FAMU-FSU College of Engineering
Department of Electrical and Computer Engineering

PROPOSAL

EEL4911C – ECE Senior Design Project I

Solar Car

Team # 2

Student team members:

James Barge, Electrical Engineering (jb09d@fsu.edu)
Adrian Cires, Mechanical Engineering (ac06e@fsu.edu)
Keith Dalick, Mechanical Engineering (kjd07c@fsu.edu)
Nelson German, Industrial Engineering (ng09@fsu.edu)
Emiliano Pantner, Mechanical Engineering (ep07c@fsu.edu)
Rajat Pradhan, Industrial Engineering (rdp08@fsu.edu)
Zachary Prisland, Electrical Engineering (zap04@fsu.edu)
Shishir Rajbhandari, Electrical Engineering (sr07k@fsu.edu)
Amanda Roberts, Industrial Engineering (akr06@fsu.edu)

Senior Design Project Instructor:

Dr. Chris Edrington
Dr. Bruce Harvey
Dr. Zohrob Hovsapian

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Project Executive Summary

The American Solar Challenge is a competition to design, build, and drive solar-powered cars in a cross-country time\distance rally event. The Solar Challenge hosted in 2012 will have teams competing in a 2400-mile course between multiple cities across the continent. It is hosted by Innovators Educational Foundation, an organization devoted to applied learning in the areas of science, engineering, and technology. FAMU-FSU College of Engineering has set up a team of senior undergraduate students from multiple disciplines to design and build a solar powered car to compete in this challenge. The team consists of three electrical engineers, three mechanical engineers, and three industrial engineers.

The energy from solar radiation is the most abundant and potentially the greatest source of renewable energy. Research is constantly conducted around the globe aimed at increasing solar cell efficiency and may one day enable us to harness the full energy of the sun. The technical design project that we have undertaken is attempting to introduce senior engineering students to solve the problem of designing, building, and racing a safe and functional car that is powered via sunlight.

The objectives of the technical design project are as follows:

1. Design a composite body
2. Design Solar array configuration
3. Design suspension system
4. Design Electrical system
5. Optimize Design
6. Test Mechanical system
7. Test Electrical system

The solar car project will be designed following lean six sigma's methodology DMEDI (Define, Measure, Explore, Develop, and Implement). DMEDI is a methodology used to systematically conduct projects that require a new designed process or product. The Define phase provides a clear problem statement that charters a project with a defined scope and Outcomes. The Measure phase is the step where the team converts the needs and specifications of the project into measurable and quantifiable targets. This allows for prioritizing and quantitative reasoning for making decisions or creating alternatives. In the Explore phase the team will then create a conceptual design of the solar car based on the data collected and analyzed in the measure phase. Then in the Develop phase the team optimizes the conceptual design to capture all the needs and specifications of the solar car. Finally, the solar efficient car will be fabricated into a full scale working design.

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Introduction

Acknowledgements

The 2010-2011 Solar Car design team would like to thank all of the people and organizations helping us to design and create a cutting edge solar powered vehicle. Particularly, the team would like to thank Dr. Bruce Harvey for giving the team direction on how to approach the task of designing and building this vehicle. The team would like to thank Dr. Chris Edrington, for the technical direction for the electrical integration, High Performance Material Institute (HPMI) and Jerry Horne, for the time and know how to create the composite body, and the FAMU-FSU College of Engineering, for the monetary donation to complete this project with the best materials available.

Problem Statement

In 2009, the FAMU-FSU College of Engineering revitalized the Solar Car design project. The solar car design project is intended to increase the knowledge of renewable energy generation, energy storage and increase the publics' awareness of advances in renewable energy technology. The students were assigned the task to reuse and update the solar car from the 1997 Solar Car design team. This project was to be Phase I of a two phase project. The team from 2009 utilized the existing frame but was unable to salvage any portion of the previous body. Their goal was to get a rolling chassis that could be used for the second phase of the project.

This year, Phase II of the project will start where the previous team of Phase I left off. The current 2010-2011 design team, comprised of electrical, mechanical and industrial engineers, are assigned with the task of designing and building a vehicle to be raced in the 2012 American Solar Challenge Race. The race regulations have changed since the 2010 race. Therefore, the new design team will take what was created from Phase I and design a new car to the 2012 race specifications.

In order to produce a vehicle to the 2012 race specifications, the team will have to work together to optimize efficiency, power and durability. To accomplish this, the team must utilize the knowledge learned from courses previously taken, keeping in mind a limited budget and a limited allotment of time. The team will incorporate some components of the previous solar car to expedite the process and to keep the cost down. The team will use the motor, motor controller and some electrical components used from Phase I. All other components will be designed and fabricated to meet the specifications of the race.

The new car will be designed using the idea of a monocoque body, which incorporates the chassis into the body. The monocoque body will be made using carbon fiber and composite materials to reduce weight and increase aerodynamic efficiency. The design will consist of three wheels, as opposed to four wheels, to reduce the overall friction loss of the vehicle. The design will undergo stress analysis to ensure safety and stability of the vehicle. Low friction disc brakes will be used on the forward two wheels for proper stopping force necessary to decelerate the vehicle in the allotted space. A rack and pinion steering system will be designed to best fit the vehicle for a turning radius specified by the race regulations.

For propulsion, the driving force for the vehicle will produced by an in-wheel brushless DC motor. The motor will be mounted on the rear trailing wheel assembly. To control the input power to the motor, a motor controller will be used by taking the power from the batteries. Sensor readings, such as temperature, voltage, will be continuously gathered to protect the batteries, motor and driver from over-heating or over-charging. Also, a protection circuitry, including breakers and fuses, will be implemented in order to safeguard components from power surges or cross wiring. These will ensure safety to the driver and vehicle, which is the number one priority of the team.

Operating Environment

During the race, the solar car may be subjected to harsh weather conditions due to the race being held on public roads and highways. Even though the route of the race has yet to be determined, it will be assumed to go anywhere in North America. The race is held in the month of July, so temperature ranges across North America can be as high as 134 °F or as low as freezing in portions of Canada. Solar radiation on a clear day increases drastically making it a factor when considering the temperature inside the vehicle.

The vehicle may have to endure areas of extreme humidity or extreme dryness. Rainfall or high winds are not uncommon during the month of July in places across North America. Keeping in mind the vehicle does require solar radiation to run; clouds and other water molecules in the air are a large factor in the production of energy from radiation. The vehicle will have to compensate for the lack of sunlight when the clouds are blocking the sunlight from striking the solar arrays.

Besides weather factors, the vehicle will have to withstand the conditions of the other traffic on the race route. Cars and trucks driving beside, in front or behind the solar car may cast shadows on the solar arrays making it impossible to produce energy from the sun. In addition to shadows, passing vehicles may generate turbulent wind conditions making it more difficult to operate the vehicle and may increase the drag on the solar car. The conditions of the roads are unknown. Therefore, the solar car may have to handle bumpy, pot hole ridden roads.

The team must consider the power required for uphill travel. There might be sections of the route that involve navigation through and around hills and mountains. Based on interstate highway standards, the maximum grade that will be encountered is six (6) percent. However, this standard does not apply to urban areas where grades can be as high as twelve (12) percent.

All factors must be taken into consideration when designing the vehicle for travel in North America.

Intended Use(s) and Intended User(s)

The solar car will be an eco-friendly way for a single driver to traverse distances with the normal speed and efficiency of a car. The car will be equipped with all the normal lights and signals of a regular vehicle and therefore should be able to safely travel on roadways throughout a city. The vehicle's top speed will prohibit it from travelling on any interstate highways or any other roads with high speed limits.

The solar car will be used primarily for daytime driving as this is the only way to collect the solar radiation necessary to charge the batteries. The vehicle will be capable of charging the batteries from certain wall sockets so it will not be entirely restricted to driving during the day, but as stated previously, will have no way to recover energy except stopping again to charge.

This project will continue on after this portion of the design is completed in the hopes that it will be able to compete in the American Solar Challenge. This challenge is a competition that occurs bi-yearly and will give the finished product a chance to compete against other schools with similar design restrictions. To enter this competition will be the primary goal of this car as it progresses through design projects.

Assumptions and Limitations

Assumptions

1. This portion of the design phase will continue to move the car towards competition in the American Solar Challenge
2. Many of the electrical systems from phase one portion of the design will be useable in the design work for this phase
3. The car will be allowed to be to carry a full charge before any competition, which may be achieved through wall charging
4. There will be changing race restrictions for future races and the car will have to be left in a state where systems can be changed cheaply and simply

Limitations

1. Budget will be restricted and it will be necessary to seek donations wherever possible
2. The solar array will be limited to a size of 6 m^2
3. The driver's eye line must be at least 70 cm off the ground and provide 100 degrees of view to the right and the left
4. A roll cage will be protecting the driver in the event of a rollover collision
5. The electrical systems must be isolatable so that power can be immediately cut by either the driver or an onlooker from outside the car
6. The car will have to pass a series of safety and performance tests outlined in the American Solar Challenge guidelines and the finished project of this phase should have a car capable of passing all these tests

Expected End and Other Deliverables

The most important deliverable will be the completed solar car from this phase of the project. This will not be delivered until the end of the project time as will be illustrated below in the schedule. The other deliverables for the project will include several design papers which will include updates as to the current design and any modifications made from previous reports. A website will be created for the purpose of displaying information about the solar car, progress to date, and will include a section for all the papers and presentations. Finally a user manual for the safe operation of the vehicle will be completed.

Proposed Design

Overview

The proposed design for the solar car will be broken down into two major areas including electrical systems and mechanical systems. All of these systems will be integrated into a final product but will be discussed in terms of individual components in order to aid the conception process. As can be imagined, this final product will be a car using electrical power for means of transportation.

The body of the car will consist of a composite materials built specifically for purposes of this car and be the base for all components of the mechanical system. The body will provide both storage and installation for not just the other mechanical systems, but for the driver and electrical systems as well. In order to make the car operable, it will also require all the functions of a normal automobile: ability to accelerate, ability to brake, and ability to control the direction of travel.

The electrical system will utilize and electric motor, batteries, and solar cells as the largest physical components. Batteries will be utilized as a storage medium for collecting solar radiation. A charging system will be designed to allow for propagation of power from the solar array to the batteries. The motor will utilize both the stored energy and generated energy from the solar cells in order to provide the overall movement.

Industrial

As a project of this scale gets started there will likely be many decisions that need to be made. It may be the placement of a component, a choice between two parts for purchase, or how to implement a specific feature. In order to make the correct decision it will be a matter of weighing the pros and cons and determining which will have the most beneficial resolution. Part of the decision process will be the attempt to consider every aspect of the design and all factors that will need to be considered.

The industrial team, having been trained using lean six sigma’s design methodology, will be able to facilitate this phase of the project. Below are a series of tables and figures created by the industrial team and the beginning of our design process.

Mechanical

Monocoque Body

The proposed design of the body will incorporate the method of a Monocoque body style, as seen in Figure 1. Monocoque body utilizes the body of the vehicle as the structural framing. The choice to use a monocoque body style was chosen to keep the weight of the vehicle down and the vehicle strength high. Normal vehicle designs use a frame with a body wrapped around the frame. Carbon fiber composite material will be used in this application due to the qualities of the material. For weight consideration, carbon fiber is on average half as dense as aluminum. The ultimate yield property provides almost fourteen (14) times the yield strength compared to aluminum. The final deciding factor for choosing carbon fiber is how easy it is to work with. Once a mold is built, the carbon fiber fabric is laid into a mold and the resin is added. This process can take half the time it takes to measure, cut, bend and weld aluminum tubing for a frame.

Figure 1 -- Monocoque Body Example (Electrick Publications and NJK, 2005)

The body style will be designed in SolidWorks for ease of analysis. SolidWorks provides structural analysis subprograms to determine if and where a portion of the body will fail. In addition to structural analysis, SolidWorks provides a subprogram for aerodynamic flow over the vehicle. The minimization of pressure drag is what is desired to keep the losses down for high efficiency. The material properties can be easily loaded into SolidWorks for proper analysis.

Suspension

The job of a car suspension, according to How Stuff Works, is to "maximize the friction between the tires and the road surface; provide steering stability with good handling and to ensure the comfort of the passengers." The car will feature an independent suspension system for each of the three wheels. Independent suspension will provide the rider with a more comfortable ride isolating the vehicle by its three (3) points of contact from the road and eliminating the disadvantages of the beam axle. Some of these disadvantages include loss of friction by the wheels, small maximum spring deflection, no control of the steering system, and over-steer. A double wishbone suspension was chosen for the front wheels, as shown in Figure 2.

Figure 2 -- Double Wishbone Suspension (Longhurst, 2010)

This suspension type includes two (2) links forming a wishbone shape where one end is fixed to the frame of the car and the other end to the lower and upper ball joints. A spring and damper combination is fitted between the two wishbones. This type of suspension allows its kinematics to be easily tuned and optimized.

