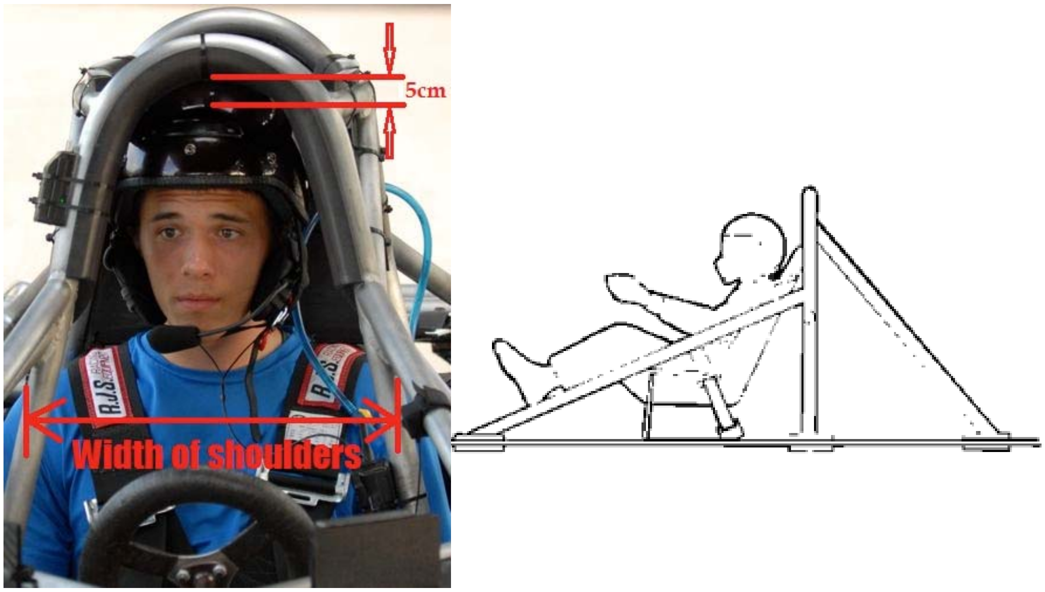

Figure 2.6: Roll Bar/Cage Design and Dimension Specs

3 Statement of Work (SOW)

3.1 Project Management

3.1.1 Objectives

The solar car team's objective this year is to begin a new phase of the solar car project with the intention of taking the solar car to a national competition. To meet this objective the team began the planning, design and building of the car while managing the budget. The mechanical tasks include redesign of the chassis, driver encasement (cockpit) design, new dc motor, design rear arm/suspension, and a latching system. While the Electrical tasks include integrating a solar array, purchasing a converter and implementing the motor and controller subsystems, along with a battery system with BMS.

3.1.2 Approach

The solar car project consists of two separate but cohesive systems, mechanical and electrical. The team will work in these two groups in order to properly address and solve the various problem and needs for the car. The mechanical engineers will analyze and solve each problem as a team in order to be cohesively informed and be able to discuss different ideas and issues for each task.

3.1.3 Managerial Duties

In order to meet the goals of this new phase of the solar car project, the team must use what worked and did not work from the previous solar car projects to complete the overall goal. To manage this project the group will have two team leaders, one for mechanical and one for electrical. They will divide up tasks weekly in order to make sure that the project goals are being completed according to the team schedule. The team manager as well as having these responsibilities will also have the duty of assigning each engineer to a task. The manager will then need to assign engineers to test the implementation of each design component.

3.1.4 Engineering Responsibilities

Each engineer will be responsible for an aspect of the car that suits their particular skill set. Each engineer will then have the responsibly of researching and designing their part of the system and presenting their result to the team for evaluation. If approved, the engineer will be in charge of implementing his or her part of the design into the solar car.

3.1.5 Website

The team will also need an engineer to build and maintain the team's website in order to keep good rapport with previous sponsors and gain new supporters for this and future year's projects.

3.1.6 Finances and Fundraising

The team treasurers, electrical and mechanical, will be responsible for keeping the team's budget under consideration as the year progresses and expenditure are required. The treasurer and project leader will be handling donations as well as coordinating fundraising events throughout the year.

3.2 Year 1

3.2.1 Solar Panels

3.2.1.1 Objectives The solar array must be designed to work simultaneously with the whole electrical system of the car. Once the solar cells are designed or purchase, the solar array need to be mounted to the body of the car to only cover 0.179 square meters. Each of the used solar cells will be tested to determine the efficiency of the sun light energy collection which will allow the team to know the solar array output parameters. The solar array design must meet the electrical system needs, which will include the motor from the mechanical side. The solar cells will be mounted into the body to reduce the solar cells effect on the aerodynamics of the car. In addition, a physical protection and electrical protection planes will be used to increase the strength of the solar cells, and stop reverse current from flowing back into the cells.

3.2.1.2 Approach The team will research, design, implement and test each of the objectives within planned scheduling see Figure 6.2.

3.2.1.3 Subtask: Research and Design

3.2.1.3.1 Objectives The main objective of the design and research process is to make sure that the solar array which will be manufactured or purchased meets the requirements and aspects that have been set on the needs analysis and requirements report. The design and research process will include getting help from Dr. Foo and his graduate students on how to build efficient solar cells by using their current research. In addition, calculation of the sun irradiation will be done to determine the individual solar cell's total output Power, Voltage, and Current. Once this information is known, the solar cell array design and layout will be determined to produce the maximum amount of energy. This in turn will help resolve to most efficient way to wiring and connect the array. A lot of research will be conducted to determine the proper mounting of the solar cells into the body without damaging the cells. In addition, there will be a physical protection to the solar cells to increase their life time.

3.2.1.3.2 Approach Plenty of time will be provided to the person who is responsible for the solar cells part of the car. The main goal will be researching the design aspect to build the most efficient cells with the help provided from Dr. Foo and his graduate students.

3.2.1.3.3 Test/Verification Plan The team will do software simulation to provide verification that all the parameters match, and all the real results meet the simulation results with litte error. This testing plan will show us the results before manufacturing or buying the actual solar cells.

3.2.1.3.4 Outcomes of Task By the end of this phase the team will decide if it's possible to build and manufacture the solar cells, or to just use the ones on the market and purchase them. Also the final design of this task will be the actual design which will be used to build the solar arrays after the agreement of the team members. By the end of this phase the final design and the software simulation must be completed and met the requirements of the project.

3.2.1.4 Subtask: Manufactoring

3.2.1.4.1 Objectives The main objective of this phase is to produce high quality solar cells. At the end of the researching and design phase the team will have an idea if it's possible to manufacture the solar cells that have been researched with Dr. Foo. As result the manufacturing task will take a place only if the team actually figured out the process of building the solar cells.

3.2.1.4.2 Approach The manufacturing process must be approved by Dr. Foo. Then research will be conducted to figure out the best place to manufacture the solar cells. Another thing that must be taken into consideration is the cost of the manufacturing process sice the team has a limited budget this year.

3.2.1.4.3 Test/Verification Plan Sample cells must be made before starting the final manufacturing process. The simulation and calculation of the sample cells will allow us to know if the lab data and parameters actually match the manufactured cells parameters. This process will assure the team that the specifications meet the requirements. Multi-meters will be used to collect data to make sure the parts won't harm the system in anyway.