A trailing-arm suspension system, shown in Figure 3, will be implemented to the rear wheel. It has an arm joined at the front to the chassis that allows the rear to swing up and down, a suited motion for the single rear wheel. A twin trailing-arm suspension will also be evaluated and compared to the single trailing-arm suspension to decide which one to implement.

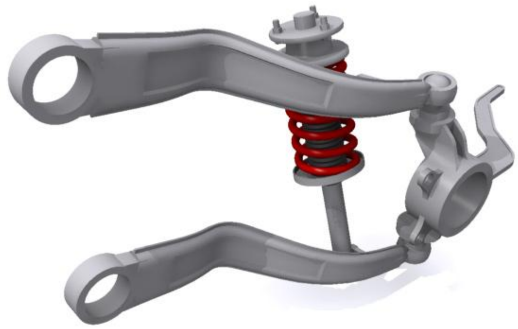


Figure 3 -- Trailing-Arm Suspension (Longhurst, 2010)

The components will be designed, analyzed, and tested in SolidWorks and MSC Adams/Car CAD software. The wishbones and trailing arm will be made out of Aluminum 6061 due to its lightweight property and cost. The spring and damper combination will be chosen depending on the total weight of the car and the expected car behavior under braking, normal, and cornering conditions modeled in the CAD software.

Steering

In order to steer the solar car, a rack and pinion steering system will be implemented on the front wheels of the car. The steering system must enable the solar car to complete various tests before being able to compete in the North American Solar Car Challenge, such as the slalom and the figure eight test. The selected steering system will be chosen with steering ratio as the most important decision factor. The steering ratio is defined as the amount of rotations of the steering wheel, to how far the rim and tire deflect from center. For the solar car a lower steering ratio is ideal due to the lightweight design of the car. A rack and pinion steering system is shown in Figure 4.

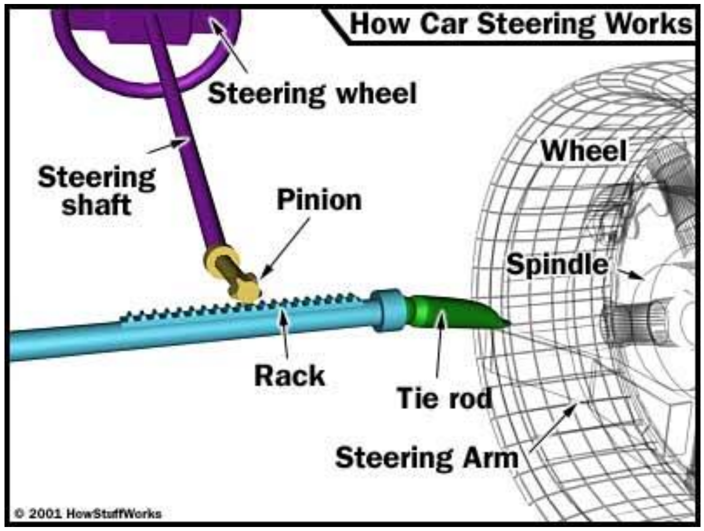


Figure 4 -- Rack and Pinion Steering System (Nice, How Car Steering Works, 2001)

Braking

The solar car will feature three independent braking systems, which are the standard, regenerative, and parking brake systems. For the standard brakes, two disc brakes will be installed on the front two wheels leaving the rear driving wheel with no brake. There will also be a regenerative braking system installed to be used a secondary power source. When the regenerative brake is engaged it will generate electrical energy that can charge the car's batteries. The parking brake will be installed with the purpose of allowing the car to remain motionless when not being driven. This will also allow the car to remain motionless when parked on a slope. An example of a disc brake system is shown in Figure 5.

Figure 5 -- Disc Brake View (Nice, How Disc Brakes Work, 2000)

Electrical

Power Generation

By definition the solar car will use solar radiation as the primary means of power generation. In order to collect the solar radiation it will require the use of solar cells set up into arrays. The arrays will be placed on top of the monocoque body in order to collect this energy. In order to maximize the power generated from the solar panels, maximum peak power trackers will be used. These devices will be capable of keeping the voltage regulated between the cells and drastically increase the overall performance.

Regenerative braking will be implemented as a secondary form of power generation. The regenerative braking will recover excess kinetic energy and convert it back into electrical power which can be used to recharge the battery. Ideally these two systems will provide enough power to keep all the systems of the solar car running during operation.

Management System

The management system will primarily consist of the store energy system and the propulsion system of the car. As can be seen in the block diagram below, Figure 6, each of these systems is comprised of four subsystems or components. The blocks that have been highlighted in green are already in a functioning state from the progress in Phase I and will be mentioned only briefly.

The stored energy system is primarily the batteries, but will also include a protection circuit, wall charging system, and state of charge measurement system. The protection circuit will prevent the batteries from over current, over voltage, under voltage, and over temperature. A wall charging system will be in place for the batteries in order to provide a secondary means of charging that doesn't involve solar radiation. The state of charge devices will allow the driver to view the current status of the batteries.

The propulsion system is focused around the electric motor which will produce that propulsion. The electric motor will be controlled by a motor control, which in of itself contains several devices that will provide that control. It will include a capacitor bank which will help keep the power to the motor stiff during the operation. It will have a DC/AC converter which is necessary to get the pulsing effect from the direct current power coming from the batteries and solar panels. There will also be a power control system which will describe the integration of the two different power sources (solar arrays and batteries) and the use of power by the motor controller.

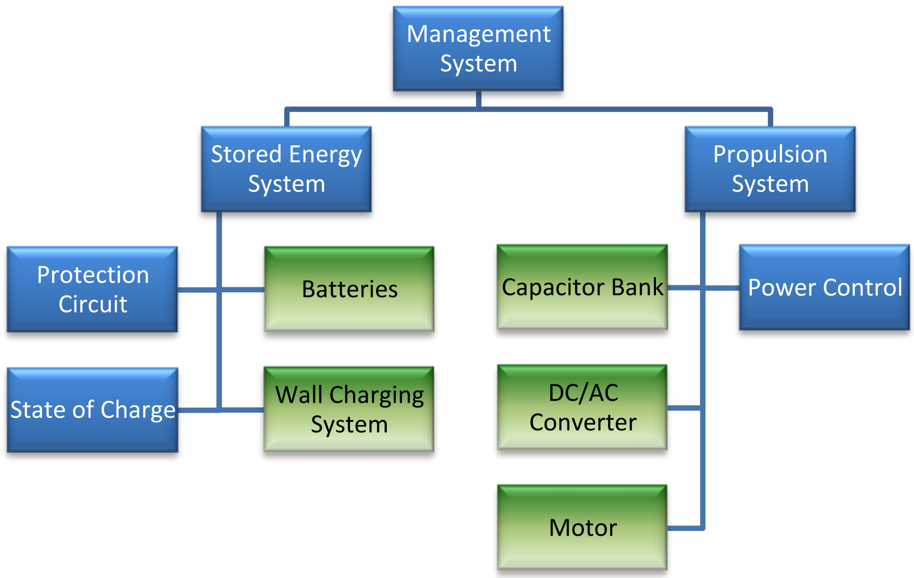


Figure 6 -- Management System Diagram

Control System Proposed Design

The control system will be built around the control system designed in the previous phase with a few improvements. A microcontroller will be added to the dashboard system to provide additional display mechanisms, automate the startup process, and communicate with the motor controller for more advanced control. The motor controller will be reconfigured to provide a serial data interface for communication with the microcontroller. Display systems to be added include a voltmeter, a state of charge meter, a rear view camera, and light controls.

Statement of Work

Project Management

Objective

The solar car project is a very large project both in design and in the amount of work involved in building each component. The objective of the project management will be to attempt to stream line this work, reducing the amount of wasted time and increasing the overall efficiency of the group.

Approach

The team assembled for the solar car project is an interdisciplinary group consisting of Electrical Engineers, Mechanical Engineers, and Industrial Engineers. The project manager will be responsible overall for the completion of all tasks including deliverables, design goals, and all actual tasks completed on the car. The project manager will assign goals for each team to accomplish in a specified time frame, per the schedule that will be discussed later. In order to keep the groups organized and working efficiently, a team leadership position has been created for each group. The team lead will then be responsible for meeting the goals set forth by the project manager and further dividing the tasks to each individual that comprise their group.

Fundraising

Objective

The objective of this task is to contact companies for monetary and material donations.

Approach

Research will be conducted to determine what companies need to be contacted for donations. Companies will be contacted for funding and in return, advertisement will be posted on the solar vehicle and vehicle trailer.

Test/Verification Plan

Members of the design team will be assigned certain companies to be contacted. The determined companies will be contacted using email, phone and in person meetings.

Outcomes of Task

With support from the contacted companies/people, the design team will have enough funding and materials to complete a successful product.

Monocoque Body

Objective

To design and produce a vehicle body using an integrated chassis made from composite materials for very lightweight application.

Approach

The monocoque body will be designed using parameters designated by the solar race. The parameters that are to be considered in the design are: surface area for solar array maximization, aerodynamic design for drag minimization, length, width, height per race specifications, and a design that can be created with the resources available to the engineers. The design will be researched extensively to create an optimum design for all components listed previously. The design will then be created using SolidWorks for the most efficient design. The monocoque body will be made of composite material by the engineers on the design team.

Test/Verification Plan

The complete body design will be created in SolidWorks for easy analysis. Structural analysis will be done on the integrated chassis using finite element analysis in SolidWorks. Aerodynamic analysis will also be done to the body to make sure there are no big issues with drag on the vehicle. Once the tests are done using the finite element analysis, any changes will be made for optimal performance of the monocoque body.

Outcomes of Task

Completion of the testing will produce the most efficient design for our application. The monocoque body will be constructed using handmade molds and composite materials.

Suspension

Objective

To design the front and rear suspension systems, and install them on the body of the car.

Approach

The suspension systems will be analyzed separately as front suspension and rear suspension. The engineer leading the suspension system work will work with the engineer leading the brake and steering systems, and the engineer leading the design of the monocoque body since the three systems and body are interrelated. Moreover, the same size wheel and hub will be used for both front and rear systems.

Front Suspension

Objective

To design a double wishbone suspension for each left and right front wheels, and choose the right shock size.

Approach

The front drive-train of a car consists of the interconnected brake, steering, and suspension systems. Due to the interconnection of these systems, the design specifications will depend on the size of the wheel hub and steering arm. Depending on the total weight of the car, the maximum force that could be applied to each of the springs will be calculated to choose the right size of the shocks (spring and damper system) and order them. The system will then be designed in SolidWorks to have a better visual of it and be able to fabricate the custom parts. Some custom parts include the wishbone shaped arms, knuckle, kingpin, and hub.

Test/Verification Plan

Once the front suspension components are designed in SolidWorks, its assembly will be tested using Finite Element Analysis to calculate fatigue and stress points within the structure under different load conditions. Also, the model will be imported into MSC Adams/Car to analyze and predict roll and vertical forces, static loads, steering characteristics, and wheel travel. Once we analyze the system, we will be able to adjust its parameters such as camber angle, caster angle, toe pattern, roll center height, scrub radius, and scuff.

Outcomes of Task

After computer aided testing is done on the designed suspension, the suspension system will be built and installed on the vehicle with the right shock sizes. Also, the suspension will be adjusted to the settings provided by the simulation software. This will provide the driver with a more comfortable and smoother ride.

Rear Suspension

Objective

To design a trailing-arm or twin trailing-arm suspension for the rear wheel, and choose the right shock size.

Approach

The electric motor used to power the car will be mounted to the rear wheel. Thus, a suitable suspension system must be design able to hold that weight and not create torque on the wheel. The design specifications such as sizing will depend on the size of the motor axle, and wheel hub. A shaft will have to be designed to directly transfer power from the motor to the wheel. In order to accomplish this more efficiently, the engineer working on the suspension will work in conjunction with the engineer in charge of the electric motor. Depending on the total weight of the car, the maximum force that could be applied to each of the springs will be calculated to choose the right size of the shock (spring and damper system) and order them. The system will then be designed in SolidWorks to have a better visual of it and be able to fabricate the custom parts. Some custom parts include the trailing arms, hub, kingpin, knuckle, and transmission shaft.

Test/Verification Plan

Once the rear suspension components are designed in SolidWorks, its assembly will be tested using Finite Element Analysis to calculate fatigue and stress points within the structure under different load conditions. Also, the model will be imported into MSC Adams/Car to analyze and predict roll and vertical forces, static loads, steering characteristics, and wheel travel. Once we analyze the system, we will be able to adjust its parameters such as camber angle, caster angle, toe pattern, roll center height, scrub radius, scuff and more.

Outcomes of Task

After computer aided testing is done on the designed suspension, the suspension system will be built and installed on the vehicle with the right shock size. Also, the suspension will be adjusted to the settings provided by the simulation software. This will offer the driver a more comfortable and smoother ride.

Test/Verification Plan

Once the correct settings for the desired handling and ride are obtained for both, front and rear, suspensions, a virtual vehicle simulation will be executed on MSC Adams/Car. With the simulation complete, the system will be analyzed as a whole and if any faults are seen, they will be adjusted and the testing will continue until we attain the desired outcome.

Outcomes of Task

To obtain the right settings for the suspension system to attain a comfortable ride for the driver.

Braking

Objective

To design a braking system to be implemented in the vehicle design.

Approach

For the standard braking system of solar car, two disc brakes will be placed on the two front wheels. Disc brake systems will be researched in order to know how its applications can impact the solar car's driving ability. The disc brakes may be salvageable from last year’s model, and if not they can be purchased or redesigned. For the parking brake, research is being conducted on how to apply a parking brake and where to locate the brake in the cockpit of the car.

Test/Verification Plan

A disc brake is a used to slow and stop the motion of a rotating wheel. The selected disc brake will conform to the 2012 North American solar car challenge rules, which are that the contact area of the brake pads cannot exceed 6 cm^2. The braking system must also allow the car to repeatedly stop from speeds of 50 km/hr with a deceleration greater than 4.72 m/s^2. For the parking brake, the solar car must be able to remain motionless when a force equal to 10 percent of the car's weight is applied to a forward and reversed direction.

Outcomes of Task

The outcome of this task is selection of the correct braking systems for the car. The disc brakes system will give the car the required stopping power and to pass the race requirements of the 2012 North

American Solar Car Challenge. The selected parking brake will enable the driver to park and leave car motionless when force is applied to car in forward and reverse directions.

Steering

Objective

Select and implement steering system to enable car to perform maneuvers when in motion

Approach

When selecting the steering system for the car, there will be an emphasis on the steering ratio of the system. Research will be conducted to learn how the weight of the vehicle can affect the decision on appropriate steering ratio. The steering ratio is the ratio of how far you turn the steering wheel to how far the wheels turn.

Test/Verification Plan

In order to test the selected steering system, the car will be put through several maneuvering tests. The car must be able to complete a slalom test where the car must complete the 126 meter course in 11.5 seconds. In addition to the slalom test, the vehicle must be driven on a figure eight (8) course in 18 seconds or less. The car must have a turning radius such that it can make a U-turn without backing up within a 16 meter wide lane. Steering stops will also be welded on to the steering system to prevent any dangerous steering

Outcomes of Task

The outcome of this task is the knowledge of how the selected steering ratio affects the steering ability of the car. Once steering ratio is determined, a steering system will be selected to ensure the car can pass the race requirements for the 2012 American Solar Challenge.

Energy Generation System

Objective

Design and integrate an Energy Generation System capable of channeling the energy from solar radiation to either charge the battery bank, or propel the vehicle.

Design and integrate a Regenerative Braking System capable of converting the energy produced from the frictional force of the brake into electrical energy, and channeling the latter energy to charge the battery bank.

Approach

Solar cells convert solar energy into electrical energy. The electrical model of solar cell will be researched and its current/voltage (I-V) characteristic will be modeled and simulated under various conditions. Their characteristics, when connected in series, will be modeled and simulated under various conditions. Maximum Peak Power Tracker (MPPT) is essential for peak efficiency of solar cells. Current MPPT technologies, methods of application, operation manuals will be researched. The method of applying regenerative braking system in the solar car design will be researched.

Solar Array

Objective

Design and integrate solar cells into a solar array system capable of generating energy to sustain the motion of the solar car or charge the battery system.

Approach

Fundraising will be partaken by the team to raise capital for the solar array system. A demo test system (module of solar panel) will be designed and fabricated to study the behavior of solar cells under different light conditions. Software feasible for modeling and simulation of solar cells under varying light conditions will be sought as donation from different companies. The software will be used to study I-V relationship of solar cells, solar modules, and solar arrays under various light conditions. As such, a solar array design will be constructed for maximum efficiency and maximum power given that maximum area allowed is less than 6 sq. meters. The solar array will be an array of solar panel emitting an output voltage (voltage potential will be determined in design phase); the solar panel consist of modules of solar cells; a module is a chain of solar cells in series of 10-12 cells. Each cells used in the chain will be closely matched for their I-V performance. Methods of soldering and combining solar cells will be studied. The output voltage of the solar array will be designed to meet the requirement of the motor and battery voltages.

Test/Verification Plane

The solar array system for the car and the test-demo will be designed and simulated in software under various light conditions. The test-demo version is a module of solar cells. It will be designed, fabricated, and tested under the sun at various times of the day. It will be tested under full shadow and half-shadow conditions. Voltage and Current measured during testing will be measured using a digital multi-meter and noted in spreadsheet. The data from spreadsheet will be matched with the data from software simulation. The correlation between the data from the test-demo version and software simulation will be analyzed. The result will be used to compute the power available in 6 sq. meters of array.

Outcomes of Task

The outcome of solar array task is the design, integration, and operation of the solar array system for the car. The task will provide knowledge of solar array implementation, operation, and troubleshooting.

Maximum Power Point Tracking (MPPT)

Objective

Purchase and integrate MPPT with solar panels.

Approach

MPPT used in solar cars will be researched and their corresponding manufacturers contacted. A MPPT feasible for safe battery operating voltage (72V – 126V, 96V nominal) of the battery system will be sought. Their ratings, functionality, efficiency, and methods of implementation on solar cells will be researched, understood, and applied on the demo-test version of solar module. MPPT’s are expensive; fundraising will be done for having this component donated.

Test/Verification Plan

MPPT is a device capable of ensuring that the solar cell operates at its maximum power point under different conditions of temperature, atmosphere, solar radiation, wind, and various other conditions. The demo-test version solar module will be analyzed under different light conditions in the absence of MPPT, and then analyzed again in the presence of MPPT. The documented data (I-V) retrieved from these test will be analyzed. These data will be calculated to give a rough estimate on the current and voltage available from the solar panels with the use of MPPT; thus giving an estimate of total power produced by a panel with the use of MPPT.

Outcomes of Task

The outcome of MPPT task is knowledge of operation of MPPT systems. The task will require the study of MPPT’s operation and user manual. Additional knowledge of troubleshooting and implementing MPPT’s in-between the solar panels and battery bank will be acquired.

Regenerative Braking

Objective

Integrate the available regenerative braking system into the solar car design to serve as a secondary source of energy.

Approach

Regenerative braking system in conjunction with motor controller and electric motor will be extensively researched. The regenerative braking system, upon asserted, converts kinetic energy of motion into electrical energy. The electric motor will thus, act as a generator supplying charge to the battery.

Research will be undertaken to better understand the process of mechanical energy to electrical energy conversion in regenerative braking systems. Limitations of regenerative braking systems will be considered. Study in the methods of implementing regenerative braking system in electric vehicles will be researched. Brake Controllers are essential components of commercial electric vehicles. Its most important function is its capability of asserting frictional brakes when the motor is not capable of handling forces necessary to stop the motion of the car. Feasibility of brake controllers in the design will be studied, and implemented if possible. A computer engineer will be needed to complete this task. The regenerative braking system will have to be tested before being implemented on the car; else the regenerative braking serves no purpose in the car.

Test/Verification Plan

The regenerative braking system will be tested on a load (resistor). Data on the amount of charge input to the load upon varying regenerative braking force will be collected. The acquired data will serve as a reference for calculation of maximum energy input from regenerative braking system. The tests will give us an approximation of maximum threshold level of regenerative braking force to apply; exceeding this force will cause permanent damage to the motor. A charge monitor will be implemented in the design to ensure proper operation of the regenerative braking system.

Outcomes of Task

The outcome of the task is integration of regenerative braking system in the solar car. The regenerative braking system will be able to supply charge to the battery when asserted. The process in which mechanical energy converts to electrical energy will be understood. Knowledge of implementing regenerative braking system in electric and solar vehicle will be attained.

Testing/Verification Plan

The Energy Generation System will be tested for proper operation. The solar array system will be tested for maximum power output. The output power will be tested to propel the vehicle. The regenerative braking system will be tested to ensure charge is supplied to the battery upon braking. Upon integration of the solar array system and the regenerative braking system to the battery bank, the energy generation system as a whole will be tested for proper functionality and operation under no-load and full-load condition.

Outcome of Task

The outcome of the task is the integration of the energy generation system, shown in Figure 7. The system will channel the energy from solar radiation and regenerative braking to either charge the battery, or propel the vehicle. Knowledge of designing, integrating, testing, and troubleshooting energy system for solar vehicle will be attained.

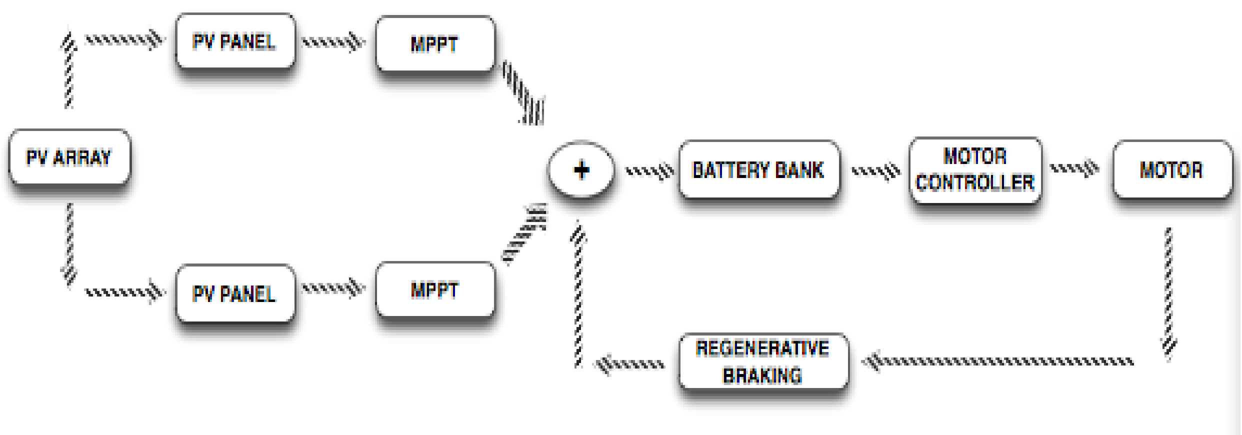


Figure 7 -- Energy Generation System Diagram

Electrical Management System

Objective

The management system's main goal will be to provide stability for all electrical systems. This system will provide stable power for the vehicle during periods when solar energy is unattainable or insufficient to power the remaining systems. It will also manage the power to the motor through the motor controller.

Approach

As much of the electrical management system was completed during the previous phase, it will be the design goal to integrate the added structures to the already existing system. This in no way implies that the components being implemented in this phase are any less important to the end product of the project but the additions to the overall design will be improvements to a structure that has already been defined and built. These improvements will have rigorous testing performed to verify complete integration into the existing system.

Protection Circuit

Objective

The protection circuit will be for the batteries to guarantee correction operation of the batteries whether they are in use or charging. There are four status checks the system will have to perform constantly to ensure correct operation including: under current, under voltage, over voltage, and over temperature.

Approach

The batteries for the system have already been purchased from the previous phase, so it will be the design goal to meet the needs of these particular units. The ideal operation will utilize these parameters to create bounds on the system to prevent operation outside of these constraints. It is possible that it will mean shutting down the system in order to prevent damage to the components.

The first phase of this project was able to implement a system shut off for over voltage which was utilized mainly during wall charging. This essentially allows the batteries to charge until they are full but will restrict current flow after. It is imperative to verify that preventing charging by over voltage will not prevent power use by the motor and dashboard systems.

The same component being utilized to measure over voltage can also be implemented to measure over current and under voltage and implement the same shut off procedures. Implementing these states will be a matter of setting up the component properly to continually check the over current and under voltage as well, which may require some rewiring.

Meeting the over temperature requirements will be a little more difficult. It will require design of a circuit around a thermistor, (a variable resistor whose resistance varies with the temperature of the device) and output a control signal. This control signal will have to carry a shut off signal as soon as the safe temperature point is breached. It may be possible to implement the previously mentioned device to implement the same shut down procedures that will occur with the other three state bounds.

Test/Verification Plane

The test plan for the protection circuit will be rather simply, but should be heavily repeated and performed rigorously to ensure consistent functionality. The tests for over current and under voltage will involve using a multimeter and attempting to get the battery conditions out of bounds.

The under voltage test will require the batteries to drained until they reach the outside bounds of their operating voltage. This can be achieved by propping the rear axle of the car up and running the motor until the power from the batteries is almost completely drained. The tester should have the multimeter hooked up so as to monitor the voltage of the batteries. As soon as the multimeter displays an out of bounds voltage the circuit should engage and cut power use from the batteries. If this does not occur some redesign or reconnecting of the devices will have to occur and the test will have to be performed again. After each test the batteries should be charged slightly so as to prevent too much time occurring in the under voltage state.

The test for over current will require a power draw greater than what the batteries are safely capable of handling. Similarly, the tester will hook up a multimeter to in order to get readings for the current being drawn from the batteries at all times. In order to actually perform the test a circuit will have to be designed as the motor controller, if functioning properly, will not meet the over current conditions. This circuit will need the have a large current draw and be rated for very high power so as to not cause dangerous conditions. The test itself will be performed very similarly to under voltage, once the power is being used by the batteries the tester should be able to verify the power is cut off at the unsafe current condition.