3.2.1.4.4 Outcomes of Task By the end of this phase actual solar cells must be totally manufactured and completed.

3.2.1.5 Subtask: Implementation

3.2.1.5.1 Objectives The main objective of this phase is to fully understand the software simulation, system design, and the solar system. The implementation phase will include the following steps: choosing the solar cells to build the system, ordering the solar cells, choosing the diodes, ordering the diodes, choosing the proper protection material, ordering the protection materials and building the final system by using the previous components.

3.2.1.5.2 Approach First of all, the parts must be searched and found to meet the requirements. For example the diodes must be rated to the same current the solar cells will produce. Secondly, the parts must be ordered and purchased, there are many points need to be taken in consideration such as choosing the right vendor, making sure the shipping time won't conflict with project timing plan. After the arrival of the parts each single element must be tested to make sure it's functioning right. At the end the parts will be used to build the final system design.

3.2.1.5.3 Test/Verification Plan Every single element must be tested after the delivery to make sure that the specifications meet the factory specs. Multi-meters will be used to collect data to make sure the parts won't harm the system in anyway.

3.2.1.5.4 Outcomes of Task By the end of this phase the solar subsystem must be completed.

3.2.1.6 Subtask: Testing

3.2.1.6.1 Objectives After the individual testing of each of the components mentioned earlier, the whole system will be tested to assure that everything works as planned as one whole unit. The overall testing will include the total power produced by the solar subsystem. At the end a test to make sure that the solar modules are attached to the body in a good way will take a place.

3.2.1.6.2 Approach The solar system's total power will be measured by connecting the solar system to a different resistive loads and measuring both the current and the voltage. The previous test will take a place in different irradiation which will include early morning sunlight, midday sunlight, late afternoon sunlight, rainy day sunlight, and cloudy day sunlight. To assure that the solar cells are mounted properly.

3.2.1.6.3 Outcomes of Task The final result of this task is an approved solar system, which will be integrated to the solar car and work with the other components of the energy system.

3.2.2 Boost Converter

3.2.2.1 Objectives The objective of this task is to design a boost converter. The boost converter matches the battery's nominal voltage, 48V, in order to act as a dual source during the operation of the car and charge the battery.

3.2.2.2 Approach There are two approaches to building the converter. One is, the team can purchase the components and build the converter. Two, the team can have the converter built by a manufacturer, in which case, the converter will be boxed and protected from other circuits. The second approach is more beneficial considering the safety of the driver and the ease of use.

3.2.2.3 Subtask: Research and Design

3.2.2.3.1 Objectives The overall objective of the research phase is to ensure that the final design meets the required specifications set forth by the needs analysis. Steps include defining parameters such as the input and output voltages ranges, individual components and simulating the design.

3.2.2.3.2 Approach The operating parameters are determined by the configuration of the solar array and the operating voltage of the battery system. The values of the inductors, the diodes, and the capacitor can be determined, as the capacitance and inductance values. The design of the boost converter will be the same as the previous year; the only difference being that the solar panels will be providing less voltage compared to last year's design.

3.2.2.3.3 Test/Verification Plan Before any parts are ordered, the boost converter will be simulated in Psim and Simulink. This will not only decrease the risk of damage to all the different part of the subsystems by verifying that the design will operate correctly before testing the actual converter in the solar car, but it will also consolidate the results.

3.2.2.3.4 Outcomes of Task The outcome of this task will be the design of the boost converter, ready to be implemented.

3.2.2.4 Subtask: Implementation

3.2.2.4.1 Objectives The overall objective of the implementation phase of the boost converter subtask is to realize the designed subsystem. Steps included in this phase are the machining of parts, the choosing of components, and forwarding the specifications to the manufacturer. Also, the converter will be tested to ensure that it performs as intended before it is connected to the solar vehicle between the PV array and the batteries.

3.2.2.4.2 Approach The manufacturer will do most of this section. He will provide a boxed-in converter, based on the given parameters, with only connections to inputs and outputs outside the box.

3.2.2.4.3 Test/Verification Plan

3.2.2.4.4 Outcomes of Task The outcome of this task is to have a complete boost converter.

3.2.2.5 Subtask: Testing

3.2.2.5.1 Objectives The overall subsystem should be tested for results before connection to the whole system.

3.2.2.5.2 Approach This testing will include monitoring of the voltage input and output of the boost converter and the current passing through it in order to compare those results to the simulations and expected values.

3.2.2.5.3 Outcomes of Task The outcome of this task is the final design boost converter subsystem, which, at this phase, will be ready to be integrated into the vehicle system congruently with the other subsystems.

3.2.3 Maximum Power Point Tracking (MPPT): Option 1

3.2.3.1 Objectives The objective of this task is to design a MPPT to increase the power delivered from the PV array to the battery system. An MPPT is an algorithm that is controlled by altering the duty cycle of the converter's switch. In very bright sunlight, a MPPT can be shown to increase the power delivered by 10%, but in less direct sunlight it can increase power by 50% or more.

3.2.3.2 Approach There are several options for off the shelf maximum power point tracking converters, but they are cost prohibitive. The approach to this solution will be for the team to design an MPPT that only offers the features required by the solar car and to use the existing Arduino board microcontroller to control the duty cycle. This should ultimately only cost a fraction of the price.

3.2.3.3 Subtask: Research and Design

3.2.3.3.1 Objectives The overall objective of the research phase is to ensure that the final MPPT design meets all required parameters set forth by the needs analysis document. Steps include defining operating parameters, such as input and output voltage ranges, using mathematical formulas to determine the value of individual components, and simulating the design using software.

3.2.3.3.2 Approach The operating parameters are determined by the configuration of the PV array and the operating voltage of the battery system. Using these values, the current and voltage ratings of the switches, the inductor, the diodes, and the capacitor can be determined, as well as the capacitance and inductance values. The capacitance and inductance values will be determined by mathematical methods found in the fundamentals of power electronics textbook.

3.2.3.3.3 Test/Verification Plan Before any parts are ordered, the MPPT will be simulated in either Simulink or PSPICE. This will decrease the risk of damage to all of the different subsystems by verifying that the design will operate correctly before testing the actual MPPT in the solar car.

3.2.3.3.4 Outcomes of Task The outcome of this task will be the design of the MPPT, ready to be implemented.

3.2.3.4 Subtask: Implementation

3.2.3.4.1 Objectives The overall objective of the implementation phase of the MPPT subtask is to realize the designed subsystem. Steps included in this phase are the machining of parts, the choosing of components, and the actual construction of the MPPT. Also, the MPPT should be tested to ensure that it performs correctly before it is finally connected into the solar vehicle between the PV array and the batteries.

3.2.3.4.2 Approach First, the parts must be assembled into the boost converter topology. Next, the microcontroller must be programmed to alter the duty cycle of the converter up or down in order to track the voltage of the batteries/motor controller. This step also includes any signal conditioning and/or level shifting.

3.2.3.4.3 Test/Verification Plan The MPPT should be tested before connection to the batteries by connecting it a variable power supply and verifying proper operation.

3.2.3.4.4 Outcomes of Task The outcome of this task is the completion of the MPPT subsystem.

3.2.3.5 Subtask: Testing

3.2.3.5.1 Objectives Aside from the testing of the individual components, testing of the overall subsystem must take place.

3.2.3.5.2 Approach This testing will include monitoring of the voltage output of the MPPT and the current passing through the MPPT in order to calculate and compare the output power of the array to the manufacturer's specifications.