Over temperature will be the easiest to perform as it can be tested without direct use of the batteries themselves. A signal monitoring device, such as a microcontroller, will be used to monitor the temperature circuit's control signal. The test will introduce the thermistor to a heat source outside the bounds of operating temperature of the batteries. Once this test has been successfully completed integration into the system itself will be required. Once again it will be necessary to retest in the battery encasement to verify that no damage occurred during installation.

Outcomes of Task

The successful completion of this circuit will provide a consistent means of automated monitoring of the batteries. This automated monitoring will automatically protect the batteries from operating outside of safe operating bounds by disabling the system. Ideally the batteries will return to safe conditions shortly thereafter.

State of Charge

Objective

The state of charge system will provide the driver with a continuous report for the state of the batteries which will include voltage and current. This will give the driver the opportunity to disable the system if running out of bounds, in the event that the protection circuit fails.

Approach

Up to date measurements reported directly will be required during this subtask. A device or multiple device will have to be purchased that can provide voltage and current measurements for the battery system. This device(s) will be chosen based and weight and also flexibility with the rest of the system.

Once the device has been chosen it will be integrated properly into the system so that it can provide accurate measurements of the batteries. From here this information will need to be relayed to a display placed in the dashboard system. Ideally the device will control the display directly without a third party component involved if possible. Otherwise a microcontroller is already being installed into the dashboard system and this microcontroller should be capable of completing this task. This will the flexibility factor that is taken into account during the device selection portion of the task.

A display device will also have to be selected to meet the needs for this task. An LED display will most likely be chosen largely because of the ease of use and small power consumption of the display itself. This device will have to be worked into the dashboard system and may share common power source from the other dashboard systems (which is discussed more thoroughly in that section). After the display is in place and receiving measurement information from the measuring devices then the testing of the devices can begin.

Test/Verification Plan

Similar to testing the protection circuit, the test plan will be rather simplistic. For this testing however the batteries never have to be in out of bounds conditions. It will require a multimeter to be connected to the system at the same time as the state of charge reporting system. The batteries should be run through several different use states (i.e. charging, steady state, and discharging) in order to verify that the device can properly keep up with quickly changing currents and voltages.

The batteries will then be put through the varying use states and the information displayed on the dashboard should match the information viewed on the multimeter. Any major variation in the two will indicate and implementation flaw and the system should be rechecked to ensure connections were made properly between all devices. These steps should be repeated until there is minor variation between the two measurement devices.

Outcomes of Task

The result of this subtask will be a fully functional system capable of providing constant monitoring of the current and voltage for the batteries. These measurements will be reported directly to the driver as a secondary means of protecting the system from out of bounds conditions.

Power Control

Objective

The power control system will be the system dedicated providing consistent power to the motor and motor controller. It will involve integrating the incoming power from the solar arrays and combining it with the power from the batteries in a balanced way.

Approach

This subtask will be largely a design procedure. It will require effective voltage regulation devices to keep the voltage potential of the two power sources as near synchronization as possible. Any variation in the two voltages from the sources will eliminate one of the sources from putting power into the system, drastically reducing the efficiency of the overall system. For this reason it will be necessary to be as meticulous as possible in the design phase of the task.

Designing the voltage regulation device will require a lot of research into this area. As voltage regulation is so pertinent to the success of many systems a plethora of information into this design process can be found online. Due to the varying amount of voltage that will be provided by the solar panels and the reducing amount of voltage provided by the batteries as they drain; it will be necessary to design the system to keep up with produce a constant voltage output regardless of the input.

Once the research has been done there will be a decision to be made; whether it is feasible to design and build a voltage regulator with enough consistency to meet the strict needs of this project or if it will be necessary to purchase a voltage regulation device to improve consistency.

After the device has been built or purchased, it will need to be integrated into the respective power sources, battery and solar cells. This integration should be rather simple, just placing it in series with the sources so that the regulated output will be seen by the motor controller.

Test/Verification Plan

Testing will follow a similar routine to the previous two systems. A multimeter will be required to measure the voltages that are leaving the voltage regulators. The voltage regulator from the battery can be tested immediately upon completion because the battery system is already in place. In order to test the voltage regulation for the solar cells it will have to wait until the implementation of the solar panels themselves. The tester should read a near constant regulated voltage. Any significant deviation will have to be investigated as even the smallest of change could greatly impact system performance.

It will be possible to test the regulator that will be used for the solar array. It will require a voltage generator and will have to output voltages similar to what will be expected from the solar power generation. The actual test itself will be performed in the same way that the battery test was performed, verifying that the multimeter measures a constant voltage output from the regulator.

Outcomes of Task

When the power control system is working properly it will keep the voltage from the batteries and the voltage from the solar array should be in perfect balance. This balance will improve the efficiency of the entire system, ensuring little to no loss from this imbalance.

Test/Verification Plan

All of the subtasks will be tested rigorously as individual components and once again after they have been integrated into the system. Therefore the only test that can truly be performed will be to verify that when all components are simultaneously operating that they do not impair the operation of another system.

Essentially the car will have to be placed into operation and all the information verified through a multimeter to be operating correctly. The state of charge and voltage regulation should be very easily monitored, but it will be a little more difficult to get the battery to out of bounds conditions. The out of bounds conditions can once again be verified in the same ways as was previously stated and while performing this test, the other systems should be tested as well.

Outcomes of Task

When the electrical management system is completed there should be a more complete control over the electrical sources in the car. There will be precautions in place to prevent any of the systems from operating in unsafe conditions. If for some reasons the system does manage to find itself in one of the out of bounds conditions, the system can be disabled manually and automatically to prevent damage to the components.

Control System

Objective

Provide the control interface for all of the main subsystems and driver dashboard displays. The control system needs to be able to control all of the operations of the vehicle.

Approach

The design will be centered on a microprocessor master control unit that will interface with all of the electrical and electromechanical systems of the vehicle. The team shall design a control system capable of starting the vehicle, governing movement of the vehicle, controlling lights, and providing a driver interface.

Main System Control Unit

Objective

The Main System Control Unit will be responsible for handling all of the controls of the car, as well as communicating with the control subsystems. Proper control of all vehicle systems is critical for high system performance. The system control unit will be used to automate the startup function of the vehicle, as well as communicating with the motor controller to enable advanced power control.

Approach

The control unit will be composed of a microcontroller board that interfaces with the dashboard and the motor controller. The microcontroller chosen will need enough inputs and outputs to interface with the dashboard and motor controller. The controller board also needs a serial port to communicate with the motor controller. Relays will be used to replace the secondary switches in order to automate the startup process. The team will write the code that the microcontroller will use to operate the vehicle. A supplementary circuit will be used to control the video feed from the rear camera. The control unit will be installed in the existing body and tested prior to installation in the new body.

Test/Verification Plan

The testing for the main controller will be performed by simulating the code for the microcontroller. After the code has been verified to work, the microcontroller will be installed and field tested using the infrastructure from the previous phase.

Outcomes of Task

The addition of the main control unit will integrate the user control and system controls, which will improve the performance of the vehicle and simplify vehicle operation.

Dashboard Control Interface

Objective

The Dashboard will contain most of the user controls that that driver will use to control the car. The dashboard will contain information about the status of the car, telemetry data, and a rear view camera display.

Approach

The dashboard will use some of the equipment from the previous phase, such as the speedometer, fuse box, and switches. The team shall redesign the dashboard controls to work with the main controller board. The dashboard shall contain power and control switches for driver operation, a state of charge display to monitor the energy level of the batteries, a voltmeter to display the system voltage, a rear view display, and a speedometer.

Test/Verification Plan

Each individual driver input can be tested independently to verify functionality and integration with the main control unit. The new dashboard components can be installed on the old body for testing purposes prior to installation in the new body.

Outcomes of Task

The new dashboard interface will provide much more information about the vehicle to the driver and make the vehicle easier to operate.

Test/Verification Plan

A complete test of the control system will be performed after the control system has been fully installed. The vehicle will be started and checked to ensure that all of the controls are functional before driving. After the preliminary tests have been passed, the vehicle will be driven and tested for performance. Additional optimizations will be performed to increase the performance of the vehicle and the vehicle will be retested to gauge improvement.

Outcomes of Task

The control system, when integrated with the rest of the vehicle, will allow the car to operate and manage all of the vehicle’s functions.

Test Plan

The mechanical and electrical system of the design will be tested using software simulation and practical tests.

Each component of mechanical and electrical system will be simulated and analyzed using computer software. The interconnection of different components in both electrical and mechanical system will be tested using computer software. MSC Adams/Car software will be used by the mechanical team, and Pspice and Simulink will be used by the electrical team. Upon completion of the design project, the actual mechanical and electrical systems will be tested as per computer simulation. The data obtained from actual testing on the mechanical and electrical systems will be correlated with the data collected from computer simulation.

Other test plans to ensure completion of the design include:

- Finite Element Method test for aerodynamic and strength
- Test battery system for physical defects and/or unsafe operating conditions
- Test electrical system is isolated
- Test solar array system
- Test regenerative braking system
- Test road-safety light system
- Test Power cut off switch
- Other test as per Regulation book

The test plan follows all testing procedures required by the American Solar Challenge, 2012. Successful completion of all tests ensures vehicle safety and vehicle operation reliability.

Documentation

A variety of documents will be used throughout Phase II to keep track of the progress:

- Team minutes for each of the team meetings.
- The electrical engineers will be keeping an engineering notebook.
- A video record will be kept to document the progress through various fabrication phases.
- A website will be created for the solar car which will include deliverables, progress to date, a list of sponsors, and team member information.
- All the deliverables which will be listed below in a following section.
- A user manual for the solar car itself will be written to assure correct operation.

Risk Assessment

There are a variety of potential risks that may be encountered during the design and build phases of the solar car project. The risks could fall into one of several categories: budget, communication, components, design, team member, or time.

Budget

The budget is the most daunting of the risks at this point. As was stated previously the initial design plan is to a have a composite body, but this will come at great cost. There will also be a great cost associated with the solar panels needed to power the car. At this point the costs associated with these components greatly exceed the budget that has been allotted. It will be up to the team to seek out donations in the form of capital and materials to actualize the project as proposed in this paper.

Communication

Communication will be very important between all members of the team. Being comprised of three small groups (electrical, mechanical, and industrial engineers) will make communication more organized. If for some reason communication is not thorough it may lead to a variety of poor results such as damaging a component, wasting time solving the same problem, or completely missing a component because it was assumed another would do it.

Components

Component issues will also be a very serious hamper to the completion of this project. The design portion of the project should be undertaken very rigorously in order to reduce the number of potential issues with components but there is always a chance that some of the issues will arise. If a number is miscalculated and the incorrect part is ordered it will impact not only the budget but greatly affect the schedule for the project. There is also a risk that a part will be damaged during the integration of components into the vehicle. This is a very real risk because many of the components from the previous phase will be reused during this portion of the design. To reduce this risk it will take some scrutinizing of the product manual in order to verify that a new component being introduced will not negatively affect an existing component.

Design

The design phase will be very important to the overall success of the project. It will require each member to take into consideration each step to actualize the goals set before them. If steps are skipped or issues are not solved during the design phase it becomes a very costly mistake both monetarily and from a time allotment perspective. Hopefully with the addition of industrial engineers to the group and a thorough use of the lean six sigma method these risks can be entirely prevented.

Team Member

There are many risks to this project that will involve team members. While there are nine team members, a single member being absent for an extended period of time could prevent the completion in a timely manner. Team members could be absent for a variety of non-project related reasons such as family issues or illness. Absences could also arise because of injury through the building of the car. The team members will be exposed to composite materials during the fabrication of the body and if correct PPE is not worn may lead to illness in one of the team members. Many batteries will be placed on board the vehicle a great amount of stored energy and if a team member somehow discharges that energy it could lead to serious injury or death. As always there will be potential for normal injuries when working with tools or in the machine shop.

Time

In order to actually produce a finished product it will take a combined effort from every member of the team. If the schedule is not planned properly and some individuals are working while others are not it may lead to time constraint issues towards the end of the phase. For this reason excellent planning will be necessary, although as with all things if too much time is spent on this portion of the phase then it may negatively impact the overall design. There is also a risk that a deadline cannot be met because of other classes and it will be up to the team to work a little harder before the next deadline to catch up with the schedule.

Qualifications

The design team in charge of this project is an interdisciplinary team composed of Computer, Electrical, Industrial, and Mechanical Engineers. Each team member has taken different classes making them proficient on a specific area of the project. This will spread the knowledge to the other team members making this a continuous learning experience. The members were given tasks in areas where they were both strong and weak at. The reason to provide them tasks of weak expertise is to foster communication and desire of learning, and the expansion and transfer of knowledge among members. Table 1 shows the task assignments for each member.

Table 1 -- Team Assignments

Assigned Task	Team Member	Skills and Knowledge
Control System	James Barge	Data Structures, Electronics Microprocessor Based System Design, C Programming, Electronics, Communications
Brake and Steering Systems	Adrian Cires	Dynamic and Mechanical Systems, Energy Conversion Systems, Engineering Design Methods, Fluid Mechanics, Mechanics and Materials, Pro/E and SolidWorks Modeling, Thermodynamics
Mechanical Engineering Leader, Vehicle Body	Keith Dalick	Energy Conversion Systems, Engineering Design Methods, Fluid Mechanics, Heat Transfer, Material Sciences and Engineering, Mechanics and Materials, Pro/E and SolidWorks Modeling, Thermodynamics
Suspension	Emiliano Pantner	Fluid Mechanics, Dynamic and Mechanical Systems, Engineering Design Methods, Mechanics and Materials, Energy Conversion Systems, Pro/E and SolidWorks Modeling
Project Manager, Electrical Engineering Leader	Zachary Prisland	Circuit Analysis, Digital Logic Design, Electronics, Fundamentals of Power Systems
Treasurer, Energy Generation System	Shishir Rajbhandari	Control Systems, Electronics, Fundamentals of Power, Signals and Systems

James Barge

James Barge is currently a senior in the FAMU/FSU College of Engineering's Computer and Electrical Engineering Bachelor's program. Pertinent classes he has taken for his assigned task include Data Structures, Electronics Microprocessor Based System Design, C Programming, Electronics and Communications. James also has extensive experience doing computer technical work as well as experience programming C language. In addition, he has previously designed and fabricated a robot to be operational only on solar radiation.

Adrian Cires

Adrian Cires is currently a Senior in the FAMU/FSU College of Engineering's Mechanical Engineering Bachelor's program. He has taken the core classes of the Mechanical Engineering curriculum and is currently taking technical electives. Relevant courses for his tasks in the project include Dynamic and Mechanical Systems, Energy Conversion Systems, Engineering Design Methods, Fluid Mechanics, Mechanics and Materials, and Thermodynamics. He is also proficient at design CAD software such as Pro/Engineering and SolidWorks. During the Summer of 2010, he gained more experience as a power system manufacturer intern where he was involved in mechanical design. He became knowledgeable in design optimization, cost analysis, material and vendor selection, as well as part modeling, dimensioning, and tolerance.

Keith Dalick

Keith Dalick is currently a Senior in the FAMU/FSU College of Engineering's Mechanical Engineering Bachelor's program. Relevant courses for his task in the project include Energy Conversion Systems, Engineering Design Methods, Fluid Mechanics, Heat Transfer, Material Sciences and Engineering, Mechanics and Materials, and Thermodynamics. He is also skilled in CAD software such as Pro/Engineer, SolidWorks, and AutoCAD, as well as G Code programming for Computer Numerical Controls. Keith works at the College's machine shop as a master fabricator making him knowledgeable in the design and building process of custom parts, as well as the use of the machines and tools used. He also has sales and fundraising experience he gained through a merchandising internship.

Emiliano Pantner

Emiliano Pantner is currently a Senior in the FAMU/FSU College of Engineering's Mechanical Engineering Bachelor's program. He has completed courses such as Dynamic and Mechanical Systems, Energy Conversion Systems, Engineering Design Methods, Fluid Mechanics, and Mechanics and Materials, relevant to his assigned task. He is also proficient in CAD software such as Pro/E and SolidWorks Modeling. He has held executive positions such as President, Vice President, and Secretary of different student organizations he has been involved with in the past. He also has communication and sales experience he gained by working in a marketing company.

Zachary Prisland

Zachary Prisland has a B.S. in Computer Engineering, and is currently obtaining his Bachelor of Science's Electrical Engineering degree at the FAMU/FSU College of Engineering. Related courses he has taken for his assigned task include Circuit Analysis, Digital Logic Design, Electronics, and Fundamentals of Power Systems. As a Computer Engineer, he has experience with design projects, and during his last year in the latter program, he worked in a team to design a scale model of a fire seeking robot.

Shishir Radhajd

Shishir Radhajd is currently a Senior in the FAMU/FSU College of Engineering's Electrical Engineering Bachelor's program. Pertinent classes he has taken for his assigned task include Control Systems, Electronics, Fundamentals of Power, Signals and Systems. He currently working towards a minor in business to further his knowledge of the finances associated with the design project. Shishir has taken a course on electric aircraft, where he had to design, fabricate and implement the controls for a successful flight.

Schedule

Figure 8, Figure 9, and Figure 10, show our proposed schedule for the project.

Figure 8 -- Schedule (1)

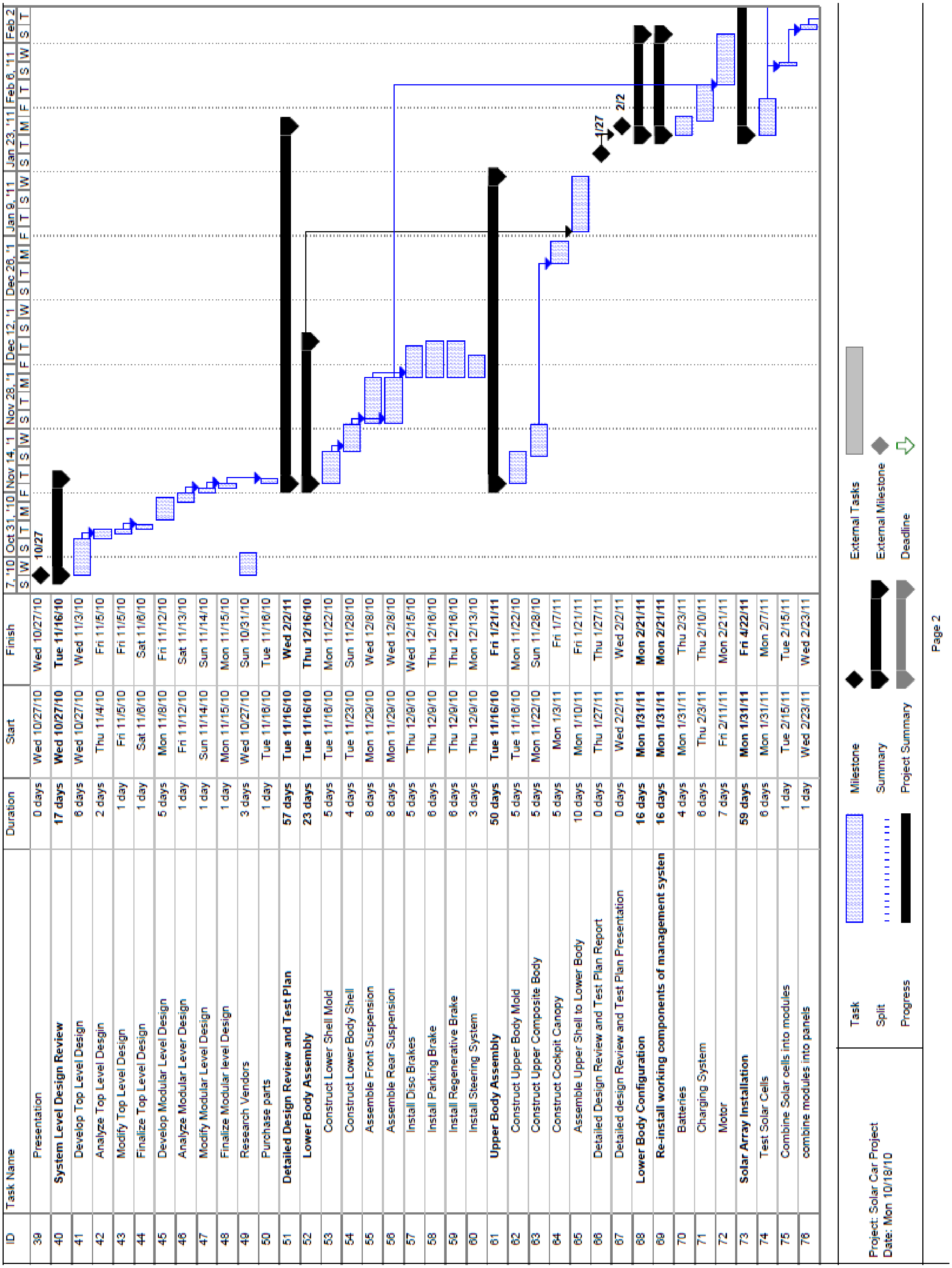
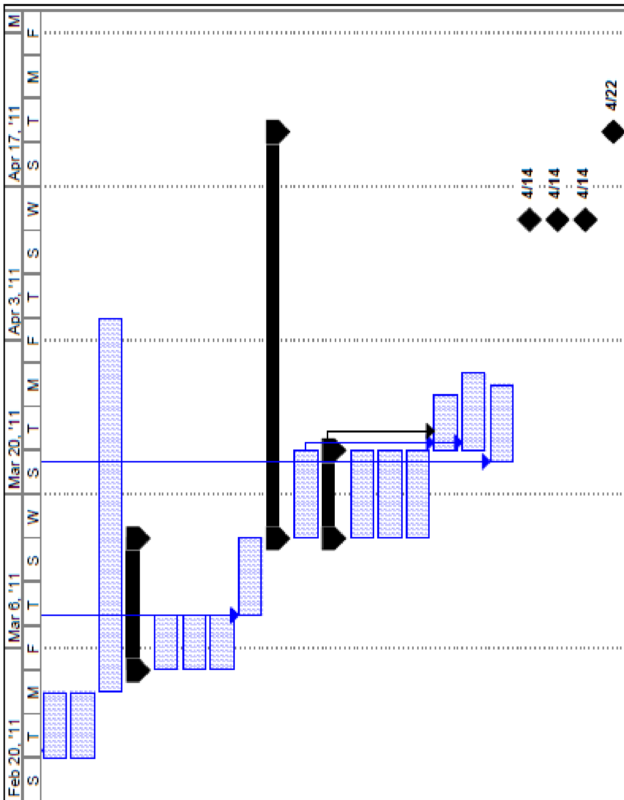


Figure 9 -- Schedule (2)

ID	Task Name	Duration	Start	Finish
77	Test MMPT integration into the panels	4 days	Thu 2/24/11	Tue 3/1/11
78	Test Solar Array Protection System	4 days	Thu 2/24/11	Tue 3/1/11
79	Test Charging Capabilities	24 days	Wed 3/2/11	Mon 4/4/11
80	**Total Body Configuration**	**8 days**	**Fri 3/4/11**	**Tue 3/15/11**
81	Install Energy Storage System	3 days	Fri 3/4/11	Tue 3/8/11
82	Install Central Interface System	3 days	Fri 3/4/11	Tue 3/8/11
83	Install Propulsion System	3 days	Fri 3/4/11	Tue 3/8/11
84	Install Energy Generation System	5 days	Wed 3/9/11	Tue 3/15/11
85	**Final Testing Phase**	**27 days**	**Wed 3/16/11**	**Fri 4/22/11**
86	Test Steering System	6 days	Wed 3/16/11	Wed 3/23/11
87	**Test Braking System**	**6 days**	**Wed 3/16/11**	**Wed 3/23/11**
88	Regenerative Brake	6 days	Wed 3/16/11	Wed 3/23/11
89	Standard Brakes	6 days	Wed 3/16/11	Wed 3/23/11
90	Parking Brake	6 days	Wed 3/16/11	Wed 3/23/11
91	Test Car Maneuver test	3 days	Thu 3/24/11	Mon 3/28/11
92	Car Stability Test	5 days	Thu 3/24/11	Wed 3/30/11
93	Test Solar Capabilites	5 days	Wed 3/23/11	Tue 3/29/11
94	**Design Fair**	**0 days**	**Thu 4/14/11**	**Thu 4/14/11**
95	Final Report	0 days	Thu 4/14/11	Thu 4/14/11
96	Final Project Oral Presentations	0 days	Thu 4/14/11	Thu 4/14/11
97	Peer Evaluations and Course Review	0 days	Fri 4/22/11	Fri 4/22/11



Project: Solar Car Project
Date: Mon 10/18/10

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

Figure 10 -- Schedule (3)

Budget Estimate

An estimated budget on the design project will be presented by the team. The budget is subdivided into Personnel, Expense, Overhead Costs, Equipment, and Total Project Cost. Every member in the team is subjected to a base salary rate of $30 per hour; each team member will be assumed to work twelve hours per week for both semesters. Fringe benefit rate of 29% will be applied on Personnel. All supplies under $1000 will be documented under Expense. Quantity, unit cost, total cost, and a reference (store name or website) for each supply will be documented under Expense. Overhead costs of the project will be presented; overhead rate of 45% of direct cost is assumed in calculation of the overhead cost. Items with cost over $1000 will be listed under Equipment. With respect to aforementioned costs, total costs necessary for successful completion of the project will be presented under Total Project Cost.