3.2.3.5.3 Outcomes of Task The outcome of this task is the final MPPT subsystem, which, at this phase, will be ready to be integrated into the vehicle system congruently with the other subsystems.

3.2.4 High Frequency Transformer: Option 2

3.2.4.1 Objectives The objective of this task is to select the proper high frequency transformer. Initially, the boost converter was given the task of amplifying the voltage from the solar panels. However, due to the selection of the motor, it may more beneficial to use a high frequency transformer.

3.2.4.2 Approach There are major possible high frequency transformers to select from, very wide range of frequency, output power, etc. from many manufacturers. However the best approach is having one custom designed to perfectly fit our design.

3.2.4.3 Subtask: Research and Design

3.2.4.3.1 Objectives The overall objective of research phase is to ensure that the final design meets the required specifications set forth in the needs analysis section. Steps includes finding the proper turn ratio for the transformer, the output power and output voltage.

3.2.4.3.2 Approach The operating parameters are determined by the configuration of the PV array and the operating voltage of the battery system. The values of primary and secondary turns are determined using a simple ratio of the primary and secondary voltage, mainly the output of the solar panels and input of the batteries. The turn ratio should be estimated high enough to amplify the voltage during cloudy moments but small enough not to overcharge the batteries

3.2.4.3.3 Test/Verification Plan Before ordering the parts, the transformers will be simulated using either Simulink, Multisim or Psim. This will decrease the risk of damaging the different parts of the subsystems mainly the batteries.

3.2.4.3.4 Outcomes of Task The outcome of this task will be the design and order of the high frequency transformer to be implemented.

3.2.4.4 Subtask: Implementation

3.2.4.4.1 Objectives The overall objective of the implementation phase of the high frequency transformer is to realize the designed subsystem. These steps include forwarding the correct parameters to the manufacturer for the fabrication.

3.2.4.4.2 Approach The manufacturer will do most of this part. He will provide boxed-in transformers based on the given transformers with only connections to inputs and outputs outside the box.

3.2.4.4.3 Test/Verification Plan The high frequency transformers will be separately tested before connection to the car, between the solar panels and the batteries packs. The transformers will not install until the proper and desired outcome is reached.

3.2.4.4.4 Outcomes of Task The outcome of this task is the completion of the high frequency transformer.

3.2.4.5 Subtask: Testing

3.2.4.5.1 Objectives The overall subsystem will be tested for proper results before connection to the whole system.

3.2.4.5.2 Approach This testing will include monitoring of the voltage input and output of the HF transformer in order to compare those results to the simulations and expected values.

3.2.4.5.3 Outcomes of Task The outcome of this task is the final design HF transformer subsystem, which, at this phase, will be ready to be integrated into the vehicle system congruently with the other subsystems.

3.2.4.5.4 Risk Assesment Since there will be a battery management system, there is no risk with the transformer.

3.2.5 Batteries

3.2.5.1 Objectives The objective of the battery system is to power the motor that propels the vehicle and use the solar array and regenerative braking system to charge the batteries. The batteries must have a battery management system to protect against over/under voltage, over current, over temperature, and state of charge.

3.2.5.2 Approach The battery system will be compromised of rechargeable lithium iron phosphate batteries that produce a 48V, 40Ah system that will be connected to the motor to power the vehicle and the solar array to charge the batteries.

3.2.5.3 Subtask: Acquire Batteries

3.2.5.3.1 Objectives With the motor already decided as a 48V 800W DC motor, the batteries must provide the necessary voltage and capacity to propel the vehicle. The batteries as specified by the SEMA must be lithium-ion based and have a maximum nominal voltage of 48V.

3.2.5.3.2 Approach To acquire the batteries Dr. Zheng was first consulted on which battery chemistry would be best for our system. Using his suggestion of Lithium Iron Phosphate (LiFePO4) batteries the internet was used to locate the batteries that will provide the necessary voltage and capacity characteristics. Multiple companies are being contacted for information and quotes on their batteries and battery packs that they offer. Once all of this data is obtained, a decision on which battery pack to use will be made.

3.2.5.3.3 Test/Verification Plan Once the battery pack arrives it will be tested to verify that the entire pack provides the voltage and capacity specified by the data sheet provided by the vendor.

3.2.5.3.4 Outcomes of Task Through testing the team will determine the functionality of the battery pack and whether it works as specified or is defective and needs to be sent back.

3.2.5.4 Subtask: Acquire Battery Management System

3.2.5.4.1 Objectives All lithium based battery packs must have active protection such that over-voltage, over-temperature (for charge and discharge rating), over-current and under-voltage cause the pack to electrically isolate the source or sink from the battery pack.

3.2.5.4.2 Approach To simplify the battery system and increase the safety of operating the car, the BMS will be purchased in a pack that includes the batteries. This will guarantee the seamless integration between the BMS and batteries.

3.2.5.4.3 Test/Verification Plan Extensive testing will be conducted to make sure that the BMS properly identifies the limits it is supposed to be monitoring. Included tests will be on over/under voltage, over current, and over temperature.

3.2.5.4.4 Outcomes of Task The testing will determine if the BMS works correctly and provides protection for the batteries against the risk of damaging the cells or catching fire. If one of these tests fails then the BMS will have to be modified and retested.

3.2.5.5 Subtask: Test/Verification Plan

3.2.5.5.1 Objectives/Approach Simulation testing using MATLAB/Simulink and Pspice will be performed to verify that the battery system will perform as intended when fully integrated with the motor and solar array. There will also be hardware in the loop testing to further evaluate and run test cases on the completed energy system. Once all the simulations are successfully conducted, the battery system will begin its integration with the motor and solar array.

3.2.5.5.2 Outcomes of Task Fully operational battery system for the car that powers the motor controller, recharges the batteries from the solar array, and has a working battery management system to protect against fire.

3.2.6 Motor

3.2.6.1 Objectives To find a suitable motor that fits into the SEMA competition requirements, provides proper torque to get the car to accelerate, and provide power efficiency at constant speeds.

3.2.6.2 Approach The motor needs to be lightweight and needs to be in in-wheel design to save space. It can be difficult to calculate efficiency with a geared motor. More difficulties lie in its specifications, weight and space it requires.

3.2.6.3 Subtask: Research and Design

3.2.6.3.1 Objectives The overall objective of the research phase is to ensure that the final choice in replacement motor and controller meets all required parameters determined by the team, in regards to required torque/power, as well as compatibility with the forseen electrical system. Steps include outlining available voltage levels that could be achieved by reconfiguring the battery system and determining the mount that connects the motor to the wheel.

3.2.6.3.2 Approach Researching a new electric motor to be used as a replacement of the solar car's propulsion consists of comparing several types of motors across multiple vendors in order to find the most economical solution that meets or exceeds the power and space requirements.

3.2.6.3.3 Test/Verification Plan The motor must be able to overcome stall torque required based on calculations of drag, weight and incline. Before purchasing the motor, a simulation will be performed using the modeled energy system to drive a motor modeled using the commercial motor parameters.

3.2.6.3.4 Outcomes of Task The outcome of this task will be a choice of a in-wheel hub design motor and a verified simulation model.