Personnel Expenses

NAME	Hours	Base Pay	Total
Barge, James	384	$30.00	$11,520.00
Cires, Adrian	384	$30.00	$11,520.00
Dalick, Keith	384	$30.00	$11,520.00
German, Nelson	384	$30.00	$11,520.00
Panther, Emiliano	384	$30.00	$11,520.00
Pradhan, Rajat	384	$30.00	$11,520.00
Prisland, Zachary	384	$30.00	$11,520.00
Rajbhandari, Shishir	384	$30.00	$11,520.00
Roberts, Amanda	384	$30.00	$11,520.00
Subtotal			$103,680.00
Fringe Benefit (29%)			$30,067.20
Total Personel Cost			**$133,747.20**

Expenses

ELECTRICAL					
Item	**Quant.**	**Unit Cost**	**Total**	**Reference**	**Reference**
Battery				NAWS	(website)
SOC Monitor	1	$319.00	$319.00	NAWS	(website)
Connection Kit	1	$98.70	$98.70	NAWS	(website)
Temperature Kit	1	$64.25	$64.25	NAWS	(website)
Syringe	9	$10.00	$90.00	ONCE	
Weller	9	$60.00	$540.00	ONCE	
Iron Tip	9	$9.00	$81.00	ONCE	
Paste Flux	10	$10.00	$100.00	Marshall Indus.	
Mount Tape	3	$47/roll	$141.00	R.S. Hughes Co	
Heat Shrink	2	$98.88	$197.80	McMaster-Carr	(website)
Fuses	8	$3.50	$28.00	McMaster-Carr	(website)
Connector	16	$0.95	$15.00	McMaster-Carr	(website)
Wires	7	$35/ft	$245.00	McMaster-Carr	(website)
3-way toggle	2	$5.00	$10.00	McMaster-Carr	(website)
2-way toggle	2	$6.50	$13.00	McMaster-Carr	(website)
push button	2	$10.00	$20.00	McMaster-Carr	(website)
Speedometer	1	$15.00	$15.00	Bycicle Store	(local)
Digital Therm.	1	$15.00	$15.00	Amazon	(website)
Ammeter	2	$45.00	$90.00	Ebay	(website)
Volt meter	1	$45.00	$45.00	Ebay	(website)
Fuses	10	$3.50	$35.00	Autozone	(local)
Camera\lcd	1	$150.00	$150.00	Ebay	(website)
Icharger	1	$170.00	$170.00	Amainhobbies	(website)
Current protec.	1	$150.00	$150.00	All-battery	(website)
Over Vol protec.	1	$200.00	$200.00	Smartec	(china)
Cell Balance Brd	1	$200.00	$200.00	Smartec	(china)
Microcontroller	2	$125.00	$250.00	Xillinx	Website
Miscellaneous			$500.00		
Subtotal			$3,782.75		

MECHANICAL					
Item	**Quant.**	**Unit Cost**	**Total**	**Reference**	**Reference**
Suspension System					
Aluminum	12 ft	$9.00	$108.00	local	(local)
Front suspension					
Coil Spring	2	$60.00	$120.00	jpc cycles	(website)
Damper	2	$49.50	$99.00	US motoman	(website)
Rear Suspension					
Coil Spring	1	$60.00	$60.00	pitstopusa	(website)
Damper	1	$49.50	$49.50	pitstopusa	(website)
Nuts & Bolts		$25.00	$25.00	Motor Sport	(website)
Miscellaneous		$125.00	$125.00		
Brake System					
Brake Pads	4	$35.00	$140.00	Motor Sport	(website)
Calipers	2	$85.00	$170.00	J C Whitney	(website)
Rotors	2	$45.00	$90.00	Moto Store	(website)
Miscellaneous					
Steering sys		$125.00	$125.00		
Wheel	1	$150.00	$150.00	advance auto	(website)
Rack & Pinion	1	$265.00	$265.00	Cabela's	(website)
Steering Column	1	$169.00	$169.00	J C Whitney	(website)
Miscellaneous		$125.00	$125.00		
Subtotal			$1,820.50		
INDUSTRIAL					
Item	**Quantity**	**Unit Cost**	**Total**	**Reference**	**Reference**
Resins	1	$500.00	$500.00	local	local
Canopy	1	$150.00	$150.00	local	build
Seats	1	$150.00	$150.00	advance auto	local
Horns	1	$35.00	$35.00	advance auto	local
Head Lights	1	$50.00	$50.00	advance auto	local
Brake Lights	1	$25.00	$25.00	advance auto	local
Reverse Lights	1	$35.00	$35.00	advance auto	local
Indicators	1	$20.00	$20.00	advance auto	local
Painting	1	$500.00	$500.00	local	local

Supplies		$500.00	$500.00		
Subtotal			$1,965.00		
Total Expenses			$7,568.25		

Overhead

PERSONNEL		$133,747.00
EXPENSES		$7,568.25
DIRECT COST		$141,315.25
Total at 45%		**$63,591.86**

Equipment

Item	Quantity	Unit Cost	Total	Reference	Reference
Solar Array	2363 cells	$6.50	$15,356.00	photonek.com	(website)
MPPT	2	$1,899.00	$3,798.00	AERL	(Australia)
Suspension	1	$1,100.00	$1,100.00	J C Whitney	(website)
Carbon Fiber	100 yds	$26.00	$2,600.00	solarcomposites	(website)
Total			**$22,854.00**		

Total Budget

PERSONNEL		$133,747.20
EXPENSES		$7,568.25
OVERHEAD		$63,591.86
EQUIPMENT		$22,854.00
Total Project Cost		**$227,761.31**

Deliverables

Hardware

Our hardware at the end of the project will be a solar powered car. It will be designed and constructed abiding the rules, regulations, and constraints set forth by the American Solar Challenge, 2012. It will be able to attain a maximum speed of at least 55 mph. The car will have lights, horn, indicators, parking brake, and other components required by law for motion of vehicle in interstate highways. The car will propel primarily from the solar energy of the sun; the regenerative braking system will aid in charging the battery.

Reports

Requirement and Needs Analysis

Requirement and Needs Analysis is a presentation report. The team member will be introduced to the panel. General outline of required capabilities, desired capabilities, functional and non-functional requirements, mechanical and electrical constraints, mechanical and electrical test plan will be presented to the panel. It is an introductory report in the form of a presentation.

Project Proposal

Proposal is a written and a presentation report. The overall design is subdivided into tasks, which are then divided into subtasks. An objective, method of approach, test plan, and outcome for each subtask will be discussed in a written report and also presented orally to the panel. The project proposal also includes risk assessment, budget, scheduling, and qualifications of team members for the design project.

System Level Design Review

System level design review is a written report and oral presentation on the preliminary design of the vehicle. The mechanical and electrical system design consideration is presented to the panel. All components used in the design will be reported. Simulation results of the basic components will be presented.

Detailed Design and Test Review

Detailed Design and Test Review is the final report of the project. It is a written report and an oral presentation. The report will provide detailed information on the methodology, design schematics, and software simulations used to develop the final design. All test plans and their corresponding results will be provided to ensure that final design product meets the rules, regulations, and constraints set forth by American Solar Challenge, 2012.

Manuals

User Manual

There will be a user manual for each component of the design. The user manual will serve as a guide for its respective component. It will provide an overview of the components along with a detailed step-by-step instruction on assembling, operating, and troubleshooting the component.

Current Design Specification Overview

Current Design Specification Overview is a written report passed onto the next phase for future team members. Due to risks and budgetary constraints, some tasks may have to be implemented by future teams. It is also possible for some tasks to be partially completed and left for the future team. As such, this documentation will introduce the next team to the design project and provide them with an outline of the tasks necessary to complete the design as per regulations set forth by ASC, 2012.

Website

A website will be developed for the team. It will introduce the project along with the current team members. It will chart the schedule for the year and document the progress of the team on a weekly basis. All documents, schematics, simulations, user manuals, program codes, and other project items will be available in the website. The website will run from the school server. The website will be passed to future team members.

Video

With the onset of YouTube, the team will document important phases in the project with the aid of a video camera. The videos will be uploaded in a YouTube account created for the team. Successful testing of solar array system, regenerative braking system, mechanical braking system, construction of uni-body, and test-driving are some examples of important phases that will be video documented. The videos will also be available on the team's website.

Works Cited

Electrick Publications and NJK. (2005). *How To Design A Solar Car That Works*. Retrieved October 15, 2010, from Speed Ace: http://www.speedace.info/solar_car_anatomy.htm

Harris, W. (2005, May 11). *How Car Suspensions Work*. Retrieved October 15, 2010, from http://auto.howstuffworks.com/car-suspension.htm

Longhurst, C. (2010, October 11). *The Suspension Bible*. Retrieved October 15, 2010, from http://www.carbibles.com/suspension_bible.html

Nice, K. (2001, May 31). *How Car Steering Works*. Retrieved October 16, 2010, from How Stuff Works: http://www.howstuffworks.com/steering.htm

Nice, K. (2000, August 21). *How Disc Brakes Work*. Retrieved October 16, 2010, from How Stuff Works: http://www.howstuffworks.com/auto-parts/brakes/brake-types/disc-brake.htm

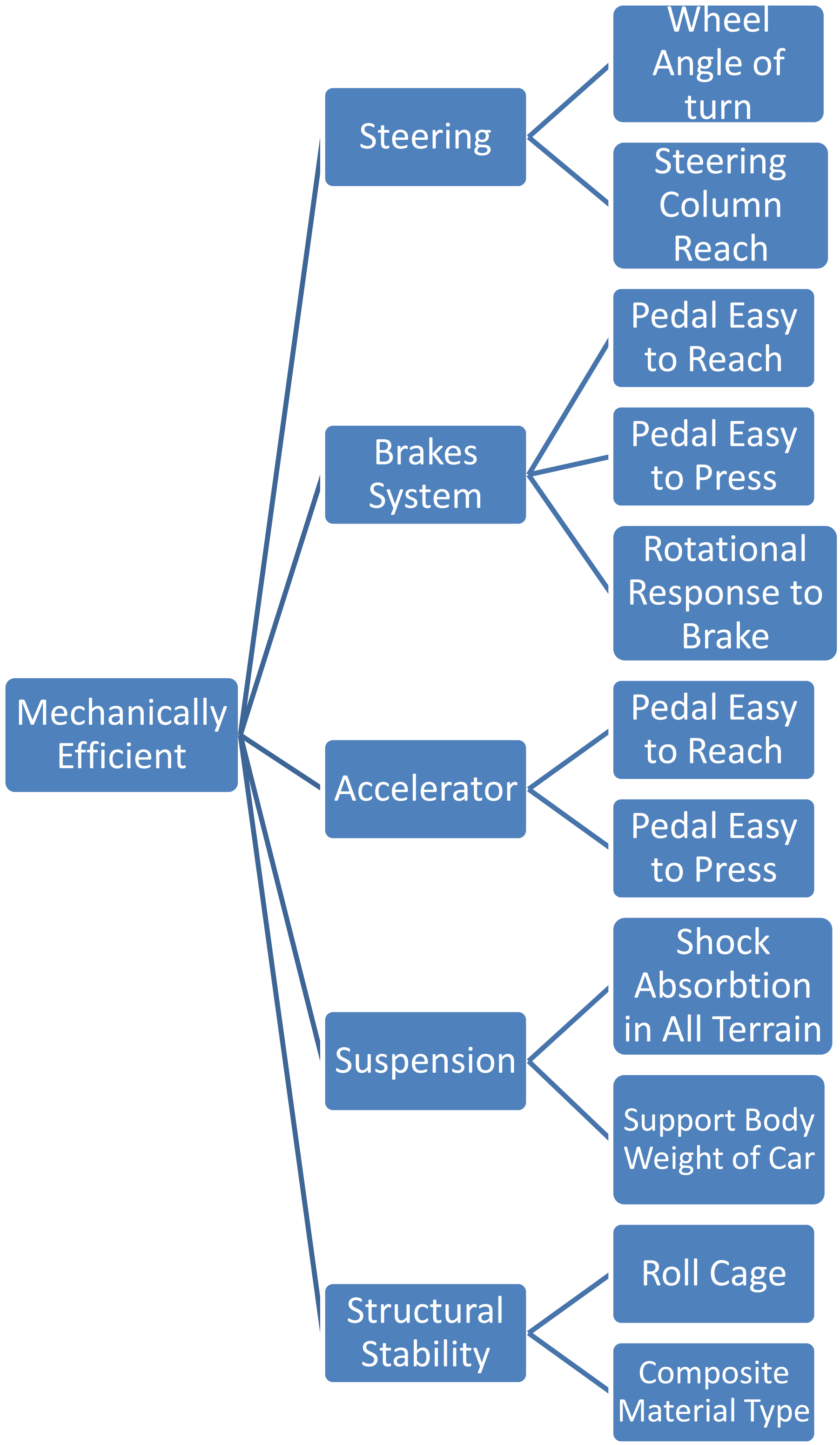
Short, S. (2002). *Vehicle Suspension Systems*. Retrieved October 15, 2010, from http://members.fortunecity.com/suspdesign/index2.html