3.2.6.4 Subtask: Implementation

3.2.6.4.1 Objectives The overall objective of the implementation phase of the motor subtask is to realize the designed subsystem. Steps included in this phase are the machining of parts, the assembly of the motor to the energy system. The motor will not be in the car at this point

3.2.6.4.2 Approach Mount the motor on a stable platform, to allow for Hardware-in-the-loop testing.

3.2.6.4.3 Test/Verification Plan The motor and controller should be tested under loaded conditions parallel with the SEMA competition.The motor will also be directly connected to the batteries to verify proper operation.

3.2.6.4.4 Outcomes of Task The outcome of this task is the completion of the motor/controller subsystem.

3.2.6.5 Subtask: Testing

3.2.6.5.1 Objectives Testing of the overall motor/motor controller subsystem.

3.2.6.5.2 Approach The car will be modeled as stable on flat pavement, and the motor will accelerate from a dead stop to pre-determined speed.

3.2.6.5.3 Outcomes of Task The outcome will be a verified and well defined motor/motor controller subsystem that uses the designed energy system, and performs to competition requirements set out by the team.

3.2.7 Chassis

3.2.7.1 Objectives The SEMA has a specific set of constraints for the chassis dimensions. These constraints void the old solar car's body unusable because of size and weight. This creates the need for a new body to be constructed. This body will be designed around the SEMA to not only meet the requirements, but to win the competition. For this, the car will have to be made as efficient as possible.

3.2.7.2 Approach The team will be designing the chassis shape based on other solar car teams. The designs chosen will be either winners or runner-ups from solar car competitions. The chassis is going to be a monocoque structure-meaning it will consist of a frame and skin together as one structure. There will be three preliminary designs made in Pro-E. Then these designs will be made into prototypes and tested in a wind tunnel. The data from the drag force will be added to the rolling resistance and the most efficient model will then be chosen. The model will then be modified to fit all the other necessary components such as suspension, steering, etc. This model will then be given to HPMI to be constructed.

3.2.7.3 Subtask: Research and Design

3.2.7.3.1 Objectives Research will be conducted throughout various other solar car teams to ensure the chassis style is the most efficient. These teams have already gone through multiple iterations to find the most optimum body style; Therefore, it is beneficial to get ideas from others work before starting on our own. The team then will make a design the team feels to be suitable and implement it with all of the other accessories.

3.2.7.3.2 Approach Solar car competitions list their winners for every year. These winners will be researched extensively on what type of material they are using and their inside/outside design. After extensive research certain body styles that performed well will be chosen and used as a basis for making the three CAD designs.

3.2.7.3.3 Test/Verification Plan The composed CAD designs will be weighed and stress tested in Pro-E. The weight will give a better understanding of the amount of rolling friction present and should be minimized. The stress test will give a better understanding of where in the body should be reinforced, if there is a force of greater than the 0.5 times the yield stress, the design should be updated to lower the stress.

3.2.7.3.4 Outcomes of Task The outcome should be a suitable body for implementation into winning the SEMA event. This includes a body that is efficient in drag, light, and still meets the necessary SEMA requirements.

3.2.7.4 Subtask: Implementation

3.2.7.4.1 Objectives Have a monocoque body able of holding a person and necessary components safely; meanwhile, being as light and aerodynamic as possible.

3.2.7.4.2 Approach The team will be using a carbon fiber body to meet the demands of light weight and high strength. It will also add to the aerodynamics of the vehicle by making it possible to have complex curves in the structure. The complex curves allow us to make a more streamlined aerodynamic shape.

3.2.7.4.3 Test/Verification Plan The team will be testing the body before by making miniature scaled models and testing these in a wind tunnel. The tests will provide data on the force due to air drag which is a significant factor on the overall efficiency. The models will then be analyzed and the best one will be picked.

3.2.7.4.4 Outcomes of Task The outcome will be a carbon fiber monocoque body that will provide a suitable body for the SEMA. It must also provide a suitable base for all of the other components going in the assembly.

3.2.7.5 Subtask: Testing

3.2.7.5.1 Objectives Test strength of chassis with real weight of equipment in it. Measure size to make sure it meets SEMA qualifications. Weigh chassis for use of determining overall weight of car.

3.2.7.5.2 Approach To measure the strength of the chassis a person or equivalent weight will be put in the driver's seat. Then equivalent weight of the electrical systems will be placed throughout in their spots. The team will then check for any deformations. If a deformation over a half inch per foot is noticed then the possibility of reinforcement will be considered. The size will be measured through a standard tape measure to get the exact size and make sure the team meets regulations. The weight will be weighed using a large scale. This value will then be used for analysis of the rolling friction.

3.2.7.5.3 Outcomes of Task A monocoque chassis made by HPMI will have been tested to meet the performance criteria of SEMA and will be able to sufficiently hold the desired weight.

3.2.8 Roll Bar

3.2.8.1 Design and Implementation

3.2.8.1.1 Objectives A solid roll bar will be constructed by HPMI entirely from carbon fiber and installed inside the solar vehicle chassis. This roll bar must extend in width beyond the driver's shoulders and 5 cm around the driver's helmet when he is seated in the normal driving position with the safety belts fastened.

3.2.8.1.2 Approach Dimensions of the driver's shoulder width and seated height (with helmet on) will be collected and implemented in the roll bar's design before construction by HPMI begins. This roll bar will be designed to withstand a minimum static load of 700 N ($\tilde{7}$0 kg) applied in any direction without deforming.

3.2.8.1.3 Test/Verification Plan This will be tested by having a team member weighing approximately 155 lbs (70kg) or more put their full weight on the roll bar from various orientations prior to installation and the team will check for any deformations in the roll bar structure.

3.2.8.1.4 Outcomes of Task Once these criteria are met, the carbon fiber roll bar will be bolted into the solar vehicle chassis. Once installed, the driver will sit strapped into the seat and it will be verified that the roll bar clears the driver's shoulders and there is at least a 5cm vertical gap between his helmet and the underside of the top of the roll bar.

3.2.9 Hatch

3.2.9.1 Design and Implementation

3.2.9.1.1 Objectives The hatch for the vehicle cockpit will be constructed of a special light-weight, impact-resistant, see-through polycarbonate material. HPMI (High Performance Material Institute) will be assisting in the solar car hatch design and implementation. The solar car operator must have access to a direct arc of visibility ahead and to 90° on each side of the longitudinal axis of the vehicle at all times.

3.2.9.1.2 Approach A polycarbonate will be chosen that will not create dangerous plastic shards (if impacted) that could potentially injure the driver. It will be ensured that the total weight of the hatch presents no issue for the driver when it comes to opening it from the inside unassisted. The hatch will be connected to the car cockpit via hinges so that it can open outward easily to the right of the cockpit. A latching device that can be opened from both the inside and outside of the vehicle will be installed to keep the hatch securely closed on the vehicle top and this latch will be clearly identified by red arrows on the outside of the cockpit.

3.2.9.1.3 Implementation Once the hatch is mounted on the vehicle, this required line-of-sight will be tested by placing cinder blocks on the ground (standing on end) 180° around the front of the car at a 4 meter radius (one every 30°).

3.2.9.1.4 Outcomes of Task The driver will sit strapped into in the vehicle with the hatch closed and, only moving his head, will confirm that he can see all seven blocks without difficulty, thus satisfying a 180° range of vision thru the cockpit.

3.2.10 Evacuation

3.2.10.1 Design and Testing

3.2.10.1.1 Objectives Once the car construction is nearing its completion, with suspension and wheels installed, and the driver cockpit nearly completed (with a minimum of the driver's seat, safety belt, and cockpit hatch completed and installed in the vehicle), the team will measure the success of solar car emergency evacuations, one where the driver must escape himself, and the other in which the team must extract the driver.

3.2.10.1.2 Testing/Demonstration The first evacuation test will demonstrate that our solar car is designed such that, should an emergency occur on the track that endangers the driver, he can evacuate the vehicle by himself within 10 seconds. The team's selected driver will be seated in the vehicle with his hands on the steering wheel, strapped in with the safety harness, and the cockpit hatch will be closed and locked into place. Another member of the team, located outside the vehicle will then signal the driver and simultaneously begin a digital stopwatch. The driver must then (unassisted by his teammates) unbuckle himself from the seat, unlock and open the car hatch, proceed to lift himself out of the cockpit and climb over the side of the vehicle. The stopwatch will be stopped once both of the driver's feet hit the ground. If this drill is performed by the driver within 10 seconds the test will be concluded a success.

The second evacuation test will demonstrate that emergency services can easily extract the driver from the solar vehicle if he should become injured and unable to get out of the car himself. This will be tested in the exact opposite manner of the previous evacuation test. The driver will once again be strapped in with the hatch sealed as before, and it will be the team's responsibility to get the driver free of the car. The team will ensure that they can, without difficulty, reach the car hatch, unlock and open the hatch, unbuckle the driver, and pull him clear of the vehicle in a timely fashion.

3.2.10.1.3 Outcomes of Task Evacuation from vehicle in less than 10 seconds.

3.3 Year 2

3.3.1 Braking

3.3.1.1 Objectives The objective is to create two independent braking systems that are each composed of a foot pedal, hydraulic line, and pneumatic piston disk brakes. These systems must act independently of each other and each be able to hold the car stationary on a 20 degree slope.

3.3.1.2 Approach To accomplish the braking three standard disk brakes will be implemented with all the wheels. The team then will calculate the needed force of braking through finding the force needed to keep the car at a 20 degree slope. And with that measurement we will be able to choose the braking scheme. There will have to be two foot pedals for each braking system which will be a standard pedal lever system.

3.3.1.3 Subtask: Research and Design Research will have to be done on different braking configurations to see which is the most affordable and lightest available. The design will then be implemented into the overall system design to make sure everything works together.

3.3.1.4 Subtask: Implementation The brakes will have to have the necessary space already allocated or it will not fit. Therefore, careful planning of the placement of brakes will have to be thought of ahead in Chassis design.

3.3.1.5 Subtask: Testing After the brakes are on testing must assure the brakes will meet the SEMA specifications. This requires us to place the car on a 20 degree slope and apply each brake independently, then the team will check if it can sustain itself statically.

3.3.2 Suspension

3.3.2.1 Subtask: Design and Implementation

3.3.2.1.1 Objectives To design a suitable suspension system that can be easily integrated into the chassis. To identify what components are needed to effectively dampen shocks from travel.

3.3.2.1.2 Approach Gather data about design specifications such as weight, maneuverability, and stability. Produce mock simulations to replicate desired results for suspension. Using CAD, configure the assembly to determine the suspension structure. From that structure, analyze individual parts to find limitations. Purchase components (dampers, shock absorbers, framing etc...) that will produce the results deemed suitable for our concept in the mock simulations. Take CAD designed parts to the College of Engineering's machine shop to have them machined and integrated with purchases materials. When chassis is available, attach suspension to chassis and make sure all components integrate successfully for testing.

3.3.2.1.3 Test/Verification Plan To begin testing the team must first purchase dampers, shock absorbers, and framing materials. One purchased, the team will need to machine the framing parts with the chassis in mind. The chassis and suspension would be designed in conjunction with each other in mind to avoid incompatibility. These systems need to be completely in sync with each other to prevent avertable failures. Once parts are machined and assembled the team can test the chassis and suspension simultaneously. We would use a mock SEMA track with assorted extremes that may be encountered at the challenge. The system should be able to withstand the weight of the car at its heaviest state so dummy weight will be installed to check its extreme conditions.

3.3.2.1.4 Outcomes of Task From the mock race track, we can verify our results from the simulations and CAD testing to determine that everything works at its ideal design condition. Once this task is complete, the suspension would be designed, machined, assembled, and tested. The suspension would provide stability for the car throughout the duration of the race.

3.3.3 Steering

3.3.3.1 Objectives The objective of this task is to design the steering system for the solar car in accordance to the Shell Eco guidelines and regulations. The steering system must be tight; there should be no delay or give when turning. At all times the driver must able to operate the steering using both hands while turning. Nothing should impede this motion. The steering is essential because the driver will have to turn radii less than six meters, have to maneuver through traffic around the track and such.

3.3.3.2 Approach There are many different approaches when it comes to steering selection. The first thing is; do you want front or rear wheeled steering. If rear steering is used, how easy will it be for driver to locate the straight ahead position? Will there be a case where differential steering is preferred? These questions among many other are crucial because they affect performance, the weight, and the overall user ability. Front wheel steering offers many advantages such as: Rear wheel steering also has its advantages and caveats. Advantages are better straight line ability and improved steering response. Rear wheeled allows for smaller turning radii which will improve cornering performance if needed. And major disadvantage it the lag time in turning response. The rear steered vehicle has the tendency to being to move in the opposite direction of turn momentarily after the turn begins. This must be taken into careful consideration when we must adhere to the SEMA regulations.

3.3.3.3 Subtask: Research and Design

3.3.3.3.1 Objectives The objective of this task is to research the different types of steering and evaluate each one for its merits and draw backs then choose which is better for the solar car. Steps will include finding out what it needed for the car's situation given the parameters the SEMA guidelines and regulations.

3.3.3.3.2 Approach Taking from previous years design the team knows what works. From there the team need to find out if that choice is the team's only option, is there a case that will produce better results. The system in the previous car was the rack and pinion steering mechanism. This type of steering is a specific form of steering mechanism which utilizes a steering gear mounted on an input shaft which is attached to the steering column. The team will see if this set up will encompass everything the team needs. If not, the team will design the car's new steering with the blueprint of the old.

3.3.3.3.3 Test/Verification Plan The steering will not be fabricated the first year but the team will have a fully articulating model to test by the time of the teams final deliverable. The team wants to check to make sure all the components mesh well together and no problems will arise from the assembly.

3.3.3.3.4 Outcomes of Task The outcome of this task is to have researched different types of steering systems and juxtapose them again what the team knows that already work. With that the team came deduce which system better suits the teams needs.

3.3.4 Horn

3.3.4.1 Research and Design

3.3.4.1.1 Objectives Install a horn that is of easy access to the driver at all moments during race.
The horn must be electric and mounted towards the front end of the solar car. It should be somewhere such that when it is engaged, the sound isn't muffled.
When operating it must meet the Shell Eco regulation standards of: emitting a sound of 85dBA (or louder) from four meters away, have a pitch tone of 40Hz or greater, and noise capacity rating of 110dBA or greater.

3.3.4.1.2 Approach The desired operating conditions are outlined clearly by the SEMA list of regulations. After purchasing the electric horn and mount it in the front of the solar car. It will be installed in a housing unit in the vehicle that is of easy access to the driver for the horn switch/button to be located.

3.3.4.1.3 Test/Verification Plan Test the assembly before mounting it in the solar car to assure that it works as it should. Install the horn as it would be for the race and test it at operational conditions. It should emit sound at 85dBA and heard from at least four meters away.