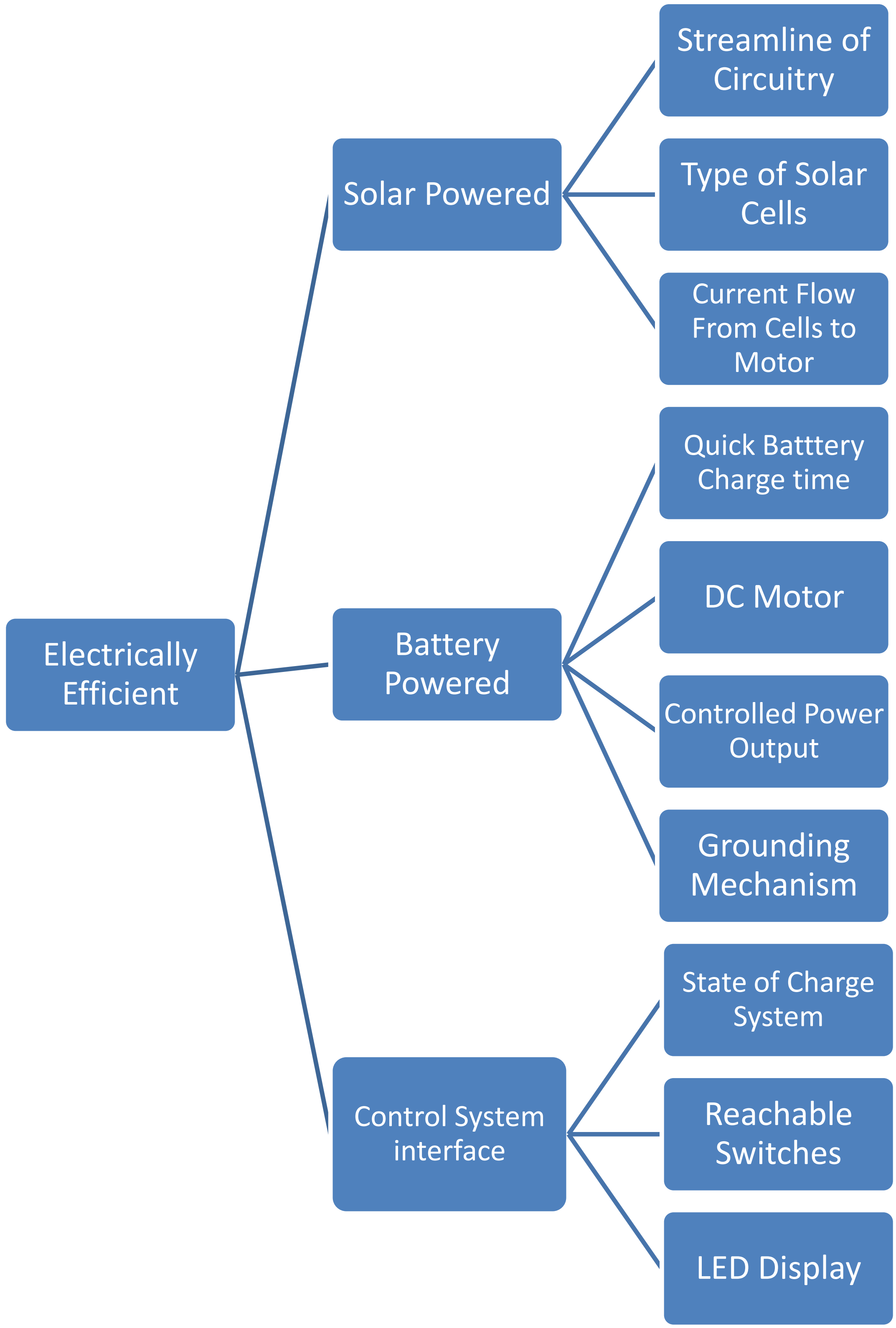
SusProg3D. (n.d.). *Suspension Types*. Retrieved Ocotober 16, 2010, from SusProg3D -- Suspension by Design: http://www.susprog.com/susptype.htm

Appendix

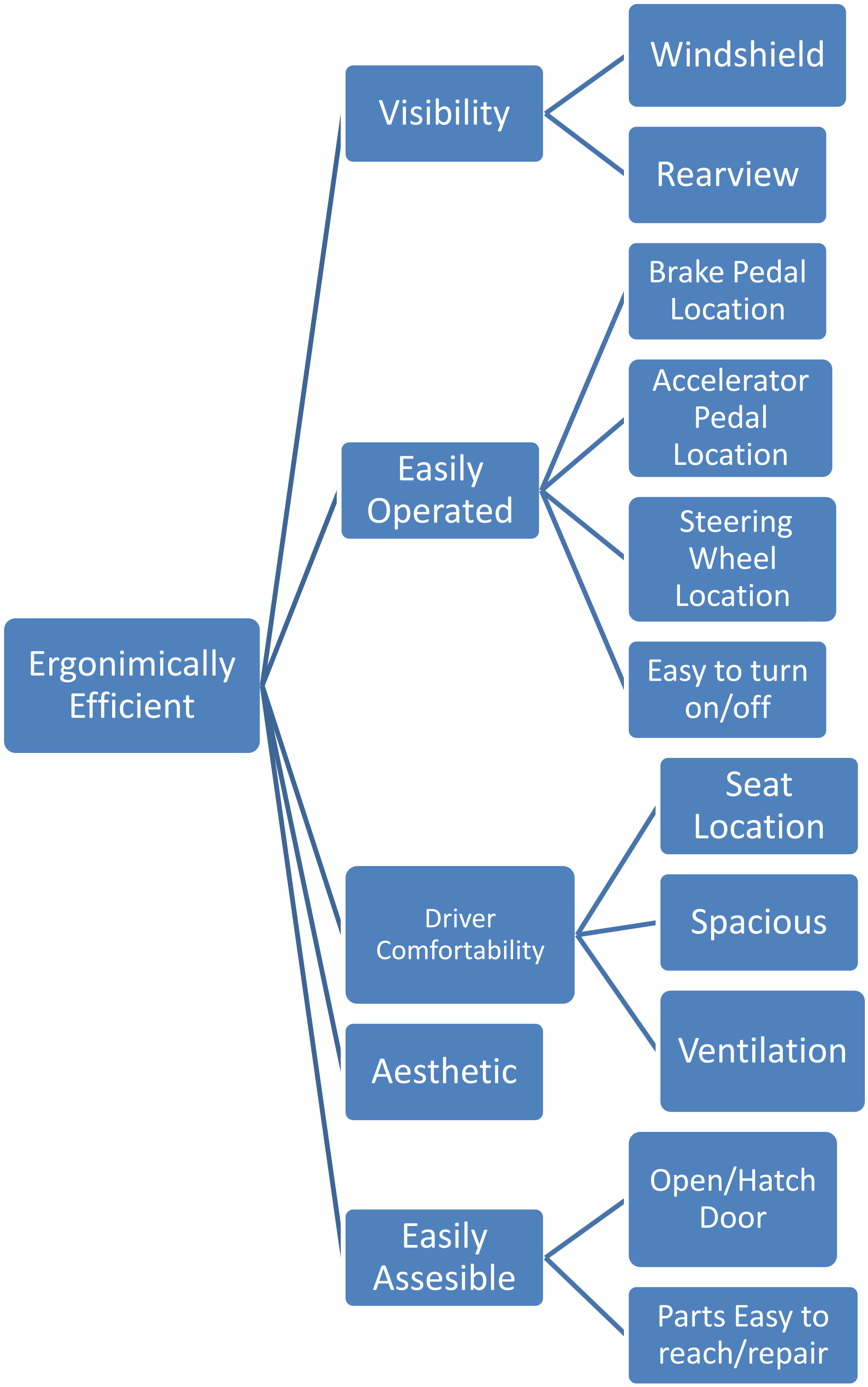
Design Figures

Industrial Engineering contribution diagrams and house of quality for the design process of the solar car.





Electrically Efficient
Solar Powered
Battery Powered
Control System interface
Streamline of Circuitry
Type of Solar Cells
Current Flow From Cells to Motor
Quick Batttery Charge time
DC Motor
Controlled Power Output
Grounding Mechanism
State of Charge System
Reachable Switches
LED Display


Ergonimically Efficient
Visibility
Windshield
Rearview
Easily Operated
Brake Pedal Location
Accelerator Pedal Location
Steering Wheel Location
Easy to turn on/off
Driver Comfortability
Seat Location
Spacious
Ventilation
Aesthetic
Easily Assesible
Open/Hatch Door
Parts Easy to reach/repair

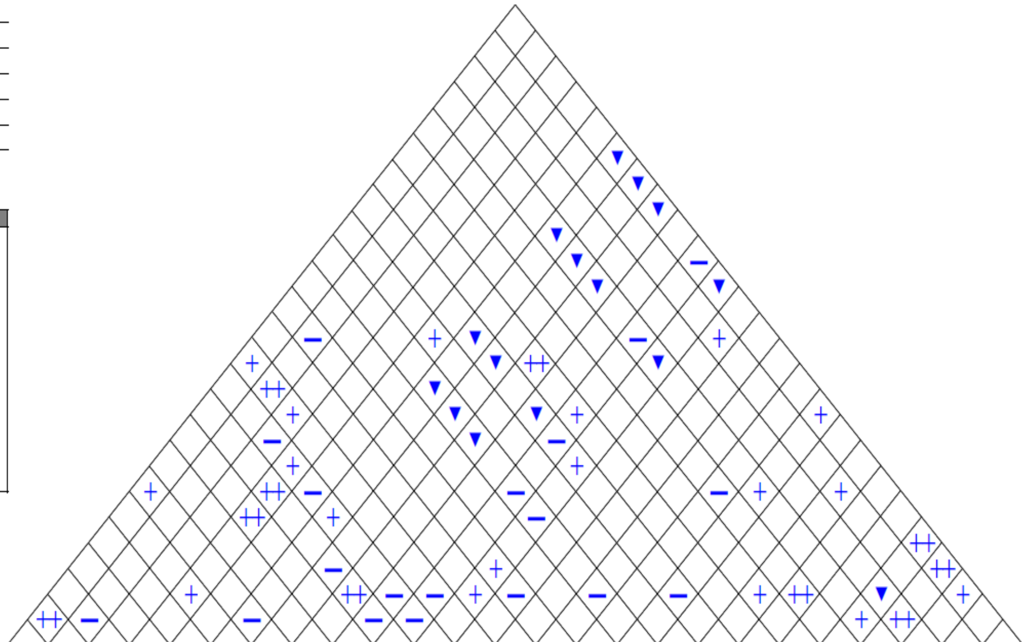
Title: Solar Car

Author: Nelson German, Rajat Pradhan, Amanda Roberts

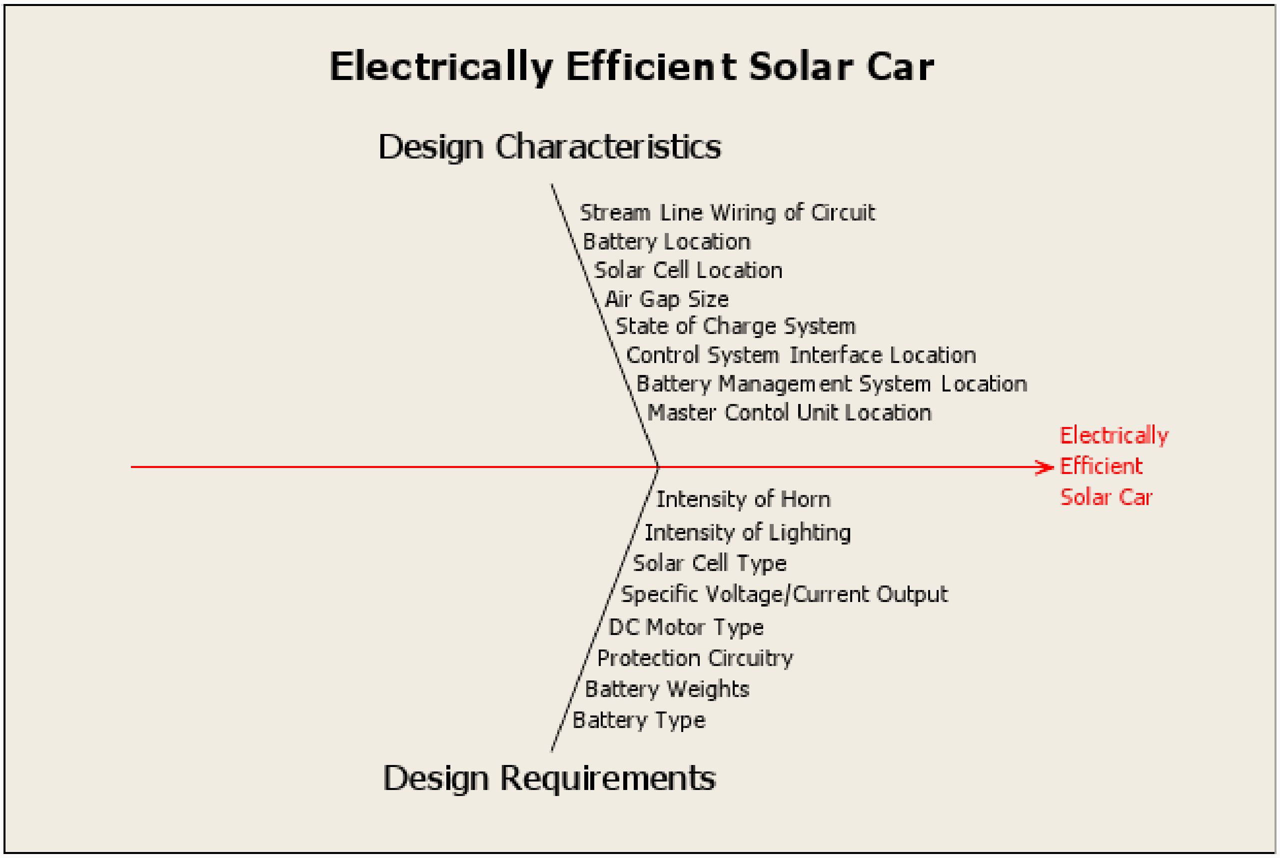
Date: 10/15/2010

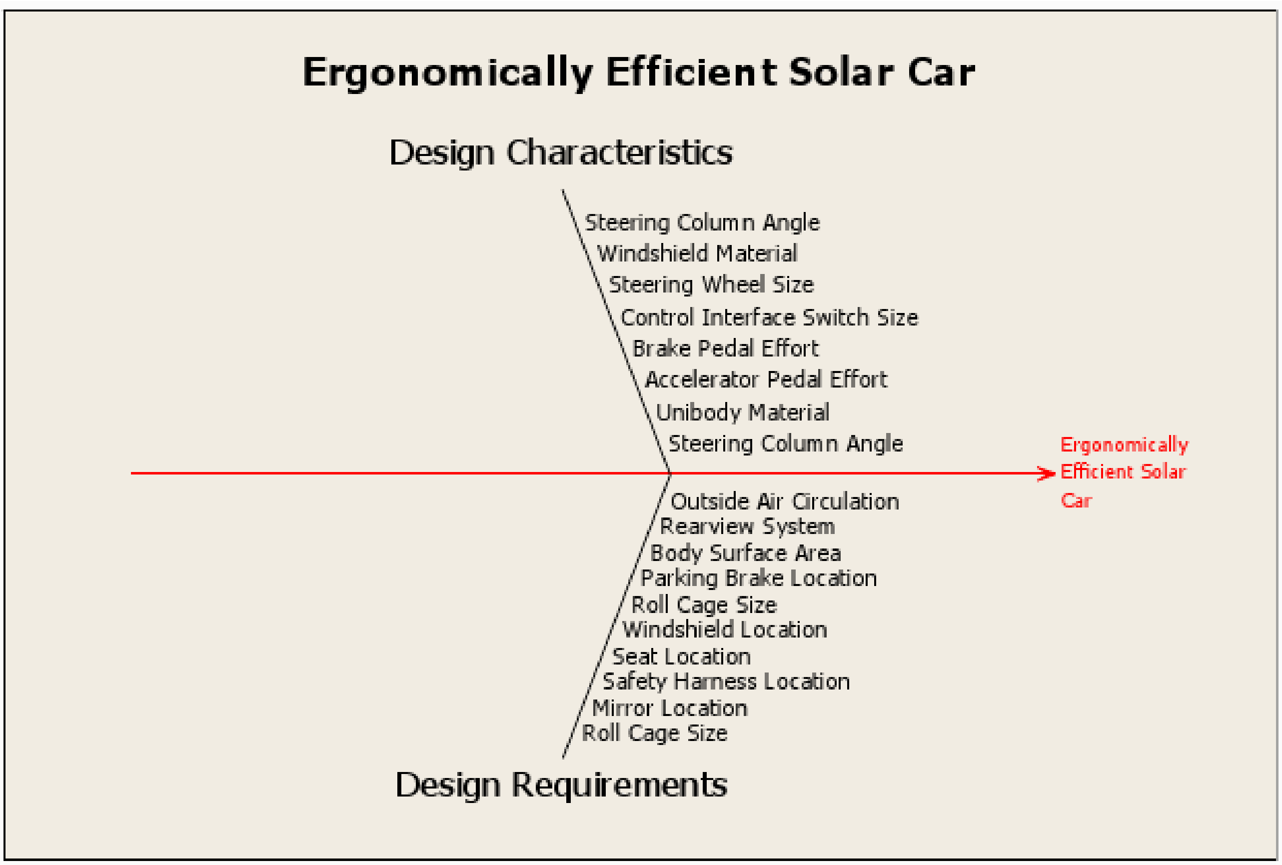
Notes:

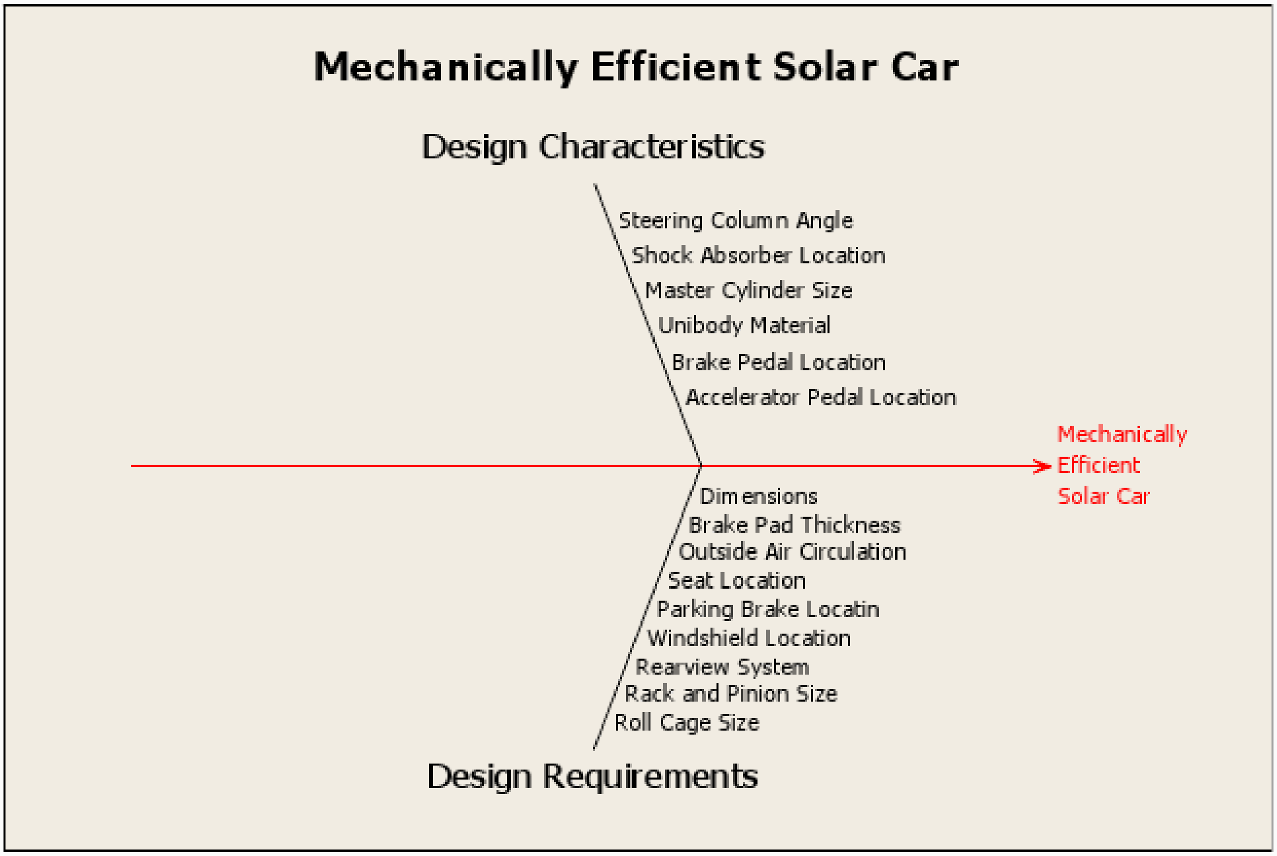
Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Suspension Type	2 Wheel Alignment	3 Brake Pedal Effort	4 Winshield Location/Rearview System	5 Acceleration pedal effort	6 Steering Column Angle	7 Rack and Pinion System Size	8 Unibody Material	9 Roll Cage Size	10 Body Surface Area	11 Seat Location	12 Parking Brake Location	13 Safety Harness Location	14 Intake Vent Location	15 Head Lights/Brake Lights/Turn Signal/Horn Intensity	16 Master Control Unit location	17 Max/Min Air Gap Size	18 Control System Interface location	19 Solar Cell Type	20 Control interface switch sizes	21 Specific Voltage/Current output from batteries	22 Battery location	23 Battery Ventilation System Flow Rate	24 Calibrated Speedometer	25 Battery management System location
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	9	5.5	7.0	Ergonomic/Spacious			Θ	Θ	Θ	Θ	O	▲	Θ	Θ	Θ	Θ	Θ	Θ				Θ		O		O			
2	9	7.1	9.0	Solar Powered								▲		Θ						Θ			Θ		Θ				
3	9	7.1	9.0	Battery Powered																Θ	Θ	Θ	O		Θ	Θ	Θ	O	Θ
4	9	4.7	6.0	Light Weight								Θ	Θ	Θ						O						Θ			O
5	9	3.9	5.0	Optimum Power					O					O							▲		Θ		Θ				
6	9	3.1	4.0	Aerodynamic		O		Θ				Θ	Θ	Θ				▲											
7	9	5.5	7.0	Optimum Steering		O				Θ	Θ				▲														
8	9	4.7	6.0	Operator Friendly			Θ	Θ	Θ	Θ					Θ	O	▲	O	▲									O	
9	9	3.9	5.0	Easily Enter/Exit Cockpit				Θ				O	Θ	O	Θ	▲	Θ					▲							
10	9	7.1	9.0	Optimum Brakes	▲		Θ								O	Θ													
11	9	3.9	5.0	Optimum Torque		▲			Θ					▲						▲	Θ		▲		Θ	▲			▲
12	9	4.7	6.0	Optimum Suspension	Θ	Θ	▲							▲															
13	9	7.1	9.0	Driver Visibility				Θ		▲			O		Θ		▲		Θ			O							
14	9	7.1	9.0	Stable Body	O	O					O	Θ		O												▲			
15	9	4.7	6.0	Weather Resistant				▲				Θ		▲									O						
16	9	6.3	8.0	Repair Assessability/Continuos Improvement	Θ			▲		▲	▲	O	Θ	Θ	O					Θ		Θ				Θ			Θ
17	9	7.1	9.0	Driver Crash Safety			Θ	Θ	Θ		▲		Θ	Θ	O		Θ			Θ		Θ				Θ			Θ
18	9	6.3	8.0	Ventilation								▲			O			Θ		O						O			O
19	9			Electrical Race Requirements															Θ	Θ			Θ		Θ	Θ	Θ		Θ
20	9			Mechanical Race Requiremets	Θ	Θ	Θ	Θ					Θ	Θ	Θ	Θ	Θ	Θ											
				Target or Limit Value																									
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)																									
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	3	9	9	9	3	9
				Weight / Importance	127.6	93.7	224.4	294.5	203.1	155.1	100.8	226.8	297.6	363.0	277.2	131.5	160.6	123.6	68.5	285.0	103.1	259.1	138.6	16.5	198.4	273.2	63.8	35.4	221.3
				Relative Weight	2.9	2.1	5.1	6.6	4.6	3.5	2.3	5.1	6.7	8.2	6.2	3.0	3.6	2.8	1.5	6.4	2.3	5.8	3.1	0.4	4.5	6.2	1.4	0.8	5.0


Electrically Efficient Solar Car
Design Characteristics
Stream Line Wiring of Circuit
Battery Location
Solar Cell Location
Air Gap Size
State of Charge System
Control System Interface Location
Battery Management System Location
Master Contol Unit Location
Electrically Efficient Solar Car
Intensity of Horn
Intensity of Lighting
Solar Cell Type
Specific Voltage/Current Output
DC Motor Type
Protection Circuitry
Battery Weights
Battery Type
Design Requirements


Ergonomically Efficient Solar Car
Design Characteristics
Steering Column Angle
Windshield Material
Steering Wheel Size
Control Interface Switch Size
Brake Pedal Effort
Accelerator Pedal Effort
Unibody Material
Steering Column Angle
Ergonomically Efficient Solar Car
Outside Air Circulation
Rearview System
Body Surface Area
Parking Brake Location
Roll Cage Size
Windshield Location
Seat Location
Safety Harness Location
Mirror Location
Roll Cage Size
Design Requirements


Mechanically Efficient Solar Car
Design Characteristics
Steering Column Angle
Shock Absorber Location
Master Cylinder Size
Unibody Material
Brake Pedal Location
Accelerator Pedal Location
Mechanically Efficient Solar Car
Dimensions
Brake Pad Thickness
Outside Air Circulation
Seat Location
Parking Brake Locatin
Windshield Location
Rearview System
Rack and Pinion Size
Roll Cage Size
Design Requirements