3.3.4.1.4 Outcomes of Task The outcome of this task is to have a functioning horn purchased, fully assembled and installed into the body of the solar car.

3.3.5 Fire Extinguisher

3.3.5.1 Research and Design

3.3.5.1.1 Objectives The solar car must have a fire extinguisher with a minimum extinguishing capacity of two pounds. If a hand held extinguisher is desired, it must be located in the cockpit of the solar and is readily available to the driver if an event occurs that he/she may need it.

3.3.5.1.2 Approach Purchase a fire extinguisher that meets the specifications of the SEMA regulations. Consider using a plumbed in system that when triggered, at the will of the driver, will release its contents to control a fire. Install a triggering system mount inside the solar car so it will be of easy access to the driver.

3.3.5.1.3 Test/Verification Plan The purchased fire extinguisher will already be certified for reliability. If a plumbed in system is built, it will be tested before installation begins. When testing the ”10 second” emergency egress, the fire extinguisher strategy will be tested.

3.3.5.1.4 Outcomes of Task The outcome of this task is to have a functioning system for a fire extinguisher in the event one is needed.

4 Risk Assessment

The greatest risk the team is facing is the time and money. Since this team is embarking on getting a working solar car to a competition for the first time in FAMU-FSU history, time is of great importance. Proper planning and life may be a true risk, but a risk the team must take. Recently the motor that has been used by prior solar car teams was found to be way to expensive and not in the ballpark of what is needed for the SEMA. Due to funding constraints and weight issues a less expensive DC motor was chosen.

The regenerative braking integration is a risk for the team because the operation and implementation with the disc brakes and the new motor is not yet fully understood until the new motor is purchased. The latching system for the lid is a risk because the design must be able to be secure at nominal speed operations. If the latch is not secure, the lid could come loose and cause injury to the driver and other bystanders. If the cockpit latch is not able to open and close easily, the driver could become trapped inside the vehicle. The cockpit material must be shatter resistant to prevent injuries to the driver if a collision were to occur. Therefore, this is a risk the team must face in designing the cockpit to be safe and reliable. A risk in designing the parking brake is that it could fail if every detail in the design is not considered. If the parking brake is not installed correctly or if the correct parking brake is not chosen for the type of primary braking system currently present in the car, the parking brake could fail and the car would not be able to stop in an emergency situation.

5 Qualifications and Responsibilities of Project Team

Project Leader \Lead EE–MATTHEW BOSWORTH Manages group as a whole and develops project plan and timeline. Relegates work load across team and delegates tasks according to skill sets. Establishes milestones and finalizes all documents. Updates team every 24-48 hours of current group standing. Responsible for all aspects of electrical and computer simulation design.
TECHNICAL RESPONSIBILITES: DSP programming, Energy System, overall design

Lead ME–CLAY NORRBIN Responsible for all aspects of mechanical design. In constant communication with Lead EE. Ability to relate concepts and ideas to team in concise manner for decision making purposes.
TECHNICAL RESPONSIBILITES: Prototype #1, Bottom Half of Car Specialist, Suspension

Finance Managers-EE,ME–AHMAD FARHAT, JOSEPH PETIT-HOMME Tracks budget expenses, faculty and industry support. Places orders, expenditure requests presented to faculty advisors.
TECHNICAL RESPONSIBILITIES: *Ahmad*–Solar panels, car shape *Joseph*–Prototype #3, Aerodynamic specialist, Interior Design, Wheels

Business Administrator-EE,ME–CHRIS DRESNER, DANIEL GREEN Liaison between industry, faculty and SES group support.
TECHNICAL RESPONSIBILITES: *Chris*–Energy System, Simulations *Daniel*–Prototype #2,Top half of car specialist, Exit Scheme, Roll Bar

Secretary–THIERRY KAYIRANGA Records meeting minutes, monitor and update online directory, including reference list.
TECHNICAL RESPONSIBILITES: Power Electronics, Energy System
The engineers on the design team are well-rounded students that are experienced in various disciplines in engineering. The amalgam of skills in different specializations will be beneficial to the design of the project and will expose each student to new skills as well as enhance the skills they've already acquired.

Matthew Bosworth is an electrical engineering major interested in large power system simulation, verification and validation. His focuses throughout his tenure at FSU have included a bachelor's degree in Applied Mathematics and Computational Science, a research position with the BioMedical Research Facility, and project manager/research assistant at FSU-CAPS. Matthew's expertise in these areas will help in the design, management and outreach needed to complete the car by 2014.

Clay Norrbin is a mechanical engineering major with a focus on dynamics at FSU. Clay is currently taking classes to enhance his major such as ”Intro to Mobile Robotics” and ”Design of Analytical Control Systems.” Along with this Clay works in the STRIDe lab where the focus is legged robotics. After his undergraduate degree he plans to continue to graduate school to pursue his doctorate in robotics. Clay's expertise will aid in the development and testing of the the solar car body, along with helping design a well-damped suspension.

Ahmad Farhat is an electrical engineering major interested in the field of power and control systems. Ahmad is an officer at HKN Electrical and Computer Engineering honer society. He also volunteers with Dr. Victor Debrunner at SAIL high school's robotic club. Ahmad is a part of the SES student organization. His interests are in the field of power in general and specially in the field of renewable energy. Ahmad will be graduating in May 2013 and hopes to start his career in the field of power right after graduation.

Joseph Petit-Homme is a mechanical engineering major with a concentration in Thermal Fluids . Joseph has done research with Dr Carl Moore's mobile robotics lab in the National High Magnetic Field Lab working in continually variable transmissions. Joseph is interested in aerospace and aviation and has worked with a company that is world renowned in this area. Joseph is graduating in Spring 2013 with my B.S in Mechanical Engineering and may continue education at FAMU-FSU college of Engineering in the pursuit of a graduate degree.

Chris Dresner is an electrical engineering major interested in power and renewable energy. He is expected to complete his B.S. in electrical engineering in the spring of 2013 from Florida State University. Mr. Dresner has worked at Florida State University's Center for Advanced Power Systems since January 2012 as an undergraduate research assistant in the power systems group. He is also a member of HKN, the Electrical Engineering Honor Society.

Daniel Green is an FSU mechanical engineering major with a focus on thermal fluids. Upon completing his undergraduate degree, he intends to extend his studies to other facets of engineering and possibly finance and higher mathematics. His plans are to relocate to Australia with his wife and seek work in his fields of interest.

Thierry Kayiranga is an electrical engineering major with a background in power systems and power electronics. Thierry is currently working with Dr. Li Hui on smart-grid and dc-dc converters. Thierry is interested in the latter, power conversion and renewable energy sources but has a passion for how quantum mechanics affects electronics and particle physics. Thierry will graduate in spring 2013 and intends to pursue my graduate studies in power electronics at FAMU-FSU college of Engineering.

6 Project Schedule

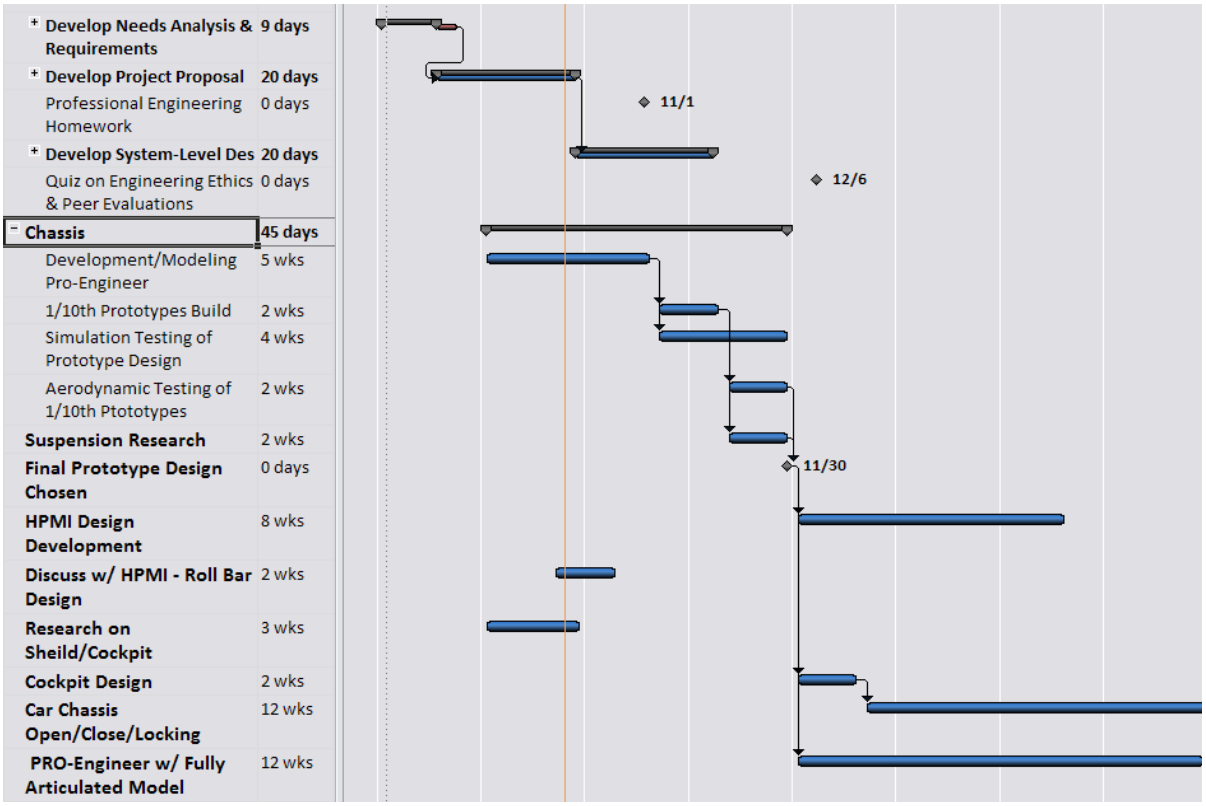

Figure 6.1: Documentation and Mechanical Schedule

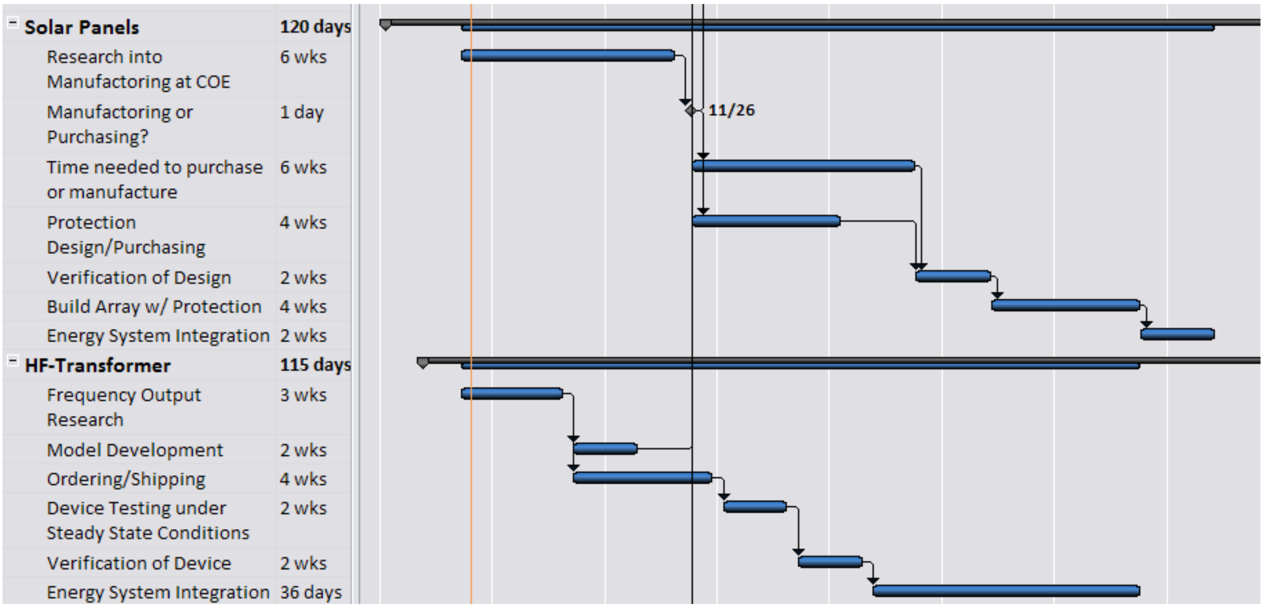

Figure 6.2: Electrical Schedule: Part 1

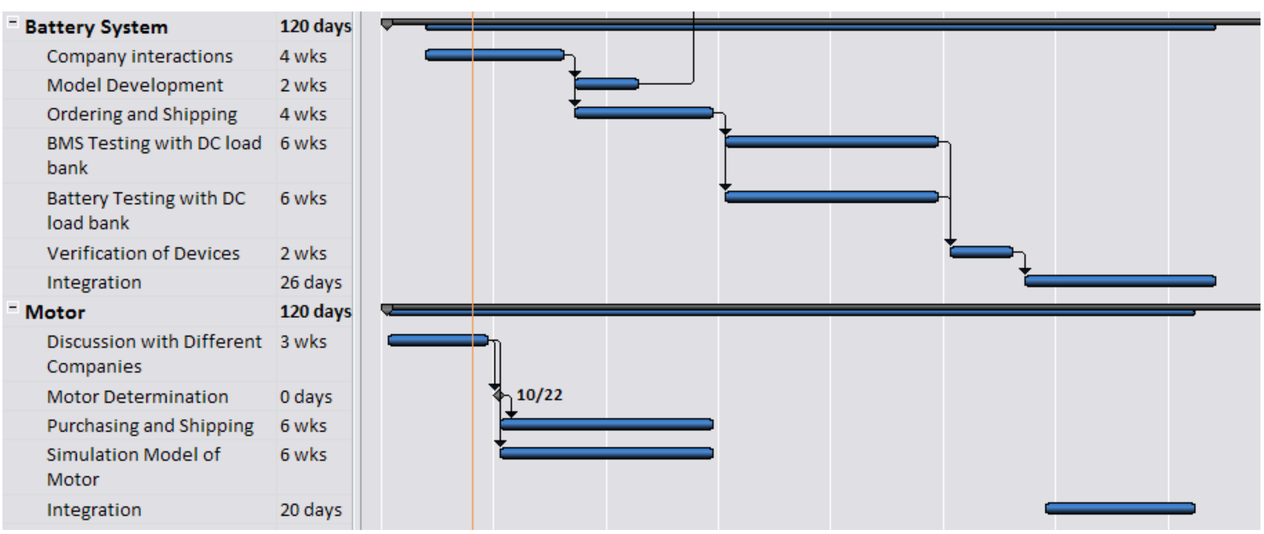

Figure 6.3: Electrical Schedule: Part 2

7 Budget

Table 7.1: Personnel Expenses

Name	Effort(hr/wk)	Base Pay(per hr)	Total(per wk)	Total(per semester)	Entire Project Cost
Matthew Bosworth	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Clay Norrbin	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Chris Dresner	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Joseph Petit-Homme	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Ahmad Farhat	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Ryan Green	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Thierry Kayiranga	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
				total:	$ 80,640.00

Table 7.2: Equipment Costs

Materials	$ 1,000.00
Motor Kit	$ 1,000.00
Chassis	$ 4,500.00
Brake	$ 800.00
Cockpit Design	$ 1,000.00
MPPT	$ 1,000.00
Battery System	$ 2,000.00
Seat	$ 200.00
Wheels	$ 400.00
Suspension	$ 1,000.00
Visor	$ 400.00
Steering	$ 300.00
total:	$ 13,600.00

Table 7.3: Misc Expenses

Mechanical Expenses	Amount
Nuts, Bolts, Screws, Washers	$ 200.00
Hinges/Latches	$ 500.00
Labor for Machining	$ 2,000.00
Spare/Extra Parts	$ 600.00
subtotal:	$ 3,300.00
Electrical Expenses	**Amount**
Ribbon Wire	$ 100.00
Solder	$ 90.00
Solder Irons	$ 150.00
Solder Iron Tips	$ 40.00
Wire	$ 150.00
Connector	$ 40.00
PV cell protection parts	$ 800.00
subtotal:	$ 1,370.00
total:	$ 4,670.00

Table 7.4: Overall Costs

Total Parts/Equipment	$ 18,270.00
Total Personnel	$ 80,640.00
Total Estimated Cost w/ Overhead	$ 145,397.70

8 Deliverables

The following deliverables and their deadlines for the Fall 2011 semester are shown in the table below:

Table 8.1: Deliverables

Deliverable Type	Deadline
Needs Analysis and Requirements Specification Document	9/20/2012
Needs Analysis and Requirements Specification Presentation	9/24/2012
Project Proposal Paper	10/18/2012
Project Proposal Presentation	10/29/2012
System Level Design Review Paper	11/15/2012
System Level Design Review Presentation	TBD
Detailed Design Review and Test Plan	2/7/2013
Midterm Hardware Review	2/28/2012
Design Fair/Hardware Demo/Final Report	4/1/13-4/15/13

9 Appendix

Figure 9.1: Single Monocrystalline Solar Cell

Figure 9.2: Tenergy Custom Built pack: Incased in metal which includes BMS and charger

Figure 9.3: Elite Power Solutions battery pack including BMS and charger

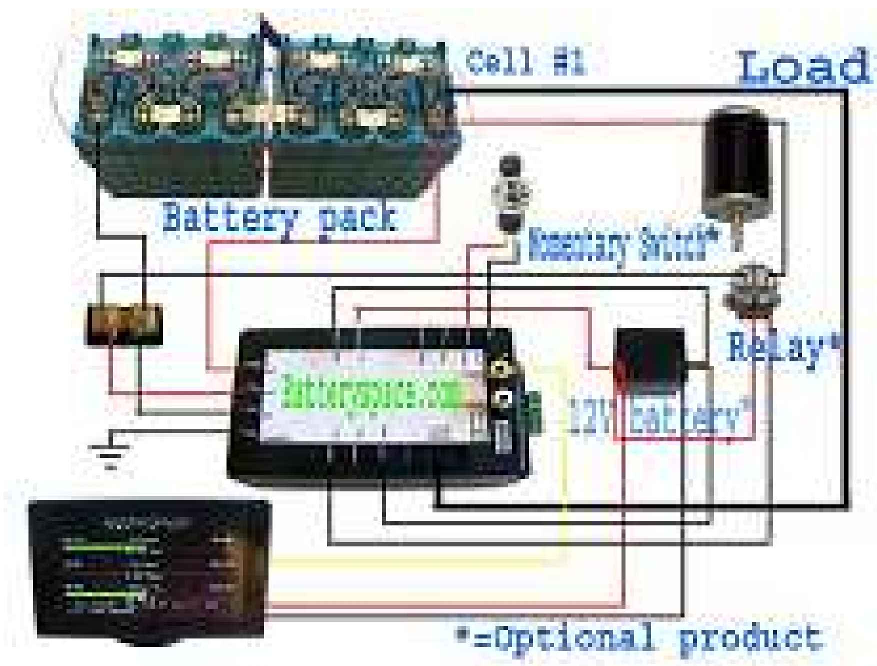

Figure 9.4: Elite Power Solutions Battery System Setup

Figure 9.5: Representative Hatch Designs being Considered

References

[1] Patrick Bresland, Bradford Burke, Jordan Eldridge, Tyler Holes, Valerie Pezzullo, Greg Proctor, and Shawn Ryster. Senior design final report. Technical report, FAMU-FSU, 2011-2012.

[2] DaSolar.com. Michigan solar car, 2012.

[3] Solar Panel Info. How much could you save with solar panels?, 2005-2012.

[4] V is for Voltage Forums. The first e-car with 7kw*2 hub motor has come out!!, 10/19/2008.

[5] Kelly Controls LLC. Products:hub motors, 2008.

[6] Photon.info. Solar module-database.

[7] POSHARP. Solar panel database, 2012.

[8] SBI. Solar facts and advice, 2010-2012.

[9] R.M. Schupbach and J.C. Balda. The role of ultracapacitors in an energy storage unit for vehicle power management. In *Vehicular Technology Conference, 2003. VTC 2003-Fall. 2003 IEEE 58th*, volume 5, pages 3236 – 3240 Vol.5, oct. 2003.

[10] T.A. Smith, J.P. Mars, and G.A. Turner. Using supercapacitors to improvebattery performance. In *Power Electronics Specialists Conference, 2002. pesc 02. 2002 IEEE 33rd Annual*, volume 1, pages 124 – 128 vol.1, 2002.

[11] Elite Power Solutions. 48v 2.1kwh turn-key system (w/can), 2009.

[12] Tenergy. The leader in total power soutions, 2011.

[13] Bin Wu, Fang Zhuo, Fei Long, Weiwei Gu, Yang Qing, and YanQin Liu. A management strategy for solar panel #x2014; battery #x2014; super capacitor hybrid energy system in solar car. In *Power Electronics and ECCE Asia (ICPE ECCE), 2011 IEEE 8th International Conference on*, pages 1682 –1687, 30 2011-june 3 2011.

[14] Hyunjae Yoo, Seung-Ki Sul, Yongho Park, and Jongchan Jeong. System integration and power-flow management for a series hybrid electric vehicle using supercapacitors and batteries. *Industry Applications, IEEE Transactions on*, 44(1):108 –114, jan.-feb. 2008.

[15] Chunbo Zhu, Rengui Lu, Likun Tian, and Qi Wang. The development of an electric bus with super-capacitors as unique energy storage. In *Vehicle Power and Propulsion Conference, 2006. VPPC '06. IEEE*, pages 1 –5, sept. 2006.